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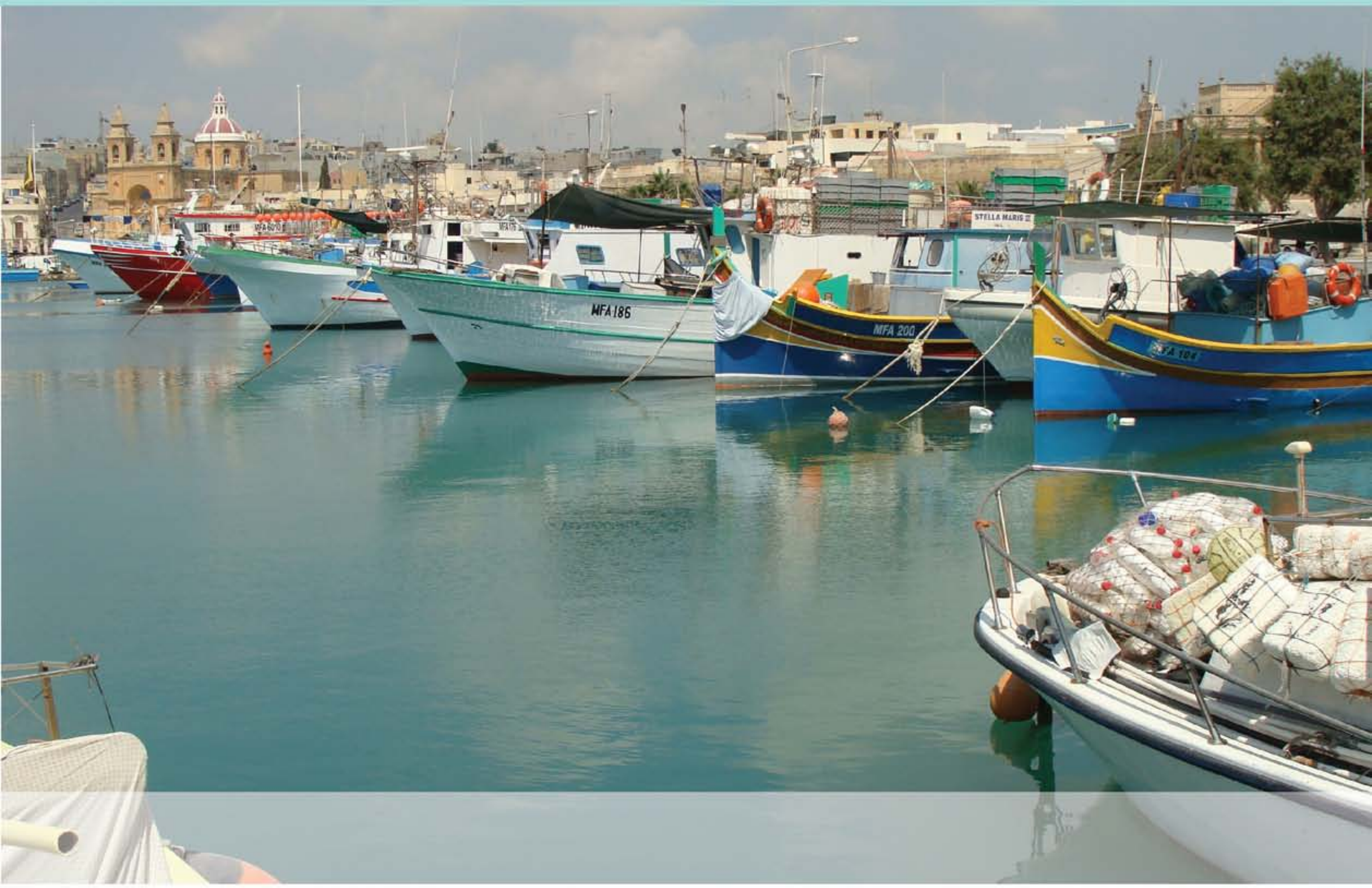
Fishing harbour planning, construction and management



Cover photograph:
Marsaxlokk fishing port, Malta; courtesy of Joseph Alan Sciortino.

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Preparation of this document

This manual was prepared by Mr Joseph Alan Sciortino, MICE, M. ASCE, C. Eng., the Food and Agriculture Organization of the United Nations (FAO) Consultant on Harbour Design and Management. The manual reflects the provisions of the FAO Code of Conduct for Responsible Fisheries in relation to fishing harbours and is an extension of Annex VI, No. 1, in the series of FAO Technical Guidelines for Responsible Fisheries. It contains proposals and guidelines to be followed with regard to the design, development, management and maintenance of ports and landing places for fishing vessels. It also provides guidance on the conduct of environmental auditing in relation to new construction and the upgrading of existing facilities. It was based on a manual prepared in electronic format in 1999, and updated and revised to integrate new guidelines, ideas, experiences and lessons from projects in different parts of the world.

The manual was technically edited by Mr John Fitzpatrick, C. Eng., C. Mar. Eng., MIMAREST, former Director of the FAO Fish Products and Industry Division. The draft of the manual was reviewed by Mr B.N. Krishnamurthy, FAO Consultant on Harbour Management and Institution Building and Mr V. Venkatesan, FAO Consultant on Community Participation in Fisheries, both under the Technical Cooperation Project on Capacity Building in Support of Cleaner Fishing Harbours in India; and Mr Simon Diffey, Chief Technical Advisor of the project on the Restoration and Improvement of Fish Landing Centres with Stakeholder Participation in Management funded by the Canadian International Development Agency in Sri Lanka.

The manual was edited by Maria Giannini. Susana V. Siar, Fishery Industry Officer, Fishing Operations and Technology Service (FIRO) of the FAO Fisheries and Aquaculture Department, provided overall supervision in the preparation and publication of this manual. The publication contributes to the achievement of the following organizational result: the operation of fisheries, including the use of vessels and fishing gear, is made safer, more technically and socio-economically efficient, environmentally-friendly and compliant with rules at all levels.

Abstract

The role of the fishing port may be considered as the interface between the netting of fish and its consumption. In many cases, the fishing harbour is also the focal point of pollution, both of the surrounding environment and the fishery products it produces. Many fishing harbours are also the source of major impacts on the physical and biological coastal environment.

Although the bulk of fish landed in fishing harbours in developing countries is destined for the local markets, it is every country's wish to improve the health hazard-free quality of its landed catch in order to increase exports of seafood products to more lucrative overseas markets. In the not-too-distant future, the growth in local consumer rights advocacy will also increase demand for health hazard-free fish.

In today's world of increased environmental awareness, a fishing port must be planned, designed and managed in harmony with both the physical and biological coastal environments. At each stage of the process, whether it is planning, design or management, both technical and non-technical persons become involved in the process. Within government departments, whether they be technical (fisheries or public works) or non-technical (budget or finance), it is not uncommon for non-technical persons to affect the outcome of technical decisions. Fisheries Departments worldwide generally have to manage and maintain harbours and landing places using non-engineering civil servants. The following manual was produced in order to tackle fishing harbours in a holistic approach.

This manual is useful to both technical and non-technical planners, both at national government level and at departmental level. It provides non-engineering staff within such departments with enough technical knowledge to better understand certain basic design requirements, which could otherwise be interpreted as superfluous and not cost effective.

The manual is of particular use to local independent consulting engineers and architects with no ports or fisheries experience involved in the design of locally tendered projects for the various international funding agencies. To technical staff of such firms, it provides a handy reference and the means for integrating Hazard Analysis and Critical Control Points (HACCP) and European Union Directive recommendations on hazard-free seafood directly into the fishing port's design.

The fishing industry as a whole can ill-afford the economic losses from lower prices received for contaminated fish. Recent European Union rulings have even gone one step further by banning outright all fish imports from certain countries.

Sciortino, J.A.
Fishing harbour planning, construction and management.
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Contents

Abbreviations and acronyms

AC	alternating current
AISI	American Iron and Steel Institute
BOBP	Bay of Bengal Programme
CFC	community fishery centre
CFCs	chlorofluorocarbons
COFI	Committee on Fisheries
DC	direct current
DGPS	Differential Global Positioning System
EC	European Community
EEZ	exclusive economic zone
EIA	environmental impact assessment
EIS	environmental impact studies
EPS	Electronic Positioning System
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FMO	fisheries management organization
GHG	greenhouse gases
GPS	Global Positioning System
GT	gross tonnage
HACCP	Hazard Analysis and Critical Control Points
HDPE	high-density polyethylene
HHWL	Higher High Water level
HHW	highest high waters
IALA	International Assocation of Marine Aids to Navigation and Lighthouse Authorities
IATA	International Air Transport Association
IEE	Initial Environmental Examination
IMO	International Maritime Organization
IPCC	International Panel on Climate Change
ISO	International Organization for Standarization
ISPS	International Ship and Port Facility Security Code
IUU	illegal, unreported and unregulated
LAT	lowest astronomical tide
LDPE	low-density polyethylene
LED	light-emitting diode
LLW	lowest low waters
LLWS	Lower Low Water Spring
LUX	1 lumen per square metre
MARPOL	International Convention for the Prevention of Pollution from Ships
MCS	monitoring, control and surveillance
MLLW	Mean Lower Low Water
m/s	metres per second
MSL	mean sea level
MSY	maximum sustainable yield
N/mm^2	Newtons per square millimetre

NGO	non-governmental organization
PAH	polynuclear aromatic hydrocarbons
ppb	parts per billion
ppm	parts per million
PVC	polyvinyl chloride
PVN	Private Virtual Network
PV	photovoltaic
RO	reverse osmosis
SAR	search and rescue
SOLAS	International Convention for the Safety of Life at Sea (IMO Convention)
SWL	safe working load
UHMW	ultra-high molecular weight
UKC	under keel clearance
UNCED	United Nations Conference on Environment and Development
UNCLOS	United Nations Convention on the Law of the Sea, 1982
uPVC	unplasticized PVC
UXO	unexplored ordinance
W/C	water-cement ratio
WGS84	World Geodetic System 1984
WHO	World Health Organization

Executive summary

The unrelenting pressure on the world's coastal resources and its coastal ecosystems is threatening the viability of fisheries as an industry. By its very nature, an ill-conceived port or fish landing structure has the potential to place a disproportionately large demand on both the local physical and biological resources and, in today's world of increased environmental awareness, a fishing port or fish landing site must be planned, designed and managed in harmony with these environments.

Fishing ports and fish landing sites are complex dynamic interface zones involving the mixing of environmental, ecological, economic and social activities and problems. This heterogeneous mix of activities demands strong cross-sector interaction at the planning stage to ensure that the resulting infrastructure may be managed in a sustainable manner. This manual is not the first effort by FAO to set forth a set of cross-sector guidelines for the planning and/or management of a fish landing site or fishing port. In various forms, information related to fishing ports design has been available since 1976, the most recent being FAO Training Series 25 on the construction and maintenance of artisanal fishing harbours and village landings (1995).

In recent years, world fisheries have become a market-driven sector of the food industry and many coastal states have striven to take advantage of this new opportunity by investing heavily, and sometimes haphazardly, in fishing port infrastructure. When, in the early to mid-1990s various international conventions and importing country directives on food safety came into force, much of this same infrastructure was found to be non-compliant, requiring further investment. Also, in the intervening period, the requirement for proper Environmental Impact Studies became mandatory in most States, further complicating the added investments required to make such infrastructure compliant.

Why this manual? The manual builds on the earlier work by FAO and introduces for the first time the international conventions and importing country directives that have a direct influence on both the planning and design of fishing port infrastructure. It is intended as a reference not only for engineers and architects involved in the design and rehabilitation of fishing ports but also for non-technical staff at departmental level in government institutions that may influence technical decisions in the field. These institutions may comprise, directly or indirectly, policy and planning, budget and finance, export and public health authorities. It may also be of use to donor agencies and non-governmental organizations when planning fisheries-related investments.

The use of this manual should enable consultants, architects and contractors involved in any stage of design or construction of a fish landing or port to avoid the mistakes of old. This manual covers all the aspects of fishing port infrastructure, from inception to final design as well as the construction and management of the fishing port or landing once constructed. This manual does not replace the textbooks required to design the single elements that constitute the fishing port, such as the breakwaters, the quay walls, etc. Any costs quoted in the manual refer to United States dollars and generally apply to any country with good connections. Operational costs in some developing countries may differ significantly due to logistics. To technical staff in general, it provides a handy reference and the means for integrating HACCP and importing country directive recommendations on hazard-free seafood directly into the fishing port's design.

The previous version of this manual was the basis of a distant-learning course. This edition is a good handbook based on the author's extensive experience in the design, construction and operation of fishing ports in many developing countries.

There are twelve chapters and five reference annexes in this manual. Each chapter deals with a particular topic and is a stand-alone document.

The first chapter presents the technical guidelines to the Code of Conduct for Responsible Fisheries. It also lists the relevant international conventions to which a State may be a party, together with third country directives that jointly will have a direct bearing on the overall design of the port and its components. These include compliance with basic engineering principles regarding the morphological degradation of the coastal zone in respect of erosion and siltation (UNCED 92), compliance with the relevant conventions concerning pollution of the aquatic environment (MARPOL 73/78) and the provision of adequate monitoring of the effects of operations on the environment (UNCED 92). The Code also addresses post-harvest practices setting out minimum standards for food safety and quality assurance.

The second chapter describes how to plan shore-based facilities and fishing ports that are commensurate with the targeted resources, within the exclusive economic zone (EEZ) of a coastal State and distant water fisheries, as the case may be, that would be environmentally sustainable and financially justifiable. It addresses the major issues that influence the size of a new port and describes in detail the classification of fishing ports, from artisanal beach landings to coastal fishing ports, offshore fishing ports and distant water fishing ports. Guidelines on the preferred siting of a fishing port vis-à-vis land use are also discussed. The chapter also dwells on post-conflict reconstruction procedures and on overcapacity (redundant vessels) and potential income diversification for fishermen faced with an ever-dwindling catch.

The third chapter tackles port management, from the simple fish landing on a beach to a proper deep water fishing port. It stresses the need for a stakeholder approach to port management whereby all the port users are represented on the management body. Typical port management bodies are described in detail covering all scenarios, from the simple village landing to a sophisticated fishing port. It also highlights the importance of a fish quality assurance regime inside the port and lists best management practices for port and boatyard operators and the prevention of pollution.

Chapter four reviews the environmental auditing procedures to be followed for all new designs. Degradation of the marine environment can result from a wide range of activities on land. Coastal erosion and siltation are of particular concern. Hence, rational use and development of coastal areas as well as conservation of the marine environment require the ability to determine the present state of these ecological systems and to predict future conditions. Systematic collection of data on marine environmental parameters is needed for an integrated management approach to sustainable development and to predict the effects of the construction of a port on the marine environment. This chapter should be of use to government institutions involved in fisheries-related development seeking international investment funds. The guidelines are also useful for the development or expansion of commercial ports which may impact fishing operations.

Hydrography is the foundation for all coastal work and chapter five covers the topic in great detail. In the past, many artisanal shelters and fishing ports were built at convenient locations, with no particular attention paid to the underwater environment. Many such ports are now plagued by erosion and siltation problems that could have been identified earlier had proper hydrographic surveys been conducted. This chapter should provide planners and engineers with cost-effective options when faced with tight budgetary restrictions and difficult logistics. It describes the amount of hydrographic detail required for a project from inception stage to construction phase.

Dredging and underwater excavation, chapter six, are an important aspect in the design and construction of key elements in a fishing port. Dredging may be required to develop a port basin or to maintain a navigation channel open, but may also be undertaken for other purposes such as land reclamation, beach nourishment and environmental remediation of contaminated sediments. Dredging may be of a permanent nature, also known as capital dredging, or of a transient nature, also known as maintenance dredging. The nature of the material to be dredged determines the type of dredging equipment required or method to be adopted but, on the whole, dredging practice is site specific. Also, in recent years, the screening for the presence of potentially harmful chemical agents in the material to be dredged has become mandatory in many countries influencing not only the method of dredging but also the method of disposal. This chapter may be used as a guide to assist in the decision-making process for the selection of appropriate dredging and disposal techniques.

Chapter seven is dedicated exclusively to breakwaters. The sea is unforgiving and wave action continually degrades human-made structures erected in the sea and breakwaters form the bulk of this construction. Therefore, engineers are normally entrusted with the design and maintenance of large deep water breakwaters. However, cases also arise when artisanal structures are required at the local level and when engineering assistance is either not available or not with the right experience. This chapter is intended primarily for non-technical staff coming to terms for the first time with marine construction and purposely does not include advanced design aids for structures in deep water, the realm of professional engineers.

Chapter eight covers quays and slipways in detail and should provide the reader with a wide range of options for both quays and maintenance structures, such as slipways and boat gantries.

Chapter nine condenses the subject of materials knowledge and suitability into a single chapter while eliminating superfluous coverage. The chapter is confined to the properties of those materials and treatments or variations thereof that are applicable to port structures. Emphasis is placed on full coverage of the basic materials that have proved most durable in the highly aggressive marine environment inside port structures.

The tenth chapter is a comprehensive overview of all the mechanical fittings and quay furniture required to run a port efficiently, from bollards and fenders all the way to marker beacons, winches and fish boxes. It provides an ideal reference guide to both technical and non-technical readers.

Chapter eleven reviews the shore-based infrastructure typical in a port operation, from water supply, power, refuelling, ice, port buildings and paved areas. Any reader will find this chapter useful, either as a reference or as a guide on how to integrate HACCP and third country directives into a port's infrastructure design.

Chapter twelve provides a holistic approach to public health issues in fisheries ranging from water and water-borne contaminants to sewage and sewage treatment options. The comprehensive detail of this chapter will enable the reader to better understand the ease with which fish, meant for human consumption, is contaminated. The chapter will also assist port planners in dealing with the prevention of pollution in fishing ports.

The manual also has a list of annexes for use as reference material. Annex 1 reproduces the text from the FAO Technical Guidelines, No. 1, Fishing Operations, on the procedures for the development and management of harbours and landing places for fishing vessels. Annexes 2 and 3 are checklists for port hygiene and port hygiene deficiencies, respectively. The fourth annex is a training manual on seafood handling prepared by Francisco Blaha, formerly FAO Fishery Industry Officer for the Technical Cooperation Project on Capacity Building in Support of Cleaner Fishing Harbours in India. The fifth annex is a useful tool already used with success in public awareness campaigns on the prevention of pollution in fishing harbours.

1. Code of conduct, conventions and importing country directives

SUMMARY

There are a number of instruments both voluntary and binding that have a bearing on site selection, construction, facilities, operation, and management of harbours and landing places for fishing vessels, as well as prevention of pollution and port security. The intention within this chapter is to set forth basic principles, some of which are binding, that will be expanded upon in greater technical detail in successive chapters and annexes. In this regard, the Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing adopted by the Conference of FAO in November 2009 will, on entry into force, add to the responsibilities of port managers and departments of fisheries alike.

In addition, countries that export seafood and seafood products may also have to address directives of importing countries regarding post-harvest care, levels of hygiene and general cleanliness within work and storage areas and, in particular, the application of the Hazard Analysis and Critical Control Point (HACCP) principle.

CONTENTS

1.1 FAO CODE OF CONDUCT FOR RESPONSIBLE FISHERIES

In accordance with the recommendations of the Committee on Fisheries (COFI) at its Nineteenth Session in March 1991 and the subsequent International Conference on Responsible Fishing, held in Cancun (Mexico) in 1992, the Twenty-eighth Session of the Conference of FAO unanimously adopted the FAO Code of Conduct for Responsible Fisheries, 1995 (hereinafter referred to as the Code). The Code was formulated so as to be interpreted and applied in conformity with the relevant rules of international law, as reflected in the United Nations Convention on the Law of the Sea, 1982 (UNCLOS), as well as with the Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, 1995, in the light of, *inter alia,* the 1992 Declaration of Cancun and the 1992 Rio Declaration on Environment and Development, in particular Chapter 17 of Agenda 21.

Whereas the Code is voluntary certain parts of it are based on relevant rules of international law, including those reflected in the United Nations Convention on the Law of the Sea of 10 December 1982. The Code also contains provisions that may be or have already been given binding effect by means of other obligatory legal instruments among the Parties such as the Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas, 1993.

With regard to harbours and landing places for fishing vessels, Article 6.17 sets out that States should ensure that fishing facilities and equipment as well as all fishing activities allow for safe, healthy and fair working and living conditions and meet internationally agreed standards adopted by relevant international organizations. More specifically, Article 8.9 addresses harbours and landing places for fishing vessels.

In adopting the Code, the Conference called for the production of technical guidelines for the implementation of the provisions of the Code. In this regard, this manual draws on the first in the series of FAO Technical Guidelines for Responsible Fisheries, entitled Fishing Operations, and in particular, Section 7, Energy Optimization and Protection of the Ozone Layer, and Section 8, Design, Construction and Modification of Harbours and Landing Places for Fishing Vessels.

In developing the guidelines and its annexes, FAO drew on experience gained over many years of field activities, and in the case of harbours and landing places, how increasing problems associated with the construction of new harbours and landing places for fishing vessels and, in particular, their operation and maintenance, had reached critical levels in some parts of the world. In many instances, the adverse effects of harbour pollution from the activities of fishing vessels as well as those of vendors and processors had been exacerbated by the almost total lack of reception facilities.

Matters had become more serious in the late 1980s with an ever increasing demand for assistance from developing countries to solve specific problems with existing harbours as well as for help in designing new installations.

A classic example was within the Bay of Bengal subregion, where the Bay of Bengal Programme (BOBP), with the cooperation of the International Maritime Organization (IMO) (within its cleaner seas programme) and FAO, commissioned a series of important studies. The results of these studies were presented at a workshop hosted by the Government of Malaysia at Penang, 9–11 December 1991, at which developments with regard to the International Convention for the Prevention of Pollution from Ships (MARPOL) were highlighted by IMO.

In parallel, the United Nations Conference on the Environment and Development (UNCED) deliberated the need for a precautionary and anticipatory approach rather than a reactive approach to prevent degradation of the marine environment. Consequently, in June 1992, UNCED recommended, *inter alia*, the adoption of environmental impact assessment procedures.

Thus, the Code and its Technical Guidelines underline the importance of environmental auditing, attention to the provisions of MARPOL and Article 21 of UNCED.

1.2 FAO TECHNICAL GUIDELINES FOR RESPONSIBLE FISHERIES NO. 1

The first in the series of FAO Technical Guidelines for Responsible Fisheries (FAO, 1996) refers to fishing operations and in Section 8 it states that, in general, competent authorities should adopt acceptable standards and follow guidelines for the design, construction, maintenance and management of harbours and landing places for fishing vessels (*reference 8.9 of the Code*) to ensure, *inter alia*:

- safe havens for fishing vessels;
- that freshwater supplies are available;
- the provision of adequate sanitation arrangements;
- that waste disposal systems (including for oil and oily water) are provided;
- that there would be no pollution from external sources (non-fisheries activities);
- that there would not be any pollution arising from fisheries activities;
- the provision of adequate servicing facilities for vessels, vendors and buyers;
- that maintenance programmes include the monitoring of the effects of operations conducted at the facility on the environment;
- compliance with relevant conventions concerning pollution of the aquatic environment;
- integration with other users as in the case of a non-exclusive facility for the fishing industry; and
- that arrangements are made to combat the effects of erosion and siltation.

The Technical Guidelines also expand on the provisions of the Code in relation to the participation of users in the management of ports, harbours and landing places (Section 8, paragraph 115), as well as the removal of offshore structures (Section 8.10 and Annex V) and the development of artificial reefs (Section 8.11).

1.3 ANNEX VI OF THE FAO TECHNICAL GUIDELINES FOR RESPONSIBLE FISHERIES NO. 1

1.3.1 General provisions

Annex VI expands on the principles set out in the Code and the Technical Guidelines, covering procedures for the development and management of harbours and landing places for fishing vessels. In addition, within the concepts of responsible fishing operations and the integration of fisheries into coastal area management, it also provides guidance on the conduct of environmental auditing with regard to proposal for new construction and the upgrading of existing facilities.

The annex provides a technical framework for the implementation of procedures as an aid to the management and development of harbours and landing places for fishing vessels.

1.3.2 Scope and objectives of Annex VI

The proposed procedures are global in scope and directed towards all persons, whether in government or the private sector, involved in the planning, design, construction, maintenance and management of harbours, harbour infrastructure and landing places for fishing vessels.

The objective is an enhanced capacity of States to ensure the adoption of environmentally sound development, management and conservation practices through:

- better standards of management in harbours and landing places for existing and future facilities;
- the establishment of environmental auditing procedures and design criteria related to future fisheries infrastructure projects; and
- appropriate training and education in environmental awareness.

It should be recalled, however, that although the Code is voluntary, some provisions of it may be or have already been given binding effect by means of legal instruments. The same statement effectively applies to this annex, since it contains references to legally binding instruments such as UNCLOS 82, the Montreal Protocol and MARPOL 73/78.

The full text of Annex VI is set out in Annex I.

1.4 INTERNATIONAL CONVENTIONS

1.4.1 United Nations Convention on the Law of the Sea, 1982

The United Nations Convention on the Law of the Sea (UNCLOS) sets up a legal regime for the sea and oceans and thus represents the attempt by the international community to regulate all aspects of the resources of the sea and uses of the ocean. In terms of the environment, UNCLOS establishes material rules concerning environmental standards and enforcement provisions regarding pollution of the marine environment.

The convention addresses ports, baselines, roadsteads and charts, as well as standards, criteria and indicators for assessing protected areas.

1.4.2 Montreal Protocol to the Vienna Convention for the Protection of the Ozone Layer

The Convention recognizes that worldwide emissions of certain substances can significantly deplete and otherwise modify the ozone layer in a manner that is likely to result in adverse effects on human health and the environment.

Substances that are required to be controlled, referred to as "controlled substances", are listed in Annexes A, B, C or Annex E to the Montreal Protocol, on Substances that Deplete the Ozone Layer, whether existing alone or in a mixture, and provisions are made for the gradual phasing out of such substances, for example, certain refrigerants.

1.4.3 International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78)

The Convention desires to achieve the complete elimination of intentional pollution of the marine environment by oil and other harmful substances and the minimization of accidental discharge of such substances. Of particular interest to harbours and landing places for fishing vessels is Annex V and its guidelines, particularly in relation to shoreside facilities for operational waste including fishing gear.

1.4.4 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 and 1996 Protocol Thereto (London Convention)[1]

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972, the "London Convention" for short, is one of the first global

[1] The Joint Group of Experts on Scientific Aspects of Marine Environmental Protection (GESAMP) is an advisory body, established in 1969, that advises the United Nations (UN) system on the scientific aspects of marine environmental protection. At present it is jointly sponsored by eight United Nations organizations *(IMO, FAO, UNESCO-IOC, WMO (since 1968), IAEA (since 1969),* UN *(since 1971), UNEP (since 1977), and UNIDO (since 2006)* with responsibilities relating to the marine environment as a mechanism for coordination and collaboration among them. GESAMP functions are to conduct and support marine environmental assessments, to undertake in-depth studies, analyses, and reviews of specific topics, and to identify emerging issues regarding the state of the marine environment. GESAMP itself consists of ideally 25–30 experts, drawn from a wide range of relevant disciplines, who act in an independent individual capacity.

conventions to protect the marine environment from human activities and has been in force since 1975. Its objective is to promote the effective control of all sources of marine pollution and to take all practicable steps to prevent pollution of the sea by dumping of wastes and other matter.

In 1996, it was agreed to further modernize the Convention and, eventually, replace it. Under the Protocol all dumping is prohibited, except for possibly acceptable wastes on the so-called "reverse list". The Protocol entered into force on 24 March 2006.

1.4.5 United Nations Framework Convention on Climate Change

The convention on climate change is important in that, along with ozone loss, climate change is the embodiment of global environmental change. Global warming is what most scientists currently think will happen as the effect of the additions humankind has made to the natural mixture of the atmosphere. The International Panel on Climate Change (IPCC) has presented a series of research reports on the mechanisms of climate change and the likely rate of future warming. The IPCC has indicated that one likely result of global warming is an increase in the rate of sea level rise. This is not the result of melting of the major ice caps, but of the melting of the smaller glaciers and the thermal expansion of the warming oceans. These two effects will cause the sea level to rise by about 5 mm per year in the future compared with a rate of a little more than 1 mm per year today. The predicted contribution of the melting ice caps is only about 12 percent. The cumulative predicted sea level rise of about 300 mm by 2050 is not large, but it will make the problems of erosion and tidal flooding more difficult to solve and should be addressed when planning harbours and landing places for fishing vessels.

1.4.6 International Convention for the Safety of Life at Sea, 1974

The Conference of Contracting Governments to the International Convention for the Safety of Life at Sea (SOLAS), 1974 (London, 9 to 12 December 2002), adopted amendments to the Annex to the Convention, as amended, in particular, new chapter XI-2 on special measures to enhance maritime security; and, the new International Ship and Port Facility Security Code (ISPS Code).

1.4.7 International Ship and Port Facility Security Code

The International Ship and Port Facility Security Code (ISPS Code) is a two-part document describing minimum requirements for security of ships and ports. Part A provides mandatory requirements; Part B provides guidance for implementation. The ISPS Code applies to ships on international voyages (including passenger ships, cargo ships of 500 gross tonnage (GT) and upwards, and mobile offshore drilling units) and the port facilities serving such ships.

The main objectives of the ISPS Code are to:

- detect security threats and implement security measures;
- establish roles and responsibilities concerning maritime security for governments, local administrations, ship and port industries at the national and international level;
- to collate and promulgate security-related information; and
- to provide a methodology for security assessments so as to have in place plans and procedures to react to changing security levels.

Whereas the ISPS Code does not specify specific measures that each port and ship must take to ensure the safety of the facility, it outlines a standardized, consistent framework for evaluating risk, enabling governments to offset changes in threat with changes in vulnerability for ships and port facilities.

For port facilities, the requirements include port facility security plans, security officers and certain security equipment. In addition, further requirements for ships and for port facilities include monitoring and controlling access, monitoring the activities of people and cargo and ensuring that security communications are readily available.

Chapter XII-2 of SOLAS and the ISPS Code apply to cargo ships of 500 GT and upwards engaged on an international voyage, thus ships engaged in unloading or loading fish or fish products would be covered.

1.4.8 Convention on Facilitation of International Maritime Traffic (FAL), 1965

The purpose of the Convention is to facilitate maritime transport by simplifying and minimizing the formalities, documentary requirements and procedures associated with the arrival, stay and departure of ships engaged on international voyages.

1.4.9 Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing

The Agreement was adopted by the Conference of FAO in November 2009. The aim of the Agreement is to provide a mechanism to combat illegal, unreported and unregulated (IUU) fishing. Key measures that parties to the Agreement will commit include:

- Foreign fishing vessels wishing to dock will be required to request permission from designated ports ahead of time, transmitting information on their activities and the fish they have on board.
- Port States will conduct regular inspections of ships according to a common set of standards. Reviews of ship papers, surveys of fishing gear, examining catches and checking a ship's records can often reveal if it has engaged in IUU fishing.
- They also must ensure that ports are adequately equipped and inspectors properly trained.
- When a vessel is denied access, port States must communicate that information publicly and national authorities of the country whose flag the vessel is flying must take follow-up action.
- These measures apply to foreign fishing vessels not flying the flag of the port State; however, the port State can also apply such measures to their own fishing fleets.

The Agreement sets out that, to the greatest extent possible, Parties shall:

(a) integrate or coordinate fisheries related port State measures with the broader system of port State controls[2];

(b) integrate port State measures with other measures to prevent, deter and eliminate IUU fishing and fishing related activities in support of such fishing, taking into account as appropriate the 2001 FAO International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing; and

(c) take measures to exchange information among relevant national agencies and to coordinate the activities of such agencies in the implementation of this Agreement.

1.4.10 Convention on Environmental Impact Assessment in a Transboundary Context (Espoo, 1991)

The purpose of the Convention is to enable contiguous countries to either, individually or jointly, take all appropriate and effective measures to prevent, reduce and control significant adverse transboundary environmental impact from proposed activities. This Convention comes into play when contaminated dredged spoil from a fishing port needs to be dumped offshore close to international boundaries.

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[2] Such as Memoranda on Port State Control.

1.5 IMPORTING COUNTRY DIRECTIVES

The Code also addresses post-harvest practices and trade within Article 11. Article 11.1.3 sets out that States should set minimum standards for safety and quality assurance and to make sure that these standards are effectively applied throughout the industry. They should promote the implementation of quality standards agreed within the context of the FAO/World Health Organization Codex Alimentarius Commission and other relevant organizations or arrangements.

The first edition of a "Code of practice for fish and fishery products" (2009), under Codex Alimentarius, will assist all those who are engaged in the handling and production of fish and fish products or are concerned with their storage, distribution, export, import and sale in attaining safe and wholesome products that can be sold on national or international markets and meet the requirements of the Codex Standards.

The issue, however, is how to control the food in international trade. At the point of entry the regulatory agency may not always know whether the incoming food was produced under hygienic conditions and the application of HACCP principles. In this situation some criteria would be needed that would have to be established according to the principles described in the Codex documents. An alternative approach may be to allow control of foodstuffs in international trade to be based on signed agreements between internationally recognized and competent bodies.

Consequently, many importing countries impose conditions for the importation of fish and fishery products that translate into conditions to be met by the exporting country and these relate not only to safety in health but also to responsible fishing practices.

An example in this regard are a number of directives issued by the European Commission (EC) that set criteria both for the exporting and importing countries and it maintains an inspection service to monitor and assist exporting countries. Other major importing countries (not members of the European Community) have also set criteria to be met by exporting countries.

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2. Infrastructure needs assessment

SUMMARY

The role of the fishing port may be considered as the interface between the harvesting of a fish and its consumption; thus the type and size of a fisheries port and its infrastructure greatly influence the way and rate at which a country's living marine resources can be exploited. The perceived need for a fishing port, however, is likely to originate from a combination of fisheries management planning and pressure from the industry to meet local consumption needs and of the export market.

In order to plan and design a fishing port that is commensurate with the targeted resources (not too large, not too small, but just large enough), a fishing port planner needs the full cooperation of fisheries managers, hydrographers and those responsible for coastal area management, fishing industry leaders and fishing communities. In particular, the port planner would need to know and understand the resources that have to be exploited (low-value high-volume or high-value low-volume), the catch potential, including seasonal variations, the local or proposed marketing systems, including export potential and consumer preferences (fresh, frozen, salted, smoked or canned fish).

This chapter describes how to plan shore-based facilities and fishing ports that are commensurate with the targeted resources within the EEZ of the coastal State and distant water fisheries, as the case may be, that would be environmentally sustainable and financially justifiable. Attention is also drawn to the aquaculture/mariculture sector. The overall objective is to make the reader aware of the decision-making process following a needs assessment.

CONTENTS

2.1 SIZING A PORT AND ITS FACILITIES

2.1.1 General

The port planner should bear in mind that sometimes new fishing port facilities are designed primarily around a specified fishing vessel's characteristics and performance, as in the case of imported, highly sophisticated and modern trawlers, leading to very complex and expensive port designs; it might, however, be possible that a country's exploitation of its available marine resources would be better achieved by the proper management of existing, indigenous fleets requiring relatively cheaper port facilities.

In some cases, where the costs for the harbour works and associated infrastructure cannot be borne by the fishery industry alone, port facilities are shared with nearby commercial harbours. In order to plan and design a fishing port that is commensurate with the targeted resources, a fishing port planner, in conjunction with the competent authorities, must:

- understand the type of resources and the catch potential of the fish stocks that have to be exploited (the stocks could be seasonal or in danger of collapse if overfished);
- have access to, and advice regarding the latest and most accurate biological statistical data available (data of proven resources taken from actual landings by the existing fleet is preferable to data extrapolated from distant areas) and fisheries management forecasts; and
- obtain knowledge of the size, composition and performance of the existing fleet[1] and fisheries management development plans.

Failure to observe the above three conditions will inevitably result in a port facility that is either too large or too small. A port facility that is too large will either collapse financially or attract too many vessels to a specific area. If a port facility is too small, it too may collapse under the impact of a busy fleet. Ideally, a fishing harbour should be designed for a fleet which is just big enough to handle the current, proven and foreseeable marine resources.

Furthermore, the size of such a fleet and anticipated growth or decline should be specified beforehand by the appropriate authorities (department of fisheries) and not by the port planner.

From the above it follows that it is preferable to underdesign a facility by a shade or two (also known as precautionary design) rather than to overdesign a facility (reactive design): whereas a slightly underdesigned fishing port may put the visible infrastructure under strain, an overdesigned fishing port would put the relatively invisible resources under strain.

In the first case, the strain may be relieved by expanding the fishing port in a phased development process, provided of course that this possible need was foreseen at the design stage, whereas in the second case the effects may be very uncertain and the remedial solution may be impractical, costly or both.

Whether dealing with small motorized canoes or large fishing vessels, fisheries infrastructure generally consists of:

- a safe mooring area (the cheapest form is beaching, the most expensive a deep-water port);
- provision for utilities and boat servicing (water, fuel, workshops);
- fish handling infrastructure (ice, cold storage, sorting areas, processing facilities); and
- marketing infrastructure (local market, road to nearest city market or connection to a motorway or airport).

[1] Note that the reference to the existing fleet could include vessels used for mariculture activities. Appendix 2 provides an insight to the needs of that fisheries sector.

2.1.2 Types of fishing ports

There are obviously different types of fishery operations, each requiring different arrangements. As a result, it is difficult to arrive at clear-cut definitions that fully and consistently characterize port infrastructure. However, one solution is to grade ports according to the type of fishery they serve, i.e. artisanal, coastal, offshore and distant-waters.

Artisanal fisheries usually involve subsistence and artisanal fishermen operating on a daily trip basis a short distance from their village. Vessels typically consist of canoes (paddle, motorized or sail-powered) beached in front of the village (Figure 1).

FIGURE 1
Fully developed artisanal landing

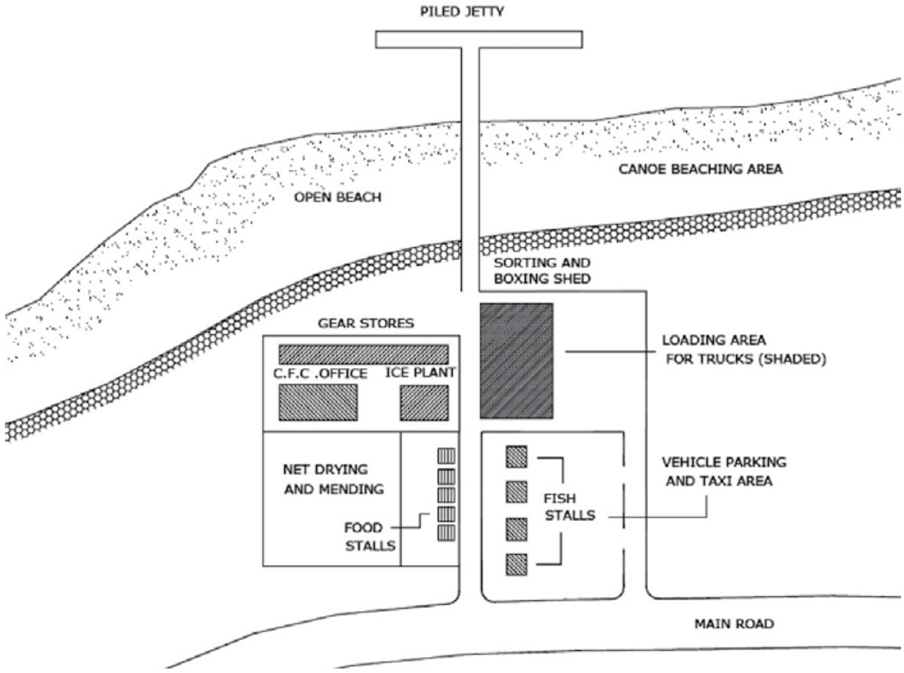


TABLE 1
Fully developed artisanal landing characteristics

Location of fishing grounds	Inshore, steaming distance up to 3 hours.
Typical fishing trip	Anywhere from 6 hours to 24 hours.
Type of vessels handled	Paddle canoes, motorized canoes and other small vessels. Fishing gear usually hand line, pole and line and set nets.
Type of landed products	A mixture of low-volume high-value and high-volume low-value. Paddle canoes high value only. Motorized canoes both.
Typical shore processing	High value – gutting, icing and boxing for onward sale. Low value – drying and smoking.
Minimum water depth required	No depth limitations as all vessels are beached for unloading.
Breakwater protection	In practice, a beach landing does not require protection. Breakwaters on beaches are reactive and unsustainable.
Auction – sorting hall	A sorting hall is required in all cases for icing and boxing. An auction hall is required if fish is auctioned locally as well.
Utilities	Mains power and water preferable. Gensets only suitable in some cases. Boreholes and seawater systems acceptable.
Ice production	Of primary importance. Should only be mains powered otherwise delivered from nearest supplier.
Cold storage	Chilled storage on ice (3 °C) is acceptable even using insulated fish boxes. Otherwise fish should be moved to a proper cold storage.
Refuelling	Small-scale installation (up to 10 000 litres) is the most suitable.
Dry docking – slipways	Slipways are not normally required. Mechanically operated winches for the larger boats are enough.

Table 1, continued

Transport links	The success or failure of the landing depends on good, all-weather road access.
Workshops	Small engine and timber hull workshops required. May be located in village.
Net repair areas	Required in all cases. A minimum of 500 m^2 should be set aside. Area should drain surface water away.
Fishermen's/seamen's facilities	A fishermen's cooperative with full facilities is highly desirable to enable all stakeholders to participate in the fishing, marketing and procurement activities. Adequate number of toilets and canteen facilities should be included.
Open storage and parking	Enough area should be set aside for parking to enable better connection with markets.
Ancillary services	Some landings also offer sea bus transport to other coastal villages and if managed properly should be encouraged.
Hinterland	A resident fishing village community nearby is desirable.

Coastal fisheries usually involve artisanal fishermen operating on one to two day trips from home. Vessels typically consist of large motorized canoes and decked and undecked fishing vessels with a maximum length of about 20 metres. These vessels would either be beached or moored in calm spots, such as bays and coves. In some cases, a proper port may be needed if the landings are high volume (Figure 2).

FIGURE 2
Coastal fisheries harbour

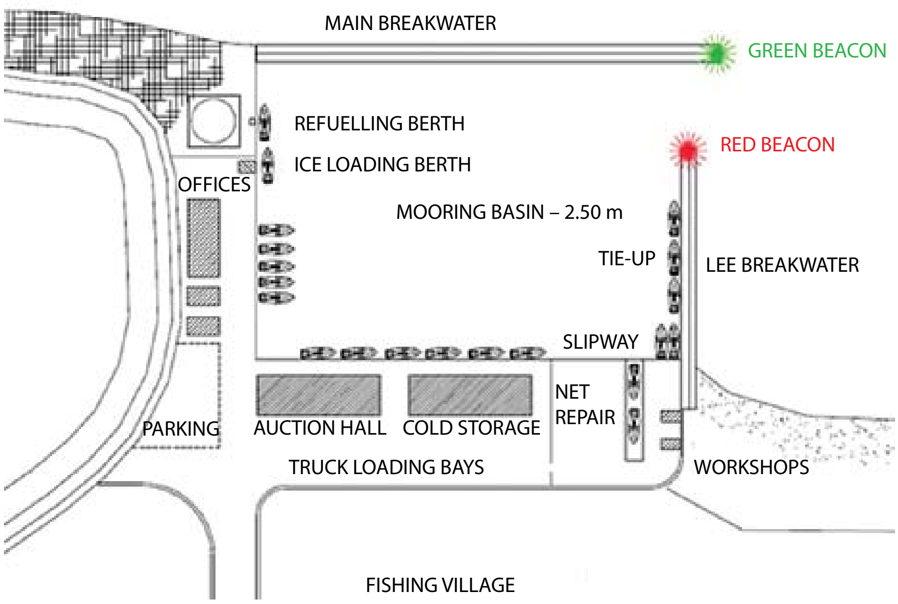


TABLE 2
Coastal fisheries harbour characteristics

Location of fishing grounds	Near coastal, steaming distance up to 6 hours.
Typical fishing trip	Anywhere from 1 to 3 days.
Type of vessels handled	Large motorized canoes and vessels up to 10 tonnes in weight. Fishing gear usually mini seine, pole and line, long line, trawl nets and gillnets.
Type of landed products	A mixture of low-volume high-value and high-volume low-value.
Typical shore processing	High value – gutting, icing and boxing for onward sale. Low value – drying and smoking.
Minimum water depth required	At least 2.50 metres below Lowest Astronomical Tide level.
Breakwater protection	Generally required unless port is inside a river estuary but breakwaters on beaches are reactive and unsustainable.
Auction – sorting hall	A sorting hall is required in all cases for icing and boxing. An auction hall is required if fish is auctioned locally as well.

Table 2, continued

Utilities	Mains power and water preferable. Gensets only suitable in some cases. Boreholes and seawater systems acceptable.
Ice production	Of primary importance. Should only be mains powered otherwise delivered from nearest supplier.
Cold storage	Cold storage required. Chilled storage on ice (3 °C) is acceptable if fish is moved to a proper cold storage elsewhere.
Refuelling	Medium-sized installation (up to 100 tonnes in weight) is the most suitable. Bowser service also acceptable.
Dry docking – slipways	Slipway to handle vessels up to 100 tonnes in weight normally enough.
Transport links	The success or failure of the port depends on good, all weather road access. Road should already exist.
Workshops	Proper engine and timber hull workshops required in loco.
	Steel or GRP hulls may need extra workshop area.
Net repair areas	Required in all cases. A minimum of 1 000 m² should be set aside. Area should drain surface water away.
Fishermen's/seamen's facilities	A fishermen's cooperative with full facilities is highly desirable to enable all stakeholders to participate in the fishing, marketing and procurement activities. Adequate toilet and canteen facilities to be provided.
Open storage and parking	Enough area should be set aside for parking to enable better connection with markets and for dry boat storage in areas where monsoons are active.
Ancillary services	Port may also act as base for coastguard and fishery protection vessels.
Hinterland	A resident fishing village or town community nearby is desirable.

Offshore fisheries usually involve both fishermen and non-fisheries-related business interests who invest in vessel fleets. Fishing trips extend to the limit of the extended economic zone offshore and last anywhere up to four weeks. The vessel sizes are usually in the 20 to 40 metre range and the vessels generally need proper port facilities (Figure 3).

FIGURE 3
Offshore fisheries harbour

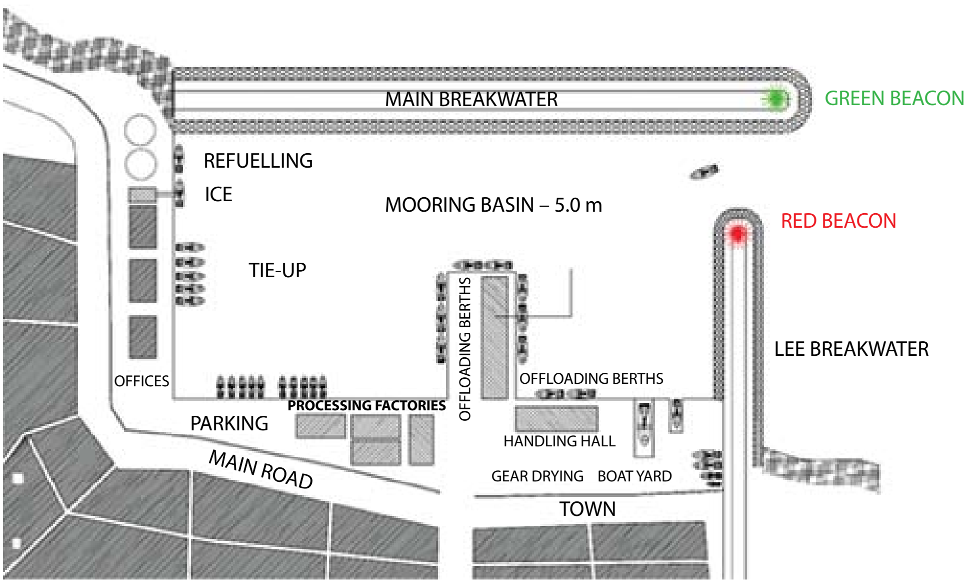


TABLE 3
Offshore fisheries harbour characteristics

Location of fishing grounds	Offshore and far coastal, steaming distance up to 1 week.
Typical fishing trip	Anywhere from 2 to 4 weeks.
Type of vessels handled	Large motorized canoes, purse seiners and trawlers. Vessels up to 100 tonnes in weight. Fishing gear purse seine and trawl nets.
Type of landed products	Mainly iced but also frozen pelagics, shrimps and other high-value species.
Typical shore processing	Canneries, fishmeal, salting, drying and smoking.
Minimum water depth required	At least 5.0 metres below Lowest Astronomical Tide level.
Breakwater protection	Generally required unless port is inside a river estuary but breakwaters on beaches are reactive and unsustainable.
Auction – sorting hall	A sorting hall and auction area is required in all cases.
Utilities	Mains power only and town supplied water. Boreholes and seawater systems acceptable in areas of low rainfall.
Ice production	Of primary importance. Should only be mains powered otherwise delivered from nearest supplier.
Cold storage	Cold storage required for buffer stocks. Chilled storage on ice (3 °C) is acceptable in some cases.
Refuelling	Large sized installation (up to 1 000 tonnes in weight) is the most suitable. Bowser service also acceptable in some cases.
Dry docking – slipways	Slipway to handle vessels up to 500 tonnes in weight normally required.
Transport links	The port is only feasible if road already exists.
Workshops	Proper engine and hull workshops required in loco. Steel or GRP hulls may need extra workshop area.
Net repair areas	Required in all cases. A minimum of 1 000 m^2 required. Area should drain surface water away and be part covered.
Fishermen's/seamen's facilities	A cooperative with full facilities (banking and wholesale supplies) is required. Full toilet and shower facilities as well as canteen services must be included.
Open storage and parking	Enough area should be set aside for parking and storage of seasonal fishing gear, as well as for dry boat storage in areas where monsoons are active.
Ancillary services	Port may also act as base for coastguard, SAR centre, oil spill combat and fishery protection vessels.
Hinterland	A town community nearby is desirable with full facilities, including hotels, hospitals, banking, shipping agents.

Distant-water fisheries involve large, modern, factory-type trawlers roaming the oceans on very long trips, 6 to 12 months at a time. Their home port can be located at specially provided facilities in commercial ports but are considered more effective when specifically designed for the industry within a properly established fishery port (Figure 4).

FIGURE 4
Distant-water fisheries harbour

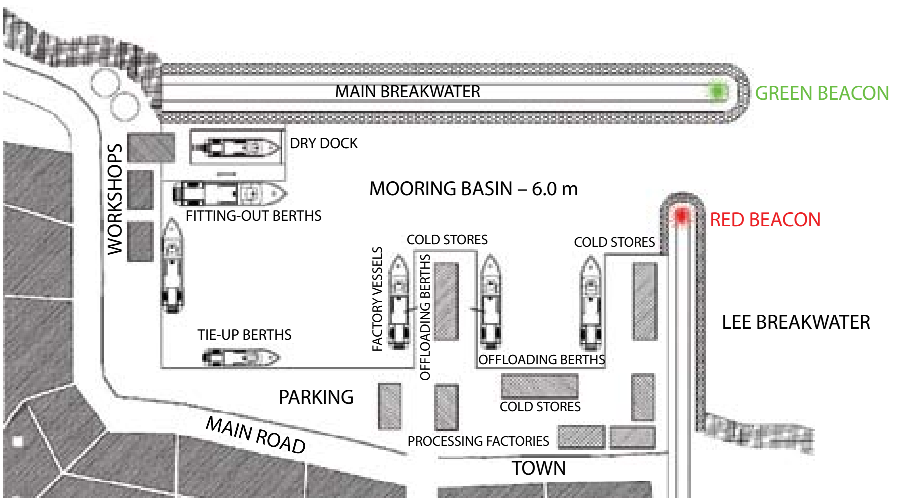


TABLE 4
Distant water fisheries harbour characteristics

Location of fishing grounds	Overseas, steaming distance up to 1 month.
Typical fishing trip	Anywhere from 6 to 12 months.
Type of vessels handled	Large trawlers (500–1 000 tonnes GRT) and factory vessels (5 000 tonnes GRT).
Type of landed products	Mainly frozen, in bulk, individually packed or ready processed for direct sale through commercial outlets.
Typical shore processing	Packaging, canneries, fishmeal and other value added processing.
Minimum water depth required	At least 6.0 metres below Lowest Astronomical Tide level.
Breakwater protection	Generally required unless port is inside a river estuary but breakwaters on beaches are reactive and unsustainable.
Auction – sorting hall	A sorting–auction area is not required in most cases.
Utilities	Mains power only and town supplied water. Boreholes and seawater systems acceptable in areas of low rainfall.
Ice production	Of secondary importance as products are all frozen.
Cold storage	Cold storage required for buffer stocks and local processing needs.
Refuelling	Large sized installation (in excess of 1 000 tonnes in weight) is generally required. Bowser service not suitable.
Dry docking – slipways	Common for vessels to dry dock at established yards, even overseas, hence not important.
Transport links	The port is dependent on road, rail and air transport links.
Workshops	Proper engine and hull workshops required.
	Steel or GRP hulls may need extra workshop area.
Net repair areas	Generally not required as nets are repaired elsewhere due to their size and complexity.
Fishermen's/seamen's facilities	A proper seamen's union with full facilities is required.
Open storage and parking	Enough area should be set aside for parking and storage of seasonal fishing gear.
Ancillary services	Port may also act as base for coastguard, SAR centre, oil spill combat and fishery protection vessels.
Hinterland	A town community nearby is required with full facilities, including hotels, hospitals, banking, shipping agents.

As a general rule:

- The size of the port is governed by the size of the fleet (as indicated by the competent fisheries authority) operating from the port and the type of vessels that make up the fleet.
- The size of the shore facilities then depends on the throughput of fish through the port and the amount of value-added processing proposed.

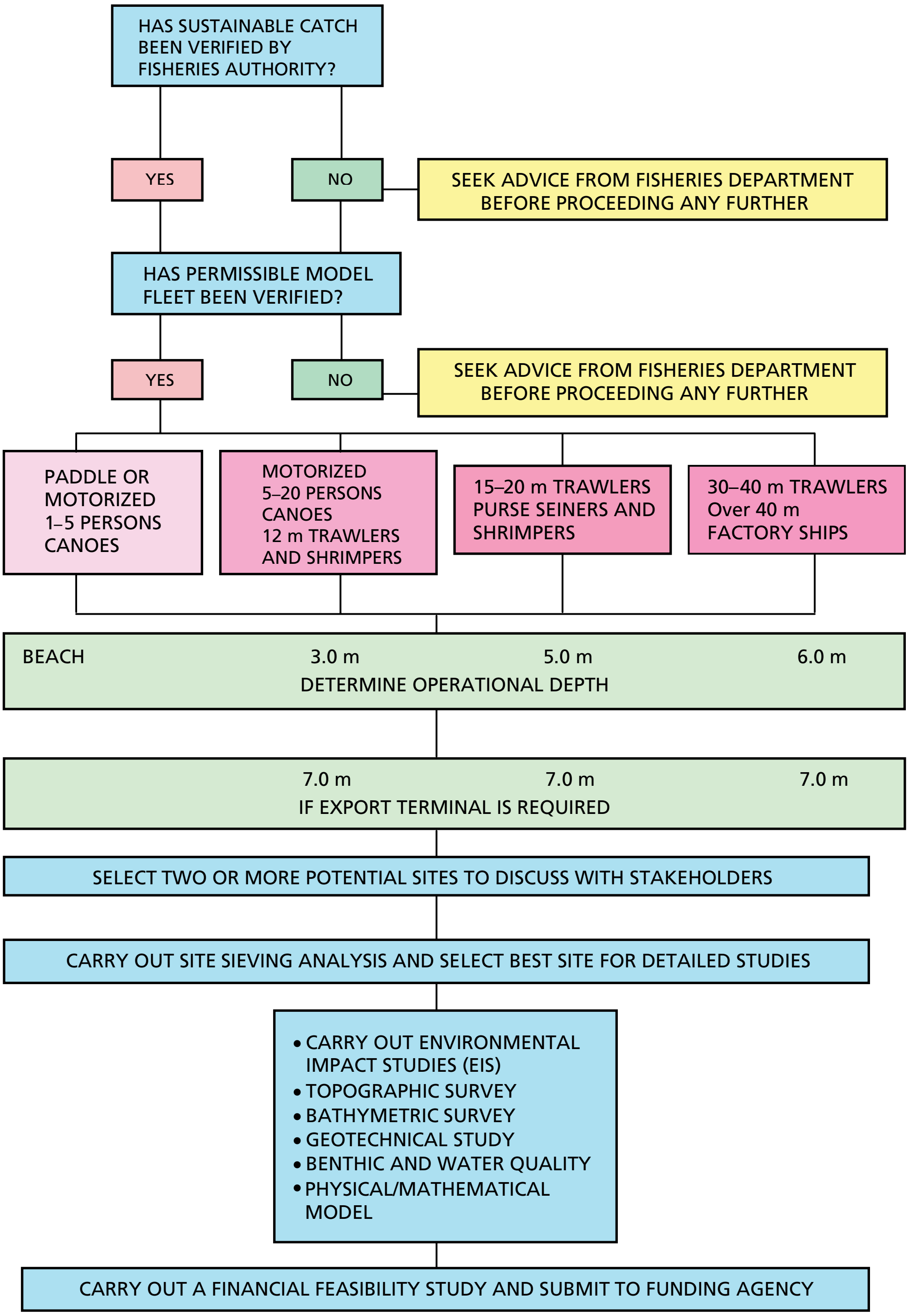
Figure 5 illustrates the flow chart of the design process for a typical fishing port all the way to financial feasibility.

2.1.3 Safe havens

Ports in areas where hurricanes and monsoons are common natural occurrences may need a safe haven or storm shelter inside the port basin or close by as an added safety measure for floating vessels. In some Asian countries, whole vessel fleets are placed ashore for the entire monsoon season and need a considerable level area for this purpose. In the Caribbean, every island has created safe havens (mainly on the leeward side).

However, the subject of safe havens has been given greater attention in recent years in relation to disaster preparedness programmes. Consequently, a port planner should be involved in the development of safe havens, particularly in relation to essential facilities and access.

FIGURE 5
Sizing a port – flow chart



2.2 SITE OF A FISHING PORT

2.2.1 Planning requirements

A new fishing port may be built on virgin land or installed in a rehabilitated existing port environment or even in an urban area. In all cases, the planning process must consider:

- the land use of the area proposed;
- the general environmental conditions of the site;
- the ease of access to the site;
- the availability of sanitary water; and
- existing and future industrial planning.

2.2.2 Land use

In general, when planning a fishing port, whether it be a small landing jetty on a beach or a large deep-water port, it is better to design a layout with arrangements flexible enough to permit adjustment at a future date, if the assumptions on which the needs assessment were based prove to be different to real life conditions. In other words, a fishing port and its land-based infrastructure should not be stuck in between fixed land boundaries (like schools, playgrounds, cemeteries, factory sites, housing, etc.) with no scope for expansion at a later date. Vice versa, if a new port is planned along a stretch of virgin coastline, a suitable buffer zone should be included around the port and land-use master plans should be strictly enforced to ensure that the buffer zone is not settled by illegal service settlements that generally crop up around such facilities in a matter of a short time.

In many cases, especially where there has been a low level of communication between agencies concerned with coastal area management and environment protection agencies, the incompatibility of heavy industries with the fisheries sector is not always questioned. As a result, fishing ports have been built next to or downwind from, *inter alia*:

- large power stations burning coal or heavy oil;
- cement manufacturing or bagging plants;
- wood or paper mills;
- fertilizer and petrochemical plants;
- chemical plants
- oil storage facilities;
- leather tanning facilities; and
- ore export terminals.

In some countries, fishing ports may also be located inside ports for merchant shipping; the reverse may also be true. In some cases, smoke-stack industries have been allowed a foothold inside urban areas that are too close to the fishing port. It is also known that these industries may have even started utilizing the fishing port for their needs. Such practices eventually lead to cross-contamination of the fish products through:

- settlement of particulate matter (dust) on fish and fish products;
- contamination of rainwater collection systems when these are required to supplement other supplies;
- fouling of harbour basin water when this may be required to alleviate the use of freshwater; and
- contamination of the groundwater aquifers themselves.

It is hence of the utmost importance to site fishing ports as far away as possible from such activities.

Clearly, when a new facility for fishing vessels is under consideration there is strong justification for close cooperation between ministries responsible for rural, industrial, urban and fisheries development issues. Such cooperation should extend to ease of access to environmental impact assessment (EIA) reports concerning planning permission for new industrial sites. For those carrying out an EIA they should also take all existing facilities into consideration (such as fishing vessel port facilities). Once a decision has been reached regarding the siting of a fishing port, legislation should be enacted to ensure that all future development in the area would not compromise the fishing port and its post-harvest facilities.

However, it is also incumbent on the fisheries department and the port planner to pay special attention to situations of incompatibility between an existing fishing vessel facility and industrial activities. In such cases where the quality of fish and fish products is adversely affected, a decision must be reached at local or national level as to what should be moved and to where or how such pollution could be regulated and how proposed solutions could be financed.

Unless this fundamental reasoning is accepted by all the parties involved, from local planners and engineers all the way up to local and national government, then unsolved problems of this nature are there to stay and will only lead to more existing fishing ports being condemned on pollution grounds; in effect, if the pollution is so bad, it may be that the industrial site has to be condemned for a multitude of reasons.

2.2.3 Accessibility

No matter what size of port is being planned, all-weather accessibility cannot be ignored or replaced with unpaved roads. Many developing countries tend to regard a good paved road as optional to the port structure due to the costs involved when the road should be part and parcel of the port.

Unpaved, or white or laterite roads, are very common in some developing countries, but in the presence of heavy rainfall these do not last more than one to two years before they require major maintenance.

2.2.4 Water

The rule of thumb where water is concerned is **No Water, No Port.** Water is required at every stage of the fishing process, both on board the vessels (for rinsing and hose-down), and ashore in the port (for rinsing, ice production and hose-down of work areas and hygiene). Whereas a town or mains supply is the preferred option, many fishing ports depend on bore wells. It is now also acceptable to replace up to 80 percent of the potable water needs with clean seawater if the port structures have been designed to resist seawater corrosion.

2.3 POST-CONFLICT RECONSTRUCTION PROCEDURES

Wars or conflicts may also leave a legacy of unexploded ordnance (UXO) contamination and it is therefore essential that this issue is tackled from the outset and at all stages of the project via internationally accepted guidelines on de-mining.

At sea, UXO may be the result of unexploded aerial bombs dropped on naval targets, sea mines or live ammunition dumped overboard in times of distress. In all cases, this may turn up in dredgers contracted out to dredge coastal areas in or near existing ports. As most of this UXO is metal based, a magnetometric survey should be commissioned in conjunction with the bathymetric survey and the position of all the positive “hits” by the magnetometer recorded and then inspected by experienced de-mining divers for presence of actual UXO.

On land, UXO may consist of unexploded aerial or artillery bombs, mortar shells and land mines. Although many areas in the world have been surveyed with a General Mine Action Assessment survey and/or a secondary Landmine Impact Survey, a

Dangerous Area Report, Mined Area Report, and/or a Landmine Impact Survey report for each Suspected Hazardous Area should be referred to before a project is undertaken in an area of known past conflict. This work must be done before the topographical and other land surveys are commissioned.

2.4 PROJECT JUSTIFICATION

Any harbour project, no matter what size, needs to be financially and technically justified if it is going to be planned, designed and managed in a sustainable manner in harmony with the surrounding environment.

Technically, the justification must be backed up with reliable data pertaining to:

- the fish stocks to be harvested (current biomass data and not mathematical extrapolations);
- the methods of fishing to be employed (environmentally sustainable);
- the technical feasibility of the proposed or chosen site (environmentally sustainable);
- the financial feasibility of the entire project (including port, services, access roads); and
- fisheries management programmes concerning fleet development.[2]

Projects with a large social component may not be self-sustaining, but when other social factors are included, such as the supply of safe drinking water, sewerage, lighting, roads, etc., some attempt must be made to monetize the project's contribution to the well-being of the community as a whole.

2.5 OVERCAPACITY IN EXISTING FISHING PORTS

2.5.1 Alternative uses

In many parts of the world, overcapacity in fishing vessels has to be faced by fisheries managers to limit effort within the maximum sustainable yield (MSY) and in many cases the solution has been to reduce the size of the fleet that is allowed to fish. Such a situation can lead to hardship for those associated with the vessels having to be decommissioned (but not necessarily sold or scrapped). This can be particularly traumatic where the fishing port may also be the hub of village life and cannot be simply dismantled.

2.5.2 Port income diversification

The possibilities to keep a fishing port operational and to offer alternative employment to fishing vessel crews is to re-engineer the port into a multioperation facility that does not rely solely on its dwindling fishing fleet but rather by hosting a number of marine-related activities. These activities could include:

- marine transport, ferries, etc.;
- diving tourism;
- eco-fishing tourism;
- support to offshore fish farming;
- coastguard and search and rescue (SAR) activities; and
- offshore industries (oil, gas and minerals).

[2] The reader is reminded that internationally agreed standards for the design, construction and equipment of fishing vessels, a combined effort between FAO, ILO: International Labour Organization, and IMO could influence management decisions as and when the provisions of the pertinent instruments are introduced as regulations in the Fisheries and or the Shipping Act.

2.5.3 Vessel income diversification

In some parts of the world, the need to drastically reduce fishing capacity has led to hardship within the industry with many vessels having to be decommissioned and the crews having to look for alternative employment. In extreme cases it led to death of fishing villages and the migration of the inhabitants to other areas.

However, the re-employment possibilities become limited in cases where there is no requirement for the training and certification of fishing vessel crews and the most probable areas to be under the greatest pressure is the small-scale fisheries sector.

This approach suggested under 2.5.2 above has been taken in a number of cases where the number of active fishing vessels had decreased, although in extreme cases it had not been found to be the complete solution. Appendix 1 to this chapter highlights the need to address the relevant national regulations when a change in a sea-going activity is under consideration.

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APPENDIX 1: CONVERSION OF COMMERCIAL FISHING VESSELS TO OTHER ACTIVITIES

Introduction

It is not uncommon to come across fishing ports with laid-up vessels that are unprofitable to operate or threatened with decommissioning by governments. With the current trend towards overfishing, this scene may become more common unless sound fisheries management practices are followed.

However, forcibly removing vessels from an active fishing fleet over a short period of time is perhaps the most traumatic way of reducing fishing capacity, particularly where the fishing port may also be the hub of village life and cannot be simply dismantled. In such cases, the first priority should be to look at alternative fisheries management systems and alternative opportunities for fishing boat owners and crew in the event that fleet reduction cannot be avoided.

Another aspect of fleet reduction would be the impact on the economy of a port due to reduced income leading to the need to explore other possibilities such as opening the port to non-fishing vessel potential users. This would imply, of course, further investment to re-engineer it into a multioperation facility to host a number of marine-related activities. These activities could include, *inter alia*:

- marine transport, ferries, etc.
- diving tourism;
- eco-fishing tourism;
- support to offshore fish farming;
- coast guard and SAR activities; and
- offshore industries (oil, gas and minerals).

In this appendix, income diversification opportunities for fishing vessel owners and their crews, in the event of a downturn in commercial fishing activities, are discussed that may have less impact on the social fabric of a local fishing community, especially in countries where historic rights exist and vessels are handed down from father to son.

It should be understood, however, that careful consideration must be given by fishing vessel owners forced to move out of commercial fishing, or by choice, into alternative vessel activities. For example, owners would be required to apply to the appropriate ministry for permission to engage in the new activity and, if approved, to apply to register the vessel accordingly. In some cases this may seem a simple process but in general there are a number of issues to address. For example, refitting work has to meet criteria under the relevant act in relation to, *inter alia*:

- the carriage of passengers;
- additional safety equipment;
- certificate of competence of those in charge of the vessel;
- mandatory insurance coverage for third party liability; and
- compliance with MARPOL Annex V if to be certified for 15 or more persons on board.

The carriage of passengers requires that the vessel has adequate accommodation and toilet facilities and the safety equipment would certainly have to be upgraded.

It should also be kept in mind that in many countries the law may not require the skippers of small fishing vessels to have a certificate of competency, but this might not be the case for other activities and the skipper (and others depending on the size of the vessel) would have to "go back to school" or otherwise be examined.

If all goes well it is likely that the vessel would lose its classification as a fishing vessel requiring it to be registered under the appropriate section of the relevant act for which the owner would have to supply documents attesting to:

- confirmation that it would be given licence to engage in sport fishing/diving/ecotourism/passenger carrying;
- compliance with the provisions of the national regulations governing the design, construction and equipment, including safety equipment, of a sport fishing/diving/ecotourism/passenger carrying vessel;
- approval of the provisions for manning;[3]
- the status of the ownership/manager in compliance with national legislation;
- evidence of the bill of sale;
- the carving note;
- confirmation that the refit had been supervised by the appropriate authority;
- the existence of a seaworthiness certificate as a sport fishing/diving/ecotourism/passenger carrying vessel; and
- mortgages and liens.

Thereafter, if all is well and where the authorization to engage in sport fishing/diving, ecotourism or passenger carrying was conditional on the vessel being registered, the one thing remaining would be proof of adequate insurance coverage.

Converting to other activities

Transport of passengers or cargo, diving and eco-fishing tourism activities could have the capacity to absorb some of the excess fleet capacity without destroying the livelihood of the fishermen and this can be obtained through vessel conversions, retooling and retraining. Note, however, that there would be no guarantee that the vessel would be allowed to reconvert to a commercial fishing vessel.

Conversion to mammal spotting and inter-island cruising

Essentially these activities would fall under regulations for the carriage of passengers and these would undoubtedly differ from region to region. Nevertheless, these regulations are unlikely to fall under the fisheries act. For this reason, conversion to the role of passenger carrying would mean that the vessel would no longer be a commercial fishing vessel. Consequently, the existing entry in the register of vessels would have to be closed and the converted vessel registered anew. In addition, it is likely that the following would have to be addressed:

- certificate of competence of the skipper and crew;
- safety equipment;
- accommodation and toilet facilities;
- authority to carry passengers;
- compliance with the collision regulations; and
- compliance with the provisions of Annex V of MARPOL (particularly if certified to carry 15 or more persons).

Conversion to sport fishing

Whereas the authorization to fish (where, when, how, species allowed and quotas) would normally fall under the Fisheries Act, the regulations covering the vessel and crew might fall under a different act. Furthermore, since the objective would be to carry "fee paying" sport fishers, it is likely that the vessel would fall under the regulations concerning the carriage of passengers and as such the conditions set out above would have to be met.

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[3] Note that the manning requirement for a sport fishing vessel, dive vessel and ecotourism vessel would be related to the safety of numbers of "sport fishermen"/"divers"/"tourists" that the vessel is so authorized to carry. The manning for a dive boat includes members of the crew specialized in diving techniques and technology.

Since the vessel would have to be classified as a sport fishing vessel, it would cease to be a commercial fishing vessel and this would have to be reflected in the process for the register of fishing vessels or ships as the case may be.

Conversion to a dive boat

Dive boats fall into two basic categories:
(i) commercial fish harvesting; and
(ii) non-fishing activities.

The first category falls under the Fisheries Act and would be subject to regulations concerning the design, construction and equipment for dive boats and compliance with fisheries management.

To convert a fishing vessel to a commercial fishing dive boat means addressing:
- the design, construction and equipment standards set out for such vessels;
- meeting the operational regulations related to qualifications for the skipper, crew and divers; and
- compliance with the collision regulations.

However, a dive boat for non-fisheries activities is unlikely to fall under the Fisheries Act in relation to its design and construction.[4] The actual conversion may be relatively simple but the manning of the vessel and specialized equipment needs to be addressed.

Therefore, provided that a typical small trawler, for example, with wheelhouse forward and fish hold aft has a clean bill of health as a fishing vessel, it could be readily converted to a dive boat provided special attention is given to the operational safety and facilities. In this regard, it is essential that the person in the wheel house has a clear uninterrupted view of the working deck and that the diving ladder has to be so arranged that the diver would be protected from the propeller. Toilets and changing accommodation would also have to be supplied, as divers might be a combination of male and female.

All safety equipment would have to be upgraded on the basis of the number of persons that the vessel would be authorized to carry, bearing in mind that the fee paying divers would be classified as passengers.

It should also be noted that the certificates of competence held by the serving skipper and crew (when it was a fishing vessel) may not be compatible with the regulations covering dive boats which would mean retraining (and examination) or replacing with suitably qualified persons. In addition, the expert diver in the crew must be suitably qualified and the whole crew, including the skipper, should undergo appropriate training before taking on board fee diver/passengers.

[4] The Fisheries Act may have to be addressed if the intention is to carry out sport fishing activities.

APPENDIX 2: SERVICING MARICULTURE FACILITIES

Introduction

Engineering solutions, such as for fish cages or suspended shellfish growout systems, have had to be developed by aquaculturists themselves. They have benefited, however, from the accumulated knowledge of seafarers in general and fishermen in particular in the design and operation of mooring and buoyage systems. More recently, when fish farmers have turned their attention to how to operate fish cages in locations further offshore where seas are rougher, the experience of the oil exploration industry has proven very valuable.

However, although most fish farming activities usually take place well away from a port or harbour facility, that sector is serviced by different types of seagoing craft that, in turn, require servicing. In addition, the sector also need, land space to prepare cages and pens for launching that might require cranes and close proximity to a fishing port or harbour facility is often preferred, particularly where offshore fish farming is practiced. Thus, during a harbour planning exercise the mariculture sector should not be ignored and indeed special attention should be given to the extent of development within the sector foreseen by fisheries managers.

Nevertheless, there are instances when a hatchery might actually be placed within the confines of a harbour facility, as shown in Figure 1, thus calling for space, access, clean (fresh/sea) water supplies and drainage systems.

FIGURE 1
Hatchery operation located within a harbour facility

Vessel servicing

The servicing of work boats in support of fish farming run parallel to the capture fisheries sector, with vessels varying in size from a sturdy canoe to relatively sophisticated vessels capable of towing large heavy sections and fitted with specialized deck equipment and, in some cases, diver support capability.

Particular attention must be given to hull cleaning, paint quality and the avoidance of the use of tributyltin-based antifouling compounds.

Land space

Cages vary in design from completely spherical shape up to more than 30 metres in diameter, to the more common tubular or cylindrical shape that may commonly vary in diameter from 20 metres to over 300 metres[5], as well as square or oblong cages. All types, however, require reasonably large areas of flat ground for their construction and the need for ready access to the sea.

Marking the position of cages in the sea

Cages and fish pens are a navigational hazard; consequently, they must be marked for their position in the sea by lights and shapes approved by the appropriate authority (Figure 2).

When an aquaculture farm is considered to represent a danger to navigation, it should be marked in accordance with the International Associations of Marine Aids to Navigation and Lighthouse Authorities (IALA) Maritime Buoyage System, using special marks, lateral or cardinal marks, or a combination thereof. The use of electronic aids to navigation such as racons or the Automatic Identification System (AIS) may also be considered. The farm (or group of farms) should be marked depending on their size, extent and location. In some cases, it may be sufficient to mark only part of the perimeter or the centre.

The harbour engineers should bear in mind that the following marking recommendations may be adjusted considering traffic density, proximity to ports, proximity to dangers, tidal considerations and other factors:

- Aquaculture farms are normally marked by special marks.
- If there is a requirement for vessel traffic between aquaculture farms, then such a channel should normally be marked with lateral marks.
- If the prevailing situation warrants it, cardinal marking alone may be used to direct mariners away from the aquaculture farm.
- To improve the effectiveness of the lighting, and taking into consideration background lighting, synchronization of the various lights should be considered.
- To improve the radar target and the visibility of the aquaculture farm, radar reflectors and reflective material should be considered.

Furthermore, charts need updating and notices to mariners issued from time to time. There is also a need to follow technology development in this sector such as self-propelled cages that requires the attention of harbour masters, national hydrographers, fisheries management and may require amendments to appropriate legislation.

FIGURE 2
Marking offshore fish cages

[5] The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) lighting and marking requirements cater for radii up to 2 000 metres.

3. Port management

SUMMARY

Irrespective of the size of an existing or projected port, whether it is for beach landing or a conventional port, that facility cannot be abandoned in the belief that it would run by itself. Experience has demonstrated that this is not so and that the facility has to be managed to ensure that it is used and maintained correctly over the period of its useful life and for a government to meet its responsibilities under international law.

Therefore, this chapter addresses a wide range of issues, from beach landing sites to integrated port facilities catering for fishing vessels and non-fishing vessels and ships. Thus various types of port management schemes are illustrated and how to select an appropriate option commensurate with the size of the port or landing facility, stressing nevertheless the responsibilities expected of selected regime and individual members.

The principal objective of this chapter is to ensure that the reader would be able to relate to specific management structures and issues under discussion and have a more clear understanding of individual and corporate responsibilities in the management and use of a facility.

CONTENTS

3.1 PORT MANAGEMENT STRUCTURES

The most effective way to run a fishing facility, whether it be for beach landing or a fully-fledged port, is through the establishment of a management body for the facility, representing the interests of all stakeholders. The right to do so, however, is not always resident in national law. The chief duties of a port management body are to ensure:

- compliance with the laws, regulations and other environmental directives governing the fisheries sector (overfishing legislation, sizes of nets, closed seasons, etc.);[1]
- compliance with the regulations for the use of the facility (landing fees, bulk handling charges, sale of potable water, bulk fuel, etc.);
- compliance with environmental conservation measures adopted by the planning authorities (waste recycling, spent-oil recovery, wet wastes disposal, etc.);
- compliance with food safety and hygiene requirements;
- integration with other users as in the case of a non-exclusive facility for fishing vessels (landing jetty may double as a passenger landing stage for coastal taxi boats); and
- transparency in the decision-making process (to prevent private interests from taking over a public facility through unfair practices).

In order for the port management body to perform its duties effectively, it must:

- be commensurate with the size of the facility and the responsibilities expected of it (one person could be enough for a small beach landing but a group of persons would be necessary inside a harbour with a large fleet of canoes, plank boats and other types of vessels);
- be adequately funded to function as intended (landing fees and handling charges should reflect current maintenance and running costs);
- represent the whole spectrum of users of the facility (if the facility doubles as a passenger landing, then the interests of the passengers must also be taken into account);
- allow for consultation between the various users (if one of a multitude of user subjects the landing or port to abnormal stresses, then this should be reflected in the maintenance charges).

3.1.1 Size and composition

Because of the diversity of situations and circumstances in which fishermen operate, it is extremely difficult to present ready-made solutions for the size and composition of a port management body. However, there are four major areas where management input is required:

- the day-to-day management of operations (unloading, sorting, icing and onward movement plus any other activity that the landing may be used for) and general maintenance;
- financial administration of the facility (fees for services rendered, licensing, sale of water and fuel, etc.);
- landing statistics; and
- administration of hygiene standards throughout the facility.

It follows that a typical port management body is generally composed of a minimum of four persons: a harbour master, an accounting officer or bookkeeper, a fishery statistics officer and a hygiene/pollution controller. A fifth person may assist the harbour master with maintenance issues when the need arises. Whereas the harbour

[1] Attention is drawn to the *Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing* adopted by the Conference of FAO in November 2009.

master's job is a full-time occupation, the other posts may be either full-time or part-time, depending on the throughput of fish at the harbour facility and the availability of trained staff.

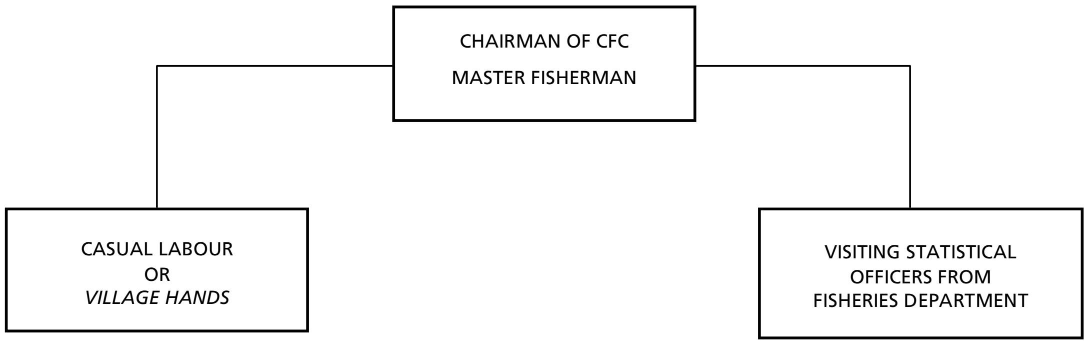
At the extreme lower end of the scale, when the landing is an artisanal beach landing, the harbour master may do all the work himself on a full-time basis and only hires workers or local village hands for specific jobs, such as repair work, cleaners, etc., when the need arises. Fisheries officers would then visit the site occasionally to gather statistics information. As the facility increases in size and importance, even the five persons mentioned above would not suffice and additional personnel would be taken on to monitor port security, fishing practices, auctioning and cleaning operations. School teachers are often employed as part-time officers in their respective field of expertise (biology and mathematics or science).

At the extreme upper end of the scale, when the port is an industrial distant fisheries port, an autonomous, municipal, state or even a private management body may be set up to run and manage the facility.

3.1.2 Artisanal landing

At the village level, the management body could consist of the community fishery centre (CFC) or a similar organization of fisherfolk. Although the facilities and services within a small village landing may be quite modest, there is still need for an organized form of management (Figure 1).

FIGURE 1
Managing a beach landing



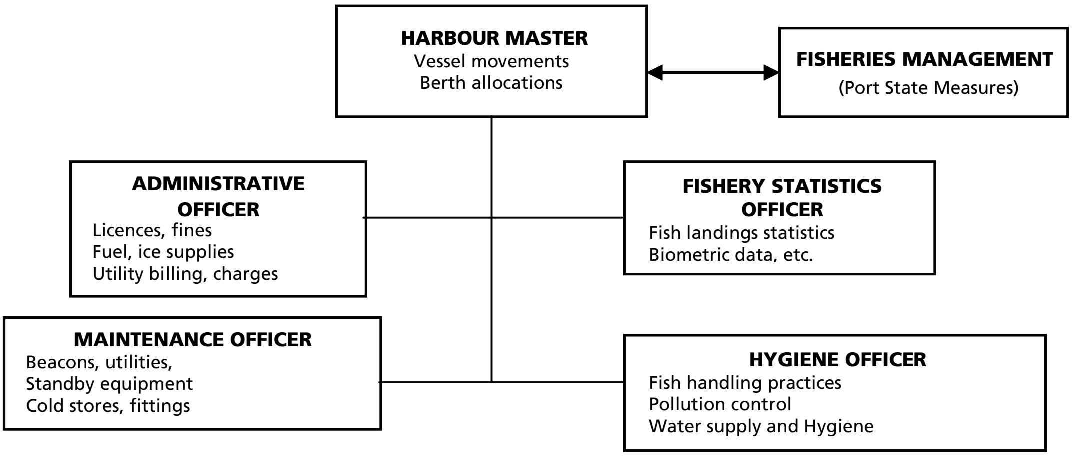
In developing countries, a master fisherman is normally appointed to run the landing with the power to hire casual local labour when the need arises. The master fisherman answers to the chairman of the CFC or directly to the village head. Fisheries officers may visit the village on a regular basis or local staff may be trained in the correct methods of recording fish landings.

3.1.3 Coastal fisheries port

A coastal fisheries port, with its myriad of fishing vessel types, which may range from simple paddle canoes all the way up to 12 metre trawlers and shrimpers, is the first type of port that requires a proper full-time management body installed in proper office space in the fishing port.

The minimum of five persons is required for the proper functioning of the port but generally a few extra staff members are always required, especially during peak landings (Figure 2). A port of this size is quite frequently run by the department of fisheries but in some countries a fishermen's cooperative is set up under the auspices of the department of fisheries to run the port on a commercially viable basis.

FIGURE 2
Managing a full-scale fisheries-only port



3.1.4 Offshore fisheries port

The landside facilities of an offshore fisheries port are considerably larger and more complex than those of a coastal fisheries facility. This type of port is normally within an urban environment and may also be used for:

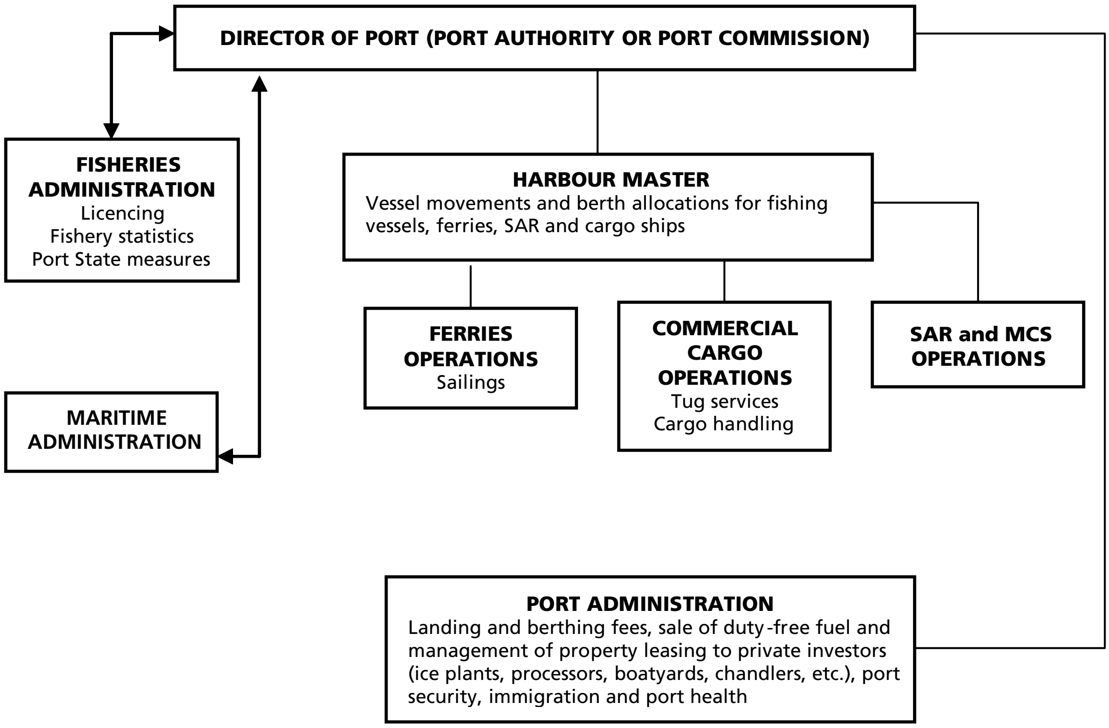
- exporting fish and fishery products directly to foreign destinations;
- basing coast guard assets; and
- ferry operations to neighbouring ports or countries.

In such cases, the fisheries port management body would operate within the context of a port administration where all the stakeholders would be represented, especially the country's national port authority (sailings to foreign destinations), immigration and police (point of entry/exit), coast guard (SAR), fisheries department (landings, hygiene, and monitoring, control and surveillance [MCS]), and travel operators (ferries). A port director would normally be appointed from the port authority or the coast guard to run such a port.

The ownership of this type of port varies from country to country and depends on the number of activities carried out from the port. Some countries classify ports as municipal, regional or central government depending on the throughput and source of funding. Others lump all sea ports under the national ports authority, while others still place all fishing related ports under the care of a fishing ports authority to distinguish them from commercial ports. In the former type, the port management body is commercially oriented while in the latter it is fisheries oriented. Figure 3 illustrates the hierarchy of a typical mixed-use port.

It is not uncommon for such ports to be run privately or under autonomous trusts or commissions, in which case the port director answers to an autonomous body. However, both fisheries and maritime administrations have an impact on the use of harbours in line with regulations in respective acts as mentioned in Chapter 1.

FIGURE 3
Managing a full-scale mixed-use port



3.1.5 Distant fisheries port

The landside facilities of a distant fisheries port comprise mainly of fish processing or forwarding operations and all the products landed at the port are either already frozen or already processed and packaged aboard factory vessels. Distant fisheries ports almost invariably sit in an urban environment due to the requirement of factory workers to run the processing operations.

Ownership and management of distant fisheries ports are similar to offshore fishing ports except for the fact that only large vessels are handled in the fisheries area, such as large trawlers, factory trawlers and mother ships and vessels engaged in the transshipment of fish and fisheries products.

3.2 MANAGEMENT BODY

3.2.1 Harbour master

The harbour master is the single most important person inside a harbour and decides how a harbour facility is used. Ideally, harbour masters should generally be recruited from former captains of vessels, who are usually fully conversant with maritime regulations and the navigational and operational needs of fishing vessels. In addition, a good harbour master should also be knowledgeable in:

- maritime law, seamanship, cartography;
- maintenance of infrastructure components (hydrography, dredging, beacons, fendering and, to a lesser extent, public lighting, cold storage, etc.);
- fishery statistics, national licencing arrangements, fishing gear regulations, etc.; and
- public hygiene and pollution prevention.

Generally speaking, the smaller the harbour or fishery landing, the more knowledgeable the harbour master has to be (to compensate for a smaller management body with fewer staff). In cases where a number of fish landing places exist a few kilometres apart, such as along big river estuaries or long rectilinear coastlines, one good knowledgeable harbour master may be employed full time to look after more than one facility. The principle tasks of the harbour master include:

- day-to-day management of the facility (ensuring that all users are following regulations);
- berth allocation and vessel traffic management; and
- implementing vessel arrival timetables in line with auction schedules.

3.2.2 Administrative officer

Whether full-time or part-time, the administrative officer has the task of keeping the harbour's books in order. The tasks would include:

- keeping a record of all the licenced craft operating from the facility, liaison with those responsible for the issue of a licence to fish and, where applicable, the register of the vessels and keep records as may be required.
- accounting for the cash receipts for harbour dues and fish handling charges;
- sale of potable water and fuel to vessels inside the port facility; and
- administer the fines imposed by the harbour master.

In busy ports, the administrative officer usually asks staff to assist in duties. The administrative officer, whose work generally decides the size of the harbour's operating budget, reports directly to the harbour master.

3.2.3 Maintenance officer

The maintenance officer, whether full-time or part-time, is generally charged with keeping the harbour infrastructure in good working order. If the harbour is too small to support even a part-time maintenance officer, the duties fall on the harbour master himself. Typical duties of a maintenance officer include:

- regular maintenance of the harbour beacons (batteries, cables, lamps, etc.), light fittings, fences, painting of steel structures, maintenance of port boundary; and
- occasional maintenance of the harbour's water supply system (replacing corroded pipe work, leaking taps, unblocking water drains, replenishing the chlorinators, ensuring the waste collection receptacles are in good working order and that the port's wastes are being handled according to the approved waste disposal plan, ensuring that the generator or pumping equipment is serviced regularly or that the right spares are available, etc.).

The maintenance officer reports directly to the harbour master. In cases where a number of fish landings exist close to one another, a full time maintenance officer may be employed to look after a number of facilities.

3.2.4 Fisheries statistics officer

The fisheries statistics officer, whether part-time or full-time, is usually a government employee (fisheries department) seconded to the port management body. The officer's duty is to compile statistics on the resources being harvested. The importance of accurate fishery statistics cannot be adequately stressed in today's climate of overfishing, stressed stocks, quotas and habitat degradation. His observations must include:

- name of vessel and its licence to fish as well as details of its registration;
- quantity of species harvested;
- individual fish sizes and/or weights, especially undersized fish; and
- wholesale prices fetched at the local auction (unless already computerized).

The fisheries statistics officer usually fills in data forms supplied by his department and these are sent to his headquarters for analysis. This work is of the utmost importance if fisheries are to be developed on a sustainable basis, because if the landed fish sizes suddenly drop it is this officer who will sound the first alarm bells that the resources are being overfished. Nowadays, computer programmes are widely available for this data to be filled in and sent to head office in real time, especially if linked to a computerized system. With the advent of area-wide WiFi networks running off the mobile telephony system, Private Virtual Networks or PVNs are easily set up and enable data to be transmitted in real time. Although vast quantities of data are normally generated, the use of dedicated statistical software makes the mundane task of reducing the numbers to valuable reference statistics an easy task.

3.2.5 Hygiene officer

The hygiene officer, whether part-time or full-time, may also be someone from government (ministry of health) seconded to the port management body. With the rising importance of fish as a primary source of healthy food, concern on the possibility of tainted fish entering the food market chain has been rising. The hygiene officer has to ensure that:

- the handling of fish or fish products is carried out according to international standards of hygiene in order to prevent contamination during handling;
- only sanitary standard water is used to wash fish for onward sale and that samples from the port's water system are regularly tested in an approved laboratory;
- the port area and its immediate surroundings are not fouled-up or invaded by sewage, rats and other vermin;
- that the port's hygiene facilities are kept clean and functional; and
- that contaminants (diesel, oil, petrol, etc.) do not come into contact with the fish.

The hygiene officer usually reports to both the harbour master (who acts on the hygiene officer's observations) and to the ministry of health. In many instances, the hygiene officer is based inside the ministry of health and covers and regularly visits more than one facility, such as, for example, abattoirs, factories and cold stores in the vicinity of the port.

3.3 STAKEHOLDER PARTICIPATION

Practically all the management strategies used to date to manage fishing ports may be described as top down, and these have not always resulted in the sustainable management of the port or landing facility. Nowadays, various participatory styles of management, commonly referred to as bottom-up or community-based management, are being introduced to foster a greater involvement of all the stakeholders in the management process and, as a result, greater transparency. The underlying premise is that the stakeholders are empowered both by this participation and by the sharing of responsibilities for the general upkeep and housekeeping inside the port.

In terms of participation, there is a need to describe the participant groups – not only fishermen or owners of vessels, but also other groups that may have a stake in the operational matters of the port and the extent to which these various stakeholders should and may participate. Concern is raised regarding the participation of a range of stakeholders with diverging interests as this might become counterproductive and may make daily management of the port impractical.

Participation will also expose disagreements among some of the stakeholders that may require additional discussion, thereby slowing down the decision-making. There are also concerns about the possibility of conflicts of interest if certain stakeholder groups are allowed an upper hand in the day-to-day management of the facility.

The stakeholders in a typical artisanal landing may comprise:

- owners of individual paddle or small two- to three-person canoes (self-employed fishermen);
- owners of large canoes or trawlers, employing 10- to 20-person crews (normally investors);
- crew associations (local village hands)
- unloaders (local formal and informal beach hands);
- fish mammies;
- fish smokers;
- other processors;
- ice suppliers;
- fuel and fuelwood suppliers; and
- transporters.

Further up the scale, in coastal or offshore fishing ports, the fisheries sector may be sharing the port with other users or the port may be located in an urban area. These additional stakeholders may comprise:

- other institutions (coast guard and police, municipality);
- other sectors of the economy (restaurants and hotels); and
- transport (ferry operators).

Participatory types of management, where responsibilities for port management functions are shared between fisheries and various user groups, are generally referred to as involving some level of co-management. In artisanal landings and coastal fishing ports, a legally-constituted fisheries cooperative or fisheries management organization (FMO) could be set up to co-manage the port and specific roles and tasks delegated to the various participants. The composition, the participatory skills and the capabilities of the various interest groups involved will affect how the cooperative functions. If responsibilities are fully devolved to a particular organization such as a cooperative or an FMO, then the approach may be described as community-based management.

Near the upper end of the spectrum (offshore or distant fishing ports), there may be arrangements for a forum for dialogue between stakeholders and the management authorities, but final decisions may still be made by those representing the owners/operators of the port.

In between the foregoing there may be arrangements where the fisheries authority has delegated much of the management responsibility to stakeholder groups, but where the authority retains certain key or basic overall decision-making powers.

Regardless, the objective of these approaches is to increase the participation of stakeholders and the transparency of the management process.

3.4 FISH QUALITY ASSURANCE

Assuring fish quality and food safety in a fishing harbour is aimed at reducing post-harvest losses and to ensure the proper handling of fish at sea as well as on shore so that the fish leaving the fishing port is of an assured quality and safe for human consumption. There are no specific regulations for the proper handling of fish on board vessels and at the fishing ports. However, both national and third country notifications and guidelines exist on food safety regulations covering cleanliness and sanitation of food contact surfaces, transportation boxes and water used in the processing chain. To achieve the desired quality assurance, food safety regulations should be integrated into a best management practice plan.

3.5 BUSINESS PLAN

Each facility, whether it is an artisanal landing or a fully-fledged port, should operate independently and generate enough revenue that can be used for the day-to-day maintenance and management operations.

The main part of a business plan is the financial plan, aimed at producing an economically viable port operation. The financial plan should identify and balance all maintenance outlays and operational costs with the revenue generated. Traditionally, investment costs, replacement costs and capital dredging costs are absorbed by the central government as and when they become due.

Revenue may be generated by:

- berthing fees charged for vessel mooring;
- fish landing charges, related to volumes handled;
- sale of ice, water and fuel;
- third party licence fees for commercial activity within the facility such as boat repair, engine workshops, food and beverage sales, fish stalls, etc.; and
- rent or lease of areas for private development, such as fish processing and packaging.

3.6 BEST MANAGEMENT PRACTICES

A fisheries port or landing should be provided with a set of best management practice guidelines for the proper management of the environment in and around the fishing port to achieve the desired level of quality assurance of the handled product. Best management practice guidelines should be drawn up for the following:

- port operations;
- boatyard operations (when a slipway is present); and
- prevention of pollution.

3.6.1 Port operations

In order to avoid, minimize and address potential environmental and management problems arising from port operations, the port management body should:

- comply with national environment and safety legislation to avoid or minimize potential impacts from vessel movements and operational emissions and wastes;
- inform all the port users about the sensitivity of the coastal environment and the potential impacts certain actions may have on the well-being of this environment. This may be achieved by strategically placed notice boards, leaflets and running of regular workshops;
- educate, train and encourage staff to avoid and minimize pollution;
- ensure that all employees (including crews from visiting vessels) follow simple good housekeeping practices to minimize the amount and type of wastes generated;
- draw up and display port users' code of conduct and fines to be levied in violation thereof;
- consider best incentives to vessel operators to avoid or minimize potential effects from vessel operations;
- consider the zoning of certain activities in space or time to address adverse impacts through the creation and enforcement of local by-laws;
- make data routinely collected by the fishing port available to national agencies that have the statutory duty to monitor conditions within fisheries; and
- liaise closely with national conservation agencies to facilitate early identification of potential impacts.

3.6.2 Boatyard operations

Vessel repair facilities pose special environmental concerns in a fishing port because of the processes and chemical materials that they use and their proximity to areas where fish meant for human consumption is handled. The area of major concern in a boatyard is hull stripping and painting. The port body should ensure that:

- abrasive or sanding is performed under covered tarpaulin enclosures or boat skirts;
- abrasive or sanding is performed over a horizontal hard impermeable surface, such as concrete, to enable proper cleaning of surface and collection of wastes;
- whenever possible, vacuum sanders are used to limit the amount of dust generated;
- sanding dust and paint chippings be removed on a daily basis and appropriate covered waste containers be provided within the facility;
- a list of the above work practices be posted at the work area for the benefit of the "do-it-yourself" vessel owners who may not be aware of the port's environmental regulations;
- techniques such as brushing and rolling take precedence over spraying to reduce overspray and solvent emissions;
- all painting be performed under covered tarpaulin enclosures or boat skirts;
- all painting be performed over a horizontal hard impermeable surface;
- whenever possible, solvents and coatings with low volatility be used;
- waste paints, solvents and rags be stored in covered waste containers to prevent evaporation to the atmosphere; and
- workers under the boat skirt be provided with appropriate full-face masks and solvent-resistant gloves.

3.6.3 Prevention of pollution

In order to avoid, minimize and address potential contamination problems arising from the day-to-day running of the port, the port management body, through the services of the hygiene officer, should ensure that:

- all food contact surfaces are cleaned and sanitized as per cleaning and sanitation schedule prepared in accordance with the required international standards;
- all the water (both fresh and seawater) and ice utilized inside the port is free of contamination and checked along pre-established national guidelines by approved laboratories;
- all hygiene infrastructure inside the port is in perfect working order and that defects are reported in an orderly fashion and repairs carried out;
- enough stockpiles of detergents and cleansing chemicals are kept on site and stored according to the manufacturer's instructions;
- the entire port area, including slipway, boatyard and servicing area, is swept and kept clean at all times;
- minor mechanical repairs involving oil or grease are not carried out on the quay or on the vessel deck;
- sewage treatment infrastructure is kept in perfect working order;
- the appropriate waste reception facilities are used as specified (bilge water separator, spent oil tanks, solid wastes bins and wet wastes bins);
- no spillage of fuel takes place within the port confines and fuel/oil absorbent materials are kept ready for use;
- a pest control schedule is implemented and monitored on a routine basis; and
- fines levied for infringements reflect the true cost of the impact on the environment.

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4. Environmental auditing

SUMMARY

The marine environment, including the oceans, all seas and adjacent coastal areas, forms an integrated whole that is an essential component of the global life-support system and a positive asset that presents opportunities for sustainable development.

Degradation of the marine environment (loss of marine habitat like coral, declining fish stocks, polluted seas, disappearing beaches, mangrove destruction) can result from a wide range of activities on land. Human settlements, land use, construction of coastal infrastructure, agriculture, forestry, urban development, tourism and industry can all affect the marine environment. Coastal erosion and siltation are of particular concern. Hence, rational use and development of coastal areas as well as conservation of the marine environment require the ability to determine the present state of these ecological systems and to predict future conditions.

Thus, systematic collection of data on marine environmental parameters is needed for an integrated management approach to sustainable development and to predict the effects of the construction of a port on the marine environment.

This chapter reviews the marine environmental parameters utilized by environmentalists to predict the effects of the construction of a port or fishing vessel landing site on the surrounding marine environment.

Within the decision-making process, regarding where to construct a port or fishing vessel landing site, the objective is to have ensured that there would be minimum adverse effects on the surrounding marine environment.

CONTENTS

4.1 ENVIRONMENTAL STUDIES

4.1.1 Introduction

In developed countries, environmental audits in support of all applications for the construction, upgrading or re-engineering of fishing ports are mandatory and planning permission only granted for successful outcomes.

In developing countries, especially those with less stringent regulations, the sense in carrying out environmental audits is sometimes not fully understood when planning a new port or remodelling an existing facility, thus the audit may be considered to be superfluous or a costly obstacle to development. On the other hand, in some instances, planning permission may be granted at the highest level of government with the understanding that environmental studies would be carried out by the developer. This may seem to be acceptable if it is conditional as to what type of outcome would be acceptable, but this may not always be the case.

Therefore, in general, an environmental audit should be drawn up in support of all applications for the construction or improvement of harbours or landing places for fishing vessels, whether in coastal zones or inland waters. For both small and large projects alike, the port planner should first seek advice and/or guidelines from the relevant ministries (environment, fisheries, etc.) before embarking on an environmental audit. In most day-to-day cases, projects are usually small and by themselves cause little environmental damage. However, the problems start with multiple small projects mushrooming along a stretch of coastline without forward planning, which together may have the same combined destructive power as a large project and may be more difficult to control.

4.1.2 Standard procedures for environmental studies

Due to their relatively high cost, environmental studies are normally carried out in steps in increasing detail as a project moves from formulation to final design. Figure 1 illustrates the steps in the procedures required when a project moves from the formulation stage to the final design stage. Briefly, the stages comprise:

- the initial environmental examination (IEE), where a number of candidate sites are examined and graded for suitability and potential environmental impact;
- the environmental impact studies (EIS), consisting of detailed studies of the prime candidate site. At the end of these studies, the findings are normally presented at a public hearing as part of the consultation process and the final design refined further; and
- at the end of the second stage, the national agency responsible for the environment then prepares an assessment of the impacts and recommendations known collectively as the environmental impact assessment (EIA), which is then forwarded to the government for a final decision.

Briefly, the Environmental Impact Studies (EIS) leading to the environmental impact assessment (EIA) consist of the following stages:

- An assessment of the existing environment prior to construction of the port facility, including the land-use characteristics (recreation areas, dwelling areas, forested zones, commercial zones, etc.) and socio-cultural activities (population dynamics, migration, cultural and ethnic preferences, etc.) at the proposed site.
- A list of the planned changes to be made to the environment by the proposed project, globally referred to as the project's footprint (land requirement, size of harbour basin, including breakwater foundations, dredging of access channels and turning areas, reclamation for factories, new access roads, power stations, etc.).
- An estimate of the anticipated impact of the planned project on the existing environment (deeper water, loss of beach, increased road traffic, high water consumption by factories, smoke and odour emissions from chimneys, etc.).

- Proposed mitigation measures to lessen the anticipated impact on the existing environment (increase of water production to compensate for higher consumption, location of chimneys to minimize unpleasant odours or smoke from drifting across the village, noise abatement around new sources of noise such as generators, treatment of all sewage, collection and disposal of spent engine oil, etc.).

4.1.3 Existing environment

The existing environment around a project site may be assessed through:

- onshore topographic and offshore bathymetric maps (down to 20 metre contour) of the site, covering at least 1 kilometre in each direction along the coast;
- aerial imagery of the above-mentioned area with a resolution not smaller than 1:2000 together with any satellite imagery available;
- details of existing or planned coastal structures within 5 kilometres of the proposed site;
- a morphological description of the coastal zone of the site, backed up by a geological description of important local features such as cliffs, sand dunes, beaches, reefs, terraces, rivers, dams on nearby rivers, river mouths;
- wave, tide or lake level statistical characteristics including probability tables for extreme conditions;
- seasonal variations in rainfall, river flows, water density, water temperature, nutrients concentration and microbial pollution levels;
- geological, petrographic and sedimentological characteristics of the coastline and seabed, including source, volume and seasonal changes in littoral transport;
- geotechnical investigation of the project site, including borings and laboratory testing of samples;
- maps of onshore and offshore habitats in and around the project site (coral reefs, lagoon systems, mangroves, sea grass meadows, tidal wetlands, estuaries etc.);
- maps of types of habitat in and around the project site (marine protected areas, areas of refuge, feeding grounds, nursery and spawning);
- lists of the species to be harvested, lists of protected or rare species and biological indicators as well as the methods of fishing;
- layouts of nearby settlements, properties, water wells, flood alleviation canals, cultural places, bathing facilities, archaeological sites, etc.;
- layouts, size and capacity of resource networks, such as water supply networks, power supply and distribution networks, road and other communications networks, sewerage networks, etc.; and
- location maps of any type of activity discharging, directly or indirectly, effluents into the aquatic environment, including distant but connected water courses, such as sewer outfalls, onshore fish farms, slaughter houses, logging/saw mill concessions, wood pulp factories, mines and ore reduction plants and other industries.

4.1.3.1 Planned changes

The planned changes to the environment should include:

- general description of the entire project, including location, type, size and typical cross-sections of the various components that together make up the project together with a description of the proposed stages of construction;
- the additional demands which would be placed on the locally available resources, both during construction and operation of the project;
- all the effluents and emissions arising from the project; and
- the changes in the landscape, including land use characteristics and socio-cultural activities envisaged in the project.

4.1.3.2 Anticipated impact

The estimation of the anticipated impact of the planned project on the existing environment should include:

- topographic, bathymetric and oceanographic changes, including siltation and erosion, during and after construction, until stable conditions are resumed, together with their effect on habitats, flora, fauna and land use, usually achieved through mathematical or physical models;
- changes in water quality (temperature, salinity, turbidity, dissolved oxygen, nutrients concentration and microbial pollution levels) during and after construction and their effect on habitats, flora, fauna and land use;
- sources of pollution discharging effluents, emissions or solid wastes during and after construction until stable conditions are resumed and their effect on habitats, flora, fauna and land use; and
- the visual impact on the seascape and the landscape and general quality of life around the proposed project site.

4.1.3.3 Mitigation measures

The proposed mitigation measures should be:

- technical, i.e. oil reception facilities, waste recycling schemes, sewage treatment systems, chlorofluorocarbon-free refrigeration equipment and bypass dredging where applicable;
- managerial, i.e. a clearly defined harbour board, commensurate with the size of the proposed project and the responsibilities expected of it; and
- legal and administrative, i.e. frameworks formulated in conformity with national laws to provide for sanctions in respect of violations.

4.1.4 Detail required and at what stages in the design

All studies connected with port projects are costly as they require the use of vessels and specialized engineering and diving equipment. It is an established fact that the detail required at each phase of the project increases as the final design stage is approached. Table 1 illustrates the increase in detail and the associated rise in costs as the final design stage is reached for typical hydrographic or bathymetric requirements for a port project.

Whereas a project may fail to get past the preliminary stage, once it reaches the final stage it is very likely that it will be constructed; hence, the cost of the bathymetric survey then becomes part of the design cost. The outline and preliminary costs are considered as unreimbursable investigative costs. Likewise for other studies, such as topographic surveys, geological surveys, geotechnical studies, benthic studies, water quality studies, etc.

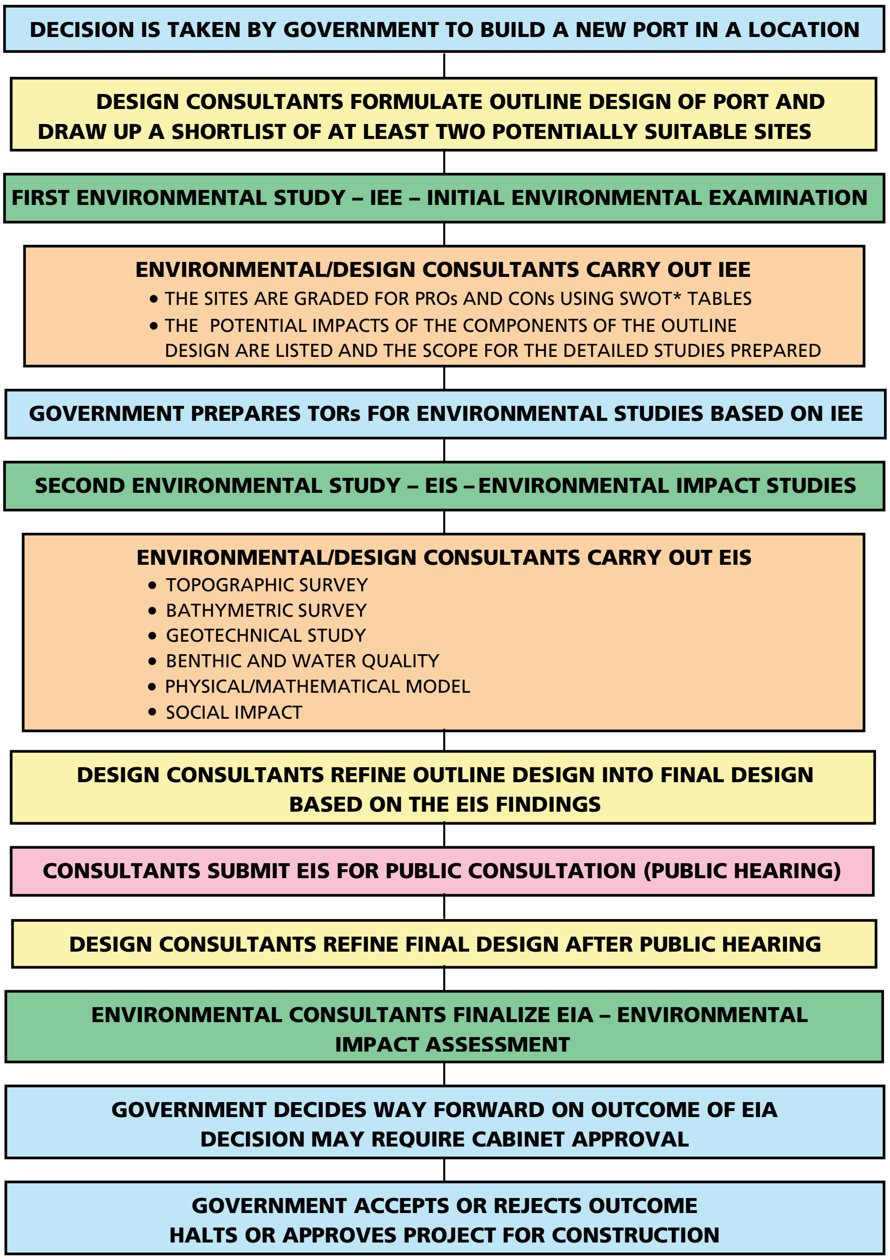
TABLE 1
Typical bathymetric requirements

Phase of project	Outline	Preliminary	Final
Phase of studies	Formulation	IEE	EIS/EIA
Standard required	Navigation chart in largest scale available	Spot soundings by handline from fishing boat	Full wide-area bathymetric survey with echosounder
Typical cost (2009) not including consultant fees	US$100	US$1 000	US$50 000

4.1.5 Procedures for environmental studies

FIGURE 1

Standard procedure for environmental studies



*Stands for strengths, weaknesses, opportunities, threats.

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APPENDIX 1: CASE STUDY

Given situation

At a small fishing village where fishing vessels are presently beached along a stretch of clean coastline and sewage from houses filters into the shoreline at various points ensuring that pollution concentration levels are low, construction of a new timber jetty is proposed and when it is built it is envisaged that a boat-repair slipway will be built together with a wet market and other shops selling food. It is envisaged that the jetty will also attract vessels from neighbouring villages to discharge fish there and service the vessels.

Possible consequences of constructing the jetty

The jetty *per se* is a simple structure and apart from the fact that timber used for its construction should be from plantation sources and not from virgin forests, it has little or no influence on the surrounding environment. The jetty, however, also acts as a magnet for other types of development which, when taken as a whole, can inflict great damage on the environment if not planned and then managed properly. Invariably, workshops, dwellings and businesses start growing up around the jetty and the once tranquil village may start to suffer from:

- increased pollution (oil) from the boat engines in the area of the jetty;
- increased road traffic, parking requirements and accidents near the jetty;
- water shortages if copious amounts of clean freshwater are diverted to the wet market;
- increased activity around the jetty will increase the amount of sewage discharged on the beach;
- a large volume of fuel for the vessels would then be required, requiring road tankers to move the fuel and increasing the risk of spillage;
- increased noise levels from cars trapped in traffic jams and generators running at all times of the day and night;
- increased pollution from works on the slipway;
- overcrowding;
- damage to existing road network from heavy vehicles, trucks, fuel tankers; and
- increased risk of drinking water pollution if supply is from groundwater.

Pretty soon, the once tranquil village would be turned into a chaotic, smelly and noisy environment, with polluted beaches and traffic jams (especially around the wet market area) and polluted air from smoke-belching vehicles, etc. This is exactly the scenario an environmental audit is meant to identify before the damage is done.

In the valuation of coastal resources, the planner should take into account all elements of value, not just those elements for which a ready market happens to exist and to which a financial figure may be attached. The fact that a resource is not traded in a market does not mean it is of no value. The health implications of fresh air cannot be ignored if a once tranquil village is turned into a busy fish marketing centre with fume-belching trucks constantly plying up and down the main street because a bypass was considered too expensive at the design stage.

- Could the market have been placed somewhere else?
- Why is the electric generator so close to houses?
- Why is the smoke-stack so short that smoke and soot engulf inhabited areas?

The social benefits of a clean beach (weekend family walkabout and permanent playing ground for children) should not be ignored if a wet market is proposed to be

built nearby; rotten fish and sewage from such places invariably end up on the beach rendering it unfit for human use. Therefore, why:
- are the effluents not treated or removed for disposal; and
- is there no outfall to discharge sewage away from the waterline.

The ecological (and sometimes tourist) importance of intact coral reefs or mangroves (which provide coastal stability against storms and support mangrove fisheries) should be borne in mind when deciding on a location for a new coastal structure thus raising the questions as to:
- was road access to an alternative, less-sensitive site considered first before the mangrove was knocked down;
- could the port have been sited opposite a natural break in the coral reef; and
- could the structure have been designed in piles to save on coral rock fill.

Furthermore, tranquillity (absence of noise) should never be ignored when deciding on the location of new roads, generators or pumps, for example:
- generators can be sound-proofed;
- a water pump can be run on electric power instead of a noisy diesel engine; and
- a generator can be moved away from dwellings.

Invariably, both the design and the construction of a project become more expensive to implement and it is up to the port planner (in conjunction with local authorities) to decide “how green” a project should be.

5. Hydrographic surveys

SUMMARY

In the past, many artisanal shelters and fishing ports were built at convenient locations, with no particular attention paid to such environmental factors as wave heights, sudden changes in water depths, uncharted reefs, currents, tidal streams, seaweed and mobile beaches (sand drift). Many of the structures were subsequently expanded and, in countless cases around the world, many of the problems that used to be considered minor have now developed into major ones, with some shelters, for example, fouling up with seaweed or silting up (shelter mouth facing the wrong direction) or just being inaccessible in rough weather (reefs too close to entrance channel).

A hydrographic survey, also known as a bathymetric survey, is therefore essential if the correct design decisions are to be made right from the project inception stage to ensure that the landing is easy to use and free of major maintenance problems under all conditions.

This chapter (related to Chapter 7) reviews the various types of hydrographic surveys and equipment that exist in relation to the amount of detail required during the design stage and illustrates clearly how this can be applied at the artisanal level. Consequently, the reader will be able to draw up appropriate terms of reference for hydrographic surveys.

CONTENTS

5.1 HYDROGRAPHIC STANDARDS AND CLASSIFICATIONS

5.1.1 Introduction

The results from a hydrographic survey are normally plotted to produce a bathymetric contour map, which is a plan of the depth of the sea bed arranged in such a manner as to show lines of equal depth from the coastline. In a hydrographic survey, the actual measurement of the water depth is the easy part. The main problem is not knowing how far the survey boat is from the coastline when the depth is recorded.

Boat A in Figure 1, for example, has no point of reference in relation to the coast. Boat B, on the other hand, is using a calibrated float line to obtain a "FIX" or position with respect to the coastline; in this case, 20 metres away on the straight line between the peg and the buoy. Hence, for each vertical depth recording, a horizontal position "FIX" is also required. Both vertical depth measurements and horizontal position measurements may be carried out either manually (low tech, low cost) or using sophisticated depth and position fixing equipment (high tech, high cost), depending on the end use of the survey.

Hydrographic surveys are required for a wide variety of purposes, ranging from simple reconnaissance (at project formulation, for instance) to payment for work carried out underwater, such as dredging or reclamation. The size of the area to be surveyed also influences the methodology to be used and hence the equipment required. In ascending order of accuracy, hydrographic surveys may be broadly classified as:

- Reconnaissance or Class 3
- Project condition or design or Class 2
- Contract payment or Class 1

Levels of accuracy for hydrographic surveys are intended to correspond directly to these three classes (Table 1). Class 3 is the lowest accuracy standard, Class 2 is a medium accuracy standard, and Class 1 is the highest accuracy standard.

Since expensive horizontal positioning and depth measurement equipment may be installed aboard a particular survey vessel, this same equipment may be typically used for all three classes. Any accuracy distinction between the classes is primarily a function of the field procedures used, along with recognized equipment limitations.

FIGURE 1
Fixing a vessel's position offshore

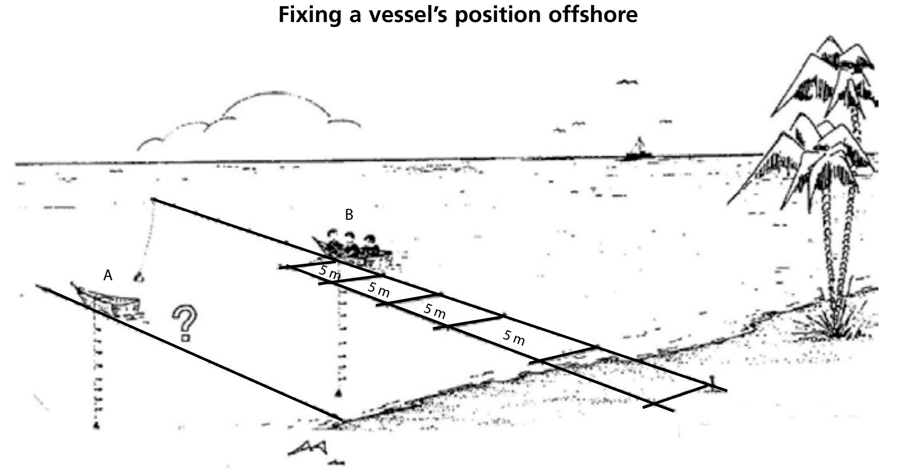


TABLE 1
Maximum allowable errors in hydrographic surveys

Type of survey	Class 3	Class 2	Class 1
Vertical accuracy	500 mm	300 mm	150 mm
Horizontal positioning	100 metres	12 metres	6 metres

5.1.2 Methodologies

There are various methodologies in use nowadays to carry out a hydrographic survey, depending on the end use of the survey and the size of the area to be surveyed. Vertical depth measurements may be carried out using:

- hand-held calibrated lead sounding line;
- simple engineering echosounder recording on paper; and
- advanced engineering echosounder recording on a data logger and linked to position fixer via integrated software (fully automated).

Horizontal position fixing measurements may be carried out using:

- hand-held optical square in conjunction with a float line;
- single theodolite in conjunction with a float line or twin theodolites;
- constant range tracking electronic positioning system (EPS); and
- differential Global Positioning System (GPS).

5.1.3 Vertical depth measurements

Figure 2 illustrates the hand-held calibrated lead sounding line, right, and on the left, the simple engineering echosounder (transducer not shown).

FIGURE 2
Echosounder and lead line

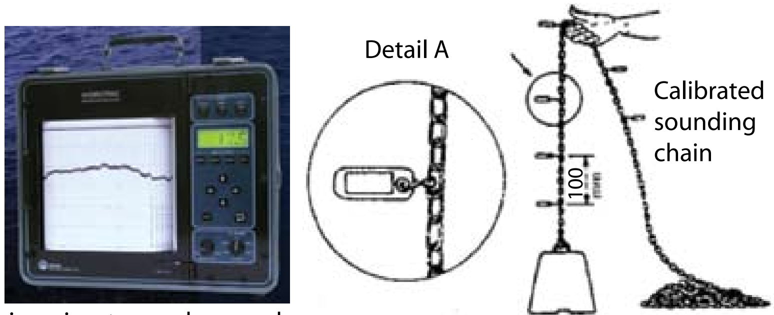


Figure 3 illustrates an advanced echosounder of the type used in modern Class 1 surveys. The echosounder is linked to a software package and yields electronic contour maps directly. This type of echosounder is also used for real-time monitoring of dredging works.

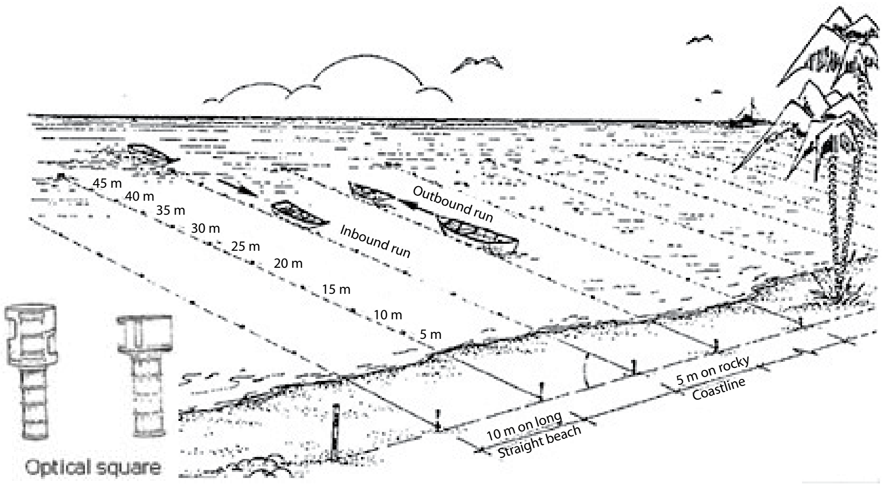
FIGURE 3
Advanced echosounder integrated with survey software (www.reson.com)

5.1.4 Horizontal position fixing

5.1.4.1 Method 1

The hand-held optical square in conjunction with a float line method, also known as the parallel line method (Figure 4), is the most basic and consists in setting out a straight baseline along the beach, say 100 metres long or more, depending on the extent of the hydrographic survey, with a ranging rod placed at either end. At every 5 or 10 metres from either end (5 metres for irregular terrain and 10 metres for flat beach), a steel peg is driven into the ground and, by means of an optical square (or theodolite), a buoy is dropped offshore at right angles to each peg.

FIGURE 4
Parallel line method



One end of the float line is anchored to the steel peg and the other to its corresponding buoy offshore. By tying in the baseline to the topographic survey, the depth readings may be plotted on paper in the right place. It is always a good practice to extend the survey about 100 metres on either side of the proposed shelter or landing.

The actual depth of the water may be read by simply lowering the calibrated sounding chain every 5 or 10 metres and the person using the chain calls out the readings to another person in the boat who records the figures on paper in the correct order. This type of recording yields a grid with spot levels only. If an engineering echosounder is available with an experienced operator, the actual soundings may be recorded on the special thermal paper roll by the instrument itself. In this case, only the operator need accompany the boat pilot on the survey vessel up and down the graduated float lines. A continuous bottom profile is thus obtained on a continuous strip chart and sounding levels scaled off the chart.

When carrying out the hydrographic survey:

- The sounding chain must reach the bottom in a vertical line; when using a sounding chain the vessel must be still when the actual reading takes place. If the area is subject to strong tidal streams, the weight of the sinker should be increased by attaching further weights to the chain.
- The depth reading must be recorded with the time at which the recording was made to allow for changes in the level of the tide.
- If an echosounder is being used, inbound runs are preferred to outbound runs. By starting an inbound run, say 50 metres away from the float, the vessel's skipper will be in a better position to place the boat parallel to the floating line.
- In both cases, stormy or windy days should be avoided as should the flood and ebb periods in strong tidal areas. The sea should be perfectly calm.

- In rocky areas, before removing the float lines, a swimmer wearing a pair of goggles (or diver) should then swim up and down the surveyed line looking for submerged rock outcrops or wrecks. The diver should point these out by placing small floats near them and measure the depth of water over the obstacle. These floats should then be plotted on the survey map by taking a series of fixes from the baseline with the theodolite, Method 2, triangulation.

FIGURE 5
A soundings plot using the parallel line method

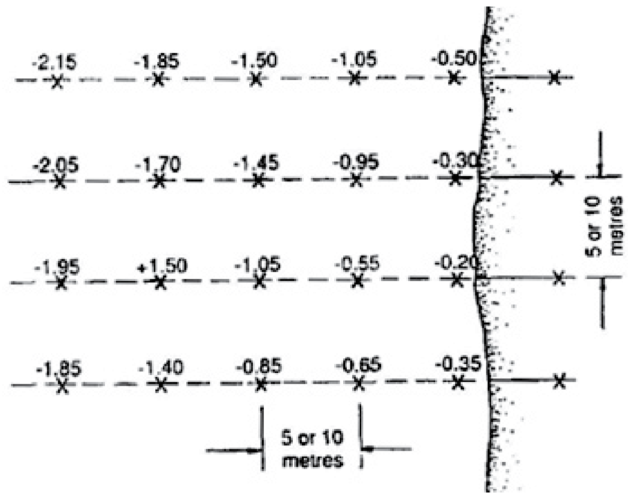
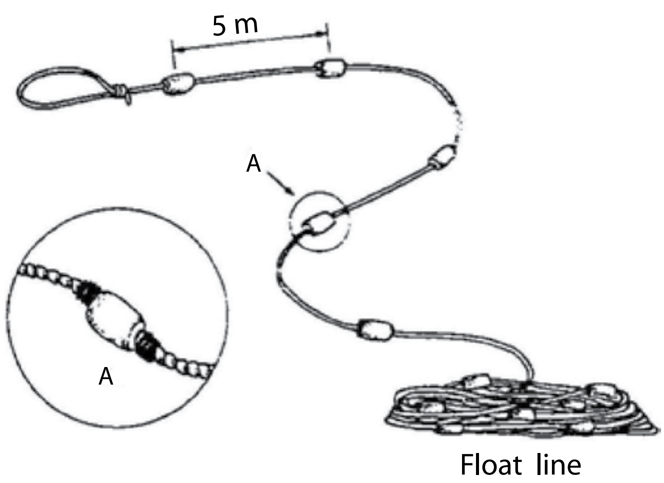


Figure 5 illustrates the type of plotted soundings derived by this method of survey. This method is considered acceptable for all three classes of surveys with a maximum offshore distance of 200 metres and is suitable for fish landing areas, small fishing ports, breakwater construction, minor reclamation and minor excavation and/or dredging.

FIGURE 6
The calibrated float line – maximum length 200 metres

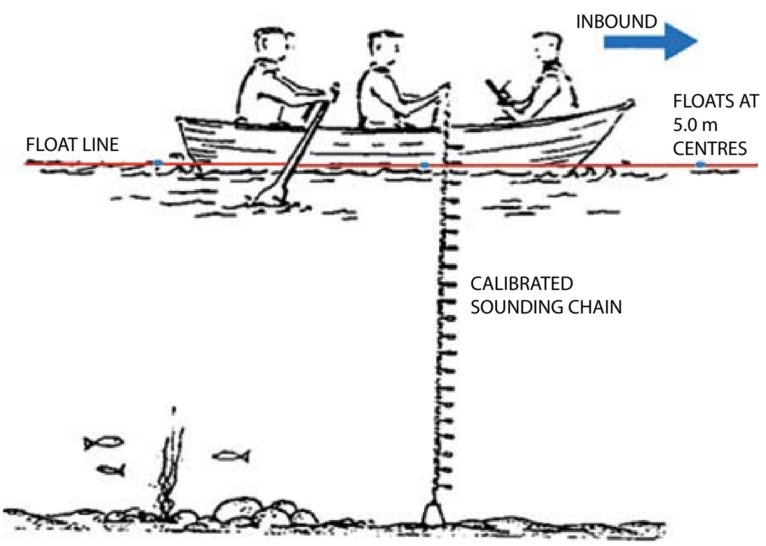


Material	Nylon	Polyethylene	Polypropylene
Stretch (elasticity)	High elongation	Low elongation	Low elongation
Weight of 200 m	20.6 kg	16.0 kg	14.5 kg
	Not suitable	Suitable	Most suitable

The calibrated float line, illustrated in Figure 6, should be made up from a length of 12 mm diameter polypropylene rope with coaxial coloured floats at 5 and 10 metre intervals. One large spherical red float should be installed every 50 metres to ease chain readings from the survey vessel. The completed float line may be either wound on a purpose-made plastic drum or stowed inside a large fishermen's basket and paid out over the bow or stern of the vessel.

The float line is rather difficult to keep stretched in a perfect line in the presence of wind, waves or current. It is therefore recommended that survey work involving float lines be carried out when the sea is perfectly calm (Figure 7).

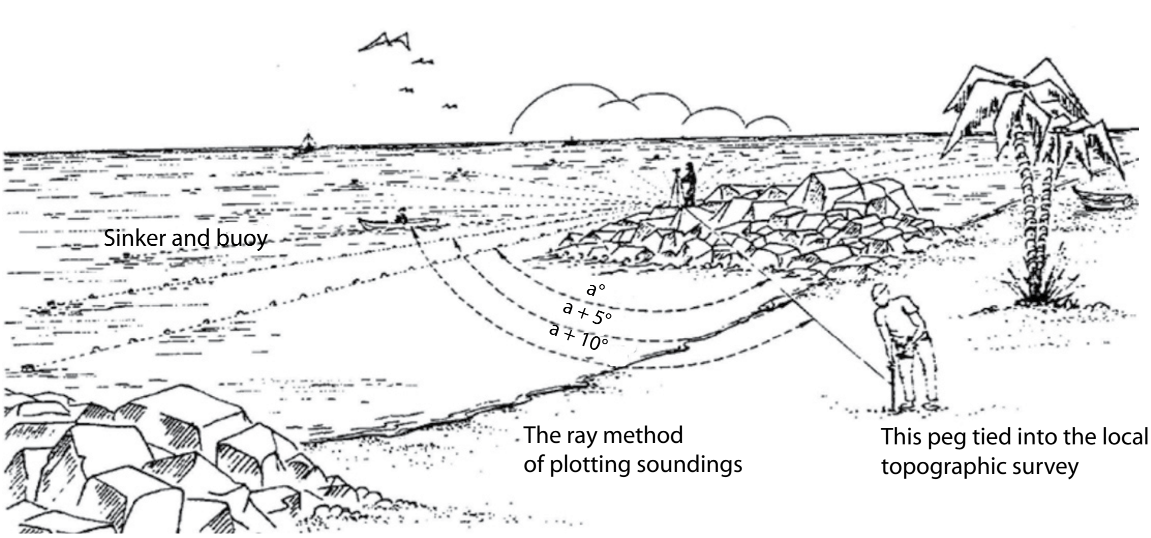
FIGURE 7
Recording the soundings manually at 5 m centres



5.1.4.2 Method 2

The single theodolite, in conjunction with a float line (ray method) or twin theodolite intersection (triangulation method), is the second most basic method of fixing positions offshore. In the past, positioning by these methods from baseline points onshore was often used to position vessels on near-shore projects.

FIGURE 8
The ray method



Although it is no longer commonly employed, this method is considered acceptable for all three classes of surveys with a maximum offshore distance of 300 metres for the ray method, Figure 8, and around 1 000 metres for the triangulation method. Beyond this distance it may be difficult to collimate the theodolite on small objects, especially during hot summer days. More often, this method is used to perform EPS calibration when fixed points are inaccessible to the vessel. Triangulation positioning techniques are labour intensive. Two shore-based transit or theodolite observers are required, along with communication equipment with which to transmit the observed angles (or direction azimuths) to the surveyor. Due to the higher precision and stability of the instruments, the resultant positional accuracy can be quite good, provided observing procedures are properly executed.

Simultaneously observed positional “fixes” are usually radioed over to the survey boat. Fixes may be at equal time intervals or as called for on a random or as-needed basis, such as during EPS calibration. Advance warning is made of upcoming fix events so that observers can initiate precise tracking of the boat. A defined point aboard the vessel (mast or aerial) is normally tracked. This well-marked point should be centred over the echosounder transducer.

5.1.4.3 Method 3

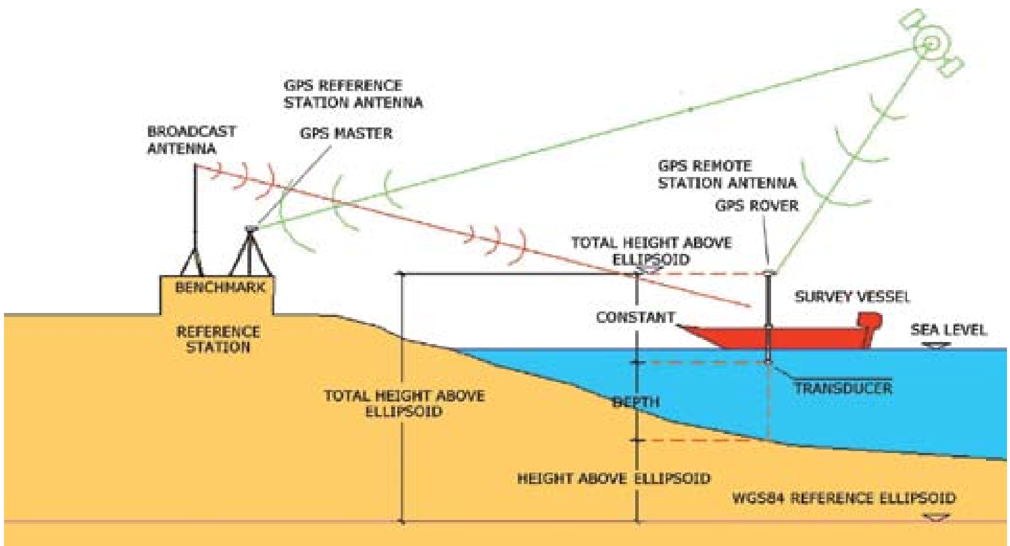
The constant range tracking EPS used to be the most commonly employed positioning method. This method replaced the triangulation theodolites with electronic microwave ranging EPS which utilize range-range positioning techniques. This method has now been superseded by GPS techniques.

5.1.4.4 Method 4

Differential GPS is the primary survey reference for all types of present-day engineering and construction activities. GPS is a continuous, all-weather, worldwide, satellite-based electronic positioning system. It is available to the general public and is known as a standard positioning service. Over the past several years, a technique has been developed to process signals from two GPS receivers operating simultaneously to determine the 3-D line vector between the two receivers. This technique is known as “*differential positioning*” (DGPS) and can produce real-time positions of a moving vessel, Figure 9.

FIGURE 9

Differential GPS real-time measurement of position of survey vessel



5.2 EFFECTS OF VESSEL ROLL PITCH AND HEAVE

Correcting observed depths for the superimposed effects of vessel roll, pitch and heave is perhaps the most difficult aspect of hydrographic surveying since all three conditions can occur simultaneously and at different periods. Roll and pitch introduce bias error in depth, resulting in a deeper reading over a level bottom (Figures 10 and 11). On side-mounted transducers, this bias error is compounded by the random up and down motion (heave) of the vessel.

Unless reliable motion compensation devices are used, the only practical method of minimizing vessel motion effects is to limit the maximum allowable sea states under which a particular class of survey may be performed.

Such limitations are highly subjective and can have significant economic impacts, due either to delayed survey work or to inaccurate payment when a Class 1 survey is performed under adverse conditions. Maximum sea state limitations must also factor

FIGURE 10
The effect of vessel roll on depth soundings

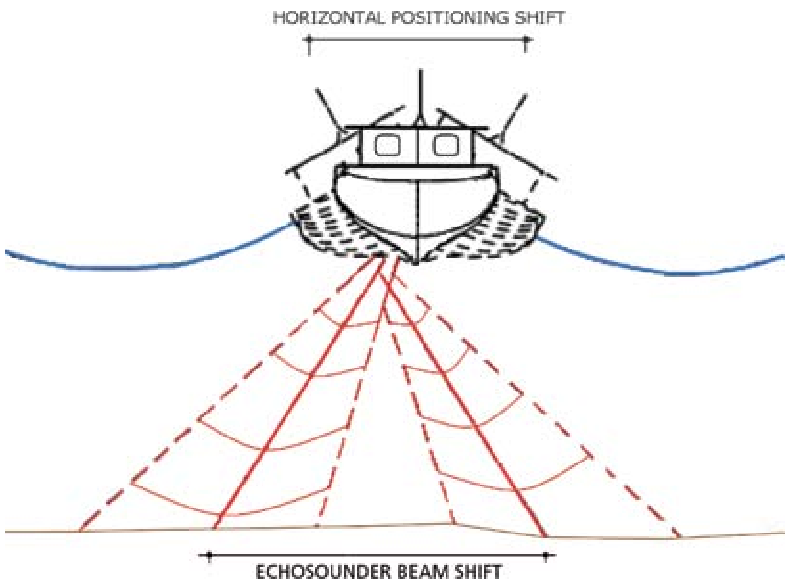
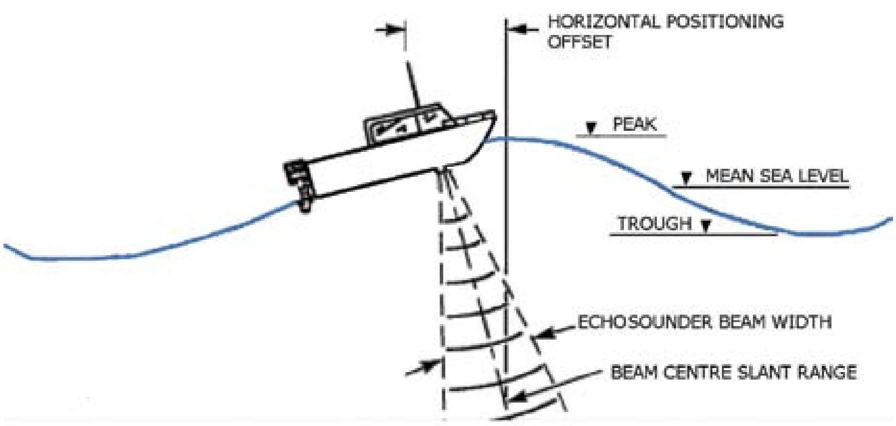


FIGURE 11
The effect of vessel pitch and heave on soundings



in the size and relative stability of the survey vessel (Figure 12), along with the effects of the prevailing wave direction relative to the survey lines or cross-sections. Thus, a simple maximum allowable wave height criterion is difficult to specify. Hence, hydrographic surveys are best performed during calm weather spells.

FIGURE 12
Typical small vessel outfitted for hydrographic surveys

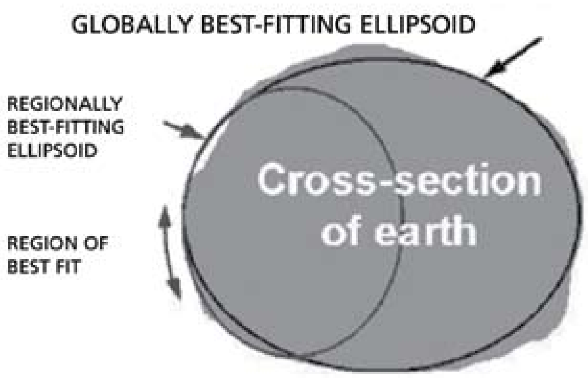
5.3 THE WGS84 DATUM

In Figure 9, GPS readings of the roving antenna are given above a datum called the WGS84 (World Geodetic System 1984). A cursory look at the topographic and oceanographic details of the globe indicates that the Earth is a very irregular and complex shape. To map positions of those details, a simpler model of the basic shape of the Earth, sometimes called the "figure of the Earth", is required.

The science of geodesy, on which all mapping and navigation is based, aims firstly to determine the shape and size of the simplified "figure of the Earth" and goes on to determine the location of the features of the Earth's land surface – from tectonic plates, coastlines and mountain ranges down to the control marks used for surveying and making maps. Hence, geodesists provide the fundamental points of known coordinates which cartographers and navigators take as their starting point. The first question of geodesy, then, is "What is the best basic, simplified shape of the Earth"?

The Earth is very nearly spherical. However, it has a tiny equatorial bulge that makes the radius at the equator about 0.33 percent bigger than the radius at the poles. Therefore, the simple geometric shape which most closely approximates the shape of the Earth is a biaxial ellipsoid, which is the three-dimensional figure generated by rotating an ellipse about

FIGURE 13
Best-fitting ellipsoid on the shape of the Earth



its shorter axis. The shorter axis of the ellipsoid approximately coincides with the rotation axis of the Earth. Because the ellipsoid shape does not fit the Earth perfectly, there are many different ellipsoids in use, some of which are designed to best-fit the whole Earth and some to best-fit just one region (Figure 13). The datum used for GPS positioning is called WGS84. It consists of a three-dimensional Cartesian coordinate system and an associated ellipsoid, so that WGS84 positions can be described as either XYZ Cartesian coordinates or latitude, longitude and ellipsoid height coordinates. The origin of the datum is the geocentre (the centre of mass of the Earth) and it is designed for positioning anywhere on Earth. The WGS84 datum is a set of conventions, adopted constants and formulae and includes the following items:

- The WGS84 Cartesian axes and ellipsoid are geocentric; that is, their origin is the centre of mass of the whole Earth including oceans and atmosphere.
- The scale of the axes is that of the local Earth frame.
- The orientation of the ellipsoid equator and prime meridian of zero longitude coincide with the equator and prime meridian of the Bureau Internationale de l'Heure at the moment in time 1984.0 (that is, midnight on New Year's Eve 1983).
- Since 1984, the orientation of the axes and ellipsoid has changed such that the average motion of the crustal plates relative to the ellipsoid is zero. This ensures that the Z axis of the WGS84 datum coincides with the International Reference Pole, and that the prime meridian of the ellipsoid (that is, the plane containing the Z and X Cartesian axes) coincides with the International Reference Meridian.

5.4 SPECIFYING HYDROGRAPHIC SURVEYS

Although hydrographic surveys have become fully automated through the use of custom-designed software, they are still considered expensive surveys to carry out, especially when the survey equipment has to be moved in from far afield.

The size of the area to be surveyed depends greatly on the project being attempted and some basic rules-of-thumb are appropriate (Table 2).

TABLE 2
Class of hydrographic surveys

Project design stage	Outline	Preliminary	Final
Phase of studies	Formulation	IEE	EIS/EIA
Standard required	Navigation chart	CLASS 3	CLASS 2
Type of construction	**Port**	**Dredging**	**Reclamation**
Standard required	Class 1	Class 1	Class 1

5.4.1 Outline design and project formulation

During project formulation no physical surveys are required. A sea chart at the appropriate scale is more than enough for selecting potential sites to insert in a shortlist for further detailed studies.

5.4.2 Preliminary design

At preliminary design or project preparation, a Class 3 survey is adequate. This can be an all manual survey carried out from a local fishing vessel using locally available equipment. If the project is located on or near a sandy beach, the area covered by the survey should extend at least 250 metres on either side of the project and down to the 7 metre contour.

5.4.3 Final design

During the final design of a port project, a physical or mathematical model may need to be built and run to determine the potential impacts of the port on the adjacent coastline. A Class 2 survey is required. If the port project is located on a rocky coastline, the area covered by the survey should extend at least 500 metres on either side of the project. If the port project lies on a sandy coastline, the survey should extend 1 000 metres on either side of the project. In both cases, the offshore extent of the survey must reach the 20 metre contour.

5.4.4 Construction phase of a port

During the construction phase of a port, a new and more detailed survey is required for the purposes of payment. Monitoring surveys may also be required in areas prone to erosion or accretion. Class 1 surveys are normally required at this stage and the extent of the survey does not need to exceed the submarine footprint of the port structures.

5.4.5 Maintenance dredging and reclamation

Only Class 1 surveys are required and the extent does not need to exceed the submarine footprint of the dredging works.

5.5 SAMPLE SURVEYS

Figures 14 and 15 are examples of the type of precision required at different stages in the design and construction process of a port. Figure 14 is a Class 2 survey that was commissioned during the environmental impact studies (EIS) for a new port to determine the behaviour of waves impacting the site via the construction and operation of a physical model. The vertical resolution required at this stage was 1.0 metre (with a Class 2 accuracy) with a horizontal grid of 100 metres (also with a Class 2 accuracy). Figure 15 illustrates a Class 1 survey utilized for the final payment of the contractor for the excavation work carried out for the construction of the breakwater. The vertical resolution is now 10 centimetres with a horizontal grid of 2.50 metres, both well below the maximum Class 1 accuracy.

FIGURE 14
A Class 2 survey used for the EIS of the breakwater (in red)

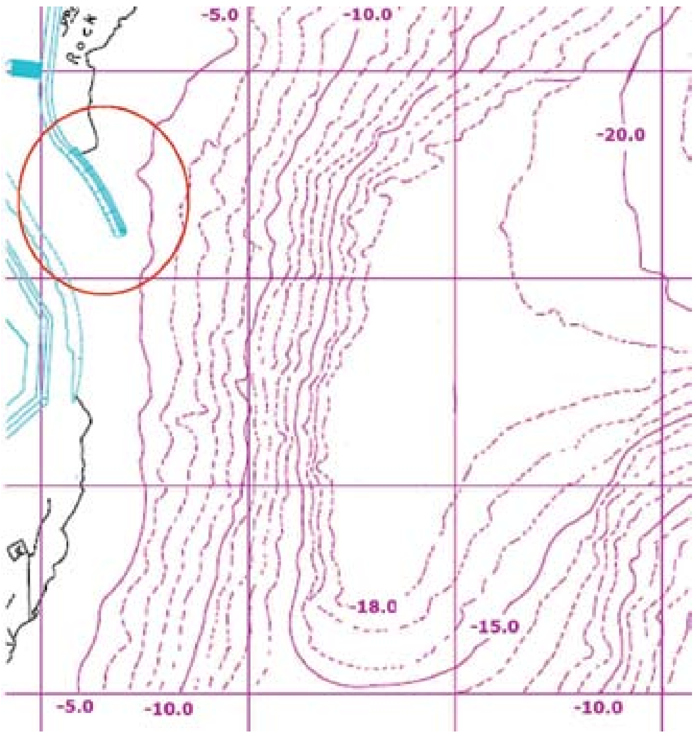
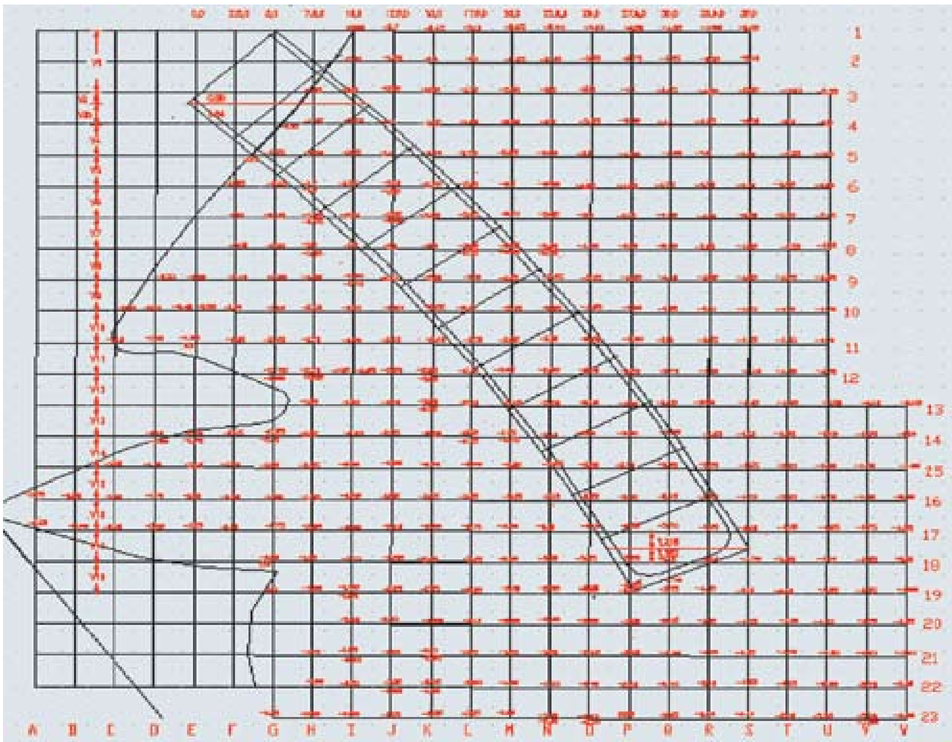


FIGURE 15

A Class 1 survey used for the payment of the excavation of the same breakwater



5.6 TIDE SURVEYS

5.6.1 Tides

"Tides" should not be confused with "tidal streams", although loose terminology has undoubtedly come to use the word "tide" for both. A tide is a periodic vertical movement in the level of the sea, whereas a tidal stream, even though resulting from a tide, is a periodic horizontal movement. Tides affect the depth of water at a place; tidal streams affect navigation courses.

A tide is a periodic vertical movement in the level of the sea. In consequence of the solar cycle, at times of new and full moon, at a place the highest high waters (HHW) and the lowest low waters (LLW) of a tide cycle – SPRING TIDES – will be experienced and **7-¼** days after these, with the first and last quarters of the moon, the lowest high waters and the highest low waters of a tide cycle – NEAP TIDES – will occur.

There are thus two separate tide cycles: height fluctuations from SPRINGS to NEAPS twice each in a lunar month (29 days), Figure 16, and height oscillations of each tide from high water to low water twice each in each lunar day.

5.6.2 Tide datum

The hydrographic surveys in tidal areas should be referenced to a base elevation or chart datum, Figure 16, normally taken as the lowest astronomical tide level, or LAT, also referred to as LLWS (Lower Low Water Spring) in some countries. This level is the result of the effect of celestial bodies only and does not include the additional effects of:

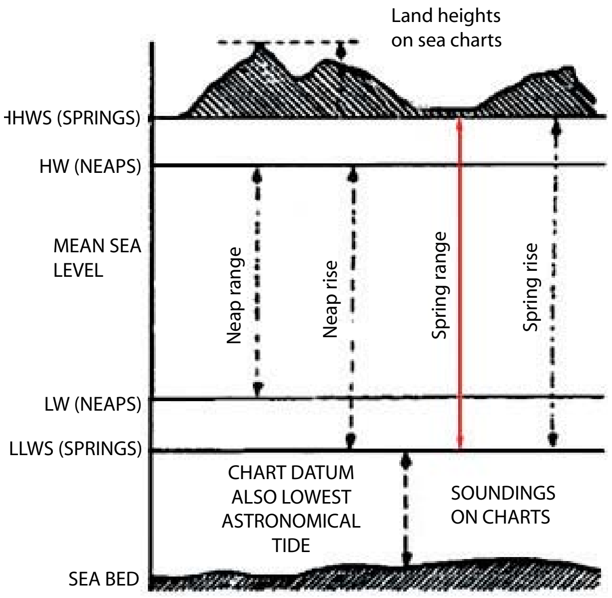
- atmospheric pressure (low pressure increases tide level);
- storm surge (increases tide level);
- wind (landward wind increases tide level); and
- heavy rainfall (increased flow in estuaries increases tide level).

In areas where this is not possible, hydrographic surveys in tidal areas should be referenced to a base elevation which has been determined by measuring the tide heights over the Tidal Datum Epoch. The Tidal Datum Epoch is the specific 19-year period or Metonic cycle (where the moon returns to exactly the same place at the same longitude and against the same constellation in the sky with the same phase) over which tide observations are taken and reduced to obtain mean values (e.g. Mean Lower Low Water or MLLW) for tidal datums.

Due to the long-term rise in global sea level and land subsidence, tidal datum readings are constantly changing and require continuous monitoring and updating.

To facilitate the process of establishing tidal datum readings, tide stations are operated at various locations (at all major and secondary port cities) for long- (primary), medium- (secondary), and short-term (tertiary) durations.

FIGURE 16
Tide datum



5.6.3 Primary tide stations

Long-term tide stations are referred to as primary control tide stations. These are tide stations at which continuous observations have been made over a minimum 19-year Metonic cycle. Their purpose is to provide data for computing accepted datums needed for a project and the predicted tides are normally published as a tide almanac. Nowadays, with the advent of the Internet, tidal predictions are available for most parts of the world, Figure 17. Tidal datum readings may also be determined by recovery of nearby tidal benchmarks from a former datum determination or by new tidal observations conducted in accordance with the correct procedures, Figure 18.

A length of plastic tape stapled to a length of steel tube makes an ideal tide board. This may either be buried in a concrete weight on a sandy bed or cemented to a rocky coast as illustrated in Figure 18. In both cases, the tide board should be installed in a sheltered area and observations carried out for at least one month. The longer the observation period, the more accurate the establishment of the tidal datum.

5.6.4 Tidal streams

The tidal phenomenon described above gives rise to tidal streams – periodic horizontal movements of the water. In open ocean this horizontal movement is either non-existent or negligible, but in inshore and coastal waters where there is any appreciable vertical movement a horizontal movement also can be expected.

The cause of tidal streams is primarily a change in water levels.

The average velocity of tidal streams depends upon the average height of the advancing tide wave: in deep ocean where this height is small the stream rate is either very feeble or negligible; where the height is large the velocity will be correspondingly great. As a tidal stream encounters any obstruction to its to-and-fro movement, its direction and velocity are affected.

FIGURE 17
Typical predicted tides for a total station showing the neap tide

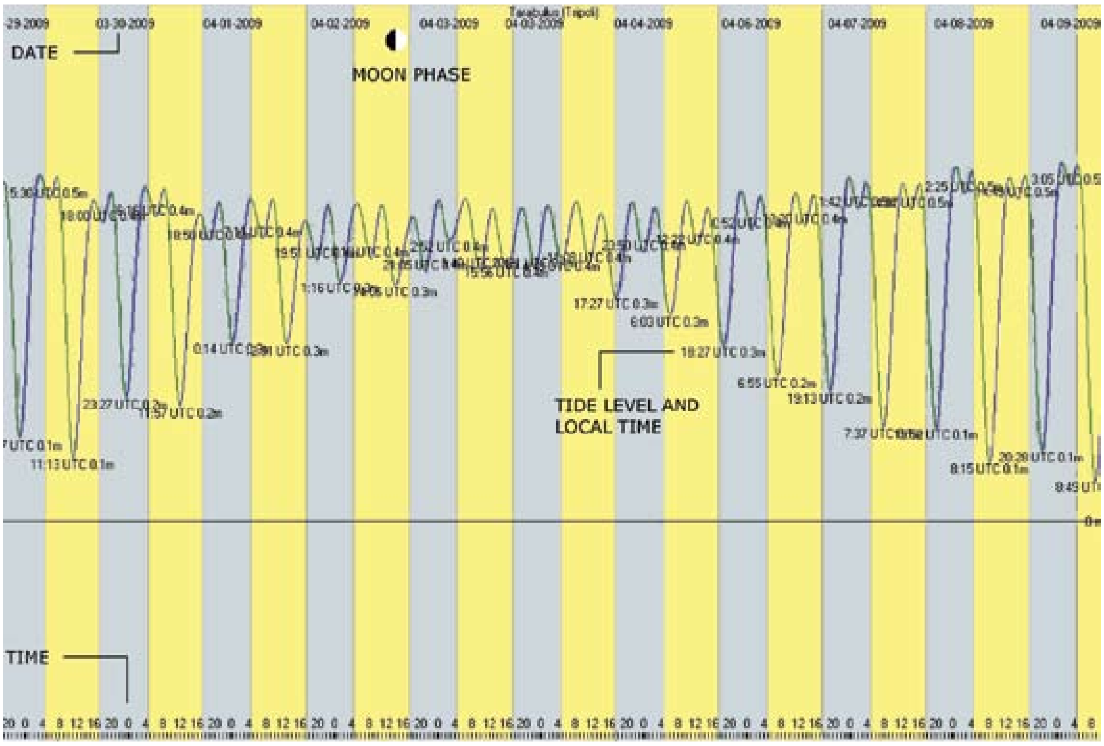
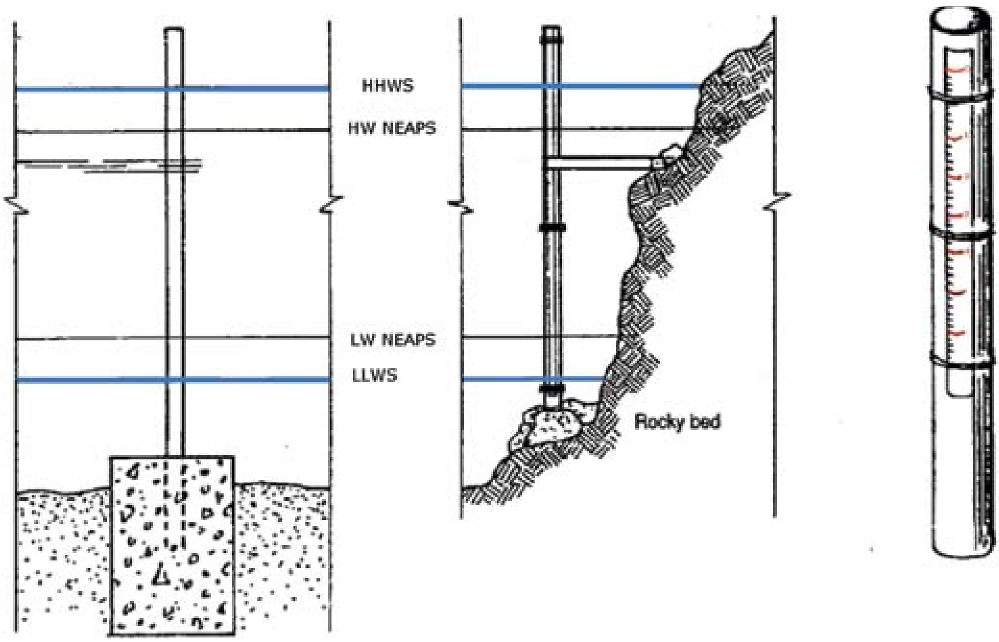
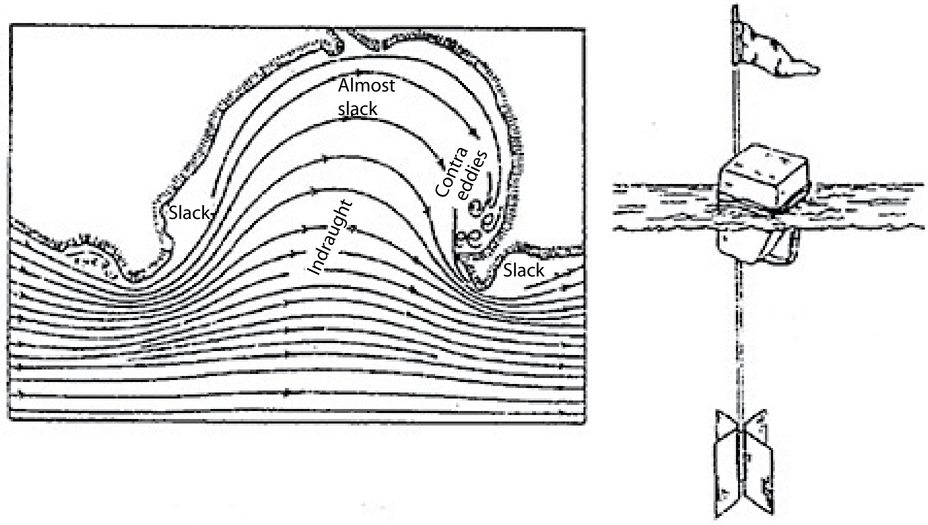


FIGURE 18
Re-establishment of tidal benchmarks



So when a tidal stream meets a headland it is deflected around it, and usually immediately off the headland its velocity is locally increased. In Figure 19 above, its direction is deflected round the headland into the bay beyond, causing an indraught of indefinite direction and velocity. In the bay itself the spreading out of the effect of the stream, combined with the fact that the real strength runs from headland to headland leaving comparatively unmoved water in between, causes a diminished velocity.

FIGURE 19
Tidal streams and a tidal float used for measuring currents



In the absence of tides, feeble sea currents may be experienced during strong sea storms. These currents, though not very great when compared to tidal streams, should be observed closely because they usually carry weeds uprooted from offshore areas.

Currents in general make navigation more difficult but not impossible. In the presence of seaweed or flotsam (including timber and vegetation carried down by rivers), however, navigation may be hindered by weeds fouling up propellers. Flotsam, or floating debris, may also prove troublesome if it piles up inside a harbour by a prevailing tidal stream or sea current. Using a simple can-float, Figure 19 right, with a counterweight hanging about a metre below water level, the strength of a current may be measured by timing it to travel a known distance along the coast, or across a bay. When measuring currents at sea, the following points should be observed:

- the general direction and duration of the storm or incoming waves, if the currents are storm generated;
- if seaweed appears, after how many hours of storm does it make its first appearance; and
- if flotsam or driftwood appears, their landfall, in many instances one particular spot or bay may accumulate more debris than adjacent ones, in which case it should be discarded as a potential harbour site.

5.7 BIBLIOGRAPHY AND FURTHER READING

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International Hydrographic Organization (other publications) (www.iho.shom.fr)

- Promulgation of Radio Navigation Warnings
- General Bathymetric Chart of the Oceans (GEBCO)
- FIG/IHO International Advisory Board on Standards for Hydrographic Surveyors
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6. Dredging

SUMMARY

Dredging and underwater excavation are an important aspect in the design and construction of certain key elements of a fishing harbour's infrastructure. Capital dredging may also be an important aspect in the design of a new port if access channels or water deepening of a basin are required for the first time. Maintenance dredging is essential to keep certain access channels, fishing port basins and canals subject to high sedimentation open to navigation.

This chapter reviews the various types of dredging techniques that exist in relation to the characteristics of the material to be dredged. Thus the reader will be able to assess the dredging requirements for small ports and be able to suggest the most suitable method of dredging in whatever type of material.

CONTENTS

6.1 REQUIREMENTS FOR DREDGING

The basic requirements to assess dredging works are:

- an accurate estimate of the volumes to be excavated or dredged; and
- an accurate evaluation of the nature of the material to be excavated.

6.1.1 Volume estimates

Accurate volume estimates are important for the choice of dredging plant, production estimates, times of execution and ultimately project costs. Expressed in quantities, a dredging operation can extend from a few hundred cubic metres to many millions of cubic metres. In order to arrive at an accurate dredging volume, the following is required:

- a detailed design layout showing areas to be dredged and the design depths required together with the relevant cross-sections;
- a Class 2 hydrographic survey of the area with bathymetric contours at 1 metre intervals for extensive projects (see Figure 14 in Chapter 5) or a Class 1 hydrographic grid with bathymetric contours at 0.25 metre intervals for isolated structures (see Figure 15 in Chapter 5); and
- a geotechnical survey, including borehole logs, *in situ* and laboratory test results and samples.

6.1.2 Characterization of materials

An evaluation of the physical, chemical and biological characteristics of the sediment to be dredged is necessary to determine potential dredging methods, beneficial use, disposal options and potential environmental impact.

6.1.2.1 Physical characteristics

The nature of the material to be dredged decides the type of equipment or method to be adopted to carry out the work thereby influencing the cost of the project, especially when mobilizing the plant from a distant site.

In practice, no sea bed material will fall precisely into a certain predetermined category, so combinations of types must be described accurately. When a specialist soil-investigation contractor is given the task of classifying the materials to be dredged, soil classification problems do not arise. Problems do arise, however, with artisanal-scale projects, where the volumes to be dredged are usually very small and the construction budgets are very limited.

In the absence of detailed geotechnical studies (i.e. on very small projects), clear descriptions should be noted down in addition to the collection of the samples in air-tight glass jars. Typical examples of such descriptions include:

(i) In sand and silt deposits:

- compacted, coarse, angular sand mixed with scattered broken sea shells;
- loose, rounded, fine to medium sand with coarse gravel;
- brown, rounded, slightly compact fine sand;
- hard, brown clay containing sand and gravel;
- soft, grey/blue, sand silt; and
- stiff, fissured, grey clay.

(ii) In clay or clayey deposits:

- very soft, may be squeezed easily between fingers;
- soft, easily moulded by fingers;
- firm, requires strong pressure to mould by fingers;
- stiff, cannot be moulded by fingers, indented by thumb; and
- hard, tough, indented with difficulty by thumb nail.

In granular deposits, it is useful to remember that if all the sand grains are visible to the naked eye, then the material is entirely sand. If individual particles are invisible, the sample is classified as silt or silty sand. Gravel may be described as rounded, irregular, angular, flaky or elongated. Its texture may be classified as polished, smooth or rough. The general classification for granular material is as follows (Table 1):

TABLE 1
Classification of granular materials (diameter in mm)

Cobbles	Gravel		Sand		
	Coarse	Fine	Coarse	Medium	Fine
256 – 76	76 – 19	19 – 5	5 – 2	2 – 0.42	0.42 – 0.074

6.1.2.2 Chemical characteristics

In 1972, the general interest in the importance of the environment resulted in the holding of the United Nations Conference on the Human Environment in Stockholm, Sweden. As part of the preparatory process for the conference an Inter-Governmental Working Group on Marine Pollution held its first meeting in London in 1971 and the Stockholm conference recommended that governments ensure that "ocean dumping by their nationals anywhere, or by any person in areas under their jurisdiction, is controlled and the governments continue to work towards the completion of and bringing into force as soon as possible of an over-all instrument for the control of ocean dumping...". In response to this recommendation, the United Kingdom of Great Britain and Northern Ireland convened a conference which met in London from 30 October to 13 November 1972 and adopted the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the "London Convention" for short).

The Convention entered into force on 30 August 1975 and the first meeting of Contracting Parties in December that year agreed to designate the International Maritime Organization (IMO) to be responsible for the Secretariat duties in relation to the Convention. The Convention's purpose is to control all sources of marine pollution and prevent pollution of the sea through regulation of dumping into the sea of waste materials. It covers materials transported to sea for the purpose of dumping. The Convention is a living document that responds to new information, pollution issues and environmental concerns through a process of consultative meeting, scientific and legal debates, consensus building and the addition of new member nations.

Past amendments and proposed future actions to the Convention reflect our growing knowledge of or different approaches to waste management or of the potential harm from certain substances or processes. The London Convention, in October 1996, adopted revisions resulting in the 1996 Protocol to the Convention. This Protocol prohibits ocean disposal, except for a few types of wastes. Dredged material is one of these.

The screening for the presence of chemical agents in the material to be dredged is required to determine where and how the material will be disposed. The screening for chemical agents is based on a step-by-step investigation of any number of the following parameters:

- verifiable data from previous chemical tests on material in the vicinity of the proposed dredging;
- known major geochemical characteristics of the sediment;
- potential routes by which contaminants could reasonably have been introduced to the sediment;
- probability of contamination from agricultural and urban runoff;
- spills of contaminants in the area to be dredged;
- industrial and municipal point discharges, past and present; and
- prior use and source of the sediment.

The sampling of the sediments from the proposed dredging site should be representative of the vertical and horizontal distribution and variability of the properties of the materials to be dredged. The sampling procedures should also anticipate the information required for the evaluation and selection of the dredging and disposal techniques.

6.1.2.3 Biological characteristics

If the potential impacts of the dredged material cannot be assessed on the basis of the physical and chemical characteristics and available benthic information, biological or effects-based testing should be considered. It is important to consider information about species known to occur in the area which may be affected and the potential effects of the sediments to be disposed on the said organisms. Biological tests should incorporate species that are considered appropriately sensitive and representative and should determine, where appropriate:

- acute toxicity;
- chronic toxicity covering an entire life cycle;
- potential for bio-accumulation; and
- potential for tainting.

See Section 6.3.2 on the classification of the sediments to be dredged. Within the London Dumping Convention regulations, dredged material may be exempted from further testing if it meets one of the criteria listed below:

- dredged material is excavated from a site away from existing and historical sources of appreciable pollution, so as to provide reasonable assurance that the dredged material has not been contaminated; or
- dredged material is composed predominantly of sand, gravel and or rock; or
- dredged material is composed of previously undisturbed geological materials.

If any one of the above applies and if the geological records do not indicate the presence of potential leachates from heavy metal mineral deposits, it may be assumed that the dredged material has not been contaminated from human sources to an extent that necessitates further investigation. The evaluation and assessment procedure in these cases may normally be restricted to proper site selection and evaluation of physical impacts. Dredged material which does not meet any of the above criteria will require further investigation.

6.2 DREDGING TECHNIQUES

Dredging is most likely to be in one of the following types of sediment:

- cohesionless deposits, such as sand or weakly cemented granular deposits;
- cohesive clayey deposits;
- silty mud from inside existing port areas; and
- rock, ranging from soft coral limestone to the much harder granite;

Depending on the consistency of the deposits, various dredging techniques may be employed. The most common techniques or equipment are:

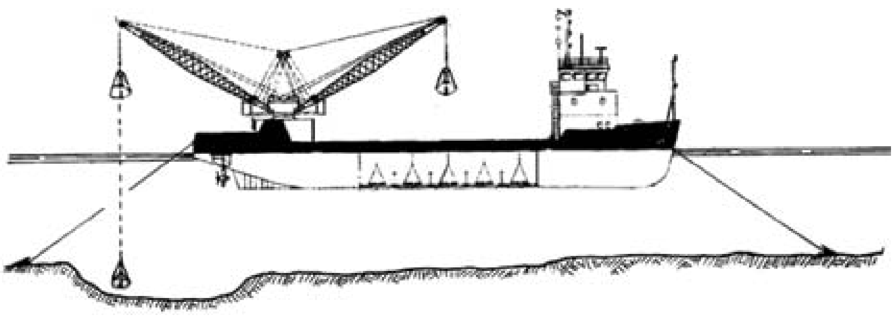
- pontoon-mounted grabbing;
- pontoon-mounted (or shoreline) dragline;
- pontoon-mounted pumping;
- self-propelled trailing suction dredging;
- blasting, using high explosives or low-power explosives;
- bucket dredging;

- cutter-suction dredging;
- backhoe dredging;
- chiselling; and
- airlift.

6.2.1 Pontoon-mounted grabbing

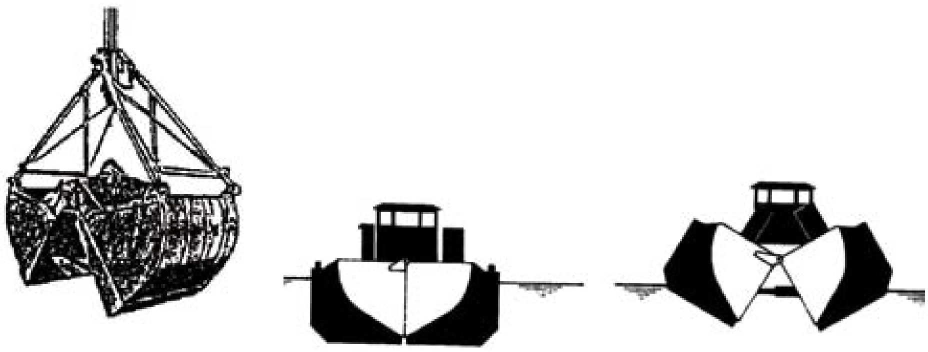
Figure 1 illustrates an ocean-going grab dredger, consisting of a self-propelled vessel with various on-board hoppers with a crane or cranes mounted on the deck. A pontoon dredger, on the other hand, consists of a barge-mounted crane, propelled by a tug and assisted by two hopper barges (see Figure 3).

FIGURE 1
Self-propelled grab dredger



A grab dredger lowers, closes and raises a single grab by means of wire rope. In operation, the clamshell grab, Figure 2 (left), is dropped to the sea bed in the open position and bites into the sediment due to its weight and the action of the closing mechanism. The materials thus dredged are either dumped into the on-board hopper wells (in ocean-going dredgers) or into adjacent hopper barges, Figure 2 (right), for transport to the authorized dump site.

FIGURE 2
The standard clamshell grab (left) and the split hopper barge



The advantages of the grab dredger are:

- flexibility of use in maintenance dredging in all kinds of marine sediments, for which a variety of grabs are available;
- efficient to depths of 35 metres, beyond which the free-fall effect of the grab limits efficiency; and
- very suitable for working along quays and in the corners of harbour basins.

The disadvantages are:
- when stationary in a navigation channel it causes an obstruction to sea traffic; and
- it leaves irregular bottom topography.

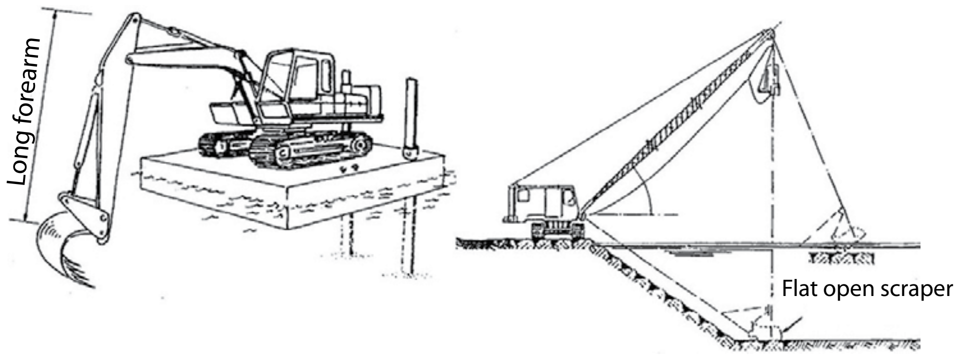
FIGURE 3
Pontoon-mounted grab dredging below a quay wall

6.2.2 Dragline

Figure 4 (right) illustrates the technique of dredging by dragline. This method consists in dragging an open steel bucket along the sea bed until it fills up. When full, the bucket is lifted and its load dumped on the shore or into a barge.

The dragline is not used much outside North America. It tends to spill much of the dredged sediment during operation and gives rise to considerable turbidity. Most of the functions of a dragline nowadays are performed more efficiently by backhoes, both from the shoreline as well as mounted on a barge, Figure 4 (left).

FIGURE 4
A normal dragline (right) and a barge-mounted backhoe (left)



6.2.3 Pontoon-mounted pumping

The pontoon-mounted pump dredger consists of a large submersible pump suspended from a pontoon and dunked into the sea bed (see Figures 5 and 6). The slurry (11 percent sand by weight) is pumped away via floating pipes. For slurries containing extremely fine-grained sand particles, the velocity in the discharge pipe should exceed 1.50 m/s and for coarser sands 3 to 4 m/s. The advantage of the pontoon pump is that

FIGURE 5
A pontoon-mounted electric pump

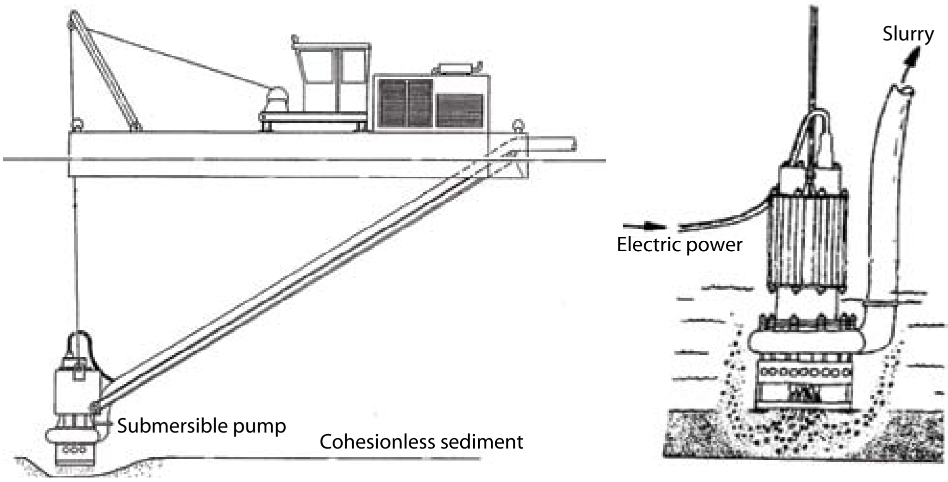


FIGURE 6
Very compact pontoon-mounted pumps

it is capable of a larger output than any other dredger of comparable size. Some pumps are also equipped with cutter blades to handle sea grass and weeds. This method, together with the airlift, is also very suitable for dredging in areas known to contain archaeological remains.

The disadvantages are:

- rough seas, especially swell, hamper this kind of dredging due to the fact that the pump does not always contact the sea bed;
- the range of sediments which can be dredged efficiently is very limited;
- it leaves an irregular bottom topography; and
- when stationary in a navigation channel it causes an obstruction to sea traffic.

6.2.4 Trailing suction

When dredging large volumes of cohesionless sediment, a trailing suction dredger is normally used. A trailing suction dredger is a hopper vessel with a trailing arm suspended over the side and dragged over the sea bed, Figure 7 and Figure 8.

The vessel usually steams forward at around 6 knots, automatically compensating for swell and tidal variations while maintaining the drag head in contact with the sea bed by means of a computerized hydraulic system.

The water/sand mixture is drawn on board by powerful pumps, passed through a series of decanters and the solids deposited inside the internal hoppers whose capacity ranges from 2 000 to more than 25 000 cubic metres. The relatively clear, decanted seawater is dumped overboard. The maximum dredging depth without intermediate pumps is around 35 metres. With one or even two intermediate pumps the dredging depth may be extended to 80 and 120 metres. These dredgers are fully automated and dredging generally takes place over a 24-hour period, non-stop. The dredged sand in the hoppers is either dumped offshore if clean or pumped onshore for reclamation via pipes laid out ashore.

The advantages of trailing suction dredgers are:

- minimum interference to sea traffic;
- versatility in handling both cohesionless and cohesive sediments;
- the dredged load may be pumped ashore as reclamation; and
- constructed in various sizes to suit most project sizes.

The disadvantages are:

- the final dredged depth is less precise, necessitating some overdredging; and
- mobilization costs can be considerable.

FIGURE 7
Trailing suction dredger

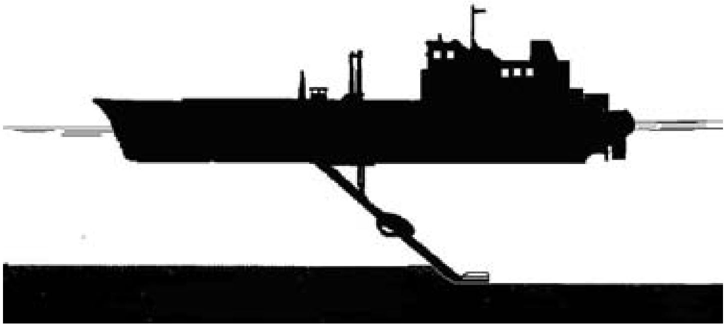


FIGURE 8
A suction-trailer approaching the shore discharge pipe (1). The hopper overflow (2) and trailing arm (3) clearly visible

6.2.5 Blasting

When thick layers of rock or isolated rocky outcrops need dredging, blasting is an efficient method of excavation. In this method, a series of closely spaced holes is drilled into the sea bed, charged with explosives and fired. The holes in the sea bed may be drilled either from above water level, Figure 9, or directly from the sea bed, Figure 10. The hydraulic power to operate the driller is supplied from a shore-based power pack via floating or submerged lines. Both systems are generally carried out by specialist subcontractors.

FIGURE 9
Drilling blasting holes from a jack-up platform

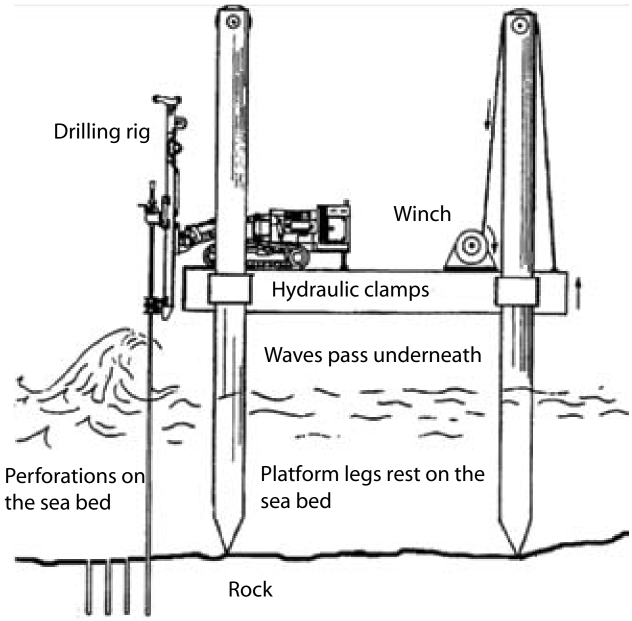
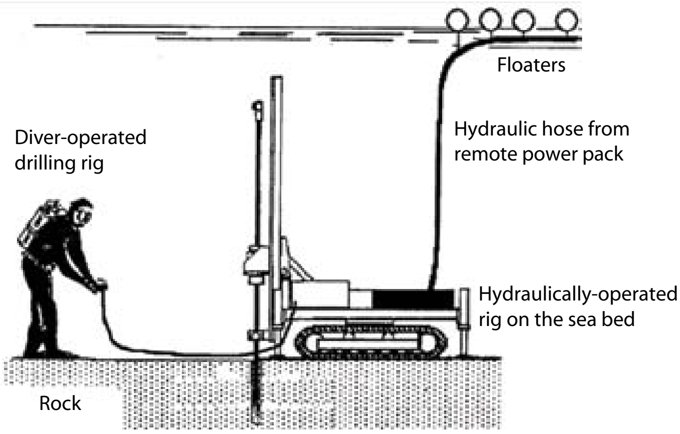


FIGURE 10
Drilling blasting holes directly from the sea bed



Blasting is a relatively quick method for dealing with small amounts of very hard rock formations like outcrops. Large quantities of hard rock are nowadays excavated by rock-cutter suction dredgers or bucket dredgers.

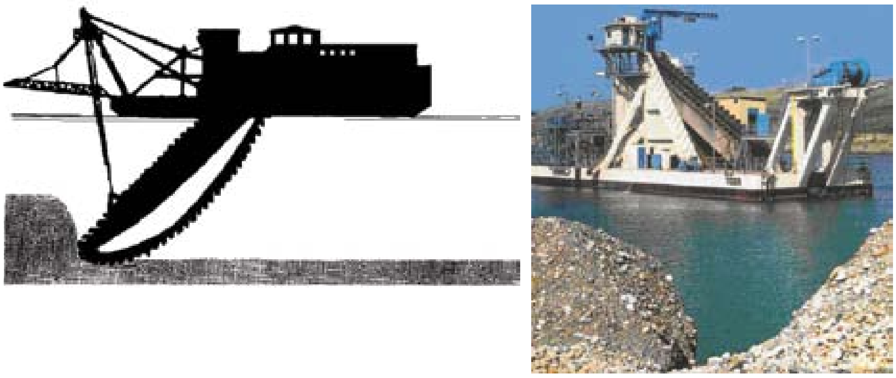
The disadvantages are:

- the blasting must be accompanied by grabbing for the removal of the spoil;
- unless carried out from the sea bed, both drilling and grabbing cause an obstruction to sea traffic;
- the indiscriminate loss of sea life during blasting;
- the percentage of fines generated by the fragmentation of coralline rock are very hard to predict; and
- mobilization costs can be considerable.

6.2.6 Bucket dredging

The bucket dredger, also known as the ladder dredger, consists of an endless bucket chain scraping the sea bed while the dredger is moved across the area to be dredged by means of a series of anchor ropes (Figure 11).

FIGURE 11
Bucket ladder dredger



Although most bucket dredgers nowadays have been replaced with cutter-suction dredgers, quite a few of these dredgers are still around. The maximum dredging depth is normally around 25 metres, although 34 metres is possible with the largest dredger of this type. The buckets range in size from 50 litres to 1 000 litres.

The advantages of a bucket dredger are:

- capability of dredging a level bottom topography;
- ability to work in narrow or restricted areas;
- versatility in handling a wide range of sediments; and
- side loaded barges are generally filled with a high solids-to-water ratio.

The disadvantages are:

- when stationary in a navigation channel it causes an obstruction to sea traffic;
- rough seas, especially swell, hamper this kind of dredging; and
- bucket dredgers are noisy and in urban areas they may be prohibited from working at night.

6.2.7 Cutter-suction

Cutter-suction dredgers are among the most popular type of dredger, available in a wide range of sizes ranging from the small portable units that fit on a large road trailer to ocean-going vessels over 100 metres long.

A small cutter-suction dredger is able to handle small volumes of weakly cemented sediments as well as weeds (Figure 12). The maximum discharge pipe diameter rarely exceeds 150 mm for the portable or demountable type of dredger.

FIGURE 12
Small cutter-suction dredgers

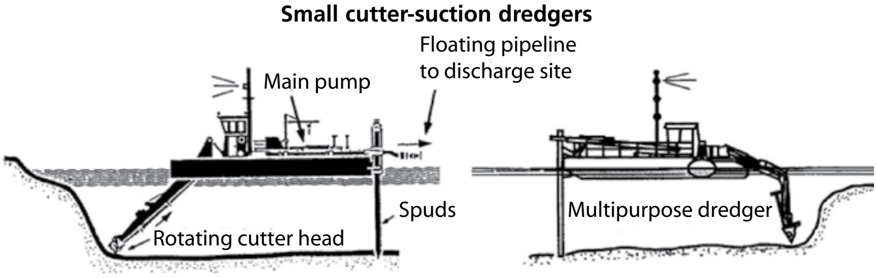


Figure 13 shows the most popular range of cutter-suction dredgers, consisting of two demountable pontoons and a centrally hinged dredging ladder capable of dredging from -3.0 metres to -7.0 metres. The power on the cutting head (Figure 14, left) may range from 40 hp on the smaller versions to 1 200 hp on the larger models, making them suitable for dredging in soft limestone. Discharge pipe diameters range from 250 to 800 mm.

Figure 14, right, shows the full-size dredger commonly used for large-scale dredging operations. Typically, the sand/water mixture is pumped a distance away and longer-than-normal distances are achieved by the installation of booster pumps along the discharge line.

The advantage of a cutter-suction dredger is:

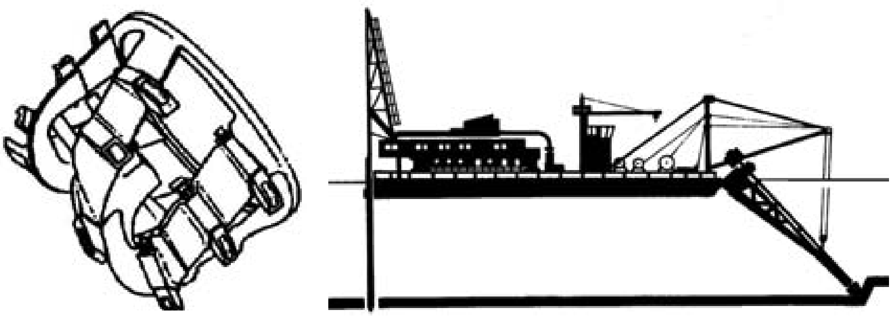
- suitability for dredging in a wide range of sediments.

The disadvantages are:

- in the presence of coralline limestone, the cutter head invariably generates considerable fines in the 10 micron range that are difficult to settle;
- the water-to-sand ratio of the dredged material is so high that it must be pumped directly to the disposal site;
- rough seas, especially swell, hamper the smaller dredgers; and
- when stationary in a navigation channel it causes an obstruction to sea traffic.

FIGURE 13
Small- and medium-sized cutter-suction dredgers

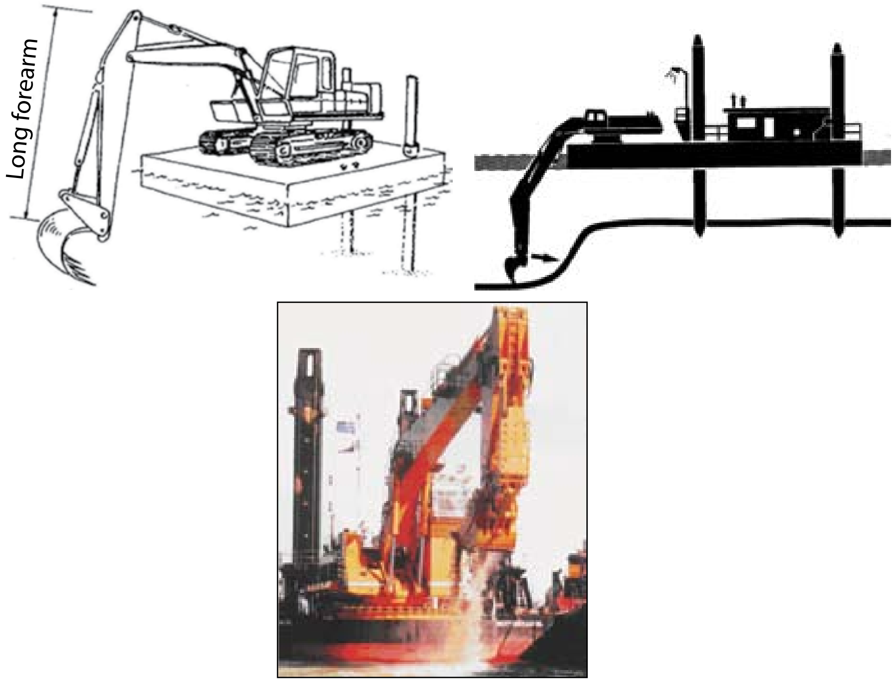
FIGURE 14
The cutter head and a typical full-size cutter-suction dredger



6.2.8 Backhoe dredgers

Backhoe dredgers are land excavators mounted on a pontoon equipped with spuds like a cutter-suction dredger (Figure 15). As with land-based excavators, various fittings are available for tackling different kinds of sediments.

FIGURE 15
Backhoe dredgers, from the smallest size (left) to the largest size (bottom)



The maximum operating depth is limited to around 18 metres.
The advantages of a backhoe dredger are:

- ability to work in narrow or restricted areas;
- versatility in handling a wide range of sediments; and
- side-loaded barges are generally filled with a high solids-to-water ratio.

The disadvantages are:

- when stationary in a navigation channel it causes an obstruction to sea traffic; and
- rough seas, especially swell, hamper this kind of dredging.

6.2.9 Chiselling

Rock breaking may be carried out by a steel chisel dropped through a height by a crane. Normally it is only used in low volume cases where trimming of rock is required. Production rates are very low.

6.2.10 Other methods

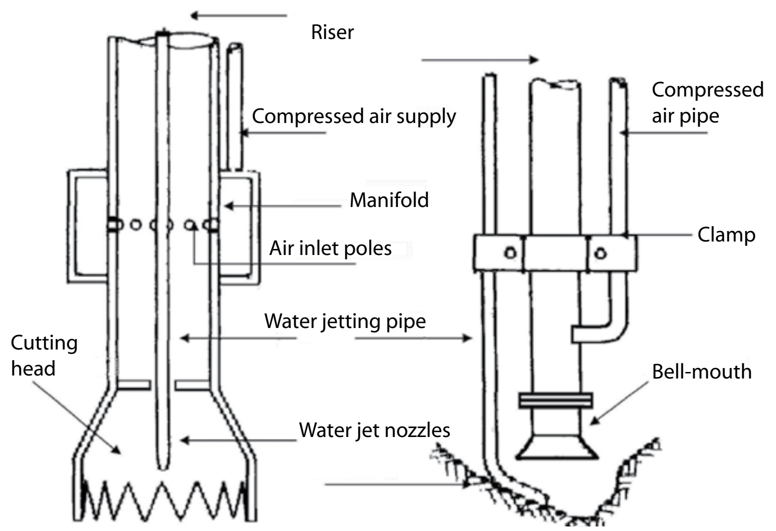
Various other methods may be encountered in practice but they range from specific experimental adaptations to exotic plant.

Airlifting, for example, is frequently used when clearing buried wrecks, but in construction, air lifting is only used to clear underwater foundation trenches from silt drift during construction. An airlift may be used to dredge very small volumes of fine cohesionless deposits only. In the presence of soft clays or clayey silts, airlifts merely form a vertical-sided hole and the material does not tend to slump towards the airlift unless assisted by independent water jets.

Figure 16 shows two types of assisted airlifts typically used in the excavation of foundations in clayey conditions. The airlift in Figure 16 (left) has been used with success on the excavation of bridge foundations in the United States of America. It consists of a 254 mm ejector pipe supplied with air through a 63.50 mm pipe at

11 cubic metres per minute, giving an up-flow velocity of 3 metres per second which is capable of lifting 60 mm gravel. The soil is loosened by a 150 mm jetting pipe operated independently of the airlift. The jetting pipe fed 4 swivelling nozzles of 38 mm diameter fed by two 7 cubic metre per minute pumps delivering water at 34 bar pressure.

FIGURE 16
Types of airlift in use in construction



6.2.11 Dredging adjacent to quay walls

Maintenance dredging adjacent to existing quay walls in fishing ports requires careful assessment of both the material to be dredged as well as the human-made rubbish discarded on the sea bed like tyre fenders, anchors, lengths of chain or wire rope, polyester rope and nets (Figure 17). In most cases, a visual inspection by divers is necessary to verify conditions on the sea bed to be dredged prior to deciding on the type of equipment to be used (cutter-suction versus grab).

In the presence of the aforementioned material, the dredging should be carried out by a grab dredger as illustrated in Figure 3.

FIGURE 17
Cutter-suction heads fouled by discarded items

6.3 DISPOSAL OF DREDGED SEDIMENTS

6.3.1 Introduction

The type of material to be dredged will greatly influence the method of disposal. However, costs can be turned into profits if the dredged material can be used to reclaim land (a process known as reclamation) for industry, roads, housing or leisure. Materials vary in their suitability for reclamation. Sand is the most suitable material for reclamation but all types of granular materials (crushed limestone, gravel, etc.) are suitable. Silt can be used for reclamation if sufficient time is available for drying out and settlement. Due to its fine texture, silt does not dry out as quickly as sand. Instead, before drying out to a fine powdery consistency, it goes through the "muddy" stage, which can take anywhere up to a few months to dry. However, mixed with sand, silty deposits tend to dry out much faster. Sand also improves the consistency of the reclaimed land. Soft clay, once churned up by a cutter-suction dredger, is not suitable as a fill unless it is dried out. This material is only suitable as agricultural fill and cannot be used for foundations or roads. Stiff clay forms into clay balls during the dredging operation and again it is only suitable as agricultural fill.

6.3.2 Classification of dredged sediments

Before deciding on the method of disposal, the dredged sediments must be first classified according to their potential to contaminate the environment where they are due to be deposited. Sediments may be classified under one of three classes:

- Class 1 – clean material, allowable for placing in any type of open water disposal site (open placement on sea bed);
- Class 2 – slightly contaminated, allowable for placing in certain open water disposal sites but requiring careful placing (inside a pit or depression of the sea bed); and
- Class 3 – contaminated material, in principle, not suitable for open water disposal but to be confined in either very strict or well-controlled disposal sites (capped atolls or reclamation).

Various tests on the standard of pollution are required by international legislation and range from the simple water leaching test to multiorganism benthic bioassays or laboratory-controlled tests on selected marine organisms.

The elutriate test is a water leaching test using one part sediment to be dredged to four parts water taken from the proposed dump site. This test, in use since 1973, has been evaluated under an extremely wide range of conditions and is useful for evaluating the short-term release of contaminants from dredged sediments into open water.

The multiorganism benthic bioassays comprise a range of laboratory tests on such organisms as algae, zooplankton, filter feeders (bivalves), deposit feeders (crustaceans) and burrowing species (polychaetes). The tests range from simple physical disruption to direct toxicity and bioaccumulation and consider the liquid, suspended and solid phases of the dumping. Even though bioaccumulation may occur from all three phases, the liquid (or leaching stage) and the suspended (dust plume) phases are of secondary concern due to their short-term occurrence. The solid phase, however, must be assessed for its bioaccumulation potential due to the long-term contact between the dumped sediment on the sea bed and marine organisms.

6.3.3 Environmental impacts of dredging

Strictly speaking, even capital and maintenance dredging in Class 1 sediment (clean material) are an environmentally disruptive exercise and an environmental impact assessment should always be carried out prior to any dredging. Dredging is characterized by three distinct operations:

- the removal of material from an existing environment;
- the method of removal of the material; and
- the dumping of the unwanted material in another environment.

The removal of the material in itself has many potential impacts on the environment and great care should be exercised in distinguishing each and every one of these impacts. For example:

- the sea bed may be used by fish for spawning (some fish require soft sand to dig a nest);
- most shellfish live in sand; and
- if seaweed is also anchored to the sea bottom, the area may serve as a nursery ground for juvenile fish.

The method of removal also has many potentially negative impacts and careful planning is required prior to mobilizing equipment. For example:

- A cutter-suction dredger is very fast but under certain conditions (especially in the presence of coral, coralline limestone and clay) it creates a dust plume visible for miles around the dredger; this plume blocks out sunlight (not particularly good for live coral) and chokes fish by depositing fine dust on their gills.
- High explosive blasting is a quick method of removing obstacles but it also kills marine life indiscriminately in the vicinity of the project.
- A leaking clam-shell grab is not suitable for dredging in a sensitive environment (clear water coral environment) due to the dispersion of fines in the water column.

Finally, the physical and chemical impacts of the actual dumping of the unwanted sediment must also be investigated. Ideally, if the material is clean material, then it should be used for reclaiming land or for filling. However, when the material consists of clay (not suitable for reclamation) mud or silt, it is usual to dump it offshore with a hopper barge, Figure 2. Dumping of Class 1 sediment, for example, may still:

- stifle growth in certain bivalve species through smothering with fine silt; and
- indefinitely render the water murky with the slightest wave agitation if the silt portion is too high.

Dumping of Class 3 sediment, for example, may:

- transpose contaminants from one environment to another and contaminate potentially fertile environments used in fisheries.

Class 3 sediments must be capped whether dumped at sea or on land.

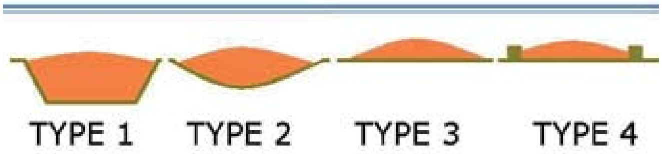
6.3.4 Open water disposal

Since dumping of dredged materials at sea is still a major means of disposal of Class 1 and Class 2 sediments, the selection of dump sites should be carried out by matching the characteristics of the sediment and the site.

Figure 18 illustrates the four basic types of aquatic disposal of sediments up to Class 2 level of contamination. Type 1 consists of a human-made depression in the sea bed (dredged or excavated channel), Type 2 consists of a natural depression in the sea bed, Type 3 consists of a level sea bed and Type 4 is lateral confinement. In all cases, the material deposited may need to be capped with a layer of clean material to isolate it from the surrounding environment.

Permission for the aquatic disposal of dredged sediments at a specific site must be sought from the delegated competent authority.

FIGURE 18
Types of open-water or aquatic disposal

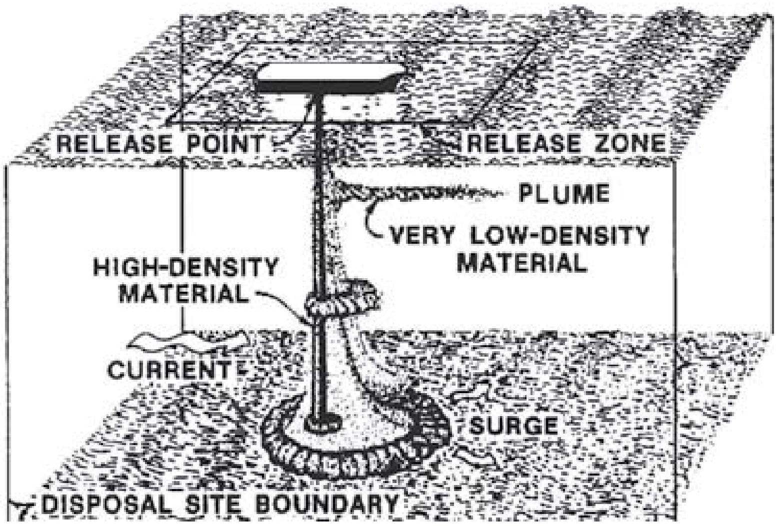


The permit conditions for a site should be designed such that:

- only those materials which have been characterized and found to be acceptable by the environmental impact studies (EIS) are placed at the site;
- material is placed within the site boundaries;
- that the dredging and disposal management techniques have been identified by the EIS; and
- that monitoring requirements are fulfilled and the results reported to the competent authority.

The transboundary drift of the dredged sediments plume, Figure 19, during or after dumping has taken place is a matter of concern when the selected dumping ground is close to territorial boundaries (see Section 1.4.10 on transboundary impacts). In such cases, the permit conditions must include the installation of real-time GPS equipment on the dumping barge and monitoring requirements must ensure that seasonal currents do not transport the plume across national boundaries.

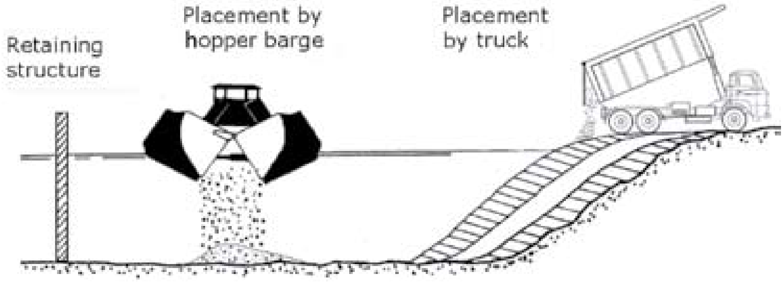
FIGURE 19
Offshore dumping by barge



6.3.5 Confined shore disposal

If dredging (granular material) is being carried out by a grab dredger, hydraulic excavator or drag line, then the material may be loaded onto trucks, carted away and tipped behind a retaining structure (a quay wall) as backfill. Typically, such material will come to a rest at a slope ranging from 1 on 2 to 1 on 6 depending on the size and roughness of the individual particles; the smaller and smoother the particles, the flatter the slope, Figure 20.

FIGURE 20
Placing of backfill behind a quay wall by dumping or tipping



If the dredging is being carried out by a suction or a cutter-suction dredger, then it may be pumped onshore via floating pipes or via a shore connection, Figures 8, 21 and 22.

FIGURE 21
Placing of backfill behind a quay wall by pumping

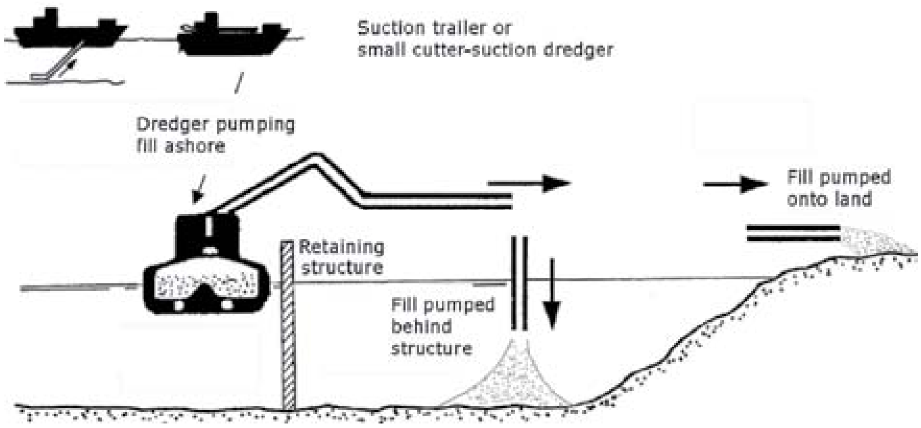
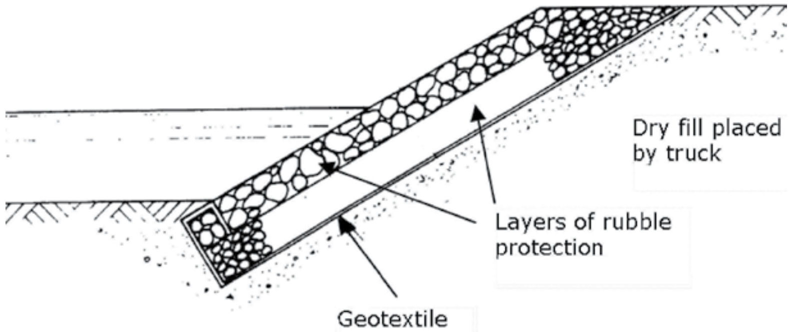


FIGURE 22
Placing of backfill behind a quay wall by pumping

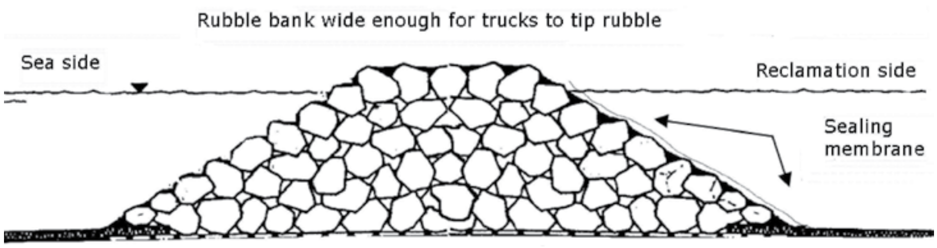
Land reclaimed by forward tipping should be protected by a geotextile filter mat (to prevent sand loss and eventual settlement of the reclaimed area) and a layer of at least 2 metres thick of graded stone, as shown in Figure 23. A mass concrete kerb may also be placed at the summit of the rubble bank to prevent vehicles from driving into the water and falls built into the paving to drain surface water away to sea.

FIGURE 23
Rubble slope protection



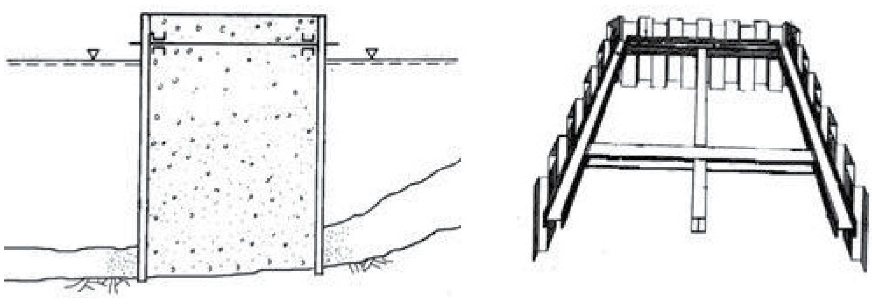
Small-to medium-sized earth retaining structures, such as bunds or quay walls, may be constructed in a variety of ways. The simplest bund is a rubble or stone bund, forward tipped by truck and sealed on the landside by an impermeable layer, Figure 24.

FIGURE 24
Rubble bund



Small quay walls may also be constructed in mass concrete by pumping concrete inside a sheet pile cofferdam, Figure 25.

FIGURE 25
Sheet pile cofferdam



Quay walls may also be constructed with conventional rectangular blocks, Figure 26; “I” section blocks in-filled with stone (lighter to handle than a rectangular block), Figures 27 and 28; “L” shaped units, Figure 29; and annular rings, Figure 30.

Deeper water solutions may be in sheet piles or caissons.

FIGURE 26
Rectangular blocks (20 tonnes)

FIGURE 27
"I" section blocks (10 tonnes)

FIGURE 28
"I" blocks in-filled with rock

FIGURE 29
"L" section blocks (12 tonnes)

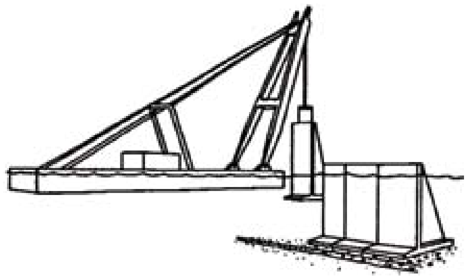
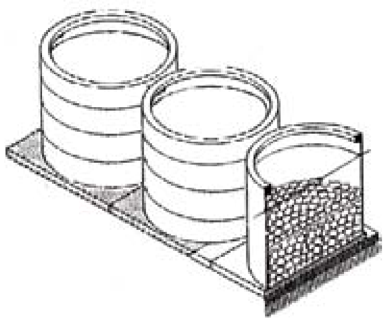


FIGURE 30
Annular rings filled with rock



6.4 DREDGING OF FAIRWAYS

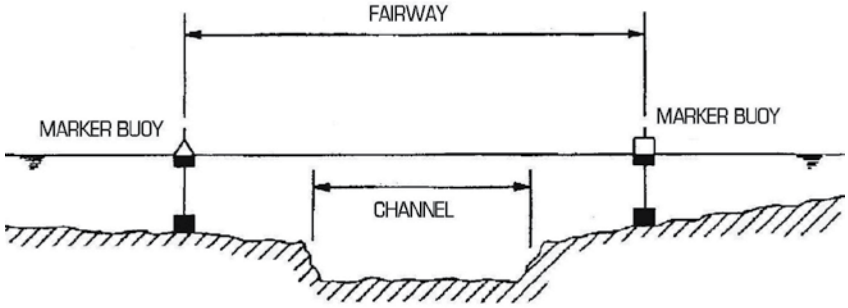
6.4.1 Minimum width

Access channels or fairways are defined in Figure 31. In many dedicated channels the navigation markers are placed close to the edge of the channel to indicate the limits for safe navigation.

In determining the channel width, some or all of the following should be considered:

- basic maneuverability of the vessels intending to use the channel;
- cross-winds, which may cause vessels with high windage to drift sideways;
- cross-currents, which may also cause deep-draft vessels to drift sideways; and
- wave action, which may be heading or following (affecting pitch and heave) or beam (affecting roll and heave).

FIGURE 31
Channel and fairway definitions



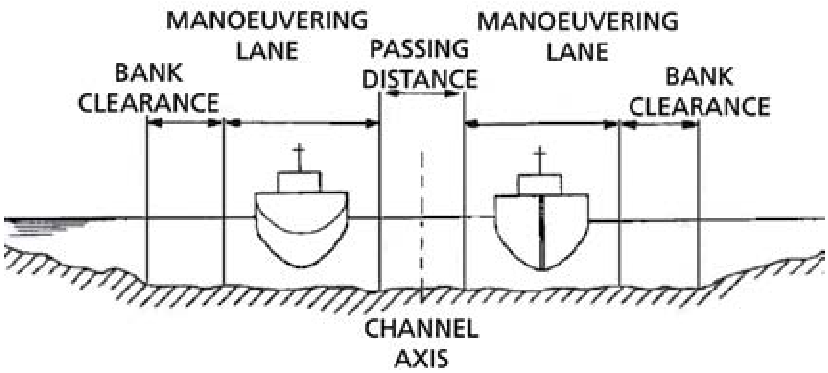
If a two-way channel is proposed, then allowance must be made for vessels to pass each other safely. Such a distance, Figure 32, must ensure that vessel-to-vessel interaction is reduced to an acceptable limit and it is usual to allow for a central safety strip, known as the "passing distance".

Bank clearance should be large enough to reduce bank effects to a minimum, especially in the presence of mobile or unstable deposits such as sand or mud. As a rule of thumb, the minimum fairway width should not be less than eight times the width of the largest vessel to enter the fishing port.

In channels with a wide range of traffic, the fairway markers should be positioned in such a way as to allow the passage of smaller vessels on either side of the dredged channel. In some cases, both the deep-water dredged channel and the shallower outer lanes for smaller vessels may be marked.

There may also be a maximum permissible speed imposed to avoid bank erosion due to backwash from the passage of vessels.

FIGURE 32
Components of channel width

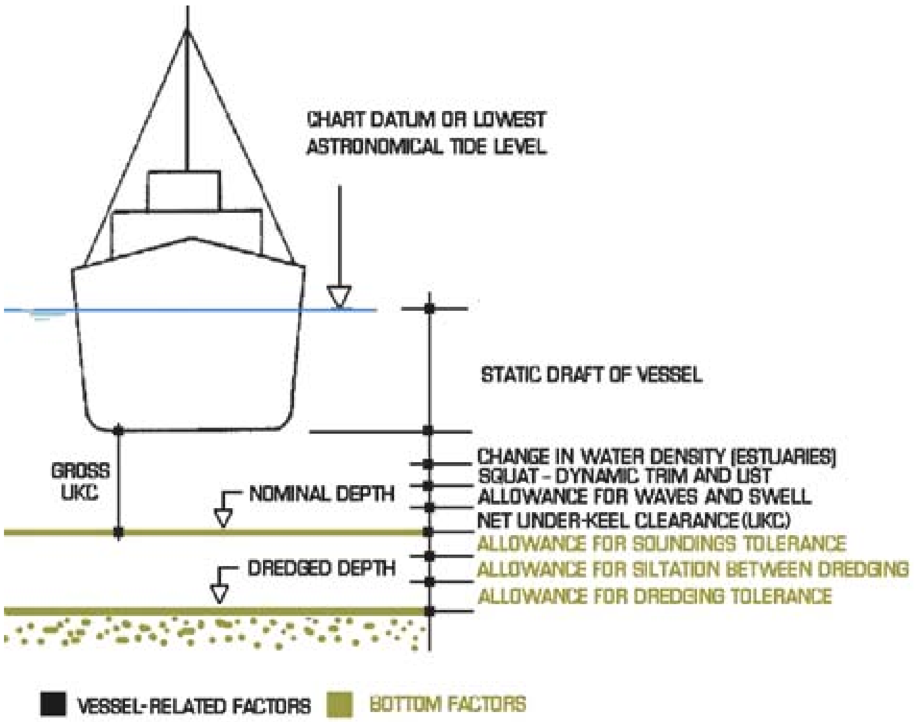


6.4.2 Minimum depth

For a vessel to safely transit the access channel or fairway, it must have adequate clearance under the keel. The under-keel clearance, also known as UKC, depends on a variety of different parameters. These parameters are related to the vessel, the type of sea bed and the water level, Figure 33.

The net under-keel clearance is the minimum margin remaining between the channel bed level and the keel of the vessel in fully loaded condition and in the most unfavourable weather condition. The net under-keel clearance should not be less than 0.50 metre for a soft sea bed (silt or sand) and not less than 1.0 metre for a hard sea bed (rock).

FIGURE 33
Components of channel depth



6.5 BIBLIOGRAPHY AND FURTHER READING

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7. Breakwaters

SUMMARY

A breakwater is a structure constructed for the purpose of forming an artificial harbour with a basin so protected from the effect of waves as to provide safe berthing for fishing vessels. There are many different types of breakwaters; natural rock and concrete, or a combination of the two, are the materials which form 95 percent or more of all the breakwaters constructed.

This chapter reviews the various cross-sections of the most common types of breakwaters and their method of construction. It does not go into great detail with regard to the design of breakwaters as this is best left to the professional engineers for specific applications. Nevertheless, a brief description of the design requirements is given for the sake of clarity.

The reader, however, will be well able to understand the different typologies of breakwaters in use nowadays and appreciate the complexity of choice and underwater construction.

CONTENTS

7.1 PARAMETERS FOR THE CONSTRUCTION OF A BREAKWATER

When a breakwater is to be built at a certain location, and the environmental impact of such a structure has already been evaluated and deemed environmentally feasible, the following parameters are required before construction can commence:

- a detailed hydrographic survey of the site;
- a geotechnical investigation of the sea bed;
- a wave height investigation or hindcasting;
- a material needs assessment; and
- the cross-sectional design of the structure.

7.1.1 Hydrographic survey

The hydrographic survey that is described in Chapter 5 is required for the calculation of the volumes of material required for the breakwater.

7.1.2 Geotechnical investigation

A geotechnical investigation of the sea bed is required to determine the type of founding material and its extent. The results of this investigation will have a direct bearing on the type of cross-section of the breakwater. In addition, it is essential to determine what the coastline consists of, for example:

- soft or hard rock (like coral reefs or granite);
- sand (as found on beaches);
- clay (as in some mangrove areas); and
- soft to very soft clay, silt or mud (as found along some river banks, mangroves and other tidal areas).

In the event that the harbour basin is to be formed by the breakwater itself, a proper advanced site investigation by a specialist contractor is recommended, particularly when project cost is expected to be considerable. On the other hand, if the proposed breakwater structure has no direct bearing on the outcome of a project (for example, if the breakwater is an added protection to a natural inlet) and if it is to be executed on an artisanal scale, then simple basic investigations may suffice.

7.1.2.1 Basic geotechnical investigations

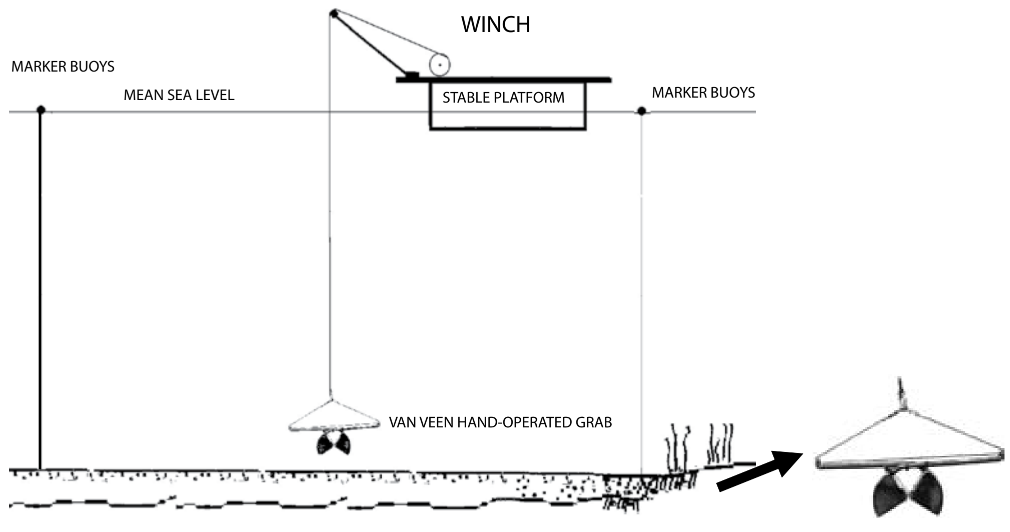
Basic geotechnical investigations normally suffice for small or artisanal projects, especially when the project site is remote and access poor. A basic geotechnical investigation should be carried out or supervised by an experienced engineer or geologist familiar with the local soil conditions. The following activities may be carried out in a basic investigation using only portable equipment:

- retrieval of bottom sediments for laboratory analysis;
- measurement of bottom layer (loose sediment) thickness; and
- approximate estimation of bearing capacity of the sea bed.

The equipment required to carry out the above-mentioned activities consists of a stable floating platform (a single canoe is not stable enough, but two canoes tied together to form a catamaran are excellent), diving equipment, a Van Veen bottom sampler (may be rented from a national or university laboratory), a 20 mm diameter steel pricking rod and a water lance (a 20 mm diameter steel pipe connected to a gasoline-powered water pump).

Before the start of any work, the area to be investigated should be marked via a set of marker buoys or a scaffold pipe frame placed on the sea bed and the exact coordinates noted for future reference. To retrieve samples from the sea bed, a Van Veen hand-operated bottom sampler is required, Figure 1. Simply picking up samples from the sea bed with a scoop or bucket disturbs the sediment layers with the eventual loss of the finer material and is not a recommended method. The sediments thus collected should then be carefully placed in wide-necked glass jars and taken to a national or university laboratory for analysis. At least 10 kilograms of sediment are normally required by the laboratory for a proper analysis.

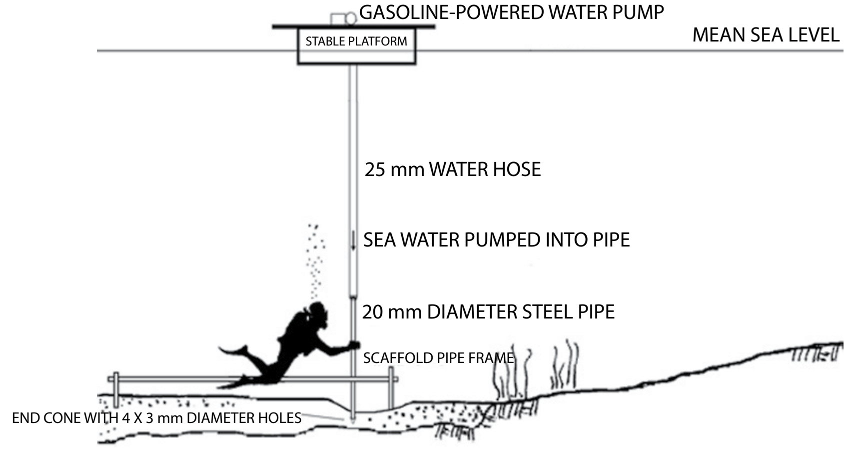
FIGURE 1
The Van Veen bottom sampler



Sometimes, a good hard bottom is overlain by a layer of loose or silty sand or mud. In most cases this layer has to be removed by dredging to expose the harder material underneath. To determine the thickness of this harder layer, a water lance is required. This consists of a length of steel tubing (the poker), sealed at the bottom end with a conical fitting and connected to a length of water hose at the top end. The water hose is connected to a small gasoline-powered water pump drawing seawater from over the side of the platform. The conical end has four 3 mm diameter holes drilled into it.

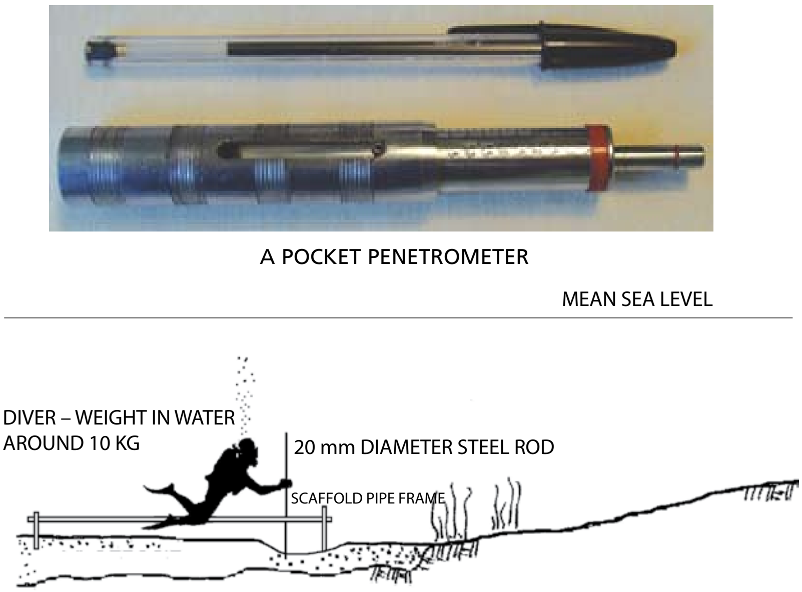
The diver simply pokes the steel tube into the sediment while water is pumped into it from above until the poker stops penetrating, Figure 2. The diver then measures the penetration. This method, also known as pricking, works very well in silty and muddy deposits up to 2 to 3 metres thick. It is not very effective in very coarse sand with large pebbles.

FIGURE 2
The water lance used to "prick" the sea bed



Once the layer of soft sediment has been identified (sampled) and measured (pricked), it is then necessary to determine the hardness of the underlying layer. The underlying layer may be rock, clay or compacted sand. If the layer is rocky, the diver should collect a piece of the material for laboratory analysis using a hammer and chisel. For softer types of material, the diver (with a submerged weight of around 10 kilograms) should use a steel probe (1 metre long, 12 millimetres in diameter) or pocket penetrometer, Figure 3. An area of around 300 mm square should be cleaned of loose sediment and the probe or penetrometer placed vertically over it. The 10-kilogram exertion on the probe will cause the probe to penetrate into the material. The diver then notes the penetration for the engineer to estimate the bearing capacity. If a pocket penetrometer is used, the bearing capacity may be read off the penetrometer scale directly.

FIGURE 3
Estimating the bearing capacity of the foundation



7.1.2.2 Advanced geotechnical investigations

An advanced geotechnical investigation normally requires the retrieval of undisturbed core samples, Figure 4, taken from the level of the sea bed down to a depth ranging from 10 to 30 metres, depending on the type of structure envisaged and the ground conditions obtaining at the site.

FIGURE 4
Core samples of hard clay retrieved from 15 metres below sea bed

Advanced geotechnical investigations are normally carried out by specialist contractors or soil laboratories and require a mobile drilling rig. The drilling rig can travel to most destinations but must be installed on a stable platform before it can be used to drill for cores over water, Figure 5.

FIGURE 5
A mobile rig temporarily installed on a trawler to drill over water

7.1.3 Wave hindcasting

The height of wave incident on a breakwater generally determines the size and behaviour of the breakwater. It is hence of the utmost importance to obtain realistic values of the waves expected in a particular area. Behaviour of water waves is one of the most intriguing of nature's phenomena. Waves manifest themselves by curved undulations of the surface of the water occurring at periodic intervals. They are generated by the action of wind moving over a waterbody; the stronger the wind blows, the higher the waves generated. They may vary in size from ripples on a pond to large ocean waves as high as 10 metres.

Wind generated waves cause the most damage to coastal structures and if winds of a local storm blow towards the shore, the storm waves will reach the shore or beach in nearly the form in which they were generated. However, if waves are generated by a distant storm, they travel hundreds of miles of calm sea before reaching the shore as swell. As waves travel across the sea they decay (they loose energy and get smaller and smaller) and only the relatively larger waves reach the shore in the form of swell.

Wave disturbance is also felt to a considerable depth and, therefore, the depth of water has an effect on the character of the wave. As the sea bed rises towards the shore, waves eventually break. The precise nature of the types of wave incident on a particular stretch of shoreline, also known as wave hindcasting, may be investigated by three different methods:

- *Method 1* – On-the-spot measurement by special electronic equipment, such as a wave rider buoy, which may be hired for a set time from private companies or government laboratories;
- *Method 2* – Prediction by statistical methods on a computer – statistical hindcast models may be performed on the computer if wind data or satellite wave data are available for the area; and
- *Method 3* – On-the-spot observation by simple optical instruments – the theodolite.

Methods 1 and 2 give very accurate results but are expensive, especially the hire of the wave rider buoys; they are usually reserved for big projects where precise wave data gathered over a period of time is of the utmost importance.

In Method 1, the observer is an electronic instrument capable of recording continuously on a 24-hour basis far out at sea where the waves are not yet influenced by the coastline (depth of water). Hiring a wave rider buoy and installing it may take anywhere up to six months, depending on the method of procurement and water depth and weather conditions at the site. A minimum of one year's observations is required but generally three to five years provide more accurate data.

Method 2 is currently the standard worldwide method of establishing the wave climate along most coastlines. The huge amount of wind and wave data gathered by specialist agencies worldwide now enables most computer models to zero-in on most sites. Offshore wave climate data is nowadays compiled from hindcasting methods using detailed wind records available for most areas from weather information agencies. Inshore wave climates are then derived on a case-by-case basis from knowledge of the local bathymetry. At today's prices, the cost of a detailed inshore wave climate is in the range of US$50 000, excluding the cost of the detailed hydrographic survey required for the area under study. Depending on how much raw data is already processed by the specialist agencies and if detailed bathymetry already exists, a good wave hindcast report takes about one month to produce.

Method 3 is not accurate but is cheaper and lies more within the scope of artisanal projects. It differs from Method 1 in one respect only, in that the observer is a normal surveyor with a theodolite placed at a secure vantage point observing waves close to the shoreline, Figure 6. This method, however, suffers from the following drawbacks:

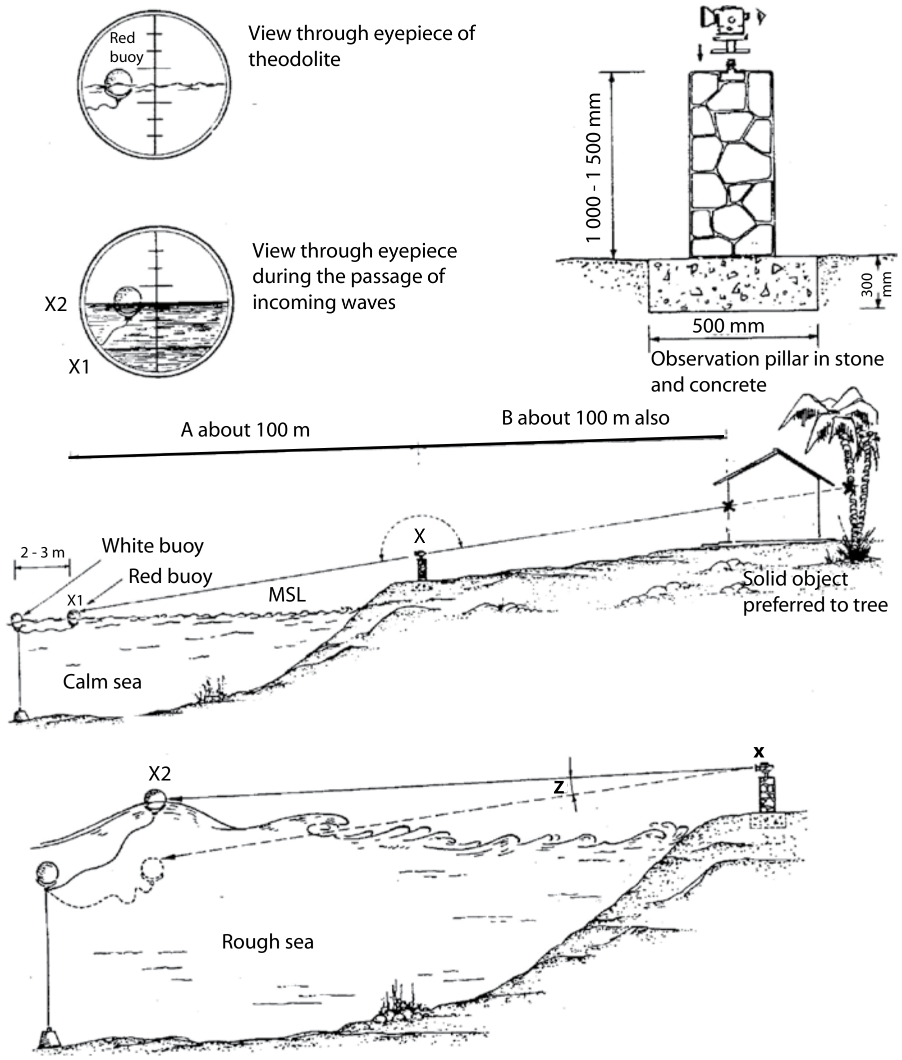
- The wave heights thus recorded will already be distorted by the water depths close to the shoreline.
- A human observer can only see waves during daylight hours, effectively reducing observation time by a half.
- In very bad weather, strong winds and rain drastically reduce visibility making it difficult to keep the buoy under observation continuously.
- The presence of swell is very difficult to detect, especially during a local storm, due to the very long time (period) between peaks, typically 15 seconds or more.

Hence, this method of calculating wave heights is only suitable for minor artisanal projects with a very small capital outlay. To set up a wave monitoring station is easy and the equipment needed consists of two large buoys (one fluorescent and one white), say 750 millimetres in diameter, a large stone and concrete sinker weighing at least 1 tonne in water, a length of 12 mm nylon rope, a theodolite, a compass and a watch with a second hand or digital readout. At a vantage point, which should be just high enough above sea level to be safe and dry during a storm, a stone pillar should be erected with an anchor screw concreted in at the top so that every time the theodolite is set up it faces the same way in exactly the same position, Figure 6. Apart from the time it takes to set up the theodolite station, observations of major waves may only be undertaken during major storms. Hence this method may take at least one year to produce enough data to be useful for a study.

The two plastic buoys should then be moored a known distance offshore where the water depth is exactly 20 metres, the white buoy to the sinker and the red fluorescent buoy to the white buoy, as shown in the figure. The white buoy keeps the mooring line taut and vertical while the red fluorescent buoy floats freely on the incoming waves.

To calibrate the station, the theodolite should be pointed at the buoy on a very calm day. A witness mark should then be placed on something robust (a wall, for example, is preferable to a tree) in such a manner that the observer can re-point the eyepiece at the buoy in its rest position (even if the buoy is actually bouncing up and down with the incoming waves during a storm) at a later date. In this way the theodolite is not tied up completely with wave height observations but can be used for other work as well in between storms. During a storm, the buoy will float up and down with the passage of the waves. By following the base of the buoy with the same centreline hairlines, the theodolite is made to traverse a small angle, Z, as shown in the figure. Using basic surveying principles, the distance A and angle Z may be used to calculate the height H of a wave which, as a rule of thumb, is twice the height of the displacement above calm water level.

FIGURE 6
Manual wave height measurement



During wave height observations, the following additional information should also be recorded:

- direction of both the incoming waves and wind using the hand-held compass;
- the time difference between each successive wave peak, also known as wave period using the second hand on a watch;
- the exact position of the buoy with respect to the coastline; and
- time of the year when each storm was recorded.

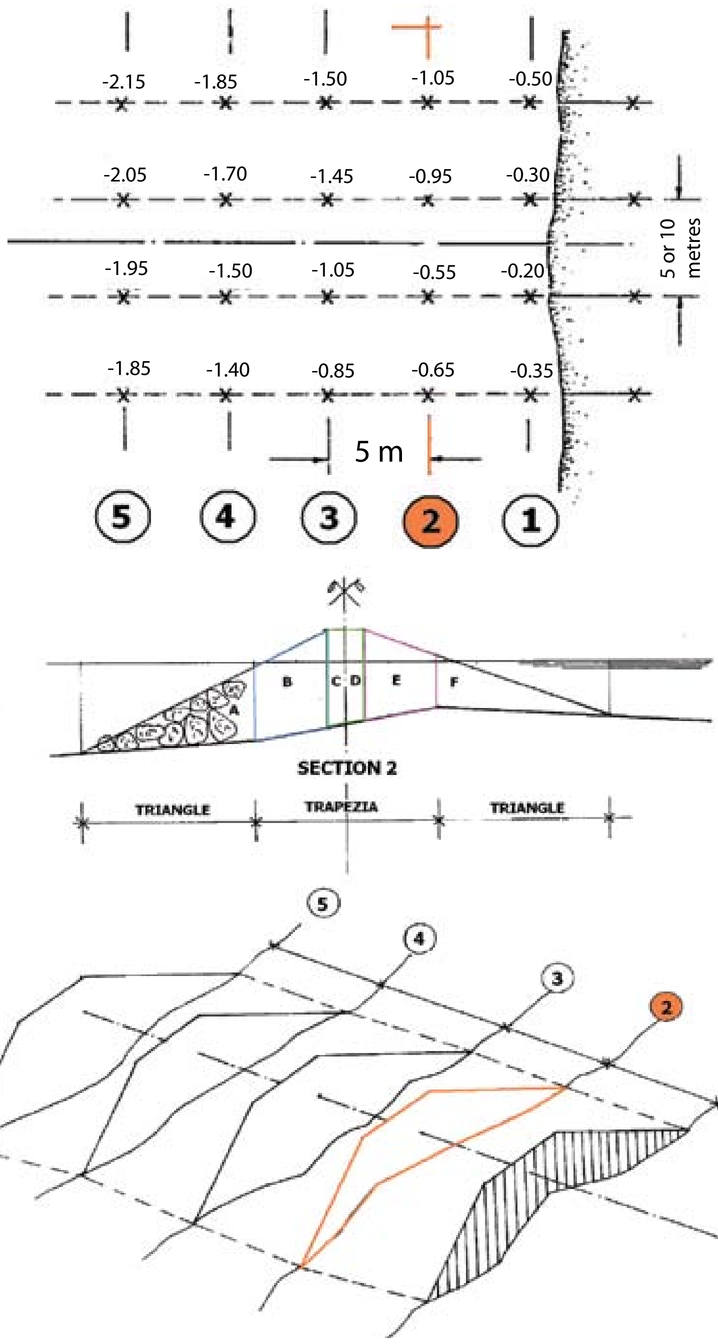
It must be re-emphasized at this stage that this calculation and the method used are only very approximate and suitable for minor projects only.

7.1.4 Material needs assessment

Given that most breakwaters consist of either rock or concrete or a mixture of both, it is evident that if these primary construction materials are not available in the required volume in the vicinity of the project site, then either the materials have to be shipped in from another source (by sea or by road) or the harbour design has to be changed to allow for the removal of the breakwater (the site may have to be moved elsewhere).

To calculate the volume of material required to build a rock breakwater, for example, equidistant cross-sections are required. Each cross-section consists of the proposed structure outline superimposed on a cross-section of the sea bed. Figure 7 shows a grid map with five cross-sections. Figure 7 (middle) also shows cross-section number 2 of the sea bed, with the breakwater cross-section superimposed on it. Each cross-section may then be divided into known geometric subdivisions, like triangles (A and F) and trapezia (B, C, D and E), whose areas are given by standard formulae. In this way, area 2 is given by the sum of areas A + B + C + D + E + F. Similarly, areas 1, 3, 4, 5, etc. may be calculated from the hydrographic chart. The volume of material required is then the sum of volume 1 + volume 2 + volume 3 + volume 4, etc., as shown in Figure 7. Each segment of breakwater, say volume 1, is given by the average of the sum of (area 1 + area 2) multiplied by the distance between sections 1 and 2, in this

FIGURE 7
Calculating the volumes of rock in a breakwater



case, 5 or 10 metres. Mathematically, this can be expressed as 1/2 [area 1 + area 2] x 5 metres. Once the volume of rock has been determined, the most likely source has to be investigated for:

- *supply* (must be large enough to supply all the rock);
- *quality* (not all rock is suitable for a breakwater);
- *environmental impact* (removing rock from the source must not cause negative impact there);
- *mining methods* (depending on the type of rock, it may have to be blasted, ripped or broken); and
- *means of transport* (if roads do not exist between source and project site, then other means of transport are required).

7.1.5 Cross-sectional design

Last but not least, a suitable cross-sectional design for the breakwater has to be produced taking into consideration all the previous data, for example:

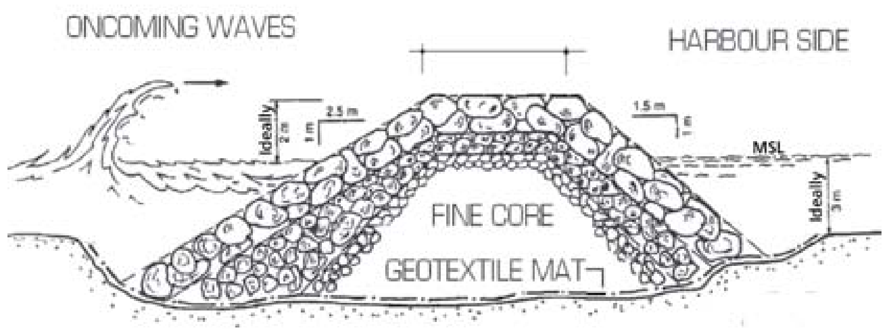
- *water depths* (in deep water, solid vertical sides are preferred to save on material);
- *type of foundation* (if ground is soft and likely to settle, then a rubble breakwater is recommended);
- *height of waves* (rubble breakwaters are more suitable than solid ones in the presence of larger waves); and
- *availability of materials* (if no rock quarries are available in the vicinity of the project, then rubble breakwaters cannot be economically justified).

In general, expert advice should always be sought before embarking on the design of a breakwater cross-section. As was mentioned earlier, waves are one of nature's least understood phenomena and considerable experience is required when designing breakwaters. If expert advice is not available, the following rules of thumb may be applied to very small projects with water depths not exceeding 3.0 metres:

For rubble mound or rock breakwaters:

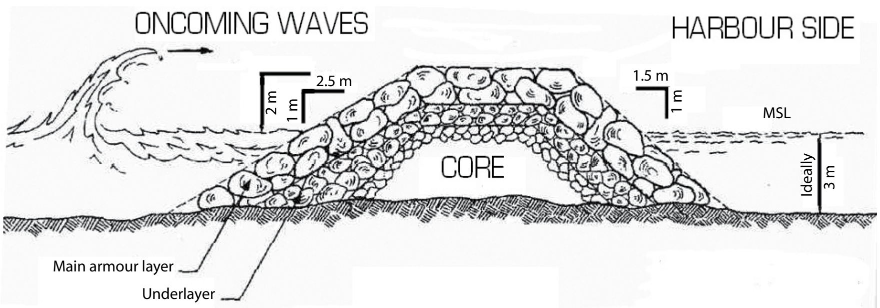
- Unaided breakwater design should not be attempted in waters deeper than 3 metres.
- If the foundation material is very soft and thick, then a geotextile filter mat should be placed under the rock to prevent it from sinking and disappearing into the mud (Figure 8).
- If a thin layer of loose or soft material exists above a hard layer, then this should be removed to expose the hard interface and the breakwater built on this surface.

FIGURE 8
Rubble mound breakwater on soft ground



- The material grading should be in the range of 1 to 500 kilograms for the fine core, 500 to 1 000 kilograms for the underlayer and 1 000 to 3 000 kilograms for the main armour layer, Figure 9.

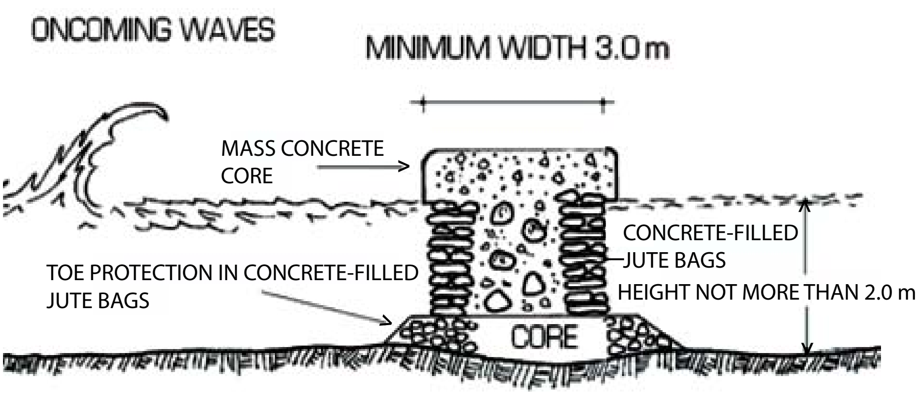
FIGURE 9
Rubble mound breakwater on hard ground



- Dust and fine particles should not be placed in the core as these will wash away and cause the breakwater top to settle unevenly.
- The outer slope should not be steeper than 1 on 2 and the inner or harbour side slope not steeper than 1 on 1.5 (Figure 8).
- In general, rock breakwaters absorb most of the wave energy that falls on them and reflect very little disturbance back from the sloping surface.

For solid or vertical breakwaters:
- Unaided vertical solid breakwater design should not be attempted in waters deeper than 2 metres and exposed to strong wave action, Figure 10.
- Vertical solid breakwaters are only suitable when the foundation is a firm surface (rock, stiff clay, coral reef); thick sand deposits may also be suitable under certain conditions.
- In the presence of thick sand deposits, a rubble foundation with adequate scour protection as shown in Figure 10 is recommended lest strong tidal streams, water currents or wave turbulence scour away the sand underneath the foundation.
- The core of a solid breakwater should be cast in concrete; not more than 50 percent of this concrete may be replaced by pieces of rock or “plums”.

FIGURE 10
A solid vertical breakwater on hard ground



Great care should be exercised when deciding the position of a solid breakwater. Solid vertical breakwaters do not absorb wave energy incident on them and reflect everything back, usually causing other parts of a harbour to experience "choppy-sea" conditions.

7.2 CONSTRUCTION METHODS

There are several types of equipment available for marine construction, both land-based and floating. The high cost of purchase, however, puts most of this equipment beyond the reach of village cooperatives, artisanal contractors and small general-building contractors.

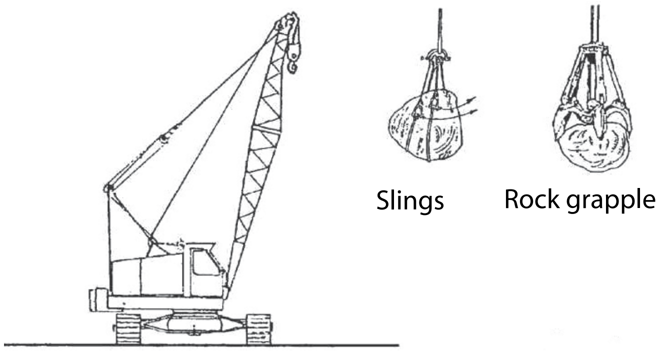
Hence, it is assumed that most of the heavy plant will be made available through the government or public works department, or local contractors, and this chapter should be used as a guide to the general type of equipment required for marine work. Large specialist marine contractors often use floating equipment (all cranes mounted on barges, for example, and material like the core is often dumped using barges). When planning the construction of a marine-related project, it would be useful to know beforehand what type and size of construction plant is available in the vicinity of the village or landing.

7.2.1 Land-based equipment

Crawler crane

Figure 11 shows a typical crawler crane. As its name implies, a crawler crane moves forward on its steel tracks. This is the most ideal type of crane for building breakwaters because it is very stable, requires no outriggers (stabilizers which extend from the crane chassis of all rubber–tyred cranes) and is less likely to bounce off an uneven rubble surface into the water.

FIGURE 11
Crawler crane



The most important characteristic is the nominal lifting capacity as this will dictate the maximum outreach that the crane can handle with a given jib size. The nominal capacity of a crane refers to the maximum safe working load that the crane can lift with the jib in the near-vertical position as shown in Figure 11. This load is dependent on the overturning moment of the load and is expressed as:

$$[\text{Load at the hook}] \times [\text{the lever arm } L_a] / [\text{Factor of safety}] = \text{A Constant}$$

This value is factory-set and is usually displayed in tables inside the crane driver's cabin. As the jib is lowered thus increasing the outreach (or lever arm L_a), the working load at the hook must be decreased to compensate for the greater overturning moment of the load. Failure to observe the proportional reduction in the suspended load as indicated in the crane's tables will result in the crane overturning. Figure 11 also shows two typical attachments required for lifting and placing rock: slings and grapples. Most slings are made from steel wire rope and these should terminate in quick-release shackles to enable the crane driver to release the rock himself once it has been placed. Rock grapples are the industry standard for handling rock. If a rock grapple is used, the weight of the grapple (anything from 500 to 3 000 kilograms) must be subtracted from the safe working load specified for a particular crane.

SAFETY PRECAUTIONS

The crane driver should always wear a hard hat and soundproof earmuffs. Consequently, it is essential to put in place a signalling system between the load handlers and the driver. Load handlers should always wear hard hats and gloves. If the loads are handled with steel-wire ropes, then the appropriate gloves should be worn to prevent injuries.

Hydraulic excavators

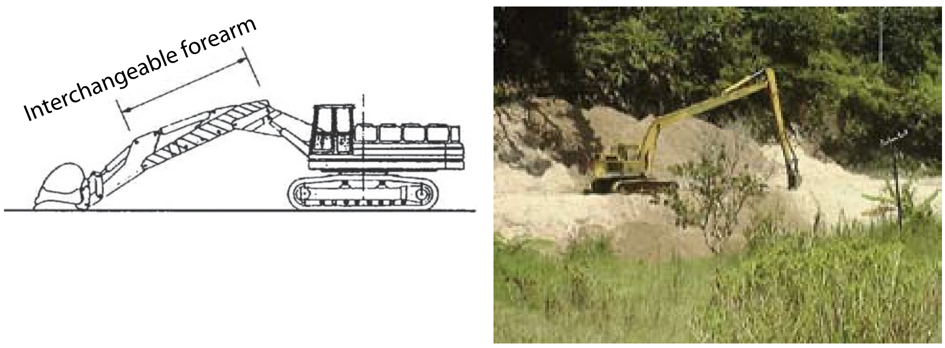
Figure 12 shows a hydraulic excavator, which now forms the backbone of most marine work.

Most models offer interchangeable forearm lengths; for normal marine work, a long forearm is required to reach as far away as possible, Figure 12, right.

Excavators can be equipped with:

- hydraulic-powered chisels (for breaking hard material);
- hydraulic-powered rotating cutter-head (for digging in soft material); and
- a range of buckets to suit any condition that may be encountered on site (wide buckets, narrow buckets, small buckets, high-capacity buckets, etc.).

FIGURE 12
Hydraulic excavator



SAFETY PRECAUTIONS

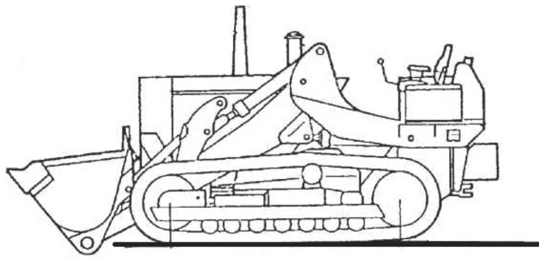
Hard hats should always be worn around an operating excavator. The operator should wear soundproof earmuffs and a signalling system set up between the other workers and the driver.

Bulldozer

Figure 13 shows a typical tracked bulldozer.

Rubber-tyred equipment should not be used on breakwaters; this kind of equipment is prone to bounce around on dumped rock and likely to lead to fatal accidents (by falling into the water). The bulldozer, on the other hand, is slower moving and more stable. This kind of machine is essential when building breakwaters as it is required to level the fine core material as it is forward dumped into the sea. Bulldozers may be equipped with blades (for levelling the core of a breakwater) or buckets. The operator's cabin may be sealed or open to the elements as shown in the figure.

FIGURE 13
Bulldozer



SAFETY PRECAUTIONS
The operator should wear both a hard hat and earmuffs and a signalling system set up between other workers and the driver.

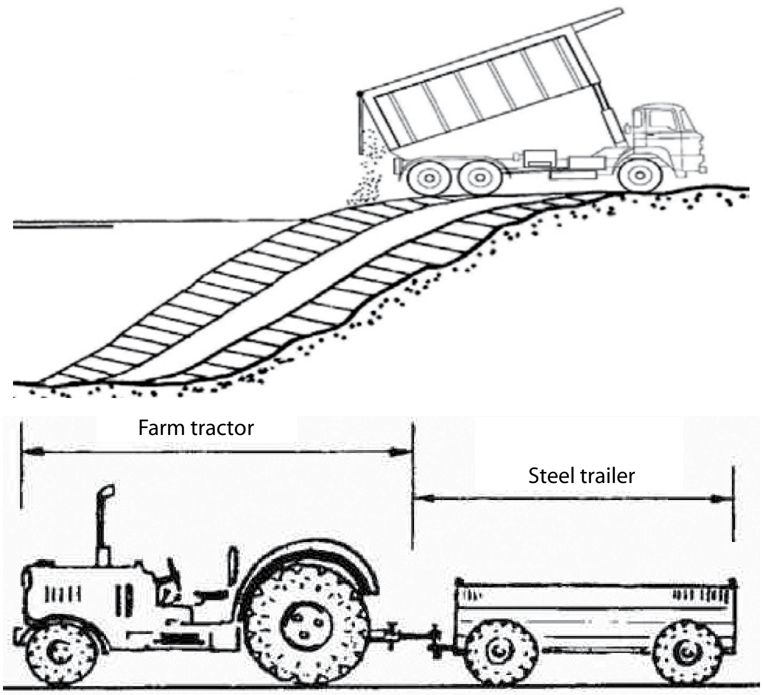
Tipper trucks

Figure 14 shows the recommended type of truck required for transporting and dumping of rubble.

If proper tipper trucks are not available for a project, then a farm tractor and trailer combination may be adapted to carry rock, aggregates and sand from a quarry to a project site. Considerably more use of direct labour is involved, but at local village level this should not present any problems. The trailers should preferably be made of steel and should be protected on the inside with timber planking. The timber prolongs the useful life of the trailer by absorbing the impacts of individual stones thrown onto the trailer. Care should be exercised when traversing the uneven surface of a rubble core with all rubber-tyred vehicles.

SAFETY PRECAUTIONS
All personnel should wear hard hats.

FIGURE 14
Tipper trucks and forward dumping



7.2.2 Floating equipment

Floating crane

Figure 15 shows a typical barge-mounted crane. The crane is either bolted or welded directly to the hull or driven on to the barge and lashed down with cable stays.

The crane can revolve through 360 degrees and the deck of the barge is usually lined with timber so that rock may be placed on the deck without damaging it. The stability of the crane in this instance is dictated by the stability of the barge and field conversions should always be checked for stability by an experienced naval architect. Normally, such cranes need a tugboat or fishing vessel to help them move from one place to another. Exact positioning is usually achieved by anchors.

FIGURE 15
Floating crane

SAFETY PRECAUTIONS

All personnel should wear hard hats. The barge should be equipped with the safety requirements stipulated for shipboard operations (life jackets, flares, raft, etc.), including MARPOL recommendations for the prevention of pollution at sea.

Tugboat

Figure 15, bottom right, shows a tugboat of the type generally used by marine contractors. The horsepower of these vessels may be anywhere from 200 to 2 000 hp, depending on the type of plant to be handled. Common sizes are in the range of 250 to 500 hp.

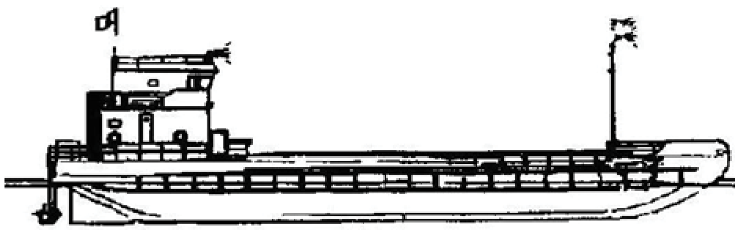
SAFETY PRECAUTIONS

The tugboat should be equipped with the safety requirements stipulated for shipboard operations (life jackets, flares, raft, etc.), including MARPOL recommendations for the prevention of pollution at sea.

Hopper barge

Figure 16 shows a general purpose hopper barge used for the transport and dumping of material at sea. Commonly, available barges have a capacity in the range of 500 to 1 000 cubic metres and are generally self-propelled. Hopper barges can be used for dumping the core of a breakwater in deep water (5 metres and deeper) and for dumping excavated or dredged material offshore.

FIGURE 16
The split hopper barge



SAFETY PRECAUTIONS

The hopper barge should be equipped with the safety requirements stipulated for shipboard operations (life jackets, flares, raft, etc.), including MARPOL recommendations for the prevention of pollution at sea.

7.2.3 Methodologies

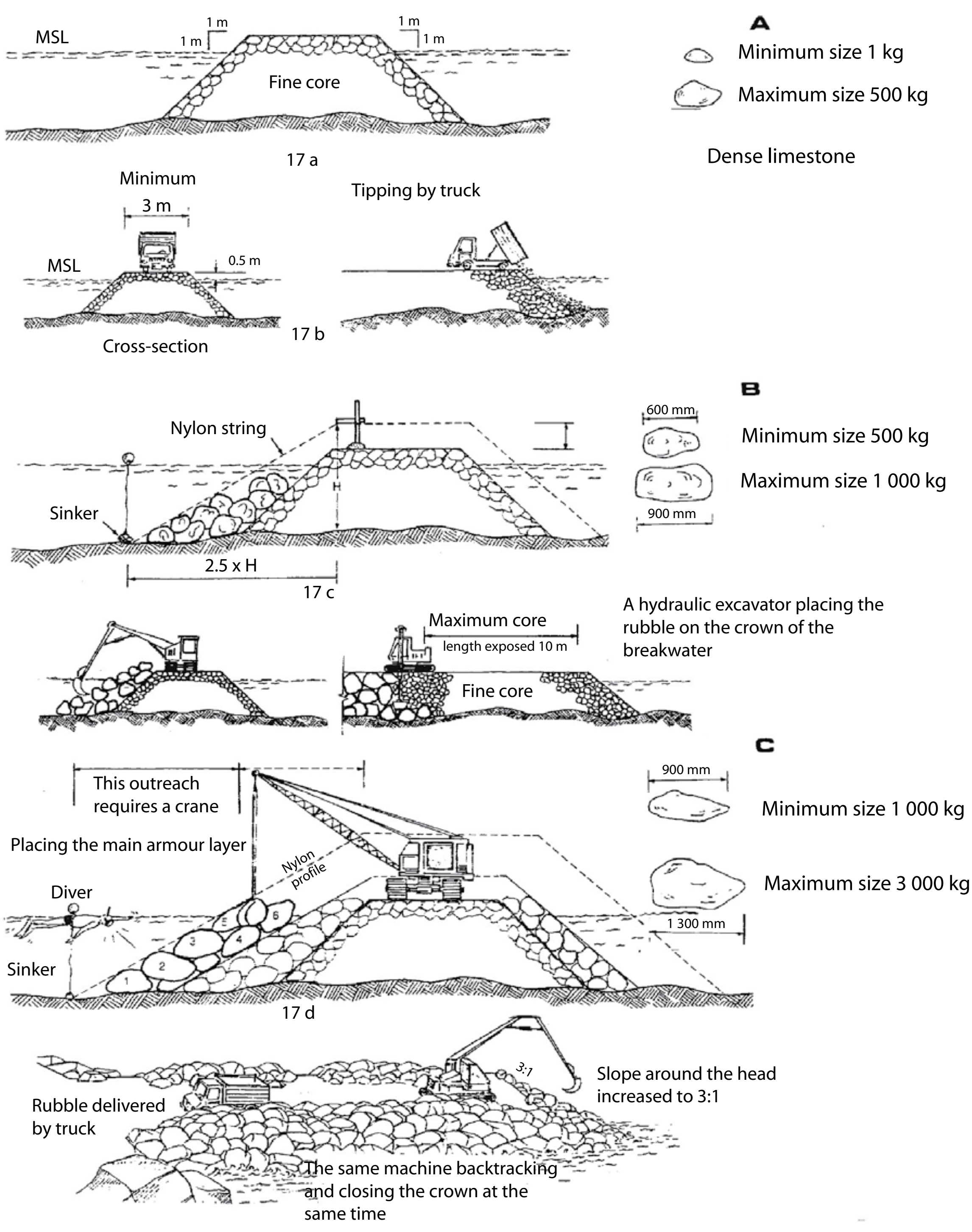
The typical breakwater illustrated in Figure 8 (shallow water only) consists of a mound of coarse stone, also known as a core, covered or protected by blankets or layers of heavier stones.

7.2.3.1 The core

The core typically consists of stone weighing between 1 kilogram and 500 kilograms, without the fine particles (dust and sand) dumped in a heap out into the sea by a dump truck. To facilitate dumping by truck, the core should be ideally four to five metres wide at the top and approximately half a metre above mean sea level or, in the presence of a large tidal range, above high water spring level, Figure 17a. The top of the core should be kept level and uniform by a bulldozer to enable the dump trucks to travel the entire length of the breakwater. When tipped into the water, the core rubble comes to rest at a slope of approximately 1 on 1, i.e. it drops down 1 metre in level for every 1 metre forward. The rubble in the core is very light, so breakwaters should be built during calm weather only.

Environmentally speaking, the core dumping may have a large negative impact on the surrounding sea due to the fine dust that gets washed off the rubble. In environmentally sensitive areas, such as coral reefs, protected fish breeding areas and nursery grounds rich in certain species of protected vegetation such as *Posidonia* sea grass, the core must be sluiced or washed before placing to limit the dust plume that would otherwise be generated by the fine dust particles. This dust plume usually persists for many days and can cause a lot of damage by either blocking out sunlight or depositing fine dust on the gills of fish and suffocating them.

FIGURE 17
Rubble mound construction



7.2.3.2 The underlayer

The underlayer of stone that protects the core rubble from being washed away, Figure 17b, usually consists of single pieces of stone whose weight varies between a minimum of half a tonne (500 kilograms) to a maximum of one tonne (1 000 kilograms). These are usually laid in a minimum of two layers at a slope which is generally shallower than that of the core; 2/1 on the outer slope and 1.5/1 on the inner slope. A slope of 2/1 means that the level drops 1 metre for every 2 metres forward.

The first layer of stone may be placed by a hydraulic excavator as shown in Figure 17c. The excavator should place the heavier stone as quickly as possible without leaving too much core rubble exposed to wave action. If a storm strikes the site with too much core exposed, there is a grave danger of the core being washed away and spread all over the intended port area.

The figure shows the set up for a given stone profile, in this case a slope of 2.5/1: the distance H is the height of the top of the new sloping layer above the sea bed. A wooden pole should be conveniently placed at the tip of the underlying core and cemented into place with mortar. At a distance equal to 2.5 x H, a heavy stone sinker with a marker buoy should be placed on the sea bed. A brightly coloured nylon string should then be strung from the sinker to the required height on the pole. This procedure should be repeated every 5.0 metres to help the crane or excavator operator with the placing of the top-most layer. A swimmer wearing goggles (and in cold waters a wet suit) should ensure that each separate rock is placed within the profile outlined by the nylon string.

7.2.3.3 The armour layer

The main armour layer, as its name implies, is the primary defence of the breakwater against wave attack. The stone sizes for the cross-section in the shallow water example should be in the range of 1 tonne (1 000 kilograms) to 3 tonnes (3 000 kilograms). Any defects in the quality of the rock, grading (size too small) or placing (slope uneven or too steep) will seriously put the whole breakwater at risk. Hence, great care must be taken when choosing and placing the stone for the main armour layer.

Figure 17c shows main armour stone being placed by a crawler crane or tracked crane, which is by far the best equipment for placing large stones. The large stones should be lifted singly using a sling or stone grapple and placed in the water with the aid of a diver swimming over the placing area. The armour layer should be placed stone by stone in a sequence which ensures interlocking; in the figure, for example, stone 2 is held in place by stones 1 and 3 whereas stone 4 is jammed between stones 3 and 5. This ensures that waves cannot pull one stone out and cause the upper stones to topple down the slope, breach the armour layer and expose the smaller rubble underneath. To ensure proper placing, the swimmer or boat crew should direct the crane operator each time a stone is placed until the stone layer breaks the surface. As with the first underlayer, two layers of armour stones are required to complete the main armour layer. Slope profiles should be set up at regular 5 metre intervals using the same procedure as described previously. Figure 17d, bottom, shows how the nearly complete breakwater is closed off layer by layer. It shows the excavator backtracking to the root of the breakwater closing the top layers simultaneously. The end or head of the breakwater is the most delicate part of the breakwater and requires extra care. The outer slope of 2.5/1 should be increased to 3/1 to improve its stability.

7.2.3.4 Solid breakwater

Figure 19 illustrates how a vertical, solid breakwater may be built. A stone rubble foundation should first be laid on a hard sea bed (rock, coral deposits or stiff clay) using the appropriate equipment illustrated in Figure 18. If the foundation is a thick deposit of good sand (no silt or soft clay or mud), then a geotextile filter mat should be placed under the rubble foundation. The rubble should consist of a well-graded mix of 1- to 5-kilogram stones. A temporary profile of the proposed section should then be erected every 2 or 3 metres as shown in Figure 19.

Concrete filled jute bags, or locally available dressed stone, should then be laid on the rubble foundation, in line with the temporary profiles. Mass concrete should then be poured into the central cavity to form a solid structure. The deck and wave wall may be built to suit local conditions or as shown in the figure. Finally, after the removal

FIGURE 18
Preparation of a level foundation bed in stone

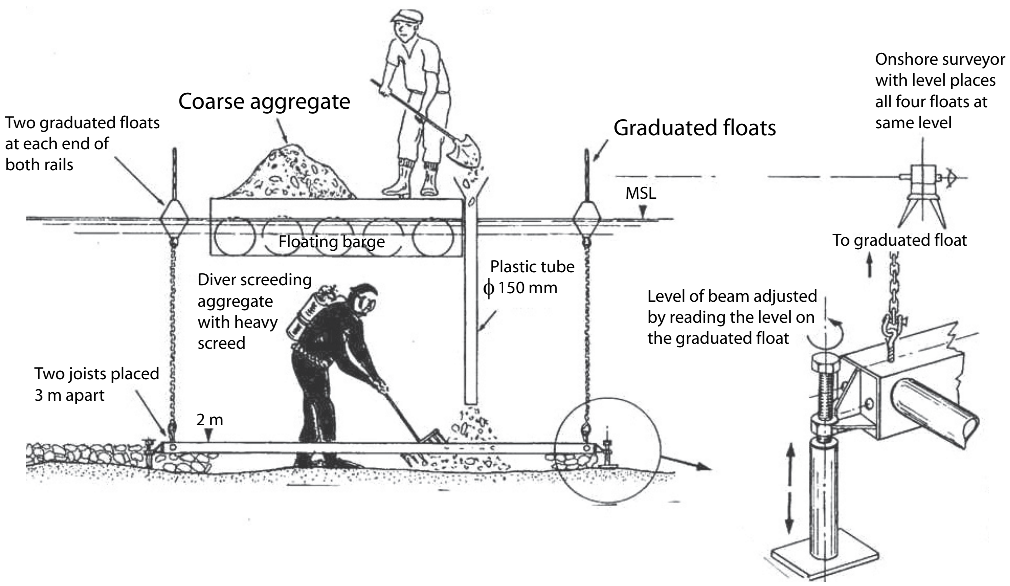
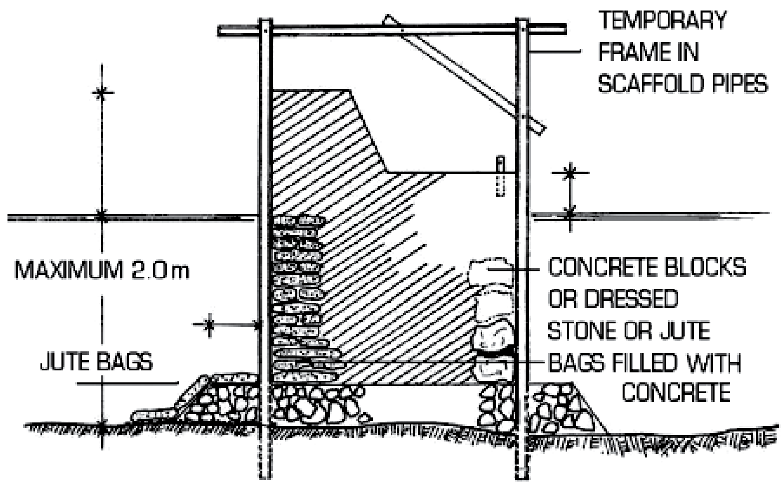


FIGURE 19
Construction of a small vertical-faced breakwater



of the temporary profiles, the sea side face of the breakwater foundation should be protected against wave scour by the application of concrete-filled jute bags as shown. In the case of a sandy bottom, these bags should come to rest on the geotextile filter. Bollards may then be cast into the deck as desired.

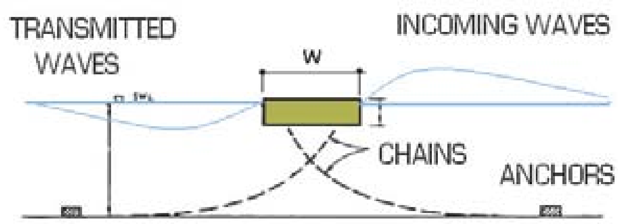
7.3 FLOATING BREAKWATERS

To be effective as a breakwater, the motions of a floating structure must be of small amplitude so that the structure does not generate waves into the protected harbour side. Although at resonance the oncoming waves can be out of phase with the transmitted waves (resulting in lower coefficients of transmission), the structure must respond to a spectrum of incident wave conditions. Hence, the design of a floating structure for resonance characteristics only is not possible given the wide spectrum of ocean waves.

The simplest forms of floating breakwaters are pontoon structures, although various modifications to their shape have been investigated in an effort to optimize the mass (and ultimately the cost).

The efficiency of a floating breakwater depends primarily on the ratio of the width of the pontoon to the wavelength of the oncoming waves (Figure 20) and, given that ocean swell has a very long wavelength, floating breakwaters are not suitable for creating protected areas along an exposed coastline and should never be installed. However, on lake shores, where the waves tend to be very short (choppy) and do not generally exceed 0.50 metre, floating breakwaters tend to work efficiently.

FIGURE 20
Transmission of waves through a floating breakwater



7.4 BIBLIOGRAPHY AND FURTHER READING

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8. Quays and slipways

SUMMARY

For the purpose of this chapter, a quay is a general term used to describe a marine structure for the mooring or tying-up of vessels, and for loading and unloading of goods and passengers. It is generally contiguous with the shore. A pier or finger jetty is a quay that projects into the water. In contrast to a normal quay, a finger jetty may be used on both sides. In areas with a high tidal range, both quays and jetties are often of the floating type.

The traditional slipway in many small beach-side communities is still the natural beach where boats are hauled ashore for scrubbing, cleaning and repair. However, a beach is not always suitable or available for servicing a vessel, especially vessels larger than small canoes. On the other hand, inside fishing harbours, the recent technological advances in boat hoists has further widened the range of options available to a would-be designer of slipways.

This chapter reviews the cross-sections of a wide variety of quays and jetties to suit an even wider range of applications. The objective being that the reader will be able to appreciate the different applications of past and more recent technologies and be better prepared to assess the potential requirements for berthing and boat maintenance structures.

CONTENTS

8.1 QUAYS

The construction of quays falls broadly into two classifications: quays with a closed or solid construction, and quays with an open construction, where the deck is supported on piles. A key element inside a typical fishing harbour, however, is the draft, ranging from 1.5 metres to 6 metres may be required, depending on the type, size and number of resident fishing vessels (Table 1). An artisanal fishing port hosting small fishing vessels having a loaded draft of no more than 1 metre would not normally require a draft of more than 1.5 metres at low tide unless large vessels visit the port during the peak fishing season.

TABLE 1
Draft requirements

Draft at low tide	Vessels[1]
1.50 metres	Large canoes to small purse seiners Maximum loaded draft 1 metre
3.0 metres	Trawlers and other coastal vessels Maximum loaded draft 2.5 metres
6.0 metres	Ocean-going distant water trawlers Maximum loaded draft

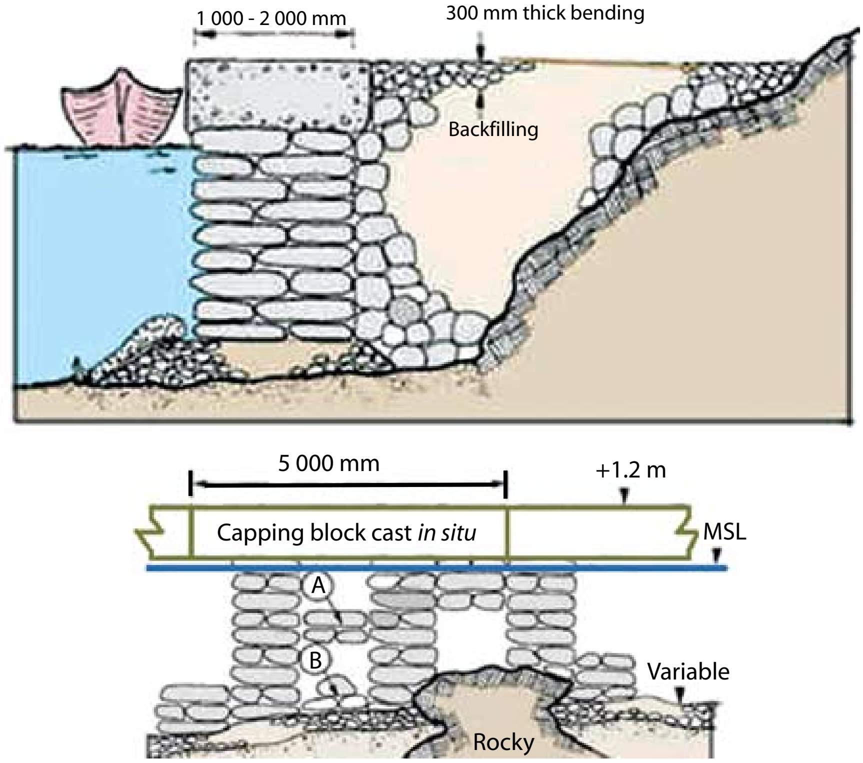
8.1.1 Solid quays – minimum draft 1.5 metres

Figure 1 illustrates one of the best ways to construct an artisanal quay with a draft of 1 to 1.5 metres. The earth-retaining structure, as the quay wall is known, consists of a number of layers of concrete-filled jute bags placed on a rubble foundation in a brick-wall fashion. This structure does not require any major cranage and may be built with the sole assistance of one or two divers. The major advantage of this type of construction is that an uneven sea bed or large boulders can be included in the foundation as shown in the front elevation in Figure 1. The jute bags should be filled with just enough concrete to form a pillow of uniform thickness, item A in Figure 1. Overstuffed bags, item B, should not be incorporated into the wall. Prior to commencing such work, a temporary guide frame should be built as shown in the construction method for solid breakwaters. The frame can be in scaffold pipes, bamboo or other timber sections.

Granular material only (no silt, mud or clay) should be used as backfill and the top surface should be blinded or sealed with graded aggregate. The blinding should be compacted properly using a vibrating plate compactor. The front or toe of the quay should also be protected against scour by both propellers and tidal streams. This protection can consist of concrete-filled jute bags laid side by side over the screeded rubble as shown in the cross-section in the figure. The concrete capping block should be cast *in situ* after the granular backfill has been placed. Each capping block should not be more than 5 metres long and should contain some reinforcement.

[1] It should be kept in mind that many fishing vessels have what is known as *"rake of keel";* therefore, the draft should be measured from the deepest part of the keel. This is particularly important when such a vessel is trimmed by the stern.

FIGURE 1
Cross-section and front elevation of artisanal quay



8.1.2 Solid quays – minimum draft 3 metres

Figure 2 shows a typical concrete blockwork quay built from concrete blocks placed by a crane on a screeded bed of stone (see Figure 18 in Chapter 7 on how to prepare a screeded bed) and rubble. This kind of earth-retaining structure is very common but requires the use of a suitable crane. The crane can either be the floating type or terrestrial.

The concrete blocks are first cast in a yard and after 28 days have elapsed, they are lifted and placed on the sea bed as illustrated in Figure 2. The blocks are placed to form pillars on the screeded rubble; Chapter 7 describes how the foundation bed is screeded. The block pillars should be kept about 50 mm apart in such a way that each pillar may settle without rubbing against adjacent pillars. To achieve this, it is common to nail wooden spacers, 50 mm thick, to one side of the blocks prior to placing. Figure 3 shows various lifting arrangements utilized in the block yard. Slings may either pass underneath the block or lift the block via hooks. The slings may be in wire rope or chain and the factor of safety in the lifting apparatus for safe working loads is 8. Some countries require a higher value to take the wear-and-tear of the slings into consideration.

FIGURE 2
Blockwork quay wall

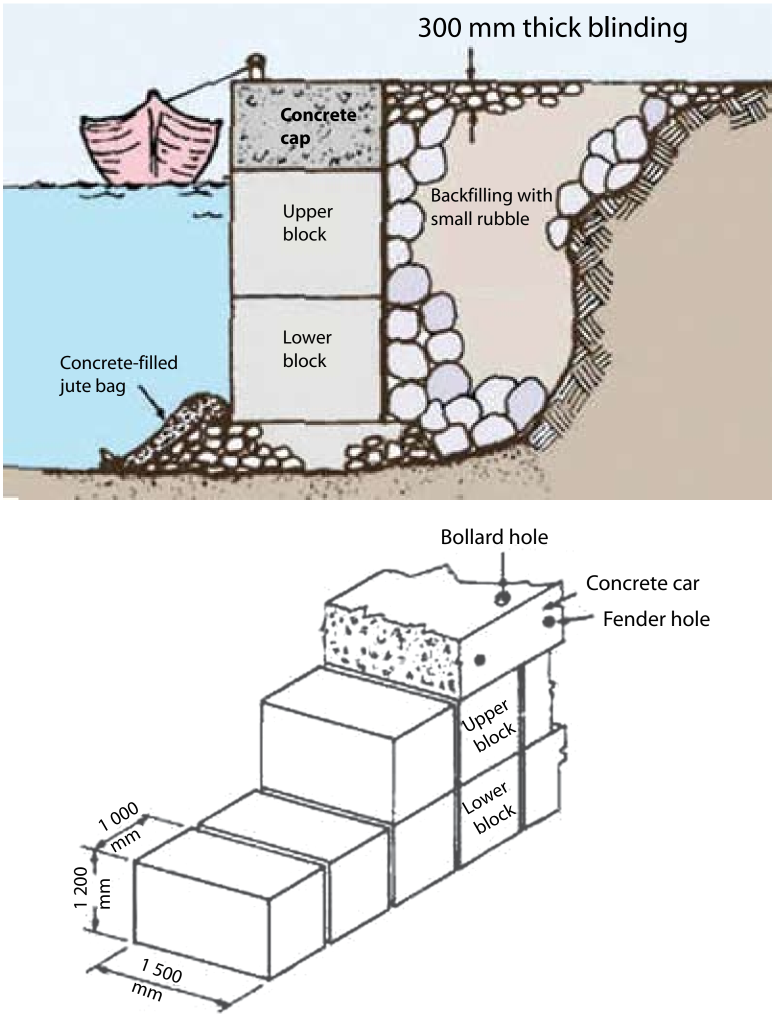
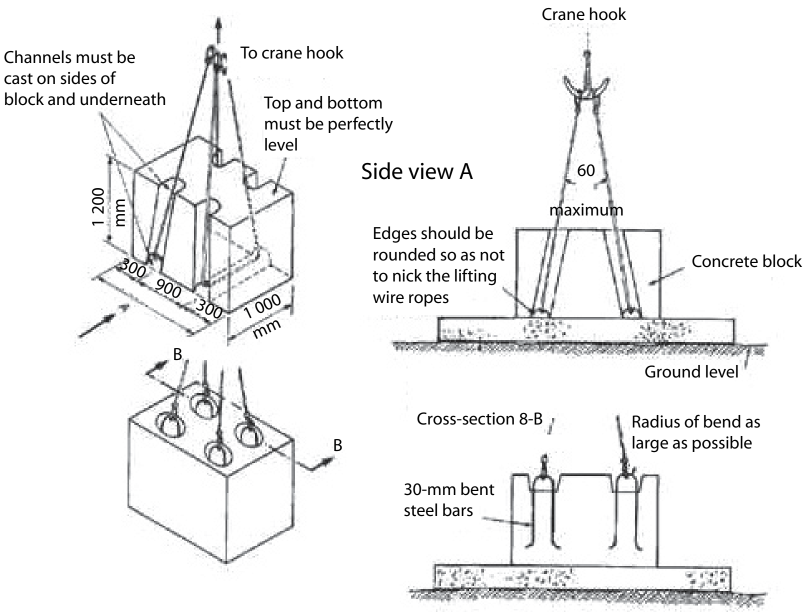


FIGURE 3
Casting and lifting precast blocks for a quay wall



Whereas rectangular blocks are the simplest to design and to cast, their weight is also a major disadvantage in remote areas with difficult access for heavy lifting plant (Figure 4, left). An alternative way to build the quay wall with lighter blocks (the design has to be wider to compensate for the loss of weight) is to use "I" section blocks and then to fill the voids with granular material (Figure 4, right).

FIGURE 4
Rectangular blocks (left) and I-section blocks with granular fill (right)

Backfill should consist of clean granular rubble. If sand is available, then the rear of the block wall should be lined with a geotextile filter to prevent sand from leaching out from in between the block pillars. Silt, clay lumps and mud should never be used as backfill and all degradable material (timber pieces, logs and other vegetation) should be removed. The backfill should not be used as landfill for household rubbish because decaying rubbish causes the backfill to settle unevenly.

The concrete capping block should be cast *in situ* after the granular backfill has been placed up to the water level. Graded aggregate should be used to seal or blind the backfill if large stones were used. The capping block should be cast in lengths to cap two or three adjacent vertical pillars and should contain some reinforcement to bind it to the pillars.

8.1.3 Solid quays – minimum draft 6 metres and beyond

The cross-section shown in Figure 4 may be adapted for a quay with a draft of 6 metres by increasing the size and width of the concrete blocks; however, the required size of the blocks would be so large as to require very large and heavy lifting equipment. A more economical solution in terms of the equipment required is shown in Figure 5.

The earth-retaining structure in this case is a special corrugated sheet of steel, known as a sheet pile, which interlocks with adjacent units to form a continuous wall, Figure 6.

FIGURE 5
A steel sheet piled quay wall

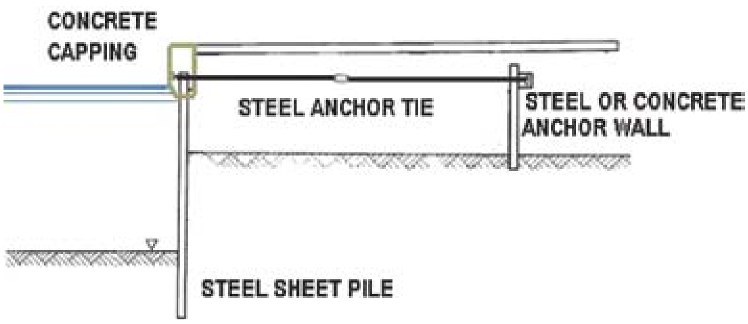
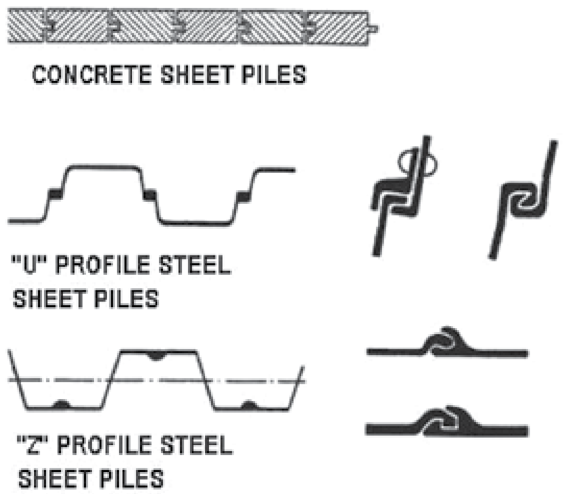


FIGURE 6
Types of sheet piles in use



This wall is driven into the sea bed, sheet pile by sheet pile as shown in Figure 7, and the top tied back to an anchor wall, which may consist of a slab of reinforced concrete or a length of the same bulkhead. A temporary timber or steel guide frame is generally erected to help drive the sheet piles vertical and in a straight line. The crane used to drive sheet piles must have a long jib to enable it to pick entire lengths of sheet pile for driving. The crane may either be mounted on a barge, in which case the sheet piles are

FIGURE 7
Driving of sheet piles

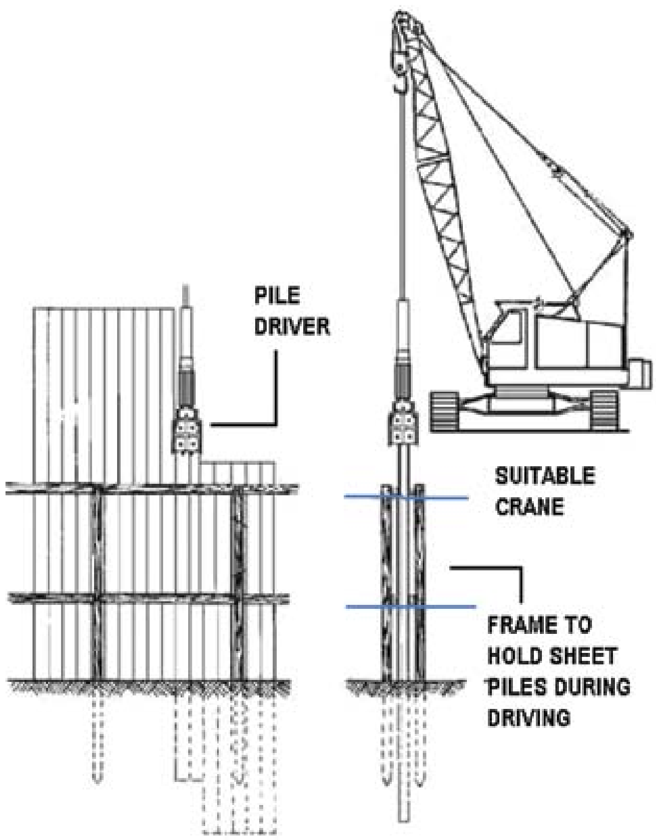


FIGURE 8
Driving from a floating barge crane (left) and from the shore side (right)

driven from the sea side of the bulkhead, or driven over a temporary reclamation and driven from the rear of the bulkhead, Figure 8. The temporary reclamation may then be used as backfill.

Sheet piles are suitable for driving into clay, sand and silt deposits, as well as some types of coral. Sheet piles cannot be driven in most types of rock and in the presence of large boulders. Hammers for driving sheet piles may be of two types: impact hammers or high-frequency hammers. Impact hammers, as their name suggests, are hammers which impart an impact to the sheet pile. In the presence of soft deposits or clay, impact hammers do not pose any problem. In the presence of difficult ground, however, such as when sand contains large boulders, the impact from the hammer may damage or bend the sheet pile.

Nowadays, high-frequency hammers are generally used to drive sheet piles in granular deposits. High-frequency hammers are not effective in the presence of clay.

The depth of penetration of a sheet pile depends on the type of material on the sea bed. The top of the sheet pile is usually anchored via thick steel rods, themselves anchored to anchor walls placed a safe distance away from the main bulkhead. The crown of the sheet pile should be finished off in an *in situ* concrete cope, typically up to 1 metre wide and 2 metres high, to accommodate quay services and allow the bollards and fenders to be bolted down in place, Figure 9.

Solid quays may also be constructed using reinforced concrete box caissons, cast on land or inside a dry dock and sunk in place to form a wall (Figures 10 and 11). By their very nature (wide), caissons exert a lower pressure on the foundation.

FIGURE 9
Preparing to cast a concrete cope (left) and a finished cope (right)

FIGURE 10
Reinforced concrete box caisson

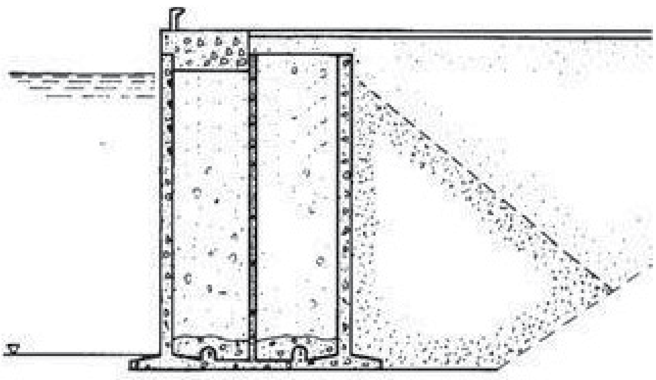


FIGURE 11
Small box caissons cast side-by-side on an existing quay

8.1.4 Open quays – minimum draft 1.5 metres

The deck of an open quay is supported on piles and the whole structure is open to full view. In view of this, an open structure is considered to be more delicate than a solid one and special fendering measures have to be incorporated in the design to prevent damage to the structure. Open quays may be constructed entirely in timber, concrete or steel, or a mixture of the three. Timber, however, may be attacked by insects; see Chapter 9 for more details.

Figure 12 illustrates how an artisanal open quay may be built using mainly locally available materials, such as timber or steel pipes. Given the small dimensions of the structure, a crane may not be needed if a light lattice tower or tripod and a piling winch are available to drive the piles, Figure 13. The figure also demonstrates the manner in which the pile heads should be prepared to receive the cross-beams.

The timber used in such a structure should be the right kind of timber and treated against decay and attack by insects as described in Chapter 9.

All fastenings should be either screws or bolts in brass or stainless steel. The heads of ordinary steel nails corrode very fast and come undone very suddenly as soon as a load is applied. Nails should not be used anywhere on a jetty. In order to render the structure shown more stable and readily accessible from the shore, graded rubble should be placed to a slope as shown in the figure. In the presence of very soft mud, silt or clay, a geotextile filter should be placed underneath the rubble to hold it in place.

FIGURE 12
An artisanal shallow water piled jetty

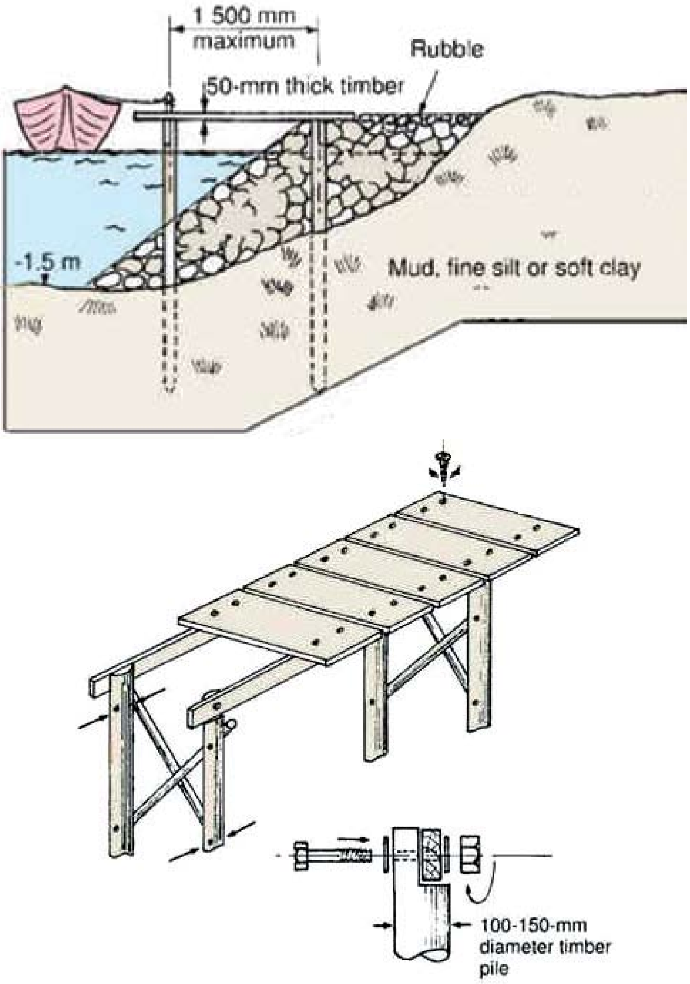
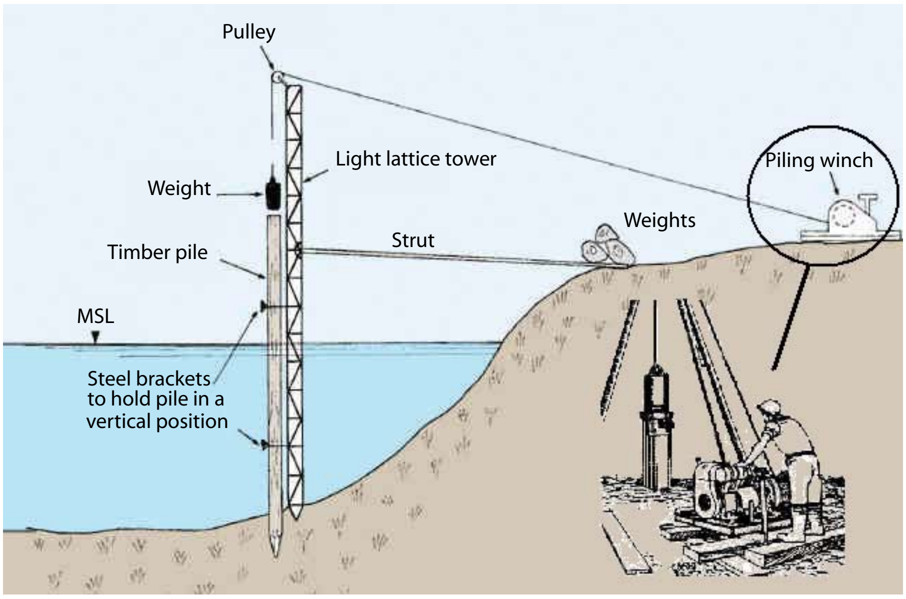


FIGURE 13
Pile driving for an artisanal quay



8.1.5 Open quays – minimum draft 3 metres and beyond

Figure 14 shows conventional, deeper water open quays of the type traditionally found in larger fishing ports. The structures are typically subdivided into two categories: with and without tidal variation. Figure 14 shows a cross-section without tidal variation, where the impact load from a vessel is transmitted directly to the deck of the quay via a simple rubber fender. Figure 15 shows a cross-section with tidal variation. The open quay, in this case, is fronted by another structure, the rubbing fender pile, which has to absorb the impact from a vessel mooring at low tide without damaging the main quay piles immediately behind it. If the quay wall is solid (sheet piles), then timber or rubber strips are applied to the sheet pile for the vessels to rub against.

Piled quays are particularly effective at absorbing wave energy due to the presence of the rubble slope underneath the deck. The rubble is normally similar to a breakwater grading, requiring core material (1–100 kilograms), armouring (200–1 000 kilograms)

FIGURE 14
Piled quay – any depth but no tide

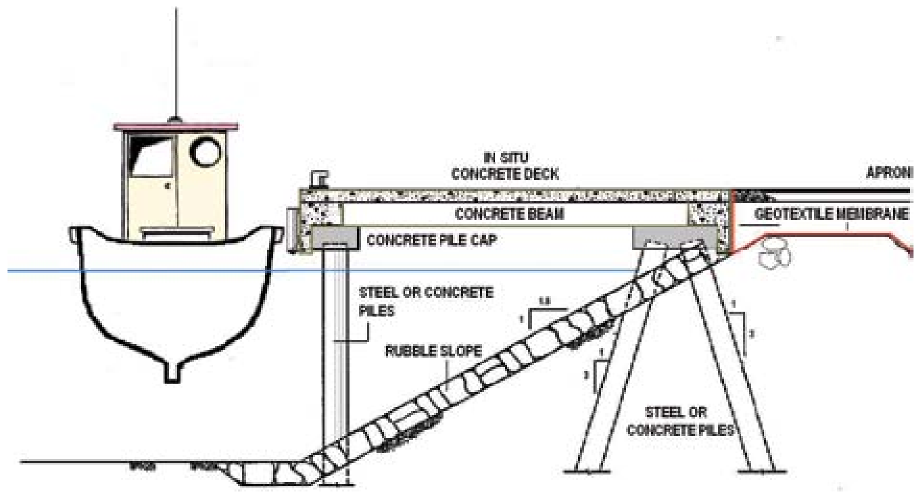
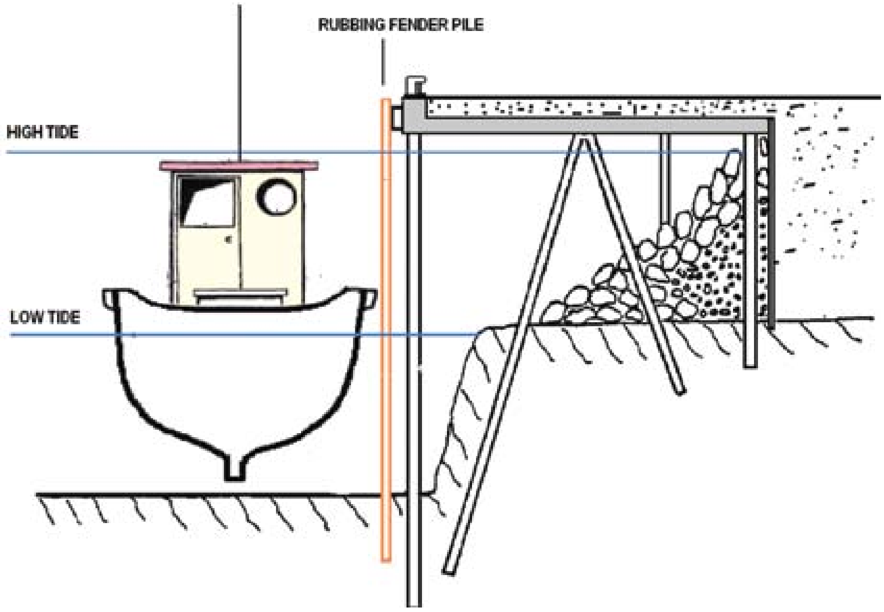


FIGURE 15
Piled quay – any depth but with tidal variation

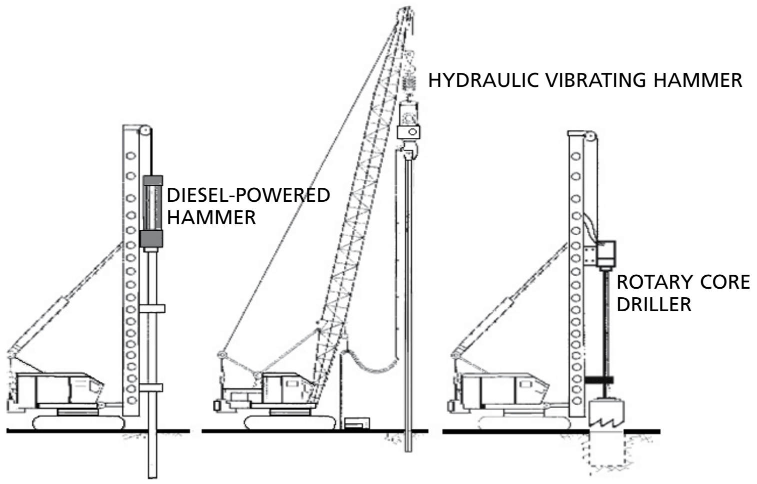


and toe berm (1 000–2 000 kilograms) to prevent scour damage. If the reclamation behind the piled structure is not sealed properly with a geotextile membrane, fines tend to leach out of the rubble, leading to uneven settlement of the apron.

The piles may either be in normally reinforced concrete, prestressed concrete, or steel. Whereas most concrete piles are solid, steel piles are usually hollow pipes. In most cases, if only small lengths of pile can be handled by the crane, piles can be jointed *in situ* to form longer lengths as required. Concrete piles are generally glued with special epoxy glues, whereas steel piles are commonly welded together via simple butt-joints. If hollow pipes are used, these may either be filled up with concrete and reinforcing steel (to prevent corrosion on the inside and add strength to the pile) or, if the pipe thickness is enough, left as open-ended piles.

Piles in general may be divided into two broad categories: driven and *in situ*. Driven piles are piles driven into the ground by a piling or vibrating hammer. *In situ* piles are piles formed in the ground by first drilling a large diameter hole and then filling it with concrete and reinforcement. A combination of the two, also known as a cased or jacketed pile, is when a steel pipe pile is first driven into the ground and then emptied of the contents and refilled with reinforced concrete. The bearing capacity of piles may be increased by the inclusion of a bulb at the foot of the pile. Figure 16 illustrates the various techniques used to drive piles and their most common applications.

FIGURE 16
Pile driving techniques and their fields of application



Piling hammer	Vibrating hammer	Rotary coring
Piling rig works on level ground	Crane may be on level ground	Drilling rig must be on shore
Floating or jack-up barge	Floating or jack-up barge	Or made-up ground, reclamation
Suitable in clayey, silty, sandy deposits as well as soft rock	Suitable for silty to sandy deposits only	Suitable for all types of deposits including most rocks
Suitable for concrete piles, steel H piles, pipe piles and sheet piles	Suitable for steel H piles, pipe piles and sheet piles only	Only suitable for cast *in situ* concrete piles, with or without steel pipe jackets
Problems with alignment in presence of coarse gravel	Not suitable in presence of any but fine gravel	Not problematic in presence of any gravel size
Impossible to drive piles over a rubble mound breakwater	Impossible to drive piles over a rubble mound breakwater	Possible only from shore line, cannot be floating
Double hammer noise, very loud, especially in hard rock	Continuous humming noise, very loud and piercing	Rumbling noise
Normally no displacement of ground material unless open pipe piles have to be filled up with concrete	Normally no displacement of ground material unless open pipe piles have to be filled up with concrete	Displacement of the entire volume of the shaft and ground down to a fine size, dust
Likely to cause vibrations in adjacent buildings, leading to damage, especially in old load bearing structures	May cause tremors in adjacent areas but not as damaging	Vibrations not normally discernable in adjacent areas

8.2 JETTIES

A finger jetty is a structure that projects out into the water and is generally suitable for mooring on both sides. The draft alongside a finger jetty may range from 1.5 metres in an artisanal port to any desired depth in large industrial fishing ports. Since there is no earth to retain, a finger jetty derives its stability from the type of foundations utilized. A finger jetty may be constructed in timber, in concrete, in steel, or a mix of any two. The construction equipment required to build jetties is similar to that used for solid and piled quays. Solid jetties in concrete or stone rubble should never be constructed on mobile sediments, like beaches, as they interrupt the littoral flow and lead to problems with erosion.

8.2.1 Jetties – any draft

Unlike quay walls that depend on a gravity structure for their stability, jetties may be constructed with relatively small equipment. Figures 17, 18 and 19 illustrate typical small-scale jetties of the types used in many ports. Figures 20, 21 and 22 illustrate various examples of jetties built in relatively remote areas with small equipment.

FIGURE 17
Traditional timber jetty

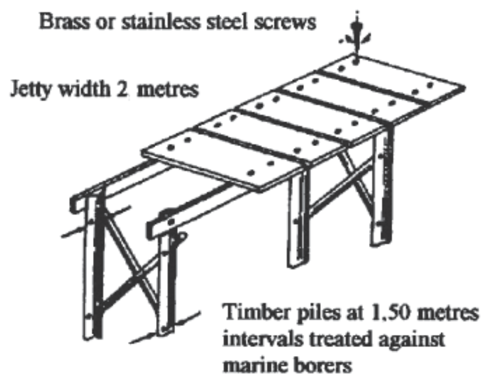


FIGURE 18
Timber jetty on concrete trestles

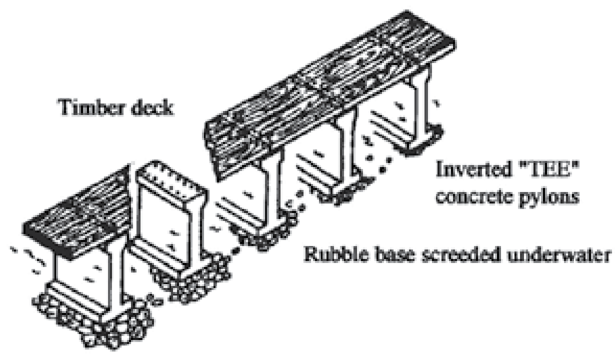


FIGURE 19
Concrete jetty on concrete piles

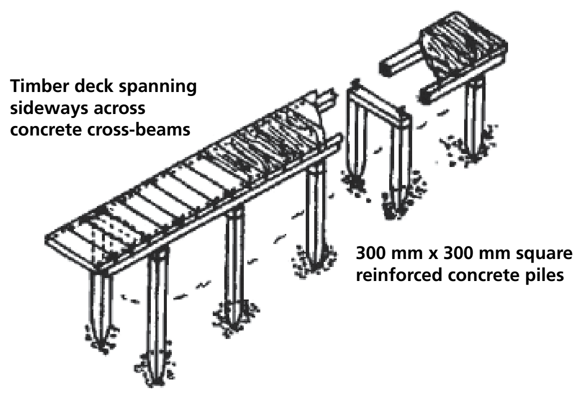


FIGURE 20
Precast concrete trestles (left) and concrete jetty under construction (right)

FIGURE 21
Timber jetty (left) and steel jetty (right)

FIGURE 22
Concrete jetty built with modular units from land

8.2.2 Floating jetties

Floating jetties come in a whole range of sizes and shapes to cater for vessels ranging from a small canoe to an ocean-going trawler.

Figure 23 illustrates a jetty in timber which may be manufactured from locally available materials like plastic or oil drums, timber and fibre rope. Figure 24 illustrates the Jetfloat unit, a commercially available system, consisting of modular floats in plastic that join up to form a floating platform of any desired shape.

FIGURE 23
Floating jetty in timber – local artisanal manufacture

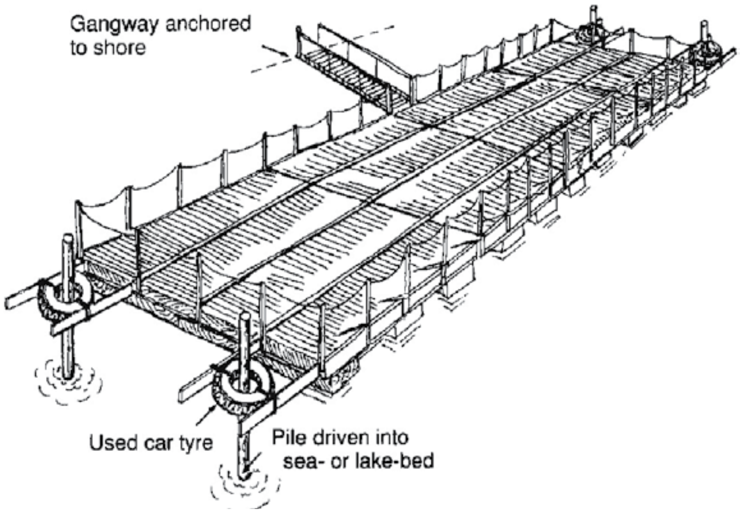
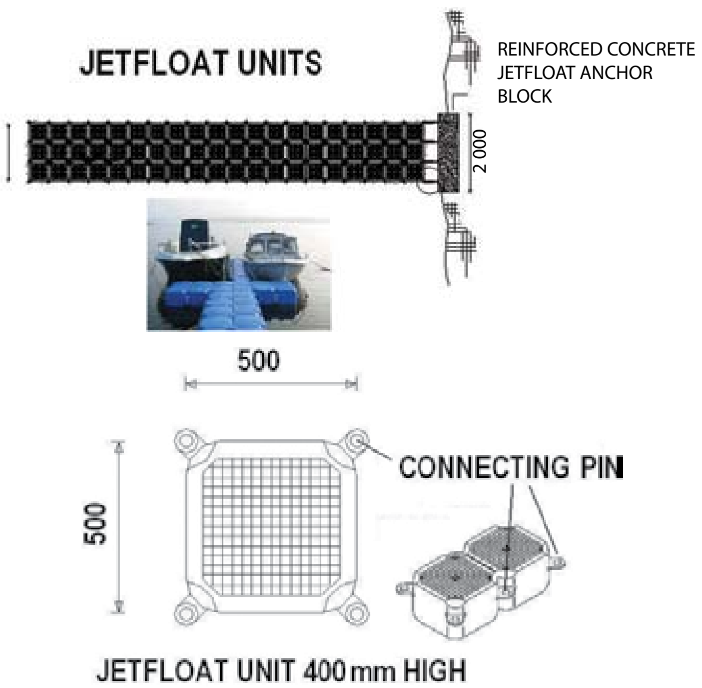
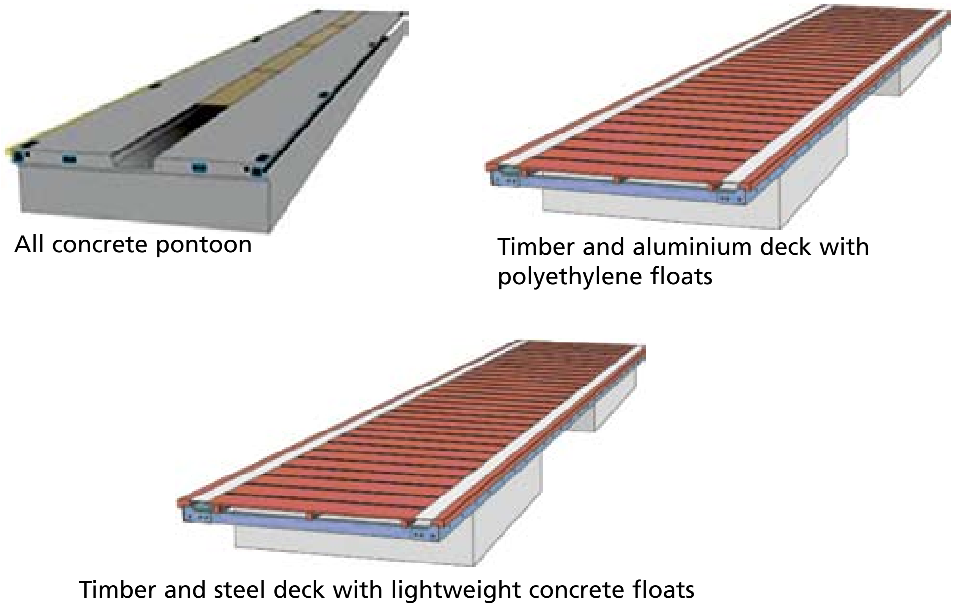


FIGURE 24
Floating jetty in off-the-shelf modular plastic float units



Ready-made pontoons in concrete or a combination of timber, metal, concrete or plastic may be purchased from a variety of sources (Figure 25). Sizes range from 6 metres to 12 metres and widths vary from 1.5 metres to 3.5 metres. All pontoons should be installed in sheltered waters with little or no current.

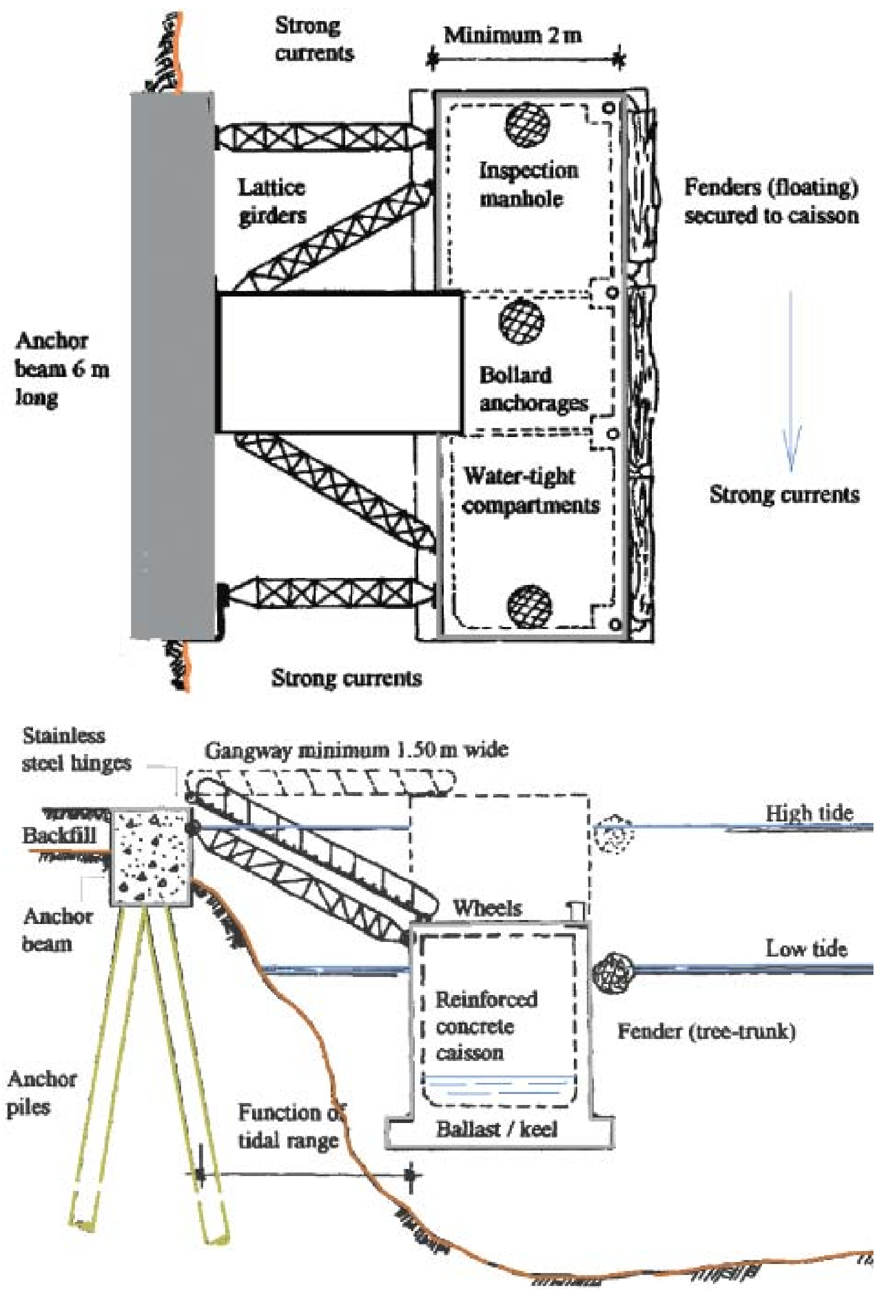
FIGURE 25
Typical off-the-shelf floating pontoons



Floating jetties may also be of the heavy duty type, suitable for the mooring of heavier vessels and able to withstand greater impact loads (Figure 26). The floating element in this case is a reinforced concrete caisson, built on a river bank and launched at high tide.

Due to the size and weight of the caisson, proper piled anchoring systems are required, especially in the presence of high tidal streams or river currents. The anchor system may consist of a reinforced concrete beam held in place by anchor piles driven into the river bank. The caisson is held away from the river bank by two outrigger lattice girders perpendicular to the caisson. Two further inclined girders absorb the transverse loads imparted to the caisson by the water current. The girders are anchored to both beam and caisson by stainless steel hinges bolted to the concrete. If longer lengths of quay are required, extra, independently anchored and restrained caissons should be placed adjacent to each other. Loose caissons should not be hinged together to anchored caissons to form a single long jetty. The caissons should be internally divided to provide separate water-tight compartments. Each compartment should be equipped with a manhole and water-tight manhole cover for internal inspection. The gangway should be hinged to the anchor beam and allowed to roll over a 5 mm steel wearing plate bolted to the caisson. Depending on the tidal range, the gangway should have timber battens at half-metre intervals to improve foot grip at high slopes during low tide. It is important to equip the caisson with proper fenders. A floating tree trunk, if available, provides very good defence against impact; otherwise, large, truck-size tyres should be employed. Due to the rather permanent nature of such structures, they are usually equipped with water and electricity.

FIGURE 26
A heavy-duty caisson-type floating jetty in plan (top) and section (bottom)

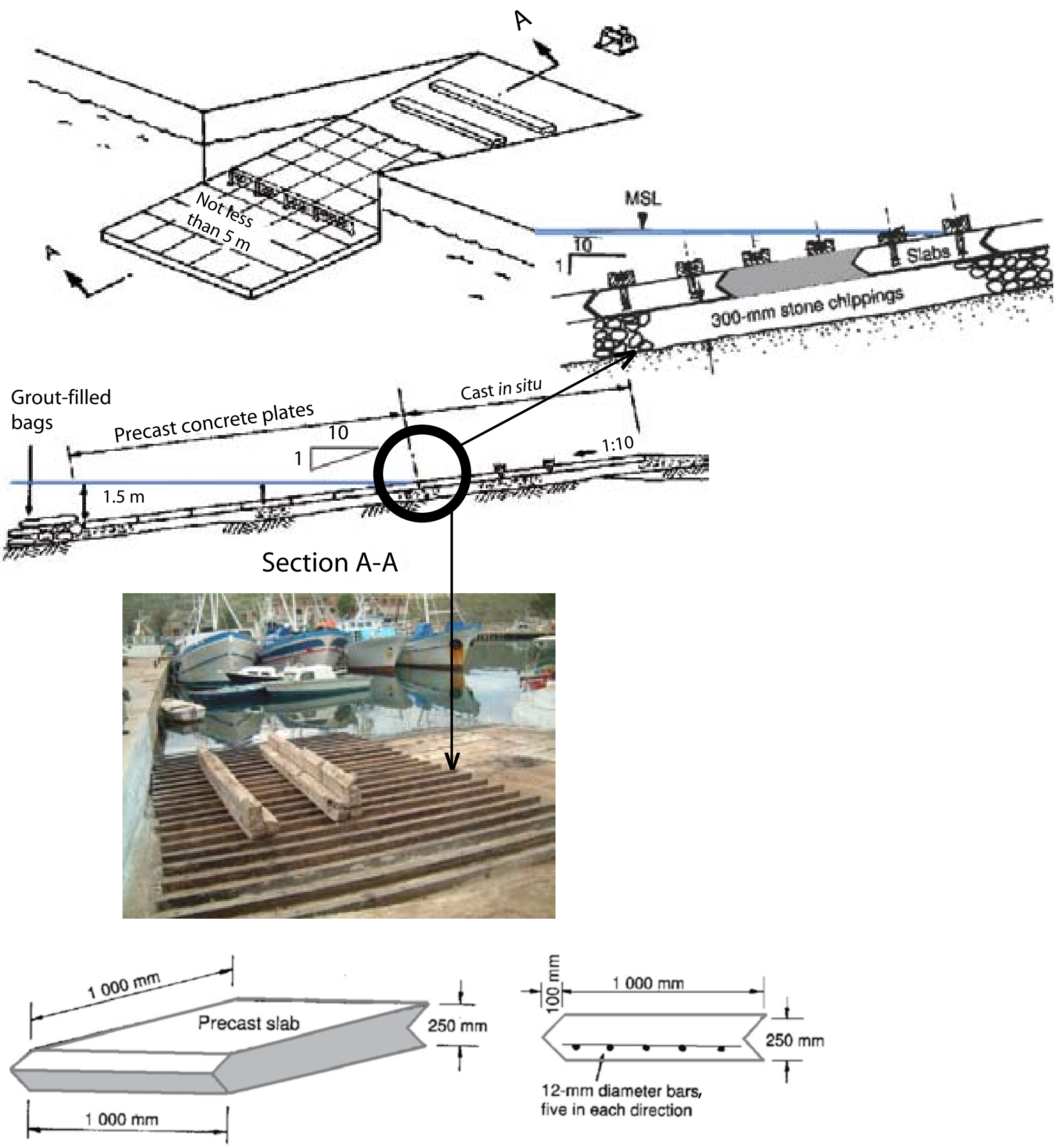


8.3 SLIPWAYS

8.3.1 Traditional slipways

Traditional slipways in use all over the world still make use of greased timber skids as a means of retrieving and launching vessels, Figure 27. This kind of slipway has no mechanical parts and no maintenance and the vessel occupies the slipway until it is relaunched after maintenance work. Typically, the slipway can handle boats up to 5 tonnes in weight. It usually cuts through the quay as shown in Figure 27. The width should not be less than 5 metres and the depth of water at the toe should not be less than 1.5 metres. The portion above mean sea level may be cast *in situ* and should not be less than 250 mm in thickness in Grade 35 concrete. The submerged portion should consist of precast units, also in Grade 35 concrete, such as the ones shown, laid to a slope on a bed of screeded stone chippings or aggregate. The toe should always be protected with heavier stone armour or concrete-filled jute bags. The timber skids, 100 mm x 100 mm in section, may then be bolted to the concrete as shown in the figure. In some countries, fishermen construct their own custom-made trailers and timber skids may not be required.

FIGURE 27
Artisanal slipway



Inside harbour or river basins, it is recommended to install a flotsam barrier as shown in Figure 28 to prevent floating rubbish from fouling up the slipway.

There is no ideal slope for a slipway; slopes may be anything from 4 percent to 17 percent steep (a 4 percent slope falls 4 metres vertically in 100 metres horizontal). Compound slopes, with the submerged part at 17 percent and the dry part at 9 percent, are also common. However, one must remember that the steeper the slope the more

FIGURE 28
Flotsam barrier

powerful the winch has to be and that the submerged part may be steeper (the vessel weighs less when in the water) for the same type of winch. Slipway equipment is illustrated in Chapter 10.

8.3.2 Slipways on beaches

It is not uncommon for heavy boatyards, which handle vessels above 5 tonnes, to be located out of town in the vicinity of a sandy coastline. Ideally, no obstructions should be constructed on a sandy beach as these give rise to erosion. Such a structure will invariably need constant dredging to keep the axis free of accumulated sand. Decked boats, including small trawlers, may be safely beached on sand if this method had been taken into consideration at the vessel design stage. Where bilge keels are attached to the sides of the hull to keep it upright they should be so designed to support the weight exerted by the vessel and the keels of wooden hulled and fibreglass vessels should be protected by a skid bar. This might be a stainless steel rubbing plate bolted to the bottom of the keel on a wooden vessel or more probably hard wood in the case of a fibreglass vessel. The end of the skeg may be curved to avoid digging in on launching. A small tractor or winch may be used to haul the vessels ashore (Figure 29).

Launching is clearly a reverse process with the same winch or tractor hauling the boat against a secure anchoring point in the water. In both landing and launching, wooden skids or rollers below the keel are often used; see section 10.7 of Chapter 10.

FIGURE 29
Beaching a vessel

8.3.3 Mechanical slipways – all sizes

Mechanically operated slipping facilities may be divided into three categories for all vessels up to 500 tonnes displacement. The three methods are:

- mechanized slipway;
- mobile gantry or travelift; and
- synchrolift or ship lift.

8.3.3.1 Mechanized slipway

A mechanized slipway is a large slope with two or three parallel beams running down 4 to 5 metres below sea level, each carrying a heavy-duty steel rail (Figure 30). A steel cradle, Figure 31, runs up and down the rails by means of a special winch.

FIGURE 30
The principle of a mechanized slipway

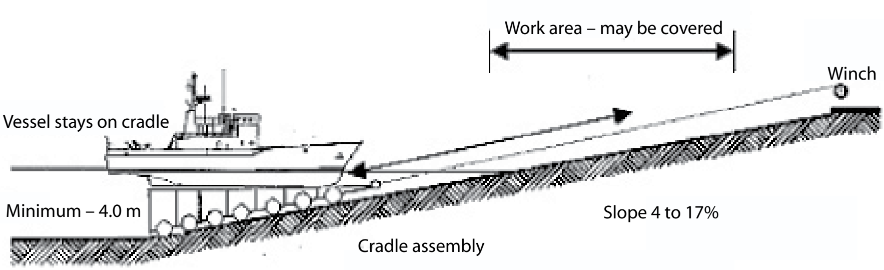
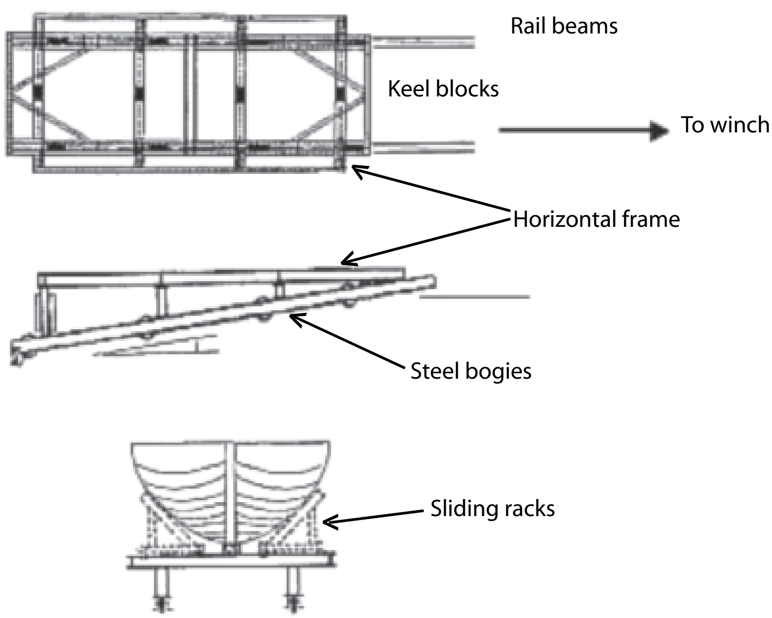


FIGURE 31
The steel cradle used on a mechanized slipway



The vessel to be slipped is floated over the cradle and secured. The cradle is then winched up the slope until it is clear of the water and then locked in the desired position. The vessel stays on the cradle throughout the maintenance period and all servicing is carried out at the water's edge. Some mechanized slipways cover the work area with a permanent building, while others with sliding or even inflatable structures to protect the work area from the harshest weather conditions only (Figure 32).

The steel cradle runs on foundation beams laid to the appropriate slope. Figures 33, 34 and 35 illustrate a typical plan and cross-section for a slipway utilizing precast beams bedded on a rubble bed. The precast beams are laid on a screeded bed of ballast

FIGURE 32
Examples of mechanized slipways

FIGURE 33
Typical plan of slipway

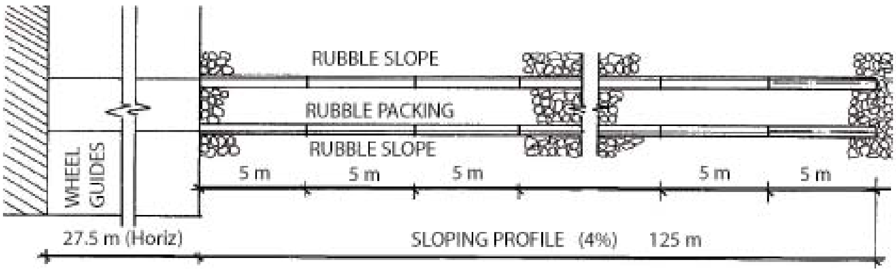
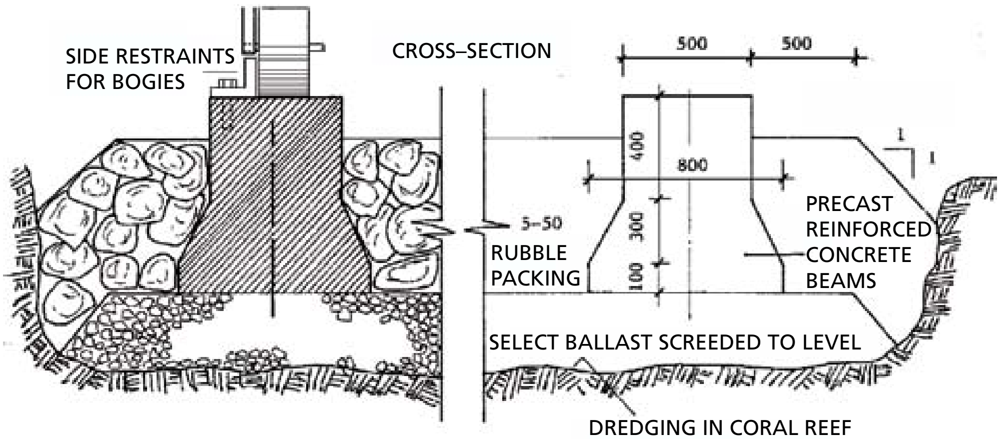
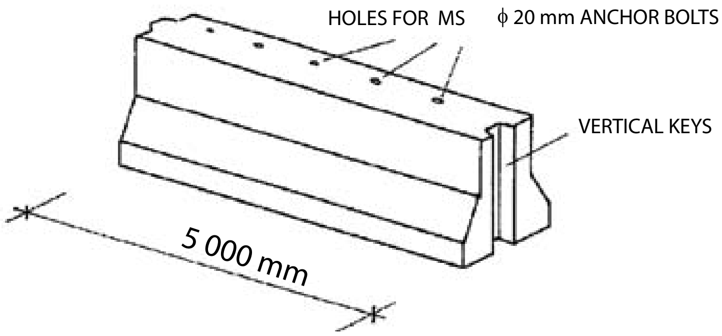


FIGURE 34
Typical cross-section across foundation beams (mm)



or coarse aggregate and the adjoining spaces packed with 5 to 50 kilogram rock. A wheel side-restraint in galvanized angle ensures that the cradle does not run off the concrete surface. The wheel or group of wheels or bogies are normally in solid steel coated with rubber. Steel rails may also be used over the beams.

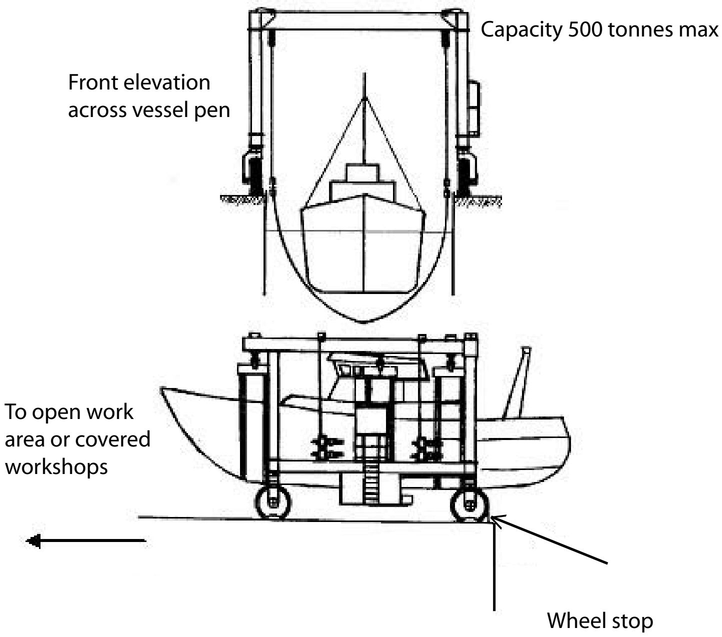
FIGURE 35
Typical precast beams



8.3.3.2 Mobile gantry or travelift

A mobile gantry or travelift facility typically consists of a rubber-tyred gantry running over a twin pier construction (Figures 36, 37 and 38). The vessels to be slipped are floated in between the piers and then hoisted out of the water by the mobile gantry or travelift using polyester straps.

FIGURE 36
Mobile gantry



The piers may protrude from the quay out into open water or the vessel pen may be incorporated in the quay structure as illustrated in Figure 37.[2] Boat servicing is carried out some distance away from the water's edge at an open work area or inside a covered workshop. The number of vessels handled at any one time is only a function of the size of the work area, whether covered or open. No cradles are utilized as the vessels are placed directly on timber frames or special steel props and often by laying their keel on the ground. There should always be an arrangement in the repair area with sumps in the ground as an aid to repairing/replacing the keel of wooden hulled boats.

FIGURE 37
Mobile gantry – 250-tonne capacity

FIGURE 38
Mobile gantries – 50- and 100-tonne capacity

8.3.3.3 Synchrolift or shiplift

Until the advent of high-capacity mobile gantries, synchrolifts were the standard equipment of established boatyards (Figures 39 and 40). Synchrolifts, however, have the capacity to lift up to 1 000 tonnes and this makes any yard equipped with a synchrolift able to offer its services to a wider range of vessels. In a synchrolift the vessels are floated over the transfer cradle that sits on the elevating platform. The platform with the cradle and vessel on top is then hoisted out of the water and brought level with the transfer rails. A tractor can then push the cradle down the line to a repair bay which may be an open work area or a covered workshop.

The number of vessels handled at the yard at any one time is a function of the number of cradles and/or work area available.

[2] The sketches do not show in detail the arrangements to keep the wheels from running "off track" and for the wheel stops.

FIGURE 39
Synchrolift or shiplift

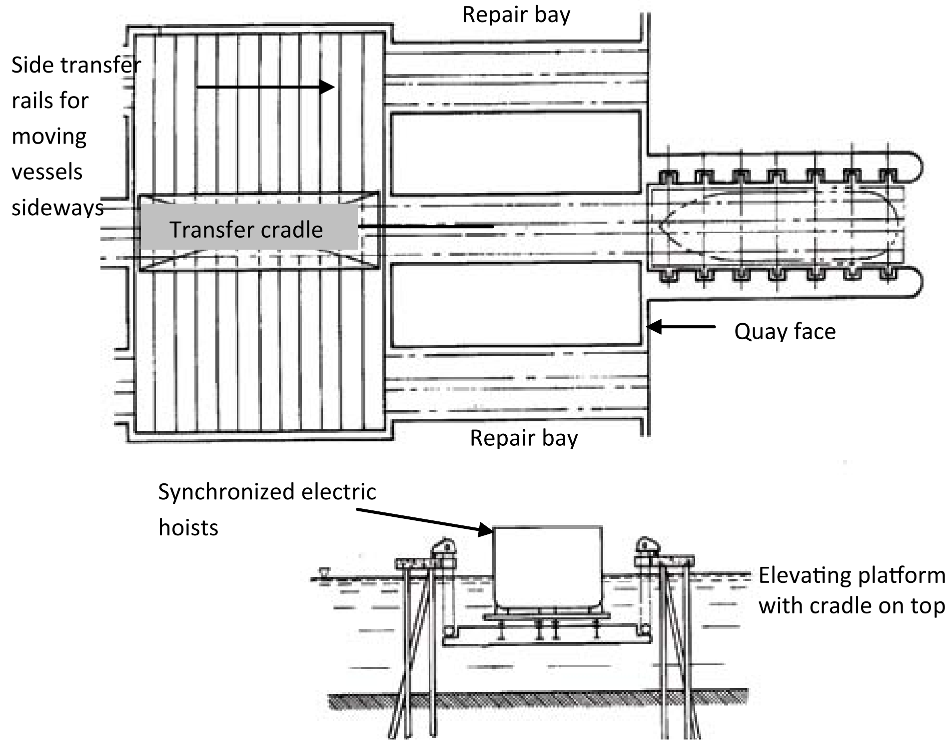


FIGURE 40
A large synchrolift (foreground) and floating dock (background)

8.3.3.4 Fixed or mobile cranes

Fixed or mobile cranes at the quayside may also be used for launching or recovering vessels (Figure 41). In this case, the vessel workshops may be located a distance away from the port.

FIGURE 41
Mobile or fixed cranes used to launch or recover vessels

8.3.4 Vessel repair facilities

8.3.4.1 Best management practice

Vessel repair facilities pose special environmental concerns in a fishing port because of the processes and chemical materials that they use and their proximity to areas where fish meant for human consumption is handled. The area of major concern in a boatyard is hull stripping and painting.

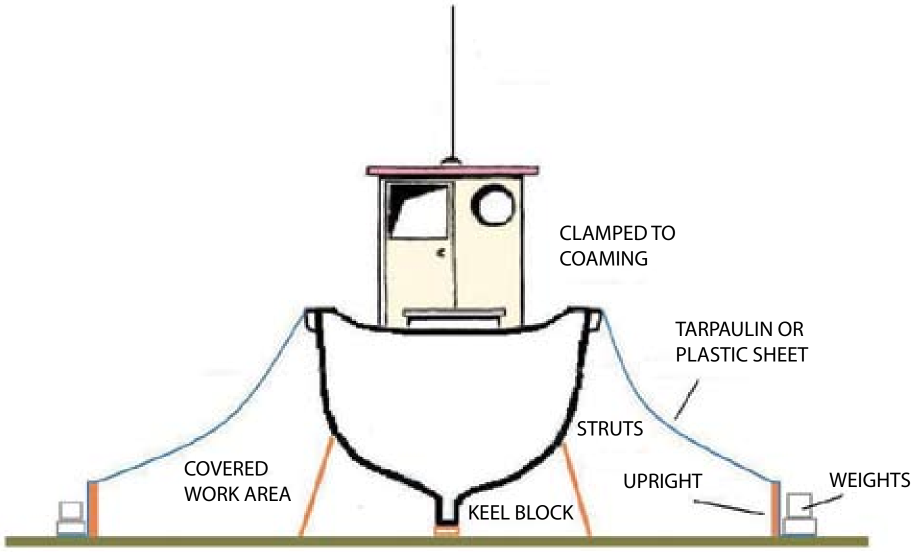
When a vessel's hull is prepared for painting the process typically starts with pressure or mechanical (hand brush) washing to remove the marine organisms and slime accumulated between maintenance intervals, Figure 42.

FIGURE 42
Power washing hull

Next, depending on whether the hull is metal or timber or glass reinforced plastic (GRP), the antifouling paint is stripped by grit blasting or mechanical sander. Both grit blasting and sanding tend to raise particulate matter into the surrounding environment and in windy conditions the entire port may be enveloped in a cloud of potentially harmful particulate matter.

Similarly, if it rains, the dust settled under the vessel may be washed back into the sea. Figure 43 illustrates how a covered work area around the vessel may be set up using simple plastic sheeting clamped to the vessel's coaming and held down at ground level with simple upright poles driven into the ground.

FIGURE 43
Covered work area around a vessel, also known as a boat skirt



The following recommended work practices should be observed at the slipway:

Hull cleaning

- perform abrasive or sanding under covered tarpaulin enclosures or boat skirts;
- perform abrasive or sanding over a horizontal hard impermeable surface, such as concrete, to enable proper cleaning of surface and collection of wastes;
- whenever possible, use vacuum sanders to limit the amount of dust generated;
- sanding dust and paint chippings must be removed on a daily basis and appropriate covered waste containers should be provided within the facility;
- workers under the boat skirt should be provided with appropriate full-face masks; and
- a list of the above work practices should be posted at the work area for the benefit of the "do-it-yourself" vessel owners who may not be aware of the port's environmental regulations.

Hull painting

- techniques such as brushing and rolling are preferred to spraying to reduce overspray and solvent emissions;
- all painting should be performed under covered tarpaulin enclosures or boat skirts;
- all painting should be performed over a horizontal hard impermeable surface;
- whenever possible, solvents and coatings with low volatility should be used;
- waste paints, solvents and rags should be stored in covered waste containers to prevent evaporation to the atmosphere; and
- workers under the boat skirt should be provided with appropriate full-face masks and solvent-resistant gloves.

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9. Construction materials

SUMMARY

Construction materials for port and coastal structures may be classified into five general categories: steel, timber, concrete, stone and synthetics. However, subject of materials and their suitability for application within a port facility is very wide and, for this reason, the intention is to condense the subject into a single chapter covering the basic principles while eliminating superfluous coverage. The chapter is confined to the properties of those materials and treatments or variations thereof that are applicable to port structures. Nevertheless, emphasis is duly placed on full coverage of the basic materials that have proved most durable in the highly aggressive marine environment inside port structures. The overall objective being the provision of sound advice to the reader regarding the selection of materials for port structures and acceptable practices as well as other less suitable materials and practices that should be avoided.

CONTENTS

9.1. METALS

9.1.1 Ferrous metals

Many ferrous (iron) alloys are used for engineering purposes. Despite this, iron alloys are used in larger quantities than the alloys of any other metal. This arises from the relative cheapness with which steels (an iron alloy) and cast iron can be produced with a variety of useful properties, by variations of composition, heat treatment and heat working. Steel is an alloy of iron and carbon, silicon, phosphorus, manganese and sulphur. Inclusion of nickel and chromium produces stainless steel.

Wrought steel components are produced by hot- or cold-working processes, although some machining may be involved. In civil engineering, the largest use of wrought steels goes into making reinforcement steel and structural sections such as beams and channels, sheet piles and pipes.

Forged steel involves hot shaping between dies and the deformation sequence is chosen so that adequate deformation is given to all parts of the component and the metal flow direction is controlled to give optimum fibre structure and properties. A limitation on the shape of forgings arises from the need to remove them from the dies. Forged steel is used in making chains, shackles, boat moorings, as well as other products.

Cast iron provides an alternative to forging for the production of complex shapes. Instead of working the metal in a die, casting is achieved by pouring molten metal into a recyclable sand mould. In general, forgings have better properties than castings because the properties of castings are determined by the solidification characteristics of casting alloys. Typical products in cast iron are manhole covers and bollards.

9.1.2 Non-ferrous materials

Non-ferrous metals and alloys are available for engineering and building purposes. Pure non-ferrous metals (like aluminium) have properties that make them suitable for engineering applications and as a building material.

However, care must be taken when, for example, aluminium is to be used in conjunction with steel in order to ensure that cathodic action will not take place.

9.2 CORROSION

9.2.1 Introduction

Corrosion is the destructive attack on a metal by chemical or electrochemical reaction with its environment (Figure 1). Rusting applies to the corrosion of iron or iron-base alloys with formation of corrosion products consisting mainly of hydrous ferric oxides. Non-ferrous metals, therefore, corrode as well but do not rust.

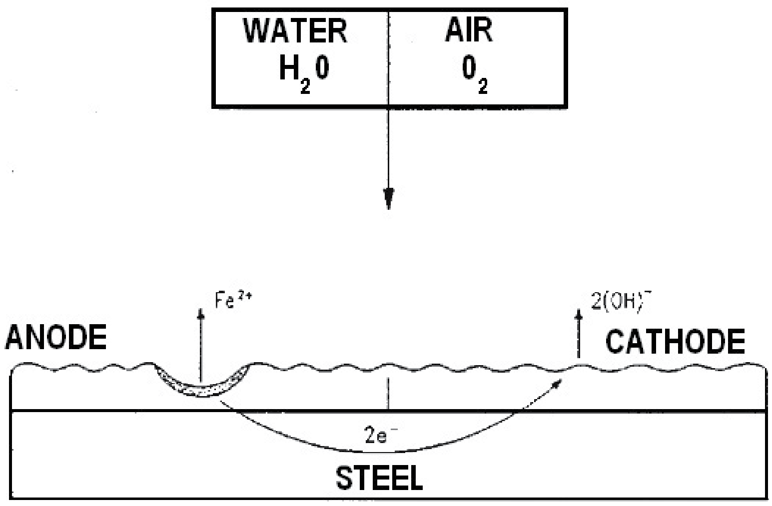
Most corrosion of steel can be considered as an electrochemical process which occurs in stages. Initial attack occurs at anodic areas on the surface, where ferrous ions go into solution. Electrons are released from the anode and move through the metallic structure to the adjacent cathodic sites on the surface where they combine with oxygen and water to form hydroxyl ions. These react with the ferrous ions from the anode to produce ferrous hydroxide which itself is further oxidized in air to produce hydrated ferric oxide: red rust.

The sum of these reactions is described by the following equation:

$$4Fe + 3O_2 + 2H_2O = 2Fe_2O_3H_2O$$

(Iron and steel) + (oxygen) + (water) = rust

FIGURE 1
The corrosion process



Two important points emerge:

- For iron or steel to corrode it is necessary to have the simultaneous presence of water and oxygen; in the absence of either, corrosion does not occur.
- All corrosion occurs at the anode; no corrosion occurs at the cathode.

However, after a period of time, polarization effects such as the growth of corrosion products on the surface cause the corrosion process to be stifled. New, reactive anodic sites may then be formed thereby allowing further corrosion. Over long periods the loss of metal is reasonably uniform over the surface and so this case is usually described as "general corrosion". Nevertheless, various types of localized corrosion can also occur such as:

Pitting corrosion occurs in some circumstances where the attack on the original anodic area is not stifled and continues deep into the metal, forming a corrosion pit. Pitting more often occurs with mild steels immersed in water or buried in soil rather than those exposed in air. Pitting can also occur on stainless steels in certain environments.

Crevice corrosion leads to crevices that can be formed by design-detailing, welding, surface debris, etc. Available oxygen in the crevice is quickly used by the corrosion process and, because of limited access, cannot be replaced. The entrance to the crevice becomes cathodic since it can satisfy the oxygen-demanding cathode reaction. The tip of the crevice becomes a localized anode and high corrosion rates occur at this point.

Bi-metallic corrosion occurs when two dissimilar metals are joined together in an electrolyte, like seawater, an electrical current passes between them and corrosion occurs on the anoxic metal. Some metals (e.g. nickel and copper) corrode preferentially themselves, thereby protecting the steel. The tendency of dissimilar metals to bi-metallic corrosion is partly dependent upon their respective positions in the galvanic series (in descending order, the galvanic series for seawater lists magnesium – zinc – aluminium – cadmium – mild steel – wrought iron – cast iron – stainless steel – lead/tin solder). The further apart the two metals are in the series, the greater the tendency. In the presence of seawater, cadmium, aluminium, zinc and magnesium all corrode preferentially to mild steel, with magnesium corroding the fastest and cadmium the slowest. Other aspects which influence bi-metallic corrosion are the nature of the electrolyte and the respective surface areas of the anodic and cathodic metals. Bimetallic corrosion is most serious for immersed or buried structures but should also be considered for steel in the atmosphere.

Stress-corrosion cracking occurs under the simultaneous influence of a static tensile stress (the metallic element is under load), which may be well below the yield strength of the steel and a specific corrosive environment. This type of corrosion is not common with ferrous metals, though some stainless steels are susceptible in chloride environments and mild steels can exhibit stress-corrosion cracking in the presence of nitrates or in highly alkaline solutions.

Bacterial corrosion can occur in soils and water as a result of microbiological activity. The most commonly encountered is that arising from the presence of sulphate-reducing bacteria. These reduce sulphates in the soil to sulphides and cause corrosion under anaerobic conditions (i.e. in the absence of oxygen). They are characterized by black corrosion products having the distinctive "rotten-egg" smell of sulphide. Bacterial corrosion is most commonly encountered in pipelines, sheet piles and other buried structures.

9.2.2 Corrosion and steel

The principal factors that determine the rate of corrosion of steel in air are:

- type and amount of pollution;
- "time of wetness", i.e. the proportion of total time during which the surface is wet; and
- temperature.

Within a given local environment corrosion rates can vary markedly. For example, steel may corrode more on a particular side of a building because it is in the shade and so remains wet for longer periods. Prevailing winds may carry airborne contaminants (e.g. exhaust from a power station or sea spray from the coast) predominantly on to one face of a structure. It is therefore the "microclimate" immediately surrounding the structure which determines corrosion rates for practical purposes. Steel is most commonly used in the following environments:

- rural atmospheric – essentially inland, unpolluted environments;
- industrial atmospheric – inland polluted environments;
- marine atmospheric – the 2 kilometre strip around the coast is broadly considered as being a marine environment;
- marine/industrial atmospheric – polluted coastal environments;
- seawater immersion:
  - (i) the splash zone, immediately above high-tide level, is usually the most corrosive zone;
  - (ii) the tidal zone, between high tide and low tide, often covered with marine growth; and
  - (iii) the low-water zone, a narrow band just below the low-water level;
- the permanent immersion zone, from low-water level down to the sea bed;
- freshwater immersion – corrosion rates are lower in freshwater than in saltwater;
- soils – the corrosion process is complex and very variable; various methods are used to assess the corrosivity of soils, such as resistivity (generally high-resistance soils are least corrosive), redox potential (to assess the soil's capability of anaerobic bacterial corrosion), pH (highly acidic soils, e.g. pH less than 3.0, can be corrosive), water content (corrosion depends upon the presence of moisture in the soil and the position of the water table has an important bearing).

Long-buried steel structures, e.g. pipelines, are most susceptible to corrosion. Steel piles driven into undisturbed soils are much less susceptible due to the low availability of oxygen.

9.2.3 Influence of design on corrosion

Design can have an important bearing on the corrosion of steel structures. The prevention of corrosion should therefore be taken into account during the design stage of a project. The main design points to be considered are:

Entrapment of moisture and dirt:

- avoid sharp edges, sharp corners, cavities, crevices;
- welded joints are preferable to bolted joints;
- avoid or seal lap joints;
- provide drainage holes for water, where necessary;
- seal the ends of hollow sections, such as pipe piles, box sections, etc.; and
- provide free circulation of air around the structure.

Contact with other materials:

- avoid bi-metallic connections or insulate the contact surfaces;
- provide adequate depth of cover and quality of concrete; and
- separate steel and timber by the use of coatings or sheet plastics.

Coatings application:

- design should ensure that the selected protective coatings can be applied efficiently;
- radius all edges and corners;
- provide vent-holes and drain-holes for items to be hot-dip galvanized;
- do not drill or cut through items that have already been galvanized; and
- provide adequate access for metal spraying, paint spraying, etc.

In general:

- large flat surfaces are easier to protect than more complicated shapes;
- ideally, locate load-bearing members in the least corrosive locations;
- provide access for subsequent maintenance; and
- provide lifting lugs in the design to reduce damage during handling and erection.

9.3 ANTI-CORROSION METALLIC COATINGS

9.3.1 Introduction

Anti-corrosion coatings for steel fall into two broad categories:

- metallic coatings, and
- paint coatings.

Due to their very thin nature, the coating thickness is measured in microns:

- 1 000 microns = 1.0 millimetre or 1 micron is equivalent to one thousandth of a millimetre.

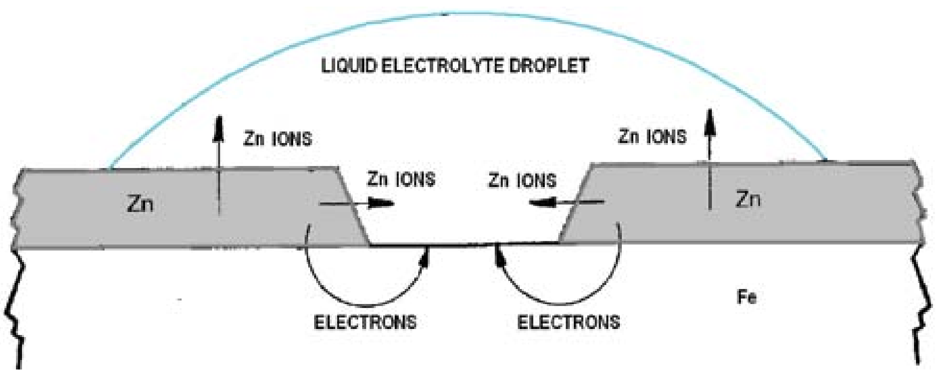
The term galvanizing has its origin with the concept of galvanic or electrochemical corrosion, which is demonstrated by placing two dissimilar metals in contact with each other in an electrolyte, such as seawater.

The principle is the same as that in an electrochemical cell or battery of cells, corrosion being the chemical attack that occurs at the anode. Conversely, batteries make use of the electrical energy produced by such a reaction. Applying this principle to galvanic protection, metals have individual electrical characteristics known as electrode potentials. The difference between these potentials is the driving force for electrochemical action such as corrosion. When dissimilar metals are connected in the presence of an electrolyte, the driving force for the corrosion reaction is released and electronic conduction (with no mass transfer) occurs by the route of least resistance through the metals from the electropositive to the most electronegative. To satisfy the requirement for more electrons at the electronegative metal interface with the electrolyte mass transfer occurs by dissolution of the metal of most electropositive potential, creating ions in the solution.

The main advantages of using zinc are the low melting point (around 420 °C) and the fact that zinc is anodic to steel: that is, when in contact with iron or steel in the presence of an electrolyte, zinc will corrode in preference to the iron or steel. The zinc acts as a "sacrificial anode", Figure 2, and corrodes by the mass transfer of zinc ions into the electrolytic solution, releasing electrons to travel the electrically conducting path through the metals to the steel/electrolyte interface where they are consumed in a reverse cathodic reaction, forming compounds with the positively charged ions from the solution. In some instances these deposit as a chemically stable film on the exposed steel surface, thereby protecting it from further corrosion and limiting reaction.

There is another factor of importance when considering the corrosion activity of zinc. The inherent corrosion resistance of zinc relies mainly on the formation on its surface of insoluble carbonates, which act as a protective film against further corrosion activity.

FIGURE 2
Galvanic protection



There are four commonly used methods of applying metal coatings to steel surfaces:

- hot-dip galvanizing;
- metal spraying;
- electroplating; and
- sherardizing.

Hot-dip galvanizing and metal spraying are best suited for large items, whereas the latter two processes are used for fittings, fasteners and other small items.

9.3.2 Hot-dip galvanizing

The most common method of applying a metal coating to structural steel is by galvanizing. The galvanizing process involves the following stages:

- The steel is cleaned properly; surface preparation of steels is described in detail further on in this text.

- The cleaned steel is dipped into a bath of molten zinc at a temperature of about 450 °C at which the steel reacts with the molten zinc to form a series of zinc/iron alloys on its surface, Figure 3.
- As the steel item is removed from the bath a layer of relatively pure zinc is deposited on top of the alloy layers.

As the zinc solidifies it assumes a crystalline metallic lustre, usually referred to as "spangling". The thickness of the galvanized coating is influenced by three major factors:
- size of the component;
- surface roughness of the steel; and
- chemical composition of the steel.

In general, thicker, heavier sections tend to produce heavier coatings.

FIGURE 3
A microsection through a galvanized coating

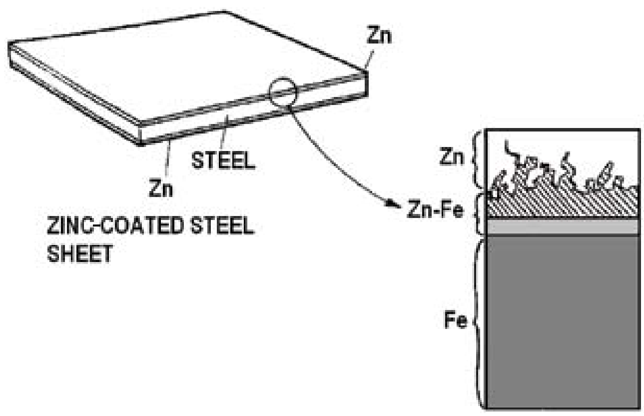


TABLE 1
Zinc coatings

Base sheet thickness (mm)	Minimum average coating (grams/mm²)	Coating thickness (microns)
Over 5 mm	610	85
Between 2 and 5 mm	460	65
Between 1 and 2 mm	335	47
Cast iron	610	85
Centrifuged components	305	43

The greater the surface roughness of the steel, the heavier the coatings (Table 1). The surface of a component may be purposely abraded by different means such as grit or shot blast to increase the surface area of the component by as much as 50 percent.

Silicon, a major chemical component of steel, can have a marked effect on the coating weight deposited. The thickness of the coating varies with an increase in the silicon content of the steel and, sometimes, these coatings may have a dull dark-grey appearance and can be brittle and less adherent.

Since this is a bath-dipping process there is obviously some limitation on the size of the components which can be galvanized. Generally, filling, venting and draining holes, with a diameter of at least 10 mm, must be provided in hollow items such as tubes to allow rapid access for the molten zinc, venting of hot gases and subsequent draining of the zinc.

For most applications, galvanized articles do not need to be painted. Where, for reasons of decorative effect, there is a need to paint, then special etch primers are normally required.

In seawater immersion, zinc coatings are effectively resistant for protecting steel against rusting, with each 0.03 mm of zinc roughly equivalent to about one year of useful life.

9.3.3 Metal spray coatings

An alternative method of applying a metallic coating to structural steelwork is by metal spraying of either zinc or aluminium. The metal, in powder or wire form, is fed through a special spray gun containing a heat source which can be either an oxy-gas flame or an electric-arc. Molten globules of the metal are blown by a compressed air jet on to the previously blast-cleaned steel surface. No alloying occurs and the coating which is produced consists of overlapping platelets of metal and is porous. The pores are subsequently sealed, either by applying a thin organic coating which soaks into the surface, or by allowing the metal coating to weather, when corrosion products block the pores. The adhesion of sprayed metal coatings to steel surfaces is considered to be essentially mechanical in nature.

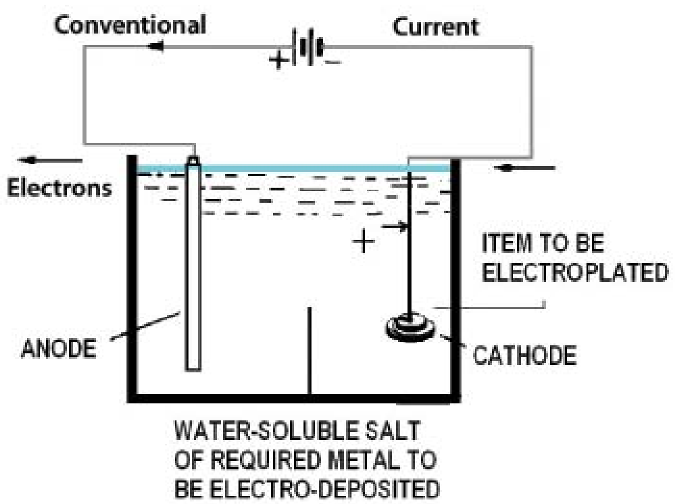
It is therefore necessary to apply the coating to a clean roughened surface for which blast cleaning with a coarse grit abrasive is normally specified, usually chilled-iron grit. Coating thickness varies from 100–250 microns for aluminium to 75–400 microns for zinc. The metals perform similarly in most environments but aluminium is more durable in highly industrial environments.

Metal spray coatings can be applied in workshops or at site and there is no limitation on the size of the component, as there is with hot-dip galvanizing. Since the steel surface remains cool there are no distortion problems. However, metal spraying is considerably more expensive than hot-dip galvanizing. For many applications metal-spray coatings are further protected by the subsequent application of paint coatings. A sealer is first applied which fills the pores in the metal-spray coating and provides a smooth surface for application of the paint coating.

9.3.4 Electroplated coatings

Together with galvanizing, electroplating is the second most important method of applying a metal coating to a steel item (Figure 4). The method consists in suspending steel articles from a cathode in an aqueous electrolyte of the metal to be plated to

FIGURE 4
Electroplating process



the article. A current is then passed through the solution and the positive metal ions migrate to the cathode and hence the article in steel to be plated. Physically, a very thin layer a few microns thick is deposited; thicker layers are obtained by prolonging the electrolyte bath. Due to its simplicity, this method can also be utilized to electrodeposit a number of noble metals such as tin, nickel, chromium and gold. This system, however, is best suited to small engineering components where precision in film thickness is of the utmost importance.

9.3.5 Sherardizing

A sherardized coating is produced by a process called sublimation. In this process, heat is applied to steel components in contact with zinc powder, which then deposits itself on the steel. Sherardizing gives a hard and wear resistant surface and is generally reserved for small components like nuts and bolts.

9.3.6 Stainless steel

Stainless steels are alloys of iron, chromium and other elements that resist corrosion from many environments. In general, steel cannot qualify for a stainless prefix unless it has at least 10 percent chromium. Stainless steels can be very complicated from the metallurgical standpoint because they can contain significant concentrations of eight or more elements and the properties of the various alloys vary from alloy to alloy.

The most popular stainless steel used in marine applications is the 316 series, known as AISI 316 (American Iron and Steel Institute).

The basic AISI 316 has extra molybdenum added to the basic alloy to improve its corrosion resistance, whereas the AISI 316L has a lower carbon content to improve its welding characteristics (Table 2). AISI 316 LN has less carbon and more nitrogen to improve its strength.

Wrought stainless steel components for the fabrication of mooring rings, step ladders and railings should be specified in AISI 316L. Fittings may be in AISI 316.

Stainless steel reinforcement is also commercially available. Stainless steels in the series AISI 304 and AISI 308 are not suitable for a marine environment and should be avoided.

TABLE 2
Properties of some stainless steels

Steel types	C max	Si max	Mn max	S max	Cr	Ni	Mo	P max	N
AISI 304L	0.07	1.0	2.0	0.03	17.0/19.5	8.0/10.5	-	0.045	≤0.11
AISI 316L	0.05	1.0	2.0	0.015	16.5/18.5	10.5/13.0	2.5/3.0	0.045	≤0.11
AISI 316LN	0.03	1.0	2.0	0.015	16.5/18.5	11.0/14.0	2.5/3.0	0.045	0.12/0.22

9.4 PAINT COATINGS

9.4.1 Introduction

Paints are made by mixing and blending three main components:

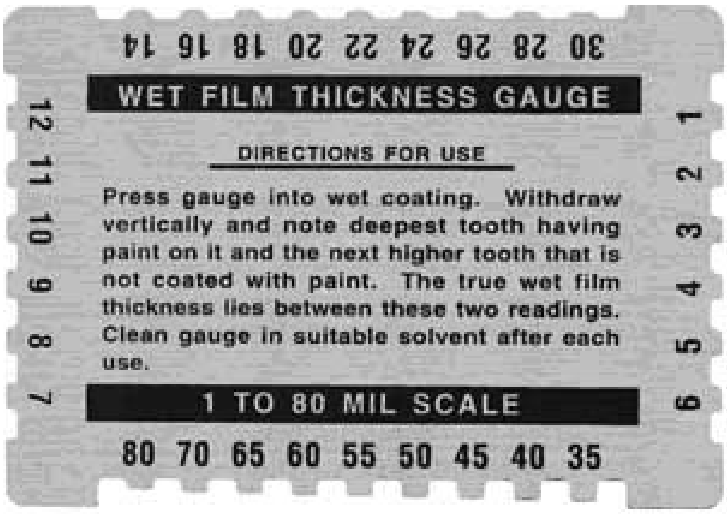
- *Pigments:* finely ground inorganic or organic powders which provide colour opacity, film cohesion and sometimes corrosion inhibition;
- *Binders:* usually resins or oils but can be inorganic compounds such as soluble silicates. The binder is the film-forming component in the paint; and
- *Solvents:* used to dissolve the binder and to facilitate application of the paint. Solvents are usually organic liquids or water.

Since, in the broadest terms, paint consists of a particular pigment, dispersed in a particular binder, dissolved in a particular solvent, the number of generic types of paint is limited. The most common methods of classifying paints are either by their pigmentation or by their binder type.

Primers for steel are usually classified according to the main corrosion-inhibitive pigments used in their formulation, e.g. zinc phosphate, zinc chromate, red lead or metallic zinc. Each of these inhibitive pigments can be incorporated into a range of binder resins, e.g. zinc phosphate alkyd primers, zinc phosphate epoxy primers, zinc phosphate chlorinated rubber primers.

Intermediate coats and finishing coats are usually classified according to their binders, e.g. vinyl finishes, urethane finishes. Paints are applied to steel surfaces by many methods but in all cases they produce a "wet film". The thickness of the wet film can be measured, before the solvent evaporates, using a comb gauge, Figure 5.

FIGURE 5
A wet film comb gauge



As the solvent evaporates, film formation occurs, leaving the binder and pigments on the surface as a "dry film". The thickness of the "dry film" can be measured usually with a magnetic induction gauge. The relationship between the applied "wet film" thickness and the final "dry film" thickness (d.f.t.) is determined by the percentage volume of solids of the paint, i.e.

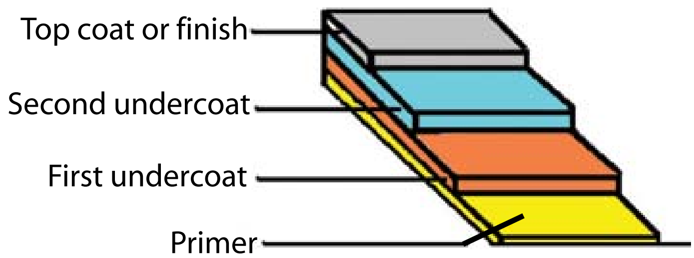
d.f.t. = "wet film" thickness x % vol. solids

In general, the corrosion protection afforded by a paint film is directly proportional to its dry film thickness.

9.4.2 Paint systems

Paints are usually applied one coat on top of another, each coat having a specific function or purpose. The primer is applied directly on to the cleaned steel surface. Its purpose is to wet the surface and to provide good adhesion for subsequently applied coats. Primers for steel surfaces are also usually required to provide corrosion inhibition. The intermediate coats (or undercoats) are applied to build the total film thickness of the system. This may involve the application of several coats. The finishing coats provide the first-line defence against the environment and also determine the final appearance in terms of gloss, colour, etc., Figure 6. The various superimposed coats within a certain system have, of course, to be compatible with one another. They may be all of the same generic type or may be different, e.g. chlor-rubber-based intermediate coats may be applied on to an epoxy primer. However, as a first precaution, all paints within a system should normally be obtained from the same manufacturer.

FIGURE 6
Paint cycle (first and second undercoats sometimes applied as one thick coat)



9.4.3 Main generic types of primers

Shop primers (also referred to as blast primers, temporary primers, weldable primers, temporary primers or holding primers) are used on steel, immediately after cleaning, to hold the reactive cleaned surface in a rust-free condition until the final painting cycle can be undertaken. The main requirements for a primer are:

- The primer should be capable of airless-spray application (see text on cleaning further on) to produce a very thin even coating. Dry-film thickness is usually limited to 15–30 microns. Below 15 microns the peaks of the blast profile are not protected and "rust-rashing" occurs on weathering. Above 30 microns the primer affects the qua1ity of welds and produces excessive weld fume.
- The primer must dry very quickly. The interval between priming and handling is usually keep as is 1–10 minutes and hence the primer film must dry within this time.
- The primer coating should provide adequate protection. It should be noted that many manufacturers make misleading claims about the durability of their blastprimers and suggested exposure periods of 6–12 months are not uncommon. In practice, such claims are never met except in the least arduous conditions, e.g. indoor storage. In aggressive marine conditions, durability can be measured in weeks rather than months.
- The primed surface, after weathering, should require the minimum of preparation for subsequent painting and must be compatible with the intended painting system.

Many proprietary blast primers are available but they can be classified under the following main generic types:

- *Etch primers* are based on polyvinyl butyral resin reinforced with a phenolic resin to uprate water resistance. The curing agent contains phosphoric acid or alkyl phosphates and can be added as a separate component immediately before application. Alternatively, the primer can be supplied in a single-pack form. In general, two-pack etch primers provide better durability than the one-pack types which are usually preferred because of their handling convenience.
- *Epoxy primers* are two-pack materials utilizing epoxy resins and usually either polyamide or polyamine curing agents. They are pigmented with a variety of inhibitive and non-inhibitive pigments. Zinc phosphate epoxy primers are the most frequently encountered and give the best durability within the group.

- *Zinc epoxy primers* can be subdivided into zinc-rich and reduced-zinc types. Zinc-rich primers produce films which contain about 90 percent by weight of metallic zinc powder. These primers provide the highest order of protection of all primers. Reduced-zinc primers are formulated with metallic zinc content as low as 55 percent by weight on the dry film, the remainder of the pigmentation usually being made up with siliceous extenders. This reduces the cost of the primer, avoids possible difficulties with intercoat adhesion in marine environments, but slightly reduces the standard of protection that can be achieved. Zinc epoxy primers all produce zinc oxide fumes during welding and gas cutting which can cause a health hazard. When exposed in marine environments, zinc epoxy primers are prone to the formation of insoluble white zinc corrosion products which must be removed from the surface before subsequent overcoating.
- *Zinc silicate primers* can be based upon either ethyl silicate or inorganic silicates e.g. sodium or potassium. Only the ethyl silicate primers are suitable as primers. Ethyl zinc silicate primers produce a level of protection which is comparable with the zinc-rich epoxy types and they suffer from the same drawbacks, e.g. formation of zinc salts and production of zinc oxide fumes during welding. They are however more expensive and usually are less convenient to use.

9.4.4 Main generic types of paint

The main generic types of paint are:

- *Air-drying paints,* e.g. oil-based, alkyd, epoxy-ester, dry and form a film by an oxidative process which involves absorption of oxygen from the atmosphere. They are therefore limited to relatively thin films. Once the film has formed it has limited solvent resistance and usually poor chemical resistance.
- *One-pack chemical-resistant paints,* e.g. chlor-rubbers, vinyls, form a film by solvent evaporation and no oxidative process is involved. They can be applied as moderately thick films, although retention of solvent in the film can be a problem at the upper end of the range. The film formed remains relatively soft and has poor solvent resistance but good chemical resistance. Bituminous paints also dry by solvent evaporation. They are, essentially, solutions of either asphaltic bitumen or coal-tar pitch in organic solvents.
- *Two-pack chemical-resistant paints,* e.g. epoxy and urethane, are supplied as two separate components, usually referred to as the base and the curing agent. When the two components are mixed, immediately before use, a chemical reaction begins. These materials therefore have a limited "pot life" by which the mixed coating must be applied. The polymerization reaction continues after the paint has been applied and after the solvent has evaporated to produce a densely cross-linked film which can be very hard and has good solvent and chemical resistance. Liquid resins of low viscosity can be used in the formulation thereby avoiding the need for a solvent. Such coatings are referred to as "solvent-less" or "solvent-free" and can be applied as very thick films.

9.4.5 Methods of applying paint

The standard methods used for applying paint to steel are brush, roller, conventional air-spray and airless-spray.

- *Brush.* The simplest and also the slowest and therefore most expensive method. Nevertheless, it has certain advantages over the other methods, e.g. better wetting of the surface; can be used in restricted spaces; useful for small areas; less wastage; less contamination of surroundings; and can be used for application of certain toxic materials like lead-based primers which cannot be sprayed.
- *Roller.* Much quicker than brushing; useful for large flat areas; demands suitable fluidity of the paint.

- *Air-spray.* The paint is atomized at the gun-nozzle by jets of compressed air; application rates are quicker than for brushing or rolling; paint wastage by overspray is high.
- *Airless-spray.* The paint is atomized at the gun-nozzle by very high hydraulic pressures; application rates are higher than for air-spray and overspray wastage is greatly reduced.

9.4.6 Preparing a steel surface for coating

Structural steel is a hot-rolled product (that is, it is rolled into sections while it is still hot). Sections leave the last rolling pass at about 1 000 °C and as they cool the steel surface reacts with oxygen in the atmosphere to produce mill scale, a complex oxide which appears as a blue-grey tenacious scale completely covering the surface of the as-rolled steel section. Unfortunately, mill scale is unstable. On weathering, water penetrates fissures in the scale and rusting of the steel surface occurs. The mill scale loses adhesion and begins to shed.

Mill scale is therefore an unsatisfactory base and needs to be removed before protective coatings are applied. As mill scale sheds, further rusting occurs and this also needs to be removed before protective coatings are applied. Surface preparation of steel is therefore principally concerned with removal of mill scale and rust. Various methods of surface preparation are available:

- *Manual preparation:* The simplest form of surface preparation involving chipping, scraping and brushing with hand-held implements. This method is not very effective (although only about 30 percent removal of rust and scale can be achieved it is nevertheless often used, usually for economic reasons). The degree of cleaning achieved can be specified by reference to photographic standards included in ISO 8501 (International Organization for Standardization No. 8501).
- *Mechanical preparation:* Similar to manual preparation but utilizes power-driven tools, e.g. rotary wire brushing. A marginal improvement in efficiency can be achieved (up to 35 percent), and the same photographic standards can be used. Care must be taken to avoid confusing burnished scale with clean steel, both of which have a similar appearance. The above methods are used on site, usually after a weathering period to promote loosening of mill scale. A suitable primer must then be applied which is tolerant of poor surface preparation. Many modern primers are quite unsuitable for such surfaces and, indeed, the old tried and trusted red lead in oil primers cannot be bettered for manually cleaned surfaces.
- *Flame cleaning:* Not used extensively. An oxy-gas flame is applied to the surface. Differential thermal expansion and steam generated behind the mill scale serve to loosen the mill-scale layer, which can then be removed by mechanical scraping.
- *Acid pickling:* The steel is immersed in a bath of suitably inhibited acids which dissolve or remove mill scale and rust but do not appreciably attack the exposed steel surface. It can be 100 percent effective. Acid pickling is always used on structural steel intended for hot-dip galvanizing but is now rarely used as a pretreatment before painting.
- *Blast cleaning:* Abrasive particles are projected at high speed on to the steel surface. The abrasive can consist of either spherical particles, described as “shot”, or angular particles, described as “grit”. The abrasive is projected towards the surface either in a jet of compressed air or by a centrifugal impeller wheel. The particles impinge on the steel surface removing scale and rust, producing a rough, clean surface. The size and shape of the surface roughness produced is largely dependent upon the size and shape of the abrasive used; angular grits produce angular surface profiles, round shots produce a rounded profile. Grit-blast abrasives can be either metallic (e.g. chilled iron grit) or non-metallic (e.g. slag grit). The latter are used only once and are referred to as “expendable”.

They are used exclusively for site work. Metallic grits are expensive and are used only where they can be recycled. Grit blasting is always used for metal-sprayed coatings, where adhesion is at least partly dependent upon mechanical keying. It is also used for some paint coatings, particularly on site and for primers where adhesion may be a problem (e.g. zinc silicates). Shot-blast abrasives are always metallic, usually cast steel shot, and are used particularly on shot-blast plants, utilizing impeller wheels and abrasive recycling. They are the preferred abrasive for paints, particularly for thin film coatings (e.g. prefabrication primers). Blast-cleaned surfaces are normally specified in terms of surface cleanliness and surface roughness. A number of standards have been used in the past but these are now superseded by ISO 8501-1: 1988, which utilizes photographic replicas of four grades of surface cleanliness after blast cleaning: Sa1, Sa2, Sa2 1/2 and Sa3. Surface roughness of blast-cleaned surfaces is defined in ISO 8503-1: 1988 and Parts 2, 3 and 4 of this standard describe methods of measuring surface roughness.

- *Wet blasting:* A further variation on the blast-cleaning process. In this process, a small amount of water is entrained in the abrasive/compressed air stream. This is particularly useful in washing from the surface soluble iron salts that are formed in the rust by atmospheric pollutants (e.g. chlorides and sulphates) during weathering. These are often located deep in corrosion pits on the steel surface and cannot be removed by conventional dry blast cleaning methods. Wet blasting has proved to be particularly useful in marine environments.

9.4.7 Typical compatible paint cycles

Paint cycles should be designed for compatibility and Table 3 illustrates some typical cycles used in a marine environment.

To avoid mistakes with incompatible paint cycles, paints should always be purchased from the same manufacturer.

TABLE 3
Typical compatible paint cycles

Surface preparation	Paint cycle	Total thickness	Method of application
Manual or mechanical	**Primer:** Oil-based alkyd (red lead) **Undercoat:** Oil-based alkyd **Finish:** Oil-based alkyd	140–160 microns	Brush or roller
Blast cleaning	**Primer:** Zinc epoxy **Undercoat:** Chlor-rubber **Finish:** Chlor-rubber	120–140 microns	Brush, roller or spray
Blast cleaning	**Primer:** Epoxy polyamide **Undercoat:** Epoxy vinyl **Finish:** Vinyl	120–140 microns	Brush, roller or spray
Blast cleaning	**Primer:** Zinc epoxy **Undercoat:** Epoxy tar **Finish:** Epoxy vinyl	300–350 microns	Brush, roller or spray

9.4.8 Painting on galvanized surfaces

Whether thermally sprayed or hot dipped, the zinc coating can provide several years of protection by itself. Components may need to be painted or it may be necessary to apply a paint system to extend corrosion protection after the zinc is consumed. Quality painting after erection is both difficult and expensive, so it is always best to apply organic coatings beforehand, preferably in a shop setting. Surface preparation and painting of components in a shop can be accomplished under controlled conditions to provide optimum protection of the metal. Shop cleaning of zinc-coated surfaces is normally limited to detergent washing to remove loose contaminants and/or solvent cleaning to remove grease or oil. Sometimes, a thin film of grease or oil is applied at the factory to protect galvanizing from corrosion during exterior storage. Also, new galvanizing is sometimes treated with chromate corrosion inhibitors for corrosion protection during storage. Such treatment should specifically be excluded in specifications for galvanized steel components to be coated.

Galvanized steel components are best protected with one coat each of epoxypolyamide and aliphatic polyurethane coatings. If a delay of over four days occurs before the top coat is applied, the finish coat of polyurethane may not adhere because of the solvent resistance of the nearly fully cured epoxy coat. A thin film of the epoxy primer applied and allowed to cure to a tacky finish (e.g. four hours) will provide a suitable surface for the polyurethane finish coat. Epoxy and urethane coatings must have at least a six-hour pot life for practical coating. Oil-based paints (including oil/alkyds) are not recommended because of the inherent incompatibility of oil-based paints with the alkaline surface of galvanizing. Premature failure by peeling is predictable.

A two-coat latex system can also be used on galvanizing, but the protection and gloss and color retention may not be quite as good as with the epoxy/polyurethane system. The corrosivity of the exposure environment should be considered when choosing between the two systems.

9.4.9 Painting of sheet piles

Sheet-pile surfaces are subjected to abrasion from direct and indirect sources which may damage a normal coating. For long-term performance immersed in seawater, the coating system must be of high quality and is often specified in combination with a cathodic protection system (see further on). The recommended paint cycle for sheet piles is shown in Table 4.

TABLE 4
Painting of sheet piles

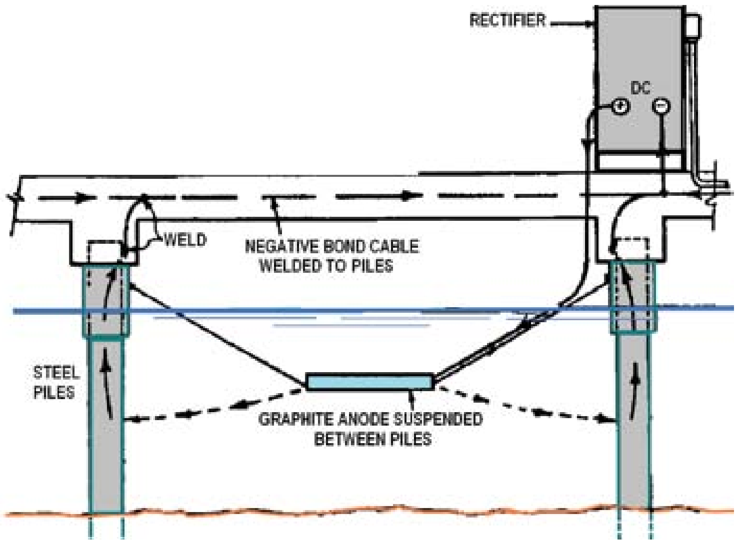
Surface preparation	Paint cycle	Total thickness	Method of application
Blast cleaning	**Primer:** Polyamide cured Epoxy primer **Undercoat:** Polyamide cured Coaltar epoxy **Finish:** Polyamide cured Coaltar epoxy	500 microns	Airless spray

9.5 CATHODIC PROTECTION

The corrosive effect on steel and other metals when submerged in seawater is known as galvanic corrosion and is analogous to the conditions prevalent in a battery, i.e. the presence of two dissimilar metals in an electrolyte. In the case of immersed steel (like a jetty's steel piles or a quay's sheet piles), the dissimilar metal consists of the nonuniformities or non-ferrous impurities in the steel. These impurities establish a flow of current from the steel (positive pole or anode) through the electrolyte (seawater) to the impurity (negative pole or cathode).

Cathodic protection consists in reversing this current flow, i.e. to the steel and not from the steel, thus preventing the iron ions from flowing out of the steel and causing its corrosion (galvanic action).

FIGURE 7
Impressed-current cathodic protection system



Cathodic protection is accomplished by establishing a direct current (DC) voltage between the pile or sheet pile and an auxiliary anode suspended in the water in the vicinity of the structure, Figure 7. The density or strength of the current required depends on the rate of corrosion (specified in millimetres per year) and differs from place to place. Corrosion rates for a given type of steel generally depend on the salinity of the seawater, the ambient temperature and other environmental factors. If the steel has been coated, the efficiency of the coating, will also have a major effect on the rate of corrosion (the better the paint coating, the slower the corrosion rate). Various experiments worldwide indicate that typical current densities are of the order of 15 to 50 mA/m^2 (milliamperes per square metre of steel surface to be protected). This impressed current may be achieved in one of two ways:

- by using a galvanic anode or sacrificial anode, made of zinc, aluminium, magnesium or their alloys; and
- by forcing an external DC current through the auxiliary anode which may consist of a soluble metal, such as iron, or an insoluble material, such as graphite.

Galvanic anodes are generally supplied as ingots (weights from 2 to 100 kilograms) with cast-in suspension brackets which may be bolted or welded directly to the steel piles to be protected. Typical characteristics of galvanic anodes are listed in Table 5.

TABLE 5
Characteristics of sacrificial anodes

Metal	Zinc	Aluminium	Magnesium
Specific gravity	7.14	2.91	1.84
Potential in millivolts	-1 100.0	-1 150.0	-1 500.0
Current ampere/hour/kg	780	2 700	1 103
Current efficiency	95%	95%	50%
Kilogram of metal consumed to produce 1 ampere/year	11.23	3.24	7.94

On large structures, however, to gain better control of the current and regulate the magnitude thereof more accurately, an impressed external source of current is usually applied. Figure 7 illustrates a schematic diagram of an impressed-current cathodic protection installation, consisting of an alternating current (AC) supply, a rectifier (to convert the AC to DC) and the suspended graphite anode slung underneath the jetty in between the steel piles. Graphite anodes also become decomposed in time, primarily due to electrochemical oxidation, and must be replaced every 5 to 15 years, depending on the quantity, size and location of the anodes. Theoretically, when applying the recommended current density, the graphite anode life is of the order of 44 000 to 176 000 ampere hours per kilogram. Assuming the lower value of 44 000 ampere hours as a conservative value, a 30-kilogram graphite anode submerged in seawater would be completely consumed only after providing 7 amperes continuously for [(44 000 x 30) divided by (7 x 24 x 365 days)] or 22 years. In practice, however, replacement must be made before the anode is greatly reduced in size in order to avoid an excessive current density as the exposed surface of the anode diminishes. The realistic useful life of a 30-kilogram graphite anode described above would be between 5 to 15 years.

Although the initial cost of the external impressed-current system is greater than that for galvanic anodes, the long-range economics over a ten-year period indicate that overall costs for impressed-current systems are considerably less than for galvanic anode systems.

The step-down transformer and rectifier are usually mounted inside a weatherproof building not far from the structure to be protected.

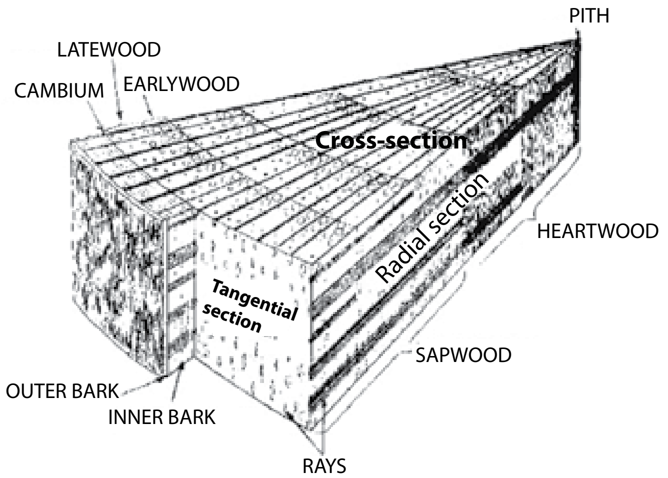
9.6 TIMBER

9.6.1 Introduction

Timber is cut and machined from trees, themselves the product of nature and time. Humans have found timber to be a cheap and effective material and continue to use it in vast quantities.

However, criticisms levelled at timber as a material are a consequence of humankind's misuse of one of nature's most important products. Unlike so many other materials, especially those used in construction, timber cannot be manufactured to a particular specification; instead, the best use has to be made of the material already produced, though it is possible to select timbers with the most desirable range of properties.

FIGURE 8
Cross-section of a trunk



A tree trunk consists of two distinct sections: the inner section or heartwood, and the outer section, or sapwood, Figure 8. The periphery of the trunk is formed of bark or, more correctly, an outer bark and an inner bark. The outer bark is rough in texture and dense enough to provide a protective "coat" covering the vital growth areas immediately inside it. The inner bark is soft, moist and spongy and transports the converted sap from the leaves to the growing parts of the tree. Between the inner bark and the actual growing timber is a thin layer of cells called the *cambium.*

It is here that growth takes place by the splitting of single cells into two cells, each of which grows and splits in a process which continues throughout the growing season, eventually forming a sheath of cells which in cross-section appears as a ring, referred to as an "annual ring". These cells, which make up the wood tissue on the inner side of the cambium, are tubular in shape with diameters between about 0.02 mm and 0.50 mm, and vary in length from about 1 mm in hardwoods to 6 mm in softwoods.

The inner layer consists of cells with comparatively large cavities and thin walls. This cellular structure is due to a more rapid spring growth and, not illogically, is referred to as springwood or earlywood. Later in the year, cells grow more slowly and have thicker walls and smaller cavities, resulting in heavier, harder and stronger material called summerwood or latewood. The amount of summerwood may vary in different species of tree and as a result of different weather and soil conditions. This affects the overall density of the timber, which has a direct relationship with the strength of the timber. A group of cells known as the medullary rays run at right angles to the main cells from the outer layers inward. These carry food material by transporting the excess towards the centre of the tree, where it is stored in cells in the inner rings which cease to function as a live part of the tree. This older timber is known as heartwood and is usually dark in colour as well as being drier and harder than the living layer, known as sapwood.

Heartwood is composed of dead tissue, its cells being completely filled, and its function is the mechanical support of the tree. Sapwood, containing more moisture, is not as strong in the "green" state as heartwood but, after seasoning, when both heartwood and sapwood are reduced to the same moisture content, the difference in density and strength is very small.

Sapwood is inferior to heartwood in respect of durability, containing starches which may attract insects and fungi. Sapwood, however, is very permeable and more easily impregnated with preservative and, where the service conditions demand treatment, it may be beneficial to use sapwood as a deliberate choice.

The botanical name for those plants which grow outwardly, acquiring a new sheath of cellular tissue during each growing season, is exogens and this classification can be subdivided into:

- angiosperms, or dicotyledons, which have broad leaves shed in the autumn and which are normally classed as hardwoods; and
- gymnosperms, or conifers, which have needlelike leaves, broadly evergreen, and which are generally classed as softwoods.

It should be noted that the terms hardwood and softwood in relation to species of tree do not necessarily indicate relative hardness or density; *balsa*, for example, although soft in texture, is a hardwood by classification whereas *yew*, softwood by classification, has a density six times that of balsa.

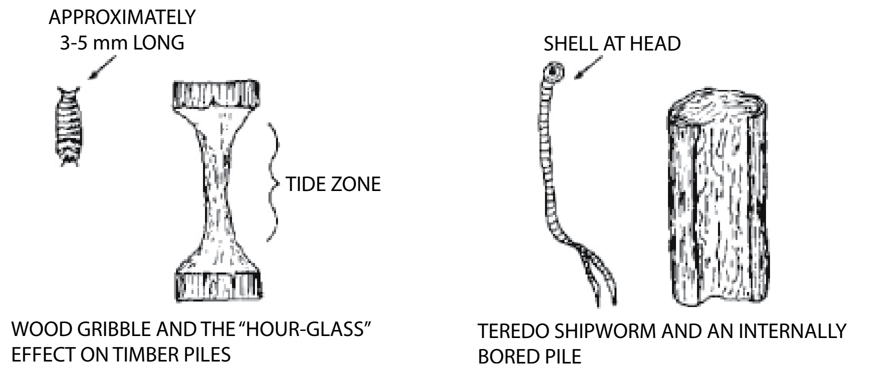
In the living tree, water is to be found not only in the cell cavity but also within the cell walls. Consequently, the moisture content of green wood (newly felled) is high, varying from about 60 percent to nearly 200 percent. Green or newly felled timber will yield moisture to the atmosphere with consequent changes in its dimensions and, with moisture contents above 20 percent, the timber is also subject to attack by fungi. For these reasons it is necessary to dry or season timber following felling of the tree.

9.6.2 Infestation

Although all timbers are susceptible to attack by at least one species of insect or fungus, in practice only a small portion of the timber in service actually becomes infested. The major types of attack are:

- Insect attack can take one of two forms. In certain insects the timber is consumed by the adult form and the best known example of this mode of attack are the termites. Few timbers are immune to attack by these voracious eaters. They are found principally in the tropics but certain species are also present in the Mediterranean region. The other mode of attack is by the grub or larval stage of certain beetles. The adult beetle lays its eggs in superficial cracks on the surface of the timber; the eggs hatch and produce grubs which tunnel their way into the timber, remaining there for periods up to three years.
- Fungal growth may be of two types: destructive or non-destructive. Some fungi, such as moulds, are present only on the surface and do not affect the strength of timber. Sapstain fungi live in the sugars present in the ray cells and impart a distinctive coloration to that region of the timber and may cause a considerable reduction in the strength of the timber. By far the most dangerous to timber are the fungi that cause decay by chemical decomposition; this is achieved by the digesting action of enzymes secreted in the fungi. The best known examples are *dry rot* or *Merulius lacrymans* and *wet rot* or *Coniophora cerebella.* Dry rot is the most destructive; during attack the wood usually darkens and in the advanced stages tends to break up into cubes and crumbles under pressure. A moisture content of 30 to 40 percent with an ambient temperature of 23 °C and lack of ventilation are required for growth. In temperatures above 26 °C, the fungus remains inactive. Wet rot may occur in timber which is excessively wet, whether located inside or outside a building. The fungus attacks all the chemical constituents of the cell wall and, unlike attack from dry rot, timber attacked by wet rot does not crumble under pressure but separates into a fibrous mass.
- Marine borers such as the shipworm (*Teredo* sp.) and the gribble (*Limnoria* sp.), Figure 9, are marine-boring animals that attack timber used in sea or brackish (salty) water. Marine borers are widely distributed, but they are particularly destructive in tropical waters. Most timbers do not have sufficient resistance to marine borers to be used untreated. Figure 9 also illustrates how the gribble and the shipworm destroy timber structures.

FIGURE 9
Marine borers



9.6.3 Durability

Durability is a term which has different meanings for many people: it is defined here in the broadest sense to embrace the resistance of timber to attack from weathering, salt water, corrosion of fastenings, fungi and insect attack.

In weathering, the action not only of light (especially ultraviolet radiation) but also of rain and wind render the timber silvery-grey in appearance: part of the process involves the degradation of the cellular fibres by ultraviolet radiation. However, the same cell walls that are attacked act as a filter for the intact cells below and the rate of erosion from the combined effects of ultraviolet radiation, light and rain is very slow indeed.

As a general rule, timber is highly resistant to a large number of chemicals. When in contact with steel in the presence of seawater, timber gives rise to a condition often known as "nail sickness". Porous timbers absorb seawater, an electrolyte, and assume the role of an electrical conductor. Alkalis are produced at the cathodic surfaces and soluble metallic salts at the anodic areas. The metallic salts so formed degrade timber.

The principal factor conferring resistance to biological attack (insect, fungi and marine borers) is undoubtedly the presence of extractives in the heartwood. The far higher durability of the heartwood of certain species compared with the sapwood is attributable to the presence in the former of toxins (many of which are phenolic in origin), decreased moisture content, increased density and deposition of gums and resins. The decay resistance of most timbers varies a great deal and even pieces cut from the same tree will often show wide differences. For this reason, timbers have been classified into five broad grades based on the performance of their heartwood in contact with the ground. Table 6 illustrates the five grades.

Untreated timber in direct contact with sea or brackish water (jetty piles for example) should be heartwood of one of the species listed as **very durable**. Durable and moderately durable timbers should only be used if treated.

Table 7 presents a list of timbers suitable for marine construction. The heartwood is naturally resistant to marine borers and does not need treatment. The sapwood, however, is perishable unless treated.

TABLE 6
Grade of durability

Grade of durability	Useful life in contact with ground (Years)
Very durable	More than 25
Durable	15 to 25
Moderately durable	10 to 15
Non-durable	5 to 10
Perishable	Less than 5

TABLE 7
Typical timber species suitable for marine construction

Botanical name	Common name	Origin	Density (kg/m^3)	Resistance
Pericopsis elata	Afromosia	Ghana, Ivory Coast	710	Very durable
Mezilaurus itauba	Itauba	Brazil	820	Very durable
Chlorophora excelsa	Iroko	Sierra Leone, Ghana	660	Very durable
Homalium species	Aranga	Philippines	881	Very durable
Ocotea rodiaei Mez	Greenheart	Guyana, Suriname, Venezuela	1 040	Very durable
Dialium species	Keranji	Malaysia	1 120	Very durable
Eucalyptus species	Ironbark	Australia	1 120	Very durable

Note: These and other hardwood species suitable for marine construction are now strictly controlled to limit indiscriminate deforestation. In general, the design of a port should contain as little tropical timber as possible and that used should be sourced from plantations only. The species used should not be on the Convention on International Trade in Endangered Species of Wild fauna and Flora (CITES) list.

9.6.4 Timber preservatives

As stated above, not all timbers require treatment with a preservative to enable them to resist infestation and decay. Many timbers, like the ones mentioned in Table 7, owe their natural resistance to attack to the presence of toxic oils and resins. However, environmental considerations (most species come from virgin tropical rain forests) and cost mean that it is sometimes necessary to use timbers not so well endowed naturally and to subject them to some form of preservative treatment which will increase their durability. Timber preservatives must, by nature, be poisonous to the agents of decay: they must also satisfy conditions of permanency, economy, availability, penetrability and be non-corrosive and non-toxic to humans, animals and plants. Preservatives are generally classed into three groups, depending on the solvent used:

- tar-oil preservatives;
- water-soluble preservatives; and
- organic solvent preservatives.

9.6.4.1 Tar-oil preservatives

Tar-oil preservatives consist essentially of mixtures of distillate oils from coal tar (an aromatic hydrocarbon) and are known as coal tar creosotes or creosote and are the most widely used. Its efficacy as a preservative lies not in any natural toxicity, but rather in its supreme water repellence. It has a very distinctive odour, stains timber, and once treated timber cannot be painted unless primed with a metallic paint. The major drawback with this type of preservative is that it is a polycylic aromatic hydrocarbon (PAH) which is a highly toxic compound. This product is gradually being phased out due to the pollution of the water environment.

9.6.4.2 Water-soluble preservatives

Water-soluble preservatives are generally odourless and non-staining. Because of the waterborne nature of this type of preservative it may be necessary to re-dry the timber to an acceptable moisture content. These preservatives function as toxins and commonly contain formulations of copper, chromium and arsenic salts. These chemicals are “fixed” in the timber and cannot leach out.

9.6.4.3 Organic solvent preservatives

These preservatives tend to be more expensive than the previous two, and are generally formulations of pentachlorophenol, tributyltin oxide or chlorinated naphtalenes. These preservatives also function as toxins and have good penetration characteristics. As with tar-oil creosotes, however, these preservatives are toxic to humans and should not be used.

Timber which has been treated with both water soluble and solvent type preservatives can be painted; it is also possible to glue together treated components. Preservatives may be applied by brush, by steeping or by pressure. Brushing is the least effective method but is better than none and, provided that the preservative is flooded over the surfaces to encourage absorption, reasonable penetration is possible in very permeable timbers. Steeping or dipping involves placing the timber sections inside a bath of preservative for a number of days. In this method of application, the timber section to be treated should be prepared in its final form, with all chamfers, holes and recesses cut. Some preheating of the preservative may be necessary to assist penetration. Pressure application is by far the most efficient and controllable method of preservation. Pressure application is the timber industry standard. In the process, the timber section is placed in a large enclosed pressure vessel and subjected to a vacuum for about an hour. While the vacuum is maintained the preservative is introduced into the vessel until it is filled. Pressure is then gradually increased until the required amount of preservative has been introduced into the timber. A further vacuum is applied for a brief period only long enough to clean the surface of the timber from excess preservative. This method assumes that timber seasoning has taken place beforehand to ensure that during subsequent storage cracks do not expose untreated timber.

9.7 CONCRETE

9.7.1 Introduction

Concrete is a human-made composite, the major constituent of which is natural stone aggregate such as gravel, sand or crushed rock. The other principal constituent of concrete is the binding medium used to bind the aggregate particles together to form a hard composite material. The most commonly used binding medium is the product formed by a chemical reaction between cement and water. When this chemical reaction takes place (also known as hydration), heat is given off (also known as heat of hydration). In its hardened state concrete is a rock-like material with a high compressive strength but a low tensile strength. Compressive and tensile strengths in concrete are measured in N/mm^2 (Newtons per square millimetre) or MPa (Mega Pascals).

$$\mathbf{1\ MPa = 1\ N/mm^2}$$

The tensile strength of normal concrete is low and this can be improved by incorporating steel bars to resist tension (reinforced concrete). The density of concrete is measured in $Tonne/m^3$ (Tonne per cubic metre) or kN/m^3 (kilonewtons per cubic metre).

$$\mathbf{1\ Tonne/m^3 = 10\ kN/m^3}$$

It is not the intention here to teach concrete mix design but rather the site practice involved in producing good-quality concrete that is durable in time and compatible with the marine environment. Almost all the topics discussed are dealt with in greater detail in national or international standards for quality control, use of which requires access to a well-equipped concrete testing laboratory.

9.7.2 Cement

Portland cement is a finely ground powder developed in 1824 and derives its name from Portland limestone because of its close resemblance to this rock after hydration has taken place. The basic components used in the manufacture of Portland cement are calcium carbonate (found in limestone rock) and iron oxide, alumina and silica (found in clay). As a result of the chemical changes which take place inside a cement-making kiln, these constituents give rise to several compounds, only four of which are considered to be important:

- tricalcium silicate, also known by its chemical abbreviation as C_3S for short;
- dicalcium silicate or C_2S;
- tetracalcium aluminoferrite or C_4AF; and
- tricalcium aluminate or C_3A.

Over time, a variety of cements have been developed to ensure good durability of the concrete under different conditions and these cements each contain different amounts of the above constituent compounds. The main types of cement currently available in practice are:

- ordinary Portland cement;
- rapid hardening cement;
- low heat Portland cement;
- sulphate resisting cement; and
- portland blast furnace cement.

Marine works require a concrete which is durable in a marine environment and to achieve this only cement which performs well in this environment should be used. Both sulphate resisting cement and Portland blast furnace cement have these required characteristics.

During the process of hydration, the chemical reaction between the tricalcium aluminate and gypsum ($CaSO_4.2H_2O$) produces a compound called calcium sulphoaluminate. In hardened cement, calcium aluminate hydrate can react with a sulphate salt from outside the concrete in a similar manner: the product of addition is calcium sulphoaluminate, forming within the framework of the concrete's cement paste. Since the increase in volume of the solid phase is over 200 percent, gradual disintegration of the concrete results.

A second type of reaction is that of base-exchange between calcium hydroxide and the sulphates, resulting in the formation of gypsum with an increase in volume of the solid phase of 124 percent.

These reactions are known as sulphate attack. The salts particularly active are magnesium and sodium sulphate. Sulphate attack is greatly accelerated if accompanied by alternate wetting and drying, as in the case of marine structures. **The remedy lies in the use of cement with a low content of C_3A and such cement is known as sulphate resisting cement**. Portland blast furnace cement is also low in C_3A and suitable for marine concrete.

When large volumes of concrete are being poured, in excess of around 15 m^3, the heat of hydration in ordinary Portland cement and rapid hardening cement will give rise to thermal cracking in the cast, depending on the shape of the cast, the ambient temperature and the temperature of the batched materials. Both sulphate resisting cement and Portland blast furnace cement have low heat characteristics and should be the preferred choice in the mix design.

9.7.3 Aggregate

Aggregate is much cheaper than cement and maximum economy is obtained by using as much aggregate as possible in a concrete mix. Its use also considerably improves both volume stability and durability of the resulting concrete. The properties of the aggregate known to have a significant effect on concrete behaviour are:

- shape and surface texture;
- grading;
- strength;
- deformation (toughness and hardness);
- porosity;
- specific gravity or the ratio of its unit weight to that of water; and
- impurities.

9.7.3.1 Shape and surface texture

The shape and surface texture of an aggregate can affect the properties of concrete in both its plastic (fresh) and hardened states. These external characteristics may be assessed by observation of the particles and classification of their particle shape and texture as shown in Boxes 1 and 2.

The best aggregate for concrete is one that is irregular and angular. Rounded aggregate provides a smaller mechanical bond with the hydrated paste, whereas the flaky and elongated aggregate tends to have little strength across the thinner sections, influencing the strength of the concrete.

The most suitable mechanical bond is obviously achieved with rough surfaces, followed by granular, smooth, crystalline and glassy. Honeycombed aggregate is generally very porous and is not suitable for good quality concrete.

BOX 1

Classification	Description of shape
Rounded	Fully water-worn such as beach shingle or pebbles
Irregular	Naturally irregular such as breccia and having rounded edges
Angular	Possessing well-defined edges such as crushed from rock
Flaky	Having a thickness considerably smaller than its length or width
Elongated	Usually angular but very long
Flaky and Elongated	A combination of the above two conditions

BOX 2

Surface texture	Characteristics
Glassy	Conchoidal fracture such as in broken basaltic rock
Smooth	Water-worn such as found on beach pebbles
Granular	Fracture showing more or less uniform rounded grains, as in sand
Rough	No visible crystalline constituents, such as crushed limestone
Crystalline	Visible crystalline structure such as in granite aggregate
Honeycombed	Visible pores and cavities such as in some types of coral stone

9.7.3.2 Grading

Grading of an aggregate defines the proportions of particles of different size in the aggregate. The size of the aggregate particles normally used in concrete varies from 0.15 mm to 37.5 mm. Generally, fine aggregate or sand has particles the majority of which are smaller than 5 mm. The rest are known commonly as the coarse aggregate. The grading of an aggregate can have considerable effect on the workability and stability of wet concrete and is a most important factor in designing a concrete mix. A mix with too little fine particles is defined as harsh and does not place easily because the main aggregate tends to segregate away from the cement paste. A mix with too many fine particles on the other hand requires more water, resulting in a concrete with inferior properties.

9.7.3.3 Strength

Strength of an aggregate limits the attainable strength of concrete only when its compressive strength is less than or of the same order as the required strength of the concrete. In other words, the strongest and not the most convenient aggregates should be used in the concrete mix. Typically, coral, which only attains strengths of the order of 20 N/mm^2 cannot be used to produce concrete with strength of 30 N/mm^2, which is considered to be the minimum strength suitable for a marine environment. Typical values of strength for good parent rock (from which the aggregates are extracted) are:

Granite	181 N/mm^2
Basalt	200 N/mm^2
Limestone	159 N/mm^2
Sandstone	131 N/mm^2
Quartzite	252 N/mm^2
Porphyry	230 N/mm^2

9.7.3.4 Deformation

Deformation characteristics of an aggregate are seldom considered in assessing its suitability for concrete work although they can easily be determined from compression tests on specimens from the parent rock. A commonly used standard is toughness or brittleness, i.e. its resistance to failure by impact. Another common standard is hardness, i.e. its resistance to wear or abrasion. Soft rock such as coral, for instance, abrades very quickly and a concrete surface made with coral aggregate ruts very easily. A good guide in the field for hardness is the “penknife scratch”; a steel penknife should not easily scratch the surface of a piece of aggregate.

9.7.3.5 Porosity

Porosity is an important factor which influences the amount of water required for a given mix and makes it very difficult to obtain good quality concrete. Porous aggregate tends to absorb the mixing water quickly, depriving the cement paste, and in the process rendering the wet concrete too dry to handle and place in the process. More water has to be added to make up for this “loss” thereby reducing the quality of the finished concrete.

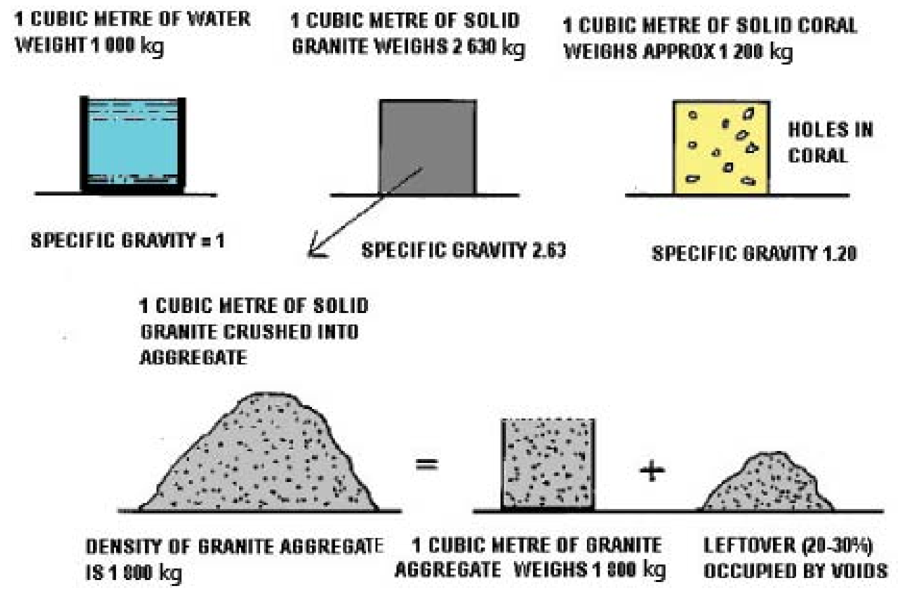
For this reason, porous aggregate stockpiles should not be exposed to rain. Direct measurement of porosity is difficult and in practice a related property, water absorption, is measured.

9.7.3.6 Specific gravity

Specific gravity of a material is the ratio of its unit weight to that of water. Generally speaking, the higher the specific gravity of the parent rock from which the aggregate has been extracted (e.g. limestone, granite, basalt, etc.), the denser the concrete and hence the more durable.

Figure 10 illustrates the various terms used in defining the “weights” of the various components. The basic unit for specific gravity is water and everything else is referred to unity. For example, a cube measuring 1 metre cubed (1 m^3) of solid granite weighs 2 630 kilograms; granite is a very dense material. Its specific gravity is 2.63. The following provides the average specific gravity for parent rock.

FIGURE 10
Relationship between specific gravity and density



Parent rock	Average specific gravity
Basalt	2.793
Granite	2.636
Hard limestone	2.60
Soft limestone	2.20
Porphyry	2.73

When a 1 cubic metre cube of solid granite is crushed to make aggregate, the bulk or the overall volume of the resulting aggregate occupies more than 1 cubic metre. The reason for this is that inside the aggregate there are now also voids and the volume occupied by these voids is the amount of leftover aggregate that will not fit inside the 1 cubic metre. The 1 cubic metre of granite aggregate typically weighs only 1 800 kilograms and the "weight" or more appropriately the bulk density of granite aggregate is specified as being 18.0 kN per cubic metre (1.8 t/m^3). The density of other types of aggregate depends mainly on the specific gravity of the parent rock, the shape of the particles (some particles fit tightly together making the aggregate denser) and the relative size of the particles (if an aggregate has a lot of fine particles, i.e. dust, it weighs more). Dry cement powder typically weighs 18.0 kN/m^3 or 1.80 Tonnes/m^3.

9.7.3.7 Impurities

Natural aggregates may be sufficiently good in themselves and yet they may not be satisfactory for concrete making if they contain organic impurities which interfere with the chemical reactions of hydration. The organic matter found in aggregate consists usually of products of decay of vegetable matter and such materials are more likely to be present in sand than in coarse aggregate, which is easily washed. Clay may be present in aggregate in the form of surface coatings which interfere with the bond between aggregate and the cement paste. Another type of fine material present in some fine aggregates (i.e. in the sand) is silt and crusher dust. Both silt and fine dust (particle diameters in the range of 1 to 60 microns) may form coatings on the aggregate similar to those of clay. The presence of loose silt and dust in a mix necessitates the use of more water in the concrete, thereby decreasing the strength.

Sand from the seashore or from a river estuary also contains salt. This has to be washed away using freshwater. Due to their porosity, coral aggregates generally contain high levels of salt and should not be used, especially with reinforcing steel. A concrete surface containing coral also exhibits efflorescence and cannot be painted or rendered.

Other types of unsound materials, such as coal, mica and iron pyrites (iron sulphide), should also be removed or limited to trace levels. Some forms of aggregate are totally unsuitable for inclusion in concrete in that they react over a length of time with the hydrated cement paste causing the concrete to deteriorate.

9.7.4 Mixing water

The quality of the mixing water also plays a vital role in the strength of the concrete because impurities in the water may interfere with the hydration of the cement paste. In many specifications worldwide, the quality of water for mixing concrete is covered by a clause saying that water should be fit for drinking. Such water rarely contains dissolved solids in excess of 2 000 ppm or parts per million (i.e. 2 000 grams of dissolved salts per cubic metre of water), and as a rule less than 1 000 ppm. While the use of potable water is generally safe, water not fit for drinking may often be used to make concrete. As a rule, water with a pH of 6.0 to 8.0 which does not taste saline or brackish is suitable for use, but dark colour or bad smell does not necessarily mean that organic substances are present. A very good way of determining the suitability of dubious water is to compare the setting time of cement made with say, tap or distilled water (the control test) and the dubious water. Brackish water contains chlorides and sulphates. When chlorides do not exceed 500 ppm and sulphates (SO_3) do not exceed 1 000 ppm, the water is harmless.

Seawater has a total salinity of around 35 000 ppm (i.e. 35 000 grams or 35 kilograms of dissolved salts per cubic metre of seawater) and 78 percent of these salts is sodium chloride (NaCl) and 15 percent magnesium sulphate ($MgSO_4$) and magnesium chloride ($MgCl_2$). When used for mixing concrete, seawater:

- may lower the long-term strength of concrete by about 15 percent;
- will increase the risk of corrosion of steel inside the concrete; and
- will cause persistent dampness and surface efflorescence.

9.7.5 Batching

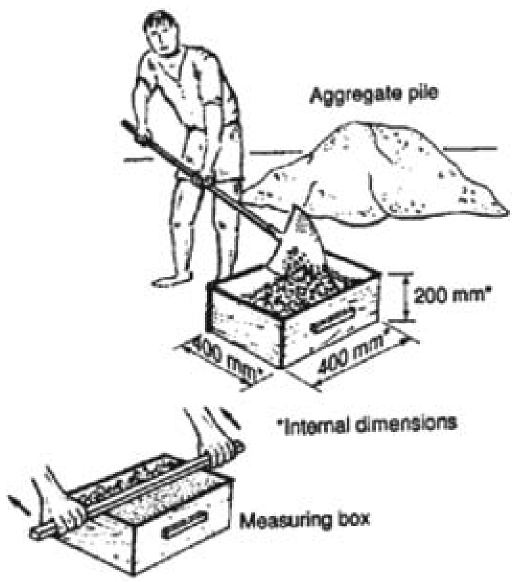
Concrete is made up from the various constituents mixed together according to a specific mix; the mix may either be a standard mix or a designed mix. Designed mixes are usually reserved for use on large projects and the science of designing a mix to suit local conditions is beyond the scope of this manual.

Concrete mixes are generally quoted by weight of the constituent materials but, knowing the densities of the constituents (remembering that cement always comes in 50-kilogram bags), mixes may also be converted to volumetric proportions; volumetric proportions are easier to follow in artisanal situations and will be dealt with in greater detail. A standard volumetric mix may be any one of those shown in Table 8.

TABLE 8
Batching volumes

Nominal proportions	Quantities of aggregate		Typical strength measured (per 50-kg bag of cement after 28 days in N/mm²)
	Fine (Sand)	Coarse	
1 : 2 : 4	0.07m³	0.14m³	20.0 (general mass concrete)
1 : 1½ : 3	0.05	0.10	25.0 (not in much use)
1 : 1 : 2	0.035	0.07	30.0 (minimum marine concrete)

FIGURE 11
Batching by hand using a standard measuring box



The above table gives the volumetric dosage of the constituent materials referred to a 50-kilogram bag of cement. The recommended minimum grade or strength for marine concrete is 30 N/mm² as this provides a good all-round mix with good durability. This mix is generally known as a “one one two” mix.

Batching is the term used for preparing the various dry constituents for mixing. To batch the aggregates by volume, a wooden measure box should be constructed with inside dimensions of 400 mm by 400 mm by 200 mm high as illustrated in Figure 11.

Each such level box contains 0.035 cubic metre of aggregate. Therefore, for each 50-kilogram bag of cement loaded into the concrete mixer, one box measure of sand (0.035 m³) and two box measures of aggregate (0.070 m³) are required. This hence completes the batching of the dry constituents.

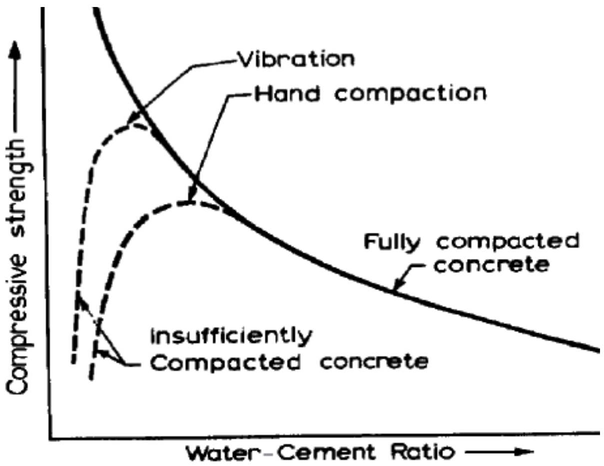
The nominal mix table purposely leaves the water dosage out. In engineering practice, the strength of the concrete at a given age (28 days are generally prescribed as the minimum for testing) is assumed to depend primarily on two major factors in the field:

- the amount of water in the mix (known as the water-cement ratio or W/C ratio); and
- the degree of compaction.

Assuming that the concrete is fully compacted (by mechanical vibration, as described later on in the text), the strength is a function of the W/C ratio (i.e. the amount of water introduced into the mix divided by the weight of the cement in the mix), Figure 12.

This means that the less water is added to the mix (beyond the necessary minimum to turn the cement into a paste, albeit a stiff one), the stronger the concrete is. However, very stiff concrete is difficult to pour from a mixer and difficult to place inside a given mould and, generally speaking, more water has to be added beyond the minimum to make the mix workable.

FIGURE 12
The effect of increasing the water/cement ratio on the strength of concrete



In practice, if the aggregates have been chosen carefully, the W/C ratio can be set at around 0.35 to 0.40 as a starting point. A W/C ratio of 0.35 means that for every 50 kilograms of cement present in the mix, 17.50 litres (0.35 x 50 = 17.50) of water should be added. This will undoubtedly result in a very stiff mix and further amounts of water will be needed to make the mix workable. Generally, water in the concrete consists of that added to the mix and that held by the aggregate at the time it enters the mixer (for example, aggregate which has been exposed to rain will automatically introduce more water into the mix, increasing the given W/C ratio). Conversely, when the aggregate is very dry (i.e. left exposed to the mid-day sun), a part of the water added to the mix will be taken away from the cement paste and absorbed by the hot aggregate during the first few minutes after mixing, decreasing the W/C ratio and resulting in a very stiff mix.

The workability of concrete has never been precisely defined. For practical purposes it generally implies the ease with which a concrete mix can be handled from the mixer to its finally compacted shape. The three main characteristics of the property are:

- consistency (a measure of the wetness or fluidity);

- mobility (the ease with which a mix can flow into and completely fill the formwork); and
- compactability (the ease with which a given mix can be fully compacted).

In this context, the required workability of a mix depends not only on the characteristics and volumetric proportions of the constituent materials but also on:
- the methods employed for conveyance and compaction;
- the size, shape and surface roughness of the formwork; and
- the quantity and spacing of any reinforcement.

A simple test devised to measure the consistency and workability of fresh concrete is the "slump test" and the apparatus involved is inexpensive, portable and robust. Figure 13 illustrates the dimensions of the steel cone required for the test. Figure 14 shows how a slump test is carried out.

When just enough water has been added to the concrete mixer to make the concrete appear wet but stiff, the cone should be filled with three layers of concrete from the mixer, each compacted by hand using a 20 mm diameter steel poker. The top of the cone should then be towelled level and the cone lifted off. As soon as the steel cone is lifted off, the concrete will slump or settle down as shown in Figure 15. The ideal slump

FIGURE 13
The slump cone

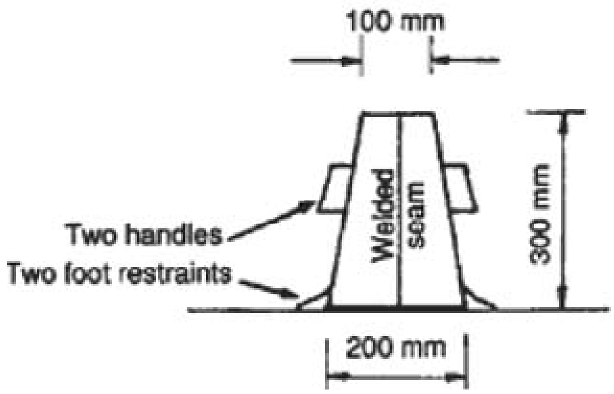
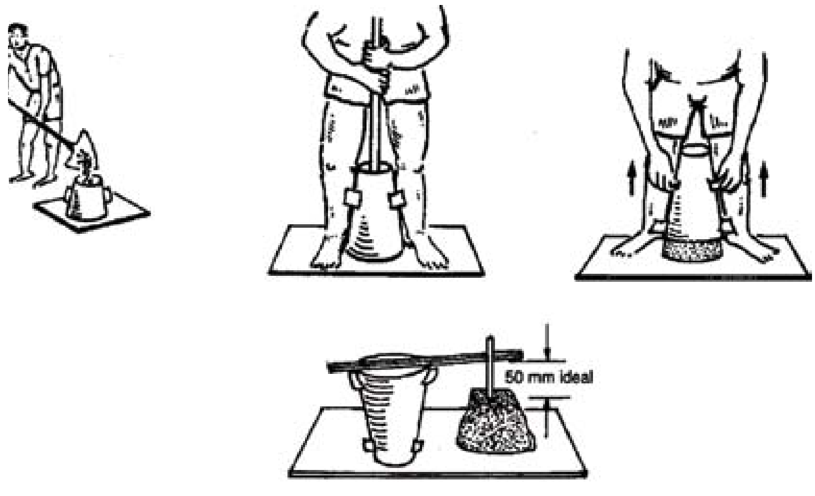


FIGURE 14
The slump test



for most practical work is 50 mm. Should the concrete not slump by 50 mm, a bit more water should be added to the mixer with a measuring can, half a litre at a time (and not directly through a water pipe). The test should then be repeated until the desired slump is achieved. This test is suitable for the quality control of consistency. It is not suitable for stiff mixes and very wet mixes.

Figure 15 illustrates the three types of slump usually observed; true, shear and collapse slumps. A true slump is observed with cohesive and rich mixes for which the slump is generally sensitive to variations in workability (the ideal case). The shear slump tends to occur more often with leaner mixes and indicates a lack of cohesion generally associated with harsh mixes (low on fines). A collapse slump is an indication of a very wet mix and is generally taken to indicate poor workmanship or poor concrete.

The standard slump apparatus is only suitable for concretes in which the maximum aggregate size does not exceed 37.5 mm. It should be noted that the value of the slump changes with time after mixing owing to the normal hydration processes and evaporation of some of the free water and it is desirable, therefore, that tests are performed within a fixed period of time, Figure 16.

FIGURE 15
Types of slump

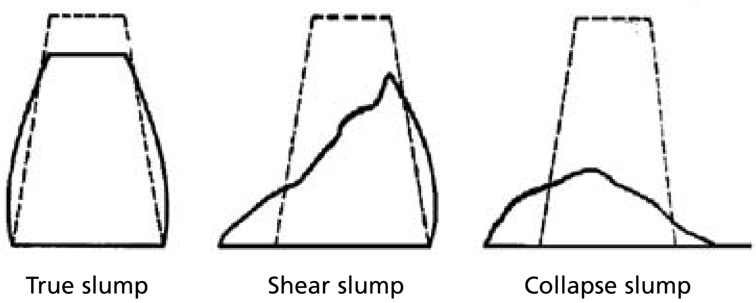
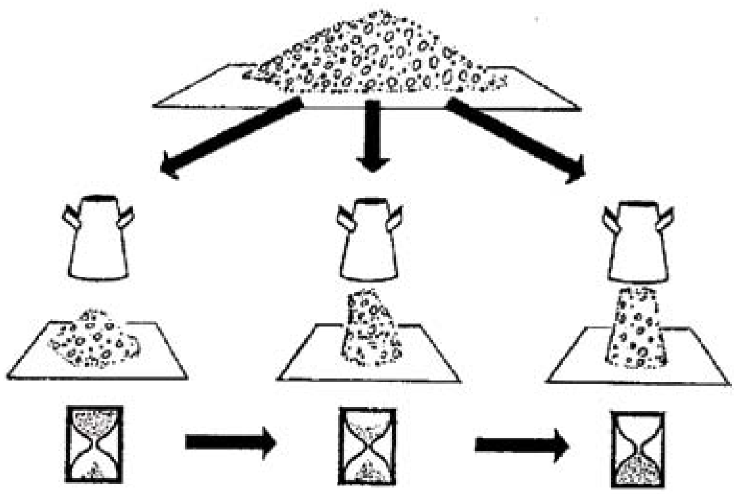


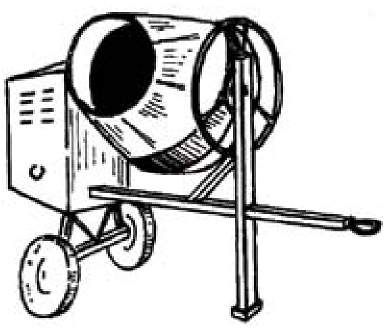
FIGURE 16
Change of workability with time



On a larger scale, concrete is batched by concrete mixers and concrete mixers come in many sizes and shapes but generally fall into three main categories:

- portable, tilting drum, mini-mixers, capacity not exceeding about 150 litres (0.15 m^3);
- transportable, fixed horizontal drum mixers, capacity not exceeding 1.0 m^3; and
- pan mixers, used mainly by ready-mixed operators, with much larger capacities.

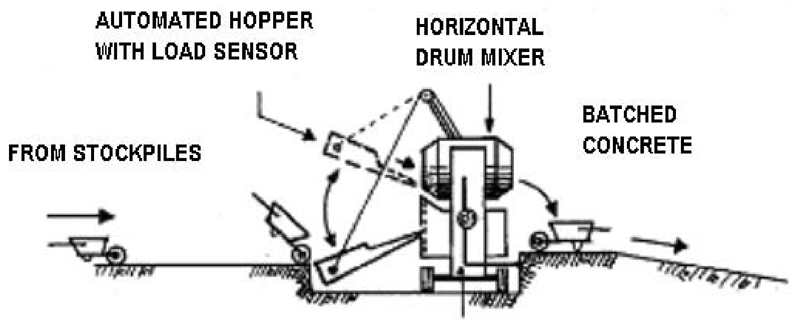
FIGURE 17
Petrol-driven portable concrete mixer



Portable mixers, Figure 17, are available with a wide range of power options, such as petrol, diesel and electricity. They are small enough to be loaded on a light truck or towed behind a suitably equipped vehicle. The capacity of the tilting drum is usually enough to hold the batch for a 50-kilogram cement bag.

Allowing for loading and a minimum mixing time of about five minutes, a crew of five people can produce an average of about 1 m^3 of fresh concrete per hour (suitable for small pours, jute-bag filling, etc.). Petrol-powered versions tend to be lighter than diesel-powered ones. Electric-powered mixers are the lightest and easiest to maintain.

FIGURE 18
Horizontal drum concrete mixer



The fixed horizontal drum mixer is quite large and heavy and when towed to a site it is generally set up on a prepared concrete platform to ease loading and discharging of concrete, Figure 18. Modern horizontal drum mixers are quite sophisticated, generally incorporating a load cell on the tipping hopper (so that the mix can be batched by weight instead of by volume) and an automatic water dosimeter for dispensing the exact volume of mixing water directly into the drum. The drum capacity can range from 0.50 m^3 to 1.0 m^3 and needs a fairly large crew to operate. A fleet of wheelbarrows is generally needed to haul enough aggregate to keep it working at full capacity and enough wheelbarrows or a motorized skip or tipper to haul away the concrete to the formwork. The wheelbarrows loading the aggregate may be replaced by a small pay-loader and the wheelbarrows loading the batched concrete may be replaced by a tipper.

Pan mixers are generally used by ready-mix companies for discharging concrete into truck mixers. Pan mixers are the most efficient way to mix concrete and need mechanized feeding of all the dry constituents.

9.7.6 Reinforcement

As mentioned earlier, the tensile strength (resistance to pulling) of concrete is very low and reinforcing steel in the form of bars or mesh is used to increase this strength. Reinforcing bars are manufactured as deformed or ribbed bars to better grip the concrete as illustrated in Figure 19. Commonly available sizes are illustrated in Table 9 and the common types of steel mesh are illustrated in Figure 20.

FIGURE 19
Steel reinforcement showing steel mill's identification marks

TABLE 9
Commonly available sizes of steel bars and steel mesh

BAR DIAMETER mm	CROSS-SECTIONAL AREA mm²
6	28.3
8	50.0
10	79.0
12	113.0
14	154.0
18	254.0
20	314.0
22	380.0
24	452.0

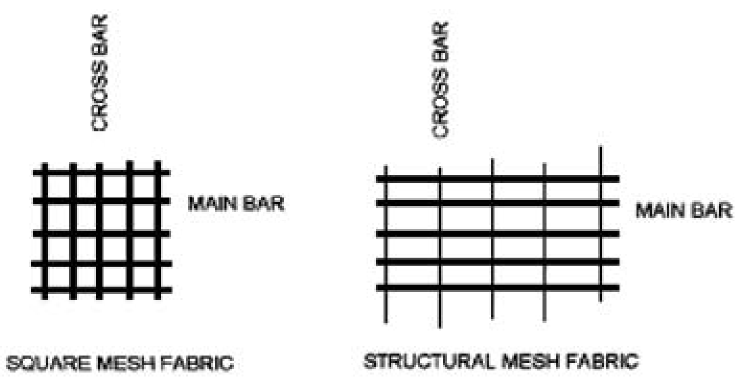
SQUARE STEEL MESH FABRIC

TYPE OF MESH	NOMINAL PITCH IN mm		BAR SIZE IN mm		STEEL AREA IN mm²		WEIGHT
	MAIN	CROSS	MAIN	CROSS	MAIN	CROSS	Kg/m²
SQUARE	200	200	10	10	393	393	6.16
SQUARE	200	200	8	8	252	252	3.95
SQUARE	200	200	7	7	193	193	3.02
SQUARE	200	200	6	6	142	142	2.22
SQUARE	200	200	5	5	98	98	1.54

STRUCTURAL STEEL MESH FABRIC

TYPE OF MESH	NOMINAL PITCH IN mm		BAR SIZE IN mm		STEEL AREA IN mm²		WEIGHT
	MAIN	CROSS	MAIN	CROSS	MAIN	CROSS	Kg/m²
STRUCTURAL	100	200	12	8	1131	252	10.90
STRUCTURAL	100	200	10	8	785	252	8.14
STRUCTURAL	100	200	8	8	503	252	5.93
STRUCTURAL	100	200	6	7	283	193	3.73
STRUCTURAL	100	200	5	7	196	193	3.05

FIGURE 20
Common types of steel mesh

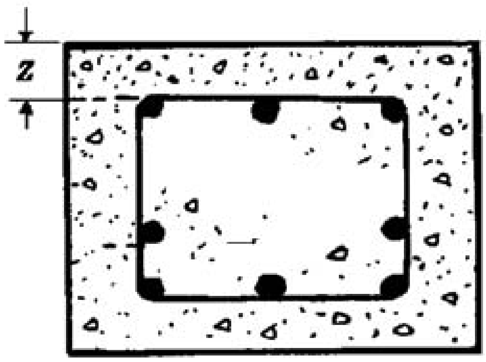


When exposed to a marine environment, the steel bars inside the concrete may corrode if:

- The concrete is of poor quality (porous) and not very dense.
- The concrete cover to the steel bars is too small, allowing salt to reach the steel.
- The concrete (aggregates or mixing water) contains too much salt.

Assuming that the concrete has been manufactured to the right standard (i.e. good quality, dense and salt-free), the minimum cover to the steel should not be less than 50 mm as shown in Figure 21.

FIGURE 21
The minimum cover to any steel bar (Z) should not be less than 50 mm



9.7.7 Placing, vibrating and curing

Placing, vibrating and curing complete the cycle of concrete construction. The formwork should be sturdy and properly anchored to prevent it from moving during the placing of concrete. It should be free of dust or organic matter (vegetation, cigarette butts, timber) and it should be properly oiled on the inside with an appropriate, water-based formwork release agent. **Diesel is not suitable for this purpose and should not be used.** The steel should be kept clean and free of oil-based compounds, such as diesel and oil. The reinforcement should be tied firmly to the sides of the formwork and workers should not be allowed to walk over it. Suitable planks should be provided across the formwork for this purpose. Concrete should not be dropped from a height exceeding 1.50 metres as this will lead to segregation of the aggregate and, if reinforcement is present, it may push the steel bars out of position. When concrete has to be placed underwater, a tremie pipe should be used, Figure 22 (left). The concrete should be made richer (cement content increased by about 25 percent from the standard nominal mix) and slightly wetter as no vibration of the concrete is allowed underwater. The flexible pipe should be raised along with the pour until the concrete breaks the surface of the water. Concrete should never be tipped into water, Figure 22 (right), as this will cause the cement to wash out. If a concrete pump is available, concrete may be pumped directly underwater.

The process of compacting the concrete consists essentially of the elimination of entrapped air bubbles. The use of vibration as a means of compaction makes it possible to use drier mixes than can be compacted by hand. Of the several types of vibrators,

FIGURE 22
Placing of concrete under water using a tremie (left)

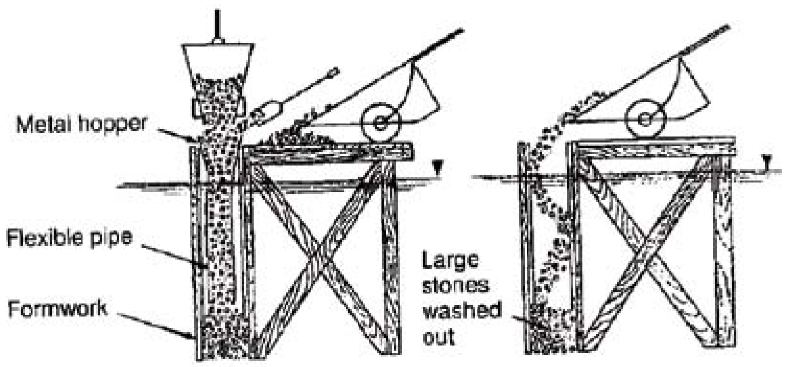
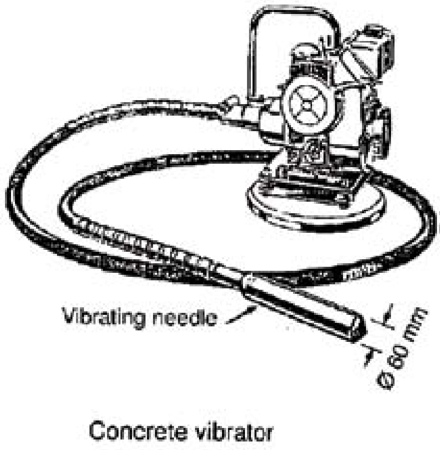


FIGURE 23
Petrol-driven poker vibrator with a 60-mm diameter poker

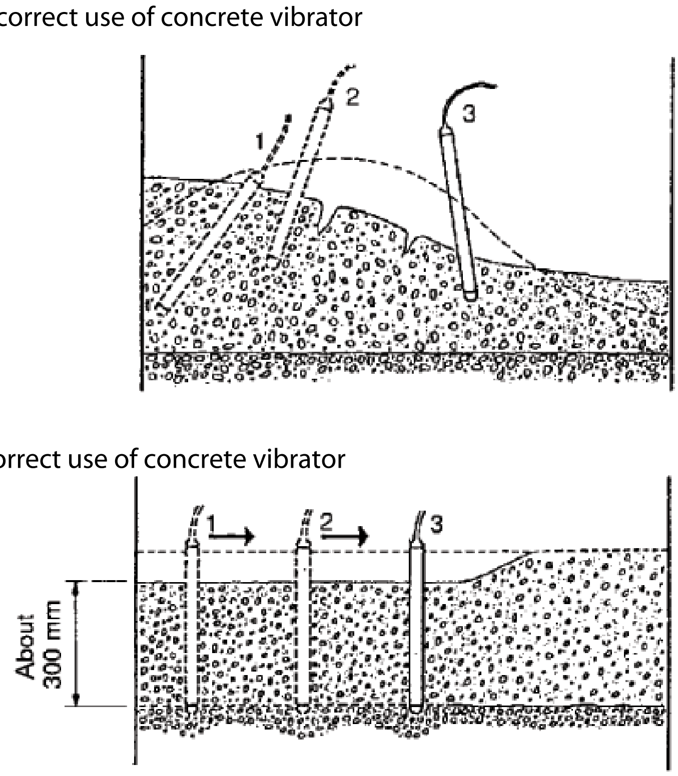


the poker vibrator, illustrated in Figure 23, is perhaps the most common one in use.

It consists essentially of a poker, housing an eccentric shaft driven through a flexible drive by a small petrol-driven engine. The frequency of vibration varies up to 12 000 cycles per minute, whereas 3 500 to 5 000 is considered as desirable minimum. The poker is easily moved from place to place, and should be applied every half a metre. The poker should be withdrawn from the concrete very gradually and in fresh layers of concrete not exceeding 300 mm in thickness. To achieve the best results it should be worked into the concrete at regular intervals in an orderly fashion, as illustrated in Figure 24. The actual completion of compaction can be judged by the appearance of the surface of the concrete, which should neither be honeycombed nor contain an excess of mortar, which is generally due to overvibration. For heavily reinforced sections, a 50 mm to 60 mm diameter poker should be used. Mass concrete pours, such as quay wall blocks, should be vibrated with pokers at least 80 mm in diameter.

In order to obtain good concrete, the placing of an appropriate mix must be followed by curing during the early stages of hardening. Curing is the name given to procedures used for promoting the hydration of cement, and consists of a control of temperature

FIGURE 24
The correct way of using a poker vibrator to compact fresh concrete



and of the moisture movement from and into the concrete. Specifically, the object of curing is to keep concrete saturated with water until the original water-filled space in the fresh cement paste has been filled to the desired extent by the products of hydration of the cement. The necessity for curing arises from the fact that the hydration of cement can take place only in water-filled capillaries. This is why a loss of water by evaporation from the capillaries must be prevented at all costs. Furthermore, water lost internally by self-desiccation (hydration of cement releases a lot of heat which in turn increases the rate of desiccation of the fresh concrete) has to be replaced by water from outside. Loss of water from the surface of freshly-poured concrete depends on:

- the ambient temperature (the higher the temperature, the greater the evaporation);
- the relative humidity (the drier the air, the faster the water evaporation);
- the wind speed (fast moving wind dries the surface very rapidly); and
- the speed at which the formwork is removed (early removal increases the exposed surface area).

Depending on the shape of the cast, curing may be achieved in a number of ways, such as:

- by flooding (suitable for large areas such as paving slabs, which can be flooded by surrounding them with an impermeable bund);
- by spraying or misting (requires a fine-mist sprinkler system and a good supply of freshwater);
- by covering the cast concrete, with damp hessian or plastic sheeting; and
- by impermeable curing membrane, a rubber latex emulsion sprayed over the cast. The membrane, provided it is not punctured or damaged, will effectively prevent evaporation of water from the concrete but will not allow ingress of water to replenish that lost by self-desiccation.

The period of curing cannot be prescribed by theory but it is usual to specify a minimum of seven days. The formwork should not be removed until at least 24 hours have elapsed since the casting operation and only if measures are taken immediately to establish a curing regime.

9.7.8 Admixtures

Nowadays, instead of using special cement, it is possible to change some of the properties of the cement in a mix by the use of a suitable additive. A vast range of proprietary products is available and these fall into three major groups:

- accelerators (they accelerate the setting of the concrete);
- retarders (they slow down the setting of the concrete); and
- water-reducers (they decrease the amount of mixing water, thereby increasing the strength of the concrete by virtue of lowering the W/C ratio).

There are other, less commonly used admixtures, such as air-entraining and water-proofing agents. An important feature of the majority of admixtures for concrete is that they are used primarily on the basis of experience or ad hoc tests: this is largely due to the marketing of admixtures as proprietary products.

9.7.8.1 Accelerators

The addition of calcium chloride to a concrete mix increases the rate of development of strength, and this accelerator is, therefore, sometimes used when the concrete needs to be "hardened" quickly, such as when concrete has to be placed underwater. Calcium chloride increases the rate of heat liberation during the first hours of mixing, but the normal process of hydration of cement is not changed. A calcium chloride content in a mix of 1 percent of the cement by weight (i.e. 0.50 kilogram per 50-kilogram bag) is generally sufficient for most purposes. Using commercially available calcium chloride flakes, the admixture should be prepared in a concentrated aqueous solution and added to the concrete in the mixer. Calcium chloride must not be used in reinforced concrete as this will increase the risk of corrosion of the steel from the chloride ions. Chloride-free proprietary formulations also exist for use with reinforced concrete.

9.7.8.2 Retarders

A delay in the setting time of the cement paste can be achieved by the addition to the mix of a retarding admixture. These admixtures slow down also the hardening of the concrete. Retarders do not alter the composition of the products of hydration. Retarders are useful in concreting in hot weather, when the normal setting time is usually shortened by the high ambient temperatures. Retarding action is exhibited by sugar, carbohydrate derivatives, soluble zinc salts, soluble borates and others. Great care is necessary in using retarders as in incorrect quantities they can totally inhibit the setting and hardening of concrete. Sugar content in a mix of 0.05 percent of the cement by weight (i.e. 0.025 kilogram or 25 grams per 50-kilogram bag) is sufficient to delay setting by about four hours. In important concrete work, the performance of sugar as a retarder should be determined by trial experiments with the actual cement which is to be used in construction. Sugar may also be used to advantage in the event of a mixer breaking down; a 1 percent addition by weight of cement will "kill" the mix inside the drum, allowing repairs to be carried out without the risk of seizure.

9.7.8.3 Water-reducers

As their name implies, these admixtures allow concrete to be mixed with less water, thereby decreasing the W/C ratio. The reduction in quantity of the mixing water that can be achieved varies between 5 and 15 percent. A part of this is in many cases due to the entrained air introduced by the admixture. The actual decrease in the mixing water depends on the cement content and the type of aggregate used. Lignosulphonic acids and their salts are water-reducing admixtures only; hydroxylated carboxylic acids and their salts are water reducing and set retarders at the same time.

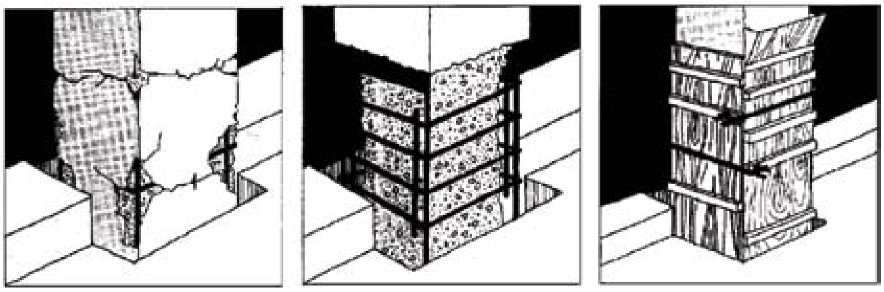
High-range water reducers are a modern type of water-reducing admixture and commonly know as a superplasticizer. Chemically, they are sulphonated naphtalene formaldehyde condensates, and at a given W/C ratio they typically increase the slump from 75 mm to 200 mm without compromising the cohesiveness of the mix. The plasticizing action of superplasticizers only lasts about 10 minutes: after about 30 to 90 minutes the workability returns to normal.

9.7.9 Polymer-modified cement mortars

Polymer-modified cement mortars are special proprietary formulations for the repair of spalled concrete. These cement mortars are generally supplied as a one-pack or a two-pack product. This type of mortar has increased mechanical strength, is very resistant to abrasion and chemical attack, and does not shrink during setting, making it ideal for repairing reinforced concrete. Its adhesive properties to old concrete are superior to those of a normal sand-cement mortar.

Spalled sections of a reinforced concrete member should be thoroughly cleaned of any residual cracked concrete, Figure 25 (middle), a tight-fitting formwork applied to the damaged sections and the cement mortar poured in from the top. Certain cement mortars are very stiff, in which case they need to be applied with a trowel.

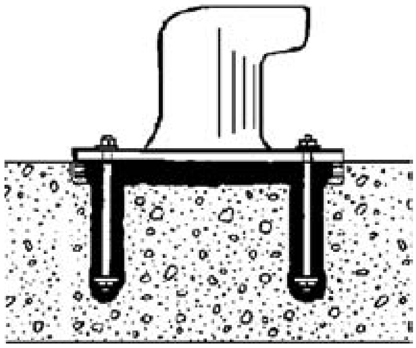
FIGURE 25
Repair of damaged or spalled reinforced concrete using polymer-modified cement mortar



9.7.10 Non-shrink grouts

Non-shrink grouts are generally used for grouting in of anchor bolts and bearing plates, such as bollards, as illustrated in Figure 26. These grouts actually expand on setting and provide a very good mechanical bond with the base concrete. They are free-flowing (pourable), harden very rapidly, and can reach strengths of the order of 60 N/mm^2. They are all sold as proprietary products and generally come prebatched in 25-kilogram waterproof bags, needing only mixing water.

FIGURE 26
Grouting of bollards



9.7.11 Epoxy flooring compounds

An exposed concrete finish is not suitable as a floor inside “wet” fish markets and fish processing halls in general for the following reasons:

- Some fish oils attack concrete and lead to pitting in the surface texture of a concrete floor, Figure 27.
- Concrete is not waterproof and as blood soaks in it gives rise to bad odours.
- A concrete floor has to be laid in bays or sections to prevent it from cracking due to shrinkage; the resulting joints are difficult to clean and generally harbour bacteria.

FIGURE 27
Pitted concrete floor inside a wet fish market

Current food hygiene legislation in many countries stipulates that the floor finish in such cases should be:

- resistant to chemical attack, including the bleaching agents used to disinfect the premises;
- waterproof; and
- of seamless construction.

The only floor finish (the base is still concrete, in the form of a slab 200 mm to 250 mm thick) that satisfies the above requisites is that made from solvent-free epoxy resins. Typically, epoxy-resin flooring compounds are self-levelling and available in two-pack or three-pack form and come in grey, green, red and yellow pigment. Epoxy-resin flooring compounds are very strong and durable; after 14 days the compressive strength typically reaches values in the region of 80 N/mm^2 and their bond to the underlying concrete is superior to that of concrete over concrete. The components are usually mixed just prior to use (the pot life being in the region of 30 minutes depending on the ambient temperature) and applied by roller or trowel in a thickness not exceeding 3 mm to 4 mm. The finish may be rendered non-skid or non-slip by the application of a second roller just before the final setting takes place and has excellent resistance to abrasion. Ideally, epoxy-resin floor finishes should be applied to newly-laid concrete floor slabs. In the event that the epoxy floor needs to be retrofitted to a floor inside an existing market, and assuming that the concrete floor slab is still homogenous, the existing floor must first be "scabbed" (the upper 15 mm to 20 mm of the existing concrete removed by grit blasting to expose a fresh concrete surface) and a suitable solvent-free epoxy primer applied prior to the flooring compound. All epoxy flooring compounds are marketed as proprietary products and specifications vary from one manufacturer to the other.

9.7.12 Epoxy concrete coatings

Epoxy concrete coatings are specifically designed to prolong the life of reinforced concrete sections exposed to a harsh marine environment by rendering the surface waterproof. Most coatings are two-pack, water-based epoxy paints, which may be applied by brush, roller or airless spray. Both grey and colourless paints are available. These coatings may be applied to either dry or damp concrete surfaces in two to three separate coats. All coatings in this category are marketed as proprietary products.

9.7.13 Bituminous coatings

When the concrete surface to be waterproofed is not visible to the eye (such as the underside of a piled jetty, concrete piles, the inside of a concrete potable water tank, etc.) and not exposed to direct sunlight (i.e. ultraviolet radiation), bitumen provides the most cost-effective surface-sealing treatment. Prior to treatment, concrete surfaces must be thoroughly dry and free of dust particles. Bituminous coatings may be applied by brush, roller or airless spray. These coatings are suitable for waterproofing surfaces that come in contact with potable water, such as water reservoirs. Sunlight degrades bitumen.

9.7.14 Site practice and safety

Careful housekeeping on site ensures that all building materials remain suitable for construction purposes. In particular:

- Building materials should not be stored in areas subject to flooding.
- Some materials must not be exposed to direct sunlight.
- Cement should be purchased sealed in good quality bags; punctured bags should not be accepted.
- Cement should not be stored on site for more than six weeks.

- Cement should be stored indoors, 150 mm off the ground; if stored outside, it should be covered with plastic sheeting with plenty of space for air to circulate.
- Steel bars should not be stored in contact with the ground.
- Aggregates should be shaded from direct sunlight with netting or plastic sheets to keep them cool.
- If rain is forecast for the day, concreting should be postponed.
- Concreting should be avoided during hours of peak temperatures; early morning is ideal.

Although concrete mixing may be considered by some as a hazard-free activity, safety on site is in fact quite a serious matter. Cement, concrete, concreting and the various epoxy formulations in use nowadays do present a hazard to human health; for example:

- Airborne cement powder is toxic to human health.
- Skin bleeds when it comes into contact with cement and fresh concrete.
- Most epoxy formulations are toxic to human skin.

FIGURE 28
Basic safety equipment on site

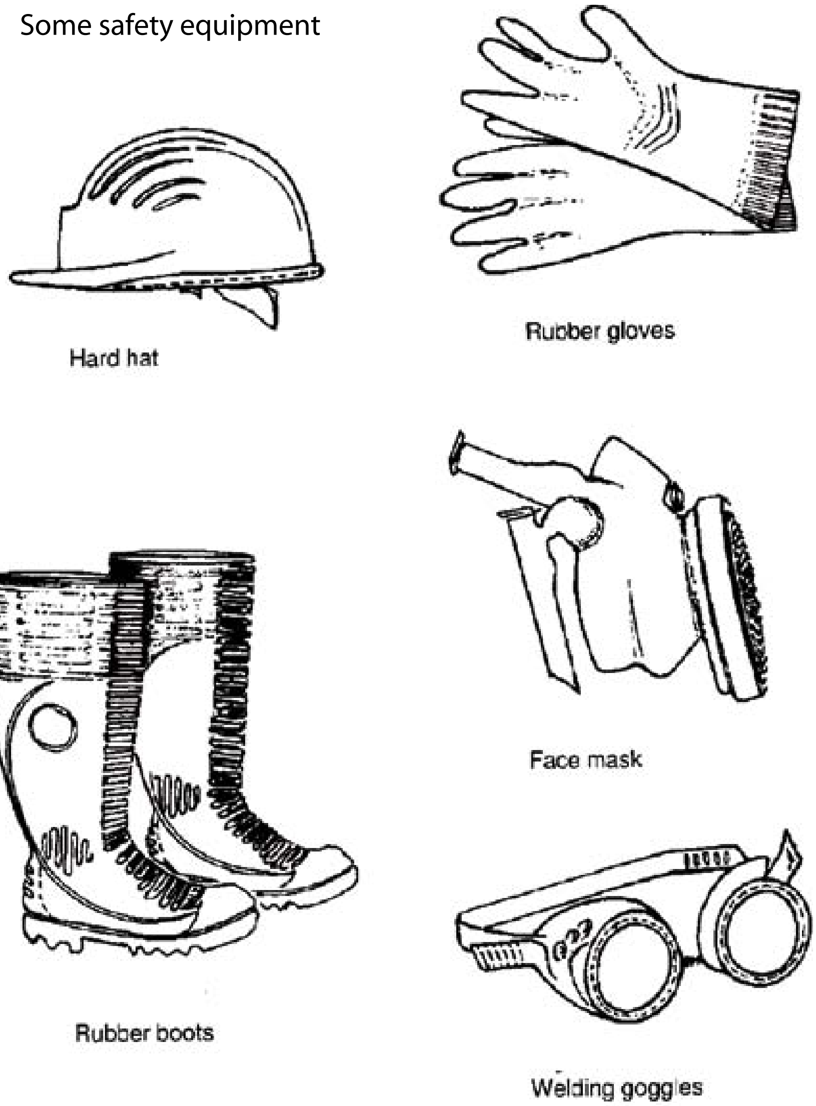


Figure 28 shows basic safety equipment to be used on site. In particular, persons handling cement (breaking bags and pouring out the contents into the mixer) should always wear goggles, a proper face mask, gloves and boots. People handling concrete should wear gloves and boots. Everybody on site should wear a safety helmet.

9.8 ROCK

9.8.1 Introduction

Stone for coastal structures should be sound, durable and hard. It should be free from laminations and weak cleavages, and should be of such character that it will not disintegrate from the action of air, seawater and undesirable weathering, or from handling and placing. In general, stone with a high specific gravity should be used to decrease the volume of material required in the structure and to increase the resistance to movement by the action of waves or currents. Characteristics that affect the durability of stone are texture, structure, mineral composition, hardness, toughness, and resistance to disintegration on exposure to wetting and drying and to freezing and thawing. Ordinarily, the most durable stone is one that is dense or fine textured, hard and tough, but exceptions to this general rule occur. The character of the stone for any project depends on what is available, and often the choice of material involves weighing the relative economy of using a local stone of lower quality against using a better quality stone from a distance.

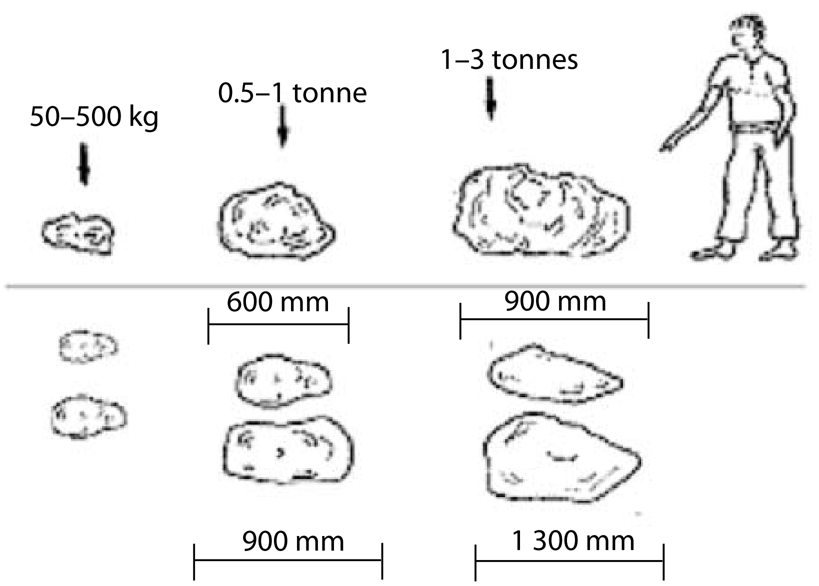
Where the local stone is markedly inferior, the greater cost of transporting durable, high-quality stone from outside the immediate area may be justified and advisable.

9.8.2 Quarries

Rock is generally obtained from quarries but quarries do not normally supply rock in the sizes required for the construction of breakwaters, Figure 29.

This is generally due to the fact that blasting systems, drilling patterns and equipment are tailored to produce only small-size aggregates for concrete or road construction. Retooling a quarry to produce breakwater-type rock sizes is very expensive and should only be carried out if the potential yield of the quarry is deemed sufficient for the purpose; experienced geologists should be called in to carry out such investigations.

FIGURE 29
Typical rock sizes for breakwater construction



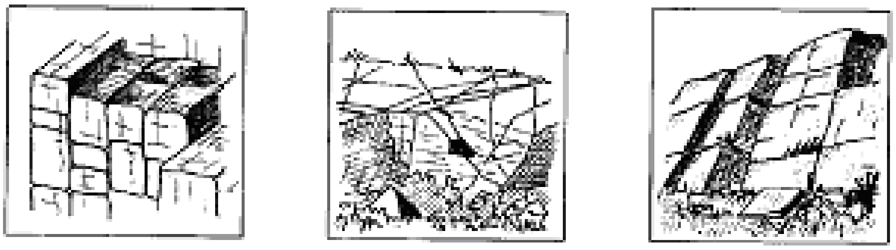
The potential yield in terms of breakwater-sized rock of a quarry depends almost entirely on the geological formation and the natural bedding of the deposits.

Figure 30 illustrates some commonly encountered geological formations or rock outcrops. The left figure illustrates regular block formation, heavily fractured, producing regular sizes of rock. The middle figure illustrates an irregular outcrop and the right figure shows heavily bedded layers that produce tabular rocks. Therefore, prior to constructing a rubble breakwater it is necessary to:

- Collect or obtain information on the geological formation of the quarry site, including faults, natural bedding of layers, etc., Figure 30;
- Obtain details of the vertical extension of the overburden (the rock strata may be underneath a top soil, which may be fertile and cannot be discarded); and
- Carry out laboratory tests to determine the geotechnical characteristics of the rock.

In addition, the quarry must be accessible without too much investment in access roads; and have adequate storage space for stockpiling and sorting of the rock into the required sizes.

FIGURE 30
Quarry deposits



9.8.3 Geological characteristics of rock

The strength of the parent rock essentially decides the degradation mechanisms of the individual armour rock. These mechanisms may be grouped into:

- *spalling,* commonly associated with salt attack, alteration of minerals within the rock and expansion or decay of clay minerals;
- *fracture*, linked to incipient planes of weakness in the rock deposit; and
- *abrasion,* caused by adjacent stones rubbing together under wave action or by much smaller particles of sand and rock thrown against the stone during wave action.

Typical deposits suitable for the production of breakwater rock are granite, basalt, limestone, sandstone, quartzite and porphyry. In the laboratory, the geotechnical characteristics of the rock are usually defined by the parameters, shown in Table 10, details of which are found in various national standards.

It is a generally accepted fact that all marine structures will degrade with time and that only adequate monitoring during the lifetime cycle will prevent serious damage from occurring to the structure.

The evaluation of a potential stone source should consider the extent that a quarry development might detract from natural beauty and otherwise cause environmental concern during and after operation. The quarry area should be graded and landscaped as practicable to restore a natural appearance and to control erosion upon closure.

TABLE 10
Geological characteristics of rock

Property	Suggested limit
Specific gravity	2.60 minimum
Water absorption	2.50 maximum
Particle shape	Angular
Surface texture	Crystalline
Impact value %[1]	25 maximum
Abrasion value %[2]	25 maximum
Magnesium sulphate	
Soundness test [3]	12 maximum

[1] Standard test for resistance to chipping from impact loads.
[2] Standard test for resistance to abrasion by other particles.
[3] Standard chemical test for resistance to chemical alteration of the minerals.

9.9 PLASTICS, RUBBER AND BITUMINOUS COMPOUNDS

Nowadays, both plastics and rubber compounds play an ever-increasing role in marine works, typically replacing steel articles such as pipes, pipe fittings, gratings and covers.

9.9.1 Polyvinyl chloride

This material is available in two forms – plasticized or unplasticized. Both types are characterized by good weathering resistance, excellent electrical insulation properties, good surface properties and they are self-extinguishing. Plasticized PVC is flexible and finds applications in wire covering. Unplasticized PVC (uPVC) is a hard, tough material which is widely used for pipes and gutters.

PVC has a specific gravity of 1.38 to 1.45 and a surface hardness (Shore D) of 70 to 90, equivalent to that of aluminium.

9.9.2 Polypropylene

Polypropylene is an extremely versatile plastic and is available in many grades and also as a copolymer (ethylene/propylene). It has the lowest density of all thermoplastics (plastics that deform with an increase in temperature) in the order of 900 kg/m^3 and this combined with strength, stiffness and excellent fatigue and chemical resistance make it attractive in many situations. Current uses of this plastic is in making fish boxes and fibre ropes.

9.9.3 Polycarbonates

The outstanding feature of these materials is their extreme toughness. They are transparent and have good temperature resistance but are attacked by alkaline solutions and hydrocarbon solvents. Typical applications include "vandal-proof" street lamp covers and lenses in marine lanterns.

9.9.4 Low-density polyethylene

Low-density polyethylene (LDPE) is one of the most widely used plastics. It is characterized by a density in the range 918 to 935 kg/m^3 and is very tough and flexible. Major applications include pipes and cold water tanks.

9.9.5 High-density polyethylene

High-density polyethylene (HDPE) has a density in the range 935 to 965 kg/m^3 and is more crystalline than LDPE. It has a surface hardness (Shore D) of 63. It is slightly more expensive than LDPE but it is much stronger and stiffer and applications include waste bins and pipes.

9.9.6 Polyurethane

This material is available in three forms: rigid foam, flexible foam and elastomer. They have high strength and good chemical and abrasion resistance. Foams find applications in insulation and elastomers in solid tyres.

9.9.7 Polyesters

The main application of this material is as a matrix for glass fibre reinforcement. The fibres (E-glass) are generally calcium aluminium borosilicate with a specific gravity of 2.05.

9.9.8 Rubber

Rubber is a unique engineering material possessing an ability to deform elastically by several hundred percent without failure. Raw rubber would in most cases be relatively unstable, so for engineering applications it is generally cross linked or vulcanized with a chemical such as sulphur. Rubber components are thus normally manufactured by means of a cure process in a metal mould. Most types of rubber used in engineering also incorporate at least one type of filler, such as carbon black or soot. Fillers generally reinforce rubber, improving its resistance to tear, abrasion.

The life and performance of a rubber component may be strongly influenced by its service environment (sunlight, weathering, ozone cracking), which can cause changes in stiffness and surface texture. Normally, effective protection against sunlight is given by the carbon black filler incorporated in the rubber; this acts by filtering out the ultraviolet radiation. If rubbers are not protected by the incorporation of appropriate antioxidants and antiozonants, then atmospheric ozone, sunlight and oxygen can damage rubber.

Nitrile rubber has the best resistance to petroleum products and is generally used for refuelling hoses. Neoprene rubber is used in the form of pads under precast concrete structural elements such as beams, lintels or roofing slabs to avoid concrete-to-concrete abrasion.

9.9.9 Bituminous compounds

All bituminous materials are for the most part used in mixtures with aggregates as binders. Binders all have certain valuable properties in common: they are water-resistant, have good adhesive properties and can withstand ordinary weathering. All binders, whether tars or bitumen, are exceedingly complex materials chemically. Different tars and bitumens have been characterized by separating them into fractions according to their solubility in a series of solvents of increasing dispersing power.

- *Tars* are obtained from the destructive distillation of coal or shale, where for engineering purposes all the lighter oils are distilled off leaving a hard, semi-solid residual material – pitch. Pitch is in itself too hard and viscous to use so lighter oils are fluxed back into the pitch to produce tar.
- *Bitumens* are obtained by the fractional distillation of petroleum (crude oil). In some cases this process occurs naturally, producing rock or lake asphalt, but the bulk of the world's bitumen is produced by refining crude oil. Chemically, bitumens are similar to tar and are also highly resistant to weathering agents.
- *Cutbacks* are mixtures of binders with light volatile oils, the resultant mixture having a much lower viscosity than the original binder, allowing various handling operations to be carried out at a much lower temperature than would otherwise be the case.
- *Emulsions* are mixtures of bituminous binders and water in a dispersant. The dispersant may consist of sodium stearate, soap or trimethyl-ammonium bromide.

- *Rubberized* binders consist of unvulcanized rubber powder, 0.50 to 5.0 percent, dispersed in bitumen. Rubberized bitumens are less susceptible to temperature changes and are more elastic.
- *Trinidad Lake Asphalt* is a natural asphalt. This asphalt has superior drying properties to those of refinery bitumens but is considerably more expensive.

The very term binder used to describe bituminous materials suggests an ability to act as adhesive and "bind" other materials together. As with all adhesives when tars or bitumens are used it is important that the materials to be bound together by these binders should be clean, dry and free from dust. If, for example, in coating stones for road mixes the binder is too thick or viscous, then it will not "wet" or coat the stone efficiently. If the stone is dusty, then the binder may not reach the stone surface. If there is water on the stone, then the binder will not adhere to the stone. Bituminous materials are used in engineering in a wide variety of consistencies or viscosity. For practical purposes, the viscosity may be measured empirically and expressed in terms of a simple unit, usually either seconds or degrees Celsius, when the liquid has been tested in a standard apparatus under specific standard conditions.

The standard test for ordinary bitumens is the penetration test. In this test a loaded needle is allowed to penetrate a sample of bitumen; the viscosity is then a measure of the depth of penetration at that temperature and under those loading conditions.

For normal test conditions in the penetration test, a 1 mm diameter needle is used, ground to a sharp point and loaded with 100 grams. The needle just touches the surface of the bitumen sample at the start and is allowed to fall under gravity for five seconds, the ambient test temperature being 25 °C. The penetration is measured in tenths of a millimetre.

If a bitumen is referred to as 70 pen, it is understood that a penetration of 70 tenths of a millimetre was obtained under the above conditions.

At ordinary temperatures most binders are much too stiff and hard to handle. In order that they may be sprayed, pumped and mixed, or compacted in a stone-binder mixture, their viscosity must be greatly reduced.

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10. Fittings and navigational aids

SUMMARY

Once the basic infrastructure (breakwater, quays, slipway, etc.) has been constructed, various minor mechanical components are required to render the harbour efficient and safe. These components include safety equipment, fenders and fendering systems, mooring systems, chains, anchor systems, winches, hydrants, access ladders, marine lanterns, floating marker buoys, fixed marker beacons or lighthouses and power supply.

This chapter reviews the various types of fittings required to complete a port. The objective is to enable the reader to understand the multitude of essential components that together with the main infrastructure are required to run a port safely and efficiently.

CONTENTS

10.1 FENDERING

Basically, fenders are installed to protect both vessel and quay during berthing operations; they also function as a rubbing surface during mooring to protect the vessel's sides against undue damage to its paint system.

10.1.1 Artisanal fenders

For solid quays, the basic fender system is the used car tyre, which can be effectively recycled into quayside fenders as shown in Figure 1. Used car tyres function properly as rubbing surfaces if the method of suspension, which may be fibre rope, chain or wire rope, does not come into contact with the vessel's hull. Figure 1 illustrates the correct way to suspend tyres for use as fenders and rubbing surfaces. If one tyre is not enough for large vessels, two tyres may be bolted together to form a thicker fender. Tyre fenders may also be placed one below the other under certain tide and weather conditions.

If the tidal variation is negligible, the cope line of a quay may also be protected by strips of timber placed along the outer edge as shown in Figure 2. The timber may be bolted directly to the concrete or inserted in between galvanized angles, themselves bolted to the concrete, Figure 3.

FIGURE 1
Rubber tyre fender

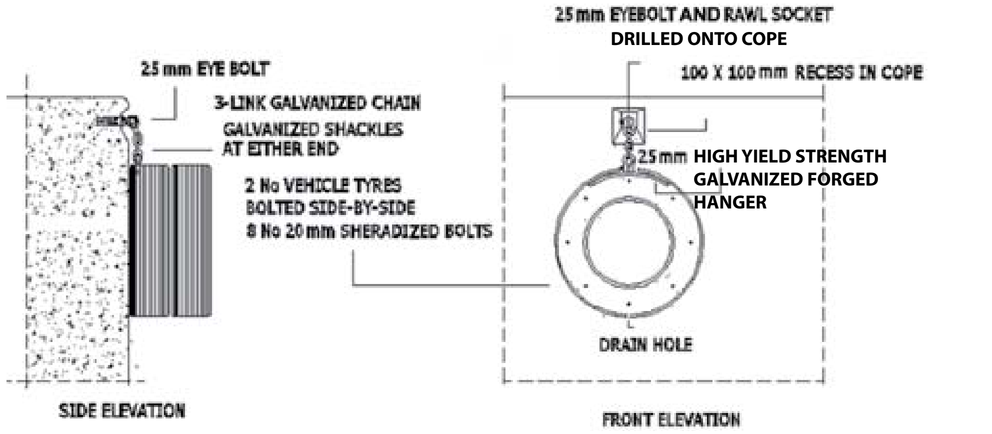


FIGURE 2
Timber coping and strip fender

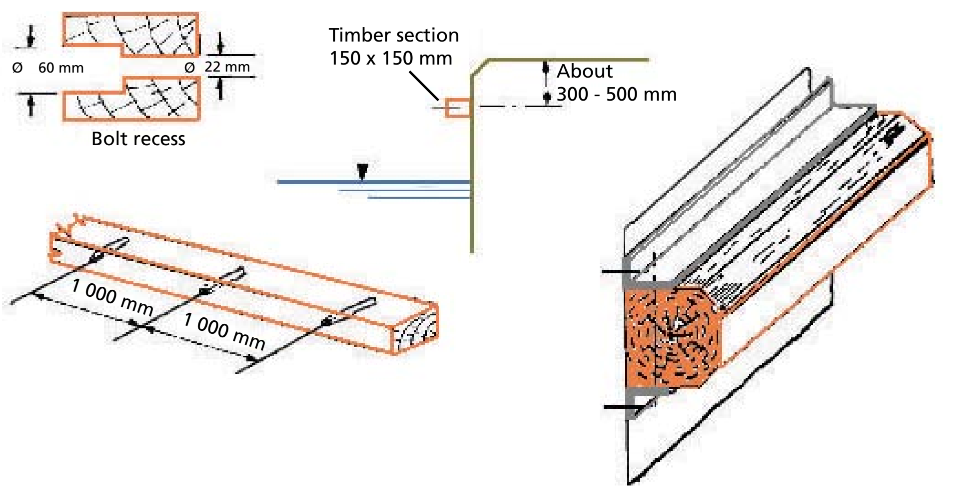
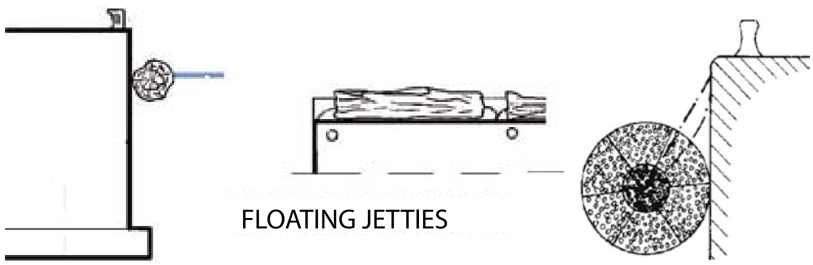


FIGURE 3
Timber strip fender on a sheet-piled quay

FIGURE 4
Other types of fenders in natural materials



In some tropical countries where large timber plantations may be available, forest brushwood or whole log fenders may also be used, Figure 4. Log fenders (left) are particularly useful on floating structures. The brushwood fenders (right) may be rolled into a fascine (with natural or man-made fibres) with a minimum diameter of 500 mm (no metals) and suspended in front of the quay.

10.1.2 Other fender types

Open piled jetties also need protection against accidental impact. In a piled structure, not all the structural components may be designed to absorb side impacts, especially in the presence of a large tidal variation. The vertical piles holding up a jetty deck, for example, must not be impacted sideways as this will result in permanent damage to the structure. Piled jetties are generally designed in such a way that the heavy concrete deck absorbs the impact from the fender system and then transmits this energy to the raked piles situated along the rear of the deck (see Figure 15 in Chapter 8). However, with lighter structures, especially finger jetties, a separate timber pile must be installed to transmit the side impact to the deck and protect the supporting piles, Figure 5.

FIGURE 5
Open piled structures

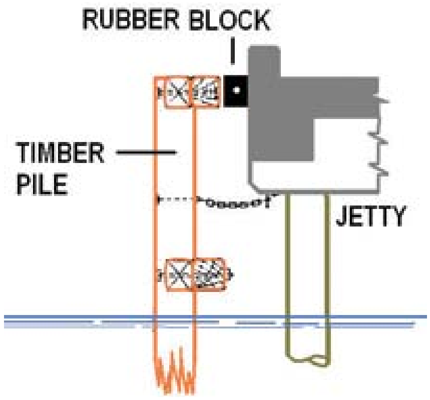
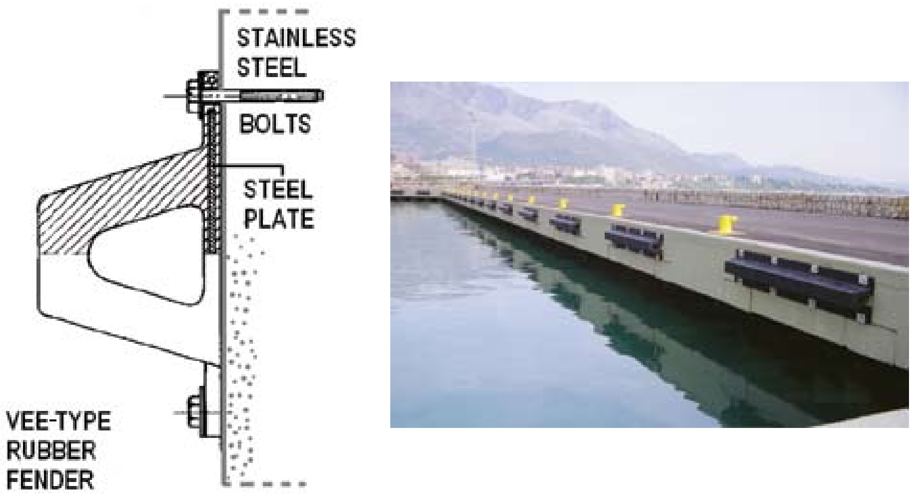


FIGURE 6
VEE-type rubber fender



Nowadays, moulded rubber sections have become the industry standard in most ports. These fenders may be solid plain square sections, hollow cylindrical sections, flat slabs or VEE-type sections, Figures 6.

The most common section in use is the VEE-type moulded section. This section incorporates a sheet of steel sealed inside the rubber base as an aid to anchoring. The section is bolted straight onto the concrete surface via stainless steel bolts.

The VEE-type fenders may be placed horizontally as illustrated, or vertically when the tidal variation exceeds about 500 mm. This fender comes in a range of cross sectional sizes and may be ordered to any length up to 6 metres. Although this type of fender is more expensive than other types of fenders, it is maintenance-free and has a long useful life. When installing fixed rubber fenders, careful consideration must be given to areas where:

- the moored vessels carry exposed riggings, as these may damage the fender; and
- the vessels have their own steel belt fenders just above the waterline as these may also damage the fender.

The suspended hollow cylindrical rubber sections, illustrated in Figure 7, are no longer used due to their high maintenance costs. The chains and chain anchor points tend to corrode and snap.

Sliding fenders, as opposed to soft rubber fenders, consist of relatively thin slabs of UHMW polyethylene (ultra-high molecular weight) plastic. This hard plastic is very tough and has a very low coefficient of friction, enabling vessels to slide along without sustaining damage. It affords the best protection to the concrete cope. The slabs are bolted directly to the concrete and cover most of the exposed vertical surface of the deck, Figure 8.

FIGURE 7
Suspended hollow cylindrical sections

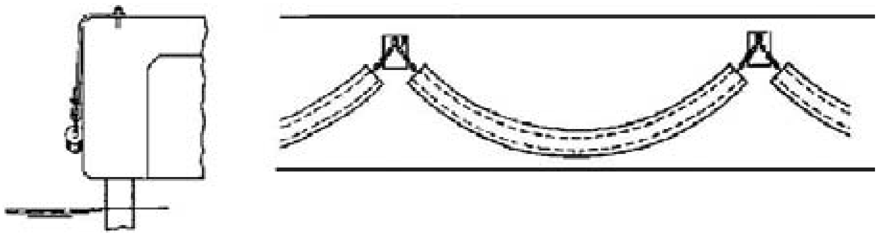
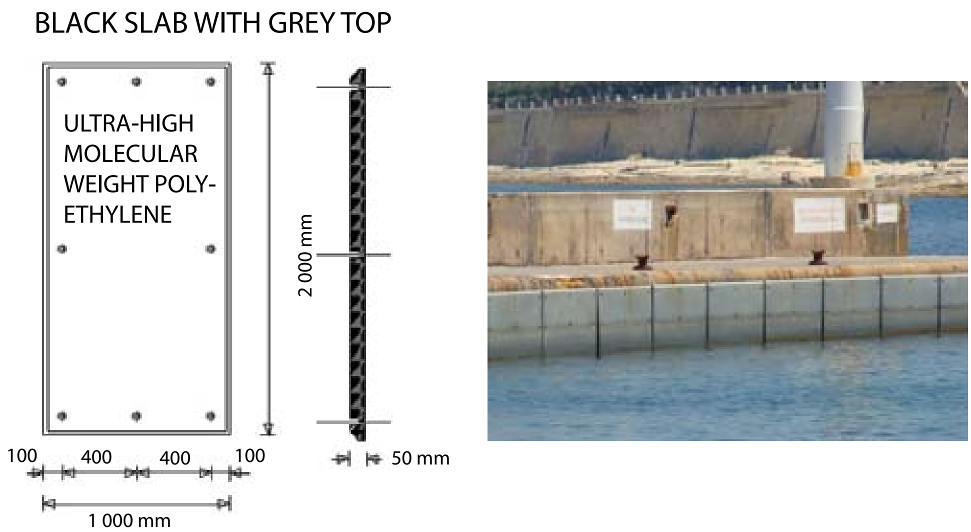


FIGURE 8
Sliding slab fenders

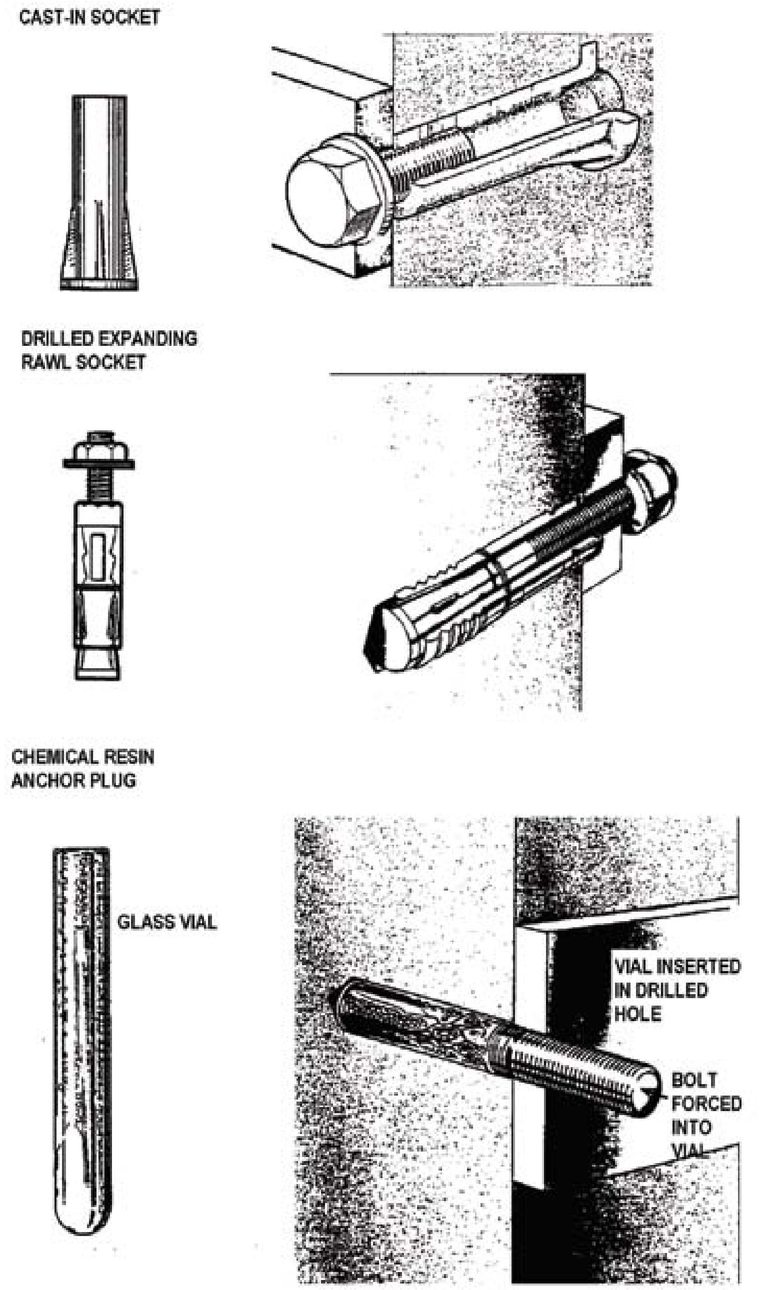


10.1.3 Anchor bolts

Most fittings are anchored into the concrete with bolts. Anchor bolts may consist of permanent bolts embedded in concrete (which cannot be removed) or fixed bolts (which may be undone at a later stage). Figure 9 illustrates the standard type of fixings generally used, both during construction and post-construction.

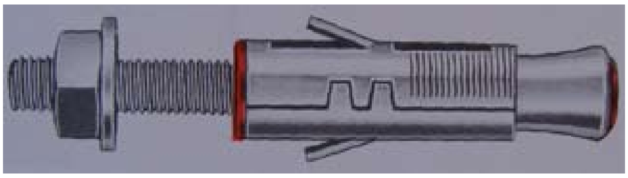
Figure 9 illustrates the cast-in plug, the expanding rawl socket and the chemical resin anchor plug, respectively. The cast-in plug (steel or high-density polyethylene [HDPE]) is generally included in the cast during concreting by a bolt passing through the formwork. The rawl socket is placed inside a hole predrilled in the concrete. The chemical resin plug is a glass vial with a polyester compound. It is inserted into a predrilled hole and a bolt pushed through it, rupturing the vial and setting off the chemical reaction to cement the plug.

FIGURE 9
Anchor bolts



Typical characteristics of drilled expanding rawl sockets are shown in Figure 10. The pull-out values of the sockets in this figure refer to a base concrete strength of 30 N/mm^2 and tightening torques as specified by the manufacturer. No factor of safety included.

FIGURE 10
Typical pull-out strengths of expanding rawl sockets (courtesy Fischer)



Diameter of bolt (mm)	Diameter of hole for socket (mm)	Depth of hole or socket length (mm)	Typical pull-out strength (kg)
6	12	60	1 600
8	15	70	1 800
10	18	80	2 370
12	22	100	3 520
16	29	130	7 360
20	36	170	9 830
24	42	210	15 050

FIGURE 11
Typical pull-out strengths of polyester resin plugs (courtesy Wurth)

Diameter of stainless steel bolt (mm)	Diameter of hole for glass vial (mm)	Depth of hole or length of vial (mm)	Typical pull-out strength (kg)
6	10	80	2 300
10	12	90	3 470
12	14	110	5 500
16	18	125	9 700
20	24	145	12 600
24	28	180	20 800

Typical characteristics of chemical resin sockets are shown in Figure 11.

The pull-out values of the chemical plugs in the above table are breakout values without a factor of safety and refer to a base concrete strength of 30 N/mm^2. The setting time at an ambient temperature of 20 °C is 30 minutes; at 15 °C the setting time is 60 minutes.

10.2 BOLLARDS

Vessels require bollards to moor alongside a quay; bollards may also be replaced with mooring rings for small- to medium-sized vessels. Mooring rings offer the following advantages over the more conventional bollards:

- they are cheaper than bollards;
- they keep the quay free of mooring lines; and
- mooring lines do not chafe on the cope edge.

Ideally, mooring rings should be set in the concrete cope during construction as illustrated in Figure 12. Mooring rings may be cast proud of the cope line (not suitable for harbours with appreciable tidal variations) or recessed into the cope (suitable for areas with tidal variations).

For medium to large vessels, the mooring rings should be manufactured to specific standards regarding pull-out strength, as illustrated in Figure 13.

FIGURE 12
Artisanal mooring ring (0.5 tonnes)

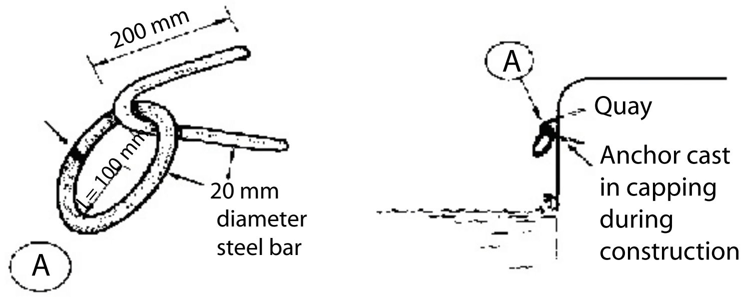
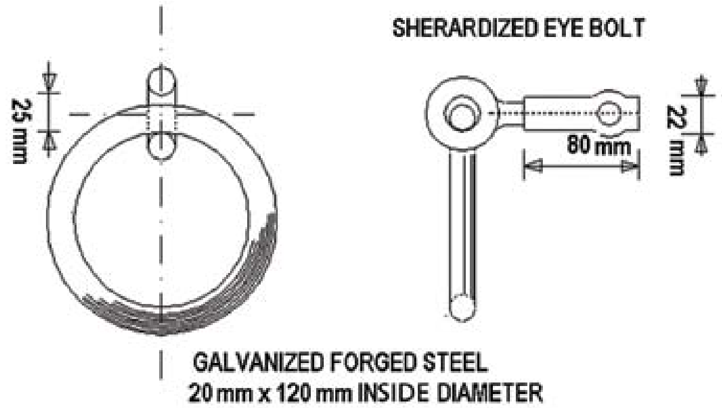


FIGURE 13
Heavy-duty mooring ring (1 to 2 tonnes)



Mooring rings should be installed every 2.50 metres or less. In areas where sea swell is predominant, vessel surge often leads to failure of the eye bolts by fatigue and proper vertical bollards should be considered.

Berths which are heavily used by large vessels and where swell is predominant should be equipped with proper bollards or a combination of bollards and mooring rings. Bollards may be constructed from welded pipe sections or purchased in cast iron, Figure 14. Figure 15 presents an illustration of 5- and 10-tonne pipe bollards and Figure 16 of mushroom bollards.

FIGURE 14
Artisanal pipe bollards

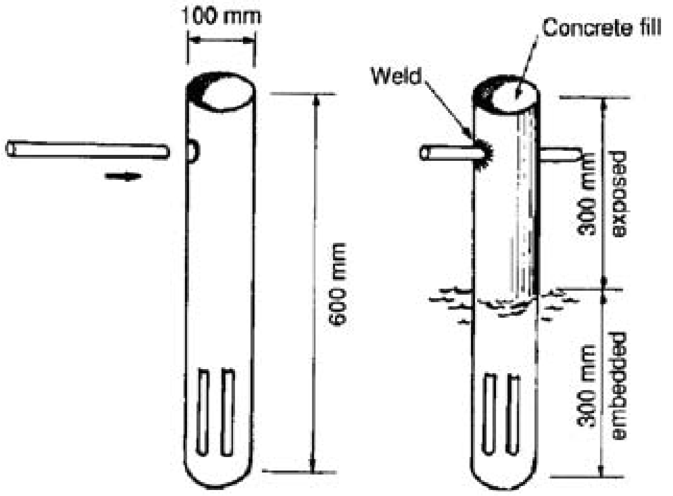


FIGURE 15
5-tonne and 10-tonne pipe bollards

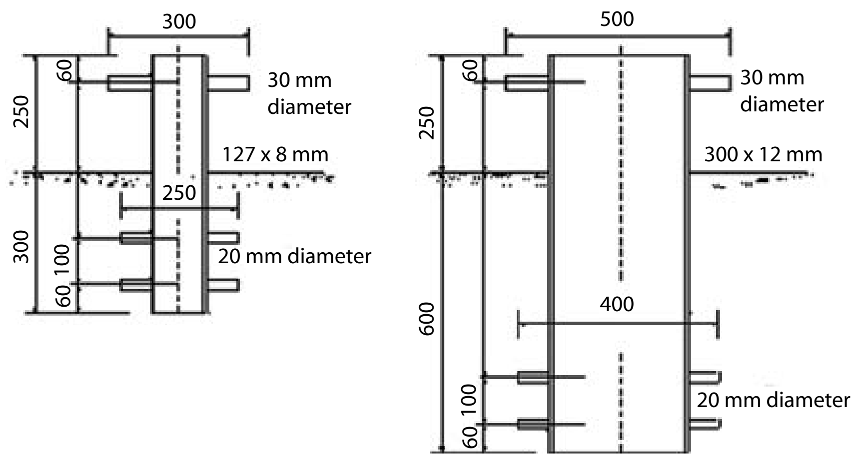
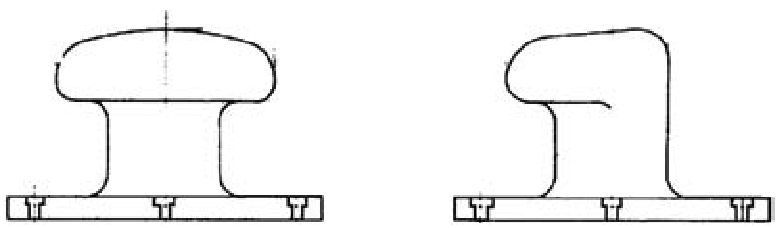


FIGURE 16
25- to 50-tonne cast iron mushroom bollards, also produced in the 1- to 5-tonne range for small vessels



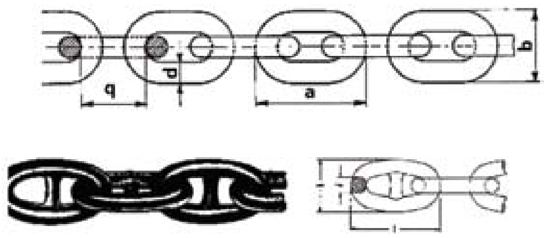
10.3 CHAINS

Mooring chain is manufactured from four different internationally accepted qualities of steel, designated grade 2, grade 3, oil rig quality (ORQ) and grade 4. Chain of grades 2, 3 and 4 is manufactured to Classification Societies Specification, like Lloyd's Register, and ORQ chain is based on the American Petroleum Institute's specification. Grade 1 chain is no longer manufactured. Grade 2 chain is the lowest quality chain manufactured. Grade 3 chain is the most common grade used in marine construction and is only marginally more expensive than grade 2. Grade 2 chain is significantly heavier than a grade 3 chain for a comparable breaking load.

Chain is manufactured in lengths of 27.5 metres, also known as shots. Chain can be ordered with or without inserted studs (studless). In order to maintain the same strength, the diameter of studless chains (i.e. open links) needs to be 20 percent greater than that of stud link chains.

Chain fittings to connect lengths of each or other items, such as anchors or buoys, are illustrated in Figure 18.

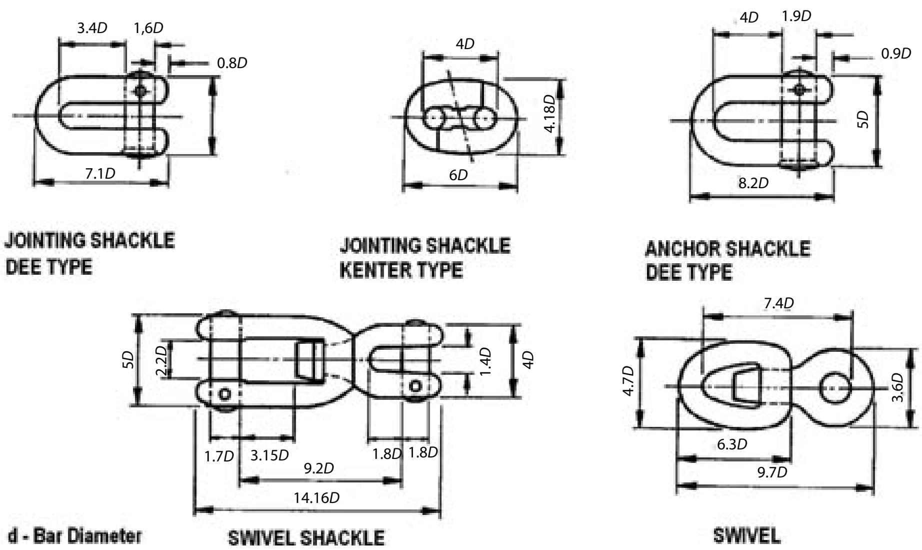
FIGURE 17
Studless chain (top) and stud link chain (lower)



Typical characteristics of studless chain

Diameter d (mm)	a (mm)	b (mm)	q (mm)	Breaking load	Weight
5	28	17	18	0.9 tonnes	0.52 kg/m
6	33	20	21	1.30	0.74
8	44	27	28	2.30	1.33
10	55	34	35	3.60	2.08
12.5	69	43	44	5.50	3.25
14.5	80	49	51	7.50	4.37
16	88	54	56	9.10	5.32
17.5	96	60	61	10.90	6.36
20.5	113	70	72	14.90	8.77
22	121	75	77	17.20	10.00
24	132	81	84	20.40	11.90

FIGURE 18
Standard chain fittings



10.4 ACCESS LADDERS

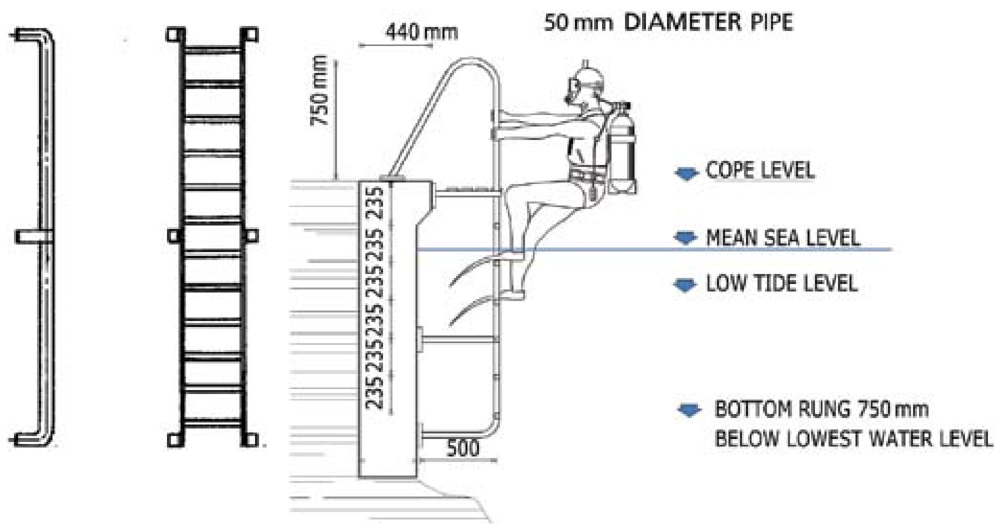
Where required, access ladders should be provided for pedestrian access to the quay from a rowing boat, small fishing vessel or vessel tender, especially inside harbours with a large tidal variation. Figure 19 shows a typical ladder made from welded steel, which should be recessed inside the cope line to prevent it from being damaged by moored vessels. Each ladder point should also be equipped with two mooring rings, one on either side of the ladder, to enable rowing boats or canoes to be moored from inside the vessel.

Maintenance (scrubbing) and underwater inspections (sacrificial anodes) of vessels are very often carried out by divers offering such services. It is hence useful to also install a diver's exit ladder to enable fully-kitted divers to exit the water safely. Such ladders should also be recessed inside the cope. If this is not possible, then they should be tucked away in a quite corner away from vessel movements.

The stringers (the vertical members) should be 180 mm wide x 20 mm thick in mild steel. The length should be equal to the height of the cope from lowest tide level. The rungs should be made from 30 mm diameter steel bars welded to the stringers at 300 mm intervals. The width of the ladder from stringer to stringer should be at least 500 mm. Mild steel cleats should be provided at both ends. If the ladder is longer than 3 metres, intermediate cleats are also required. The whole ladder assembly should be heavily galvanized just prior to placing, i.e. when all surface work on the ladder (welding and drilling) has been terminated.

Access ladders are also produced in 40 mm diameter stainless steel pipe, polyester resin (PE) and HDPE.

FIGURE 19
Simple access ladder (left) and a diver's exit ladder (right)



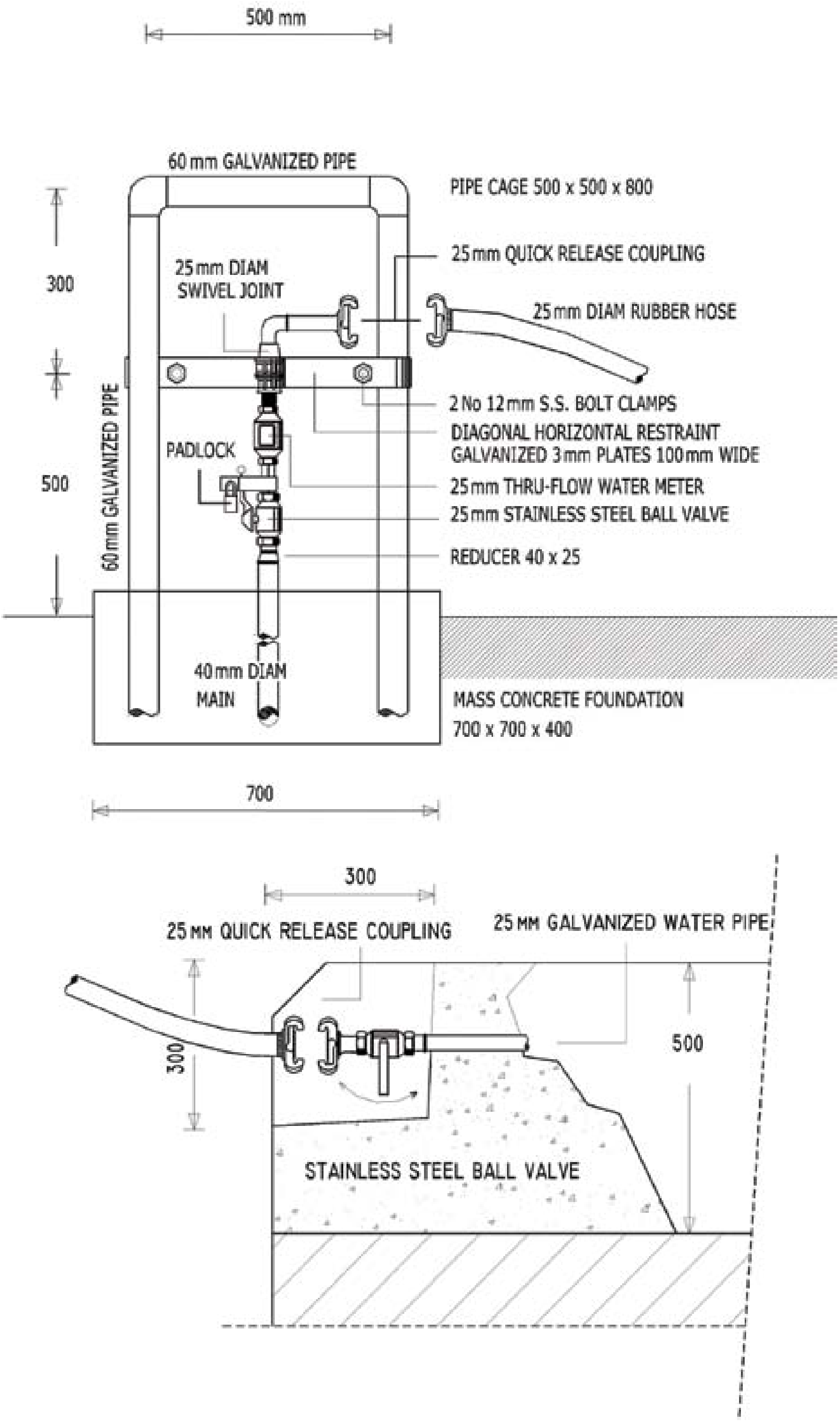
10.5 HYDRANTS

Water hydrants should be provided at the quay side for the hosing down of boxed fish, vessel decks, equipment, etc. The hydrants may be freshwater or seawater, depending on the local water supply conditions. Freshwater hydrants should supply drinking-quality water whereas the seawater hydrants should supply clean seawater drawn from a borehole outside the port basin area. Harbour basin water should never be used on-board moored vessels.

All seawater systems should be separate from freshwater systems and the pipework clearly marked and colour coded. All pipework for both systems should be in HDPE plastic and all fittings (swivel joints, quick-release couplings, ball valves, hydrants) suitable for seawater operating conditions and made from HDPE with stainless steel or bronze components. All exposed HDPE plastic should be resistant to ultraviolet.

Figure 20 top, shows an above-ground hydrant. Above-ground hydrants should not be placed too close to the cope line as this would interfere with mooring and unloading

FIGURE 20
Above-ground hydrant (top) and quay-side hydrant (bottom)



operations. This type of hydrant consists of a strong square cage in 60 mm diameter galvanized pipe (not welded) embedded in a concrete foundation block. The standpipe is fixed but can rotate through 360° by means of a swivel joint attached to the ball valve. The end terminates in a quick-release coupling to which various hoses may be attached (shipboard hose, market hose, auction hall hose, etc.) for hose-down operations. The supply may be metered. Figure 20, bottom, shows a simple quay-side hydrant suitable for small harbours serving small artisanal vessels. In this case, the hydrant is placed at the edge of the quay inside a small recess. A quick-release coupling engages directly to the ball valve. The flexible hoses leading from the hydrants to the various work areas should be sturdy enough to withstand abrasion and direct sunlight. Plastic garden-hose types are not suitable on both counts. Although more expensive, reinforced rubber hoses should be used as these last much longer and are unlikely to split open as plastic ones do.

10.6 CAPSTANS AND WINCHES

Mechanical winches are required in ports and landing areas to haul vessels out of the water, whether on to a simple beach or up on a slipway.

10.6.1 Artisanal winching systems

In areas where vehicles have easy access to the beach area, a four-wheel drive vehicle or agricultural tractor plus a length of rope passed through a snatch block tied to a tree is the easiest and most economical way to haul a vessel on to the beach, Figure 21.

If the beach is in a remote area or not accessible to vehicles, artisanal capstans should be installed. These range from the very simple type, Figure 22 left, to the more advanced type constructed from steel sections welded together, Figure 22 right. The simple type depends on its own self weight (normally a concrete block) for stability, whereas the

FIGURE 21
Beach accessible to vehicles

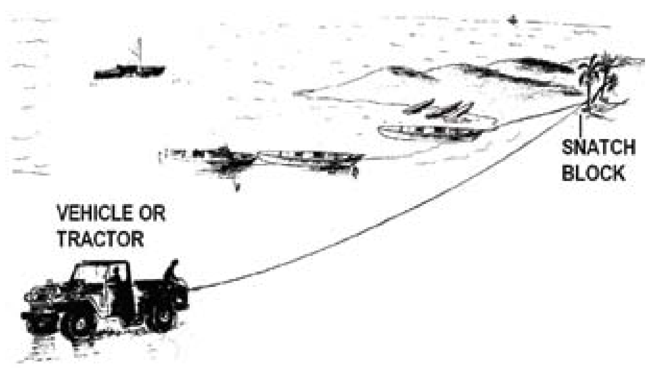
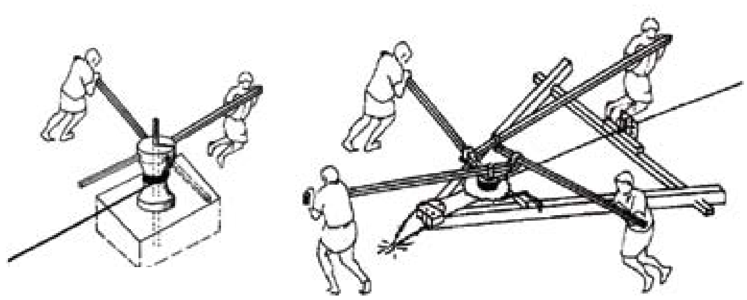


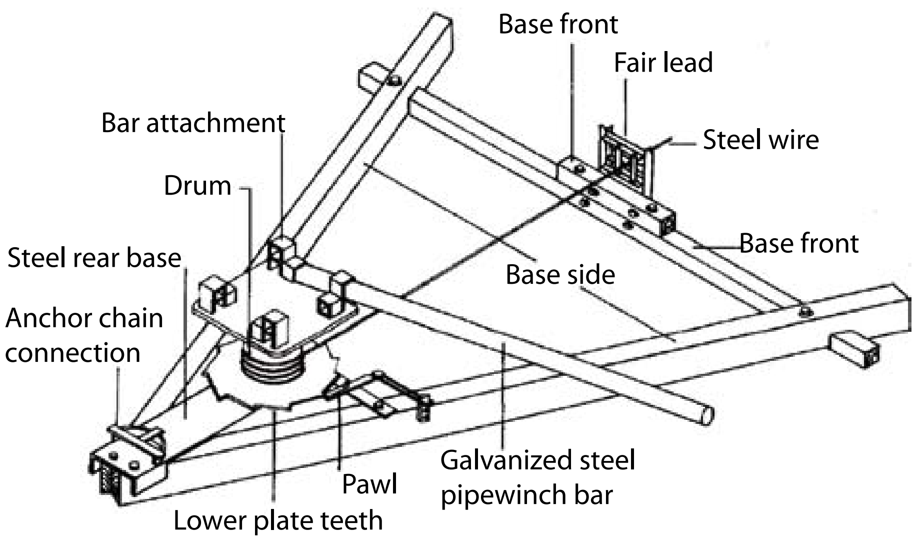
FIGURE 22
Simple winch (left) and a workshop-manufactured frame capstan



advanced frame capstan is very light (can be moved from one area to another) but digs itself into the sand and may be anchored by pegs.

The simple capstan may be constructed from locally available materials, such as oil drums, large diameter tree trunks, oars and concrete. Frame capstans, on the other hand, should be constructed in a proper workshop equipped with welding and cutting equipment. Figure 23 illustrates the technical details of the frame capstan.

FIGURE 23
Technical details of a frame capstan



10.6.2 Mechanized winching systems

Mechanical winches generally consist of a horizontal drum coupled to a set of reduction gears via a powered drive (Figure 24). The type of power drive is entirely dependent on the availability of electricity at the site of the slipway. Electric and hydraulic motors are the preferred systems as they are generally low in maintenance (Figure 25); diesel or petrol require considerably more maintenance and stocks of spare parts. The winch comes with a sturdy mounting which should be bolted to a concrete foundation block according to the manufacturer's instructions.

FIGURE 24
Mechanical winches

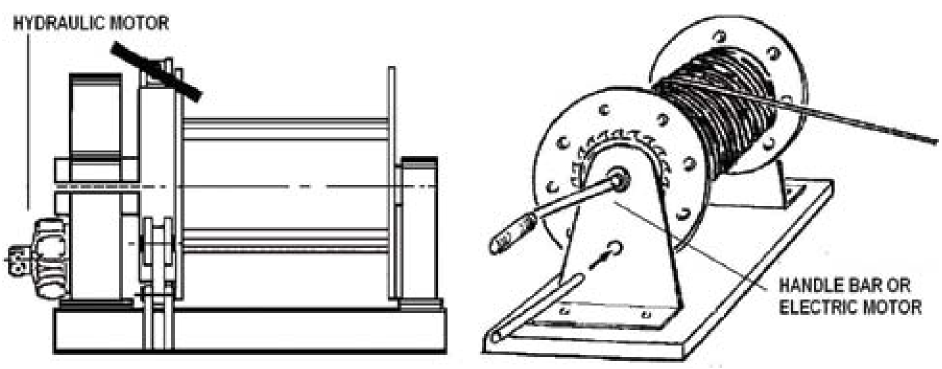


FIGURE 25
Electric-powered 10-tonne pull winch awaiting installation

Typical characteristics of heavy-duty hydraulic winches

Pull (tonnes)	Low speed (metres/minute)	High speed (metres/minute)	Rope size (mm)	Rope length (metres)	Weight (kilograms)
9.0	21	42	24	200	2 000
11.5	21	42	28	220	2 300
14.0	21	42	28	220	2 400
18.0	21	42	32	280	3 200

10.7 TROLLEYS

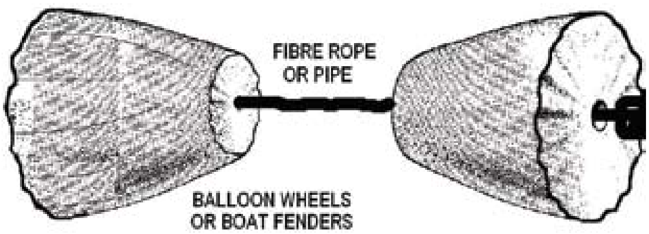
Beached vessels can be pulled straight up a beach by a strong winch with the keel sliding directly on the sand. The pulling power required can however be drastically reduced by using rollers under the vessel's keel to reduce the friction of the keel on the sand and the abrasion on the paint finish. Large vessels on slipways require a cradle or trolley and cannot be hauled up on their keel.

10.7.1 Rollers

The simplest type of artisanal roller is a section of tree trunk. However, the larger the diameter of the roller, the less effort is required to move a vessel on sand. To overcome this problem, balloon wheels in rigid plastic are now available, Figure 26.

The wheels can be attached by a rope or by a rigid pipe to form a cradle as shown in the figure.

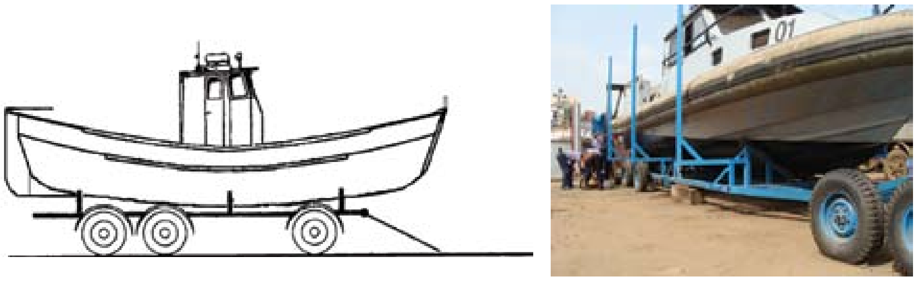
FIGURE 26
Balloon wheel rollers



10.7.2 Trailers

Boat trailers able to travel on a paved road are normally used for vessels of intermediate size up to a length of around 20 metres. Trailers may be purpose built or converted from old truck chassis. Figure 27 illustrates a fisheries patrol vessel on a custom-built trailer. A major problem with trailers is the corrosion of the wheel axle bearings and it is not uncommon for trailers to lose wheels during long road journeys.

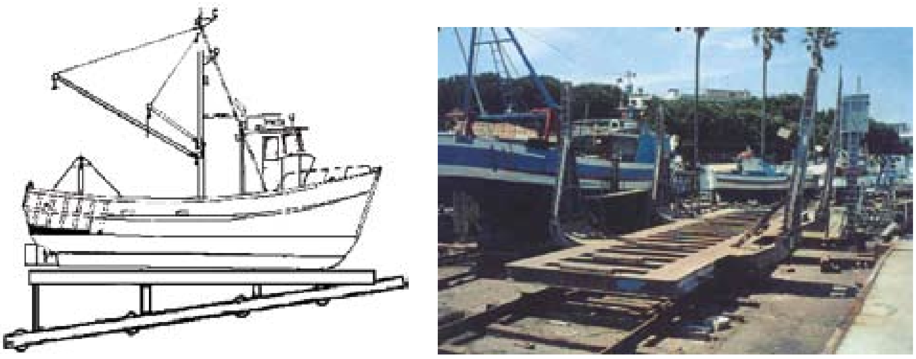
FIGURE 27
Rubber-tyred boat trailers



10.7.3 Steel cradles

The boat cradle or trolley, illustrated in Figure 28, consists of a frame made up from steel channels, typically 300 mm high, welded back-to-back with cast-steel wheels fixed in between. On top of this frame sits another frame, rendered horizontal by means of spliced channels. On top of this horizontal frame sit the sliding racks which slide inwards and outwards to adjust to the vessel's dimensions.

FIGURE 28
Steel cradles



Timber keel blocks are bolted to the horizontal frame to permit the vessel's keel to come to rest in contact with timber. The typical length of the lower frame may be up to 25 metres and the width varies with the local vessel sizes. The wheel axles should not be placed more than 2 metres apart. The rear end of the lower frame should be provided with a pawl and rack arrangement in order to stop the cradle running back into the water should the hauling wire rope break during a slipping operation. The wire rope should be attached to the cradle via an appropriate shackle connected to a bolted anchor point on the lower frame. Depending on the size and weight of vessels to be serviced, the cradle wheels may be in steel or UHMW polyethylene. With vessels not heavier than 5 tonnes, solid plastic wheels running on a smooth concrete surface may be used. For heavier vessels, steel bogies running on steel rails anchored to concrete beams should be used.

10.8 ROPES

Both wire and fibre ropes are utilized around a fishing port. Wire ropes are normally used on slipways and on hauling drums aboard trawlers whereas fibre rope is used to moor vessels.

10.8.1 Wire rope

Wire ropes generally consist of a number of bundles made up of individual steel strands of differing diameters and bundled together to form a thick rope. The central core may consist either of an oil-impregnated fibre or more steel strands or a mixture of both.

Winches generally require what is known as a 216 + 1 wire rope (rope diameters up to 26 mm) or a 216 + 49 wire rope (rope diameters from 28 mm to 40 mm and used on most powered winches). A 216 + 1 wire rope consists of 6 bundles of strands + 1 fabric core; each bundle, in turn, consists of 37 strands of steel of varying diameters, which together form a very compact cross-section. A 216 + 49 wire rope consists of 6 bundles of strands + 1 central bundle; each bundle consisting of 36 strands of steel of varying diameters; the central bundle is made up of 49 strands. Wire ropes meant for use in a slipway should be made of galvanized steel strands.

Wire rope is very expensive and requires good care in handling and maintenance. The correct size of the rope must be used when ordering attachments such as pulleys and Figure 29 illustrates the correct way to measure rope diameter.

A new wire rope should be unreeled from an idle spool holder as shown in Figure 30. It should never be unwound from a static spool.

To ensure that the wire rope spools on to the drum without chafing, the distance of the winch drum from the first static pulley should be such that the subtended angle at the pulley does not exceed 2° as shown in Figure 31.

FIGURE 29
Measuring the diameter of a wire rope

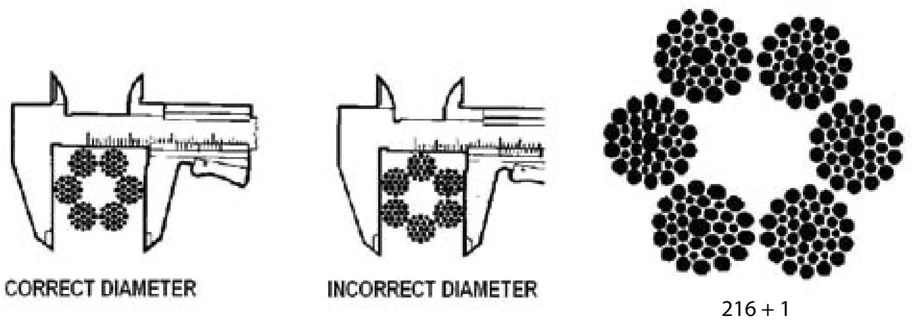
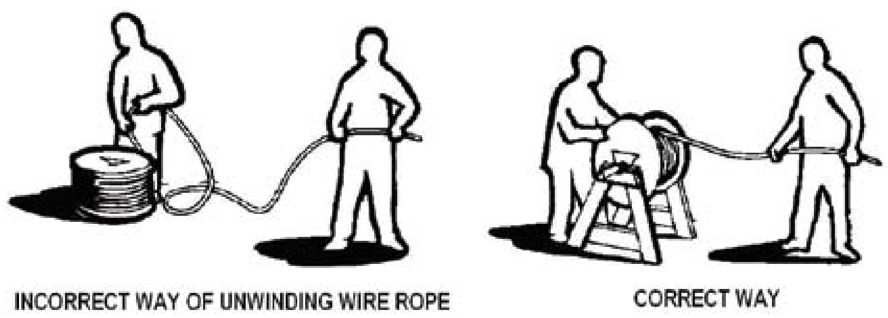


FIGURE 30
Unwinding a reel of wire rope



To ensure maximum durability, the minimum diameter of a winch drum or pulley should not be less than 25 times the diameter of the wire rope as measured in Figure 29 (that is, a 28 mm rope should not be wound round a drum or pulley with a diameter less than 25 x 28 = 700 mm). To use a drum that is, for example, half the recommended size (say, only 12.5 times the diameter of the rope), the rope should be subjected to only 80 percent of its recommended maximum load. Wire rope should never be allowed to scrape the ground or chafe over metallic objects, such as rails or metallic sleepers; timber sleepers or rollers should always be placed under wire ropes.

Wire rope should never be threaded through shackles without thimbles and the thimble size should be adequate for the rope diameter, Figure 32.

Figures 33A and 33B show unseated strands resulting from wire ropes being twisted or warped by pulleys that are too small.

Figure 33C shows kinks in a wire rope developed by abrupt loads or jerks. Figure 33D shows the result of a rope that was overloaded and Figures 33E and 33F wire ropes that were bent around very small diameters such as shackles.

FIGURE 31
The minimum winching distance

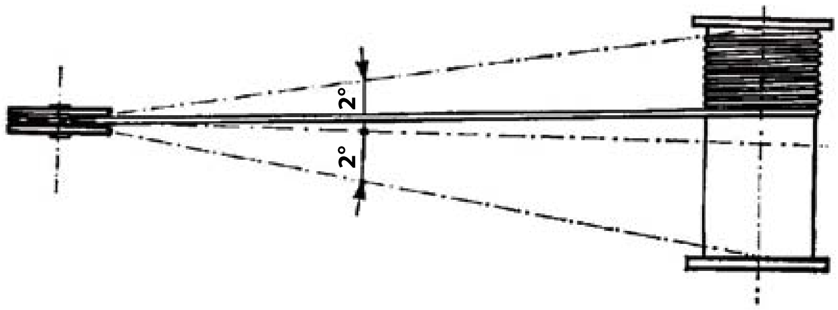


FIGURE 32
Correct use of thimbles

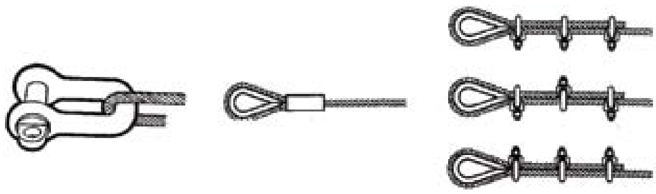
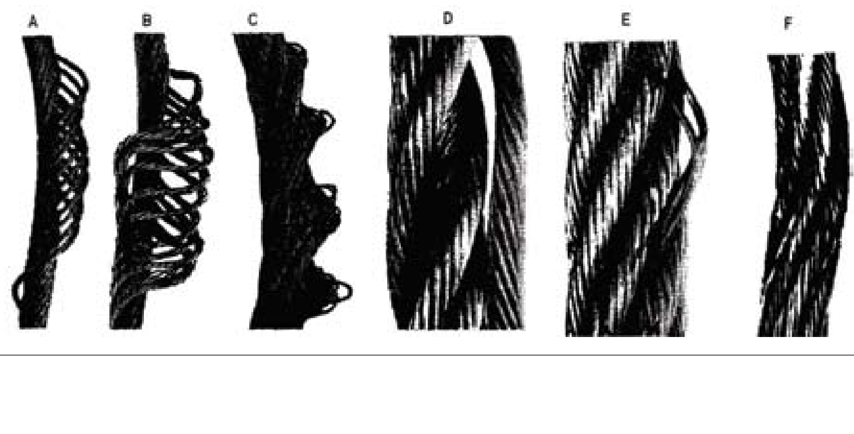


FIGURE 33
Damaged wire rope



Corroded ropes should be replaced immediately as should wire ropes showing definite signs of fatigue, such as broken strands, pulled strands, uneven wear, strongly visible kinks.

Wire ropes are supplied with specific strength characteristics, the most important of which is the safe working load, or SWL. The safe working load is the maximum load that the wire rope can carry without damage to the steel fibres divided by a factor of safety. The factor of safety for wire ropes ranges between 5 and 8 and depends on a number of factors, such as the equipment using it (winch, crane, elevator) and the country's national health and safety code requirements (Table 1).

The typical equivalent SWL for a 216 + 1 wire rope is much smaller than that for 216 + 49 shown in the above table; this means that for the same load requirements, using a 216 + 1 wire rope implies using a thicker rope, which in turn means using a larger diameter pulley, drums and fittings in general.

TABLE 1
Typical safe working load for a 216 + 49 wire rope

Diameter (mm)	Safe working load (tonnes)	Weight (kg/metre)
20	6.80	1.68
22	8.20	2.05
24	9.40	2.40
26	11.20	2.83
28	13.0	3.28
30	15.0	3.75
32	16.40	4.25

10.8.2 Fibre rope

Fibre ropes come in a vast range of materials each with differing mechanical characteristics (Table 2). The materials available are nylon, polyester, polypropylene and polyethylene.

Nylon rope is very elastic and when under load it stores considerable energy. This characteristic makes it ideal for use as springs in mooring lines in the presence of ocean swell, avoiding jerking, and sudden loads on the bollards or mooring rings.

Polypropylene rope is not elastic and is not affected by seawater. Polyethylene rope has very good abrasion and does not absorb water. It is not as strong as polypropylene.

Polyester rope displays excellent fatigue life and has a low water absorption rate. Polyester rope is moderately elastic.

TABLE 2
Characteristics of commonly used fibres

Property	Nylon	Polyester	Polypropylene	Polyethylene
Specific gravity	1.14	1.38	0.91	0.95
Floats	No	No	Yes	Yes
Continuous fibres	Common	Common	Not available	Common
Short fibres	Not common	Not common	Not available	Not common
Monofilament	Not common	Not common	Common	Not common
Combustion	Melts and forms yellow droplets	Melts and burns bright	Melts and burns pale blue	Melts and burns pale blue
Colour of smoke	White	Black	White	White
Smell	Fishy	Oily	Candle wax	
Residue	Yellow droplets	Black droplets	Solid droplets	Brown droplets

Table 3 presents the breaking strengths generally quoted as the minimum strength of the rope, excluding any factors of safety that may be applicable locally.

TABLE 3
Typical breaking strengths of some sizes of rope

Material	Diameter (mm)	Weight (kg/100 metre)	Breaking strength (kg)
Polyethylene monofilament	24	27.40	6 100
Polypropylene split fibre	24	26.0	7 600
Nylon	24	37.50	12 000
Polyethylene monofilament	28	37.30	8 030
Polypropylene split fibre	28	35.50	10 100
Nylon	28	51.0	15 800
Polyethylene monofilament	32	48.70	10 400
Polypropylene split fibre	32	46.0	12 800
Nylon	32	66.50	20 000

10.8.3 Fibre slings

With the advent of the mobile gantry, fibre slings are widely used in most boatyards (Figure 34 and Table 4).

FIGURE 34
Fibre slings

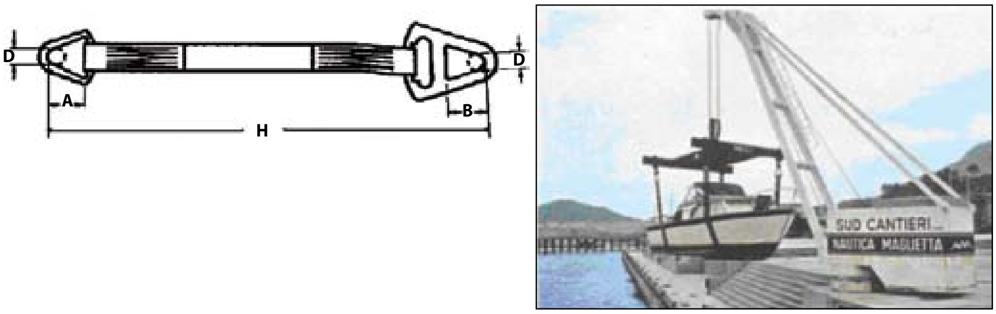


TABLE 4
Typical characteristics of fibre slings

Material	Width (mm)	Safe working load (factor of safety of 6) (kg)
Polyamide	50	1 080
Polyamide	100	2 000
Polyamide	150	2 600
Polyamide	225	3 600
Polyester	50	720
Polyester	100	1 440
Polyester	150	1 800
Polyester	200	2 160

10.9 ROPE AND CHAIN FITTINGS

10.9.1 Sheaves and snatch blocks

Sheaves (or pulley blocks with two to four pulleys inside the same block) and snatch blocks are required to increase the pull from a winch to cover a whole range of vessel sizes (Figure 35). A small 5-tonne vessel may be hauled directly on a 10-tonne pull winch, but a 100-tonne vessel (which may need a 20-tonne pull) has to be hauled through a system of sheaves if the winch cannot produce more than 10 tonnes of pull.

Utilizing the appropriate wire rope diameter, ropes should seat properly in a pulley as shown in Figure 36 below. The throat diameter D of the pulley should correspond to the rope diameter as measured in Figure 29.

FIGURE 35
Snatch block (left) and a sheave (right)

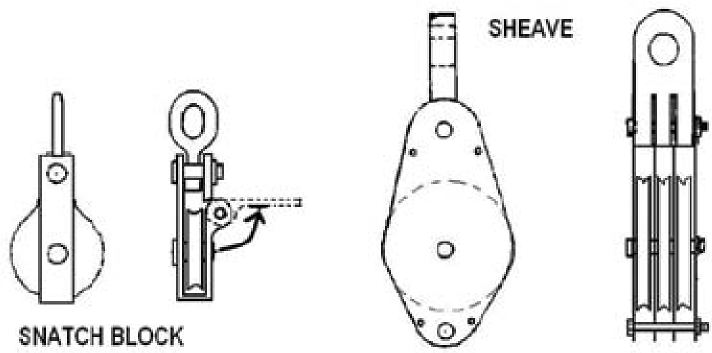


FIGURE 36
Throat diameter of pulley

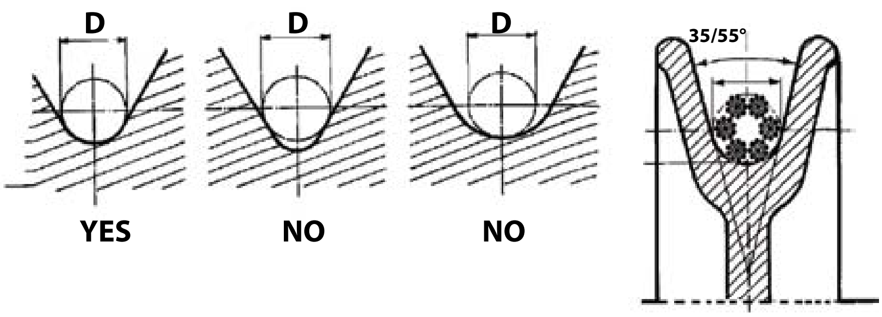


FIGURE 37
One winch serving more than one slipway

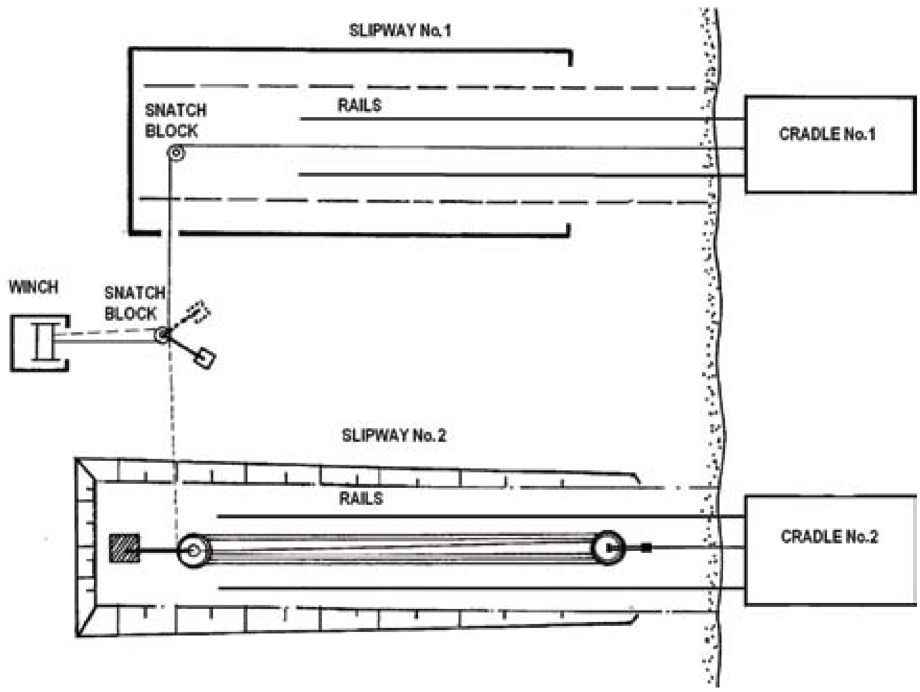


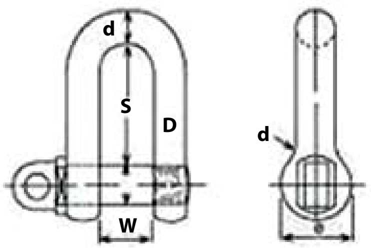
Figure 37 illustrates how a maintenance yard may be organized around a single winch. The yard may have a covered work area and an open work area. The wire rope from the winch may be rerouted to either area by a snatch block anchored to a mass concrete block. Sheaves and snatch blocks are usually anchored to blocks of concrete using lengths of heavy chain coupled to embedded shackles. When light vessels are handled, a single direct rope may suffice as shown on slipway No. 1. A 3-pulley sheave will multiply the pull from the winch by a factor of 6, allowing heavier vessels to be hauled out of the water. In some cases (especially when timber cradles are equipped with skids instead of wheels), slipways may also be equipped with a single pulley at the far end of the slipway, under water, to pull the cradles back into the water.

10.9.2 Shackles

Shackles are multipurpose connections used to connect all kinds of rope and chain to other fixtures, Figures 38 and 39.

FIGURE 38
Commercially available Dee shackles

Dee shackles

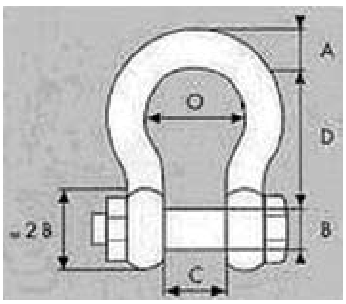


Higher tensile steel shackles to BS3032:1958 tested

Small Dee

SWL (tonnes)	d (inches)	D (inches)	W (inches)	S (inches)	e (inches)	Weight each (kg)
0.30	1/4	3/8	3/8	7/8	3/4	0.06
0.60	3/8	1/2	5/8	1.3/8	1	0.15
1.00	1/2	5/8	7/8	1.7/8	1.1/4	0.33
1.75	5/8	3/4	1	2.1/4	1.1/2	0.61
2.50	3/4	7/8	1.1/4	2.3/4	1.3/4	0.93
3.50	7/8	1	1.3/8	3.1/4	2	1.80
4.50	1	1.1/8	1.1/2	3.5/8	2.1/4	2.15
5.50	1.1/8	1.1/4	1.3/4	4.1/8	2.1/2	3.02
7.00	1.1/4	1.3/8	1.7/8	4.1/2	2.3/4	4.20
8.00	1.3/8	1.1/2	2.1/8	5	3	5.34
10.75	1.1/2	1.3/4	2.3/8	5.1/2	3.1/2	8.36
13.00	1.5/8	1.7/8	2.1/2	5.7/8	3.3/4	9.35
14.75	1.3/4	2	2.3/4	6.3/8	4	12.39
16.75	1.7/8	2.1/8	2.7/8	6.3/4	4.1/4	15.30
19.00	2	2.1/4	3	7.1/4	4.1/2	18.40
20.00	2.1/8	2.3/8	3.1/4	7.3/4	4.3/4	23.60

FIGURE 39
Commercially available Crosby shackles



SWL TON	A mm	B mm	C mm	D mm	O mm	W KG
2	13	16	22	51	32	0.44
3.25	16	19	27	64	43	0.79
4.75	19	22	31	76	51	1.26
6.5	22	25	36	83	58	1.88
8.5	25	28	43	95	68	2.79
9.5	28	32	47	108	75	3.8
12	32	35	51	115	83	5.26
13.5	35	38	57	133	92	7.0
17	38	42	60	146	99	8.8

10.10 LANTERNS AND MARKER BUOYS

10.10.1 Lanterns

On almost all coasts, landmarks and off-lying hazards are illuminated at night. These lights may be divided into three broad groups:

- landfall lights, including lighthouses, which are invariably very powerful and are usually clearly visible from a great distance;
- position lights, generally less powerful, their primary function being to indicate the position of a harbour mouth; and
- lighted aids to navigation, including light buoys that mark offshore shoals, rocks or navigable channels. Channel marker buoys come in two different shapes and colours for use during daylight.

All lights, buoys and signs should conform to the specifications contained in the laws of harbours and pilotage of the country concerned. Lights or beacons are distinguishable from each other by their character, colour and period.

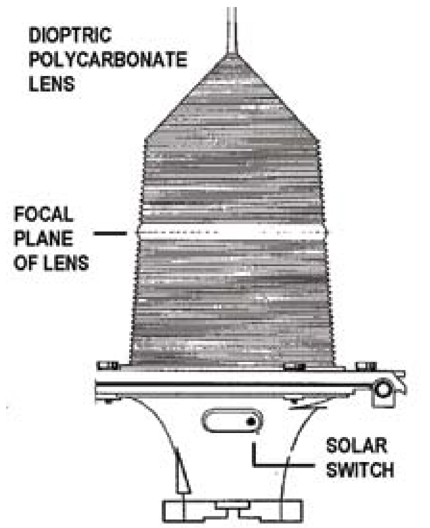
Character: A light can be fixed, flashing or occulting (occulting lights are steady lights which are eclipsed or blanked-out at regular intervals). Light buoys nearly always carry flashing or occulting lights to distinguish them from the lights of moored vessels.

Colour: Lights should normally be white unless they are for a specific purpose. Position lights are usually red (port or left side) and green (starboard or right side).

Period: The period of a light is the interval between the beginning of one phase and the beginning of the next one. In a simple flashing light, the period is the length of time between one flash and the next; in a group flashing system, it is the interval between the beginning of one complete phase of flashes and the beginning of the next.

Before any lights are installed, the appropriate agency (maritime authority or coast guard) should be consulted so that current sea charts of the area may be updated. Figure 40 illustrates the basic type of lantern currently in use. It consists of a sturdy plastic housing in HDPE, an automatic lamp changer which automatically replaces burnt lamps from the lens' focal plane, a solar switch, and holes for bolting the lantern to a structure. When a lamp burns out, a motor relay is closed and a small electric motor is set in motion actuating the lamp changer. As soon as the new lamp is in position, the current again flows into this lamp and the motor relay deactivates.

FIGURE 40
Basic marine lantern

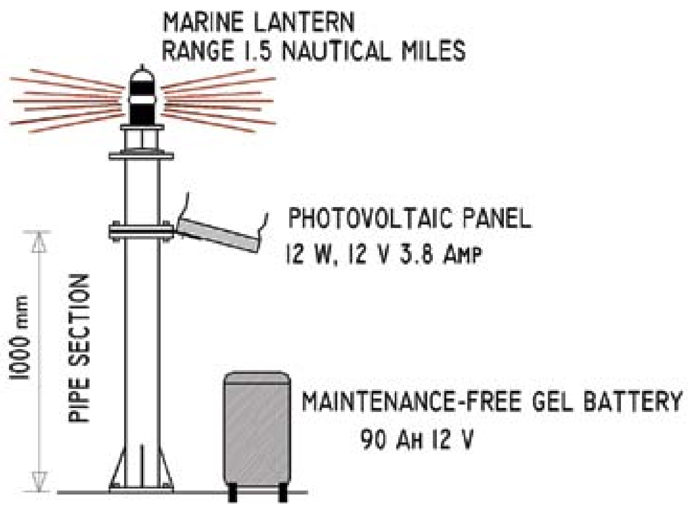


Solar switches are generally incorporated into the body to activate the lanterns at sunset. At dusk, the solar switch switches the lantern off to conserve power. The power required for position lights is measured in candles and Table 5 illustrates typical ranges for various candle powers. Figure 41 illustrates the typical installation for a position beacon.

TABLE 5
Typical ranges of marine lanterns

Power of lantern (Candles)	Range limpid condition (Nautical miles)	Range light mist (Nautical miles)
0.40	1.0	0.50
1.05	1.5	1.0
1.95	2.0	1.5
3.45	2.5	1.5
5.34	3.0	1.5
8.20	3.50	2.0
11.50	4.0	2.5
13.70	4.25	2.5
16.20	4.50	2.5
19.0	4.75	2.5
21.85	5.0	2.5

FIGURE 41
Typical installation for a position beacon



Current lanterns use state-of-the-art, high flux, light-emitting diode (LED) units. The LEDs are mounted in a cluster to approximate a marine signal lamp located at the focal point of the lens. The life expectancy of a single LED cluster is in excess of 100 000 hours depending on the current, rendering the old lamp changer units obsolete. Many of the existing lanterns can be retrofitted with LED units.

10.10.2 Buoys

Buoys can be lighted or unlighted and used for daylight purposes only as in the case of channel markers. Nun buoys, Figure 42a, are unlighted with a conical top projecting above the water and are generally positioned on the starboard side (right) of an access channel when entering a harbour. They are normally painted red and numbered with even numbers. Can buoys, Figure 42b, are unlighted with a flat top projecting above the water and are generally positioned on the port side (left) of an access channel when entering a harbour. They are normally painted green or black and numbered with odd numbers.

Spar buoys, Figure 42c, are unlighted long thin masts generally placed inside channels where high velocity currents or tidal streams are present. Spherical buoys, Figure 42d, have a domed top projecting above the water line and are generally used to mark special positions in the channel, such as shoals or wrecks. They may be lighted and the colour usually depends on their use.

Currently, buoys are made almost exclusively from plastic materials (HDPE or polyester skin-filled with polyurethane foam) to better resist the effects of corrosion, Figure 43, left.

Buoys are generally anchored to the sea bed via a suitable chain connected to a proper anchor or heavy concrete block. Figure 43 shows a typical anchoring arrangement for a small buoy in 6 meters of water. A 32 mm diameter bottom chain anchored to a concrete block is joined to a 22 mm rising chain connected to the buoys anchor pin via two swivel joints. The bottom chain should be at least three times the depth of the water plus any variation in tide level. All fittings should be in the appropriate grade of steel.

FIGURE 42
Unlit buoys

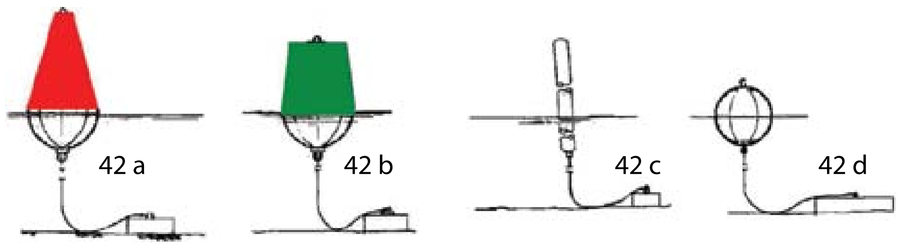
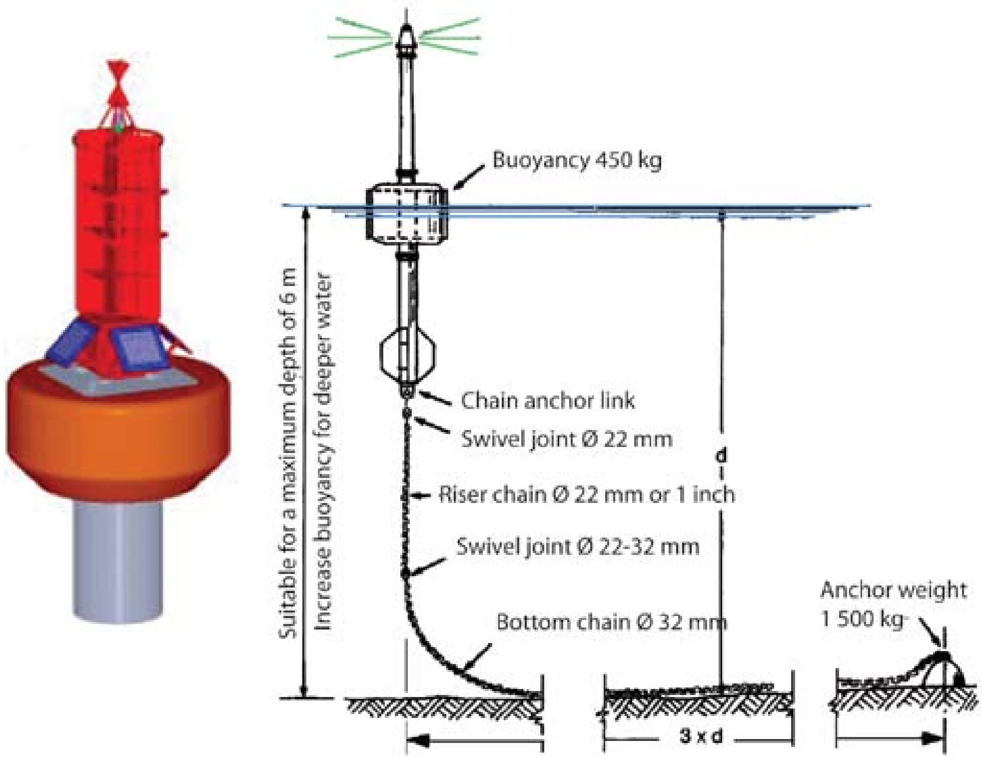


FIGURE 43
Buoy in polyurethane (left) and mooring assembly (right)



10.11 FISHERIES EQUIPMENT

10.11.1 Fish boxes

Proper fish boxes are required for the packaging of fish in a fish hall for onward transport. The basic requirements for a fish box are sturdiness, stackability and ease of cleanliness; the box must be sturdy to avoid damage to the fish, it must also be stackable without damaging the fish in the underlying box, and it must be made of a material which does not harbour bacteria and is easy to clean.

There are many types of boxes available, both improvised versions from other uses and custom-made for the fisheries industry. Fish boxes must be perforated to drain melt water away.

Figure 44 shows a very lightweight box made of polystyrene and meant only for the transport of fish by air. This box is very fragile and is meant for single use only (polystyrene is not impermeable and may harbour bacteria if the same box is used repeatedly). Polystyrene boxes need large storage areas because unlike other types they are not nestable. They are also not recyclable and are cause for concern when discarded into the environment, Figure 44 right.

Timber crates, Figure 45, make good fish boxes if no other means are available. They are cheap to make and may be recycled as fuelwood; they stack five or six high and, like the polystyrene boxes, they are not nestable and take up a lot of storage space. They are ideal for single species, such as sardines or anchovies, but repeated use of the same box may prove unhygienic as timber absorbs blood very easily.

FIGURE 44
Single-use polystyrene boxes

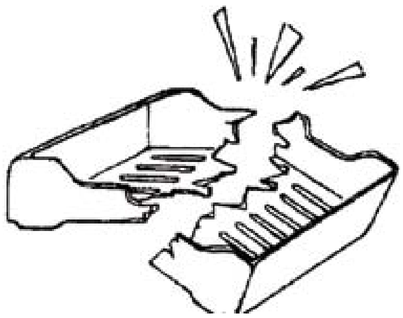


FIGURE 45
Wooden crate

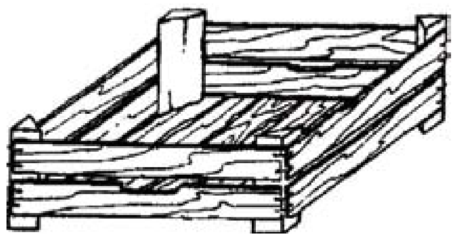


FIGURE 46
Plastic boxes and tubs

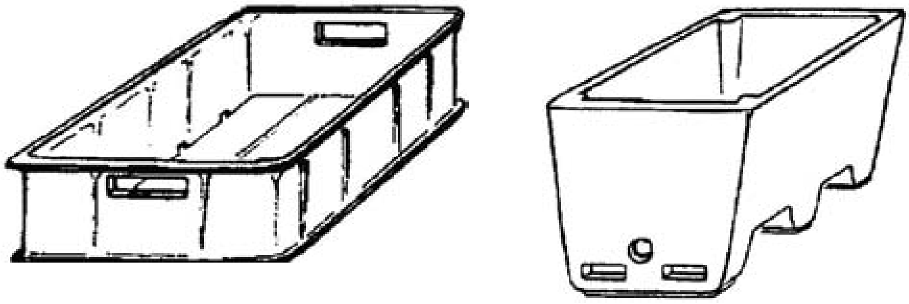
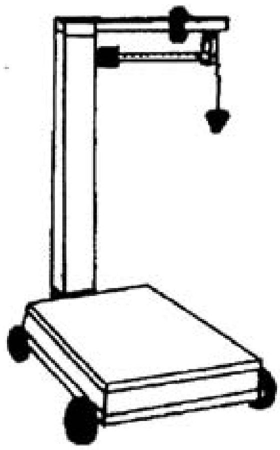


Figure 46 illustrates fish boxes and tubs in HDPE. They are produced specifically for fish and come in a number of sizes ranging from 100 to 1 000 litres. HDPE also comes in a number of colours making it easier to keep track of ownership. These boxes are all nestable when empty and by turning them backward front when full they stack without damaging the fish. They are easy to clean and disinfect. HDPE boxes are expensive in capital outlay but their initial cost is outweighed by their long lifetime.

10.11.2 Scales

Weighing scales should be heavy duty, platform-type scales with a tare adjustment to compensate for the weight of the fish boxes (Figure 47). Scales should be made of stainless steel and kept in clean operating conditions at all times. They should be graduated in 100-gram increments and capable of weighing loads up to 200 to 300 kilograms. Electronic load-cell digital scales are also available but purely mechanical units are recommended for most outdoor situations.

FIGURE 47
Platform scales



10.11.3 Trolleys and forklifts

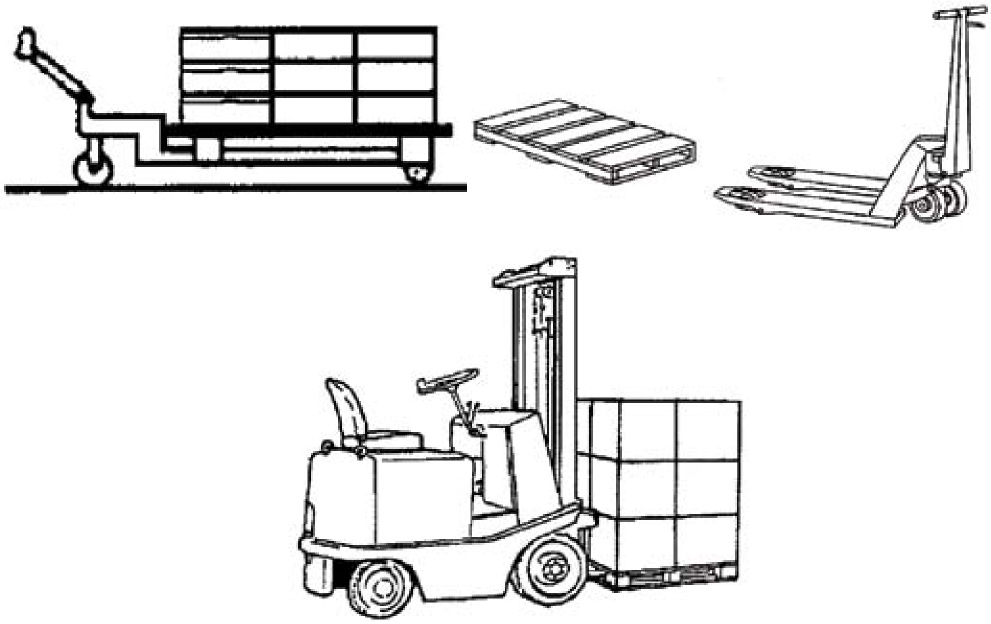
Depending on the size of the landed catch and the number of daily sortings, the speed with which fish boxes have to be transported between the quay and the sorting area is governed by the means of transportation. Boxes may be moved on manual trolleys, on pallets or by forklift (Figure 48).

The normal platform trolley is still the mainstay of many fishing ports and halls. The trolley should be steerable and built from stainless steel and have large diameter rubber wheels. Small diameter metal wheels should be avoided as these may cause damage to the paving and gutter drains. Only electric powered forklifts are suitable for use inside a fish hall. Diesel, petrol, kerosene or gas-powered forklifts should not be permitted to enter the building.

10.11.4 Sorting tables

Rinsing and sorting tables should be made of stainless steel. However, concrete or masonry tables built from locally available materials may also suffice in remote areas provided that the workmanship is of a good standard.

FIGURE 48
Forklift and platform trolley



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11. Shore-based infrastructure and renewable energy

SUMMARY

Fishing ports, large and small, need a whole range of supporting infrastructure to function and this includes the water supply system, refuelling facilities, cold rooms, landing and sorting halls, office space, electricity supply and a host of other small-scale civil works.

This chapter reviews the various infrastructure requirements in civil and mechanical works to render the port functional. It also reviews many of the specifications against which the components should be designed in line with international guidelines.

Whereas guidance is primarily given to those engaged in port planning, those responsible for making policy decisions in relation to fisheries management would also benefit through a better understanding of the intricacies and implications of port planning and operation.

CONTENTS

11.1 WATER SUPPLY AND STORAGE

11.1.1 Peak daily demand

Fishing harbours, small and large, need clean water to function. The adage or rule of thumb stating that *"No water – No port"* is often taken too lightly by planners and fishing ports have been known to be missing a water supply system in their shore-based infrastructure. To plan the water supply system for a harbour, it is first necessary to estimate the peak daily demand for water for which good landing statistics are required. These statistics should include:

- peak (seasonal) fish landings, in kilograms or tonnes;
- number, size and type of vessels likely to use the harbour during peak landings;
- size of the crews on board the vessels and the maximum number of port workers; and
- demand for water from secondary sources (processors, intermediaries, food outlets, etc.).

Table 1 shows how the water requirement may be calculated.

In the table:

- The gross daily volume for fish rinsing should be 1.25 times the peak daily landing.
- The volumes of water required for hosing down the auction hall and washing of fish boxes may be reduced by over 50 percent if high-pressure cleaning machines are used instead of a plain water hose.
- The volume for personal hygiene also includes allowance for showers.

TABLE 1
Daily water requirement

Activity	Quantity of water required
Fish rinsing	1 litre per kg of fish landed every day
Auction hall hose down	10 litres per square metre of covered area
Fish box washing	10 litres per fish box
Personal hygiene	100 litres per person (including crews, unloaders, port staff)
Canteen	15 litres per person
Vessel bunkering	Dependent on type of vessels
Ice	Peak daily requirement – sales records

11.1.2 Sourcing water supply

Internationally accepted guidelines on water supply in fishing ports stipulate non-contaminated water; this water may be either freshwater or raw seawater. Table 2 illustrates the applications that may safely use clean seawater if adequate supplies of freshwater are not available. Chapter 12 describes the quality of the water required.

TABLE 2
Replacement of freshwater with seawater for certain operations

Activity	Freshwater	Raw seawater
Fish rinsing	Yes	Yes
Auction hall hose down	Yes	Yes
Fish box washing	Yes	Yes
Personal hygiene	Yes	No
Canteen	Yes	No
Vessel bunkering	Yes	No
Ice	Yes	Not recommended

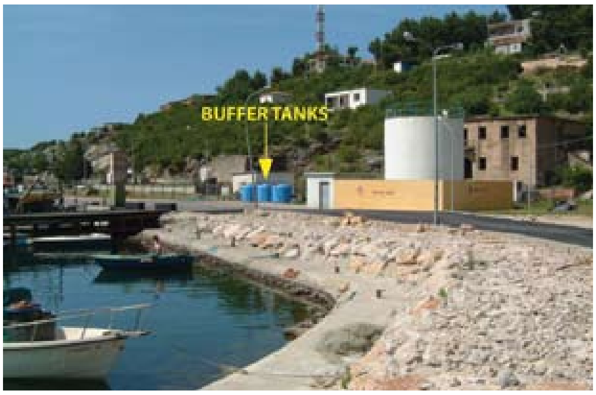
Freshwater may be sourced from a town's supply or a borewell and may be augmented by a rainwater harvesting system if environmental conditions permit. In extreme cases, it may also be desalinated on site from brackish or seawater.

Raw seawater may be sourced from a nearby clean beach or a distant clean beach, but in both cases it must be drawn from inside the sand and not directly from the water column.

11.1.2.1 Town water mains

Many fishing ports in developing countries lie within or close to a town's water supply network and, in theory, hooking up the port's network to a water main should not present any problems. In practice, however, many such supplies often prove to be very erratic, with water trickling in at a very low rate or none at all for days on end. In such cases, the supply may need to be augmented or adequate buffer storage provided, Figure 1.

FIGURE 1
Buffer tanks to even out fluctuations in town mains supply

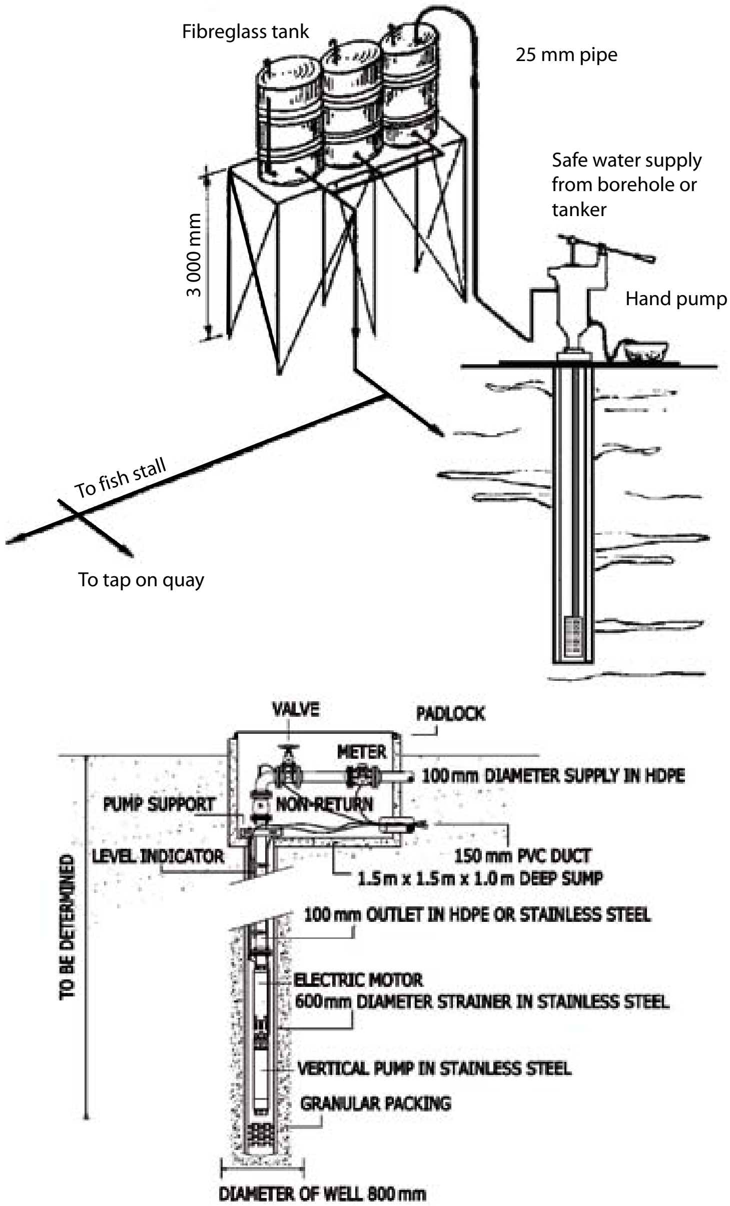


11.1.2.2 Borewells

Borewells may be drilled in and around the port or some distance away. The geological investigation of the substrata is generally carried out by a specialist subcontractor. This investigation consists in the drilling of a small diameter borehole (80 mm to 100 mm diameter) and the recovery of water samples (Figure 2). Samples are then

FIGURE 2
Drilling an exploratory borewell

FIGURE 3
Artisanal borewell (top) and typical borewell with vertical pump (bottom)



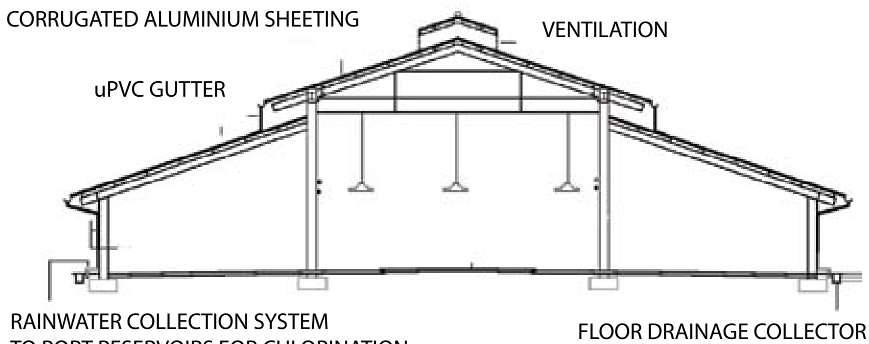
taken for analysis. More than one borehole may be required for a complete assessment. The depth to which the borehole is driven does not depend on the local water table. Instances frequently occur when a shallow waterbody (easily contaminated) overlies a "submerged" freshwater reservoir several metres below it. The "porosity" or permeability of the water-bearing deposits will determine the maximum rate of extraction of water. Figure 3 shows diagrams of an artisanal borewell and a typical borewell with vertical pump.

11.1.2.3 Rainwater harvesting

In areas with high precipitation, rainwater harvesting is the best way for augmenting the freshwater supply, especially if large roof surfaces are available.

The rainwater thus collected should be pumped to the port's reservoirs (see further on) where it can be chlorinated before use. To prevent the potential for the roof runoff to pick up contaminants from bird droppings, the initial runoff during a precipitation should be channelled off into the floor drainage collector, Figure 4.

FIGURE 4
Rainwater harvesting from roof areas

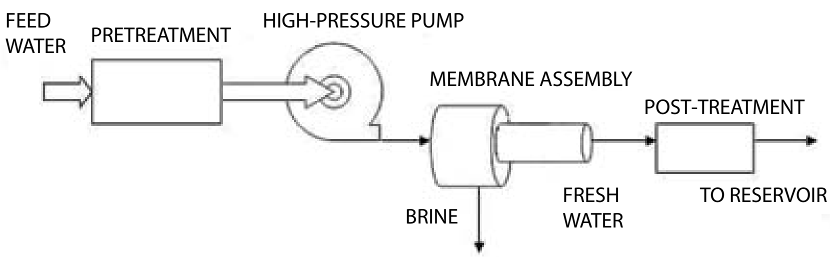


11.1.2.4 Desalination

Desalination is a process that removes dissolved minerals (including but not limited to salt) from seawater, brackish water or treated wastewater. A number of technologies have been developed for desalination but the most commonly used system nowadays is reverse osmosis (RO). In reverse osmosis, feed water is pumped at high pressure through permeable membranes, separating salts from the water, Figure 5. The feedwater is pretreated to remove particles that would clog the membranes. The quality of the water produced depends on the pressure, the concentration of salts in the feedwater, and the salt permeation constant of the membranes. Product water quality can be improved by adding a second pass of membranes, whereby product water from the first pass is fed to the second pass.

Desalination plants may use seawater (directly from the sea through offshore intakes or from wells located on a beach), brackish groundwater, or reclaimed water as feedwater. Since brackish water has a lower salt concentration, the cost of desalinating brackish water is generally less than the cost of desalinating seawater. Intake pipes for desalination plants should be located away from sewage treatment plant outfalls to

FIGURE 5
Flow diagram of a reverse osmosis system



Pretreatment to post-treatment

Pretreatment	Pressurization	Separation	Post-treatment
Conventional filtration Cartridge filtration Chlorine and anticoagulant Antiscalant	High-pressure pump	Reverse osmosis	pH adjustment Sterilization

prevent intake of discharged effluent. If sewage treatment discharges or other types of pollutants are ingested in the intake, however, the pre- and post-treatment processes should remove the pollutants.

RO desalinators produce a water product that ranges from 10 to 500 ppm in total dissolved solids (tds). The recommended World Health Organization (WHO) drinking water standard for maximum tds is 500 mg/l, which is equivalent to 500 ppm. In desalination plants that produce water for domestic use, post-treatment processes are often employed to ensure that the product water meets the health standards for drinking water as well as recommended aesthetic (organoleptic) and anti-corrosive standards (pH value). The desalinated product water is usually more pure than drinking water standards, so when water product is intended for domestic use, it is mixed with water that contains higher levels of total dissolved solids. Pure desalination water is highly acidic and is thus corrosive to pipes, so it has to be adjusted for pH value, hardness and alkalinity before being piped to a domestic reservoir.

Pretreatment processes are needed to remove substances that would interfere with the desalinating process. Suspended solids and other particles in the feedwater must be removed to reduce fouling of the membranes.

Sand is removed by sand or fine bag filtration methods and suspended solids are removed by special wound cartridge filters. Algae and bacteria can grow in RO plants, so a biocide (usually less than 1 mg/l chlorine) is required to clean the system. Some RO membranes cannot tolerate chlorine, so dechlorination techniques are sometimes required. Ozone or ultraviolet light may also be used to remove marine organisms. If ozone is used, it must be removed with chemicals before reaching the membranes. The filters for the pretreatment of feedwater must be cleaned every few days (backwashed) to clear accumulated sand and solids. The main membranes must be cleaned approximately four times a year and must be replaced every three to five years.

The product water recovery relative to input water flow is 15 to 50 percent for most seawater desalination plants. For every 100 litres of seawater, 15 to 50 litres of pure water would be produced along with brine water containing dissolved solids. The recovery of freshwater varies from plant to plant, partly because plant operations depend on site-specific conditions. In several locations, a small pilot project is proposed first to test plant operations before a full-scale plant is installed. Table 3 illustrates typical power requirements for commercially available RO systems. The figures refer to brackish water with 2 000 ppm and seawater with 35 000 ppm of sodium chloride and an operating temperature of 25 °C. For every 1 °C below 25 °C, efficiency drops by 3 percent. Figure 6 shows a 1 000 m^3/day RO assembly.

TABLE 3
Typical characteristics of RO systems

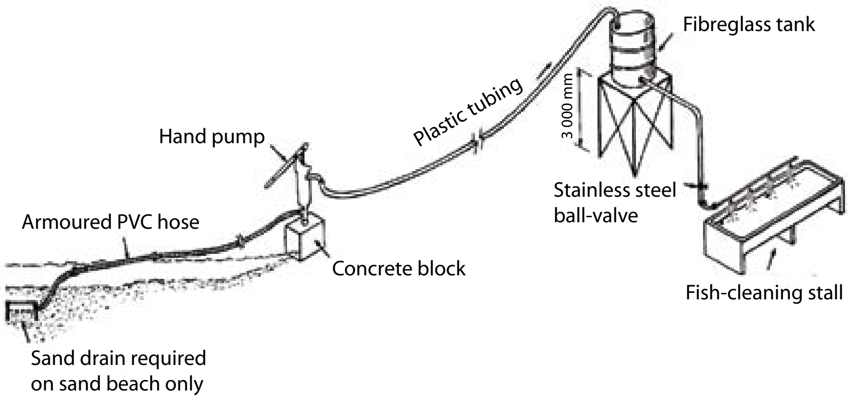
Feedwater	Operating pressure (bar)	Power requirement (kW)	Water production (cubic metres per day)
Brackish	45	5.0	12.50
Brackish	45	5.5	25.10
Brackish	45	5.8	37.60
Brackish	45	6.8	50.10
Brackish	45	11.0	100.20
Seawater	56	9.8	17.10
Seawater	56	18.2	45.60
Seawater	56	37.1	91.20
Seawater	56	59.5	136.80

FIGURE 6
A 1 000 m³/day RO assembly (courtesy Graham Tek PTY)

11.1.2.5 Raw seawater

Raw seawater may be drawn off a beach using a sandbox drain or via a proper bore well (Figures 7 and 8).

FIGURE 7
An artisanal raw seawater supply

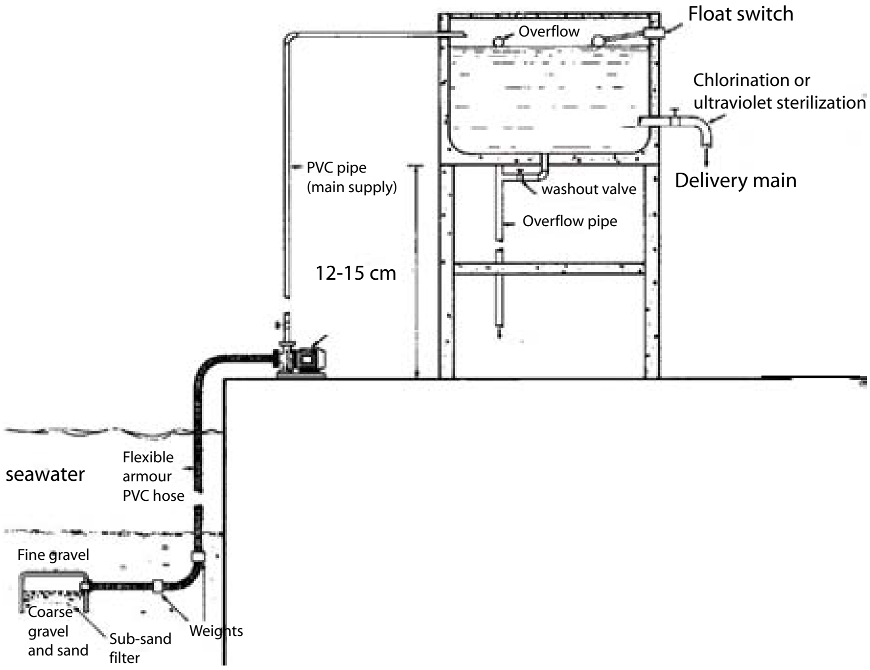


11.1.3 Sterilization

A town's water mains would normally supply chlorinated water and hence no extra sterilization precautions would be needed. However, all water derived from augmentation schemes (rainwater harvesting, groundwater bore wells, desalinated water and raw seawater) needs to be sterilized prior to being pumped into storage as a safeguard against pathogenic bacteria. Chlorine has been found to be the most satisfactory chemical for this purpose. The efficiency of chlorine for disinfection purposes depends upon the following six factors:

- The nature of the organisms to be destroyed, their concentration and condition in the water to be disinfected.
- The nature and concentration of the disinfectant employed in terms of the products that it releases when it comes into contact with water.
- The nature of the water to be disinfected. Suspended matter shelters embedded organisms against chemical disinfection.
- The ambient temperature of the waterbody. The higher the temperature, the more rapid the disinfection.

FIGURE 8
A mechanized raw seawater supply



- The time of contact. The longer the time, the greater will be the extent of disinfection.
- The pH value of the water. Lower pH values require smaller contact period to kill the same percentage of organisms.

Commercially available automatic chlorinators (Figure 9) utilize a wide range of disinfectants, such as elemental chlorine (chlorine gas in a cylinder), calcium hypochlorite and hypochlorous acid.

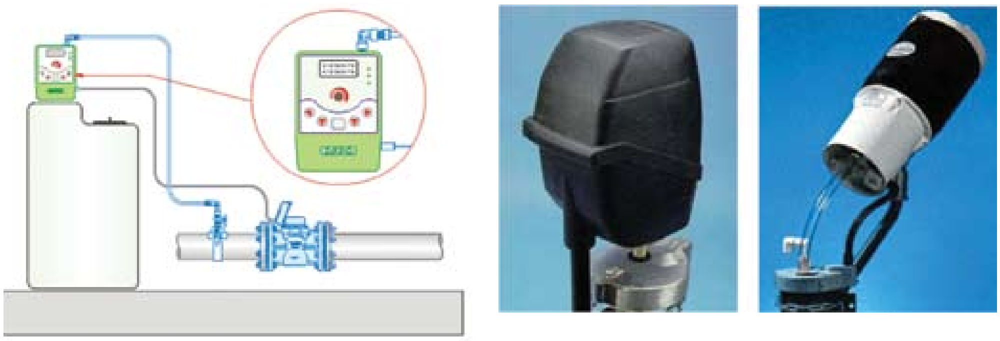
The percentage of available chlorine in the most common compounds is:

Compound	Chemical composition	% chlorine by weight
Chlorine gas	Cl_2	100.0
Hypochlorous acid	HOCl	135.4
Calcium hypochlorite	$Ca(OCl)_2$	99.2

From the above it is evident that elemental chlorine or pure chlorine gas is the most efficient disinfectant in terms of weight considerations. The disadvantage, however, is that a gas chlorinator requires a steady supply of chlorine gas cylinders which may pose supply and logistics problems. Calcium hypochlorite is also efficient but comes in powder or tablet form. Hypochlorous acid is in liquid form and is traditionally utilized in small, inexpensive chlorinators.

Dissolved chlorine remains as a residual in treated water and is a safe check against bacteria. Residual chlorine levels should be between 0.05 to 0.20 ppm (parts per million).

FIGURE 9
Liquid chlorinator (courtesy Oppo) and pellet chlorinators (courtesy G.E.)



11.1.4 Storage

Water storage on site may consist of one of a number of solutions, depending on the quantity of water to be stored. Table 4 shows the recommended water storage structures and Figures 10, 11 and 12 show examples of those structures.

11.2 ICE SUPPLY AND STORAGE

The first step in planning ice production is to confirm whether an ice plant is actually required inside the port area. Other ice plants in town may be a reliable source of suitable ice and, even with the additional transport cost, they may still be more competitive. Ice may be produced in blocks of 50 kilograms or less, in flakes, in tube form and plate form. Other than by description of the ice produced, there is no simple way to classify the different types of ice.

TABLE 4
Recommended water storage structures

Stored capacity	Recommended structure
Up to 5 cubic metres	Interconnected 1 cubic metre plastic drums, sometimes used as header tanks, gravity feed, suitable for artisanal landings
Up to 10 cubic metres	Low-density polyethylene tanks, gravity feed or pumped feed
Up to 100 cubic metres	Reinforced concrete water tower or steel modular tanks, gravity feed
Over 100 cubic metres	Above or below ground reinforced concrete reservoirs

FIGURE 10
Interconnected HDPE 5 m³ tanks and 50 m³ elevated concrete tank

FIGURE 11
Modular steel tanks, elevated (top) and at ground level (bottom)

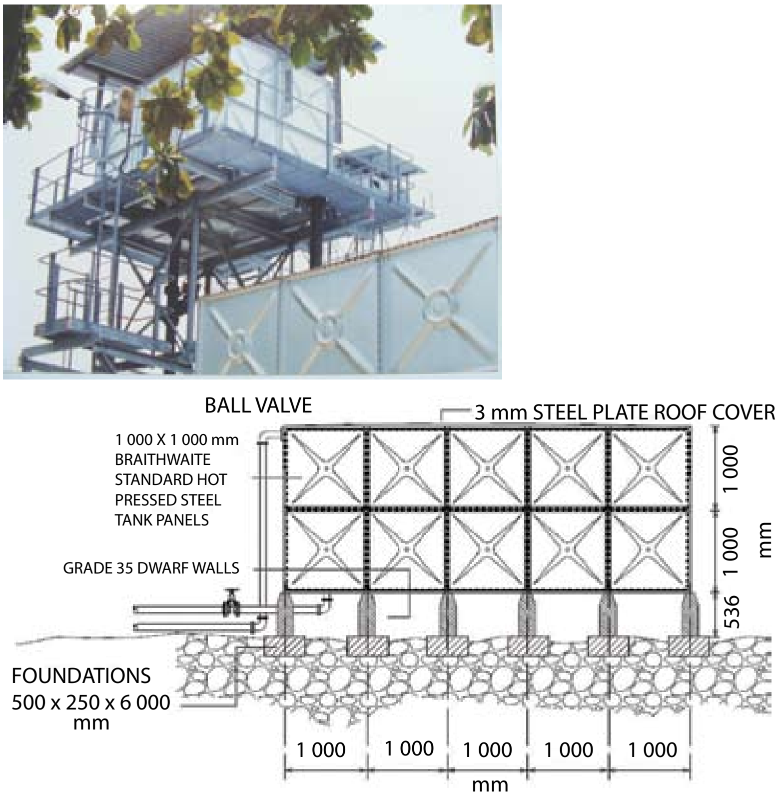
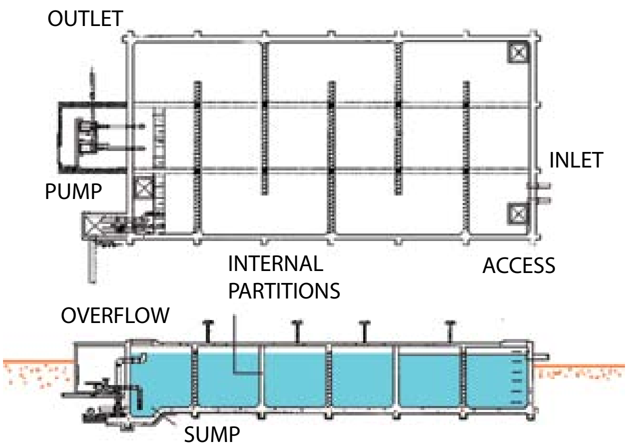


FIGURE 12
Underground reservoir in reinforced concrete,
plan (top) and section



11.2.1 Refrigerants

The Montreal Protocol on Substances That Deplete the Ozone Layer is an international treaty designed to protect the world's ozone layer by phasing out the production of a number of substances believed to be responsible for ozone depletion. Table 5 shows the environmental characteristics of industrial refrigerants. Chlorofluorocarbons (CFCs) are used as refrigerants in some refrigeration systems. CFCs are considered to be 100 percent ozone depleting, meaning that they are the standard for efficiency in the catalytic breakdown of ozone. Trichlorofluoromethane, commonly known as

Freon 11, was for a time utilized extensively as a refrigerant. Its production has been halted in line with the Montreal Protocol because of its role in the destruction of atmospheric ozone.

TABLE 5
Environmental characteristics of industrial refrigerants

Refrigerant	Type	Ozone depletion potential	Global warming potential
R-11	CFC[1]	1.0	1.0
R-12 Freon	CFC	1.0	2.1
R-22 Freon	HCFC[2]	0.05	0.43
R-142b	CFC	0.06	0.46
R-32	HFC[3]	0	0.14
R-125	HFC	0	0.71
R-134a	HFC	0	0.34
R-500	CFC	-	-
R-503	CFC	-	-
Ammonia	-	0	0
R-404a	HFC	0	0

[1] **CFC** = Chlorofluorocarbon.
[2] **HCFC** = Hydrochlorofluorcarbon.
[3] **HFC** = Hydrofluoorocarbon.

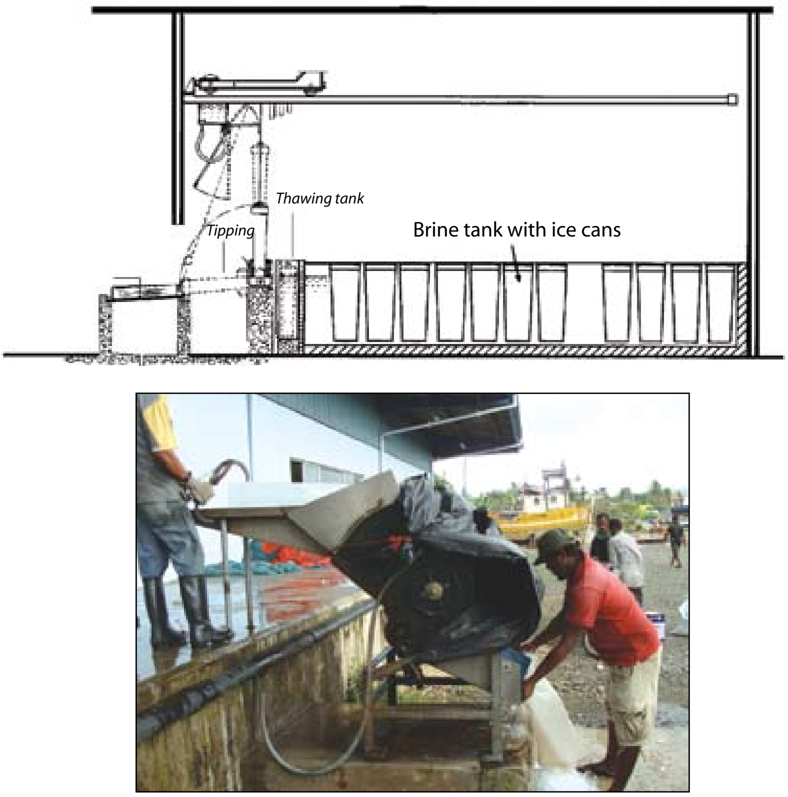
In many refrigeration systems R-22 or Freon, a hydrochlorofluorocarbon (HCFC), is utilized. HCFCs are considered to be only 5 percent ozone depleting and are less of a danger to the ozone layer. However, non-ozone layer depleting refrigerants are the most desirable. The refrigerants with the required characteristics under the Montreal Protocol are ammonia and R-404a, both with a zero ozone depleting and global warming potential. R-404a is an HCFC and consists of a blend of 52 percent R-143a, 44 percent R-125 and 4 percent R-134a and is designed as a replacement for R-22 Freon. Ammonia is not as popular due to the danger of inhalation of toxic fumes in case of leakage. However, the port planner should take into consideration agreements made by his or her government under the schedule for phasing out HCFC since the requirements differ for developed and developing countries.

11.2.2 Block ice

The traditional block ice factory makes ice blocks in steel cans which are submerged in a tank containing circulating refrigerated sodium or calcium chloride brine. The dimensions of the can and the temperature of the brine are usually selected to give a freezing period of between 8 and 24 hours. Too rapid freezing results in brittle ice. The block weight can vary from 12 to 150 kilograms, depending on requirements; 150 kilograms is considered the largest size of block one man can conveniently handle. Blocks less than 150 mm thick are easily broken and a thickness of 150 mm to 170 mm is preferable to prevent the block from toppling. The size of the tank required is related to the daily production. A travelling crane lifts a row of cans and transports them to a thawing tank at the end of the freezing tank, where they are submerged in water to release the ice from the moulds.

The cans are then tipped to remove the blocks, refilled with freshwater and replaced in the brine tank for a further cycle. This type of plant often requires continuous attention and a shift system is operated by the labour force which may be 10 to 15 workers for a 100 tonne/day plant. Block ice plants require a good deal of space and labour for handling the ice. The latter factor has been the main reason for the development of modern automatic ice-making equipment. Block ice still has a use, and sometimes an advantage, over other forms of ice in tropical countries. Storage, handling and transport can all be simplified if the ice is in the form of large blocks; simplification is often obligatory in small-scale fisheries and in relatively remote situations. With an appropriate ice-crushing machine, block ice can be reduced to any particle size, Figure 13, but the uniformity of size will not be as good as that achieved with some other forms of ice, particularly flake ice. In some situations, block ice may also be reduced in size by a manual crushing method. The rapid block ice plant can produce blocks in only a few hours and this means that the space requirements are considerably reduced compared with a conventional block ice plant. Block sizes vary with 25, 50 and 150 kilograms each being typical. In one type of machine, the relatively quick freeze is obtained by forming the block in a tank of water, around tubes through which the refrigerant is circulated. The effective thickness of ice to be frozen is a good deal less than in a conventional block ice plant. The tubes are arranged so that as the ice builds up it fuses with the ice on adjacent tubes to form a block with a number of hollow cores. These blocks are released from the tubes by a defrost procedure and they can then be harvested automatically from the surface of the tank.

FIGURE 13
Cross-section of a block ice plant and block ice crushers in use (top). Both the ice cans and the ice crushers should be in stainless steel



Some manual effort is required for storage or feeding to a breaker if the ice is required in the crushed form. In another type of rapid ice machine, the refrigerant is circulated through a jacket around each can of water and also through pipes running through the centres of the cans. Ice then forms simultaneously both at the outside and at the centre of the can. After a hot gas defrost, blocks are then removed by gravity. An advantage of a rapid block ice plant is that it can be stopped and started in a relatively short time, since there is no large tank of brine to be cooled initially as in the conventional block ice machine in which the refrigeration system is often kept in continuous operation even when ice production has ceased.

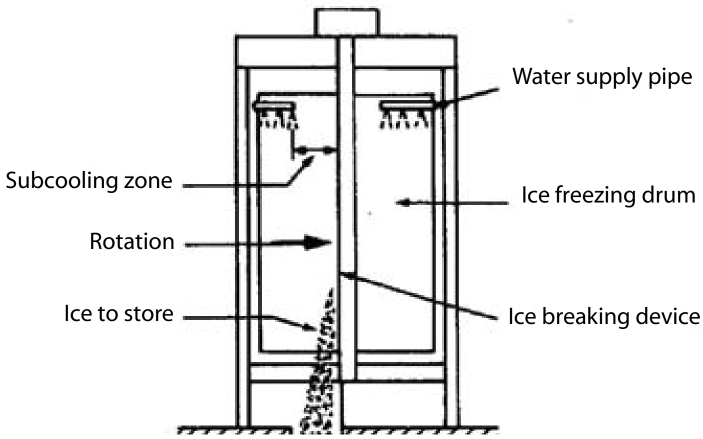
11.2.3 Flake ice

This type of machine forms ice 2 mm to 3 mm thick on the surface of a cooled cylinder and the ice is harvested as dry subcooled flakes usually 100 mm to 1 000 mm^2 in area (Figure 14). In some models, the cylinder or drum rotates and the scraper on the outer surface remains stationary. In others, the scraper rotates and removes the ice from the surface of a stationary drum, in this case, built in the form of a double-walled cylinder. It is usual for the drum to rotate in a vertical plane but in some models the drum rotates in a horizontal plane. One distinct advantage of the rotating drum method is that the ice-forming surfaces and the ice-release mechanism are exposed and the operator can observe whether the plant is operating satisfactorily. The machine with the stationary drum has the advantage that it does not require a rotating seal on the refrigerant supply and take-away pipes.

However, this seal has been developed to a high degree of reliability in modern machines. The ice is subcooled when harvested, the degree of subcooling depending on a number of factors but mainly the temperature of the refrigerant and the time allowed for the ice to reach this subcooled temperature. The subcooling region of the drum is immediately before the scraper where no water is added for a part of the drum's rotation and the ice is reduced in temperature. This ensures that only dry subcooled ice falls into the storage space immediately below the scraper. The refrigerant temperature, degree of subcooling and speed of rotation of the drum are all variable with this type of machine and they affect both the capacity of the machine and the thickness of the ice flakes produced. Other factors such as ice make-up water temperature also affect the capacity of the machine. Thus, the optimum operating conditions will depend on both the local conditions and the thickness of ice preferred. The normal refrigerant temperature in a flake-ice machine is -20 to -25 °C, a good deal lower than in other types of ice makers. The low temperature is necessary to produce higher ice-making rates, thus keeping the machine small and compact. The extra power requirement resulting from operating with a lower temperature in the ice maker is somewhat compensated for by the fact that the method does not require defrosting. There is, therefore, no additional refrigeration load incurred by the method of releasing the ice from the drum.

The range of unit sizes for this type of machine now extends from units with a capacity of 0.5 to 60 tonnes/24 hours. However, rather than use a single unit, it is often expedient to use two or more. This gives a better arrangement for operating at reduced capacity and also provides some degree of insurance against complete breakdown. This advice is also applicable to other types of automatic ice makers. Flake-ice plants have

FIGURE 14
A flake-ice machine



the added advantage that they may be placed at the water's edge and the ice loaded directly into fishing vessels (Figure 15).

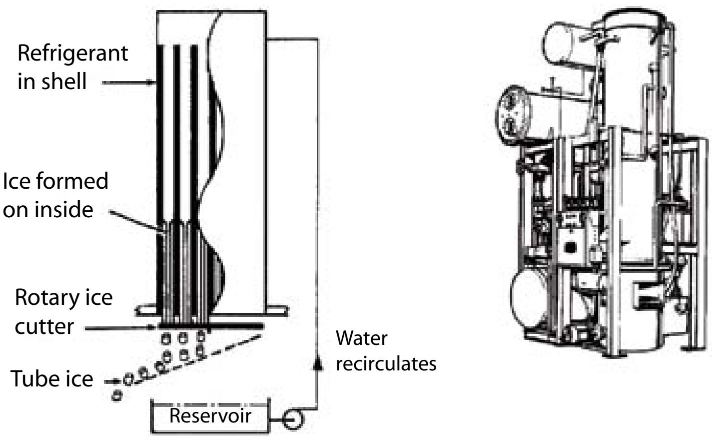
FIGURE 15
Typical flake-ice plants located at the water's edge

11.2.4 Tube ice

Tube ice is formed on the inner surface of vertical tubes and is produced in the form of small hollow cylinders of about 50 mm x 50 mm with a wall thickness of 10 mm to 12 mm (Figure 16). The tube-ice plant arrangement is similar to a shell and tube condenser with the water on the inside of the tubes and the refrigerant filling the space between the tubes. The machine is operated automatically on a time cycle and the tubes of ice are released by a hot gas defrost process. As the ice drops from the tubes a cutter chops the ice into suitable lengths, nominally 50 mm, but this is adjustable. Transport of the ice to the storage area is usually automatic, thus, as in the flake-ice plant, the harvesting and storage operations require no manual effort or operator attendance. Tube ice is usually stored in the form it is harvested, but the particle size is rather large and unsuitable for use with fish. The discharge system from the plant therefore incorporates an ice crusher which can be adjusted to give an ice particle size to suit the customer's requirement. The usual operating temperature of this type of plant is -8 °C to -10 °C.

The ice will not always be subcooled on entering the store but it is usually possible to maintain the store at -5 °C since the particle size and shape allow the ice to be readily broken up for discharge, especially with a rake system.

FIGURE 16
Tube-ice machine (schematic and actual shape)



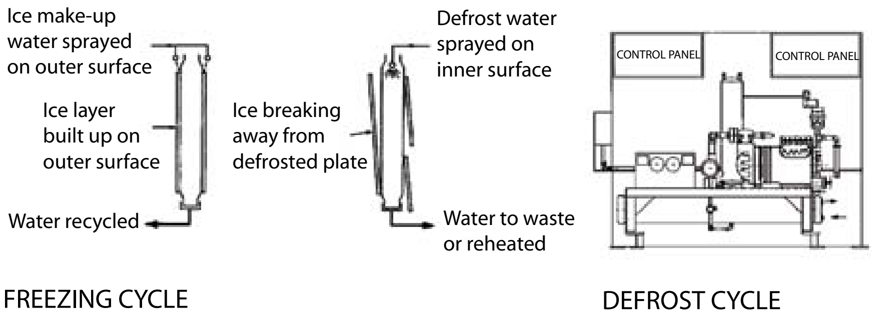
11.2.5 Plate ice

Plate ice is formed on one face of a refrigerated vertical plate and released by running water on the other face to defrost it. Other types form ice on both surfaces and use an internal defrost procedure (Figure 17).

Multiple plate units are arranged to form the ice-making machine and often these are self-contained units incorporating the refrigeration machinery in the space below the ice maker.

The optimum ice thickness is usually 10 mm to 12 mm and the particle size is variable. An ice breaker is required to break the ice into a suitable size for storage and use. Water or defrost requires heating if its temperature is less than about 25 °C; below this value the defrost period is too long, resulting in a loss in capacity and an increase in cost. This machine, like the tube-ice machine, operates on an automatic timed cycle and the ice is conveyed to the storage area, or if the machine can be located directly above the storage space harvesting can be achieved using gravity flow.

FIGURE 17
Plate-ice machine (schematic and actual shape)



11.2.6 Ice and space requirements

Table 6 presents the approximate ice requirements for various activities.

The on-board figures may be reduced by 30 to 50 percent if the hold is refrigerated. The space requirement for machinery depends largely on the type of plant. Modern ice makers are compact compared with conventional block ice plants, but a direct comparison of the space requirements of the various types cannot be readily made. The capacity varies with the operating conditions and it is usual to quote a capacity range when referring to ice-manufacturing capabilities. Some types of plants are more suited to high rates of production than others and are made in large units whereas others are made in small unit sizes only. Table 7 gives some idea of the space requirements for a number of the more widely-used types of ice makers, producing 50 tonnes of ice per day.

TABLE 6
Ice requirements

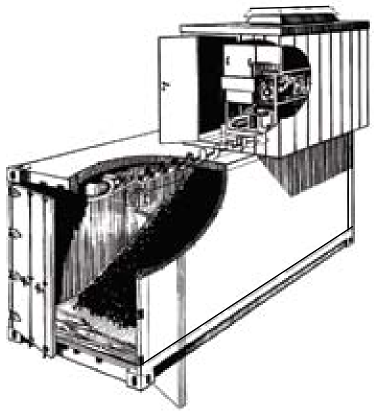
Activity	Quantity required
On-board, trip greater than 1 week	1.0 tonne of ice per 2 tonnes of fish (temperate waters)
On-board, trip less than 1 week	0.7 tonne of ice per 2 tonnes of fish (temperate waters)
On-board, short duration	1.0 tonne of ice per 1 tonne of fish (tropical waters)
Auction hall, repacking	1.0 tonne of ice per 1 tonne of fish (hot waters)

TABLE 7
Typical space requirements

Type of ice plant	Output (tonne/24 hours)	Floor space (m^2)	Height (m)
Block ice	50	190.0	5.0
Rapid ice block	50	30.0	3.5
Plate	50	15.0	1.8
Tube ice	50	3.3	6.6
Flake ice	50	2.7	3.7

The space requirements given in Table 7 are for the ice maker only. Since the ice maker is comparatively compact in modern types of plants (plate, tube and flake ice), the requirements for refrigeration machinery and handling and storage space are far in excess of the above figures. Like most machinery of this type there is an effect of scale, with larger sizes generally requiring less space per unit of ice-making capacity. In some plants it is also possible to stack the units over-and-under and both floor space and height can be varied to suit individual requirements, especially if the plant is installed at the water's edge to discharge directly into vessel holds, Figure 15. Self-contained units with a rating of up to 10 to 20 tonnes/24 hours can be located within the floor space required for storage, with the ice maker and refrigeration equipment on top, Figure 18.

FIGURE 18
Containerized ice maker and store



11.2.7 Ice storage

Ice manufacture and demand rates are seldom in phase. Storage is therefore necessary to ensure that the plant caters for peak demand. Storage allows the ice maker to be operated 24 hours per day. It also acts as a buffer against any interruption to the ice supply due to minor breakdowns and routine maintenance procedures.

TABLE 8
Typical storage parameters for ice

Type of ice	Floor space m^2/tonne
Flake ice	2.2–2.3
Tube ice	1.6–2.0
Crushed blocks	1.4–1.5
Plate ice	1.7–1.8

Therefore, a potential buyer should calculate the storage capacity necessary to satisfy the above requirements (Table 8). Account should be taken of both short-term and seasonal variations and also variations in the capacity of the ice maker. Peak demand for ice in the warmer seasons also coincides with adverse plant operating conditions when make-up water and condenser cooling water temperatures are higher. There is no general rule for estimating ice-storage capacity requirements. This is normally done by plotting the likely pattern of ice production and ice usage over a period of time, and selecting a storage capacity which will ensure that ice will be available at all times. In most cases, ice-storage capacity is never less than twice the daily rate of production and more usually it is four or five times this value. Storage space requirements for different types of ice vary in relation to their bulk density. Although flake ice requires more storage space for a given weight, this subcooled ice can be stored to a greater depth in a silo, thus floor space requirements will be much the same as for more compact types of ice.

Silo storage is generally used with a free-flowing subcooled ice such as flake ice and, in order to be effective, it must have an independent cooling system to maintain the ice in this subcooled condition. The cooling is usually by means of an air cooler in the jacket space between the silo and the outer insulated structure. The air cooler is normally placed at the top of the jacket space adjacent to the ice maker and the air space is cooled by gravity or fan circulation. Ice is collected by gravity flow with the aid of a chain agitator which scrapes the ice from the walls of the silo. The silo allows for a first-in-first-out (FIFO) system of storage but, if the storage space is not cleared periodically, only the central core of ice is used, leaving a permanent outer wall of compacted ice. An access hatch should therefore be provided at the top of the silo so that a pole can be inserted to collapse the outer wall of ice into the central core at least once daily. Silo storage is expensive for small quantities of ice and although units are made for as little as 10 tonnes, this method of storage is more suited for storing 40 to 100 tonnes of ice.

Bin storage may mean anything from a box holding no more than 500 kilograms to a large installation of 1 000 tonnes or more. Bin storage can be used for any type of ice and may incorporate a separate cooling system. Whatever the size of system used, ice storage should always be within an insulated structure since the saving made by reducing ice melt, particularly in warmer climates, is always worth the extra cost of the insulation. An insulation thickness of 50 mm to 75 mm of polystyrene is suggested. Small bins may be arranged with the ice maker above the storage space; the bin is filled by gravity and a FIFO system is operated by removing the ice at a low level. This simple bin system is suitable for processors making and using their own ice, such as that in Figure 18. Large bins require considerable floor space because the recommended maximum depth of storage is limited to about 5 metres, due to the fact that excessive storage depth increases pressure and results in fusion of the ice. A large-capacity storage bin will require a mechanical unloading system.

11.2.8 Ordering an ice plant

The general rule when ordering an ice plant is that the buyer should supply as much information as possible. The more facts the buyer supplies, the easier it will be for ice-plant manufacturers to submit competitive tenders which can be compared on a common basis. At this stage of planning, some decisions should have been made and specific instructions given on such things as type of ice required, site location, building layout and services available. The following is a checklist of the information the buyer should provide when ordering an ice plant, and Tables 9, 10, 11 and 12 provide useful information for decision-making.

Main purpose for which ice is intended:

- type of ice required (block, flake, tube, plate, freshwater, seawater ice, etc.);
- ice production capacity (tonnes of ice/24 hours); and
- local maximum ambient temperature and humidity or exact location of plant.

Information on ice make-up water:

- purity (details of hygienic quality, hardness, etc.);
- temperature range (°C); and
- pressure (kg/cm^2).

Information on condenser cooling water:

- type available (tap, well, river, sea, etc., with details of quality);
- quantity available;
- cost;
- temperature range; and
- pressure.

Information on electricity supply:
- reliability;
- voltage;
- frequency (Hz);
- phase;
- maximum installed power (kW);
- maximum starting current allowable; and
- details of separate power source if required, generator, direct drive, engine, etc.

General characteristics:
- refrigerant preferred (ammonia);
- ice-storage capacity (tonnes of ice or m^3);
- type of storage preferred (silo, bin, bin with mechanical unloading of ice);
- whether a prefabricated or site-built store is required;
- preferred method of discharging ice (gravity, rake, bucket or screw);
- rate of discharge required (tonnes of ice/hours); and
- details, with sketch, of any existing plant and store buildings.

TABLE 9
Weight of ice needed to chill 10 kilograms of fish to 0 °Celsius

Starting temperature of fish (in °C)	5	10	15	20	25	30
Weight of ice required (kg)	0.7	1.3	1.9	2.5	3.1	3.8

TABLE 10
Effect of temperature on ice production

Ice make-up water temperature (in °C)	0	5	10	15	20	25	30	35
Ice production (in tonnes)	4.3	4.2	4.0	3.9	3.8	3.7	3.6	3.5

TABLE 11
Energy consumption in ice production

Type of ice	**Energy consumption (kWh/tonne)**	**Energy consumption (kWh/tonne)**
	Temperate climate	**Tropical climate**
Flake ice	50–60	75–85
Tube ice	40–50	55–70
Block ice	40–50	55–70

TABLE 12
Useful constants

Density of freshwater at 15 °C	1 kg per litre
Density of seawater 0 °C – salinity of 3.5%	1.027 kg per litre
Latent heat of fusion	80 kcal/k freshwater 77-80 kcal seawater
Freezing point of seawater – salinity of 3.5%	-1.9 °C
1 horsepower	0.736 kW
1 kcal/h	1.163 kW

11.3 REFUELLING

11.3.1 Design

Fuel and oil are the commonest constituents of water pollution and this is due to either incorrect storage methods or improper handling of fuel at the quay side. Safety, security, access and maintenance needs should all be considered when designing fuel and oil storage facilities, irrespective of size. Table 13 shows the characteristics of common fuels.

TABLE 13
Characteristics of common fuels

Product	Specific gravity
Diesel	0.83–0.86
Kerosene	0.77–0.84
Petrol	Volatile at ambient temperature

Ideally, fuel should not be stored in significant risk locations (that is, within 10 metres of a quay or watercourse or 50 metres of a well or borehole).

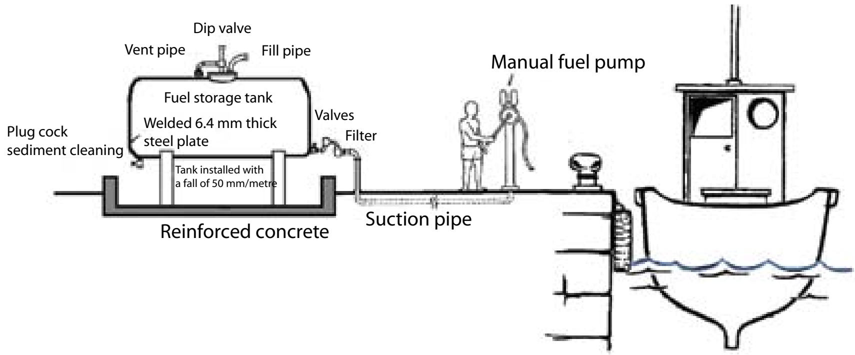
Fuel should be stored in a tank of sufficient strength, shape and structural integrity to ensure that it is unlikely to burst or leak in ordinary use. The tank or tanks should be in steel and above ground. Figure 19 shows an artisanal refuelling facility. For facilities up to 10 000 litres, Figure 20, consideration should be given to prefabricated proprietary tanks tested to a recognized standard and produced to that standard under a quality assurance system. Larger facilities should be in custom-welded tanks, Figure 21, installed by technicians registered within a professional scheme, Figure 22.

Secondary containment should be provided to prevent fuel escaping to the environment in the event of leakage from the tank or ancillary equipment, Figure 19. All tanks and their ancillary equipment should be situated within an oil-tight secondary containment system such as a bund. The potential escape of fuel beyond the bund area by jetting can be minimized by keeping the primary container as low as possible and increasing the height of the bund wall.

The secondary containment structure should be impermeable to fuel and water and there should be no direct outlet to any drain, sewer or watercourse. The oily water collected from inside the secondary containment must be treated via an oily water separator before being discharged into a sewer or watercourse. The secondary containment system must provide storage of at least 110 percent of the tank's maximum capacity. If more than one container is stored, the system must be capable of storing 110 percent of the biggest container's capacity or 25 percent of their total capacity, whichever is the greater. The 10 percent margin is intended to take into account a range of factors. These include:

- loss of the total contents, for example, due to vandalism;
- sudden tank failure;
- overfilling;
- containment of fire-fighting agents;
- overtopping caused by surge following tank failure; and
- an allowance for rainwater in the bund.

FIGURE 19
An artisanal refuelling facility



Any valve, filter, sight gauge, vent pipe or other ancillary equipment should be situated within the secondary containment system and arranged so that any discharges of oil are contained. A filter or isolating valve fitted in a gravity feed to protect the draw-off pipe or downstream equipment is not considered to be ancillary to the container. These should be located within the secondary containment. To prevent the risk of the tank contents draining from a leak in a gravity-feed system, the outlet should be a top draw-off pipe.

A security fence with controlled access should be constructed around the fuel tank if the secondary containment bund is too low.

All pipework should be properly supported and should be sited above ground to make inspection and repair easier. Fill pipes, draw-off pipes and vent pipes should be positioned away from any vehicle traffic to avoid collision damage. Pipework should be adequately protected against corrosion. Underground pipework should be clearly marked and adequately protected from physical damage such as that caused by excessive surface loading or ground disturbance. If mechanical joints have to be used, they should be readily accessible for inspection under a manhole cover. Underground pipework should have adequate facilities for detecting leaks. Continuous leak detection devices should be maintained in working order and tested at appropriate intervals.

Work areas should be illuminated to the minimum intensity required by national legislation.

Tanks, pipes, fences, canopies, motor cabinets, transformers, generators, metallic switchgear panel boards and all other exposed conductive items should be grounded to protect them against fault current and lightning.

FIGURE 20
Prefabricated proprietary fuel tanks

FIGURE 21
Custom-designed facility in cross-section

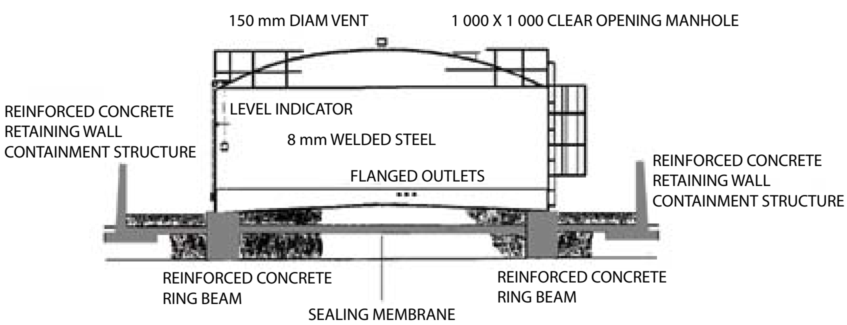


FIGURE 22
Typical 100-tonne facilities

Marine refuelers or fuel dispensers, Figure 23, should have a flow rate of between 100 to 300 litres per minute depending on the type of vessels calling at the port. They should be positioned to minimize the risk of collision damage, be fitted with a non-return valve in the feed line and protected from unauthorized use. Roadside fuel pumps or gravity-fed mobile tanks, Figure 24, are not suitable for vessels requiring in excess of 100 litres fuel. Figure 25 shows examples of improper storage of fuel.

FIGURE 23
Marine refuelers with a flow rate of 300 litres/minute

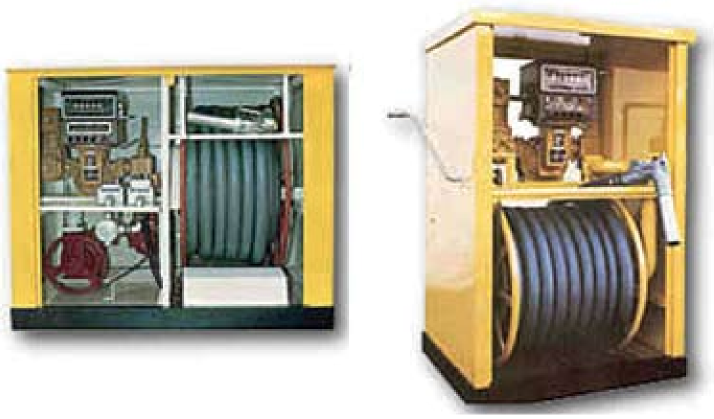


FIGURE 24
Unsuitable fuel pumps for trawlers (flow rate 40 litres/minute)

FIGURE 25
Examples of improper storage of fuel

11.4 POWER AND LIGHTING

11.4.1 Introduction

When designing a new port or upgrading an existing facility, the first step in the electrical engineering design process should be the energy audit. An energy audit is required to calculate the power requirements of the port. Briefly, the power requirements may range from a few kilowatts for an artisanal landing to several hundred kilowatts for a medium-sized fishing harbour complete with ice-producing facilities and cold storage. Power may be required for:

- water extraction (borehole pumps) and storage (header tank pumps);
- ice production facilities;
- cold storage (chill rooms and cold stores);
- slipway winch;
- workshop equipment;
- hygiene facilities if hot water showers are provided;
- lighting and security;
- commercial outlets, if present on site; and
- cathodic protection of immersed steel structures when present.

The energy audit should be followed by a breakdown of the power sources to be tapped in relation to their carbon footprint. The carbon footprint of a port is the total set of greenhouse gas emissions, caused directly and indirectly, expressed as CO_2 equivalent. In the case of port operations, both direct and indirect greenhouse gas emissions are of concern. This encompasses direct emissions from any standby generators inside the port as well as emissions from vessel engines. The indirect emissions cover the electricity usage to run lighting, heating, cooling and powering of equipment inside the port.

Solar photovoltaic (PV) panels are suitable for water extraction and storage, office equipment and all lighting needs inside the port, and solar water heaters are suitable for providing hot water in showers. The rest of the equipment requires a disproportionately large amount of energy and should be sourced from the mains supply.

Micro-wind turbines may also be used in conjunction with solar PV panels to augment the charging of batteries if the local annual average wind speed is 6 m/s or more.

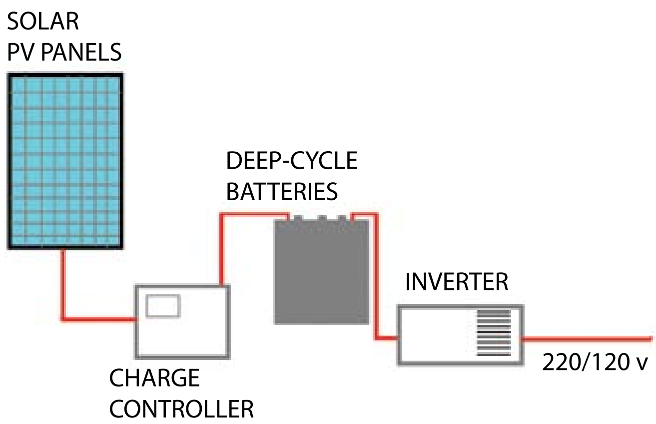
Generators should only be installed as a backup to the mains supply or a solar PV system (to charge batteries during long overcast spells) and never as the primary source of power, especially for ice production. In many remote areas, generator spares, maintenance and fuel logistics render the whole operation unsustainable.

11.4.2 Photovoltaic systems

Photovoltaic (PV) systems use cells to convert solar radiation into electricity. The PV cell consists of one or two layers of a semiconducting material, usually silicon. When light shines on the cell it creates an electric field across the layers, causing electricity to flow; the greater the intensity of the light, the greater the flow of electricity.

PV systems generate no greenhouse gases and now come in a variety of shapes and colours, ranging from grey "solar tiles" that look like roof tiles, to panels and transparent cells that can be used to provide shading as well as generating electricity. If the roof surface is in shadow for parts of the day, the output of the system decreases. Solar panels are heavy and the roof must be strong enough to support their weight, especially if the panel is placed on top of existing trussed roofs with light galvanized sheeting. Solar PV installations should always be carried out by a trained and experienced installer. The average cost of a PV system at 2009 prices is approximately US$8 000 per kW of power installed. This figure can vary according to the geographical latitude (insulation coefficient) and number of days of sunshine per year for a particular site. Expert advice is required when dimensioning PV systems.

FIGURE 26
The four primary components for producing solar electricity



The four primary components for producing electricity using solar power are the solar PV panels, the charge controller, storage batteries and the inverter, Figure 26. The PV panels charge the battery, the charge controller ensures proper charging of the batteries and the converter converts the output to 220 or 120 V in alternating current.

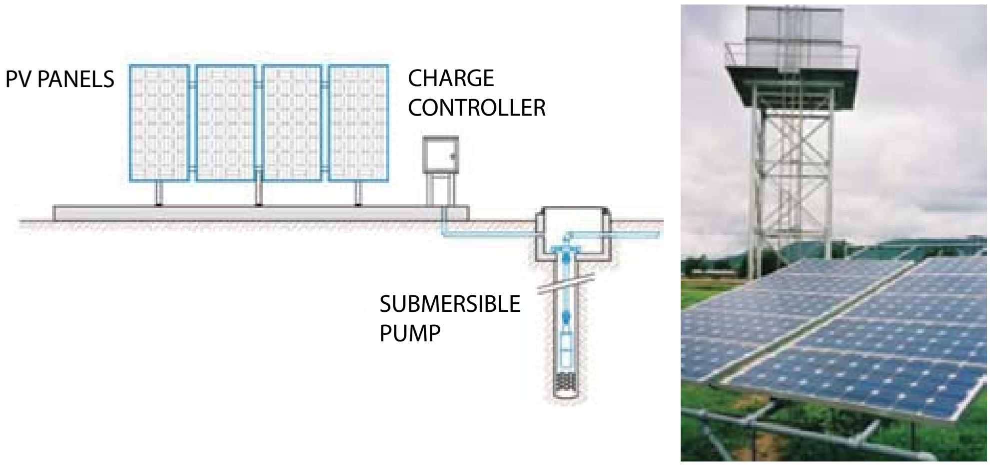
11.4.2.1 Water supply systems

Solar-powered water pumps typically consist of a PV array connected directly to an electric motor via a charge controller. The water is pumped into an overhead storage tank that provides a gravity feed for the entire port area, Figure 27. There are two basic types of solar pumping systems:

- lower-flow deep-well direct current submersible pumps; and
- higher yield alternating current surface pumps.

Solar pumps are equally suited to any off-grid application, whether as a stand-alone system or part of an off-grid energy solution.

FIGURE 27
Solar-powered water supply



11.4.2.2 Lighting systems

Solar-powered lights, both wired indoor systems and autonomous outdoor systems, are also commercially available worldwide.

Typical indoor lighting systems consist of roof-mounted PV panels feeding a four-component circuit like the one illustrated in Figure 26. An independent indoor circuit then distributes the power to all the light fittings inside the building. The light fittings may be of the energy-saving type or LED units.

Typical outdoor systems are fully independent, stand-alone systems. They consist of flat PV panels mounted above the luminaire and the maintenance-free gel battery as illustrated in Figure 28. All fittings are in aluminium and stainless steel and, when mounted on timber piles, they are ideal for port applications (no corrosion potential). No cables are required.

FIGURE 28
A 2.50 kW array for office lighting and solar-powered outdoor lighting

11.4.3 Wind-powered systems

Small-scale wind-powered systems are particularly suitable for remote off-grid locations where conventional methods of supply are impractical. Most small wind turbines generate direct current electricity, which may be used to top-up the charge in the batteries during long overcast spells but only if the local annual average wind speed is 6 m/s (metres per second) or more. Wind power is proportional to the cube of the wind speed, so relatively minor increases in speed result in large changes in potential output. Individual turbines vary in size and power output.

The electricity generated at any one time by a wind turbine is highly dependent on the speed and direction of the wind and the wind speed itself is dependent on a number of factors, such as location, height of the turbine above ground level and nearby obstructions. Ideally, a professional assessment of the local wind speed for a full year at the exact location of the port should be undertaken. Wind speed increases with height, so it is best to have the turbine high on a mast or tower. Generally speaking, the ideal siting is a smooth flat coastline with clear exposure, free from excessive turbulence and obstructions such as large trees or other buildings.

Systems up to 1 kW will cost around US$2 000 at 2009 prices whereas larger systems in the region of 2.5 kW to 6 kW would cost between US$12 000 to US$22 000 installed, inclusive of the turbine, mast, inverters, battery storage (if required) and installation. Final costs, however, depend on location and the size and type of system. Turbines can have a useful life of up to 22.5 years but require service checks every few years to ensure they work efficiently.

11.4.4 Generators

Diesel-powered electric generators are very dependable, have good efficiency ratings, simple maintenance and relatively low capital cost for small ratings. Generators can supply two kinds of power: standby power (for continuous electrical service during interruption of normal power) and prime power (for continuous electrical service).

As a general rule, generators should not be installed as prime power but only as standby power to a grid or solar PV supply. Experience has demonstrated that the spares and fuel logistics for remote sites renders generators unreliable as prime sources of power. The fuel consumption ranges from 0.20 to 0.30 kg/kWh.

11.5 BUILDINGS

Buildings are required within the port boundary to house the different operations required to make the fishing port functional. Typically, the following buildings are required:

- administration building;
- market or sorting hall;
- cold storage (chill rooms and cold stores);
- hygiene facilities;
- ancillary buildings (workshop, crate washing facility, guardhouse, generator room, pump room, winch room, gear stores, food stalls, restaurants, etc.); and
- fishermen's rest and net repair platforms.

11.5.1 Designing for durability

As a general rule, all buildings should conform to the national architectural and sanitary standards, irrespective of the size of the port. However, due to the aggressive nature of the salty environment in and around a port or fisheries landing, buildings should be designed for durability by:

- specifying higher grades of concrete than normal in columns, beams and foundations (Grade 35 minimum recommended);
- using special admixtures in the external rendering to make it resistant or impervious to sea spray or salt;
- avoiding the use of untreated mild steel in external applications, see Chapter 9 for more details;
- preventing galvanic corrosion by avoiding dissimilar metals from coming into contact (screws holding fittings should be of the same metal), see Chapter 9 for more details;

- specifying heavy-duty PVC to replace the use of timber and metal for door and window frames; and
- ensuring that all plumbing is in HDPE plastic.

Coupled to these specifications, a strict quality assurance programme should be adopted during the construction phase.

11.5.2 Designing for a low carbon footprint

Port buildings should be designed for a low carbon footprint at the inception stage, both through design features as well as installed equipment.

In hot climates, the design features should include:

- correct orientation of buildings to make the best use of shade to cut down on cooling requirements;
- if not possible, application of appropriate eaves or shades to prevent the build up of heat from direct sunlight;
- large windows with white internal paint schemes to cut down on lighting requirements, Figure 29; and
- abundant landscaping to absorb reflected light, provide shaded areas and absorb treated wastewater.

FIGURE 29
Fisheries management organization offices – small windows versus large windows with eaves

The equipment features should include:

- installation of roof-mounted solar PV panels to power lights and most office equipment;
- installation of two separate power circuits, one for heavy loads and one for solar-powered loads;
- energy saving light bulbs or LED units applied directly to fittings (no ballast);
- use of laptops as workstations (easier to recharge and do not emit the same amount of heat as a tower personal computer [PC];
- installation of ceiling fans to reduce the use of air-conditioning systems (except for monitoring, control and surveillance rooms [MCS] with radar screens);
- installation of smart energy systems to conserve power, like trip switches on windows and doors to shut down air-conditioning automatically if windows or doors are opened;
- installation of rainwater harvesting coupled to large water reservoirs to augment water supply for hygiene services; and
- installation of sewage treatment for use in the landscaping.

11.5.3 Administration buildings

Irrespective of the size of a fish landing or fisheries port, an administration building should always be included in the layout. An administration building may consist of a single room with one desk for the harbour master to a proper building with offices for the harbour master, statistics officers and other key personnel. Generally speaking, the larger the port, the more management staff are required and, hence, the larger the building required.

FIGURE 30

Typical layout of a large two-storey administration building (left) and a small administration building run by a fisheries management organization (right)

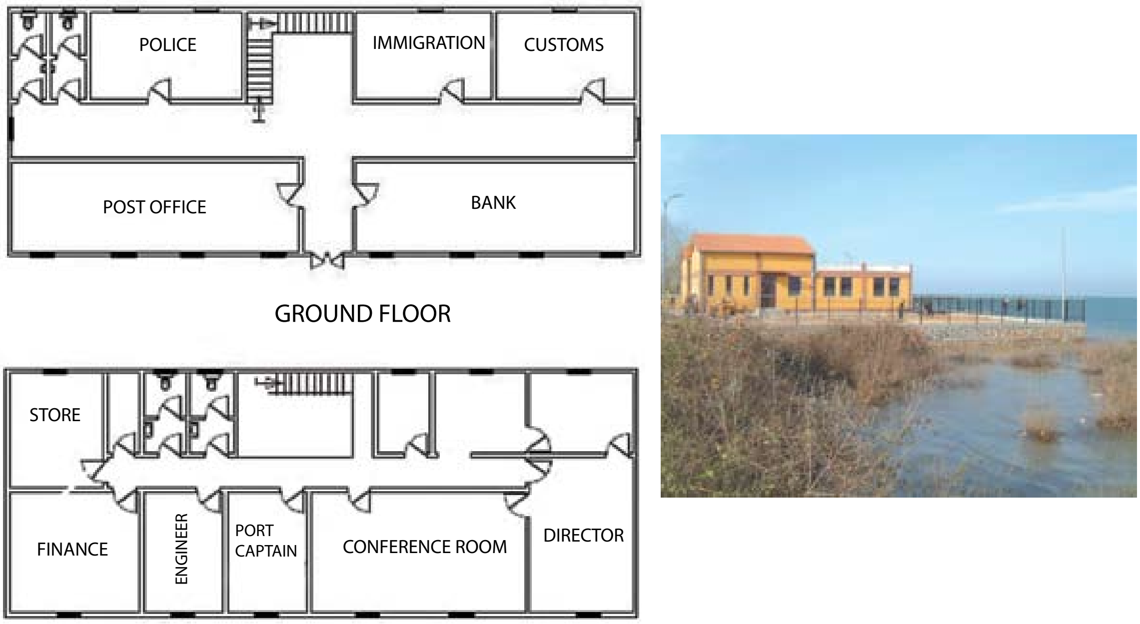


Figure 30 illustrates a typical ground-floor plan for a two-storey building suitable for port administration. The top floor should be reserved for the management staff, whereas the ground floor should include all types of interface services, such as police, customs and immigration, if required, and bank or post office. Office space destined for the installation of MCS radar screens should have adequate air-conditioning facilities.

11.5.4 Market or sorting hall

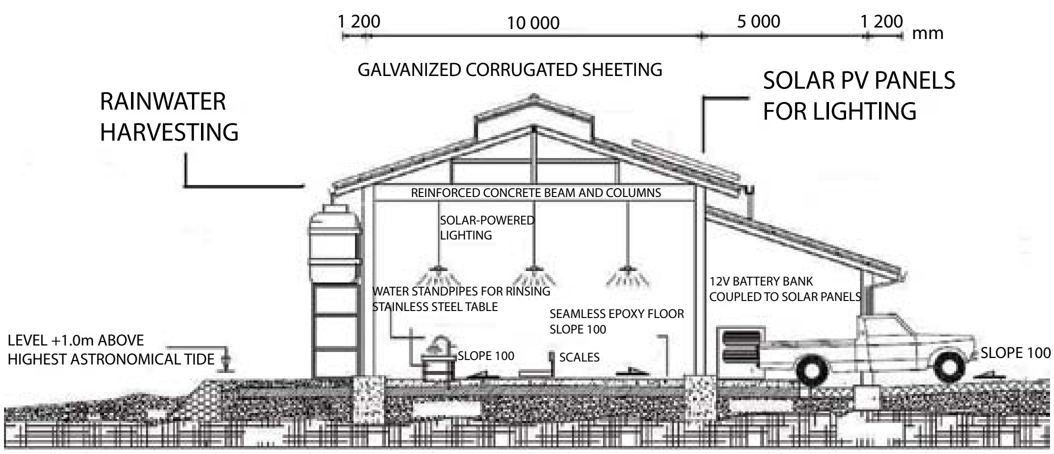
In designing new fish marketing or sorting premises, a smooth sequence of operations from the receipt of the fish to its loading and transportation should be achieved. All operations should be conducted off the floor, at a height convenient for workers to perform their tasks in a standing position. In some Asian countries where workers prefer to crouch, low integral sorting platforms, about 150 mm high, and draining melt water to a dish channel should be included in the design, Figure 31.

FIGURE 31
Crouching-only sorting platforms under construction

The structure should be a single-storey building – a short distance from the landing area – to enable fast handling of fish along the quay and marketing operations inside the market hall. This type of design will also allow easy access to vehicles for loading purposes. Figure 32 illustrates a small artisanal auction hall.

Ample, natural air circulation should be provided for covered halls. In hot climates hollow-brick walls or chain-link fences are often used. Properly designed long eaves for protection against direct sunlight and rain are essential. An adequate pitch of the roof serving a rainwater collection system is also an important factor in areas with high rainfall. Vehicles waiting to load fish should be under cover to prevent spoilage of fish from heat. Orientation in relation to the prevalent direction of the elements (sunlight and wind) should also be taken into consideration.

FIGURE 32
A small artisanal auction/market hall



Floors

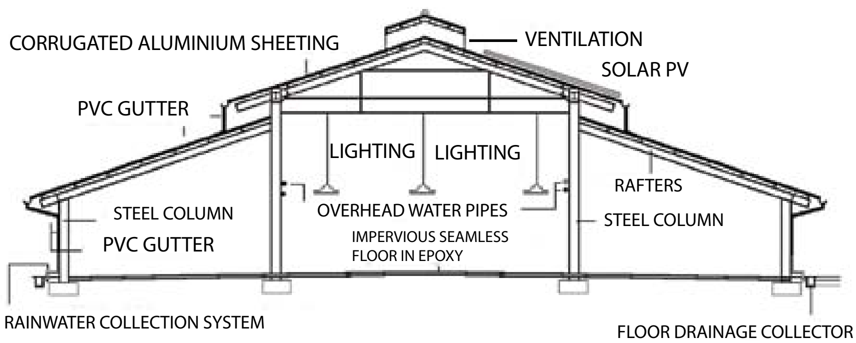
Floors should ideally be hard-wearing, non-porous, washable, seamless, easy to drain, non-slip and resistant to possible attack from brine, weak ammonia, fish oils and offal.

The choice of the flooring materials will depend on the characteristics of the materials available in the area and their cost. In artisanal situations, granolithic concrete, terrazzo and clay tiles can be used, but clay tiles are preferable. Generally speaking, the harder the tiles, the less absorbent but the more slippery they are. Tiles with slightly abrasive surfaces are less slippery. All paving should be light coloured to reflect light and show up dirt. Tile laying on a cement mortar requires professional supervision to ensure that all the joints between the tiles are complete and permanently sealed. The junctions with the walls should be curved for ease of cleaning. A slope of 2 percent from the highest point of the floor to the drainage channel around the hall should be adequate. Steeper slopes may be required in small halls to drain water away faster. If finances permit, an epoxy floor should be considered as this is the only kind of floor finish that satisfies all the requisites of functionality, hygiene and low maintenance. Epoxy floor finishes are described in detail in Chapter 9.

Drainage

The floor should drain sideways into appropriate dish channels and the runoff channelled to a plastic or stainless steel basket drain where solids (wet wastes) may be collected prior to the effluent entering any pipework (Figure 33). Drainage pipes should not be smaller than 100 mm in diameter. Sharp bends in the drainage system (pipework or deep channels) should be avoided as these are difficult to clear in case of blockages (from waste paper, vegetation and plastic bags, etc., that occasionally find their way into the system). The roof drainage system should incorporate a rainwater collection network.

FIGURE 33
A modern, all-steel construction fish hall – no side walls



Walls

Walls should be constructed of materials that have smooth, washable and impervious surfaces. Walls should be painted in light colours to increase the brightness inside the building and make dirt more visible. For easy cleaning, they should be rounded at the junctions with other walls, and ceilings should be kept as free as possible from ledges, projections or ornamentation to avoid dust collection. If walls are not tiled, then they should be finished in plaster and good-quality, washable paint. Walls which are intended primarily as partitions should be strong enough for fish boxes or other light equipment to be piled up against them. The lower part of all walls should preferably consist of a solid *in situ* concrete wall, as this area receives the most impacts (from equipment). Hollow block walls, once punctured and not immediately patched up, are prone to infestation by vermin. Modern fish halls are built entirely in steel without side walls, especially in hot climates. Internal partitions for box storage areas, for instance, may be in chain-link fence.

Doors

Doors should be of simple and functional design. The main doors should be sufficiently high and wide to permit circulation by internal transport vehicles such as box trolleys, forklifts, etc.

When forklifts are in use a 2.8-metre-high door will be required with a width of between 1.5 to 2.5 metres. Internal doors should be self-closing and fitted with metal kick plates at the bottom. Due to the wet nature of the working conditions inside a fish hall, it is preferable to use light metal doors in aluminium or polyvinyl chloride (PVC). Timber doors are not recommended as they absorb water, need a lot of maintenance and may be subject to attack by wet rot.

Lighting

The building should provide adequate natural light for most operations to be carried out. Adequate windows and skylights should be provided to reduce the need for electric lighting. Artificial overhead lighting should be provided in order to allow personnel to work early in the morning before sunrise. Fluorescent lighting is particularly suitable (daylight type) for fish-market areas where a shadowless light with very little glare is required continuously for a long time; even though the initial costs are relatively higher than other lighting systems, operational costs are lower. A light level of 220 lux as minimum is considered adequate. All lighting fixtures should be watertight. Metal fittings, conduits, etc., should be avoided. Cabling should be adequate for peak demands and suitable for the environment. Given the size of most roofs, due consideration should be given to installing solar PV panels on the roof in order to run the building lights on solar power. Additional strengthening of the roof to support the PV panels is normally required.

Sanitary facilities

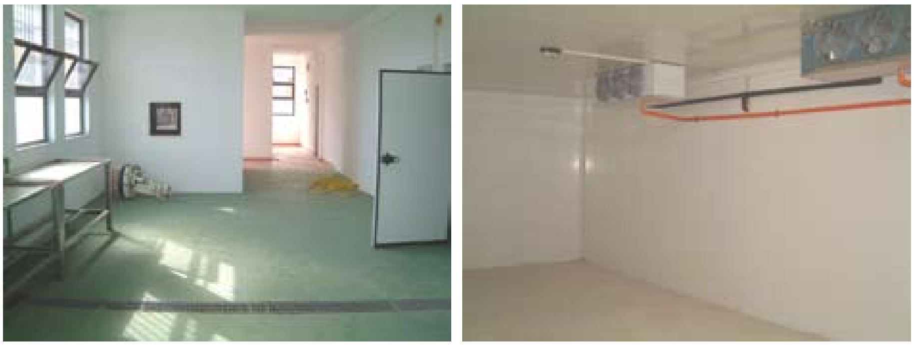
Adequate sanitary facilities should be provided for the staff, fishers, handlers and merchants working in or around the fish hall. Chapter 11 describes this topic in detail. In particular, toilets should be constructed to the highest possible standards to guarantee the maximum working life of the facilities with the lowest maintenance costs. Bad design (cheap materials) and lack of supervision during construction generally lead to facilities with a working life measured in weeks or months. This situation gives rise to "toilets of opportunity" elsewhere, exacerbating hygiene conditions inside the port. Hygiene blocks should be equipped with an adequate number of wash-hand basins.

Signs and billboards spelling out sanitary regulations should form part of the infrastructure. Sanitary facilities should not open onto a working area lest a blocked drain causes flooding.

11.5.5 Cold rooms

Refrigerated chill rooms are required for the temporary storage of freshly iced fish (Figure 34). The operating temperature inside a chill room is around 1 °C. Chill rooms are expensive and need to be designed properly by an expert.

FIGURE 34
Small sorting hall with a 2-tonne chill room



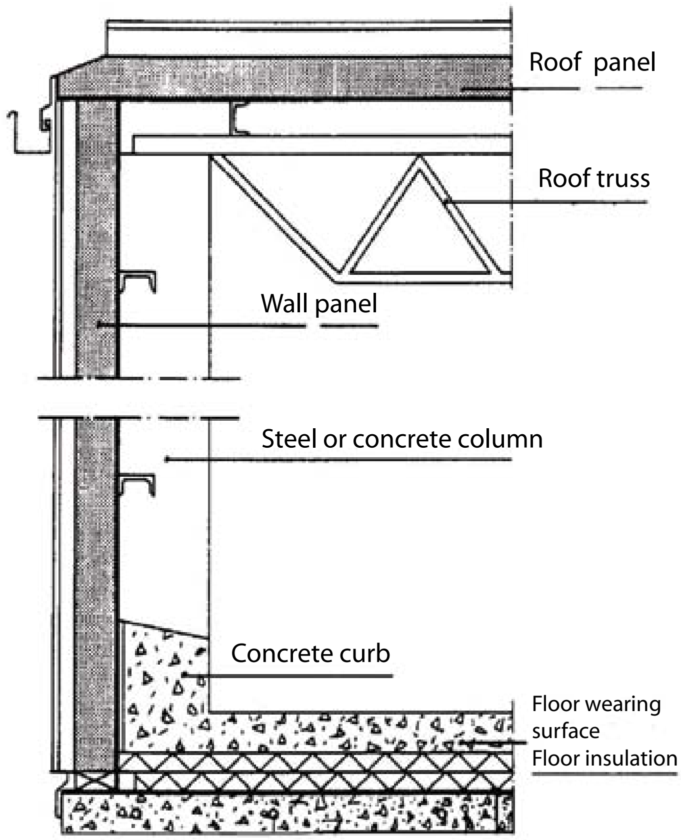
The design should take into account:
- total maximum weight of products to be stored;
- handling methods to be employed;
- ambient temperature of the products entering the chill store; and
- availability and cost of electricity, labour and servicing facilities.

Standby equipment should also be provided for emergencies.

11.5.6 Cold stores

Cold stores generally consist of a single-storey building having a single or a multiple number of cold rooms operated at temperatures in the range -24 °C to -30 °C (Figure 35). Cold stores are very expensive items in a port's inventory and due to their complexity it is recommended that cold storage specialists handle such projects, all the way from feasibility to commissioning, including supervision and training of the local management responsible for the future operation of the cold store. For further information on cold stores, the reader is referred to other more specialized texts; see bibliography.

FIGURE 35
Typical cross-section through a simple prefabricated cold store



11.5.7 Hygiene facilities

Hygiene facilities are required inside the administration building, the market/sorting hall and as stand-alone facilities spread around the port area, Figures 36 and 37.

In areas around the sorting or market hall, the ratio of male to female facilities needs to be adjusted to reflect local employment customs.

FIGURE 36
Typical layout for toilets near offloading areas

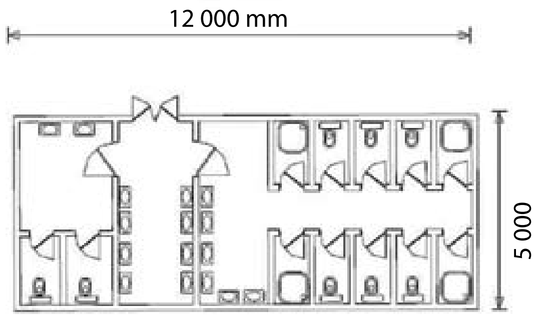
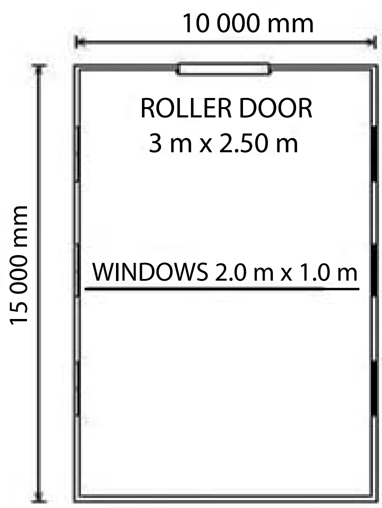


FIGURE 37
Wash-hand basins and showers

The building should be simple in layout, airy, brightly coloured with plenty of ventilation and light. All the floor drains inside the building should be bar drains placed centrally across the room with water draining away from the walls to prevent flooding. The drains should be in plastic and easily removed to clear blockages.

The provision of showers in small- to medium-sized ports is important for crews returning from long fishing trips. Hot water is very desirable and should be provided by solar water heaters.

FIGURE 38
Workshop building



11.5.8 Workshop facilities

Workshops are an integral part of a fishing port (Figure 38). Both engine and hull workshops are normally required, the one dealing with the inboard or outboard engines and the other with timber or metal hulls.

The workshop building may be built in an all-metal construction as illustrated in Figure 39 or in concrete and masonry as illustrated in Figure 40. Both single-phase and three-phase power is normally required to run equipment. Compressed air lines fed from a central compressor are also an added advantage.

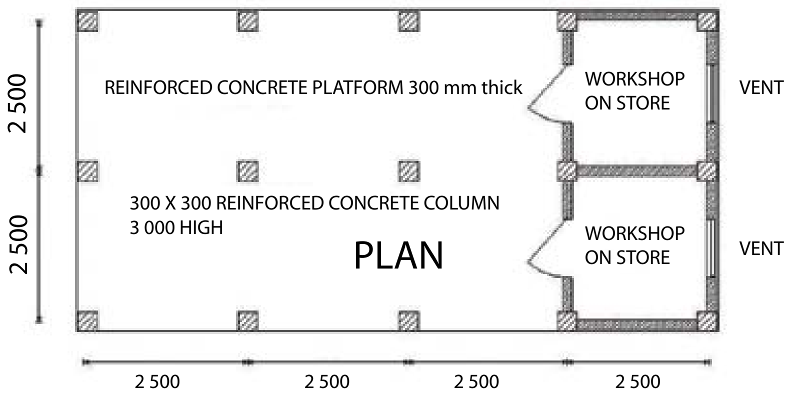
FIGURE 39
All-metal workshop under construction

FIGURE 40
Workshops in concrete (outboards only, left, inboard, right)

11.5.9 Net repair and social meeting platforms

Artisanal fish landings located on beaches require a clean level platform for the repair of nets. This platform often incorporates small gear stores for the storage of bulky equipment, Figure 41.

FIGURE 41
Typical small-scale net repair platform with integral stores (mm)



Platforms should be designed to drain runoff away from the work areas and should be located away from all sources of pollution, like oils and fuel (Figures 42 and 43). Fishers also use the platforms as social meeting points during their time between fishing trips.

FIGURE 42
Small-scale net repair platform and an ad hoc shade on a quay

FIGURE 43
Large-scale net repair structures

11.6 PARKING AREAS

A detailed picture of vehicle traffic movements would have emerged from the environmental impact assessment study if one was performed for the fishing harbour; otherwise, a traffic study assessment should be performed before planning any parking areas, and the port's as well as the town's master plan, should be consulted.

11.6.1 Parking densities

The parking density is a measure of how many vehicles may be squeezed into a parking lot without loss of access to any one vehicle. Typical car dimensions may vary from one country to another depending on local preferences. The dimensions illustrated in Figure 44 to Figure 47 may have to be increased by 15 percent to allow for large vehicles, insulated vans or pick-ups.

FIGURE 44
In-line parking area per vehicle 20 m² against a kerb or 23.8 m² against a wall

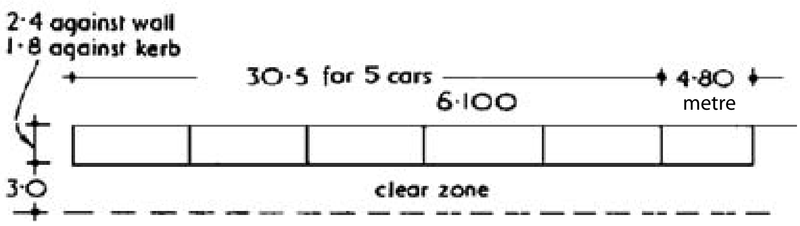


FIGURE 45
Individual standard vehicle parking bay

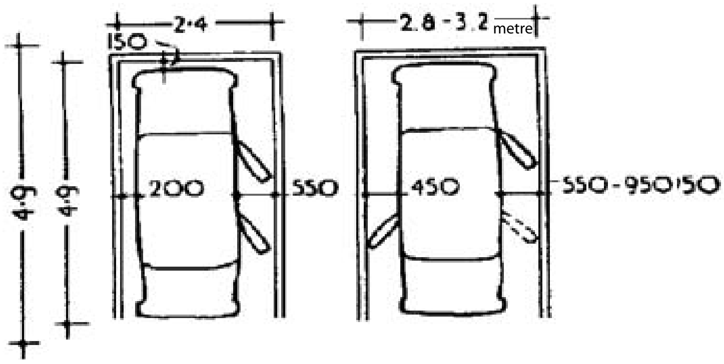


FIGURE 46
Echelon parking (45°), area per car 22 m² or 9.2 m² where interlocking in adjacent rows

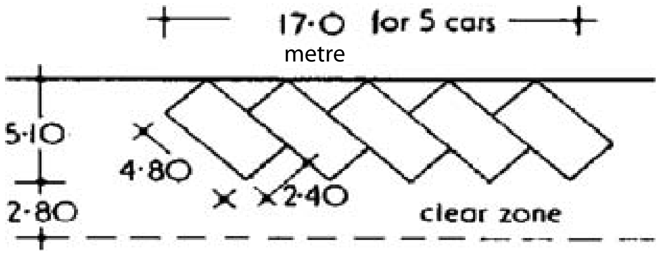
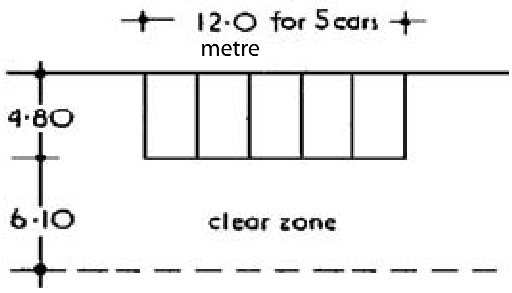


FIGURE 47
Head-on parking, area per vehicle 18.8 m²



11.6.2 Turning radii

In addition to the actual areas occupied by the vehicles and the clear zones for manoeuvring, vehicle turning radii are also important, Table 14.

TABLE 14
Turning radii

Type of vehicle	Turning radius (outer wheel) in metres	Swept radius (truck body) in metres
Cars and pick-ups	3.0	3.0
Small 1 tonne van	6.1	6.4
Long 2 tonne van	6,55	7.0
2-axle lorry or truck-mixer	9.15	9.45
2-axle 16 tonne flatbed lorry	10.5	11.0
3-axle tractor with ISO cargo container	12.0	15.0
5-axle articulated with refrigerated body	12.0	15.0

11.6.3 Paved areas

Depending on the size of the fishing port and the landings, various types of vehicles will call at the port to either deliver supplies, such as fuel, ice, etc., or to pick up fish. The vehicle sizes may range from a simple half-tonne pick-up to a full-sized, containerized refrigerated articulated truck. Even in small artisanal harbours, it is not uncommon to find large containerized refrigerated trucks, Figure 48, parked by the quay for a number of days to collect a full payload of around 40 tonnes of fish. Paving is an expensive but necessary cost in a fishing port and the type and quality of the pavement will depend on the type (and hence the weight or axle load) of vehicles intending to use the facility, the typical use for the pavement (main access, parking area, lay-by, quayside, refuelling area, etc.) and the type of existing ground (sandy cohesionless reclaimed land, cohesive clayey land, etc.).

Figure 49 shows four different kinds of pavement, precast concrete rafts or slabs, interlocking precast concrete blocks, rigid concrete and asphalt. The respective thickness and characteristics of the materials employed depend on design considerations; however, interlocking precast concrete block pavements are now an accepted industry standard due to their flexible nature and ease of placing. Interlocking concrete block paving may be designed to take the full range of axle loads (by increasing the thickness of the block), can easily be re-laid if settlement has occurred, does not rut and if laid properly it is practically maintenance-free.

FIGURE 48
A large truck picking up fish from a small fishing vessel

FIGURE 49
Typical types of pavement inside a harbour area

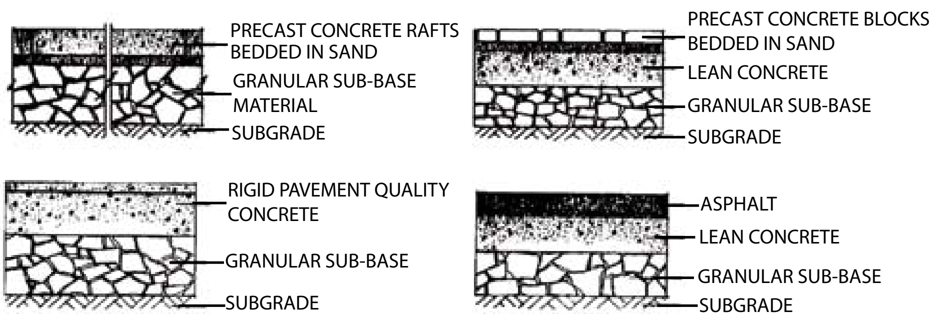
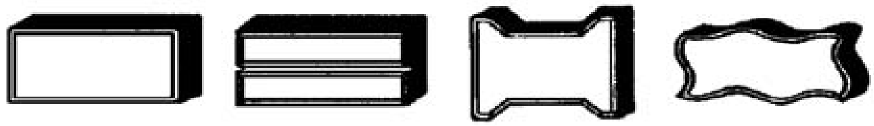


FIGURE 50
Typical shapes of interlocking concrete blocks

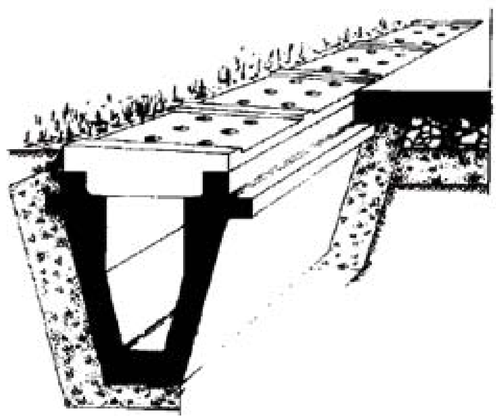


The typical standard rectangular block, Figure 50 left, is 200 mm long and 100 mm wide with a thickness range of 60 mm to 100 mm, depending on the end use of the pavement. Blocks are available in various colours, including grey, red, yellow and green. The blocks are bedded on a graded layer of sand (5 mm maximum size) 50 mm thick, laid over a layer of lean concrete laid to the levels and cross-falls required for drainage. Various laying patterns are possible, both with the standard rectangular block and the non-traditional designs shown in Figure 50. Block paving should not be used in wet market areas.

All paved areas should be laid to cross-falls draining into appropriate channels. Typical falls are 1 to 2 percent (a 1 percent falls 1 metre in 100 metres) and it is common to break cross-falls at least every 10 metres, depending on the local intensity of rainfall (the longer the distance between the breaks, the longer the rainwater has to travel to drain away). Drainage channels should be appropriate and suitable for a particular location. Drainage channels may be of the open type, also known as dish channels, Figure 51, or of the covered type, as illustrated in Figure 52.

FIGURE 51
Open dish channel

FIGURE 52
Heavy-duty covered drains in precast concrete



Covered channels should not be used in areas where mobile sand is a problem, especially where wind occurrences are very frequent. In these cases, dish channels should be used as these are easy to maintain. Covers over drains may consist of perforated concrete slabs, cast iron bar drains, galvanized steel grilles or glass reinforced polyester. Inside market and processing halls, lightweight glass reinforced polyester grilles should be used as these may be lifted easily by one person to clear clogged drains.

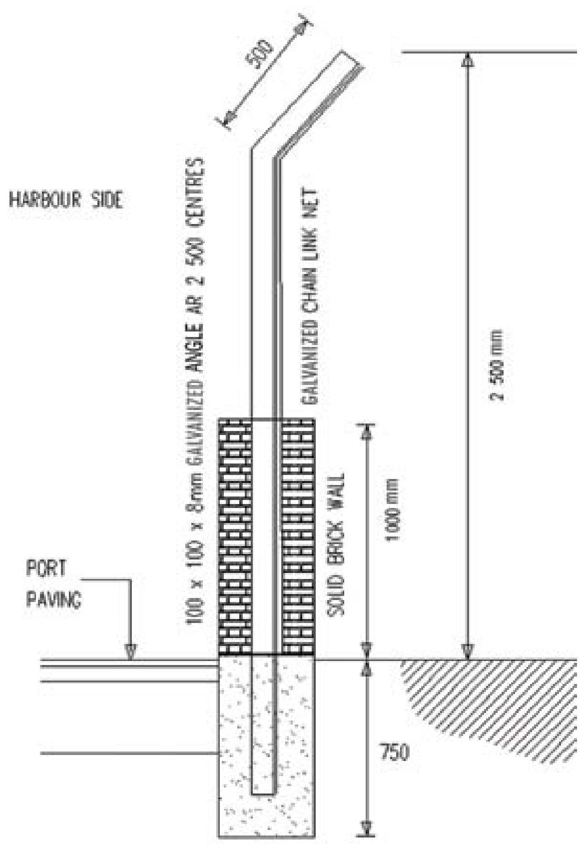
11.7 PORT SECURITY

With the exception of open beach landings, fishing ports should be designed as secure areas. Perimeter or boundary walls provide security against theft and vandalism but they also keep out unwanted pests which may otherwise pose a health hazard. When fish and fishery products are exported directly from a fishing port to overseas markets, the standard of the port's security must follow the International Ship and Port Facility Security (ISPS Code).

11.7.1 Perimeter wall

Whenever possible, perimeter walls should be built in concrete or brick and provided with adequate manned access gates (Figure 53). Simple wire netting is not satisfactory for this purpose as it is easily breached at road level to gain access. Chain-link fences, on the other hand, are useful for segregating specific areas inside the port boundary, thus limiting access, such as the auction hall area, fish box storage area, open-air net stores, net repair areas, etc.

FIGURE 53
Typical cross-section across boundary wall

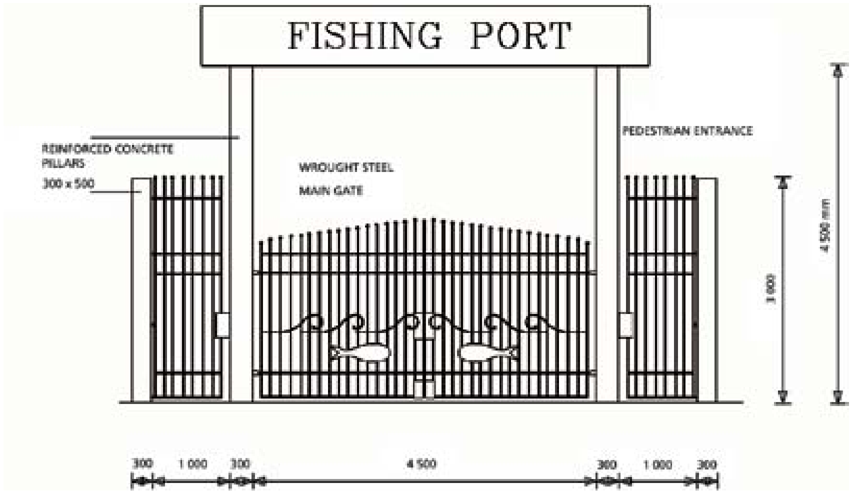


The perimeter wall in mass concrete or masonry should sit on a mass concrete foundation and rise up to 1 metre above finished road level. From 1 metre to 2.5 metres above road level, the wall should consist of galvanized wrought iron railings or sturdy angles bent to shape to hold galvanized chain-link in place. Whenever possible, the perimeter wall should be illuminated at night, especially in the vicinity of the main gate and around the cattle grid.

11.7.2 Main gate

The main gate is required to control the influx of people during the landing and marketing hours. During these hours, only people connected with the fisheries should be allowed into the port area, such as the buyers, their loaders and sorters and other fisheries-related staff. Some countries operate a tagging system whereby each operator is handed a number of colour-coded tokens for his staff to come and go as they please.

FIGURE 54
A typical controlled-entry main gate



Outside working hours, the gate should be closed to prevent unauthorized entry into the port, or, if the port is a public facility, prevent entry into the market hall. The main gate should be manned at all hours, Figure 54.

Should the port fall under the ISPS Code, the main gate should be the only point of controlled access to the port and all other breaches (such as back entrances) in the perimeter must be sealed off. An area should also be set aside for vehicle inspection purposes as required by the ISPS Code.

When the fishing port is located inside an urban area, the port authorities may allow the general public to wander through the port, especially when restaurants are located nearby. As long as adequate parking is located outside the port, this activity helps to maintain a cleaner environment, as restaurants would then lose customers if the port environment is not kept clean.

11.7.3 Cattle grid

In some developing countries, domestic and stray animals are allowed to wander about untethered posing a health risk to fishing port operations. In such cases, the main gate must be equipped with a cattle grid to prevent animals from wandering into the port area. This area should be illuminated at night.

11.7.4 Billboard

At the entry to the port, a billboard is required to display information pertinent to the running of the port operations (Figures 55 and 56). This should be placed either at the entrance, outside the main gate, facing outwards over the perimeter fence or inside the port area in a prominent position. The billboard or billboards should list, among other things:

- the port authority that has jurisdiction over the facility;
- the port regulations;

- fishing and/or hygiene by-laws;
- the fines levied for each contravention; and
- prices for services rendered.

Telephone numbers (normally coast guard, police and hospital) are also useful.

FIGURE 55
Dimensions for a simple billboard (mm)

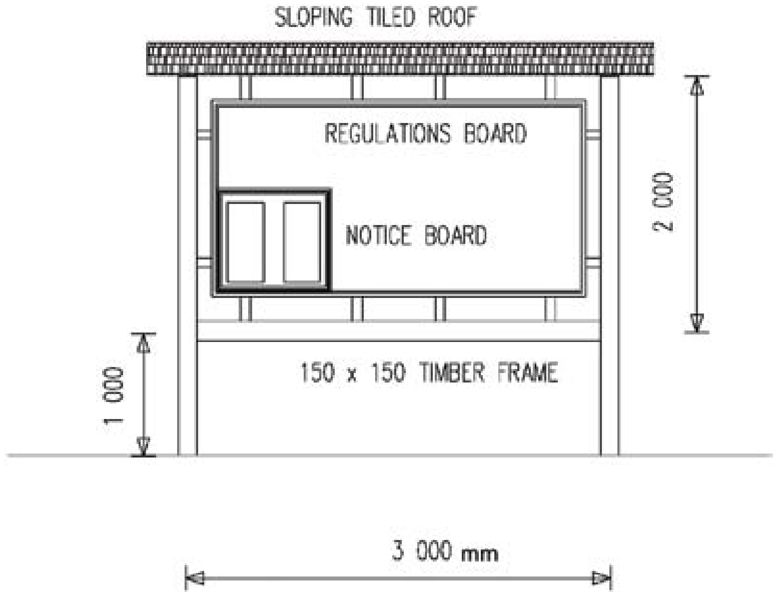


FIGURE 56
Billboards displaying pricing structure (left) and regulations (right)

11.7.5 Closed-circuit television

When a port exports fish and fishery products directly to overseas markets, then the port's security system is governed by the ISPS Code; see Chapter 1 for more details. In this case, strategically located closed-circuit television monitoring is required as part of the port's security arrangements. Professional assistance should be sought at the design stage to ensure that the appropriate power supplies and connections are installed together with the required illumination standards. Modern video surveillance systems may also be run on solar power.

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12. Public health, hygiene and waste disposal

SUMMARY

The numbers are staggering. An estimated six million people worldwide contract a food-borne illness each year. It is not just the person infected with the illness that suffers. Damage of food-borne illness to an operation can include loss of customers, reputation and sales. A fishery is a food producing operation and fish is a highly perishable product. The fishing harbour is the focal point of the fishing effort (and sometimes the village life revolves around the activities of the fishing harbour) and it is here that fish is likely to be contaminated.

What is contamination and what constitutes pollution are commonly asked questions and the view taken by some scientists is that a distinction must be made between contamination and pollution. Contamination is the presence of elevated concentrations of substances in the environment that are above the natural background level for the area and for the organism. Pollution on the other hand is the introduction by humans, directly or indirectly, of substances or energy into the water, resulting in such deleterious effects as harmful to living resources and hazard to human health.

Therefore, this chapter deals exclusively with the environment within a fishing port, such as water quality standards, personal hygiene, sewage treatment and disposal, and waste reception facilities and disposal. The objective is to have health, hygiene and waste disposal issues addressed by port planners when designing new ports and upgrading existing facilities as well as by port managers at all times. Thus, the standards for sanitary water that should be used in all aspects of fisheries, including the routes of contamination, are reviewed and solutions proposed. In particular, methods for the disposal of all types of waste likely to arise from fishing operations are discussed.

Consequently, the readership, port engineers, port managers and those responsible for safety and health would be better equipped to design systems that can withstand the rigours of a new modern fishing port and, with regard to existing fishing ports, to identify potentially weak points in their public health applications as well as waste disposal systems. The ultimate beneficiaries will be the consumers of fish and fish products.

CONTENTS

12.1 HAZARD ANALYSIS AND CRITICAL CONTROL POINT PROGRAMME

By charting the flow of fish through the fishing harbour (from the time it is discharged on the quay to the time it leaves the port boundary), points can be identified where contamination or growth of micro-organisms occur. Control features can then be implemented based on the identified health hazard. This technique is known as a Hazard Analysis and Critical Control Point programme or HACCP in short. To the fishing port planner, the three major areas of concern are:

- water quality standards of all the water used in the port (potable and seawater);
- personal hygiene of the shore-based workers; and
- standard of cleanliness of the port in general.

Under HACCP, these three areas of concern translate into drastic changes in the long term. In particular, these involve:

- minimizing and eventually eliminating harbour and coastal pollution from point and non-point sources;
- improving sanitation and hygiene throughout the fishing harbour; and
- maintaining port and harbour infrastructure in good working order.

In order to comply with these directives, a fishing port planner needs to have a good understanding of both the natural environment existing around the fishing harbour as well as the environment generated within the harbour's infrastructure and with it the wastes generated by the various components of the fishing effort.

This chapter deals exclusively with the environment within the fishing harbour, such as water quality standards, personal hygiene, sewage treatment and disposal, and waste reception facilities and disposal.

12.2 WATER QUALITY STANDARDS

Water is the underlying link which connects the various fishing activities together, such as harvesting, storing and icing on board, handling inside a harbour and eventual sale to consumers. Assuming that fish is generally caught offshore in relatively pollution-free waters, potable water, and hence ice, come into contact with it all the way down the process in port, right up to the fish vendor's market stall.

Generally speaking, most fishing harbours are connected to an approved mains supply: in some developing countries, however, the water is supplied from local resources such as lakes, rivers or underground aquifers which may or may not be contaminated. This fact alone makes it vitally important for a fishing harbour planner to understand water quality standards, the types of pollutants which may be present in the water supply and the most likely sources for these pollutants. Also, due to the acute shortage of potable water in and around some fishing harbours in many developing countries, raw seawater (i.e. drawn from within the harbour basin) often replaces freshwater in the shore-based activities, implying that, in addition to freshwater, harbour basin or estuary waters has also to be tested for contaminants.

Contamination of water by physical and bacteriological agents may be evaluated by laboratory tests. Test results are usually expressed in parts per million (*milligrams per litre or simply* ppm) or parts per billion (*micrograms per litre or* ppb) for physical parameters and bacterial counts per 100 millilitres for organisms. For both types of contaminants, maximum levels are usually stipulated and these levels may differ from country to country. The major contaminants of concern in potable water supplies are:

- suspended solids;
- biodegradable organics (proteins, carbohydrates and fats);
- pathogens;
- nutrients (nitrogen, phosphorus and carbon);

- priority pollutants (highly toxic chemicals);
- refractory organics (pesticides, phenols, surfactants);
- heavy metals; and
- dissolved inorganics (nuisance chemicals).

12.2.1 Suspended solids

The presence of suspended solids in water gives rise to turbidity. Suspended solids may consist of clay, silt, airborne particulates, colloidal organic particles, plankton and other microscopic organisms. The presence of particulate matter in water, whether organic, inorganic or due to higher micro-organisms, can protect bacteria and viruses from the action of disinfectants. The adsorptive capacity of some suspended particulates can lead to entrapment of undesirable inorganic and organic compounds present in the water and in this way turbidity can bear an indirect relationship to the health aspects of water quality. Airborne particulate matter is of particular concern to facilities located near mineral stockpiles (coal, iron ore, bauxite, etc.) or downwind from large power stations (fly ash), timber saw mills (saw dust) or cement factories (cement dust). Rainwater collection systems are particularly sensitive to such airborne particulates because they usually augment local potable water systems and act as conduits for the pollutants to enter the potable water system. Large quantities of aromatic hydrocarbons are also generated by the combustion of fossil fuel in oil-fired power stations and industrial kilns.

12.2.2 Biodegradable organics

Composed principally of proteins, carbohydrates and fats, biodegradable organics are measured most commonly in terms of biological oxygen demand (BOD). BOD is the quantity of oxygen required for the oxidation of organic matter by bacterial action in the presence of oxygen. The higher the demand for oxygen (the more organic the pollution), the less oxygen is left to support life. Urban sewage commonly has a BOD of 500 mg/litre. Harbour basin water should have a BOD in the range of 50 to 150 mg/litre.

12.2.3 Pathogens

The most common and widespread danger associated with drinking water is contamination, either directly or indirectly, by sewage, by other wastes, or by human or animal excrement (Table 1). If such contamination is recent, and if among the contributors there are carriers of communicable enteric diseases, some of the living causal agents may be present. The drinking of water so contaminated or its use in the preparation of certain foods may result in further cases of infection. Natural and treated waters vary in microbiological quality. Ideally, drinking water should not contain any micro-organisms known to be pathogenic to humans. In practice, this means that it should not be possible to demonstrate the presence of any coliform organism in any sample of 100 ml.

12.2.3.1 Bacteria

Faecal pollution of drinking water may introduce a variety of intestinal pathogens – bacterial, viral and parasitic – their presence being related to microbial diseases and carriers present at that moment in the community. Intestinal bacterial pathogens are widely distributed throughout the world. Those known to have occurred in contaminated drinking water include strains of *Salmonella, Shigella,* enterotoxigenic *Escherichia coli, Vibrio cholerae, Yersinia enterocolitica* and *Campylobacter fetus.* These organisms may cause diseases that vary in severity from mild gastroenteritis to severe and sometimes fatal dysentery, cholera or typhoid.

TABLE 1
Infectious agents potentially present in drinking water contaminated by sewage

Organism	Disease	Remarks
Bacteria		
Escherichia coli	Gastroenteritis	Diarrhoea
Legionella pneumophila	Legionellosis	Acute respiratory illness
Leptospira (150 spp.)	Leptospirosis	Jaundice, fever
Salmonella typhi	Typhoid fever	High fever, diarrhoea
Salmonella (~1700 spp.)	Salmonellosis	Food poisoning
Shigella (4 spp.)	Shigellosis	Bacillary dysentery
Vibrio cholerae	Cholera	Extremely heavy diarrhoea
Yersinia enterolitica	Yersinosis	Diarrhoea
Viruses		
Adenovinus (31 types)	Respiratory disease	
Enteroviruses (67 types)	Gastroenteritis, meningitis	
Hepatitis A	Infectious hepatitis	Jaundice, fever
Norwalk agent	Gastroenteritis	Vomiting
Reovirus	Gastroenteritis	
Rotavirus	Gastroenteritis	
Protozoa		
Balantidium coli	Balantidiasis	Diarrhoea, dysentery
Cryptosporidium	Cryptosporidiosis	Diarrhoea
Entamoeba histolytica	Amoebic dysentery	Prolonged diarrhoea with bleeding
Giardia lamblia	Giardiasis	Mild to severe diarrhoea, nausea
Helminths		
Fasciola hepatica	Fascioliasis	Sheep liver fluke
Dracunculus medinensis	Dracunculosis	Guinea worm
Ascaris lumbricoides	Ascariasis	Roundworm
Enterobius vericularis	Enterobiasis	Pinworm
Hymenolepis nana	Hymenolepiasis	Dwarf tapeworm
Taenia saginata	Taeniasis	Beef tapeworm
Taenia solium	Taeniasis	Pork tapeworm
Trichuris trichiura	Trichuriasis	Whipworm

The modes of transmission of bacterial pathogens include ingestion of contaminated water and food. The significance of the water route in the spread of intestinal bacterial infections varies considerably, both with the disease and with local circumstances. Among the various water-borne pathogens, there exists a wide range of minimum infectious dose levels necessary to cause a human infection. With *Salmonella typhi*, ingestion of relatively few organisms can cause disease; with *Shigella flexneri*, several hundred cells may be needed, whereas many millions of cells of Salmonella serotypes are usually required to cause gastroenteritis. Similarly, with toxigenic organisms such as enteropathogenic *E. coli* and *V. cholerae*, as many as 108 organisms may be necessary to cause illness. The size of the infective dose also varies in different persons with age, nutritional status and general health at the time of exposure.

The significance of routes of transmission other than drinking water should not be underestimated as the provision of a safe potable supply by itself will not necessarily prevent infection without accompanying improvements in sanitation and personal habits. Education in simple applied and personal hygiene is essential.

Surveillance of the bacterial quality of water is also important, not only in the assessment of the degree of pollution, but also in the choice of the best source and the treatment needed. Bacteriological examination offers the most sensitive test for the detection of recent and therefore potentially dangerous faecal pollution, thereby providing a hygienic assessment of water quality with a sensitivity and specificity that is absent from routine chemical analysis. It is essential that water is examined regularly and frequently as contamination may be intermittent and may not be detected by the examination of a single sample. For this reason, it is important that drinking water is examined frequently by a simple test rather than infrequently by a more complicated test or series of tests. Priority must always be given to ensuring that routine bacterial examination is maintained whenever human resources and facilities are limited. It must be appreciated that all a bacteriological analysis can prove is that, at the time of examination, contamination, or bacteria indicative of faecal pollution, could or could not be demonstrated in a given sample of water using specified culture methods. In addition, the results of routine bacteriological examination must always be interpreted in the light of a thorough knowledge of the water supplies, including their source, treatment and distribution.

Whenever changes in conditions lead to deterioration in the quality of the water supplied, or even if they should suggest an increased possibility of contamination, the frequency of bacteriological examination should be increased so that a series of samples from well-chosen locations may identify the hazard and allow remedial action to be taken. Whenever a sanitary survey, including visual inspection, indicates that a water supply is obviously subject to pollution, remedial action must be taken, irrespective of the results of bacteriological examination. For unpiped rural supplies, sanitary surveys may often be the only form of examination that can be undertaken regularly.

The recognition that microbial infections can be water-borne has led to the development of methods for routine examination to ensure that water intended for human consumption is free from excremental pollution.

Although it is now possible to detect the presence of many pathogens in water, the methods of isolation and enumeration are often complex and time-consuming. It is therefore impractical to monitor drinking water for every possible microbial pathogen that might occur with contamination. A more logical approach is the detection of organisms normally present in the faeces of humans and other warm-blooded animals as indicators of excremental pollution, as well as of the efficacy of water treatment and disinfection. The presence of such organisms indicates the presence of faecal material and thus that intestinal pathogens could be present.[1] Conversely, the absence of faecal commensal organisms indicates that pathogens are probably also absent. Search for such indicators of faecal pollution thus provides a means of quality control. The use of normal intestinal organisms as indicators of faecal pollution rather than the pathogens themselves is a universally accepted principle for monitoring and assessing the microbial safety of water supplies. Ideally, the finding of such indicator bacteria should denote the possible presence of all relevant pathogens.

Indicator organisms should be abundant in excrement but absent, or present only in small numbers, in other sources; they should be easily isolated, identified and enumerated and should be unable to grow in water. They should also survive longer than pathogens in water and be more resistant to disinfectants such as chlorine. In practice, these criteria cannot all be met by any one organism, although many of them are fulfilled by coliform organisms, especially *Escherichia coli* as the essential indicator of pollution by faecal material of human or animal origin.

Other micro-organisms described as "faecal coliforms" such as faecal streptococci and sulphite-reducing clostridia, especially *Clostridium perfringens*, that satisfy some of these criteria (though not to the same extent as coliform organisms) can also be used as secondary indicators of faecal contamination.

The significance that can be attached to the presence or absence of particular faecal indicators varies with each organism and especially with the degree to which that organism can be specifically associated with faeces. Coliform bacteria should not be detectable in treated water supplies, and if found, indicate inadequate treatment or post-treatment contamination.

[1] The human intestinal tract contains countless rod-shaped bacteria known as coliform organisms and each person discharges from 100 billion to 400 billion coliform organisms per day in addition to other kinds of bacteria.

Furthermore, coliform bacteria are derived not only from the faeces of warm-blooded animals but also from vegetation and soil. For these reasons, the presence of small numbers of coliform organisms (1 to 10 organisms per 100 ml), particularly in untreated groundwater, may be of limited sanitary significance provided faecal coliform organisms are absent.

When coliform organisms are found in the absence of faecal coliform organisms and *E. coli*, secondary indicators may be used to confirm the excremental nature of the contamination.

12.2.3.2 Viruses

Viruses of major concern in relation to water-borne transmission of infectious disease are essentially those that multiply in the intestine and are excreted in large numbers in the faeces of infected individuals. Concentrations as high as 108 viral units per gram of faeces have been reported. Even though replication does not occur outside living hosts, enteric viruses have considerable ability to survive in the aquatic environment and may remain viable for days or months. Viruses enter the water environment primarily by way of sewage discharges. With the methods available at present, wide fluctuations in the number of viruses in sewage have been found. On any given day, many of the 100 or so known enteric viruses can be isolated from sewage, the specific types being those prevalent in the community at that time.

Procedures for the isolation of every virus type that may be present in sewage are not yet available. As sewage comes into contact with drinking water, viruses are carried on and remain viable for varying periods of time depending upon temperature and a number of other less well-defined factors. It is generally believed that the primary route of exposure to enteric viruses is by direct contact with infected persons or by contact with faecally contaminated objects.

However, because of the ability of viruses to survive and because of the low infective dose, exposure and consequent infections may occur by less obvious means, including ingestion of contaminated water. Explosive outbreaks of viral hepatitis and gastroenteritis resulting from sewage contamination of water supplies have been well documented epidemiologically. In contrast, the transmission of low levels of virus through drinking water of potable quality, although suspected of contributing to the maintenance of endemic enteric viral disease within communities, has not yet been demonstrated. In some developing areas, water sources may be heavily polluted and the water-treatment processes may be less sophisticated and reliable. Because of these factors, as well as the large number of persons at risk, drinking water must be regarded as having a very significant potential as a vehicle for the environmental transmission of enteric viruses. As with other microbial infections, enteric viruses may also be transmitted by contaminated food. Enteric viruses are capable of producing a wide variety of syndromes, including rashes, fever, gastroenteritis, myocarditis, meningitis, respiratory disease and hepatitis. In general, asymptomatic infections are common and the more serious manifestations rare. However, when drinking water is contaminated with sewage, two diseases may occur in epidemic proportions – gastroenteritis and infectious hepatitis. Apart from these infections, there is little, if any, epidemiological evidence to show that adequately treated drinking water is concerned in the transmission of virus infections. Gastroenteritis of viral origin may be associated with a variety of agents. Many of these have been identified only recently occurring as small particles with a diameter of 270–350 microns in stools of infected individuals with diarrhoea. Viral gastroenteritis, usually of 24–72 hours' duration with nausea, vomiting and diarrhoea, occurs in susceptible individuals of all ages. It is most serious in the very young or very old where dehydration and electrolyte imbalance can occur rapidly and threaten life if not corrected without delay. Hepatitis, if mild, may require only rest and restricted activities for a week or two, but when severe it may cause death from liver failure, or may result in chronic disease of the liver. Severe hepatitis is tolerated less well with increasing age and the fatality rate increases sharply beyond middle age. The mortality rate is higher among those with pre-existing malignancy and cirrhosis.

12.2.3.3 Protozoa

Protozoa are single-celled eucaryotic micro-organisms without cell walls. The majority of protozoa are aerobic. Protozoa feed on bacteria and other microscopic micro-organisms. Of the intestinal protozoa pathogenic for humans, three may be transmitted by drinking water: *Entamoeba histolytica, Giardia* spp. and *Balantidium coli*. These organisms are the etiological agents of amoebic dysentery, giardiasis and balantidiasis, respectively, and have all been associated with drinking water outbreaks. All three have worldwide distribution. As a group, the intestinal pathogenic protozoa occur in large numbers in the faeces of infected individuals in humans and a wide variety of domestic and wild animals. Coliform organisms do not appear to be a good indicator for *Giardia or E. histolytica* in treated water because of the increased resistance of these protozoans to inactivation by disinfection.

12.2.3.4 Helminths

A great variety of helminth eggs and larvae have been detected in drinking water and it is clear that all those infective to humans should be absent if the water supply is to be safe. However, the majority of helminths are not water-borne and it is neither feasible nor necessary to monitor water for them on a routine basis. Two groups of helminths are more directly related to water supplies:

- those transmitted wholly by the ingestion of infected copepod intermediate hosts; and
- those whose cercariae are directly infective to humans. A third category groups the remainder of the species.

The first group (*Dracunculus, Spirometra*) comprises helminths that develop in aquatic copepods and are acquired by humans ingesting water containing the intermediate host crustacea. The most important member in this group is the guinea-worm (*Dracunculus medinensis*), a filarial parasite of humans. Tapeworms of the genus *Spirometra*, though much rarer in humans, also have a stage in aquatic copepods. Adult worms are found in the small intestine of cats. Eggs pass out in the faeces and hatch in water where they may be ingested by copepods.

The second group (*Schistosoma, Ancylostoma, Necator*) comprises a miscellaneous group of flukes and roundworms whose infective larvae are able to penetrate the human skin and mucous membranes. The human hookworms *Ancylostoma duodenale* and *Necator americanus*, both with a wide tropical and subtropical distribution, have eggs that hatch and develop in the soil to the third stage larvae, which then reinfect humans by penetrating the skin. Hookworms of domestic animals may also invade humans.

The third group of helminths has resistant eggs or cysts infective to humans. If these gain access to drinking water and are ingested, humans become infected. The most widespread intestinal helminths are *Ascaris lumbricoides* (roundworm) and *Trichuris trichuria* (whipworm). The human tapeworms of the genera *Hymenolepis*, with a direct life cycle, and *Echinococcus*, where humans are infected by ingesting eggs usually acquired from dogs, have the potential for spread in drinking water.

12.2.3.5 Malaria and dengue

Both malaria and dengue are not transmitted directly by drinking water but by vectors or carriers that breed in water, in this case mosquitoes. In order to prevent the spread of these diseases, it is of the utmost importance that in all endemic areas, drinking water reservoirs within the port area be adequately covered to prevent mosquitoes from gaining access to the free water surface. These reservoirs comprise:

- elevated water distribution tanks (access manholes);
- reinforced concrete reservoirs (access manholes);
- header tanks, whatever size; and
- water cisterns in all toilets.

All manholes should be covered with purpose-made manhole covers and all vents should be equipped with mosquito-net filters. Furthermore, all horizontal areas should be laid to falls to prevent the rainwater forming ponds and adequate drains installed to handle runoff. These areas include roofs, parking areas, access ways and derelict land within the port's boundaries.

12.2.4 Nutrients

Nitrates and nitrites are considered together because conversion from one form to another occurs in the environment. The health effects of nitrates are generally a consequence of its ready conversion to nitrite in the body. Nitrates are widely present in substantial quantities in soil, in most waters and in plants, including vegetables. Nitrites also occur fairly widely, but generally at very much lower levels than nitrates. Nitrates are products of oxidation of organic nitrogen by the bacteria present in soils and in water where sufficient oxygen is present. Nitrites are formed by incomplete bacterial oxidation of organic nitrogen. One of the principal uses of nitrate is as fertilizer. Nitrates are also used in explosives, as oxidizing agents in the chemical industry and as food preservatives. Its occurrence in water is brought about by fertilizer use, decaying vegetable and animal matter, sewage effluents, industrial discharges, leachates from refuse dumps.

Nitrates in the water are limited to 10 ppm.

12.2.5 PRIORITY POLLUTANTS

12.2.5.1 Introduction

These are organic or inorganic compounds selected on the basis of their known or suspected carcinogenicity, mutagenicity, teratogenicity or high acute toxicity.

12.2.5.2 Arsenic

Arsenic is notorious as a toxic element. Its toxicity, however, depends on the chemical (valency) and physical form of the compound, the route by which it enters the body, the dose and duration of exposure and several other biological parameters. It is recommended that, when water is found to contain arsenic at levels of 0.05 ppm, an attempt should be made to ascertain the valency and chemical forms of the element. Arsenic is commonly associated as an alloying additive with lead solder, lead shot, battery grids, cable sheaths and boiler piping. Nowadays, most arsenic originates from paints or pharmaceuticals and is commonly found in sewage. The concentration of arsenic in seawater is around 0.002 ppm. The primary concerns are carcinogenicity and mutagenicity.

12.2.5.3 Asbestos

Asbestos is a general term for fibrous silicate minerals of the amphibole and serpentine mineral groups. Six minerals have been characterized as asbestos: chrysotile, crocidolite, anthophyllite, tremolite, actinolite and amosite. Asbestos is commonly found in domestic water supplies. The use of asbestos-cement (170 grams of asbestos per kilograms – 80 percent chrysotile and 20 percent crocidolite) for pipes in distribution systems could contribute to the asbestos content of drinking water. Background levels are reported to be in the range of less than 1 million to 10 million fibres per litre. The primary concern is carcinogenicity. Use of asbestos is now banned.

12.2.5.4 Barium

Barium is present in the earth's crust in a concentration of 0.50 g/kg and the mineral barytes, barium sulphate, is the commonest source. Traces of barium are present in most soils.

Barium is also present in traces in many foodstuffs, such as brazil nuts. Barium is also used in various industrial processes, such as in vacuum tubes, spark-plug alloys, Getter alloys, Fray's metal and as a lubricant for anode rotors in X-ray machines. Drinking water should not contain more 0.050 ppm.

12.2.5.5 Beryllium

Beryllium is commonly found as part of feldspar mineral deposits and may exist as the mineral beryl in small localized deposits. The primary source of beryllium in the environment is the burning of fossil fuels, although contamination is normally light. Beryllium can enter the water system through weathering of rocks in ground aquifers, atmospheric fallout on rain water collection systems and industrial and municipal discharges. Beryllium is used in metal alloys and certain electrical components. Not all countries have set standards for limits of beryllium in drinking water. Those that have limit its presence to 0.20 ppb.

12.2.5.6 Selenium

As a result of geochemical differences, levels of selenium in soil and vegetation vary within broad limits. The chemical form of selenium, and thus its solubility, is another decisive factor as regards its presence in drinking water. Selenium has been identified as an essential nutrient in several animal species, including humans. Dietary selenium levels of 5 mg/kg of food or more may cause chronic intoxication, and in seleniferous areas this value has been considered as the dividing line between toxic and non-toxic feeds. Drinking water in general does not represent the only or main source of selenium exposure for the resident population in seleniferous areas. There is a range of selenium intake by humans that is consistent with health, and outside this range deficiency or toxicity can occur. Selenium in drinking water is limited to 0.01 ppm.

Selenium is widely used in the electronics industry, television cameras, solar batteries, computer cores, rectifiers, xerographic plates and ceramics as a colorant for glass. It is also used as a trace element for animal feeds.

12.2.5.7 Silver

Silver occurs naturally in elemental form and as various ores. It is also associated with lead, copper and zinc ores. Because some metals such as lead and zinc are used in distribution systems and also because in some countries silver oxide is used to disinfect water supplies, silver levels in tap water may sometimes be elevated. The levels of silver in drinking water should not exceed 1 ppb.

In industry, silver is used in the manufacture of silver nitrate, silver bromide and other photographic chemicals, water distillation equipment, mirrors, silver plating equipment, special batteries, table cutlery, jewellery, and dental, medical and scientific equipment including amalgams.

12.2.6 REFRACTORY ORGANICS

12.2.6.1 Introduction

This group of contaminants is wide ranging and consists of chlorinated alkanes (carbon tetrachloride), chlorinated ethenes (polyvinyl chloride, or PVC), polynuclear aromatic hydrocarbons (naphtalene, coal tar), pesticides, herbicides and fumigants (DDT, endrin, aldrin, lindane, methoxychlor, toxaphene and silvex), mono-dichlorobenzenes (solvents), benzenes (benzene, toluene), phenols and chlorophenols and trihalomethanes (chloroform, bromoform).

12.2.6.2 Chlorinated alkanes

One of the major uses of chlorinated alkanes in the chemical industry is as an intermediate in the production of other organochlorine compounds. They are therefore produced in large quantities and consequently many are found in raw and finished drinking water. Carbon tetrachloride is a haloalkane with a wide range of industrial and chemical applications. It has been found to be an occasional contaminant of chlorine used in the disinfection of drinking water but is not produced in drinking water as a result of the chlorination process itself. Carbon tetrachloride was extensively used as a propellant for aerosols. This chemical has been found to be a carcinogen to laboratory animals. The guideline limit of this chemical is 3 ppb.

12.2.6.3 Chlorinated ethenes

This group of compounds is used widely in a variety of industrial processes as solvents, softeners, paint thinners, dry-cleaning fluids, intermediates, etc. Because of their wide use, they are often found in raw and treated drinking water. Because of their high volatility, they are usually lost to the atmosphere from surface water and therefore generally occur at lower concentrations. Vinyl chloride is mainly used for the production of PVC resins which, in turn, form the most widely used plastics in the world. Low concentrations of PVC have been detected in effluents discharged by chemical and latex manufacturing plants and in drinking water as a result of leaching from substandard (improperly cured) PVC pipes used in water distribution systems. Vinyl chloride is associated with cancer and is mutagenic in a number of biological systems, including *Salmonella* and *E. coli*. Other chlorinated ethenes include 1,1-dichloroethene (used in the packaging industry), trichloroethene (used as a dry-cleaning solvent) and tetrachloroethene (used in dry-cleaning and as a degreasing agent in metal industries). The guideline limit for PVC is 20 ppb.

12.2.6.4 Polynuclear aromatic hydrocarbons

Polynuclear aromatic hydrocarbons (PAHs) are a large group of organic compounds present in the environment from both natural and industrial sources. PAHs are rarely encountered singly in the environment and many interactions can occur with mixtures of PAHs whereby the potency of the known carcinogenic PAH may be enhanced. These systems are not well understood, however, and their significance as regards environmental exposure to PAH is not yet clear. Contact with coal-tar based linings during distribution is known in some instances to lead to an increase in PAH concentration in water. Because of the close association of PAH with suspended solids, the application of treatment to achieve an acceptable level of turbidity will ensure that minimum PAH levels are achieved. Aromatic hydrocarbons may enter the aquatic environment of the harbour basin from discharges from vessels as ballast water, bilge pumping, engine exhaust, effluents from coastal refineries, crude oil power stations, terrestrial runoff (particularly from urban storm water containing road asphalt particles) and leaching (creosoted components from jetties and wharves). A guideline of 0.01 ppb is recommended.

12.2.6.5 Pesticides

Pesticides that may be of importance to water quality include chlorinated hydrocarbons and their derivatives, persistent herbicides, soil insecticides, pesticides that are easily leached out from the soil, and pesticides systematically added to water supplies to control disease vectors, such as mosquito larvae (malaria and dengue fever).

Of these compounds, only the chlorinated hydrocarbon insecticides occur frequently and these are very persistent in the environment where they have become ubiquitous. Typical pesticides include:

- *Dichlorodiphenyltrichloroethane (DDT)*: a persistent insecticide, stable under most environmental conditions and resistant to complete breakdown by enzymes present in the soil micro-organisms.
- *Aldrin and dieldrin*: two related and very persistent pesticides which accumulate in the food chain. Currently may be used for termite control around the roots of fruit trees.
- *Chlordane*: a broad-spectrum insecticide also used for termite control and for homes and gardens.
- *HCB or hexachlorobenzene*: produced commercially for use as a fungicide.
- *Heptachlor*: another broad-spectrum insecticide used to control agricultural soil insects. Heptachlor is very persistent.
- *Lindane*: a wide-spectrum insecticide of the group called organochlorine insecticides and used in a wide range of applications, including treatment of animals, buildings, water (for mosquitoes), plants, seeds and soil.
- *Methoxychlor*: an insecticide used for the treatment of agricultural crops and livestock. Guidelines for refractory organics limit total "*drins*" to 0.03 ppb and total "*ddt*" to 1.0 ppb.
- *Mono-dichlorobenzenes*: monochlorobenzene is widely used as a solvent and in the manufacture of several chemicals, such as insecticides and phenols. Dichlorobenzenes are important intermediates for dyes, moth repellants, deodorants, dielectric fluids, heat transfer fluids and insecticides.
- *Benzenes*: benzene and toluene are produced mainly from petroleum or as a by-product in the manufacture of gas. Both chemicals are widely used in the chemical industry both as intermediates and for the production of styrene, phenol, acetone and cyclohexane (used in manufacturing nylon). Significant quantities of toluene are used in the manufacture of plastics, paints, detergents and as petrol additives. The guideline for benzene in water is 10 ppb.
- *Phenols and chlorphenols*: chlorphenols are used as biocides and are found in water as a result of chlorinating water supplies containing phenol. Chlorphenols are well known for their low taste and odour thresholds. For aesthetic reasons therefore individual phenols should not, as a general rule, be present in drinking water above 0.1 ppb. The best approach to controlling pollution by chlorphenols is to prevent the contamination of the source water by phenol (from petrochemical industries) and chlorinated phenolic pesticides (agriculture).
- *Trihalomethanes*: trihalomethanes (chloroform and bromoform) in drinking water occur principally as products of reaction of chemicals used in oxidative treatment reacting with naturally occurring materials present in the water. Their formation is particularly associated with the use of chlorine for disinfecting water supplies. Notwithstanding this, it is important to recognize the fact that chlorine is an effective water disinfectant and the hazards of disease arising from microbiological contaminants resulting from incomplete disinfection are substantial. Trihalomethanes have several adverse effects on health and the guideline value limits chloroform in drinking water to 30 ppb.

12.2.7 DISSOLVED INORGANICS

12.2.7.1 Introduction

Dissolved inorganic compounds are generally associated with the aesthetic and organoleptic (taste and odour) characteristics of drinking water. For health-related contaminants, what is unsafe for one is unsafe for all, while aesthetic and organoleptic characteristics are subject to social, economic and cultural considerations.

Since the majority of consumer complaints regarding water quality relate to its colour, taste or odour, the quality of drinking water, as perceived by the senses, largely determines the acceptability of a particular water.

12.2.7.2 Aluminium

Aluminium does not appear to be an essential nutrient to humans. Compared to the aluminium intake from food, that from water is small. The incidence of discoloration in drinking water in distribution systems increases if the aluminium level exceeds 0.1 ppm.

12.2.7.3 Chlorides

Chlorides are widely distributed in nature and are present in mineral deposits, in seawater and some industrial processes. The taste threshold for chloride in drinking water is dependent upon the associated cation, but is usually within the range of 200 to 300 ppm of chloride. Based on organoleptic considerations, the guideline value for chloride is 250 ppm.

12.2.7.4 Colour

Colour in drinking water may be due to the presence of coloured organic substances, such as humics (decay of vegetation in the water); metals such as iron and manganese; or highly coloured industrial wastes, of which pulp, paper and textile wastes are the most common. Chlorine from the chlorination process is likely to give rise to high levels of trihalomethanes due to the reaction of chlorine with dissolved humic substances.

12.2.8 Heavy metals

12.2.8.1 Introduction

Trace quantities of many metals are important constituents of most waters. Many of these metals are also classified as pollutants. The presence of any of these metals in excessive quantities will interfere with many beneficial uses of the water because of their toxicity.

12.2.8.2 Cadmium

Cadmium is widely distributed in the Earth's crust but is particularly associated with zinc and copper and is produced commercially only as a by-product of zinc smelting. Cadmium shows no signs of being an essential trace element in biological processes; on the contrary, it is highly toxic to the human organism. Like mercury, cadmium and its compounds only enter the environment from geological or human activities (metal mining, smelting and fossil fuel combustion).

Cadmium and its compounds are blacklisted materials, which by international agreement may not be discharged or dumped into the environment. Cadmium is a cumulative poison and a maximum level of 0.005 ppm is permitted for drinking water.

12.2.8.3 Chromium

Most rocks and soils contain small amounts of chromium. Chromium in its naturally occurring state is in a highly insoluble form; however, most of the more common soluble forms found in soils are mainly the result of contamination by industrial emissions.

The major uses of chromium are for chrome alloys, chrome plating, oxidizing agents, corrosion inhibitors, pigments for the textile glass and ceramic industries as well as in photography. Hexavalent chromium compounds (soluble) are carcinogenic and the guideline value is 0.05 ppm.

12.2.8.4 Lead

Lead is not only the most abundant of heavy metals occurring in nature, it was also one of the first metals used on a large scale by humans. Although it is not a nutritionally essential element, its monitoring is important because of its toxicity to human health. Lead is a cumulative poison. Most of the lead produced in metallic form, in batteries, cable sheathing, sheets and pipes, etc., is recovered and recycled, but most lead used in compound form, such as paints and petrol additives, is lost to the environment, eventually ending up in the aquatic environment. Lead compounds, similar to the ones used in petrol additives are reportedly being used in the production of mercurial fungicides. The presence of lead in drinking water is limited to 0.01 ppm.

12.2.8.5 Mercury

Although a comparatively rare element, mercury is ubiquitous in the environment, the result of natural geological activity and human-induced pollution. Mercury from natural sources can enter the aquatic environment via weathering, dissolution and biological processes. Although extremely useful to humans, mercury is also highly toxic to the human organism, especially in the form of methyl mercury, because it cannot be excreted and therefore acts as a cumulative poison. The potential for long-term human health hazards from ingesting mercury-contaminated fish has led several nations to establish regulations and guidelines for allowable seafood mercury levels. Nearly all levels above 1 ppb in water are due to industrial effluents connected with chlorine and caustic soda production, pharmaceuticals, mirror coatings, mercury lamps and certain fungicides.

12.2.8.6 Nickel

Nickel is ubiquitous in the environment. Nickel is almost certainly essential for animal nutrition and, consequently, it is probably essential to humans. Nickel is a relatively non-toxic element; however, certain nickel compounds have been shown to be carcinogenic in animal experiments.

12.2.8.7 Tin

Tin and its compounds are significant and controversial chemicals in the environment. As is the case with other elements, not all chemical forms of tin are equally biologically active. In contrast to the low toxicity of inorganic tin (derived from eating canned foods), some organic tin compounds, also known as organotins, are toxic. Tributyltin and triphenyltin, constituents of anti-fouling paints, are highly toxic and their presence in harbour waters is limited to generally 0.002 and 0.008 ppb respectively.

A new International Maritime Organization Convention prohibits the use of harmful organotins in anti-fouling paints used on ships and will establish a mechanism to prevent the potential future use of other harmful substances in anti-fouling systems. The International Convention on the Control of Harmful Anti-fouling Systems on Ships was adopted on 5 October 2001. However, in many countries, organotin anti-fouling paints are still available from old stocks and the start of the fishing season generally sees an increase of this compound in the water as freshly painted vessels are launched back into the water.

12.2.8.8 Copper

The presence of copper in the water supply, although not constituting a hazard to health, may interfere with the intended domestic uses of water. Copper enhances corrosion of aluminium and zinc fittings, stains clothes and plumbing fixtures. Copper is used in alloys, as a catalyst, in anti-fouling paints and as a wood preservative. Urban sewage contains substantial amounts of copper. The human taste threshold for copper is low, 5.0–7.0 ppm, and the taste is repulsive. The limit for drinking water is 1.0 ppm.

12.2.8.9 Iron

The presence of iron in drinking water is objectionable for a number of reasons unrelated to health. Under the pH conditions existing in drinking water supplies, ferrous salts are unstable and precipitate as insoluble ferric hydroxide, which settles out as rusty silt. Such water tastes unpalatable, promotes the growth of "iron bacteria", and the silt gradually reduces the flow of water in the piping. The recommended guideline level of iron in water is 0.3 ppm.

12.2.8.10 Manganese

Anaerobic groundwater often contains elevated levels of dissolved manganese. The presence of manganese in drinking water is objectionable for a number of reasons unrelated to health. At concentrations exceeding 0.15 ppm manganese imparts an undesirable taste to beverages and stains plumbing fixtures. The recommended value is 0.1 ppm.

12.2.8.11 Sodium

The sodium ion is ubiquitous in water owing to the high solubility of its salts and the abundance of mineral deposits. Near coastal areas, wind-borne sea spray can make an important contribution, either by fallout on to land surfaces where it drains to the water source or from washout by rain. Domestic, commercial and industrial discharges are another source of sodium in water. In general, sodium salts are not acutely toxic substances because of the efficiency with which mature kidneys excrete sodium. The effects on infants, in contrast to adults, are different because of the immaturity of infant kidneys. A maximum of 200 ppm is allowed in drinking water.

12.2.8.12 Zinc

The concentration of zinc in tap water can be considerably higher than that in surface water owing to the leaching action of zinc from galvanized pipes, brass and other zinc alloys. Zinc imparts to water an undesirable astringent taste and in concentrations in excess of 5 ppm water may appear opalescent and develop a greasy film on boiling. Levels of zinc should be kept well below this value.

12.2.8.13 Petroleum hydrocarbons

Humans have a very low taste threshold for petroleum hydrocarbons and the taste is particularly repulsive. All components of crude oil are degradable by bacteria, though at varying rates, and a variety of yeasts and fungi can also metabolize petroleum hydrocarbons. Water-soluble components of crude oils and refined products include a variety of compounds that are toxic. High-molecular-weight tars are less damaging in the water than medium-molecular-weight compounds such as diesel. Low-molecular-weight compounds are generally unimportant because they are very volatile and rapidly evaporate. Therefore, a diesel spillage at sea is more damaging than crude oil (very tarry) or petrol spillage. For harbour basin water, the limit for dissolved hydrocarbons should not exceed 0.30 ppm. Polluted harbour water can impart an unpleasant flavour to fish if used for washing. Commercial fishermen may also risk tainting a whole catch if their nets have been fouled by diesel or oil.

12.2.8.14 Sulphates

Sulphates are widely distributed in nature and excessive amounts of dissolved sulphates in drinking water lead to problems with hardness. Taste threshold concentration for the most prevalent sulphate salts are: 200 to 500 ppm for sodium sulphate; 250 to 900 ppm for calcium sulphate; and 400 to 600 ppm for magnesium sulphate. In drinking water, dissolved sulphates are limited to 400 ppm.

12.2.8.15 Hardness

Water hardness is the traditional measure of the capacity of water to react with soap, hard water requiring a considerable amount of soap to produce lather. The degree of hardness of drinking water has been classified in terms of its equivalent $CaCO_3$ concentration as follows:

Soft	0–60 ppm
Medium hard	60–120 ppm
Hard	120–180 ppm
Very hard	180 and above

Soft water has a greater tendency to cause corrosion of pipes and, consequently, certain heavy metals such as copper, zinc, lead and cadmium may be present in the water.

Very hard water, on the other hand, can cause considerable incrustations in pipes and fittings, especially in fish processing plants.

12.2.8.16 pH

The value of the pH, expressed as a value ranging between 1 and 10, is a good indicator of the state of the water. Values of 9.5 and above are alkaline in taste. Values of 3 and below are acidic in taste. Values lower than 6 cause problems with corrosion. Values below 4 support little life in a marine environment. Drinking water should have a pH in the range 6.5 to 8.5. Harbour water should have a pH of between 6 and 9.

12.2.8.17 Hydrogen sulphide

Hydrogen sulphide occurs as a by-product in septic tanks when proteins in sewage are attacked by certain bacteria. Traces in excess of 0.05 ppm cause taste and odour problems.

12.3 MONITORING

Depending on the actual state of the fishing harbour infrastructure and the environmental conditions obtaining in and around the harbour itself, monitoring tests for contaminants should be carried out according to a specific programme. Unless local sanitary standards are rigidly enforced, typical monitoring programmes should reflect local environmental conditions.

12.3.1 Boreholes

Potable water supplies based on borehole extraction are very susceptible to contamination by sewage, pesticides and salt water intrusion. Contamination may also arise from pollutants entering the water table some distance from the port or from sewage entering the borehole itself in the port area through cracked or corroded casings. In cases where overdrawing is evident (water is brackish), bacterial tests should be run very frequently, say once a week; otherwise, every month. Complete tests should be run every six months.

12.3.2 Municipal mains

It is not uncommon for municipal or mains water supply to be contaminated at source (through malfunctioning or inoperative chlorination equipment) or for the supply to pick up contaminants through corroded sections of a pipeline leading to the fishing harbour. Complete tests should be run every six months and the relevant authorities informed of the results.

12.3.3 Water towers and reservoirs

Both types of structure are susceptible to bacterial growth if the residual chlorine levels in them are low or non-existent. Testing may not be necessary if periodic scrubbing is carried out. If the water tower cannot be decommissioned for maintenance, then bacteria tests should be carried out every six months or so.

12.3.4 Harbour basin water

Typically, harbour basins should be tested once a year. However, in areas where monsoons are very active, it may be advisable to test at the peak of the dry season (when effluent point discharges tend to remain concentrated in the water course) and then again during the wet season (when agricultural runoff may find its way into the water course). Another critical period for harbours is the peak of the fishing season (when most of the fleet is up and running and fuel and oil are discharged from the bilges).

12.3.5 International water standards

The tables given in Appendix 1 and 2 to this chapter illustrate standard water quality parameters for both potable water (World Health Organization) and harbour basin waters (European Union Directives). If harbour basin water is being used for rinsing fish, then it too must satisfy drinking water standards for contaminants.

12.4 PERSONAL HYGIENE AND PORT SANITATION

The standard of personal hygiene of the workers employed inside a fishing harbour depends on both the sanitary infrastructure available and the harbour management in enforcing certain directives. The sanitary infrastructure is made up of:

- toilet facilities (with adequate showers);
- adequate supplies of soap and detergents; and
- appropriate signs and billboards displayed at strategic places.

In general, the sanitary infrastructure should be able to cater for the total number of potential workers within the harbour boundary; this is especially so for harbours with high seasonal landings, where for a period of one to three months in the year the increase in the number of workers may swamp the facilities meant for a low-season workforce.

12.4.1 Sanitary fittings

Toilets should be constructed to the highest standards possible to ensure the maximum lifetime. Poorly built facilities break down very quickly and generally lead to "toilets of opportunity" elsewhere around the port. Toilet facilities should always be properly maintained and full-time manning by attendants is desirable. Toilets should never open on to a work area where fish is being handled due to the risk of flooding from blocked drains. The standard of personal hygiene of the workers employed inside the fishing port depends on the quality of the facilities provided.

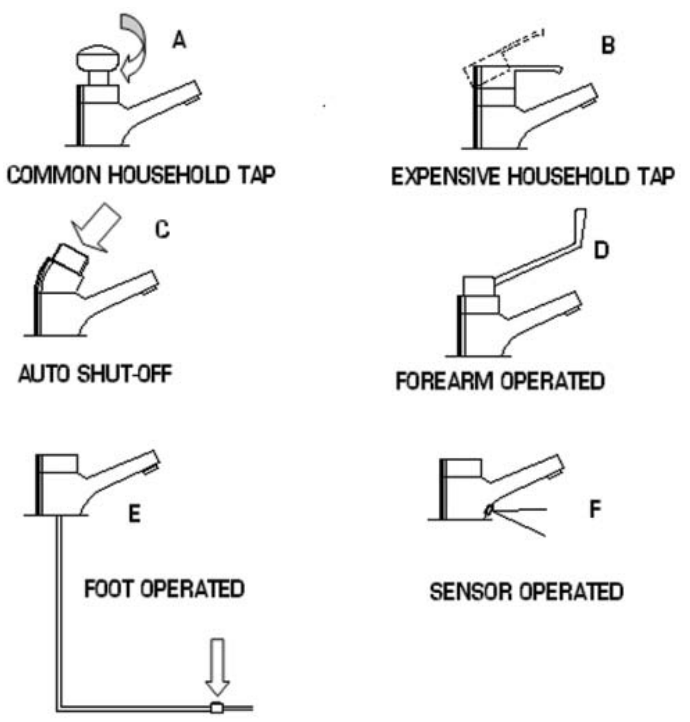
In many developing countries, the major reason for breakdown is not vandalism but incorrect design and specification of the fittings at the design stage, followed by a total lack of supervision during construction and poor operational management and maintenance. The three most common fittings likely to break down prematurely under current design practices are:

- water taps;
- toilet flush systems; and
- shower heads.

It is not uncommon to enter a public toilet facility inside a fishing port and notice that water taps are either inoperable or missing altogether. In all probability, the taps specified would have been the most economical variety of the common household tap. Figure 1 shows the most common types of water taps available on the market today, ranging from the very economical household variety to the more sophisticated sensor operated type. For the fitting to satisfy health hygiene regulations it may not be of the types shown in Figures 1A and 1B because reclosing the tap by hand may retransfer bacteria on to a clean hand. In addition to this, the household taps often specified are not designed for the wear and tear of a public facility. In most public places such as airports, train stations and restaurants, the water taps are of the self-closing type shown in Figures 1C, 1E and 1F. The forearm operated type shown in Figure 1D, typically seen at the doctor's or dentist's clinic, is also suitable and may be more economical than the other types. However, the industry standard is the foot-operated unit as illustrated in Figure 2.

Shower units (shower head and tap) are also problematic, especially if slightly saline or calcium-rich borehole water is in use. Most household shower heads corrode easily as do most wall-mounted valve or tap handles. To ensure a longer lasting unit, all pipes, heads and valves should be in PVC or HDPE plastic. Valves should be of the ball type with few moving parts. Pipework should not be embedded in the walls but fixed externally with appropriate anchor fixings. The internal cubicles of showers should be glazed. Mortar finishes are not suitable for a damp environment.

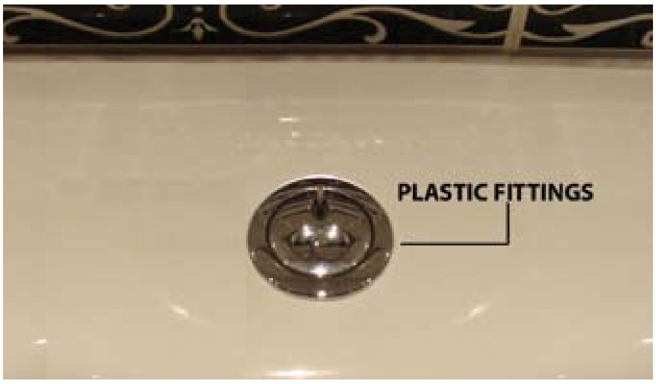
FIGURE 1
Typical types of water taps available



Many types of toilet flush systems are available on the market, but as with the other types of sanitary fittings household varieties are not suitable for repeated use in a public facility. Most household cisterns are very fragile and often break down for the most minor of things (Figure 3).

FIGURE 2
Correct type of water tap recommended

FIGURE 3
Household-type cistern with fragile plastic fittings



12.4.2 Buildings

The building should be simple in layout, airy, brightly coloured and with plenty of ventilation (Figure 4). All the floor drains inside the building should be bar drains placed centrally across the room with water draining away from the walls to prevent flooding (Figure 5). The drains should be in plastic and easily removed to clear blockages.

All toilet facilities should be equipped with lighting to enable use during night-time unloading and auctioning operations. Toilet facilities should be attended, especially in artisanal harbours where the facility may also serve the village residents.

Steel piping in sanitary facilities is gradually being replaced with PVC or HDPE (high-density polyethylene) piping. The obvious advantages over steel are resistance to corrosion and ease of installation and maintenance. However, when installing external pipework, care must be taken to employ a material that is ultraviolet stabilized. Ultraviolet rays from the sun attack certain plastics and the proper material should be specified for all external pipework.

FIGURE 4
Optimal layout of small toilet facility

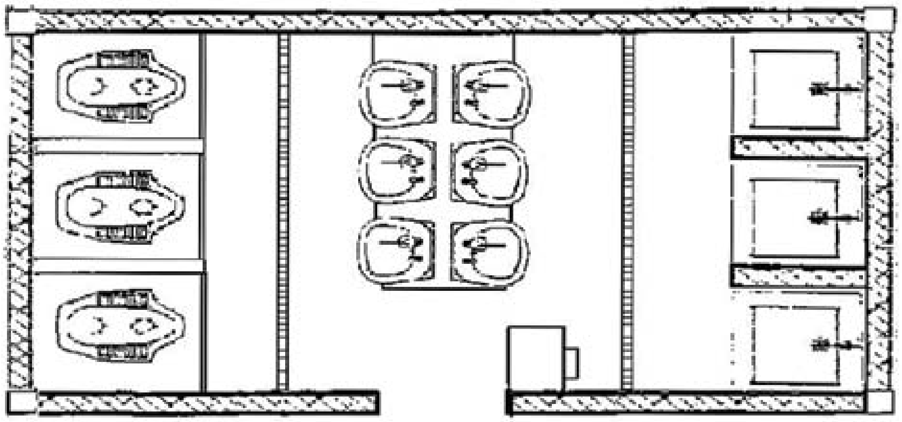
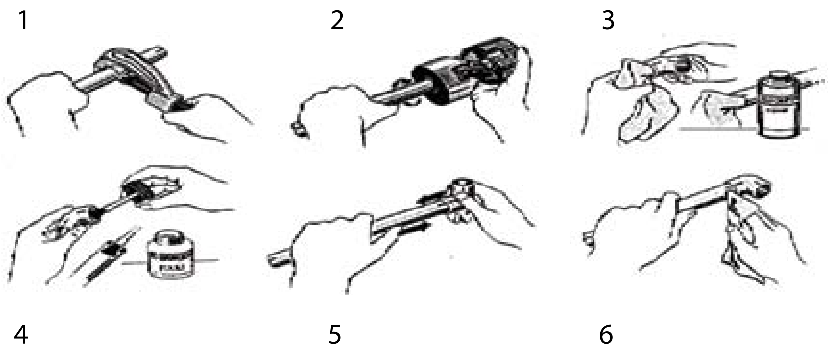


FIGURE 5
Required standard of finish for toilet facilities

Two methods of jointing plastic pipe are available: heat welding or glue. Heat welding involves heating the pipe ends by a small heater similar to a hairdryer and then applying force to weld the seams together. Gluing, however, is now the accepted industry standard because it involves little capital equipment, apart from the glue, Figure 6.

FIGURE 6
Gluing an elbow joint



1. Cutting, 2. Reaming, 3. Cleaning, 4. Application of glue, 5. Fixing, 6. Wiping joint clean

Similarly, repairing a leaking elbow joint or length of pipe is also very quick and needs no special tools, Figure 7.

The traditional bronze or brass gate valves are also being gradually replaced with ball valves, Figure 8. Ball valves are made from resistant plastic with a stainless steel ball valve. They have fewer moving parts and no corrodible fittings.

FIGURE 7
Repairs to a PVC pipe are simple

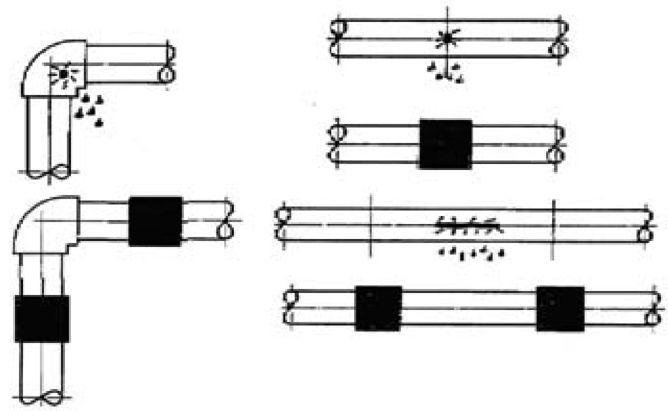
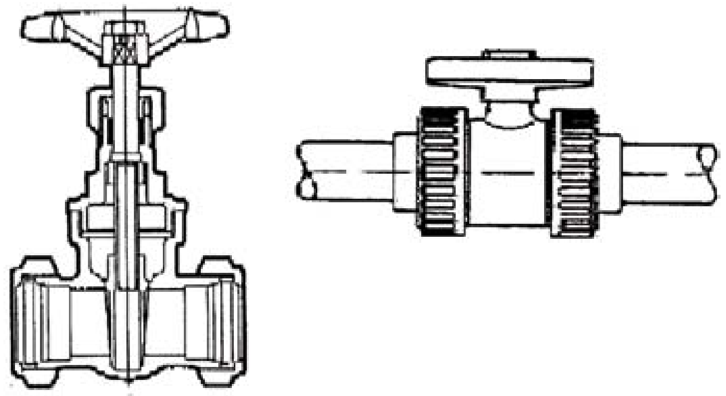


FIGURE 8
Gate valves (left) and ball valves (right))



12.4.3 Signs and billboards

Port sanitation is to the port what personal hygiene is to the workers employed by the port. Appropriate signs and billboards listing food hygiene regulations should form part of the harbour's sanitary awareness infrastructure. These signs should be displayed at all the strategic locations within the port boundary, for example:

- "*NO SMOKING, NO SPITTING, NO EATING*" signs should be posted wherever fish is being handled;
- "*HAVE YOU WASHED YOUR HANDS*?" signs should be posted at all toilet exits.

Adequate signs should also be posted in prominent locations indicating the direction to the toilets. Proper and frequent training of the port workers in personal hygiene should form part of the harbour master's management brief.

Port sanitation is best explained by the following simple regulations:

- All water supplies inside the port boundary should comply with the World Health Organization drinking water standards or national drinking water standards where these are higher.
- All ice, including that brought in from outside suppliers, should also comply with the above drinking water standards.
- All chlorination equipment should be functional and adequate supplies of the chlorination agent should be held in stock.
- All sampling and testing carried out inside the port should be carried out by ISO certified laboratories only.
- Appropriate signs should be displayed within the port area covering, among other things, dumping, spillage, use of seawater from inside harbour basin, spitting, eating areas, prohibited access to domestic animals, etc.
- Appropriate billboards should be displayed at strategic locations listing fines for the contravention of port hygiene rules.
- All drainage systems (indoor and outdoor) should be kept in perfect working order.
- Port perimeter fences should be properly maintained to keep unauthorized people and domestic animals from entering the port area at any time.
- The entrance and exit to a fishing port area should be manned during business hours to prevent unauthorized people from gaining entry to the fish handling areas.
- Disinfection of required areas should be carried out on a regular basis.
- No excessive trash and wet wastes should be left to accumulate in work areas.
- No rodent harbourage should exist in and around the port area (tall weeds, junk piles and municipal rubbish).
- No birds should be nesting inside open-sided auction halls and fish handling sheds.
- Only employees and officially recognized fish traders should be allowed access to work areas during fish handling operations and auctions.
- Toilet and shower facilities should be kept scrupulously clean and in perfect working order.
- Only electrically powered machinery should be allowed inside the auction or handling sheds to prevent oil, petrol and diesel from leaking onto the floors which are sometimes used as auction surfaces for large fish.
- The entire fish handling area should be hosed down properly at the end of business and locked up to prevent unauthorized entry until the next auction.

12.5 SEWAGE TREATMENT

The sewage effluent or wastewater from a fisheries harbour typically consists of three major biologically degradable constituents:

- **Type 1** – effluent from the toilets, faecal matter in water (typically low-volume discharge);
- **Type 2** – effluent from the wash hand basins and showers, soapy water (detergents present, also low-volume discharge); and
- **Type 3** – effluent from the fish cleaning operations, fish blood, scales and fish solids, high-volume discharge.

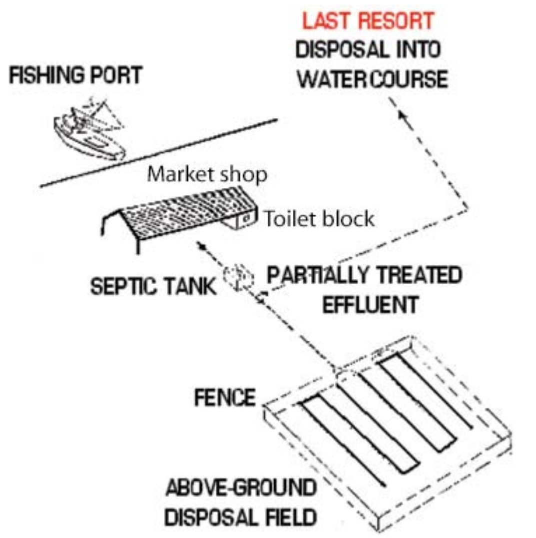
The combined effluent from a fishing harbour should ideally be connected to a municipal sewer to be taken away and treated with normal household sewage. If such a sewer is not available within a reasonably economic distance, then the effluent has to be treated before being discharged into a watercourse. Depending on the size of the fishing harbour, the effluent may be treated either via septic tanks and on-site natural treatment systems (artisanal harbours only) or via a proper sewage treatment plant (coastal, offshore and distant-water harbours). In both cases, adequate space should be provided for the purpose.

12.5.1 Type 1 effluent – artisanal harbours

Artisanal harbours are more often than not situated in areas where basic municipal infrastructure is very primitive or even totally absent; introduction of sophisticated mechanical wastewater effluent treatment systems may also not be a viable option due to the costs involved. Natural treatment systems, on the other hand, may be designed to take advantage of the physical, chemical and biological processes that occur when water, soil, plants, micro-organisms and the atmosphere interact. The processes involved in natural systems include many of those used in sophisticated mechanical treatment systems, such as sedimentation, filtration, gas transfer, adsorption, ion exchange, chemical precipitation, chemical oxidation, and biological conversion and degradation – plus others unique to natural systems such as photosynthesis, photo-oxidation and plant uptake. In natural systems, the treatment process occurs at natural rates and tends to occur simultaneously in a single ecosystem reactor. In a mechanical system, the processes occur sequentially in separate tanks at accelerated rates as a result of energy input. Figure 9 provides a typical solution for artisanal fishing harbours.

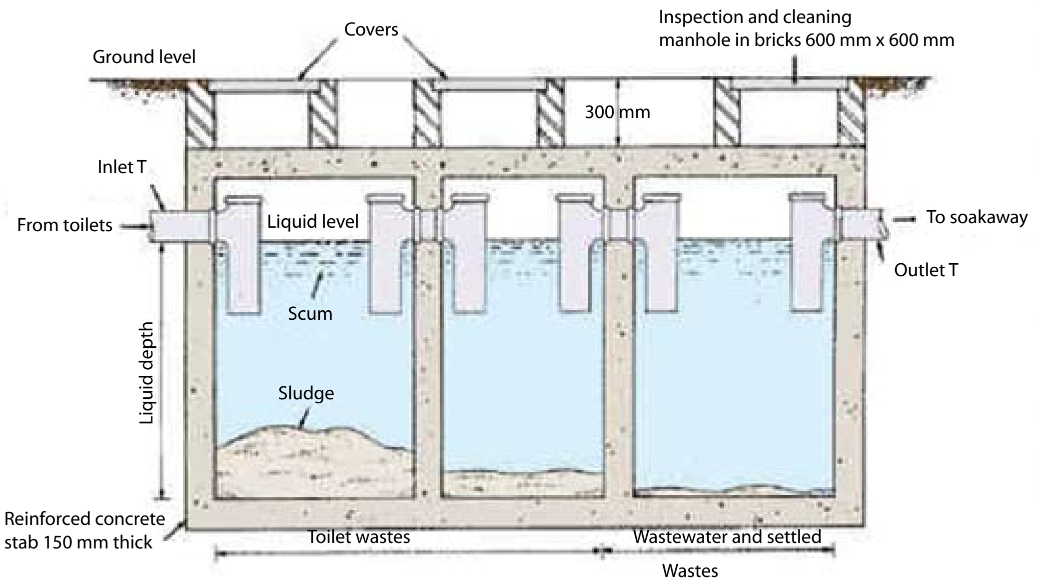
The first stage of a natural treatment system is the septic tank, Figure 10, generally located in or around the harbour and into which all the effluent should be directed. A three-stage septic tank is a rectangular underground chamber divided internally into three compartments. After coarse screening through a basket sump, the effluent is retained inside the compartments for a minimum period of three days; during this period, the solids in suspension settle to the bottom of the first compartment where they are attacked and digested by bacteria. As a result, the volume of sludge is greatly reduced and the effluent clarified to some extent. Appropriate manholes should be provided over each compartment to enable sludge to be removed (pumped out) during maintenance.

FIGURE 9
Typical solution for an artisanal fishing port



The dimensions of the chamber should be such that peak total daily effluent flows are retained for a minimum period of three days inside the tank. Obviously, the larger the volume to be treated, the larger the tank should be. Various methods are available to reduce the volume of water to be treated, such as high-pressure jet cleaners for hosing down operations (largest consumer of water), automatic or spring-loaded taps over wash-hand basins and dual-flush action toilet flushing equipment.

FIGURE 10
Typical three-stage septic tank



The following guidelines may be used when calculating a harbour's total daily effluent flow rate.

Auction hall flow rate

- 1 litre per kilogram of fish landed every day;
- 10 litres per square metre of covered area (reduced to 2.5 litres if a high pressure jet cleaner is used); and
- 10 litres per fish box handled (reduced to 2.5 litres if a high pressure jet cleaner is used).

Toilet and shower facilities flow rate

- 100 litres per person per day (full-time employees + part-time handlers and sellers + crew in port).

Canteen services (hot food cooked on premises) flow rate

- 15 litres per serving per day.

The total volume should be adjusted for peak summer landing conditions when fish handling and visiting crews are at their peak numbers.

The effluent from the septic tank should then be piped for further treatment to one of several types of natural treatment systems and only discharged into a waterway or into the sea as a last resort. Natural treatment systems may consist of one of the following:

- Slow rate treatment (effluent is sprayed or channelled over vegetated land to provide treatment), Figure 11.
- Constructed wetlands – emergent plants (effluent is fed into inundated areas that support growth of emergent plants such as cattail, bulrush, reeds or sedges), Figure 12.
- Constructed wetlands – floating aquatic plants (effluent is fed into inundated areas that support plants of the floating species such as water hyacinth and duckweed), Figure 13.
- Rapid infiltration (effluent is applied intermittently to shallow spreading basins and lost into the ground), Figure 14.

Slow rate treatment, the predominant natural treatment process in use today, involves the application of effluent or wastewater to vegetated land to provide treatment and to meet the growth needs of the vegetation, Figure 11. The applied water is either consumed through evapotranspiration or percolates vertically and horizontally through the soil profile. Any runoff is usually collected and reapplied to the system. This system needs moderately slow soil permeability and in areas of high precipitation needs effluent storage. The effluent may be applied via sprinklers or furrows. Typical area requirements for this system are 15 to 45 acres per million litres of effluent per day.

Two types of constructed wetland systems have been developed for wastewater treatment: free water surface flow systems and subsurface flow systems, Figure 12.

FIGURE 11
Typical above-ground slow rate treatment field

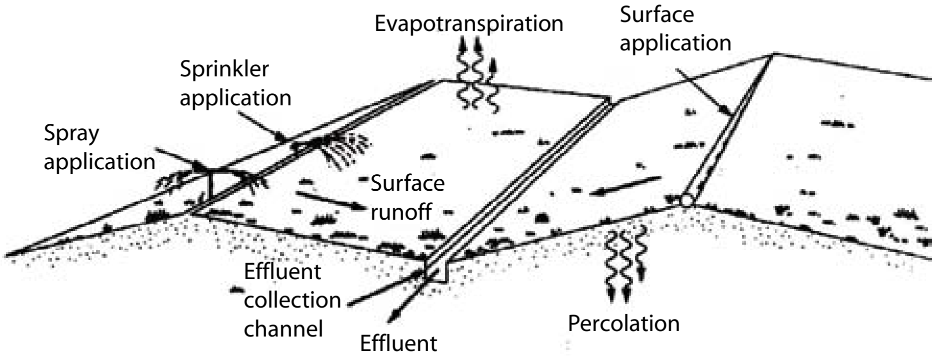
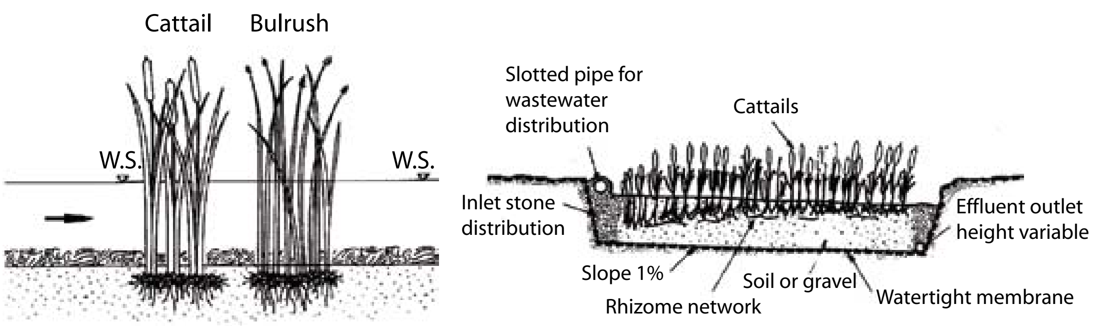


FIGURE 12
Subsurface water flow (right) and free water surface flow (left)

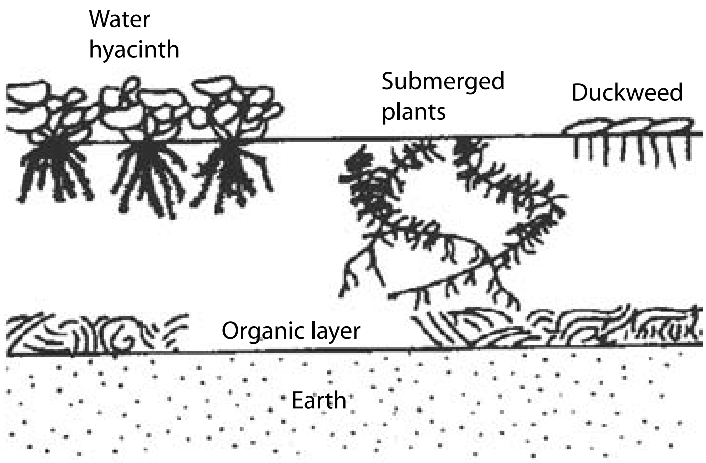


The water depth in this system is typically very shallow, ranging from 0.10 to 0.60 metres. Subsurface flow systems are designed with an objective of secondary or advanced levels of treatment. These systems have also been called root zone or rock reed filters and consist of channels or trenches with relatively impermeable bottoms filled with sand or rock media to support emergent vegetation.

This system is generally classified as a constructed wetland where the effluent may be collected after treatment and reutilized in agriculture. Lack of a free water surface in the subsurface flow system also makes it ideal for areas prone to mosquito infestation. Effluent storage is needed in areas of high precipitation and, typically, 4 to 14 acres per million litres of effluent treated daily are required.

Constructed wetlands offer all of the treatment capabilities of natural wetlands but without the constraints associated with discharging to a natural ecosystem. Floating aquatic plant systems are similar in concept to free water surface systems except that the plants are floating species such as water hyacinth and duckweed. Water depths are typically deeper, ranging from 0.50 to 1.80 metres, Figure 13.

FIGURE 13
Wetland with floating aquatic plants



Supplementary aeration has been used with floating plant systems to increase treatment capacity and to maintain aerobic conditions necessary for the biological control of mosquitoes. For this reason, the ponds should be stocked with mosquito fish. Area requirements are similar to other wetland systems.

In rapid infiltration systems, wastewater effluent is applied on an intermittent schedule usually to shallow infiltration trenches or spreading basins. Vegetation is not usually provided. The evaporative losses in this system are only a small fraction of the applied water and, hence, most of the applied effluent percolates through the soil profile where treatment occurs. The treatment potential of rapid infiltration systems is somewhat less than that for slow rate systems because of the lower retention capacity of the soil and relatively higher inflow of water. In coastal areas, where the groundwater level is high or the underlying strata not permeable enough, pressure-dosed field trenches have been successfully used, Figure 14. Pressure distribution, which serves to distribute the effluent evenly over the sand in the trench, is a key factor contributing to the success of this type of disposal.

FIGURE 14
Sand-filled trench

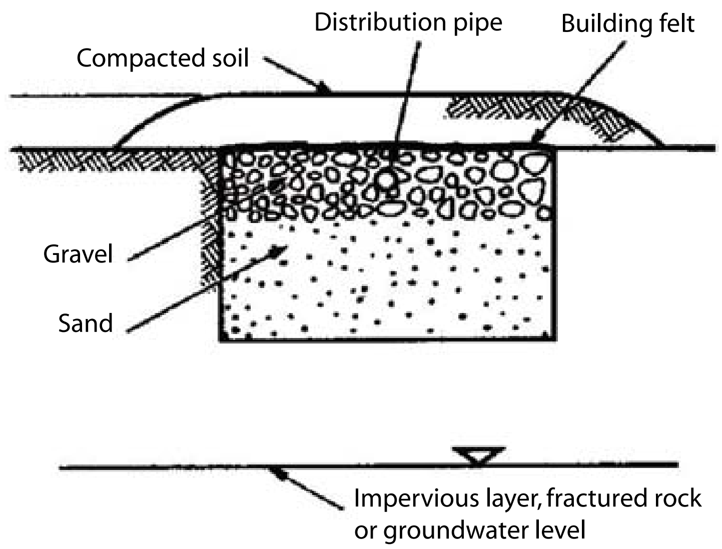
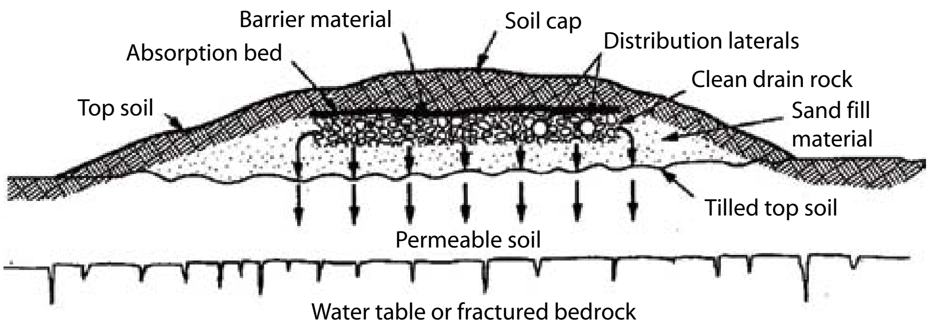


FIGURE 15
Mound system



The mound system, Figure 15, is essentially an intermittent sand filter that is placed above the natural surface of the ground. The effluent in this system is pumped from the septic tank through a piped pressure distribution system placed at the apex of the gravel layer. Mound systems have been used in areas where the soils are permeable and the water table very high or the soils not permeable at all. The system works well only if the water accumulated under the mound can be pumped away. This system requires mechanical pumping at all stages of the treatment and may not be suitable in areas which lack a steady power supply.

Which system is the most suitable?

This question cannot be answered until the site has been evaluated. The principal considerations in the design of a natural wastewater treatment system are:

- a preliminary site assessment;
- detailed site evaluation; and
- assessment of the hydraulic assimilation capacity of the terrain.

The preliminary site assessment should consider the geomorphological features of the area, such as surface slopes, existing marshes or wetlands, flooding potential, groundwater extraction, water-table levels and landscaping.

The detailed site evaluation should include identification of the soil characteristics, percolation coefficients and hydrogeological characterization of the area.

From these investigations it should be possible to determine the hydraulic assimilation capacity of the area, i.e. the suitability of the area to receive septic tank effluent without jeopardizing the environment and public health.

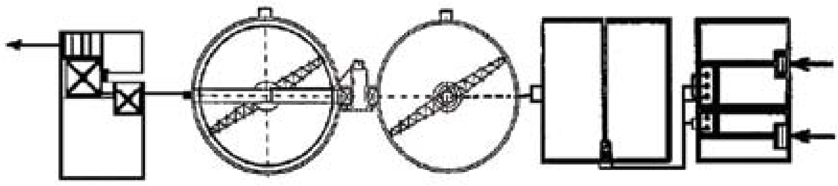
Freshwater should be utilized in the toilet flushing system when septic tanks are used for treating wastewater. The presence of seawater (up to 30 percent) in the raw effluent decreases the efficiency of the bacterial decomposition of the sludge. Beyond 50 percent of seawater, bacterial decomposition is seriously compromised.

12.5.2 Type 1 effluent – other ports

Other harbour installations situated away from municipal centres should install proper sewage treatment plants which can handle a larger volume of water and produce an effluent which may be discharged directly into a watercourse. Depending on the required degree of purity of the effluent, a sewage treatment plant (Figure 16) may consist of:

- screening and disintegration (removal of major solids);
- sedimentation (to settle out organic solids into sludge);
- biological filtration (over a pebble bed inside circular tanks); and
- tertiary treatment such as micro-straining, aeration and upward flow rapid gravity sand filters.

FIGURE 16
Typical modern sewage treatment plant



In small plants, screening for large solid matter which may interfere with pipe flow is generally carried out with manually racked bar screens at 60° to the flow.

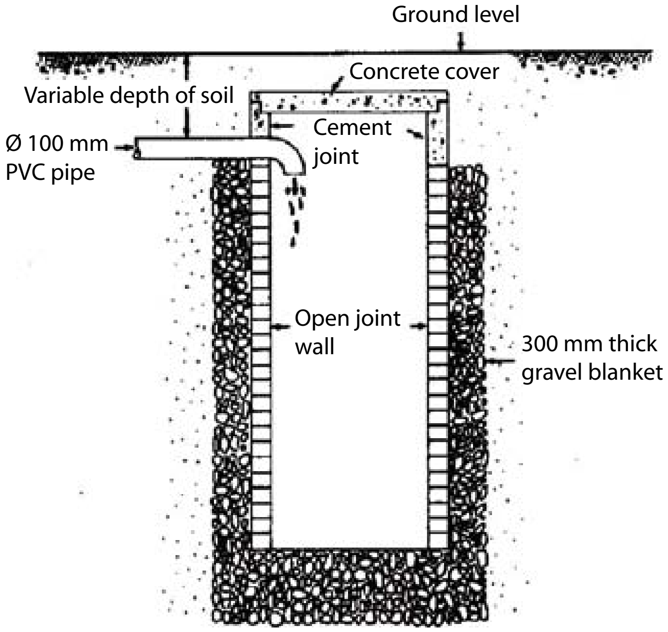
The rest of the organic solids are then macerated by means of a special pump and the fluid pumped into long sedimentation tanks; there, the drop in velocity allows some of the suspended matter to settle as sludge which is then removed periodically, dried and disposed of (buried, burned or dumped offshore). The biological treatment is achieved by spraying the liquid from the sedimentation tanks over a pebble bed by slow-moving rotating arms. Here, biological oxidation takes place (aerobic digestion) by micro-organisms in the slime covering the stone pebbles. If further treatment is necessary, the fluid is then pumped into a tertiary treatment section; otherwise, the liquid is pumped to an outfall which should be located a distance away from the harbour.

12.5.3 Type 2 effluent – wash-hand basins

In artisanal ports, where the sewage is treated through a septic tank, the effluent containing detergents from the wash-hand basins and the shower units may be discharged into a soakaway away from the septic tank or to a constructed wetland (Figure 17).

Although soakaways have the potential to drastically reduce the volume of sewage to be treated, they are only suitable for sandy terrain and their location must be such that it does not contaminate drinking water borewells.

FIGURE 17
The soakaway



12.5.4 Type 3 effluent – market floor runoff

Market, auction and processing floors are generally hosed down using copious amounts of water; the water may contain both solids (fish scales, discards, entrails, etc.) and liquids (blood and fish oils). This runoff is not a health hazard in itself but rather a nuisance; it may indirectly attract pests to the food handling area, such as flies. Before entering the drainage system, this runoff should be channelled to a basket drain to separate all the solids which may otherwise cause blockages in the drainage system. The basket drain should be in stainless steel or plastic and easily accessible for cleaning. Moreover, due to the large volume of water involved, this runoff should preferably never be mixed with the toilets effluent as this will appreciably increase the flow rate through the septic tank. This runoff water is best diverted to a soakaway, and if clean seawater is used for this purpose, then an adequate outfall should be installed to channel it directly back into the sea.

In larger installations it may still be uneconomical to channel this large volume of runoff to the treatment plant as this will increase the basic cost of treatment for all effluent. If environmental conditions permit (absence of sharks, outfall placed outside the harbour basin, strong currents present near shore, etc.), this runoff may also be channelled directly into the sea via a long underwater outfall.

An alternative solution to the dilemma of the increased volume of water is to reduce drastically the volume of runoff at source, i.e. at the handling halls and this may be achieved by the use of high-pressure cleaning equipment.

Small compact high-pressure cleaners manage to clean a surface using about one fifth to one fourth of the volume of water normally used by a common 20 mm diameter hose. The potential savings in water consumption may outweigh the cost of the electric power (3 to 5 Kw) required to operate the cleaners, Figures 18 and 19. Most cleaners come equipped with a small container to inject disinfectant (bleach) into the water jet, a useful requirement for washing and sterilizing fish boxes simultaneously.

FIGURE 18
A typical mobile high-pressure cleaner for use in auction hall

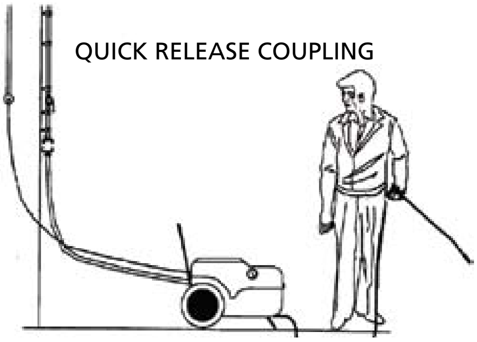
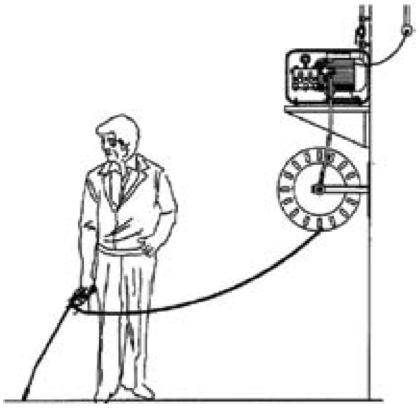


FIGURE 19
A typical wall-mounted high-pressure cleaner for fish box washing




12.6 PORT WASTES[2]

Apart from sewage, a port's waste stream consists of five different types of wastes which may be broadly classified as toxic and non-toxic. The toxic wastes are:

- batteries;
- spent engine oil and bilge water oil; and
- contaminated spares and consumables.

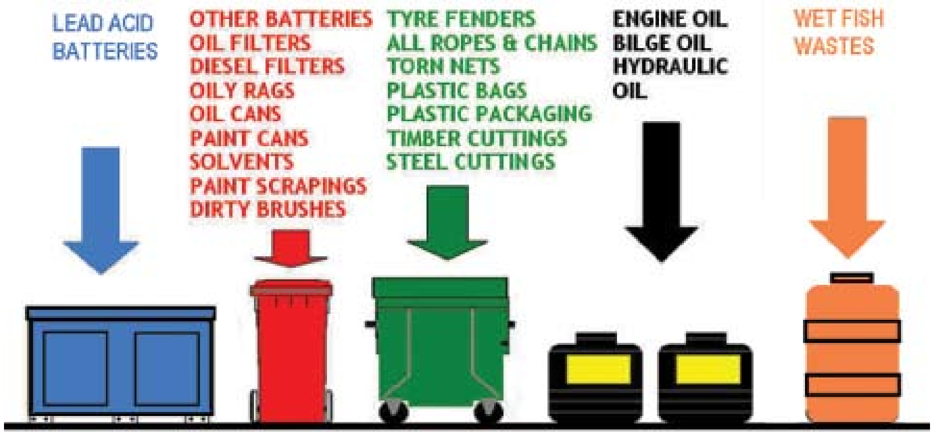
The non-toxic wastes are:

- plastic consumables and dunnage, including nets; and
- wet fish wastes.

Figure 20 indicates the layout and colour coding used in most countries to distinguish between the different waste streams.

[2] The port planner should keep abreast of debates at the IMO Committee on Flag State Implementation with regard to facilities to be provided by port States.

FIGURE 20
A fishing port's waste stream



12.6.1 Batteries

Rechargeable lead-acid batteries contain plates of lead immersed in sulphuric acid inside a plastic case. Lead-acid batteries are recyclable and most suppliers take spent batteries back for industrial reprocessing. Sunlight may decompose the plastic casing, so proper on-site storage of spent batteries is required to prevent the highly toxic contents from spilling out (Figure 21).

FIGURE 21
Abandoned battery with split casing (left) and the recommended battery on-site storage container (right)

12.6.2 Spent oil

Oily wastes discharged to reception facilities are usually mixtures of oil, water and, in some cases, solids. The composition ratio of these solids can differ considerably, depending on the type of wastes. Waste oil and fuel residues consist mainly of oil contaminated with water, whereas bilge water consists mainly of water contaminated with oil. Waste oil may be 100 percent recycled and in many countries it is now mandatory to collect used oil from different sources for recycling. Reception facilities for used engine oil inside harbours, Figures 22 and 23, are intended as a temporary storage only, whereas the reception facilities for bilge water need to separate the oil from the considerably larger volume of water. This oil can then be transferred to the used oil storage facilities for collection at a later date and the treated water returned back to the sea.

FIGURE 22
Used oil drums may be converted to spent-oil storage in artisanal ports

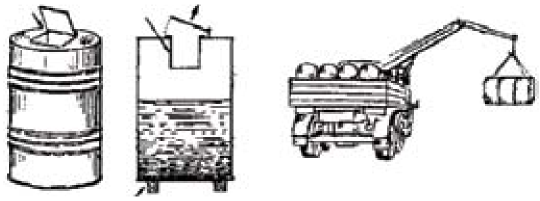
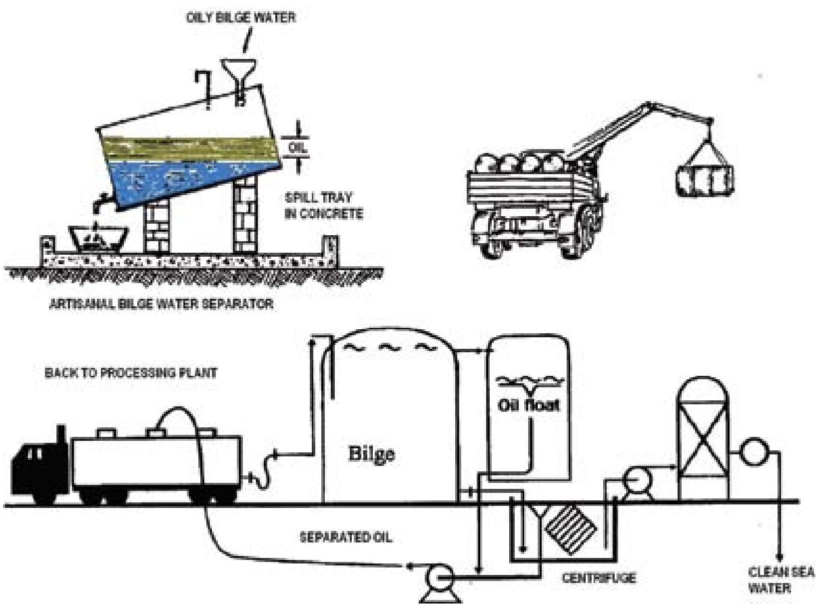


FIGURE 23
Artisanal storage (left) and modern storage equipment (right)

12.6.3 Bilge water separation

Oily bilge water is normally found on inboard motorized fishing vessels and consists of engine oil (leaked out from the engine) mixed with seawater (leaked into the vessel from various sources including around the propeller shaft of many vessels), and if left standing still long enough, the oil fraction separates from the seawater and coalesces on the surface. Bilge water should not be dumped overboard but collected at the port for separation and eventual recycling of the oil fraction. The separated seawater may be returned to the sea. Both artisanal and commercial separators are available, Figure 24. Many of the larger fishing vessels are equipped with oily water separators;

FIGURE 24
Oily bilge water separators



the oil being returned to a holding tank and the water pumped overboard. If the oil (often a mixture of lubricating oil and fuel oil) cannot be clarified and purified on board (for further use) it has to be discharged ashore when in port for treatment. Figure 25 shows a modern vertical oil coalescer.

FIGURE 25
Modern vertical oil coalescer in plastic (no moving parts)

12.6.4 Solid waste bins

Non-toxic solid waste comprises all kinds of bulky items such as old tyre fenders, pieces of rope and netting, broken fish boxes, etc. The equipment for handling this waste should facilitate the reception, segregation and temporary storage. Part of this waste may be recycled. However, the actual processing should not take place inside the port. Disposal of this waste may be handled by municipal waste services.

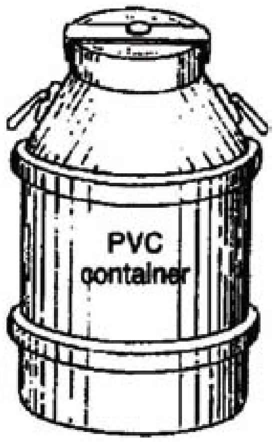
Toxic solid waste comprises normal batteries, oil filters, engine spares, oil and paint cans, solvents, oily rags, etc. None of this waste is normally recycled and this waste is not normally handled by municipal services. This waste must not be sent to a municipal landfill but must be disposed of in a hazardous waste landfill.

The receptacle capacity should match the demand, both in terms of size and number of receptacles that are required and space availability. Small receptacles such as barrels or oil drums are not suitable for bulky items. Household garbage from neighbourhood communities should not be dumped inside the port facilities. In practice, it may be found that both open top and closed containers are needed, especially in areas where wind is very strong and where common garbage is generated inside the port and cannot be stored in open top skips due to the presence of pests (cats and dogs) (see Figure 26).

FIGURE 26
Solid waste bins

12.6.5 Wet waste bins

FIGURE 27
Air-tight PVC container



In theory, fish should be cleaned and gutted on board the fishing vessels on their journey back to port and dumped out at sea where it provides food for other fish. In practice, however, much cleaning and gutting still goes on inside harbours and it is well worth installing reception facilities for the collection and eventual disposal of wet wastes. Irrespective of the size of the harbour, the best receptacle to use is an airtight PVC drum (Figure 27).

These airtight containers should be placed at vantage points all round the fish handling areas. They should be placed in cool sheltered spots away from direct sunlight to avoid rapid decomposition of the fish. The disposal methods for wet wastes are various and all appear to produce the desired result, i.e. removal of wastes which may attract pests or vermin. The following methods are practiced in various countries:

- burial of limited quantities to produce fertilizer;
- reloading on designated vessels for offshore dumping (a minor fee is levied on the landings to pay for this service); and
- privatizing the service via a concessionary agreement with an animal feed cottage industry.

12.6.6 Flotsam collection and disposal

Whether a fishing port is located inside a river mouth or on an open coastline, flotsam inevitably finds its way into the harbour area. This floating debris may consist of:

- natural flotsam such as branches, logs, seaweed, etc.; and
- rubbish caused by humans including fishing netting, wet fish wastes, carcasses of domestic animals, household plastic litter and spilt oil.

Besides being a hazard to navigation, some of this material may also be a hazard to public health (raw harbour water may be in use for rinsing fish) and should be removed. Depending on the particular site conditions, the flotsam should be gathered and disposed of in the proper manner. Figure 28 illustrates a vessel designed to scoop up flotsam.

FIGURE 28
Self-propelled flotsam scooper

Figure 29 illustrates how two fishing vessels trawling in tandem (pair trawling) can scoop flotsam over a wide area. The net, suitably buoyed with plastic floats, is towed across by two fishing vessels proceeding at a low steady speed. The flotsam in the net may then be brought ashore for sorting and disposal.

FIGURE 29
Tandem trawling for flotsam by two vessels

12.6.7 Fuel and oil spill response

Diesel fuel may leak into the harbour basin through careless handling during the refuelling operations and engine oil may be pumped out during the emptying of the bilges. All fishing ports should be equipped with a standard oil spill response package consisting of disposable oil spill booms and absorbent pads, disposal bags, latex gloves and plastic barrels for the sealed disposal of the oil-soaked disposable items (Figure 30). The port management staff should be instructed in the proper handling of fuel and trained in emergency oil-spill management.

FIGURE 30
Disposable oil-spill response equipment

12.7 PEST CONTROL

In many developing countries it is not uncommon to see domestic animals wandering about the fishing port or landing site. Some animals, such as goats and poultry, are sometimes purposely kept whereas dogs and cats move in to mop up scraps of food left lying around. It is also very common for rodents and houseflies to invade such places, especially when fish is part-processed (dried) inside the port area. Birds also find shelter and ideal roosting places among the roof trusses of the old-fashioned type sheds. Table 2 presents the best practice options for pest control.

TABLE 2
Best practice options for pest control

Type of nuisance	Type of issue	Best practice option
Rodents	Infrastructure-Management	Provide receptacles for wet wastes and enforce housekeeping
Flies	Infrastructure-Management	Provide net-covered hangars and enforce use
Birds nesting inside fish-handling shed	Infrastructure	Install netting or false ceilings under trussed roofs. New roofs should be of a flat slab design or trussless
Cows, dogs, goats and cats	Infrastructure	Install fence and controlled access

12.7.1 Rodents

The best method to keep rodents at bay is strict housekeeping. Wet-waste bins, as illustrated in Figure 27, should be made available all round the port area and all fish wastes disposed of properly. Strict housekeeping rules must be enacted and enforced. All unwanted fish carcasses (Figure 31) must be removed immediately and haphazard use of the port area for slaughtering large fish should be forbidden.

FIGURE 31
Abandoned fish carcasses and uncontrolled processing inside port area

12.7.2 Flies

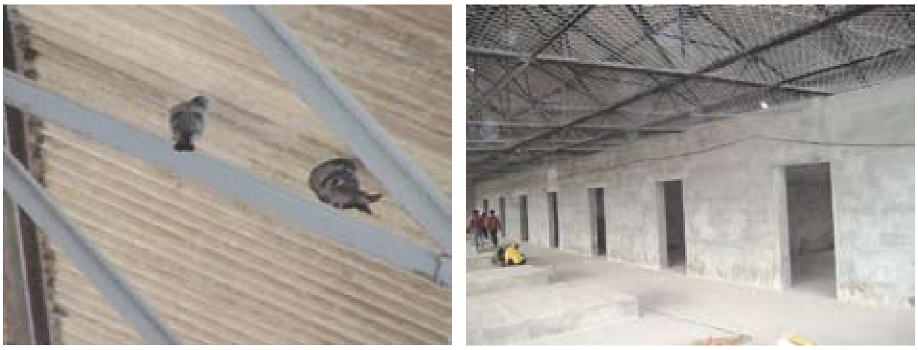
Fish drying in the open air invites flies to lay eggs in the exposed flesh rendering the finished product unhygienic. Fish drying should take place under a netted steel or aluminium structure as illustrated in Figure 32. These structures are commonly used in fish farming.

FIGURE 32
Net-covered metal framework suitable for fish drying or smoking

12.7.3 Birds

All port structures with open trussed roofs offer birds ample opportunities for roosting and building nests. Bird droppings on the working surfaces below present a hygiene hazard, especially if the fish is exposed during sorting or icing. All such structures should be made bird proof by installing wire or plastic netting on all the undersides and ensuring that all the roofing panels are intact (Figure 33).

FIGURE 33
Pigeons nesting on a truss (left) and a bird-proofed truss (right)



12.7.4 Domestic animals

Domestic animals should not knowingly be kept inside port and fish landing areas and fresh meat markets should not be allowed within the port or landing area. The major requirements for controlling domestic animals around a port are illustrated in detail in Chapter 11 and consist of:

- controlled main entry gate;
- cattle grid; and
- perimeter boundary wall.

The boundary wall should not take the form of a fence as this is easily breached to create shortcuts. The first metre of wall off the ground should be solid masonry and this may be topped by a steel or wire fence as illustrated in Figure 53 in Chapter 11.

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APPENDIX 1

WORLD HEALTH ORGANIZATION
MAXIMUM ALLOWABLE LIMITS FOR DRINKING WATER STANDARDS

PARAMETER	UNIT	LIMIT
Aluminium	mg Al/l	0.2
Arsenic	mg As/l	0.05
Barium	mg Ba/l	0.05
Berylium	ug Be/l	0.2
Cadmium	ug Cd/l	5.0
Calcium	mg Ca/l	200.0
Chromium	mg Cr/l	0.05
Copper	mg Cu/l	1.0
Iron total	mg Fe/l	0.3
Lead	mg Pb/l	0.01
Magnesium	mg Mg/l	150.0
Manganese	mg Mn/l	0.1
Mercury	ug Hg/l	1.0
Selenium	mg Se/l	0.01
Sodium	mg Na/l	200.0
Zinc	mg Zn/l	5.0
Chlorides	mg Cl/l	250.0
Cyanide	mg Cn/l	0.1
Fluorides	mg F/l	1.5
Nitrates	mg NO_3/l	10.0
Nitrites	mg NO_2/l	-
Sulphates	mg SO_4/l	400.0
Suphides	mg H_2S/l	0
TOTAL "drins"	ug/l	0.03
TOTAL "ddt"	ug/l	1.0
Hydrocarbons	mg/l	0.1
Anionic detergents	mg/l	0
pH		6.5 – 8.5
Total dissolved solids	mg/l	500
Total hardness	mg/l	500
Alkalinity	mg/l	500

MICROBIOLOGICAL PARAMETERS		
Total bacteria	Count/ml	100
Coliform	Count/100 ml	0
E. Coli	Count/100 ml	0
Salmonella	Count/100 ml	0

ug = microgram

mg = milligram

APPENDIX 2

EUROPEAN UNION DIRECTIVES
SUGGESTED ALLOWABLE LIMITS FOR
ESTUARY AND HARBOUR BASIN WATERS

PARAMETER	UNIT	VALUE
Mercury	ug Hg/l	0.50 (D)
Cadmium	ug Cd/l	5.00 (D)
Arsenic	mg As/l	0.50 (G)
Chromium	mg Cr/l	0.50 (G)
Copper	mg Cu/l	0.50 (G)
Iron	mg Fe/l	3.00 (G)
Lead	mg Pb/l	0.50 (G)
Nickel	mg Ni/l	0.50 (G)
Zinc	mg Zn/l	50.00 (G)
Tributyltin	ug /l	0.002
Triphenyltin	ug /l	0.008
Aldrin	ug /l	0.01
Dieldrin	ug /l	0.01
Endrin	ug /l	0.005
Isodrin	ug /l	0.005
TOTAL "drins"	ug /l	0.03
TOTAL "ddt" all 4 isomers	ug /l	0.025
para-ddt	ug /l	0.01
Hexaclorocyclohexane	ug /l	0.02
Carbon tetrachloride	ug /l	12.0
Pentachlorophenol	ug /l	2.0
Hexachlorobenzene	ug /l	0.03
Hexachlorobutadiene	ug /l	0.10
Chloroform	ug /l	12.0
Ethylenedichloride	ug /l	10.0
Perchloroethylene	ug /l	10.0
Trichlorobenzene	ug /l	0.40
Trichloroethylene	ug /l	10.0
Hydrocarbons	ug /l	300.0 (G)
Phenols	ug /l	50.0
Surfactants	ug /l	300.0 (G)
Dissolved oxygen	% Saturation	80-120 (G)
pH		6 - 9
Sulphide	mg /l	0.04 (S)
MICROBIOLOGICAL PARAMETERS		
Faecal coliforms	per 100 ml	2 000
Total coliforms	per 100 ml	10 000
Salmonella		0
Entero viruses		0

ug = microgram
mg = milligram
D - Dissolved
G-Guideline
S-Suggested

Annex 1

FAO Technical Guidelines for Responsible Fisheries – Fishing Operations – 1 (Annex VI)

Annex VI. Procedures for the Development and Management of Harbours and Landing Places for Fishing Vessels

A. INTRODUCTION

1. The increasing problems associated with the construction of new harbours and landing places for fishing vessels and, in particular, their operation and maintenance, reached critical levels in some parts of the world. In many instances, the adverse effects of harbour pollution from the activities of fishing vessels as well as those of vendors and processors was exacerbated by the almost total lack of reception facilities. Matters became more serious in the late 1980s with an ever-increasing demand for assistance from developing countries to solve specific problems with existing harbours as well as for help in designing new installations.
2. In the Bay of Bengal subregion, the matter gave great cause for concern and, with the cooperation of the International Maritime Organization (within its cleaner seas programme), the Bay of Bengal Programme (BOBP) commissioned a series of important studies. At the same time, FAO also embarked on the preparation of a manual in relation to harbours and landing places to give guidance on design, construction and maintenance of harbours and landing places. An important component of this manual dealt with the reduction of pollution.
3. In connection with the activities of the BOBP, the Government of Malaysia hosted a subregional workshop at Penang, 9-11 December 1991, at which the results of the studies carried out by the BOBP project were presented. The FAO secretariat reported on its activities in other regions and IMO highlighted developments with regard to MARPOL.[1]
4. At the United Nations Conference on Environment and Development (UNCED), June 1992, in relation to the protection of the marine environment, the need for a precautionary and anticipatory approach rather than a reactive approach was seen to be necessary to prevent degradation of the marine environment. UNCED recommended, *inter alia*, the adoption of environmental impact assessment procedures.
5. In recent years, environmental auditing has become an accepted norm for development within coastal areas. It ensures that a State, in consultation with the promoter of a project proposal, can jointly make an assessment of a project and the effect of the planned activities with regard to any significant adverse impact upon the environment. The auditing mechanism also provides for a preliminary assessment or partial audit, on the basis of which a government can decide whether or not to go ahead with a proposal. It also provides the basis

[1] International Convention for the Prevention of Pollution from Ships 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78).

for a decision with regard to a full environmental audit. In addition, taking into consideration the size and cost of the project, as well as the practicality of the exercise, it can provide the terms of reference for the full audit.

6. Although it was apparent from the studies undertaken by the BOBP and FAO, that impact assessments with respect to coastal development seemed to be a matter of common sense, the reality of the matter indicated otherwise. Similarly, the level of cooperation between users of the coastal area often fell far short of what was needed.
7. Therefore, in the preparation of this Annex, account has been taken of the requirement for better systems of management identified by the BOBP workshop in Penang, recent developments in the implementation of MARPOL with regard to cleaner harbours (port reception facilities), Agenda 21 of UNCED and Articles 8 and 10 of the Code of Conduct for Responsible Fisheries (the Code).

B. STANDARD PROCEDURES

1. General Provisions

1.1 Within the concepts of responsible fishing operations and the integration of fisheries into coastal area management, this Annex provides a technical framework for the implementation of procedures as an aid to the management and development of harbours and landing places for fishing vessels.

1.2 Provisions are made for the formulation and implementation of environmental audits for future fisheries related infrastructure projects.

1.3 Although forming a part of the Code of Conduct for Responsible Fisheries, that is voluntary, some provisions of this Annex may be or have already been given binding effect by means of legal instruments, such as UNCLOS 82[2], the Montreal protocol[3] and MARPOL 73/78.

2. Scope And Objectives

2.1 The proposed procedures are global in scope, and directed towards all persons, whether in government or the private sector, involved in the planning, design, construction, maintenance and management of harbours, harbour infrastructure and landing places for fishing vessels.

2.2 The objective is to enhance the capacity of States to ensure the adoption of environmentally sound development, management and conservation practices through:

a) better standards of management in harbours and landing places for existing and future facilities;
b) the establishment of environmental auditing procedures and design criteria related to future fisheries infrastructure projects; and,
c) appropriate training and education in environmental awareness.

3. Management

3.1 States should ensure that an appropriate legal and institutional framework is adopted to manage coastal zone development.

3.2 The fisheries sector should be an integral part of the coastal zone management arrangements in order to ensure that:

a) due account is taken of the rights of coastal fishing communities and their customary practices to the extent compatible with sustainable development; and,

[2] United Nations Convention on the Law of the Sea of 10 December 1982.
[3] Montreal Protocol to the Vienna Convention.

b) that the fisheries sector, together with fishing communities are consulted in the decision making process regarding fisheries related projects as well as providing for their inputs in non-fisheries activities related to coastal area management.

3.3 States should take measures to establish effective management bodies at the fish landing or harbour levels to ensure:

a) compliance with the laws, regulations and other legal rules governing the duties of a port State in relation to a fishing harbour or a fish landing facility;
b) compliance with environmental conservation and monitoring measures adopted by the competent authorities at the national level as well as measures adopted on a regional or subregional basis;[4]
c) integration with other users (as in the case of a non-exclusive facility for fishing vessels); and,
d) transparency in the decision making process.

3.4 In establishing a management body, the competent authorities should ensure that such bodies:

a) are adequately funded to function as intended;
b) represent the whole spectrum of users of the facility;
c) allow for consultation between the various users;
d) are commensurate with the size of the facility and the duties of the body and the responsibilities assigned to it.

3.5 At the village level, the management could be entrusted to a Community Fishery Centre (CFC) or similar organization of fisherfolk. Although the facilities and services within a particular village or area may be quite modest, there is still a need for an organized form of management.[5]

3.6 At the industrial level, the management should be implemented by a well defined body (Private, Autonomous, Municipal or State), with the members drawn from the various constituent users of the port as well as the community at large. An exception to the rule would be where the facilities are owned by a single company. Nevertheless, the company would remain accountable, within the overall management structure, for its operations.

4. Environmental Auditing Procedures

4.1 States should ensure that development proposals are formulated in a precautionary rather than a reactive manner to minimize unwarranted degradation of the aquatic environment.

4.2 States should also establish procedures for the inclusion of future development proposals for harbours and landing places for fishing vessels into national development plans, and where applicable, fisheries or coastal zone management plans. These procedures should be sufficiently flexible to accommodate requests for proposals within a programming period which may arise, for instance, as a consequence of unforeseen changes in the fisheries sector, including natural disasters.

4.3 States should also ensure that all such proposals are supported by clearly defined justifications.

4.4 States should adopt environmental audits in support of all applications for construction or improvement of harbours or landing places for fishing vessels, whether in coastal zones or inland waters.[6]

[4] The provisions or regional or subregional agreements to which the coastal State is a party would normally be incorporated in national legislation.

[5] See FAO guidelines for the establishment and operation of Community Fishery Centres.

4.5 The auditing procedures required for carrying out a full environmental audit in compliance with commonly accepted standards, should:
   a) assess the existing environment, including the land-use characteristics and socio-cultural activities at the proposed site;
   b) list the planned changes to be made to the environment by the proposed project;
   c) estimate the anticipated impact of the planned project on the existing environment[7];
   d) propose mitigation measures to prevent (or mitigate) the anticipated impact on the existing environment; and,
   e) establish a system of environmental monitoring in the vicinity of the project site.

4.6 In order to commence an auditing process, States should ensure that all applications submitted in respect of new constructions are accompanied by a detailed outline design of the proposal.

4.7 A detailed outline design of the proposal should be a stand-alone document. It should consist of a detailed description and layout of the project proposal in relation to its surroundings, the anticipated demand on the resources of the area both during construction and operation, together with mitigation and environmental monitoring proposals. The detail in the detailed outline design should be commensurate with the size of the proposed project; the larger the project the more detail required. This document should form part of the environmental audit up and until full planning or building permission has been issued by the competent authorities.

5. Environmental Assessments

5.1 The existing environment around a project site should be assessed through:
   a) onshore topographic and offshore bathymetric maps (down to the 20 metre contour) of the site, covering at least 1 km in each direction along the coast;
   b) aerial imagery of the above-mentioned area with a resolution not smaller than 1:2000 together with any satellite imagery available[8];
   c) details of existing or planned coastal structures within 5 km of the proposed site;
   d) a morphological description of the coastal zone of the site, backed up by a geological description of important local features such as cliffs, sand dunes, beaches, reefs, terraces, rivers, dams on nearby rivers, river mouths;
   e) wave, tide or lake level statistical characteristics including probability tables for extreme conditions;
   f) seasonal variations in rainfall, river flows, water density, water temperature, nutrients concentration and microbial pollution levels;
   g) geological, petrographic and sedimentological characteristics of the coastline and seabed, including source, volume and seasonal changes in littoral transport;
   h) maps of onshore and offshore habitats in and around the project site (coral reefs, lagoon systems, mangroves, estuaries, etc.);
   i) maps of types of habitat in and around the project site (areas of refuge, feeding grounds, nursery and spawning);

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6 Institutional bodies or private sector organizations with the capacity to carry out such audits should be identified.

7 See FAO paper on fishery harbour planning, reference 1.

8 Satellite images are available for many parts of the world. The FAO remote sensing unit and its network of regional stations could provide appropriate reference points.

j) lists of the species to be harvested, lists of protected or rare species and biological indicators as well as the methods of fishing;
k) layouts, size and capacity of resource networks, such as for water supplies, power supply and distribution, road and other communications and sewerage networks, etc.; and,
l) location maps of any type of activity discharging directly or indirectly effluent into the aquatic environment, including distant but connected watercourses, such as sewer outfalls, onshore fish farms, slaughterhouses, logging/saw mill concessions, wood pulp factories, mines and ore reduction plants and other industries.

6. Planned Changes

6.1 Assessments should address the planned changes to the environment and should include:

a) a general description of the entire project, including location, type, size and typical cross-sections of the various components that together make up the project together with a description of the proposed stages of construction;
b) the additional demands which would be placed on the locally available resources, both during construction and operation of the project;
c) details of all the effluents and emissions arising from the project; and,
d) the changes in the landscape, including land use characteristics and socio-cultural activities envisaged in the project.

7. Anticipated Impact

7.1 The estimation of the anticipated impact of the planned project on the existing environment should include:

a) topographic, bathymetric and oceanographic changes, including dredging and reclamation, during and after construction until stable conditions are resumed, together with their effect on habitats, flora, fauna and land use;
b) changes in water quality (temperature, salinity, turbidity, dissolved oxygen, nutrients concentration and microbial pollution levels) during and after construction and their effect on habitats, flora, fauna and land use;
c) sources of pollution discharging effluent, emissions or solid wastes during and after construction until stable conditions are resumed and their effect on habitats, flora, fauna and land use; and,
d) the visual impact on the seascape and the landscape and general quality of life around the proposed project site.

7.2 In the valuation of the coastal resources, the competent authorities should take into account all elements of value, not just those elements for which markets happen to exist. The fact that a resource is not traded in a market does not mean it is of no value (consider for instance the social benefits of a clean beach, the tourist potential of a coral reef, or the health implications of clean air).

8. Mitigating Measures

8.1 The detailed outline design should list the proposed measures to prevent or reduce (mitigate) the negative effects upon the environment. The mitigation measures should be:

a) technical, i.e oil reception facilities, waste recycling schemes, sewage treatment systems, CFC-free refrigeration equipment and by-pass dredging where applicable;
b) managerial, i.e. a clearly defined harbour board, commensurate with the size of the proposed project and the responsibilities expected of it; and,

c) legal and administrative, i.e. frameworks formulated in conformity with national laws to provide for sanctions in respect of violations.

8.2 The detailed outline design should also list the proposed monitoring measures to identify environmental degradation as early as possible.

8.3 In the first instance, such proposals should identify the appropriate indicators and secondly the institutional bodies with the capacity to carry out the monitoring process. These indicators could be:

a) physical parameters (i.e. changes in coastal morphology such as erosion or siltation);
b) biological parameters (i.e. edibility of certain shellfish);
c) chemical parameters (water quality); and,
d) socio-economic parameters (such as population density and income levels).

9. Design Criteria

9.1 In general, States should adopt acceptable design criteria for the design and construction of harbours and landing places for fishing vessels to ensure against unwarranted degradation of the aquatic environment. Design criteria for both the detailed outline design and the final design should ensure, *inter alia*:

a) compliance with basic engineering principles regarding the morphological degradation of the coastal zone in respect of erosion and siltation (UNCED 92)[9];
b) compliance with all relevant conventions concerning pollution of the aquatic environment (MARPOL 73/78); and,
c) the provision of adequate monitoring of the effects of operations on the environment (UNCED 92).

9.2 The detailed outline design should enable the competent authorities to make a preliminary assessment of the project and the effect of the planned activities with regard to any significant adverse impact upon the existing environment.

9.3 The detailed outline design of a project proposal should be based on the following minimum technical requirements:

a) detailed current topographic and bathymetric maps, resolution not smaller than 1:1000;
b) wave, tide or lake level statistical hindcast studies, including probability tables for extreme conditions;
c) geological, petrographic and sedimentological characteristics of the coastline and seabed; and,
d) mathematical and/or physical hydraulic modelling of the anticipated changes in the shoreline (including erosion, and siltation) and conditions at sea (including wave reflections and circulation).

9.4 The competent authorities should ensure that:

a) the resolution and accuracy of the maps are adequate and verifiable;
b) the wave statistical and hindcast studies are reliable;
c) the geological studies are adequate in extent and detail; and,
d) the hydraulic models are adequate in extent and calibration and the results reliable.

9.5 Final design should only be submitted after the environmental audit has been approved by the competent authorities.

9.6 States should ensure that final design adheres strictly to the detailed outline design (and approved modifications) as approved by the competent authorities in the final version of the environmental audit.

[9] The United Nations Conference on Environment and Development, 1992.

9.7 The final design should comply with the relevant provisions of International Conventions to which the State is a party, such as:

a) **UNCLOS 1982** – which establishes rules concerning environmental standards as well as enforcement provisions dealing with pollution of the marine environment;

b) **MONTREAL PROTOCOL 1987** – which protects the ozone layer by taking measures to control equitably total global emissions of substances that deplete it;

c) **MARPOL 73/78** – which protects the marine environment by eliminating completely pollution due to oil and other harmful substances; and,

d) **LONDON CONVENTION 1972** – which controls pollution of the sea by dumping.

10. Education and Training

10.1 States should promote awareness of environmental issues related to fishing harbours and landing places. The target audience should include:

a) direct users;

b) other user groups;

c) those responsible for the management and operation of such facilities; and,

d) the general public.

10.2 States should ensure that the provisions of the Code in relation to harbour and landing places are brought to the attention of those responsible for the training and certification of fishermen. Awareness programmes should ensure that these provisions are brought to the attention of all those employed directly in the fisheries industry, and their families.

10.3 Such training and awareness programmes should incorporate guidelines on personal hygiene, public health (sanitation) and on how to maintain harbours and landing places in a clean condition.

10.4 Other user groups may be served through community based arrangements supported by government extension services, such as:

a) Community Fishing Centres (CFCs)[10]

b) Fishery Development Units[11] (FDUs); and,

c) Vocational training programmes, which could include the general public.

10.5 States should ensure that their awareness programmes are supported by requiring those responsible for the management and operation of fishing harbours and landing places, to prominently display by-laws and regulations (billboards, posters and newspapers) for the benefit of all users.

10.6 The general public, and as appropriate, those still at school, could also be targeted by community wide awareness programmes or association of these issues with environmental studies.

11. References

Fishery Harbour Planning – FAO Fisheries Technical Paper No. 123, Food and Agriculture Organization of the United Nations, Rome 1973.

Community Fishery Centres: Guidelines for Establishment and Operation – FAO Fisheries Technical Paper No. 264. Ben-Yami M, Anderson A.M., Food and Agriculture Organization of the United Nations, Rome 1985.

Construction and Maintenance of Artisanal Fishing Harbours and Village Landings – FAO Training Series No. 25. Sciortino J.A., Food and Agriculture Organization of the United Nations, Rome 1995.

[10] FAO/IMO Guidelines Ref. 3 and 5.

[11] Fisheries Technical Paper No. 264 on Guidelines for the establishment and operation on FDUs.

Linking Government Agents and Local Users: Participatory Urban Appraisal for Artisanal Port Development – Reusen R., Johnson J. International Institute for Environment and Development, Issue No. 21. Nov. 1994.
Guidelines for Cleaner Fishery Harbours, BOBP (Madras 1993).

Annex 2
Port hygiene checklist

INTRODUCTION
The standard of personal hygiene of the workers employed inside a fishing harbour depends on both the sanitary infrastructure available and the harbour management in enforcing certain directives. The following principles are based on actual cases.

TOILETS
Toilets should be constructed to the highest standards possible to ensure the maximum lifetime. Poorly built facilities break down very quickly and in hot climates they give rise to "toilets of opportunity" elsewhere. Toilet facilities should always be properly maintained and full-time manning by attendants is desirable. Toilets should never open on to a work area where fish is being handled due to the risk of flooding from blocked drains.

WASH-HAND BASINS
An adequate number of wash-hand basins should be provided within each toilet block. These should be equipped with arm or foot-operated faucets and soap should be available at all times. Household-type fittings should not be specified as these do not withstand the rigours of constant use. Water saving spring loaded faucets should be provided in areas where water is scarce.

SHOWERS
The importance of showers in hot climates should not be underestimated; fishermen returning from long journeys always welcome a shower with proper running water. As with toilets, showers should be built to the highest standard possible and manned by attendants. When the harbour is not offloading fish, showers should be cleaned and locked up.

SIGNS AND BILLBOARDS
Appropriate signs and billboards listing food hygiene regulations should form part of the harbour's sanitary awareness infrastructure. These signs should be displayed at all the strategic locations within the port boundary, for example:

- "*NO SMOKING, NO SPITTING, NO EATING*" signs should be posted wherever fish is being handled; and
- "*HAVE YOU WASHED YOUR HANDS* ?" signs should be posted at all toilet exits.

Adequate signs should also be posted in prominent locations indicating the direction to the toilets. Proper and frequent training of the port workers in personal hygiene should form part of the harbour master's management brief. Port sanitation is to the port what personal hygiene is to the workers employed by the port.

Port sanitation is best explained by the following simple regulations:

1. All water supplies inside the port should comply with the national drinking water standards;
2. All ice, including that brought in from outside suppliers, should also comply with the above drinking water standards;

3. All chlorination equipment should be functional and adequate supplies of the chlorination agent should be held in stock;
4. All sampling and testing carried out inside the port should be carried out by International Organization for Standardization (ISO) certified laboratories only;
5. Appropriate signs should be displayed within the port area covering the prohibition of dumping, spillage, use of seawater from inside harbour basin, spitting, eating areas, access for domestic animals, etc.;
6. Appropriate billboards should be displayed at strategic locations listing fines for the contravention of port hygiene rules;
7. All drainage systems (*indoor and outdoor*) should be kept in perfect working order;
8. Port perimeter fences should be properly maintained to keep unauthorized people and domestic animals from entering the port area at any time;
9. The entrance and exit to a fishing port area should be manned during business hours to prevent unauthorized people from gaining entry to the fish handling areas;
10. Disinfection of required areas should be carried out on a regular basis;
11. No excessive trash and wet wastes should be left to accumulate in work areas;
12. No rodent harbourage should exist in and around the port area (tall weeds, junk piles and municipal rubbish);
13. No birds should be nesting inside open-sided auction halls and fish handling sheds;
14. Only employees and officially recognized fish traders should be allowed access to work areas during fish handling operations and auctions;
15. Toilet and shower facilities should be kept scrupulously clean and in perfect working order;
16. Only electrically powered machinery should be allowed inside the auction or handling sheds to prevent oil, petrol and diesel from leaking onto the floors which are sometimes used as auction surfaces for large fish;
17. All equipment inside the fish handling areas, from block ice crushers to platform trolleys, should be in stainless steel; and
18. The entire fish handling area should be hosed down properly at the end of business and locked up to prevent unauthorized entry until the next auction.

Annex 3

Port hygiene deficiencies checklist

INTRODUCTION

The sanitary infrastructure inside many fishing harbours always gives cause for concern, especially when health or food hygiene inspectors are expected for an official visit. The following infrastructure deficiencies are among the most common infractions which the inspectors look for and are based on actual cases:

A. WC Facilities

1. Toilets are sometimes totally absent from the harbour infrastructure;
2. Toilets open out onto work areas where sewage can flood directly into the processing/handling area;
3. Toilet drains are often uncovered and full of rubbish like plastic bags, fruit, etc., causing blockages;
4. Toilets do not have an adequate water supply to flush;
5. Toilet and wash-hand basin fittings are often out of order, broken or missing;
6. Toilet wash-hand basins are often left without soap or wipe towels/blowers;
7. No "**HAVE YOU WASHED YOUR HANDS**" signs posted inside toilets;
8. Doors are often unserviceable and removed off the hinges because the timber from which they are manufactured absorbs too much moisture and renders them inoperable ;
9. Toilets are often flooded from leaking pipes or roofs; and
10. Sewage disposal or treatment is either absent or totally inadequate.

B. Auction Hall

1. No fish sorting tables in sorting hall and fish is handled on the floor;
2. No sanitary water is available inside the harbour to rinse fish; and
3. No sanitary water is available inside the harbour to wash floors.

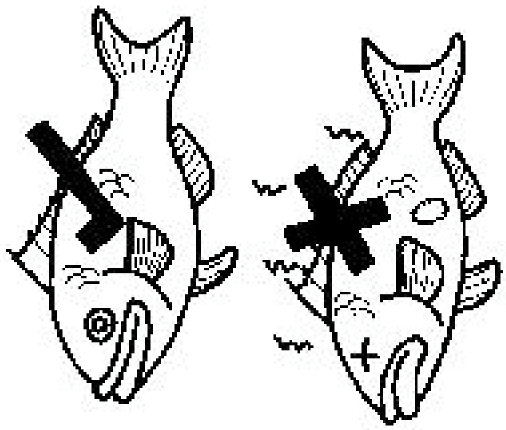
Annex 4

Training Manual on Seafood Handling

TRAINING MANUAL

on

Seafood handling

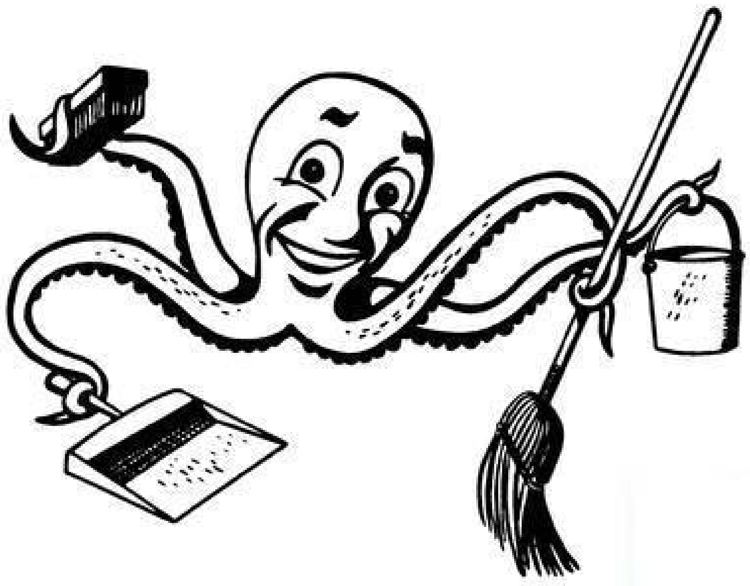


Clean Ports Initiative

Capacity building in support of cleaner fishing harbours

Francisco Blaha
Fishery Industry Officer
Food and Agriculture Organization of the United Nations

Index



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Illustrations reprinted from training resources by the
New Zealand Seafood Industry Training Organization (www.sito.co.nz)

1. Spoilage

After a fish dies, its flesh begins to break down (rot).
This is called spoilage; this process cannot be avoided. It can be slowed, but not stopped. After some time, the fish gets softer, smellier, loses its bright colours, and begins to produce harmful substances that can make people sick.

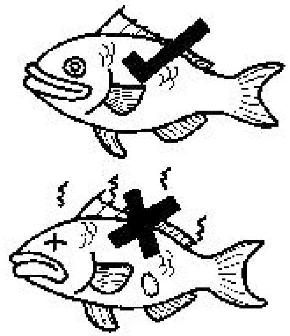
Seafood spoils quickly; when it does:

- it goes to waste;
- it is not healthy because there are fewer nutrients;
- it can make you, your family or other people sick;
and
- those selling lose money as people do not want to buy it.

Activity

1. Where have you found bad fish?

2. What made these fish go bad?



Agents of spoilage

Fish go bad, or spoil, when agents of spoilage attack the flesh after the fish is dead.

The two main agents of spoilage are:

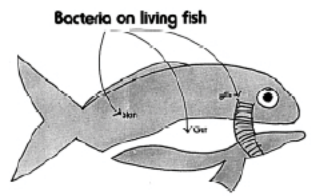
- bacteria
- enzymes

Bacteria and enzymes are the enemies in the battle to preserve food products.

Bacteria are simple - and very tiny - organisms.

They live almost everywhere, including:

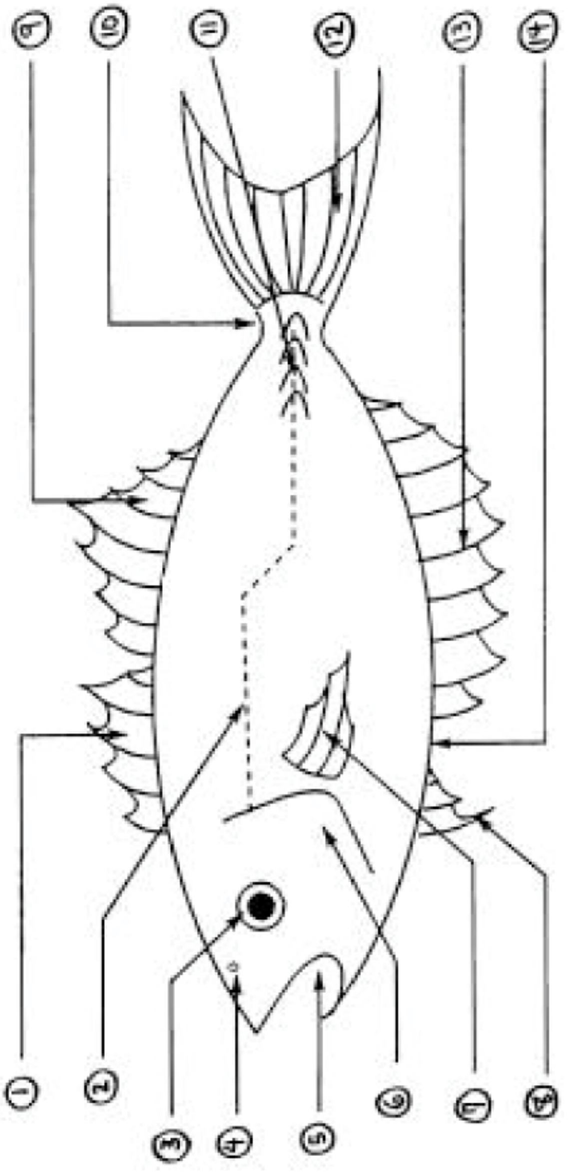
in the air
on land
in the sea (and on the ocean floor)
on plants and animals
on the skin, gills and guts of fish.



One place bacteria do NOT normally grow is in the flesh of a live, healthy fish. Bacteria are found only on exposed surfaces such as the skin (and body slime), gills and gut.

Activity

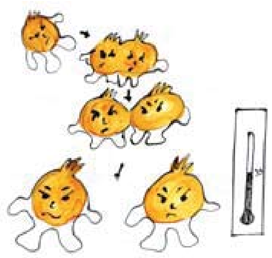
1. Label parts of a fish using local names



Which parts of the fish have the most bacteria?

Bacteria on the skin, the guts and the gills cause no harm to a living fish. However, when the fish dies, these bacteria grow quickly in number, especially in warm conditions. If there is a tear or a hole in the skin, the bacteria can enter the flesh - an ideal place for bacteria to grow - and make the flesh smell and taste bad, look awful and possibly make those eating it sick.

When are there more bacteria?



Bacteria are greater in number if the seafood:
is washed with polluted waters (harbour waters);
touches dirty hands, boats, boxes, etc;
is handled or gutted without care;
is stored at high temperatures; or
has fed just before capture (more bacteria in the gut).

When does fish go bad?

Fish goes bad when bacteria numbers grow.
In tropical countries, fish can go bad within 12 to 20 hours, depending on the species and method of capture.

Some types of fish go bad more quickly than others. For example, white reef fish meat keeps longer in ice than red tuna meat. This is because tuna have a higher body temperature compared to reef fish, making it easier for bacteria to grow. Their thicker body shape also makes them slower to chill.

If fish are dead a long time before being taken out of the water, bacteria may start to attack the flesh.

Enzymes

Enzymes are proteins that are present in the muscles, organs and gut of fish (and all animals). Metabolic enzymes are the "workers" in the body and help to speed up processes such as digestion. Digestive enzymes break down food until the gut can absorb the nutrients in the food. The body can then use the nutrients for growth and energy.

When a fish dies, enzymes keep working in the body, causing changes in the flesh. The digestive enzymes continue to break down the food in the fish's gut. If the fish is not gutted, the enzymes begin to eat holes through the gut lining, allowing bacteria to enter the flesh and break it down.

Sometimes the gut cavity swells up with gas and eventually bursts, making it even easier for bacteria to enter the flesh. This is known as 'belly burst'.

'Belly burst' is more likely to occur:
in well-fed fish
(because there are more digestive enzymes in their guts); or
if the fish is warm
(because enzymes work better in warmer temperatures).

Enzymes cause changes in the flesh and can assist the spread of bacteria from the gut.
The enzymes cause:
loss of flavour or an **increase in bad flavour**;
loss of texture; and
loss of colour.

Activity

Answer these questions :

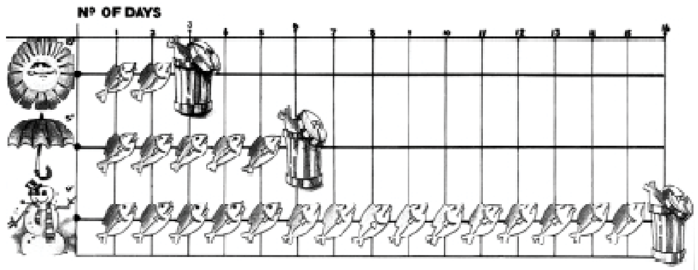
1. Which parts of the fish are likely to have high amounts of bacteria?

2. Enzymes are not a problem when the fish is living. Why are they a problem when the fish is dead?

3. What causes 'belly burst'?

4. How can you stop 'belly burst'?

How long before fish goes bad?



The fresh fish test

If a fish is kept in conditions allowing bacteria or enzymes to attack the flesh, it will quickly lose its freshness and quality. However, a person who buys or eats fish would like it to be fresh.

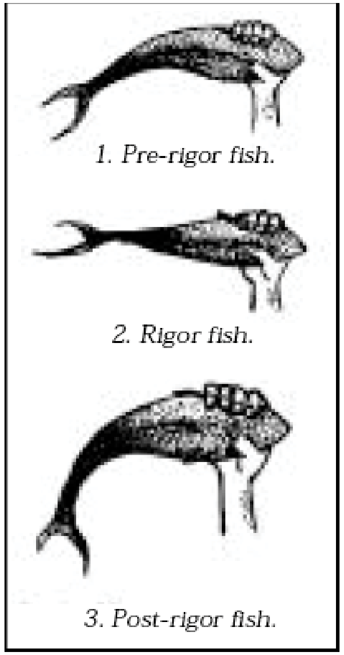
A fresh fish:
has bright colours;
has clear, bright eyes;
has bright red gills;
smells likes fresh seaweed;
feels firm and springy;
does not have overly slimy skin or gills;
tastes good.

A fresh fish is more nutritious and is less likely to make you sick.

Stiff fish and spoilage

Just after a fish is caught, it quickly dies. A dead fish goes through three stages, known as the stages of rigor.

Stage 1 The fish is soft immediately after it dies.
Stage 2 The fish becomes stiff within several minutes to several hours after death, depending on the temperature it is kept at - the quicker it is chilled the longer it will take to reach this stage. The fish will also be stiff longer if it is bigger and is kept cool.
Stage 3 The fish becomes soft again after some time. If you push your finger into the side of the fish, it is not as springy as it was in the first stage.



Stages of rigor

Bacteria and enzymes are more active in Stage 3 and fish will then go bad very quickly. **Fishers should try to keep fish in Stage 1 and Stage 2 for as long as possible.**

The cooler a fish, the longer it will take to reach Stage 3.
Cover it, and/or even better, **put the fish on ice.**

2. Contamination

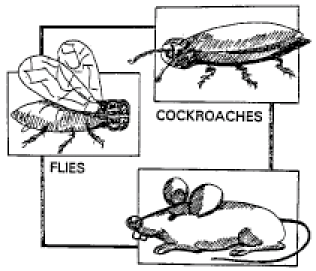
Contamination can be classed as anything on or in **fish that is not supposed to be there.**

Contamination can originate from different sources.

For example, in the case of poor personal hygiene, contamination can be any pathogenic organisms transferred to the fish from people handling it or through unhygienic work practices.

In the case of poor cleaning and sanitation, contamination can be any matter (biological, chemical or physical) which is transferred to the fish as it is handled and stored on the vessel, at the port or the factory.

Sometimes contamination can come from pollution of the environment, for example, bacteria from sewerage, heavy metals from industry, pesticides from agriculture, etc.



Poor personal and environmental hygiene.

Examples of types of contamination

Source	Contamination	Transfer to fish/product
Personnel	Pathogens	From handling product without proper hand washing. Coughing. Sneezing over product. Eating over product. Incorrect clothing.
Unloading area and equipment	Physical contaminants	Jewellery. Sticking plasters (could contain pathogens). Hair.
	Pathogens	From unclean surfaces, droppings of animals, dead insects.
	Chemicals	Cleaning chemicals not rinsed, machine oils/grease.
Storage areas	Physical contaminants	Metal, paint flakes, glass, vermin, etc.
	Pathogens	From condensation drip, use of hose (splash), area not cleaned.
	Chemicals	Excessive use of chemical cleaners and sanitisers. Not rinsing. Machine oils/ grease.
Product containers and contact surfaces	Physical contaminants	Metal, paint flakes, glass, vermin, etc.
	Pathogens	From unclean surfaces, build up of bacteria in conveyors and other difficult to clean equipment.
	Chemicals	Cleaning chemicals not rinsed, machine oils/grease.
Water and ice	Physical contaminants	Metal, plastic, vermin, etc.
	Pathogens	From contaminated or non potable sources, or stored and transported in a non hygienic way.
	Chemicals	Excessive use of chemicals (i.e. chlorine), or enviromental contaminants.

3. Sickness

Introduction

Seafood is normally a healthy food choice. Unfortunately, food from the sea sometimes contains germs or toxins that make people sick.
You probably know somebody who has been sick after eating seafood. You may have even been sick yourself.

People get sick from eating fish that is not safe. Too many of some bacteria on fish can create substances on fish that are bad for people. This fish can be contaminated. Contamination means that there is something on the fish that is not supposed to be there, for example, bacteria from faeces or flies or petrol or chemicals.
Bacteria that cause sickness are called pathogenic bacteria.

Activity

1. Can you remember someone you know getting sick from eating spoiled or rotten or poisonous fish? Who? When?

People can get sick from seafood:

if the fish was contaminated

if too many pathogenic bacteria have grown on the fish

if the fish has been kept for too long

if the fish has been kept at a temperature that allows bacteria to grow

When someone gets sick, they not only feel bad, but they need costly medicine, cannot go to work, cannot cook, cannot look after the baby.
If people get sick, they don't buy seafood from the same place again.

This means that local people will not eat as much fresh seafood and may buy more tinned foods, which are more expensive and not as healthy as fresh unspoiled seafood.

Overseas customers do not want to buy seafood that may make them sick.

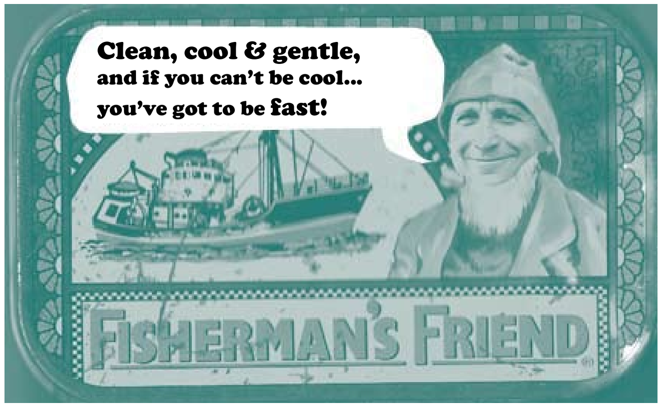
If an area becomes known for its disease causing seafood, then overseas customers will refuse to buy from that area, or they will want the seafood tested to see if it is safe. Tests cost money and the exporter may have to pay fishers less for their fish in order to stay in business.

This is not to scare you from eating seafood but to help you understand what things can cause sickness and ways to avoid it.

How to avoid fish going bad and people getting sick

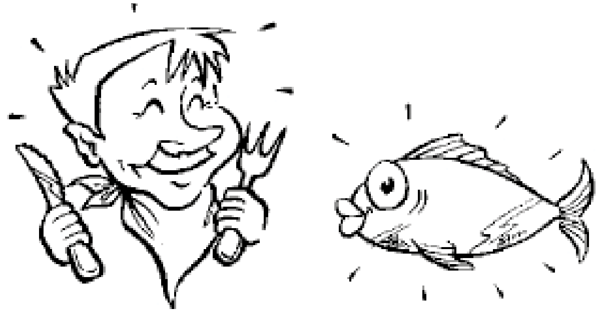
The most important ways to fight spoilage of fish and to prevent people getting sick from eating seafood are:

- keeping the fish and everything the fish touches clean
- avoiding cross contamination
- keeping the temperature of the fish down (cool)
- treating the fish as gently as possible to minimise tears
- gutting the fish if possible



In the next section we will talk about the ways we have to manage the problems of spoilage and sickness.

One of the most important things when you're handling fish is the practice of cleaning and sanitising the place where fish is being handled and the personal hygiene of the people doing this work.



4. Personal Hygiene

Introduction

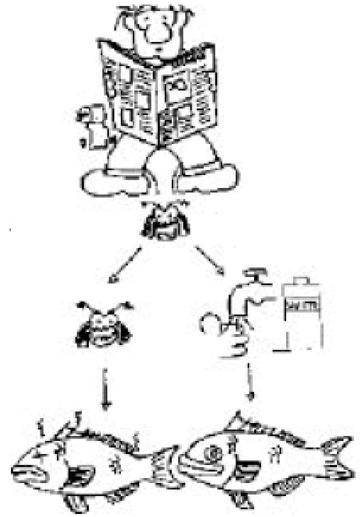
The main objective of personal hygiene and hygienic work practices is to minimise cross contamination.
Cross contamination includes any pathogenic or food poisoning organisms which may be transferred to product from people (or their equipment) during their handling of the fish or fish product.
Many people harbour pathogenic organisms that could lead to food poisoning if they are able to contaminate seafood products. They are not always a problem for the person carrying the organism, but can be transferred to product if good personal hygiene and hygienic work practices are not followed.

Common pathogenic organisms you may know:
- Staphylococcus aureus (or staph)
- Salmonella
- Shigella
- Eschericia Coli (or E coli)

Personal Hygiene includes:
- The wearing of clean protective clothing
- The washing of hands

Hygienic Work Practices include:
- Personal conduct (eg not eating, drinking, sneezing, coughing, etc. over the product)
- Keeping your work areas clean
- Handling dropped product and contaminated product appropriately
- Using equipment, tools, protective clothing, etc. in a sanitary manner

Good personal hygiene and hygienic work practices prevent you from contaminating the product with pathogenic organisms, which cause food poisoning, illness or infection.



Wash hands after toilet.

Good personal hygiene and hygienic work practices, minimise the risk of contamination.

Cuts and Sores

Infected cuts and sores must be treated, for the benefit of both the worker and product safety.
Once treated, cuts must be well covered with waterproof dressings and gloves for hands, before the worker is allowed to handle product.

Illness

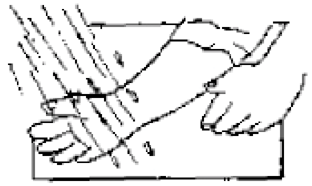
For people who are ill or feeling ill, a judgement is required as to whether work can be carried out in areas away from direct product handling, or whether the person should be sent home.
Those who are suffering from vomiting or diarrhoea should be sent home.
Personnel may often come to work when they are not feeling well or if they have infected cuts. This can be a significant risk for product safety if it is not managed.

Summary

The main objective of personal hygiene and hygienic work practices is to minimise cross contamination.
The reasons for good personal hygiene and hygienic work practices are to produce safe food and meet legislative requirements.
Cuts and sores must be treated and completely covered with a waterproof dressing.
People who are ill or feeling ill should not be at work, if there is a risk of contamination to the product.

Correct Handwashing Procedure

1. Roll up sleeves to the elbow

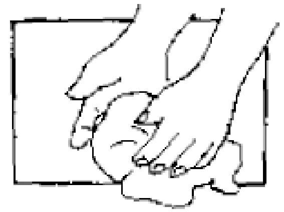


2. Rinse up to the elbow

3. Apply soap carefully

4. Brush hands and nails

5. Rinse to eliminate soap
6. Rinse with clean water



7. Dry hands with a clean personal towel or, better still, with a paper towel.

5. Cleaning and Sanitising

After completing this section you will be able to:
- Describe the difference between cleaning and sanitising.
- Describe why cleaning and sanitation are important.
- Describe what happens if we don't clean and sanitise.

Cleaning and sanitising are activities that occur quite regularly in seafood processing premises. The main purpose of cleaning and sanitising is to minimise the risk of cross contamination. Contamination can lead to spoilage of the product or cause someone to become ill when they eat the product.

The types of activities used as part of cleaning and sanitising will vary, depending on the product being processed, what is being 'cleaned or sanitised', and the time available. Each processing plant is likely to have something different in their cleaning and sanitation procedures.

Cleaning

Cleaning is the process of removing the visible 'dirt'. Cleaning is helped with the use of detergents, which soften the "dirt" and allow water to get in. Cleaning is also helped by the use of friction and elbow grease – in other words, scrubbing. Even foam cleaners, which can create their own friction as the millions of tiny bubbles burst, need the additional application of the scrubbing brush in difficult areas.

Sanitising

Sanitising is the process of killing the bacteria. This relies on the action of a chemical which will only work once cleaning has been completed. Sanitising chemicals won't work if there is still a lot of dirt present.

Importance of Cleaning and Sanitation

There are a number of reasons why good cleaning and sanitation procedures are important for ports seafood processing premises.
The main reason, as discussed above, is to produce a product that is safe to eat and one that is good quality (not spoiled). The other reasons include helping to maintain the plant and equipment in good condition and to help prevent the 'fishy' smell that is caused by the breakdown of seafood flesh, gut and slime, by bacteria. The presence of a 'fishy' smell indicates that both seafood matter and bacteria are still present at the end of the cleaning and sanitation process.

The reasons why cleaning and sanitizing is important are:

- To ensure the food we produce is safe to eat
- To ensure the food we produce is good quality
- To help provide a pleasant place to work
- To meet legislative requirements

The Consequences of Not Cleaning and Sanitising

If cleaning and sanitizing is not carried our correctly then the chances of meeting any of the above things are not very high.

- The product may be contaminated and unsafe to eat
- The product may not be good quality
- The plant and equipment will not last
- The place you work in won't be very pleasant at all
- Meeting legislative requirements will be very hard

First clean then sanitise

Good cleaning will remove over 90% of the bacteria as the dirt is washed away.
Sanitisers act once cleaning has been completed. They won't work if there is still a lot of dirt present.

Different sanitisers act in different ways to kill bacteria.
For example, Chorine acts by invading the bacterial cell and interfering with its life functions. Another common sanitiser, Quat, (or QAC – quaternary ammonium compound) acts more quickly, by breaking down the bacterial cell wall. Whichever type is used, the correct amount of time in contact with the equipment surface must be allowed for the sanitiser to complete the job.

Current practice of chemical companies has been to combine both detergents and sanitisers into one material. This means that the cleaning and sanitation process can be carried out much more quickly and easily.

Activity

1. Give some examples of products you have access to to clean and sanitise.

General routine for cleaning and sanitising

In all premises the general routine for the main clean down of processing areas is as follows:

1. Tidy the area.

2. Hose all surfaces with cold water to remove most of the fish waste.

3. Dismantle equipment if required.

4. Apply detergent or detergent/sanitiser that has been made up to the correct concentration.

5. Scrub surfaces to loosen dried on dirt - fish, scales and slime. For combined detergent/sanitisers, ensure that the chemical is left in contact with surfaces for the required time (for sanitiser to work).

6. Rinse off using low pressure water.

7. Apply sanitiser at the correct concentration and temperature. Leave for the required time (this may be overnight).

Note: Sanitiser may be applied after a combined detergent/sanitiser in problem areas or for additional assurance of sanitising effect.

6. Managing Food Safety

Food safety aspects of fish products are considered to be part of the overall quality of those products.

In the modern world, however, food safety has become one of the most important factors in food quality. In fact, the concern about food poisoning and food contamination by consumers the world over, means that food safety is now non-negotiable.

Food must first be safe to eat. Then, it can be good to eat.

The implications of any producer releasing unsafe food onto the market are wide ranging and in recent years there have been many examples of this occurring throughout the world.

These implications include:

- harm, illness or even death of consumers
- widespread media involvement
- loss of customer
- loss of market for the companies involved
- companies out of business
- reduced market access for the industry as a whole

Seafood, as a product category, contributes on a regular basis to incidences of food poisoning. Closer examination of the data, however, will show that some seafood products are more likely to be involved in these incidences than others are.

Why are some seafood product more likely to be "unsafe" than another?

This has to do with the causes of unsafe food, or the food safety "hazards", which may be associated with a food. Foods which have a high number of food safety hazards associated with them will have a high risk of causing food poisoning, or harm to consumers, if those hazards are not controlled.

Hazards are categorised in the following way:

Biological hazards include, most commonly, bacteria and other micro-organisms which cause food poisoning, illness or infection. They are called food pathogens or pathogenic micro-organisms. They may occur on the food naturally or through contamination, but due to some lack of control, they grow to high numbers on the food product. It is either the organisms themselves, or toxins produced by them, which make people ill.

Chemical hazards include any form of chemical compound which may contaminate food products and which result in illness or harm to consumers. These may include fuel or oil from the catching vessel, cleaning chemicals, contamination from industrial activities (heavy metals, poisons, etc.).

Physical hazards can include a wide variety of contaminants such as glass, metal, bone, shell, etc, which may cause harm to the consumer while they are eating the food product. In many cases, objects that are called physical hazards are in fact the source of biological hazards. These would include sticking plasters, insects, rodent droppings, etc., which are themselves contaminated with pathogenic organisms.

In order to manage food safety, producers must have a good knowledge of how to control the food safety hazards that may be expected on their products. They then need a system in place that ensures that the specific controls are carried out when required.

7. HACCP

The system used internationally today is called HACCP (Hazard Analysis Critical Control Point).

This is a system that identifies the hazards that may occur with the processing of each product, and then establishes a set of controls that are based on preventing the hazard from developing into a food safety problem. The controls may completely remove the hazard or they may only reduce it or prevent it from reaching significant levels.
HACCP is a system that is designed for each product and process. It takes account of the severity of the hazards associated with each product (that is, the seriousness of the hazards), the risk of the hazard (the likelihood that the hazard will occur) and also the expected way in which the product will be consumed. All of these factors will combine to determine the level of control required.

The HACCP system consists of the following seven principles:

1. Conduct a hazard analysis.
2. Determine the Critical Control Points (CCPs).
3. Establish Critical Limits
4. Establish a system to monitor control of the CCP.
5. Establish the corrective action to be taken when monitoring indicates that a particular CCP is not under control.
6. **Establish procedures for verification to confirm that the HACCP** system is working effectively.
7. Establish documentation concerning all procedures and records appropriate to these principles and their application.

It is outside the scope of this book to fully detail the HACCP system, its design and implementation. Further information is available from many other documents.

However this publication can introduce the concept of prerequisite programmes in relation to HACCP.

Prerequisite programmes

Prerequisite programmes may also be referred to as Good Hygienic Practices, Good Manufacturing Practices, Standard Operating Procedures, umbrella programmes or satellite programmes.

They relate to HACCP by providing the foundation of food safety controls from which HACCP systems can be developed.

In a food handling environment, there are many other things which can influence the safety of products that are not directly part of the process.

These include:

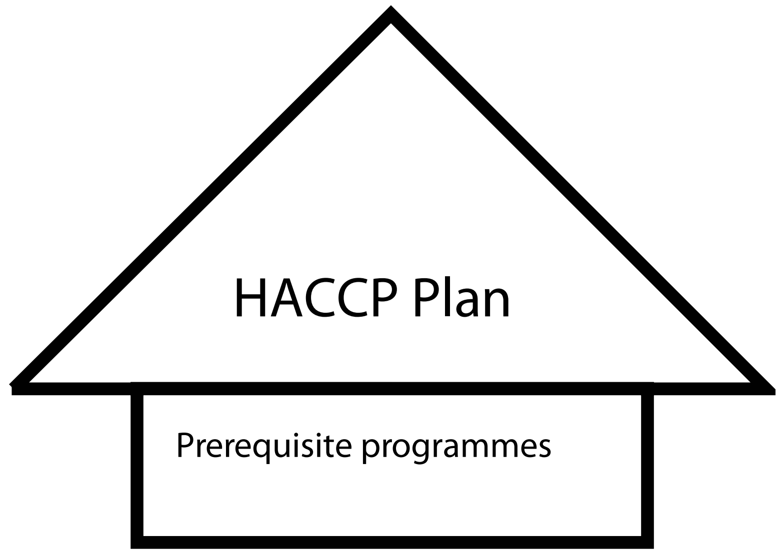
- quality (potability) of the water and ice supply
- **quality (safety) of the incoming fish**
- construction of buildings and equipment
- cleaning and maintenance of the buildings and equipment
- behaviour and hygiene standards of the staff (level of training)
- correct storage of product
- transport of product prior to reception and after dispatch
- presence of vermin waste disposal

Within fishing port, the management of these activities is carried out through documented systems as required by legislation.

As part of the management of food safety management, all these activities are still expected to be controlled in some way.

Like a HACCP plan, these programmes themselves are controlling food safety hazards and it is very important that they are effectively managed. Without this effective management, the HACCP plan has no foundation of food safety control from which to work.

Problems with, or lack of control of, the prerequisites will result in the failure of the HACCP plan.



Annex 5

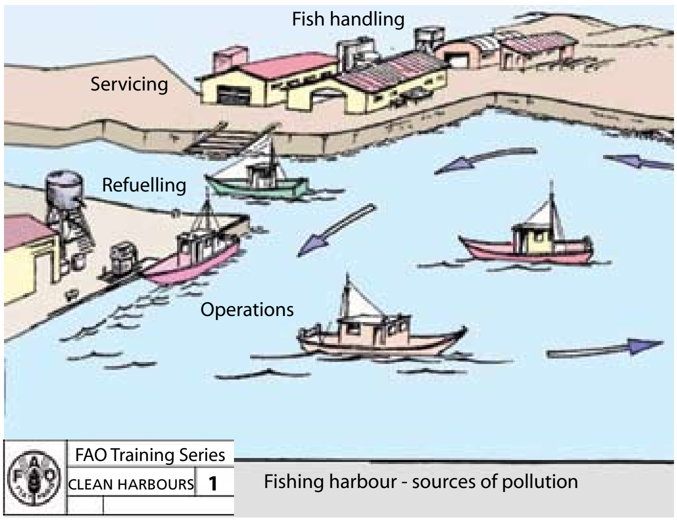
Prevention of pollution

INTRODUCTION

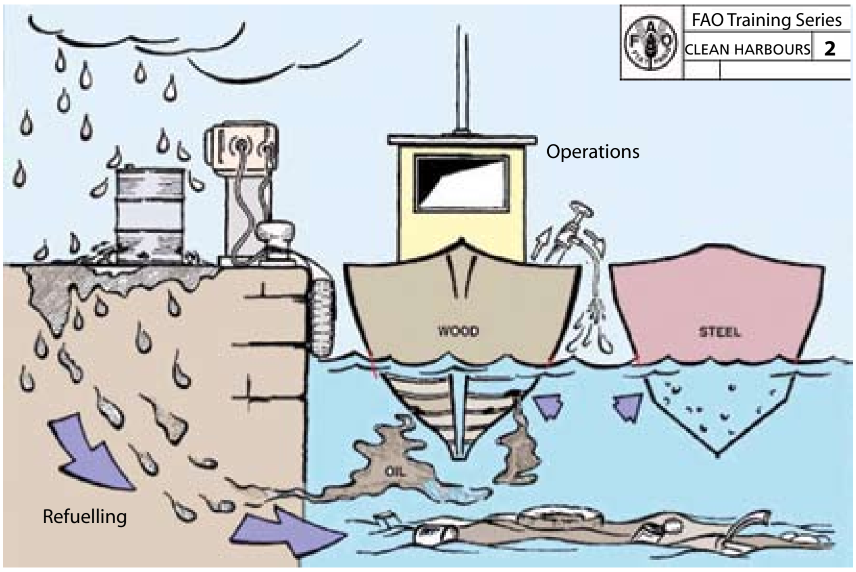
The following is a series of cartoons taken from the Cleaner Harbours publication in the FAO Training Series. They may be adapted to make them compatible with the different regions of the world.

Who should use them?

The drawings are for use by extension workers in the field, fisheries training colleges, fisheries enforcement officers and harbour-masters. The drawings may also be used as part of an elementary public awareness programme within a larger educational framework. Some of the drawings are also suitable as posters.

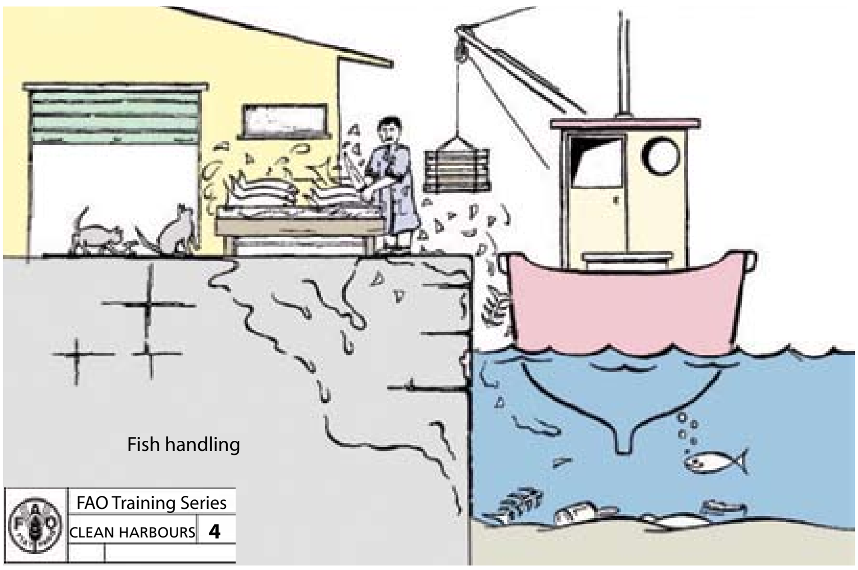


Drawing No. 1 outlines the four major sources of pollution in a typical fisheries harbour; operations; handling; servicing; and refuelling.

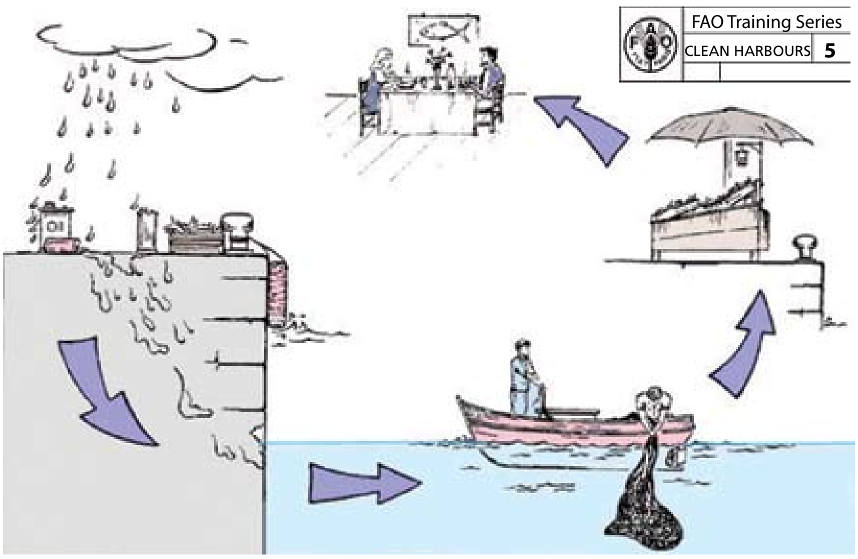


Drawing No. 2 shows how split fuel oil attacks the caulking on timber vessels. Metal cans on the sea-bed attack metal hulls and fittings, such as the propeller and the shaft.

Drawing No. 3 shows the discarded waste that is typical when vessels are serviced carelessly.

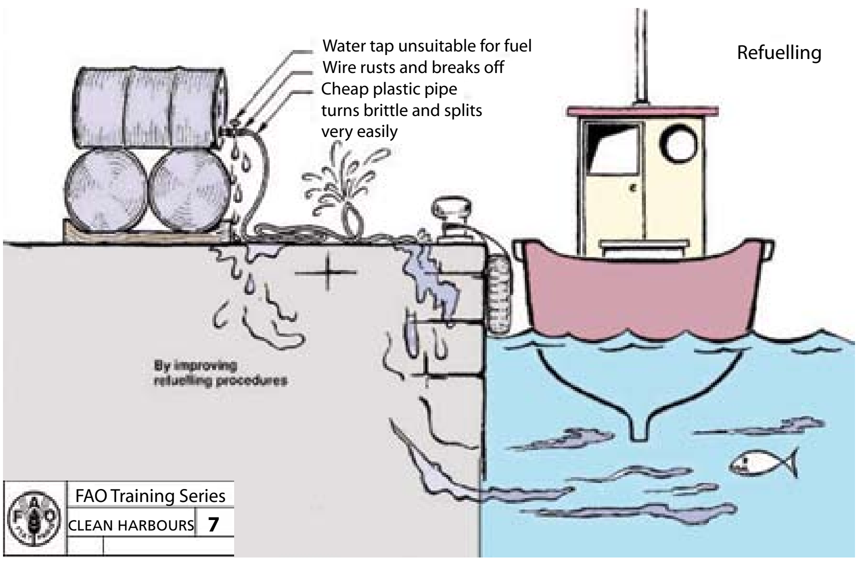


Drawing No. 4 emphasizes the health hazard of gutting fish inside the harbour – pests are invariably drawn to the area.

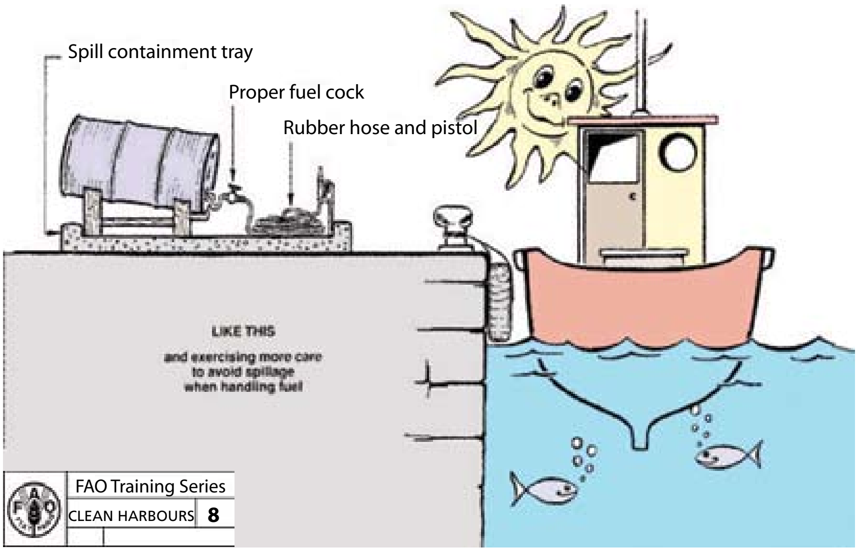


Drawing No. 5 shows how dangerous chemicals find their way into the food-chain.

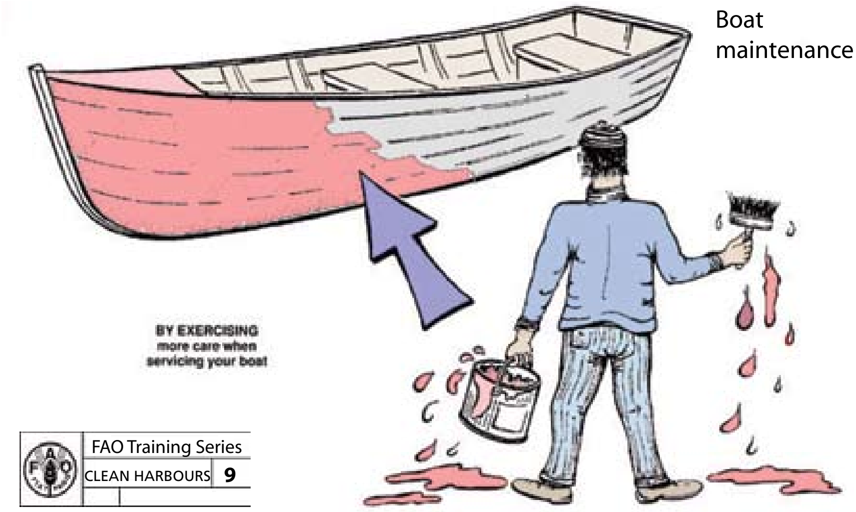
Drawing No. 6 asks the important question without laying blame on any one particular sector of the fisheries industry.



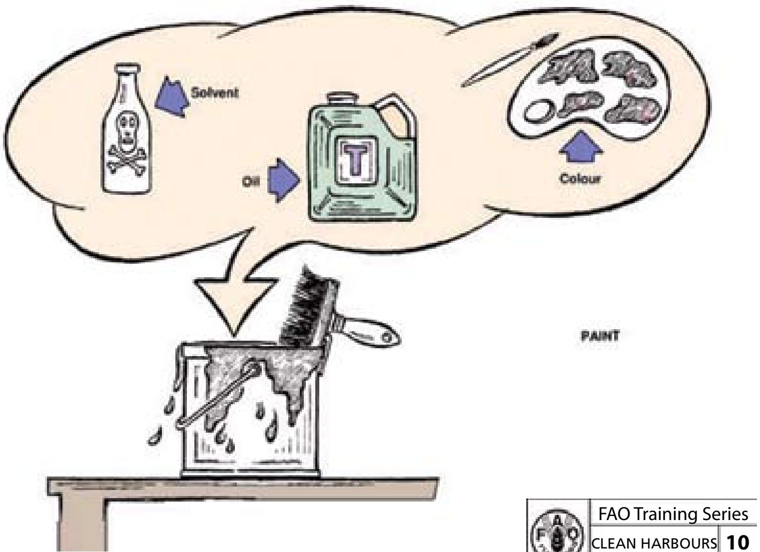
Drawing No. 7 shows the typical mistakes made by people who are not aware of the consequences of spilling fuel. Case history slides should be inserted in-between slides of drawings No. 8 onwards.



Drawing No. 8 shows the correct way to store and dispense fuel at the quayside.

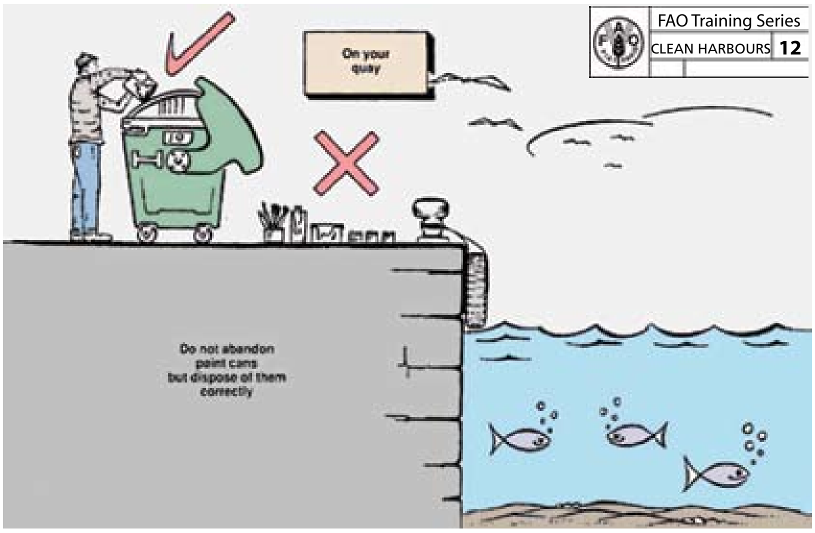


Drawing No. 9 shows a careless boat owner servicing his boat with little attention to the mess around him.

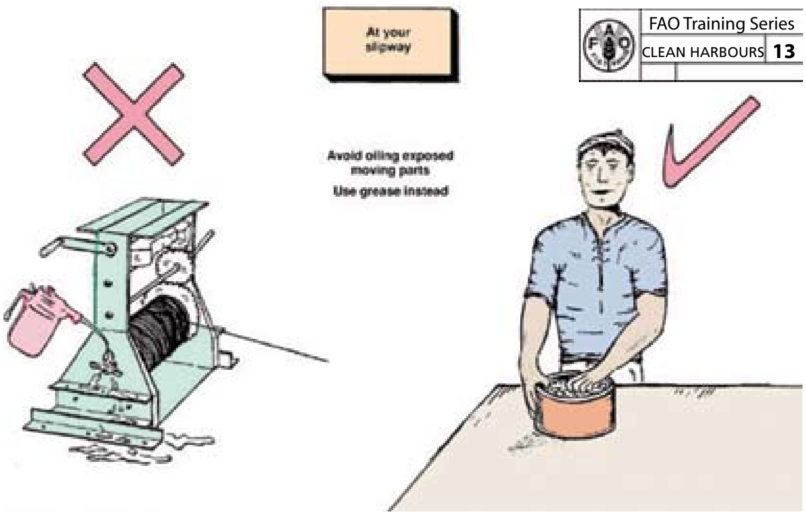


Drawing No. 10 explains in very simple terms the various chemicals that make up paint and their toxicity to humans.

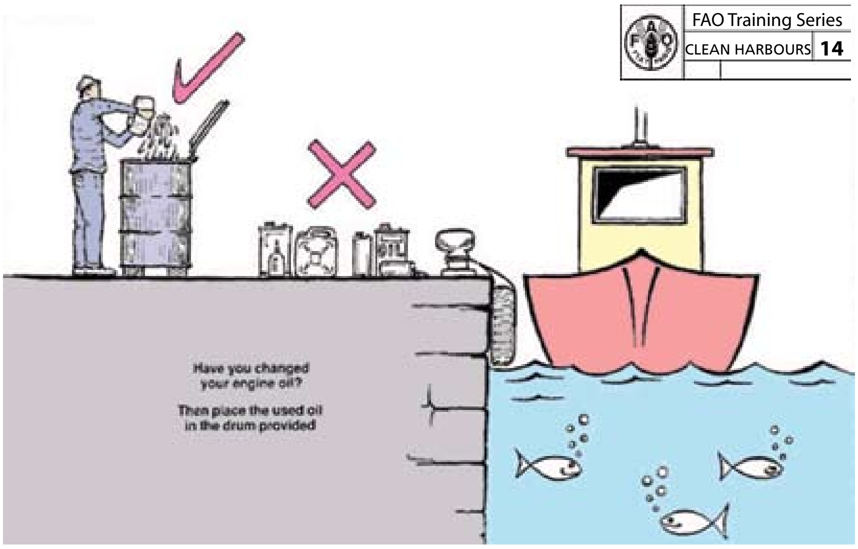
Drawing No.11 stresses the point that any material abandoned near the water's edge invariably ends up in the water. For example, wind blows some empty cans and children kick the rest in.



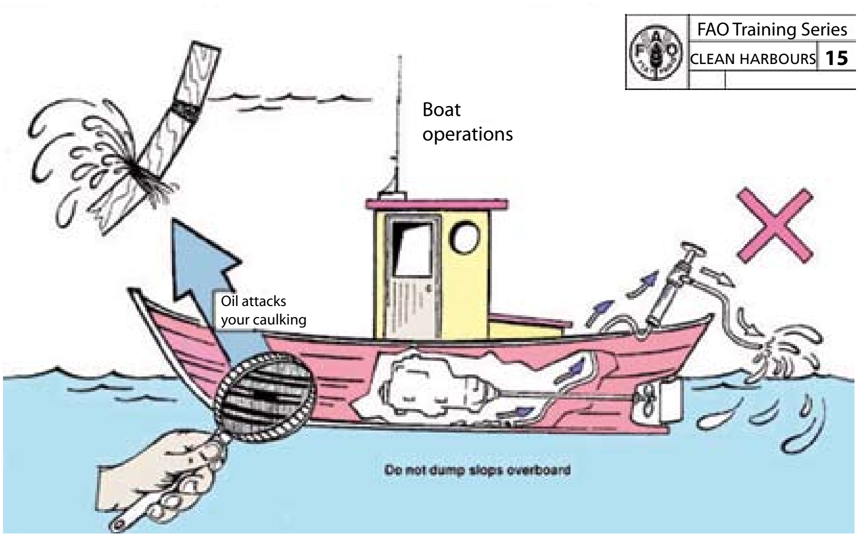
Drawing No.12 shows the correct method of can disposal. The container shown should look like the one intended for use at the particular landing.



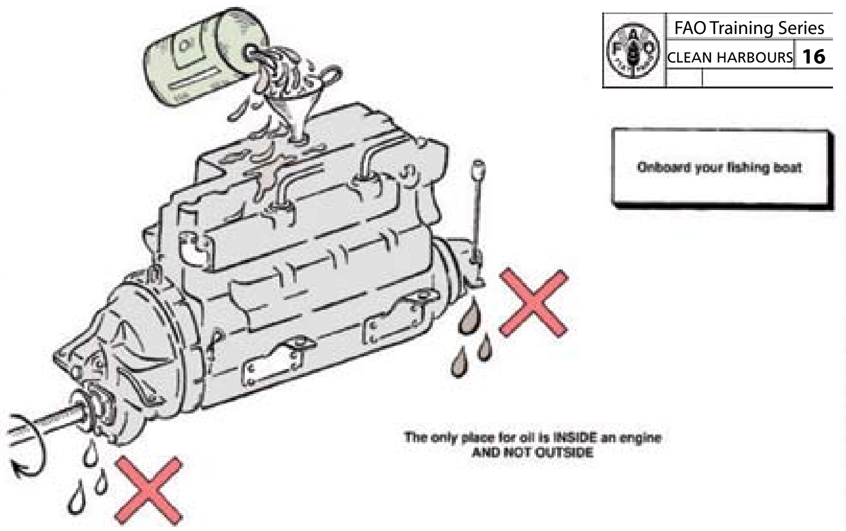
Drawing No.13 explains the importance of greasing moving parts rather than oiling them.



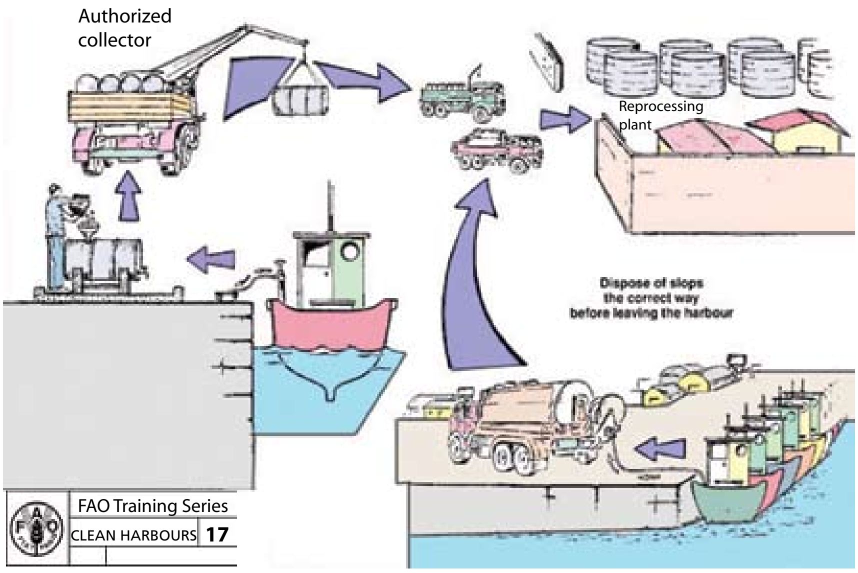
Drawing No.14 shows the correct method of oil disposal. The container shown should look like the one intended for use.



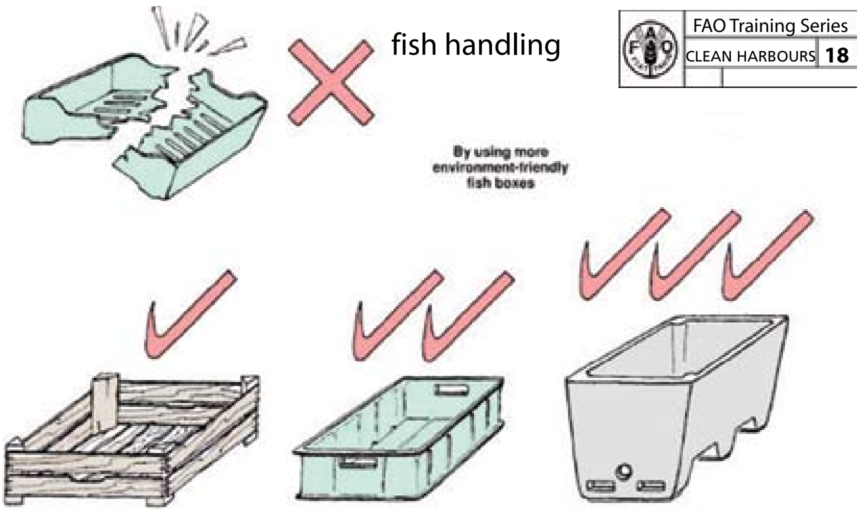
Drawing No.15 shows the effect that oil has on a vessel's caulking.



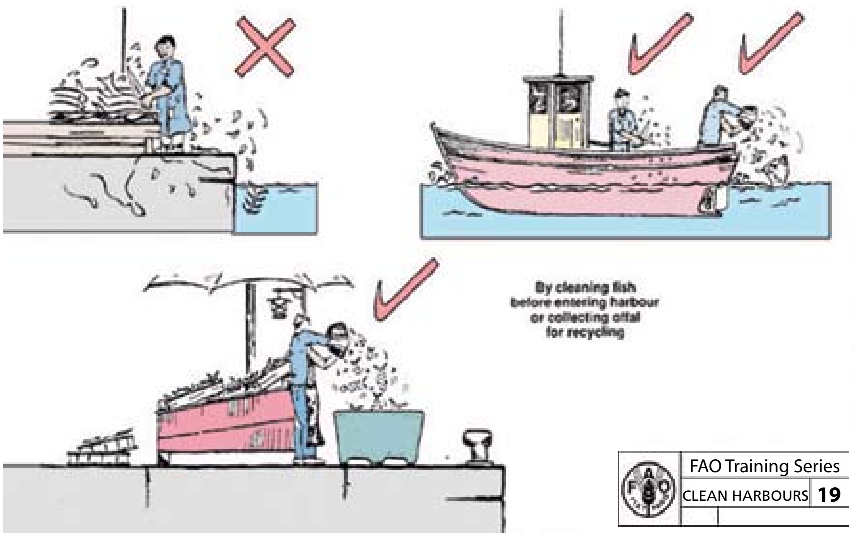
Drawing No.16 emphasizes the need to maintain engines properly (oil seals) and avoid oil spillage. If outboards are very popular in a specific country, an outboard engine should be added to this drawing.



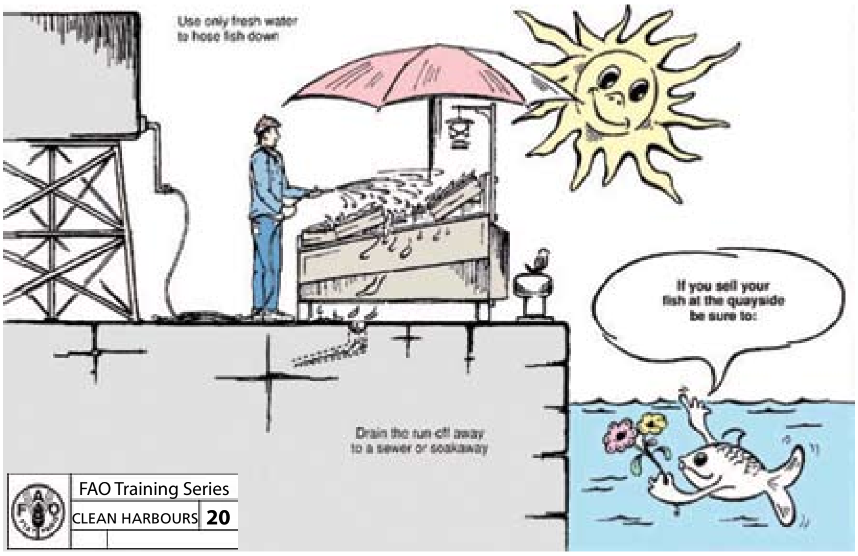
Drawing No.17 shows collection and treatment of slops at both the artisanal and industrial levels.



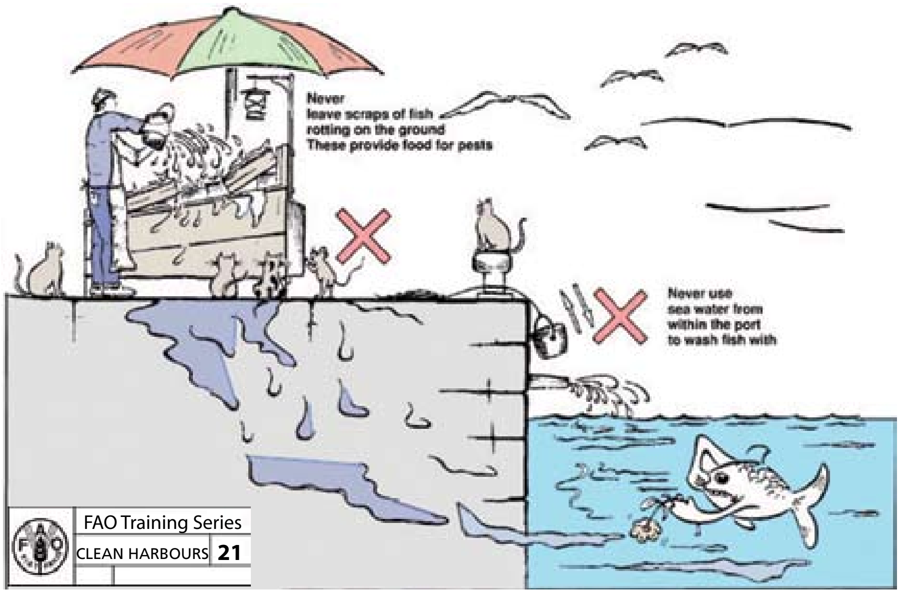
Drawing No.18 suggests more environment-friendly methods of storing fish. Foam and timber boxes accumulate bacteria and are not suitable for continuous use. However, timber boxes are made locally and can be used as fuel when they break.



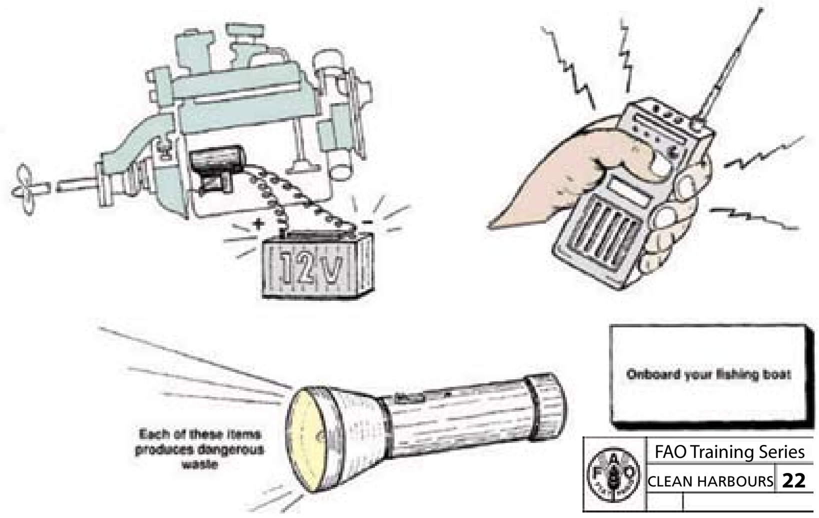
Drawing No.19 shows how to keep the problems associated with offal to a minimum.



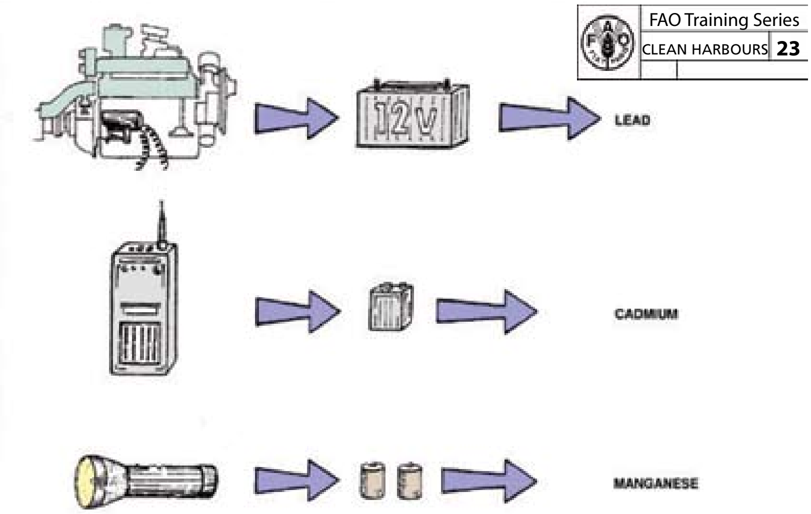
Drawing No. 20 explains the importance of using clean fresh water to rinse fish. Note also that the run-off containing blood is drained into a soakaway and not into the harbour.



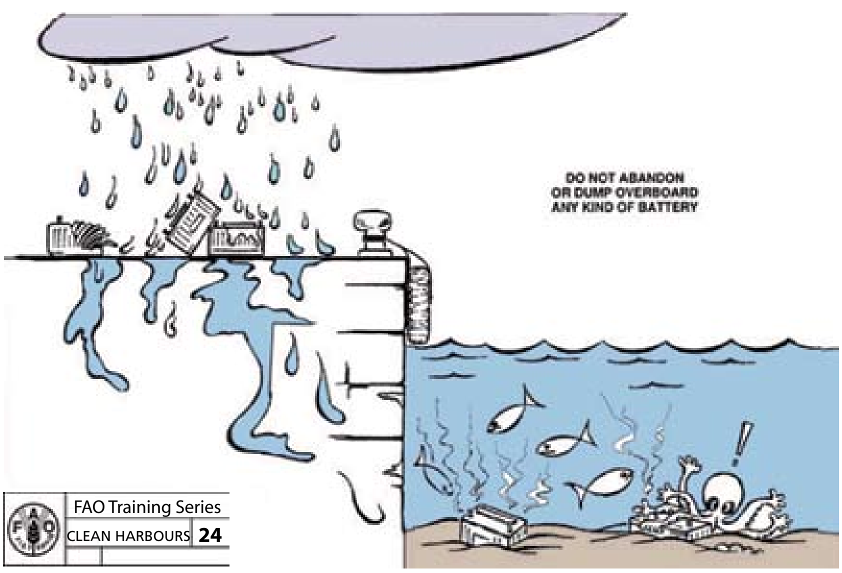
Drawing No. 21 shows bad fish-cleaning techniques. The fishmonger is using dirty water from the harbor, where raw sewage might be present, and dumping scraps of fish which attract pests and disease. Note the absence of soakaway.



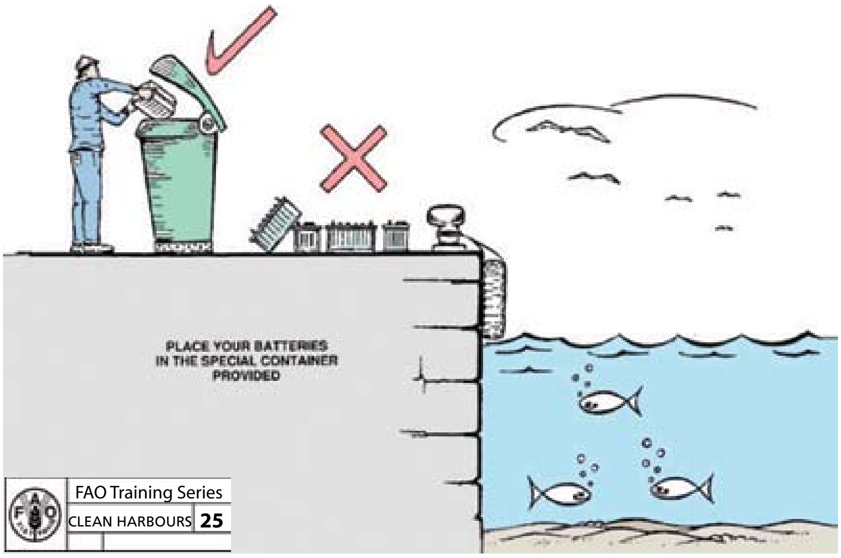
Drawing No. 22 illustrates the sources of highly toxic heavy metal pollution.



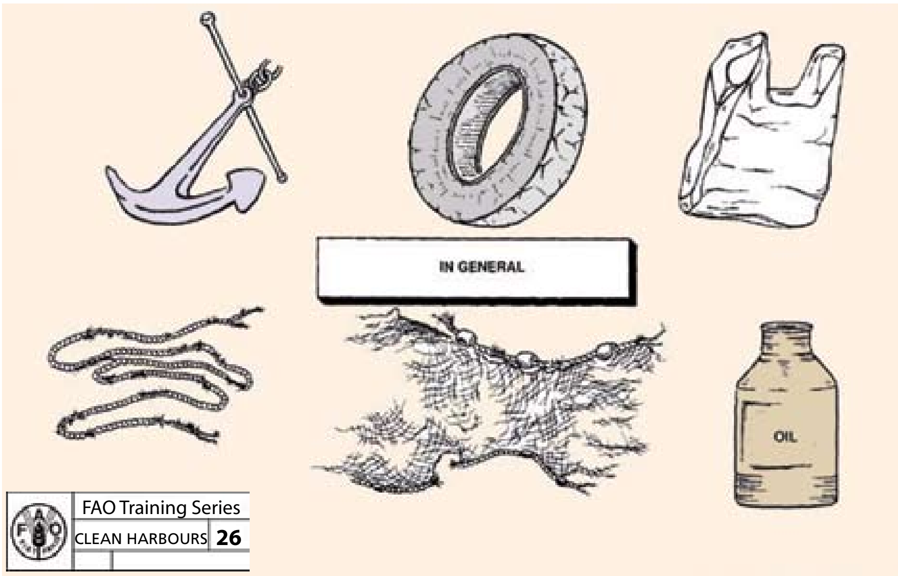
Drawing No. 23 shows which toxins the items shown in Drawing No. 22 contain. Although the manganese powder filling of the torch battery is not considered toxic, it always contains traces of mercury which is highly toxic.



Drawing No. 24 illustrates how batteries break up and release toxic lead into the environment.

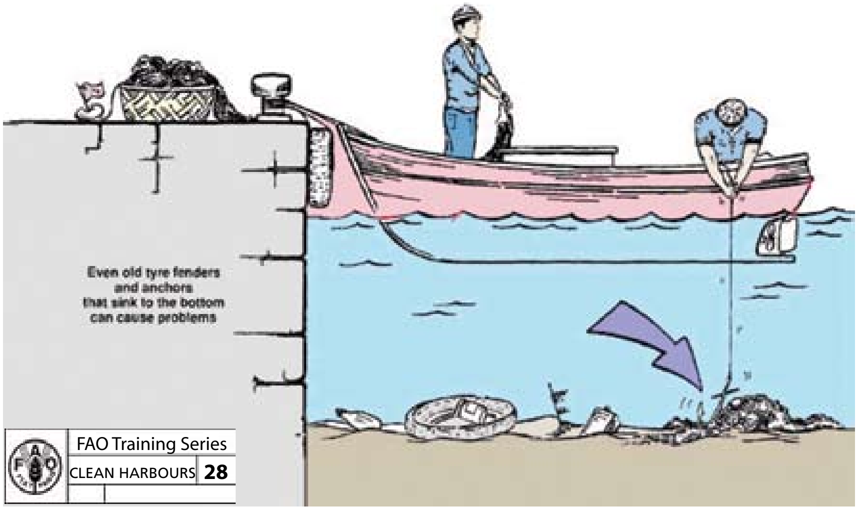


Drawing No. 25 illustrates a recommended collection method. The size and shape of containers illustrated should match local market conditions.

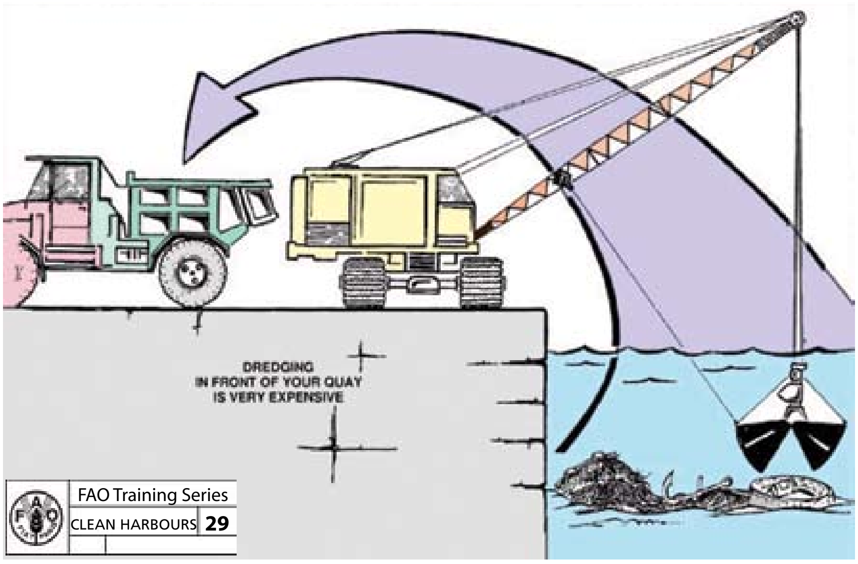


Drawing No. 26 Illustrates items which are sometimes "lost" over the side of boats.

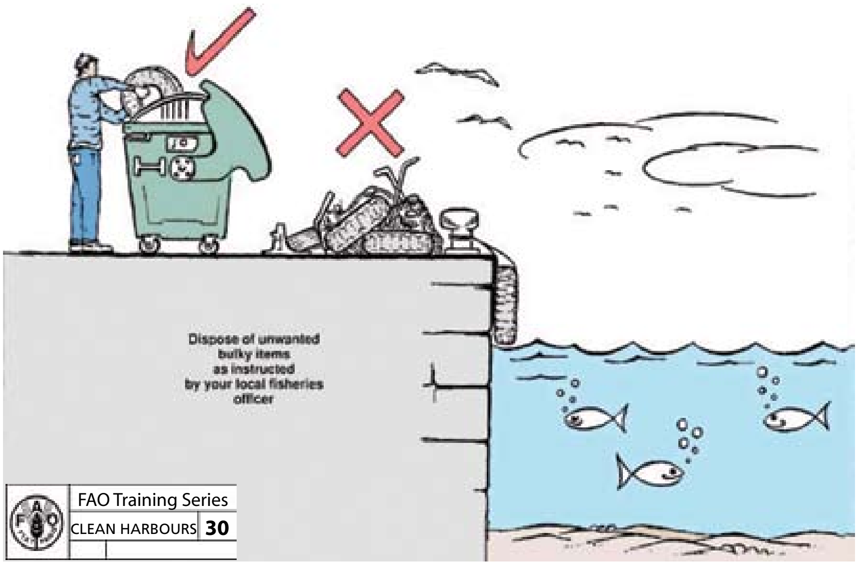
Drawing No. 27 illustrates two cases where such items cause inconvenience to other vessels.



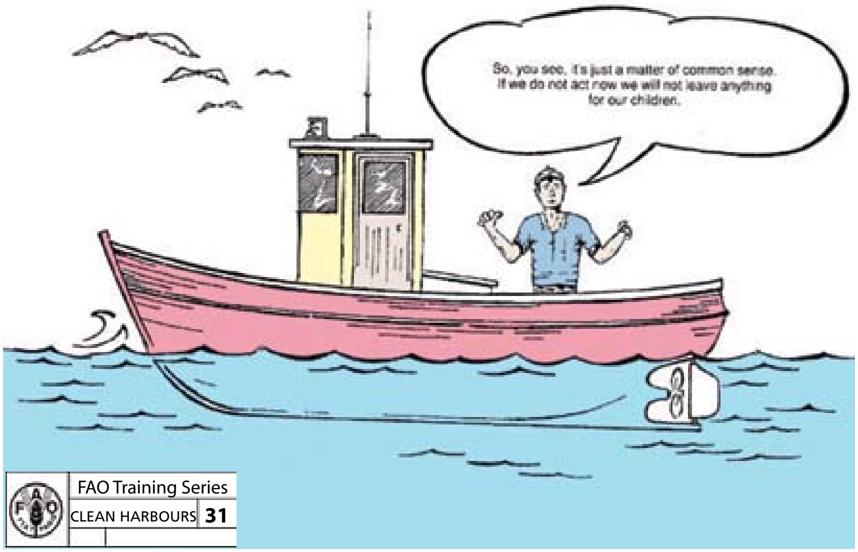
Drawing No. 28 illustrates another such inconvenience.



Drawing No. 29 focuses on the cost of removing this sort of rubbish.

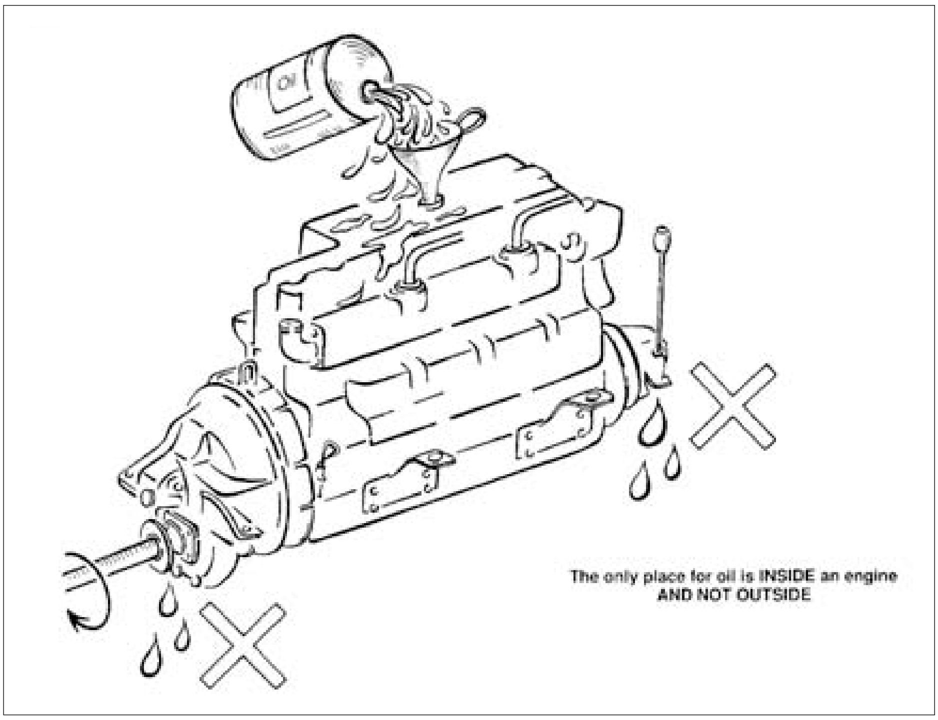


Drawing No. 30 illustrates the correct method of rubbish disposal. The container should resemble the one intended for use.



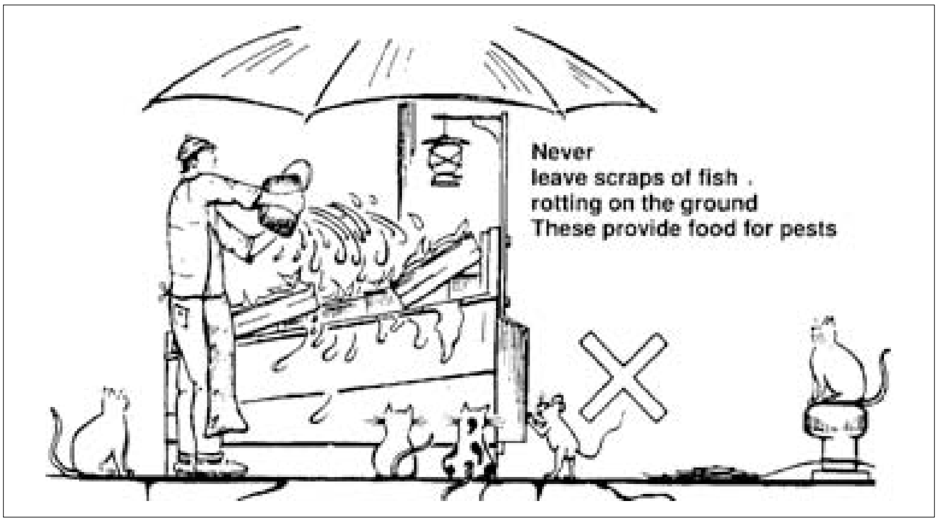
Drawing No. 31 can be used to illustrate the commentator's summing-up remarks.

PRACTICAL POSTERS
Based on FAO POSTER TRAINING SERIES



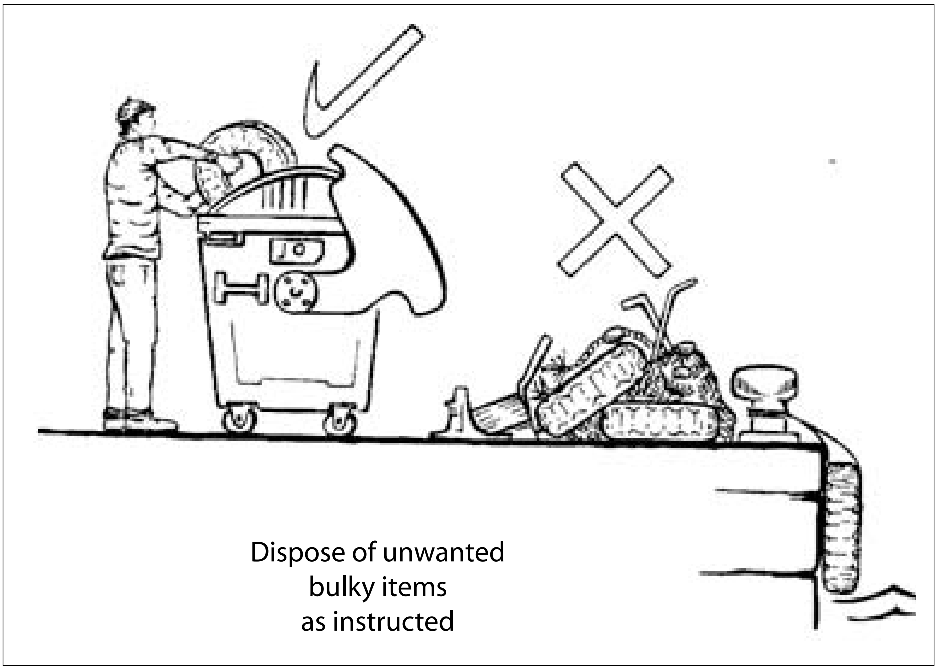
Drawing for a poster to be affixed in fishing harbours to remind fishermen to replace leaking oil seals and to exercise care when replacing engine oil.

Leaking oil seals and oil spillage contribute to create oily bilge water which must then be treated before being returned to the sea. Although it is an offence under MARPOL to dump oily bilge water at sea, very few fishermen seem to understand the process. Invariably, most bilge water ends up in the sea.



A poster to be affixed inside the port area where fish hawkers congregate to sell fish.

Although fish gutting and cleaning should be forbidden inside the harbour area, sometimes this practize cannot be helped. In order to avoid the spread of diseases which accompanies the presence of household pests, hawkers should be instructed on the proper disposal of unwanted wastes. Wet waste bins should be provided in ample quantities and placed in strategic locations. They should be shaded from sunlight to prevent higher rates of decomposition and foul smells.



The figure shows a drawing for a poster instructing harbour users to utilise the harbour waste receptacles for their bulky inorganic wastes.

Posters indicating the different types of wastes catered for and the respective bins to use should be placed at the entrance to the harbour as well as in strategic locations around the port. The bins for the different wastes (non-toxic, toxic and wet wastes) should be colour coded and suitable for the kind of waste.

Fines levied by the management for non-observance of the port regulations should be listed and placed in a prominent location inside the port boundary.

The role of the fishing port may be considered as the interface between the netting of fish and its consumption. In today's world of increased environmental awareness, a fishing port must be planned, designed and managed in harmony with both the physical and biological coastal environments. At each stage of the process, whether it is planning, design or management, both technical and non-technical persons become involved in the process. This manual was produced in order to tackle fishing harbours in a holistic approach. It should be of use to both technical and non-technical planners, both at government level and at departmental level. It provides non-engineering staff within such departments with enough technical knowledge to better understand certain basic design requirements, which could otherwise be interpreted as superfluous and not cost effective.

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