Chapter 8
Research on drainage materials

The first information from research on drainage materials came from studies, made with analogue sand tank models (Wesseling and Homma, 1967; Segeren and Zuidema, 1969). Sand tank model research has contributed to the identification of relevant parameters. Theoretical studies (Widmoser, 1968; Nieuwenhuis and Wesseling, 1979) and electrolytic model research (Dierickx, 1980) on pipe and envelope characteristics have resulted in their quantification and have increased the knowledge in this field. Relevant practical information on the need of drainage envelopes, i.e. the retention of soil particles in envelopes was obtained from permeameter research (Samani and Willardson, 1981; Dierickx and Yüncüoglu, 1982; Stuyt, 1982; Lennoz-Gratin, 1987).

The material discussed in this chapter deals almost exclusively with drain envelopes, because envelopes are an integral part of many subsurface drainage systems. If they fail, the whole drainage system fails. Problems concerning the application of drain pipes are limited and well understood. Frequent problems and an ever-expanding choice of materials make drainage envelope research important.

There are two categories of investigations into the functioning of drain envelopes, which are not always clearly distinguished. These categories are:

- *'black box'* investigations intended to evaluate the suitability of specific envelopes rather than to understand the factors which determine their applicability; and
- investigations which are intentionally made to try to *reveal the factors* and to define the associated parameters which determine the applicability of envelope materials in general terms.

The first category may be labelled as *evaluation of envelopes*, the second as *fundamental research on envelopes*.

Testing of drain envelopes is usually conducted in two consecutive steps, namely examination in the laboratory and subsequently in the field. Thus, promising envelopes – as based on laboratory test data - are subjected to field performance tests. In the following, guidelines have been drafted for laboratory and field research projects. The components of these guidelines are discussed and a family of practically oriented *do's* and *don'ts* concerning the set-up and the monitoring of conducting laboratory experiments and pilot areas is established.

Prior to setting up a research project (laboratory as well as field research) to investigate the suitability of envelope materials for a specific application, it should be considered which question(s) can be answered, and which questions cannot.

RELEVANT SOIL CHARACTERISTICS AND ENVELOPE PARAMETERS

Research on drainage materials (both laboratory and field research) requires that the specifications of the envelope and the relevant soil characteristics are well known. The performance of an

envelope is largely determined by physical and chemical soil properties. Permeameter tests should therefore be carried out with soil of the experimental field where the drains will be installed, taken at drain depth, or with soil that will be used to blind the drains. When permeameter research is carried out, it is also important to know and control the soil conditions (moisture content, bulk density etc.) in the permeameter, so that the field performance can be predicted in relation with installation conditions. To evaluate drainage envelope materials from field research, the soil in which they will be installed as well as the applied envelope material should be clearly specified. The following physical and chemical properties of the soil and the envelope specifications in both laboratory and field research should therefore be determined.

Relevant *soil* characteristics (see Chapter 6, Section *Physical properties of the soil*) are:

- particle size distribution (soil texture);
- plasticity index, which requires the determination of the liquid limit and the plastic limit;
- soil density (for permeameter research only); and
- salinity and sodium, calcium and iron content of the soil and of the irrigation water.

Relevant parameters of *synthetic envelopes* (see Chapter 3, Section *Specifications for prewrapped envelopes*) are:

- thickness;
- characteristic opening size (preferably O_{90}) or the whole pore size distribution curve (which gives more specific information); and
- water penetration resistance (occasionally).

Relevant parameters of *granular envelopes* (see Chapter 3, Section *Specifications for gravel envelopes*) are:

- particle size distribution; and
- chemical components.

LABORATORY ASSESSMENT OF ENVELOPE APPLICABILITY

Testing of large numbers of envelope materials in the field is time consuming and expensive. Therefore some kind of analogue modelling can eliminate envelope-soil combinations that are obviously unacceptable. Analogue models, i.e. sand tanks and flow permeameters, have been extensively used for this purpose. A review of the development of analogue modelling of envelope functioning in The Netherlands is given by Stuyt (1992a).

Sand tank models

In the 1960s, sand tank models were quite popular in The Netherlands. These models were used primarily to investigate the entrance resistances of various sorts of pipes, like clay tiles, smooth plastic pipes and corrugated plastic pipes. Standards for corrugated pipes were not established yet, and the experiments were focused on perforation patterns and some envelope materials. Later on, sand tanks have been used extensively to test envelopes.

Sand tank models have led to useful results:

- All investigations carried out in sand tank models confirm the favourable effect of drain envelopes (Watts and Luthin, 1963; Feichtinger, 1966); even of sheet envelopes.

- The entrance resistance decreases with increasing envelope thickness (Wesseling and Homma, 1967; Segeren and Zuidema, 1969).

- Studies with sand tanks revealed that the number, shape, and size of perforations affect the entrance resistance less profoundly than does the envelope material.

- Luthin and Haig (1972) proved that a suitable gravel surround acts as a completely permeable drain, making gap spacing of clay and concrete pipes virtually unimportant.

- Investigations into the hydraulic performance of drainage systems with partial surrounds indicated that there is not so much difference compared to complete surrounds (Segeren and Zuidema, 1969; Saulmon, 1971; Dennis and Trafford, 1975). Yet, in many cases complete surrounds are safest in preventing excessive pipe sedimentation.

Despite their usefulness, accurate study with sand tank models is very difficult (Wesseling and Homma, 1967). Drainage materials can only be compared when the investigations are carried out under strictly similar circumstances. Wesseling and Van Someren (FAO, 1972) assessed the disadvantages of sand tank models as follows:

- The drainage materials are tested in a rather short time. Wesseling and Homma (1967) however found that the entrance resistance of subsurface drains increased with time.

- Results are closely connected with the way the analogue model is filled with soil material. To obtain consistent data, very homogeneous sand has to be used. This makes it difficult to gain insight related to the properties of the material to be expected over a long period in practice, where field conditions may differ widely from the laboratory conditions.

Conventional sand tank models were quite large, e.g. 1.5(*L*)×1.0(*W*)×1.0(*H*)m. They were filled with cohesionless sand or cohesionless soil types originating from, or similar in texture to the soil of the area to be drained. A large amount of sand was required to fill such models. Moreover, the filling had to be done as homogeneously as possible, which was quite labour-intensive. Therefore most experimentally used soils contained only a small percentage of clay and silt particles and organic matter, and were, as such, often different from most soil types that were found in the field. If the envelope performed well in a test, it was recommended for field use. In many sand tank experiments, the objective was to quantify the entrance resistance, yet in reality, an 'approach flow resistance' was recorded. In addition, the sand-tightness was tested and the envelope was accepted for use in practice if no substantial passage of mineral particle was observed.

Laboratory experiments in sand tank models, made in the sixties and seventies, could not give straightforward clues on the performance of drain lines because:

1. envelopes were examined without attempting to understand and analyse the physical processes involved;
2. only sandy soils could be used;
3. envelope parameters like characteristic pore size were not considered;
4. the relevance of presumably important envelope parameters to the functioning of envelopes was not systematically investigated;
5. installation circumstances and soil conditions (moisture content and bulk density) were not covered, hence the reproducibility of tests was low; and
6. long-term, time-dependent phenomena, like seasonal changes, and the rate of mineral and chemical clogging in the long run (e.g. one year or longer) could not be simulated.

Point 5 deals with the moisture conditions under which the pipes were installed in the sand tanks. Cavelaars (1966) found that the measured 'approach flow resistance' as well as the hydraulic conductivity were quite sensitive to the moisture content of the soil samples the sand tanks were filled with. Indeed, in many sand tank experiments, a substantial decrease of conductivity with time was found near the drain. According to Willet (1962), Van der Meer and Willet (1964) and Koenigs (1964), this decrease is caused by local blocking of soil pores by fine particles, which have been dispersed by the puddling of the soil at high moisture content. A high susceptibility to puddling under wet conditions in the field is found in certain soils high in particles under 50 µm. Decreases in hydraulic conductivity up to a factor 20 were observed; facts that of course appeared to be of great importance for determining the performance of drains in the field.

Drains, installed in other than sandy soils (e.g. loamy and silty soils) may also require envelopes. The physical properties of such soils cannot be easily simulated in analogue models. In these cases, parallel flow permeameters and field experiments are indispensable to examine envelope applicability.

During the First International Drainage Workshop, held in Wageningen, The Netherlands in 1979, Knops and Dierickx (1979) concluded that there was a great need to acquire more knowledge about the most efficient and effective use of synthetic fibre fabrics as drain envelopes. This need was prompted because of the then rapidly increasing availability of synthetic envelope materials. Research that would be more fundamental than the investigations made so far, was required to evaluate the interactions between soils and drain envelopes. It was carried out to deepen the insight into the sensitivity of a soil to internal erosion and the processes influencing soil particle movement. This research was to provide the necessary information to develop a reliable methodology for predicting the need for an envelope in any soil type and for any soil condition. The parallel flow permeameter proved to be a suitable means for this type of research.

Parallel flow permeameters

Permeameter research simulates the flow towards a plain or wrapped drainpipe by one-dimensional flow towards a flat piece of drainpipe, an envelope material, or a combination of both. An example of a permeameter apparatus with upward flow for testing the performance of drainage materials is shown in Figure 44. It consists of a plexiglass cylinder with an inside diameter of 100 mm and a length of at least 150 mm in which a soil sample with a height of 50 to 100 mm is packed. A flat piece of drainpipe wall is used on top of the soil sample as an external support, with the envelope (if any) in between. A spring with support (screen and geotextile or perforated disk) maintains a positive contact, even when small amounts of soil particles are washing out. The hydraulic heads in the system are monitored by piezometers connected to a manometer board. Obviously, the tests should be carried out within a gradient range that is representative for the hydraulic gradients that may develop near the drains in the field. The laboratory tests should be run at progressively higher gradients until the envelope material fails or until the highest obtainable gradient is reached. In this way, the possible failure gradient of the soil-envelope combination can be recorded. Failure can be mineral clogging of the envelope, excessive movement of soil through the envelope material or the collapse of the soil structure, resulting in a substantial decrease in hydraulic conductivity. Conclusion on the performance of a soil-envelope combination may not be based on one single experiment but on a number of replicates, in which soil preparation and filling of the permeameter must be done according to certain rules. Soil aggregates should be passed through a sieve to form aggregate fractions. Then, soil samples are again reconstituted with known amounts of each fraction. The

FIGURE 44
Cross section of a permeameter apparatus for evaluating soil-envelope interactions
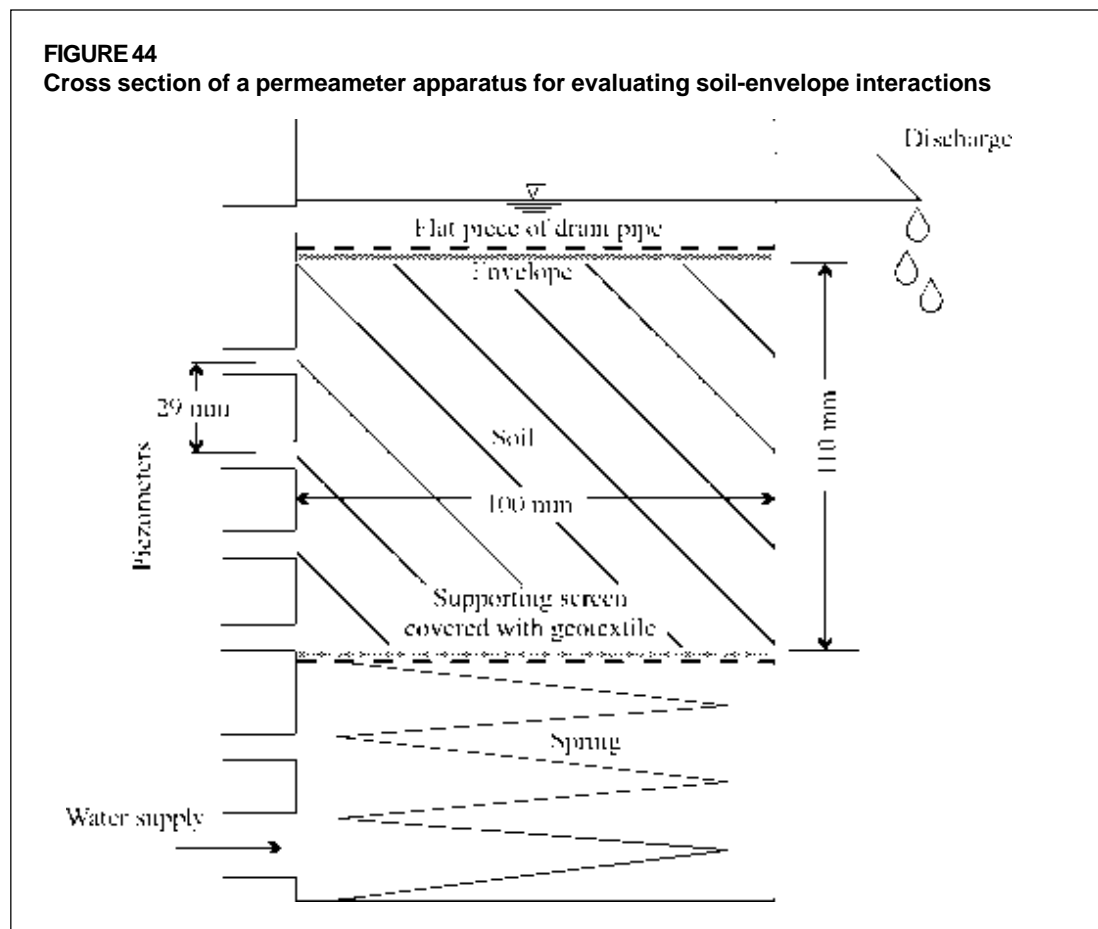
filling of the permeameter with a given soil has to be done in the same way, with the same quantity of soil, and at the same moisture content, in order to obtain the same bulk density for each replicate.

The US Army Corps of Engineers (1977) used a parallel flow permeameter to evaluate geotextile-soil compatibility. This test became known as the 'gradient ratio test', and was accepted as the standard testing procedure for the assessment of the mineral clogging potential of a geotextile-soil combination (ASTM D5101-96, 1996). Willardson and Walker (1979) also designed a parallel flow permeameter that was used by Samani and Willardson (1981) to develop the concept of the hydraulic failure gradient, i_f (see Chapter 4, Section *Hydraulic failure gradient)*. A parallel flow permeameter was used by Dierickx and Yüncüoglu (1982) in Belgium to gain more information on the performance of envelope materials in structurally unstable soils. It was also used to gain a better understanding of the mechanism of particle migration at and near the soil-envelope interface. In The Netherlands, Stuyt (1982) set up permeameter research to simulate the physical process of particle passage and envelope clogging with structureless soil. Stuyt and Oosten (1986) reported on permeameter research with undisturbed and disturbed samples of weakly cohesive soils. Permeameter research in France (Lennoz-Gratin, 1987) resulted in a standard test method (NFU 51-161, 1990) to diagnose mineral clogging hazards in subsurface drainage systems (Lennoz-Gratin, 1992). Parallel flow permeameters have been used by many engineers and researchers all over the world to get answers on the interaction between geotextile and soil (Qureshi *et al*., 1990; Fischer *et al*., 1994; Chin *et al*., 1994; Shi *et al*., 1994). Vertical

flow permeameters are used in Egypt (Dierickx, 1988), Pakistan (Dierickx, 1991) and India (Dierickx, 1998c) to assess the applicability of synthetic envelopes and to evaluate the performance of imported and locally made materials with various soil types and at various soil conditions. In Egypt and Pakistan, permeameter research has contributed to the introduction of synthetic envelopes and resulted in the successful use of locally made drain envelope materials in experimental fields.

Parallel flow permeameter models overcome some of the disadvantages of sand tank models and are more suitable to study the physical interaction between envelopes and soils. The reasons are manifold:

- only small amounts of soil material are required;
- both cohesionless as well as cohesive soil may be used;
- the filling with soil can be adequately controlled, hence the repeatability of the tests is high;
- soil conditions, in terms of moisture content and density, can be adequately maintained;
- physical processes in the soil can be simulated; and
- the average hydraulic gradient can be varied and maintained fairly easily.

Parallel flow permeameter testing has proven its validity for assessments of the following phenomena:

- the need of drainage envelopes (Dierickx and Yüncüoglu, 1982; Lennoz-Gratin *et al.*, 1992);
- functional differences between various envelopes (Stuyt, 1982; Stuyt and Oosten, 1986; Lennoz-Gratin, 1987; Rollin *et al.*, 1987; Stuyt and Willardson, 1999);
- the effect of soil conditions on drainage performance (Dierickx and Yüncüoglu, 1982; Kabina and Dierickx, 1986; Stuyt and Oosten, 1986; Stuyt and Willardson, 1999);
- retention criteria of envelopes with respect to soil particles and aggregates (Dierickx, 1987; Dierickx and Van der Sluys, 1990; Qureshi *et al.*, 1990);
- the soil retention properties of gravel (Vlotman *et al.*, 1992b), organic and synthetic envelope materials (Kabina and Dierickx, 1986; Stuyt and Oosten, 1986);
- the interaction of a geotextile-soil combination (Stuyt, 1982; Stuyt and Oosten, 1986; Dierickx, 1986b; Dierickx *et al.*, 1987; Lennoz-Gratin, 1987; Rollin *et al.*, 1987; Qureshi *et al.*, 1990; Chin *et al.*, 1994; Shi *et al.* 1994);
- the heterogeneity of flow patterns near drains by means of dye tracers (Stuyt and Oosten, 1986); and
- the textural composition of micro soil samples from the soil core, of soil material entrapped in the envelope, and of the soil material that passed the envelope and drain pipe (Stuyt and Oosten, 1986; Stuyt, 1992a).

Through these analogue model tests, the need of drain envelopes could be linked to soil characteristics (Samani and Willardson, 1981). Simple and useful retention criteria have been assessed for PLM envelopes and geotextiles used as drain envelopes (Dierickx, 1993). Design criteria for gravel envelopes have been redefined based on elaborate tests carried out by Vlotman *et al.* (1992a).

Guidelines for permeameter research

Permeameter tests may be carried through to evaluate a soil-envelope-pipe combination. The results of the permeameter tests will however strongly depend on the way in which the soil

sample is prepared. In implementing permeameter research, a number of crucial guidelines should be considered.

1.   Soil preparation

Permeameters should not be filled with dry soil clods, as these tend to burst upon wetting, rendering the soil almost impervious. After passing air-dried soil clods through a 5-mm square hole sieve, they should be brought to the desired moisture content (usually field capacity) by spraying water with a paint gun and then passed again through sieves (e.g. 4.76-, 3.36- and 2.00-mm square hole sieves) to make aggregate fractions. Soil samples can be prepared using e.g. 40 percent aggregates between 0 and 2.00 mm, 40 percent aggregates between 2.00 and 3.36 mm and 20 percent aggregates between 3.36 and 4.76 mm. However, aggregate sieving and soil sample preparation are soil dependent. No general rules can be given on moisture content, aggregate fractions and percentage of each fraction for the various soil types. Too small aggregates of swelling clays may result in an impervious soil when saturated. Therefore, some preliminary research on aggregate size, stability and swelling at various moisture contents may be required.

2.   Simulate conditions vulnerable to failure

The soil in the permeameter should not be compacted too strongly because dense soil does not exhibit problems and does not correspond with field conditions where loose, excavated soil is more common, especially in backfilled trenches. The soil condition, moisture content and hydraulic gradient should be simulated as much as possible in accordance with the conditions that are most likely to occur in the field. This is not an easy task.

3.   Measure after equilibrium has been reached

After proper filling of the permeameter, the soil is saturated and the air in the permeameter removed. The experiment cannot be started until equilibrium is reached, which usually takes a few hours depending on the soil. At the same time, the soil column should be checked on visual disturbances along the plexiglass wall of the permeameters. Tests which show piping should be discontinued.

4.   Downward or upward flow direction

Upward water flow is preferred because then the drag force of the water flow counteracts the gravitational and the cohesive force - if present - and promotes an unstable situation as soon as these opposite forces cancel. Downward flow tends to mechanically stabilize the soil, because the flow force acts in the same direction as the gravitational force.

5.   Apply increasing hydraulic gradient

The hydraulic gradient near drainpipes is subject to variation. With permeameters, any dynamic sequence of hydraulic gradients may be simulated. Soil particle passage through envelopes occurs as soon as a critical level is reached. A gradual increase of the hydraulic gradient is a good standard.

6.   Assessment of soil erosion

The hydraulic gradient in the soil near the drainpipe determines whether soil erosion will occur. The susceptibility of a soil to erosion can be examined by gradually increasing the hydraulic

gradient. Attempts to estimate the *amounts* of sediment in the field from permeameter tests are useless since the hydraulic and other conditions there may be quite different.

7.   Relationship between laboratory and field data

Mineral clogging of field drains wrapped with envelopes found to be suitable in earlier permeameter experiments may still occur. In such cases the envelope should not be immediately blamed. First an accurate field survey should be made into other possible causes, e.g. damaged pipes or envelopes, soil invasion during connection with a collector or a manhole, defective connections, ochre formation, etc.

8.   Interpretation of results obtained with permeameters

Under ideal and well-maintained conditions, results of identical tests should be similar. Permeameter flow tests should therefore be made with three replicates at least, in which aggregate size, moisture content and soil density should be the same. If the test results deviate substantially, additional tests should be made, again in three replicates. When all additional results correspond with the results of two of the first series, a corresponding reliable conclusion can be made. In all other situations, the tests must be redone. If results are widely scattered again while the testing conditions are similar, the envelope must be considered unreliable.

FIELD ASSESSMENT OF ENVELOPE APPLICABILITY

Field research

No 'analogue' simulation can fully reproduce the physical processes that occur in the field. Phenomena that require further study in the field are the long lasting behaviour of envelopes due to seasonal changes, chemical and microbiological clogging, peculiar soil invasion processes and root growth.

Combinations of drains and envelopes that come out favourably from a laboratory test should be installed under field conditions to investigate the long term effects mentioned above. They can be tested again to assess their performance in relevant soils and under various installation conditions.

Conclusions on the performance of drain envelopes from field research cannot always be drawn due to a large variability in results because of:

- the variability of the physical properties of the soil;
- uncertain effects of installation (quality of the work and general wetness);
- mineral clogging through damaged pipes and/or envelopes, and defective connections;
- soil invasion during connection with collectors or manholes; and
- ochre formation.

Special attention should be paid to other problems with drainage materials which may affect the results of field investigations. The most frequently occurring problems are:

- loose and/or damaged exit pipes (in systems with open collector ditches only);
- interrupted drains due to poor pipe quality (broken pipe) or detached pipe connectors;
- entrapped air (or methane) inside a drain which has been installed with an irregular grade; and

- challenging soil properties, such as soils with ochreous seepage, acid sulphate soils, low-permeability loam and 'unripened' clay soils with very high seepage rates.

Evaluation of the performance of drainage systems in drained lands is out of the scope of this publication, although checking the performance of the drainage materials is a major component of such evaluations. The constraints defined above are more accentuated in this case. Therefore, the selection of the fields to be evaluated should be done after a sound reconnaissance survey of the project area.

Guidelines for field research

A good field research project requires some basic guidelines. These are:

1.   Selection of experimental fields

Experimental fields must be carefully selected in order to reduce the influence of different soil types as far as this is possible and practical. The large variability of soil texture, structure, and condition (e.g. moisture content and bulk density) along the drain lines makes it very difficult to evaluate the performance of an envelope in the field, because the functioning of the entire drainage system, including the effect of the soil near the drain is evaluated. Therefore, it is recommended to try to select a location where soil heterogeneity is known to be small.

One should be aware of regional components of groundwater flow. In any region where a new experimental field is scheduled it must be known or verified if any appreciable rate of deep percolation or seepage exists. Laterally oriented components of groundwater flow that may interfere with a subsurface drainage system may also exist. As long as the intensity of these phenomena is restricted, their interference with the results will also be small. The threat of soil heterogeneity, in combination with percolation and seepage, seriously challenges the validity of the recorded data.

2.   Parameters to measure

Monitoring the effect of one single factor on the composite result of a complex physical process is often difficult. If the impact of one factor notably exceeds the cumulative effect of the other ones, field research is more likely to be successful, because the underlying problem can be investigated more easily.

To determine approach flow resistances and to correlate them to envelope types, drain discharge is measured together with the approach head loss and the total head loss (Figure 23):

- the *approach flow head loss* is measured as the vertical difference between the water level in a piezometer located at a distance of 40 cm away from the drain, and the water level in a piezometer in the drain pipe; and
- the *total head loss* is measured as the vertical difference between the water level in a well tube midway between two drains and in a piezometer in the drain pipe.

Drain discharges and water levels in piezometers are recorded frequently in order to determine the variation of the approach flow resistance (Eq. 6 in Chapter 4, Section *Entrance and approach flow resistance*). To monitor changes of soil and water flow conditions near the drain, right after installation, daily recording is required. If unsteady state flow prevails, daily observations are necessary during the peak period. During tail recession and if drain discharges can be considered quasi steady state, the recording frequency can be lower.

Furthermore, excavations are made in order to check drain clogging rates and the possible microbiological decomposition rate of organic envelopes (Scholten, 1988). Sometimes determination of soil texture and soil chemical properties at various locations is useful to explain differences in the performance of drainage systems. Procedures for field testing of drain lines and processing of collected data can be found in Dieleman and Trafford (FAO, 1976).

3.   Design and construction of the experimental field

All field parameters which are not associated with drainage materials, but which may affect drainage performance, such as drain spacing and drain depth, should be kept constant because they impose a disturbing 'noise' on the results.

Given the implicit heterogeneity of the soil and the random effects that are induced by the installation of pipe drains, the *use of replicates* of objects under study (mostly laterals) is essential when various envelope materials must be compared. There are, in principle, two options regarding the layout of a field experiment.

- *Laterals, wrapped with identical envelope materials, in contiguous groups of at least three drains.* This layout has the advantage that the interference by laterals wrapped with other envelope materials, is smallest. Hence the data on drain performance will be the most reliable. This is particularly true for the laterals located near the centre of the group. This layout is the most appropriate, despite the risk that soil heterogeneity affects the data.

- *Each envelope is located next to different types.* In this layout, interference between adjacent drains will impose noise on the data. The data may therefore be not very reliable and difficult to interpret. However, this layout has the advantage that the effect of heterogeneity of soil properties is minimized.

To minimize the risk that substantial 'noise' is imposed on the results, it is recommended:

- to have the drains installed by a well-qualified contractor, and
- to use drainage materials that are uniform along the lateral.

4.   Data collection

Data collection must not start before the soil around the drains has settled. For the collection of data strict guidelines must be observed, because erroneous data will lead to undetected misinterpretation. The frequency of measurement must be adapted to the variability of the parameters with time, e.g. water table depth, hydraulic heads and discharge. The recording frequency of data must be the highest during and after storm events and irrigation supplies. In order to get information about soil heterogeneity it is recommended to install an additional number of piezometers alongside at least one drain. Valid recommendations on how to measure groundwater levels and how to construct piezometers may be found in e.g. Dieleman and Trafford (FAO, 1976).

5.   Data processing and analysis

The emphasis of the data analysis procedure should be on long-term trends. Small differences in performance between drains are not relevant, because they are probably due to the heterogeneity of the soil profile. Large differences should be analysed carefully before conclusions on envelope performance can be drawn. Suggestions on how to analyse the functioning of drains are given

by many authors, e.g. Wesseling (1967), Kessler (1970), Huinink (1991), and Ochs and Bishay (1992).

In field experiments, it is common practice to evaluate the performance of drainage materials following Dieleman and Trafford (FAO, 1976). In the procedure that they propose, the discharge is measured together with the total head loss and the head loss 0.40 m away from the drain centre which they consider beyond the boundary of the trench. They define the vertical difference between the latter head and the head at the centre of the drain pipe as 'entrance head loss' and the collected date are used to calculate the entrance resistance and to express the entrance head loss as a fraction of the total head loss. The entrance resistance, which results from such measurements is, in fact, an 'approach flow resistance' and the corresponding head loss is the corresponding 'approach flow head loss' (see Chapter 4, Section *Entrance and approach flow resistance*).

The main reasons why the entrance resistance, defined by Dieleman and Trafford (FAO, 1976), differs from the theoretical entrance resistance are:

- the head loss for the approach flow (h_{ap}) and the head loss for the entrance flow (h_e) are different (see Chapter 4, Section *Entrance and approach flow resistance*);
- the piezometer for measuring the entrance head loss is not placed at the drain/soil interface, but at some distance from it;
- the flow pattern around the drain is not fully radial, even if water is standing above the drain; and
- water enters the drain through a sector of the drain circumference only.

The approach flow resistance, W_{ap}, obtained from field experiments should be a constant. There are, however, so many associated factors that it is quite a difficult parameter to evaluate. Factors that affect the approach flow resistance are:

- soil heterogeneity, and heterogeneously distributed hydraulic conductivity;
- heterogeneously distributed drain inflow, even with uniform water supply;
- heterogeneous supply of water due to local irrigation gifts; and
- the variability of head loss along the drains.

Dieleman and Trafford (FAO, 1976) made classes for the 'approach flow head loss fraction' (Table 11) and the 'approach flow resistance' or 'approach flow head loss' (Table 12).

TABLE 11
Classification according to the 'approach flow head loss fraction' (after Dieleman and Trafford, FAO, 1976)

Approach flow head loss fraction h_{ap}/h_t	Drain line performance
smaller than 0.2	good
0.2 - 0.4	moderate
0.4 - 0.6	poor
larger than 0.6	very poor

TABLE 12
Classification according to 'approach flow resistance' or 'approach flow head loss' (after Dieleman and Trafford, FAO, 1976)

Approach flow resistance W_{ap} (d/m)	Approach flow head loss h_{ap} (m)	Drain line performance
smaller than 0.75	smaller than 0.15	good
0.75 – 1.50	0.15 – 0.30	moderate
1.50 – 2.25	0.30 – 0.45	poor
larger than 2.25	larger than 0.45	very poor

It should be kept in mind that the classes in both tables are valid for the conditions they have been drafted for (drain depth of 1.8 m; drain spacing of 50 m; water table depth of 1.0 m one or two days after irrigation and a discharge rate of 4 mm/d at that water table depth). For other conditions, another appreciation should be given to the obtained values (Dierickx, 1996b). Therefore, any attempt to compare approach flow resistances emerging from different field experiments is meaningless unless all conditions of the experimental fields are the same and are well documented.

In addition, the following general recommendations for field research projects must also be taken into account (Ritzema, 1997):

- Make sufficient arrangements for site-office requirements and for resources (human resources, laboratory, and computer facilities).
- Arrange to safeguard unlimited accessibility of the pilot area, at all times.
- Make agreements with farmers, which should be actively involved in the project.
- Provide regular maintenance of the monitoring network, in a separate project.
- Provide data storage facilities in conformity with database tools and software that are locally available and used.
- Process and interpret the data immediately and continuously in order to detect data and/or testing inconsistencies.
- Utilize data presentation techniques (like graphs or summarizing tables) for unambiguous interpretation of results.
- Formulate proposals for a follow-up for the project, reformulating objectives, possibly deciding to discontinue the investigations, or adjustment of the research programme in a subsequent project.

RECOMMENDATIONS FOR FUTURE RESEARCH

Theoretical studies, laboratory and field research have all contributed to a gradual increase of knowledge on drainage materials and their performance. The complexity of the physical properties of the soil is, however, the reason that some problems are not yet adequately solved. These problems are only slightly related to drainage materials. Rather, they are associated with soil type, soil condition at the moment of installation and accuracy of installation. This implies that the resulting drain line performance is, to some extent, unpredictable. This is the more so in 'new' areas, where systematic investigations are few or missing. In these regions there is scope for 'reconnaissance-type' of investigations. The best approach would be a search for fields with poorly functioning or failing drains, followed by investigations into the causes and mechanisms of the failures.

Experience gained in the Netherlands in the 1960s may serve as an illustration. A great number of field experiments were carried out by various agencies to test and compare different drainage materials, with the emphasis on entrance resistance. In the light of the researchers' expectations, the results were often disappointing or outright frustrating. The measured data generally showed a wide variation, and rarely reflected a significant difference between the investigated drainage materials. Plotted data often yielded scatter diagrams that resembled, in the words of one researcher, a 'cloudless sky by night'. Really poor functioning, let alone outright failures, hardly were found in the experiments. Thus the conclusion might have been that there was no real reason to worry about entrance resistances or, consequently, about materials at all. On the other hand, drainage failures did turn up in scattered places, but no clear relation with

materials could be established. In large projects, a few percent of failures form an awful heap of complaints, which usually make their way to the director's desk.

A good deal of insight was acquired from a reconnaissance campaign, specifically implemented to track down fields with poorly functioning or (preferably) failing drains. Cavelaars (1967) discusses the results of investigations on 64 fields. The search for failures was difficult because those, responsible for the drain installation (contractors and/or supervising agencies), were not very keen to come up with failures of their work. The subsequent steps consisted of diagnostic field investigations as referred to above; to find out, as accurately as possible, the method of drain installation and the conditions under which this had been done.

Drain pipes

Flow into drains

The calculation of the discharge capacity of drainpipes requires knowledge of their roughness coefficients. Roughness coefficients have been determined experimentally of all kinds of perforated and unperforated drainpipes, be it full flowing pipes or not. The discharge capacity can be calculated according to two principles: the transport principle and the drainage principle. The drainage principle, with a constant inflow per unit drain length and a gradually increasing discharge, corresponds more accurately with the situation in the field than the transport principle whereby the pipe is assumed to have a constant discharge over its entire length (see Chapter 4, Section *Discharge capacity of drainpipes*).

Still, reality is likely to be different from the theoretical concept of a constant inflow per unit drain length, because of the heterogeneity in flow pattern and in mineral clogging. The main water conveying features are inter-aggregate voids, macropores made by worms and plant roots, and thin, relatively permeable horizontal soil layers (Stuyt, 1992a, 1992c). The accuracy of the grade line of laterals may also affect the uniformity of water inflow. The concept of a constant inflow flow per unit drain length needs further research. It is an important issue since this concept is not only used for design purposes but also to evaluate performances of drainage materials in the field.

Safety factor for design

Sedimentation and irregularities in alignment may reduce the discharge capacity of drainpipes up to 50 percent (El Atfy *et al.*, 1990). The hydraulic properties of drainpipes are well known, but the accuracy of laying, and future pipe sedimentation necessitate the introduction of a reduction coefficient or a safety factor. The question is to what extent such a safety factor is justified, taking into account the modern installation techniques and the use of reliable and well-designed drainage materials.

Drain envelopes

Soil influx into drains

X-ray analyses of wrapped drain samples, made by Stuyt (1992a, 1992b, 1992c), revealed that water flow patterns near drains in fine sandy, weakly-cohesive soils, as well as mineral clogging of envelopes are often quite heterogeneous. These findings emphasize the discrepancy between theory and practice, as far as the analysis of water flow near and into drains is concerned. The consequence is that it is presumably quite difficult to accurately measure the entrance head loss

near drains in a pilot area. Drain envelopes may affect the performance of a drainage system, but the effect of soil properties on water acceptance of drains often dominates. This conclusion of the field research of Stuyt (1992a, 1992b, 1992c), together with all other existing information from laboratory research and field experiments indeed limits the necessity of further research on drainage envelopes. As long as chemical and/or microbiological clogging (especially ochre formation) are unlikely to occur, the proposed design criteria can be applied successfully.

Soil influx recognised by Stuyt (1992a) as 'mushroom'-shaped soil patterns near perforations has also been mentioned by Van der Molen in an experimental drain in the Wieringermeerpolder in The Netherlands (personal communication) and elsewhere by Dierickx (1986a) and Van der Louw (1986). Both Dierickx and Van der Louw used a drain endoscope, while Stuyt used a miniature video camera. Van der Louw and Stuyt assume that 'mushroom'-formation is the result of soil being squeezed through drain envelopes and pipe perforations. Only one week after jetting drains, Van der Louw found 'fresh mushrooms' inside drains, supposedly due to squeezing of liquid soil by the overburden. Yet, a one-by-one particle accumulation during a substantial period (months at least) may be another valid explanation for this phenomenon. This kind of soil influx and its influence on the water acceptance of the drainage system needs further investigation.

Chemical and/or biochemical clogging

In case of chemical and/or biochemical clogging, further research may be necessary about the interaction between envelope, soil, and clogging agent. Such research cannot be done in a laboratory. Sophisticated and expensive equipment is required to investigate and to quantify these clogging phenomena. The processes associated with this kind of clogging, however, will continue, regardless of whether an envelope is installed or not. In such cases, some design measures may be considered. If an envelope is required, a voluminous (i.e. with a thickness greater than 5 mm), coarse-structured synthetic envelope is recommended. Regular maintenance of drain lines is often, but not always necessary. It would therefore be useful to quantify the adequacy of such measures, and especially the suitability of voluminous, coarse structured synthetic envelopes, as compared to other types.

Clogging by substances, related to calcium

Ochre formation is a frequently occurring phenomenon that has received much attention. Less known, however, is the precipitation in envelopes of calcium carbonate ($CaCO_3$) or gypsum ($CaSO_4.2H_2O$). There is ample scope for systematic investigation on lime and gypsum depositions with pipe drains. It would include an inventory of the extent of the problem and the conditions under which it is likely to develop.

Laboratory testing of locally made PLMs and geotextiles

In many countries where gravel envelopes are used by convention, there is a pronounced hesitation to apply synthetic alternatives to conventional envelopes, mainly due to a lack of experience. This concerns mainly imported geotextiles. In many cases, similar products are locally available; if competitive, they should be seriously considered as envelopes. Waste fibres from the carpet industry, original or modified carpet backings and other locally produced geotextiles may be suitable for envelope application. If no experience with such kind of materials exists, applied research with permeameters should be seriously considered. This kind of evaluation does not

contribute to the basic knowledge of the interaction between soil and envelope, but can be quite useful to:

- overcome resistance and hesitation against the use of these newly proposed materials;
- assess the suitability of these materials;
- evaluate their performance as compared to conventional or imported envelopes; and
- make a pre-selection of potentially suitable products for subsequent field evaluation.

Soil properties

Applicability of the hydraulic failure gradient

In many cases, the need for envelopes is not yet accurately predictable. With the exception of some specific problem soils, unequivocal guidelines for the necessity of envelopes cannot be specified yet. Differences in the performance of various envelope materials that have distinct parameters are not easy to assess. Only some trends are recognized. Permeameter tests can also be performed to ascertain the need of drain envelopes for a particular soil, if soil characteristics do not give a decisive answer. In this respect, the concept of the hydraulic failure gradient, i_f , (see Chapter 4, Section *Hydraulic failure gradient*) introduced by Samani and Willardson (1981) requires further consideration. More experience should be gained with the i_f of a soil, which was proposed as a tool to predict the need for a drain envelope.

Aggregate stability

Various methods for determining aggregate stability have been proposed and applied with varying results. Development of a standard technique for application in drainage is required. The effect of soil sodicity on soils around drains seems an intriguing aspect, which needs further investigation.

Chapter 9
Standards for pipes and envelopes

Standards on drainpipes specify the required properties of the materials (clay, concrete and plastics) from which the pipes shall be manufactured, and the specifications of these raw materials, e.g. in terms of chemical composition and additives, as well as the standard pipe strengths. For plastic drains, the standards usually specify whether the use of recycled raw materials is permitted, and under which conditions. The physical dimensions are also subject to specification, e.g. the inside and outside diameters, and the size and location of perforations.

The mechanical properties of drainpipes refer to transport, installation, and error-free functioning. Important requirements are crushing strength for clay and concrete tiles, and for plastics the impact strength, brittleness, and pipe stiffness on the short and long term. Flexible pipes may only very slightly deform due to the overburden of the soil if they are properly installed.

The use of antioxidants and UV inhibitors in plastics should be restricted to quantities that do not change the mechanical properties of the pipes. Some specifications, such as ASTM standards, limit the period of outdoor storage to two years; others give no time limit.

In large-scale drainage projects, testing of pipes and envelopes is of interest for engineers, contractors, and supervisors to check whether drainage materials comply with specifications as required in tenders. In particular, this will be the case in countries where drainage materials are not supplied with official certificates that guarantee compliance with certain standards.

Existing standards for drainage materials originating from countries with a long drainage history are useful to countries that are virtually without any drainage experience. They can be used as a reference to develop a national standard, which is adapted to specific, local circumstances. However, the number of parameters tested should be limited in order to keep the cost of testing within reasonable limits.

The use of sophisticated testing equipment is not always necessary; simple tools can be applied instead. Occasionally, simple rules of thumb can be applied, like striking a clay tile with a metal object: a good quality tile will then give a clear 'ring sound'. Another simple procedure would be to try to crush a 50-mm corrugated PVC pipe by simply loading it with a specified weight. Testing for cold brittleness can be done by a hammer after putting a section of pipe in a refrigerator for 12 hours.

Continuous quality control during manufacture is indispensable to keep inferior quality pipes and unreliable envelope materials off the market. Many countries, where a substantial number of subsurface drainage projects are carried out, have their own national standards or specifications for drainage materials. They have been developed by standardization committees, consisting of specialists from governmental research institutes and private companies. Standards were drafted for clay and concrete pipes, followed by standards for smooth and corrugated plastic pipes. The use of drain envelope materials resulted in the simultaneous development of standards for envelopes.

Instead of publishing an incomplete list of the numerous existing national standards with their various aspects, only the standards of the American Society of Testing Materials (ASTM), some Canadian standards, the draft standard of the International Organisation for Standardisation (ISO) and the draft EN-standard of the European Committee for Standardisation (CEN – Comité Européen de Normalisation) will be referenced. Although the draft ISO and EN-standards cannot be legally imposed, they are the result of discussions between experts from many countries and organizations.

For more details, reference is made to the standards themselves or to the Annex that contains the draft EN-standard on corrugated plastic piping systems. This standard is not yet published and hence not readily available. The draft ISO-standard has not been included in this Annex, since it contains the fundamentals and the concepts on the basis of which the EN standard was developed.

TESTING PARAMETERS FOR DRAINPIPES

For drainpipes the inside and outside diameter are specified with their tolerances. Moreover the following parameters are usually included in standards:

Clay and concrete pipes

- ovality and curvature;
- verticality of the end planes;
- resistance to weathering and deterioration in soil;
- resistance to freezing and thawing cycles;
- density;
- water absorption; and
- crushing strength.

Concrete pipes

In addition to the above:

- sulphate resistance; and
- acid resistance.

Plastic pipes

- stiffness and elongation resistance;
- impact strength and brittleness;
- flexibility and coilability;
- perforations and hydraulic properties; and
- handling and installation instructions.

The substitution of clay and concrete pipes by corrugated plastic pipes made standards for clay and concrete pipes less important although they are still useful in countries where clay and concrete pipes are still installed, including larger diameter collector drains.

Requirements for drain envelope materials include the following parameters:

Granular materials

- granulometry or particle size distribution;
- permeability; and
- chemical composition.

PLMs and geotextiles

- appearance;
- thickness and mass per unit area; and
- pore size.

Geotextiles

In addition to the above:

- permeability; and
- wetability.

NORTH AMERICAN STANDARDS

In the United States, specifications for clay pipes include three classes, namely *standard*, *extra quality*, and *heavy duty*; for concrete pipes a fourth class, namely *special duty*, has been added. Standard-quality pipes are satisfactory for drains of moderate sizes and installation depths. There is a family of ASTM-standards for clay and concrete pipes. The latest version of the relevant standards is given in Table 13.

TABLE 13
ASTM-standards for clay and concrete drainpipes

Material and type	Standard
Clay drain tile and perforated drain tile	ASTM C4-99[1]
Clay drain tile, perforated	ASTM C498-95
Clay pipe, vitrified, perforated	ASTM C700-99
Concrete drain tile	ASTM C412M-99
Concrete pipe, perforated	ASTM C444-95
Concrete pipe for irrigation or drainage	ASTM C118M-99
Reinforced culvert, storm drain, and sewer pipe	ASTM C76-99
Concrete sewer, storm drain, and culvert pipe	ASTM C14M-99

[1] The last two digits give the year of publication of the latest version while M indicates that the standard is in SI (metric) units

Shortly after corrugated plastic pipes were first installed in the United States, the need for standards was recognized and ASTM adopted the first standard in 1974 for corrugated PE pipes and fittings (see ASTM F405-97). In 1976, a standard for large diameter pipes (see ASTM F667-97) was added, and in 1983, a standard for PVC pipes (ASTM F800-83) was adopted, yet standardization work on PVC pipes was discontinued in 1992. Since 1972, over 30 ASTM standards have been developed for corrugated plastic pipes. A partial list of ASTM and other standards in Canada and the United States is given in Table 14.

TABLE 14
United States and Canadian standards for corrugated plastic pipes

Material and type	Nominal inside diameter (mm)	Standard
Plastic pipes, drainage	75-300	CGSB[1] 41-GP-29Ma (1983)
Plastic pipes and fittings	100-300	BNQ[2] 3624-115 (1985)
Polyethylene pipes and fittings	75-150	ASTM F405-97
Polyethylene pipes	200-300	ASTM F667-97
Polyethylene pipes	100-200	USBR[3] (1974)
Polyethylene and polyvinyl chloride pipes	250-300	USBR[3] (1981)
Polyvinyl chloride pipes and fittings	100-200	ASTM[4] F800-83
Polyvinyl chloride pipes	100-200	USBR[3] (1976)
Polyvinyl chloride pipes	75-300	SCS[5] 606 (1980)

[1] Canadian General Standard Board
[2] Bureau de Normalisation du Quebec
[3] US Bureau of Reclamation (1993)
[4] Revision discontinued in 1992
[5] USDA Soil Conservation Service, presently: National Resource Conservation Service (NRCS, 1998)

EUROPEAN STANDARDS

In 1973, the International Standard Organisation (ISO) began to prepare an international standard on 'Pipes and fittings of unplasticized polyvinyl chloride (PVC-U) for sub-soil drainage specification'. In 1985, the draft version was published (Schultz, 1990), and the work discontinued. To date, no final version has been drafted.

Within the European Union, technical specifications are established, in principle within Comité Européen de Normalisation (CEN). Through the creation of this CEN committee, all national standardization work in the participating countries on issues that are subject of European standardization had to be discontinued. This almost ended standardization work by the member states. All European and European Free Trade Association (EFTA) countries can now participate in the co-ordination and harmonization of standards. ISO-representatives may participate as observers in the CEN/TC meetings. Wherever possible, decisions are made by consensus. European Standards are mandatory for all public procurement projects within the European Union.

In 1990, Working Group 18 (WG18) for land drainage, created within the Technical Committee 155 (TC155) of CEN was in charge of 'Plastic piping systems and ducting systems'. CEN/TC155/WG18 (1994) prepared a first draft of the European (EN) standard 'Plastics Piping Systems for Agricultural Land Drainage (PVC-U)'[1]. Although the draft has already passed the CEN-enquiry stage, no further progress has been made since then and, like the ISO standardization work on corrugated pipes, it came to a standstill. In spite of this, the draft standard contains useful information, which includes general functional requirements for *pipes*, *fittings* and *envelopes*, as well as a recommended practice for installation.

In 1989, CEN/TC189 was established to agree on common testing procedures, methods of identification and assessment techniques for *geotextiles*. TC189 is working on a family of relevant test procedures for geotextiles and geotextile related products that will be common to all participating countries. The presentation of index values in all countries will be based on the same test methods but the requirements will be left to the responsibility of the individual countries. In practice, nearly all geotextiles will be produced and sold according to EN-standards. Relevant EN-standards for geotextiles used as drainage envelopes are given in Table 15.

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[1] Unplasticized polyvinyl chloride.

TABLE 15
European (EN) standard for geotextiles and geotextile-related products which can be useful when used as envelopes in agricultural drainage

Title	Standard	Issued
Identification on site	EN ISO 10 320[1]	1999
Sampling and preparation of test specimen	EN 963	1995
Determination of the thickness – single layers	EN 964-1	1995
Mass per unit area	EN 965	1995
Geotextiles : vocabulary	pr EN 30 318[2]	1998
Tensile test for joints/seams by wide-width test method	EN ISO 10 321	1996
Method of simulating abrasion damage (sliding block)	EN ISO 13 427	1998
Static puncture test	EN ISO 12 236	1996
Wide-width tensile test	EN ISO 10 319	1996
Water permeability	EN ISO 11 058	1999
Opening size	EN ISO 12 956	1999
Water flow capacity in the plane	EN ISO 12 958	1999
Water penetration resistance	pr EN 13 562	1999
Water permeability under load	CEN/TC189/WI26[3]	1999
Resistance to weathering	ENV 12 224[4]	1996
Resistance to microbiological degradation	ENV 12 225	1996
General tests for evaluation following durability testing	ENV 12 226	1996
Resistance to hydrolysis	ENV 12 447	1997
Resistance to liquids	ENV ISO 12 960[1]	1998

[1] EN ISO or ENV ISO is both an EN (or an ENV) and an ISO standard

[2] prEN is a draft standard which is not yet finalized

[3] Work item 26 of CEN/TC 189 under discussion

[4] ENV is a pre-standard, established as a prospective standard for provisional application (validity period of 2 years)

The draft EN-standard for corrugated PVC pipes for land drainage also deals with drainage envelopes; it includes geotextiles and PLMs. This part of the draft standard reflects the kind of drainage envelope materials that are used in the European Union. Furthermore, information is given on the evaluation process (equipment, measurement procedure, accuracy, etc.). The specifications are based on consensus and do not necessarily correspond with those of a particular country, although the influence of experienced countries may be obvious.

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Annex

Draft European standard on corrugated polyvinyl chloride drainpipes

INTRODUCTION

This Annex contains the draft European standard on corrugated polyvinyl chloride drainpipes as it was at the moment that its standardization work came to a standstill. Consequently, this document exhibits some shortcomings and imperfections.

As can be seen from the 'Foreword' of the draft standard, it should consist of seven parts. The current version of this Annex has only 6 parts. Part 7 on 'Evaluation of Conformity' was and is not yet available because the Commission of the European Union has to impose the kind of evaluation of conformity that applies to 'Plastics Piping Systems for Agricultural Land Drainage (PVC-U)'.

The main drawback of the existing document concerns references. Frequently references to which is referred, are not included in the normative references, or they contain references which do not apply. References of draft documents or standards are not updated since the standstill and may not be useful anymore. Sometimes references in the various parts of the draft standard do not match.

Symbols are not always defined and lack units, while other symbols are defined but not used. Moreover the used symbols were not always straightforward. Furthermore other discrepancies were found throughout the document.

These shortcomings do not question the value and the importance of the present draft standard, but they may disturb those who consider the standard more closely. Some obvious discrepancies and inconsistencies have been amended, yet with the risk to introduce additional errors. Other ambiguities are maintained because correct information on what would be most likely to be correct could not be obtained.

The draft EN-standard on corrugated polyvinyl chloride drainpipes is a useful document, in spite of the above-mentioned drawbacks, which would certainly disappear if the standardization work could be finalized. The draft standard gives information on requirements for drainpipes, fittings, envelope materials and on installation practice, and can be useful for countries with little or no experience with current drainage materials. Therefore it was decided to include the draft standard in this FAO Irrigation and Drainage Paper.

CORRUGATED PLASTIC PIPING SYSTEMS
FOR LAND DRAINAGE
UNPLASTICIZED POLYVINYL CHLORIDE (PVC-U)

FOREWORD

This draft European standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directives.

It was prepared by CEN/TC 155 "Plastics piping and ducting systems"/WG 18 "Subsoil drainage piping systems". It did not yet receive approval and is therefore not yet mandatory for the CEN members.

This standard for corrugated plastic piping systems made of unplasticized polyvinyl chloride for agricultural, horticultural and sportsfield drainage is part of a system standard for plastic piping systems.

System standards are based on the results of the work being undertaken in ISO/TC 138 "Plastics pipes, fittings and valves for the transport of fluids", which is a Technical Committee of the International Standardisation Organisation (ISO).

They are supported by separate standards on test methods to which references are made throughout the system standard.

The system standard relates to standards on general functional requirements and recommendations for installation.

This standard consists of the following Parts, under the general title "Corrugated plastic piping systems for land drainage, unplasticized polyvinyl chloride (PVC-U)":

— Part 1: General,
— Part 2: Pipes without envelope,
— Part 3: Fittings,
— Part 4: Envelopes,
— Part 5: Fitness for purpose of the system,
— Part 6: Recommended practice for installation,
— Part 7: Evaluation of conformity.

This European standard specifies the required properties for the piping system made from unplasticized polyvinyl chloride and its components, when intended to be used for land drainage. It includes recommended practice for installation and the required level of certification.

This standard is intended to be used by authorities, design engineers, testing and certification institutes, manufacturers and users.

This standard is applicable to unplasticized polyvinyl chloride (PVC-U) piping systems to gather and convey excess water by gravity. Agriculture, horticulture and sportfields constitute the fields for these systems.

Pipes for these systems cover a nominal diameter range from *DN* 50 to *DN* 1000. Above *DN* 630, pipe are not presently manufactured.

European standards incorporate by reference provisions from specific editions of certain other publications. These normative references are cited at the appropriate points in the text and the publications are listed in the standard. Subsequent amendments to, or revisions of, any of these publications apply to this European Standard only when incorporated in it by amendment or revision.

PART 1: GENERAL

1 SCOPE

Part 1 specifies the general aspects, the material requirements and the test parameters for test methods referred to in the system standard.

2 NORMATIVE REFERENCES

- ISO 2507. Thermoplastic pipes and fittings - Vicat softening temperature - Test method and basic specification.
- ISO 1183. PVC-U pipes and fittings - Determination and specification of density.
- CEN/TC 155 N 708 Rev. Proposal for text regarding material including reprocessable and recyclable materials for individual systems standards. 1992.07.01. 18 pp.
- CEN/TC 155 WI 137. Determination of PVC content.
- CEN/TC 155 WI 043. Determination of Vicat softening temperature.

3 DEFINITIONS

For the purposes of this Part the following definitions and abbreviations apply :

3.1   Land drainage: Removal of surface or subsurface water from land.

3.2   Virgin material: Material in a form such as granules or powder that have not been subjected to use or processing other than that required for its manufacture and to which no reprocessable or recyclable materials have been added.

3.3   Own reprocessable material: Material prepared from rejected PVC-U unused pipes and fittings, including trimmings from that production of pipes and fittings, that will be reprocessed in a manufacturer's plant after having been previously processed by the same manufacturer by a process such as moulding or extrusion, provided the complete formulation is known.

3.4   External reprocessable material: Material comprising either one of the following forms :
a)   Material from rejected unused PVC-U pipes or fittings or trimmings, that will be reprocessed and that were originally processed by another manufacturer.
b)   Material from the production of unused PVC-U products other than pipes and fittings, regardless of there where they are manufactured, that will be reprocessed into pipes and/or fittings.

3.5   Recyclable material: Material comprising either one of the following forms :
a)   Material from used PVC-U pipes or fittings which have been cleaned and crushed or ground.
b)   Material from used PVC-U products other than pipes or fittings which have been cleaned and crushed or ground.

3.6   Nominal diameter (*DN*): A numerical designation of diameter which is common to all components in a piping system. It is a convenient round number for reference purposes approximate to the manufacturing diameter, expressed in mm. For this system standard, it is based on the outside diameter of the corrugated pipes. For Scandinavia, nominal diameters are based on inside diameter.

4 MATERIALS

4.1 General

The material of the pipes and fittings shall consist substantially of PVC-U material to which may be added only those additives that are needed to facilitate the manufacture of good surface finish and mechanical strength pipe, conforming to this standard.

4.2 Minimum PVC content

When tested in accordance with CEN/TC 155 WI 137, the content of PVC shall be at least 80 percent by mass for pipes and 88 percent by mass for fittings. In case of use of virgin and own reprocessable material, the minimum PVC content can be calculated.

> *NOTE: The minimum PVC content of fittings fabricated from pipe shall conform to the content required for the pipe.*

4.3 Virgin material

The use of virgin material is permissible without limitation.

4.4 Reprocessable and recyclable materials

4.4.1 Own reprocessable materials

The use of own reprocessable material for production of pipes and fittings is permitted without limitation. If fitting material is used for pipes, it shall be considered as recyclable material.

4.4.2 External reprocessable and recyclable materials with agreed specifications

External reprocessable and recyclable materials from pipes and fittings of PVC-U that are available in relevant quantities and frequencies may be added to virgin or own reprocessable material or a mixture of those two materials for production of pipes and shall be added only under the following conditions.

a)   A specification of the material shall be agreed between the supplier of reprocessable or recyclable material, the pipe manufacturer and the certification body. It shall at least cover the characteristics given in Table 1. When determined in accordance with the methods given in Table 1 the actual values for these characteristics shall conform to the agreed values within the deviations permitted in Table 1. The quality system of the supplier of reprocessable or recyclable material shall be certified to ISO EN 9002.

b)   Each delivery shall include a certificate showing conformity to the agreed specification.

c)   The maximum quantity of reprocessable and recyclable material that is to be added to the virgin material is specified by the pipe manufacturer.

d)   The quantity of reprocessable and recyclable material that is actually added to the virgin material in each production series shall be recorded by the pipe manufacturer.

e)   The PVC content of the end product shall meet the requirements specified in 4.2.

TABLE 1
Specification of characteristics to be covered by the agreement and maximum allowable tolerances for these items

Characteristic	Unit	Test method	Maximum permitted deviations
PVC content*)	% by mass	WI 137	± 4 % absolute
K value*)		WI 083	± 3 units
Density*)	kg/m³	ISO 1183	± 20
Vicat softening temperature*)	°C	prEN 727	± 2 units
Particle size[1)	Requirements shall be agreed and stated in the specification.		
Type of stabilizer[1)*)	Requirements shall be agreed and stated in the specification.		
Impurities[1)	Based on the source of material and the recycling process a relevant test method and requirements shall be agreed and stated in the specification. Both the test method and the requirements shall be published.		
[1) The relevant requirements depend on the recycling process and on the end product.			
)If the source of the material is pipes and fittings produced with a national or European quality mark, those material characteristics specified in that relevant standard, in such a way that one or more of the requirements to characteristics marked with "" are satisfied, do not have to be tested.			

f)   Type testing of the end product shall be carried out for the maximum specified amount and for each type of reprocessable or recyclable material with agreed specification.

4.4.3 External reprocessable and recyclable material not covered by an agreed specification

PVC-U pipes and fittings shall not contain this type of material.

5 REFERENCE CONDITIONS FOR TESTING

The mechanical and physical properties specified in all Parts of this standard shall, unless otherwise specified, be determined at 23 ± 2°C.

PART 2: PIPES WITHOUT ENVELOPE

1 SCOPE

Part 2 specifies the required properties for PVC-U pipes.

2 NORMATIVE REFERENCES

- prEN 496. 1991. Plastic piping systems - Plastic pipes and fittings - Measurements of dimensions and visual inspection of surfaces.
- EN 1411. Plastic piping and ducting systems - Thermoplastics pipes - Determination of the resistance to external blows by the staircase method.
- CEN/TC 155 WI 124. Extensibility.
- CEN/TC 155 WI 125. Brittle fracture test.
- ISO 3. Normal numbers, normal numbers series.
- ISO 2507. Thermoplastic pipes and fittings - Vicat softening temperature - Test method and basic specification.
  ISO 2507-1. Vicat softening temperature Part 1: General method.
  ISO 2507-2. Vicat softening temperature Part 2: Special conditions for PVC-U, PVC-C and PVC-HI pipes.
- ISO 3126. Out-of-roundness.
- ISO 9967. Thermoplastic pipes - Determination of creep ratio.
- ISO 9969. Thermoplastic pipes - Determination of ring stiffness - Constant speed method.

3 DEFINITIONS

For the purposes of this part, the definitions, and abbreviations given in Part 1 apply together with the following.

3.1   Nominal diameter (DN): Numerical designation of the outside diameter (D_o) of the pipe declared by the manufacturer. For Scandinavia, nominal diameter is based on internal diameter (D_i) as stated in Table 3.

3.2   Mean outside diameter: The measured length of the outer circumference of the pipe, divided by π (= 3.142) and rounded to the next higher 0.1 mm.

3.3   Total length: The distance between two planes normal to the pipe axis and passing through the extreme end points of the pipes measured along the axis of the pipe.

3.4   Nominal length: Numerical designation of a pipe length declared by the manufacturer which is equal to the pipe's total length in metres stated as a whole number.

3.5   Ring stiffness: The value of initial resistance to radial deflection under external load obtained by testing in accordance with ISO 9969.

3.6   Creep ratio: A physical characteristic of the pipe obtained by testing in accordance with ISO 9967. It is a measure of the long-term resistance to radial deflection under external load.

4 PIPE MATERIAL

The material from which the pipes are made shall conform to the requirements given in Part 1.

TABLE 1
Pipe material characteristic

Characteristic	Unit	Requirement	Test parameter	Test method
Vicat	°C	minimum 77	1 mm penetration 50 $\pm$ 1 N	TC 155 WI 043 (ISO 2507)

5 GENERAL REQUIREMENTS

5.1 Appearance

When viewed without magnification the internal and external surfaces of pipes shall be clean and free from scoring and other surface defects. The surface shall not be tacky. The ends of the pipe shall be square to the axis of the pipe and cut cleanly.

> *NOTE:*   *The pipe may be of any colour.*

5.2 Nominal length and coil size

Unless otherwise specified, pipes longer than 20 m up to *DN* 200 shall be delivered in coils and pipes greater than *DN* 200 shall be delivered in straight lengths.

Unless otherwise specified, coiled pipes longer than 20 m shall be supplied in lengths of any multiple of 5 m. In order to fit continuous laying machines, the internal and outside diameters of a coil of pipe shall be agreed between the interested parties, provided that the functional requirements of this standard are conformed to.

Straight lengths longer than 3 m shall be supplied in lengths of any multiple of 1 m.

5.3 Total length

The total length of the pipe shall not be less than the nominal length declared by the manufacturer.

6 GEOMETRICAL CHARACTERISTICS

6.1 Diameter

> *NOTE:*   *The general approach is for the values of the outside diameters to be the reference for designation by nominal size. Manufacturers whose nominal diameters are based on D_i shall comply with the corresponding outside diameter as declared by the manufacturer for the referring standard.*

This part does not include requirements for wall thickness for pipes, and it is not intended to include such requirements at a later date. This is to allow the maximum possible freedom in the choice of design.

Method of measurement shall comply with the method given in prEN 496.

6.1.1 Nominal diameter

The nominal diameter shall be chosen from those given in Table 2.

TABLE 2
Nominal Diameters *DN/D$_o$* (based on *D$_o$*)

50	60	65	80	100	125	160	200[1]
250	280	(296)	315	355	(375)	400	450
(470)	(475)	500	560	(580)	630[2]		

[1] For any new production of *DN* above 200, the Renard series R20 dimensions in the table shall be chosen as specified in ISO 3 (the non-R20 dimensions in Table 2 shown in brackets are not preferred).
[2] Above *DN* 630, pipes are not presently manufactured. *DN* 710, 800, 900, 1 000 are the preferred dimensions for this upper range of nominal diameters.

Diameter sizes based on internal diameter are given in Table 3.

TABLE 3
Diameter sizes based on *D$_i$*

Mean inside diameter *D$_i$* (mm)	Permitted deviations (mm)	Corresponding outside diameter *D$_O$* (mm)
50	-0 +2	58
65	-0 +2	75
80	-0 +3	92
113	-0 +3	127
145	-0 +5	160
180	-0 +5	200

Inclusion of these diameters shall be reconsidered at the first revision of this system standard.

6.1.2 Minimum inside diameters

When measured to an accuracy of 0.1 mm or 0.05 % whichever is the greater value, the average of the measured mean inside diameters shall not be less than the minimum D_i given in Table 4 for the relevant nominal diameter, *DN*. An internal micrometer or a plug gauge with an accuracy of 0.1 mm shall be used for the measurement of the inside diameter up to 180 mm. Above D_i 180 mm, any suitable measurement device may be used.

TABLE 4
Minimum inside diameters (based on *D$_o$*)

DN/D$_O$	*D$_{i\ min}$* mm	*DN/D$_O$*	*D$_{i\ min}$* mm
50	43	315	280
60	52	355	315
65	57	375	315
80	70	400	355
100	90	450	400
125	113	470	417
160	143	475	400
200	180	500	450
250	224	560	500
280	250	580	500
296	250	630	530

6.1.3 Tolerances on mean outside diameter

The mean outside diameter of a pipe shall not deviate from the nominal diameter by more than the permissible deviations given in Table 5 when measured in accordance with prEN 496.

TABLE 5
Specified pipe mean outside diameters and tolerances

Nominal diameter DN/D_O	Permissible deviation from mean outside diameters	
	+ mm	- mm
$\geq$ 50 and $\leq$ 100	1.0	1.5
$\geq$ 125 and $\leq$ 200	1.5	1.5
$\geq$ 250 and $\leq$ 400	1.5	2.0
$\geq$ 450 and $\leq$ 630	1.5	4.0

6.2 Out-of-roundness

6.2.1 Requirement

When measured in accordance with 6.2.3 using test pieces conforming to 6.2.2, the out-of-roundness O, shall be less than the applicable value given in Table 6 equivalent to 10 percent of DN, where (in accordance with ISO 3126) O, in mm, is given by the following equation:

$$O = D_{o\ max} - D_{o\ min}$$

where : $D_{o\ max}$ is the maximum outside diameter, in mm;
$D_{o\ min}$ is the minimum outside diameter, in mm.

TABLE 6
Specification of the out-of-roundness

DN/D_O	O (mm)	DN/D_O	O (mm)
50	5.0	315	31.5
60	6.0	355	35.5
65	6.5	375	37.5
80	8.0	400	40.0
100	10.0	450	45.0
125	12.5	470	47.0
160	16.0	475	47.5
200	20.0	500	50.0
250	25.0	560	56.0
280	28.0	580	58.0
296	30.0	630	63.0

6.2.2 Length of test pieces

The length L, in metres, of the test pieces shall be as follows :

$L = 0.2 \pm 5$ % for pipes with $DN \leq 200$;
$L = 0.4 \pm 5$ % for pipes with $DN > 200$.

6.2.3 Test method

On each test piece, mark four generating lines with an angle of approximately 45° between them and in a plane square to the pipe axis.

Using a slide calliper conforming to prEN 496, measure the four corresponding diameters and record the four individual measurements. Calculate the difference between the highest value and the lowest value and relate the difference to the nominal value as specified in 6.2.1.

6.3 Perforations

6.3.1 General

Perforations to admit water shall be in the form of slots and made in the valleys of the corrugations. Inspection to verify conformity shall be made on a 1 ± 0.01 m length of pipe taken at random.

6.3.2 Distribution of perforations

Perforations shall be arranged in any pattern which provides an even distribution around the whole of the circumference in not less than four rows, with at least two perforations per 100 mm of each single row.

6.3.3 Perforation width

6.3.3.1 Nominal perforation width

The chosen and declared nominal perforation width shall be between 1.0 mm and 2.3 mm by increment of 0.1 mm.

6.3.3.2 Tolerances

The average perforation width shall not deviate more than 0.2 mm from the declared nominal perforation width.

No single perforation shall exceed the nominal perforation width by more than + 0.4 mm.

6.3.4 Perforation area

The total area A (see 6.3.5.4) of effective perforations per metre of pipe shall not be less than 1200 mm^2.

6.3.5 Test method

6.3.5.1 Sampling

On a piece of pipe 1 ± 0.01 m long, determine the number of rows of perforations n, for each row, without taking into account the quality of the perforations, count the number of perforations, $a_1, a_2, ... a_n$. Add up $N = a_1 + a_2 + ... a_n$. Without taking into account the quality of the perforations, using a table of random numbers, mark P perforations in each row in accordance with Table 7.

TABLE 7
Number of perforations *P* for control of perforations

Number of perforation rows (*n*)	4	5	6	7	8	9	10	11	12
Number of perforations to be marked on each row (*P*)	10	8	7	6	5	5	4	4	4

6.3.5.2 Measurement

The measurement of the perforation dimensions (width and length) shall be carried using a calliper rule or an episcope.

In case of an imperfect perforation (see 6.3.5.3), the area of the perforation shall be taken as equal to zero.

6.3.5.3 Criteria for imperfect perforations

A perforation shall be considered as imperfect in any of the following cases :
a)   the perforation does not conform to 6.3.3.2 for its width;
b)   perforation is not made;
c)   a piece of material is still attached to the pipe on the perforation circumference.

6.3.5.4 Calculations

Add the surface areas of the *n P* perforations. Let this be *B*. Calculate the total area of the perforations per linear metre using the following equation :

$$A = (B\ N)/(n\ P)$$

where N is the total number of perforations per linear metre;
n is the number of rows;
P is the number of perforations marked on each row.

Out of the *n P* measured perforations, note the number of imperfect perforations. Let I_p, be this number. Calculate the total percentage of imperfect perforations, *d*, using the following equation:

$$d = 100\ I_p/(n\ P)$$

6.3.6 Requirement on imperfect perforations

The quantity of imperfect perforations, *d*, in percent shall not exceed 10 % of the total number of measured perforations, i. e. I_p shall not exceed (*n P*)/10.

7 MECHANICAL CHARACTERISTICS

Necessary precaution shall be taken when using test pieces from coiled pipes.

7.1 Impact resistance

When tested in accordance with EN 1411 amended as in annex A of this Part, the following requirements shall be conformed to as applicable:

a)   If $50 \leq DN \leq 200$, the pipes shall comply with the four following requirements:

$$(X_f + X_p)/2 = H_{50} \geq 0.9 \text{ m}$$
$$H_{50sl} \geq 0.6 \text{ m}$$
$$H_{50pl} \geq 0.6 \text{ m}$$
$$H_{i\,min} \geq 0.4 \text{ m}$$

b)   If $DN > 200$, the pipe shall conform with the four following requirements :

$$(X_f + X_p)/2 = H_{50} \geq 1.2 \text{ m}$$
$$H_{50sl} \geq 0.9 \text{ m}$$
$$H_{50pl} \geq 0.9 \text{ m}$$
$$H_{i\,min} \geq 0.6 \text{ m}$$

where: X_f is the average of the dropping heights when failure occurred;
X_p is the average of the dropping heights when test pieces passed;
H_{50sl} designates the seam lines H_{50};
H_{50pl} designates the perforation lines H_{50};
$H_{i\,min}$ designates the minimum fall height without failure of the test.

7.2 Ring stiffness

7.2.1 Requirements

When tested in accordance with ISO 9969, the of ring stiffness S_o shall not be less than the applicable value given in Table 8.

TABLE 8
Minimum ring stiffness values

Nominal diameter DN/D_O	Minimum ring stiffness (kN/m^2)	
	Normal series	Special series (V-plough)
50	6.3	8
> 50 and ≤ 80	4	8
≥ 100 and ≤ 125	2	4
> 125 and ≤ 630	2	No special series

7.2.2 Marking of ring stiffness series

All pipes shall have their corresponding series, i.e. "normal" or "special" series, clearly indicated on the label of the coil.

7.3 Creep ratio

When tested in accordance with ISO 9967, the creep ratio shall not be greater than 2.7.

7.4 Extensibility

This characteristic is not applicable for $DN > 200$.

When tested in accordance with EN [155 WI 124], no test piece shall have an elongation greater than 55 mm. If the first test piece has an elongation less than 45 mm, the result is considered to be satisfactory. If the first test piece has an elongation between 45 mm and 55 mm, the average of the elongations of this test piece with the two additional ones shall be less than 50 mm.

7.5 Brittle fracture test (rapid tensile test)

This characteristic is only applicable for pipes up to DN 80 inclusive.

When tested in accordance with EN [155 WI 125], disregarding the first failure occurring within one nominal diameter, of the pipe being tested, from the anchoring devices, the result from three test pieces shall not include more than one failure. If one failure has occurred, the results from six further test pieces shall include no failures.

7.6 Stock conformity

To ensure stock conformity at delivery, manufacturers shall demonstrate compliance with the standard in accordance with Part 7.

8 MARKING

All pipe marking and labelling shall be in accordance with 5th draft of AHG 30. In addition, the following applies:

8.1 Pipe

Each pipe shall be clearly and indelibly marked at least every 6 m. The marking shall include the following information :

a)   the manufacturer's name and/or trade mark;
b)   the nominal diameter;
c)   the material (PVC-U);
d)   the year of manufacturing by punching;
e)   the "CE" mark and the European certification voluntary mark.

> *NOTE: Trade mark, identification of manufacturing unit and complete manufacturing date are optional.*

8.2 Labelling

A coil label or equivalent device shall be attached to the pipe and include the following information:

a)   the manufacturer's name and/or trade mark;
b)   the identification of manufacturing site;
c)   the nominal diameter;
d)   the material (PVC-U);
e)   the nominal perforation width, in mm;
f)   the "L normal" or "L special" ("L" for land drainage, and either "normal" or "special" concerning the ring stiffness series as dealt in 7.2);
g)   pipe length or coil length, in m;
h)   the "CE" mark and the European certification voluntary mark;
i)   the manufacturing date (i. e. year, month and day: e.g. 92.06.05).

> *NOTE : Trade marks and other quality marks are optional.*

8.3 Additional information

The pipe manufacturer shall declare a list of compatible fittings manufacturers and/or trade marks.

NORMATIVE ANNEX A (concerning 7.1)

Additional parameters for EN 1411 on staircase method

The test method given in EN 1411 shall be modified as follows, where the clause numbers given correspond to those in EN 1411.

5.1 Preparation

Before cutting the test piece, the two seam lines shall be marked with different colours.

5.2 Number

a)   Up to 10 pieces may be used for each part of the preliminary test (see 7.2).

b)   32 test pieces are used for the main test (see 7.3).

6 CONDITIONING

Condition the test pieces for 15 min in a liquid bath or 60 min in air at $0 \pm 1°C$.

7.1 General

a)   The striker shall be type d90 with a mass of 1 kg.

b)   The circumferential orientation of the test piece in the V-block shall be in accordance with 7.2 and 7.3 (as modified by this annex).

c)   Failure

A blow is considered as a failure if any of the following characteristics occurs :

-      the test piece breaks into two or more parts;
-      fragmentation of the test piece occurs (see detail A in Figure A.l);
-      the test piece shows at least one crack joining continuously any couple of perforations (see detail B in Figure A.l);
-      a crack can be seen with the naked eye on the seam line and is longer than 5 mm.

Examples of these cases are shown in Figure A.l.

7.2 Preliminary test procedure

The whole clause 7.2 is replaced by the following wording:

> *NOTE: The purpose of the preliminary test is to obtain an indication of the H_{50} value and to identify the first test piece from which the result will be used in the main test (see 7.3). The preliminary test includes two series with up to 10 test pieces in each series: when testing in accordance with 7.2.3,*

failures from each of the first two test pieces are considered indicative of an H_{50} less than the specified value and/or an excessive scatter of results.

7.2.1

Set the drop height of the striker at 0.4 m.

7.2.2

After conditioning (see clause 6) for every test piece, within 10 s :

- in series one, impact the test pieces on a perforation line selected at random, determine and record whether or not the test piece fails and how it failed, and note the dropping height values.
- in series two, impact the test pieces alternately on seam line one and on seam line two.

7.2.3 Seam line

If the first test piece fails, test a second test piece, and if this also fails, then record the pipe as not having passed the impact test.

7.2.4

This clause in supporting standard is not applicable here.

7.2.5 Perforation line

If the first test piece fails, test a second test piece, and if this also fails, then record the pipe as not having passed the impact test.

7.2.6

Consider the dropping height at which the first test piece fails in each series to be the initial dropping height to be used in the corresponding series of the main test.

7.3 Main test

The main test is also divided into two series. Here, each series includes 16 test pieces.

In series one, ensure that each test piece is hit by the striker on a perforation line selected at random. In series two, ensure that the test pieces are hit by the striker alternately on seam line one and on seam line two.

Record the dropping height values for the test pieces and note whether or not the test piece failed.

Calculate the H_{50} failure level using the following equation :

$$H_{50} = (X_p + X_f)/2$$

where X_f is the average of the dropping heights when failure occurred;
X_p is the average of the dropping heights when the test pieces passed.

Calculate two values of H_{50}, designated H_{50pl}, and H_{50sl} as follows :

H_{50pl} is the value derived from the 16 blows on the perforation lines;
H_{50sl} is the value derived from the 16 blows on the seam lines.

FIGURE A.1
Illustration of failures of test piece
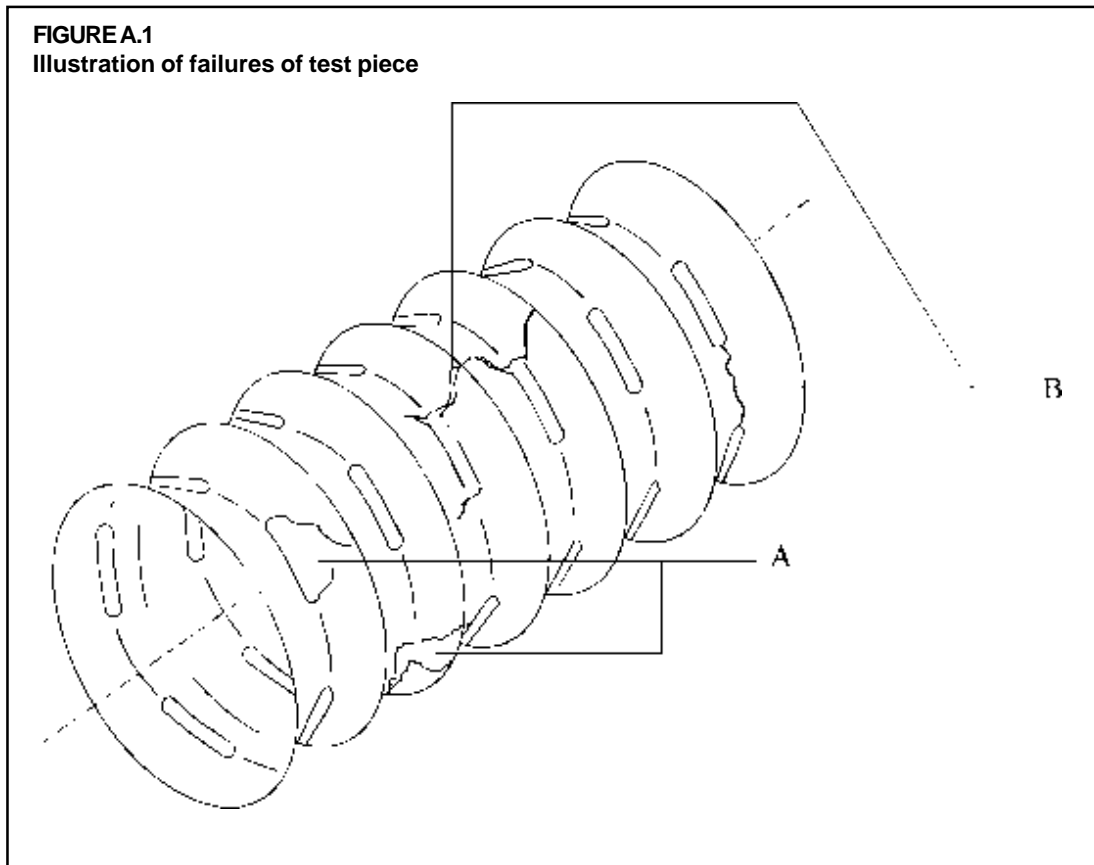
A blow is considered as a failure if :

- the test piece breaks into two or more parts ;
- fragmentation of the test piece occurs (detail A) ;
- the test piece shows at least one crack joining continuously any couple of perforations (detail B) ;
- a crack can be seen with the naked eye on the seam line and is longer than 5 mm.

PART 3: FITTINGS

1 SCOPE

Part 3 specifies the requirements for PVC-U fittings. It also specifies the test parameters for the test methods referred to in this Part of this standard.

Polyethylene (PE) and polypropylene (PP) fittings may be used with PVC-U pipes.

2 NORMATIVE REFERENCES

- ISO 2507. Thermoplastic pipes and fittings - Vicat softening temperature - Test method and basic specification.
  ISO 2507-1. Vicat softening temperature - Part 1: General method.
  ISO 2507-2. Vicat softening temperature - Part 2: Special conditions for PVC-U, PVC-C and PVC-HI pipes.
- ISO 4439. PVC-U pipes and fittings - Determination and specification of density.
- CEN/TC 155 WI 127. Joint strength.

3 DEFINITIONS

For the purposes of this European standard, the following terms are illustrated in Fig. A.1 of annex A: coupler, T piece, Y junction, clip-on junctions, reducer, end cap and conic stopper, outlet pipe, vermin grating.

4 FITTINGS MATERIAL SPECIFICATION (FITTINGS MADE FROM PVC-U)

The material from which the fittings are made shall be PVC-U, and shall conform to the requirements specified in Part 1 of this standard. In addition, fittings made from PVC-U shall conform to the requirement of Table 1.

TABLE 1
Material requirement for fittings moulded from PVC-U

Characteristic	Unit	Requirement	Test parameter	Test method
Vicat	°C	minimum 79	1 mm penetration 50 ± 1 N	TC 155 WI 043 (ISO 2507)

Fittings fabricated from pipe shall conform to the Vicat softening temperature required for pipe conforming to Part 2 of this standard, i.e. 77 °C.

5 GENERAL REQUIREMENTS

5.1 Types of fittings

The types of fittings include the following :
- couplers;
- branches (T piece or Y junction);
- clip-on junctions;
- reducers;
- end caps and conic stoppers;
- outlet pipes.

5.2 Appearance

The internal and external surfaces of fittings shall be smooth, clean and free from grooving, blistering and any other surface irregularity likely to impair their performance. Fitting ends shall be cleanly cut and square with the axis of the fitting.

NOTE: The fittings may be of any colour.

6 GEOMETRICAL CHARACTERISTICS

6.1 Dimensions of fittings

6.1.1 Diameter

The nominal diameter(s), *DN*, of a fitting shall correspond to and be designated by the nominal diameter(s) of the pipes conforming to Part 2 of this standard for which they are designed.

The maximum inside diameter, D_i, for fittings shall conform to the applicable value given in Table 2.

TABLE 2
Requirements for maximum inside diameters

DN of the pipe	$D_{i\ max}$ (mm)	*DN* of the pipe	$D_{i\ max}$ (mm)
50	51.5	100	102.0
60	61.5	125	127.0
65	66.5	160	162.5
80	81.5	200	202.5

The difference between the maximum measured inside diameter of the fitting, in mm, and the nominal diameter (outside diameter for Scandinavia) of the pipe to which it is fitted shall be less than 1.5 mm up to and including *DN* 80, less than 2.0 mm from *DN* > 80 up to and including *DN* 125, and 2.5 mm for *DN* > 125.

6.1.2 Minimum wall thickness

The minimum wall thickness, *e*, of fittings shall be as follows :

- *e* ≥ 1.5 mm for *DN* 50 to *DN* 80 inclusive;
- *e* ≥ 1.8 mm for *DN* > 80 and *DN* ≤ 125;
- *e* ≥ 2.5 mm for *DN* larger than 125.

NOTE: Angles
For branches, the preferred nominal angles are: 30°, 45°, 60°, 67.5°, 90°.

NOTE: Inserting length
Fittings should allow the junction between two different coils of pipes or between minor and major pipes. This should be made in such a way as to prevent soil entering the drains and also to prevent the end of the pipe forming the minor pipe protubing into the major pipe and obstructing flow. No fitting should cover or otherwise obstruct the perforations for a greater length than 300 mm for pipes up to and including DN 125, and 400 mm for pipes over DN 125 up to and including DN 630.

7 MECHANICAL CHARACTERISTICS

7.1 Assembly force and push through force test

This test is not required for *DN* larger than 200 mm.

When tested in accordance with EN [155 WI 127]-1, the forces, in N, shall conform to the applicable values given in the Table 3.

TABLE 3
Requirements for assembly force and push-through force

DN	Assembly force	Push-through force
≥ 50 and ≤ 125	≤ 200 N	≥ 300 N
> 125 and ≤ 200	≤ 300 N	≥400 N

7.2 Resistance to separation (tensile force)

When tested in accordance with EN [155 WI 127]-2 and according the forces indicated in Table 4, the joint shall not part.

TABLE 4
Required force for resistance to separation

DN	Applied force
≤ 65	150 N
65 < and ≤ 110	200 N
≥ 110	300 N

8 MARKING

8.1 Fitting

a) Fittings shall be marked in a clear and durable way so that legibility is maintained when handled, stored and installed in accordance with Part 6 of this standard.

The marking may be printed or formed, integral on the fittings. The marking shall not damage the fitting.

The marking shall include the following information :

a) the manufacturer's name and/or trade mark;
b) the dimension (*DN*(s)) and the angle if relevant;
c) the material;
d) the "CE" mark and the European certification voluntary mark;
e) the "L" letter.

8.2 Labelling

The label shall be fixed directly on the packaging without string.

The label shall include the following information :

a) the manufacturer's name and/or trade mark;

b) the identification of manufacturing site;
c) the dimension (*DN*(s)), and the angle, if relevant;
d) the material;
e) the other quality mark;
f) the date of manufacturing: year and month;
g) the "CE" mark and the European certification voluntary mark;
h) the "L" letter.

All marks shall remain legible till the installation of the fittings.

If preferred, information on the packaging label may be mentioned on the fitting itself.
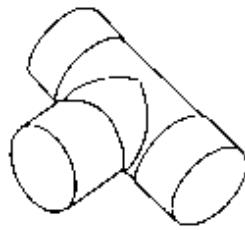
8.3 Additional information

The pipe manufacturer shall declare a list of compatible fittings manufacturers and/or trade marks.

ANNEX A (informative)

Typical pipe junctions and connectors

FIGURE A.1
Typical fittings for sub-soil drainage
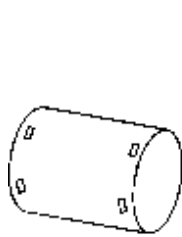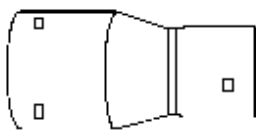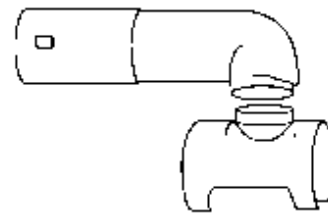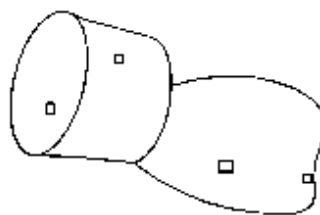

Coupler

T piece

Y junction

Clip-on junctions

Reducer

End cap

Conic stopper

Permanently fixed vermin grating

Outlet pipe

PART 4: ENVELOPES

1 SCOPE

Part 4 specifies requirements applicable to envelopes used for wrapped pipes.

It also specifies the test parameters for the test methods referred to in this standard.

2 NORMATIVE REFERENCES

- ISO 554. Standard atmospheres for conditioning and/or testing – specifications.
- ISO 565. Test sieves - Metal wire cloth, perforated metal plate and electroformed sheet - Nominal sizes of openings.
- ISO 9 862. Geotextiles - Sampling and preparation of test specimens.
- ISO 9 863. Geotextiles - Determination of thickness at specified pressures.
- ISO 9 864. Geotextiles - Determination of mass per unit area.
- ISO 10 318. Geotextiles – Vocabulary.
- EN ISO 10 320. Geotextiles and geotextile-related products - Identification on site.
- EN ISO 12 956. Geotextiles and geotextile-related products – Determination of the characteristic opening size.

3 DEFINITIONS

For the purposes of this Part the definitions given in the other Parts of this European Standard apply together with the following:

3.1   Geotextile: A permeable, polymeric, synthetic or natural, textile material, in the form of manufactured sheet, which may be woven, non-woven or knitted, used in geotechnical and civil engineering applications.

> *NOTE: The definition of "woven", "non-woven" and "knitted" geotextile are included in ISO 10 318.*

> *NOTE: The term "geotechnical" as mentioned hereabove includes the land drainage application.*

3.2   Prewrapped loose material (PLM): A permeable structure consisting of loose, randomly oriented yarns, fibres, filaments, grains, granules or beads, surrounding corrugated drain pipe, assembled within a permeable surround or retained in place by appropriate netting and used in drainage applications.

3.3   Particle diameter limit d_m: The diameter of soil particles at which m percent of the soil particles are, by dry weight, finer than that grain size.

3.4   Pore size index O_{90}: Opening size appertaining to the 90 percent particle size (d_{90}) retained by the envelope as a result of sieving with specified sand fractions.

3.5   Pore size index O_{95}: Opening size appertaining to the 95 percent particle size (d_{95}) retained by the envelope as a result of sieving with specific sand fractions.

4 SAMPLING AND CONDITIONING

4.1 Sampling

Cut five clean and undamaged pieces of pipe, each of at least 2.5 m long, from five selected coils. Avoid damage to or loosening of the envelope.

Mark the pipe sections for identification regarding :

- Trade-mark/manufacturer's name;
- Information supplied on the marking tape and optionally on the attached label;
- Coil number or other identification;
- Sampling date.

Dry moist sections at maximum 40 °C and at a relative humidity of maximum 50 percent until a constant mass is obtained.

If not being used for testing within 24 h, store the pipe sections free from dust, within a dry, dark atmosphere at ambient temperature and protected against chemical and physical damage.

4.2 Sample preparation

Carefully cut a length of 1000 ± 5 mm from each of the wrapped drain pipes for thickness and mass determination.

Carefully cut another length of 500 ± 5 mm from each of the wrapped drain pipes for pore size index determination.

For geotextiles only, carefully cut a length of 1000 ± 5 mm from each of the wrapped drain pipes for wettability measurements.

Transfer the identification marking of each pipe section to the corresponding samples.

Store the samples free from dust within a dry, dark atmosphere at ambient temperature and protect them against chemical and physical damage until the tests are performed.

4.3 Conditioning

Condition the samples in accordance with ISO 554 for a period of 24 h**.**

5 SPECIFICATIONS

> *NOTE:* *The material of which the envelopes are made is not specified but has to conform to the requirements of this standard.*

> *NOTE:* *As test requirements for geotextiles are significantly different from those for PLM, the specifications need to be specific for each of these two categories, in most cases.*

5.1 General requirements

NOTE: *These requirements are applicable to geotextiles and PLM.*

5.1.1 Appearance

When inspected visually without magnification, the envelope shall be regular and no open spots shall be apparent.

> *NOTE: The envelope material may be of any colour.*

5.2 Specifications for geotextiles

5.2.1 Thickness

When measured in accordance with ISO 9 863, the nominal thickness shall not deviate more than 10 percent from that declared by the manufacturer.

5.2.2 Mass per unit area

When measured in accordance with ISO 9 864, the mass per unit area shall not deviate more than 10 percent from that declared by the manufacturer.

5.2.3 Pore size index

When measured in accordance with EN ISO 12 956, the opening size shall not deviate more than 30 percent from that declared by the filter manufacturer.

5.2.4 Wettability

When measured in accordance with annex A of this Part, the water head shall not exceed 5 mm and the wet area shall be 100 percent of the surface of the ten test pieces.

5.3 Specifications for PLM

5.3.1 Thickness requirements

When measured in accordance with the methods described in annex B, the requirements shall be as follows.

a)   Minimum thickness

The minimum thickness requirement shall depend on the material used as given in Table 1.

TABLE 1
Minimum thickness e_{min}, in mm, requirement for prewrapped loose materials

Synthetic		Organic	
Fibrous	Granular	Fibrous	Granular
3.0	8.0	4.0	8.0

b)   Mean average thickness requirement

The mean average thickness of each test piece should not deviate by more than 25 % from that declared by the manufacturer.

5.3.2 Mass per unit area

When determined in accordance with annex C, individual measurements shall not deviate by more than 25 percent from the manufacturer's declared mass per unit area.

5.3.3 Pore size index

When determined in accordance with annex D, all individual measurements of the O_{90} size shall lie between the limits given for the class represented by the marking.

Two classes of PLM, depending on the pore size index O_{90}, are accepted :

    PLM-F (F: fine): $300\,\mu\text{m} \leq O_{90} < 600\,\mu\text{m}$;

    PLM-S (S: standard): $600\,\mu\text{m} \leq O_{90} \leq 1100\,\mu\text{m}$.

6 Marking

For geotextiles, the required information (see Table 2) shall, if possible, be printed on the envelope, at least on both ends of the coil.

For other geotextiles and for PLM, where marking on the envelope is not appropriate, marking shall be done on an adhesive tape, at least on both ends of the coil - unless it is not feasible to print all the required information on the marking tape, in which case the information may be given on a label attached to the pipe or on the geotextile itself. At least the date of manufacturing and wrapping should remain after installation on the filtered pipe.

The marking shall include the information required by Table 2.

TABLE 2
Minimum marking requirements

Information	Geotextile	PLM
Name of wrapping company	√	√
Raw material of filter	√	√
Type of filter	WG: woven geotextile KG: knitted geotextile NG: non-woven geotextile	PLM
Thickness	optional	√
Mass per unit area	optional	√
Pore size index	optional	F or S (see 5.3.3)
Wrapping date	(yy/mm/dd)	(yy/mm/dd)

The marking shall be weather resistant and legible after installation.

ANNEX A (normative)

Determination of the wettability of a geotextile

A.l Definitions

Wettability: Capacity of a dry geotextile to have a low initial resistance to water penetration.

A.2 Principle

The resistance of a geotextile to the passage of water is measured by :

- the maximum hydraulic pressure (h) needed to pass the geotextile perpendicularly to its plane.
- the percentage of the surface area (s) of passage of the water through the geotextile. This surface area is the outer surface area of the water.

A plane test piece of a geotextile is progressively subjected to an increasing water pressure.

The maximum hydraulic pressure needed for the water to pass completely through the test piece is noted as well as the wetted surface.

A.3 Apparatus

A.3.1 A measuring cylinder, made of a transparent material, of inside diameter at least equal to 80 mm, with a base plate comprising a rigid mesh which can support a test piece. A water-tight seal, comprising a silicone mastic or elastomeric seal, is incorporated between the test piece and the adjacent rim of the cylinder.

A.3.2 A water supply, comprising water in a container from which an increasing water pressure can be applied. The device is such that the water pressure is applied vertically, either from the top downwards, or from the bottom upwards. The water used for the test may be coloured with a solution of 1 per 1000 fluorescent dye type $C_{20}H_{10}Na_2O_5$.

A.3.3 A pressure measuring device, comprising one of the following forms (see Figures A.l and A.2):

a) When the water flows from the top downwards, the pressure can be measured by the water head in the cylinder.
b) When the water flows from the bottom upwards, the pressure can be measured with a dynamometric cell.

> NOTE: **Recommended apparatus (wettabilimeter).** *Supply from the top downwards is easy to build (see Figure A.3), but its design needs to take into account the risk of clogging by fluorescein. In order to clean it regularly, it is necessary to be able to plug in/out the stainless pipe insert and to dismantle the bottom part of both of the container and the measuring cylinder in a convenient way (see Figure A.4-a and Figure A.4-b).*

A.3.4 Thickness determination

Means for determining the thickness of a test piece to within 0.01 mm are specified in ISO 9 863.

FIGURE A.1
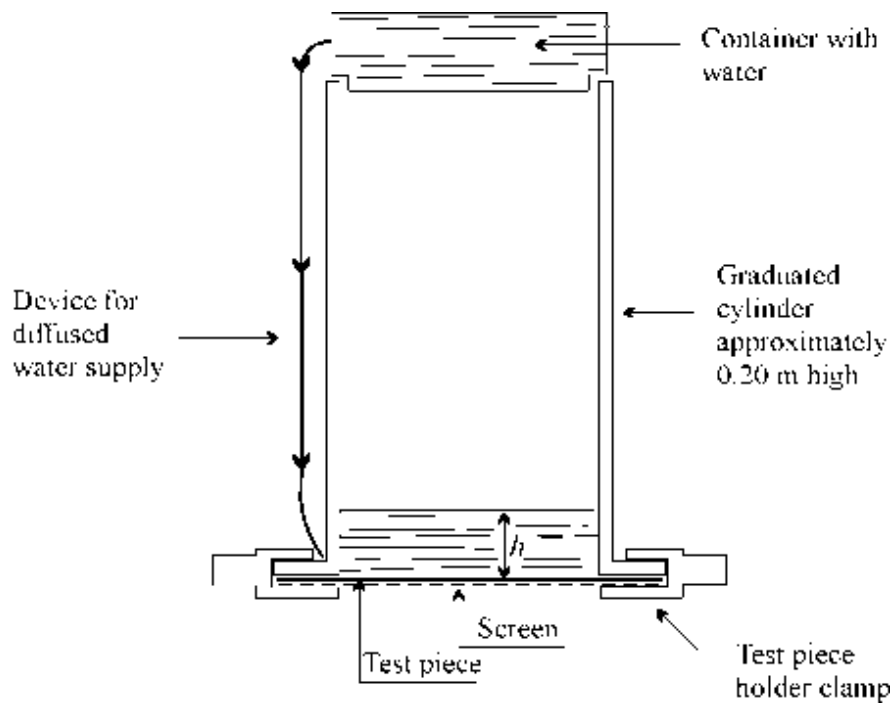**Apparatus with water supply from the top downwards**

Container with water

Device for diffused water supply

Graduated cylinder approximately 0.20 m high

h

Screen

Test piece

Test piece holder clamp

FIGURE A.2
Apparatus with water supply from the bottom upwards

Dynamometric cell

Displacement force → *h*

Test piece holder cylinder

Test piece glued to the stand

Container with water
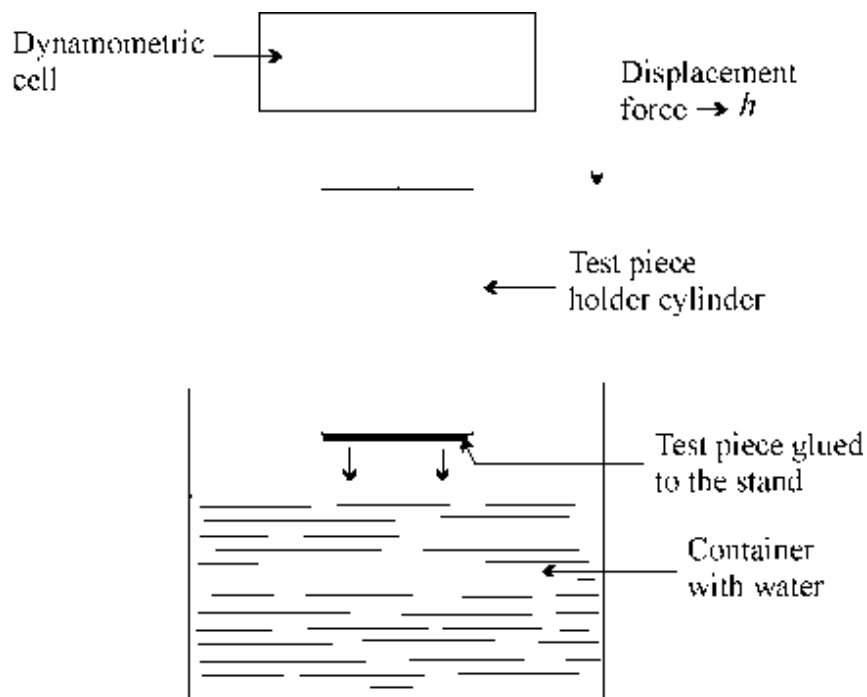
FIGURE A.3
Wettabilimeter: general sketch

Lid with spirit level

Water and fluorescein container with :

Flushing out

Plug with its rod

Sub-container for supplying

Stainless pipe

Rubber pipe

Measuring cylinder with :

Stainless pipe

Ruler

Wing nut

Upper joint

Test piece

Lower joint

Supporting grid

Flange and bolts

Base of the container (see Fig. A.4-a)

Base of the measuring cylinder (see Fig. A.4-b)

Support

Reception sink

Adjustable stand

Emptying pipe

FIGURE A.4a
Base of the container

Transparent wall

Flushing out

Sub-container
for supplying

Clickable pipe

Bottom that can
be dismantled

Plug with its rod

Joint

FIGURE A.4b
Base of the measuring cylinder

Transparent wall
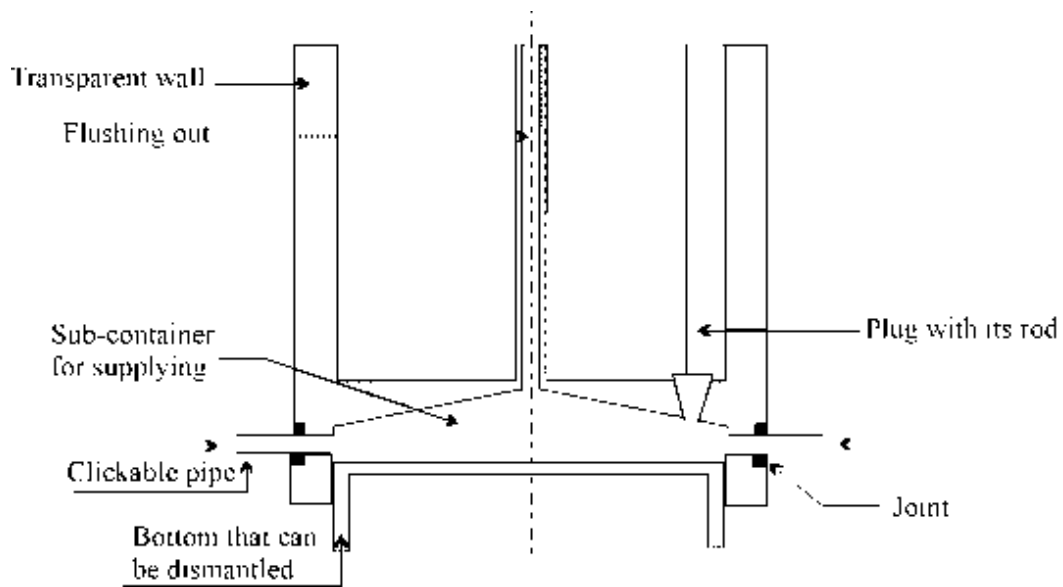
Ruler

Wing nut

Clickable pipe

Joint

Upper joint

Test piece

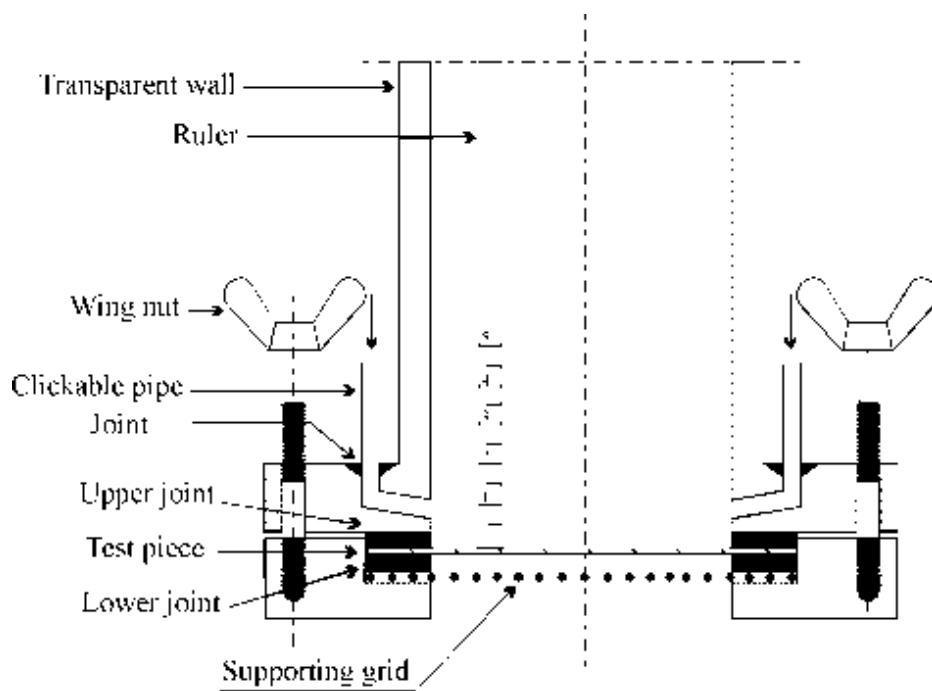Lower joint

Supporting grid

A.3.5 Mass per unit area determination

Means for determining the mass per unit area of a test piece to within 0.01 g/m² are specified in ISO 9 864.

A.4 Test piece

A.4.1 Preparation

The test piece shall comprise plane panel cut from a sample of the geotextile to fit across the end of a cylinder (A.3.1) having an inside diameter of at least 80 mm.

>   *NOTE: The geotextile should be handled as infrequently as possible and not folded in order to prevent disturbing the surface structure.*

A.4.2 Sampling

At least ten test pieces shall be cut from positions regularly distributed along and across a sample at least 1 m long taken at random from the geotextile material.

>   *NOTE: It is recommended that additional test pieces are obtained to replace any which may be discarded in the event of leakage past their edge while under test.*

A.5 Conditioning

Maintain each test piece for 24 h in one of the testing atmospheres described in ISO 554.

Keep the test piece in a flat position without any load.

A.6 Procedure

Mount and seal the test piece in position on the appropriate end of the cylinder (A.3.1). After verifying that the measuring cylinder is vertical, increase the water pressure at a speed of the order of 10 mm/min. Record the maximum water height attained to within 1 mm.

During the test, observe the passage of the water through the test piece, and reject as unsatisfactory any test in which there is a passage at the joint. Repeat such tests using a fresh test piece.

Measure the effective area(s) of passage of the water on the outer surface area of the test piece, using any suitable method to determine the outlines of the wetted area(s).

>   *NOTE: Observation under the light of an ultra-violet lamp is recommended.*

Measure, in mm², the areas of passage, to within 1 %.

When the water head attains 100 mm, measure the time taken by water to penetrate.

A.7 Results

For each test piece, record the maximum hydraulic pressure, to within 1 mm, and the percentage of the area of passage to the total area of the test piece, to within 1 percent of variation.

Calculate the arithmetic mean of the values obtained and the coefficient of variation. For the valid test pieces used, i.e. excluding any rejected in accordance with A.6, calculate the mean mass per unit area and the mean thickness.

A.8 Test report

The test report shall include at least the following information :

a) the number and date of this standard ;
b) the identification of the geotextile according to EN ISO 10 320 ;
c) the mass per unit area of each test piece and the mean mass per unit area of the test pieces ;
d) the nominal thickness adjacent to the test piece and the mean thickness of the test pieces ;
e) details of apparatus used, including a diagram ;
f) the area of the exposed test pieces ;
g) the tabulated results of the experimental data and calculations ;
h) the mean water head resistance to water penetration and the maximum water head resistance value ;
i) the mean and maximum time taken by water to penetrate after 100 mm water head has been attained ;
j) the mean percentage of the wetted area of the exposed test pieces and the maximum percentage of the wetted area of the exposed test pieces.

ANNEX B (normative)

Determination of the thickness of prewrapped loose material (PLM)

B.l Principle

For minimum thickness, the smallest distance among those run by needles going through the prewrapped loose material is taken. For mean thickness, both wrapped pipe and uncovered pipe diameter are measured by a tape at a specified pressure.

B.2 Minimum thickness

Determination of the minimum thickness, e_{min}, of the envelope shall be done with a measuring device, as shown in Figure B.l, on the five samples with a length of 1000 mm.

The measuring device shall have a measurement range up to 20 mm with a reading accuracy of 0.1 mm.

Visually inspect the pipe sections to assess the minimum thickness.

Put the foot on a hard, flat surface and adjust the gauge to zero.

Press (by hand) the pins through the envelope till at least one pin reaches the pipe wall.

Read the minimum thickness and round off the measured value to the nearest 0.1 mm.

FIGURE B.1
Measuring device for the determination of the minimum thickness
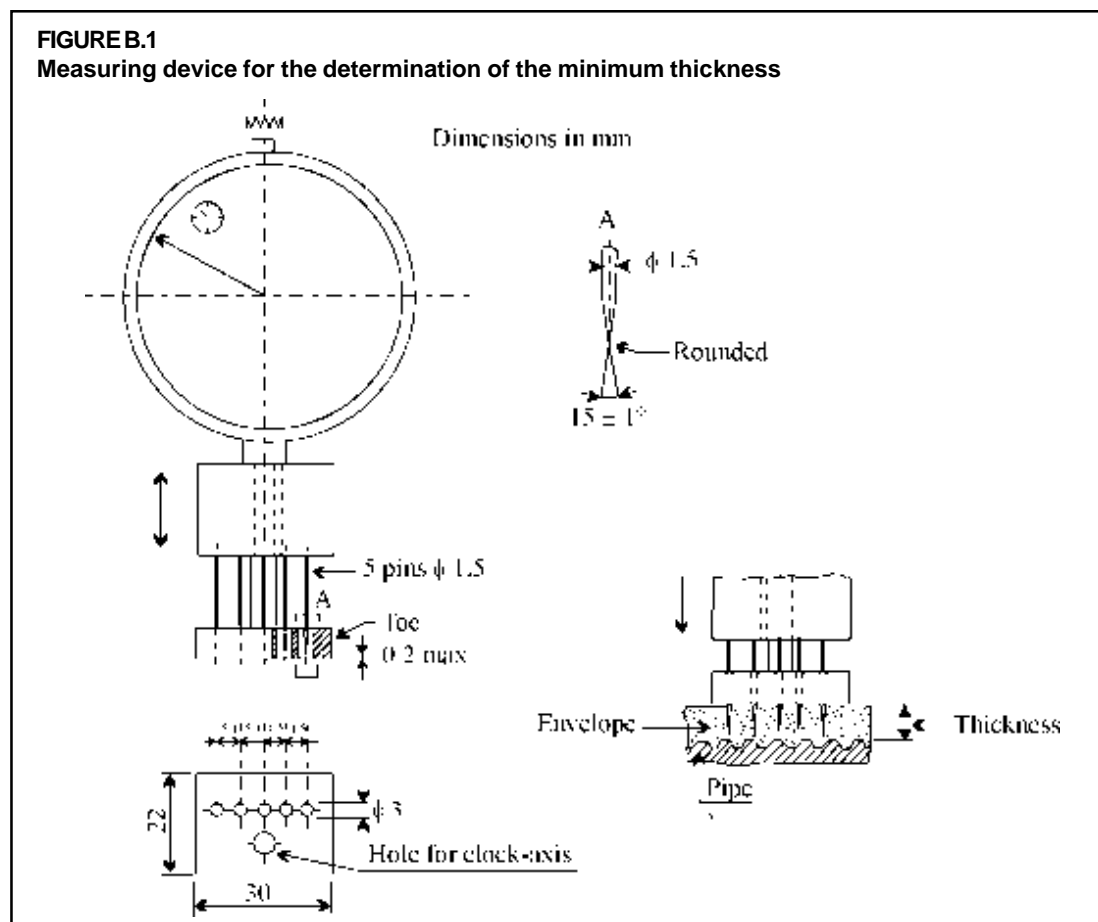
B.3 Mean average thickness

B.3.1 Apparatus

Determination of the mean average thickness *e* of the envelope on the five samples with a length of 1000 mm, i. e. in fact the test piece, requires a measuring tape which is subjected to a load of 1.75 ± 0.25 N for a tape width of 8 mm; the load shall be 2.50 ± 0.25 N for a tape width of 16 mm; for tape widths between 8 mm and 16 mm, the required load shall be linear interpolated between 1.75 N and 2.50 N.

B.3.2 Procedure

Determine either the outside circumference or directly the outside diameter of pipe plus envelope four times on equally distributed places of the test piece with a measuring tape to an accuracy of 0.1 mm.

Carefully remove the envelopes and put them aside for determination of mass (see annex C.2).

Repeat the procedure to determine either the outside circumference or outside diameter of the pipe.

B.3.3 Calculation

Calculate either the average outside circumferences P_o and P_m or the average outside diameter D_o and D_m from the four measurements on the test piece and round off the result to the nearest 0.1 mm.

Calculate the mean average thickness *e* of the test piece using the following equation:

$$e = (P_o - P_m)/2 \ \pi = (D_o - D_m)/2$$

where: *e* is the mean average thickness of the wrapping material (mm) ;
P_o is the average outside circumference of pipe and envelope (mm) ;
P_m is the average outside pipe circumference (mm) ;
$\pi = 3.142$;
D_o is the average outside diameter of pipe and envelope (mm) ;
D_m is the average outside pipe diameter (mm).

B.4 Test report

The test report shall include at least the following information :

a) the number and date of this standard ;
b) the conditioning atmosphere and the time of relaxation ;
c) the minimum and mean average thickness of each test piece ;
d) the coefficient of variation at specified pressure ;
e) deviation of the mean average thickness of each test piece from the manufacturer's thickness ;
f) if required, the experimental data and calculations of the minimum and mean average thickness of each specimen can be tabulated.

ANNEX C (normative)

Determination of the mass per unit area of prewrapped loose material (PLM)

C.l Principle

A specified area of wrapping material is weighed to assess the average quantity of envelope material around the pipe.

C.2 Procedure

The mass per unit area is calculated from weighing the prewrapped loose material of the test piece with a length of 1000 mm after removal of the wrapping twines for fibrous envelopes and the surround for granular envelopes.

Weigh separately each removed envelope of the five test pieces to an accuracy of 0.1 g after the thickness measurements have been performed according to annex B.

The obtained mass is the mass per linear meter of pipe m_1 and is expressed in g/m.

C.3 Calculation of the results

Calculate the corresponding mass per unit area, with its mean average thickness e, using the following equation:

$$m = 1000 \, m_1 / \, [\pi \, (D_m + e)]$$

with $D_m = P_m/\pi$ = outside pipe diameter in mm ;
         e = mean average thickness in mm as determined according to B.3.

D_m and e are given with an accuracy of 0.1 mm; m is expressed in g/m^2 and calculated to the nearest 1 g/m^2.

C.4 Test report

The test report shall include at least the following information :

a) the number and date of this standard ;
b) the conditioning atmosphere and the time of relaxation ;
c) if required, the experimental data and calculations of the mass per unit area of each specimen can be calculated ;
d) the mass per unit area of each specimen ;
e) deviation of the mass per unit area of each specimen from the manufacturer's mass.

ANNEX D (normative)

Prewrapped loose material: determination of the pore size index

D.l Principle

A test piece disc of the envelope is taken, fixed in a frame and placed horizontally on a sieving apparatus. An amount of a specific sand fraction is poured on the test piece. A vertical vibration with a specific frequency and amplitude is applied to the test piece for a specific time. The amount of sand remaining on and in the test piece reflects the largest pore sizes.

D.2 Material

D.2.1 Sand fractions

The sand fractions shall be composed by dry sieving sand according to ISO 563 using a stack of ISO-sieves selected from the R20-series of ISO 565 with mesh sizes given by the fraction limits in Table D.l.

TABLE D.1
Fraction limits and average particle diameter of the sand fractions

Fraction limits (µm)		Average particle diameter (µm)
d_{min}	d_{max}	d_m
90	125	108
125	160	143
160	200	180
200	250	225
250	315	283
315	400	358
400	500	450
500	630	565
630	800	715
800	1 000	900
1 000	1 250	1 125
1 250	1 400	1 325

### D.3 Apparatus

D.3.1 Cutting die

A circular metal cutting die with internal diameter of 135 ± 0.1 mm shall be used to obtain the test pieces from the sample.

D.3.2 Sieve apparatus

The sieve apparatus shall generate a vertical vibration with an amplitude of 0.75 mm and a frequency of 50 Hz.

D.3.3 Test piece holder

The test piece holder shall be composed of the following elements (see figure D.l) :

FIGURE D.1
Envelope clamping device
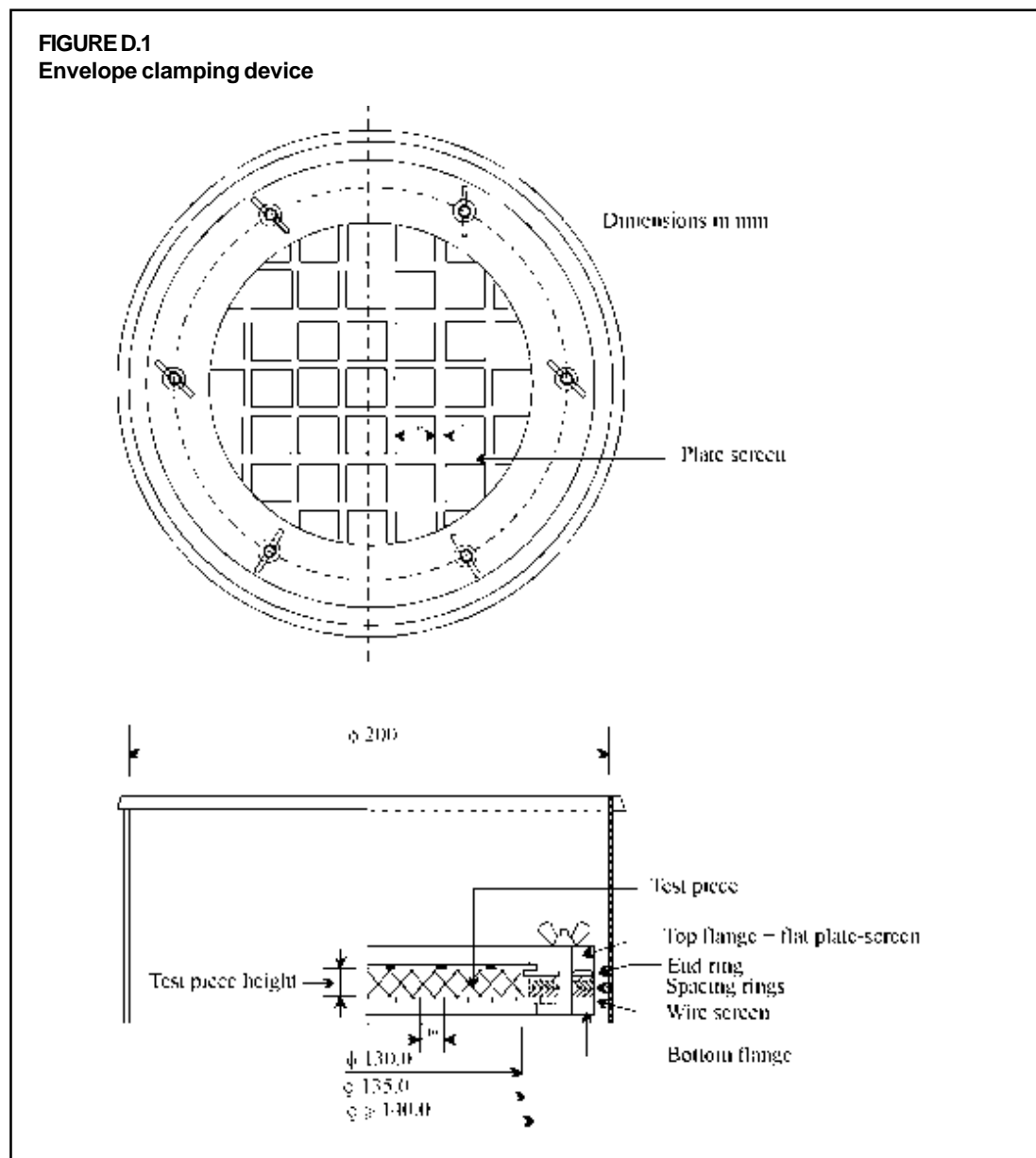
a. wire screen with a mesh size of 10 mm ;
b. a bottom flange with an internal diameter of at least 140 mm ;
c. a number of flat, rigid and stackable spacer rings with internal diameter of 135 ± 0.1 mm, increasing in thickness with steps of 0.2 mm and one rigid end ring with an internal diameter of 130 ± 0.1 mm and a thickness of 1.0 mm ;
d. a top flange having an internal diameter of 135 ± 0.1 mm and a height of at least 10 mm, with a flat plate-screen attached at the bottom side with a mesh size of 16 mm.

D.3.4 Bottom plate and weight

Pore size index assessment requires the test piece height under load. Therefore a steel bottom plate weight with a combined mass of 9.3 ± 0.1 kg and a combined total height h_t, measured to an accuracy of 0.1 mm are required (Figure D.2). The stiff, flat bottom plate has an outside diameter of 135 ± 0.1 mm and a thickness of 4 ± 0.1 mm.
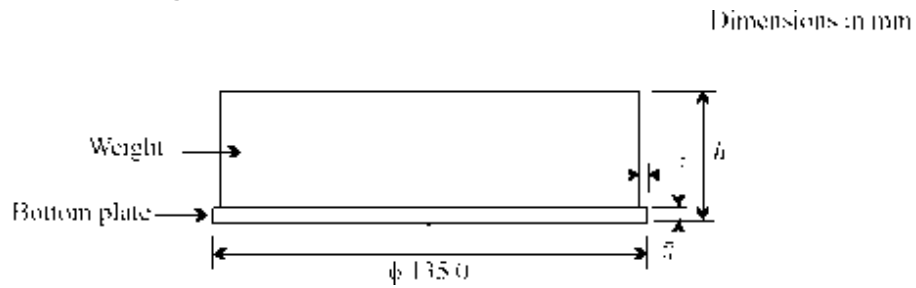
FIGURE D.2
Bottom plate and weight

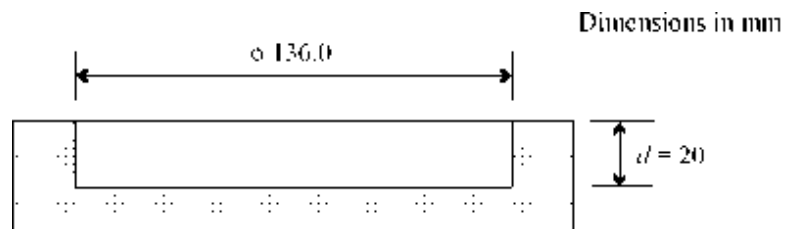Dimensions in mm

Weight

Bottom plate

φ 135.0

h

FIGURE D.3
Tray

Dimensions in mm

o 136.0

$d = 20$

FIGURE D.4
Thickness determination under load of a test piece of fibrous envelopes

Measuring points

Dimensions in mm

Sliding gauge

Weight

Bottom plate

Table

Fibrous material

Test piece height e
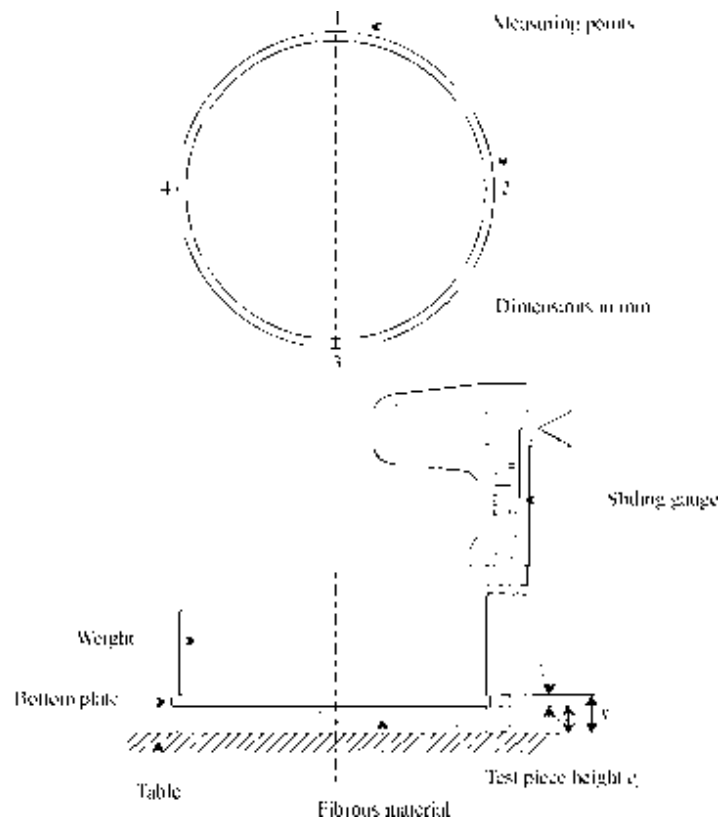
Additionally granular envelopes require a tray with a diameter of 136 ± 0.1 mm and a minimum depth L of 20 mm measured to an accuracy of 0.1 mm (Figure D.3).

D.4 Procedure for fibrous envelopes

D.4.2 Selection of spacer rings

Carefully remove the envelope from the samples with length of 500 mm, starting at the seam. If the seam can not be found use a pair of scissors.

Cut a test piece from the removed envelope with the cutting die and a sledgehammer.

Place the test piece on a flat surface and put the bottom plate and weight on it.

> NOTE: This force approximates to the load exerted on the envelope due to soil load.

After 600 ± 15 s, determine with a sliding gauge, as shown in Figure D.4, the thickness x to an accuracy of 0.1 mm.

Repeat this measurement at 3 other locations and calculate the average value x_m to an accuracy of 0.1 mm.

Calculate the test piece height e_l in reducing x_m with 4.0 mm.

Select a stack of spacer rings (including the end ring) corresponding to the test piece height e_l. Spacer rings and the sample must closely fit.

Fit the test piece tensionless and flat in the test piece holder (see Figure D.1), the contact side with the drain pipe directed downwards.

Put the top flange in place and mount the test piece holder on the collecting tray of the sieve apparatus.

D.4.3 Sieving procedure

Choose a sand fraction d_m closest to the assumed O_{90}.

Weigh 50 g of the chosen sand fraction with an accuracy of 0.01 g.

Ensure that the sieve apparatus is level.

Pour the sand on the test piece, ensuring that during sieving the sand spreads evenly on the test piece. Close the lid of the sieve apparatus.

Activate sieve apparatus during 300 ± 2 s.

Remove the test piece holder from the sieve apparatus, ensuring that the sand on top and inside the test piece does not falls into the collecting tray.

Weigh the sand of the collecting tray with an accuracy of 0.01 g.

Remove the sand on top and inside the test piece by turning and shaking the test piece holder. In total at least 49 g of sand shall be recovered.

Choose the sand fraction for the next sieve analysis based on the first sieve result.

Repeat the sieve procedure.

Determine the pore size index according to D.4.4.

If necessary, repeat the sieve procedure, with a chosen sand fraction which includes the expected pore size index.

Determine, according to this procedure, the pore size index of the other four test pieces.

Each sand fraction shall be used only five times.

D.4.4 Calculation of results

For each test piece, plot the percentage of each fraction that passed the test piece on a diagram against the mean fraction diameter with the latter on a logarithmic axis and the percentage on a probability axis. Manually fit and draw a straight line through the plotted points. The intersection of this straight line with the 10 percent line marks the pore size O_{90} or the pore size index. The pore size index is expressed in µm and rounded off to the nearest 5 µm.

D.5 Procedure for granular filters

D.5.1 Selection of spacer rings

> NOTE: *Contrary to the fibrous prewrapped envelopes, determination of the pore size index of a granular envelope is not possible. Procedures for thickness under load and hence test piece preparation are different.*

Carefully remove the surround from the sample with a length of 500 mm and put each amount aside for later use.

Collect the granular material in a dish.

> NOTE: *The dish is preferably made of glass.*

Weigh the collected granules of the sample with an accuracy of 0.01 g and determine the mass G_m in g/m.

Determine the mass G_l in g using the following equations :

$$G_l = (A_l/A)\ G_m = 4.56\ G_m/\ (D_m + e)$$

where: G_l is the mass of granular material to determine test piece height for the sieve test (g) ;

$A_I = \pi\ 135^2/4$; mean surface area of each of the four test pieces (mm^2) ;

$A = \pi\ (D_m + e)1000$; mean surface area of pipe plus envelope for one meter length (mm^2);

G_m is the mass of granular material per meter of pipe length (g/m) ;

e is the mean average envelope thickness of the pipe sample (mm) according to B.3.

G_I is expressed in g and calculated to the nearest 1 g.

Collect an amount of granular material in the tray equal to the mass $G_I \pm 0.1$ g.

Spread the granular material evenly in the tray.

Use the cutting die to cut a disc out of the surround and put it on top of the granular material.

Place bottom plate and load on the test piece in the tray. After 300 ± 15 s, determine the sliding gauge reading x with an accuracy of 0.1 mm at four places as indicated in Figure D.5 and calculate the average value x_m.

FIGURE D.5
Thickness determination under load of a test piece of granular envelopes
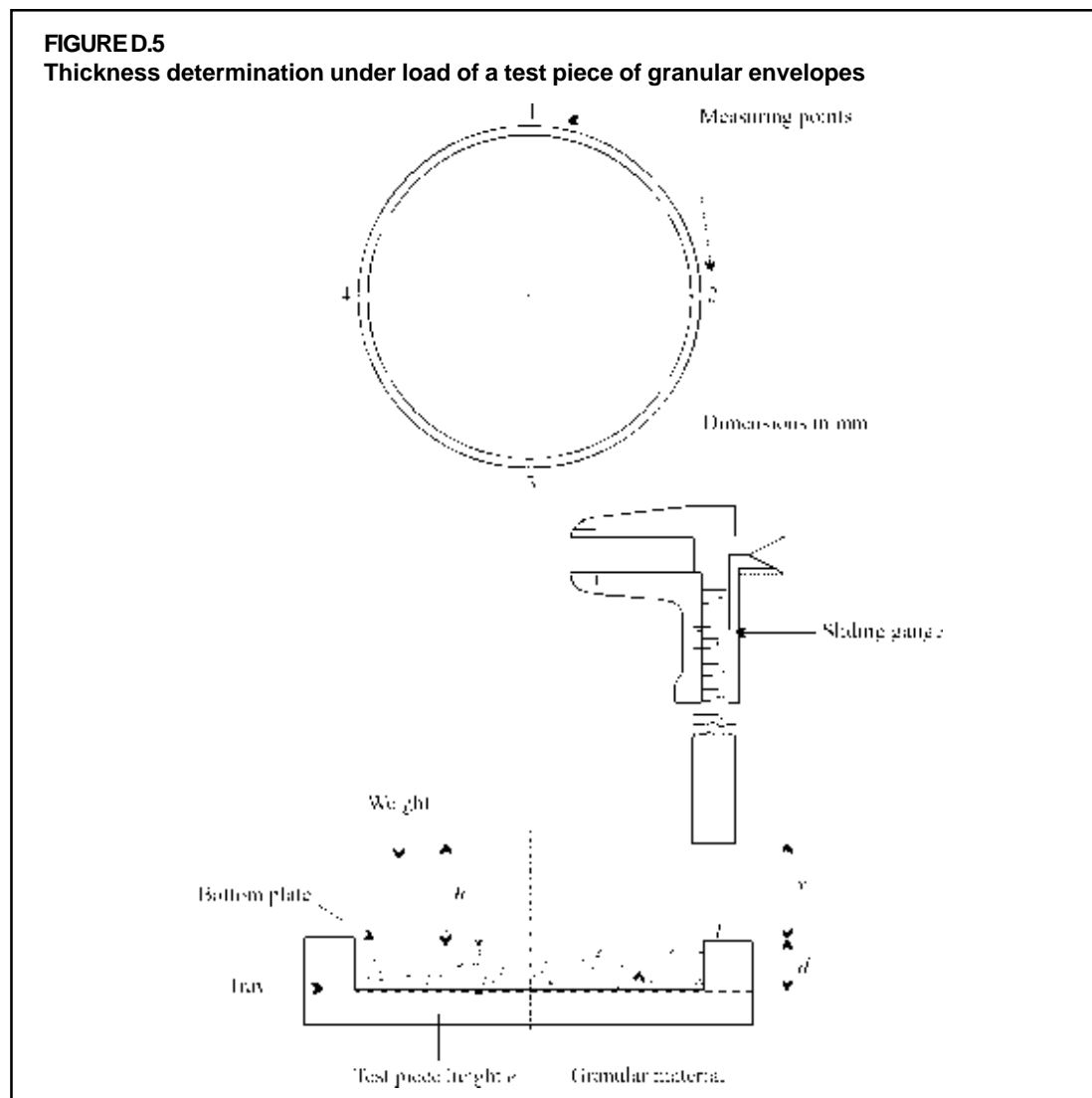
Calculate the test piece height under load e_l using the following equation :

$$e_l = d + x_m - h_l$$

with d the depth of the tray ;
       x_m the average sliding gauge reading ;
       h_l the height of the bottom plate plus weight.

All values are expressed in mm and determined with an accuracy of 0.1 mm.

Select a stack of spacer rings (including the end ring) corresponding to the test piece height e_l.

Bring the granular material from the tray into the test piece holder and spread evenly.

Put the surround on top of the granular material.

Put the upper flange in place and put the test piece holder on the collecting tray of the sieving apparatus.

D.5.2 Sieving procedure

The procedure for fibrous envelopes as given in D.4.3 is applicable.

D.5.3 Calculation of the results

The determination of results is similar as with fibrous envelopes according to D.4.4.

D.5.4 Report

The test report shall include at least the following information :

a)   the number and date of this standard ;
b)   details of apparatus including a diagram, if required ;
c)   the tabulated values of the used granular material. If required, the experimental data and
       calculations of the amount of retained granular material can be tabulated ;
d)   the pore size index (O_{90}) of each specimen.

Bibliography

– EN ISO 12 956. 1999 Geotextiles and geotextile related products - Determination of the
  opening size.
– EN 964-1. 1994. Geotextiles and geotextile-related products - Determination of thickness at
  specified pressures - Part 1: Single layers.
– EN 965. 1994. Geotextiles and geotextile-related products - Determination of mass per unit
  area.

PART 5: FITNESS FOR PURPOSE OF THE SYSTEM

1 SCOPE

Part 5 includes tests which relates to the reciprocal adaptability between fittings and pipe. If these latter are sold together the reciprocal adaptability is under the mutual responsibility of the fittings manufacturer and the pipe manufacturers. If they are sold separately, the installer and his partners should make sure that they comply with this standard.

2 NORMATIVE REFERENCES

No normative references.

3 ASSEMBLY FORCE AND PUSH THROUGH FORCE TEST

This test shall not be achieved for *DN* larger than 200 mm.

When tested in accordance with the method specified in Fig. A.1 of annex A, the forces (in N) shall be as indicated in Table 1.

TABLE 1
Maximum assembly and minimum push-through forces

DN	Assembly force	Push-through force
50-100 inclusive	≤ 200 N	≥ 300 N
125-200 inclusive	≤ 300 N	≥ 400 N

4 JOINT STRENGTH

When carried out according to the supporting standard EN [155 WI 127], joint shall not part.

5 GAP BETWEEN COUPLER OR END PIPE AND PIPE

The gap g between couplers or reducers and pipes depends on the outside diameter of pipes. It shall not be more than as follows :

- up to *DN* 80 (inclusive): $g \leq 1.5$ mm,
- from *DN* 100 (inclusive) to *DN* 125 (inclusive): $g \leq 2.0$ mm,
- from *DN* 160 (inclusive) to *DN* 200 (inclusive): $g \leq 2.5$ mm.

ANNEX A – Couplers

Test method for assembly force and push-through force measurement

A.1 General

This test obtains the force required to bring a pipe end to the pipe stop of the coupler (assembly force) and the force required to push a pipe corrugation past the pipe stop of the coupler (push-through force).

A.2 Procedure

A.2.1 Apparatus

A compression testing machine with a pair of steel plates is required. During testing these plates shall not distort in any way.

A.2.2 Samples

To avoid buckling the length of the sample is indicated in Table A.1, according to *DN*.

TABLE A.1
Length of pipe sample to avoid buckling

DN	Sample length (mm)
50	80
60	80
65	100
80	100
100	150
125	150
160	200
200	200

The ends of the samples shall be cut square to the axis of the pipe.

A.2.3 Testing

Place coupler and pipe on the lower plate as shown in Figure A.1. Apply a force on the pipe by lowering the upper plate with a velocity of 30 mm/min.

The pipe shall not buckle during testing. In case buckling occurs, the test shall be repeated.

Both ends of coupler shall be tested, each end with a different pipe sample and a different coupler. The procedure shall take into account that, as far as possible, even when the marking on the coupler is symmetrical.

FIGURE A.1
Testing assembly force and push-through force

Force

Upper plate

Pipe

Sample

Bumper →

Medium stop → ← Fitting

Lower plate
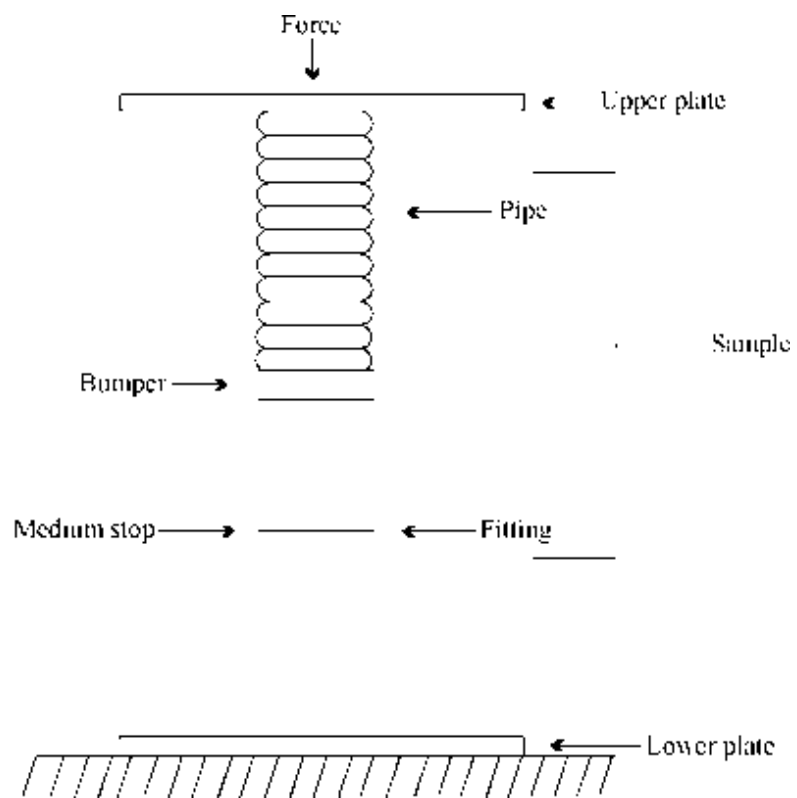
PART 6: RECOMMENDED PRACTICE FOR INSTALLATION

1 SCOPE

Part 6 describes the recommended practice for installation of the piping system.

2 NORMATIVE REFERENCES

- ISO/TR 7073. Recommended techniques for the installation of unplasticized polyvinyl chloride (PVC-U) buried drains and sewers.

3 DEFINITIONS

For the purposes of this Part the definitions given in the other Parts of this European standard apply together with the following :

3.1   Lateral drain: Drainage pipe, direct receiver of water over full or partial length through perforations in pipe walls.

3.2   Collector drain: A pipe which collects water from lateral drains and conveys the combined flow to an outlet. If perforated, it may also act as direct receiver of water.

3.3   Inspection shaft: Auxiliary equipment at the junction of a lateral and collector drain or at the junction of several collector drains, used to change the gradient and/or direction and/or to facilitate inspection of a drainage network. Its design permits silt and sand to settle.

3.4   Trenching machine: A machine which digs a trench, generally of 0.10 m to 0.50 m width, and continuously lays the pipe at the bottom of that trench, which has to be backfilled after pipe laying.

3.5   Trenchless machine: A machine which continuously lays the drainage pipe, without any trench or excavation being opened, through a slit made with a vertical or V-form counter (e.g. V-plough).

3.6   Backfill material: Material which is installed on and/or under the drainage pipe during installation.

3.7   Drain cleaning provision: Auxiliary equipment which is composed of different plastic fittings, is installed on the collector drain and is used for cleaning the lateral drain with water under pressure.

3.8   Mole drainage: An operation of a limited life whereby a vertical counter fitted with a cylindrical bullet as optional expander is drawn through the soil to form a channel.

4 TRANSPORT, STORAGE AND HANDLING

4.1 Transport

Vehicles should have a clean flat bed, free from nails and other projections which might cause damage to wrapped or unwrapped pipes.

Side supports should be flat and have no sharp or rough edges.

When transporting a mixed load of products (coils and/or straight lengths), it is important that the upper load does not damage the lower load. Large deflection and overhanging should be avoided.

4.2 Storage

For long term storage, it is important that the pressure on the lowest coil is kept as low as possible in order to prevent deformation of the pipe. Generally, a stock of four coils is appropriate in the field and eight coils at the manufacturer's premises or other prepared site. The coils should be stacked on a flat surface, free of materials which can damage the pipe. This applies to both wrapped and unwrapped drainage pipe.

Following delivery from the manufacturer until the effective installation, the storage duration between April to September inclusive should be as follows :

- for moderate climates - Scandinavia, the United Kingdom, Eire, Benelux and Germany - the outdoor maximum duration is three months.
- for severe climates - Iberian Peninsula, Italy, Greece and France - the outdoor maximum duration is 1.5 months.

In case of storage longer than these maximum durations, the coils should either be stored inside buildings or the stacks covered.

When pipes or coils are stored outside in climates having ambient temperatures greater than 23°C, stacks should be arranged to allow free passage of air around the pipes and coils.

Characteristics of envelopes (prewrapped loose materials and geotextiles) are much sensitive to weathering effects. In cases of long storage duration outside and for ambient temperatures above 23°C, filtered pipe should be stored inside buildings or covered.

4.3 Handling (loading and unloading)

Pipes should not be dragged along the ground or against hard objects. Whenever mechanical handling techniques are used, all equipment coming into contact with the pipes should present no protrusion.

When unloading pipes and coils, they should not be dropped on the ground. Pipes and coils should always be carefully lowered onto the ground or stacked where they are to be stored.

Whenever straight pipes have been transported one inside another, the inner pipes should always be removed first and stacked separately.

For products at low temperature as specified in 5.6, it is necessary to take extra precautions, particularly avoiding violent shocks to the pipes.

5. Installation procedure

5.1 General

It is assumed that laying of drainage pipes is mainly executed mechanically. The conformity of the delivery should be visually recorded by a representative of the customer.

5.2 Site examination

Topographical (level) and soil surveys carried out before design should be adequate to allow an accurate assessment of drainage problems and a full and adequate drainage design to be compiled.

The location and condition of any existing drains and buried services should be determined where possible and incorporated into the new system.

Consultation with the land owner and all relevant authorities should take place before work commences. Scheme design should, where possible, avoid crossing buried pipes or cables and eliminate the need to work beneath overhead electricity cables.

5.3 Drainage plans

Detailed plans under drainage should be prepared showing the layout, pipe size and type, use and depth of permeable backfill material and details of any mole drainage and subsoiling.

5.4 Use of machinery

Machines should not be employed on an area until the preparatory work, such as initial pegging of the location of branch drains or any other topographical locating of future drainage pipes has been completed.

5.5 Trafficability and subsoil conditions

Surface and subsurface soil conditions should be such as to avoid unnecessary smear or compaction at the surface or near the drain. High water tables, wet topsoil, puddles, can be detrimental to the drainage installation.

Surface tracking should be minimised at all times, especially when draining through growing crops.

Excessively high water table and excessively dry soil conditions should be avoided.

5.6 Weather conditions

Pipe laying and the placement of permeable backfill over unplasticized polyvinyl chloride (PVC-U) pipes should not normally be carried out when the air or pipe temperature is below 0°C. When local climates dictate installation in lower temperature condition, pipe may be laid provided additional precaution are taken. Voluminous prewrapped unplasticized polyvinyl chloride (PVC-U) pipes may be used at temperature down to – 3°C.

In temperatures greater than 30°C care should be taken to avoid stretching of plastic drain pipes.

5.7 Setting up and checking of laser equipment

The grading and depth control of land drains is of utmost importance. To obtain the correct grading and depth requirements, laser grade control equipment is now commonly used with land

drainage machines. The correct functioning and setting up of laser equipment is of great importance. Therefore, this equipment will require checking before it is used (see annex A).

5.8 Pipe laying

5.8.1 General requirements

Drain trenches should run in straight lines, unless topographical features dictate otherwise, at the required depth and gradient.

The pipe should be installed with a minimum depth of cover of 0.6 m from the top surface to avoid damage from surface traffic and preferably the pipe should be installed below the maximum depth of frost penetration.

All lateral drain lines should be plugged at the upper end to avoid ingress of soil or animals.

All collector drains should be installed from their downstream end to their upstream end. They should be prepared and installed before lateral drains.

All lateral drain lines should be installed from their downstream end.

Where mole channels should be drawn across the lateral drains, the pipe depth should be such that the invert of the mole channel is at least 100 mm above the top of the pipe. A minimum trench width of 100 mm is recommended and permeable backfill should normally be used.

Existing drains which are still active should be positively connected into the new system. All other existing drains should be connected to the new drains either by a positive connection or with permeable backfill.

Pipes with sealed joints or unperforated corrugated plastic pipes (in all other respects to the requirements of this standard) should be used where pipes are laid under any of the following conditions :

a)   through windbreaks consisting of trees and/or shrubs ;
b)   closer than 5 m from hedges or trees (other than in orchards) ;
c)   where leakage from the drain could cause erosion or scouring and displacement of the pipe.

A correct position is promoted by exerting some tensile stress on the pipes while laying them. A braking device on the reel for instance, is a useful auxiliary for this purpose. A pressure roll or similar device can also be used.

5.8.2 Pipe laid in trenches excavated by machine

5.8.2.1 Preparation of drain trenches

The drain trench should be excavated in such a way that the ingress of water into the trench is not impeded by smearing of the trench walls.

The bottom of the trench should consist of naturally occurring soil. Normally, the base of the trench should be shaped by a tool to form a V-shaped groove, with the base of the groove radiused to a value not less than the outside radius of the pipe being laid.

5.8.2.2 Laying of drain pipes

Drain pipes should be laid as trenching advances and secured in their position.

If pipe laying is suspended, the pipeline should be temporarily closed off.

Where pipe drains should be laid in very soft conditions, across backfilled trenches, or similar situations, a rigid drain bridge should be used to support the pipe.

Drain bridges can be of any suitable rigid material and should be laid in such a way so as to rest on at least 600 mm of firm soil on each side.

Soil beneath the drain bridge should be firmly compacted and any voids totally filled. Bridges should be installed during or immediately following drain installation. Pipes may require fixing to the bridge.

5.8.2.3 Securing of the position of pipes

Drain lines should conform to the following requirements with regard to deviations from the prescribed slope line :

a)   the deviation of the inner bottom side of the pipe from the slope line stipulated should not be more than half its inner diameter ;
b)   at the same time the deviation may nowhere be such that in consequence of a negative slope more than half the pipe section remains filled with water after the drain discharge has ceased.

Before the drain trench is backfilled, correct positioning of the drain pipe and connections should be ensured.

The space between the drain pipe and the wall of the trench should be filled in such a way that the position of the pipe is not affected.

Wherever there is a risk of excess water causing pipe flotation, drains should be covered immediately after laying.

5.8.2.4 Backfilling excavated material

Pipe trenches should be carefully backfilled as soon as practicable after installation with material placed in such a way that the pipes are not damaged or displaced. Trenches should be filled to a level sufficiently above the soil surface to allow for settlement. In case of sandy soils the trench should be filled with about 100 mm permeable non-humus soil over the pipe.

Frozen soil and soil which, due to excessive water content, tends to silt-up or to deliquesce, should not be used for filling the drain trenches.

5.8.3 Pipe laid by a trenchless machine

Normally, the base of the laying device should be shaped by a tool to form a V-shaped groove, with the base of the groove radiused to a value not less than the outside radius of the pipe being laid.

When drainage pipes are laid by trenchless machines it is necessary to avoid jerky or tearing movements of the vehicles to overcome drags, or in case of soil slippage.

5.8.4 Connections

Immediately after being formed, the gradient and the connection should be secured against shifting by underpacking and lateral interlocking, using non-compacting durable materials.

When lateral drains should preferably be connected from above onto the collector drains, a rigid pipe with a minimum of 1 m should be used to form a connection and be suitably graded and supported.

Purpose-made junctions should be used when connecting lateral drains to collector drains. Under no circumstances should the lateral drain be permitted to extend into the collector drain.

5.8.5 Inspection shafts

Inspection shafts should be suitable for their function, durable and able to withstand their service load. No deviation should occur in the drain line. Shafts should be built on a frost-free foundation.

If the shaft is serving as a sludge or sand trap, the bottom of the shaft should be at least 0.30 m below the lowest pipe invert.

The inlets and outlets of collector drains should be constituted of rigid plastics pipes.

5.8.6 Drain cleaning provisions

The drain cleaning provisions should be installed in such a way that no deviations will occur in the drain line and that the drain can be cleaned in an upstream direction. The various parts should be firmly fastened and well fitted to secure the drain cleaning fittings. Backfill should be placed in well-compacted horizontal layers, about 0.30 m thick.

5.8.7 Collector outlets

A properly constructed outfall, of a suitable type, should be provided wherever a drain pipe discharges into an open channel. The invert, wherever possible, should be positioned at least 150 mm above the normal ditch water level.

A minimum 1 m length final drain should be of a rigid type. Any projection of the drain pipe beyond the bank should also be rigid and frost resistant. Vermin gratings should be fitted.

Headwall designs of outfalls should include slope protection and splash plates and should be securely anchored in position.

5.8.8 Maintenance

An auxiliary device such as a jetting piece may be connected to the piping system. In this case the end of the pipe should be closed by installing an end cap. Otherwise when possible the jetting piece should be directly connected to a chamber with a cover.

5.9 General considerations

5.9.1 Safety

5.9.1.1 Human safety

Due regard should be paid to all safety measures both on site and during transport.

The systems of work should be adopted and plant and equipment used so far as reasonably practicable, safely and without risks to the health of persons at work and others who may be at risk from the activities of persons at work.

Attention is drawn to the importance of ensuring that anything which may create a hazard and, in particular parts of machinery, are adequately guarded and that excavations are safe and adequately supported. Temporary excavations should be covered or guarded when the site is left, to reduce the risk of accidents to children and animals.

5.9.1.2 Underground services

All interested parties who have buried services in the land to be drained should be approached and enquiries made in writing as to the nature and location of such services. Farmers should be questioned concerning the presence of any buried services before work commences.

In all cases, the buried utility should be located and exposed by hand digging before drain laying. In the case of oil and gas pipelines, an inspector should be present during excavation and during pipe laying near or across the buried services. All contact with buried services should be reported immediately to the responsible authority.

5.9.2 Conservation

Careful consideration should be given to the landscape and its wildlife habitats when undertaking underdrainage works. Suitable planning beforehand can ensure that the execution of drainage operations and their future maintenance will have a minimal effect on the environment.

Furthermore, a new scheme can often provide an opportunity to create new conservation features such as ponds.

ANNEX A

Recommended practice for use of laser equipment

A.1   The tripod of laser transmitter needs to be placed firmly and free from influence by vibrations or similar effects. On soft ground - like peat - it is desirable that the transmitter is positioned outside the field to be drained if practical.

A.2   If overhead power lines are in the area, and if the instrument is sensitive to them, it can not be placed under the power lines in order to prevent their influence on the laser.

A.3   If the influence of radar is discovered, and if the instrument is sensitive to it, the drainage work can only proceed if the radar is not in use. The radar can also be transferred on request.

A.4   A maximum distance of 300 m to the laser transmitter should be maintained during good weather conditions. During strong winds the maximum distance should be reduced to 200 m. During very high winds and under fog conditions drainage work should not be carried out. The speed of the drainage machine should be adjusted in accordance with conditions.

A.5   To minimize the influence of wind during the setting up of the laser equipment, the following procedures are recommended :

a)   Place one of the tripod legs opposite the direction of the wind.
b)   Check if the snap-on couplings and bolts are tight and, if necessary, adjust them.
c)   Wind the cables to transmitter and receiver round one leg of the tripod or around the receiver mast.
d)   Tie down the tripod by placing a hook around the foot of each tripod leg, and place sandbags on them, or fix rubber bands between the middle of each leg and a weight or pin placed in the ground in the middle of the tripod.
e)   Protect the laser position by installing a temporary windbreak, or possibly use a van as wind protection. In this case, take care of turbulence behind the windbreak.
f)   Install the laser transmitter as low as possible and adjust the receiver mast accordingly.
g)   Keep the transmitter low in relation to the tripod and if a higher position is required, extend the tripod legs to maximum.

A.6   Check if the grade installed compares with the real grade of the laser beam and repeat this check during installation of drains.

A.7   Check the laser properly periodically.

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Materials for subsurface land drainage systems

This publication presents practical guidelines to assess the need for envelopes and to select appropriate materials (i.e. pipes and envelopes) for the proper and lasting performance of subsurface drainage systems. In addition, it contains guidelines for adequate installation and maintenance of drainage materials as well as the required specifications and standards of such materials, which may be used in tender documents for implementation of subsurface drainage works. Practical guidelines for the implementation of laboratory and field investigations to evaluate the performance of drainage materials have also been included. This paper aims to provide this practical information to drainage engineers and contractors who are in charge of drainage projects.