TECHNICAL SPECIFICATION

ISO/TS 10465-1

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Underground installation of flexible glass-reinforced pipes based on unsaturated polyester resin (GRP-UP) —

Part 1: **Installation procedures**

Installation enterrée de canalisations flexibles renforcées de fibres de verre à base de résine polyester insaturée (GRP-UP) —

Partie 1: Modes opératoires d'installation

Reference number
ISO/TS 10465-1:2007(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of normative document:

— an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;

— an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

An ISO/PAS or ISO/TS is reviewed after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/PAS or ISO/TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TS 10465-1 was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 6, *Reinforced plastics pipes and fittings for all applications*.

This first edition of ISO/TS 10465-1 cancels and replaces ISO/TR 10465-1:1993, of which it constitutes a technical revision.

ISO 10465 consists of the following parts, under the general title *Underground installation of flexible glass-reinforced pipes based on unsaturated polyester resin (GRP-UP)*:

— *Part 1: Installation procedures* [Technical Specification]

— *Part 2: Comparison of static calculation methods* [Technical Report]

— *Part 3: Installation parameters and application limits* [Technical Report]

Introduction

Work in ISO/TC 5/SC 6 (forerunner to ISO/TC 138/SC 6) on writing standards for the use of glass-reinforced plastics (GRP) pipe and fittings was approved at that subcommittee's meeting in Oslo in 1979. An *ad-hoc* group was established and the responsibility for drafting various standards later given to the Task Group that would become ISO/TC 138/SC 6.

At the ISO/TC 138/SC 6 meeting in London in 1980, Sweden proposed that a Working Group be formed to develop documents regarding a code of practice for GRP pipes. This was approved by the subcommittee and Working Group 4 (WG 4) formed for the purpose. Since 1982, many WG 4 meetings have been held and have considered the following matters:

— procedures for the underground installation of pipes;

— pipe/soil interaction with pipes having different stiffness values;

— minimum design parameters;

— an overview of various static calculation methods.

During this work it became evident that unanimous agreement could not be reached within the Working Group on the specific methods to be employed. It was therefore agreed that the related documents would be published as either Technical Specifications — the case for this part of ISO 10465 — or Technical Reports.

This part of ISO 10465 describes procedures for the underground installation of GRP pipes. It concerns particular stiffness classes for which performance requirements have been specified in at least one product standard; but it can also be used as a guide for the installation of pipes of other stiffness classes.

ISO/TR 10465-2 presents a comparison of the two primary methods used internationally for static calculations on underground GRP pipe installations:

a) the ATV method [1];

b) the AWWA method [2].

ISO/TR 10465-3 gives additional information which is useful for static calculations primarily when using an ATV-A 127 type design system in accordance with ISO/TR 10465-2 of items such as

— parameters for deflection calculations,

— soil parameters, strain coefficients and shape factors for flexural-strain calculations,

— soil moduli and pipe stiffness for buckling calculations with regard to elastic behaviour,

— parameters for re-rounding and combined-loading calculations,

— the influence of traffic loads,

— the influence of sheeting,

— safety factors,

— allowable depth of cover for different pipe stiffnesses in different native soils,

— minimum pipe stiffness, depth of cover and compaction for GRP pipes installed under traffic surfaces,

— minimum pipe stiffness in relation to embedment conditions for GRP pipes which need to sustain negative pressures,

— re-rating of pressure pipes which are used under conditions, such as depth of cover, other than those for which the standard pipe has been designed, and

— the influence of sheeting on allowable depth of cover.

Since publication of the previous edition of this part of ISO 10465, both the AWWA and the ATV-DVWK design systems have been revised and now contain design features which reflect the increased knowledge and experience gained by the pipeline industry during the last decade. The revision of this and the other parts of ISO 10465 has been made to take account of those changes.

NOTE Although significant advances in trenchless construction have been made in recent years, this type of installation has not been considered.

Underground installation of flexible glass-reinforced pipes based on unsaturated polyester resin (GRP-UP) —

Part 1: Installation procedures

1 Scope

This part of ISO 10465 describes the procedures for underground installation of flexible glass-reinforced thermosetting resin (GRP) pipes. It refers generally to GRP pipes as specified in the system standards ISO 10467 and ISO 10639, but it can also be used as a guide for the installation of other GRP pipes. It does not include jacking, relining or above-ground installations; nor does it cover health and safety or environmental conditions, these being addressed in national regulations at the place of installation.

NOTE The installation nomenclature, dimensions and soil moduli zones referred to in this part of ISO 10465 are shown in Figure 1.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 10467, *Plastics piping systems for pressure and non-pressure drainage and sewerage — Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin*

ISO 10639, *Plastics piping systems for pressure and non-pressure water supply — Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin*

3 Terms and definitions

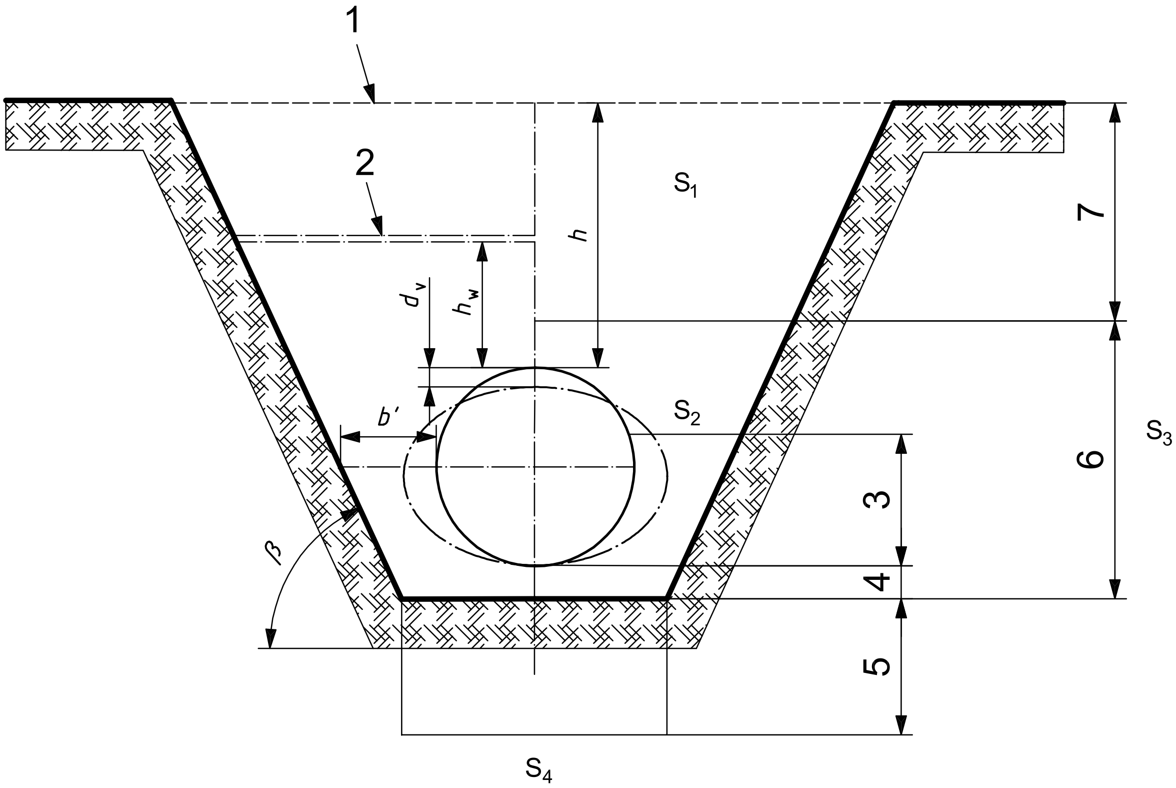
For the purposes of this document, the following terms and definitions apply.

3.1
trench-stops
dams or weirs built around the pipe across the trench to prevent flow of water along the trench through the bedding and foundation materials

NOTE Trench-stops can be formed from clay which may be available on-site, or from bags of sand, or cement stabilized sand, packed around the pipe and across the trench extending to within 150 mm of the finished surface.

3.2
bulkhead
concrete wall poured around the pipe and spanning the trench

NOTE The bulkhead is keyed into the trench walls to form a pipe anchor and extends to within 150 mm of the finished surface level. Drainage holes are normally placed at the lower part of the embedment zone to eliminate long-term retention of water behind the bulkhead. See Figure 1.



Key

b′ distance from trench wall to pipe

d_v vertical deflection

h depth of cover to top of pipe

h_w height of water surface above pipe

S_1 trench backfill above pipe embedment [a]

S_2 pipe embedment [a]

S_3 undisturbed native soil to side of trench [a]

S_4 undisturbed soil below trench [a]

β trench wall angle,

1 ground-level

2 water table level

3 thickness of primary embedment

4 thickness of bedding

5 thickness of foundation (if required)

6 pipe embedment

7 thickness of backfill

a Soil moduli zones.

Figure 1 — Trench installation nomenclature, dimensions and soil moduli zones

4 Installation — Design considerations

4.1 General

Glass-reinforced thermosetting resin (GRP) pipes are classed as flexible pipes which are designed to deflect under external load to an extent that does not cause structural damage to the pipe. The performance of GRP pipes is primarily controlled by the external and internal loads applied and the resistance provided by the embedment conditions. Allowable strain levels within the pipe wall vary, depending upon

a) the type of raw materials used to manufacture the pipe,

b) pipes wall formation, and

c) manufacturing process.

Several installation design procedures exist which can be used to determine the deflection that can be expected in a particular installation. In ISO/TR 10465-2, the two most commonly used procedures — namely, the German ATV 127[1] method and the American AWWA M 45[2] method — are compared.

For a particular pipeline, the optimum pipe installation system employed will be governed both technically and economically by the site conditions. Nevertheless, due to the differences in geological formation that have occurred during the life of the earth, a diverse range of soils and geophysical conditions exists. For these reasons, Clause 7 and Clause 9 to Annex A contain only information that is relevant internationally. Any pipeline installation system shall be in accordance with the applicable national standards and regulations in force at the place of installation.

4.2 Site assessment

The topics in this subclause cover matters which should always be considered when surveying a site.

4.2.1 Water-table level

Water tables that are higher than the bottom of the trench can produce problems such as a reduction in passive resistance, erosion of trench sides, migration of fines within the embedment, instability of the trench, possibility of pipe floatation and inadequate foundation. Where a site has a high water table, consideration should be given to additional ground drainage and the use of suitable installation design methods to cope with the possibility of the buried pipe floating during and after installation. Additionally, the possibility of the water table changing over time should be surveyed using any existing shallow-drilled wells or springs, water levels in surface watercourses and reliable information from the local inhabitants.

4.2.2 Soil stability

During the site survey, locations which show signs of previous ground instability, i.e. slipping, faulting or uplifting/sinking should be investigated in detail. Fundamentally, the route of the pipeline should be selected to avoid such ground conditions. In cases where this is not possible, a detailed soil survey of the area should be conducted. This survey should be conducted with the assistance of an experienced geologist and/or soil mechanics engineer. Problems identified by the survey which have not been considered in the pipeline design should be discussed with pipeline designer/specifier.

4.2.3 Soil exploration

The actual ground conditions prevailing along the proposed route of the pipeline should be surveyed before beginning the design or installation. Geological features and the engineering properties of the soil are elements which will have an influence on the selection of the route, minimum pipe stiffness required, trench proportions and installation techniques to be employed.

The techniques to be employed during the survey will typically include at least one or more of the following: boring, sounding, physical survey, prospecting, water-table evaluation and determination of soil properties at the site and in the laboratory. The degree of detail required from the survey will be specified by the responsible designer of the pipeline and will take into account the scale of pipeline, risk assessment and critical nature of the location.

4.2.4 Soil classifications

The ground conditions will vary at different locations along the intended route of a pipeline and it is important that an accurate description of the soil be given to the designers and contractors. To ensure an accurate assessment is made, the descriptors used in the report on the survey should be based on standards using the unified soil classification system (see Annex A) or be in accordance with the country's national design standard.

4.2.5 Location of existing pipeline utilities and structures

A preliminary site survey should be conducted along the route of the pipeline to ascertain whether other services such as water supply, sewerage, electricity or gas are present. Prior to commencing installation, precautions to prevent damage to existing services should be undertaken. The precautions should include minimum isolation distances to such services as may be prescribed by national regulations.

Furthermore, there is the possibility that historical or cultural assets could be encountered, and in such cases the regulations of the country or region shall be followed.

4.3 Flexible pipe — Technical concepts

Glass-reinforced thermosetting resin (GRP) pipes are classed as flexible pipes that may be expected to deflect under external load with no structural damage. The performance of GRP pipe is affected by the amount of strain induced in the pipe wall by external loads and/or internal pressure.

Allowable strain levels vary with the type of raw materials, wall structure and manufacturing process. It is necessary to control the deflection and distortion of the pipe to ensure that the manufacturer's allowable strain level is not exceeded.

In an underground installation, the soil and traffic loads above a buried flexible pipe cause a decrease in the vertical diameter and an increase in the horizontal diameter of the pipe. The horizontal movement of the pipe walls into the soil material at the sides of the pipe develops a passive resistance that helps the pipe support the external load. The resistance of the soil is affected by the type of soil, its density, depth of overburden and the presence of ground water. The higher the soil resistance, the less the pipe will deflect. Proper installation techniques are essential to develop the passive soil resistance required to prevent excessive pipe deflections and/or distortions.

The deflection of a buried flexible pipe depends on the soil and on the pipe. The amount of deflection is a function of the depth of burial, the stiffness of the pipe, the passive resistance of the soil at the sides of the pipe, the time-consolidation characteristics (time lag factor) of the soil and pipes, the applied live load and the degree of support given to the bottom of the pipe (bedding constant).

Several procedures exist that can be used to obtain the mathematical relationship of these parameters and the deflection that will occur in a particular installation.

NOTE In ISO/TR 10465-2, the two major design procedures [1], [2] are compared.

4.3.1 Behaviour of flexible pipes under load

The flexibility of GRP pipe combined with the natural structural behaviour of soils provides an ideal combination for transferring vertical load. Unlike rigid pipes, which may break under excessive vertical load, the GRP pipe's flexibility combined with its high strength allow it to bend and redistribute the load to the surrounding soil. The deflection of the pipe serves as an indicator of the stresses generated in the pipe and the quality of the installation.

The initial deflection is the deflection which is present following installation. The pipe continues slowly to have an increase in deflection but reaches a final value within a reasonable period of time. Almost all of the increase in deflection takes place during 1 to 2 years after installation and thereafter the deflection stabilizes. It is not unusual for the long-term deflection value to be 30 % to 50 % higher than the average initial deflection. The change in deflection after installation is caused mainly by settlement and consolidation of the surrounding soil. If the pipeline is pressurized, the pipes will start to re-round and a reduction in deflection will occur.

The use of the installation procedures detailed in this part of ISO 10465 will minimize the levels of both the initial and final deflections.

4.3.2 Limiting deflection

There are several methods of structural design (see ISO/TR 10465-2 and ISO/TR 10465-3) that may be used to estimate the deflection of a pipe under load but, although they are capable of being in reasonable agreement, they do not give exactly the same answers for a given condition. For any particular method, the values calculated are usually the expected average deflections.

The property requirements for GRP-UP pipes in accordance with ISO 10467 and ISO 10639 assume that the maximum permissible initial deflection is 3 % and the maximum long-term deflection is 6 %. If the recommendations for installation in this part of ISO 10465 are followed, it is expected that the deflections achieved will be less than these limiting values.

4.4 Pipe selection

The selection of the pressure class, stiffness class and joint type of a buried pipe system is based on the operational conditions of the pipeline (operating pressure, surge pressure and possible vacuum conditions) as well as on the external forces applied to the pipe from soil loading and superimposed live or traffic loading.

As the operating and burial conditions can vary over the length of a pipeline, the selected pressure and stiffness classes can differ at different locations along the pipeline. Depending on such factors as how pressure thrust is accommodated and the need to connect to fittings and other systems, joint selection can also differ along the course of a pipeline.

4.4.1 Pressure class selection

The selection of the appropriate pressure class for a pipe at any particular location in a pipeline system requires either knowledge of the static head pressure or of the pumping pressure or system operating pressure. Typically, a hydraulic analysis will determine the acceptable flow velocities and identify areas of high static or pumping heads. Surge pressure conditions also need to be determined. An unusually high surge pressure could require a higher pressure class pipe.

Depending on the application and operation requirements of the pipeline system, the system designer may incorporate such items as head breakers, pressure reduction valves, pressure relief valves, orifice plates and surge suppressors to control the flow and pressure in the pipeline.

4.4.2 Pipe stiffness class selection

Before the necessary stiffness can be determined, the following need to be considered.

4.4.2.1 Soil survey

If a soil survey is carried out prior to construction, the native soil and the backfill material should be classified in accordance with Annex A. The classification will help in the selection of a suitable nominal stiffness in accordance with 4.4.2.2

The classification will also indicate the areas of suitable materials for pipe zone backfill, so that importation of material may be minimized. Native materials conforming to the recommendations of this part of ISO 10465 or soil groups 1, 2, 3 and 4 (see Annex A) are all suitable as backfill in the pipe zone. If backfill materials have to be imported it is recommended that group 1 or 2 materials be used.

4.4.2.2 Matters influencing selection of suitable pipe stiffness

The selection of an appropriate pipe stiffness class for a pipeline will depend on a number of factors, including

- burial depth,
- trench width,
- native soil,
- pipe zone backfill material and its degree of compaction,
- water table location,
- traffic (live) loading conditions,
- surface surcharge loads,
- vacuum conditions, and
- the limiting properties of the pipes.

Calculations to determine the predicted deflection level of installed pipes should be performed (see ISO/TR 10465-2 and ISO/TR 10465-3 for discussion and information on the most common calculation systems for GRP pipe systems). The predicted deflection must be within the allowable deflection limits of the selected pipe.

If consideration is being given to the use of pipes with a nominal stiffness less than SN 2 000, the possible effect of high compaction effort producing distortion should also be considered. It is recommended that a stability analysis be made which investigates the effects of the loading from soil overburden and, if applicable, internal vacuum.

4.4.2.3 Joint selection

The selection of the joint type will depend on several factors, of which the key considerations are

- operating pressure,
- method of thrust restraint,
- need for joining to ancillary fittings and/or other piping materials, and
- system layout.

In many piping projects it will be common to have several different joining methods, each addressing a specific need in the most economical manner.

5 On-site inspection, transportation, handling and storage

5.1 Inspection

It is recommended that at the commencement of the pipeline installation project an inspection and test plan be prepared. The testing and inspection should routinely confirm that the project specification is being met.

5.2 Transportation

5.2.1 Packaging

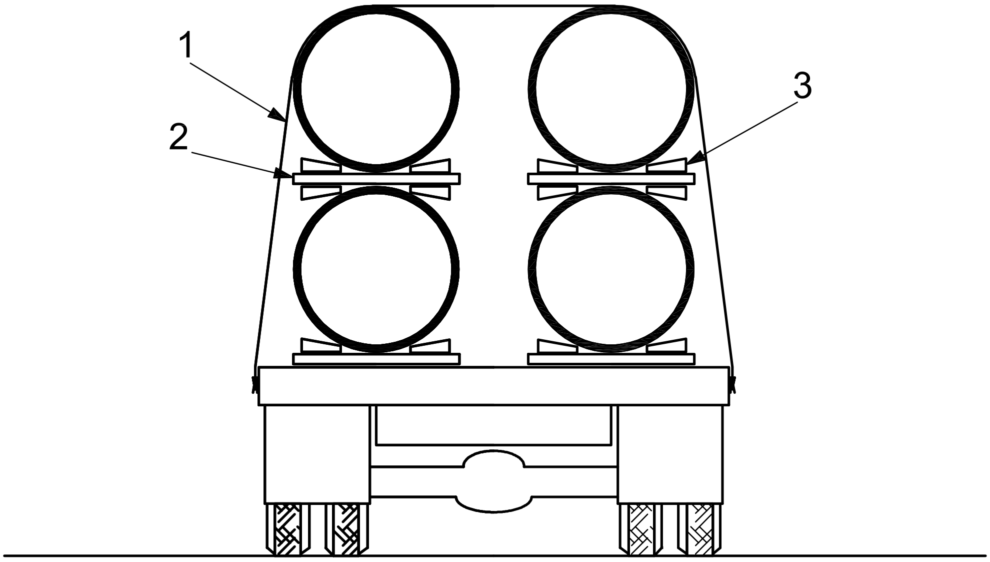
When transporting pipes and fittings, use either flat-bed or purpose-made vehicles. Secure the pipes and fittings well before transportation. When loading bell end pipes, stack the pipes so that the bells are not in contact with adjacent pipes. All supports, restraints and packing bearing on pipe and fitting surfaces shall be padded or wrapped with material suitable to prevent point loading or other damage during transportation. Chains and wire ropes shall not come into direct contact with the pipes and fittings.

5.2.2 Transportation stack height

The height of the pipe stacks shall be limited to minimize deformation during transport. The largest diameter pipes shall be placed on the bed of the vehicle. When pipes or fittings require special transportation practices, the manufacturer shall notify the customer of the procedure to be used.

5.2.3 Pipe transportation on-site

If it is necessary to transport pipes and fittings on the job site, use either flat-bed or purpose-made vehicles which are free from nails and other protuberances (see Figure 2). It is best to use the original shipping dunnage if that is available; if not, support all pipes on flat timber at a maximum spacing of 4 m with a maximum overhang of 2 m. Contact between individual pipes should be prevented and chocks should be used to prevent movement. The maximum stack height should be limited to approximately 2 m: strap pipes to the vehicle over the support points using pliable straps or ropes. Never use chains or steel ropes.



Key

1 rope or fabric strap

2 timber bearer

3 timber chock fixed to bearer

Figure 2 — Transport of pipes

5.3 Pipe handling

5.3.1 General

Care should be exercised when unloading the product in order to prevent damage from hitting rigid objects. Do not use hooks, chains or cables at the ends of the pipes. The timber bearings supporting the pipes shall not be used to lift the pipes unless allowed by the manufacturer.

Pipe handling and unloading can be hazardous and must be carried out in accordance with the manufacturer's recommended practice. Typically pipe handling will include the following precautions.

a) Avoid rough handling of the pipe or pipe packs which could cause impact against hard objects or resting upon surfaces which could cause point loading.

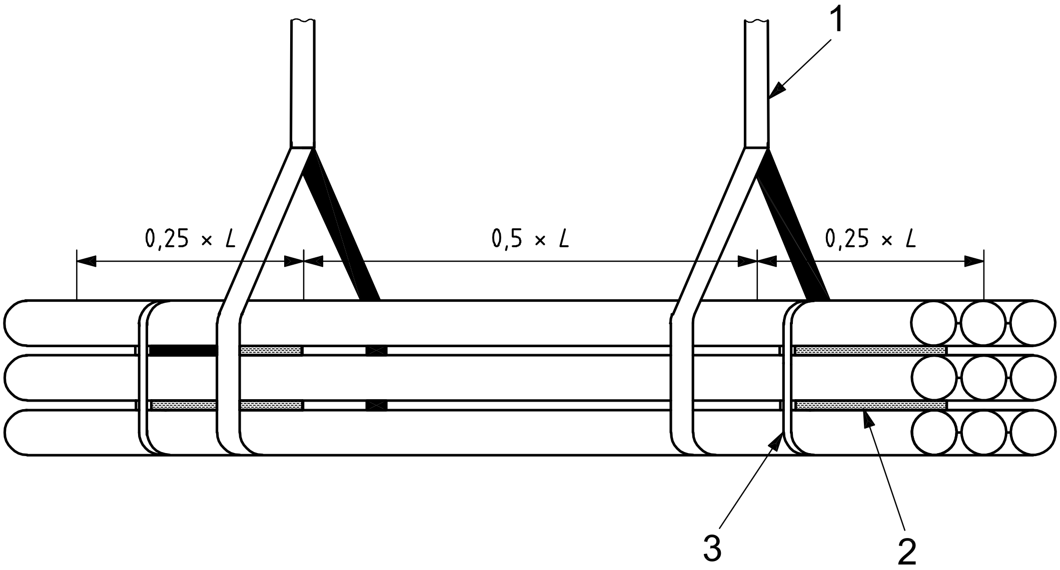
b) During the unloading process, maintain control of the load. The use of guide ropes will assist in controlling the load and spreader bars might also assist when multiple support locations are necessary.

5.3.2 Pipe units

Pipes can be packaged as units. These may be handled using a pair of fabric slings as shown in Figure 3.

CAUTION — Do not use chains or wire ropes.

Pipe bundle units are normally designed to be lifted from the top, but forks or slings that go under the units may be used.



Key

1 fabric sling

2 timber bearer

3 pipe bundle binding

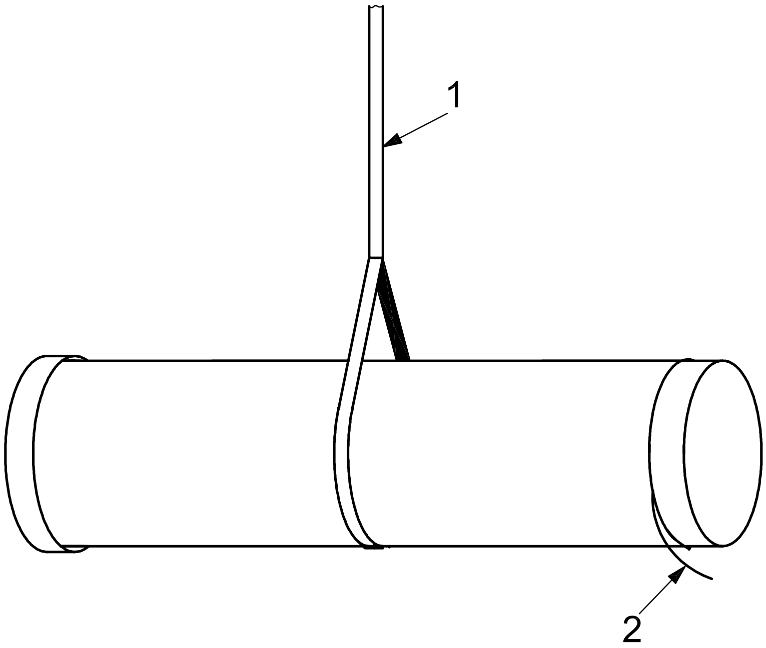
Figure 3 — Lifting pipe bundle unit

5.3.3 Single pipe

When handling single pipes it is recommended that fabric slings or ropes be used (see Figures 4 and 5.)

CAUTION — Do not use chains or wire ropes to lift pipe; do not use hooks at the pipe ends or ropes passed through pipes as a means of lifting.

Pipes should not be rolled over rough or rocky ground.

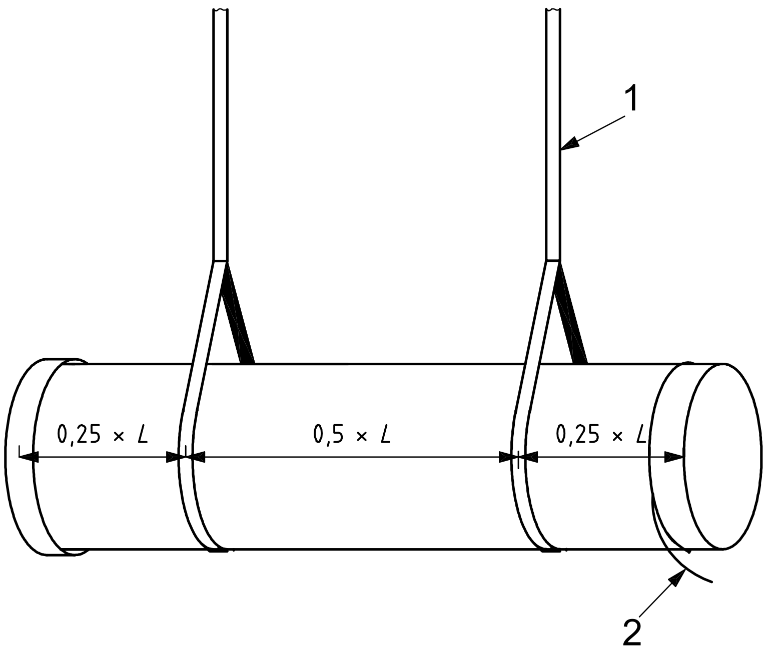


Key

1 fabric sing

2 rope used to control and manoeuvre the pipe

Figure 4 — Lifting pipe using single sling



Key

1 fabric sling

2 rope used to control and manoeuvre the pipe

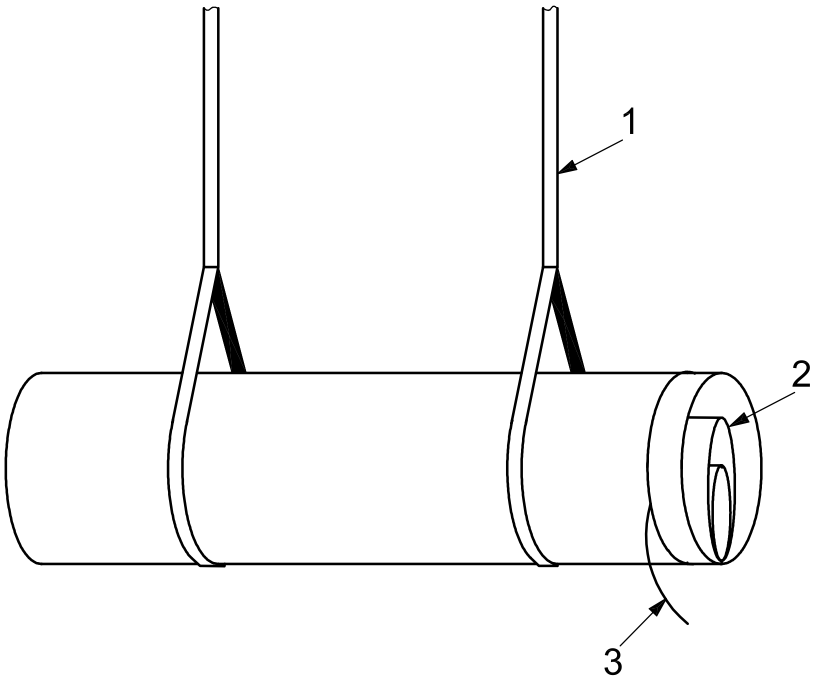
Figure 5 — Lifting a pipe using two slings

5.3.4 Nested pipes

Pipes which are shipped for long distances may be nested (small diameters inside larger diameters) to reduce transportation costs. These pipes usually have special packaging and can require non-standard procedures for unloading, handling and storage, information on which will normally be supplied by the manufacturer.

CAUTION — Always lift a nested bundle using two slings.

See Figure 6.



Key

1 fabric sling

2 Pipes nested inside largest pipe

3 rope used to control and manoeuvre the pipe

Figure 6 — Nested pipes lifted using two slings

Nested pipes are normally best stored in their original packaging and de-nesting should be undertaken at a site equipped for that purpose following the instructions provided by the pipe manufacturer.

5.4 Storage

5.4.1 Pipe

Store and transport pipe in accordance with the manufacturer's recommendations.

Select a site having sufficient area for storage of the pipes and room for vehicle movements. Where necessary, clear site of hazardous combustible vegetation and minimize fire risks.

Pipe may be stored on the ground, provided that it is flat, free of rocks and any other potentially damaging debris. However, it is generally advantageous to place the pipe on flat timber supports, as these facilitate placement and make the removal of slings easier.

SAFETY PRECAUTIONS — All pipes should be chocked to prevent rolling which may be initiated by uneven ground, wind-loads or other external forces.

Pipes may also be supported on sand bags or soil mounds.

Pipes may be stacked, but the height of the stack should be limited in order to minimize distortion and ovalization during storage (see Table 1). When pipes are stored in stacks, the bottom layers can become distorted; these should be removed from the stack, prior to installation, allowing sufficient time for re-rounding to occur.

Table 1 — Recommended maximum number of layers in a stack of pipes

Nominal size (DN)	150	200	250	300	400	500	600 to 700	800 to 1200	1 400 and over
Number of pipe layers	9	8	7	6	5	4	3	2	1

If pipes are nested, the number of supports between layers should be increased so that the magnitude of loads at the bearing points is no greater than for un-nested pipes.

If the exposed storage time is likely to exceed 12 months and any of the materials used for the pipe and fittings are sensitive to ultra-violet light radiation, some additional protection could be required to prevent damage.

5.4.2 Gaskets and lubricant

Rubber ring gaskets, if shipped separately from the couplings, should be stored in the shade in their original packaging. The gaskets should be protected from exposure to greases and oils which are petroleum derivatives and from solvents and other deleterious substances.

Gasket lubricant shall be carefully stored to prevent damage to the container. Partially used lubricant containers should be carefully resealed to prevent contamination.

5.5 On-site inspection

5.5.1 Load inspection

All pipes should be inspected upon receipt at the job site to ensure that there has not been any damage in transit and that the pipes and fittings comply with the product specifications and contract documents. Depending upon the length of time in storage, the amount of job site handling and other factors that can influence the condition of the product, it may be prudent to re-inspect the pipe just prior to installation.

5.5.2 Pipe marking

Ensure that the pipe quantities and markings comply with the bill of lading and the contract documents with respect to size, stiffness and pressure class requirements. Where the pipe is to be used for the conveyance of potable water, ensure that it has been tested and certified by an acceptable certifying organization for use under the local regulatory requirements.

5.5.3 Pipe and fittings inspection

Make an overall inspection of the load. If the load is intact, ordinary inspection of the pipe will normally suffice to ensure that the pipe and fittings have arrived without damage. If the load has shifted or there are signs of damage, each pipe should be inspected carefully.

Damaged pipe might or might not be repairable, depending upon its type and the application for which it is being used. Any damaged pipe should be clearly marked and quarantined. Repairable pipe should be repaired according to the manufacturer's instructions. Pipe which cannot be repaired should be removed from the site.

Inspect gaskets, seals and fittings to ensure that the correct items have been supplied and that the correct materials have been used in their manufacture.

6 Trench construction

6.1 Excavation

Excavate trenches ensuring that sides will be stable under all working conditions. Slope the trench walls or provide supports in conformance with all local and national standards for safety. Open only that portion of the trench as can be safely maintained by the available equipment. Place and compact the backfill in the trench as soon as practicable, preferably no later than the end of each working day.

Where trench walls are stable or supported, provide a width sufficient, but no greater than necessary, to ensure working room to properly and safely place and compact the haunch and other backfill materials.

The space between the pipe and the trench wall shall be wider than the compaction equipment used in the pipe zone.

In addition to safety considerations, the trench width in unsupported, unstable soils will depend on the size and stiffness of the pipe, stiffness of the backfill and native soil and depth of cover.

Specially designed equipment can facilitate the satisfactory installation and backfill of pipe in trenches narrower than specified below. If it is determined that the use of such equipment can provide an installation consistent with the requirements of this practice, minimum trench widths may be reduced if approved by the engineer.

6.2 Minimum trench width

Minimum trench width for single pipes should be at least 1,25 times the outside diameter of the pipe plus 300 mm. The clearance between the pipe and the trench wall shall be wider than the embedment compaction equipment which will be used.

6.2.1 Trench width – multiple pipes

For multiple pipes in the same trench, spaces between pipes shall be at least equal to the average of the radii of the two adjacent pipes for depths of cover greater than 3,5 m and 1/3 of the average radii for depths of cover less than 3,5 m.

The distance from the outside pipe to the trench wall shall not be less than if that pipe were installed as a single pipe in a trench.

The space between the pipes and the distance from the outside pipe to the trench wall shall be wider than the embedment compaction equipment being used.

An indicative value for safe working room is 500 mm (for larger diameters) or at least half the external pipe diameter between the pipes and the distance from the outside pipe to the trench wall (for smaller diameters).

6.3 Trench-bottom

Excavate trenches to a depth of at least 100 mm below the pipe.

See Clause 7 for guidance on installing a foundation and bedding.

6.3.1 Rock

When ledge, rock, hardpan or other unyielding material, cobbles, rubble or debris, boulders or large stones are encountered in the trench bottom, excavate a minimum depth of 150 mm below the pipe bottom, or as directed by the engineer.

NOTE Table 2 gives guidance on maximum stone sizes allowable with respect to pipe diameter.

6.3.2 Unstable base

If the trench bottom is unstable or shows a “quick” tendency, over-excavate to a depth required by the engineer.

6.4 Water control

It is always good practice to remove water from a trench before laying and backfilling pipe. While circumstances occasionally require pipe installation to take place in standing or running water conditions, such practice is outside the scope of this part of ISO 10465. At all times, prevent run-off and surface water from entering the trench.

6.4.1 Ground water

When ground water is present in the work area, de-water to maintain stability of native and imported materials. Maintain the water level below the pipe bedding. Use, as appropriate, sump pumps, well points, deep wells, geotextiles, perforated under-drains or stone blankets of sufficient thickness to remove and control water in the trench. When excavating while lowering the ground water level, ensure that ground water is below the bottom of the cut at all times to prevent wash-out from behind sheeting or sloughing of exposed trench walls. Maintain control of water in the trench before, during and after pipe installation, and until backfill is installed and sufficient backfill has been placed to prevent flotation of the pipe. To preclude loss of soil support, employ de-watering methods that minimize removal of fines and the creation of voids in the native soil and backfill.

6.4.2 Running water

Control running water arising from surface drainage or ground water so as to prevent undermining of the trench bottom, walls, foundation or other zones of backfill. Provide dams, cut-offs, or other barriers periodically along the installation to prevent transport of water along the trench bottom. Backfill all trenches as soon as practicable after the pipe is installed to prevent disturbance of pipe and backfill.

6.4.3 Materials for water control

Use suitably graded materials in the foundation as drainage blankets for transport of running water to sump pits or other drains. Use properly graded materials or perforated under-drains, or both, to enhance transport of running water. Select the gradation of the drainage materials to minimize migration of fines from surrounding materials.

The bedding and backfill materials selected for such installations should consist of materials that do not have fine particles which could be removed by the effects of water; alternatively, the installation should utilize geotextile fabrics that will prevent the fine materials from migrating to the trench walls (see 7.2).

6.5 Support of trench walls

6.5.1 Temporary support

When supports such as trench sheeting, trench jacks, trench shields or boxes are used, ensure that support of the pipe and the backfill is maintained throughout the installation process. Ensure that sheeting is sufficiently tight to prevent washing out of the trench wall from behind the sheeting. Provide tight support of trench walls below viaducts, existing utilities or other obstructions that restrict driving of sheeting.

6.5.2 Support left in place

Unless otherwise directed by the engineer, sheeting driven into or below the pipe zone should be left in place to preclude loss of support of foundation and backfill materials. When the top of the sheeting is to be cut off, make the cut 0,5 m or more above the crown of the pipe. Leave supports in place as required to support cut-off sheeting and the trench wall in the vicinity of the pipe zone. Timber sheeting to be left in place is considered a permanent structural member, and should be treated against biological degradation (e.g. attack by insects or other biological forms) as necessary, and against decay if above ground water.

NOTE Certain preservative and protective compounds pose environmental hazards. Determination of acceptable compounds is outside the scope of this part of ISO 10465.

6.5.3 Movable trench-wall supports

Do not disturb the installed pipe and its backfill when using movable trench boxes and shields. Movable supports should not be used below the top of the pipe backfill zone, unless approved methods are used for maintaining the integrity of backfill material. Before moving supports, place and compact the backfill to sufficient depths to ensure protection of the pipe. As supports are moved, finish placing and compacting backfill, and ensure the compaction of backfill materials against the undisturbed native soil.

6.5.4 Removal of trench-wall support

If the engineer permits the use of sheeting or other trench-wall supports that extend into the pipe zone, ensure that neither pipe, foundation, nor backfill material is disturbed by support removal. Fill any voids left on removal of supports, and compact all material to required densities. It is recommended that sheeting be removed in stages and that compact backfill be carried out between each stage.

6.6 Trenching on slopes

The angle at which slopes can become unstable depends on the properties of the soil. The risk of unstable conditions increases dramatically with slope angle. In general, pipes should not be installed on slopes greater than 15° (a slope of 1 to 4) without suitable anchors (bulkheads, see 3.2) or supports. In areas where slope instability is suspected, conditions should be verified by a geotechnical investigation.

Installing pipes above ground may be a preferred method for steep slopes, as above-ground structures such as pipe supports are more easily defined and, therefore, the quality of installation is easier to monitor and settlement easier to detect.

Pipes may be installed on slopes greater than 15° (a slope of 1 to 4) provided that

a) long-term stability of the installation can be ensured with proper geotechnical design,

b) pipes are backfilled with granular material with high shear strength or the shear of the backfill is assured by other means; the backfill should be compacted to a minimum of 90 SPD,

c) pipes are installed in straight alignment (plus or minus 0,2°) with a minimum gap between pipe ends,

d) absolute long-term movement of the backfill in the axial direction of the pipe does not cause joint separation,

e) the installation is properly drained to avoid washout of materials and ensure adequate soil shear strength, and

f) stability of individual pipes is monitored throughout the construction phase and the first stages of operation.

6.7 Exposing pipes when making service-line connections

When excavating for a service-line connection, excavate material from above the top of the existing pipe before removing material from the sides of the pipe. Materials and density of service-line embedment should conform to the specifications for the existing line or with this practice, whichever is more stringent.

6.8 Trench bottom in weak soils

In weak soils, where it is not possible to work safely in the trench, reinforcement of the trench bottom can be necessary before laying the bedding. Reinforcement may be made by using soil improvement techniques, geotextile reinforcement, concrete slabs or other suitable settlement minimizing methods.

Care should be taken when using these techniques to ensure that the reinforcement weight does not cause soil settlement.

These reinforcements have only marginal influence on the structural circumferential behaviour of the flexible pipe. They should not be used to improve the pipe stability.

7 Foundation and bedding

7.1 General

Recommendations for use of various types of backfill materials for the foundation and embedment zone are given in 9.1. In addition, consult the pipe manufacturer for recommendations specific to the product.

NOTE Installation of pipe in areas where significant settlement can be anticipated, such as in backfill adjacent to building foundations, in sanitary landfills or in other highly unstable soils, requires special engineering expertise and is outside the scope of this part of ISO 10465.

Install foundation and bedding materials as required by the engineer, depending on the conditions in the trench-bottom.

In the presence of ground water, a reduction of the soil support around an installation can occur for a number of different reasons, including

— transition from one type of native soil to another, and

— migration of fine soil particles from both the bedding and backfill zones, either into the trench wall or along the alignment of the pipeline or vice-versa.

A reduction in support to the pipe can cause excessive diametral deflection, which could cause failure.

If large scale movements are expected, such as in earthquake and flood zones, it is recommended that expert advice be obtained.

7.2 Migration control of bedding materials

When open-graded material is placed adjacent to a finer material, fines can migrate into the coarser material under the action of hydraulic gradient from ground water flow. Significant hydraulic gradients can arise in the pipe trench during construction when water levels are controlled by various pumping or well-pointing methods, or after construction, when permeable under-drain or backfill material acts as a drain under high ground water levels. Migration can result in significant loss of pipe support, resulting in increasing deflections that can ultimately exceed design limits. The gradation and relative size of the backfill and adjacent materials shall be compatible in order to minimize migration. In general, where significant ground water flow is anticipated, avoid placing coarse, open-graded materials above, below or adjacent to finer materials, unless methods are employed to impede migration. Consider the use of an appropriate soil filter or a geotextiles filter fabric along the boundary of incompatible materials.

The following filter gradation criteria, given by Equations (1) and (2), may be used to restrict migration of fines into the voids of coarser material under a hydraulic gradient.

$$\frac{D_{15}}{d_{85}} \leqslant 5 \quad (1)$$

where

D_{15} is the sieve opening size passing 15 % by weight of the coarser material;

d_{85} is the sieve opening size passing 85 % by weight of the finer material.

$$\frac{D_{50}}{d_{50}} \leqslant 25 \quad (2)$$

where

D_{50} is the sieve opening size passing 50 % by weight of the coarser material;

d_{50} is the sieve opening passing size 50 % by weight of the finer material.

These criteria may not apply if the coarser material is well graded.

If the finer material is a medium plastic or highly plastic clay, then the criteria expressed by Equation (3) may be used in lieu of those of Equation (1):

$$D_{15} \leqslant 0{,}5 \text{ mm} \quad (3)$$

where D_{15} is the sieve opening size passing 15 % by weight of the coarser material.

The above criteria may need to be modified if one of the materials is gap-graded. Materials selected for use based on filter gradation criteria should be handled and placed in a manner that will minimize segregation.

7.3 Trench foundation

7.3.1 General

The trench foundation shall be firm. Where over excavation exists, the area shall be filled and compacted to provide a satisfactory grade and density.

The excavation of the trench will vary according to the nature of the native soil.

In uniform, relatively soft, fine-grained soils free from large stones and other hard objects, and where the bottom can readily be brought to an even finish, providing a uniform support for the pipes over their whole length, it may be satisfactory to lay pipes with nominal sizes up to and including DN 700 directly onto the raked and trimmed bottom of the trench. In such cases, the soil should be excavated locally at the couplings so that the pipe is supported on the pipe barrel and not on the couplings.

The bottom of all trenches shall be continuous, uniform and free of hard spots such as boulders or cobbles.

7.3.2 Rock foundation

When rock, cobbles or other unyielding materials are present, over-excavate the trench bottom to a depth of at least 150 mm to remove all such hard objects, fill the trench bottom with granular material compacted to provide a satisfactory grade and density, then install a layer of bedding, 150 mm minimum thickness, below the bottom of the pipe.

7.3.3 Unstable trench bottom

Where quicksand or similar organic soils which exhibit volume changes with moisture exist, over-excavate the trench-bottom and construct a foundation with a suitably graded material. Each situation should be evaluated on a case-by-case basis during construction, in order to determine the extent of over excavation and the type of foundation material to be used. Where ground water conditions could cause migration of fines and loss of pipe support, the use of a geotextile material should also be considered. For severe conditions, the engineer could require a special foundation such as piles or sheeting capped with a concrete mat.

7.3.4 Over-excavation

If the trench bottom is over-excavated below the intended grade, either intentionally (see 7.3.2) or accidentally, it is recommended that the material for the foundation zone be as for the primary embedment zone compacted to Class W (see Annex A).

7.3.5 Sloughing

If the trench sidewalls slough off during any excavation or installation of pipe zone embedment, remove all sloughed and loose material from the trench.

7.4 Bedding

The pipe needs to be uniformly supported along its full length; this support being provided by the bedding layer (see Figure 1). The bedding layer should be made of granular material, such as sand or crushed rock, and provide a firm, stable and uniform bedding for the pipe barrel and any protruding features of its joint.

The bedding should be spread evenly across the full trench width and levelled to the required grade. A maximum bedding thickness of 150 mm, with minimum thicknesses of 100 mm below the barrel and 75 mm below any other part of the pipe, is recommended, unless otherwise specified.

In uniform, relatively soft, fine-grained soils free from large stones and other hard objects, and where the bottom can readily be brought to an even finish providing a uniform support for the pipes over their whole length, it may be satisfactory to lay pipes with nominal sizes up to and including DN 700 directly on to the raked and trimmed bottom of the trench.

Where there is the possibility of fines migration, consider the installation recommendations given in 7.2.

8 Pipe laying and jointing

8.1 Quality assurance

The satisfactory installation of the pipeline requires that the inspection or quality assurance procedures be conducted throughout all phases of the installation process, in accordance with the following.

a) The trench excavation should conform to the specified width, depth and gradient.

b) The trench foundation shall be firm. Where over-excavation exists, the area shall be filled and compacted to provide a satisfactory grade and density.

c) The pipe embedment material shall comply with the specification. The fill depth and compaction of the material in the trench shall also satisfy the specified requirements.

d) The pipe should be visually inspected for damage prior to laying. Spigots should be clean and pipe bells/sockets should be free of dirt and soil. Jointing should be made using a method approved by the pipe manufacturer, using a suitable pipe lubricant. Joints require inspection to ensure that the correct depth of insertion of the pipe spigot has been achieved and that the pipe-to-pipe deflection does not exceed the specification.

e) During placement and compaction of the embedment material, ensure that pipe support is being created under the haunches of the pipe and check that the vertical and horizontal angular deflections of the pipe are within the limits prescribed.

f) Pipe diametral deflection should be checked soon after installation has been completed to ensure that it is within specification.

g) For pipe where interior access is possible, check the alignment of adjacent pipe ends. A step between the ends should be compared to the maximum allowed by the manufacturer for the type of joint.

h) Store and handle the pipe in accordance with the manufacturer's recommended practices so as to prevent pipe damage. Carefully inspect each pipe, especially the jointing surfaces, for damage prior to installation. It is also advisable to check for blockage and possible contamination.

i) Where it is expected that ground water could flow through the granular embedment, the provision of barriers or trench-stops should be considered.

j) The free fall height of backfill materials onto the pipe crown should be kept to a minimum.

8.2 Pipe laying

Pipes should be lowered into the trench using equipment suitable for the weight and size of the pipe. The positioning of the sling to ensure a proper balance should be checked when the pipe is lifted just clear of the ground. Prior to lowering the pipe into the trench, all persons should vacate the section of trench into which the pipe is being lowered. Prior to and following jointing of the pipe, remove any construction materials from inside the pipe.

Pipe should be laid on flat, uniform material that is at the appropriate grade. Do not bring the pipe to grade by the use of mounds of soil or other material at points along the length of the pipe. Lay the pipe in the trench so that it bears evenly on the bedding throughout its length. Make an allowance for thermal movement (see 9.6.6), particularly if installation takes place under extreme weather conditions. Place the pipe and fittings in the trench with the invert conforming to the required elevations, slopes, and alignment. Provide bell holes in pipe bedding that are no larger than necessary, in order to ensure uniform pipe support. Where a pipeline is to be deflected at the joint, the deflection shall take place after the joint has been made. Join in accordance with the manufacturer's recommendations and take into account, where applicable, the guidance given in Clause 9.

Fill all voids under the bell by working in bedding material. In special cases where the pipe is to be installed to a curved alignment, maintain angular "joint deflection" (axial alignment) within acceptable design limits.

When pipe laying is not in progress, fix a temporary closure to the open end of the pipeline to prevent contamination and access. If there is a risk of the trench being flooded before the backfilling has been completed, take precautions to avoid flotation. A minimum of one pipe diameter of cover is suggested to prevent flotation of an empty pipe when full soil saturation to the surface is possible (see 9.6.3).

8.3 Jointing pipes laid on steep gradients

Where pipes are laid on steep gradients using non-end load-bearing joints, and where the pipe/soil friction is low, care should be taken to ensure that no excessive spigot entry or withdrawal occurs. As soon as the joint assembly has been completed, the pipe should be held in place and the pipe backfilled over the barrel. Unless the gradient is 1 in 4 or steeper, anchorages are not normally necessary; but if this is found not to be the case, the pipe manufacturer should be informed, as this could affect the design of the pipe (see 6.6).

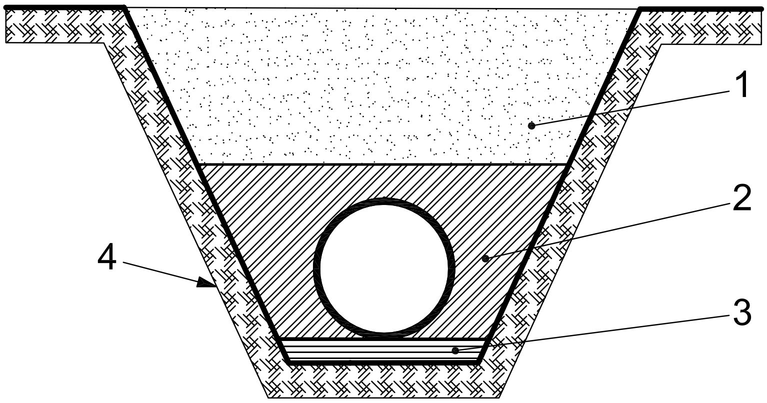
9 Embedment and backfill

9.1 Pipe zone backfill configurations

The two most commonly used configurations of pipe embedment zone backfill for GRP-UP pipes are

a) to surround the pipe with the same material (see Figure 7),

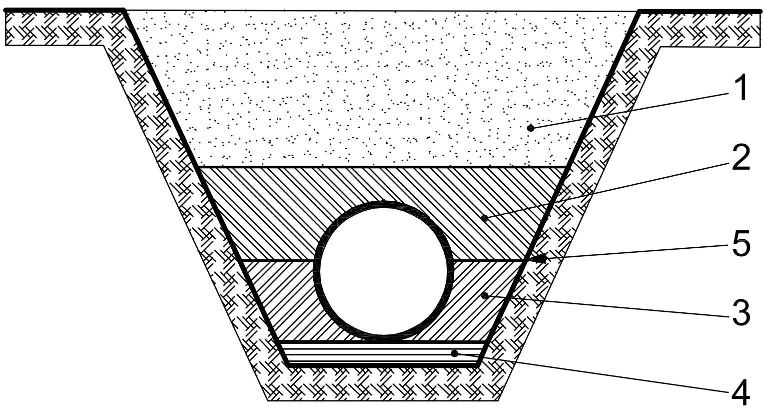
b) a split surround where the surround is made either from two materials or two degrees of consolidation (see Figure 8) — the use of such a split surround normally only being found to be practical with pipes of nominal sizes greater than DN 600.



Key

1 trench backfill
2 pipe embedment zone
3 pipe bedding
4 undisturbed native soil

Figure 7 — Single embedment



Key

1 trench backfill
2 secondary embedment zone backfill
3 primary embedment zone backfill
4 pipe bedding
5 embedment zones split

Figure 8 — Split embedment

If a split surround is used, it is important that the split occurs at a height of more than 60 % of the pipe diameter above the bedding. This is to prevent the possibility of generating high stresses/strains at the change of surround when the pipe deflects. To ensure the split surround provides the same degree of support to the pipe as the full surround, the following rules shall be applied. See Figure 8.

a) The material in the primary embedment zone of a split surround should be at least one grade stiffer than that required in the embedment zone of a full surround. A grade is a particular combination of material group and a compaction class, a change by one step in either of which comprises a one-step change of grade. Thus a one-grade change may be achieved by either

   1) increasing the compaction class or

   2) using a higher group of material (see Table 3).

   For instance, if an application using a full surround requires backfill material group 2 moderately compacted, then for the primary embedment zone, a split surround would require either a well-compacted group 2 material or a group 1 material with moderate compaction.

b) The material in the secondary embedment zone of a split surround may be up to two grades less stiff than that in the embedment zone of a full surround. Nevertheless, care shall be taken that the maximum total difference between the primary and the secondary zone is not more than two grades.

   Care should also be taken to adjust the compaction level for the secondary zone material such that it is based on the actual compaction level achieved on the primary zone material, in order to ensure that the two grades difference is not exceeded. This may also be achieved by changing either the material group and/or the compaction class.

   In any case, the lowest allowable soil stiffness is achieved using an uncompacted material of group 4. For example, for the case described in item a), the requirements would be fulfilled in the secondary embedment zone by using uncompacted group 2 (one grade lower) or moderately compacted group 3 (also one grade lower) or uncompacted group 3 (three grades lower) material. The last option is not permitted because in this case the maximum two grades difference rule would be exceeded.

9.2 Embedment materials

9.2.1 Imported material

Where imported material is used for the primary embedment zone (see Figures 7 and 8) it is recommended that a well-graded granular material with maximum particle size in accordance with Table 2 be used. Where single-sized materials are used it is recommended that the maximum particle size should be one size smaller than that given in Table 2.

Table 2 — Maximum particle size

Nominal size of pipe **DN**	**Maximum particle size** mm
DN < 100	15
100 ⩽ DN < 300	20
300 ⩽ DN < 600	30
600 ⩽ DN	40

9.2.2 Native soil

The native soil may be used for the embedment zone backfill, providing it conforms to all of the following criteria:

a) no particles greater than the applicable limit given in Table 2;

b) no soil lumps greater than twice the applicable maximum particle size given in Table 2;

c) no frozen material;

d) no debris (e.g. asphalt, bottles, cans, trees);

e) where compaction is specified, the material shall be compactable.

Fine-grained soils with medium-to-high plasticity and organic soils (with group 5 or group 6 classification, see Annex A) are generally considered unsuitable for primary embedment zone backfill material unless the pipe and installation have been designed for this condition. The structural properties of the embedment zone backfill material are primarily dependent upon the type of material and the degree of compaction achieved. The degree of compaction achieved can be varied by either using different types of equipment and/or by varying the number of layers. Table 3 gives the degree of compaction, expressed in standard proctor density (SPD), for the groups of backfill material classified in Annex A when compacted to classes W, M or N.

9.3 Placing and compacting embedment materials

9.3.1 Pipe embedment zone

Place the material evenly on each side of the pipe by a method that will not disturb or damage the pipe. Work in and compact the haunch material in the area between the bedding and the underside of the pipe before placing and compacting the remainder of the pipe embedment zone material. Compacting from the trench wall towards the pipe is preferred. Follow the recommendations for compaction given in this section. Do not permit compaction equipment to contact and possibly damage the pipe. Use compaction equipment and techniques that are compatible with materials used and location in the trench.

Table 4 gives the recommended maximum layer thicknesses and the number of passes required to achieve the compaction classes for the various types of equipment and pipe zone backfill materials. Also included are recommended minimum cover thicknesses needed above the pipe before the relevant piece of equipment can be used over the pipe.

The details given in Table 4 are for guidance, and where the installation is of a sufficient size, it is recommended that trials using a variety of the above combinations be carried out so that the optimum practice is selected for the purpose.

9.3.2 Embedment of angularly deflected pipe joints

When pipe joints are angularly deflected to accomplish large radii of curvature bends in pipelines that will operate at internal pressures of more than 1 bar[1)], the backfill surrounding the joint shall be well compacted. Consult the manufacturer for recommendations. Consult the pipe or fitting manufacturer for minimum depths of burial and additional restraint that can be required when the angular deflection is vertical.

9.3.3 Localized loadings

Minimize localized loadings and differential settlement wherever the pipe crosses other utilities or subsurface structures, or whenever concrete-capped piles or sheeting are used. Provide a 150 mm minimum cushion of bedding between the pipe and any such point of localized loading. The use of short pipe lengths to provide increased flexibility at crossings with other subsurface utilities or structures may be considered.

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1) 1 bar = 0,1 MPa = 10^5 Pa; 1 MPa = 1 N/mm^2

9.4 Placement of trench backfill

9.4.1 General

Following completion of the formation of the embedment zone, the remaining part of the trench filling can be made with excavated material with a maximum particle size of up to 300 mm, providing there is at least 300 mm cover above the pipe. If compaction is required, the material shall be suitable for compaction and shall have a maximum particle size not greater than 2/3 of the applicable compaction layer thickness given in Table 4.

IMPORTANT — Attention is drawn to any relevant local and/or national regulations. Note that having a lower compaction requirement at the lower portion, in order to be within the limits and improve compaction, a practice which is thought to improve the installation, could actually result in having a higher difference than that allowed.

Under non-trafficked areas, compaction class N (see Table 3) is considered to be sufficient.

Under trafficked areas, compaction class W (see Table 3) shall be used.

Table 3 — Standard proctor densities (SPD) for compaction classes

Compaction class	SPD %			
	Backfill material group			
	4	3	2	1
N	75 to 80	79 to 85	84 to 89	90 to 94
M	81 to 89	86 to 92	90 to 95	95 to 97
W	90 to 95	93 to 96	96 to 100	98 to 100

N not
M moderate
W well

In the process of backfilling the trench, protect the pipe from falling objects and direct impact from compaction equipment or other sources of potential damage. When the backfill is to be compacted up to the ground surface, do not use the compaction equipment directly above the pipe until sufficient backfill has been placed. Do not use rolling equipment or heavy tampers to consolidate the final backfill unless their use is recommended by the pipe and equipment manufacturers. Provide at least the minimum thickness over the pipe crown given in Table 4, or a greater amount if recommended by the pipe and equipment manufacturers, before using such consolidation equipment.

Consolidation of cohesionless material with water (jetting or saturation with vibration) may be used when backfilling, but only under strictly controlled conditions after approval by the engineer. Before consolidation of the backfill with water, compaction of the embedment area and thickness of the backfill cover shall be verified in order to avoid buoyancy. The correct amount of water in the soil is crucial and is best determined by trial test areas. Trial test areas can also be useful in determining the size of internal vibrators required and the appropriate spacing of their insertion into the soil.

CAUTION — If buoyancy occurs due to lack of compaction of the embedment area or insufficient thickness of backfill, the pipe will rise due to the Archimedes forces, thereby creating gaps between the foundation and the pipe bottom. Sludge displaced with the water will fill these gaps and destroy the required invert level up to eventual rupture of the pipe. This phenomenon can occur with all pipe systems, independent of the material choice.

9.4.2 Compaction quality control

Conformance with the design assumptions should be confirmed by one or more of the following methods:

a) close monitoring of the backfill procedures;

b) verification of the initial deflection of the installed pipe;

c) on-site verification of the degree of compaction.

After repair and additional connection procedures, care should be taken that when replacing side fill and backfill the new density values are approximately equal to those immediately adjacent to the replaced zones.

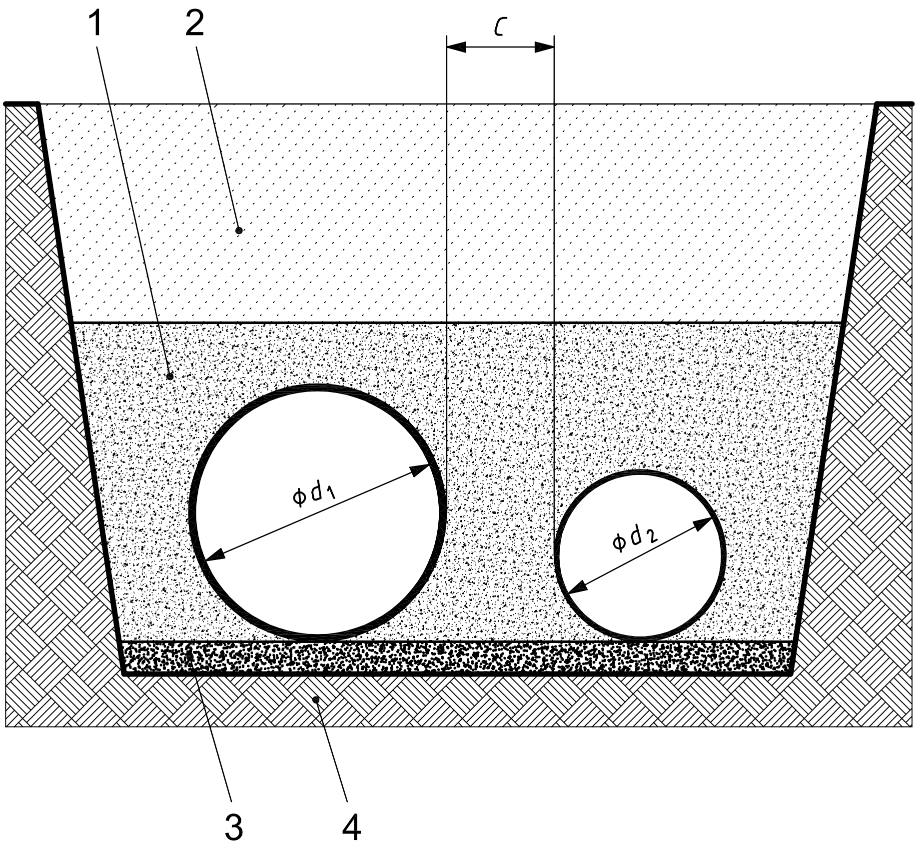
Table 4 — Recommended layer thicknesses and number of passes for compaction classes

Equipment	**Number of passes for compaction class**		**Maximum layer thickness after compaction** m				**Minimum thickness over pipe crown before compaction** m
			Soil group (see Annex A)				
	Well	**Moderate**	**1**	**2**	**3**	**4**	
Foot or hand tamper:							
min. 15 kg	3	1	0,15	0,10	0,10	0,10	0,20
Vibrating tamper:							
min. 70 kg	3	1	0,30	0,25	0,20	0,15	0,30
Plate vibrator:							
min. 50 kg	4	1	0,10	—	—	—	0,15
min. 100 kg	4	1	0,15	0,10	—	—	0,15
min. 200 kg	4	1	0,20	0,15	0,10	—	0,20
min. 400 kg	4	1	0,30	0,25	0,15	0,10	0,30
min. 600 kg	4	1	0,40	0,30	0,20	0,15	0,50
Vibrating roller:							
min. 15 kN/m	6	2	0,35	0,25	0,20	—	0,60
min. 30 kN/m	6	2	0,60	0,50	0,30	—	1,20
min. 45 kN/m	6	2	1,00	0,75	0,40	—	1,80
min. 65 kN/m	6	2	1,50	1,10	0,60	—	2,40
Twin vibrating roller:							
min. 5 kN/m	6	2	0,15	0,10	—	—	0,20
min. 10 kN/m	6	2	0,25	0,20	0,15	—	0,45
min. 20 kN/m	6	2	0,35	0,30	0,20	—	0,60
min. 30 kN/m	6	2	0,50	0,40	0,30	—	0,85
Triple heavy roller (no vibration):							
min. 50 kN/m	6	2	0,25	0,20	0,20	—	1,00

9.5 Parallel or crossing piping systems

Parallel piping systems laid within a common trench shall be spaced sufficiently far apart to allow compaction equipment, if used, to compact the pipe zone backfill material between the pipes. A clearance at least 150 mm greater than the width of the widest piece of compaction equipment used is considered as a practical clearance between the pipes. (See Figure 9.)

It is advisable when laying pipes of different diameters in the same trench to lay them at the same invert level (see Figure 9).The pipe zone backfill material between the pipes shall be compacted to the same compaction class as the material between the pipe and the trench wall.



Key

C minimum distance between pipes

d_1, d_2 external diameter of pipes

1 pipe embedment

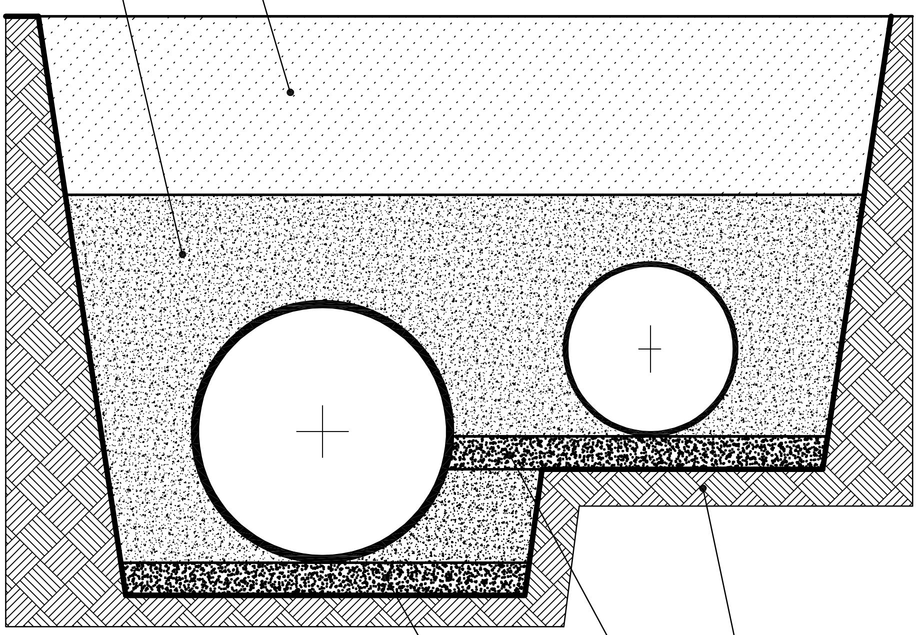
2 trench backfill

3 pipe bedding

4 undisturbed native soil

Figure 9 — Parallel pipes in same trench

In cases of parallel piping systems laid within a stepped trench, the pipe zone backfill material shall be granular and shall be compacted to compaction class W. (See Figure 10.)



Key

1 pipe embedment zone
2 trench backfill
3 bedding
4 undisturbed native soil

Figure 10 — Parallel pipes in stepped trench

The minimum distance between parallel pipes, C (see Figure 9), shall be calculated using either Equation (4) or (5), but in any case, shall be not less than 150 mm or shall be such that there is sufficient room to place and compact the pipe zone backfill material between the two pipes:

— where cover is less than 4,0 m:

$$C \geqslant \frac{(d_1 + d_2)}{6} \tag{4}$$

— where cover is greater than 4,0 m:

$$C \geqslant \frac{(d_1 + d_2)}{4} \tag{5}$$

When a new pipeline crosses an existing pipeline it is recommended that the distance (C) between the underside of the new pipeline and the top of the existing one be not less than the value given by Equation (4) or (5), as applicable. This space should be filled with well-compacted granular material to ensure an even support to the new pipeline while avoiding point loading on the existing pipeline (see also 9.2).

9.6 Special precautions

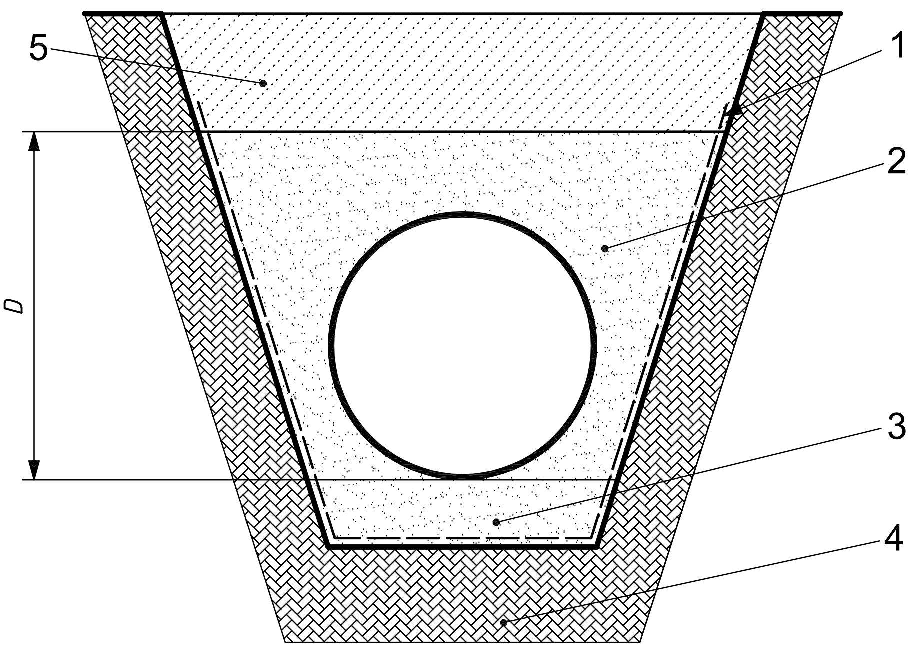
9.6.1 Migration of fines

Reduction of the soil support around an installed pipe can occur for a number of different reasons. The transition from one type of native soil to another or the presence of ground water can cause changes in the pipe bedding and backfill material. If large-scale movements are expected, such as in zones subject to earth tremors or severe flooding, it is recommended that expert advice be sought.

In some installation conditions, the presence of ground water can cause migration of fine materials from either the bedding, the backfill material or the trench wall into the adjacent material along the alignment of the pipeline. Movement of fines from one material to another will cause a reduction in the support provided to the pipe, which can result in an increase in the diametrical deflection of the pipeline and possible failure.

If there is a potential for migration between the bed and the backfill material as a result of water flow in the vertical direction (e.g. rain water seepage through the pipe zone area), mixing of the bed and the backfill material shall be considered as an option for eliminating the possibility of migration between the two zones.

Among special conditions that can be encountered during laying are the occurrence of running or standing water in the bottom of the trench, and the bottom of the trench exhibiting a soft or unstable consistency. In these cases, remove the water by using such means as well points or under-drains until the pipe has been installed and the trench has been backfilled to a height sufficient to prevent flotation of the pipeline or collapse of the trench. The bedding and backfill materials selected for such installations should consist of materials not having fine particles which could be removed by the effects of water (see 7.2); alternatively, the installation should utilise geotextile fabrics that prevent the fine materials from migrating to the trench walls or vice versa. (See Figure 11.)



Key

D ⩾ pipe zone backfill depth

1 geotextile

2 embedment zone

3 bedding

4 undisturbed native soil

5 trench backfill

Figure 11 — Protection against material migration

If filter fabrics are welded or overlapped, consult the fabric manufacturer for specifications. If specifications are not available, welded fabrics shall be laid with at least 0,3 m overlapping and unwelded fabrics with an overlap of at least 0,5 m.

9.6.2 Vehicle loads

A minimum depth of backfill above the pipe should be maintained before allowing vehicles or heavy construction equipment to traverse the pipe trench. The minimum depth of cover for protection from surface loads should be established by the engineer based on an evaluation of specific project conditions, including the pipe embedment material and its density, the native-soil characteristics, pipe stiffness, pipe diameter, surface pavement, surface loads and final backfill compaction.

9.6.3 Flotation

A minimum of one pipe diameter of cover is suggested to prevent flotation of an empty pipe when full soil saturation to the surface exists.

Immediate backfilling after joining is recommended, as it will prevent two hazards: floating of the pipe due to heavy rain, and thermal movements due to large differences between day and night temperatures. Floating of the pipe can damage the pipe and create unnecessary reinstallation costs.

9.6.4 Adjacent rigid structures

Extra care and caution shall be taken to replace and properly compact backfill adjacent to any rigid structure. Construction of concrete structures will frequently require over-excavation for formwork, etc. This extra-excavated material must be restored to a density level compatible with surroundings or excess deformation and or joint rotation adjacent to the structure is likely to occur. The use of stabilized backfills adjacent to large structures has been found to be very effective in preventing excess joint deformation in large diameters (DN $>$ 1 600).

9.6.5 Trench shields

Take precautions when removing sheeting, safety shields or other trench protection to avoid disruption of the compacted material. Remove the protection in stages, as the side filling proceeds, with as little disruption of the compacted side fill as possible. Take care to fill voids and re-compact. If the possibility of disruption cannot be excluded with a sufficient degree of certainty, use a pipe designed to tolerate those installation uncertainties. In some cases it may be necessary when designing the pipeline either to reduce the assumed nominal proctor density and/or to choose a higher nominal pipe stiffness class.

9.6.6 Thermal considerations

Thermal expansion and contraction can cause loss of seal due to movement of several pipe lengths accumulated at one joint. If sections of pipe are placed into the trench and backfilling is delayed, each pipe should have the centre section backfilled to the crown to help minimize movements at the joint.

10 Thrust resistance and rigid connections

10.1 Support for control devices

All control devices (such as valves) should be individually supported so that the pipe is not subjected to any additional load for which it has not been designed.

10.2 Thrust restraint

10.2.1 Hydrostatic thrust

When a pipeline is pressurized, unbalanced thrust forces occur at bends, reducers, tees, blank ends, closed valves and any change in line direction. These forces, if not adequately restrained, can cause pipeline movement resulting in separated joints and/or pipe damage.

Thrust forces are

— hydrostatic thrust due to internal pressure of the pipeline, and

— hydrodynamic thrust due to changing momentum of the flowing fluid.

Since most pressure lines operate at relatively low fluid velocities, the hydrodynamic force is very small and is usually ignored.

10.2.2 Thrust resistance

For buried pipelines, unbalanced horizontal thrust forces have two inherent sources of resistance:

a) frictional drag from dead weight of the pipe, earth cover and contained fluid;

b) passive resistance of soil against the pipe and fitting in the direction of the thrust.

If this resistance is not sufficient to resist the thrust, then it shall be supplemented by increasing the supporting area on the bearing side of the fitting with a thrust block, by increasing the frictional drag of the line by tying adjacent pipes to the fitting, or by otherwise anchoring the fitting to prevent movement.

Unbalanced uplift thrust at a vertical direction change is resisted by the dead weight of the fitting, earth cover and contained fluid. If this resistance is not sufficient to resist the thrust, then it shall be supplemented by increasing the dead weight with a gravity-type thrust block: effectively increasing the dead weight of the line by tying adjacent pipes to the fitting or otherwise anchoring the fitting to prevent movement.

10.2.3 Anchor and thrust blocks

With non-end load-bearing joints, thrust blocks are required for pressures over 1 bar. The concrete thrust block should be cast against undisturbed native soil to minimize block movement. For GRP fittings it is generally preferable to totally encase the fitting in concrete. The fitting joint shall be clear so that joining to adjacent pipes can be made. The interface between the thrust block and the pipe shall be done properly to avoid problems of joint rotation and movement. See the section on connection to rigid structures (10.3). Depending on the type of fitting and the operating pressure, the concrete could need to be reinforced to prevent cracking from forces transmitted from the fitting to the block (see 10.3).

The need for, and design of, thrust blocks is generally the responsibility of the system owner’s engineer. However, the following are some general guidelines, as well as requirements, and considerations on the use and construction of thrust blocks.

a) Fittings that require thrust blocking include bends, tees, reducers or tapers, blank ends and bifurcations.

b) Generally, “nozzles” which are small tee branches do not require thrust blocking if the nozzle diameter is $\leqslant$ 300 mm and the header pipe diameter is greater than or equal to three times the nozzle diameter.

   Care should be taken that the adjoining pipe can withstand the axial force induced by the nozzle.

   Nozzles and any blinded branches (e.g. manholes) subjected to full thrust load during operation or testing shall be capable of resisting the thrust load applied during such operation or testing, regardless of the joint type used along the main pipe.

c) The field test pressure of the pipeline shall be considered when determining the amount of thrust that will need to be restrained.

d) Adjacent excavations must be examined. If the block does not bear against undisturbed soil, it will not perform as intended.

e) Accurate knowledge of the bearing strength of the native soils is essential for correct sizing of thrust blocks.

10.2.4 Restrained joints

Unbalanced thrust forces at fittings may also be resisted by end-load-bearing joints adjacent to the fitting. This method fastens a number of pipes or other soil-friction-generating devices (such as ribs and puddle flanges) on each side of the fitting to increase the frictional drag of the connected pipes to resist the fitting thrust. The number of joints that must be tied together will depend on the magnitude of the thrust and the frictional resistance developed by the pipe, soil conditions and any other restraint-developing devices.

Not only must the joints be capable of withstanding the end load, but the pipe must also be capable of carrying the end load from the pressure thrust. Depending on the length and layout of the pipeline system, a combination of non-end load-bearing pipe and joints with thrust blocks and end-load-bearing joints and pipe may be the optimum solution.

10.3 Connections to rigid structures

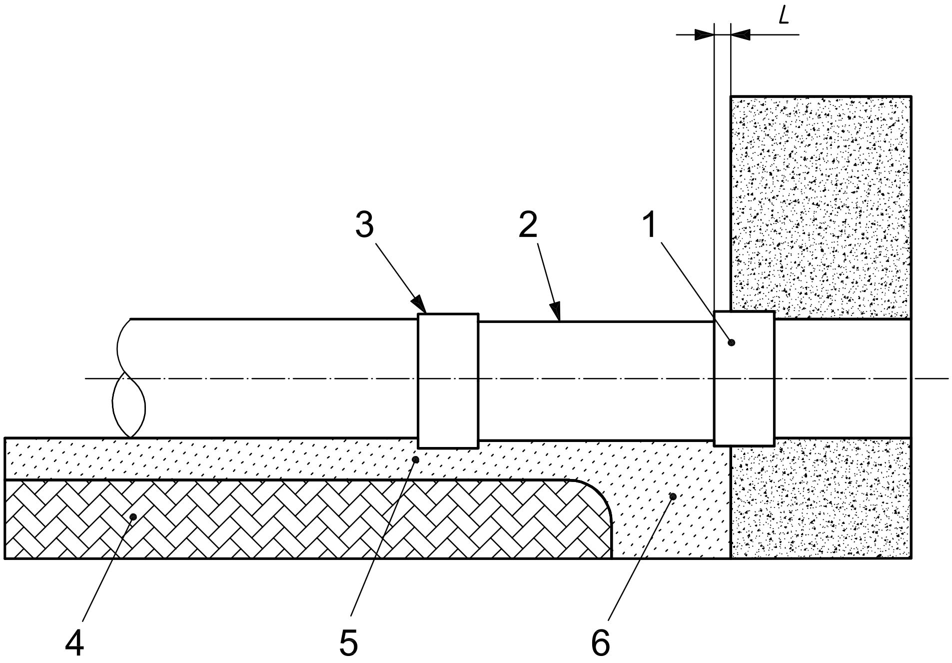
Where a pipeline enters or exits a structure such as a building, manhole or anchor block, a means of tolerating differential settlement should be provided. Typical connections to rigid structures using flexible joints are shown in Figures 12 and 13, while a method of providing protection of rigid joints is shown in Figure 14. The acceptability of any type of flexible joint should be checked against national and/or local regulations.

When casting a coupling in concrete, as shown in Figure 12, maintain its roundness so that later joint assembly can be accomplished easily. It has been found useful for larger diameter (DN $>$ 1 200 mm) lower stiffness (SN $<$ 5 000) pipe to increase the stiffness of the short length to maintain pipe roundness.

10.3.1 Connections using flexible couplings

To accommodate the anticipated differential settlement which can occur between a rigid structure and a pipe connected to that structure, a short length of pipe should be installed with flexible couplings to provide a means of allowing movement to occur without placing excessive stress on the pipe.

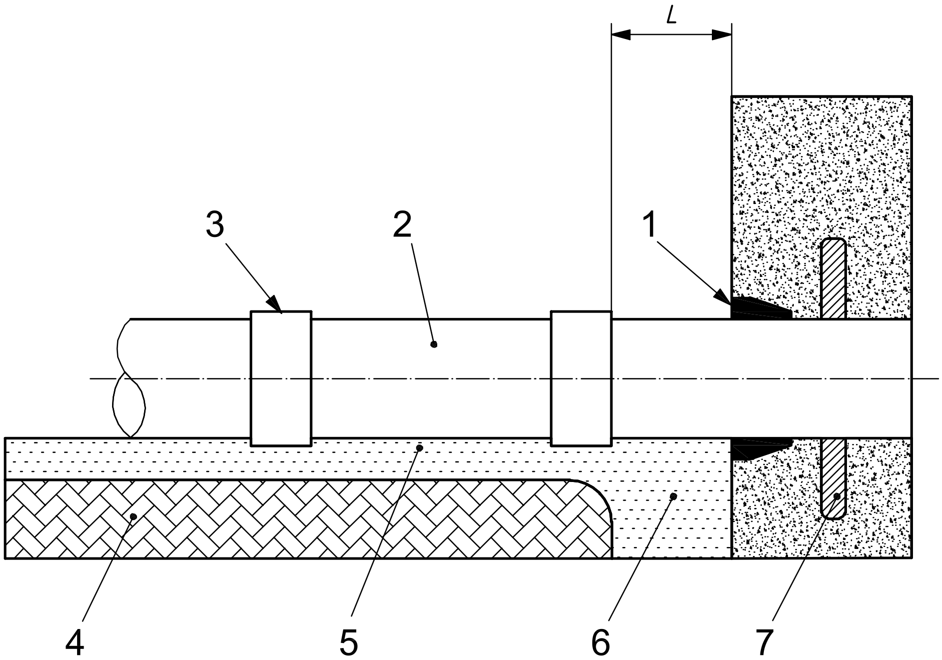
The short length of pipe, called a “rocker pipe”, should be installed in direct alignment with a short length of pipe coming out of the rigid structure (see Figure 13) or, alternatively, connected to a flexible connection built into the rigid structure (see Figure 12), which commonly occurs in prefabricated manholes.



Key

L protrusion ⩽ 25 mm
1 flexible joint built into the structure
2 short length of pipe (min. 1 m; max. 2 m)
3 flexible joint
4 native soil
5 pipe bedding
6 well compacted material

Figure 12 — Connection to rigid structure using flexible joint — Type 1



Key

L distance: 400 mm or half pipe outside diameter, whichever is the greater
1 compressible material
2 short length of pipe (min. 1 m; max. 2 m)
3 flexible joint
4 native soil
5 pipe bedding
6 well compacted material
7 puddle flange

Figure 13 — Connection to rigid structure using flexible joint — Type 2

For connections such as that shown in Figure 13, place the first flexible joint within a distance, L, of 400 mm or half the outside diameter of the pipe, whichever is the greater. A strip of compressible material, such as chloroprene rubber or bitumen wrap, about 10 mm thick and at least 100 mm wide located at the concrete interface can provide stress relief from expansion, shear and/or bending loads. This is particularly important for limiting radial shear and discontinuity stresses in a pressure pipe. To minimize shear and bending stresses in a pipe protruding from the structure, provide effective support by ensuring thorough compaction of the material beneath the pipe immediately outside the structure. This is particularly necessary where over-excavation of the trench has occurred.

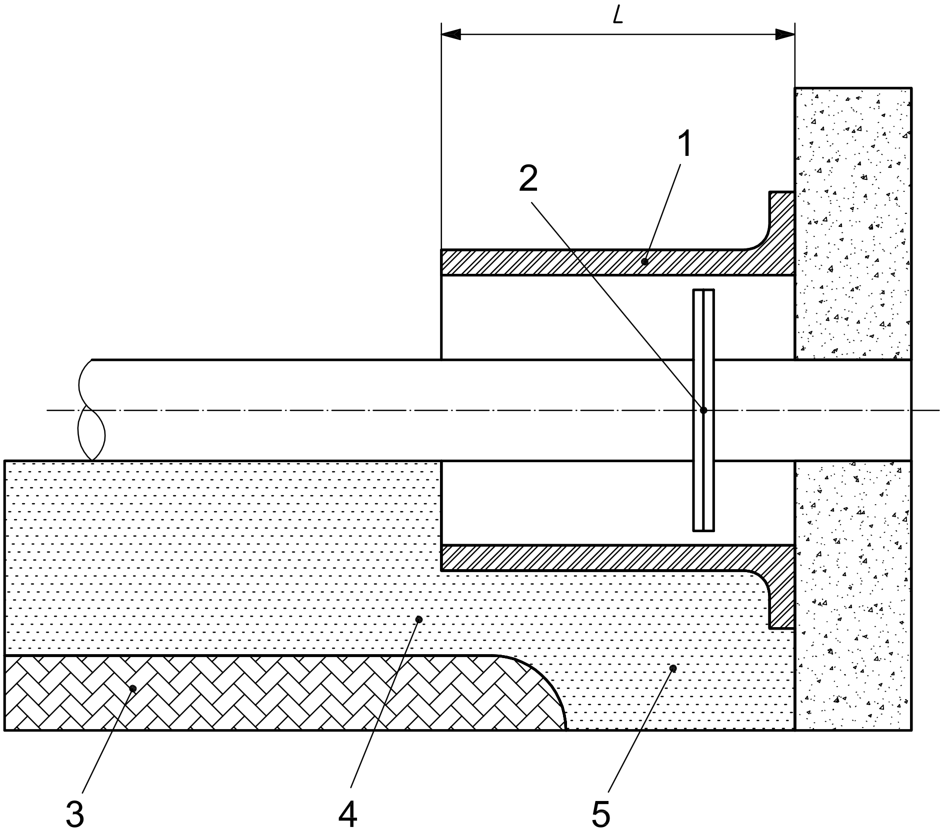
Where watertightness between the pipe and structure is required, use a short pipe onto which a puddle flange has been attached (see Figure 13). Puddle flanges should not be used to resist thrust unless the pipe and the puddle flange have been specifically designed to do so.

10.3.2 Connections to vertical risers

Provide support for vertical risers as commonly found at service connections, cleanouts and drop manholes to preclude vertical or lateral movement. Prevent the direct transfer of thrust due to surface loads and settlement, and ensure adequate support at points of connection to main lines.

10.4 Connections with rigid joints

When connecting to rigid structures with rigid joints, one method of reducing bending and shear loads on the pipe is to use a pipe shield as shown in Figure 14.



Key

L	shield length at least three times pipe outside diameter	3	native soil
1	shield pipe	4	pipe bedding
2	rigid joint (flange, wrapped, mechanical, etc.)	5	well compacted material

Figure 14 — Connection to rigid structures using rigid joint — Protection of rigid joint

11 Pipe joints

11.1 Joint characterization

Pipe joints can be flexible or rigid:

— flexible joints allow relative movement between the components being joined;

— rigid joints do not allow relative movement between the components being joined.

Joints are also characterized by whether or not they are end-load-bearing. End-load-bearing joints are capable of withstanding the longitudinal forces induced from internal pressure.

Depending on the design and configuration, a particular type of joint (flange, coupling, butt-wrap, etc.) might or might not be end-load-bearing.

Either category of joint can form an integral part of sockets already provided on the pipe itself, in which case they are termed “preformed joints”. Alternatively, two joints can be combined as a double socket for joining pipes with smooth ends, in which case they are termed “couplings”.

Where non-end load-bearing joints are connected to valves or bends which can experience end thrusts generated by hydraulic pressure within the pipe, suitable anchors shall be provided to restrain the pipe and fitting.

As it could be necessary to dismantle the piping system, the selection of the joint should take this into account.

11.2 Adhesive bonded joints

Adhesive bonded joints include tapered bell and spigot, straight bell and spigot and tapered bell and straight spigot. In all cases, the manufacturer’s detailed instructions for making the joint shall be followed. Typically, adhesive bonded joints are end-load-bearing.

Adhesives used to fabricate the joint shall be suitable for use with the materials to be joined and shall satisfy the performance requirements of the relevant system standard.

When the pipeline is used for the conveyance of drinking water, it shall comply with the local national regulations on water quality. The fabrication of a cemented joint shall be carried out in accordance with the manufacturer’s instructions.

11.3 Butt and wrapped joints

These joints are fabricated by applying glass mats and/or fabrics impregnated with thermosetting resin over two pipes butted together. The design and fabrication of such joints shall be carried out in accordance with the manufacturer’s detailed instructions. The joint may or may not be end-load-bearing, depending on the design.

The materials used for this type of joint are normally glass fabrics and thermosetting resin. The design and fabrication of this joint should be carried out in accordance with the manufacturer’s instructions.

11.4 Bolted flanged joints

Flanges can be used for joining together GRP-UP pipes and for joining them to metal flanges, valves and flanged fittings.

These joints can be of integral or loose ring design. The elastomeric sealing elements can be flat-faced gaskets, an O ring or other configuration, designed to reduce potential damaging bending stresses. The manufacturer’s instructions for assembly shall be followed to obtain proper sealing without damage. The joint might or might not be end-load-bearing, depending on the design.

The seal is usually effected by either a flat elastomeric gasket or an “O” ring compressed between the flanges by means of bolts which also serve to connect the pipes rigidly. Gaskets of other materials, metallic and/or non-metallic, are available for special applications. It is essential that flanged joints be tightened to a predetermined torque using clean bolts lubricated on all mating surfaces, in order to ensure that the design load is obtained. Advice as to the correct torque can be obtained from the joint manufacturer.

11.5 Socket and spigot with elastomeric sealing elements

The socket can be formed on the pipe itself or can be in the form of a double socket coupling used to joint plain end pipes. Frequently, double-socket couplings are supplied mounted on one end of the pipe. With the addition of supplemental restraining elements (i.e. locking keys), the joint may be end-load-bearing.

11.6 Flexible joints with elastomeric seal

The seal can be located in the socket or the spigot. The details of the seal and of the joint depend on the manufacturer’s design. The joint can be made integral with the pipe or a double bell coupling connector can be supplied. Frequently, the double bell coupler is supplied mounted on the pipe. The seals to be used shall be those supplied by the manufacturer for the assembly system. If the seal is not in place at the time of delivery, clean the groove and then locate the seal correctly.

The following requirements also apply.

a) The elastomeric material(s) of the sealing component shall conform to the applicable part of the relevant national or International Standard.

b) As these are typically non-load-bearing joints, not intended to withstand end thrust, particular attention shall be paid to the correct anchorage of the elements.

c) Assembly of some joints requires them to be lubricated in accordance with the manufacturer’s instructions prior to jointing. Use a lubricant which does not have any harmful effect on the pipe, fitting or seal. If the pipe is to carry water intended for human consumption, the lubricant shall conform to the requirements given in the relevant system standard.

d) Following lubrication, the spigot shall be aligned with, and introduced into, the socket, taking care to avoid any risk of contamination. The spigot shall be inserted into the socket up to the reference mark if present.

   NOTE Seals which have slipped out of place and dirt under the seals are the most frequent causes of leaks. Both problems can be avoided by using the correct jointing procedure.

e) The pipes may be cut on site, but if this is done, the cut shall be square with the longitudinal axis of the pipe and the end shall be chamfered as appropriate for the joint.

11.7 Mechanical compression joints

These are similar to double socket coupling joints, the main difference being that the elastomeric ring is compressed by means of an external tightening system. Examples are slip-on couplings and band couplings. Mechanical compression joints are useful for joining pipes of different materials, using adapters where necessary.

Care should be taken not to over compress the seal in contact with the plastics pipe; otherwise, there is a risk of the pipe deforming and the tightness of the joint being impaired. For some pipes, a stiff internal sleeve may be used to increase their rigidity.

11.8 Slip-on coupling

A slip-on coupling is designed for use with plain-ended pipes. It consists of a sleeve at the ends of which are wedge-shaped elastomeric gaskets and flanges held together by bolts. Tightening the bolts compresses the gaskets between the sleeve and pipe to seal the joint.

11.9 Mechanical band couplings

A slip-on coupling is designed for use with plain-ended pipes. It consists of a metallic band encasing a shaped elastomeric profile. The elastomeric profile is compressed by tightening up circumferential bolts positioned at one point on the circumference. Care shall be taken to make sure the elastomeric profile is uniformly compressed around the circumference. Typically, such joints are not end-load-bearing. They can be useful when joining to other materials or to pipes of different sizes or tolerances.

12 Special installations

12.1 Casings

It can necessary in certain circumstances to install the pipe within a concrete or steel casing, itself installed under a railroad, roadway or other obstacle where normal trenching procedures are not applicable. In such cases, ensure that the inner surface of the casing does not damage the GRP-UP pipe when it is inserted into the casing. The rubbing surfaces may also be lubricated or the pipe over-wrapped with a protective material to facilitate insertion into the casing. In order to avoid shearing loads on the pipe, compact the trench soil at the casing ends to a density that results in soil resistance properties greater than or equal to that of the compacted initial pipe zone backfill material. To prevent movement, secure the inner pipe by blocking that will not result in load concentration or by partially or completely filling the void space with sand or grout. As the space is filled, use the manufacturer’s recommended allowable external grouting pressure to ensure that excessive deflection, distortion or damage does not occur.

12.2 Submarine pipelines

The frequent use of GRP pipes in applications such as seawater intake piping systems, outfall piping systems or when a piping system is required to cross a body of water (a lake or river) has led to the development of submarine pipe installation techniques. This section provides general guidelines for these types of installation.

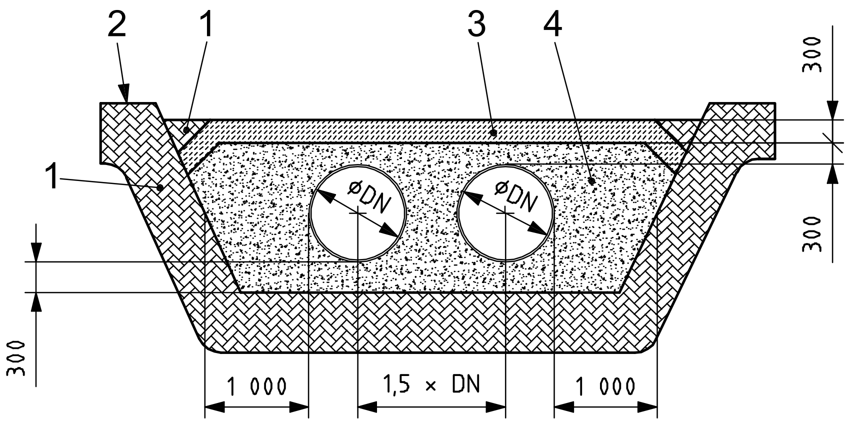
Submarine pipe installations are normally made by specialist contractors; it is recommended that all designers collaborate with such experts when a submarine installation is being designed.

12.2.1 Installation design

The design of subaqueous pipe installations utilizes the same principles used for normal trench installations, the only difference being that the water level above the pipe is much greater. Various trench configurations are used, with typical designs being shown in Figures 15, 16 and 17. The choice of installation method will depend on factors such as pipe diameter, length to be installed, degree of protection require, stability of the seabed soil and water depth and potential wave action.

Other alternative installations can include complete concrete encasement, or installation of the pipe on the sea (or river) bed.

Dimensions in millimetres

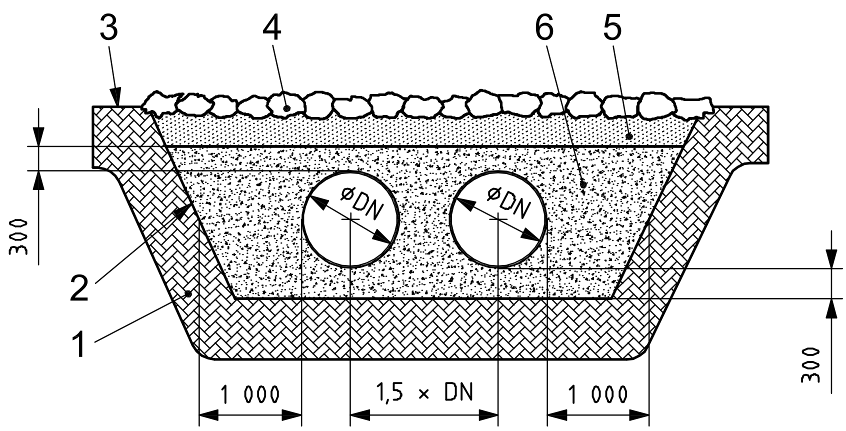


Key

1 native soil
2 level of seabed
3 fabric form concrete-filled mattress
4 pipe embedment formed from well-graded crushed aggregates (max. particle size 25 mm)

Figure 15 — Subaqueous installation — Configuration 1

Dimensions in millimetres

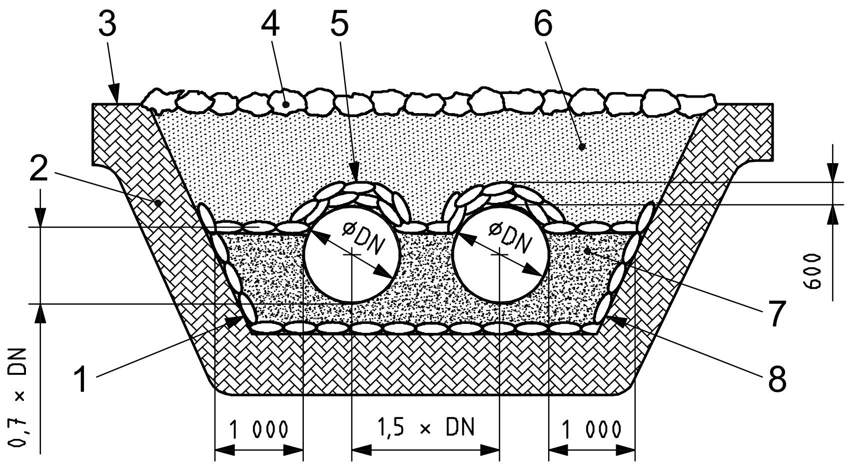


Key

1 native soil
2 filter fabric (used if erosion expected)
3 level of sea-bed
4 rock (rip rap), approximate size of boulders 300 mm to 400 mm
5 mixture of native soils, maximum particle size 100 mm
6 pipe embedment formed from well-graded crushed aggregates (max. particle size 25 mm)

Figure 16 — Subaqueous installation — Configuration 2

Dimensions in millimetres



Key

1 sand sacks

2 native soil

3 level of seabed

4 rock (rip rap), approximate size of boulders 300 mm to 400 mm

5 two layers of sand sacks

6 mixture of native soils, maximum particle size 100 mm

7 pipe embedment formed of well-graded crushed aggregates (max. particle size 25 mm)

8 filter fabric (used if erosion is expected)

Figure 17 — Subaqueous installation — Configuration 3

12.2.2 Installation method

There are various options which may be considered for placement of submarine pipes. These include the following:

a) individually placing and joining each pipe using a placement barge above the trench, for which special “marine harness lugs” might be required to aid underwater jointing of the pipes (see Figure 18);

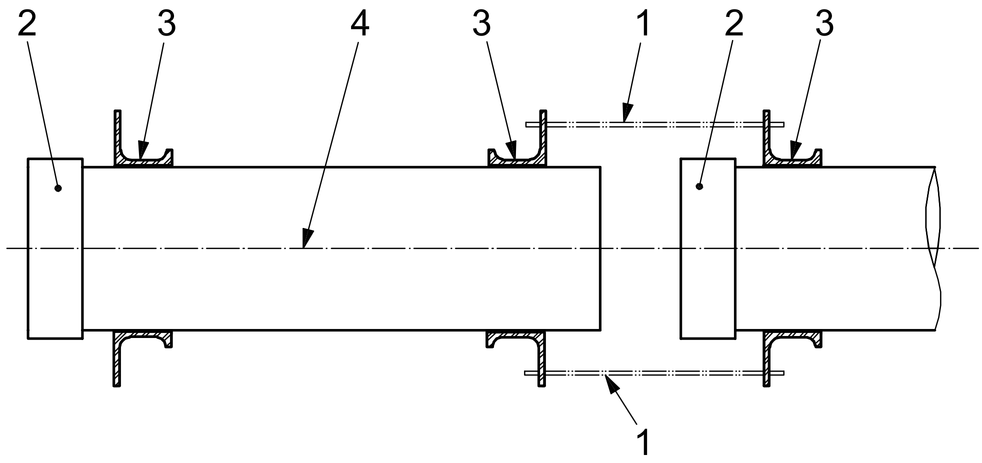
b) assembly of several sections of pipe at a launching area, with either flexible or rigid joints and with transportation of the assembly to the installation site by lowering using a special rig and jointing under water;

c) assembly of long lengths of pipe which are towed to the installation and the pipe string-lowered into the trench by filling the pipe with water and using a special lowering frame, for which construction locked joints may be required.

These placement options can require the use of additional accessories to the pipes (e.g. marine harness lugs, threaded bolts, threaded cables, buoyancy devices) to allow easier handling and joining of pipes or pipe sections.

Supporting the pipe sections in the trench on sand- or gravel-filled bags is common practice before backfilling.

Typically, the most significant load subaqueous piping must endure is the force from the overburden placed to protect the pipe from impact damage (e.g. from anchors) and resistance to minor buoyancy effects. Within these minimal requirements, the need for backfill support is minimized and the use of gravity-placed gravel or coarse sand is adequate.



Key

1 threaded tie-bar

2 coupling

3 rolled steel, angle-iron marine harness lug

4 pipe spring-line

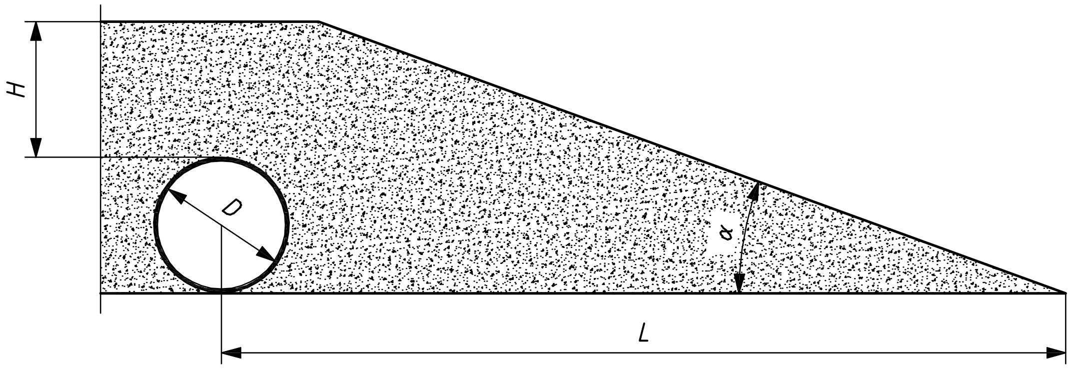
Figure 18 — Marine harness lugs

12.3 Embankment installations

When the pipe is installed with the top of the backfill material above the ground surface, the installation is considered as an embankment. Embankment installations can range from having part of the pipe above the surrounding ground level to the installation of the complete pipe without excavating trenches.

Figure 19 and Table 5 present the slope requirements for a typical cross-section of embankment installation using crushed rock or sand as the embankment material. The bed layer of 150 mm is also to be provided. Side protection for long-term stability to the side slopes of the embankment material might or might not be required, depending on the site conditions.

The minimum cover depth, H, will depend on the pressure rating and the applied angular deflection. For low-pressure applications, a minimum cover of 1,0 m is adequate.



Key

α slope angle

D diameter of pipe

H minimum depth of cover

L minimum distance

Figure 19 — Embankment installation

Table 5 — Material-dependent embankment dimensions

Embedment material	Minimum distance L	Slope angle, α °
Sand	$4{,}5 \times D$	20
Crushed-rock	$3{,}9 \times D$	30

13 Testing

13.1 Deflection testing

Pipe-laying work can be checked during or after installation, particularly in respect of compaction and the use of the correct bedding material, by monitoring the vertical change in pipe internal diameter (percentage deflection) along the pipeline length (deflection testing).

The maximum permissible vertical change in pipe internal diameter, in percent, is material-dependent and should be as recommended by the manufacturer.

The measurement of change in vertical diameter when made from inside shall be at locations not affected by the joint stiffness, e.g. at least 1 m from the joint.

The pipe's deflection shall not exceed the permissible level given in the relevant system standard(s).

In the event of one or more pipes exceeding the limit, due consideration should be given to the actions required (such as re-excavation and re-installation or replacement).

During internal deflection measurements, due consideration should also be given to any noticeable uneven change in pipe diameter such as bulging or non-uniformity in deflection distribution around the pipe circumference.

13.2 Pressure testing

The satisfactory installation of the pipeline requires that, prior to pressure testing, the following inspection and quality assurance procedures be followed.

13.2.1 Factors influencing testing

There are a number of factors that can influence the outcome of a site pressure test, including

— length of test section and pipe nominal size,

— test pressure and rate of pressurisation,

— air in the test section,

— joint type,

— movement of fittings and thrust blocks (if used),

— amount of support from bedding and backfill,

— accuracy of testing equipment,

— changes in ambient temperature during the test,

— presence of fittings and other materials in the test section,

— end point connection to other structures (if included),

— presence of leaks, and

— availability and handling of the test water quantities required for water tests.

13.2.2 Preparatory test checks

Prior to a pressure test being carried out, carry out the checks.

a) Ensure that the pipeline, and in particular the bends, thrust blocks and other fittings, have been designed to resist the forces to be exerted by the test pressure.

b) Ensure that the test circuit has been considered in the design stage for rigid joint systems.

c) Inspect the completed installation to ensure that all work has been finished properly (pipe deflection within limits, proper joint assembly, uplifting forces at flexible joints are resisted by adequate cover depth, angular deflections within allowable limits, anchoring of valves and pumps, tightening of flanges, etc.).

d) Where pressure testing is required, ensure that all blanking flanges and valves are adequately supported to resist forces generated during the testing and, where necessary, provide temporary thrust-resisting structures.

e) Ensure that all air valves are working correctly.

f) Perform a pressure test in accordance with the requirements of the contract, not exceeding the maximum allowable test pressure of the piping system under test; or, if this information is not available, use the appropriate procedure according to 13.3 or 13.4.

NOTE Components such as closed valves might not be allowed to be subjected to pressures above their rated pressure.

13.2.3 Other test considerations

The following possible occurrences during testing should be checked and evaluated prior to performing the test.

a) Effect of unrecoverable displacement after pressure test

The piping system has a tendency to move when subjected to internal pressure. This movement is higher when the system does not have end restraints such as thrust blocks. Once the pressure is released, the soil or backfill material resists the return of the piping system to its original position. Care should be taken to ensure that such unrecoverable displacement will not cause rework, especially at the connection points or at the underground/aboveground interface points.

b) Effect of relative expansion at both sides of the same joint

In cases where the joint at the fitting end and/or other joints are prevented from circumferential expansion during testing by encasing concrete (see Figure 12), ensure that the concrete reinforcement is adequate to prevent cracks within the concrete and that it will not allow different pipe end expansions at the same joint that could result in joint leakage.

c) Testing combined joint type

When testing an underground combined joint piping system, ensure that the required backfill on the end-load-bearing section (connected to the fittings ends) has the required backfill to develop the calculated soil restraints. In general, this section should be covered to the final grade level.

d) Testing without backfilling

It is possible to perform pressure testing for pressure pipes when the joint type is end-load-bearing without backfilling. This will ease the inspection and allow the pipe system to recover the expansion caused by the test pressure after testing.

13.3 Non-pressure pipelines

The pipeline can be tested by means of an air or water test, in lengths determined by the course of construction, in accordance with the programme. A further test should be performed after backfilling is completed.

SAFETY PRECAUTIONS — In the event that an air test is used, a danger could be posed to personnel or property if the line is overpressured and/or plugs or caps are not properly restrained. Observe the following minimum safety precautions.

Do not allow personnel in manholes during the test.

Install and restrain all caps and plugs securely.

Brace all plugs and caps for additional safety.

Pressurizing equipment shall have a relief valve and it shall be set at a pressure no higher than 2 kPa above the test pressure.

13.3.1 Air test

Pump air into the pipeline by suitable means until a pressure of 30 kPa is reached. After a period of stabilization, stop the pumping and monitor the pressure change for at least 5 min[2)]. The pipeline may be accepted if the pressure does not drop below 25 kPa[2)].

Failure to pass this test should not preclude acceptance of the pipeline if a successful water test performed in accordance with 13.4.1 is subsequently carried out.

13.3.2 Water test

For gravity pipelines the test pressure should be not less than 1,2 m head of water above the pipe crown or ground water level, whichever is the higher at the highest point, and not greater than 6 m head at the lowest point of the section under test.

Fill the pipeline with water and then allow it to stand for a period of not less than 2 h to stabilize, following which restore the original water level. Then add water from a measuring vessel at intervals of 5 min over a 30 min period and note the quantity needed to maintain the original water level. The pipeline may be accepted if the quantity of water added over the 30 min period is less than 0,5 l/m of pipeline per metre of nominal diameter.

13.3.3 Joint test

As an alternative to the full water test, a joint test may be carried out as installation progresses to ensure leak tightness. The joint test may be performed from inside using an internal joint tester for nominal diameters above 600 mm, or from outside if the joint is fitted with an external joint nipple for double O-ring joints. Consult the pipe manufacturer for the maximum allowed joint test pressure. During the joint test, ensure that the pipes at both sides of the joints have adequate resistance from surrounding backfill to prevent pipe separation at the joint.

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2) To be verified by field test measurements and the practices of experienced contractors.

NOTE The joint test is intended to ensure that the joint assembly has been completed correctly, resulting in a leak-free joint. Owing to the nature of the forces applied during the operation, the maximum joint test pressure is dependent on the pipe nominal diameter and pipe stiffness.

13.3.4 Infiltration test

Non-pressure pipelines and manholes should be tested for infiltration after backfilling. All inlets to the system shall be effectively closed, and any residual flow is deemed to be infiltration. The pipeline, including manholes, can be accepted as satisfactory if the infiltration, including infiltration into manholes, in 30 min does not exceed 0,5 litre per linear metre per metre of nominal diameter.

Notwithstanding the satisfactory completion of the infiltration test, if there is any discernable flow of water entering the pipeline at a point which can be ascertained by visual inspection or using closed circuit television (CCTV), measures should be taken to stop the infiltration.

13.4 Pressure pipelines

13.4.1 Water test

The test is performed in two stages:

a) preliminary test, see 13.4.1.2;

b) main pressure test, using either water loss method A (see 13.4.1.3.1) or method B (see 13.4.1.3.2).

The system maximum test pressure (SMTP) is calculated from the maximum design pressure (MDP). The MDP is the design pressure for a system including an allowance for surge. Surge can be calculated or assumed to be at least 200 kPa (2 bar). The SMTP is derived as follows, as appropriate, with the maximum value not exceeding 1,5 × PN, where PN is the nominal pressure classification of the pipes under test:

$$\text{SMTP} = \text{MDP} \times 1{,}5$$

or, if less

$$\text{SMTP} = \text{MDP} + 5 \text{ bar}$$

13.4.1.1 Filling and air removal

Whenever possible, use potable water to test drinking water pipelines. It is essential to remove as much air as possible. Before filling the pipeline, open all air venting systems. If possible, locate the fill and test position at the lowest point of the pipeline profile to encourage expulsion of air as the pipeline is filled. It is assumed that automatic air valves will have been installed at all high points of the pipeline and that these are operating normally. After ensuring that the pipeline is fully charged with water, close all air vents.

13.4.1.2 Preliminary test

The preliminary test is intended to

— stabilize the pipeline by allowing most of the time-dependent movements to occur, and

— allow pressure-dependent changes in the volume of the flexible pipes, prior to the main test.

Raise the pressure so that the pressure at the lowest point in the test section does not exceed the SMTP.

Maintain the pressure for a sufficient time to carry out an inspection of the test section. If any unacceptable changes to the pipeline position have occurred, or if any leaks are detected, stop the test, depressurize the test section and correct the fault. During depressurizing, ensure that adequate air is allowed into the pipe to prevent creation of a vacuum that could damage the piping system.

Otherwise, perform the main pressure test according to 13.4.1.3.

13.4.1.3 Main pressure test (water loss method)

Increase the pressure at a steady rate until the calculated SMTP is reached at the lowest point in the test section. Measure the water loss using method A or B.

13.4.1.3.1 Method A (volume pumped in)

Maintain the pressure by additional pumping if necessary, for a period of at least 1 h. During this period, record the quantity of water added to maintain the pressure at SMTP. Alternatively, use method B.

13.4.1.3.2 Method B (volume drawn off)

Close all valves and disconnect the pump from the pipeline. Monitor the pressure for at least 1 h and record the pressure at the end of the test period. Re-establish the original test pressure (SMTP) by injecting a measured quantity of water into the test section. Carefully draw off water into a calibrated container until the pressure reached at the end of the test period is again reached.

During depressurizing, ensure that adequate air is allowed in so as not to create an internal vacuum that could damage the piping system.

13.4.1.4 Allowable water loss

A section of pipeline subjected to a hydraulic pressure test will normally exhibit a reduction in test pressure during the test period; this can occur because of either joint leakage, internal volume increase of the pipeline due to pipe wall strain and/or material creep, pipe re-rounding under pressure, dissolving of entrapped air, thrust block movement or a combination of these factors. The quantity of water required to restore the test pressure to its original value is called the allowable water loss, usually expressed in litres per hour.

The allowable water loss for a test section can be dependant upon the pipeline diameter, the number of joints, the length of the pipeline test section, the nature of the pipeline material and the pressure at which the test is conducted.

A variety of formulae for determination of the allowable water loss have been published in national standards, public authority specifications and manufacturers' literature. The loss values determined using some of these methods give varying results. It is recommended that the allowable loss value be stated either by the designer or the prospective pipeline owner and it should conform to the applicable national standard or local authority specification. GRP pipelines can exhibit significant volume changes resulting from pipe wall strain and re-rounding. It is recommended that the pipe manufacturer be consulted when determining an acceptable allowable loss value.

14 Disinfection of water mains

14.1 Swabbing

On completion of the pressure test on a water main, a foam swab shall be passed through the main for final cleansing sufficient times to achieve clear wash water.

14.2 Disinfection

Following swabbing, fill the main with water and circulate the water through the pipeline at a controlled rate of flow. Add a 10 % solution of Sodium Hypochlorite to the flow at a dosing station until the water in the main has a chlorine concentration of between 50 g/l and 60 g/l. Circulate the water for 24 h and then add Sodium bisulphate to remove the chlorine. Then discharge the water from the pipeline into a water course or sewer. Add fresh drinking water to the pipeline and circulate it for 24 h; sample this for bacteriological and chemical analysis. When the results from such tests show that the pipeline conforms to the regulations existing at the place of the contract, it may be used for drinking water supply.

The pipeline should be brought into operation within fourteen days of completion of the disinfection operation.

Annex A
(informative)

Classification of soils and consolidation class terminology

In this part of ISO 10465, three types of soil are considered: granular, cohesive and organic. Each of these has subgroups, which for granular material are based on particle size and gradation and for cohesive material are based on levels of plasticity. Table A.1 shows the criteria and the suitability for use as a backfill material.

Table A.1 — Soil groups

Soil type	Soil group					May it be used for backfill?
	No.	Typical name	Symbol[a]	Distinguishing features	Example(s)	
Granular	1	Single-sized gravel	[GU]	Steep gradation line, predominance of one-grain-size	Crushed rock, river and beach gravel, morainic gravel,	YES
		Well-graded gravels, gravel-sand mixtures	[GW]	Continuous gradation line, several grain-sizes	Scoria, volcanic ash	
		Poorly graded gravel-sand mixtures	[GP]	Step-like gradation line, one or more grain sizes absent		
	2	Single-sized sands	[SU]	Steep gradation line, predominance of one grain size	Dune and drift sand, valley sand, basin sand	YES
		Well-graded sands, sand-gravel mixtures	[SW]	Continuous gradation line, several grain sizes	Morainic sand, terrace sand, beach sand	
		Poorly graded sand-gravel mixture zones	[SP]	Step-like gradation line, one or more grain sizes absent		
Granular	3	Silty gravels, poorly graded gravel-sand-silt mixtures	[GM]	Broad/intermittent gradation line with fine-grained silt	Weathered gravel, slope debris, clayey gravel	YES
		Clayey gravels, poorly graded gravel-sand-clay mixtures	[GC]	Broad/intermittent gradation line with fine-grained clay		
		Silty sands, poorly graded sand-silt mixtures	[SM]	Broad/intermittent gradation line with fine-grained silt	Liquid sand, loam, sand loess	
		Clayey sands, poorly graded sand-clay mixtures	[SC]	Broad/intermittent gradation line with fine-grained clay	Loamy sand, alluvial clay, alluvial marl	
Cohesive	4	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands	[ML]	Low stability, rapid reaction, nil to slight plasticity	Loess, loam	YES
		Inorganic clay, distinctly plastic clay	[CL]	Medium to very high stability, no to slow reaction, low to medium plasticity	Alluvial marl, clay	

Table A.1 (*continued*)

Soil type	Soil group					May it be used for backfill?
	No.	Typical name	Symbol[a]	Distinguishing features	Example(s)	
Organic	5	Mixed-grained soils with admixtures of humus or chalk	[OK]	Admixtures of plant or non-plant type, decay smell, light weight, large porosity	Top soils, chalky sand, tuff sand	NO
		Organic silt and organic silt clay	[OL]	Medium stability, slow to very quick reaction, low to medium plasticity	Sea chalk, top soil	
		Organic clay, clay with organic admixtures	[OH]	High stability, nil reaction, medium to high plasticity	Mud, loam	
	6	Peat, other highly organic soil	[Pt]	Decomposed peats, fibrous, brown to black coloured	Peat	NO
		Muds	[F]	Sludges deposited under water, often interspersed with sand/clay/chalk, very soft	Muds	

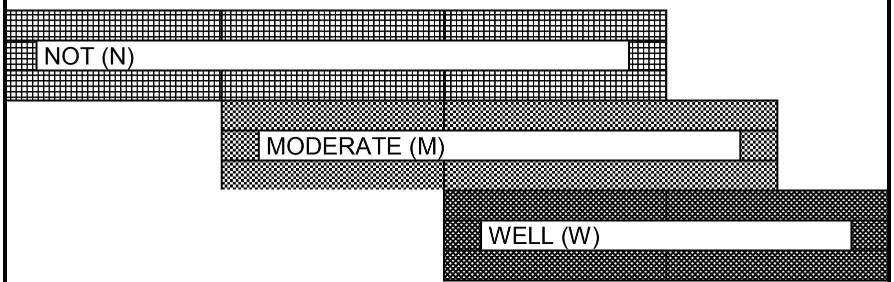
[a] The symbols used are from the unified soil classification system.

Where a soil is a mixture of types, then whichever is the predominant one present can be used for the classification.

Frequently, the density or degree of consolidation is indicated for a soil. This can be in the form of words or numbers. Table A.2 gives the approximate relationship for the various descriptions used.

Where detailed information of the undisturbed native soil is not available, then it is usually assumed that it has a consolidation equivalent of between 91 % and 97 % standard proctor density (SPD).

Table A.2 — Consolidation class terminology

	Degree of consolidation			
SPD	$\leqslant$ 80	81 to 90	91 to 94	95 to 100
Blow count	0 to 10	11 to 30	31 to 50	$>$ 50
Expected degrees of consolidation achieved by the compaction classes in this part of ISO 10465				
Granular soil	Loose	Medium dense	Dense	Very dense
Cohesive and organic soil	Soft	Firm	Stiff	Hard

NOTE This table is intended as an aid for interpretation of descriptions for degrees of consolidation, used in various sources and in this part of ISO 10465.

Bibliography

[1] ATV-A 127, *Guidelines for static calculations on drainage conduits and pipelines.* Third edition, August 2000 3)

[2] AWWA M 45, *Fiberglass pipe design manual M 45.* 2005 4)

3) German association for water, wastewater and waste.

4) The American Water Works Association.

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