FIBERSTRONG™

Installation Guide
For Underground Pipe Systems

Glass Reinforced Polyester Pipe Systems

FUTURE PIPE INDUSTRIES

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PREFACE

Future Pipe Industries L.L.C. reserves the right to change the data published in this brochure without any prior notification. Published data can be changed by the said company for specific project requirements.

For any technical query, please consult **Future Pipe Industries L.L.C.**

For shortening, **Future Pipe Industries L.L.C.** is referred to by "**FPI**" or the "Manufacturer".

TABLE OF CONTENTS

1. INTRODUCTION

This guide deals with handling, laying and testing of buried Fiberstrong™ pipes and fittings manufactured by Future Pipe Industries (FPI). It is to be used in connection with the Fiberstrong™ Product Data and is intended to assist and provide the installer the basic requirements and procedures required for the successful handling, laying and testing of Fiberstrong™ pipe systems. For the standard product range, the nominal pipe diameters (DN) range from 80 mm up to 4000 mm with nominal pressure classes (PN) of 1, 3, 6, 10, 12, 16, 20 or 25 barg and nominal stiffness classes (SN) of 2500, 5000 or 10000 Pa. The table 1 shows Fiberstrong™ pipe standard lengths.

Table 1: Standard Pipe Length

Nominal Pipe Diameter (mm)	Standard Pipe Length (m)
80	6 /6.5
100-300	6 /6.5 / 10 / 12
350 - 600	10 / 12
700 and above	12

This guide should be carefully read by the Contractor responsible for laying the pipes as well as the owner's Engineer. This information should be considered only as a guide. The Engineers or others involved in pipeline design or laying should establish for themselves the procedures best suited to the actual site conditions. Sound engineering practices should always be followed. This document mainly addresses the usual circumstances that may be encountered in the site. Unique situations requiring special considerations are not addressed and should be resolved in coordination with FPI.

Our field service representatives are at the disposal of the Contractor / end user in order to advise on the handling and installation of the pipes. The installation procedures outlined in this guide and the advice of the site services representative, when carefully followed, are designed to provide a successful installation enabling the achievement of the long-term benefits and performance of GRP pipe. Consult FPI on any questions or when variations from this installation guide are being considered.

1.1 Field Services

Future Pipe Industries provides the services of qualified field representative as per the project specific agreement with the customer. The site representative can advise the Purchaser and/or the Contractor to help him achieve a satisfactory pipe installation. It is recommended that "on the job" site service should be engaged in the initial stages of installation and may continue periodically throughout the project. The service may range from continuous (essentially full time) to intermittent depending on agreement between Purchaser and FPI.

The responsibilities of FPI field service representative include:

- Periodic visits to the job site throughout the duration of pipe installation to advise the contractor on the proper and applicable handling, storage, bedding, laying, jointing, backfilling and site testing procedures necessary to achieve a satisfactory Fiberstrong™ pipe installation. These procedures are detailed in this guide.

- FPI representative is available at the site strictly in an advisory capacity only.

- It is the responsibility of the Contractor to make available this Fiberstrong™ pipe installation guide to his installation crew, and to ensure that they are familiar with, and understand and follow the procedures described therein.

- It is the responsibility of the Contractor to strictly follow and implement the installation procedures published in this installation guide, as well as any additional advice given by FPI site representative.

- FPI shall not be liable for any failures related to installation arising from failure of the Contractor to follow and implement our written Installation instructions, method statements and any additional advice or recommendation made by the FPI site representative.

2. HANDLING

2.1 Receiving of Pipe

Generally, pipes will be handed over to the Contractor or his representative at the factory or at the job site or as agreed upon in the Contractor's purchase order.

In case of Ex-works (EXW) delivery, the pipes and fittings shall be loaded on the Contractor's trucks by the factory loading staff. If the loading staff considers the transport unsuitable, they will advise the Contractor or his representative accordingly. Inspection is thoroughly made by the factory loading staff of the goods being loaded. Nevertheless, the Contractor or his representative should make their own inspection of the goods during dispatch. Title of the goods and risk is transferred to the contractor (buyer) when goods are loaded on contractor's (buyer's) trucks at FPI's factory.

The Contractor should make the following inspection at the time of the reception of the goods:

- All pipes and fittings should be inspected upon receipt at the job site to ensure that no damage has occurred during transport.
- Total quantity of pipes, couplings, rubber rings, fittings, lubricant, etc. should be carefully counted and checked against the delivery notes.
- Any damaged or missing item must be pointed out to the dispatcher or driver and noted on the delivery note.
- Materials that have been damaged during transportation should be isolated and stored separately on site, until the material is inspected by the FPI site representative (where possible) and repaired or replaced.
- In case the goods are insured, the contractor (buyer) must promptly inform the insurance agent and file a claim (typically within 21 days) for any loss or damage as the case may be.

In case of export outside the country of origin, the contractor (buyer) should be familiar with Incoterms 2010 which defines the respective roles of the buyer and seller (FPI) in the arrangement of transportation and other responsibilities and clarifies when the transfer of ownership (title and risk) of the merchandise takes place.

Note 1: Damaged or defective material must not be used before it is inspected (where possible), repaired or replaced.

2.1.1 Repair

Pipes with minor damage can be repaired at the job site by a qualified technician. If in doubt about the condition of the pipe, do not use it.

The site services representative can help to determine whether repair is required, possible and practical. Repair methods can vary due to pipe thickness, wall composition, application, and the type and extent of the damage. Therefore, do not attempt to repair a damaged pipe without consulting FPI first. Repairs must be made by a Trained and certified bonder technician. Improperly repaired pipes may not perform as intended.

2.2 Unloading of Pipe

Unloading the pipe at the job site must be carried out carefully under the control and responsibility of the Contractor. Do not drop the items. Extreme care should be taken to avoid impacting the pipe with any solid object (i.e. other pipes, ground stones, truck side etc.).

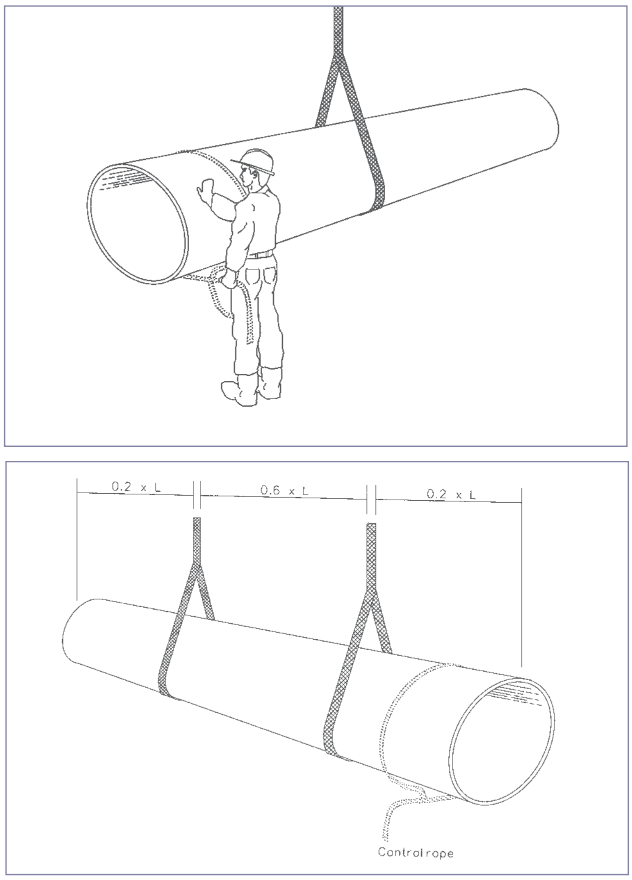

Figure 1: Lifting Single Pipe.

2.2.1 Unloading by hand

Unloading by hand with two men is only allowed for small diameter pipes, not exceeding 60 Kg weight.

Note 2: See Appendix I for pipe and coupling weights.

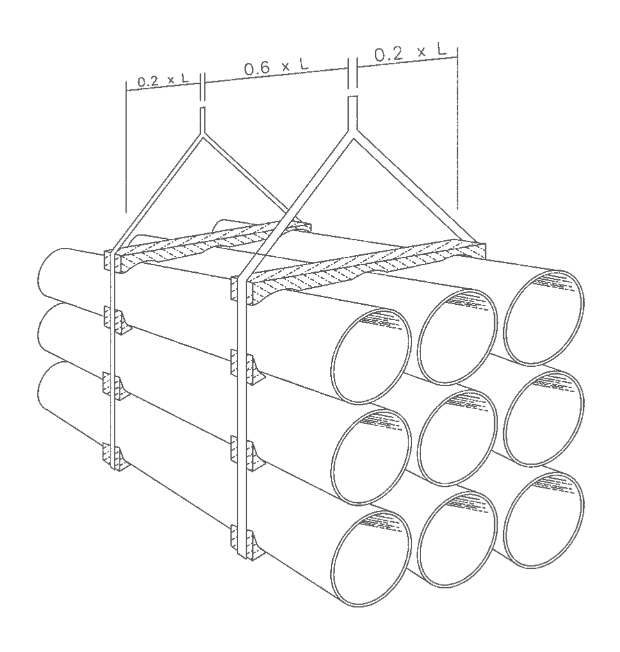

Figure 2: Lifting Unitized Package.

Caution: Hooks must not be used at the pipe ends to lift the pipes, nor should the pipe be lifted by passing a rope or sling through the pipe.

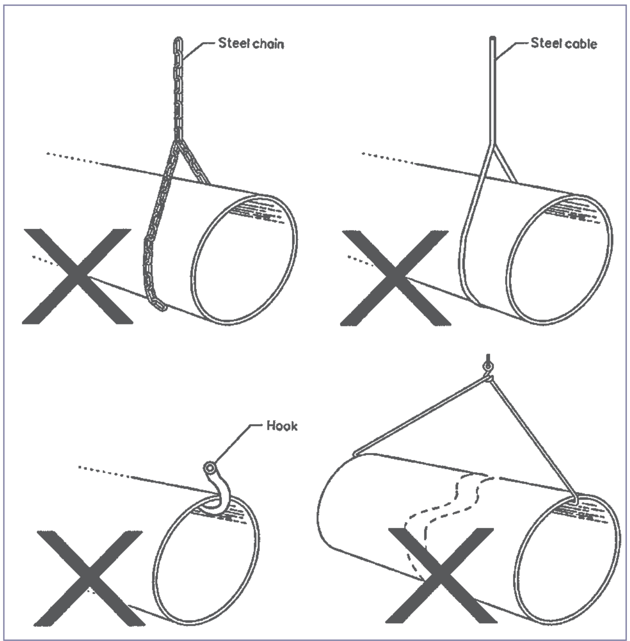

Figure 3: Wrong Lifting Practices (to be avoided)

2.2.2 Mechanical Unloading

Mechanical unloading is required for pipes heavier than 60 kg. Flexible slings or straps should be used combined with a mobile crane. When unloading is done with a mobile crane, care must be taken that the pipes do not slide off the slings. Therefore, it is recommended to use two slings or nylon lifting straps to hold and lift the pipes. Steel cables must not be used for lifting or handling FIBERSTRONG® pipes. The pipes can also be lifted with one sling or strap balanced in the middle with the aid of a guide rope. To lift a unitized package, two support points are always required.

2.3 Unloading Couplings

Couplings shall be unloaded with care. At any circumstances, couplings must not be thrown off the truck on the ground. In general, couplings are strapped and bundled in the factory and can be off loaded like the pipes.

2.4 Storing Rubber Rings and Lubricant on Site

Rubber rings are delivered in closed bags from the factory and must be stored in shaded and dry area in their original packing, protected from direct sunlight, until they are ready for use. Also, the rings must be protected from exposure to greases, oils, solvents and other substances harmful to rubber. In case a longer storage is expected (more than 3 months), then a cold storage (AC room where needed) with a maximum temperature of 25 oC is recommended for storage of the rubber rings.

Vegetable based lubricant should be carefully stored in shaded area. Partially used buckets should be sealed again to prevent contamination of the lubricant.

In case of pipes delivered with couplers mounted at the factory, the contractor shall consider storage time for such pipes to be not longer than 3 months with no cover to avoid deterioration of the rubber.

2.5 Storing Pipe on Site

2.5.1 Distribution along the Trench

It is preferable to unload Fiberstrong™ pipes alongside the trench directly from the truck. If the trench is opened, string out the pipes on the opposite side to the excavated earth. Allow sufficient space between pipes and the trench for excavator, cranes, etc. Avoid placing the pipes where they can be damaged by traffic or blasting operations. If possible, store pipes on soft level ground (e.g. sand), timber bearers or sandbags.

It is generally advantageous to store pipe on flat timber to facilitate placement and removal of lifting slings around the pipe.

Caution:

- Pipes must not be stored on rocks or stones. Always use flat timber supports at maximum 3 meters spacing
- Nesting of the pipes during transportation or storage at site is strictly not allowed!

2.5.2 Storing in stockpiles

Care must be taken that the storage surface is leveled, firm and clear of rocks or solid objects that might damage the pipes. Store the pipes in separate stockpiles according to their class and nominal diameter. If it is necessary to stack pipes, it is best to stack on flat timber supports at maximum 3 meters spacing. T The maximum number of layers shall be limited to a 1.5-meter stack height if the pipes are loose, and 2.5 meter if the pipes are crated or supported (As per ISO 14692 Part-4 : 2017 Annex B). Stacking of pipes larger than 1400 mm diameter is not recommended. This height is limited for safety considerations and to avoid excessive loads on the pipe during storage.

Wooden wedges, which are used in order to prevent the pipe stack from sliding should be placed on both sides of the stack on the timber bearer, as shown in figure 4.

The change in appearance Fiberstrong™ pipe undergoes when exposed to sunlight over an extended period of time is strictly a surface phenomenon caused by UV effect on the sacrificial resin-rich outer layer of the pipe (called the topcoat). In general, underground pipes are not being produced with UV Inhibitor in the topcoat. Therefore, it is recommended to cover those pipes (e.g. Tarpaulin or tent fabric) in order to avoid this surface discoloration. This issue arises particularly when the pipes are not immediately installed in the trench upon delivery to the site.

For pipes produced for above ground applications, UV inhibitor is added as a part of the pipe structure. Therefore, it can be stored for outside in direct sunlight for a maximum duration of 3 months, otherwise it shall be covered. GRP pipe can burn. Keep pipe away from open flames and intense heat sources.

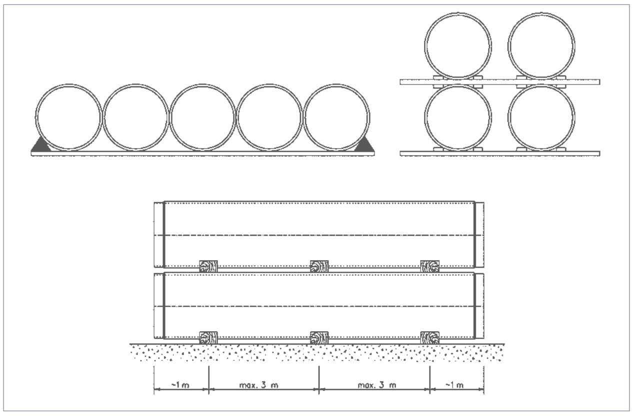

Figure 4: Pipe Storage

2.6 Handling of Nested Pipes

Pipes may be delivered nested (smaller diameter pipes inside larger diameters). Special handling procedures must be followed when unloading, handling and de- nesting such pipe loads.

When handling nested pipes, never use a single sling or strap. Nested pipes must always be lifted using at least two straps or slings. A spreader bar will help ensure the load is lifted uniformly. Mobile lifting equipment should move slowly when handling nested pipes and all such movements should be kept to a minimum to ensure the safety of site personnel. The Contractor should ensure that the crane operator realizes that the smaller pipes inside the larger nested pipes may slip out and fall during movement. All necessary precautions should be taken.

De-nesting a load is easily accomplished inserting a forklift fork into a padded boom. The forklift lifting capacity should be appropriate to handle the weight and length of the pipes being de-nested. Figure 5 shows how this is accomplished. Proper padding is essential. Rubber, several wraps of corrugated cardboard sheets, a PVC or PE pipe slipped over the boom are all suitable options to avoid damaging the inside of the nested pipes.

The Forklift operator should lift the innermost pipe sufficiently, so the pipes do not touch each other when the inner pipe is being pulled out.

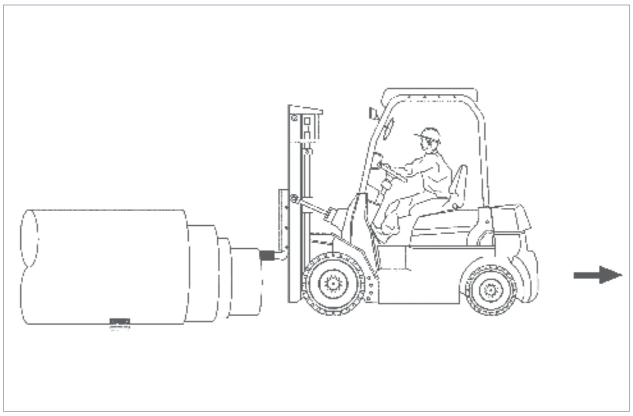

Figure 5: Pipe de-nesting

2.7 Lowering Pipes into the Trench

Manual lowering of small diameter pipes into the trench can be executed by at least two men using ropes. It is recommended that the weight carried by one man do not exceed 30 kg. The ropes must be anchored to stakes as indicated in figure 6.

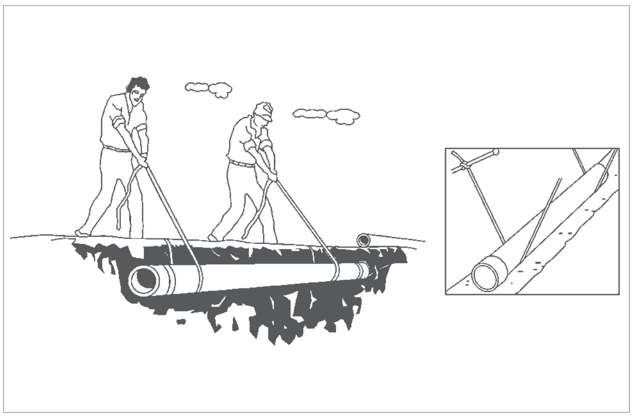

Figure 6: Lowering Small Diameter Pipes with Ropes

Mechanical lowering is used for larger diameter pipes, especially when combined with pipe assembly in the trench. Two straps or slings can be used from an excavator boom if no separate lifting equipment is available, as shown in Figure 7.

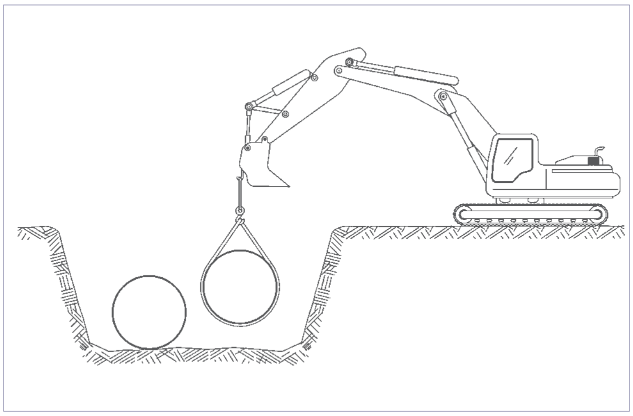

Figure 7: Lowering Pipes Using Excavator

3. TRENCH SPECIFICATIONS

3.1 The Trench

The trench excavations should not be too far ahead of the pipe-laying team to ensure a better control of the trench and for safety reasons. The excavated soil should be placed on one side of the trench leaving the other side clear for equipment and pipe handling. If the trench consists of various layers of soils, these should be placed separately in order to use the stone-free granular material for backfilling.

3.2 Trench Width

The trench width must be maintained within certain limits. A very wide trench will, increase the volume of backfilling material required and compaction labor and effort. A very narrow trench will render laying, handling and joining of pipes, as well as difficulty in compacting side backfill. For a single pipe, the minimum recommended trench width as given in AWWA is 1.25 times the outside diameter of the pipe plus 12in (300mm), W = 1.25*DN + 300.

Note3: In poor native soil conditions and depending on pipe stiffness and burial depth, a wide trench (up to 4 x ND) might be required. See section 4.6.1 for additional details.

Note 4: The minimum distance between the pipe and the trench wall "X" shall be at least 150 mm wider than the width of the equipment used for compaction of the backfill material

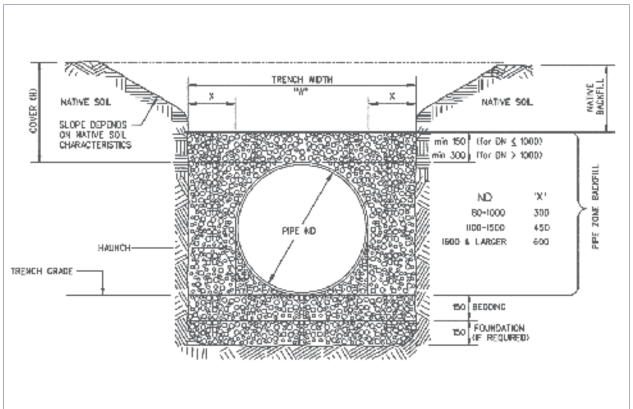

Figure 8: Trench Width

3.3 Parallel Pipes in the Same Trench

Where two, or more, Fiberstrong™ pipes are installed in parallel in the same trench, the minim distance between the pipes "X" as shown in Figure 9 shall be at least the average of the radius of the two adjacent pipes for burial depths greater than 3.5 m and two- thirds of the average of the radius of the two adjacent pipes for burial depths less than 3.5 m as per AWWA M45. This is to allow for sufficient room to place and compact the backfill material under the pipe haunches. The distance between the pipes should be at least 300 mm or 150 mm wider than the width of the equipment used for compaction of the backfill material, whichever is greater.

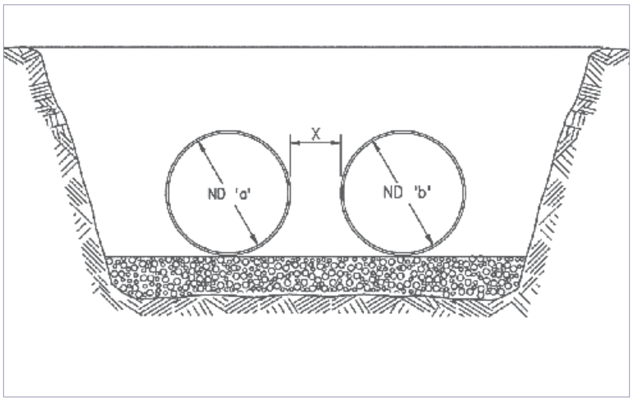

Figure 9: Pipes in the same trench

3.4 Pipes Crossing

Where two Fiberstrong™ pipes are crossing each other as shown in figure 10, the minimum vertical distance between the two pipes "x" shall be at least the average of the radius of the two pipes, in any case this distance should not be less than 300 mm.

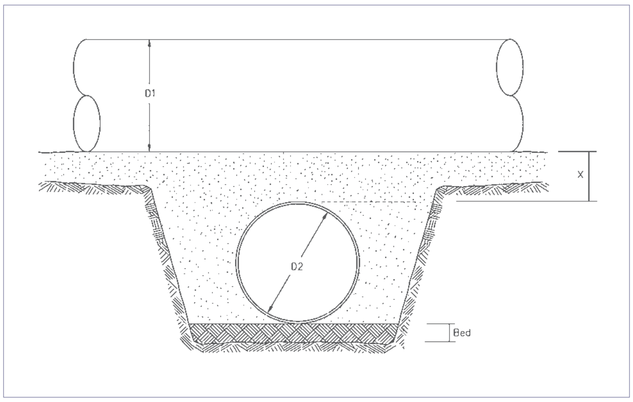

Figure 10: Pipe Crossing

3.5 Cover Depth

3.5.1 Minimum Cover Depth

Generally, the cover depth of pipe is specified by the Design Engineer or as shown on the profile drawings. When there is no traffic load over the pipe nor high water table, the minimum recommended burial depth is 0.6 m. In the presence of traffic loads, a minimum cover as given Table 2 shall always be maintained for all stiffness classes.

Table 2: Minimum Cover Depth

Load Type	Traffic (wheel Load)		Minimum Burial Depth (m)
	kN	lb	
AASHTO HS20	72	16,000	1.0
BS 153 HA	90	20,000	1.5
ATV LKW 12	40	9,000	1.0
ATV SLW 30	50	11,000	1.0
ATV SLW 60	100	22,000	1.5
Cooper E-80 Railroad			3.3

For buried pipelines with design pressure of 16 bar and above, the minimum cover depth should be 0.8 m for DN < 300 mm and 1.2 m for DN > 300 mm.

Note on negative pressure: Where the expected negative pressure in the pipes is greater than 0.6 bars for SN 5000 pipes or greater than 0.3 bars for SN 2500 pipes, a minimum cover of 1.0 meters shall be provided and backfill shall be compacted to at least 30 cm above pipe crown.

In case of high ground water table, a minimum cover depth equal to 0.8 times the pipe diameter of granular soil (minimum dry density of 1900 kg/m3) must be provided to prevent Fiberstrong™ pipes from floating. Always ensure that this minimum cover is available before turning off dewatering systems.

3.5.2 Maximum Cover Depth

The maximum cover height depends on the type of installation, backfill material and its compaction, pipe stiffness class as well as the native soil conditions. See tables 3 and 4 for typical maximum burial depth for non-restrained pipe installation.

3.6 Road Crossing

Road crossings require particular attention and requirements. Precautions shall be taken to protect the pipes, which cross underneath roads against the possible consequences of traffic loads. The influence of the wheel load of traffic passing a buried pipe reduces with increased burial depth. A minimum cover depth above the pipes (Detailed in Table 2) shall always be maintained for all stiffness classes.

Minimum cover depth can be reduced with special installation such as:

- Installing the GRP pipe inside a Sleeve pipe (e.g. RCP or Steel), or
- Concrete Protection Slabs, or
- Concrete encasement of the pipe

3.6.1 Sleeve Pipe

The FIBERSTRONG pipe is nested inside a sleeve pipe. In order to avoid direct contact between both pipes, spacers are used to center the GRP pipe inside the sleeve pipe (Figure 11). The sleeve pipe should be longer than the width of the road. The sleeve may be grouted, or the annular space left open depending on the stability of the GRP pipe and any restraint required.

The maximum grouting pressure shall not exceed the following limits:
0.3 bar for SN 2500 pipe
0.6 bar for SN 5000 pipe
1.20 bar for SN 10000 pipe

Concrete Protection Slab

Two types of concrete protection slabs exist:

1) Concrete Relief Plate: This protection slab is specially designed and dimensioned to minimize the transfer of wheel load on the pipe and divert the load away from the pipe. The plate has a rebate which must be kept free from soil during installation (for example by means of synthetic foam). The distance between the relief plate and crown of the pipe shall be 50% of pipe diameter as a maximum. The plate must not be installed too high because the spread of the load will cause increased load on the pipe. The plate shall be positioned at the recommended distance to provide the required protection to the pipe.

2) Concrete Protection Slab at Grade Level: This concrete slab dissipates the effect of traffic loading and minimize the transfer of wheel load on the pipe by increasing the contact surface between the truck wheel and the soil. The concrete slab must be with appropriate length to ensure that the slab is rested on undistributed walls of the trench.

3.6.2 Concrete Encasement

Concrete encasement provides additional support for the pipes and shields the internal GRP pipe from external loads. Refer to section 6.5 for details.

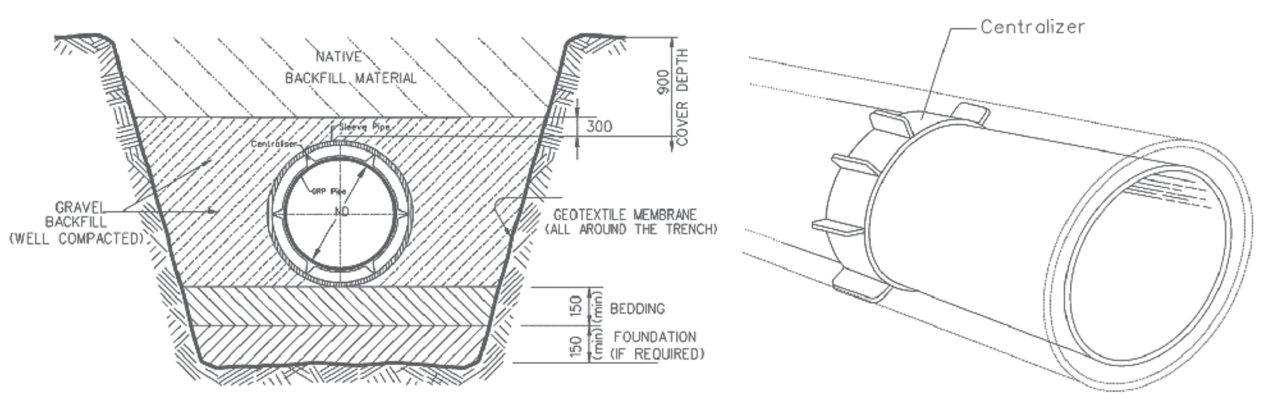

Figure 11: Sleeve Pipe

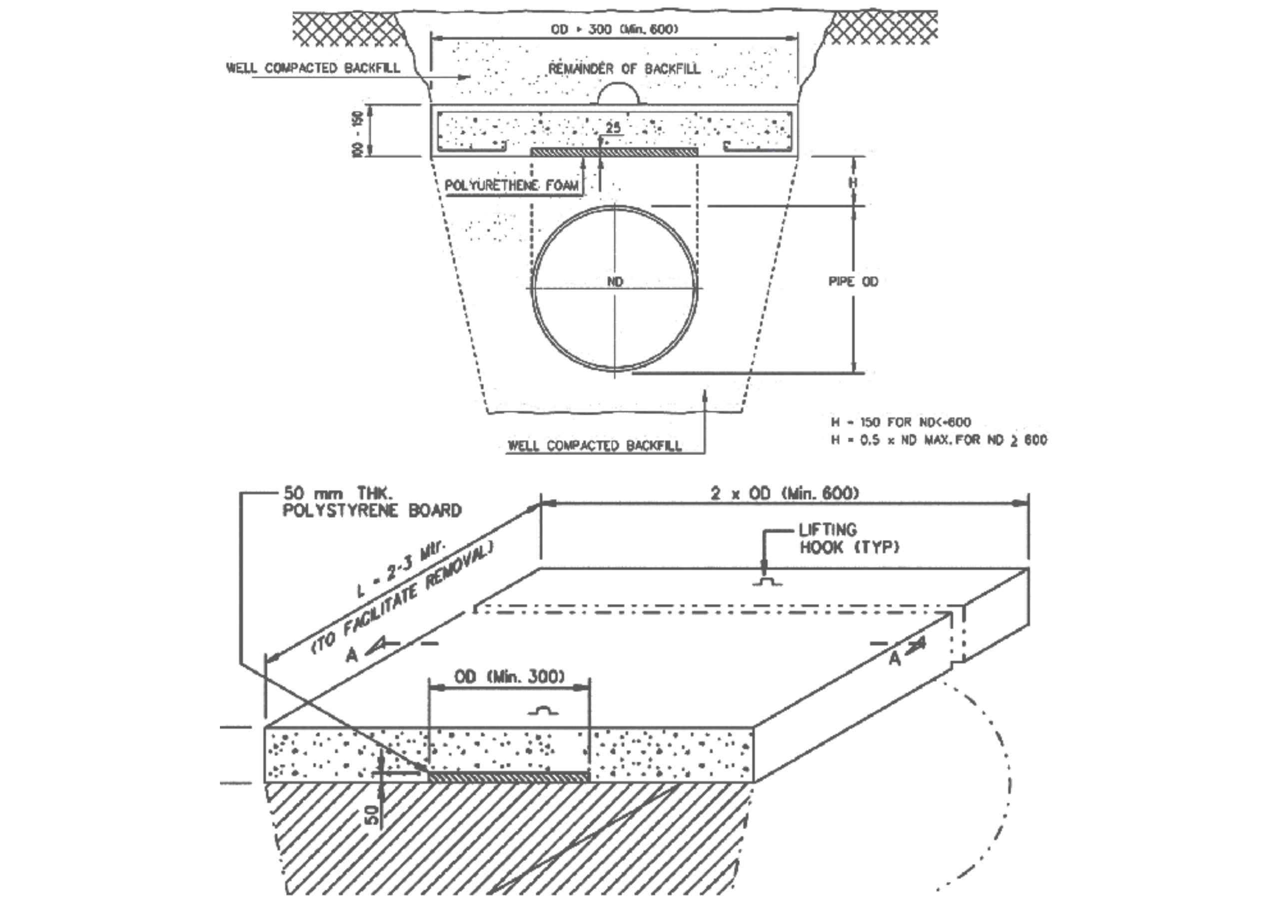

Figure 12: Concrete Relief Plate

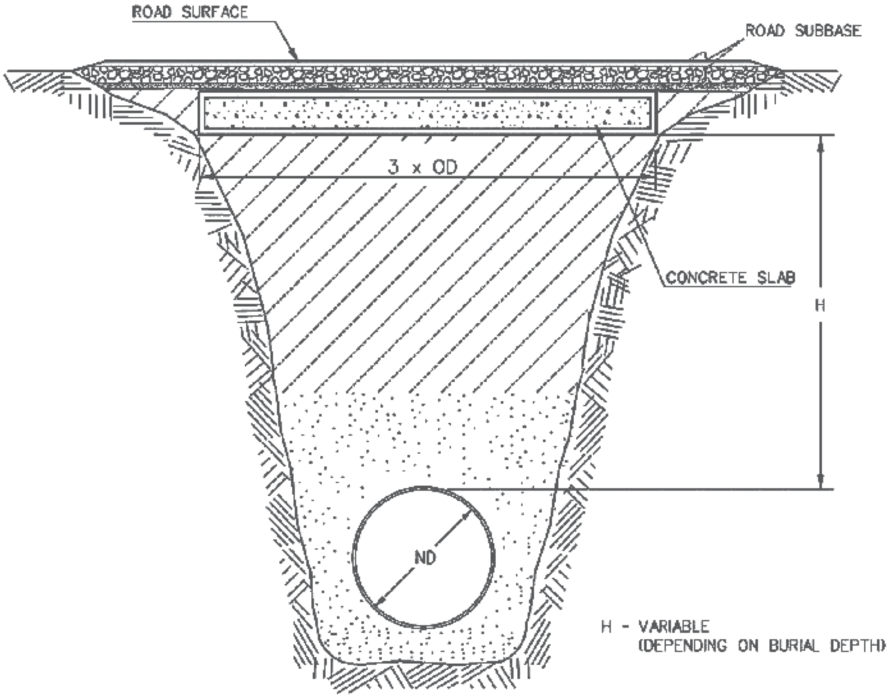

Figure 13: Concrete Protection Slab

4. BACKFILL AND INSTALLATION SELECTION

The installation type and choice of Pipe Embedment Zone material is normally specified by the design engineer based on the specified nominal pipe stiffness class (SN), maximum burial depths, vacuum requirements, and native soil conditions.

4.1 Foundation, Bedding and Backfill Materials

Most coarse-grained soils are generally acceptable as backfill material for the foundation and pipe embedment zone. The following materials may be used if compacted to the required degree.

SN = Minimum initial specific stiffness, Pa

Table 3 - Acceptable Backfill Material as per AWWA M45:

Soil Classes	Unified Soil Classification System Soil Groups
Class I	Crushed rock: ≤ 15% sand, Maximum 25% passing the 3/8in. sieve and maximum 5% passing No. 200 sieve
Class II	Clean, coarse grained soil: SW, SP, GW, GP or soil beginning with one of these symbols with 12% or less passing No. 200 sieve
Class III	Coarse-grained soils with fines: GM. GC, SM, SC or soil beginning with one of these symbols with > 12% fines Sandy/Gravelly fine-graded soils: CL, ML (or CL-ML, CL/ML, ML/CL) with more than 30% retained on a No. 200 sieve
Class IV	Fine-graded soils: CL, ML (or CL-ML, CL/ML, ML/CL) with 30% or less retained on a No. 200 sieve
Class V	Highly plastic and organic soils: MH, CH, OL, OH, PT

Table 4 – Maximum particle size as per AWWA M45:

Pipe Diameter	Maximum particle Size
DN ≤ 450 mm	13 mm
450 mm < DN ≤ 600 mm	19 mm
600 mm < DN ≤ 900 mm	25 mm
900 mm < DN ≤ 1200 mm	32 mm
DN > 1200 mm	38 mm

If the native soil meets the specifications in Tables 5 and 6 above, the same soil may be used in the Pipe Embedment Zone.

4.2 Migration

When backfill materials such as gravels and crushed rocks are placed in a trench adjacent to a finer native material, the finer material may migrate into the coarser material under the flow pressure force of the ground water table. Migration can also occur when selected sand is used as backfill in a trench where the native soil is coarser.

Significant hydraulic gradients may arise in the pipeline trench during construction, when water levels are controlled by various pumping or well-pointing methods.

Gradients may also arise after construction, when permeable underdrain or when the open graded embedment materials act as a "French" drain under high ground water levels. Migration can result in significant loss of pipe support and increasing pipe deflections that may eventually exceed the design limits of the Fiberstrong™ pipe.

The gradation and relative size of the embedment and adjacent native soils must be compatible in order to minimize migration. In general, where significant ground water table is above the foundation or bedding level and when the native soil is finer than the backfill, avoid using open graded materials such as crushed rocks and gravel, unless a geotextile filter fabric is used to line the trench bottom and sides.

The following gradation criteria as per AWWA M45 may be used to restrict the migration of finer material into a coarser material under a hydraulic gradient.

- D 15 / d85 <5 where D15 is the sieve opening size passing 15 percent by weight of the coarser material and d85 is the sieve opening size passing 85 percent by weight of the finer material.
- D 50 / d50 < 25 where D50 is the sieve opening size passing 50 percent by weight of the coarser material and d50 is the sieve opening size passing 50 percent by weight of the finer material. (These criteria don't apply if the coarser material is well graded)

4.3 Determination of Native Soil Properties

In order to choose the appropriate installation type and to identify the allowed burial depth limits, it is necessary to determine native soil properties. Proper soil investigation along the pipeline route is an engineering practice that should be executed by the Contractor in case no soil data is provided by the end user. When no soil data is available, borehole samples should be taken along the pipeline route at intervals of not more than 500 meters. If the native soil properties and appearance are not consistent over this distance, shorter intervals for sampling should be adopted. Soil samples must be taken to a depth at least 3 m below invert level so that it provides the necessary information at the pipe embedment zone level of the pipeline, and under the pipe.

Important soil properties:

- Physical characteristics, type, appearance, and gradation
- Water table location
- Blow counts (N) per ASTM D1586 (Standard Penetration Test)

4.4 Classification of Native Soils

Native soils can be classified into five main groups and two subgroups; cohesive and granular.

Table 5 - Native Soil Groups as per AWWA M45

	1	2	3	4	5	6
Blows	>50	30-50	15 - 30	8 - 15	4 - 8	2 - 4
Cohesive Soils	Very Hard	Hard	Very Stiff	Stiff	Medium	Soft
Granular Soils	Very Dense	Dense	Compact	Slightly Compact	Loose	Very Loose

4.5 Standard Installation

Installation selection, unless otherwise specified by the end user shall be based on the native soil properties, pipe stiffness class (SN), and burial depths. Figure 14 illustrates four standard installations types. See AWWA M-45 3rd Ed. section 6.0 and ASTM D-2487.

- **Installation Type I**
  Full gravel/crushed stones (SC1: Class I according to AWWA M 45/ASTM D 2487: Crushed rock with≤ 15% sand, Maximum 25% passing the 3/8in. sieve and maximum 5% passing No. 200 sieve. Full surround compacted to 70% Relative Density or better. Compact in maximum 30 cm layers. Provides highest soil stiffness and highest maximum burial depths.

- **Installation Type II**
  Full sand (SC2: Class II according to AWWA M 45/ ASTM D 2487: Clean, coarse grained soil with less than12% fines passing No. 200 sieve) Full surround compacted to 90% SPD or better. Compact in maximum 30 cm layers.

- **Installation Type III**
  Full sand (SC3: Class III according to AWWA M 45/ ASTM D 2487: Clean, coarse grained soils with > 12% fines passing No. 200 sieve or Sandy/Gravelly fine-graded soils with more than 30% or less retained on a No. 200 sieve). Full surround compacted to 95% SPD. Compact in maximum 15 cm layers.

- **Installation Type IV**
  Full sand (SC4: Class IV according to AWWA M 45/ASTM D 2487: Sandy/Gravelly fine-graded soils with 30% or less retained on a No. 200 sieve fines passing No. 200 sieve). Full surround compacted to 95% SPD or better. Compact in maximum 15 cm layers. May not be suitable for deep sewer

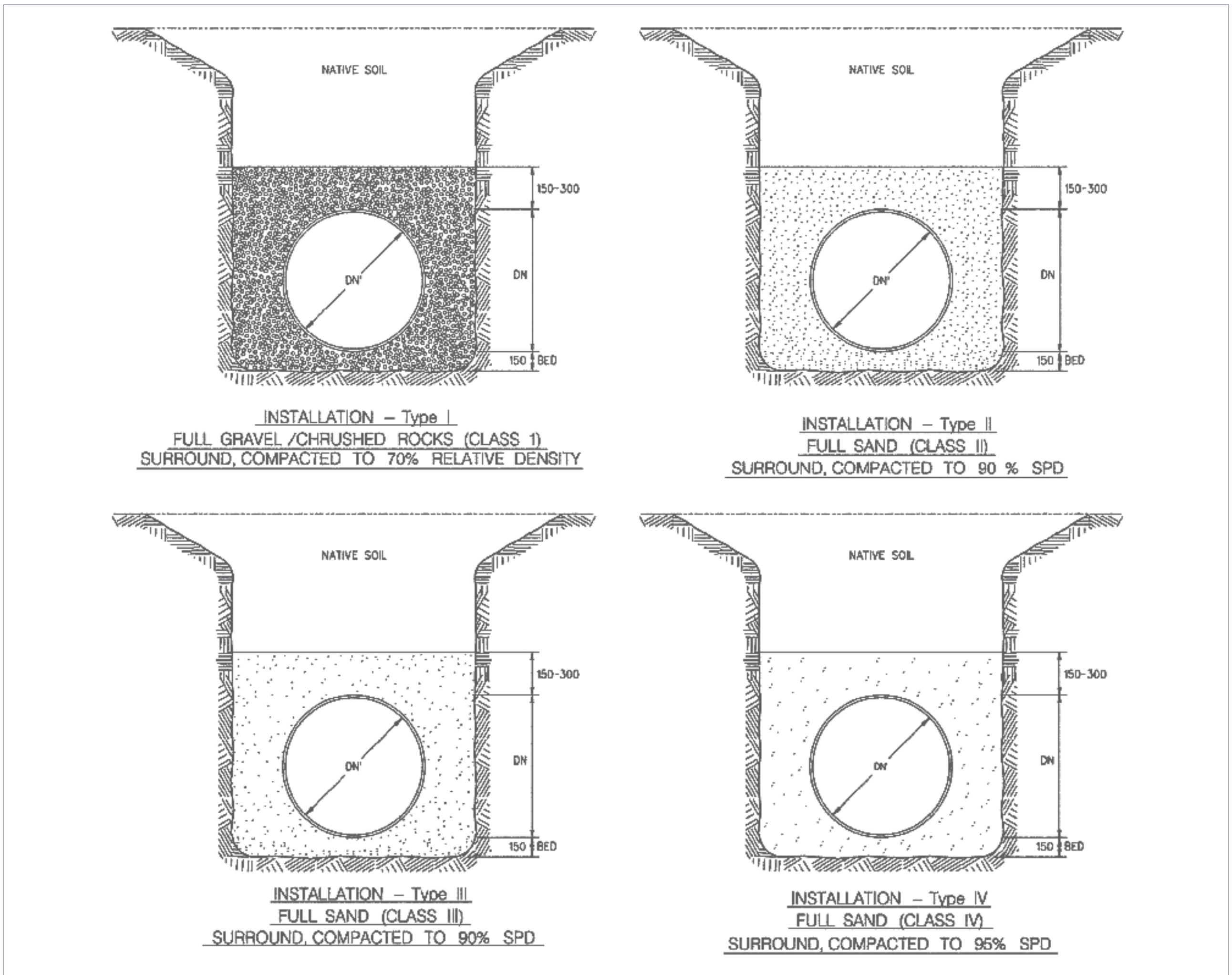

Figure 14: Standard Installation Types

4.6 Alternative Installations

If the burial depth requirement for the selected pipe stiffness, installation type and native soil group exceeds the limits given by the standard installation design calculations, the following three alternative installation methods may be considered:

- Wider Trench
- Permanent Sheeting
- Cement Stabilized Backfill

4.6.1 Wider Trench

Increasing the trench width shifts the poor native soil further away from the pipe and improves the composite constrained soil modulus "Msb". This allows a deeper installation since the pipe is better supported with the compacted pipe surround material.

4.6.2 Permanent Sheeting

Permanent sheeting can be used to distribute the pipe's lateral loads appropriately. The sheeting should be at least 300 mm higher than the pipe crown level and driven below the foundation level. The sheeting system is to be designed by a specialist and the material to be of quality to last the lifetime of the pipe.

4.6.3 Cement Stabilized Sand Backfill

Cement stabilized sand is a mixture of one sack of cement (50 kg) and one ton of clean sand. This backfill material provides excellent support for Fiberstrong™ pipe where native soil conditions are poor. The mixture should be placed in the foundation, bedding, haunches and Pipe Embedment Zone in layers of 15-20 cm. each layer should be wetted with clean water and compacted with plate vibrators before the cement sets.

4.7 Pipe Bedding and Foundation

To ensure a firm support for Fiberstrong™ pipe, a proper bedding must be provided under the pipe. During trench excavation, a pipe bedding thickness of at least 150 mm must be provided.

In case of very loose and very soft or unstable native soils (silt, clay or mud) an additional foundation layer must be provided below the bedding to replace the native soil. Mechanical compaction of the trench bottom is also recommended.

Selected backfill material should be placed at the foundation and bedding layers and thoroughly compacted by plate vibrators or by hand tamping.

Wetting of sand bedding/foundation material prior to compaction will improve and facilitate the achievement of the degree of compaction required.

Reference shall be made to the soil investigation (Geotechnical) report available to determine the foundation layer thickness, material, and its compaction for the specific site conditions.

Pipe laying should always take place in dry trenches. It is not acceptable to lay pipes in flooded trenches. The Contractor should provide the necessary dewatering equipment to enable installation to proceed in a dry trench. Dewatering equipment should be removed, and pumps turned off only after completion of backfilling the Pipe Embedment Zone, and sufficient backfill has been provided to prevent pipes from floating, if the normal ground water level is above the pipe invert. A minimum cover depth equal to 0.8 times the pipe diameter of granular soil (minimum dry density of 1900 kg/m3) must be provided to prevent Fiberstrong™ pipes from floating.

Prior to lowering of the pipe into the trench small holes should be dug under each joint location so the pipe does not rest of the joints. The compacted bedding material should provide firm and continuous support over the entire length of the pipe excluding the joint areas. The bedding layer must be flat, level and fully compacted and at the correct level before lowering pipe into trench.

The Contractor should lower the pipe into position after checking the proper levels and alignment of the pipeline

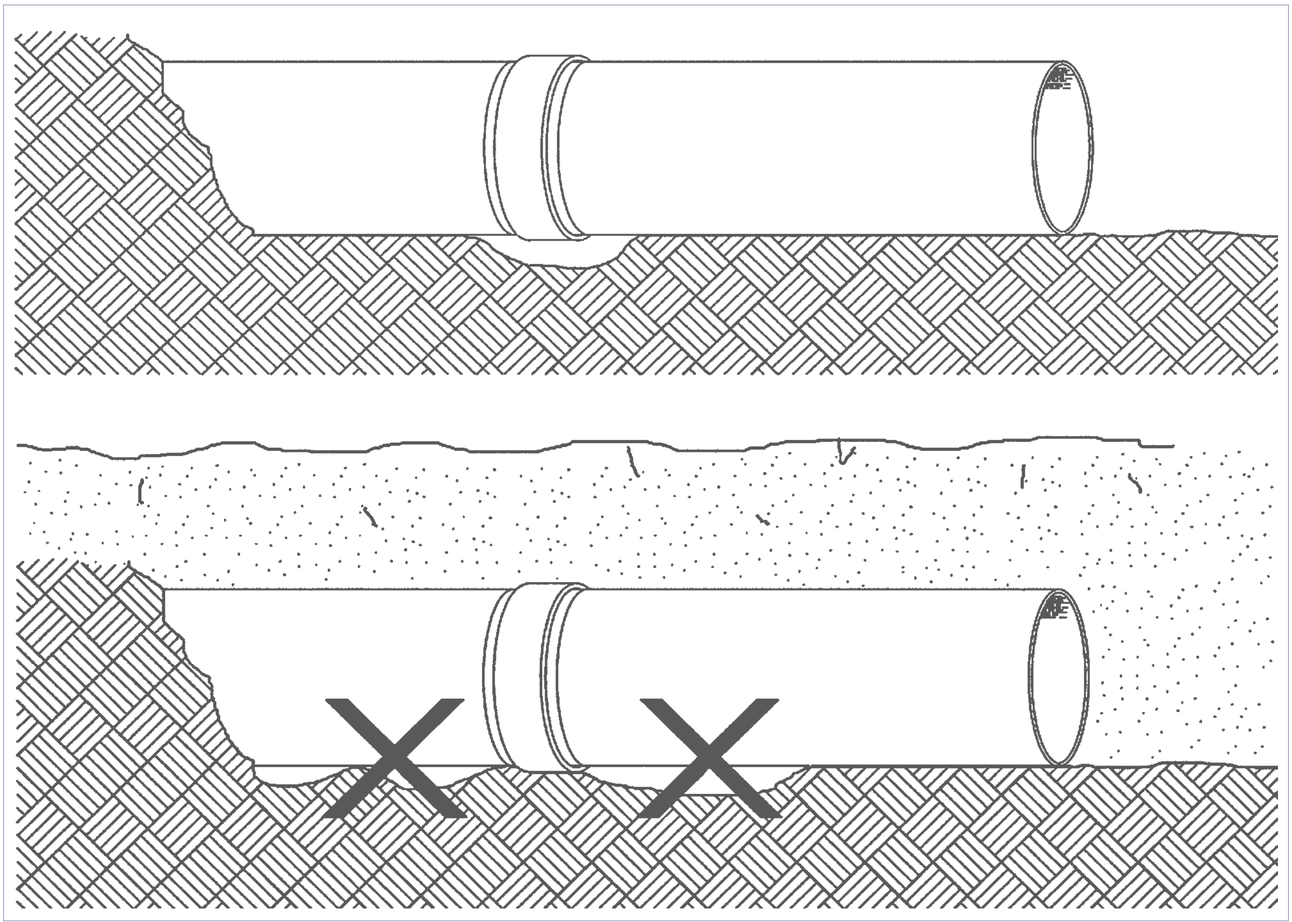

Figure 15: Piping Bedding and Support

4.8 Pipe Embedment Zone

The selected backfill material should be evenly placed and properly compacted on both sides of the pipes. Appropriate hand or mechanical tamping shall be carried out by the Contractor to achieve the specified degree of compaction required by the selected installation type. During the first one or two lifts (lift height shall not exceed 150 mm), special care should be taken to place and compact the backfill material under the pipe haunches. The best way to achieve this compaction is to do it manually with the mean of a wooden board. This is one of the most important installation steps and should be executed with care. Failure to place and to compact the backfill material under the pipe haunches may cause ovalization, localized loads, and over deflection of the pipes.

Pipes joined in the trenches should not be left for more than a few days without backfilling as some joints may end up with excessive and unsafe gaps between pipe ends inside the coupling as a result of the irregular daily expansion and contraction of the pipes due to ambient temperature fluctuation over several days across numerous joints. However, the joints may be left partially exposed for visual inspection during the site hydrotest. These joints must be backfilled immediately after the test to avoid damage to the couplings.

The Contractor should note that the compaction of clean and mixed sands is best achieved when the material is at its optimum moisture content. While the wetting of sand is recommended prior to compaction, trench flooding should be avoided to prevent pipes from floating.

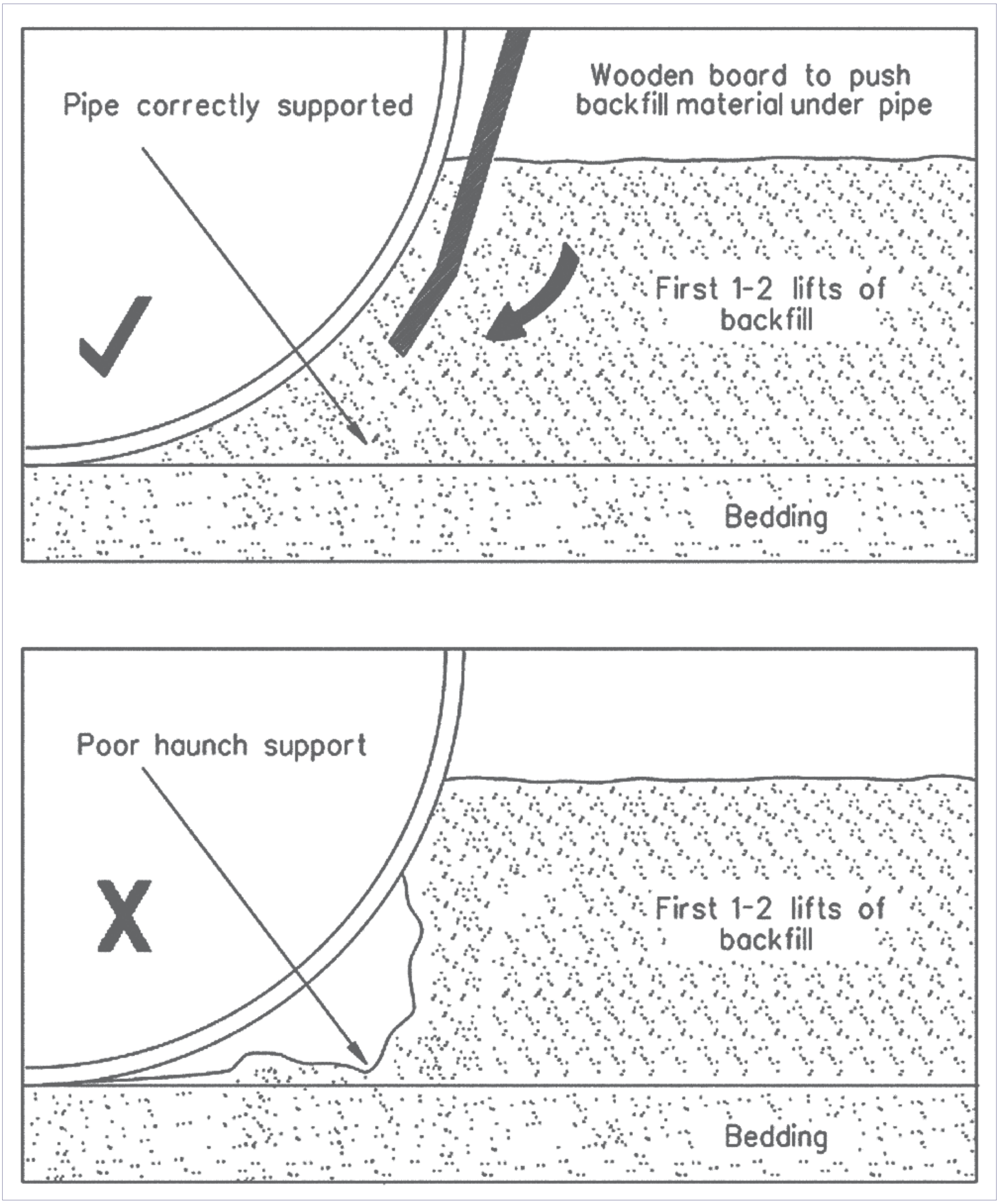

Figure 16: Backfilling Pipe Haunches

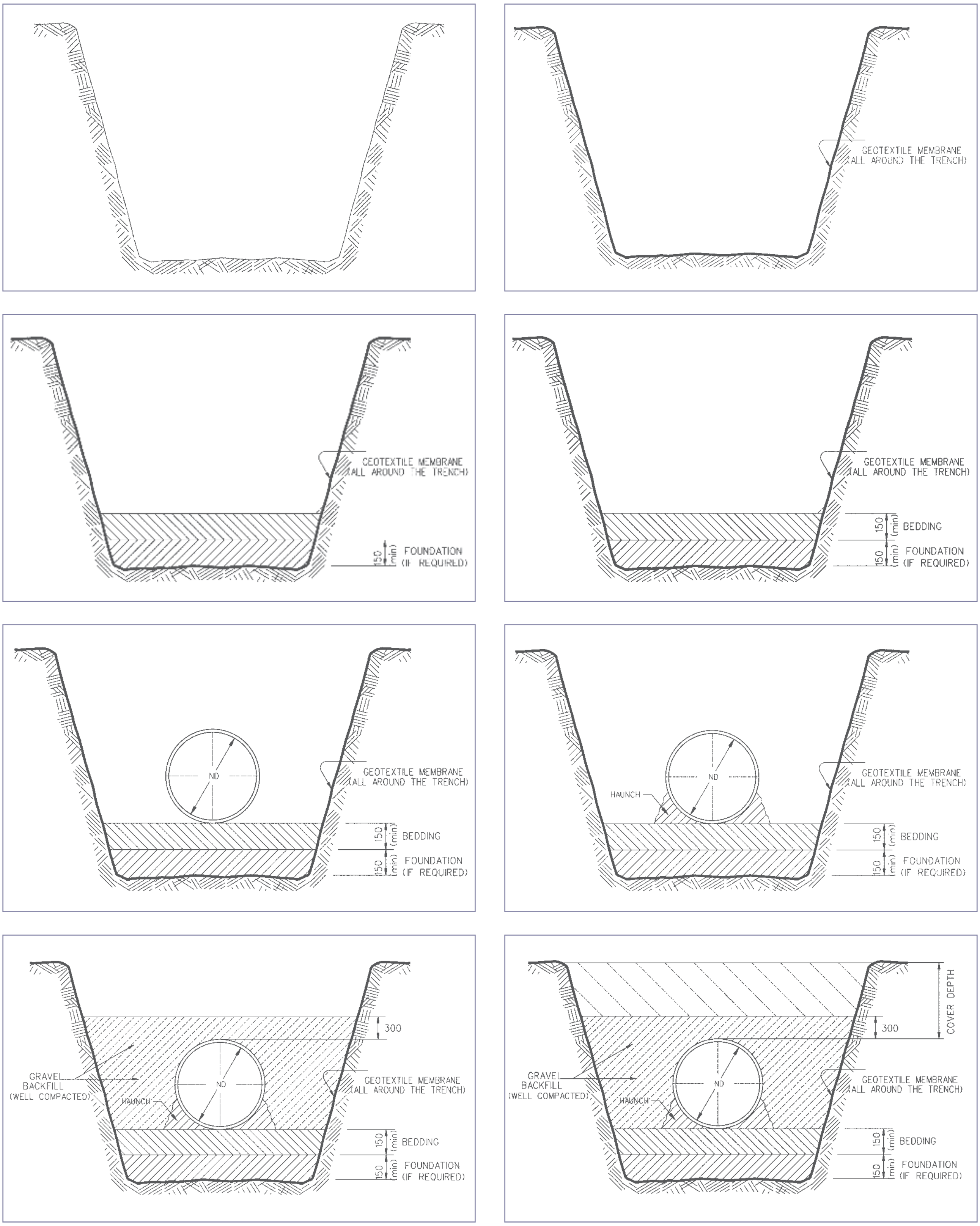

Figure 17: Trench Backfilling Step by Step

Note 5: Trench wall inclined shall be according to the soil characteristics and angle of repose.
Note 6: Foundation thickness, material and compaction must be in line with the geotechnical report recommendations.
Note 7: The first two lifts at the pipe zone embedment shall not exceed 150mm.

Following the first two layers where the backfill has been sufficiently placed, compaction should proceed from the sides of the trench towards the pipe evenly on both sides of the pipe. The Pipe Embedment Zone backfill should proceed in 150 to 300 mm lifts depending on backfill type (see section 4.1 and Note 8). Backfilling on one side of the pipe at a time must be avoided as it can cause horizontal movement of the pipe and an undesirable horizontal angular deflection at the joints.

Note 8: Uniform fine sands (SP) with more than 50% passing a No.100 sieve shall be compacted in maximum 150 mm layer thickness.

The Pipe Embedment Zone backfilling and compaction should continue until the backfill reaches at least 150 mm above the pipe crown. For pipes larger than 1,000 mm in diameter, backfilling the Pipe Embedment Zone should continue to 300 mm above the pipe crown. After completion of backfilling in the Pipe Embedment Zone, native material excavated from the trench may be used to complete backfilling to final grade. No compaction is required in these final backfilling layers except where specified by the Engineer, or in the case of traffic or other high external loads over the pipe where settlement of the native backfill is to be avoided.

Caution: Sand layers of more than 300 mm cannot be compacted properly and may result in loss or reduced support for the pipes. The best compaction results are achieved with wet sand near its optimum moisture content. Flooding of the trench must be avoided as pipe floatation may occur. A minimum backfill height as given in section 3.5.1 is required to prevent Fiberstrong™ pipes from floating. The use of plate vibrators to compact the pipe backfill is highly recommended. For SC1 and SC2 backfill materials a 200 kg plate vibrator is required to compact the backfill in 15 cm layers, and a 500 kg plate vibrator is required to compact the backfill in 30 cm layers. For SC3 and SC4 backfill materials a 500 kg plate vibration is required to compact the backfill for both lift cases. Before using plate vibrator directly above the pipe crown, insure that backfill reaches 25 cm above pipe crown for 200 kg vibrators and that backfill reaches 40 cm above pipe crown for 500 kg plate vibrators.

4.9 Offshore Pipelines

This installation method is used for the offshore portion of FIBERSTRONG® pipes. The pipe joints are assembled under the water. Steel angle irons lugs will be provided on the two ends of pipe to allow divers to assemble the standard FIBERSTRONG® REKA coupling joints under water. It may be possible to assemble on the barge up to 3 lengths of pipe and to lower the assembled section (total length of 36 m) into the excavated sea bed trench. Spreader beam or sea horse shall be used for lifting the preassembled segments

Caution: Standard Fiberstrong™ pipe is not designed to be assembled on-shore in long lengths and then dragged out to the sea.

Installing Fiberstrong™ pipe under water requires a trench similar to the onshore trench, accepting the fact that the trench width is larger. The typical underwater trench width is equal to 2 x ND but is no case less than ND + 1 meter. Consult FPI Engineer for recommendation of the minimum burial depth over the pipe crown.

The divers should make backfilling with self-compacting material in maximum 300 cm lifts, paying particular attention to placing of the backfill under the pipe haunches. Backfilling should be made evenly on both sides of the pipe to avoid horizontal pipe displacement. Vibrators or seabed water jetting may be used for placing and spreading the backfill material.

Protection shall be allowed for the backfilled sea bed over the pipe trench. Large stones or rocks (rip-rap) or concrete mattresses may be used for this purpose.

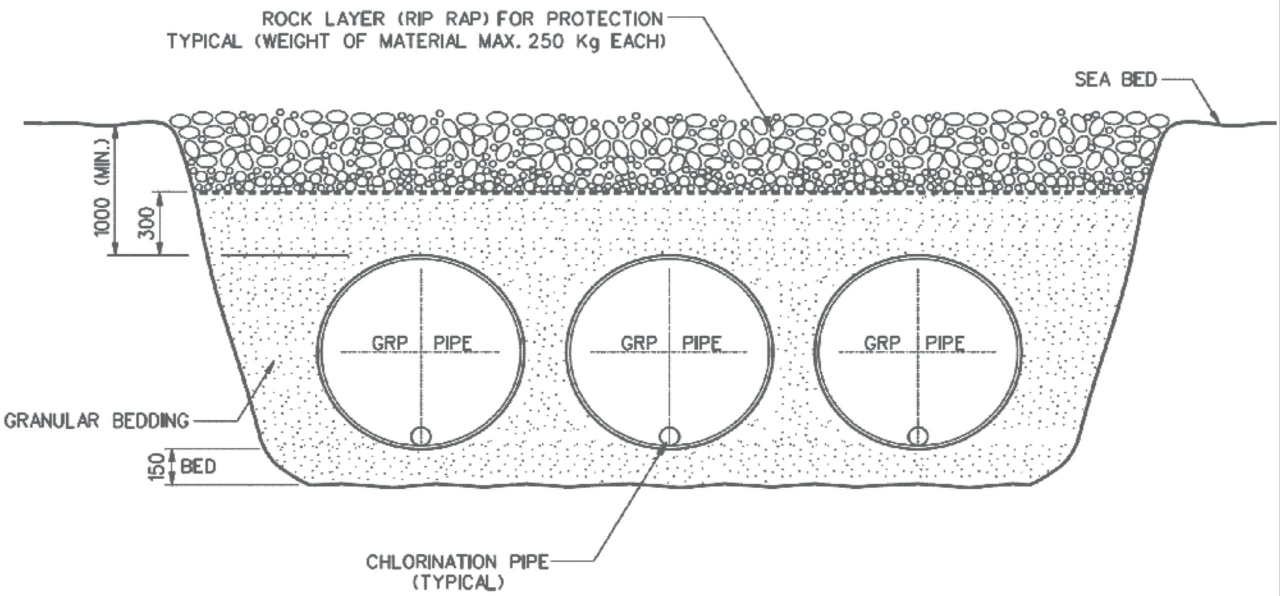

Figure 18: Offshore pipelines installation

4.10 Trenching on Slopes

The angle at which slopes can become unstable depends on the quality of the soil. The risk of unstable conditions increases dramatically with slope angle. In general, pipes can be installed on slopes up to 15° (a slope of 1:4). General recommendations give below shall be respected:

- Long-term stability of the installation should be ensured with proper geotechnical design.
- Pipes are backfilled with coarse-grained material (SC1) with high shear strength or the shear strength of the backfill is assured by other means. The maximum accepted granular size to be 25 mm, also the backfill should be compacted to at least 95% of maximum standard Proctor density (ASTM D698).
- Pipes are installed in straight alignment (±0.2°) with minimum recommended gap between pipe ends.
- Absolute long-term movement of the backfill in the axial direction of the pipe should be less than 0.75 in. (20 mm) to avoid joint separation.
- The installation is properly drained to avoid washout of materials and ensure adequate soil shear strength.
- Stability of individual pipe is monitored throughout the construction phase and the initial stages of the operation.

Consult FPI engineers for more specific installation details and procedure.

Caution: For slopes more than 15°, consult FPI for the recommend types of products and installation method that can be used for such applications.

5. JOINTS

Fiberstrong™ pipes are generally joined using Double Bell Couplings. Other jointing system such as flanges, mechanical couplings, and lamination joints may also be used for joining the Fiberstrong™ pipes.

5.1 Double Bell Coupling

Couplings may be delivered separately or mounted on one end of the pipe from the factory. If the couplings are supplied separately, it is then be mounted at the storage yard or at the trench. A home line is marked on the pipe ends as an aid for jointing; the coupling is pushed on to the pipe spigot end in order to align the home line.

Pipes delivered with couplings mounted at the factory should not be left exposed for long periods in storage as their rubber rings may be degraded by prolonged environmental exposure. Couplings with rubber center registers (stoppers) may be supplied on certain projects by FPI.

5.1.1 Joint Angular Deflection

Fiberstrong™ double bell coupling joints allows for a certain angular deflection. The maximum allowed angular deflection in operation, distributed equally on both sides of the joint, and the resulting offset and the radius of curvature (R) are given with respect to the pipe nominal diameter and the section lengths, in table 8 and table 9.

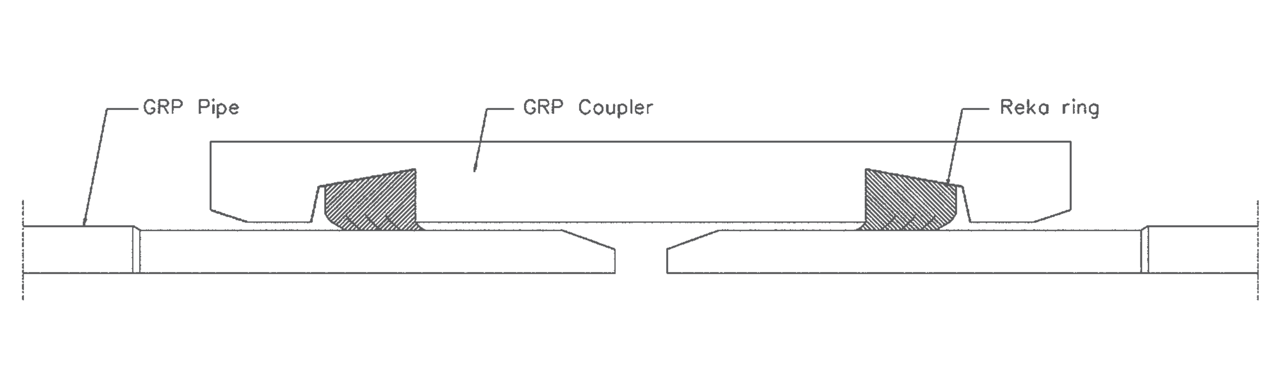

Figure 19: Double Bell Coupler Joint

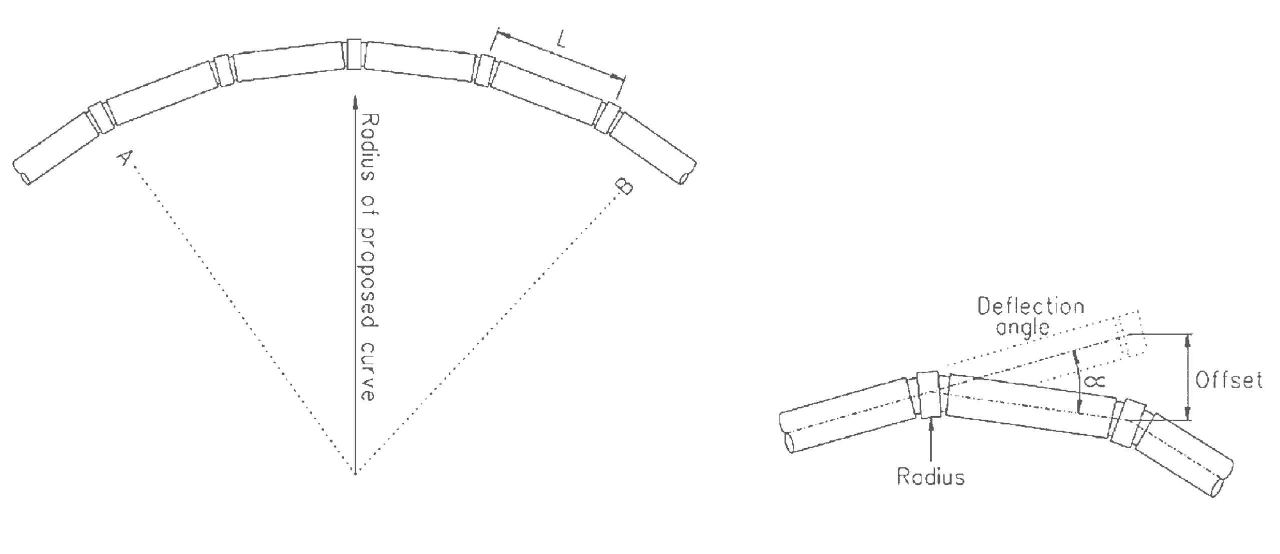

Figure 20:- Double Bell Coupler Angular deflections, offset and radius of curvature

Table 6 - Allowable Double Bell Coupler joint angular deflection for PN ≤ 16

DN (mm)	Joint deflection (degree)	Offset (mm)			Radius (m)		
		L = 3 m	L = 6 m	L = 12 m	L = 3 m	L = 6 m	L = 12 m
≤ 500	3	157	314	629	57	115	229
500 < DN ≤ 900	2	105	210	419	86	172	344
900 < DN ≤ 1800	1	52	105	209	172	344	688
DN > 1800	0.5	26	52	105	344	688	1375

Table 7 - Allowable Double Bell Coupler joint angular deflection for PN > 16

DN (mm)	Joint deflection (degree)	Offset (mm)			Radius (m)		
		L = 3 m	L = 6 m	L = 12 m	L = 3 m	L = 6 m	L = 12 m
≤ 500	1.5	79	157	314	115	229	458
500 < DN ≤ 900	1.0	52	105	209	172	344	688
900 < DN ≤ 1800	0.5	26	52	105	344	688	1375
DN > 1800	0.25	13	26	52	688	1375	2750

Note 8: The angular deflection can occur in the horizontal as well as in the vertical plane. It is recommended that above limits not to be reached during installation.

Note 9: The jointing must be done in fully straight position. Later the required angular deflection may be applied.

Note 10: Up to 50% of the above deflection angles are allowed to be used during the installation stage.

5.1.2 Joint Lubricant

For lubricant, use only a vegetable based soft soap, available from FPI. In dusty conditions lubricate generously the coupling only. The recommended amount of joint lubricant required is shown below:

Table 8 - Lubricant Consumption

DN (mm)	Amount of lubricant required per joint (kg)
80 - 300	0.05
350 - 500	0.10
600 - 800	0.12
900 - 1000	0.20
1100 - 1200	0.25
1300 - 1400	0.30

DN (mm)	Amount of lubricant required per joint (kg)
1500 - 1600	0.40
1700 - 1900	0.45
2000 - 2200	0.50
2400	0.75
2600	1.00
2800	1.20
3000	1.30
3200	1.40
3400	1.50
3600	1.70
3800	1.80
4000	2.00

Caution: Never use petroleum m product grease or automotive oils to lubricate the joint, as they will damage the rubber rings.

5.1.3 Preparation of Coupling

In order to avoid damage, the sealing rubber (REKA) ring must be inserted into the Fiberstrong™ coupling just before laying starts.

- For larger sizes, lay the coupling horizontally for better control and safety.
- Clean the groove in the coupler and the rubber ring before inserting it.
- Insert the rubber ring into the groove, leaving uniform loops extending out of the groove. There should be one loop for every 500mm of ring circumference. Do not lubricate the rubber or the groove at this stage.
- With uniform pressure, push all the loops simultaneously into the groove.
- Make sure that the compression in the ring is uniformly distributed all around the circumference.
- Install the rubber center registers in case they are provided by FPI and the GRP couplings contains a central groove.

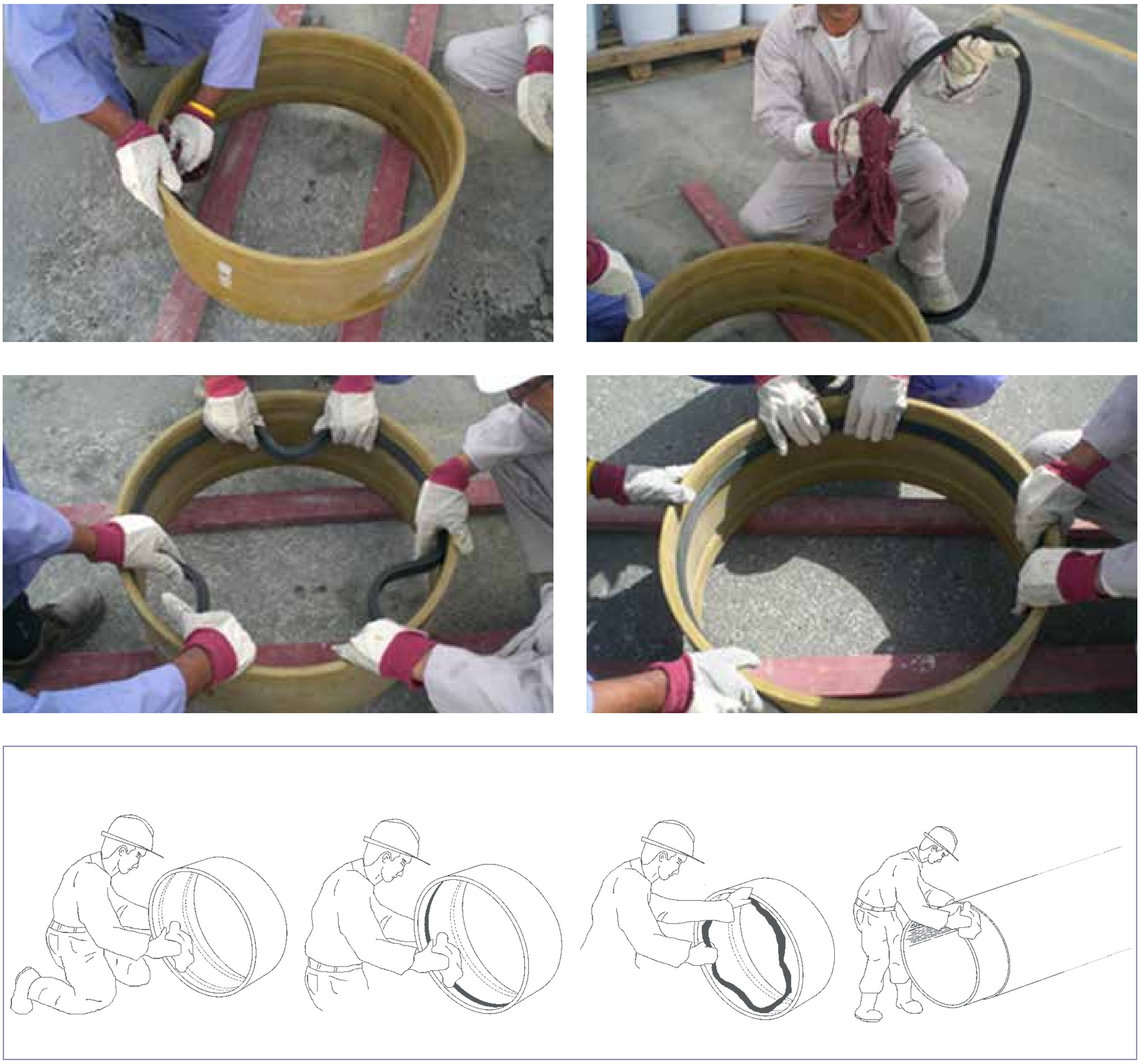

Figure 21 - Mounting the Rubber Ring Inside Coupling and Cleaning the Spigot

5.1.4 Mounting the coupling on the pipe

This operation can be carried out either inside or outside the trench. In the latter case it is recommended to lower the pipe with the free end towards the laid portion of the line. Clean coupling and pipe ends with a firm brush and inspect them thoroughly. Lubricate the pipe end and the coupling rubber ring by means of a dry clean piece of cloth or a sponge.

For small diameter pipes (DN ≤ 350 mm) the coupling can be mounted by hand or with a crow bar. Use a timber block to protect the coupling and force the coupling into the correct position that is indicated by the home line on the pipe spigot.

For pipes with diameters above 350 mm, a come-along type puller is used. This apparatus is fixed to the outside of the pipe by friction.

Caution: Under no circumstance should brute force be applied to mount the coupling. The pipes and couplings are dimensioned within tolerances that allow jointing to be carried out without using excessive effort. Below is the maximum recommended mounting force per mm of pipe diameter:

Table 9 – Maximum Mounting Force / mm of DN

DN	Maximum Mounting Force / mm of DN
< 500	1 Kg
500 - 2500	1.5 Kg
2600 - 4000	2 Kg

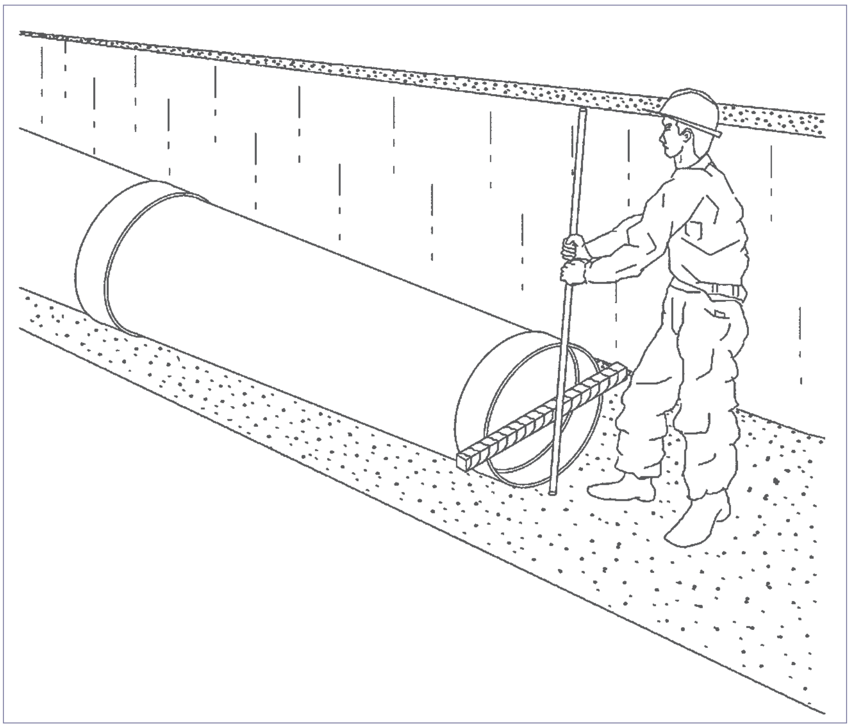

Figure 22 : Mounting the coupling for DN > 350 mm

5.1.5 Inserting pipe in the coupling

Joints should be made inside the trench following the procedures shown in figures 23 and figure 24. A steel strap with rubber lining must be fixed on the installed pipe at the home line in order to stop the insertion of the pipe in the coupler at the pipe home line. Alternatively, a wooden spacer may be used inside the couplings to maintain the correct spacing. All spacers must be removed immediately after jointing the pipes. Spacers may damage air valves and other valves fitted in the system if they are not removed before the hydrostatic test. Before insertion, the two pipes should be perfectly aligned and leveled to avoid any damage to the rubber rings.

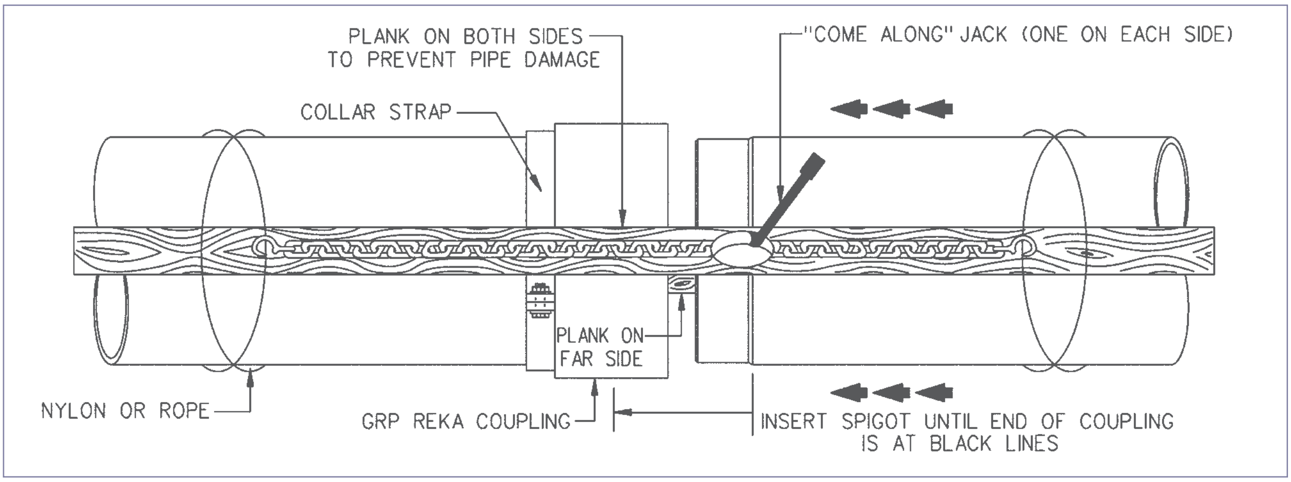

Figure 23: Pipe Jointing using a "come along" jack

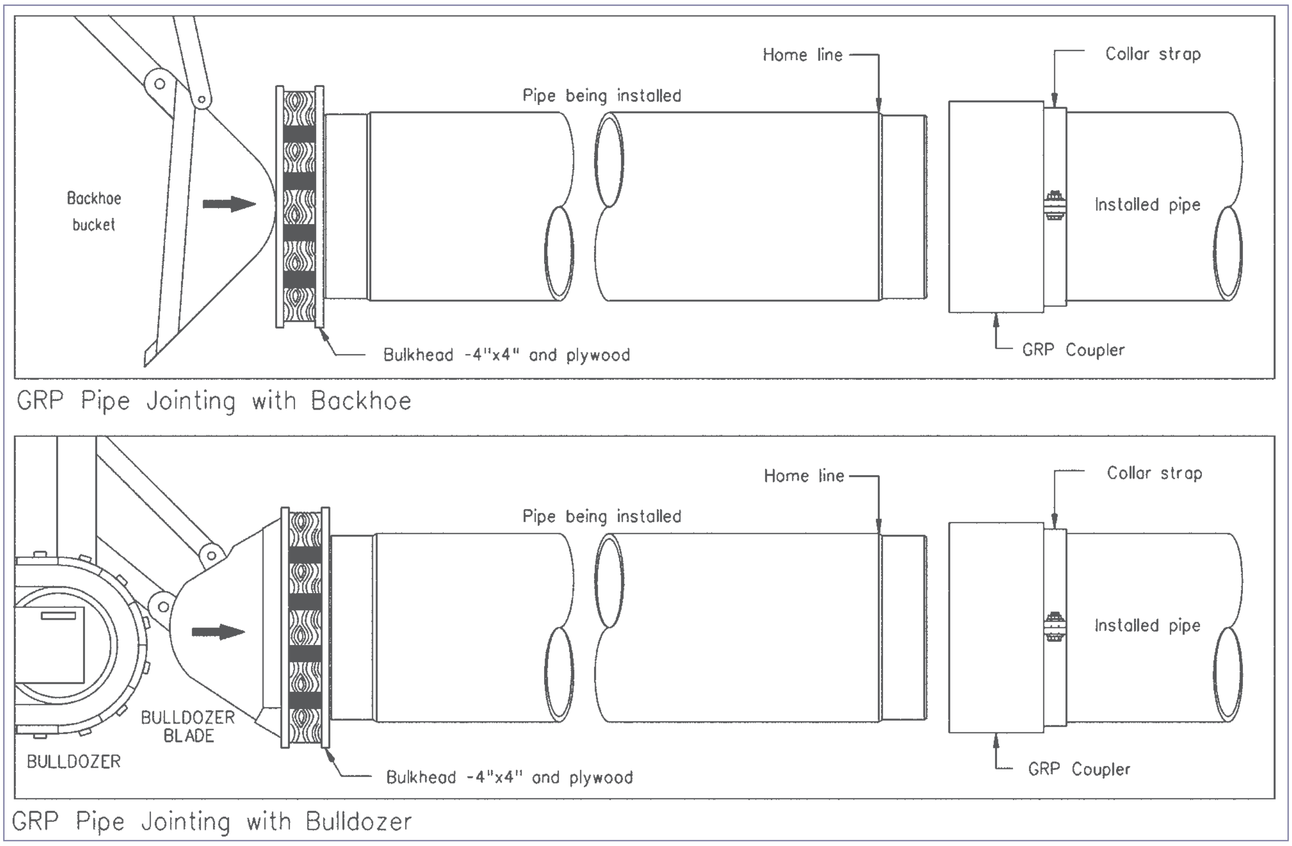

Figure 24: Pipe jointing using construction equipment - use with caution

Working with mounting equipment, although very efficient, should not be carried out by unskilled laborers. Risks of damaging or dislodging a rubber ring should not be disregarded. It is essential to push the coupling to the home line and not beyond, otherwise the pipes in the coupling will touch each other and will consequently not allow for any expansion or deflection inside the joint. Only skilled operators should attempt to use the boom of an excavator to push either coupling or pipe, as the direction of the applied force is not under control and might damage the pipes and/or the coupling. No steel tools should come into direct contact with the edges of the pipe or its external surface. Pipe edges should be protected with a timber.

5.2 Pipes with Locked Joints

For some underground applications, Fiberstrong™ pipes might be provided with a restrained mechanical joint with rubber ring (can be REKA rubber or O-Ring rubber) and locking strip as shown in figure 25. In this case special Fiberstrong™ pipe designed to resist the high longitudinal stresses is provided. One locking key (strip) is inserted into the joint to restrain the two-pipe sections jointed. Typical joint configurations for rubber seal locked joint (restrained bell and spigot joint) are shown in Figure 25.

The joint assembly shall be done as per the following recommendations:

- Clean the spigot and socket thoroughly with a clean cloth.
- Position the rubber ring into the groove of the pipe spigot end. Both the rubber and the groove should be cleaned before fixing the rubber ring.

Ensure that the tension is well distributed around the rubber ring by passing a screwdriver radially underneath the rubber ring.

- Lubricate the rubber ring and the socket inner surface. Avoid lubricant under the rubber ring in order to prevent it from slipping out of the groove.
- The two pipes should be kept aligned and leveled before and during assembly. The joint should be assembled in such a way that the position of the hole in the socket allows the locking strip to be inserted easily.
- Lubricate lightly the first 15-20 cm section of the locking key (strip).
- The beveled end of the locking key should be resting against the inside surface of the socket when inserting. The insertion should be made using a wooden hammer or a piece of wood to tap the key until it rests against the first part of the key.
- The Contractor must ensure that the locked joint is stretched after assembly and that both the spigot stop and coupling (Bell) stop are in contact with the locking key.
- The maximum allowable joint deflection for "locked" socket joints is shown in Table 12. It is recommended not to reach this value during installation. Only 50% of this limit is allowed during the installation

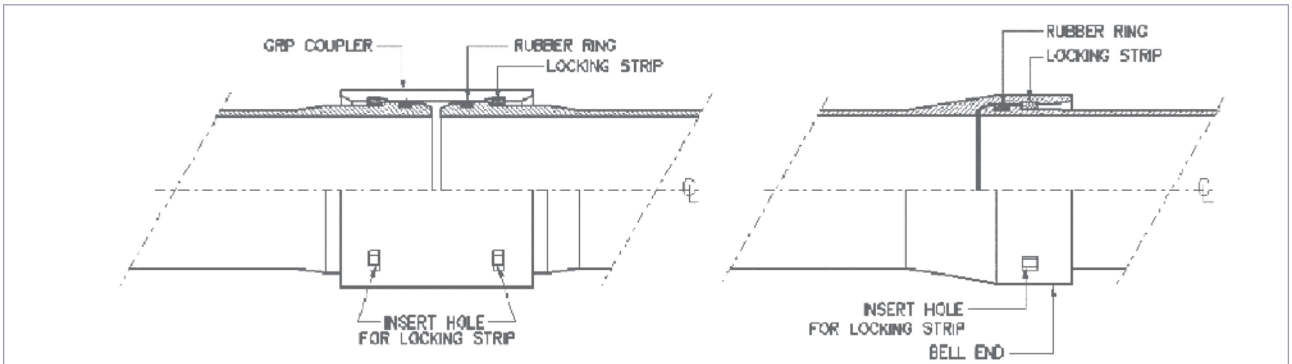

Figure 25: Typical Locked Joint

Table 10: maximum allowable joint deflection for "locked" socket joints

DN (mm)	Angular Deflection (°)
300	1.0
350	1.0
400	1.0
450	1.0
500	1.0
600	1.0
750	0.5
800	0.5
900	
100	0.5
1,000	0.5
1,200	0.5

5.3 Lamination Joint

This joint is made from glass fiber reinforcement impregnated in resin. The length and thickness of the joint depends on the diameter and pressure.

This type of joints requires special designs, working conditions and should be performed only by FPI technicians or experienced skilled workers. Job-specific lamination recipes will be provided by FPI.

Always consult FPI before performing lamination joints. Under no conditions should laminated joints be made under wet conditions or water allowed to contact the pipe, glass reinforcement or resin until the joint is cured. Keep resin away from open flame or intense heat sources as the resins are flammable liquids.

5.4 Flanged Joint

Flanged pipes and fittings can be provided for use inside valve chambers. Both fixed flange and stub-end with a loose flange ring can be used for the installation. The loose flange ring can be rotated to easily align with the bolt holes in the mating flange.

Contact FPI for flange thickness values before ordering flange bolts or stud bolts as they are thicker than steel flanges. Also, to consider the Fiberstrong™ flange thickness when designing the chambers to have adequate assembly space. Always use a torque wrench to tighten Fiberglass flanges. Always use washers under bolt heads and nuts. For Tightening of Flanges, tightening sequence and flange torque values, please refer to FLG GUIDE 001

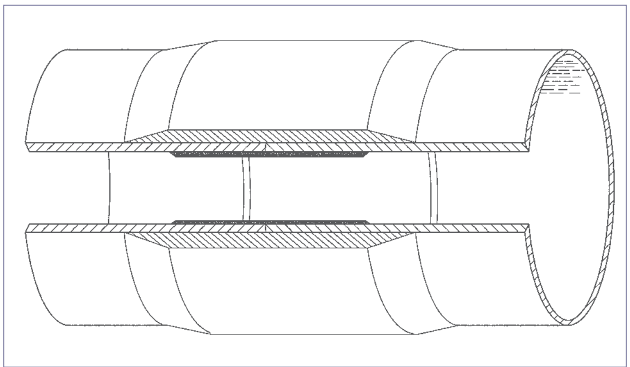

Figure 26 : Lamination Joint

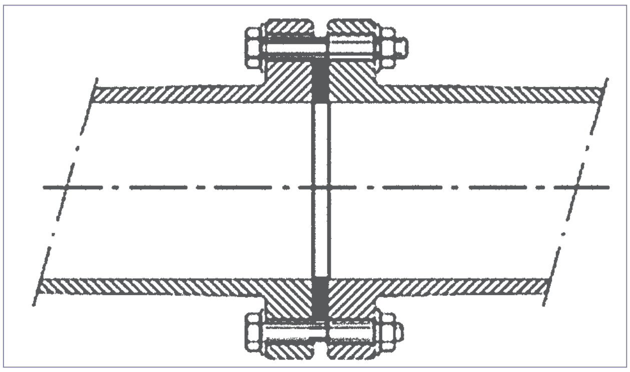

Figure 27 : Flanged Joints with flat gasket

6. SPECIAL REQUIREMENTS

6.1 Standard Short Pipe Length

Standard short Fiberstrong™ pipe lengths are required in various situations, such as:

- Outside rigid structures (i.e. water reservoirs, pumping station, thrust blocks, valve chambers, manholes etc.)

- To connect the pipes to a line fitting such as bends or tees inside thrust blocks.

Standard short lengths of pipes shall be planned ahead by the Contractor. The recommended length (L) of standard short pipe is as shown below.

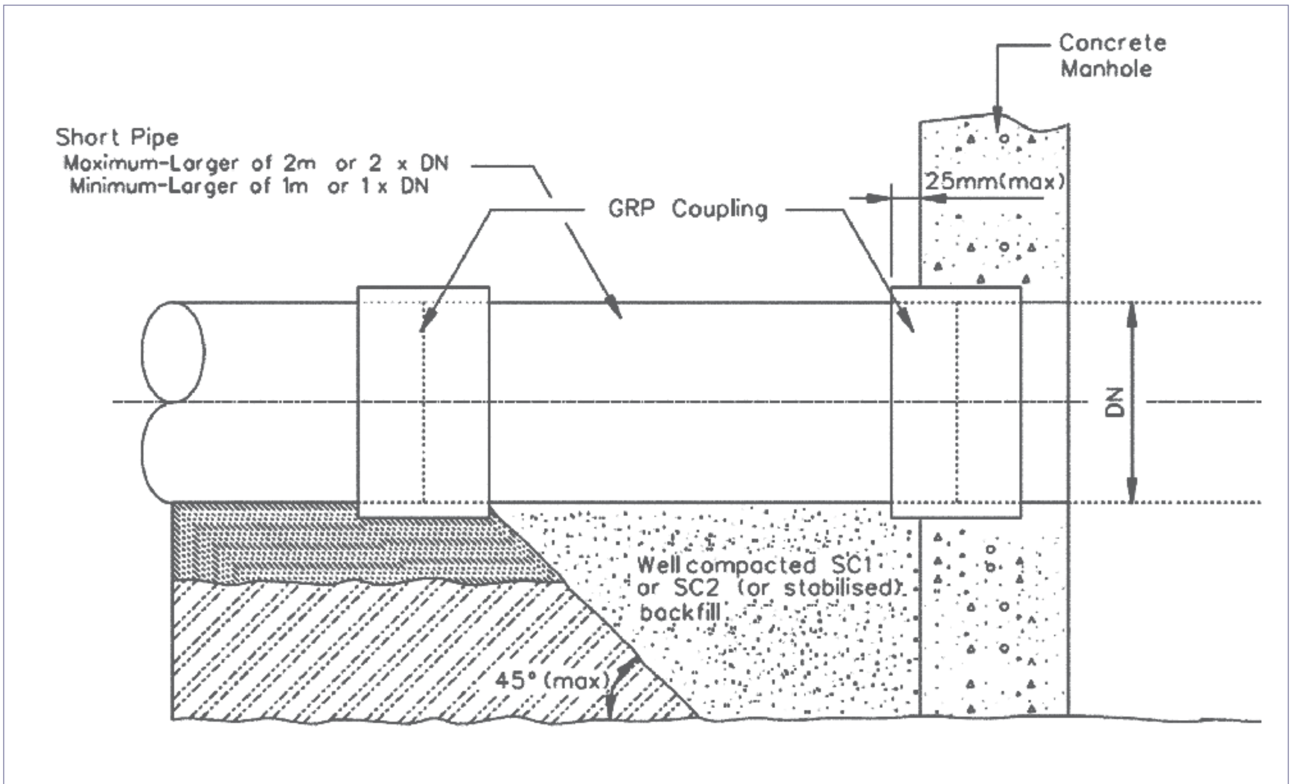

Figure 28: Standard Short Pipe

Caution:

1. The expected settlement for massive concrete structure shall be calculated by the geotechnical engineer to determine the number of short pipes & couplers required to withstand the settlement without excessive loads onto the pipes.

2. Backfilling outside concrete structures shall be thoroughly compacted with the same selected backfilling material. Using backfill of granular Class I material (0-25mm) compacted to 95%SPD is recommended to minimize differences in deflection of couplings and adjacent pipe. Cement stabilizing soil can be also used at this area (outside the concrete structures).

3. FPI's technical team should be consulted for recommendations under special situations where the anticipated differential settlement is high.

6.2 Wall Penetration

Recommended wall penetration protection and rubber wrapping are shown in the figure 29 and 30.

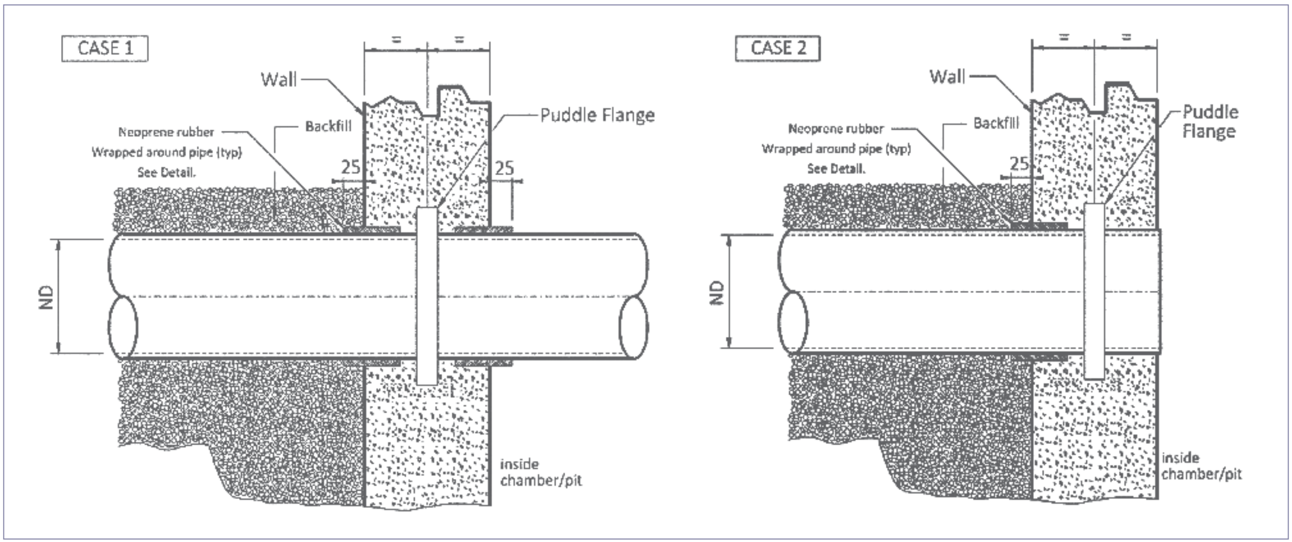

Figure 29: Wall Penetration

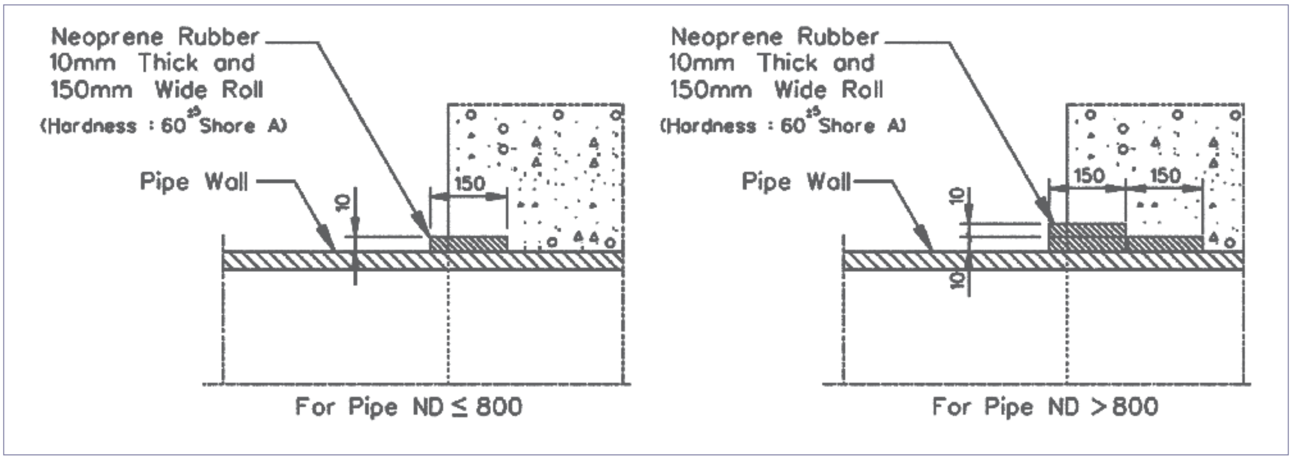

Figure 30: Rubber Wrapping

6.3 Pipeline Closure

For a closure in a line it is required to order a special short pipe from the factory with double spigot width calibration. The Contractor should clearly indicate in his order that a short pipe closure is required. In closure pipes, the length of the machining is equal at least to the width of the Fiberstrong™ Reka coupling plus 30 mm. In case of export jobs or where the site is very far from the factory, cutting and machining of closure pipes must be carried out on site. FPI will provide supplementary instructions for export projects.

Before ordering a closure pipe, the Contractor should measure accurately the gap between the two ends of the line. The length of the pipe to be fitted must be 32 mm less than the measured length to allow a gap of 16 mm between the jointed ends in both couplings. Mark the home line on the machined ends and lubricate them abundantly. The assembly of the short length pipe is made as indicated in the Figures 31 and 32.

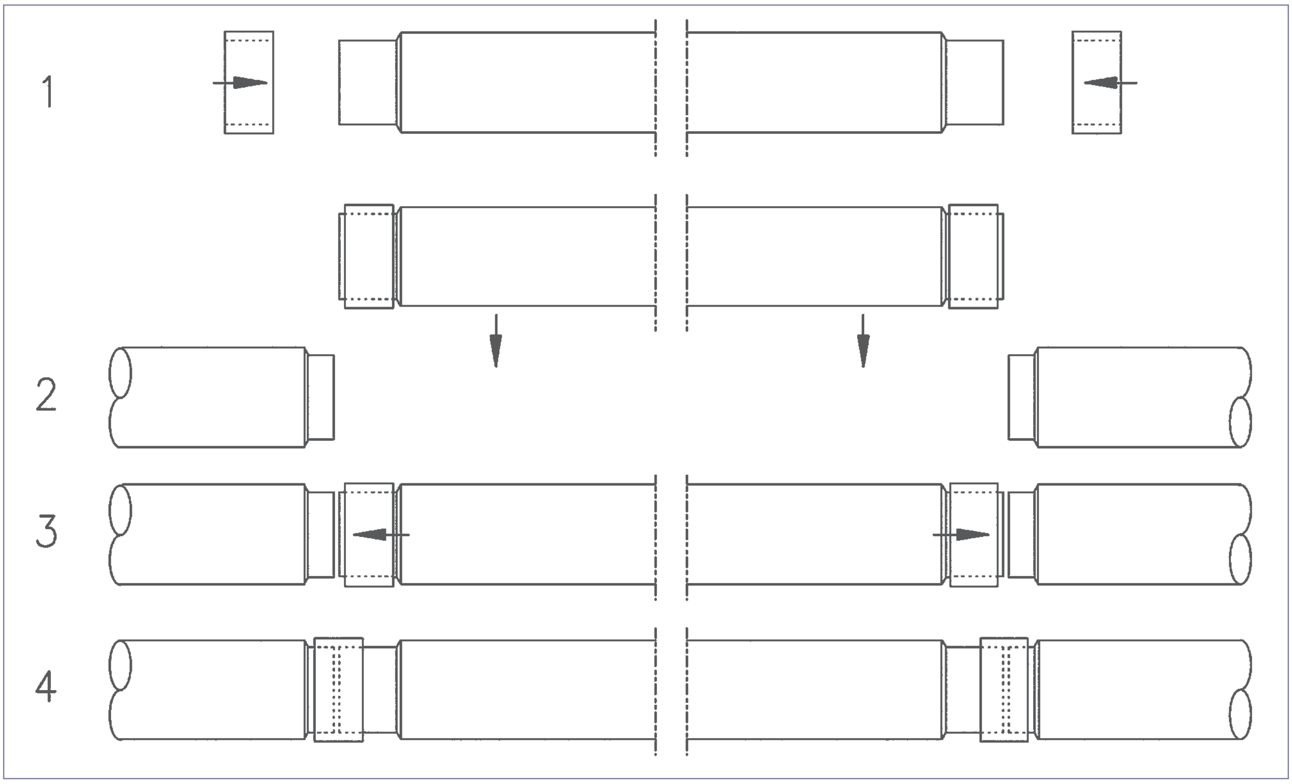

Figure 31: Pipeline closure

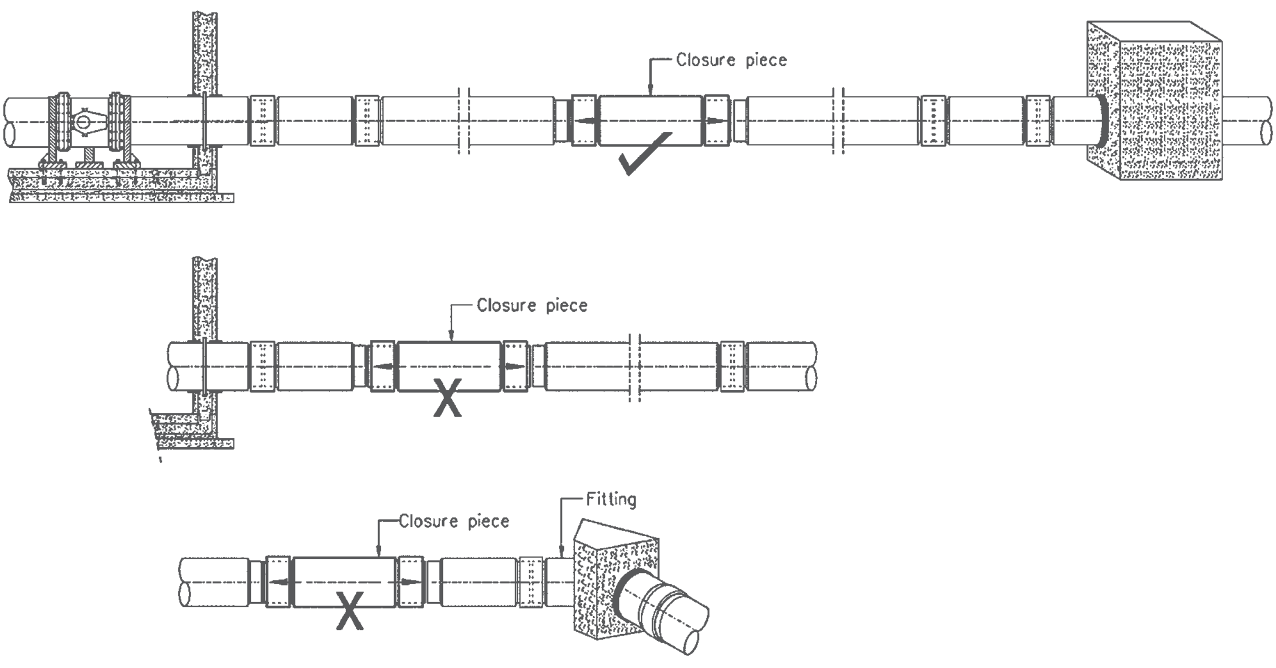

Figure 32: Planning the location of “Closure” piece

Caution:
When pulling the couplings over the closure pipe it is necessary to pull the second rubber ring smoothly over the chamfered end of the pipe to avoid damaging it. For that purpose, apply a continuous layer of approved lubricant.

6.4 Thrust Blocks and Anchoring

Thrust blocks must be used in pressure pipeline systems wherever thrust loads are expected, such as at:

- Changes of direction (bends, Tees, Wyes)
- Cross section changes (reducers)
- Valves and hydrants
- Dead ends
- Elevation difference (slope)

The thrust blocks are dimensioned and designed by the Contractor's or owner's Engineer according to the expected thrust load during operation and testing, as well as native soil properties. Thrust block spaces must be foreseen in the design and trench excavations. At vertical bends, the line or the bend must be anchored by thrust blocks or other means to resist outward thrusts. Thrust blocks must be cast against undisturbed trench walls (native soil) and must completely encase the Fiberstrong™ fitting, except at the joint area. The maximum allowable displacement of fittings is 0.5% of the diameter, or 6 mm; whichever is less. The outlet part of the encased Fiberstrong™ fitting in the concrete block shall be rubber wrapped as shown below in figure 30. See appendix II for additional information about thrust blocks. Elbows, reducers, standard tees, and blind flanges (dead ends) at operating pressures of 1.0 bar and below, do not require thrust blocks when installed underground.

Caution:

1. Always provide a standard short pipe length outside thrust blocks (see section 6.1) to protect the pipeline from differential settlement.
2. Laying length of fittings shall be considered while designing the thrust block dimensions.
3. Exposed length of fitting shall be considered while designing the thrust block. Minimum distance as shown in figure 28 shall be considered.

Nozzle connections normally do not require concrete encasement of the header or the nozzle branch. Nozzles are defined as being tee branches meeting all the following criteria:

1. Nozzle diameter ≤ 300 mm
2. Header diameter ≥ 3 times nozzle
3. If the nozzle is not concentric and /or not perpendicular to the header pipe axis, the nozzle diameter shall be considered to be the longest cord distance on the header pipe wall at the nozzle/pipe intersection.

6.5 Concrete Encasement

Pouring concrete around the pipe results in uplifting forces that can damage the pipe and / or joint. To avoid such movement, the pipe should be anchored downward by straps hooked to a rigid base as shown in figure 33.

The straps should be of flat material of minimum 25 mm width and strong enough to withstand flotation uplift forces. The distance between straps should not exceed 4 meters, with a minimum of two strap per section length. The straps should be tightened to prevent pipe uplift, but should not be over-tightened to avoid additional pipe deflection.

The pipe should be supported in such a way that the concrete can easily flow completely around and fully underneath the pipe. Also, the supports should result in an acceptable pipe shape (less than 3% deflection and no bulges or flat areas).

The concrete must be placed in stages allowing sufficient time between layers for the cement to set. This is to avoid excessive buoyant forces or shrinkage stresses exerted on the pipe. The maximum lift height depends on the pipe stiffness class:

- Stiffness class SN 2500 Pa, maximum of 300 mm or 1/4 pipe diameter
- Stiffness class SN 5000 Pa, maximum of 450 mm or 1/3 pipe diameter
- Stiffness class SN 10000 Pa, maximum of 600 mm or 1/2 pipe diameter

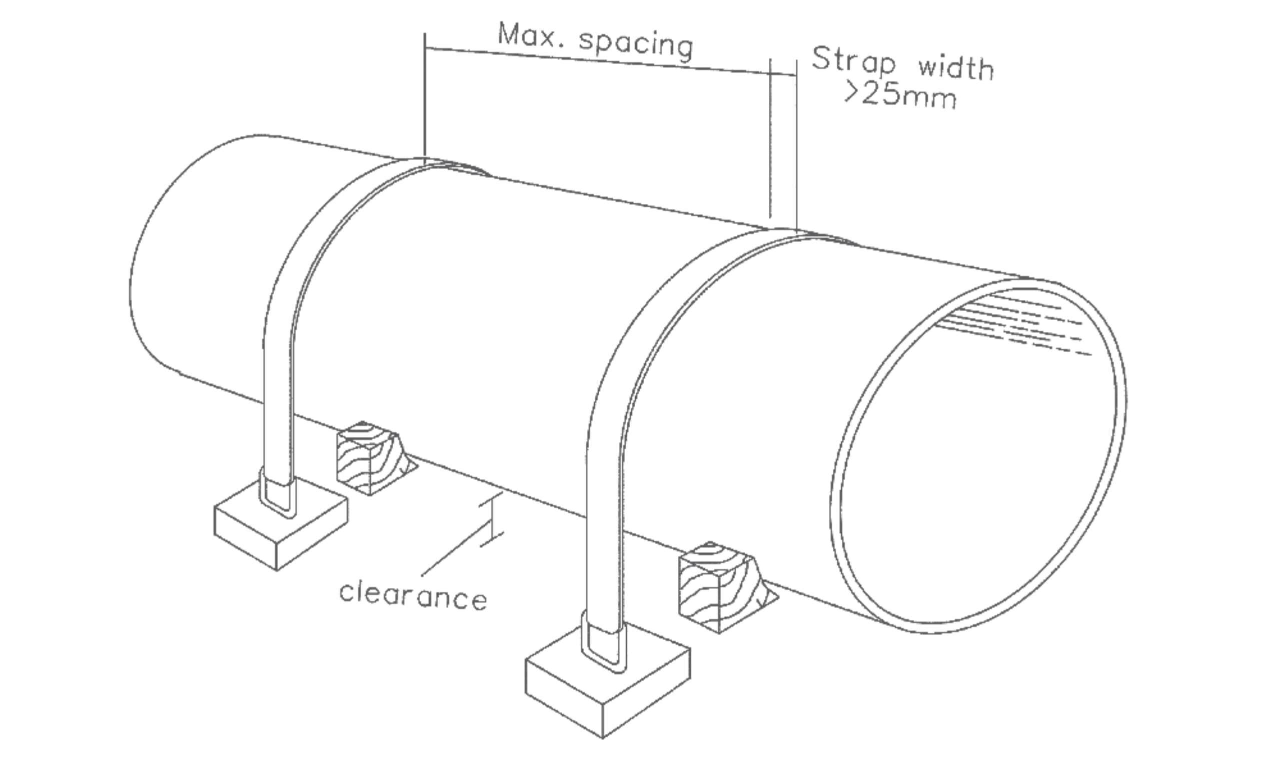

Figure 33: Pipe anchored by straps

7. PIPE DEFLECTION

The deflection of Fiberstrong™ pipe depends on the pipe diameter, pipe medium, and native soil classification. Pipe deflection is defined as the percentage reduction in vertical diameter after installation, as shown in figure 34

$$\text{Deflection } \% = \frac{\text{Actual Undeflected Pipe ID-Installed Vertical ID}}{\text{Actual Undeflected Pipe ID}}$$

To ensure that the long-term deflection does not exceed the maximum allowable limit, the preliminary & initial deflection of the pipe must be monitored and controlled on site by the Contractor. Maintaining the deflection within the allowable limit is achieved by proper selection of pipe stiffness, installation method related to the native soil conditions, and maximum burial depth.

Measuring pipe deflections is easy and is the best way for the contractor to check if the installation was executed properly. Fiberstrong™ pipes deflection is measured in the following manner:

For pipe sizes 800 mm and larger, where human entry inside the pipes is possible, the installed vertical pipe ID can be measured by means of a suitable mechanical inside micrometer at 3 to 4 m intervals along the pipe length. An electronic deflectometer can be used to measure the deflection of the pipes of diameter within the range of 150 to 800 mm. A probe with sensor arms is pulled through the line, recording the pipe ID on a data logger kept outside the line. The results are then presented on a computer-generated report.

Note 11: It is important that pipe deflection measurements are done at the same time frame of pipe laying operations and within one month from completing backfill. This will allow for early detection of any installation deficiencies and allow corrective action to be taken quickly in order to reduce the time and expenses necessary to rectify defective installations.

7.1 Preliminary Deflection

This measurement should be taken when backfill reaches 300 mm above pipe crown. At this stage the measured deflection should be slightly negative, but not exceeding -2%. A negative % deflection means the pipe vertical ID has increased because of the compaction forces/ stresses coming from the side backfill and indicates good compaction effort by the contractor.

A positive % deflection at this stage indicates inadequate compaction in the Pipe Embedment Zone, hence improvement in the quality of installation and compaction is required. In such cases, it is advisable to remove the backfill down to about ¼ of the pipe ID from the pipe invert level and to re-compact the backfill in stages up to the top of the pipe zone, with special care to the compaction of the pipe haunches backfill area. After this rectification, the preliminary deflection should be measured again

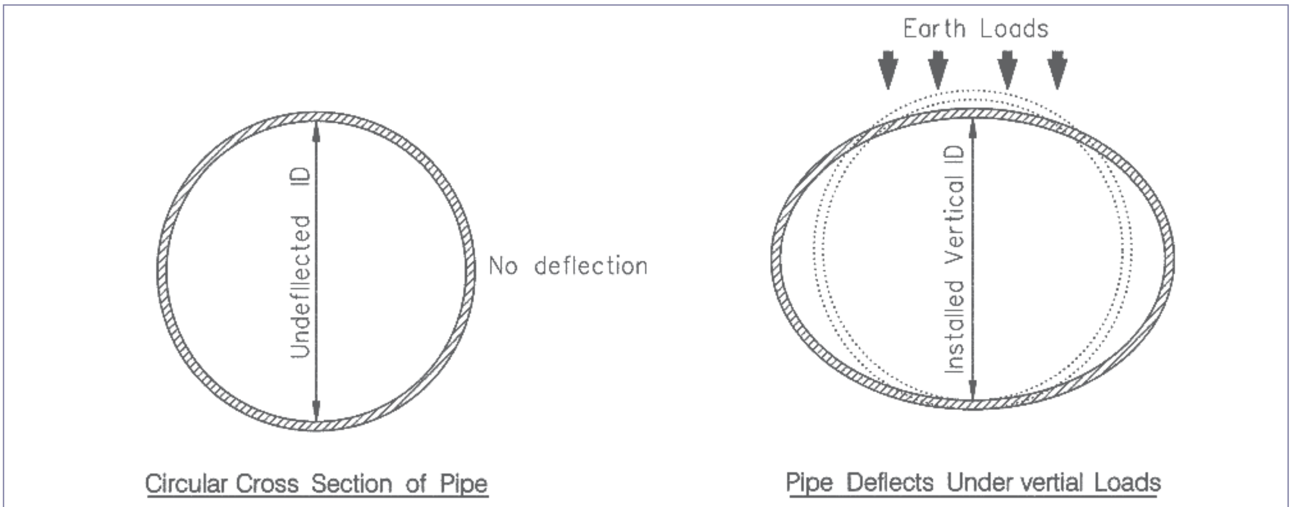

Figure 34: Pipe deflection

7.2 Initial Deflection

This measurement should be done immediately after the backfilling reaches the final grade and all de-watering systems have been turned off for two days. The initial % deflection limits shown in table 10 are set to account for soil creep and soil consolidation with time.

If the initial deflection exceeds the allowable limits shown below up to 8% of the pipe diameter, the Contractor should re-excavate the trench (by hand from 0.3 m above pipe crown), remove the pipe embedment zone backfill down to the bedding level and then to start re-backfilling the pipe, paying attention to the pipe haunches and backfilling in appropriate lifts to reach the required compaction.

If the initial deflection slightly exceeds (by no more than 1 %) the allowable limits below, the recommended remedial action is the re-excavation and re-backfilling

of the pipe in accordance with 7.1, however at the discretion of the Engineer – the pipe can be left in place and deflection may be monitored over the following 6 months period with monthly deflection measurements. If the % deflections readings at the end of the 6 months do not exceed the allowable long-term deflection limit, the pipeline section may be considered as accepted.

Any recently installed pipe exhibiting % deflections equal or greater than 9% (7% for pipes SN 10,000) must be replaced. Such pipe must not be re-installed nor incorporated in any permanent works on site.

"Good" pipe installations where high compaction of sand bedding and backfill is achieved, should exhibit initial % deflections measurements of 2 % or less for SN 5000 and SN 10000 stiffness pipe. "Good" installations with compacted gravel/ crushed stones bedding and backfill, should exhibit initial % deflections of around 1 % or less for all stiffness classes. Initial pipe deflections are a good indicator of the quality of installations. The pig design shown in Figure 35 should be limited to DN1200, large diameter pipe deflection can be measured manually using telescopic measuring rod as shown in Figure 36.

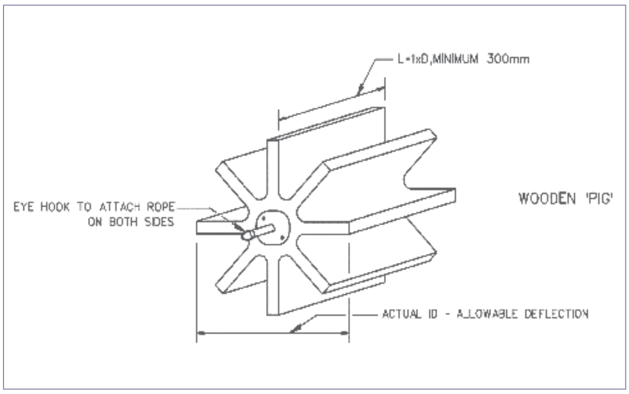

Figure 35: Pipe pig

Figure 36: Telescopic measuring rod

7.3 Final Deflection

When practically possible or in case of doubt, this measurement should be done at least 6 months after the initial deflection test is done. The maximum long term % deflection at this stage should not exceed the limits specified in table 10.

Table 11 - Maximum allowable deflection - initial and long term

Native soil group	Deflection (% of Pipe Diameter)				
	1	2	3	4	5
Large Diameter Pipes, DN > 300 - Water and Sewer					
Initial	3.5	3.5	3.0	2.5	2.0
Long Term	5.0	5.0	5.0	5.0	5.0
Small Diameter Pipes, DN < 300 - Water					
Initial	3.0	3.0	2.5	2.0	2.0
Long Term	5.0	5.0	5.0	5.0	5.0
Small Diameter Pipes, DN < 300 - Sewer					
Initial	2.5	2.5	2.0	1.5	1.5
Long Term	4.0	4.0	4.0	4.0	4.0

Note 12: refer to the project specific deflection test for detailed information

8. SITE TESTING

8.1 Line Hydrostatic Testing

8.1.1 Preparation

Prior to the hydrostatic test, several points must be checked in order to avoid failures.

While the contractor tends to test long sections to increase his efficiency, the length of the test section should be short enough to allow an easy detection of any possible leak. It is also difficult to fill a very long line without the risk of air entrapment.

It is highly recommended to test the first few sections with a maximum distance 500m in order to confirm that the installation sequences/ procedures were done according to the FPI installation procedures and to detect and correct any shortfalls in contractor's installation procedures. The test section length may be progressively increased based on the specific project plan & requirements. Longer test sections make the detection of leaks more difficult.

The backfilling must have been carried out properly and reached a level that would restrain the pipes to avoid movements during testing. For the pipeline installed in straight alignment and test pressure > 16 bar, the pipes shall be backfilled to the minimum cover depth and the couplings shall be backfilled at least to the crown prior to the hydrotest. For the pipeline installed with angular deflection or test pressure > 16 barg, the pipes and couplings shall be backfilled to the final grade prior to the hydrotest. It's also recommended to mark the coupling location with wooden stakes or equivalent marker for easy reference in case any failure took place. The thrust blocks, which are part of the pressure test section, should be of permanent constructions and concrete should be poured at least 7 days before testing. The opened ends of a line must be sealed temporarily with a GRP or steel/Cast iron end caps. GRP testing end caps can be purchased from FPI. Refer to the project specific hydrostatic MS for further details.

All the end-caps should have an inlet for water filling and an outlet for venting. The inlet should be placed at the bottom of the end cap at the low end of the test section and the venting outlet at the top of the end cap at the high end. See figure 37 for a typical arrangement of a test section and apparatus. The approximate end thrust force is given in table 11. Testing against closed valves is not advisable and the contractor should note that most butterfly valves do not provide a water-tight seal at 1.5 x their rated pressure.

The contractor shall plan the hydrotesting to proceed in parallel with the progress of installation works and not to lag behind. It is highly recommended to test the pipeline sections within a maximum of 1-2 months after completing pipe installation and backfilling.

Table 12 - End Thrust during pressure testing

DN (mm)	End Thrust Force (Metric Tons)						
	Test Pressure (bar)						
	4.5	9	15	18	24	30	37.5
80	0.2	0.5	0.8	0.9	1.2	1.5	1.9
100	0.4	0.7	1.2	1.4	1.9	2.4	3.0
150	0.8	1.6	2.7	3.2	4.2	5.3	6.6
200	1.4	2.8	4.7	5.7	7.5	9.4	11.8
250	2.2	4.4	7.4	8.8	11.8	14.7	18.4
300	3.2	6.4	10.6	12.7	17.0	21.2	26.5
350	4.3	8.7	14.4	17.3	23.1	28.9	36.1
400	5.7	11.3	18.9	22.6	30.2	37.7	47.1
450	7.2	14.3	23.9	28.6	38.2	47.7	59.6
500	8.8	17.7	29.5	35.3	47.1	58.9	73.6
600	12.7	25.5	42.4	50.9	67.9	84.8	106
700	17.3	34.6	57.7	69.3	92.4	115	144
800	22.6	45.2	75.4	90.5	121	151	189
900	28.6	57.3	95.4	115	153	191	239
1000	35.3	70.7	118	141	189	236	295
1100	42.8	85.5	143	171	228	285	356
1200	50.9	102	170	204	271	339	424
1300	59.7	119	199	239	319	398	498
1400	69.3	139	231	277	369	462	577
1500	79.5	159	265	318			
1600	90.5	181	302	362			
1800	115	229	382	458			
2000	141	283	471	565			
2200	171	342	570	684			
2400	204	407	679	814			
2600	239	478	796				
2800	277	554	924				
3000	318	636					
3200	362	724					
3400	409	817					
3600	458	916					
3800	510	1021					
4000	565	1131					

(Some diameter/pressure combinations might not be available)

8.1.2 Bracing Test-ends and Set-up

Due to the thrusts occurring at the testing endcaps, temporary blocks must be used to brace the pipe end caps in order to prevent line displacement as indicated in figure 37.

Jacks should be placed in the gap between the end of the pipeline and the block as shown in figure 37. The last pipe length should also be wedged on both sides, at the top and at the bottom, in order to prevent lateral and vertical movements.

Note 13: It may be possible to reduce the size of the concrete blocks by driving into the ground several meters deep, two or more steel sheet piles (curtains) back to back. Sheet pile positioned behind the concrete blocks will provide additional bracing.

8.1.3 Filling the Line with Water

The line being tested should be filled slowly with water from the lowest end point. At high points, air vents should be installed to release the entrapped air. After filling, the temperature shall be allowed to stabilize before commencing pressurization. This may take around 6 to 48 hours, depending on the temperature difference between the fill water, the soil surrounding the pipeline, type of soil, air temperature, etc.

Once the temperature is stabilized, the pressure will be raised to the strength test pressure in the following steps:

- Raise the pressure to 0.5 x Test pressure with half-hour stabilization and monitoring.
- Raise the pressure to 0.8 x Test pressure with half-hour stabilization and monitoring.
- Raise the pressure to final test pressure. The rate of pressurization shall not exceed 2 bar per minute.

Following the stabilization period and after expelling all the entrapped air out of the pipe test section, the air vents should be closed.

Volume of water required

Table 10 indicates, the approximate volume of water required in order to fill FIBERSTRONG® pipes per 100 meters of pipeline.

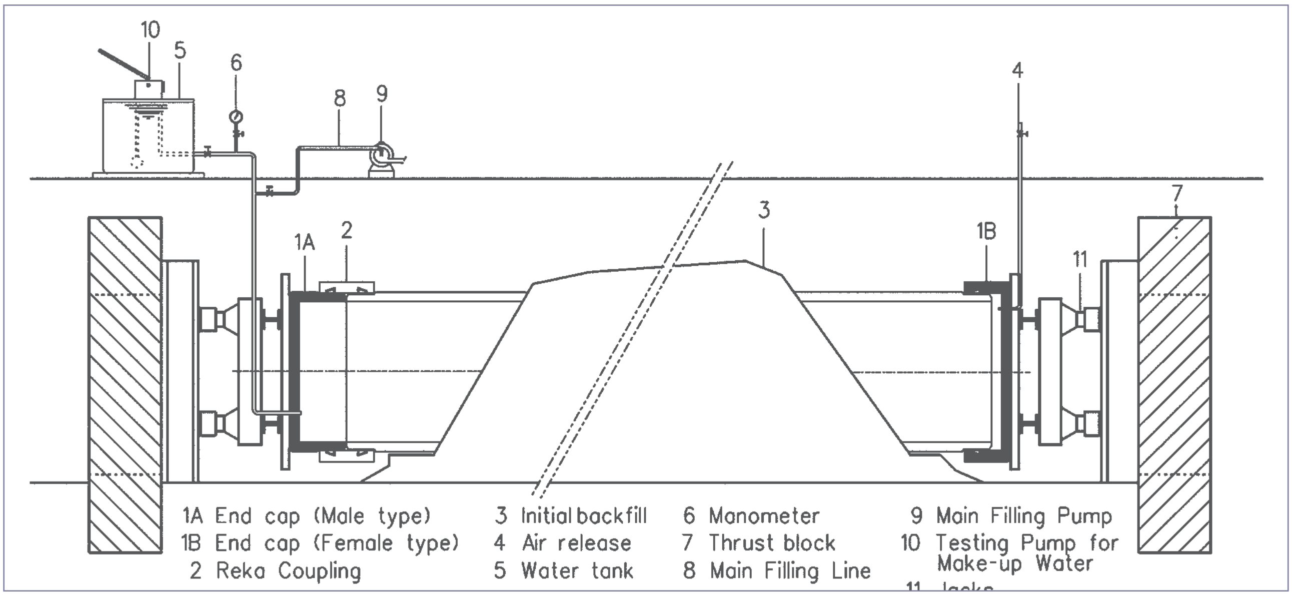

Figure 37: Thrust blocking pipe ends and site pressure test set up

Table 13 - Volume of water required/100 m of pipeline

DN (mm)	Water volume (m3) / 100 m of pipeline
80	0.5
100	0.8
150	1.8
200	3.1
250	4.9
300	7.1
350	9.6
400	12.6
450	15.9
500	19.6
600	28.3
700	38.5
800	50.2
900	63.6
1000	78.5
1100	95.0
1200	113.0
1300	132.7
1400	153.9
1500	176.6
1600	201.0
1700	226.9
1800	254.3
2000	314.0
2200	379.9
2400	452.2
2600	530.7
2800	615.4
3000	706.5
3200	803.8
3400	907.5
3600	1017.4
3800	1133.5
4000	1256.0

8.1.4 Sectional Leakage Test

After the stabilization period, the pressure shall be raised gradually at a maximum rate of 2 bar/min for low pressure systems and 5 bar/min for high pressure systems. The pressure is increased until the intended test pressure at the lowest point in the pipeline is reached.

Unless otherwise specified by the Engineer, the test pressure shall be equal to 1.5 times the intended working pressure of the pipeline section, ensuring that the test pressure in the section shall not exceed 1.5 times design pressure of the system. Once the required test pressure is reached, the test pressure should be maintained for a "holding period" not exceeding 2 hours as per ISO 14692-Part 4 – clause 4.6.23.1 by pumping if necessary, the pump should then be disconnected, and no further water permitted to enter the pipeline section.

At the end of this holding period, the original test pressure shall be maintained (if there is a drop in pressure) by pumping water from a graduated water tank and measuring the amount of water necessary to restore and maintain the test pressure. This period shall not exceed one hour, during which the makeup water should not exceed 0.02 liter/mm of nominal diameter, per kilometer of pipeline, per 24 h duration, per bar of test pressure applied (average test pressure of section).

Example:
Diameter = 600 mm, test section length = 0.5 km, test P = 16 bars-average, duration = 1 hr

Allowable loss during test =
(0.02/24) x 600 mm x 1 hr x 16 bars x 0.5 km = 4 liters

During the pressure test, all joints, flanges and closed valves should be visually inspected (where possible) (refer to section 8), and all visual leaks must be repaired. In case the test is not satisfactory, the locations of the leaks shall be determined and rectified and the line re- tested in the same manner as specified above. The test section shall be accepted only after successfully passing the above leakage test.

Note 14: the contractor should note that while pressure testing large diameter pipe on site, there is a possibility of a slight rotation/pivoting of REKA coupling (generally for high pressure systems). This is the result of uneven pressure against the various parts of coupling and is inevitable during normal joint assembly where a perfectly centered and aligned joint can never be achieved. In the unlikely event that one or more coupling(s) starts to rotate or to shift during the pressure test, it's advisable to reduce the pressure and to backfill the joints completely using selected, properly compacted backfill prior to resumption of the pressure test. Any joint that has shifted significantly should be centered again before resuming the pressure test.

During the test period, if the pressure drops, make sure that the thermal effect and the air entrapped is not the cause.

8.1.5 Pipeline Testing
After final backfilling has been completed and the entire pipeline construction has been completed and pressure tested (except at the closing ends or tie-in joints of the pipeline), the line may be subjected to a final pressure test (if required), if the line can be isolated from service connection or other pipelines, following the same basic procedures described in section 8.1.4. The final test pressure is equal to 1.25 times the intended working pressure of the pipeline at the lowest point (unless otherwise specified by the Engineer). The duration of this test shall not be less than two hours, or the time to visually inspect the closure joints and the overall soundness of the entire pipeline, whichever is greater.

8.2 Joint Testing using internal joint tester

The purpose of the joint test is to provide assurance to the contractor on large diameter pipe, that the two rubber rings are installed properly and that the joint is watertight up to 2-3 barg which can allow the contractor to proceed with further installation and backfilling works.

Joint testing is applicable only for diameters of 1200 mm and above. This method is recommended in the case of:

- Non availability of a sufficient water supply source.
- Unstable soils, which is a potential problem in the case of section testing
- Test pressures is 3 bars or less

Contact FPI for more information about the joint tester which are available for purchase from FPI.

As laying proceeds, each coupling is tested for Its water tightness by applying internal hydrostatic pressure by means of a mobile joint testing apparatus fitted internally and designed to seal internally the gap between the pipe ends. Through the pressure applied, a high thrust result, and the pipes must be solidly anchored and wedged laterally.

The last pipes laid must be at least 2 pipes ahead of those to be tested. Prior to the test, the pipe sections must have at least 1 x DN of cover above the pipe crown, with a minimum of 300 mm and maximum of 1 m. It is not essential to leave the joints exposed to ambient atmosphere in this test method. The test pressure shall generally not exceed 3 barg.

Caution:
Pipe joint testing shall be performed in well ventilated pipelines. The safety of the operators inside the pipe must always be assured. For safety considerations, the operators must preferably work at the free end of the joint tester (near to the pipe access). All operators must be securely hooked to a guide rope with other workers terminating outside the pipeline to allow pulling them out from the pipes in case of an emergency.

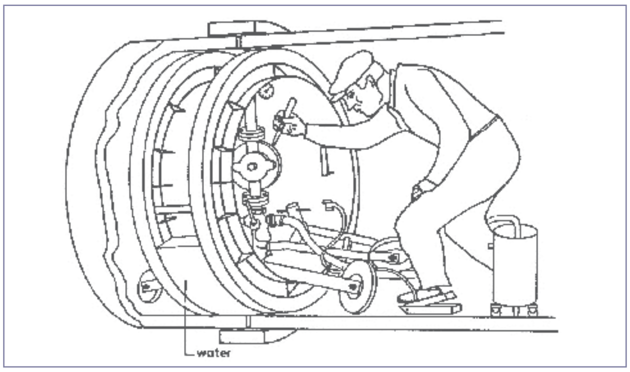

Figure 38: Internal Joint Hydrotester

8.3 Testing Gravity Lines

Two methods are available for testing gravity (PN 1 bar) lines, a low head water test or a low-pressure air test.

8.3.1 Low Head Water Test

The Contractor should plug both ends of the pipeline section (between two manholes) with suitable plugs. The test section should not exceed 200 meters. The plugs should have connections for a standpipe (typically 50 or 75 mm in diameter) connected to the pipe plug with a 90-degree elbow. At the upstream manhole, the standpipe shall extend 1.2 m above the crown of the gravity pipe, or 1.2 m above the existing ground water level. This level is called the test level. The test section shall be filled slowly from the upstream manhole while releasing the air out.

Allow the water to stand for about 1 hour for stabilization, then add water until the test level is again reached in the standpipe at the upstream manhole. Start the test, and over the next 30 minutes, the amount of water necessary to maintain a constant test level water head shall be measured using graduated containers of water. The line shall pass the test if the exfiltration amount does not exceed 15 liters per 24 hours per mm of pipeline diameter per kilometer of pipe. A typical test setup is shown in figure 39.

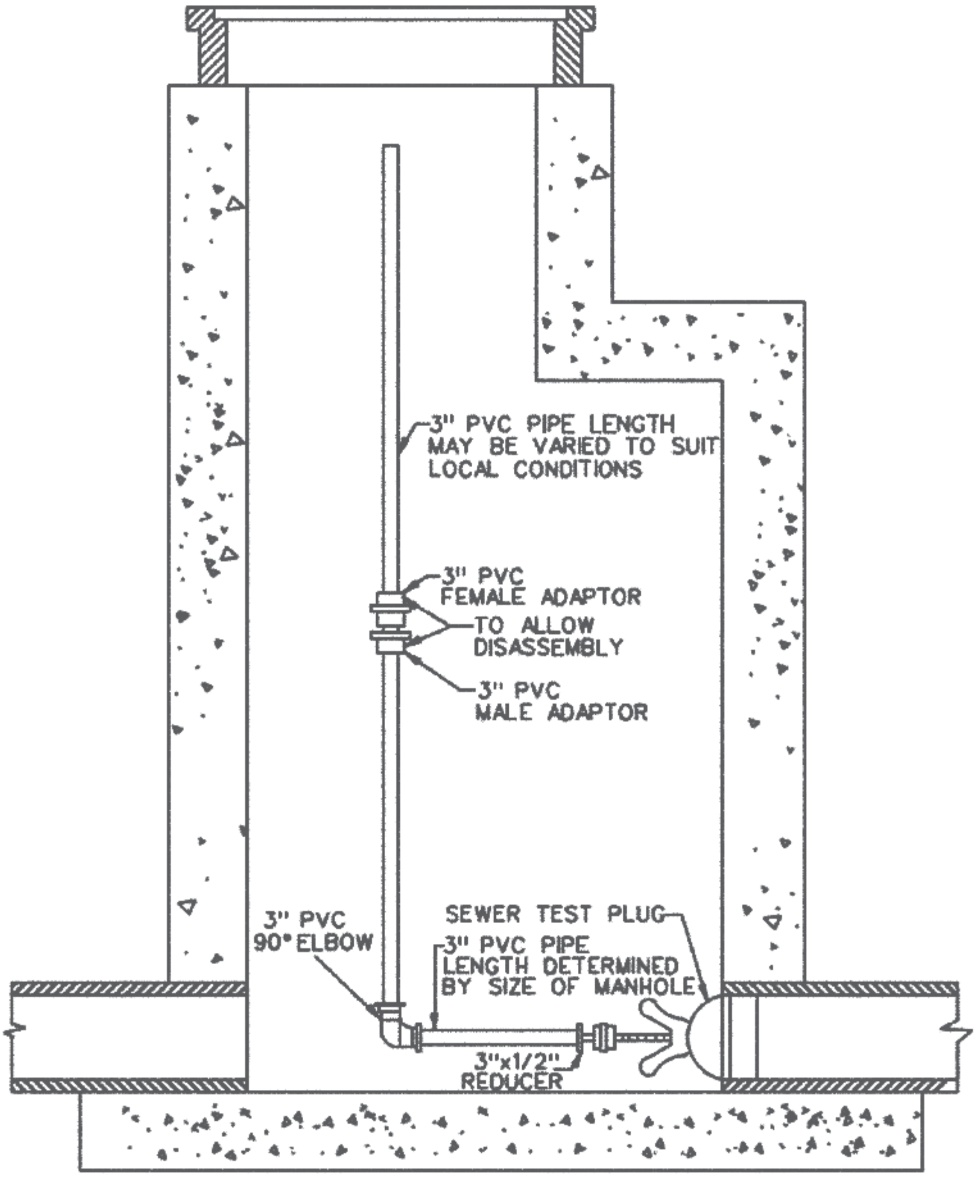

Figure 39: Low head water test installation detail

8.3.2 Air Test

The Contractor should plug both ends of the pipeline section (between two manholes) with suitable plugs. The plugs should have connections for air and a manometer or air pressure gauge. Air shall be pumped into the line until a pressure of 25 KPa is indicated on the manometer or air pressure gauge. After a 5-minute stabilization period, air may be added to restore the pressure up to 25 KPa. During the test period shown in table 11, if the pressure drop does not exceed 7 KPa, the line shall be considered as having passed the air test.

Note 15: In cases where the pipes are laid below the ground water table, the test pressure shall be increased by 10 kPa for every 1 meter of ground water above the pipe crown. If the resulting air test pressure exceeds 35 kPa, the air test method should not be used and the infiltration method is recommended.

Caution:

Air test can be dangerous if the line is not prepared properly and safety precautions are not taken. It is very important to install the test plugs properly and brace them to prevent blowouts. Air pressure must always be relieved before attempting to remove the test plugs. The test equipment should include a pressure relief valve designed to release air and prevent pressure from exceeding 40 kPa (5.8 psig).

Table 14 - Test time for low pressure air test

Diameter (mm)	Time (min.)
80 - 150	3
200 - 300	5
350	10
400	10
500	10
600	10
700	15
800	15
900	20
1000	20
1100	25
1200	25
1300	30
1400	30
1500	35
1600	40
1800	45
2000	50
2200	55
2400	60

9. PIPELINE COMMISSIONING

After completing the hydraulic test, the line must be thoroughly flushed out and disinfected (in case of potable water lines), as specified by the engineer or local regulations. In the absence of any such regulations, the following guidelines may be followed.

Disinfecting potable water lines is normally performed using either one of the following chemical mediums:

- Liquid Chlorine
- Sodium Hypochlorite solution
- Calcium Hypochlorite granules or tables

This application gives a solution containing at least 20 to 25 mg/l of free chlorine initially. The disinfecting period is normally 24 hours after which the residual chlorine should not be less than 10 mg/l. After the 24 hours disinfecting period, the line is flushed and filled with potable water.

When commissioning a pipeline, first ensure that all air valves are fully opened to release entrapped air. Do not open valves quickly and fully during filling. After releasing all air, close air valves and hydrants and open inlet valve fully. If the line is coupled to a pump, the inlet valve should be closed when the pump starts running. Later on, the inlet valve shall be opened slowly. The discharge valve should be closed slowly before shutting down the pump.

More information is contained in AWWA C651 “Standard for disinfecting water mains”.

10. AIR IN PIPELINES, AIR VALVES AND SURGE CONTROL

Air in pressure pipelines can cause major operational problems. Typical problems induced by the presence of such air are the reduction in flow capacity because of reduced cross-sectional areas, and fluctuation in flow caused by expansion and contraction of the air pockets in the line. High surge pressures can result from the flow fluctuations, which cause sudden movements of the air from one location to another, followed by slugs of water. Also, surge (water hammer) can occur in pipelines from opening and closing valves and from the start-up and shutdown of pumps.

Air can enter a pipeline from many locations:

- Line Drains
- Negative surges (vacuum) causing air to enter at air valves in the pipeline
- Intake Source
- Release of dissolved air from the waterb y temperature and pressure variation
- Draining parts of the pipeline or the pipe system during normal shut-down

In the first instance, air shall be prevented from entering the line. This will reduce operational difficulties.
Suggested solutions for controlling entrapped air in pipelines are as follows:

- The intake point should be provided with low water level pump cut-off

  Release of air: Air dissolved in the water at the intake and released due to temperature and pressure fluctuations cannot be prevented. However, the quantities of such air are not large and provisions for releasing the air can be made by the means of air valves. Proper selection of air valves is essential.

- While draining the line, air cannot be prevented from entering the line. Large orifice air valves should be provided for exhausting the air during refilling. Long filling times will allow the complete release of air.

- Negative surges (vacuum) - Large volumes of air may be involved here and can cause serious operational problems. The best way to prevent air from entering under these conditions is by proper design to eliminate the possibility of water column separation.

Studies have shown that suddenly released entrapped air under apparently static conditions creates a situation similar to a water hammer. Generated pressures can be of the order of several times the pipeline test pressure. Any pipeline material can be seriously affected by the quick increase in the magnitude of pressure loads.

Remedial actions against entrapped air and water hammer are as follows:

1. Lay the pipe line essentially to grade wherever possible, avoiding major slopes. It may be advantageous to create artificial high points by providing a small slope of around 3-4 mm per 1000 m to facilitate air collection at high points. Also, for drainage, it is recommended to provide a slope of 1-2 m per 1000m.

2. Automatic continual acting air release valves should be used at all major high points. Almost all the air release valve Manufacturers limit the maximum distance between air release valves to around 750 meters

3. Air should be sucked out from pipeline slowly.

4. Maximum filling velocity of the pipeline is 0.3 m/s. 5. Use d/D = 1/10 to 1/15.
   d = diameter of air release valve D = pipe diameter

6. Using motorized actuated valves is an effective means of limiting positive surges to an acceptable level by controlling the rate of opening and closing the valves.

7. Flywheels on pump motors allow the pump to keep on running for a short period of time after any power shutdown, before it gradually stops.

8. Installing open or pressurized surge tanks in critical area such as near pump discharge.

Note16: For some pumped systems where the client/ owner is concerned about upset conditions or frequent start/stop of the pumps and/or frequent opening and closure of valves, a system surge analysis may be considered to insure that positive and negative pressure surges predicted are within acceptable limits for the pipe pressure and stiffness class supplied. Such surge analysis are typically performed using programs such as: Pipenet, Bosfluids, FlowMaster, HAMMER, and Hytran by specialized Engineering companies .The Young's modulus of elasticity E of pipe supplied should be requested from FPI when undertaking such surge analysis.

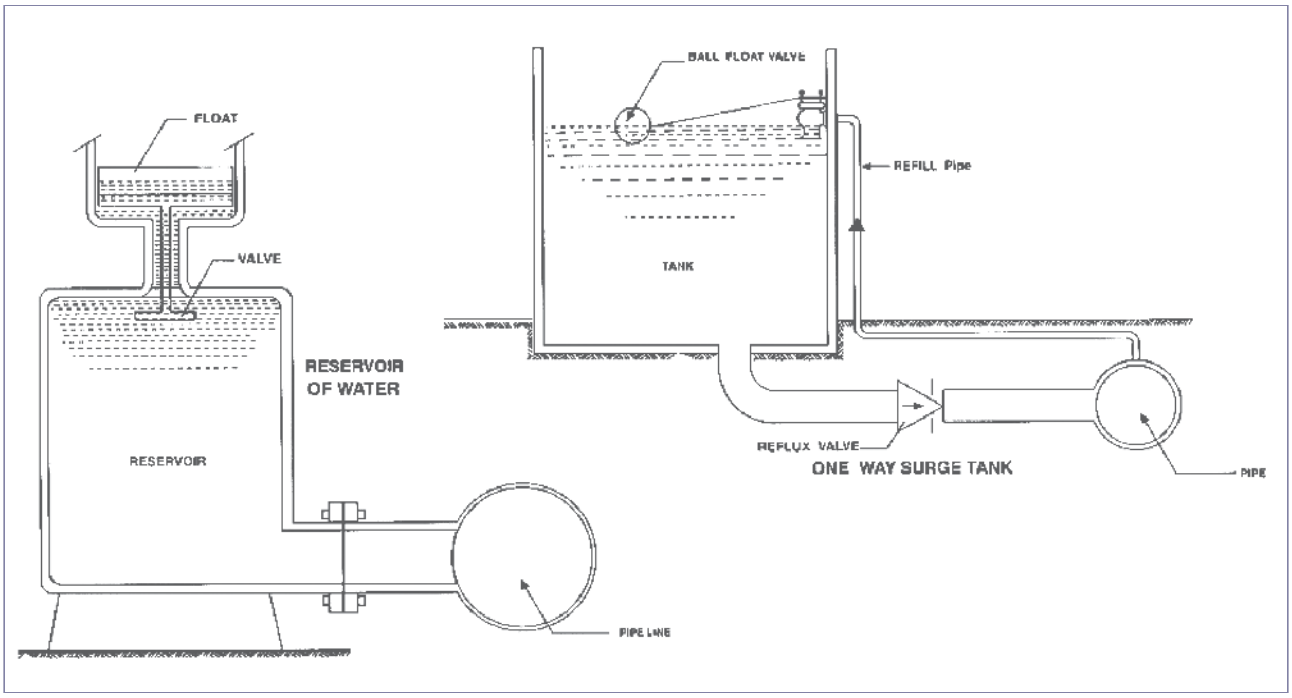

Figure 40: Typical Surge Control Devices

11. REPAIR AND REPLACEMENT OF PIPE

The replacement of a pipe or a fitting in a double bell coupling joints system is similar to that of a closure (i.e., laying the last length of pipe or fitting which closes or completes the line or a section of the line.)

To replace a damaged pipe, cut out a ring from its length and pull out the remaining two sections from the couplers that connect it to the adjacent pipes. Pull out these couplers and replace the sealing rings. Insert the new pipe as indicated below:

- Carefully measure the gap where the replacement piece has to be fitted. The replacement piece must be 32 mm shorter than the length of the gap. The pipe must be well centered, and an equal clearance of 16 mm must be left between the inserted pipe and the adjacent ones.
- Use a special pipe with double calibrated spigot ends especially ordered from FPI.
- Mount the coupler into the calibrated ends of the new pipe after abundantly lubricating the ends and the sealing rings. It will be necessary to gently help the second sealing ring over the chamfered end of the pipe.
- After cleaning them thoroughly, lubricate the ends of the two adjacent pipes.
- Insert the pipe in its final position and pull each coupler over the adjacent pipe up to the home line.

APPENDIX I : APPROXIMATE WEIGHT OF PIPES AND COUPLINGS (FOR HANDLING PURPOSES ONLY)

DN (mm)	SN 2500 (kg/m)	SN 5000 (kg/m)	SN 10000 (kg/m)	Coupling (kg/pc)
80		2	2	1
100		3	3	1
150		4	4	2
200		6	8	4
250	7	9	11	5
300	8	10	12	6
350	10	13	16	11
400	13	16	21	12
450	16	20	26	13
500	19	24	32	15
600	27	35	45	25
700	36	46	61	30
800	46	60	78	34
900	58	75	99	39
1000	71	92	121	44
1100	85	111	145	49
1200	101	131	171	54
1300	118	153	201	59
1400	136	178	230	65
1500	155	203	266	70
1600	175	230	301	76
1700	198	260	340	82
1800	221	290	378	88
2000	271	357	464	100
2200	327	430	560	113
2400	387	512	668	131
2600	455	599	776	234
2800	525	693	905	256
3000	668	833	1031	279
3200	757	937	1175	302
3400	851	1067	1328	325
3600	954	1191	1489	349
3800	1068	1330	1641	374
4000	1165	1470	1830	402

APPENDIX II: DESIGN CONSIDERATIONS FOR PIPELINE ANCHORING

Anchoring the pressure pipeline is an important consideration in the safe and dependable operation.

If pressure pipelines are not anchored properly, the thrust loads can lead to displacement of pipes and fittings sections. Thrust loads occur in pipelines wherever there is a change in diameter (e.g. reducers), a change in direction (elbow, tees, and wyes etc.) or at dead ends (e.g. .blind flanges, closed valves, bulk heads).

The determination of the thrust occurring in these situations is relatively simple. The figures and formulas in the following sections show the values of thrust occurring in various types of fitting configurations, common to all pressure pipelines. It is not the intention of this section to provide the design methods of thrust blocks. Specialized engineers should do these kind of studies. The main design considerations of thrust blocks are as follows:

- The pressure is assumed to be acting on the joint area, and not on the internal pipe cross sectional area.
- Where concrete thrust blocks are used, they should be poured against undisturbed native soil. This is required to ensure proper load distribution, and that pressures induced by the surrounding soil do not exceed the maximum design bearing capacity. A soil investigation is recommended to establish the proper soil bearing capacities.
- Upward thrust forces can be absorbed by a combination of pipe weight, water in the pipe and the soil on top of the pipe. If these restraining forces are not sufficient, concrete blocks can be used to provide additional weight on top of the pipe.
- In the case of a horizontal thrust (the most common case), concrete blocks, both non-reinforced and reinforced are typically used. Pilings may also be used where native soils are unstable. It may also be possible to provide special axially reinforced pipes and to tie several sections of pipe together on both sides of an elbow for example. Tied pipe sections plus the weight of water plus the soil weight provide support which resists by friction the thrust forces in the pipeline. Tying of FIBERSTRONG® pipe and fitting sections is normally done by laminated joints or alternatively by rubber gasket locked joints.
- The ground on which the pipes are laid normally absorbs downward thrust forces. The designer should note that where unstable soils are present, a proper foundation and bed constructed with good granular material shall be provided.
- The typical coefficients of friction (f) used for design purposes are the following:
  - Concrete on concrete 0.65
  - Concrete on dry clay 0.50
  - Concrete on wet clay 0.33
  - Concrete on gravel 0.65
  - Concrete on sand 0.40
- The table below provides typical vertical soil bearing capacities which may be used for the preliminary design of thrust blocks. The designer should note that proper testing and identification of native soil is essential to determine the proper soil bearing capacity values. Lateral (horizontal) safe bearing capacities of soil are typically 7-10 % of the vertical bearing capacity values.

Soil type	Safe bearing capacity (strength) (KN/m²)
Hard rock (e.g. granite)	3200
Soft rock	450
Coarse sand	450
Medium sand	250
Fine sand	150
Soft shell/ stiff clay	100
Loose gravel	250
Dense gravel	450
Soft clay	100
Very soft clay	50

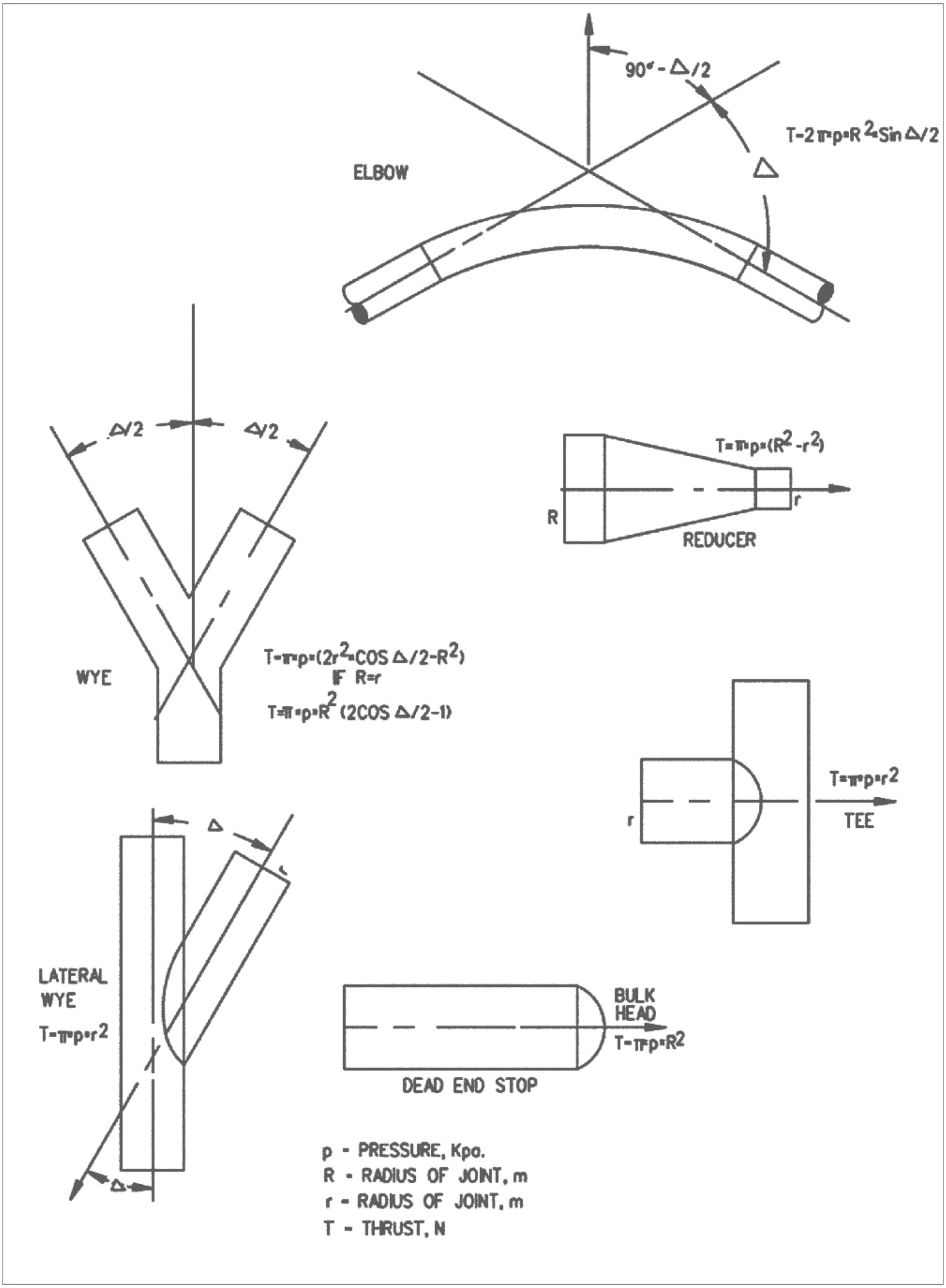

Figure II-1: Thrust in Fittings

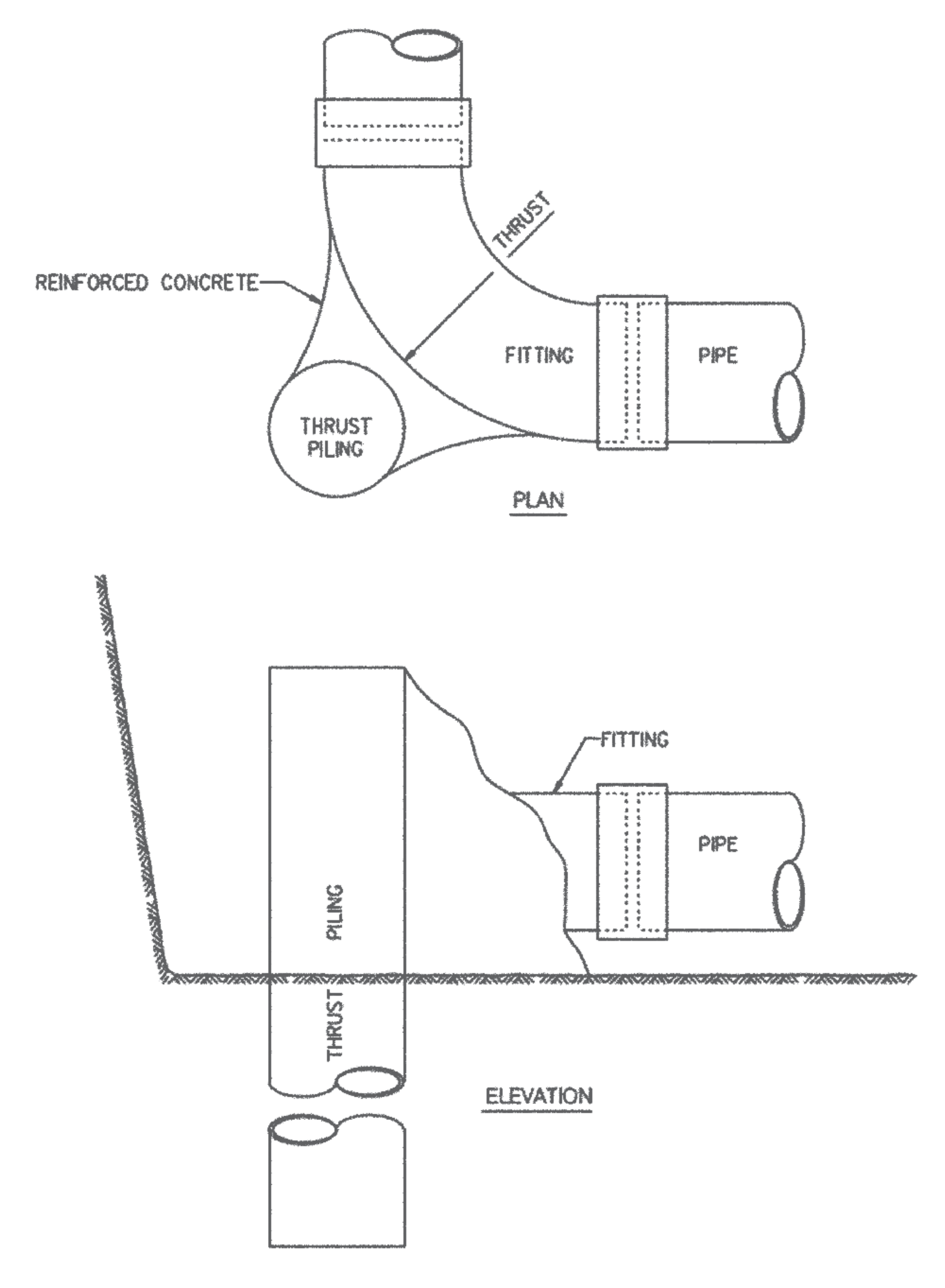

Figure II-2: Thrust Piling

APPENDIX III: LIST OF REFERENCES

Fiberglass Pipe Institute Fiberglass pipe Handbook - 1989

AWWA M45	Fiberglass Pipe Design - Third Edition
AWWA C 950	Standard Specification for Fiberglass Pipe
ASTM C 924	Standard practice for Testing Concrete Pipe Sewer Lines by Low-Pressure Air Test Method.
ASTM C 969	Standard practice for Infiltration and Exfiltration Acceptance Testing of Installed Precast Concrete Sewer Lines
ASTM D 1586	Standard Method for Penetration Test and SplitBarrel Sampling of Soils.
ASTM D 2487	Classification of Soils for Engineering Purposes
ASTM D 3839	Standard practice for Underground Installation of "Fiberglass" Pipe
BS 8010 Part 1	Pipelines on Land - General
BS 8010 Part 2.5	Pipelines on Land - Design, Construction & Installation - GRP pipelines.
BS 8010 Part 3	Pipelines: Sub-sea: Design, Construction & Installation.
ISO/TS 10465-1	Underground Installation of Flexible Glass-Reinforced Pipes Based on Unsaturated Polyester Resin (GRP-UP) - Part 1: Installation Procedures.
ISO/TR 10465-3	Underground Installation of Flexible Glass-Reinforced Pipes Based on Unsaturated Polyester Resin (GRP-UP) – Part 3: Installation Parameters and Application Limits.