GRP-BRP INSTALLATION HANDBOOK

TOPFIBRA
EFFECTIVE FILAMENT WINDING® PIONEERS

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REINFORCED OVERLAY JOINTS AND REPAIRS

REINFORCED OVERLAY JOINTS AND REPAIRS

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1. FOREWORD

This chapter contains general descriptions of the procedures for performing on-site butt joints and laying operations. The references made to the raw materials (and the trade name) are employed by our Company and concern the pipes for water transportation applications.

The following pages also cover the defects which may be encountered during the production, damages which may occur on-site, as well as the relevant repairing procedures.

2. RAW MATERIALS

The main characteristics of the raw materials used for the lamination of the reinforced overlay joints are:

2.1. Isophthalic Resin

Viscosity at 20°C	340 centipoises
Density at 20°C	1.06 gr/cm^3
Styrene content	50 %
Temperature of distortion under heat	120° C
Barcol hardness (pure resin)	35÷40°
Flash point	+32° C

2.2. Cobalt Octoate Accelerator

Flash point: +32°C

2.3. Dimethyl Aniline NL 63-100 Accelerator

Flash point: +63°C

2.4. NL CL 10 Inhibitor

Ter-butyl catechol: 10% solution in styrene

Flash point: +32°C

2.5. Catalyst

Peroximon K 1 and Butanox LPT

Methyl ethyl ketone peroxide: 50% solution

Active oxygen content: 10%

Flash point: +100° C

2.6. Paraffin

Heavy alkanes: 25% solution in styrene

Flash point: +32°C

2.7. Glass

Chopped strands mat (CSM): 450 and 600 gr/m^2

Woven roving: 500 and 800 gr/m^2.

2.8. Acetone

Density: 0.8 gr/cm^3

Flash point: –19°C

3. STORAGE AND SAFETY PRECAUTIONS

The packages containing raw materials used for making joints, such as resins, acetone, catalyst and so on, should be scrupulously and separately stored (away from each other), in a covered area and at the temperatures below 25°C.

The glass bobbins in particular have to be sealed in plastic envelopes to protect them from dampness.

These materials are highly inflammable and must be stored away from open flame and sources of heat. Apart from the fire danger, incorrect storage may reduce the working life of the materials to less than 6 months (6 months is their standard working life). Depending on the varying chemical nature of these materials, the actions that should be taken will be now outlined.

3.1. Resin

If any resin is spilt, it should be covered with sand or sawdust and the area of spillage should afterwards be cleaned with acetone or detergents.

In case of fire, use water and CO2 or dry fire extinguishers. Dry fire extinguishers must be used to put out fires in the proximity of the electric panels and cables.

To avoid direct contact with the skin, we recommend using rubber gloves when handling these materials. If they come in direct contact with the skin, wash the skin with acetone and rinse with plenty of water.

3.2. Acelerators

If the accelerators are spilt, wipe the area with disposable rags, and wash it with acetone.

In case of fire, use water and CO2 or dry fire extinguishers. Dry fire extinguishers must be used to put out fires in the proximity of the electric panels and cables.

If accelerators come in direct contact with the skin, repeatedly wash the skin with soap and water.

3.3. Catalyst

In case of fire or if the skin comes in contact with the catalyst, proceed as described in paragraph - Resin 3.1.

Take care to not work near the rust, metallic powders or cardboard cartons which can make the catalyst decompose or catch fire.

When handling the above materials, do not touch the eyes with contaminated hands. If this should inadvertently happen, firstly immediately rinse the eyes with plenty of water and then rinse the eyes with a 2% solution of boric acid or a 5% solution of ascorbic acid.

4. PREPARING THE RESINS AND PUTTIES

The resins used on-site should be prepared just before the application and according to the method given in this chapter.

We recommend preparing a sufficient amount of resin to complete the work and to avoid any excess of resin, since it hardens quickly.

4.1. Resin

Neutral Isophthalic

- low reactivity isophthalic resin is used for the stratification by hand lay-up of thick laminates at elevated temperatures of the working environment;
- adding a 0.3% (660 gr. per drum) of cobalt accelerator with a 6% of active cobalt to the resin, the gel time at 20°C will be about 45 minutes and the hardening time will be 70 to 80 minutes.

Pre-Accelerated Isophthalic

- isophthalic resin has short gel time and is used for the stratification by hand lay-up of the thin laminates (less than 5 mm), and when the temperature of the working environment is below 15°C;
- adding a 0.3% (660 gr. per drum) of cobalt accelerator with a 6% of active cobalt to the resin, the gel time at 20°C will be about 20 minutes and the hardening time will be about 30 minutes.

If gel time of the resin has to be modified, one or more of the following steps should be taken:

- modifying the quantity of the cobalt accelerator;
- modifying the quantity of the catalyst;
- adding an inhibitor to the resin.

a) Quantity of the Cobalt Accelerator.

The effects of different quantities of the cobalt accelerator on the gel time are:

0.2 % of the accelerator	65 minutes gel time
0.3 % of the accelerator	45 minutes gel time
0.4 % of the accelerator	35 minutes gel time
0.5 % of the accelerator	25 minutes gel time

Do not exceed 0.5% because the resin pot life will decrease.

b) Quantity of the Catalyst

By increasing or reducing the amount of the catalyst, gel time is shortened or extended, respectively. It is recommended to keep the catalyst within the limits of a minimum 1% and maximum 2%. If the percentage is less than 1%, the polymerisation is not complete, and if it is more than 2% there is a risk of local burns in the laminate because of the violent exothermic curing reaction due to high concentrations of the catalyst.

c) Addition of Inhibitors

The addition of inhibitors causes the prolongation of gel time. The amount of the inhibitor should never exceed 50% of the cobalt accelerator.

Adding, for example, a 0.1 % of inhibitor to a short gel time isophthalic resin, accelerated by a 0.3% of cobalt, the expected gel time is about 35 to 40 minutes, which is 10 minutes longer than with the basic preparation.

The inhibitor is active in the resin up to the 40-50°C; above that temperature, it evaporates and loses all its effectiveness.

4.2. Putty

Putty is made with the isophthalic resin and Aerosil 200 (Cab-O-Sil). While the accelerated resin is being mixed, Aerosil 200 (which is a thixotropic agent) is added, causing the resin to thicken until it is semi-solid.

The amount of Aerosil 200 that has to be added depends on the degree of viscosity required by the operator. Generally, it is about 5÷6 % by weight.

Note that Aerosil 200 adsorbs a certain amount of accelerator, leaving a smaller quantity of the accelerator in the resin and increasing the gel time. To avoid this shortcoming, a few drops of dimethyl aniline are added.

4.3. Paraffined Resin

To prepare the paraffined resin, it is necessary to add the 5% paraffin solution to the quantity of the isophthalic resin, which has been already accelerated according to the methods described earlier.

4.4. Definitions

- Gel time: starting from when the catalyst is added, gel time is the time it takes the resin to become gelatinous and unworkable;
- total curing time: is the period of time after the catalyst is added to the resin and the resin becoming fully polymerised and reaching its maximum exothermic peak;
- pot life: is the time the resin can stay in the drum in good condition, without the catalyst.

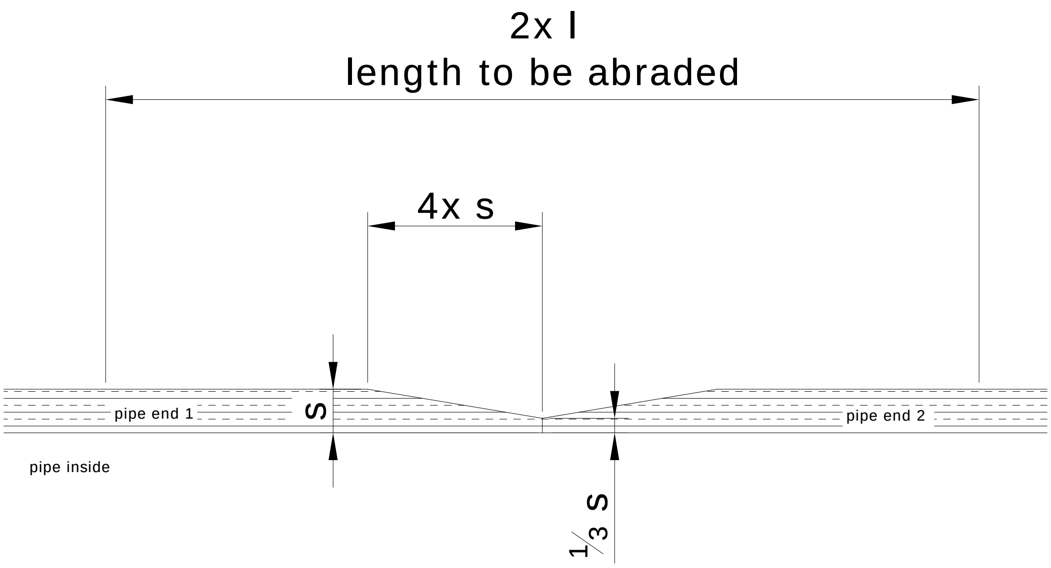
5. LAYING-UP OPERATIONS TO STRAP BUTT JOINTS

The joints between the pipe lengths, and between the pipes and specials, are made by butt welds with strapping. It is advisable to carry out welds and strapping at the temperature above 15°C and in the relative atmospheric humidity that is not higher than 60%.

The necessary raw materials, used for this operation, are only those supplied by the workshop. They should be prepared according to the instructions given earlier.

Before starting the on-site job, the raw materials should be checked to make sure that they have not deteriorated. If the raw materials are not deteriorated, proceed as:

- abrade the area that is going to be strapped along the whole length;
- proceed to bevel the ends, as in the figure below, where "s" is the pipe thickness, and "l" is the half length of the overlay (the bonding length);



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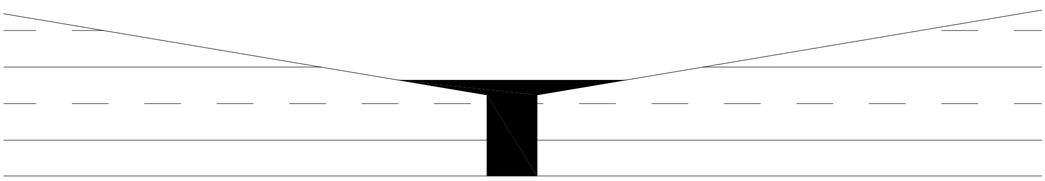
- the bevelled and ground surfaces should be washed with acetone to avoid the deposits, which might impair the good conditions of the strapping;
- proceed to assemble the sections or pieces that will be welded and apply the isophthalic putty, taking care that the cement film fully covers the two edges in contact;



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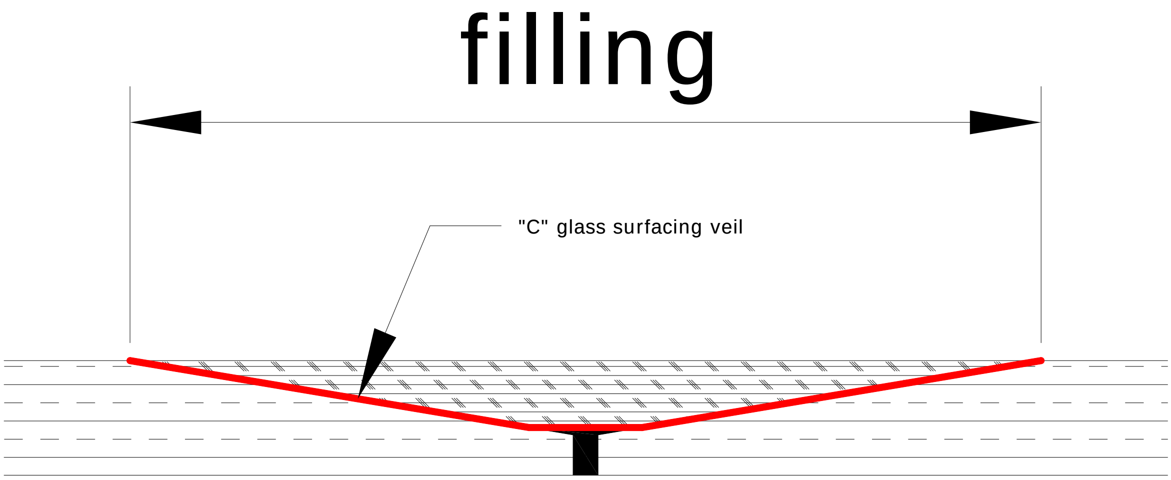
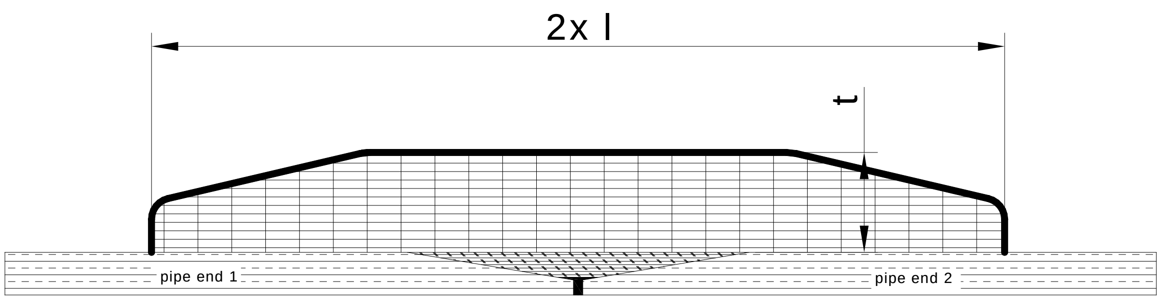
- When the joint has been puttied in this way and then smoothed, the first layer of the resin should be applied and a surfacing veil placed afterwards;

This is the beginning of the first laying phase, the so-called "filling phase", which ends when the alternate layers of resin and glass (mat) are sufficient to cover the area of the bevelled parts of the pipes and/or fittings which will be joined together. In this way, an even surface is obtained. During this operation it is necessary to take care to eliminate, as far as possible, all the air bubbles by exerting a light pressure with a metal roller.



- Proceed with the second phase of laying-up the actual strapping of the joint, employing mat and woven roving impregnated with resin, in due sequence and working as in the preceding point;
- this operation should be continued at intervals, as further specified, until the required thickness and dimensions are reached;



- when the strapping is completed and the joint has reached the right degree of polymerisation of the resin, proceed to abrade the whole area which is covered with the strapping. Then lay-up a protection layer of the paraffined resin, prepared according to the method described in the section 4.3 – Paraffined Resin;
- when required and possible, the strapping can also be applied to the inside of the pipe; the total thickness and the bonding length can be divided;
- it is always advisable to perform a light internal lamination with 1 or 2 layers of CSM. TOPFIBRA also recommends finishing the hand lay-up with a layer of the "C" surfacing glass or coating with the resin mixed with the "C" glass flakes (10% by weight);
- the alternate plies of resin and glass should not be more than four in number for each interval in order to avoid delaminations, which might be created by the too violent exothermic reaction of polymerisation. After an interval and before proceeding with the next lay-up application, care should be taken to grind the surface. This will allow the plies in contact with each other to achieve a perfect adhesion;
- depending on the diameters of the worked pieces, the lay-up operations should be done with a brush and a metal roller or with a roller brush and a metal roller.

The total length and thickness of the reinforcement wrap can be calculated by means of the Design Programs for Joints and Fittings and can also be found in the Dimensional Tables for the more common classes.

If the joint is a male-female type and performed according to the method described in this section, it will have the strength that is at least equal to the pipes or fittings which will be joined together and a one-piece. Thus, the continuous structure will be ensured.

When butt joints are made in a pipeline, it is necessary to keep a proper distance between the strappings to avoid the overlapping of the strapped areas. If the distances are not big enough, it is necessary to install stubs of pipe to obtain the required distance.

6. REPAIRS OF THE MAIN DEFECTS AND DAMAGES

When the fault in a pipeline does not require a replacement, repairs should be carried out following the instructions outlined in the next chapters.

However, the basic steps which have to be followed when preparing the resins and other materials are the same as those described for the laminated joints.

The defects which may affect the production of the pipes and vessels, manufactured with the automatic machines or at the hand lay-up of fittings and specials, are quite rare. Their occurrence is generally related to an improper choice of the raw materials, quality or preparation, and not to an incorrect use of the equipment.

The reconditioning of the defective or damaged items depends not only on the nature and the extent of the defect or damage, but also on the possibility to reach that area.

6.1. Air Bubbles and Voids

This defect consists of the air entrapment in and between the plies and appears as non-interconnected spherical voids.

The reasons for this defect are: poor rolling out during the lay-up or a poor and dirty surface of the mould. The whipping action during the mixing of the resin and a high viscosity, increase the possibility for the defect to occur.

The air bubbles in the structural wall get repaired only when their dimensions are greater than 4 - 5 mm in diameter or when there is a large concentration of them on a limited surface. In this situation the recommended repairing procedure consists of the following steps:

1. abrasion with a grinder. The fault is eliminated with care by chamfering the surface;
2. blow off the dust with compressed air and clean the area with acetone;
3. hand lay-up over the abraded portion, using the same raw materials in quality, quantity and number of layers that originally formed the abraded part;
4. smoothing the hand laid-up repaired surface, using a fine-grained abrasive disk;
5. using a brush, apply a protection layer of the paraffined resin of the same quality as was used for the inner ply.

The air bubbles in the liner require special attention because they may cause the rejection of the manufactured item:

- generally, the air bubbles are not repaired and are not a reason for the rejection, if they are rather small but not near to the surface, even if they are scattered over a large area. It is possible to evaluate the position of the bubbles with regard to the surface by how much strength is required to break through the air bubbles with a ball-point pen or a pencil;
- when the air bubbles are bigger in size (4 – 5 mm or greater) but very reduced in number, or when they are concentrated in a limited area, making it possible to identify all of them during the inspection; even if they are near the surface, repairing is possible with the same procedure described earlier;
- if the air bubbles are scattered over an important portion of the laminate and if they are near to the surface so that breaking through them is easily achieved, no repair is advisable and the item should be rejected or de-rated from the pressure to gravity service.

6.2. Pinholes in the Inner Liner

The pinholes or pits are small, regular or irregular, craters on the surface, usually with a nearly equal width and depth and with dimensions which are normally not greater than 2 - 3 mm.

Figure 1: Red-coloured pinholes

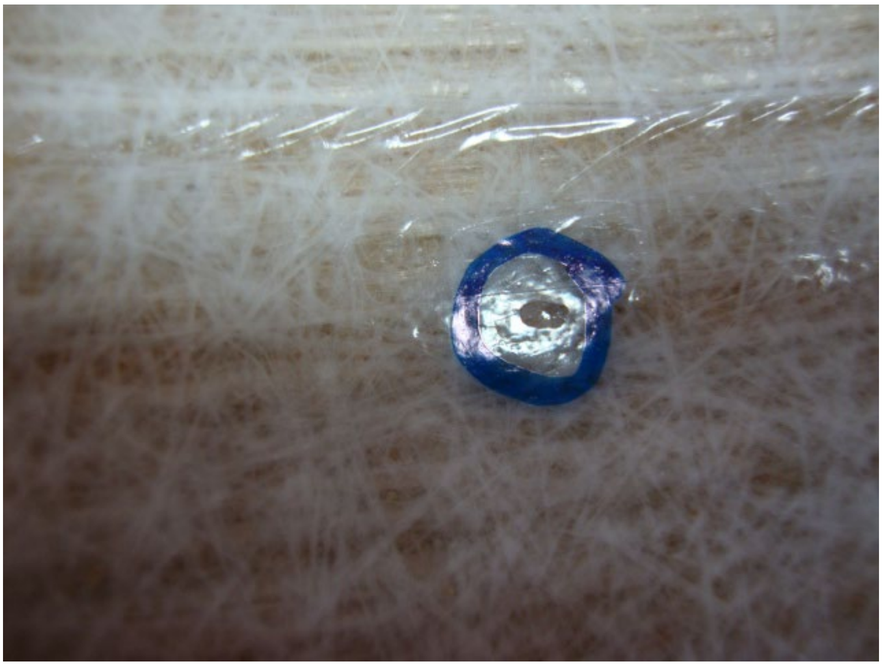


Figure 2: Pinhole

The air bubbles that rise to the surface, cure before smoothing. The main cause of this defect is the viscosity of the resin which is too high. In some circumstances this may be accompanied by wicking (unimpregnated glass fibres on the surface).

The occurrence of the pinholes, related to the preparation of the resin and to the temperature of the working environment, is generally not limited to a reduced area, therefore, the repairing works are not always possible or advisable.

If the pinholes are very small, localized in an identified area and there is no or little risk of wicking, the recommended repairing procedure consists of the following steps:

1. using a fine-grained disk, slightly abrade the identified surface;
2. blow off the dust with compressed air;
3. clean the area with acetone;
4. use a brush to apply a protection layer of the paraffined resin that has the same quality as the liner.

The bigger and deeper pinholes present the risk of wicking. The recommended repairing procedure consists of the following steps:

1. clean the surface with acetone. To fill the craters, use a flexible metal spatula to apply a putty made of resin, which has been thickened with the silica gel (Cab-O-Sil);

2. using a fine-grained disk, slightly abrade the affected surface;
3. blow off the dust with compressed air;
4. hand lay-up a layer of the "C" glass, impregnated with the same resin that was used for the liner;
5. slightly abrade with a fine-grained disk to smooth the surface;
6. Blow off the dust, clean the area with acetone and use a brush to apply a protection layer of the paraffined resin that is the same quality as the liner.

The occurrence of the pinholes should always be considered a good reason for de-rating the pressure class pipes and fittings.

6.3. Delaminations

Delamination is a separation of layers due to poor glass saturation, dirty surface, glass content that is too high, failure to remove the air inhibition coat before applying the next layers or, more frequently, due to the impact.

Figure 3: Delamination

Delaminations may also occur during the hand lay-up of the thick layers, due to excessive heat developed during the exothermic curing reaction, which causes the separation of layers.

The delaminations can generally be repaired with the following procedure:

1. abrade with a grinder, until the fault has been eliminated, taking care to chamfer the surface;
2. blow off the dust and clean with acetone;
3. hand lay-up over the abraded portion using the same raw materials in quality, quantity and number of layers originally forming the abraded part;
4. using a fine-grained abrasive disk, smooth the repaired, hand laid-up surface;
5. use a brush to apply a protection layer of the paraffined resin that is same quality as the inner ply.

In case of delaminations affecting the whole thickness of the laminate, this repairing procedure should be performed starting from the inside (liner) for a few layers and then continued and completed from the outside.

6.4. Cracks

Cracks can be of two different types:

- **Impact cracks:** appear as separation of the material throughout the entire thickness and are visible on the surfaces. They generally appear due to the impact in one surface spot because of an insufficient reinforcement or where a concentration of the resin is high. In this case, the repairing procedure is the same as is used for the delaminations.
- **Surface cracks** (or crazing): appear as a pattern of fine cracks on or beneath the surface. The most common reasons for this defect are the impact, the isolated areas rich in resin, intermittent service causing the temperature differences, wetting/drying cycling, and the resin shrinkage.

The crazing of the inner liner is usually very superficial and can be repaired by using a brush to apply a protection layer of the paraffined resin of the same quality as is the inner ply, after roughening the cracked surface by slight abrasion.

6.5. Inner Areas with the Resin Lack or Dry Spots

This defect appears in the areas of reinforcement that were not wetted, or not wetted enough, with the resin. It usually occurs during the moulding manufacturing operations, most often at the laminate edge.

The occurrence of this defect on the inner liner of the pipes and fittings generally appears only as a surface defect, in which case it is sufficient to roughen the surface by hand, using a fine-grained abrasive paper and then apply a protection layer of the paraffined resin of the same quality as is the inner ply, while taking care that no uncovered fibres remain, which could cause the wicking.

In case of the non-impregnated fibres or a more significant fault, the same procedure, as described for the delaminations, should be applied.

6.6. Surface Roughness

Usually this defect is not subjected to repair, unless it is accompanied by wicking.

Figure 4: Surface roughness

6.7. Wicking - Unimpregnated Glass Fibres on the Surface

In case of a very superficial and slight defect, proceed as:

1. slightly abrade the surface with a fine-grained disk to smooth it;
2. blow off the dust with compressed air;
3. use a brush to apply a protection layer of the paraffined resin that is the same quality as the affected surface.

In case of a bigger defect, the fault must be removed by grinding. A hand lay-up must be provided over the portion, using the same raw materials that originally formed the abraded part.

6.8. Air Bubbles in the Shell Before Filament Winding

If the bubbles are small, the item is fixed by injecting the resin from the outside. Two holes of 2-3 mm are made from the outside to the bubbles and the resin containing the catalyst is injected with a syringe (the second hole acts as a breather and enables the bubble to be filled completely).

If, instead, the bubbles are large in size, the repairs should be carried out following these steps:

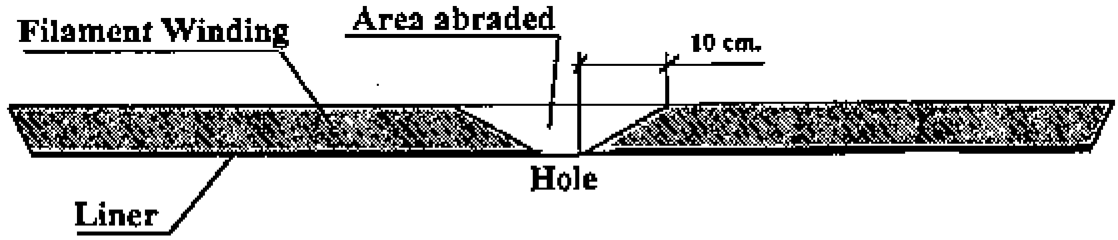
1. remove the affected part of the laminate from the inside before the filament winding (use a cutter with a diamond-tipped disk or a grinder with a disk, but take care not to cut into the plies laid-up by the filament winding);
2. abrade with a grinder with an abrasive disk, down to the plies which are delaminated;
3. lay-up by hand over the abraded part (use the same quantity and quality of the glass reinforcement and the same resin as was originally used for the abraded part);
4. abrade the repaired surface;
5. varnish with a brush, using the paraffined resin that is the same quality as was used for the inner ply.

6.9. Wrongly Positioned Opening

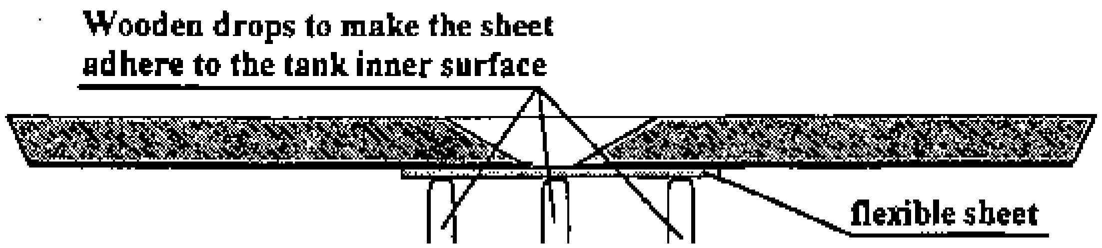
If it is discovered, during the control at the finishing shop, that an opening has been wrongly positioned, the best solution is to leave the flange closing it with a blank flange.

If this solution is not possible, repairs should be carried out as follows:

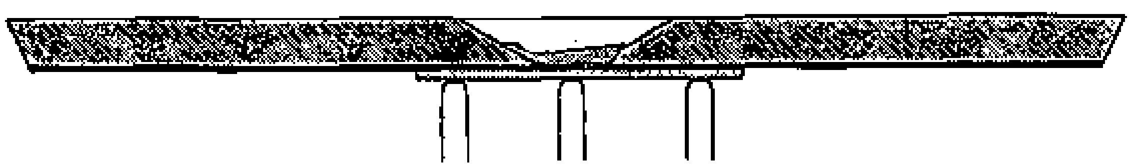
1. Cut and remove the flange, then abrade the edges of the hole;



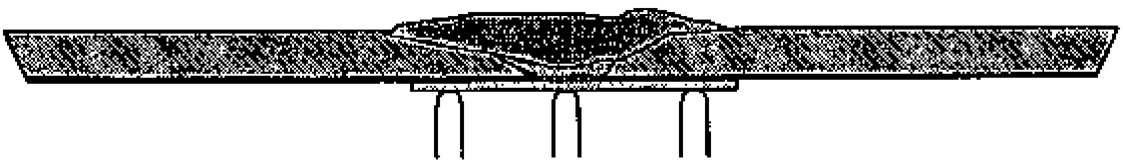
2. on the bottom of the hole, position a sheet of PVC or other flexible material from the inside; if the material is not self-released, treat the contact surface with the wax and polyvinyl alcohol;



3. lay-up the liner by hand;



4. abrade the repaired area;
5. when laying-up the reinforcement, use plies of mat until a unit weight of glass is reached, so that its strength is greater than that of the roving in the filament winding. The type of the resin used is the same as for the filament winding and compensates for its weakening;



6. remove the PVC sheet;
7. abrade the inner side and the lay-up (one or two plies of mat). When the polymerization has taken place, abrade once more and varnish with the resin containing paraffin, the resin should be the same type as the one used in the liner.

8. If the internal repairs are carried out after the heat treatment, the tank or pipe should be put back into the oven for further heat treatment. If the repair is small, the treatment can be done with the infrared ray lamps.

JOINING METHODS

JOINING METHODS

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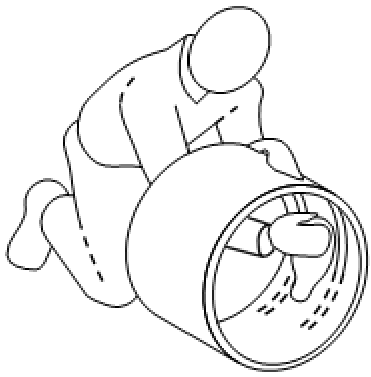
1. DOUBLE BELL COUPLINGS

1.1. Pressure Coupling

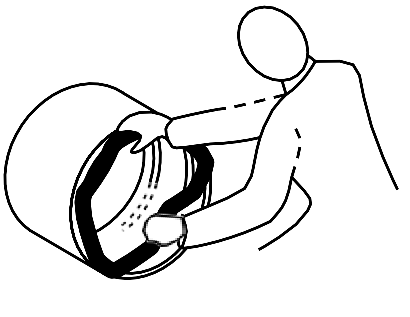
Steps for joining the pipes:

1) **Foundation and bedding** - The bed must be over-excavated at each joint location to ensure that the pipe will have continuous support and that it does not rest on the couplings. The coupling area must be properly bedded and backfilled after the joint assembly is completed.

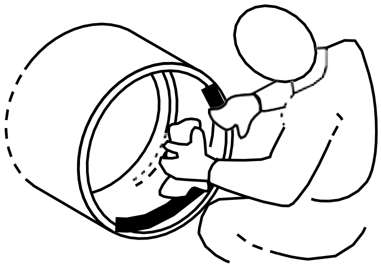
2) **Cleaning the coupling** - Thoroughly clean the double bell coupling grooves and rubber gasket rings to make sure no dirt or oil is present.



3) **Gasket installation** - Insert the gasket into the groove and leave loops of rubber (typically two to four), extending out of the groove. Do not use any lubricant in the groove or on the gasket at this stage of assembly. Water may be used to moisten the gasket and groove to ease the positioning and insertion of the gasket. With uniform pressure, push each loop of the rubber gasket into the gasket groove. When installed, carefully pull in the radial direction around the circumference to distribute compression of the gasket. Also check that both sides of the gasket protrude equally above the top of the groove around the whole circumference. Tapping with a rubber mallet will be helpful to accomplish this task.

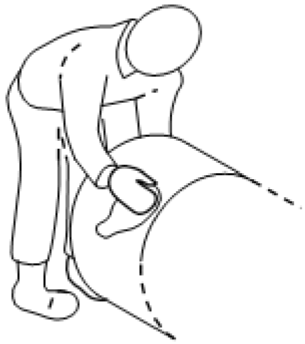


4) **Gasket lubrication** - Apply a thin layer of lubricant to the rubber gaskets.



5) **Cleaning spigots and lubrication** - Thoroughly clean the pipe spigots to remove any dirt, grit, grease, etc. Inspect the spigot sealing surface for possible damage. Apply a thin layer of lubricant to the spigots from the end of the pipe to the black alignments stripe. After lubricating, take care to keep the coupling and spigots clean. Placing a cloth or a plastic sheet, approximately one square metre in size, under the jointing area, will keep the spigot ends and gasket clean. Lubricants which are suitable for low temperatures are available on request.

Caution: It is very important to use only the correct lubricant. The supplier provides sufficient lubricant with each delivery of couplings. If, for some reason, you run out, please contact the supplier for additional supply or advice on alternative lubricants. Never use a petroleum based lubricant.



Joining the coupling - If the coupling is not pre-mounted, it should be mounted on the pipe in a clean, dry place, before the pipes are joined. This is accomplished by placing a clamp or a sling around the pipe 1 to 2 m away from the spigot on which the coupling will be mounted. Make sure the pipe spigot is resting at least 100 mm above the ground surface so it is kept away from dirt. Manually push the coupling on the pipe spigot end and place a 100 x 50 mm timber across the coupling. Use two come-along jacks, connected between the timber and the clamp, and pull the coupling into position i.e. until the coupling is aligned with the “home line” or until the spigot touches the centre register.

The next steps (6 to 8) apply to joining pipes using clamps or slings and "come-along jacks". Other techniques may also be used, providing the general objectives outlined here are met. In particular, insertion of the pipe spigot ends should be limited to the home-line and any damage to the pipe and coupling should be avoided.

6) **Pipe placement** - The pipe with the mounted coupling is lowered on the trench bed. In the location of the joint, the trench should be over-excavated to ensure that the pipe will have a continuous support, will be well aligned and will not rest on the couplings. The maximum allowable misalignment of the adjacent pipe ends is 5 mm

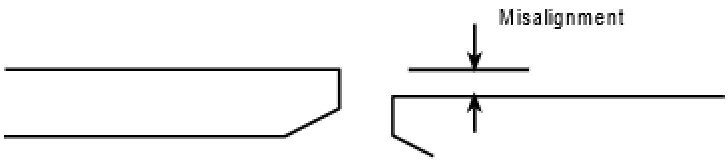


Figure 5: Misalignment

It is recommended to monitor the misalignment near thrust blocks, valve chambers and similar structures, and at closure or repair locations.

7) **Fixing of the clamps** - Clamp (or sling) A is fixed anywhere on the first pipe or left in position from the previous joint. Fix the Clamp (or sling) B on the pipe which will be connected, in a convenient position

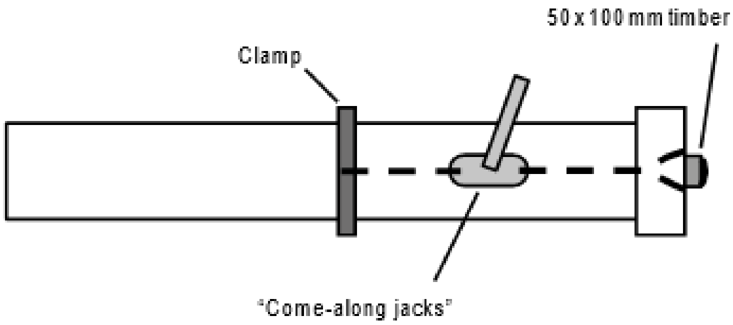


Figure 6: Mounting a coupling

Note: Clamp contact with the pipe shall be padded, or otherwise protected, to prevent damage to the pipe as well as impart the high friction resistance with the pipe surface. If clamps are not available, nylon slings or rope may be used, but care must be taken in the alignment of the coupling.

8) **Coupling joining** - Come-along jacks are placed on either side of the pipe and connected to the clamps. The pipe is pulled into position in the coupling, until it reaches the home-line or touches the centre register. Clamp A is then moved onto the next pipe which will be joined.

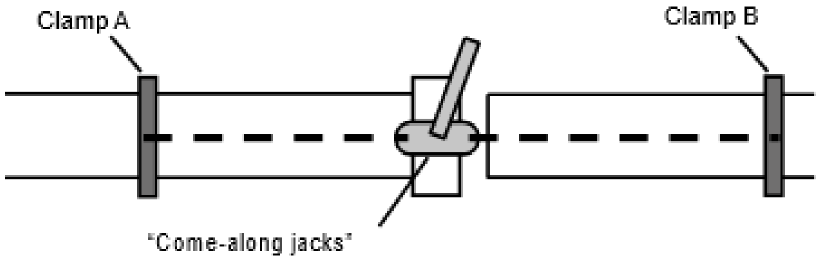


Figure 7: Pipe joining, using clamps.

Pipes can also be mounted by an excavator shovel or a crowbar (up to DN 300). The spigot ends have to be protected from any damage. The approximate mounting force can be calculated as:

Mounting forces in tons = (DN in mm / 1000) x 2

Note: Shovel installation requires a lot of experience in pipe handling. Care must be taken to avoid damages on the pipes and couplings.

1.2. Sewer Couplings

A gasket is used for the sewer couplings, which is pre-equipped and fixed to the coupling groove. With that, the steps described in the previous section (cleaning of the grooves and installing of the gasket) can be skipped. All other working instructions and user data are identical with the steps described in the previous section.

1.3. Angular Deflection

Maximum angular deflection in service at each coupling, taking into account the combined vertical and horizontal deflection, must not exceed the values given in this table:

Nom. Pipe Diameter (mm)	Pressure (PN) in bars			
	Up to 16	20	25	32
		Max. Angle of Deflection (degrees)		
DN ≤ 500	3.0	2.5	2.0	1.5
500 < DN ≤ 900	2.0	1.5	1.3	1.0
900 < DN ≤ 1800	1.0	0.8	0.5	0.5
DN > 1800	0.5	0.4	0.3	NA

This can be utilized to accommodate the gradual changes in line direction. The pipes should be then joined in a straight alignment and thereafter deflected angularly as required. The maximum offset and corresponding radius of curvature are shown in this table:

Angle of Deflection (deg)	Maximum Offset (mm) Pipe length			Radius of Curvature (m) Pipe length		
	3 m	6 m	12 m	3m	6m	12 m
3.0	157	314	628	57	115	229
2.5	131	262	523	69	138	275
2.0	105	209	419	86	172	344
1.5	79	157	314	115	229	458
1.3	68	136	272	132	264	529
1.0	52	105	209	172	344	688
0.8	42	84	168	215	430	859
0.5	26	52	105	344	688	1375

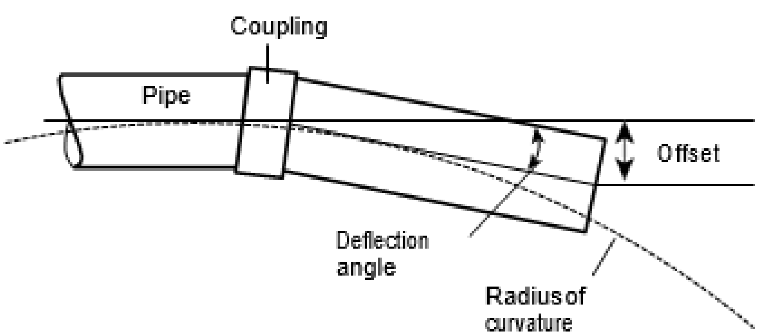


Figure 8: coupling and an angular joint deflection.

For the installation that requires greater angles, special joint systems should be used.

Note: This is for information purposes only. The minimum allowable length is a function of nominal pressure and backfill class and compaction, but in general it should be not less than 3 metres.

Angular deflected coupling joints are stabilised by the stiffness of the soil surrounding the pipe and coupling. Pressure pipes (PN>1) should have angularly rotated joints backfilled to the minimum 90% Standard Proctor Compaction (SPC). Coupling joints that are placed with a vertical angular rotation, where the direction of the thrust is upward, should be backfilled to a minimum cover depth of 1.2 metres for the operating pressures of 16 bar and more.

2. LOCKED JOINTS

Locked joint is a double bell with rubber gaskets and locking rods to transfer the axial thrust from one pipe section to another. On each side, the coupling bell has a standard rubber gasket and a rod-groove system, through which the load is transferred. The pipe spigot for locked joints has a matching groove.

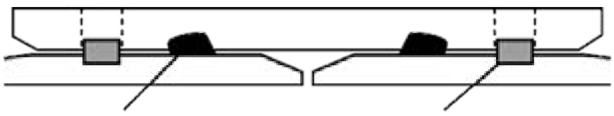


Figure 9: Locked joints.

The joint is assembled by a similar procedure as the standard pressure coupling, except that there is no centre register. Steps 1 through 6, which are listed in the section 1.1 – Pressure Coupling, should be followed. For the step 7, the pipe is pulled in position until the groove in the pipe is visible through the opening in the coupling. The locking rod is then pushed into position with a hammer. Generally, an installation with an excavator is not recommended. Lock joints shall be installed only in straight alignment. Pipeline must be backfilled before pressure testing.

3. FLANGED JOINTS

Flanged connections are used for:

- the vane and pump connections;
- for transitions between different types of pipes (such as connection of a steel pipe with a GRP pipe);
- for the water tank or manhole connections.

While connecting two flanges, alignment of bolts is very important in order to avoid loading the bending stress on the bolts.

3.1. GRP Fixed Flange (Flat Face)

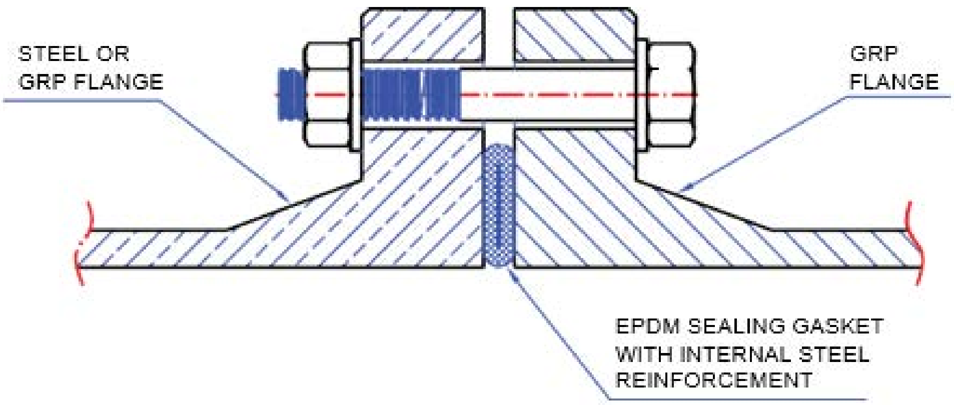


Figure 10: GRP fixed flange.

GRP flanges should be joined according to the following procedure:

1) thoroughly clean the flange face;
2) ensure that the sealing gasket is clean and undamaged. Do not use defective gaskets;
3) position the sealing gasket in the flat face. It is recommended that the gasket is secured with small stripes of tape or adhesive;
4) align the flanges which will be joined;
5) insert bolts, washers, and nuts. All hardware must be clean and lubricated to avoid incorrect tightening. It is important that the mating surface between the

bolt head/washers and the backing ring plate is well lubricated to avoid excessive torque build up;

6) washers must be used on all the GRP flanges;

7) using a torque wrench, tighten all the bolts following a pattern of tightening sequences (Figure 11). It is important to tighten the bolts in several stages. Adjust each bolt to 25% of the allowable torque.;

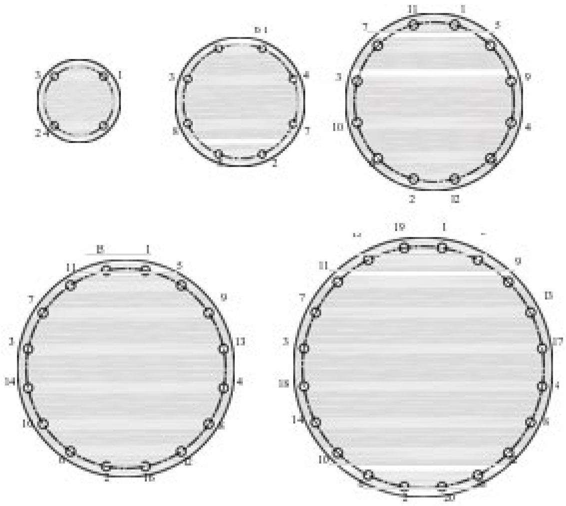


Figure 11: Tightening sequence.

8) repeat this procedure, raising the bolt torque to 50% of the allowable torque and then repeat again to 70%. Do not exceed this torque. To do so may cause permanent damage to the GRP flanges.

9) Check the bolt torques one hour later and adjust them to 70% if necessary.

3.2. GRP Fixed Flanges, Using O-Ring gasket

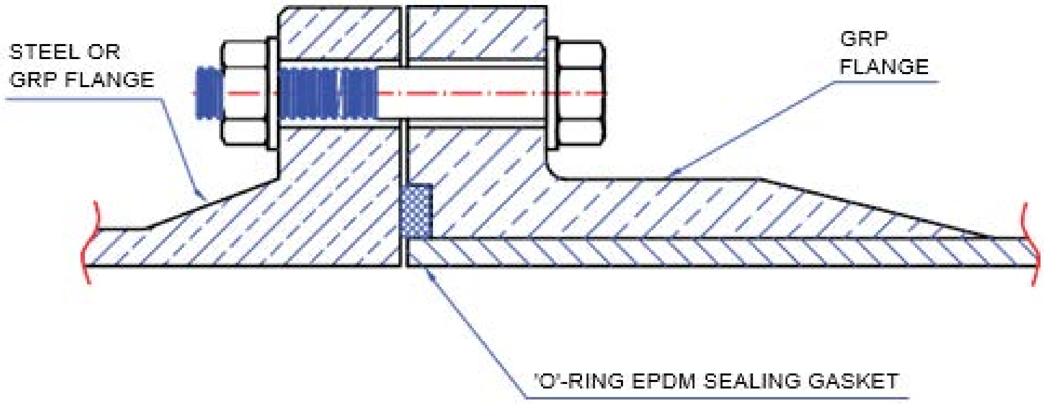


Figure 12: GRP fixed flange, using O-ring gasket.

GRP flanges using O-ring gasket should be joined according to the following procedure:

1) thoroughly clean the flange face and the O-ring groove;
2) ensure that the sealing gasket is clean and undamaged. Do not use defective gaskets;
3) position the sealing gasket in the flat face. It is recommended that the gasket is secured with small strips of tape or adhesive;
4) align the flanges which will be joined;
5) insert bolts, washers, and nuts. All hardware must be clean and lubricated to avoid incorrect tightening. It is important that the mating surface between the bolt head/washers and the backing ring plate is well lubricated to avoid excessive torque build up;
6) washers must be used on all the GRP flanges;
7) using a torque wrench, tighten all the bolts, following a pattern of tightening sequences. It is important to tighten the bolts in several stages. Tighten all the bolts to 35 Nm torque, (20 Nm for small diameter - DN 250);
8) repeat this procedure, raising the bolt torque to7 0 Nm, (35 Nm for small diameter) or until the flanges touch at their inside edges. Do not exceed this torque. To do so may cause permanent damage to the GRP flanges;
9) check the bolt torques one hour later and adjust to 70 Nm (35 Nm for small diameter) if necessary.

Note: When connecting two GRP flanges made with an O-ring gasket, only one flange shall have a gasket groove in the face.

Torque settings for the O-ring gasket type (maximum torque is based on the standard flange dimensions according to ISO 7005 and EN 1092):

PN	Maximum torque Nm
6	50 x Pipe OD (in m)
10	100 x Pipe OD (in m)
16, 20	200 x Pipe OD (in m)
25	225 x Pipe OD (in m)

3.3. GRP Loose Ring Flanges

The loose ring can be rotated to easily align with the bolt holes in the mating flange. The loose ring flange is manufactured for a profile gasket with steel ring for flat flange surfaces (no groove required) as shown in Figure 13:

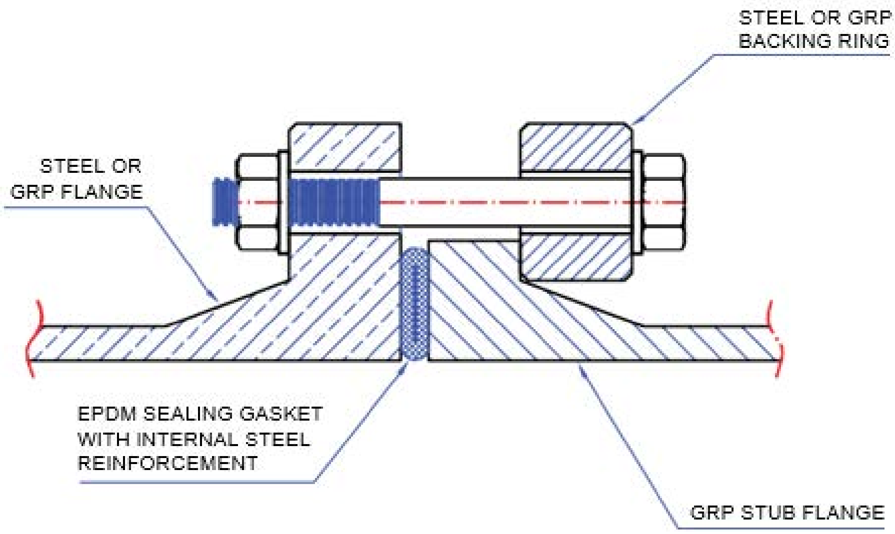
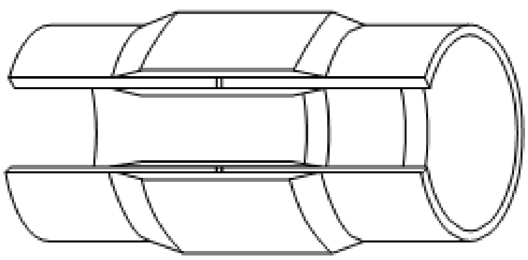


Figure 13: GRP loose ring flange.

The joining procedure for the GRP loose ring flange is identical to the GRP Fixed Flange, described in section 3.1.

4. BUTT-WRAP JOINT

This type of joint is made from the glass fibre reinforcements, impregnated with the polyester resin. It requires special designs, clean and controlled conditions, and skilled and trained personnel. Special instructions will be provided when this type of joint is required.



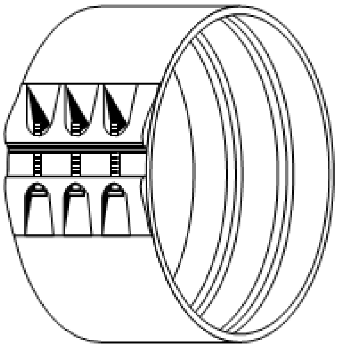
5. OTHER JOINING METHODS

5.1. Flexible Steel Coupling

When connecting the pipe to other pipe materials with different outside diameters, flexible steel couplings are one of the preferred jointing methods. These couplings consist of a steel mantle with an interior rubber sealing sleeve. They may also be used to join together the pipe sections, for example for closure or repair.

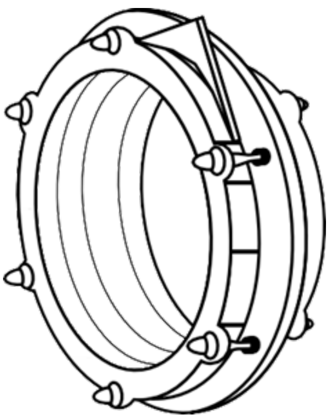
Three grades of flexible steel couplings are commonly available:

- coated steel mantle;
- stainless steel mantle;
- hot dip galvanized steel mantle.



Control of the bolting torque of the flexible steel couplings is important. Do not over torque as this may over stress the bolts or the pipe. Follow the recommended assembly instructions for couplings, but with the recommended bolt torque limits.

Dual bolt mechanical coupling:



5.2. Mechanical Steel Couplings

Mechanical couplings have been successfully used to join pipes made of different materials and diameters, and to adapt to the flange outlets. A wide design variation exists for these couplings, including bolt size, number of bolts and gasket design. Large variations also exist in the diameter tolerance of other materials, which often result in higher bolt torque than necessary in order to achieve a tight seal.

Consequently, we cannot recommend the general use of mechanical couplings. If a mechanical coupling is used to join a pipe to another pipe material, only the mechanical couplings with a dual independent bolting system should be used. This allows for the independent tightening, which typically requires less torque than recommended.

5.3. Corrosion Protection

Regardless of the corrosion protection applied to the steel mantle, the balance of the coupling needs to be corrosion protected as well.

6. FIELD JOINT TESTER

Portable hydraulic field joint test equipment can be used for the 800 mm diameters and above.

This equipment can be used to internally test the selected pipe joints. It is required that each pipe, which is adjacent to the tested joint, is sufficiently backfilled to prevent pipe movement during the testing.

Caution: This equipment is designed to test the joint to verify that it has been assembled properly, with gaskets in proper positions. This equipment is limited to a maximum 6 bars pressure test level.

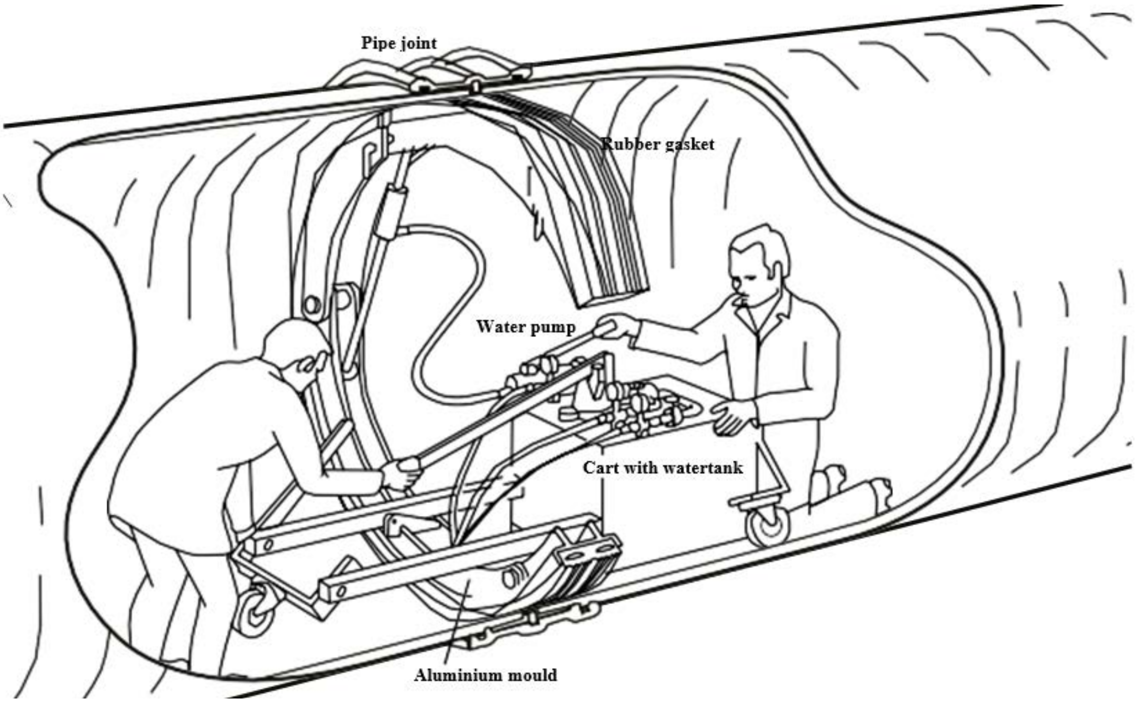


Figure 14: Field joint tester.

INSTALLATION OF PIPES

INSTALLATION OF PIPES

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1. LOADING, UNLOADING AND TRANSPORTATION

While transporting, moving, loading and unloading the pipes and fittings, maximum care should be taken to avoid any structural damage and prevent any kind of impact with rigid objects to avoid structural damage. The control of the pipes during loading and unloading should always be maintained. Loading and unloading techniques should be determined based on the on-site conditions and the following steps should be followed during these operations:

- identify the proper lifting points and methods;
- identify the proper moving methods and vehicles;
- visually inspect each moved item for damages or cracks;
- compare and inspect the total quantity of moved or transported items with the order quantity;
- report any damages or missing items. Damaged goods should not be used!

Loading and unloading of the pipes with DN ≥ 300 mm should be done with the appropriate loading equipment or a machine. Based on the pipe diameters, lengths and weights, as well as the jobsite conditions, crane-lifting strap method or forklift can be used for these operations.

To lift the pipes, nylon or hemp ropes or belts must be used. The steel cables must not be used as they can damage the pipes' surface.

Transportation vehicle should never be loaded over capacity while transporting pipes. To prevent any structural damage due to the movement and vibration during transportation, pipes should be detached from each other.

Depending on the type of the transport that is chosen and with the consideration of the local regulations concerning the transport of goods, it is necessary to choose a suitable packing system. In general, the pipes are stacked on trucks with the help of evenly spaced wooden joists (flat timbers, spaced at maximum 4 metres (3 metres for diameter ≤ DN250), with a maximum overhang of 2 metres). They are fixed by wedges which are nailed at the sides.

In practice, the system is the same as the one used to store the finished pipes in the yard. However, the number of wooden joists per pipe section, pertaining to the diameter and thickness (stiffness), will be increased by one or two units to take into consideration the vehicle jolts. The packages should be secured with straps fixed at the sides of the carrier.

Maximum stack height for the pipes on a vehicle is approximately 2,5 m. Pipe bundles should be fastened on the vehicle with pliable straps or ropes over the support points. If steel strips or chains are used for fastening, place fabric pads between the strips/chains and the pipe to prevent abrasion.

The wooden crates are preferably used for the delivery of fittings.

Apart from these considerations, which should be adapted to the local requirements, the following precautions must be taken into account while choosing and making the packages for delivery, to ensure that the least possible damage is caused during the transportation of the goods:

- pipes are sensitive to impact and should be adequately protected,
- excessive deformation can cause damages of the inner liner. Therefore, for the pipes with a low stiffness the number of wooden joists should be increased and/or the height of the stack should be reduced, or the returnable or non-returnable wooden cradles have to be used to hold and separate the pipes;
- machined ends for sleeve coupling should be protected against dirt and damages due to impact.

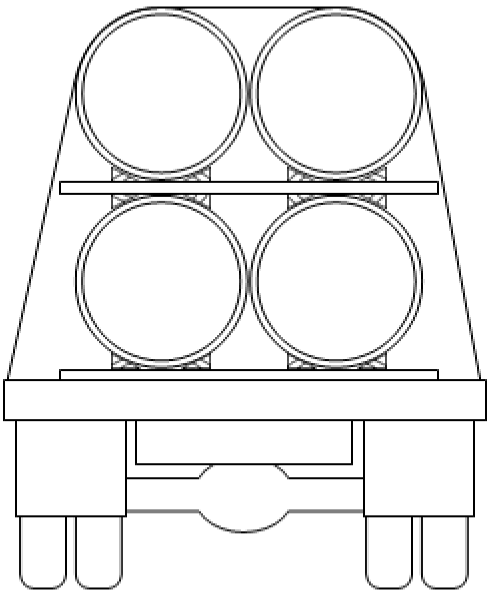


Figure 1: Transportation of pipes.

1.1. Unloading, Handling and Storage of the Nested Pipes

In many cases, the pipes with different diameters are telescoped (nested – when a smaller diameter pipe is placed inside bigger diameter pipe) inside one another to reduce the transportation costs. This procedure should be carried out with great care to avoid damages to the inner liner. It is good practice to slide the pipes in and out through a thermoplastic (PVC or polythene) sled. These pipes generally have special packaging and may require special procedures for unloading, handling, storing and transporting.

General recommendations:

- always use at least two lifting slings to lift the nested pipes. Since their weight is much higher than the weight of a single pipe, ensure that the lifting slings are strong enough to handle the total load. Consult TOPFIBRA for lifting points and lifting method for nested pipes;

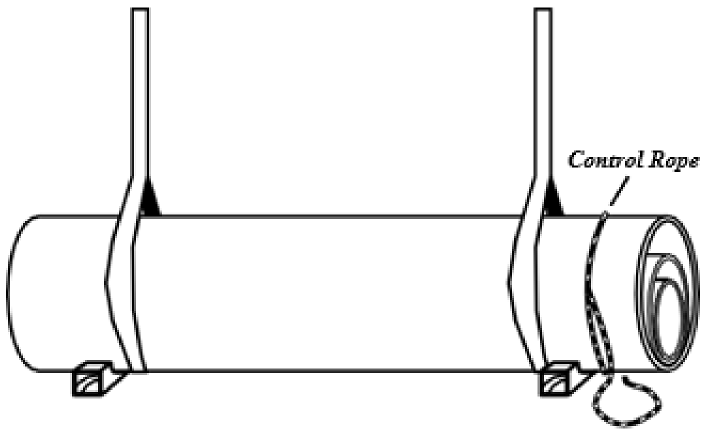


Figure 2: Double support for the nested pipes.

- in many cases it is preferred to use the nested pipes, because they reduce storage cost and space. It is usually best to store the nested pipes in the transport packaging, however, do not store nested pipe bundles in stacks (always store them in a single level) unless otherwise specified;
- to prevent the movement of the inner pipes while transporting, special packaging should be used. Do not remove the packaging of the nested pipes until installation;
- before de-nesting the inner pipes, be sure to remove all packaging such as steel strips, wooden wedges, sand bags etc. without damaging the pipes;

- using a forklift with a padded boom, fixed on one of its forks, is the most common way to de-nest the pipes. The padded boom is generally a steel tube covered with plastic. Before de-nesting the pipes, make sure that the forklift capacity is sufficient for this operation.

Procedure to de-nest the pipes with the forklift:

1) forklift operator places the boom inside the innermost pipe (in the smallest in size), without touching the pipe walls, then very slowly starts to lift the boom;
2) the boom slightly lifts the pipe until the lifted pipe becomes completely loose inside the outer pipe;
3) operator drives the forklift backwards and the lifted pipe is taken out of the bundle.
4) After de-nesting, pipes should be visually checked for damages. To keep the pipe bundle stable, it is recommended to perform de-nesting at a de-nesting station. If the weight and length of the pipes, or the unloading equipment capacity, do not allow for the described de-nesting operations, please consult TOPFIBRA for further instructions.

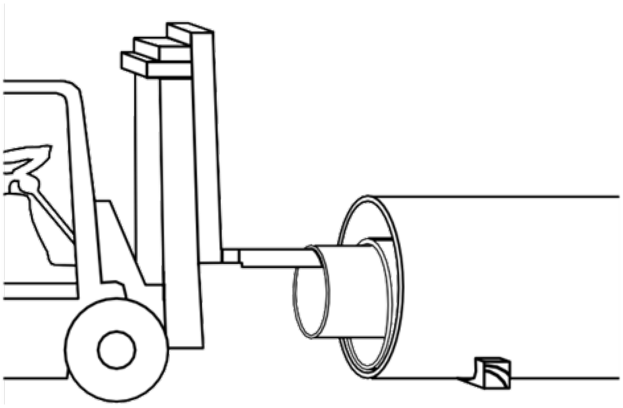


Figure 3: De-nesting with a padded boom.

2. ON-SITE STORAGE

General directions that should be followed when storing pipes on-site:

- pipes can be stacked and stored in the open, with precautions mentioned in the previous chapter, in order to avoid damages to the inner liner due to excessive deformation;
- because pipes are made of flammable materials, the storage areas should be selected with great care. The chance of accidental fires, such as the weeds fire, should be duly considered;
- the storage area should be flat, levelled and clear of objects such as rocks, stones, sharp edges, etc.;
- the storage ground should be resistant to the heavy loads and should not be exposed to the strong winds. Generally, the pipes are unloaded on-site along the trench. In this case they should not be laid on rocks, stones or on unstable conditions, which may cause them to be rolled away by the wind storm;
- it is recommended to keep the pipe ends lifted from the soil to prevent the sand, mud or dirt to affect the sleeve coupling, the elastomeric gasket, and the machined portion which will be nested;
- it is good practice to use the wooden joists or to lay the pipe sections on the sand heaps;

Figure 4: Storing pipes in a single level.

- pipes can be stored in piles to minimize the storage area within the allowed limits;
- when pipes are stored in piles, wooden cradles should be placed between the pipe levels. The first level pipes should be supported with the wooden wedges to prevent sliding;

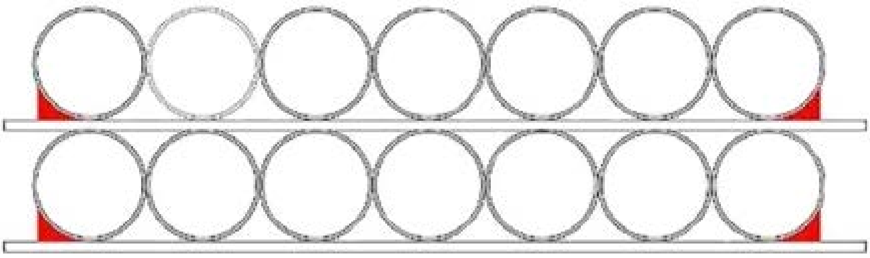
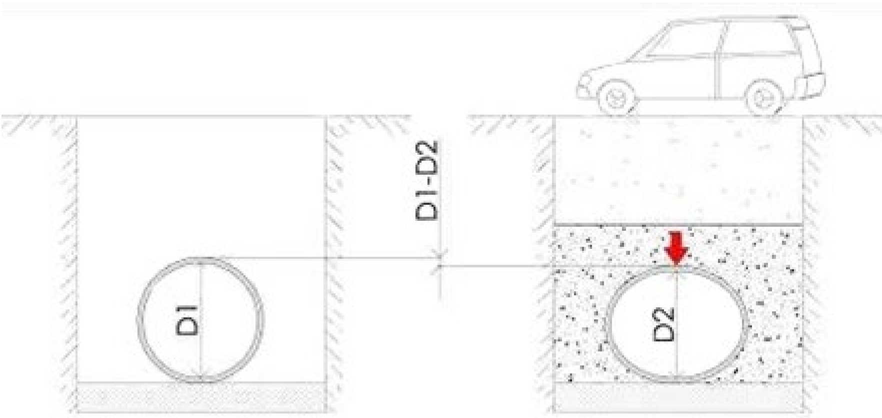


Figure 5: Storing pipes as piles.

- make sure the stack of pipes will be stable in case of high winds, uneven storage surface, or horizontal loads. If the occurrence of winds is likely, consider using ropes or slings to tie the pipes down;
- it is recommended to store pipes on flat timbers (which are at least 75 mm wide) to facilitate placement and removal of the lifting slings around the pipe, as well as enable easy handling of the pipes with a forklift. If possible, use the original shipping dunnage;
- flat timbers should be placed at a distance of ¼ of the pipe length from each pipe end;
- if couplings are delivered as bundles, they should be stored in a horizontal position to prevent the radial deflection;
- maximum piling height is around 2,5 meters (Superlit) or 3 meters (Flowtite). It is not recommended to store pipes as piles for diameters bigger than DN 1200 mm.

Change of the pipe's round form to oval form, as a result of the vertical loads, is defined as "vertical deflection" and calculated as:



$$\text{Deflection \%} = \frac{(D1-D2)}{D1} \times 100$$

Figure 6: Vertical deflection.

Maximum allowed vertical deflection, while storing pipes as piles/stacks, should not exceed the values in this table:

Stiffness Class (SN)	Maximum Deflection (% diameter)
2500	2.5
5000	2.0
10.000	1.5

Another way to describe the storage height is to express the number of stacking layers:

Diameter DN (mm)	Maximum number of stacking layers	
	SN 2500	SN 5000 & 10000
200 – 450	4	5
500 – 700	3	4
700 – 900	2	3
1000 – 1200	2	2
> 1500	1	1

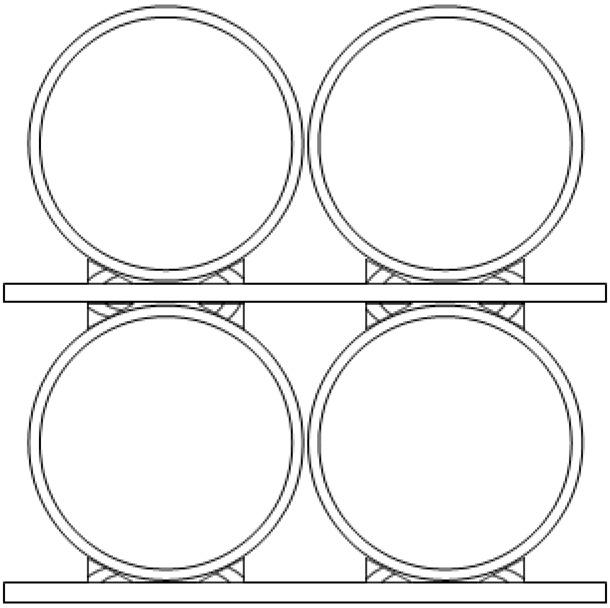


Figure 7: Pipe storage.

3. LAYING PIPES ABOVE GROUND

The distance between the supports, the type of supports, the anchorage and the fixing points are established in the design phase.

In general, the pipes should be supported by the steel or concrete cradles surrounding the pipes over an arc of 180° with a layer or rubber at least 4 mm thick in between and a Sore hardness of 40 – 60°.

During the laying operations, it is necessary to take all possible steps to avoid damaging the product. In particular, the following points should be kept in mind:

- tightening of the fixed points clamps should be carried out with the pipe at the temperature foreseen during the working conditions, the design values should be scrupulously respected;
- bolts of flanges should be tightened at the specified loads;
- elbows should be anchored when it is foreseen that the pipe will undergo torsion stresses;
- all fittings not made of the FRP (such as valves, steel flanges etc.) should be supported individually;

- all battery limits, such as connections with the equipment or with the pipelines, made from a different material, should not transfer supplementary stresses to the FRP pipeline;
- all tee connections should be supported to avoid the interactive stresses between the main line and the branch.

This general information obviously cannot cover all the problems involved during the laying of the pipes above ground, therefore, during the design work, the stress should be analysed for each individual case and the most suitable support system should be selected.

Furthermore, when the pipes are installed in contact with the flammable products, all metal parts must be earthed to prevent the build-up of the electrostatic charges which can lead to sparks.

Figure 8: Above ground installation.

4. LAYING PIPES BELOW GROUND

The underground pipes are laid on a bed of sand or on the screened material, compacted to the levels envisaged in the design. Then, the backfilling is carried out at the sides and above the pipe in 20-30 cm layers, each with the same material as was used for the bed.

The first layer of the backfilling should be applied with great care since it provides a firm support below the pipe. Each layer must be compacted with the methods and systems depending on the nature of the used material, taking care to avoid any damage to the pipe during this operation.

A 1% - 3% increase of the vertical diameter of the pipeline during the laying operations is beneficial in order to compensate for the reduction of the vertical diameter, which takes place during the pipeline service.

It is impossible to give full instructions about the laying operations, since each installation is a case of its own. However, the following recommendations can be useful:

- the trench walls should be dug as vertical as possible;
- any contact between the pipe and large stones or rocks should be avoided;
- where installing below the water table, a continuous drainage should be provided in the trench until the backfilling has been carried out;
- crossing areas, subjected to heavy external loads (permanent or mobile), must be very carefully analysed to establish if special steps must be taken. For example: a different stiffness to fit the situation or an increased burial depth, or if a sheath of a steel pipe, or a reinforced concrete cover should be used;
- in the soils with a low modulus of reaction, such as clayey soil or grounds with a high content of organic substances, the width of the trench should be increased and the pipes should be surrounded with compacted and selected backfilling material;
- the behaviour of the underground pipes is greatly affected by the surrounding soil, that is why it is essential, when carrying out the laying operations, to comply with the conditions of the design.

An engineer designing the underground pipelines should take great care when examining the soil parameters. In case of doubts he should assume the worst conditions.

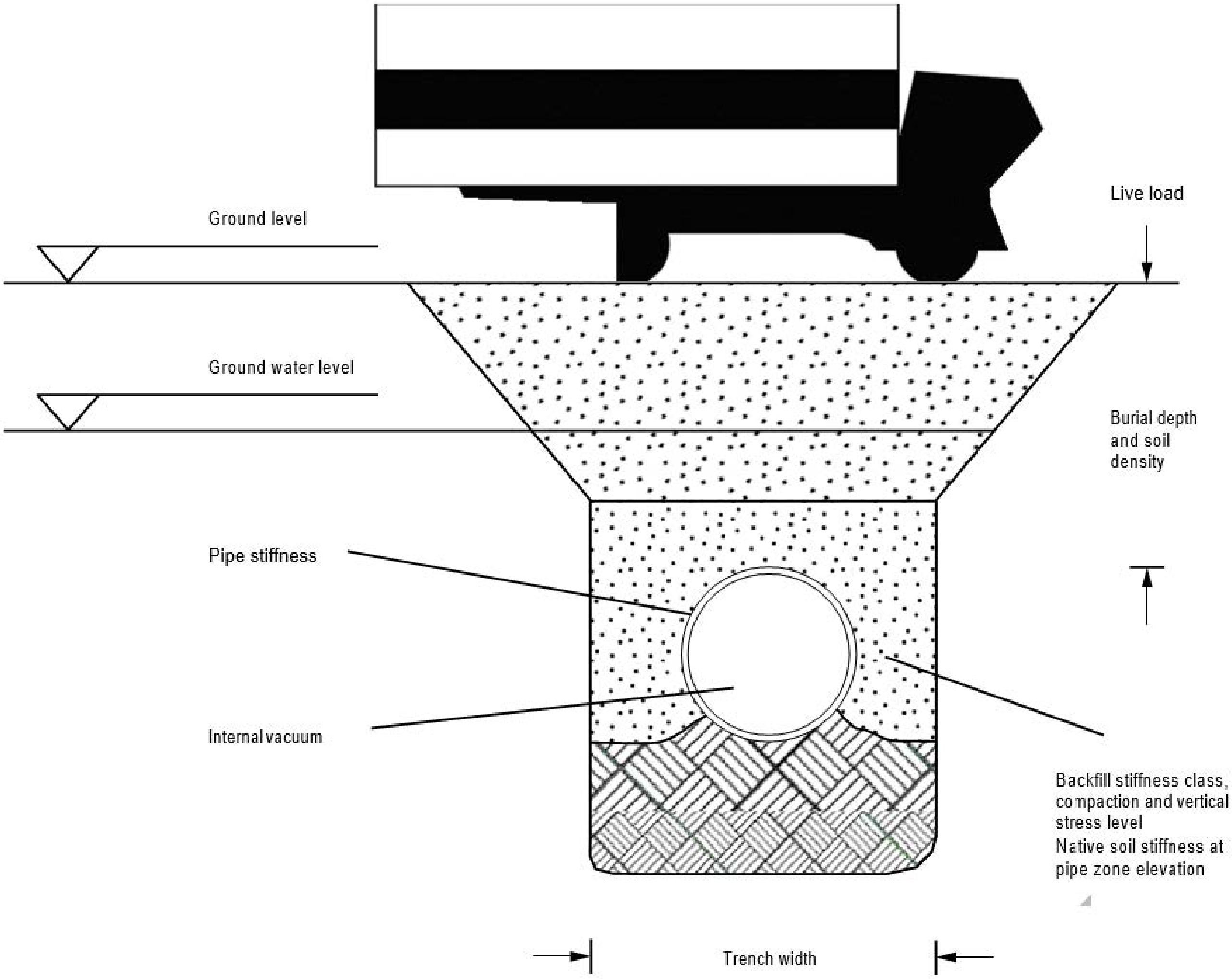


Figure 9: Design parameters.

4.1. Concrete Encasement

When pipes (or fittings) have to be encased in concrete (for thrust blocks, stress blocks, or to carry unusual loads) installation procedures require specific additions.

When the concrete is being poured, an empty pipe or fitting will experience large uplift (flotation) forces. The pipe must be restrained against movement that could be caused by buoyancy forces. This is normally accomplished by strapping the pipe to a base slab or other anchors. Straps should be from a flat material with a minimum 8% DN width, or 25 mm wide (whichever is wider). Straps should be strong enough to withstand the flotation uplift forces. At least two straps per pipe have to be used.

The maximum spacing between the straps is shown in this table:

DN	Maximum Strap Spacing (m)
< 200	1.5
200 – 400	2.5
500 – 600	4.0
700 – 900	5.0
≥ 1000	6.0

For the PN1 pipes, the maximum strap spacing should be reduced by 33%. The straps should be tightened to prevent the pipe uplift and movement. They must not be so tight as to cause additional pipe deflection. Tees and elbows require at least a 3 strap fixing. To prevent the lateral movement, cross strapping is recommended. Pipes should also be strapped adjacent to joints to avoid misalignment.

The pipe should be supported in a way that the concrete can easily flow around the pipe completely and fully underneath it. The supports should result in an acceptable pipe shape (less than 3% deflection and no bulges or flat areas). For the pressure pipes, the deflection should be limited to less than 1% to avoid high loads on the surrounding concrete due to pressure re-rounding of the pipe. It is recommended to internally support all the pipes larger than DN1500 during the concrete encasement. The internal supports shall have large, shaped contact surfaces to avoid stress concentrations in the pipe and should be tied with the anchoring straps.

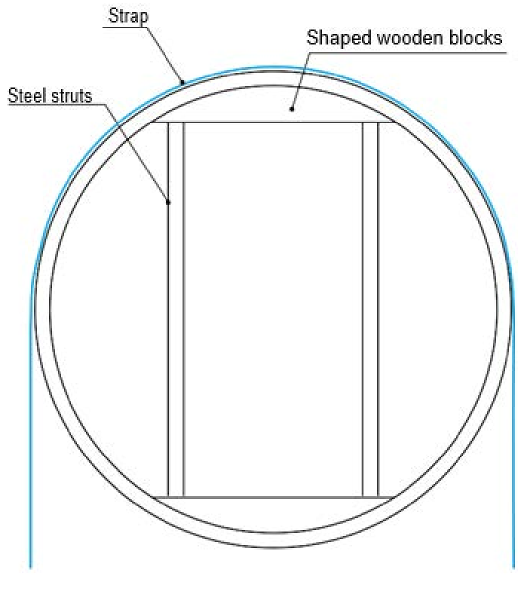


Figure 10: Internal pipe support.

Concrete must be poured in stages. This ensures sufficient time for the layers of cement to set and no longer exert buoyant forces. The maximum lift heights, as a function of stiffness class, are shown this table:

SN Maximum lift	DN Maximum Spacing (m)
2500	Larger than 0.3 m or DN/4
5000	Larger than 0.45 m or DN/3
10.000	Larger than 0.6 m or DN/2

Maximum lift is the maximum thickness of the concrete that can be poured at one time for a given nominal stiffness class.

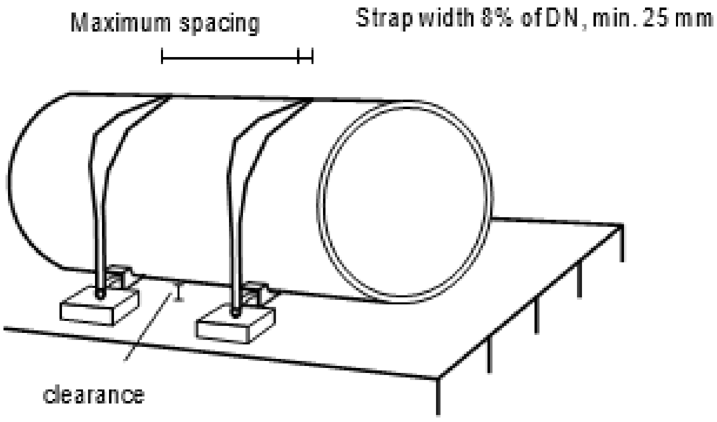


Figure 11: Pipe anchoring, the maximum spacing of the straps.

Note: The need for anchoring and supporting the pipes, when pouring the concrete, can be reduced by actively controlling and limiting the buoyancy exerted on the pipes.

5. FIELD ADJUSTEMENTS

5.1. Length Adjustment

A large majority of pipes have the outside diameter of the barrel of the pipe within the tolerance range of the calibrated spigot. These pipes are marked as Adjustment Pipes or similar. The following procedures will assist in making the correct length adjustments:

1) determine the required length and mark it with a square cut on the selected pipe;
2) cut the pipe at the appropriate location using a circular saw with a diamond-coated blade. Use proper eye, ear and dust protection. Use health & safety protection according to your local country regulations;
3) clean the surface of the jointing area, sand smooth any rough spots using a grinder bevel, and grind the pipe end to ease the assembly (see Figure 12). No further grinding is necessary.

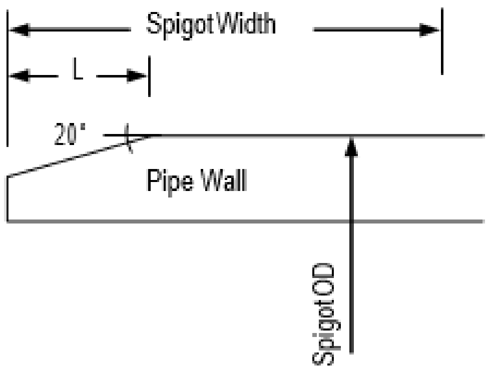


Figure 12: Pipe spigot and bevel dimensions for coupling joints.

For the field closure section, double the spigot width. The design of the pipes does not require any sealing of the spigot ends after field cutting. However, be sure to comply with the local/national norms and regulations on sealing, e.g. adhering to the industrial health and safety standards.

It is very important that the interior edge of an adjustment pipe is rounded after field cutting with a specific cutting and chamfering equipment.

5.2. Field Closures with Couplings

Couplings can be used for field closures and repairs. The minimum length of the closure pipe should be 1 metre. In addition, the closure pipe should not be adjacent to a "rocker" pipe (the short length pipe which provides flexibility adjacent to the rigid connections).

5.2.1. Procedure

Measure the distance between the pipe ends where you want to set in the closure pipe. The closure pipe should be 10-20 mm shorter than the measured length. The narrower the gap the easier it will be to make the closure.

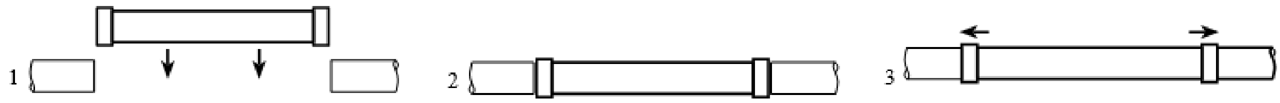


Figure 13: Closure selection assembly.

5.2.2. Pipe Selection

Choose a pipe which is within the spigot diameter tolerance. These pipes will have the required outside spigot dimension for joining along the entire pipe length. If possible, choose a pipe with the outside dimension at the low end of the spigot range, presented in this table:

Table – Spigot dimensions and tolerances up to PN16

Diameter series	DN (mm)	Spigot width (mm)	L (mm)
B2	300	130	6
B2	350	130	8
B2	400	130	10
B2	500	130	14
B1	600	160	17
B1	700 - 2400	160	20
B1	2500 - 3000	175	20
B1	3100 - 4000	185	20

Series B2 matches with Ductile Iron spigot O.D. Series B1 is GRP-BRP O.D. series. In some countries, the Ductile Iron (B2) series may not be used.

5.2.3. Pipe Preparation

Mark the required pipe length and make a square perpendicular cut on the pipe's axis with a circular saw. Use a grinding tool to make a 20-degree bevel on the pipe end and then round-off the corners.

Be careful that the remaining thickness on the pipe spigot end is not less than one half the pipe thickness. It is also important to have a minimum chamfer length, L, for guiding the pipe end without damaging the gasket. Follow the recommended lengths in the previous table. After bevelling, use sandpaper to remove any sharp corners on the pipe surface which may have been caused by the cutting. Smooth the spigot of any rough spots.

The spigot width must be at least equal to the coupling width. This will be twice the values shown in the previous table.

Please make sure that the surface has no grooves, and that the spigot OD is within the limits shown in the previous table.

5.2.4. Installation

Description below is a brief summary. Installation information is extensively described in the chapter Joining methods, section 1 – Double Bell Couplings:

1) Select two couplings, remove the centre registers, and leave the gaskets in place. Clean the couplings if necessary. The gasket groove must be free of dirt to allow for an unrestricted deformation of the gasket;
2) lubricate carefully, including between the lips;
3) lubricate the clean spigot ends of the closure pipes with a thin, continuous layer of lubricant. Lubricate the bevelled surfaces as well;
4) place one coupling square onto the end of the closure pipe so the entire circumference of the gasket is in contact. Uniformly push or pull the coupling onto the closure pipe, until the entire coupling is resting on the spigot end. It may be necessary to gently help the second ring over the chamfered end of the pipes. Repeat with the second coupling on the other end;

5) mark home-lines on the adjacent pipe spigot ends to control the uniform backward movement of the coupling. The home-line's location is calculated as follows:

   HL = (Wc-Wg)/2

   Where:

   HL = the homeline;

   Wc = width of the coupling;

   Wg = width of gap between the closure pipe and the adjacent pipe (measured);

6) set the closure pipe in the trench, in alignment with the adjacent pipes and with equal clearance on either side. Any angle or tilt will complicate the assembling process;
7) clean the spigot ends of the adjacent pipes and lubricate with an even, thin layer of the lubricant. Install special tools to pull the coupling back to the closing position. It is recommended that you pull the couplings over both sides simultaneously, keep the closure pipe centred and minimize the pipe end contact. Stop pulling when the coupling's edge touches the home-line. For man-entry size pipes, an individual inside the pipe, watching the assembly process, can be advantageous;
8) the compaction of the backfill around a field closure pipe is very important and should be no less than 90% SPD. Often, the closure area is over excavated for easier access, which is also recommended to prevent the excessive movement and joint rotations.

After the coupling is in final position, a feeler gauge may be used to assure that the gasket lips are properly oriented.

Specific installation tools might be required to carry out a proper installation!

BURIED PIPE INSTALLATION

BURIED PIPE INSTALLATION

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1. FOREWORD

Complete instructions for handling and laying of the TOPFIBRA Reinforced Thermosetting Resin Pipe (RTRP) are outlined in this handbook. With proper installation techniques and the inherent properties of the flexible (RTRP) piping system, heavy soil and traffic loads can be sustained without the excessive deflection or detrimental effects. It has to be kept in mind that only the pipe and the backfill together, constitute a high-performance pipe/soil system which will provide a reliable and long lasting installation.

It is important that the end-user, designer and contractor understand that TOPFIBRA pipes are designed so that the bedding and the backfill provide the structural support. If the conditions arise, which are not explicitly covered in this handbook, TOPFIBRA Technical Department should be consulted for clarifying.

2. APPLICABLE DOCUMENTS AND SPECIFICATIONS

ASTM D 698	Moisture-Density Relations of Soil
ASTM D 883	Definitions of Terms Relating to Plastics
ASTM D 3839	Underground Installations of Flexible Reinforced Thermosetting Resin Pipe and Reinforced Plastic Mortar Pipe
ASTM D 2049	Test for Relative Density of Cohesionless Soils
ASTM D 2310	Classification for Machine-Made Reinforced Thermosetting Resin Pipe
ASTM D 2487	Classification of Soil for Engineering Purposes
ASTM D 2498	Recommended Practice for Description of Soils (Visual/Manual Procedure)
ASTM D 2996	Specification for Filament-Wound Reinforced Thermosetting Resin Pipe

3. DEFINITIONS

Terminology used in this section is represented in Fig. 1:

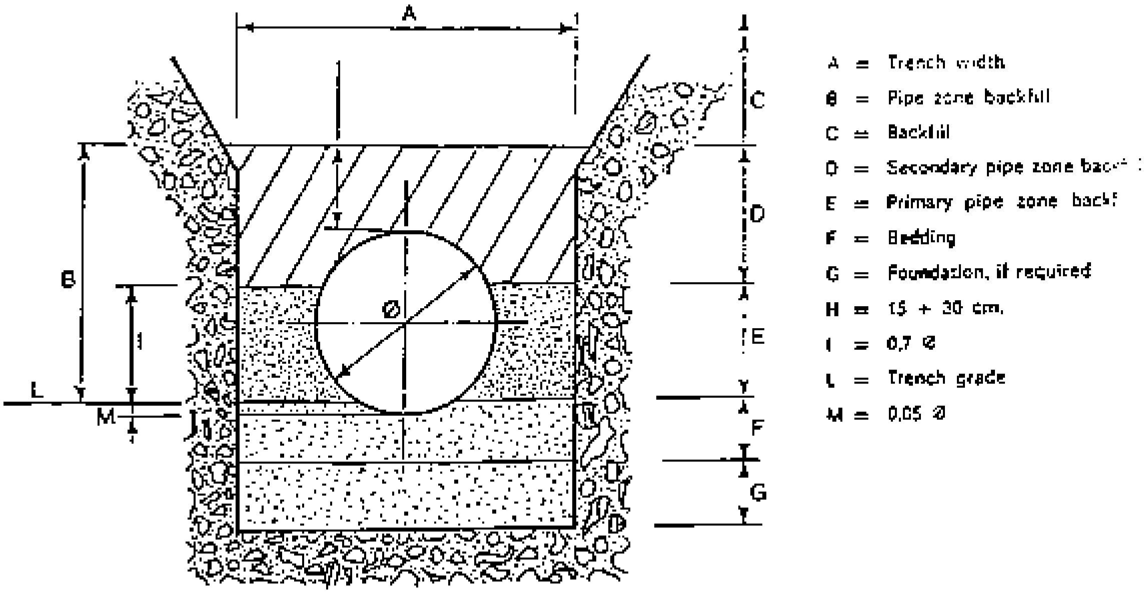

Fig. 1 - Trench Cross Section Showing Terminology Relationship.

3.1. Bedding (F)

Bedding is the supporting soil directly beneath the pipe in the trench bottom. Bedding includes the basic trench foundation plus any specially prepared layers on which the pipe will rest.

3.2. Sound Granular Soil

It is the crushed rock (pea gravel or sand) with a 5 - 25 mm size range.

3.3. Unstable Soil

Unstable soil stands for the native soils which are soft, mushy and/or unable to stand vertically when excavated. These type of soils cannot be expected to provide a firm foundation or side support.

3.4. Pipe Zone (B)

Pipe zone is the trench cross section area from the bottom to the top of the pipe.

3.5. Primary Backfill (E)

This is the initial (up to 0.7x Ø) compacted backfill within the pipe zone, on which the pipe will rest for the side support.

3.6. Secondary Backfill (D)

Secondary backfill is found between the primary backfill and the backfill (C).

3.7. Relative Compaction

Relative compaction is the density of the compacted, dry job-site soils, expressed as a percentage of the laboratory standards, as determined by the procedures of ASTM D 698.

3.8. Ring Deflection

Ring deflection stands for an out-of-round condition of a pipe section, as a result of the external loads imposed upon it.

4. ON-SITE INSPECTION

As soon as the pipe has arrived at the job-site, the following steps should be taken:

1. inspect the transport cradles, padding, crates, retaining strapping and any other protection for failures and record the results;
2. if the load has shifted or indicates a rough treatment due to transportation, carefully inspect the exterior, interior and ends of the pipes for any damage and record the results;
3. check the quantity of each item against the bill of lading or the consignment note and record the results;
4. if any damage to the pipes is found, it must be reported to the Carrier and to the Supplier to take the necessary actions.

DO NOT USE DEFECTIVE PIPES!

5. UNLOADING AND HANDLING OF THE PIPES

For more information, see chapter "Installation of pipes".

The following procedures should be followed to eliminate the potential damage to the pipes and to maintain the maximum safety:

1) use pliable straps, slings or ropes to lift the pipes. These can be canvas or polyester belts with a minimum width of 10 cm, or nylon ropes with a minimum diameter of 30 mm. Do not lift pipes using hooks at pipe ends or by passing a rope, chain or cable through the pipe section;

DO NOT USE STEEL CABLES OR CHAINS FOR LIFTING!

DO NOT DROP, IMPACT OR BUMP THE PIPES, PARTICULARY THE PIPE ENDS!

2) straight continuous lengths of a pipe can be lifted with one or two lifting straps. However, because of the pipe's very smooth surface, it is recommended to lift it at two points for its safety (Fig.2 and 3). It is also easier to control the balance when using two straps. When using one lifting strap, the strap should be fastened at the pipe's centre of gravity. Both methods should be carried out very carefully and the fastening points should be controlled and secured. To prevent any possible accidents, ensure that there is nobody under the pipe while lifting them;

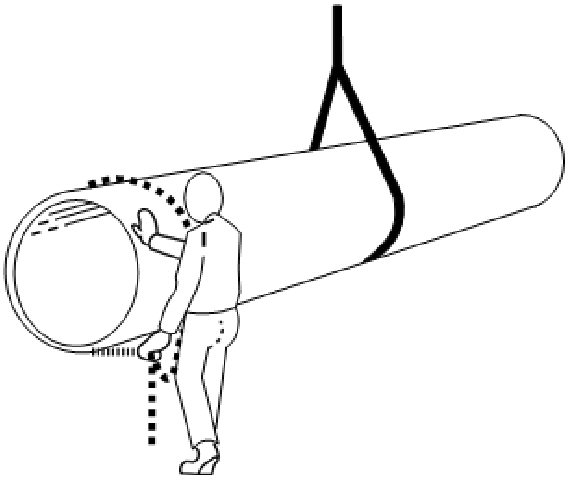

Figure 2: Lifting a pipe at one support point.

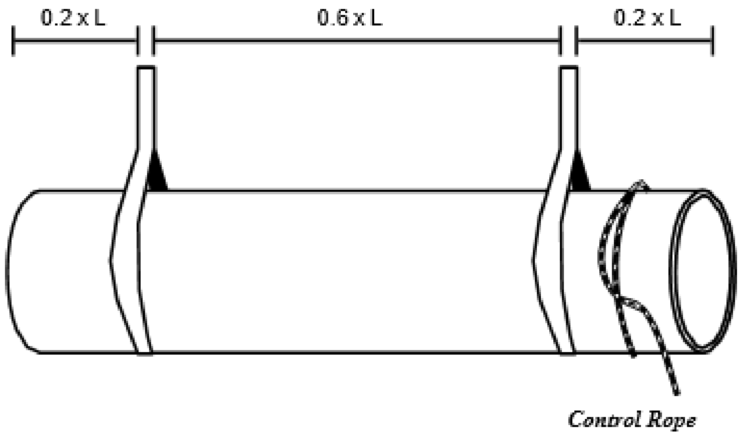

Figure 3: Lifting a pipe at two support points.

3) pipe assemblies, fabricated in multiple sections or special pieces, require two lifting points;
4) guide ropes can be tired around the pipe and used to control the pipe while it is in the air. It is particularly strongly advised to use this method in high winds. Controlling the pipe with guide ropes should be done at a distance and not from underneath the pipe;
5) unitized loads may be handled using a pair of slings. Do not lift a non-unitized stack of pipes as a single bundle. Non-unitized pipes must be unloaded and handled separately (one at a time).

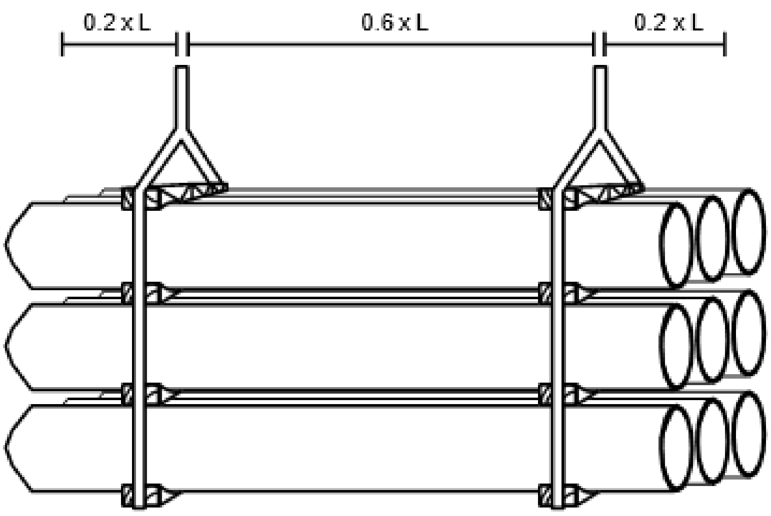

Figure 4: Lifting a unitized stack.

5.1. Loading and Unloading with the Forklift

Forklift is generally used for the factory loadings or for the wagon loadings of the railway transportation. However, since there is generally no need for a forklift at the infrastructure jobsites, unloading is performed with the crane-lifting strap method.

If forklift is used, ensure that it is operated by a licensed forklift operator. Pipes should be placed on wooden cradles and forklift should lift the pipe together with the cradle.

Figure 5: loading and unloading with the forklift.

Figure 6: Loading and unloading with the forklift.

5.2. Loading and Unloading of Couplings and Fittings

Every fitting should be carried and unloaded with maximum care, regardless of its dimensions. In case fittings are delivered plain (without external packaging), it is critical to determine the correct lifting points and unloading techniques. To unload fittings with packaging, pipe unloading methods can be used.

The centre of gravity and balanced distribution of mass factors should always be taken into account when fittings are being lifted, loaded and unloaded.

6. STORAGE OF THE PIPES

For more information, see chapter "Installation of pipes", section 2 – "On-Site Storage".

1) Pipes with diameters below 1m can be stored directly on the sandy soil. Please, check to ensure that the ground is flat and free of rocks bigger than 40 mm in diameter or of other potentially damaging debris;

DO NOT STORE PIPES ON THE HARD OBJECTS OR UNEVEN SURFACES!

2) pipes with diameters over 1m can be stored on their delivery cradles. Narrow flat supports are not an adequate substitute;

DO NOT STORE PIPES NEAR INFLAMMABLE LIQUIDS!

3) pipes can be stored in the open for a period of 12 months without any detrimental effects being caused by the ultra-violet (UV) degradation. Consult TOPFIBRA regarding longer periods of storage in the open.

7. TRENCH EXCAVATION

- The following points should be considered during the trench excavation:
- take the necessary safety precautions to ensure a safe working environment;
- prevent penetration of water into the trench;
- during the excavation, make sure that trench walls remain in a vertical position;
- remove all obstacles and sharp edges such as rocks, gravels, concrete, etc. from the trench to achieve flat bedding;
- remove all organic items such as plants, tree roots, etc. from the trench ground;
- ensure that the trench ground is strong and stable;
- if the trench ground is not stable enough, increase the trench depth for stabilization;
- discharge water (if there is any) from the trench before preparing the bedding;
- when the underground water level is high, it might cause pipes to float. To prevent floatation, increase the trench depth to increase the height of the backfilling;
- ensure that the trench width is sufficient enough for the bedding and backfilling compaction works;
- ensure that the excavated materials are piled away from the trench so they do not roll back into the trench.

Sometimes, a new pipeline route passes underneath an existing pipeline. In such cases, the existing pipeline should be shut down (if possible) and the excavation should start only after the existing pipeline has been stabilized with supports. The new pipes should be lowered into the trench without interacting with the supports and should be slowly laid underneath the existing pipeline.

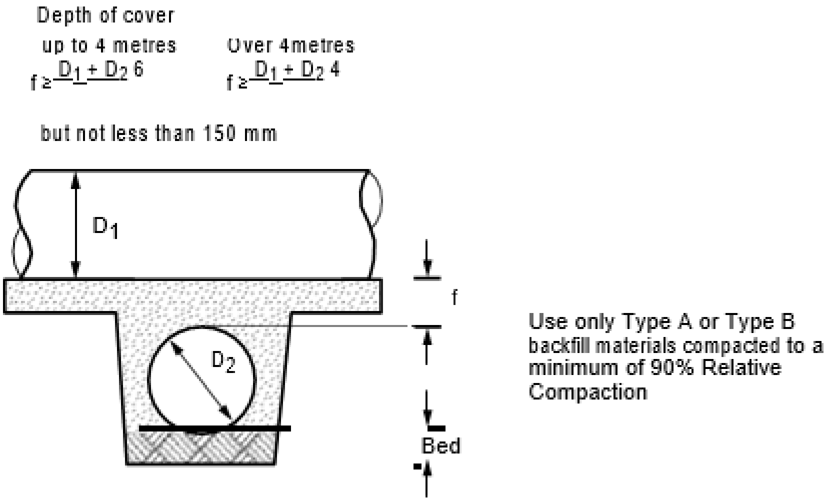

Figure 7: Crossing pipes.

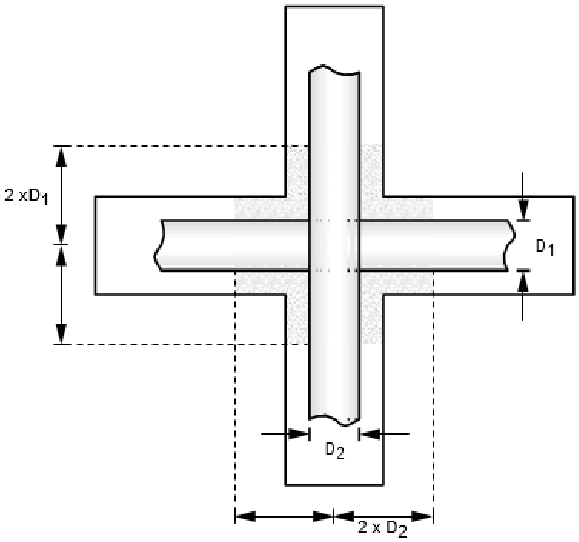

Figure 8: Top view of the backfill in the cross-over.

When the new pipeline passes above the existing pipeline, extra care should be taken not to damage the existing pipe. It should be protected by fastening it to a steel beam which crosses over the trench. It is also advisable to wrap the pipe in order to protect it from the impact damage. When the new pipe is laid, backfill material SC1 or SC2 class must be placed back into the trench and must be completely compacted to a minimum of 90% SPD around both pipes, plus 300 mm above the crown of the upper pipe. This backfill should extend at least twice the diameter into each trench.

7.1. Standard Trench

The width of the trench at the springline of the pipe does not need to be greater than necessary to provide the adequate room for jointing the pipe in the trench and compacting the pipe zone backfill at the haunches. Typical values for "A" (see Figure 9) are given in the table below.

Note: Where the rock, hard pan, soft, loose, unstable or highly expansive soils are encountered in the trench bottom, it may be necessary to increase the depth of the bedding layer to achieve uniform longitudinal support.

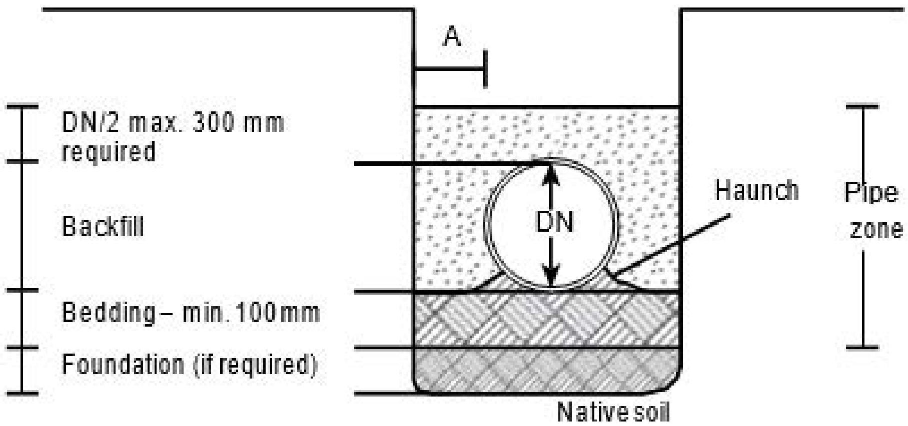

Figure 9: Pipe backfill nomenclature.

Table of the typical A values:

Nominal size DN	A mm
DN ≤ 400	200
400 < DN ≤ 900	400
900 < DN ≤ 1600	500
1600 < DN ≤ 2400	600
2400 < DN ≤ 4000	900

7.2. Trench Contour

The surface at the trench grade should be continuous, smooth and free of big rocks more than 1.5 times the thickness of the pipe if rounded, or more than 1.0 times the thickness of the pipe if rocks have sharp edges and can cause point-loading of the pipe. Where the ledge rock, hardpan, big rocks, timber or other foreign materials are to be found, it is advisable to pad the trench bottom with the sand or compacted fine-grained soils at least 15 cm thick to provide an adequate foundation.

7.3. Trench Width

The width of the trench at the top of the pipe should not be wider than necessary to provide adequate room for jointing the pipe in the trench and for compacting the backfill in the zone of the pipe at the sides. If necessary, bell holes are allowed at the joints.

For standard the installations, minimum trench width is advised as:

- DN < 600, Trench width = DN + (2 x 300 mm)
- DN < 1000, Trench width = DN + (2 x 400 mm)
- DN ≥ 1000, Trench width = DN + (2 x 450 mm)

If the soil is unstable, loose or soft, the trench width can be increased, based on the pipe stiffness and trench depth. Increasing the trench width places the pipe further away from the soft native soil, allowing a deeper installation and higher allowable negative pressure (vacuum).

The soil support for a buried pipe installation, expressed as the composite constrained soil modulus M_s, depends on the constrained modulus of the backfill and the native soil, M_{sb} and M_{sn}, as well as the trench width.

For pipe installation in the soft native soils, where M_{sn} is lower than M_{sb}, the composite modulus M_s, will be lower than the backfill modulus M_{sb}. This effect is less pronounced for wider trenches and can be disregarded for trenches wider than 5 times the pipe diameter at elevation of the pipe springline. This means that a wider trench provides a better soil support.

For installations in firm native soils, where Msn is higher than M_{sb}, the composite modulus will be higher than the backfill modulus. This effect will be less pronounced for a wider trench, which in this case will provide less soil support.

The trench must always be wide enough to allow for adequate space to ensure proper placement and compaction of backfill in the haunch region. It must also be wide enough to safely operate compaction equipment without damaging the pipe.

7.4. Trench Depth

The trench depth is determined by the intended service, pipe properties, design of the pipeline, size of the pipe, local properties of the soil and the combination of the static and dynamic loading.

The trench depth should be sufficient to prevent the conveyed fluids from freezing. Sufficient cover (backfill and the final backfill) should be provided to prevent the pipe flotation in potentially high ground water areas.

Generally accepted trench depths are:

Pipe Stiffness (SN)	Trench depth (meter)
2500	1-3
5000	1-5
10000	1-7

Minimum trench depths:

Surface loads	Live (wheel) load		Min. trench depth
	Kilo Newton	lbf	meter
AASHTO H20 (C)	27	16.000	1.0
BS 153 HA (C)	90	20.000	1.5
ATV LKW 12 (C)	40	9.000	1.0
ATV SKW 30 (C)	50	11.000	1.0
ATV SLW 60 (C)	100	22.000	1.5
Cooper E80		Railway	3.0

8. STABLE TRENCH CONDITIONS

Stable trench conditions occur in soils where only a small displacement (strain) is caused by variations in the pressure (stresses) or moisture content. Such conditions enable the trench wall to be made vertical from the bed to the top of the pipe without using the shoring or sheet piling (Fig 3).

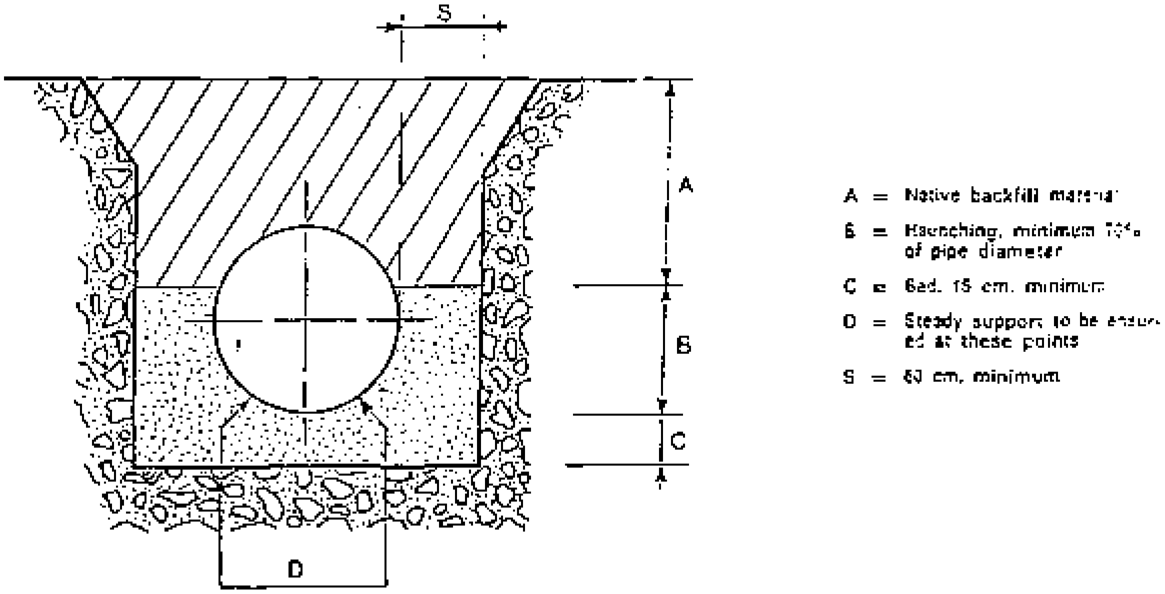

Fig. 3 - Installation in stable soils: method of trench construction.

9. UNSTABLE TRENCH CONDITIONS

Trench bottom is described as unstable if it contains loose, soft, or highly expansive soils, with cohesion less than 1440 kgs/m^2, as calculated by an unconfined compression test:

CONSISTENCY FOR THE COHESIVE SOILS	
Consistency	Cohesion in kgs/m^2 from the unconfined compression test
Very soft	≤ 1220
Soft	1220 ÷ 1440
Medium	1440 ÷ 4880
Stiff	4880 ÷ 9765
Very stiff	9765 ÷ 19530
Hard	≤ 19530

In unstable conditions, the bottom and the sides of the trench must be stabilized before laying the pipeline, or a foundation must be constructed to minimize the differential settlement of the trench bottom to prevent joint rotation or misalignment. This can be accomplished (Fig. 4) by: lowering the water table by at least 25 cm below the elevation of the invert with well-points, shoring the sides; or (Fig. 5) by over-excavating the bottom and sides of the trench and replacing them with a mixture of sand and coarse gravel or crushed stone; or a combination of the above methods.

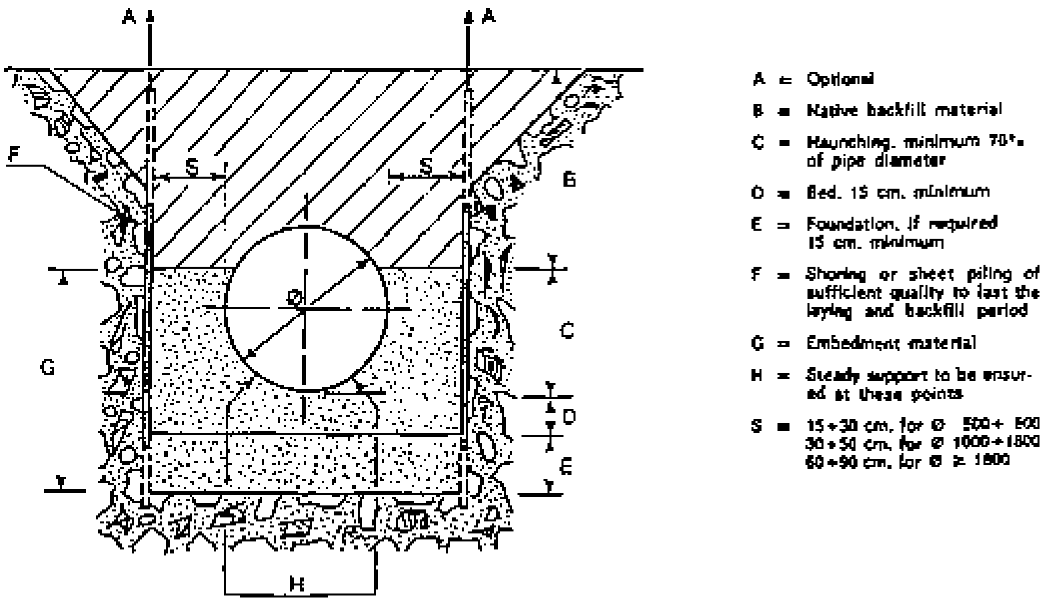

Fig. 4 - Method of trench construction for unstable soil conditions. - 1st alternative.

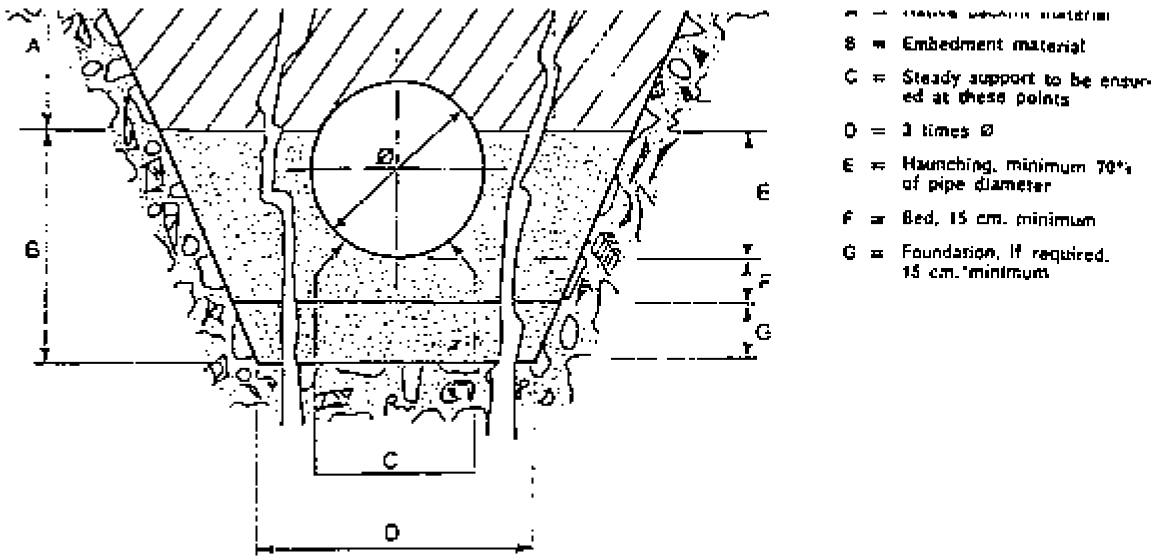

Fig. 5 - Method of trench construction for unstable soil conditions. - 2nd alternative.

The depth of the sandy gravel or crushed stone material, used for the foundation, depends on the trench bottom soil conditions, but it should not be less than 150 mm thick. Normal bedding must be placed on top of such foundations. When crushed rock is used, a filter cloth or geotextile can be laid on the foundation, which will completely surround the foundation material. It will also prevent the foundation and the bedding materials from migrating into one another and causing a loss of the pipe support. Filter cloth is not needed if the same material is used for the foundation and the bed, or if the graded sandy gravel is used for the foundation.

Additionally, the maximum pipe section length between the flexible joints should be less than 12 m. For very unstable conditions, the pipe lengths should not exceed 6m.

In case of the specific site conditions, please consult TOPFIBRA's Technical Department.

9.1. Sheet Pile Application During the Trench Excavation

Trench walls should be supported with sheet piles if the natural ground soil is loose or unstable, if underground water level is high, or if the trench depth is higher than is usual for the standard conditions.

Backfill compaction is subjected to disruptions during the removal of the sheet piles, which decrease the pipe support. To overcome this problem, removal of the sheet piles should be done step by step and after each sheet pile has been removed, backfilling should be controlled and compacted until the desired compaction level.

It is recommended to use crushed rock as the backfilling material for the trenches where the sheet piles are used. Since the underground water level is generally high in these types of trenches, crushed rock size should be big enough to resist the water washout.

If sheet piles are used, "DN+2m" trench width is advised, up to the nominal pipe diameter DN 1000, and a "3xDN" trench width for the nominal pipe diameter DN 1000 and above.

Figure 10: Sheet piles.

9.2. Trench Supports

Care must be taken to ensure proper support between the native soil and backfill when sheeting is removed.

Removing the sheeting in steps and then compacting the pipe-zone backfill against the trench wall will provide the best support to the pipe, thus filling the voids that frequently occur behind sheet piling. If the sheeting is pulled after the pipe-zone backfill has been placed, the backfill loses the support, which in turn reduces the support to the pipe, especially when voids form behind the sheeting. To minimize this loss of support, the sheeting should be vibrated during the removal.

There should be no voids, or lack of backfill, between the outside of the sheeting and the native soil, up to at least 1 m above the pipe crown. Only SC1 or SC2 class backfill should be used between the temporary sheeting and the native soil, compacted to at least 90% SPD.

For the permanent sheeting, sufficiently long sheeting should be used to properly distribute the pipes' lateral loads at least 300 mm above the pipe crown. The quality of the permanent sheeting should good enough to last as long as the design life of the pipe.

Backfill procedures are the same as for the standard installations. Permanent sheeting can be assumed to be a group 1 native soil.

9.3. Trench Dewatering

When the water level can be kept below the pipe invert, the installation can proceed normally. If this condition cannot be observed, please consult the TOPFIBRA's Technical Department. However, the usual and most economical method of laying pipes in such conditions is:

1. open the trench enough to lay one or two lengths of the pipe and then backfill;
2. remove the ground water by starting the construction at the outlet and place the pipe upstream. In this position, the water will drain through the pipe;
3. if the pipe has to be laid from the inlet downstream, the water may have to be pumped to the ground surface at the top of the trench to dispose of it (see chapter 11 – Flotation).
4. When the groundwater table is above the trench bottom, the water level must be lowered to at least the trench bottom (preferably about 200 mm below it) prior to preparation of the bed. Different techniques may be used, depending on the nature of the native material. For the sandy or silty soils, a system of well-points to a header pipe and a pump is recommended. The spacing between the individual well-points and the depth at which they will be driven depends on the groundwater table and the permeability of the soil. It is important to use a filter around the suction point (coarse sand or gravel) to prevent the clogging of the well-points by the fine grained native material. When the native material consists of clay or bedrock, well-points will not work. Dewatering is more difficult to achieve in this case. The use of sumps and pumps is recommended.
5. If the water cannot be kept below the top of the bedding, sub-drains must be provided. The sub-drains should be made by using a single size aggregate (20 - 25 mm), which is totally embedded in filter cloth. The depth of the sub-drain under the bed depends on the amount of water in the trench. If the groundwater can still not be kept below the bed, filter cloth should be used to surround the bed (and if necessary, the pipe zone area as well) to prevent it from being contaminated by the native material. Gravel

or crushed stone should be used for bed and backfill. When dewatering pay attention to:

- long distance pumping through the backfill materials or native soils should be avoided, since the loss of support to the previously installed pipes may occur (due to removal of the materials or migration of the soil);
- the dewatering system must not be turned off, to prevent the pipe flotation, until the sufficient cover depth has been reached.

9.4. Constructing a Trench in Rock

Where the rock ends and the pipe passes into a soil trench area (or reverse), a smooth transition and flexible joints should be created and used.

Alternatively, cement stabilised backfill can be used for the foundation and bedding of a pipe, which is just passing through a rock-soil transition. This negates the need to locate a flexible joint at this transition.

Trench construction should be according to the method applicable for the native soil condition.

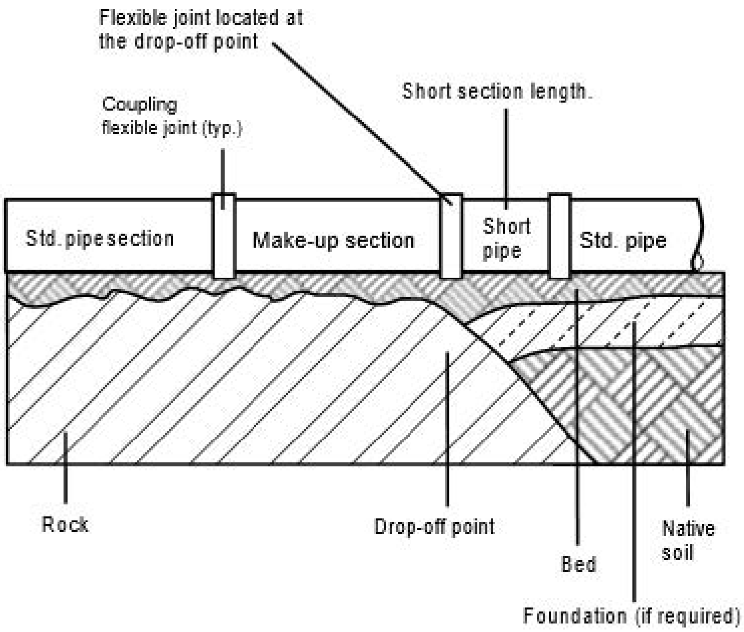

Figure 11: Method for constructing the trench and the pipe layout at the rock-soil trench transition or at the abrupt changes in bedding conditions.

9.5. 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 the slope angle.

In general, pipes should not be installed on slopes greater than 15°, or in areas where the slope instability is suspected, unless supporting conditions have been verified by a proper geotechnical investigation.

The preferred method for installing pipes on the steep slopes is above ground. It is recommended to support the pipes with the steel or concrete cradles, which surround the pipes over an arc of 180° with a layer or rubber at least 4 mm thick in between and a 40 – 60° Sore hardness.

If the pipes are installed underground and the slope of the trench ground is 15° or higher, the GRP-BRP pipes should be manufactured with ribs. In such trenches, the use of rounded gravels for bedding and backfilling is not suitable, since the rounded gravels are subjected to the washout, which leads to reduction of the pipe support. For the bedding and backfilling material in sloped trenches, it is advisable to use crushed rocks with the 42° internal friction angle.

The most critical problem is the risk of erosion of the backfilling. Therefore, erosion should be taken into account when determining the backfill material and the compaction level.

Erosion is a result of the strong underground water flows, rain, wind, and dust storms. In any of these conditions, the granular backfilling material should be resistant to erosion. In some cases, methods such as placing the rip-rap (big rock pieces), claying, or asphalt can be used.

When installing pipes on slopes greater than 15° and parallel to the hillside, the following minimum conditions have to be achieved for the buried installation:

- long-term stability of the installation can be ensured with a proper geo-technical design;
- for slopes over 15°, either SC1 or cement-stabilised backfill should be used as the backfill material;
- installation should always start and proceed from the low point and progress up the slope. Each pipe should be properly backfilled before the next pipe is placed in the trench;
- the surface, covering the completed pipe trench, must be protected against erosion from the flowing water;

- pipes have to be installed in straight alignment (plus or minus 0.2 degrees), with a minimum gap between the pipe spigots;
- the absolute long-term movement of the backfill in the axial direction of the pipe must be less than 20 mm;
- the installation must be properly drained to avoid the washout of the materials and thus ensure the adequate soil shear strength;
- stability of the individual pipes is monitored throughout the construction phase and the first phases of operation. This can be done by controlling the gap between the pipe spigots;
- a special pipe design may be required.

When pipes are installed perpendicular to the fall line of a steep slope, especially when the slope angle exceeds 15°, it is recommended to consult a geotechnical engineer to assure that the hillside remains stable.

The surface of the completed trench must be re-contoured to eliminate the depressions and prevent the formation of water puddles. The collection of water on a slope reduces the slope stability and may contribute to the internal slide and shear conditions.

NOTE: The preferred method for installing pipes on the steep slopes is above ground, because the above ground structures (such as pipe supports) are more easily defined, the quality of the installation is easier to monitor and the settlement is easier to detect.

Figure 12: Trenching on slopes.

10. BEDDING, BACKFILL AND COMPACTION

10.1. Bedding

Trench bedding should always be flattened, levelled and compacted all along the trench. Under unstable soil conditions, trench depth and bedding thickness can be increased

The pipe should be uniformly and continuously supported throughout its whole length by a firm stable bedding material. The bedding should be placed in such a way that it provides a complete contact between the bottom of the trench and the pipe. Pipe bedding should not be less than 15cm high and should be prepared with compacted granular material, which it should be compacted to provide a minimum compaction of 90% Standard Proctor Density. Other suitable bedding material can be used at minimum 95% Standard Proctor Density.

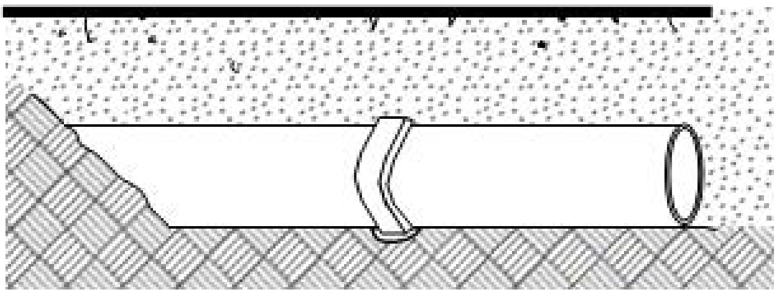

Figure 13: The proper bedding support.

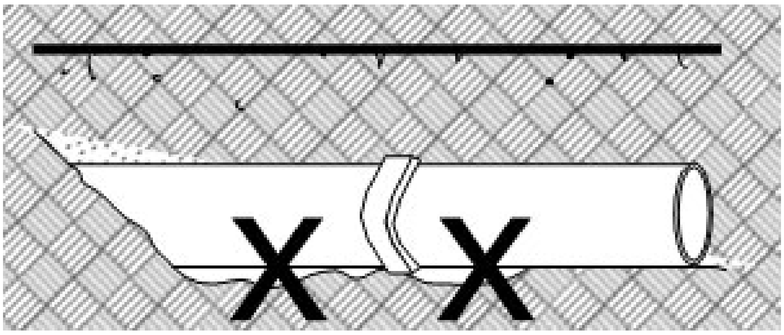

Figure 14: Improper bedding support.

If the pipe is supported by the grade elevation with the use of timber or of tapered wedges, these MUST be removed and NOT left in place. They can usually be pulled out after the bedding has been compacted to the specified minimum compaction. The voids from where the timber has been removed must be properly filled and compacted.

Bedding depth should be increased if soil is unstable, loose or soft. If bedding material is sandy, it should be moisturized and compacted with vibrating compactors.

10.2. Backfilling

Backfill should be placed in layers that don't exceed a depth per layer, which can be compacted to a minimum of 85% Standard Proctor Density. Lifts should normally not be greater than 30 cm in height and the height differential on each side of the pipe should be limited to this value to prevent the lateral movement of the pipe.

Since the pipe resists deflection through the combination of the pipe stiffness and soil support, it is important that a proper backfill compaction is achieved or exceeded. Otherwise, an excessive deflection of the pipe can occur. The height of the backfill material compacted to a minimum of 85% Standard Proctor Density should reach at least 30 cm above the top of the pipe. Above that point, the specified ground compaction for the local site work should be used.

Heavy earth-moving equipment used for the backfilling should not be brought in until the cover over the pipe achieves the minimum thickness of 90 cm when using the wide-tracked bulldozers, or 120 cm when using the wheeled loaders or roller compactors.

After joining the pipes, immediate backfilling is recommended as it will prevent:

- floating of the pipe due to the heavy rain which can cause damage and create unnecessary reinstallation costs;
- thermal movements due to the large temperature fluctuations. The cumulative effect of the thermal expansion and contraction over several lengths can compromise seal integrity at one joint.

If pipe sections are placed into the trench and backfilling is delayed, each pipe should have the centre section backfilled to the crown to help minimize the movements at the joint.

Proper selection, placement, and compaction of the pipe zone backfill is important for controlling the vertical deflection and is critical for the pipe performance. The backfill material must not be contaminated with debris or other foreign materials that could damage the pipe or cause the loss of support. The haunching material in the area between the bedding and the underside of the pipe must be worked in and compacted before placing the remainder of the backfill

The depth of the compacted layer, as well as the energy placed into the compaction method, have to be well controlled. Proper backfilling is typically done in 100 mm to 300 mm lifts, depending on the backfill material and the compaction method. When gravel or crushed stone is used as a backfill material, 300 mm lifts will generally be adequate, since gravel is relatively easy to compact. Finer grained soils need more effort for compaction and the lift height should be limited. Note that it is important to achieve the proper compaction of each lift to ensure that the pipe will have adequate support.

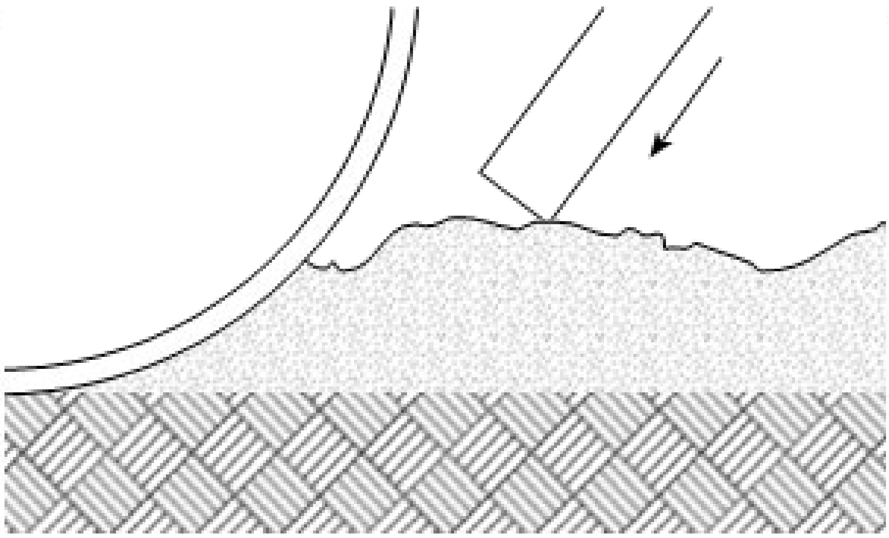

Figure 15: Proper haunch backfill the pipe is correctly supported.

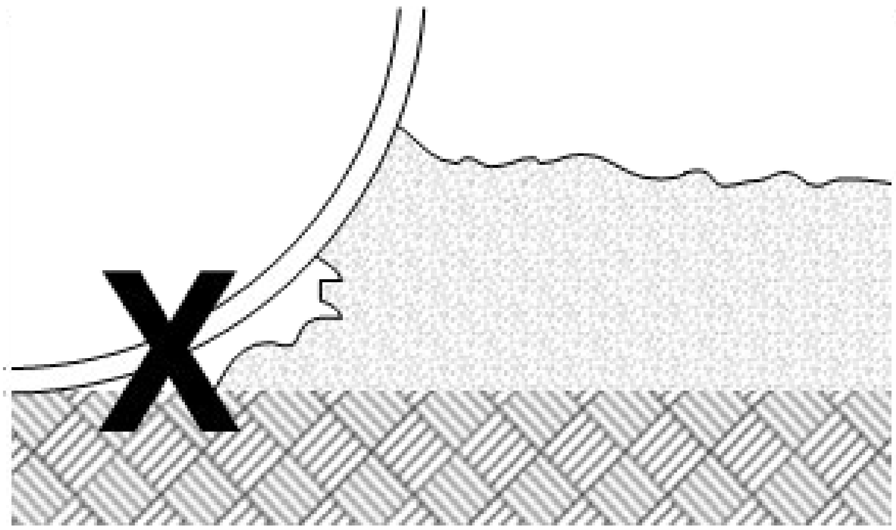

Figure 16: Improper haunch backfill.

Backfill SC1 and SC2 categories are relatively easy to use and are very reliable as the pipe backfill materials. These soils have low moisture sensitivity. Backfill can be easily compacted using a plate vibrator compactor in 200 to 300 mm lifts. Occasionally, a filter fabric should be used in combination with the gravel soils to preclude fines migration and subsequent loss of the pipe support.

Backfill category SC3 soils are acceptable as backfill and are often readily available. Many local soils, in which the pipe is installed belong to the SC3. This means the excavated soil can be directly reused as a pipe-zone backfill. Precaution is to be taken with these soils as they can be moisture sensitive. Moisture control may be required when compacting the soil to achieve the desired density with reasonable compaction energy and easily used compaction equipment. Compaction can be achieved by using impact compactor in 100 to 200 mm lifts.

Backfill class SC4 can only be used as pipe-zone backfill with the following precautions:

- moisture content must be controlled during the placement and compaction;
- do not use them in installations with unstable foundations or with standing water in the trench;
- compaction techniques may require considerable energy. The practical limitations of the relative compaction and the resulting soil stiffness must be considered;
- when compacting, use 100 and 150 mm lifts with an impact compactor such as the Whacker or a pneumatic rammer (pogo stick);
- compaction tests should be conducted periodically to assure that a proper compaction is achieved.

Deflection of the backfilled pipe is a good indicator of the quality of the installation. The expected initial vertical pipe deflection after backfilling to grade level is less than 2% for most installations. A value exceeding 2% indicates that the desired quality of the installation has not been achieved and should be improved for the next pipes (i.e. increased pipe zone backfill compaction, coarser grained pipe zone backfill materials or wider trench, etc.).

The consistency of the installation needs to be checked continuously. Differential deflections of adjacent pipe spigots must be kept within the allowable joint limitations. Particular attention should be paid to the pipe misalignment or varying deflection between two pipe spigots within one joint as a sign of non-uniform bedding conditions for the pipes.

Deviations can be corrected by the improved backfill and compaction work. It is recommended to check the pipe deflection as soon as the pipe has been backfilled to grade level in order to get a continuous feedback on installation quality.

Allowable initial vertical deflection:

	Deflection % of Diameter
Large Diameter (DN ≥ 300) Initial	2.0

10.3. Cement Stabilised Backfill

Cement is mixed with the moist sandy soil. This mixture is placed and compacted in the same way as a typical backfill soil. The amount of type 3 Portland cement, which is added to the sandy soil is approximately 4 to 5 parts per hundred weight of the soil. The moisture level should be in the 5-10% range. The required compaction density depends on the cover depth before the stabilised backfill sets. If the desired cover depth is low, the required density is low. The cement-stabilised backfill can set in one or two days and the cover fill can be placed to grade, with a maximum 5 metres total cover depth.

The mixture is 100 parts soil (dry weight), 4 to 5 parts type 3 Portland cement, and 12% water (+/-6%). The natural moisture content of the soil has to be accounted for when adding water. The soil can be SC2 or SC3 class. SC2 soil is the easiest to mix; however, other classes may be used. Mixing can be done on the ground by spreading a layer of a backfill soil, then spreading a thin layer of cement over it, and then mixing the two together. They can be mixed by hand, with a hoe, or mechanically with an appropriate device. The backfill should be placed within two hours of mixing.

The cement-stabilised backfill will have high stiffness without the need for significant compaction. Be sure to place backfill under the pipe haunches and compact it with a haunch-compaction tool. A Whacker compactor is required to compact the cement-stabilised backfill next to the pipe. One pass of the compactor with the 300 mm lifts is sufficient for most conditions in which the cover depth is less than 2 metres.

The pipe deflection has to be checked to assure the compaction is adequate to support the pipe. If the initial deflection exceeds 2.5%, the amount of compaction has to be increased or less cover has to be used, until the cement-stabilised backfill sets in one or two days. If a significant depth of cover will be placed before the cement-stabilised backfill is allowed to set, a higher level of compaction is required to prevent the excessive pipe deflection. The initial deflection must not be more than 2.5%. The amount of the required compaction effort depends on the cover depth, lift height, and the specific soil used in the mixture.

It is also recommended to use the stabilised backfill in the immediate vicinity of the large thrust blocks, valve chambers, and in areas of significant over-excavation.

10.4. Compaction

Both, the bedding and the backfill, must be compacted to the specified percentage of the maximum density, as described in the ASTM Method D 698. Care should be taken to avoid moving the pipe when compacting the sidefill. During compaction, the moisture content of the backfill material should be within ± 2% of its optimum value according to the ASTM Method D 698.

Vibratory methods are preferable for compaction. Compaction within distances of 15 cm to 45 cm from the pipe is usually done with hand tampers, i.e. the impulsive type, closest to the pipe. The plate-type vibrators should be used near the edge of the trench.

After the sidefills have been compacted to the required density, a 30 cm layer of the same material should be placed over the top of the pipe and lightly tamped. Excessive tamping of this top layer should be avoided, as it may result in distortion of the pipe. In wide, deep trenches, lightweight tractor-powered, track-mounted equipment, with a pressure of less than 0.35 kgs/cm^2 can be permitted at least 60 cm away from the pipe, but not across the pipe, until 120 cm of the overburden has been compacted. Wet puddling or water flooding to consolidate the backfill is not recommended since it may lead to the degradation of an uncured joint or to a trapped air cavity around the perimeter of the pipe. But water may be added to obtain the optimum compaction of the backfill material.

During the compaction of the backfill towards the top of the pipe, a beneficial pre-deflection of the pipe may occur where the pipe is higher than wider. As the backfill height increases, the vertical height of the pipe decreases, causing a deviation in the vertical height only a few percent less than the nominal pipe diameter.

If the proper compaction procedures produce a deflection of more than 5%, please consult TOPFIBRA.

10.5. Backfill Compaction

Recommendations for the pipe-zone backfill compaction:

Backfill stiffness classes	Hand-operated Impact Compactor	Hand-operated Vibrating Plate Compactor	Recommendations
SC1		300 mm	Two passes should provide a good compaction.

SC2		200 – 250 mm	Two to four passes are needed, depending on the height and the required density.
SC3	100 – 200 mm		Height of the layer and the number of passes are dependent on the required density. Near optimum moisture content should be used and soils' compaction should be checked.
SC4	100 – 150 mm		May require considerable energy for compaction. Moisture content should be controlled and compaction should be verified.

Compaction of the finer grain backfill is most easily accomplished when the material is at or near its optimum moisture content. When backfilling reaches the pipe's spring-line, all compaction should start near the trench sides and proceed towards the pipe.

Minimum cover for compaction above a pipe:

Equipment	Minimum thickness over pipe crown before compaction (m)	Equipment	Minimum thickness over pipe crown before compaction (m)
Foot or hand tamper min. 15 kg	0.20	Vibrating roller min. 15 kN/m min. 30 kN/m min. 45 kN/m min. 65 kN/m	0.60 1.20 1.80 2.40
Vibrating tamper min. 70 kg	0.30	Twin vibrating roller min. 5 kN/m min. 10 kN/m min. 20 kN/m min. 30 kN/m	0.20 0.45 0.60 0.85

Plate vibrator min. 50 kg min. 100 kg min. 200 kg min. 400 kg min. 600 kg	 0.15 0.15 0.20 0.30 0.50	Triple heavy roller (no vibration) min. 50 kN/m	1.00

10.6. Bedding and Backfilling Material Classification

Backfilling material must not include soil clumps, which are greater than twice the maximum particle size, frozen material, organic material or foreign debris such as waste, bottles, metals, etc.

Bedding and backfilling materials are classified according to AWWA M45 (Fiberglass Pipe Design, Manual of Water Supply Practices).

Soil stiffness category	
SC1	Crushed rock, containing less than 15% of sand (maximum 25% when passing through a 9.5 mm sieve and maximum 5% when passing through no. 200 sieve).
SC2	Clean, coarse-grained soils (SW, SP, GW, GP and similar soils with a maximum 12% of fines* when passing through a no. 200 sieve)
SC3	Clean, coarse-grained soils (SW, SP, GW, GP and similar soils with a minimum 12% of fines when passing through a no. 200 sieve), or sandy or gravelly fine-grained soils (CL, ML, CL-ML type soils with minimally 30% of them retained on a no. 200 sieve).
SC4	Fine-grained soils (CL, ML, CL-ML type soils with maximum 30% of them retained on a no. 200 sieve)
SC5	Highly plastic and organic soils (MH, CH, OL, OH, PT).

*% fines is the weight percentage of the soil particles that pass a no. 200 sieve with a 0.076 mm opening

SC1 soils have a low sand and fine containment and provide maximum pipe support, based on the compaction level, due to a low content of the sand and fines. Compaction of the material is easy and displays the maximum support, even under moist conditions. The high permeability of these materials, can help control the water. They are often used for embedment in rock cuts, where water is frequently encountered. However, when groundwater flow is anticipated, consideration should be given to the potential of migration of fines from the adjacent materials into the open graded SC1 material.

SC2 soils have a high compaction level and display high level of pipe support. However, open graded groups may allow migration and should be checked for compatibility with the adjacent materials.

SC3 soils display a lower pipe support, compared to the SC1 and SC2 soils. Compaction requires more effort and moisture content must be near optimum to achieve the required density. High moisture conditions decrease the pipe support level. These materials provide a reasonable level of pipe support once proper the density has been achieved.

SC4 soils require geotechnical evaluation before they can be used for bedding or backfilling. Compaction is difficult and the desired level of compaction is directly dependent on the moisture conditions. The moisture content must be near optimum to achieve the required density. When properly placed and compacted, they can provide a reasonable level of pipe support. This type is of soil is not suitable for bedding or backfilling for deep burial depths, under traffic loads, if ground water is present in the trench, or when compacting with high energy vibratory compactors and tampers.

They can only be used as pipe-zone backfill with the following precautions:

- moisture content must be controlled during the placement and compaction;
- do not use these soils in installations with the unstable foundations or with standing water in the trench;
- compaction techniques may require considerable energy and practical limitations of the relative compaction. Resulting soil stiffness must be carefully considered;
- 100 and 150 mm lifts should be used to compact them, with an impact compactor such as a Whacker or a pneumatic rammer (pogo stick);
- compaction tests should be conducted periodically to assure that proper compaction is achieved

SC5 soils are not suitable for bedding or backfilling.

Maximum particle size:

Nominal Diameter (DN)	Maximum Particle Size (mm)
≤ 450	13
450 - 600	19
600 - 900	25
900 - 1200	32
1200 <	38

For any given backfill soil class the higher the compaction the higher the soil modulus and the higher the support. In addition, the soil modulus also increases with the vertical soil stress level i.e. with the burial depth.

The backfill above the pipe zone may be made with the excavated material with a maximum particle size of up to 300 mm, providing there is at least 300 mm cover over the pipe. Stones exceeding 200 mm should not be dropped from a height greater than 2 m on the 300 mm layer covering the pipe crown.

Processed excavated material or the imported backfill may contain oversized particles. Using crushed rocks has proven to be a cost-effective solution. The maximum oversize particle must be less than 2x the allowable particle size. Oversized content share is limited to 10%. Graded material is recommended to achieve the easiest compaction results.

Self-compacting flowable materials, such as stabilised ground or liquid soil, are a proven alternative solution as the backfill material. It should be noted that the suitability of these materials must be proven in terms of soil mechanical parameters according to the project design requirements.

Characteristic of the bedding material are very important in order to achieve the proper support for the pipes. It is generally preferred that the bedding and backfilling materials have the same characteristics. If the excavated material is going to be used as a backfilling material, the excavated soil should be analysed for its suitability.

It is also important to take into consideration the possibility of having different soils with different characteristics along the pipeline.

You can also carry out field testing to assist with the classification of the native soils:

Native Soil Characteristics	Measurable group
1	Can be barely penetrated with a thumb.
2	Can be penetrated with a thumb to 4 mm.
3	Can be penetrated with a thumb to 10 mm.
4	Can be penetrated with a thumb to 25 mm.
5	Can be penetrated with a thumb to 50 mm.

10.7. Backfill Constrained Modulus M_{sb}

The measure of the backfill level soil support is expressed as the constrained soil modulus M_{sb} in MPa. For the design of the pipe installations, suitable backfill soils are classified in 4 different stiffness soil classes, SC1, S C2, SC3 and SC4.

Dumped material should always be worked into the haunch zone.

To analyse the pipe installation requirements, the native soils are classified in six groups and related to stiffness through blow counts, as defined by a standard penetration test using a split barrel sampler, ASTM D1586. These native soils, which form the trench walls, range from very stable, dense granular soils and very hard cohesive soils to relatively weak, fine grained soils. These native soils must be approved before using them as backfill.

Several different cone penetrometer tests are use around the world. With the potential for significant variations in these different tests, an approximate correlation to the standard penetrometer blow counts N, based on ASTM D1586, can be provided. With the output of the cone penetrometer test qu, expressed in kg/cm^2, the corresponding standard penetrometer blow count N is:

N = qu/4 for the mechanical cone penetrometer, and N = qu/3 for the electrical cone penetrometer.

Representation of the native soil is given in next table, which follows the general recommendations provided by AWWA M45. The blow count which should be used, is the lowest value found over an extended period of time in the pipe zone. Normally, the weakest condition of the soil exists when the soil has been subjected to wet conditions for an extended period of time.

For simplifying reasons, the tables have been calculated with compacted granular / very stiff cohesive soil.

Native soil stiffness groups. Values of Constrained Modulus, M_{sb}:

Soil class	Granular		Cohesive		Modulus M_{sn} MPa
	Blow count[1]	Description	q_u kPa	Description	
-	> 50	Very dense	> 600	Very hard	138.0
-	30 – 50	Dense	400 – 600	Hard	69.0
1	15 – 30	Compact	200 – 400	Very stiff	34.5
2	8 – 15	Slightly compact	100 – 200	Stiff	20.7
3	4 – 8	Loose	50 – 100	Medium	10.3
4	2 – 4		25 – 50	Soft	4.8
5	1 – 2	Very loose	13 – 25	Very soft	1.4
6	0 – 1	Very	0 – 13	Very very soft	0.34

[1] Standard penetration test per ASTM D1586

M_{sb} for SC1 Backfill Soil:

Burial Depth (Soil Density 18.8 kN/m³) m	Vertical Stress Level kPa	Compaction, % maximum Standard Proctor Density	
		Compacted MPa	Uncompacted (dumped) MPa
0.4	6.9	16.2	13.8
1.8	34.5	23.8	17.9
3.7	69.0	29.0	20.7
7.3	138.0	37.9	23.8
14.6	276.0	51.7	29.3
22.0	414.0	64.1	34.5

M_{sb} for SC2 Backfill Soil (reduced values below ground water table in parentheses):

Burial Depth (Soil Density 18.8 kN/m³) m	Vertical Stress Level kPa	Compaction, % maximum Standard Proctor Density			
		100 MPa	95 MPa	90 MPa	85 MPa
0.4	6.9	16.2	13.8	8.8 (7.5)	3.2 (2.2)
1.8	34.5	23.8	17.9	10.3 (8.8)	3.6 (2.5)
3.7	69.0	29.0	20.7	11.2 (9.5)	3.9 (2.7)
7.3	138.0	37.9	23.8	12.4 (10.5)	4.5 (3.2)
14.6	276.0	51.7	29.3	14.5 (12.3)	5.7 (4.0)
22.0	414.0	64.1	34.5	17.2 (14.6)	6.9 (4.8)

M_{sb} for SC III Backfill Soil (values below ground water level in parentheses):

Burial Depth (Soil Density 18.8 kN/m³) m	Vertical Stress Level kPa	Compaction, % maximum Standard Proctor Density			
		100 MPa	95 MPa	90 MPa	85 MPa
0.4	6.9	-	9.8 (4.9)	4.6 (2.3)	2.5 (1.3)
1.8	34.5	-	11.5 (5.8)	5.1 (2.6)	2.7 (1.4)
3.7	69.0	-	12.2 (6.1)	5.2 (2.6)	2.8 (1.4)
7.3	138.0	-	13.0 (6.5)	5.4 (2.7)	3.0 (1.5)
14.6	276.0	-	14.4 (7.2)	6.2 (3.1)	3.5 (1.8)
22.0	414.0	-	15.9 (8.0)	7.1 (3.6)	4.1 (2.1)

Msb for SC IV Backfill Soil (values below ground water level in parentheses):

Burial Depth (Soil Density 18.8 kN/m³) m	Vertical Stress Level kPa	Compaction, % maximum Standard Proctor Density			
		100 MPa	95 MPa	90 MPa	85 MPa
0.4	6.9	-	3.7 (1.11)	1.8 (0.54)	0.9 (0.27)
1.8	34.5	-	4.3 (1.29)	2.2 (0.66)	1.2 (0.36)
3.7	69.0	-	4.8 (1.44)	2.5 (0.75)	1.4 (0.42)
7.3	138.0	-	5.1 (1.53)	2.7 (0.81)	1.6 (0.48)
14.6	276.0	-	5.6 (1.68)	3.2 (0.96)	2.0 (0.60)
22.0	414.0	-	6.2 (1.86)	3.6 (1.08)	2.4 (0.72)

Msb values at intermediate vertical stress levels not given in these tables, can be obtained by interpolation.

Note: The maximum Standard Proctor Density % indicates the dry density of the compacted soil as a percentage of the maximum dry density, determined in accordance with ASTM D698.

10.8. Backfill Migration

When open graded material is placed adjacent to a finer material, fines may migrate into the coarser material because of the hydraulic gradient from the groundwater flow. Significant hydraulic gradients may arise in the pipeline trench during construction, when water levels are controlled by pumping, or after construction, when permeable underdrain or embedment materials act as a drain under high ground water levels. Field experience shows that migration can result in significant loss of pipe support and increase in deflections.

To minimize migration, the gradation and relative size of the embedment and adjacent materials have to be compatible. In general, where significant groundwater flow is anticipated, avoid placing coarse, open-graded material such as SC1, below or adjacent to the finer material, unless using methods to impede migration. Please take drainage properties of trenches into consideration. Consider the use of an appropriate soil filter or a geotextile filter fabric along the boundary of incompatible materials.

The following filter gradation criteria may be used to restrict migration of fines into the voids of coarser material under hydraulic gradient:

- $D_{15}/d_{85} < 5$ where D_{15} is the sieve opening size passing 15 percent of the coarser material by weight and d_{85} is the sieve opening size passing 85 percent of the finer material by weight;
- $D_{50}/d_{50} < 25$ where D_{50} is the sieve opening size passing 50 percent of the coarser material by weight and d_{50} is the sieve opening size passing 50 percent of the finer material by weight. This criterion does not apply if the coarser material is well graded (see ASTM D 2487).

If the finer material is a medium to highly plastic clay (CL or CH), then the following criterion may be used instead of the D_{15}/d_{85} criteria: D_{15}<0.5 mm where D_{15} is the sieve opening size passing 15 percent of the coarser material by weight.

The aforementioned criteria may need to be modified if one of the materials is gap graded. Selected materials, based on the filter gradation criteria, should be handled and placed in such a way that they will minimize segregation.

Where incompatible materials have to be used, they must be separated by a filter fabric, designed to last as long as the life of the pipeline, to prevent wash-away and migration. The filter fabric must completely surround the bedding and pipe zone backfill material. It must be folded over the pipe zone area in order to prevent the contamination of the selected backfill material.

10.9. Negative Pressure

In order to provide proper soil stabilizing support, a minimum burial depth of 1.0 metre is recommended for the situations with negative pressure (vacuum), where the negative pressure is in excess of 0.25 bar for SN2500 and 0.5 bar for SN5000 pipes.

The maximum allowable negative pressure (vacuum) in the pipe depends on the burial depth, native soil, pipe and backfill soil stiffness as well as the trench width

Some sections of a buried pipeline, such as valve pits or chambers, may not be soil supported. As the stabilizing support of the soil is not present, the negative pressure capability has to be evaluated separately.

The allowable negative pressure (in bars) for unburied sections, between pipe restraints (3, 6 and 12 meters):

DN	SN 2500				SN 5000				SN 10000			
mm	1,5 m	3 m	6 m	12 m	1,5 m	3 m	6 m	12 m	1,5 m	3 m	6 m	12 m
100-250	-	-	-	-	-	-	-	-	1,00	1,00	1,00	1,00
300	0,47	0,29	0,27	0,27	0,78	0,56	0,54	0,54	1,00	1,00	1,00	1,00
400	0,77	0,31	0,27	0,27	1,00	0,59	0,54	0,54	1,00	1,00	1,00	1,00
500	0,83	0,35	0,28	0,27	1,00	0,64	0,55	0,54	1,00	1,00	1,00	1,00
600	0,91	0,41	0,28	0,27	1,00	0,71	0,55	0,54	1,00	1,00	1,00	1,00
700	1,00	0,51	0,29	0,27	1,00	0,84	0,56	0,54	1,00	1,00	1,00	1,00
800	1,00	0,66	0,30	0,27	1,00	1,00	0,57	0,54	1,00	1,00	1,00	1,00
900	1,00	0,79	0,32	0,27	1,00	1,00	0,60	0,54	1,00	1,00	1,00	1,00
1000	1,00	0,81	0,34	0,27	1,00	1,00	0,62	0,54	1,00	1,00	1,00	1,00
1200	1,00	0,88	0,40	0,28	1,00	1,00	0,70	0,54	1,00	1,00	1,00	1,00
1400	1,00	1,00	0,49	0,28	1,00	1,00	0,82	0,55	1,00	1,00	1,00	1,00
1600	1,00	1,00	0,63	0,29	1,00	1,00	1,00	0,57	1,00	1,00	1,00	1,00
1800	1,00	1,00	0,77	0,31	1,00	1,00	1,00	0,59	1,00	1,00	1,00	1,00
2000	1,00	1,00	0,79	0,33	1,00	1,00	1,00	0,61	1,00	1,00	1,00	1,00
2400	1,00	1,00	0,87	0,39	1,00	1,00	1,00	0,69	1,00	1,00	1,00	1,00
2800	1,00	1,00	0,99	0,49	1,00	1,00	1,00	0,81	1,00	1,00	1,00	1,00
3200	1,00	1,00	1,00	0,62	1,00	1,00	1,00	0,98	1,00	1,00	1,00	1,00
3600	1,00	1,00	1,00	0,76	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
4000	1,00	1,00	1,00	0,78	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

The restraints should be stiff enough to keep the pipe round.

10.10. Minimum Burial Limitations

Minimum recommended burial depth for pipes with operating pressures of 10 bar or less is 0.5 metres, provided that pipes are joined without the vertical joint deflection.

10.10.1. Traffic Loading

When pipes will be buried under a roadway, or continuous traffic loading is anticipated, the backfill material should be compacted to a grade level. Consult road construction codes that are in practice for the local requirements and recommendations. Minimum cover restrictions may be reduced with special installations such as concrete encasement, concrete cover slabs, castings, etc.

In general, a minimum cover depth of 1.0 metre or more is recommended good practice for traffic loading using well compacted granular soils as backfill.

The recommended minimum cover depths for traffic load in standard conditions (detailed depth calculation depends on the project conditions):

Load Type	Traffic (Wheel) Load (kN)	Recommended minimum Cover Depth (metres)
ATV LKW 12	40	0.6
ATV SLW 30	50	0.6
AASHTO HS20	72	0.8
AASHTO HS25	90	1.0
BS153 HA	90	1.0
ATV SLW 60	100	1.0
MOC	160	1.5
Cooper E80 Railroad Engine		3.0

Smaller cover depths maybe used when the system design permits that.

10.10.2. Construction Traffic Loading

In some cases, large and heavy earth moving equipment or construction cranes may be present in or near the pipe installation area. These types of equipment can result in very high localised surface loads. The effects of such loading must be evaluated on a case by case basis, to establish proper procedures and limits.

10.10.3. Negative Pressure

A minimum burial depth of 1.0 metre is recommended for negative pressure (vacuum) situations, where the negative pressure is in excess of 0.25 bar for SN2500 and 0.5 bar for SN5000 pipes.

10.10.4. High Pressure

High pressures requires consideration of the possible uplift forces at joints, during the operation and during field hydrotesting.

For operating pressures of 16 bar and greater, the minimum burial depth should be 1.2 metres for DN 300 mm pipes and larger and 0.8 metres for less than 300 mm DN pipes.

During the field hydrotesting at pressures below 16 bar, the couplings should be backfilled at least to the crown and pipes should be backfilled to the minimum cover depth.

During field hydrotesting at pressures 16 bar and greater:

- pipes, which are in a straight alignment, should be backfilled to the crown of the coupling or higher, before performing the field hydrotest. Pipes must be backfilled to the minimum cover;
- when pipes are installed with an angular deflection, the pipe and the coupling must be covered to the final grade before the field pressure test.

10.10.5. High Water Table

Minimally 0.75 diameter of earth cover (minimum dry soil bulk density of 19 kN/m3) is required to prevent an empty submerged pipe from floating.

Alternatively, the installation may proceed by anchoring the pipes.

In case of any doubts about anchoring and minimum cover depth with anchors, please consult TOPFIBRA.

10.10.6. Frost Line

The pipe and other pipe materials, have to be buried BELOW the anticipated frost level. Consult the local construction codes of practice for other techniques when installing the pipe within the frost level.

10.10.7. Installation Tables

Pipe installation design tables are based on an assumed AASHTO HS20 load and show the minimum backfill compaction. The minimum backfill compaction is given at different burial depths for all practical combinations of the backfill soil class, native soil stiffness group and pipe stiffness. Both standard trenches are covered (B_d/D = 1.8, and wide B_d/D = 3.0).

Tables are provided for selected combinations of:

- The groundwater level;
- traffic load;
- internal vacuum.

All of the tables are valid for the working pressure anywhere in the range from atmospheric to the nominal pressure of the pipe.

The minimum backfill compaction is expressed as percent Standard Proctor density, for the backfill soil categories SC2, SC3 and SC4. For crushed rock as backfill SC1, the minimum compaction is expressed either as uncompacted (dumped) D, or compacted C. Note that SC1 backfill material also has to be worked into the haunch zone for the installation conditions, where compaction is otherwise not required.

The recommended compaction values are to be considered as the minimum values. Field densities should be the same or higher than the required. Considerations for seasonal variations should be included when assessing the potential for moisture content of in situ and the backfill soils. The backfill compaction tables are calculated following the current AWWA approach, assuming the soil and bedding properties which are:

- the deflection lag factor D_L = 1.5;
- dry unit weight of overburden, $\gamma_{s,\,dry}$ = 18.8 kN/m^3;
- wet (buoyant) unit weight of overburden, $\gamma_{s,\,wet}$ = 11.5 kN/m^3;
- bedding coefficient (typical direct bury condition) k_x = 0.1.

Backfill compaction tables have been calculated for the loading and installation conditions listed in next 3 tables.

Note: You can find tables B-4 to B-17 in the Appendix. For the installations where the traffic load and vacuum can occur, use the highest compaction requirement found in the Table: B–5. For installations with groundwater below the pipe, use the highest compaction requirement found in the Table: B–6. For the installation with groundwater to level, use the highest compaction requirement found in the Table: B–8 and Table: B–9.

Load combinations for Type 1 installation of DN ≥ 300 mm pipes:

Traffic Load AASTHO	Internal Vacuum bar	Ground Water	Trench Width at Pipe Springline B_d/D	Installation Table
0	0	Below pipe	1.8 and 3.0	Table B–4
HS 20	0	Below pipe	1.8 and 3.0	Table B–5
0	1	Below pipe	1.8 and 3.0	Table B–6
0	0	To level	1.8 and 3.0	Table B–7
HS 20	0	To level	1.8 and 3.0	Table B–8
0	1	To level	1.8 and 3.0	Table B–9

Load combinations for the Type 1 installation of DN ≤ 250 mm pipes with backfill:

Traffic Load AASTHO	Internal Vacuum bar	Ground Water	Trench Width at Pipe Springline B_d/D	Installation Table
0	0	Below pipe	3.0 and 5.0	Table B–10
HS 20	0	Below pipe	3.0 and 5.0	Table B–10
0	1	Below pipe	3.0 and 5.0	Table B–10
0	0	To level	3.0 and 5.0	Table B–11
HS 20	0	To level	3.0 and 5.0	Table B–11
0	1	To level	3.0 and 5.0	Table B–11

Note: For installations where traffic load and vacuum can occur, use the highest compaction requirement the two load cases.

Load combinations calculated for the large diameter pipes, DN ≥ 300 mm, Type 2 installation with backfill:

Internal Vacuum	Ground Water	Trench Width at Pipe Springline	Backfill Below 0.6 x DN	Backfill Above 0.6 x DN		Installation Table
bar		B_d/D	Category	Category	% SPD	
0.0	Below pipe	1.8 and 3.0	SC I, SC II	SC III	85 / 90	Table B–12
0.0	Below pipe	1.8 and 3.0	SC I, SC II	SC IV	90	Table B–12
0.5	Below pipe	1.8 and 3.0	SC I, SC II	SC III	85 / 90	Table B–13
0.5	Below pipe	1.8 and 3.0	SC I, SC II	SC IV	90	Table B–13
1.0	Below pipe	1.8 and 3.0	SC I, SC II	SC III	85 / 90	Table B–14
1.0	Below pipe	1.8 and 3.0	SC I, SC II	SC IV	90	Table B–14
0.0	To level	1.8 and 3.0	SC I, SC II	SC III	85 / 90	Table B–15
0.0	To level	1.8 and 3.0	SC I, SC II	SC IV	95	Table B–15
0.5	To level	1.8 and 3.0	SC I, SC II	SC III	85 / 90	Table B–16
0.5	To level	1.8 and 3.0	SC I, SC II	SC IV	95	Table B–16
1.0	To level	1.8 and 3.0	SC I, SC II	SC III	85 / 90	Table B–17
1.0	To level	1.8 and 3.0	SC I, SC II	SC IV	95	Table B–17

For other installation and/or operating conditions, consult the appropriate AWWA or ATV installation design documents.

11. FLOTATION

When piping has a cover greater than one pipe diameter, tie-downs preventing flotation are not required when the pipe is empty. If the pipe cover is less than one pipe diameter and the water table is expected to be above the invert of the pipe, then precautions should be taken to prevent the flotation.

For other conditions, consult TOPFIBRA’s specialists.

Figure 17: Gap between the pipes, caused by flotation.

Figure 18: Flotation.

12. INSTALLATION PROCEDURE

12.1. Pre-Installation

Installation can start after the trench excavation and bedding have been completed. Pipes and fittings should be stored along the pipeline, next to the trench, according to the daily installation program for a faster and easier installation. Stored goods should not block the working path of the construction machines such as cranes, excavators, bulldozers, etc.

12.2. Lowering the Pipes on the Trench Bed

Lifting straps should be tied around the pipes at the appropriate lifting points. When fittings are being lifted, special lifting and alignment requirements should be taken into consideration (for example, the arm angle of the tee part).

Lifting can be done with a crane or with the excavator. Pipes should be slowly lowered on the bedding. During lifting and lowering inside the trench, field teams have to direct the operator of the excavator, to make sure the pipe will be placed in the right location. A newly lowered pipe should be positioned close to the previously installed pipe and should be carefully aligned.

12.3. Pipe Installation

More information can be found in the chapter: Specifications for making field sleeve joins - Laying of the pipes.

Clean the pipe ends of dust and dirt. Visually check the pipe ends for delamination (delamination is separation of the pipe layers).

Clean the rubber gasket and remove any stones, gravel or dust from the grooves of the gasket.

Apply lubricants on the gasket with a piece of soft fabric. Lubrication material should be organic. Never use petroleum based lubricants. Use a brush to apply the neutral grease, soap or a grease free acids or solvents (for instance, liquid Vaseline, tyre-repairer’s soap, silicone grease)

Approximate amount of lubricant for each connection can be determined from this table:

Pipe diameter (mm)	lubricant (kg)
100-350	0,1
400-600	0,2
700-900	0,3
1000-1200	0,4
1300-1500	0,5
1600-1800	0,6
1900-2100	0,7
2200-2400	0,8
2500-2700	0,9
2800-3000	1,0
3100-3300	1,1
3400-3500	1,2
3600-4000	1,3

For easier assembly of the pipes, a pit should be excavated for the coupling to settle in. After the pipe has been connected to previous pipe, the coupling pit should be filled with a backfill material and compacted.

12.4. Checking the Vertical Deflection After Installation

Initial vertical deflection of the pipes should be kept under control to reach the allowable long term vertical deflections. The maximum allowable initial deflection is 2.5% and the maximum allowable long term deflection is 5.0%.

It is rather difficult to measure the long term vertical deflections. Deflections generally appear minimally 6 months after the completion of the installation and in most cases, stopping a pipeline in service to measure the deflections is not allowed. The recommended method is to measure the deflections 3 days after the completion of the backfilling.

Deflection controls should be performed parallel to the progress of the pipe installation. In this way it is easier to detect a deflection at the initial stage and take immediate corrective actions. The costs and the spent time for corrective actions will be much lower as well.

Whenever it is possible for a person to enter a pipeline (which is generally valid for the 800 mm diameters and above), the vertical internal diameter can be measured every 3 meters with a laser-meter device. For smaller diameters, the pig method can be used. The pig is a wooden disc with a height, which is equal to the allowable deflected vertical internal diameter. The pig is pulled through the pipeline and if it enters through one end and exits through the other end without obstruction, the vertical deflection is accepted to be within the allowable limits.

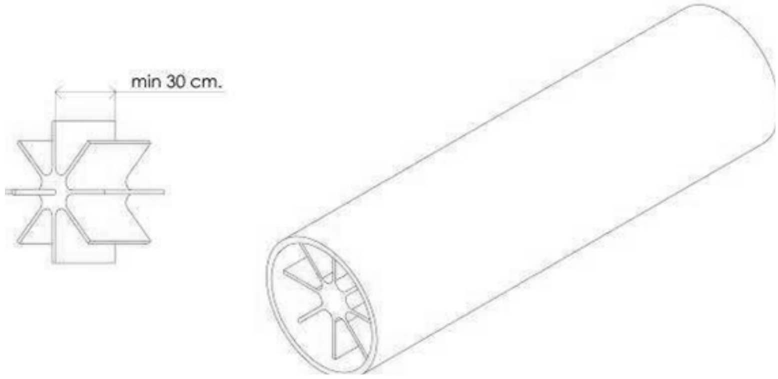

Figure 19: Using the pig.

Deflection values, which are over the allowable limit, generally happen because of an improper backfilling. If an initial deflection over the allowable limit is detected, backfilling should be excavated. The bottom sections of the pipe backfilling should be controlled and re-compacted. After ensuring that the pipe bottom sections are well compacted, backfilling should be repeated.

After this corrective action, deflection measurements should be repeated monthly. If the vertical deflection stays below 5% after 3 or 4 additional controls, the corrective action can be considered successful. If the vertical deflection is over 5% in any of these additional controls, corrective action should be immediately repeated.

13. DIFFERENTIAL SETTLEMENT

Where differential settlement is to be expected (such as at the ends of a pipe casing or where the pipeline enters a structure or an anchor block), a flexible joint should be provided within 0.45 m or one pipe diameter, whichever is greater, from the end of the casing, or the face of the structure, or an anchor. This will alleviate any shear stresses or vibrations which may occur.

Another precaution has to be taken when a pipe passes through a concrete structure or a wall. A band of neoprene rubber of 40 to 70 Shore Hardness, 12.5 mm thick and 150 mm wide, should be wrapped around the pipe prior to the casting of any concrete. This band should be wrapped around the pipe within the area of the concrete and with the edge of the rubber at the embedment/concrete interface. For other conditions, please consult TOPFIBRA.

13.1. Connections to Rigid Structures

Excessive bending and shear stresses can develop in a pipe when there is a differential settlement (movement) between the pipe and the rigid structure. This may occur when a pipe passes through a wall (e.g. valve chamber or manhole), is encased in concrete (e.g. thrust block), or is flanged to a pump, valve or other structure. To manage, or at least to lower this bending stress, short pipes should be used, especially at connections with manholes, vanes and pumps.

For all connections to rigid structures, action must be taken by the installer to minimize the development of the high discontinuity stresses in the pipe. Angular deflection and misalignment at joints close to thrust blocks shall be avoided during installation.

Two options are available. The standard (preferred) method uses a coupling joint cast into the concrete-pipe interface. With the alternate method, a short pipe is wrapped with rubber sealing to ease the transition (rubber sealing should be placed before concrete casting with a recess of 25 mm).

When casting concrete, ensure that the coupling keeps its original shape (roundness). Otherwise, pipe might not slide into the coupling. Use a high stiffness pipe at connections with rigid structures. Ensure that pipe is not subjected to high deflections.

Short pipe length can be determined as 2xDN with an upper limit of 2 meters or as 1xDN with an upper limit of 1 meter. Make sure that bedding and backfill of the short pipe is compacted properly.

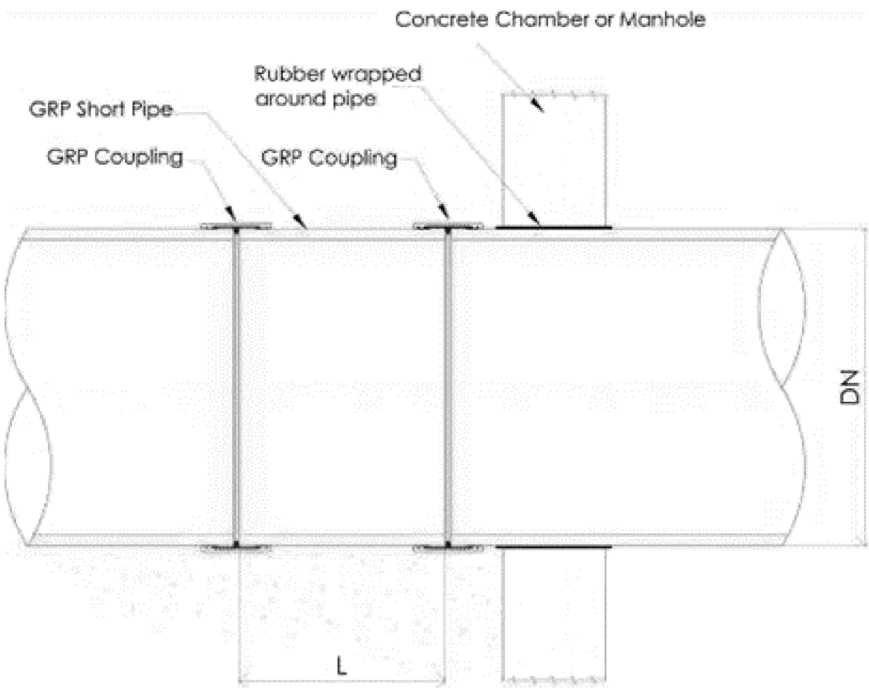

Figure 20: Short pipe connection.

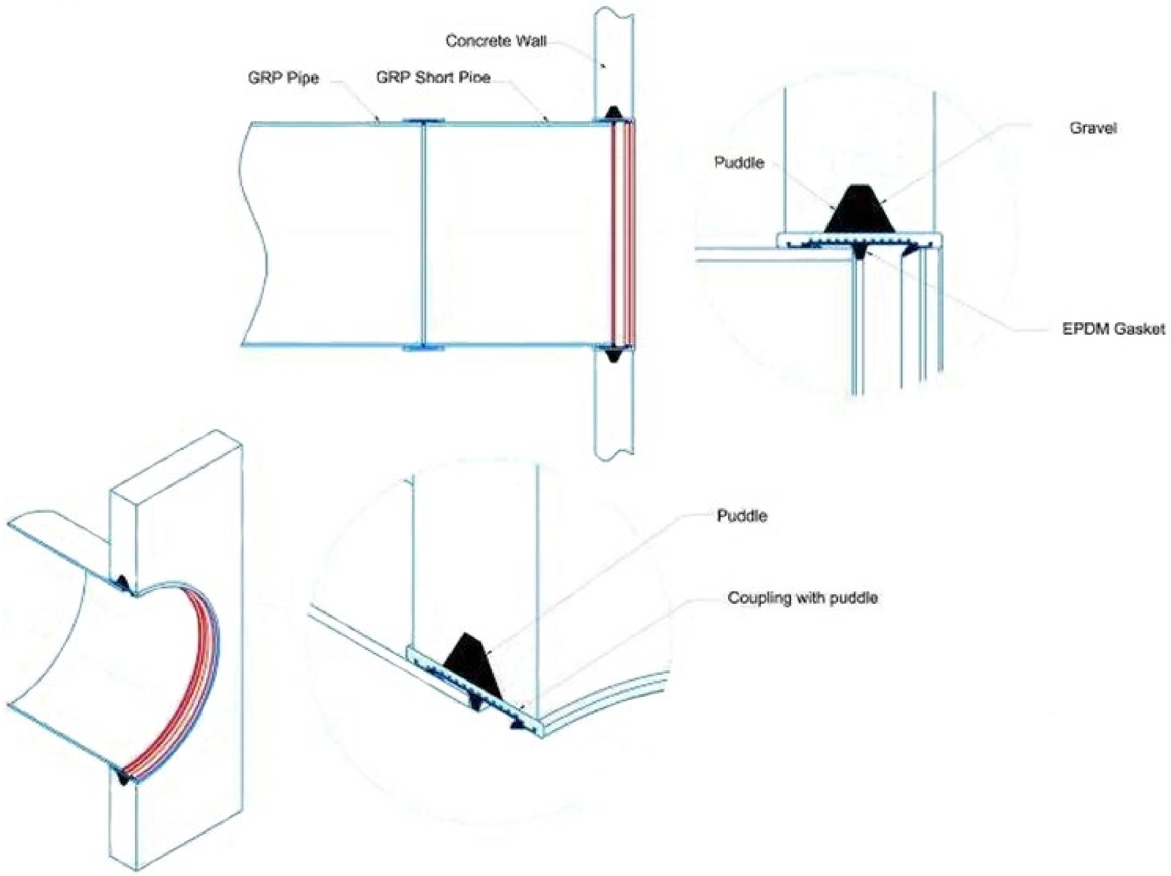

Figure 21: Short pipe connection.

13.1.1. Standard Connections

For the standard connections, a coupling joint is cast in the concrete at the interface, so that the first pipe outside the concrete has a complete freedom of movement (within the limits of the joint). For PN larger than 16, this standard method should be used, and the length of the short section pipe should be kept at the maximum indicated in Figure 22:

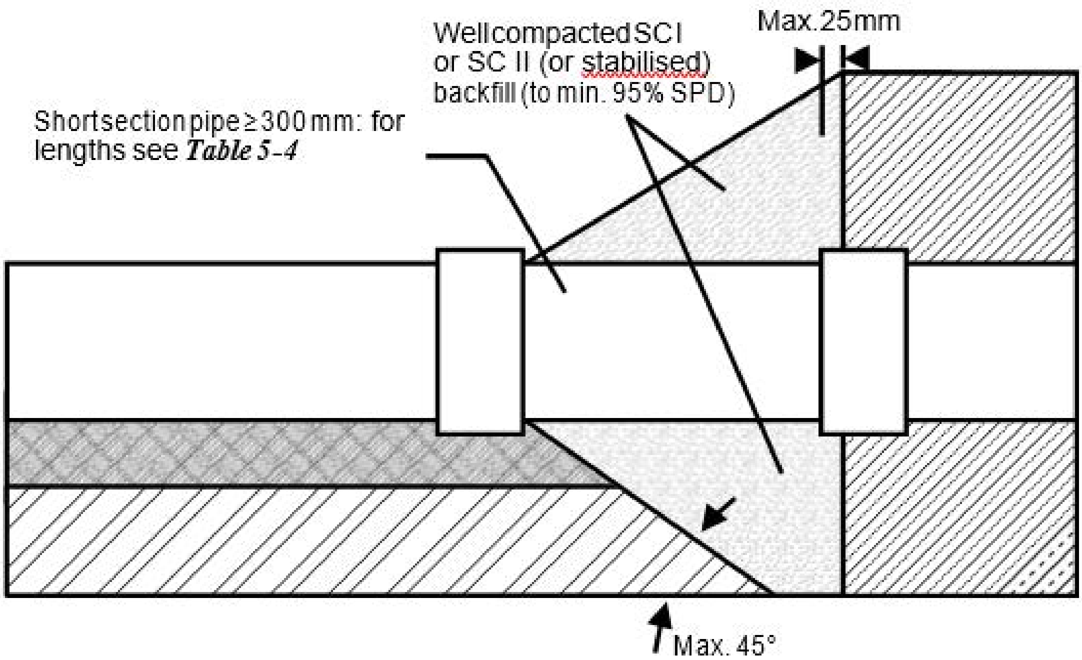

Figure 22: Standard connection – coupling cast in concrete.

- when casting a coupling in concrete, be sure to maintain its roundness so later joint assembly can be accomplished easily. Alternatively, make up the joint prior to pouring the concrete;
- since the coupling that is cast in concrete is rigid, it is very important to minimize the vertical deflection and deformation of the adjacent pipe;
- it is recommended to connect the rocker pipe first, before concrete encasement. If this is not possible, care must be taken to keep the coupling in the round shape.

13.1.2. Alternate Connections

Where the standard method is not possible, wrap a band (or bands) around the pipe prior to placing any concrete in such a way, that the rubber slightly protrudes (for 25 mm) from the concrete. Lay out the pipeline so the first completely exposed coupling joint is located as shown in the Figure 23. For PN larger than 16, this alternate method is not recommended.

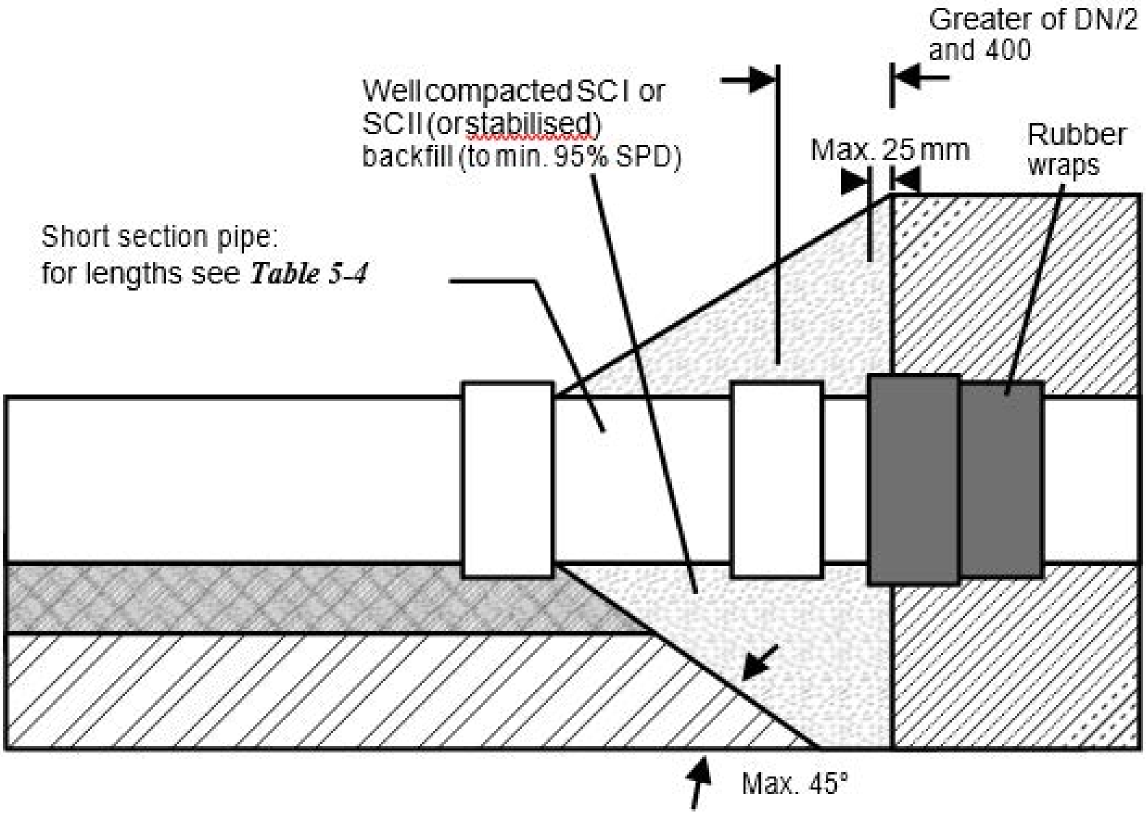

Figure 23: Alternate connection – rubber wrap encased in concrete.

Configuration of the rubber wraps:

DN	BL [mm]*	BL_{min} [mm]	BL_{max} [mm]
100	500	500	1000
150	500	500	1000
200	500	500	1000
250	500	500	1000
300	500	500	1000
350	500	500	1000
400	500	500	1000
450	500	500	1000
500	1000	1000	1000
600	1000	1000	1200
700	1000	1000	1400
800	1000	1000	1600
900	1000	1000	1800
1000	2000	1000	2000
1100	2000	1100	2200
1200	2000	1200	2400

DN	BL [mm]*	BL_{min} [mm]	BL_{max} [mm]
1300	2000	1300	2600
1400	2000	1400	2800
1500	3000	1500	3000
1600	3000	1600	3200
1700	3000	1700	3400
1800	3000	1800	3600
2000	3000	2000	4000
2200	3000	2200	4400
2400	3000	2400	4800
2600	3000	2600	5200
2800	3000	2800	5600
3000	3000	3000	6000
3200	3200	3200	6400
3400	3400	3400	6800
3600	3600	3600	7200
3800	3800	3800	7600
4000	4000	4000	8000

13.1.3. Construction Guidelines

- When considering the design of the concrete structure, it should be noted that any excessive settlement of the structure relative to the pipe, can be the cause for a pipe failure;
- including a short length (rocker pipe) near the rigid connection is a good way to accommodate the differential settlement (see Figures 23 and 22). The minimum length of the short length should be the larger of one DN or 1 metre. The maximum length should be the larger of two DN or 2 metres. For the small diameter pipe (DN < 300 mm) the length of the short piece is 500 mm. This rocker pipe section is used to account for some differential settlements that may occur. The rocker pipe should have a straight alignment with the concrete structure at the time of installation, to provide the maximum flexibility for the subsequent movements. Multiple short lengths or rocker pipes should not be used, as the short spacing between the couplings may result in an unstable condition. Misalignment problems should be remedied by re- bedding the full pipe sections leading to the rocker pipe;
- care must be taken to replace and properly compact the backfill which is adjacent to the concrete structure. Construction of the concrete structure will frequently require over-excavation for formwork, etc. This extra excavated material must be restored to a density level which is compatible with the surroundings, to prevent the excess deformation or the joint rotation adjacent to the structure. SC1 or SC2 class backfill, compacted to 95% Standard Proctor Density (SPD), should be brought up to 60% of the pipe's diameter at the interface with the rigid structure (see Figures 23 and 22) and gradually tapered back. Stabilised backfill (cement) may also be used for this purpose.

13.1.4. Rubber Wrap Placement

1) Position the rubber wrap (as shown in the Figures 24 and 25) and tape all the seams and edges to assure no cement can get between the rubber and the pipe, or between the rubber wraps:

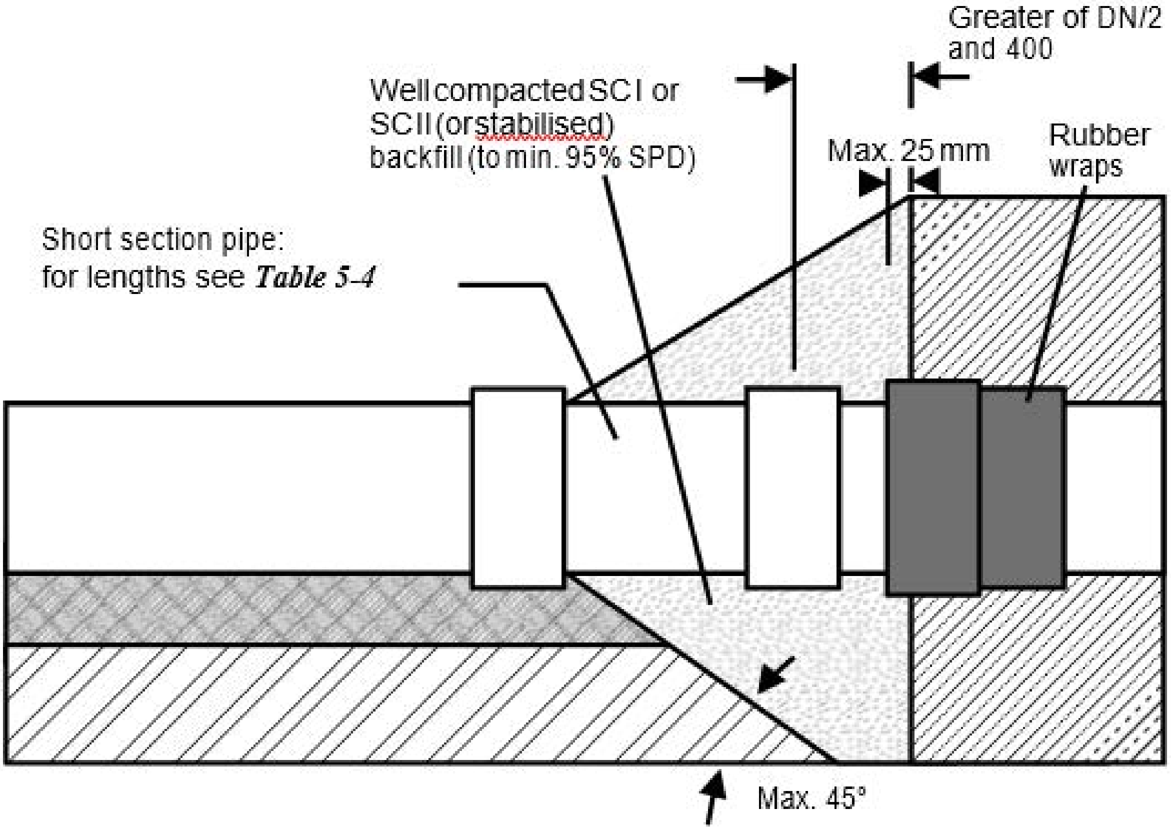

Figure 24: Alternate connection – rubber wrap encased in concrete.

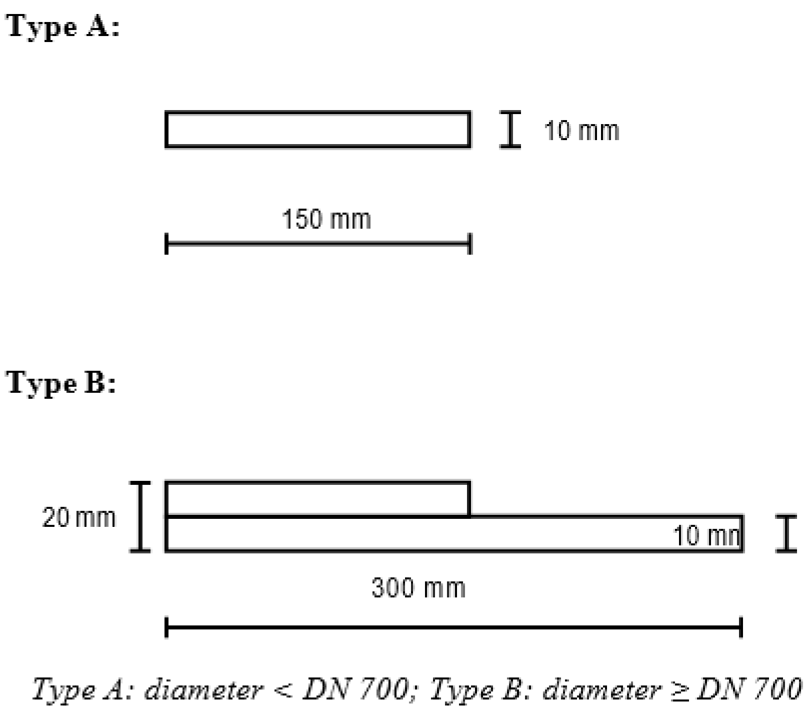

Figure 25: Rubber wrap configuration (rubber shall have 50-60 Shore A hardness).

13.2. Casings (Tunnels)

When a standard pipe (with an unequal exterior flush) is installed in a casing, the following precautions should be observed:

1) pipes may be placed into the casing by pulling (drawing) or pushing (jacking). The maximum insertion length/force has to be calculated;

2) for an easy insertion, and to protect them from the sliding damage, the pipes should be equipped with plastic spacers, steel sleeves or wooden skids, as shown in the Figures 26 and 27. They must provide sufficient height to permit clearance between the coupling joints and the casing wall:

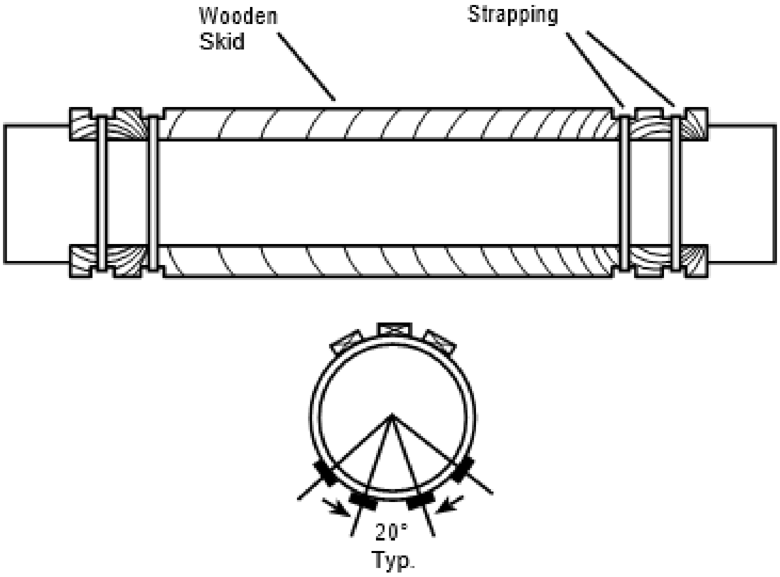

Figure 26: Typical skid arrangement.

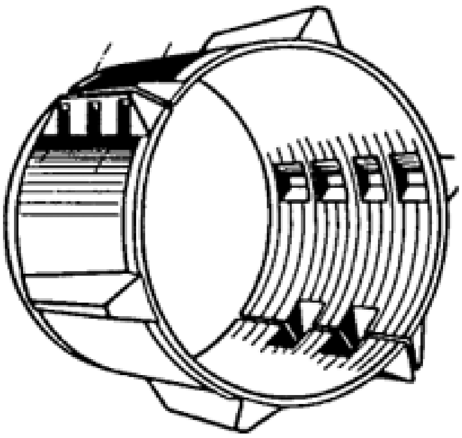

Figure 27: Plastic spacer unit.

3) installation into the casing is made considerably easier by using a lubricant between the skids and the casing wall. Do not use a petroleum based lubricant as it may cause harm to some gaskets;

4) the annular space between the casing and the pipe may be filled with sand, gravel or cement grout. Care must be taken not to overstress or collapse the pipe during this step, particularly when grouting. Maximum grouting pressure (pipe invert) without the internal supports is given in this table:

SN	Maximum Grout Pressure (bar)
2500	0.35
5000	0.70
10.000	1.35

Do not wedge or brace the pipe in a manner that would cause concentrated or point loads on the pipe.

Adequate attention must be paid to the pipe`s stiffness and installation procedure if the annular space is not grouted and the pipe will be subjected to negative pressure. If you have any doubts, please consult TOPFIBRA.

Where required or specified, pipe systems using flush joints can be used:

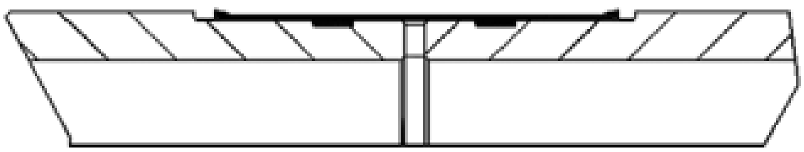

Figure 28: Flush joint.

13.3. Concrete Wall Sealings

When a pipe has to pass through a concrete wall and it is required to be water tight, a water tight sealing is necessary to ensure continuous leak tightness of the system.

The connection systems are divided into two categories:

- made in situ;
- precast.

For connecting a pipeline, please follow the instructions in the section 13.1- Connections to Rigid Structures.

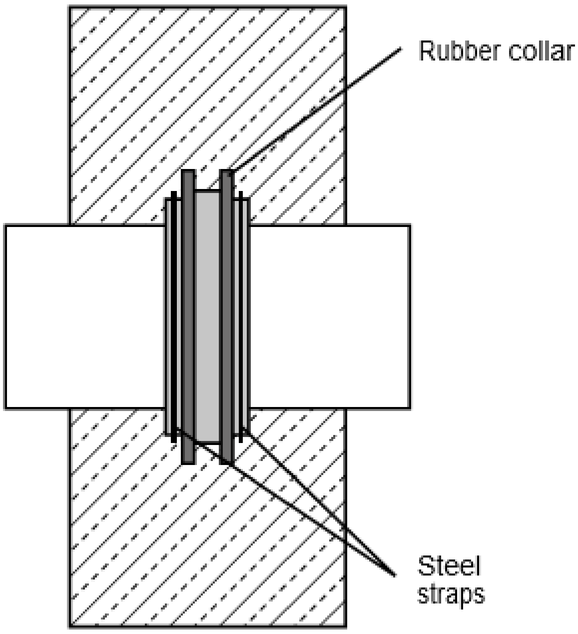

Figure 29: A rubber collar.

14. PARALLEL PIPING SYSTEMS

Parallel piping systems laid in a single trench should be spaced far enough apart to allow the use of the compaction equipment to compact the soil between the pipes. A clearance that is 15 cm greater than the width of the widest piece of the compacting equipment may be considered to be the practical clearance between the pipes.

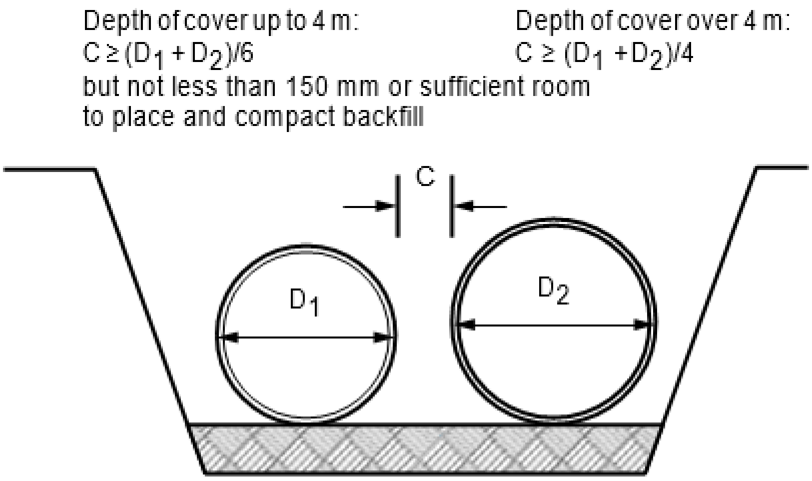

Figure 30: Spacing between the pipes in the same trench.

Otherwise, the distance between any of the two pipes is determined with the formula:

$$(r1+ r2) / 2$$

Where r1 is the radius of the first pipe, and r2 is the radius of the second pipe. The following values for the distance between the pipes in the same trench are recommended:

Diameter	**Minimum distance between the pipes**
200 – 600 mm	300 mm
700 – 1200 mm	600 mm
1300 – 2000 mm	1000 mm
2100- 3000mm	1500 mm
3000 mm and above	2000 mm

After the pipes have been placed, the backfill material should be used to close the gap between them and it should be compacted in the same manner as the soil between the pipe and the trench wall or by hand. It is also recommended to add a small amount of cement to the backfill material. Special care should be taken when compacting the soil underneath the haunches of each pipe.

When laying pipes of different diameters in the same trench, it is advisable to lay them with the same invert elevation. When this is not possible, SC1 or SC2 class backfill material should be used to fill all the space from the trench bottom to the invert of the higher pipe. Proper compaction must be achieved as well (min 90% SPD).

Figure 31: Parallel pipes.

15. SUMMARY

These chapters do not cover all the installation situations: any unusual or specific conditions should be referred to TOPFIBRA's Technical Department.

However, the general philosophy of installation has been expressed here so the Contractors can approach the installation of flexible pipes in a rational manner. The basic concept lies in the fact that the pipe and the soil form an interdependent structural system.

The backfill support is the single most important parameter in the flexible pipe performance. The degree of backfill compaction is proportional to the support provided by the soil and inversely proportional to the deflection of the pipe.

It should always be kept in mind that the flexible pipe performance heavily depends on the surrounding soil. A little extra care in the installation of the pipe will go a long way. A properly laid RTRP pipeline will result in a system which will not require maintenance for many years.

SPECIFICATIONS FOR MAKING FIELD SLEEVE JOINTS

SPECIFICATIONS FOR MAKING FIELD SLEEVE JOINTS

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1. PURPOSE

This specification is provided as a guide for the correct laying of pipes which are jointed with sleeves with rubber gaskets. These type of joints have an elastomeric profile fitted into the GRP-BRP sleeve, which covers the pipe's tightened surface. The hydraulic sealing is achieved through the pressure of the conveyed fluid against the profile lips and by the compression of the elastomeric profile between the pipe's external surface and the sleeve's internal surface.

The pipes are delivered to the work site with the sleeve already applied at one end of the pipe.

This specification is also valid for the GRP-BRP pipes manufactured with an integral bell and spigot joint.

2. CHECKS AT JOB SITE

As soon as the pipes have been delivered to the site, it is recommended to carry out the following checks:

- check the delivery saddles, packages, cases, fixtures belts and all other types of protection and record the results;
- if the load of pipes has been displaced at transportation or shows signs of incorrect treatment during the carriage, make a careful inspection of the outside and of the ends of the pipes and record the results;
- check the quantities delivered, comparing each item against the dispatch documents and record the results;
- any found damages must be reported to the transport company and to the pipe manufacturer for further instructions. Record the results.

UNDER NO CIRCUMSTANCES USE DEFECTIVE MATERIALS!

3. LAYING OF THE PIPES

- Laying will only take place after the trench and the surface supporting the pipes have been prepared according to the instructions given in the chapter - BURIED PIPE INSTALLATION
- before placing a pipe in a trench, it is necessary to clean any remains of the soil, sand or mud from the outside of the free spigot end and from the opposite end bearing the sleeve with the elastomeric gasket. After cleaning, run a hand outside the spigot to ensure that there are no residues of hardened resin which can be readily removed with a chisel;
- place the pipe in the trench, taking care to dig a small hollow at each end so that the spigot and the sleeve are well separated from the sand or gravel in the bottom of the trench (see Fig. 1);

Figure 1: Laying a pipe in the trench.

- anchor the first pipe section that was laid and leave its ends free. Also leave enough space for insertion of the next section and for inspection. Place the next pipe section in the trench and leave enough space for the operator to be free to move and work between the two pipe sections to carry out the cleaning and checking operations (see Fig. 1);

- clean the coupling area of the joint once more with a cloth and lubricate the elastomeric gasket and the external surface of the spigot. Use a brush to apply the neutral grease, soap or a grease free acids or solvents (for instance, liquid Vaseline, tyre-repairer's soap, silicone grease);

ANY AREA OF THE GASKET WHICH LACKS THE LUBRICANT WILL IMPAIR GOOD INSERTION OF THE PIPES!

- align the two pipe sections by their orthogonal axes. Bring both sections together until the elastomeric packing touches the bevelled edge of the spigot. Examine the centring of the two parts and, above all, ensure again that no sand or other foreign matter is present. Fit the spigot into the sleeve very slowly and proceed with the joint until the nesting mark is reached. The next pipe section must not be fitted until the previous one has been anchored with an overlay of sand.

4. MISALIGNMENT OF THE JOINT AND ANGULAR DEFLECTION

When the joint has to be misaligned during the pipeline installation, such misalignment at an angle should be applied only after the pipes have been inserted and the joint checked.

The maximum allowable misalignment of an adjacent pipe end is 5 mm. It is recommended to monitor the misalignment near the thrust blocks, valve chambers and similar structures, and at closure or repair locations.

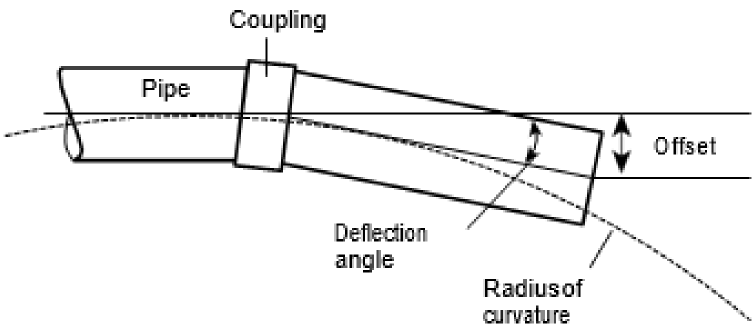


Figure 2: Coupling and an angular joint deflection.

In all cases the pipe to pipe deflection and the pipeline bending radius must remain within the following limits, for the CFW pipe with Sleeve Joint:

Pipe diameter	**Pipe to Pipe Angular Deflection**	**Bending Radius**	
		L = 6 m	L = 12 m
300 ≤ DN ≤ 700	4.0°	85	170
700 < DN ≤ 1500	3.5°	95	195
700 < DN ≤ 1800	3.0°	110	125
1800 < DN ≤ 2200	2.5	135	270
2200 < DN ≤ 2800	2	170	340
DN > 2800	1.5°	225	455

The bending radius depends on the length of the pipe section. In the above table the data is given for the standard section lengths of 6 m and 12 m, but it can be easily calculated since it is in inverse relation to the section length (a 3 m section length will be half of the radius of the 6 m section length).

Before applying an angular deflection, pipe should be installed to the pipeline in a straight position, then the angular deflection should be performed.

Angularly deflected coupling joints are stabilised by the stiffness of the soil which is surrounding the pipe and the coupling. Pressure pipes (PN>1) should have angularly rotated joints, backfilled to a minimum 90% Standard Proctor Compaction. Coupling joints that are placed with the vertical angular rotation, where the direction of the thrust is upward, should be backfilled to a minimum cover depth of 1.2 metres for operating pressures of 16 bar and greater.

Procedure for correcting the pipes deflected up to 8% of the diameter:

1) first, excavate to the haunch area, which is approximately 85% of the pipe diameter. Excavation just above and at the sides of the pipe should be done by hand tools, to avoid impacting the pipe with heavy equipment;
2) inspect the pipe for damage. Damaged pipes should be repaired or replaced;
3) re-compact the haunch backfill and ensure that it is not contaminated with unacceptable backfill material;

4) backfill the pipe zone again with the appropriate material, compacting each layer to the required relative compaction density;
5) backfill to grade and check the pipe deflections to verify they have not exceeded the initial values.

If the pipe deflection is over 8% of the pipe diameter, the pipes should be replaced completely. Do not attempt to jack or wedge the installed over-deflected pipe to correct the deflection, because this may cause damage to the pipe.

If multiple pipes are being excavated, care must be taken not to mound the cover from one pipe over the adjacent one. The extra cover and reduction of the side support could increase the over-deflection.

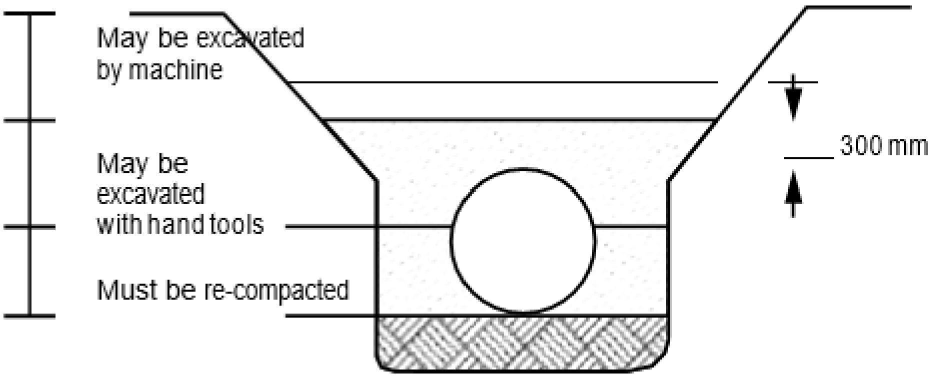


Figure 3: Excavating the over-deflected pipe.

5. METHODS OF INSERTION

- The pipe should be inserted into the coupling until it touches the stopper of the coupling. For the big diameter pipes, field technicians can enter the pipe after the installation to control the alignment of the stopper and the pipe. However, for small diameter pipes, a different technique has to be used, since there is no possibility to get into the pipe. In such cases, distance from the coupling outer end to the stopper is measured and marked on the pipe. The pipe is then pushed inside the coupling until the marked section meets the coupling end;

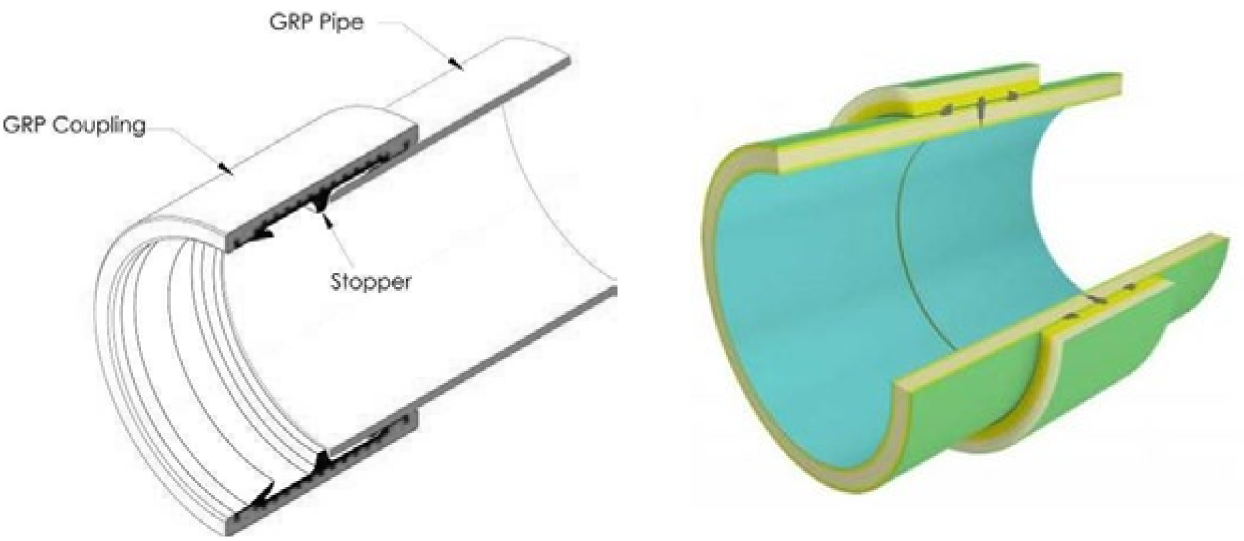
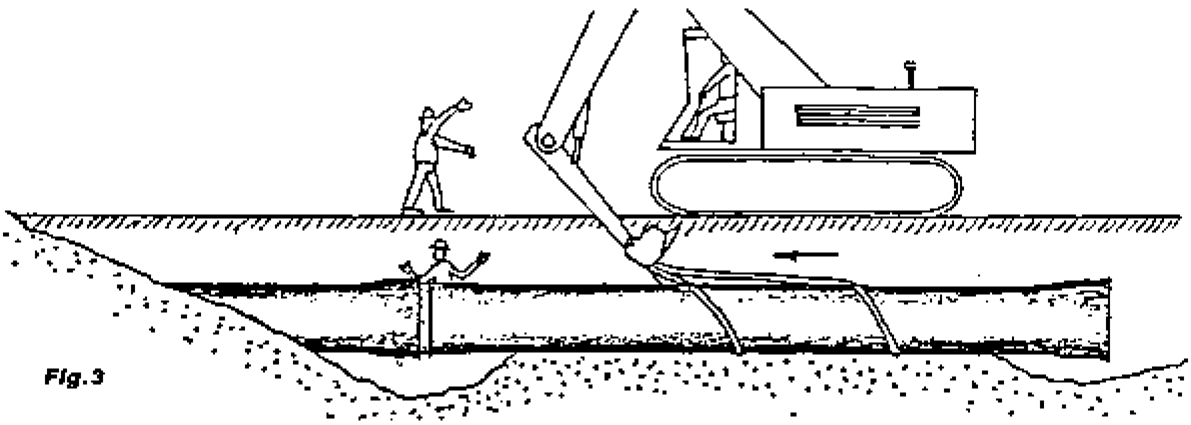


Figure 4: Stopper (left) and Reka stopper (right).

- when installing the small and medium size pipes and where the trench is deep, the pipe section can be inserted by an excavator positioned astride or alongside the trench;
- in front of the end of the spigot, place a plug that consists of the thick wooden boards, crossed over each other and suitable for protecting the end of the pipe section from the bucket of the excavator. The bucket then rests against the plug and is rotated to couple the joint;
- when installing the pipes with a medium diameter (for instance ND 600¸ 800), instead of the bucket being rotated, the excavator can be moved slowly forwards, astride or alongside the trench (see Fig. 2); this operation is possible only when a tracked excavator is used;
- under no circumstances should the arm of the excavator be moved, since this would cause coupling to happen too fast, not leaving the possibility to keep the operations under control.

- when installing the pipes with a medium diameter in shallow trenches, which are wide enough for the purpose, the pipe sections can be inserted by making the excavator move alongside the trench, with the pipe section slung at two points. Care should be taken to make the excavator bucket run as close as possible to the upper generating line of the pipe (see Fig. 3) and thus, to prevent the lifting of the pipe, which would cause the joint misalignment.

Use nylon or canvas slings for such handling; never use chains or steel cables.



- for small and large diameter pipes, suitably sized hand ratchet blocks (come along) may be used for the insertion.

Canvas or nylon belts should be used for slinging of the pipes or, when dealing with a large diameter pipes, half rings constructed according to the drawing should be used. (see Figure 5).

Figure 5: Using belts.

INSTRUCTIONS FOR MAKING FIELD-WELDED JOINTS

INSTRUCTIONS FOR MAKING FIELD-WELDED JOINTS

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1. FOREWORD

This chapter contains details and step-by-step instructions for making field-welded joints for the pipes and fittings, manufactured according to the TOPFIBRA's specifications.

The procedures described here can be employed to joint or repair the majority of the reinforced plastic components, as well as to impart to the joint or the repaired area, a strength as great or even greater than that of the GRP-BRP component so jointed or repaired; at the same time, they ensure the same degree of corrosion resistance.

In other words, a structure is obtained, which is fully comparable to the one produced in the factory.

In case of each individual type of installation, TOPFIBRA provides the standards for making field-welded joints. These standards give the dimensional characteristics of the joints - width, thickness, number of plies and the type of the material, and are prepared in such a way that they suit the design and the working conditions.

The raw materials are determined by the construction specifications and are the same type and quality, or better, as those used for the production of the pipes and fittings. In this way the homogeneity of the installation is ensured.

The procedures described are simple and flexible, so that they can also be readily carried out by unexperienced personnel.

2. TYPES OF JOINTS

The information given in this chapter can be applied to two types of joints, classified as:

- spigot-and-socket joint with cement and overlay;
- butt joint.

These joints differ from each other only in some working details, which are made clear every time in the description of the various working phases.

3. WORKING PHASES

3.1. Step 1: Necessary Tools and Materials

Make sure that you have all the tools and materials available that are needed to make the joint directly in the field. For this purpose, the following list may be useful:

- **work table:** usually a 125 x 150 cm metal sheet, but instead, a sheet of ply-wood covered with kraft paper (neither waxed nor coated) can be used;
- **glass reinforcements**: such as mat, woven roving, net and surfacing mat;
- **resin:** which is employed according to the applications;
- **paraffined resin:** it is used for the outer (final) protection;
- **catalyst, accelerator and inhibitor:** for the preparation of the resin;
- **putty:** for butt joints;
- **cement:** for spigot-and-socket joints;
- **electric/air disk grinder** supplied with abrasive disks;
- **hack saw or cutter** provided with disks for cutting pipes, and when necessary, for butt joints;
- grip for the rollers and rollers with woollen covers resistant to solvents;
- serrated and lamellar plastic or aluminium **rollers;**
- mixing paddles;
- **50 cc. graduated container:** for measuring the catalyst;
- **containers:** for preparing the resin (1 - 2 l jugs when the resin is going to be applied with a brush, or 5 - 10 l pans when the resin is going to be applied with a roller);
- 70 x 30 mm and 50 x 15 mm **paint brushes;**
- **spatulas:** for applying putty and cement;
- **scissors:** for cutting or shaping the glass reinforcements;
- **solvent and rags:** for personal cleaning and for cleaning the working tools;
- a good supply of **kraft paper or corrugated cardboard:** for re-covering the work-table if using a sheet of plywood.

3.2. Step 2: Preparing the Surfaces

At this stage, respective parts of the joint should be roughened by grinding. For spigot-and-socket joints with cement and overlay, it is necessary to roughen both, the spigot and the socket. The roughened surface should be at least 5 cm wider on each side than the surfaces that will be welded.

Carefully remove all the dust, with for example a jet of compressed air, and clean the surface with a rag soaked in acetone.

To obtain a joint with an optimum strength, it is essential that the surfaces, which will be welded, are fully dry and clean.

Figure 1: Preparing the surface.

3.3. Step 3: Alignment and Application of the Resinous Putty or Cement

When using butt joints, the lengths of the pipe which will be welded, are aligned with their ends to bring them in contact and are then fixed in this position. Putty is normally prepared on a board and is applied with the spatula to the ends in contact, to make the surface that will be welded continuous and to prevent the resin from dripping inside the pipe through any cracks or uneven areas.

Before starting the next step, let the putty cure. While it is curing, the same operation can be carried out on other joints, provided that care is taken to prevent any movement of the pipe.

In case of spigot-and-socket joints with the use of cement, the lengths of the pipe are aligned, centred, and positioned with a gap between them, which is big enough for a person to pass through.

The resinous cement is applied with a spatula to the inner part of the socket and the outer part of the spigot.

The lengths of the pipe are brought together until the spigot has been fully inserted with a tackle. The excess of cement is removed by bevelling the edge in such a way that the area of the weld is smoothly contoured.

Other joints can be made while the cement is curing, provided that care is taken to not move the pipe.

3.4. Step 4: the “Hot Patch” Application

A “hot patch” is merely a tack weld to keep the pipe aligned until the final overlay has been applied. Normally, it is not required for spigot-and-socket joints but it is essential when jointing plain-ended pipes (butt points).

A “hot patch” consists of a small piece of mat, impregnated with resin, to which the catalyst has been added in quantity three times greater than normally used, so the resin cures in a few minutes. This small glass reinforcement is applied to the line of the joint and all the trapped air bubbles are removed with a serrated roller.

Small "hot patches" may be needed to keep the pipes aligned, depending on their dimensions.

3.5. Step 5: Reinforcement Preparation for the Overlay "Pack"

Prepare enough resin, according to the mixing instructions in a jug, or in a pan if the woollen rollers are going to be used.

The glass reinforcement normally consists of various alternate plies of mat and woven roving, cut into strips. The width of the strips is given in the jointing standards. The reinforcement is laid on the work-table. Care should be taken to put the Mylar film or cellophane on the table beforehand, to prevent the unnecessary cleaning or maintenance.

When laying the plies, it is advisable to centre the successive strips on the first one and to ensure that the ends are overlapping by at least 2.5 cm to create a "step" arrangement, to avoid a ridge when additional “packs” are applied.

Each single strip of the glass reinforcement should be saturated with the resin. The “pack” prepared in this way, should be rolled vigorously to squeeze out all the air bubbles and to ensure a complete impregnation and compactness.

A "pack" should never consist of more than 5 plies of woven roving and 7 plies of mat.

NOTE: When a greater number of plies is required to reach the thickness of the joint, envisaged in the standards, the first “pack” should be left to polymerize on the pipe before the others are applied.

Figure 2: Preparation of the overlay pack.

3.6. Step 6: Application of the “Pack”

The resin saturated "pack" should be carefully peeled from the work-table and then turned over and applied to the zone of the joint so that the NARROWEST STRIP IS PLACED AGAINST THE SURFACE OF THE PIPE FIRST.

Figure 3: Applying the pack.

Using a film of cellophane or Mylar, which is put on the top of the work-table for the preparation of the overlay “pack”, is very useful during this step.

When the “pack” is applied, make sure that it is neither wrinkled nor curled.

3.7. Step 7: Air Bubbles Elimination

Using serrated rollers, press the bandage of plies of glass reinforcement, forming the "pack", hard against the pipes and roll them, working from the middle towards the edges.

This operation is alternated with rolling parallel to the line of the joint, again starting from the middle of the overlay.

In this way all the air bubbles are squeezed out and the bond and continuity of the reinforcing material with the basic structure are ensured.

Figure 4: Eliminating air bubbles.

3.8. Step 8: Top Coat Application

When the overlay has been completed and is fully polymerized (or "cured"), the whole surface is sanded down to remove any rough edges. The dust is carefully cleaned off by a jet of compressed air.

A layer of the paraffined resin - possibly including an ultraviolet ray absorber for the above-ground installations - is then applied with a brush to the whole surface, which has been roughened, to prepare it for the overlay.

Several joints can be left to cure and are then coated at the same time.

It should be kept in mind that the top coat will not adhere to the parts which have been coated beforehand, either at the factory or on the field

Figure 5: Applied top coat.

4. GENERAL NOTES AND INFORMATION

4.1. Cleaning

It is essential that the surfaces, which will be welded, are clean and dry. Roughened ends of the pipes that were left unprotected overnight should be thoroughly cleaned with rags soaked in iso-propyl alcohol or acetone to eliminate any traces of dampness.

In bad weather conditions, the work on the overlay can be carried out if the working area is suitably sheltered from the rain and dampness.

In case of a strong wind, it is advisable to arrange a suitable protection so that the dust or sand do not come into contact with the reinforcing plies impregnated with the uncured resin.

4.2. Uniformity and Quality of the Overlay

The presence of the air bubbles; unimpregnated zones; blisters; and hollows in the resin, indicate that the overlay is of poor quality. The outer protective coating (the top coat) should be smooth and the whole area of the joint should be free of the rough zones.

The quality of the welds also depends on the cleanliness of the used tools. In particular, when the brushes and woollen rollers are not in use they should be kept ready, placed in a receptacle containing acetone.

Before using, these tools should be shaken hard to remove the solvent.

A brush or a roller used for the resin, which already contains a catalyst, should not be put into pans or jugs of the resin not containing a catalyst.

4.3. Curing Time

Until the overlay and the outer coating don't contain any heat, produced by the exothermic curing reaction, the pipes should not be moved. Polymerization can be readily checked in the field with the acetone test. In regards to moving, handling, and laying of the pipeline, it is advisable to wait for 4 hours, starting from the moment when the overlay has reached the ambient temperature. Trials and setting the line to work can take place after 24 hours.

4.4. Acetone Test

Rub the surface of the resin lightly with a pad of cotton wool or with a rag soaked in acetone until the solvent has evaporated.

If the surface becomes soft or tacky, it means the resin is not fully cured and the coating described in section 3.8 – Step 8: Top Coat Application, should be renewed over the tested area.

4.5. Brief Considerations Regarding the Temperature

The temperature is a very important factor in all jointing processes for two basic reasons:

a) **Effect on the resin**: the resin is usually prepared in such a way that its gel time is 25 minutes and its curing time is 40 minutes.

An increase in the ambient temperature speeds up the reaction and shortens the optimum application time.

A decrease in temperature slows down the reaction and sometimes does not allow a complete cure to be obtained. Such effects of the temperature are neutralized by adjusting the quantities of the accelerator, the inhibitor and the catalyst, which are added during the preparation of the resin, all of which affect the gel time.

In particular, when preparing a batch, it should be kept in mind that the accelerator should not exceed 1%. Greater percentages are allowable if all the resin is going to be used within one or two days.

The quantity of the catalyst is most often adjusted to suit the ambient conditions. It is advisable that the catalyst content should not be less than 1%, because otherwise, a complete polymerization will not take place. However, it should not be more than 2%, since a greater quantity involves the risk of local burns in the laminate.

The inhibitor, which modifies the gel time for about 10 minutes for each addition of 0.1%, is effective up to the temperatures of 40-50°C. Beyond this limit it evaporates and loses all its effect.

NOTE: For each individual installation, depending on the type of the resin envisaged, TOPFIBRA provides a more detailed information regarding the preparation of the resin and the actions that have to be taken to suit the local climatic conditions.

Figure 6: Using protection above the pipe.

b) Effect on the quality and effectiveness of the joint: direct exposure to the sun rays, especially in the tropical zones, can make the overlay, during curing, reach the temperatures high enough to cause the "burning" of the joint. Under such conditions it is essential to make arrangements to protect the area of the joint.

The "burning" is the polymerization, which has occurred due to a high temperature, and leads to the shrinkage and lessening of the mechanical strength of the laminate and sometimes to the separation of the plies of the glass reinforcement, resulting in the loss of effectiveness of the weld. When this happens, the overlays and the "burnt" areas should be eliminated and the work should be re-done properly.

When using the spigot-and-socket joints with cement and overlay, it is best to bear in mind that differences between the day and the night temperatures can lead to cracks in the cement and even to the separation of the socket from the spigot. For this reason, cement should only be applied to joints which can then be completed with their overlay during the same day.

5. STORAGE OF THE MATERIALS

5.1. Resins, Catalyst, Accelerators, Acetone, Putties, Cement

Packages of these materials should be stacked separately, product by product, and stored in a cool, dry, shaded place at the temperatures below 25°C, or possibly underground. Storing them at temperatures above 25°C or on the direct sun is not advisable.

NOTE: These materials are highly inflammable and should be kept far away from open fire and any sources of heat.

5.2. Glass Reinforcement Materials

It is important that the glass reinforcement materials are protected from dampness. They should be stored in sealed plastic bags and kept in a clean, dry place.

5.3. Gaskets and Lubricant storage

Rubber ring gaskets, when shipped separately from the couplings, should be stored in the shade in their original packing and should not be exposed to sunlight, except during the pipe joining. The gaskets must be protected from exposure to the petroleum-derived greases and oils, as well as solvents and other harmful substances.

Gasket lubricant should be carefully stored to prevent damage. Partially used buckets should be resealed to prevent contamination of the lubricant. If temperatures during installation are below 5°C, gaskets and lubricant should be sheltered until used. A special lubricant for temperatures under 5°C is available on request.

Figure 7: Storage.

6. SAFETY RULES

6.1. Liquid Resin, Catalyst, Accelerators and Solvents

a) When making joints, it is advisable not to smoke in the vicinity of the working area or approach the area with naked flames;

b) in regards to the catalyst in particular, care should be taken not to work near rust, metal dusts or cardboard, which may catch fire by the decomposition of the catalyst itself;

c) any remains of the catalysed resin left to cure in the receptacles or pans will develop heat and fumes. Such containers must not be closed with lids or other random means. Whenever possible, it is advisable to empty the resin while it is still in a liquid state.

We also recommend to take special care when storing and disposing of the waste.

6.2. Hygiene Rules

a) When handled duly and carefully, these materials do not involve any health risks. While working with them, it is advisable to follow the standard norms of the industrial hygiene, such as having adequate ventilation and personal cleanliness. In particular, we recommend the use of rubber gloves to obviate the direct contact with the skin. We also recommend wearing the protective goggles during the grinding operations;

b) do not touch then eyes with dirty hands. If that happens inadvertently, rinse out the eyes with plenty of water.

c) If the catalyst comes in contact with the eyes, rinse them first and then disinfect them with a 2% solution of boric acid or with a 5% solution of ascorbic acid. In more severe cases, please consult a doctor.

6.3. Accidents

a) If the resin, catalyst or accelerator leak, use sand or sawdust to absorb them or clean the area with the throwaway rags. Afterwards, clean the area with acetone or detergents;

b) in case of fire, use water and CO_2 extinguishers or dry extinguishers. Dry extinguishers must be kept near the electric cables, according to law.

HYDROSTATIC ON-SITE TESTING OF THE FILAMENT WOUND FIBERGLASS PIPE

HYDROSTATIC ON-SITE TESTING OF THE FILAMENT WOUND FIBERGLASS PIPE

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1. FOREWORD

The hydrostatic test is performed on an installed fiberglass piping system or a sub-system, to verify the structural integrity of the field-welded joints and the overall design performance of the piping system. Field tests can be performed with water for pressured or non-pressured pipelines. This chapter outlines the general procedures and steps to be followed. However, the individual testing requirements for specific jobs have to be determined on each occasion.

Since a fiberglass underground piping system is designed as a pipe/soil system (see Engineering Handbook, chapter "General Design Specification"), it is recommended that the pipe is backfilled all along its length, except for the field joints, so that they can be latter visually inspected during the testing. All changes in the direction, such as elbows, tees, etc., must be backfilled or supported to eliminate any excessive movement detrimental to the structural integrity of the piping system. Before a fiberglass piping system or sub-system is hydrostatically tested, all supports and anchors must be installed to prevent the damage. It is recommended that a fiberglass piping system is tested at a pressure 1.5 times the design of the working pressure of the system.

The design working pressure is defined as the operating pressure of the system under the worst conditions.

The piping systems under test should not be tested to 1.5 times the nominal pressure of the GRP-BRP pipe and the components, because generally, the Designer selects a nominal pressure higher than the working operating pressure to take into account other loads, which could possibly act on the system and which could be also present during the test.

Before starting the test, safety precautions should be applied around the pipeline. If possible, people should vacate the tested areas of the pipeline.

2. TESTING PROCEDURES

To perform a satisfactory testing program, it is recommended to follow the next procedures and steps:

2.1. Step 1

After the fiberglass system or sub-system has been properly installed, anchored, and backfilled according to the design and the installation procedures, a complete visual inspection should be carried out and any physical damage should be recorded and repaired.

2.2. Step 2

Air-release valves should be installed at high points in the pipeline; these valves are normally connected to the blind flanges covering the manholes (see Fig. 1). The air-release valves should be left OPEN during the filling.

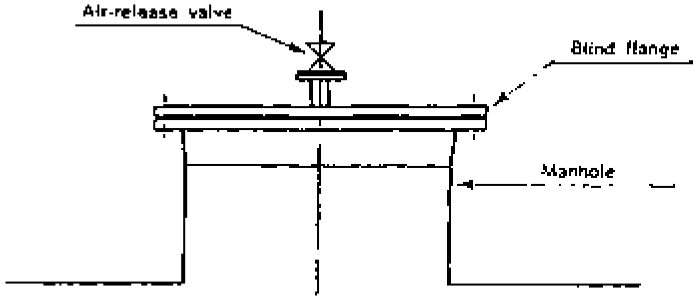


Fig. 1 -Typical design of a purging system

2.3. Step 3

Connect a pressure gauge to the fiberglass piping system and measure the elevation of the gauge as compared to the axis of the pipeline to which the test pressure will be applied. In this way, the pressure read on the gauge can be corrected and the correct pressure can be identified (see Fig. 2).

Pressure (test) = Pressure (gauge) - Height 10-1
(kg/cm^2) (kg/cm^2) (m)

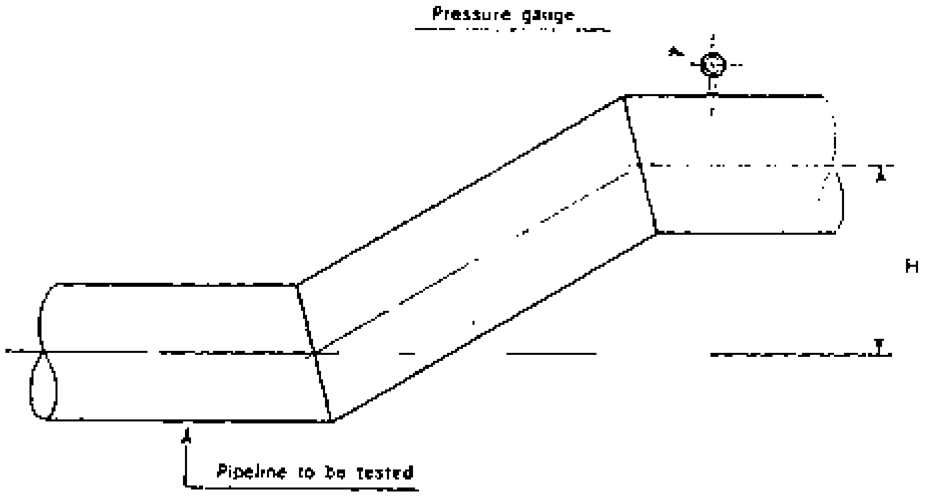


Fig. 2 - Hydrostatic test of a pipeline with the pressure gauge at a different elevation

NOTE: The pressure gauge should be calibrated before and after the test. The maximum pressure of the gauge should not be greater than 3 times the test pressure.

2.4. Step 4

Slowly fill the pipeline with water and allow all the air to escape through the air-release valves. As soon as the water comes out of the valves (lowest level first), close them very slowly. When the water starts coming out of the highest air-release valve, stop pumping and close the valve.

The system should then be allowed to settle and reach the mechanical and thermal equilibrium.

2.5. Step 5

The pipeline can now be pressurized with a pump, which is able to pressurize the system up to the required test pressure at a pre-set rate.

During the initial pressurization, the cross sectional area of the pipe will increase due to the elastic modulus of the material, resulting in a slight increase in the volume and a drop in the pressure.

The system or sub-system should be allowed to settle for a period of time before any measurements of losses are made.

The maximum permitted rate of leakage is 4.5 litres per centimetre of the diameter per kilometre of line per 24 hours.

If the leakage is greater than the maximum permitted rate after the test period, the source of the leakage should be fixed and the hydrostatic test repeated until a successful result is obtained.

2.6. Step 6

The test pressure should be held for a period of time that is not shorter than 10 minutes and not longer than 2 hours. All visible joints should be then inspected for leaks and the results should be recorded.

3. TESTING PIPELINES UNDER PRESSURE

The tested line will be divided in segments, which will range in length from 500 to 1000 m, unless otherwise specified by the management in charge of the works.

In general, the tested section length is chosen, as far as possible, in function of battery limits, flanges, check points such as valves or pits, to facilitate the closure of the ends.

Note: when testing the large diameter GRP-BRP pipes, with nominal pressure 10 bars and above, the couplings might rotate. For the high pressure pipelines, test pressure should not be increased if the coupling tops are left unfilled for visual inspection. If a coupling rotation is detected, test should be immediately stopped, coupling should be aligned and test should be repeated from the beginning.

3.1. Definition of Pressure

- NP = nominal pressure;
- PW = working pressure;
- PS = surge pressure;
- PT = testing pressure, generally 1.5 PW.

The following allowance is accepted for the GRP-BRP pipes:

$PW < NP$ and $PW + PS < 1.4\ NP$

3.2. Backfilling Before Testing

The segments of the tested line should be covered with bridges of the backfilling material, while the joints must be left uncovered so they can be visually inspected.

The methods and the materials for the backfilling are specified in the report that accompanies the design of the pipeline.

3.3. Anchorages and Thrust Blocks

The pressure test shall take place only after the execution of the anchorage. In general, for the underground installations, anchorage consists of the concrete thrust blocks, which must be allowed to cure to reach a sufficient degree of strength before proceeding with the pressure test.

Temporary anchorages are made at the ends of the segment of the tested line, such as final thrust blocks, which must be designed according to the test pressure and to the permissible load of the supporting soil.

When the pipeline is pressurized, unbalanced thrust forces occur at bends, reducers, tees, wyes, bulkheads and other changes in line direction. These forces must be restrained to prevent joint separation. Usually, the most economical way to accomplish this is by using thrust blocks, or alternatively, by direct bearing and friction between the pipe and the soil.

Thrust blocks must limit the displacement of the fitting, relative to the adjacent pipe, to preserve the leak tightness of the coupling joint.

For operating pressures above 10 bar (PN>10) the block must completely surround the fitting. For lower pressures, special fittings can be used that allow a partial embedding. The block should be placed either against the undisturbed earth or the backfill, which has been selected and compacted to meet the original native soil's strength and stiffness.

Thrust blocks are required for the following fittings, when the line pressure exceeds 1 bar (100 kPa):

- for all bends, reducers, bulkheads and blind flanges;
- tees, when the branch pipe is concentric to the centreline header pipe;
- concentric manways (blind flange tees), drains and air vents, which do not generate unbalanced thrust in operation They do not require encasement, but they require thrust resistant branches and fittings.

Note: The exact shape of the thrust block will be dependent on design and project requirements. The shapes in the Figure 3 are merely illustrative.

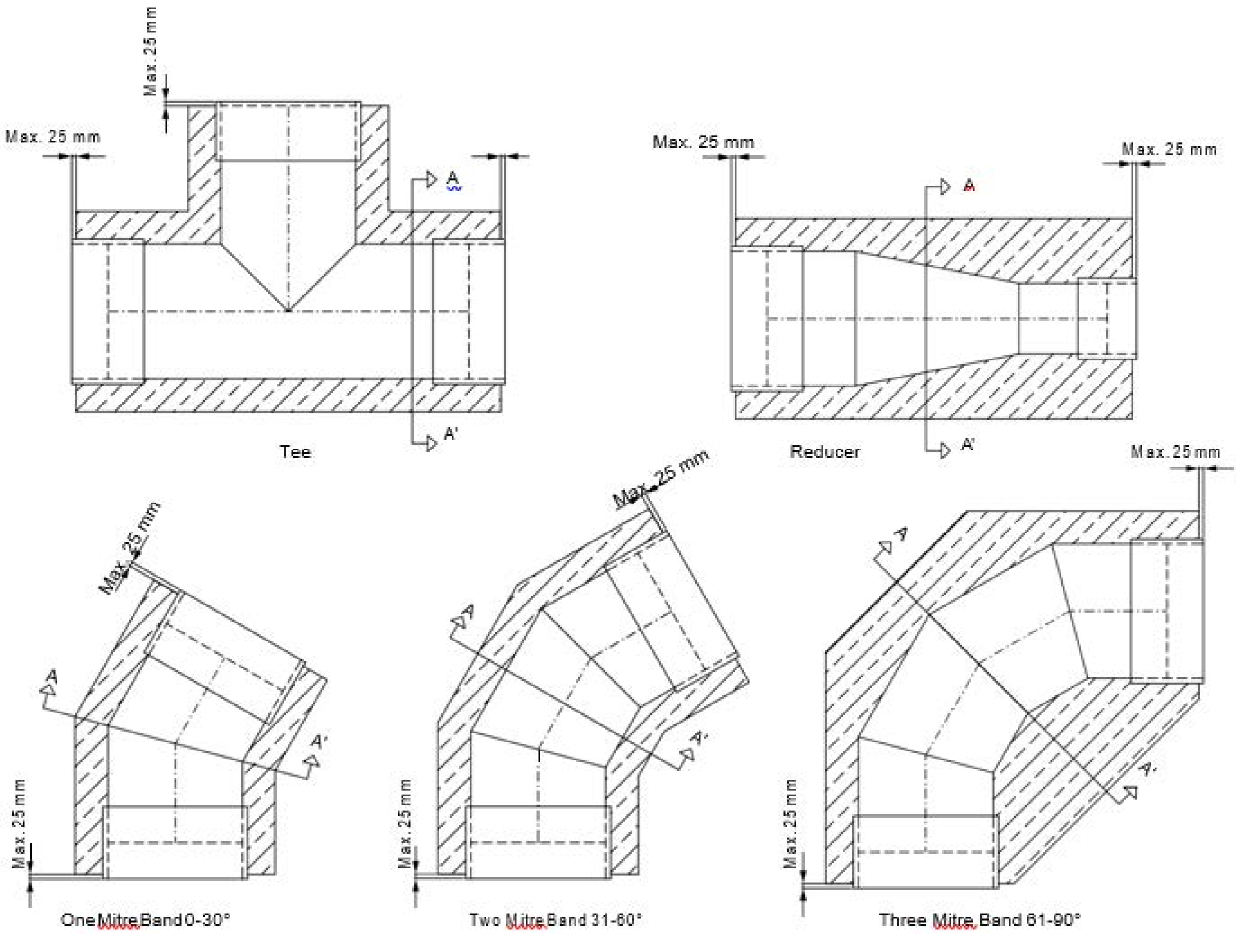


Figure 3: Thrust blocks.

Valves must be sufficiently anchored to absorb the pressure thrust.

Nozzles are tee branches, which have to meet all of the following criteria:

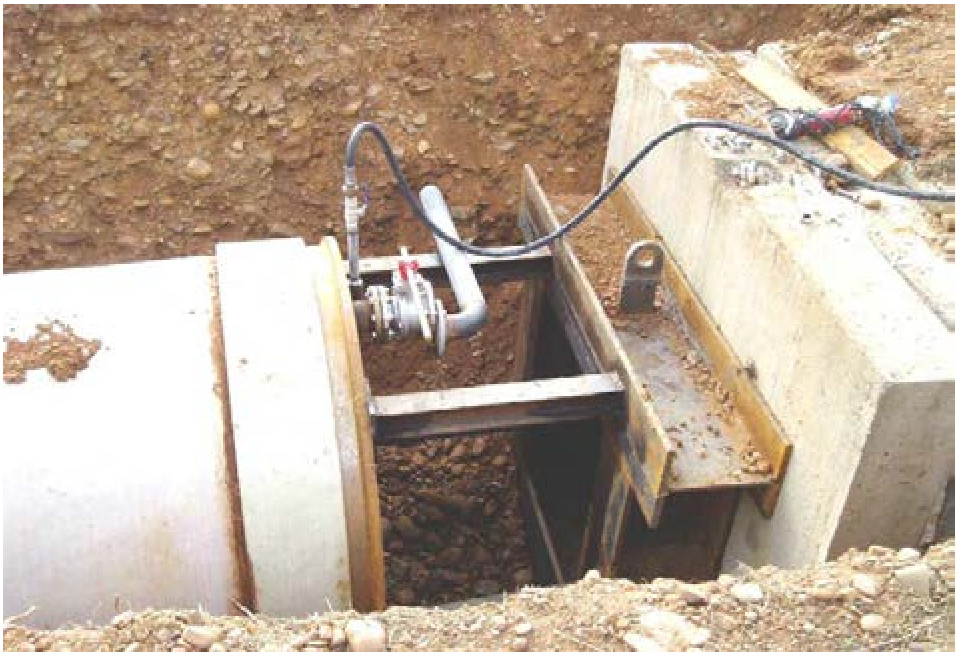
- nozzle diameter has to be ≤ 300 mm;
- header diameter had to be ≥ 3 times the nozzle diameter.

It is not necessary to encase nozzle connections in concrete.

3.4. Closing Ends of the Tested Segment

The two ends of the tested segment are closed by suitable closures such as plugs or end caps. For this purpose, shut-off means can be employed, such as valves, provided they are suitably anchored.

In case there are no other branch lines along the segment under the test, the closures should be equipped with fittings for filling/discharging and a pressure gauge.



Breather pipes should be applied at the highest points of the segment to allow the air to exit.

3.5. Filling the Test Segment

The test segment should be slowly filled with water, to ensure a complete discharge of air. Whenever possible, the filling should take place at the lowest point of the segment. Of course, during the entire operation the breather pipes must remain open.
When the pipeline is full, the flow rate is reduced and the filling is continued, so all the air bubbles can leave through the upper breather fittings. The filling operation will be finished when only water exits the breather pipes.

The test segment of the line shall now be left to rest for about 24 hours, until the mechanical and thermal equilibrium has been reached.

After this settlement period and before the pressure is applied, care should be taken to complete the filling once more.

3.6. Test Equipment

- Ensure that all the testing equipment is functional and in good condition;
- pressurisation of the line is obtained with a suitable pump, generally a piston type or a diaphragm type pump, which ensures a proper control of the pumping rate;
- the pump should be equipped with a graduated tank or with a litre counter to allow reading of the volume of water which has to be fed into the pipeline to keep the desired pressure;
- the reference pressure gauge should be positioned at the lowest point of the test segment in a position fully visible from the pressurisation area;
- if necessary, a second pressure gauge, for the comparison purposes, can be fitted to one of the breather pipes located along the pipeline;
- reading accuracy of the employed gauges should be 0.01 MPa;
- special attention should be paid to the selection of the shut-off devices to prevent any backflow.

3.7. Preliminary Test

After completing the settlement and filling, the test segment is brought to the nominal pressure at a pressurization rate no greater than 0.1 MPa per every 10 minutes.

The line shall then be allowed to settle for a period of time to show any leakage. The end of the settlement period will be shown by the asymptotic stabilization at a fixed value of the pressure in the test segment.

The pressure is then risen to the initial value and the test lasts for 12 hours, starting from the moment at which the applied pressure remains constant.

During and after such period, visible parts of the segment should be carefully inspected and if no leakage or appreciable displacements of the pipeline are observed, the segment is submitted to the actual pressure test.

3.8. Pressure Test

Upon obtaining the positive results of the preliminary test, the pressurisation of the system is continued at the same rate until the test pressure is reached.

The test pressure is generally 1.5 times the nominal pressure, but the value can be modified according to the real working conditions and by the mutual agreement between the end user and the pipe manufacturer.

3.9. Duration of the Test

The test pressure shall be maintained for 2 hours without any further pumping.

Due to the settling of the material, a small drop in pressure may take place during the test, which is about 1/20 of the test pressure as found by trials and experience.

If the pressure stabilizes at a constant value, the test is considered successful. Otherwise, the test segment should be inspected to find the leakage.

For this purpose, the pump shall draw water from a graduated tank or through a litre-counter and the required amount shall be recorded at one-hour intervals.

A constant withdrawal of water proves a leak occurrence in the test segment. When the leak has been repaired the test should be repeated, following the same procedure.

Figure 4: Gauge.

3.10. Permitted Topping-Up During the Test

When the system has reached a mechanical and thermal equilibrium, meaning that the test segment has reached its elastic stability, topping-up with water is permitted to the following extent:

a) topping-up is dependent on the diameter and length of the pipeline: 4.5 litres per centimetre of the diameter and per kilometre of line over a period of 24 hours;
b) topping-up based on the test pressure and the number of joints:

$$L = \frac{ND * n * \sqrt{P_m}}{3700}$$

Where:

L = the permitted loss in l/unit of time;

N = number of joints;

ND = the nominal diameter of the pipeline in cm;

Pm = the average pressure, recorded during the loss per unit of time in kPa.

4. TESTING THE GRAVITY PIPELINES

- Where the inspection or shut-off pits are provided along the line, the segments which undergo the test are the ones included between the two consecutive pits. Otherwise, the test segment may consist of a length ranging from 500 to 1000 m;
- the construction supervisor may also restrict the test to a sample segment chosen at random along the installed line;
- the operations of backfilling, closing ends, and filling are the same as described for the pressure lines;
- when the segment has been filled, it should be left to rest for 24 hours, so that it can attain a condition of the resilient stability. Then an internal hydrostatic pressure of 0.04 MPa, measured at the highest point of the segment, shall be applied;
- this test should last for 30 minutes. Afterwards, the joints are inspected to ensure that there is no leakage. If there is leakage, it is necessary to repair the joints and repeat the test;

- the permissible rate of leakage must be 8 litres per centimetre of the diameter and per kilometre of pipeline for 24 hours, or it must comply with the AWWA Standard C 600-64, Section 137.

4.1. Field Air Test

An alternative leak test for the gravity pipe (PN 1 bar) may be conducted with the air pressure instead of water. In addition to the routine care, normal precautions and typical procedures, the following suggestions and criteria should be followed:

1) as with a hydrotest, the line should be tested in small segments. This is usually the section of the pipe between the adjacent manholes;
2) ensure that the pipeline and all the materials, stubs, accesses, drops, etc. are adequately capped or plugged and braced against the internal pressure;
3) slowly pressurize the system to 0.24 bar. The pressure must be regulated to prevent over pressurisation (maximum 0.35 bar);
4) allow the air temperature to stabilise for several minutes, while maintaining the pressure at 0.24 bar;
5) while the temperature is stabilising, it is advisable to check all plugged and capped outlets with a soap solution to detect leakage. If leakage is found at any connection, release the system pressure, seal the leaky caps or plugs and slowly start pressurising the system again (like in step 3);
6) after the stabilisation period, adjust the air pressure to 0.24 bar and shut-off or disconnect the air supply;
7) the pipe system passes this test if the pressure drop is 0.035 bar or less during the time period given in this table:

Diameter (mm)	**Time (min.)**	**Diameter (mm)**	**Time (min.)**
100	2.50	1000	25.00
150	3.75	1100	27.50
200	5.00	1200	30.00
250	6.25	1300	32.50
300	7.75	1400	35.00
350	8.75	1500	37.50
400	10.00	1600	40.00
500	12.50	1800	45.00

600	15.00	2000	50.00
700	17.50	2200	55.00
800	20.00	2400	60.00
900	22.50		

8) if the tested section fails the air test requirements, the pneumatic plugs can be coupled fairly close together and moved up or down the line, repeating the air test at each location, until the leak is found. This method to locate the leak is very accurate, pinpointing the location of the leak to within one or two metres. Consequently, the area that must be excavated to make the repairs is minimized, resulting in lower repair costs and saved time.

This test determines the rate at which the air under pressure escapes from an isolated section of the pipeline. It is suited to determine the presence or absence of the pipe damage and/or the improperly assembled joints.

CAUTION: CONSIDERABLE ENERGY IS STORED IN A PIPELINE UNDER PRESSURE. THIS IS PARTICULARLY TRUE WHEN AIR IS THE TEST MEDIUM (EVEN AT LOW PRESSURES). TAKE GREAT CARE TO ENSURE THE PIPELINE IS ADEQUATELY RESTRAINED WHERE LINE DIRECTION CHANGES. FOLLOW THE SAFETY PRECUATIONS FOR DEVICES SUCH AS PENUMATIC PLUGS.

VALVES AND CHAMBERS

VALVES AND CHAMBERS

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1. FOREWORD

For practical purposes, it is necessary to position the in-line valves along the most pressurised pipelines to:

- isolate a portion of the supply or the distribution system;
- control the release of the accumulated air at high points with the air and vacuum relief valves;
- introduce air in order to avoid under pressure, drainage or clean-out.

Many different methods can be used to incorporate the valves and chambers into a pipeline and a professional engineer has the ultimate responsibility for the design of the piping systems. This section of the handbook offers a design engineer or a contractor some guidelines on how to incorporate the valves and chambers in a pressure pipeline

2. ANCHORING IN-LINE VALVES

Pipes are designed to handle nominal axial loads, but they are not designed to accommodate thrust and shear loads that may result from the inclusion of valves in the piping system.

Loads from valves must be externally restrained as required by AWWA C600. This section will describe several methods for anchoring the valves. The best method will depend on the specific operating conditions for each system. Generally, the best method is dependent on the pipe diameter and operating pressure. There are two basic considerations for in-line valves: directly accessible (installed in chambers) or not accessible (direct bury). Generally, smaller diameter valves are direct buried without using concrete chambers for easy access.

2.1. Direct Bury

2.1.1. Type 1

To achieve the lowest cost and the easiest installation for a small diameter valve, is to direct bury it, encapsulated in its own concrete thrust block.

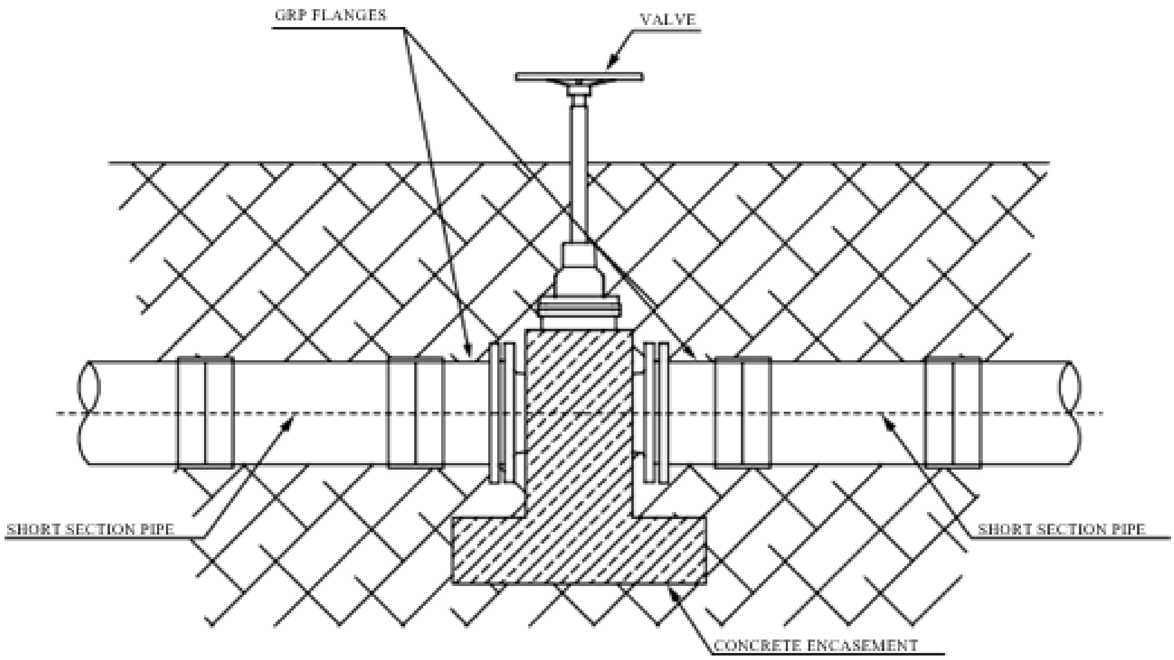

Figure 1: Type 1 - valve encased in thrust block.

This method can also be used with larger valves. The only limit is a reasonable thrust block design. The reinforced concrete thrust block must be properly designed to resist thrust from a closed valve with limited movement to ensure the leak tightness of the joint.

Designing guidelines:

- the size of the thrust block is based on the local soil stiffness, backfill material and installation conditions. Lateral movement must be limited to preserve the leak tightness of the joint;
- flanged stubs should not be longer than 1000 mm, with a coupling on the outside leg which connects the stub to a rocker pipe.

2.1.2. Type 2

The anchoring method for Type 2 is similar to Type 1, except that the valve body can be accessed.

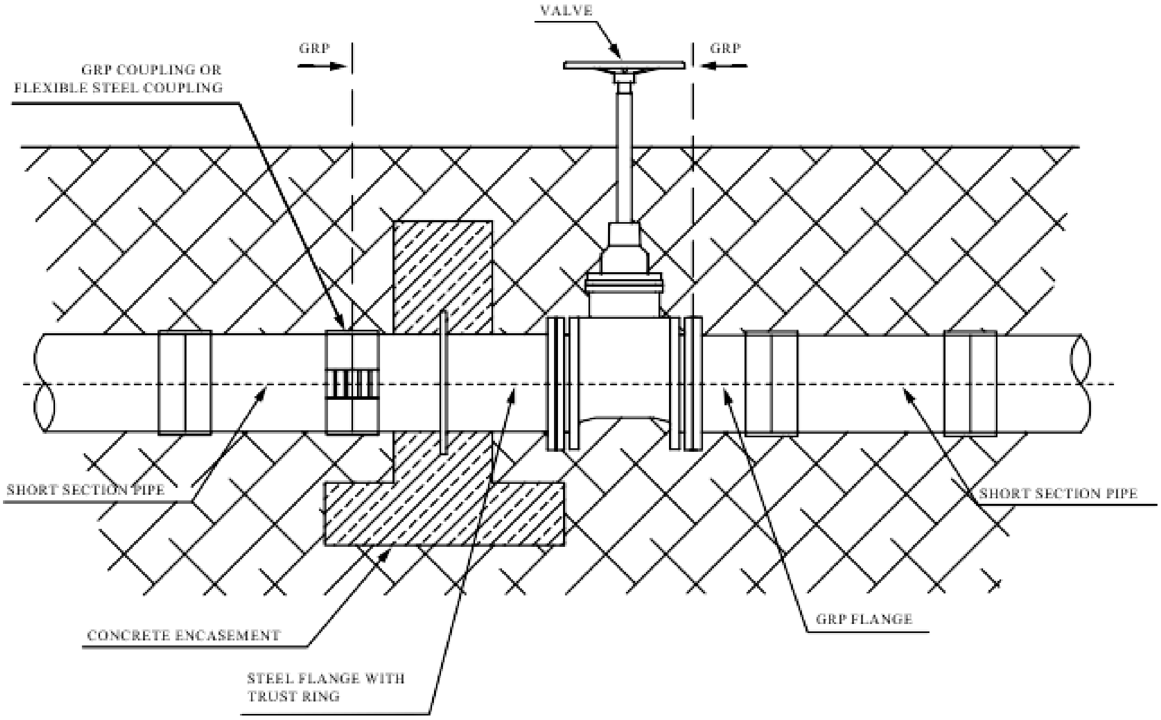

Figure 2: Type 2 – thrust block adjacent to valve.

The installation is relatively simple and the valve is available for servicing. Usage depends on the stub strength of the steel or the ductile iron pipe and the attached anchoring collar. For small thrust loads, only one side of the valve needs to be anchored.

Designing guidelines:

- the size of the thrust block is based on the local soil stiffness, backfill material and installation conditions. Lateral movement should be limited to preserve the leak tightness of the joint;
- the flanged stubs should not be longer than 1000 mm. The stub, with the flange or an anchor collar, connects to the rocker pipe with the standard coupling;
- if steel or ductile iron stubs are used, it is recommended the use the flexible steel couplings or the transition (dual bolting) mechanical couplings.

2.1.3. Type 3

This method can be used for all valves except the larger, higher pressure valves. Usage depends on the ability to place the structural support system into the valve chamber. The support system must be designed to accept the total axial thrust without over-stressing the valve flanges or the reinforced concrete valve chamber walls. The valve chamber acts as the thrust block and must be designed as such. The thrust restraint is placed on the compression side of the valve to transfer the thrust directly to the chamber wall. The other end of the pipe system is relatively free to move axially, allowing for movement due to the temperature changes and the Poisson`s effect.

The assumption, made in Figure 3, is that the thrust acts only in one direction. However, the possibility of back pressure on a closed valve has to be considered, which could create a thrust load in the opposite direction. To accommodate this possibility, the structural support system can be designed to handle the load in either direction. The details are left up to the design engineer.

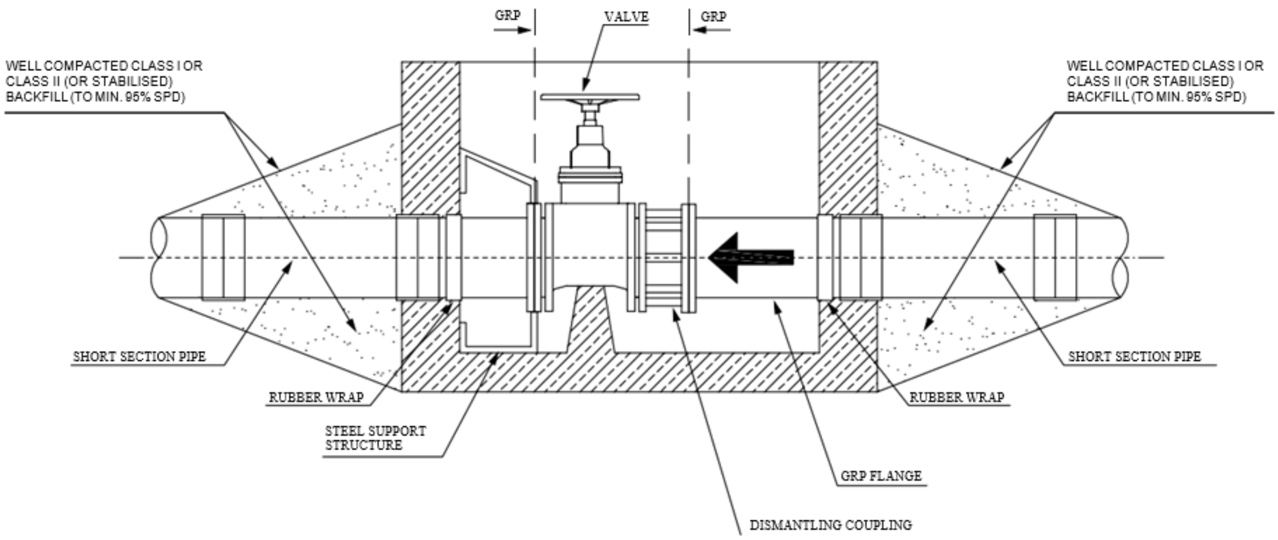

Figure 3: Type 3 – using the structural support system to accommodate thrust forces.

Design guidelines:

- the valve thrust and shear has to be supported with a steel frame support system;
- the standard pipe either must have a rubber wrap, or coupling where it penetrates the concrete wall. This is to reduce the local stresses, which are caused by the constraint of the free radial displacement during pressurization;

- the valve chamber must be designed to accept the full axial thrust and vertical weight of the valve. It is required to have local reinforcements in the foundation of the valve chamber and walls, so they can accept the axial forces at the attachment points;
- the valve chamber has to be designed as a thrust block, to resist the axial thrust. The backfill selection, placement and compaction, have to be sufficient to resist settlement and lateral forces created by the valve closure. Lateral movement must be limited to preserve the leak tightness of the joints;
- a rocker pipe must be placed outside the valve chamber, according to the standard installation practices;
- thrust is taken via compression of the structural support system. No axial load is transmitted to the pipe;
- use cement stabilised backfill, or gravel, compacted to minimum 95% relative compaction, to fill the void beneath the pipe where the valve exits the chamber structure

2.1.4. Type 4

This method can be used to anchor any valve with pressures up to 16 bar. Use of this method is limited by the practical limits of the pipe reinforcement and puddle flange length. The puddle flange is placed on the compression side of the valve, directly loading the chamber wall, which acts as a thrust block. The other side of the pipe system in the chamber is relatively free to move axially, to allow movement due to the temperature changes and the Poisson's effect.

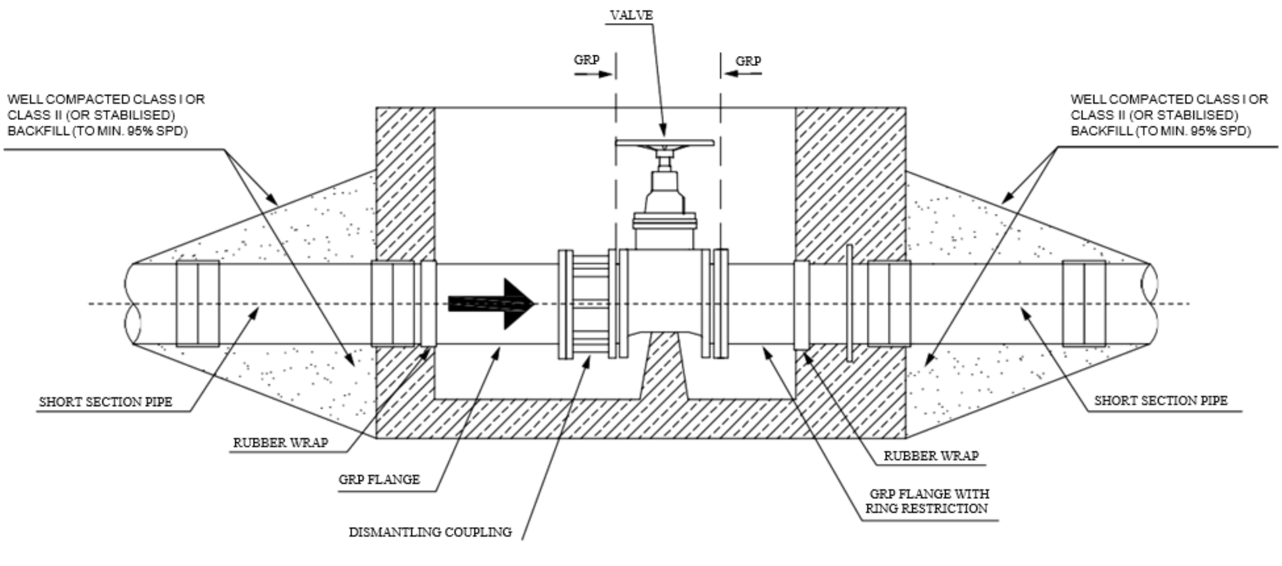

Figure 4: Type 4 – using puddle flange to accommodate thrust forces.

Design guidelines:

- a “special” pipe will have a GRP-BRP puddle flange fabricated on the compression-side, which is embedded into the valve chamber wall and acts as an anchor;
- the other pipe leg is free to move axially through the sealing gasket in the valve chamber wall;
- the weight of the valve has to be supported from the base of the valve chamber. The valve chamber has to be designed to accept the full axial thrust of the valve. A concentration of reinforcement bars will be required to accept the axial forces from the embedded puddle flange;
- the valve chamber has to be designed as a thrust block, to resist axial thrust. The backfill selection, placement and compaction have to be sufficient to resist settlement and lateral forces which are created by the valve closure. Lateral movement has to be limited to preserve the leak tightness of the joint;
- the “special” pipe will have a coupling embedded in the valve chamber wall. The “special” pipe within the valve chamber will be reinforced to accept the axial loads and local stresses at the interior face of the concrete chamber. The proper reinforcement has to be designed based on the maximum anticipated thrust loads;
- a rocker pipe must be placed outside the valve chamber, according to the standard installation practices
- use cement stabilised backfill, or gravel compacted minimum to 95% relative compaction, to fill the voids under the pipe outside the valve chamber.

2.1.5. Type 5

This anchoring method may be used for any application. Its use is limited only by the size of the valve chamber. The valve chamber has to be designed as a thrust block. When the dimensions of the required thrust block face are larger than the physical dimensions of the valve chamber, the dimensions of the down-stream side of the valve chamber have to be extend to meet the thrust block requirements. The thrust restraint flange is placed on the compression side of the valve to transfer the thrust directly to the chamber wall, which acts as a thrust block. The other end of the pipe system is relatively free to move axially to allow movement due to the temperature changes and the Poisson's effect.

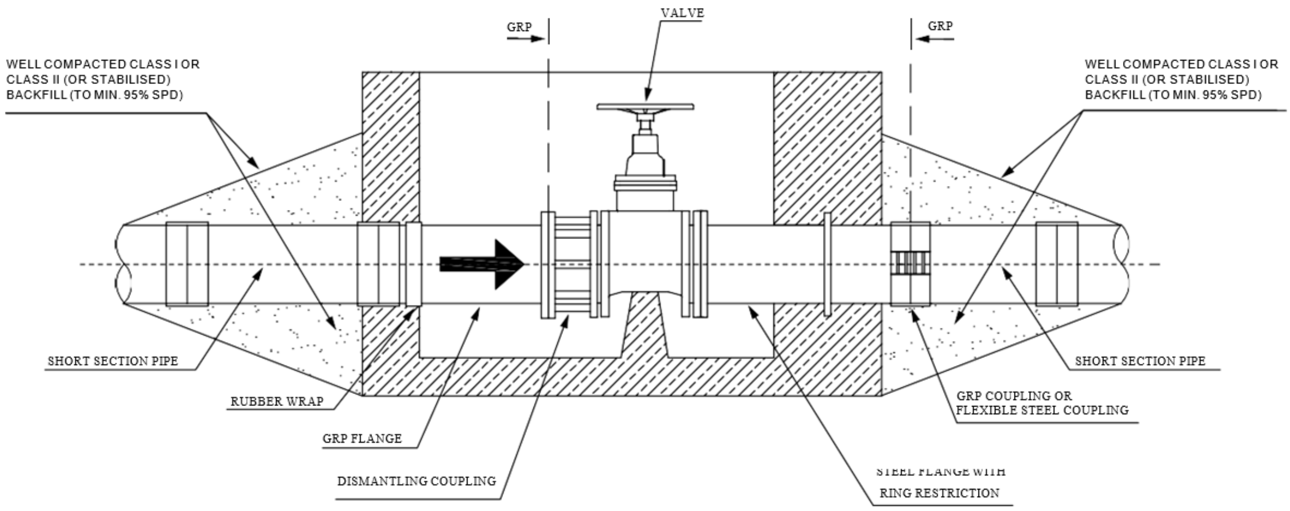

Figure 5: Type 5 – anchoring.

Design guidelines:

- the weight of the valve has to be supported from the base of the valve chamber. The thrust from a closed valve has to be absorbed by a steel puddle flange, which is anchored into the valve chamber wall by a welded flange on the compression side of the valve;
- a flexible steel coupling or a transition mechanical coupling has to provide the transition between the steel pipe stub and a standard rocker pipe outside the valve chamber;
- the other pipe leg is free to move axially through the sealing gasket in the valve;
- the size of the thrust block is based on the local soil stiffness, backfill material and installation conditions. Lateral movement has to be limited to preserve the leak tightness of the joint;
- a rocker pipe must be placed outside the valve chamber, according to the standard installation practices;
- use cement stabilised backfill, or gravel compacted minimum to 95% relative compaction, to fill the void beneath the pipes which exit the valve chamber structure.

3. AIR AND VACUUM VALVES

It is common practice to locate air relief valves, or a combination air/vacuum relief valves, at high points in a long transmission line. The valves should be designed to slowly release any accumulated air at the high point of a line, which might limit or block the flow.

Likewise, vacuum relief valves limit the amount of negative pressure a pipeline might experience by opening, when under pressure is sensed by the valve. This handbook offers general guidelines and a general layout of fittings and structures, which accommodate these off-line valves.

There are two ways air/vacuum relief valves can be used in a pipeline system. The most common method is to mount the valve directly on the vertical flange nozzle. Alternatively, for heavy valves, a tangential nozzle can also be designed to accommodate the assembly.

3.1. Air/Vacuum Valves

The simplest way to accommodate the small air/vacuum valves is to mount the valve directly on top of a vertical flanged nozzle, which is rising from the main below. Typically, the valve is housed in a concrete chamber, which provides safe and easy passage of air through the valve assembly. When designing and constructing the valve chamber directly over the pipe, it is important to ensure that the weight of the concrete chamber is not directly transferred to the vertical nozzle, and thus to the pipe below. This can be avoided by having the vertical opening in the base of the chamber larger than the outside diameter of the riser nozzle. Figure 6 provides the general illustrations of these features:

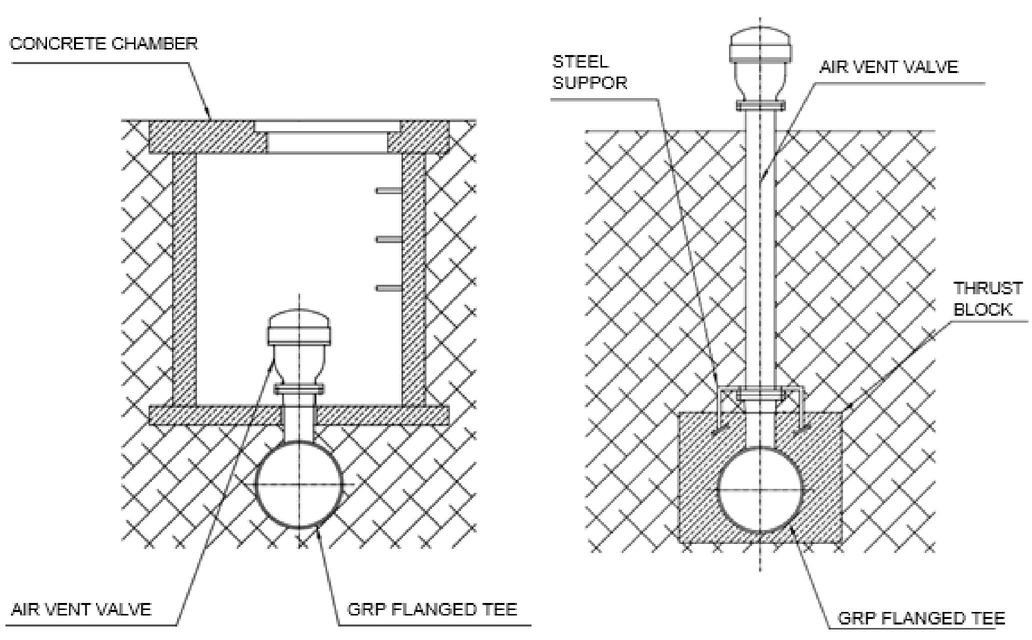

Figure 6: Small diameter air/vacuum valve.

3.2. Large Air/Vacuum Relief Valves (>100mm)

The preferred method of installing the heavier and larger air/vacuum relief valves, is to provide a GRP-BRP flanged tee with large branch DN (≥600), to accommodate the high axial load of the lave. This valve is attached on a steel blind flange which is connected to the GRP-BRP branch.

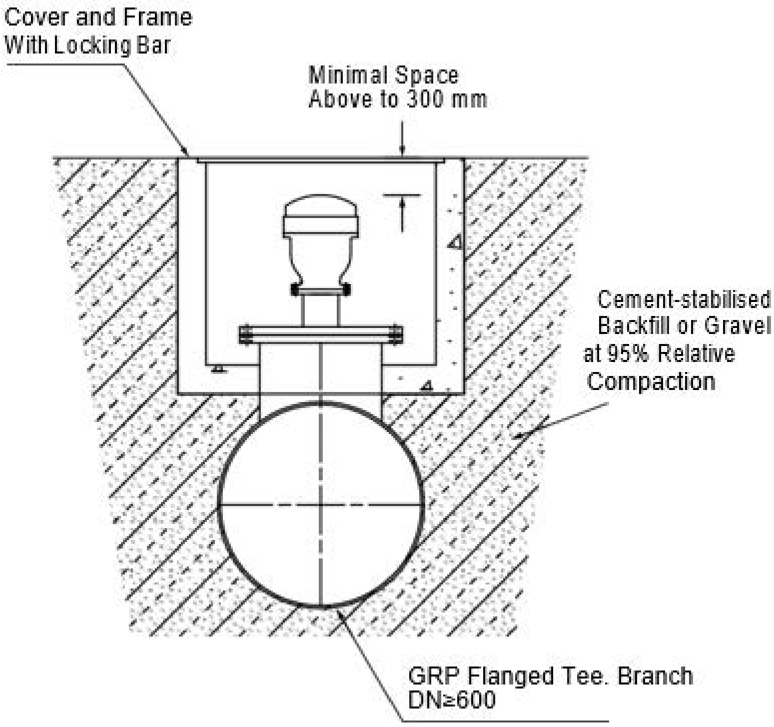

Figure 7: General illustration of a large air/vacuum valve.

An alternative method is with not putting valve's directly weight on the riser, but on a tangential nozzle which leads to the valve installed in an adjacent chamber. The tangential nozzle can be parallel to the horizontal axis, or at a slight vertical angle (< 22.5 degrees) with an elbow. Please refer to chapter: Hydrostatic On-Site Testing for the Filament Wound Fiberglass Pipe, section 3.3 – Anchorages and Thrust Blocks, for guidance on whether a thrust block alone or a combination of a thrust and stress block would be required. In general, if the tangential branch pipe's diameter (chord length) is more than 50% of the diameter of the header pipe, then a thrust/stress block is required. Otherwise, only a thrust block is required.

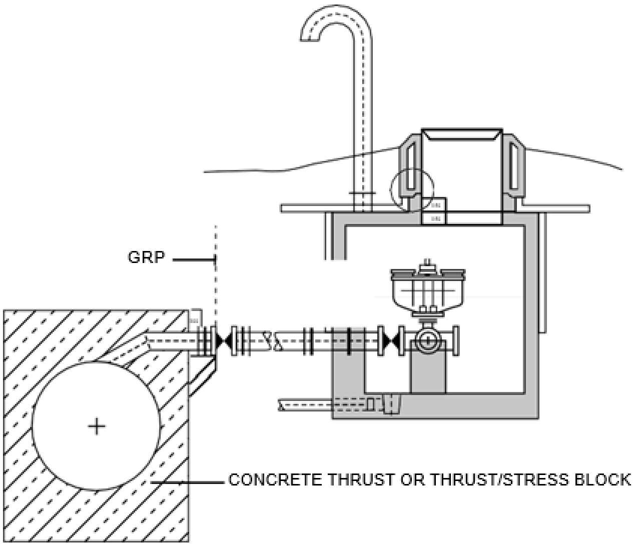

Figure 8: An alternative method to accommodate a large air/vacuum valve.

3.3. Wash Out- and Scour Valves

Installing wash out valves and scour valves is similar to installing a large diameter air valve. The difference is that the branch is tangential to the invert of the pipe. The same rules for thrust and thrust blocks apply. If the tangential pipe diameter of the branch (chord length) is more than 50% of the diameter of the header pipe, then a thrust block is required (chapter: Hydrostatic On-Site Testing for the Filament Wound Fiberglass Pipe, section 3.3 – Anchorages and Thrust Blocks). Figure 9 shows typical arrangement for accommodating these types of valves in a pressure pipeline. All the valves must be properly supported.

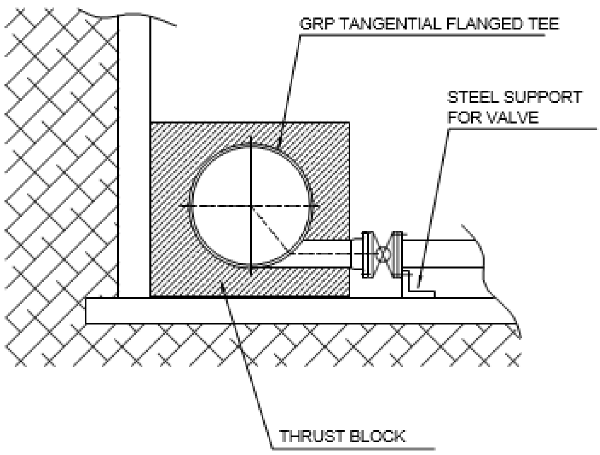

Figure 9: Wash out- and scour valves.

CLEANING THE PIPES

CLEANING THE PIPES

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1. FOREWORD

Several methods are used to clean the gravity sewer lines, depending on the diameter, the degree and nature of blockage. All of the methods either use mechanical means or a water jet to clean the interior of the pipe. When mechanical means are used, we recommend using the plastic scrapers to avoid damage to the pipe's inner surface.

Using a high pressure water jet, emitted through the jet nozzles, is a practice followed in some countries for cleaning the sewer pipes. However, water emitted under high pressure through a jet nozzle can cause damage to most materials if it is not properly controlled. You have to follow the guidelines outlined in this chapter in order to avoid damage to the installed pipes. If you are unsure about the most suitable cleaning method for your pipeline, please consult TOPFIBRA for more information.

2. CLEANING THE SEWER AND PRESSURE-SEWER PIPES

Guidelines for cleaning the sewer and pressure-sewer pipes:

- maximum pressure input is 120 bars (it is only allowed to clean the pipes with a jet-power-density of 330 W/mm². If the set up nozzle and jet holes are used and a flow rate of 300 l/min, a pressure of 120 bars will occur). Due to the smooth interior surface of GRP-BRP pipe, adequate cleaning and removal of blockages can normally be achieved below this pressure;
- nozzles with the jet holes around the circumference have to be used. Nozzles with the cleaning chains or wires, as well as rotating, aggressive or damaging nozzles must not be used;
- the water discharge angle should not exceed 30°. An angle smaller than 20° is usually sufficient for the GRP-BRP pipe, as the smooth surface of the material inhibits adhesion and only the interior is required to be washed;
- the number of jet holes should be 6 to 8 and the hole size must be at least 2.4 mm;
- the external surface of the nozzle must be smooth and the maximum weight must be 4.5 kg. The nozzle length, corresponding the weight, should be at least 170 mm. For small and medium range diameters (DN100 - 800) the lighter nozzles (approximately 2.5 kg) should be used;
- the forward and backward moving speed of the nozzle shall be limited to 30 m/min. Uncontrolled movement of the nozzle is not allowed. When inserting the nozzle into the pipe, it should be prevented from hitting the pipe wall;

- jetting/swabbing sleds with several runners, provide a bigger distance between the nozzle and the pipe wall, resulting in less aggressive cleaning;
- using equipment or pressures that do not meet these criteria, can cause damage to the installed pipe.

Minor, local chipping of the surface of the abrasion layer is not considered to have a damaging effect on the operational performance of the pipe.

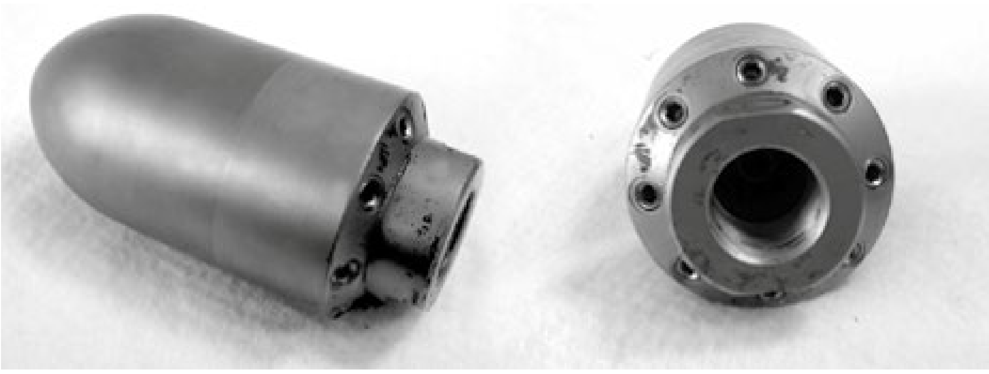

Figure 1: 4.5kg nozzle with jet holes around the circumference.

Figure 2: 2.5kg nozzle with jet holes around the circumference.

3. CLEANING THE PRESSURE PIPES

Guidelines for pressure pipes (FP) which are used in sewer applications:

- maximum pressure input is 80 bars. Due to the smooth interior surface of the GRP-BRP pipe, adequate cleaning and removal of blockages can normally be achieved below this pressure;
- nozzles with jet holes around the circumference should be used. Nozzles with cleaning chains or wires, as well as rotating, aggressive or damaging nozzles should not be used;
- the water discharge angle must be between 6° and 15°, relative to the pipe axis;
- the number of jet holes should be 6 to 8 or more and the size of the holes must be at least 2.4 mm;
- the external surface of the nozzle shall be smooth and its maximum weight should be 2.5 kg;
- the forward and backward moving speed of the nozzle shall be limited to 30 m/min. Uncontrolled movement of the nozzle is not allowed. When inserting the nozzle into the pipe, it should be prevented from hitting the pipe wall;
- jetting/swabbing sleds with several runners are required, since they provide a greater distance between the nozzle and the pipe wall (see Figure 3);
- using equipment or pressures that do not meet these above criteria can cause damage to the installed pipe.

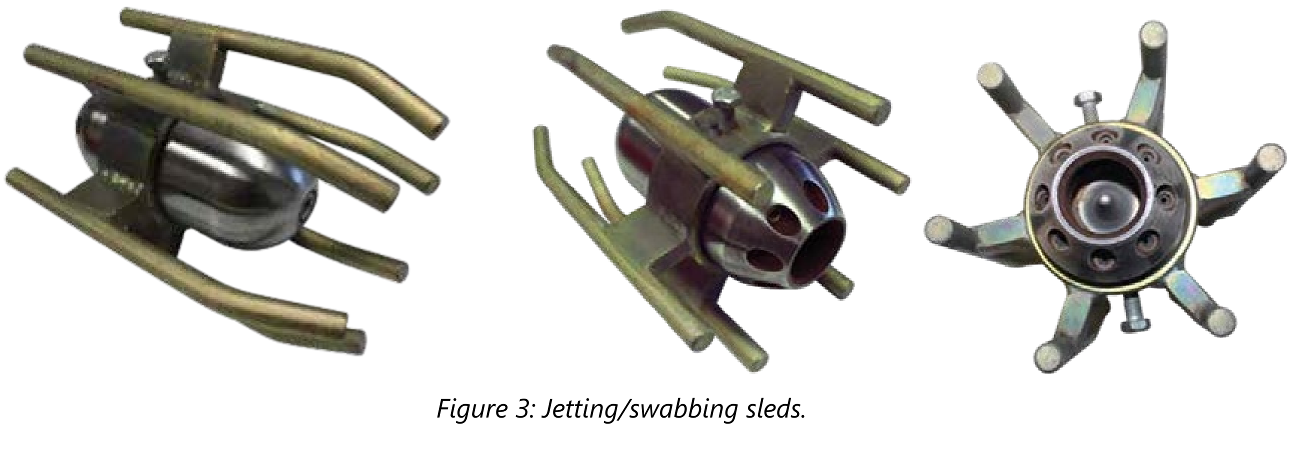

Figure 3: Jetting/swabbing sleds.

SUBAQUEOUS INSTALLATION

SUBAQUEOUS INSTALLATION

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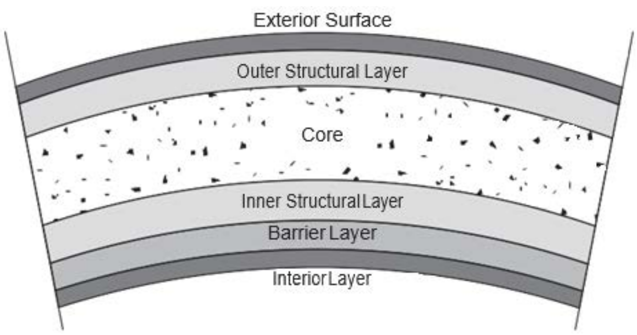
1. PRODUCTION

For more information, please refer to the Techno-Commercial handbook, chapter: Submarine Pipe Design Report.

The basic raw materials used in the pipe manufacturing are resin, fibreglass and silica sand. Pipes are manufactured with the continuous advancing mandrel process, which allows the use of the continuous glass fibre reinforcements in the circumferential direction. For a pressure pipe, the principle stress is in the circumferential direction. Incorporating the continuous reinforcements in this direction yields a higher performing product at a lower cost. A very compressed laminate is created, which maximizes the contribution from the three basic raw materials. Continuous glass fibre rovings as well as choppable rovings are incorporated to achieve high hoop strength and axial reinforcement. A sand fortifier, placed near the neutral axis in the core, is used to provide the increased stiffness by adding extra thickness.



2. GRP-BRP PIPE ADVANTAGES

GRP-BRP products and accessories offer many advantages in subaqueous installations:

- material is corrosion resistant. Linings, coatings, cathodic protection or other forms of corrosion prevention are not needed and corrosion surveys are not required;
- excellent mechanical resistance;
- economic and easy installation and handling due to low weight (approx. 10% of concrete) and pre-assembled gasketed couplings. They are economic, easy to install and handle in difficult terrain as well;
- excellent efficiency of joining systems. Precisely manufactured couplings with flexible gaskets enable easy installation and prevent infiltration and exfiltration;
- minimum internal roughness and low headloss due to the smooth inner surface;
- long service life, high resistance to wear and abrasion;
- low maintenance costs;
- low operating costs.

2.1. Superior Corrosion Resistance

GRP-BRP is completely resistant to corrosion from the inside (to the sanitary fluids) and from the sea water on the outside. Because of its inherent corrosive resistance, GRP-BRP provides a longer life cycle and has no scale build-ups. This makes the GRP-BRP pipes virtually maintenance free. GRP-BRP pipes do not require any protective coatings or inner linings.

2.2. Higher Hydraulic Efficiency

Based on tests carried out on the pipes in existing new installations, the Colebrook-White coefficient may be taken on-site as 0.029 mm. This corresponds to a Hazen-Williams flow coefficient which is approximately C = 150. The Manning coefficient is n = 0.009. In contrast to other corroding materials, the inner surface roughness of the pipes does not change with time, as GRP-BRP pipes display no corrosion. Velocities of up to 4 m/s can be used if the water is clean and contains no abrasive materials.

The smooth interior surface provides higher hydraulic efficiency. There is no scale build and no further degradation. Head losses will not vary significantly during pipe's life, as long as no sedimentation takes place. This saves pumping energy and pump costs. GRP-BRP pipes are produced with resin rich interior layer, resulting in a very low fluid resistance. This either increases the discharge of the fluids, compared to the same diameter pipes made of traditional materials, or allows usage of the reduced pipe diameters that meet the required discharge flow rate.

2.3. Higher Strength to Weight Ratio

GRP-BRP pipes have low thicknesses and high mechanical properties. They can withstand higher pressure, compared to the pipes that have the same diameters and are made out of traditional materials. The elasticity of the GRP-BRP pipes allows a better laying on the uneven profile of the seabed.

2.4. Light Weight

GRP-BRP pipes are easy to load and unload and do not require any heavy equipment for this purpose. This also reduces transportation costs and enables faster installation.

2.5. Higher Resistance to Surge Pressure

GRP-BRP pipes are flexible and have a higher elastic modulus. They absorb higher pressures and thus reduce the risk of failures due to the water hammer.

2.6. Chemical Resistance

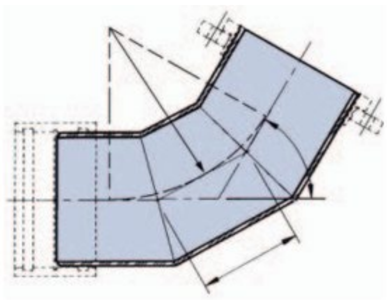
GRP-BRP pipe systems can be used for almost all types of fluids, which are generally discharged in outfalls. They are also suitable for seawater intake lines. Selecting the resin type for the GRP-BRP piping systems is based on fluid corrosiveness, as well as on the operating and design temperature. TOPFIBRA can assist in selecting the best type of resin.

2.7. Economical Solution

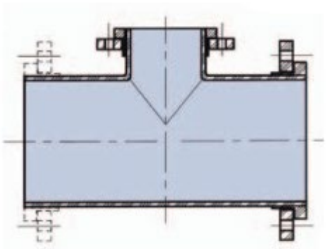
GRP-BRP pipes are maintenance friendly and have a long service life. That makes the GRP-BRP pipe systems an economical, low cost solution, based on total life cycle of the pipeline.

3. ACCESSORIES

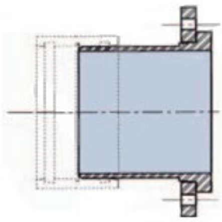
The high flexibility of the material allows tailor-made manufacturing of fittings. This includes bends, tees, branches, flanges, reducers, diffusors, saddles, manholes or pre-assembled, custom designed spools.



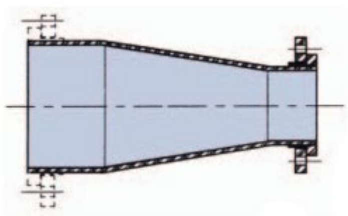
Bends 5-90°



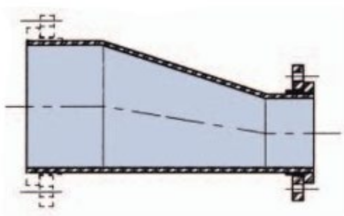
Tee 90°



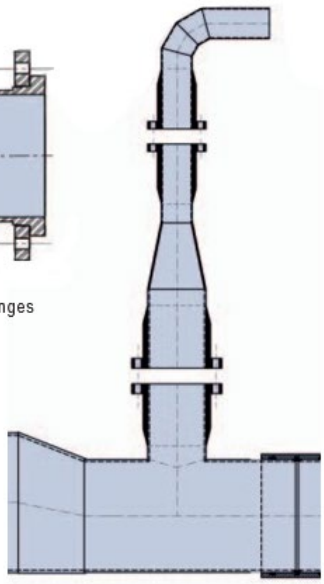
Loose / fixed flanges



Concentric Reducer



Eccentric Reducer



Diffusor

4. INSTALLATION

GRP-BRP is among the best suited materials for intakes and outfalls. It offers a wide variety of possibilities and variations based on the fluid characteristics, type of installation and the nature of local conditions. For more information, please refer to the Techno-Commercial handbook, chapter: Submarine Pipe Design Report.

4.1. Jointing

Jointing system ensures that the system works through its whole estimated service life. Joints also allow for transitions to other materials such as connection to valves or other accessories.

Pipes are usually used with the following type of joints in intakes and outfalls. In addition to these, various other types of joints are available and have to be selected based on the project requirements:

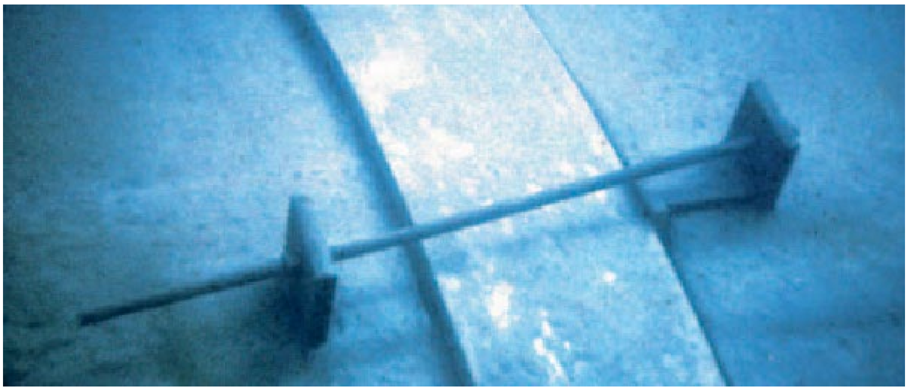
- double bell coupling joints with marine harness lugs;
- key lock joints;

- laminated joints;
- flanged joints;

4.2. Double Bell Coupling Joints with Marine Harness Lugs

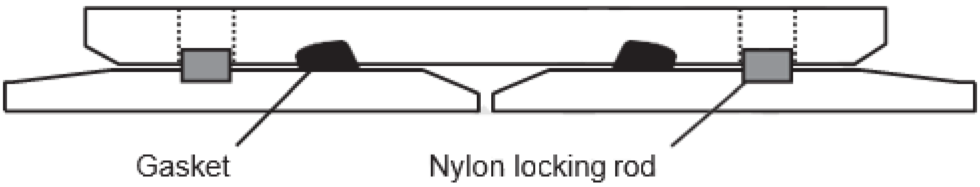
This system is suitable for large diameter piping discharges. It provides installation flexibility and accommodates the effects of the sea without hampering the performance. Coupling has rubber gaskets which prevent proper ex-filtration and infiltration. The additional marine harness lugs are used to keep together the preassembled pipe strings of several pipes, during loading, transferring, and sinking. This also to assist divers with the jointing under water. It also compensates for the angular deflections due to the differential settlement between the pipes and joints in the event of the sea bed erosion. Depending on the pipe diameter, two, three or four pieces of marine harness lugs are fixed around the ends of the pipes. The steel lugs are fixed using glassfibre and resin.

A special test system can be installed for testing the tightness of all joints.



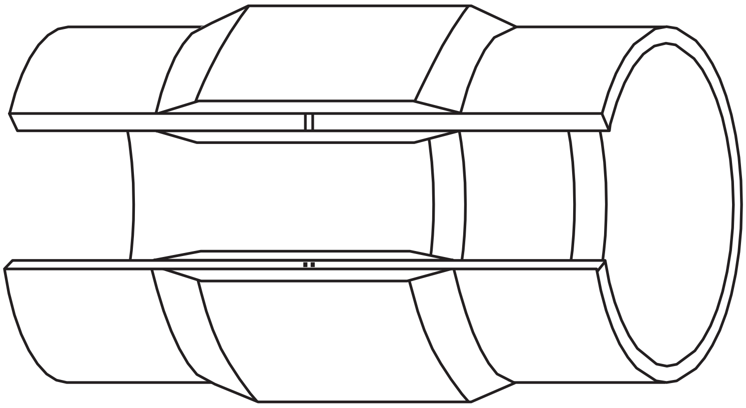
4.3. Keylock Couplings

Another method involves using biaxial pipes and/or key lock joint systems, which reliably absorb the axial forces. These joints are based on a key lock, which can be easily installed onshore and then laid underwater by divers. If necessary, they can also be used in combination with the double bell joints.



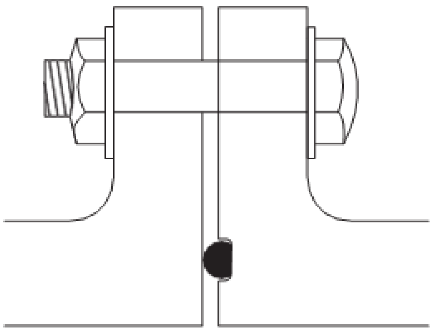
4.4. Laminated Joints

Butt and strap joints or laminated joints also absorb the additional forces. They are permanent joints, which consist of a laminate of glass mats and tissues with resin. They are predominantly used directly at the jobsite. This type of joint guarantees a safe and long-lasting connection that accommodates all axial strengths.

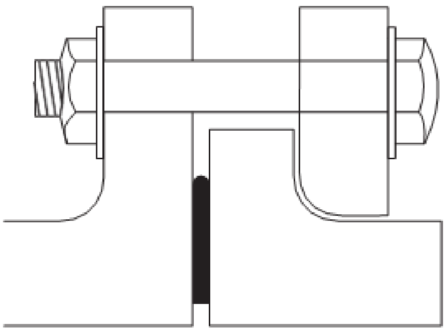


4.5. Flanged Joints

Flanged joints offer the same safety and allow the installation to be dismantled at a later stage. Flanges are also a good solution for connections with other pipe materials, valves and accessories. For example, this joint is used in the submarine pipelines to connect the diffusers to the pipes, for inspecting the manholes, and for connecting to the pumps or it is used where the joint has to be frequently disassembled. Flanges are available with holes, complying to the main standards. They are available as fixed and loose flanges.



Fix flange with O-ring



Loose flange with flat gasket

4.6. Installation Methods

The light weight of the GRP-BRP pipes allows them to be considerably easy to handle. In the case of submarine outfalls, this makes the operations for installing the structure much easier, even in the environmental conditions that are far from ideal.

Depending on the project requirements and on-site or weather conditions, different installation techniques are used:

- single pipe installation: with this method the pipes are lowered in water and joined one by one under water;
- multiple pipe installation: two or three sections of pipes are preassembled on land or barge. Then they are lowered in water and joined under water.
- multiple pipe installation using pipe strings (towing).

Long pipe sections (100 m – 300 m – 500 m – etc.) are preassembled on land or barge. They are then lowered in water and joined under water. They have to be designed with an adequate axial and bending strength. This type of installation is fast, economical and can be used for pipes for up to 2000 mm diameter. Depending on the sea bottom, weather conditions and adequacy of equipment, different tow methods are selected:

- surface tow: The outfall sections, which float due to their arrangement or with the aid of floats, are pulled or dragged to the correct position on the route. According to the design criteria, the sections may either be joined on the surface or on the bed.

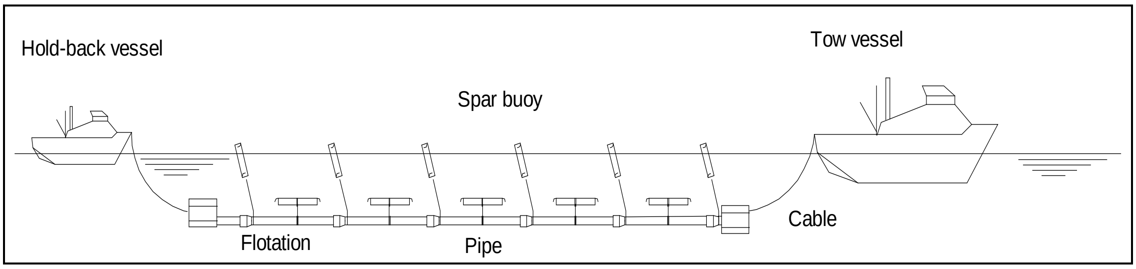


Figure 1: Surface tow.

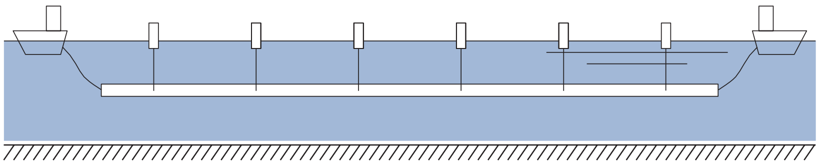


Figure 2: Float and sink.

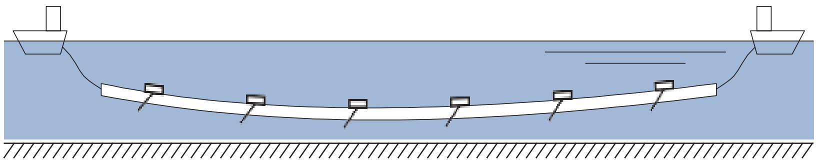


Figure 3: Sub-surface tow.

- controlled depth tow:

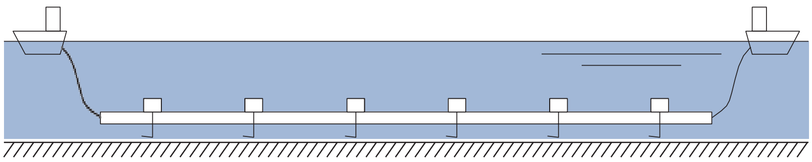


Figure 4: Off-bottom tow.

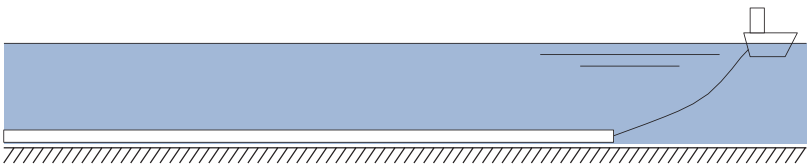


Figure 5: Bottom pull, side view.

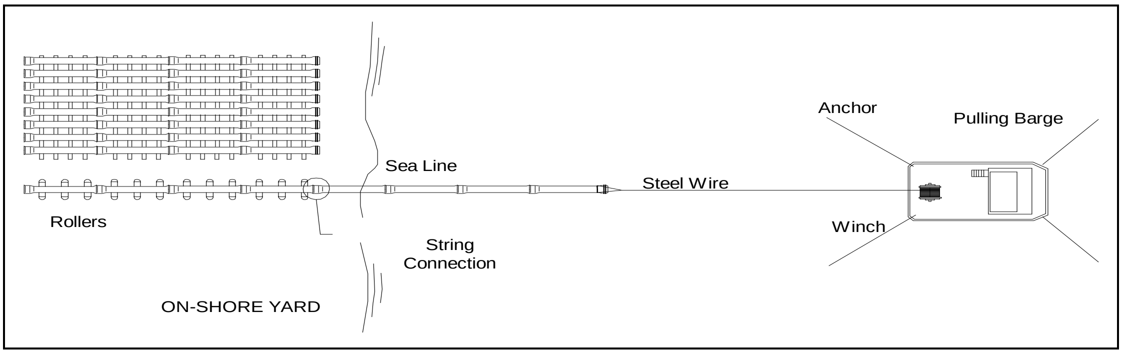


Figure 6: Bottom pull, top view.

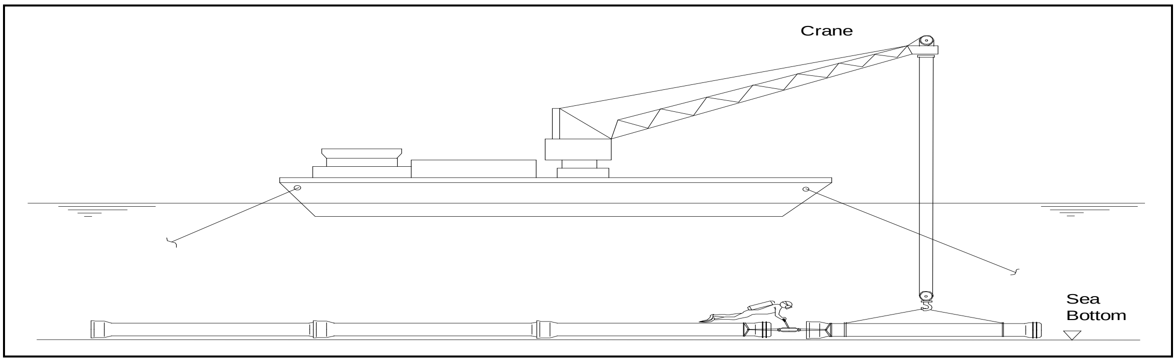
Once a column has been installed, the pulling stops and the next column is positioned and joined to the end of the previous one. Joining is carried out on land at a special station, at the end of the installation line. The system can also be used for the simultaneous parallel installation of several outfalls. On certain occasions, the pipes may be installed empty, sunk, or held up by floats. They may be placed on a natural bed that has been levelled or in a pre- excavated trench.

Figure 7: Launching and Jointing machine.

GRP-BRP pipes can be installed by dredging the sea bed and burying the pipe. This method is recommended for big diameters. The pipes are embedded in selected bedding and backfill material which has to be evaluated. GRP-BRP pipes with appropriately selected joints can also be installed on the sea bed by anchoring at required locations.

For joining the pipes under water, different methods are used. Usually come along jacks with steel clamps are used. But depending on marine conditions, marine harness lugs are also used to join the pipes under water.

4.7. Installation from a Pontoon



This is nowadays possibly the most commonly used method, particularly for pipes with large diameters. The size of a self-mobile or towed pontoon must be suitable for stowing sufficient quantities of pipes and holding all the required equipment for joining. The size of the pontoon affects the assembly and installation, as well as the progress of the work. The pontoon crane raises each bar and immerses it into the sea, where it is rested on the previously prepared bed, in the proximity of the already installed bar.

Coupling the bar to the installed outfall section is performed underwater by diving specialists, who use the come-along jack and slings to joint the pipes. A special "bell configuration" on one end of the pipe, provides a "self-aligning" joint and eases the underwater operations.

5. PIPE ALIGNMENT

While jointing, pipes need to be aligned. Depending on the project requirements, marine, and weather conditions, different equipment is used to align the pipe ends, which will be joined together. Some of the solutions are:

- steel truss:

- special GRP coupling:

- hydraulic sea horse:

- bands:

SAFETY PROCEDURES

SAFETY PROCEDURES

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1. DURING PRE-INSTALLATION

a) Local health and safety instructions, as well as the environmental regulations for construction work should always be taken into consideration;

b) glass- reinforced polyester (GRP-BRP) is not recommended to be used for applications which are exposed to intense heat or flames;

c) all site personnel should complete technical and safety trainings for jobsite activities, including loading, unloading, storing and installation of the pipes before accessing the jobsite;

d) "Jobsite Safety Procedures" booklet should be prepared and distributed to all jobsite personnel. Warning labels and plates should be placed at the appropriate places on the jobsite;

e) during safety trainings, prior accidents and experiences should be presented in the form of pictures and videos. Undesired outcomes of the accidents should be emphasized. It is vital to persuade and convince the job site personnel of the importance of jobsite safety to be able to strictly enforce and apply the procedures;

f) a Safety Supervisor should be assigned. Responsibilities, duties and authority of the safety supervisor should be clearly defined and declared to all personnel;

g) safety equipment such as helmets, safety shoes, safety gloves, etc., should be provided and consigned to each worker with a signed declaration receipt;

h) site personnel should be strictly controlled in terms of utilization of the safety equipment;

i) supplied safety equipment should be quality certified by the independent accredited agencies;

j) periodic maintenance and control of the safety equipment should be performed. Old, torn out or non- functional equipment should be replaced;

k) personnel who do not obey and apply the Jobsite Safety Procedures should immediately be discharged from the jobsite area and pre-determined penalties should be exercised.

2. TRENCHES

Operations in trenches are carried out in potentially hazardous conditions.

a) Where appropriate support the trench walls with the shore, sheet, brace, slope or other means, to protect the personnel in the trench;

b) take precautions to prevent objects from falling into the trench;

c) take precautions to prevent the collapse of the trench caused by the position or movements of adjacent machinery or equipment, while the trench is occupied;

d) excavated material should be deposited at a safe distance from the edge of the trench;

e) the proximity and height of the soil bank should not be allowed to endanger the stability of the excavation.

3. DURING THE INSTALLATION

a) The Safety Supervisor should strictly control whether or not the installation activities are performed as described during the installation trainings. In a case, which requires application of a non-standard installation procedures, such a procedure should only be applied under the permission and supervision of the Safety Supervisor;

b) installation equipment should be free of damages and defects and should be completely functional;

c) machines and vehicles such as excavators, bulldozers, graders, etc., should only be operated by certified and licensed operators without any exceptions;

d) ensure that the communication system among the jobsite personnel is clear, correct, uninterrupted and not subjected to misunderstanding or misinterpretation (for example, communication between a worker inside the trench and a crane operator lowering a pipe into the trench)

e) avoid exposing the pipes to welder’s sparks, cutting- torch flames or other heat/flame/electrical sources, which could ignite the pipe material. This precaution is particularly important when working with volatile chemicals when making layup joints and repairing or modifying the pipe in the field.

4. ENTERING A PIPELINE

When entering a pipeline for inspection or repairs, the following points should be taken into consideration:

a) entering a pipeline should only be done with the Safety Supervisor's permission. Safety Supervisor should evaluate all potential risks before permitting the entrance. Personnel with health problems and personnel who are not willing to enter, should not be allowed to enter the pipeline;

b) if the gas and oxygen level tests have to be performed, they should be performed by an authorized and certified personnel;

c) if the oxygen level inside the pipeline is not sufficient, personnel who enter the pipeline should be equipped with the oxygen tubes;

d) personnel entering a pipeline should be equipped with safety equipment and should always have spare lighting;

e) communication between team entering the pipeline and the outside team should be clear and uninterrupted. If communication is lost, the inside team should immediately exit the pipeline.

5. ON-SITE REPAIRS

a) Safety procedures that are followed during the installation, should also be applied when removing a pipe or a fitting from an installed pipeline;

b) repairing works should be performed at a repairing station. Boundaries of the repairing station should be clearly marked;

c) only the authorized repair personnel should have access to the repair station;

d) repair station environment should be clear of any possible fire risks;

e) repair station should be equipped with fire extinguishers;

f) equipment used for the repairs should be functional, in good condition, clean and clear of defects;

g) Safety Supervisor should continuously inspect utilization of the safety equipment during the repairs;

h) if repairing is done inside the pipeline, the personnel entering the pipeline should wear isolated work suits and gas masks. If the oxygen level is not sufficient, personnel should be equipped with oxygen tubes. Sufficient ventilation should be supplied to remove the dust from the pipeline;

i) if the repair inside of the pipe is done at the height of 2 m or more, suitable scaffolding should be provided.

6. STORING CHEMICALS AND RAW MATERIALS

a) Chemicals and raw materials, which will be used for repairs, should be stored in a closed and locked storage room;

b) storage room should have natural ventilation and should not be exposed to high temperatures;

c) storage room should be protected from humidity, rain, snow, etc.;

d) storage room should be equipped with fire extinguishers.;

e) all chemicals and raw materials should be stored in their original packaging;

APPENDIX

APPENDIX

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1. INSTALLATION TABLES

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Type 1 DN ≥ 300	No Traffic Load – No Internal Vacuum – Ground Water Level Below Pipe Invert																								
	Standard Trench, B_d/D = 1.8												Wide Trench, B_d/D = 3.0												
Backfill	SC I			SC II			SC III			SC IV			SC I			SC II			SC III			SC IV			<= NativeSoil
Pipe SN / Burial Depth, m	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	
1,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	Group 1
1,5	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
2,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
3,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
5,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	90	90	85	95	95	90	
8,0	D	D	D	85	85	85	90	90	90	95	95	95	D	D	D	90	90	90	90	90	90		95	95	
12,0	D	D	D	90	90	85	90	90	90			95	D	D	D	90	90	90	95	95	95				
20,0	D	D	D	90	90	90	95	95	95				D	D	D	90	90	90			95				
30,0	D	D	D	95	95	95							D	D	D	95	95	95							
1,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	Group 2
1,5	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
2,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
3,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
5,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	90	90	85	95	95	90	
8,0	D	D	D	85	85	85	90	90	90	95	95	95	D	D	D	90	90	90	95	90	90			95	
12,0	D	D	D	90	90	90	95	95	90				D	D	D	90	90	90	95	95	95				
20,0	D	D	D	95	90	90			95				D	D	D	95	95	95							
30,0	C	C	C	100	100	100							D	D	D	95	95	95							
1,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	Group 3
1,5	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
2,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
3,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
5,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	90	90	85	95	95	95	
8,0	D	D	D	90	90	85	90	90	90	95	95	95	D	D	D	90	90	90	95	95	95				
12,0	D	D	D	90	90	90	95	95	95				D	D	D	90	90	90	95	95	95				
20,0	C	C	C	100	100	100							D	D	D	95	95	95							
30,0													C	D	D	100	95	95							
1,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	Group 4
1,5	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
2,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
3,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
5,0	D	D	D	85	85	85	90	90	85	95	95	90	D	D	D	90	85	85	90	90	90	95	95	95	
8,0	D	D	D	95	90	90	95	95	95				D	D	D	90	90	90	95	95	95				
12,0	C	C	D	100	100	95							D	D	D	90	90	90	95	95	95				
20,0													D	D	D	95	95	95							
30,0													C	C	C	100	100	100							
1,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	Group 5
1,5	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
2,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
3,0	D	D	D	90	90	85	95	90	85		95	90	D	D	D	85	85	85	85	85	85	95	90	90	
5,0	D	D	D	95	95	90			95				D	D	D	90	90	85	95	90	90			95	
8,0	C	C	C	100	100	100							D	D	D	90	90	90	95	95	95				
12,0													D	D	D	95	95	95							
20,0													D	D	D	95	95	95							
30,0													C	C	C	100	100	100							
1,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	Group 6
1,5	D	D	D	90	85	85	90	85	85	95	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
2,0	D	D	D	90	90	85	95	90	85			90	D	D	D	85	85	85	85	85	85	90	90	90	
3,0	D	D	D	95	95	90			95				D	D	D	90	85	85	90	90	85	95	95	90	
5,0			C			100							D	D	D	90	90	90	95	95	95				
8,0													D	D	D	95	90	90		95	95				
12,0													D	D	D	95	95	95							
20,0													C	C	C	100	100	100							
30,0														C	C		100	100							

Table: B-5 – Installation Type 1, DN ≥ 300. Traffic load with groundwater level below the pipe invert. Minimum Backfill Compaction, % Standard Proctor Density. (D = uncompacted (dumped), C = Compacted).

Type 1 DN ≥ 300	**Traffic Load AASHTO HS 20 - No Internal Vacuum - Ground Water Below Pipe Invert**																								
	Standard Trench, $B_d/D = 1.8$												Wide Trench, $B_d/D = 3.0$												
Backfill	**SC I**			**SC II**			**SC III**			**SC IV**			**SC I**			**SC II**			**SC III**			**SC IV**			<= NativeSoil
Pipe SN / Burial Depth, m	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	
1,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	Group 1
1,5	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
2,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
3,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
5,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	90	90	85	95	95	95	
8,0	D	D	D	85	85	85	90	90	90	95	95	95	D	D	D	90	90	90	90	90	90			95	
12,0	D	D	D	90	90	85	90	90	90			95	D	D	D	90	90	90	95	95	95				
20,0	D	D	D	90	90	90	95	95	95				D	D	D	90	90	90			95				
30,0	D	D	D	95	95	95							D	D	D	95	95	95							
1,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	Group 2
1,5	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
2,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
3,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
5,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	90	90	85	95	95	95	
8,0	D	D	D	85	85	85	90	90	90	95	95	95	D	D	D	90	90	90	95	90	90			95	
12,0	D	D	D	90	90	90	95	95	90				D	D	D	90	90	90	95	95	95				
20,0	D	D	D	95	90	90			95				D	D	D	95	95	95							
30,0	C	C	C	100	100	100							D	D	D	95	95	95							
1,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	Group 3
1,5	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
2,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
3,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
5,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	90	90	85	95	95	95	
8,0	D	D	D	90	90	85	90	90	90	95	95	95	D	D	D	90	90	90	95	95	95				
12,0	D	D	D	90	90	90	95	95	95				D	D	D	90	90	90	95	95	95				
20,0	C	C	C	100	100	100							D	D	D	95	95	95							
30,0													C	D	D	100	95	95							
1,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	95	90	90	Group 4
1,5	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
2,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
3,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	95	90	90	
5,0	D	D	D	90	85	85	90	90	85	95	95	95	D	D	D	90	85	85	90	90	90	95	95	95	
8,0	D	D	D	95	90	90	95	95	95				D	D	D	90	90	90	95	95	95				
12,0	C	C	D	100	100	95							D	D	D	90	90	90	95	95	95				
20,0													D	D	D	95	95	95							
30,0													C	C	C	100	100	100							
1,0	D	D	D	90	85	85	95	90	85		95	90	D	D	D	85	85	85	85	85	85	95	95	90	Group 5
1,5	D	D	D	85	85	85	90	85	85	95	90	90	D	D	D	85	85	85	85	85	85	90	90	90	
2,0	D	D	D	85	85	85	90	85	85	95	95	90	D	D	D	85	85	85	85	85	85	90	90	90	
3,0	D	D	D	90	90	85	95	95	85			90	D	D	D	85	85	85	90	85	85	95	95	90	
5,0	D	D	D	95	95	90			95				D	D	D	90	90	90	95	90	90			95	
8,0	C	C	C	100	100	100							D	D	D	90	90	90	95	95	95				
12,0													D	D	D	95	95	95							
20,0													D	D	D	95	95	95							
30,0													C	C	C	100	100	100							
1,0	D	D	D	95	90	90			95				D	D	D	85	85	85	90	90	85	95	95	90	Group 6
1,5	D	D	D	90	90	85	95	95	90			95	D	D	D	85	85	85	90	85	85	95	95	90	
2,0	D	D	D	95	90	90		95	90				D	D	D	85	85	85	90	85	85	95	95	90	
3,0	D	D	D	95	95	90			95				D	D	D	90	85	85	90	90	85	95	95	95	
5,0			C			100							D	D	D	90	90	90	95	95	95				
8,0													D	D	D	95	95	90		95	95				
12,0													D	D	D	95	95	95							
20,0													C	C	C	100	100	100							
30,0														C	C		100	100							

Table: B-6 - Installation Type 1, DN ≥ 300. Vacuum 1.0 bar, groundwater level below the pipe invert. Minimum Backfill Compaction, % Standard Proctor Density. (D = uncompacted (dumped), C = Compacted).

Type 1 DN ≥ 300	**No Traffic Load - 1 bar Internal Vacuum - Ground Water Level Below Pipe Invert**																								
	Standard Trench, B_d/D = 1.8												Wide Trench, B_d/D = 3.0												
Backfill	**SC I**			**SC II**			**SC III**			**SC IV**			**SC I**			**SC II**			**SC III**			**SC IV**			<= Native Soil
Pipe SN / Burial Depth, m	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	
1,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	95	90	90	Group 1
1,5	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	95	90	90	
2,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	90	85	95	95	90	90	
3,0	D	D	D	85	85	85	85	85	85	95	90	90	D	D	D	85	85	85	90	85	95	95	95	90	
5,0	D	D	D	85	85	85	90	85	85	95	90	90	D	D	D	90	85	85	90	90	95	95	95	90	
8,0	D	D	D	90	85	85	90	90	90	95	95	95	D	D	D	90	90	90	95	90	90		95	95	
12,0	D	D	D	90	90	85	95	90	90			95	D	D	D	90	90	90	95	95	95				
20,0	D	D	D	95	90	90		95	95				D	D	D	95	90	90			95				
30,0	C	D	D	100	95	95							C	D	D	100	95	95							
1,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	95	90	90	Group 2
1,5	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	95	90	90	
2,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	90	85	95	95	90	90	
3,0	D	D	D	85	85	85	85	85	85	95	90	90	D	D	D	85	85	85	90	85	95	95	95	90	
5,0	D	D	D	85	85	85	90	85	85	95	90	90	D	D	D	90	85	85	90	90	95		95	90	
8,0	D	D	D	90	85	85	90	90	90		95	95	D	D	D	90	90	90	95	90	90			95	
12,0	D	D	D	90	90	90	95	95	90				D	D	D	90	90	90	95	95	95				
20,0	D	D	D	95	90	90			95				D	D	D	95	95	95							
30,0		C	C		100	100							C	D	D	100	95	95							
1,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	85	85	85	95	90	90	Group 3
1,5	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	90	85	95	95	90	90	
2,0	D	D	D	85	85	85	85	85	85	90	90	90	D	D	D	85	85	85	90	85	95	95	90	90	
3,0	D	D	D	85	85	85	85	85	85	95	90	90	D	D	D	90	85	85	90	85	95	95	95	90	
5,0	D	D	D	90	85	85	90	85	85	95	95	90	D	D	D	90	85	85	95	90	95		95	95	
8,0	D	D	D	90	90	85	95	90	90		95	95	D	D	D	90	90	90	95	95	95				
12,0	D	D	D	95	90	90		95	95				D	D	D	95	90	90		95	95				
20,0		C	C		100	100							D	D	D	95	95	95							
30,0													C	C	D	100	100	95							
1,0	D	D	D	85	85	85	85	85	85	95	90	90	D	D	D	85	85	85	90	85	95	95	90	90	Group 4
1,5	D	D	D	85	85	85	90	85	85	95	90	90	D	D	D	85	85	85	90	85	95	95	95	90	
2,0	D	D	D	85	85	85	90	85	85	95	90	90	D	D	D	90	85	85	90	85	95	95	95	90	
3,0	D	D	D	90	85	85	90	85	85	95	90	90	D	D	D	90	85	85	90	90	95	95	95	90	
5,0	D	D	D	90	90	85	95	90	85		95	90	D	D	D	90	90	85	95	90	90		95	95	
8,0	D	D	D	95	90	90		95	95				D	D	D	90	90	90	95	95	95				
12,0		C	D		100	95							D	D	D	95	90	90		95	95				
20,0													C	D	D	100	95	95							
30,0														C	C		100	100							
1,0	D	D	D	90	90	85	95	90	85			90	D	D	D	90	85	85	90	85	95	95	95	90	Group 5
1,5	D	D	D	95	90	85	95	95	85			95	D	D	D	90	85	85	90	90	95		95	90	
2,0	D	D	D	95	90	85		95	90			95	D	D	D	90	85	85	90	90	95		95	90	
3,0	D	D	D	95	90	90		95	90				D	D	D	90	90	85	95	90	95		95	95	
5,0	C	D	D	100	95	90			95				D	D	D	90	90	85	95	95	90			95	
8,0		C	C		100	100							D	D	D	95	90	90		95	95				
12,0													D	D	D	95	95	95							
20,0													C	D	D	100	95	95							
30,0														C	C		100	100							
1,0		D	D		95	90			95				D	D	D	90	90	85	95	90	95		95	95	Group 6
1,5		D	D		95	90			95				D	D	D	90	90	85	95	90	95		95	95	
2,0		D	D		95	95			95				D	D	D	90	90	85	95	90	90			95	
3,0		C	D		100	95							D	D	D	90	90	85	95	95	90			95	
5,0			C			100							D	D	D	95	90	90	95	95	95				
8,0													D	D	D	95	90	90		95	95				
12,0													C	D	D	100	95	95							
20,0													C	C	C	100	100	100							
30,0															C			100							

Table: B-7-Installation Type 1, DN ≥ 300. Groundwater level to ground level. Minimum Backfill Compaction, % Standard Proctor Density. (D = uncompacted (dumped), C = Compacted).

Type 1 DN ≥ 300	No Traffic Load - No Internal Vacuum - Ground Water Level to Ground Level																								
		Standard Trench, B_d/D = 1.8												Wide Trench, B_d/D = 3.0											
<=Native Soil	Backfill	SC I			SC II			SC III			SC IV			SC I			SC II			SC III			SC IV		
	Pipe SN / Burial Depth, m	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000
Group 1	1,0	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	85	85	85	95	95	95
	1,5	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	85	85	85	95	95	95
	2,0	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	85	85	85	95	95	95
	3,0	D	D	D	85	85	85	85	85	85		95	95	D	D	D	85	85	85	90	90	85			95
	5,0	D	D	D	85	85	85	90	90	90				D	D	D	90	90	85	95	95	90			
	8,0	D	D	D	90	90	90	95	95	95				D	D	D	90	90	90	95	95	95			
	12,0	D	D	D	90	90	90	95	95	95				D	D	D	90	90	90						
	20,0	D	D	D	95	90	90							D	D	D	95	95	95						
	30,0	C	D	D	100	95	95							C	D	D	100	95	95						
Group 2	1,0	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	85	85	85	95	95	95
	1,5	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	85	85	85	95	95	95
	2,0	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	85	85	85	95	95	95
	3,0	D	D	D	85	85	85	85	85	85		95	95	D	D	D	85	85	85	90	90	85			95
	5,0	D	D	D	85	85	85	90	90	90				D	D	D	90	90	85	95	95	90			
	8,0	D	D	D	90	90	90	95	95	95				D	D	D	90	90	90	95	95	95			
	12,0	D	D	D	90	90	90	95	95	95				D	D	D	90	90	90						
	20,0	D	D	D	95	95	95							D	D	D	95	95	95						
	30,0		C	C		100	100							C	D	D	100	95	95						
Group 3	1,0	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	85	85	85	95	95	95
	1,5	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	85	85	85	95	95	95
	2,0	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	85	85	85	95	95	95
	3,0	D	D	D	85	85	85	85	85	85		95	95	D	D	D	85	85	85	90	90	85			95
	5,0	D	D	D	85	85	85	90	90	90				D	D	D	90	90	85	95	95	95			
	8,0	D	D	D	90	90	90	95	95	95				D	D	D	90	90	90			95			
	12,0	D	D	D	95	90	90							D	D	D	95	90	90						
	20,0		C	C		100	100							D	D	D	95	95	95						
	30,0													C	C	C	100	100	100						
Group 4	1,0	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	85	85	85	95	95	95
	1,5	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	85	85	85	95	95	95
	2,0	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	85	85	85	95	95	95
	3,0	D	D	D	85	85	85	90	85	85		95	95	D	D	D	85	85	85	90	90	85			95
	5,0	D	D	D	90	90	85	95	95	90				D	D	D	90	90	90	95	95	95			
	8,0	D	D	D	95	95	90							D	D	D	90	90	90			95			
	12,0	C	C	C	100	100	100							D	D	D	95	95	95						
	20,0													C	D	D	100	95	95						
	30,0														C	C		100	100						
Group 5	1,0	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	85	85	85	95	95	95
	1,5	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	85	85	85	95	95	95
	2,0	D	D	D	85	85	85	90	85	85		95	95	D	D	D	85	85	85	90	85	85		95	95
	3,0	D	D	D	90	90	85	95	95	90				D	D	D	90	85	85	95	90	90			
	5,0	D	D	D	95	95	95							D	D	D	90	90	90	95	95	95			
	8,0			C			100							D	D	D	95	90	90						
	12,0													D	D	D	95	95	95						
	20,0													C	C	C	100	100	100						
	30,0														C	C		100	100						
Group 6	1,0	D	D	D	85	85	85	90	85	85		95	95	D	D	D	85	85	85	85	85	85	95	95	95
	1,5	D	D	D	90	85	85	95	90	85			95	D	D	D	85	85	85	90	85	85		95	95
	2,0	D	D	D	90	90	85		95	85			95	D	D	D	85	85	85	90	90	85			95
	3,0	D	D	D	95	95	90							D	D	D	90	90	85	95	95	90			
	5,0			C			100							D	D	D	90	90	90			95			
	8,0													D	D	D	95	95	95						
	12,0													D	D	D	95	95	95						
	20,0														C	C		100	100						
	30,0																								

Table: B-8 - Installation Type 1, DN ≥ 300. Traffic load, groundwater level to ground level. Minimum Backfill Compaction, % Standard Proctor Density. (D = uncompacted (dumped), C = Compacted).

Type 1 DN ≥ 300	Traffic Load AASHTO HS 20 - No Internal Vacuum - Ground Water Level to Ground Level																								
	Standard Trench, B_d/D = 1.8												Wide Trench, B_d/D = 3.0												
Backfill	SC I			SC II			SC III			SC IV			SC I			SC II			SC III			SC IV			
Pipe SN / Burial Depth, m	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	<=Native Soil
1,0	D	D	D	85	85	85	90	85	85		95	95	D	D	D	85	85	85	90	90	85			95	Group 1
1,5	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	90	85	85			95	
2,0	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	90	90	85			95	
3,0	D	D	D	85	85	85	90	85	85			95	D	D	D	85	85	85	90	90	90				
5,0	D	D	D	85	85	85	90	90	90				D	D	D	90	90	85	95	95	95				
8,0	D	D	D	90	90	90	95	95	95				D	D	D	90	90	90	95	95	95				
12,0	D	D	D	90	90	90	95	95	95				D	D	D	90	90	90							
20,0	D	D	D	95	90	90							D	D	D	95	95	95							
30,0	C	D	D	100	95	95							C	D	D	100	95	95							
1,0	D	D	D	85	85	85	90	85	85		95	95	D	D	D	85	85	85	90	90	85			95	Group 2
1,5	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	90	85	85			95	
2,0	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	90	90	85			95	
3,0	D	D	D	85	85	85	90	85	85			95	D	D	D	85	85	85	90	90	90				
5,0	D	D	D	85	85	85	90	90	90				D	D	D	90	90	85	95	95	95				
8,0	D	D	D	90	90	90	95	95	95				D	D	D	90	90	90	95	95	95				
12,0	D	D	D	90	90	90	95	95	95				D	D	D	90	90	90							
20,0	D	D	D	95	95	95							D	D	D	95	95	95							
30,0		C	C		100	100							C	D	D	100	95	95							
1,0	D	D	D	85	85	85	90	85	85		95	95	D	D	D	85	85	85	90	90	85			95	Group 3
1,5	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	90	85	85			95	
2,0	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	90	90	85			95	
3,0	D	D	D	85	85	85	90	85	85			95	D	D	D	85	85	85	90	90	90				
5,0	D	D	D	85	85	85	90	90	90				D	D	D	90	90	90	95	95	95				
8,0	D	D	D	90	90	90	95	95	95				D	D	D	90	90	90			95				
12,0	D	D	D	95	95	90							D	D	D	95	90	90							
20,0		C	C		100	100							D	D	D	95	95	95							
30,0													C	C	C	100	100	100							
1,0	D	D	D	85	85	85	90	85	85			95	D	D	D	85	85	85	90	90	85			95	Group 4
1,5	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	90	90	85			95	
2,0	D	D	D	85	85	85	85	85	85	95	95	95	D	D	D	85	85	85	90	90	85			95	
3,0	D	D	D	85	85	85	90	90	85			95	D	D	D	85	85	85	90	90	90				
5,0	D	D	D	90	90	85	95	95	95				D	D	D	90	90	90	95	95	95				
8,0	D	D	D	95	95	90							D	D	D	90	90	90							
12,0	C	C	C	100	100	100							D	D	D	95	95	95							
20,0													C	D	D	100	95	95							
30,0														C	C		100	100							
1,0	D	D	D	90	85	85		95	90				D	D	D	85	85	85	95	90	90				Group 5
1,5	D	D	D	90	85	85	95	90	85			95	D	D	D	85	85	85	90	90	85			95	
2,0	D	D	D	90	85	85	95	90	85			95	D	D	D	85	85	85	90	90	85			95	
3,0	D	D	D	90	90	85		95	90				D	D	D	90	90	85	95	95	90				
5,0	D	D	D	95	95	95							D	D	D	90	90	90	95	95	95				
8,0			C			100							D	D	D	95	90	90							
12,0													D	D	D	95	95	95							
20,0													C	C	C	100	100	100							
30,0														C	C		100	100							
1,0	D	D	D	95	95	90							D	D	D	90	90	85	95	95	90				Group 8
1,5	D	D	D	95	90	90			95				D	D	D	90	85	85	95	95	90				
2,0	D	D	D	95	95	90			95				D	D	D	90	90	85	95	95	90				
3,0	D	D	D	95	95	95							D	D	D	90	90	85	95	95	95				
5,0			C			100							D	D	D	90	90	90			95				
8,0													D	D	D	95	95	95							
12,0													D	D	D	95	95	95							
20,0														C	C		100	100							
30,0																									

Table: B-9 - Installation Type 1, DN ≥ 300. Vacuum 1.0 bar, groundwater level to ground level. Minimum Backfill Compaction, % Standard Proctor Density. (D = uncompacted (dumped), C = Compacted).

Type 1 DN ≥ 300	No Traffic Load - 1 bar Internal Vacuum - Ground Water To Level																								
Backfill	Standard Trench, B_d/D = 1.8												Wide Trench, B_d/D = 3.0												
	SC I			SC II			SC III			SC IV			SC I			SC II			SC III			SC IV			
Pipe SN / Burial Depth, m	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	<= Native Soil
1,0	D	D	D	85	85	85	90	85	85			95	D	D	D	90	85	85	95	90	85				Group 1
1,5	D	D	D	85	85	85	90	90	85			95	D	D	D	90	85	85	95	90	90				
2,0	D	D	D	85	85	85	90	90	85			95	D	D	D	90	85	85	95	90	90				
3,0	D	D	D	90	85	85	95	90	90				D	D	D	90	90	85	95	95	90				
5,0	D	D	D	90	90	85	95	95	90				D	D	D	90	90	90	95	95	95				
8,0	D	D	D	90	90	90	95	95	95				D	D	D	90	90	90		95	95				
12,0	D	D	D	90	90	90		95	95				D	D	D	95	90	90							
20,0	C	D	D	100	95	90							C	D	D	100	95	95							
30,0		C	D		100	95							C	C	D	100	100	95							
1,0	D	D	D	85	85	85	90	85	85			95	D	D	D	90	85	85	95	90	85				Group 2
1,5	D	D	D	85	85	85	90	90	85			95	D	D	D	90	85	85	95	90	90				
2,0	D	D	D	85	85	85	90	90	85			95	D	D	D	90	85	85	95	90	90				
3,0	D	D	D	90	85	85	95	90	90				D	D	D	90	90	85	95	95	90				
5,0	D	D	D	90	90	85	95	95	90				D	D	D	90	90	90	95	95	95				
8,0	D	D	D	90	90	90		95	95				D	D	D	95	90	90			95				
12,0	D	D	D	95	90	90			95				D	D	D	95	95	90							
20,0		D	D		95	95							C	D	D	100	95	95							
30,0			C			100								C	D		100	95							
1,0	D	D	D	85	85	85	90	85	85			95	D	D	D	90	85	85	95	90	85				Group 3
1,5	D	D	D	85	85	85	90	90	85			95	D	D	D	90	85	85	95	90	90				
2,0	D	D	D	85	85	85	90	90	85			95	D	D	D	90	85	85	95	90	90				
3,0	D	D	D	90	85	85	95	90	90				D	D	D	90	90	85	95	95	90				
5,0	D	D	D	90	90	85	95	95	90				D	D	D	90	90	90		95	95				
8,0	D	D	D	95	90	90		95	95				D	D	D	95	90	90			95				
12,0	C	D	D	100	95	90							D	D	D	95	95	90							
20,0			C			100							C	D	D	100	95	95							
30,0														C	C		100	100							
1,0	D	D	D	90	85	85	95	90	85			95	D	D	D	90	85	85	95	90	90				Group 4
1,5	D	D	D	90	85	85	95	90	85			95	D	D	D	90	90	85	95	90	90				
2,0	D	D	D	90	85	85	95	90	85			95	D	D	D	90	90	85	95	95	90				
3,0	D	D	D	90	90	85	95	95	90				D	D	D	90	90	85	95	95	90				
5,0	D	D	D	95	90	90		95	95				D	D	D	90	90	90		95	95				
8,0		D	D		95	90							D	D	D	95	90	90			95				
12,0		C	C		100	100							D	D	D	95	95	95							
20,0													C	C	D	100	100	95							
30,0														C	C		100	100							
1,0	D	D	D	95	90	85		95	90				D	D	D	90	90	85	95	95	90				Group 5
1,5	D	D	D	95	90	90			95				D	D	D	90	90	85	95	95	90				
2,0	D	D	D	95	90	90			95				D	D	D	90	90	85	95	95	90				
3,0	C	D	D	100	95	90							D	D	D	90	90	90		95	95				
5,0		C	D		100	95							D	D	D	95	90	90			95				
8,0			C			100							D	D	D	95	95	90							
12,0													C	D	D	100	95	95							
20,0														C	C		100	100							
30,0															C			100							
1,0		D	D		95	95							D	D	D	90	90	90		95	95				Group 8
1,5		C	D		100	95							D	D	D	90	90	90		95	95				
2,0		C	D		100	95							D	D	D	90	90	90		95	95				
3,0			D			95							D	D	D	95	90	90			95				
5,0													D	D	D	95	90	90							
8,0													C	D	D	100	95	95							
12,0													C	C	D	100	100	95							
20,0															C			100							
30,0																									

Table: B-10 - Installation Type 1, DN ≥ 250. Groundwater level below the pipe invert. Minimum Backfill Compaction, % Standard Proctor Density. (D = uncompacted (dumped), C = Compacted).

Type 1 DN ≤ 250	No Traffic Load No Internal Vacuum Ground Water Level below Pipe Invert								Traffic, AASHTO HS 20 No Internal Vacuum Ground Water Level below Pipe Invert								No Traffic Load 1 bar Internal Vacuum Ground Water Level below Pipe Invert								
	$B_d/D = 3.0$				$B_d/D \geq 5.0$				$B_d/D = 3.0$				$B_d/D \geq 5.0$				$B_d/D = 3.0$				$B_d/D \geq 5.0$				
Backfill	SC I	SC II	SC III	SC IV	SC I	SC II	SC III	SC IV	SC I	SC II	SC III	SC IV	SC I	SC II	SC III	SC IV	SC I	SC II	SC III	SC IV	SC I	SC II	SC III	SC IV	<= Native Soil
Pipe SN / Burial Depth, m	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	
1,0	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	95	D	85	85	90	D	85	85	90	Group 1
1,5	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	
2,0	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	
3,0	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	95	D	85	85	90	D	85	85	90	
5,0	D	85	90	95	D	90	90	95	D	85	90	95	D	90	90	95	D	85	90	95	D	90	90	95	
8,0	D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		
12,0	D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		
20,0	D	95			D	95			D	95			D	95			D	95			D	95			
30,0	D	95			D	95			D	95			D	95			D	95			D	95			
1,0	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	95	D	85	85	90	D	85	85	90	Group 2
1,5	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	
2,0	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	
3,0	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	95	D	85	85	90	D	85	85	90	
5,0	D	85	90	95	D	90	90	95	D	85	90	95	D	90	90	95	D	85	90	95	D	90	90	95	
8,0	D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		
12,0	D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		
20,0	D	95			D	95			D	95			D	95			D	95			D	95			
30,0	C	100			D	95			C	100			D	95			C	100			D	95			
1,0	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	95	D	85	85	90	D	85	85	90	Group 3
1,5	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	
2,0	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	
3,0	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	95	D	85	85	90	D	85	85	90	
5,0	D	85	90	95	D	90	90	95	D	85	90	95	D	90	90	95	D	85	90	95	D	90	90	95	
8,0	D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		
12,0	D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		
20,0	D	95			D	95			D	95			D	95			D	95			D	95			
30,0	C	100			D	95			C	100			D	95			C	100			D	95			
1,0	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	95	D	85	85	90	D	85	85	90	Group 4
1,5	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	
2,0	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	
3,0	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	95	D	85	85	90	D	85	85	90	
5,0	D	90	90	95	D	90	90	95	D	90	90	95	D	90	90	95	D	90	90	95	D	90	90	95	
8,0	D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		
12,0	D	95			D	90	95		D	95			D	90	95		D	95			D	90	95		
20,0	D	95			D	95			D	95			D	95			D	95			D	95			
30,0	C	100			D	95			C	100			D	95			C	100			D	95			
1,0	D	85	85	90	D	85	85	90	D	85	85	95	D	85	85	95	D	85	85	90	D	85	85	90	Group 5
1,5	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	
2,0	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	D	85	85	90	
3,0	D	85	85	90	D	85	85	90	D	85	90	95	D	85	85	95	D	85	85	95	D	85	85	90	
5,0	D	90	95		D	90	90	95	D	90	95		D	90	90	95	D	90	95		D	90	90	95	
8,0	D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		
12,0	D	95			D	90	95		D	95			D	90	95		D	95			D	90	95		
20,0	C	100			D	95			C	100			D	95			C	100			D	95			
30,0	C	100			D	95			C	100			D	95			C	100			D	95			
1,0	D	85	85	90	D	85	85	90	D	85	90	95	D	85	85	95	D	85	85	95	D	85	85	90	Group 6
1,5	D	85	85	90	D	85	85	90	D	85	85	95	D	85	85	90	D	85	85	95	D	85	85	90	
2,0	D	85	85	90	D	85	85	90	D	85	85	95	D	85	85	90	D	85	90	95	D	85	85	90	
3,0	D	85	90	95	D	85	85	90	D	90	90	95	D	85	85	95	D	85	90	95	D	85	85	90	
5,0	D	90	95		D	90	90	95	D	90	95		D	90	90	95	D	90	95		D	90	90	95	
8,0	D	95			D	90	95		D	95			D	90	95		D	95			D	90	95		
12,0	D	95			D	90	95		D	95			D	90	95		D	95			D	90	95		
20,0	C	100			D	95			C	100			D	95			C	100			D	95			
30,0					D	95							D	95							D	95			

Table: B-11 Installation Type 1, DN ≥ 250. Groundwater level to ground level. Minimum Backfill Compaction, % Standard Proctor Density. (D = uncompacted (dumped), C = Compacted).

Type 1 DN ≤ 250	No Traffic Load No Internal Vacuum Ground Water Level to Ground Level								Traffic, AASHTO HS 20 No Internal Vacuum Ground Water Level to Ground Level								No Traffic Load 1 bar Internal Vacuum Ground Water Level to Ground Level								
	$B_d/D = 3.0$				$B_d/D \geq 5.0$				$B_d/D = 3.0$				$B_d/D \geq 5.0$				$B_d/D = 3.0$				$B_d/D \geq 5.0$				
Backfill	SC I	SC II	SC III	SC IV	SC I	SC II	SC III	SC IV	SC I	SC II	SC III	SC IV	SC I	SC II	SC III	SC IV	SC I	SC II	SC III	SC IV	SC I	SC II	SC III	SC IV	
Pipe SN / Burial Depth, m	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	<= NativeSoil
1,0	D	85	85	95	D	85	85	95	D	85	90		D	85	90		D	85	85		D	85	90		Group 1
1,5	D	85	85	95	D	85	85	95	D	85	85		D	85	90		D	85	90		D	85	90		
	D	85	85	95	D	85	85	95	D	85	90		D	85	90		D	85	90		D	85	90		
3,0	D	85	90		D	85	90		D	85	90		D	85	90		D	85	90		D	85	90		
5,0	D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		
8,0	D	90	95		D	90			D	90	95		D	90			D	90	95		D	90			
12,0	D	90			D	95			D	90			D	95			D	90			D	95			
20,0	D	95			D	95			D	95			D	95			D	95			D	95			
30,0	C	100			C	100			C	100			C	100			C	100			C	100			
1,0	D	85	85	95	D	85	85	95	D	85	90		D	85	90		D	85	85		D	85	90		Group 2
1,5	D	85	85	95	D	85	85	95	D	85	85		D	85	90		D	85	90		D	85	90		
2,0	D	85	85	95	D	85	85	95	D	85	90		D	85	90		D	85	90		D	85	90		
3,0	D	85	90		D	85	90		D	85	90		D	85	90		D	85	90		D	85	90		
5,0	D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		
8,0	D	90			D	90			D	90			D	90			D	90			D	90			
12,0	D	95			D	95			D	95			D	95			D	95			D	95			
20,0	D	95			D	95			D	95			D	95			D	95			D	95			
30,0	C	100			C	100			C	100			C	100			C	100			C	100			
1,0	D	85	85	95	D	85	85	95	D	85	90		D	85	90		D	85	85		D	85	90		Group 3
1,5	D	85	85	95	D	85	85	95	D	85	85		D	85	90		D	85	90		D	85	90		
2,0	D	85	85	95	D	85	85	95	D	85	90		D	85	90		D	85	90		D	85	90		
3,0	D	85	90		D	85	90		D	85	90		D	85	90		D	85	90		D	85	90		
5,0	D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		
8,0	D	90			D	90			D	90			D	90			D	90			D	90			
12,0	D	95			D	95			D	95			D	95			D	95			D	95			
20,0	D	95			D	95			D	95			D	95			D	95			D	95			
30,0	C	100			C	100			C	100			C	100			C	100			C	100			
1,0	D	85	85	95	D	85	85	95	D	85	90		D	85	90		D	85	90		D	85	90		Group 4
1,5	D	85	85	95	D	85	85	95	D	85	85		D	85	90		D	85	90		D	85	90		
2,0	D	85	85	95	D	85	85	95	D	85	90		D	85	90		D	85	90		D	85	90		
3,0	D	85	90		D	85	90		D	85	90		D	85	90		D	85	90		D	85	90		
5,0	D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		D	90	95		
8,0	D	90			D	90			D	90			D	90			D	90			D	90			
12,0	D	95			D	95			D	95			D	95			D	95			D	95			
20,0	C	100			D	95			C	100			D	95			C	100			D	95			
30,0	C	100			C	100			C	100			C	100			C	100			C	100			
1,0	D	85	85	95	D	85	85	95	D	85	90		D	85	90		D	85	90		D	85	90		Group 5
1,5	D	85	85	95	D	85	85	95	D	85	90		D	85	90		D	85	90		D	85	90		
2,0	D	85	85	95	D	85	85	95	D	85	90		D	85	90		D	85	90		D	85	90		
3,0	D	85	90		D	85	90		D	90	95		D	85	90		D	90	95		D	85	90		
5,0	D	90	95		D	90	95		D	90			D	90	95		D	90	95		D	90	95		
8,0	D	95			D	90			D	95			D	90			D	95			D	90			
12,0	D	95			D	95			D	95			D	95			D	95			D	95			
20,0	C	100			D	95			C	100			D	95			C	100			D	95			
30,0					C	100							C	100							C	100			
1,0	D	85	85	95	D	85	85	95	D	90	95		D	85	90		D	90	90		D	85	90		Group 6
1,5	D	85	85	95	D	85	85	95	D	85	90		D	85	90		D	90	95		D	85	90		
2,0	D	85	85		D	85	85	95	D	85	95		D	85	90		D	90	95		D	85	90		
3,0	D	90	95		D	85	90		D	90	95		D	85	90		D	90	95		D	85	90		
5,0	D	90			D	90	95		D	90			D	90	95		D	90			D	90	95		
8,0	D	95			D	90			D	95			D	90			D	95			D	90			
12,0	C	100			D	95			C	100			D	95			C	100			D	95			
20,0					D	95							D	95							D	95			
30,0					D	95							D	95							D	100			

Table: B-12 - Installation Type 2, DN ≥ 300. No Vacuum, groundwater level below the pipe invert. Minimum Backfill Compaction, % Standard Proctor Density. (D = uncompacted (dumped), C = Compacted).

Type 2 DN ≥ 300	No Traffic Load – No Internal Vacuum – Ground Water Level below Pipe Invert																								
	Standard Trench, $B_d/D = 1.8$												Wide Trench, $B_d/D = 3.0$												
Upper Backfill	SC III 85% SPD						SC III, 85% SPD or SC IV, 90% SPD						SC III 85% SPD						SC III, 85% SPD or SC IV, 90% SPD						<= NativeSoil
Backfill	SC I			SC II			SC III			SC IV			SC I			SC II			SC III			SC IV			
Pipe SN / Burial Depth, m	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	
1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 1
1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 1
2,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 1
3,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 1
5,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 1
8,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		90	90	Group 1
12,0	D	D	D	90	90	90			D			90		D	D		90	90							Group 1
20,0		D	D		90	90									D			95							Group 1
1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 2
1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 2
2,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 2
3,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 2
5,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 2
8,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		90	90	Group 2
12,0	D	D	D	90	90	90			D			90		D	D		90	90							Group 2
20,0			D			95																			Group 2
1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 3
1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 3
2,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 3
3,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 3
5,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	90	85	85	Group 3
8,0	D	D	D	90	90	90	D	D	D	90	90	90	D	D	D	90	90	90		D	D		90	90	Group 3
12,0		D	D		90	90			D			90		D	D		90	90							Group 3
20,0																									Group 3
1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 4
1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 4
2,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 4
3,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 4
5,0	D	D	D	90	90	90	D	D	D	90	85	85	D	D	D	90	90	90	D	D	D	90	90	85	Group 4
8,0	D	D	D	95	95	90		D	D		95	95	D	D	D	90	90	90			D			90	Group 4
12,0			C			100								D	D		95	95							Group 4
20,0																									Group 4
1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 5
1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 5
2,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 5
3,0	D	D	D	90	90	90	D	D	D	90	90	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 5
5,0	C	D	D	100	95	95		D	D		95	95	D	D	D	90	90	90	D	D	D	90	90	90	Group 5
8,0														D	D		90	90			D			90	Group 5
12,0															D			95							Group 5
20,0																									Group 5
1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 6
1,5	D	D	D	90	90	90	D	D	D	90	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 6
2,0	D	D	D	90	90	90	D	D	D	90	90	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 6
3,0	C	D	D	100	95	90		D	D		95	90	D	D	D	90	90	90	D	D	D	90	85	85	Group 6
5,0													D	D	D	90	90	90		D	D		90	90	Group 6
8,0														D	D		95	95							Group 6
12,0																									Group 6
20,0																									Group 6

Table: B-13 - Installation Type 2, DN ≥ 300. 0.5 bar vacuum, groundwater level below the pipe invert. Minimum Backfill Compaction, % Standard Proctor Density. (D = uncompacted (dumped), C = Compacted).

Type 2 DN ≥ 300	No Traffic Load – 0.5 bar Internal Vacuum – Ground Water Level below Pipe Invert																								
	Standard Trench, B_d/D = 1.8												Wide Trench, B_d/D = 3.0												<= Native Soil
Upper Backfill	SC III 85% SPD						SC III, 85% SPD or SC IV, 90% SPD						SC III 85% SPD						SC III, 85% SPD or SC IV, 90% SPD						
Backfill	SC I			SC II			SC III			SC IV			SC I			SC II			SC III			SC IV			
Pipe SN / Burial Depth, m	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	
1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 1
1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
2,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
3,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
5,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85	
8,0	D	D	D	90	90	90		D	D		85	85	D	D	D	90	90	90			D			90	
12,0	D	D	D	90	90	90			D			90		D	D		90	90							
20,0			D			90																			
1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 2
1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
2,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
3,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
5,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85	
8,0	D	D	D	90	90	90		D	D		85	85	D	D	D	90	90	90			D			90	
12,0		D	D		90	90			D			90			D			90							
20,0			D			95																			
1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 3
1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
2,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
3,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
5,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85	
8,0	D	D	D	90	90	90			D			90		D	D		90	90			D			90	
12,0			D			90									D			90							
20,0																									
1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 4
1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
2,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
3,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
5,0	D	D	D	90	90	90		D	D		85	85	D	D	D	90	90	90			D			85	
8,0		D	D		95	90			D			95		D	D		90	90							
12,0			C			100									D			95							
20,0																									
1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 5
1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
2,0	D	D	D	90	90	90		D	D		85	85	D	D	D	90	90	90	D	D	D	85	85	85	
3,0		D	D		90	90			D			85	D	D	D	90	90	90		D	D		85	85	
5,0			D			95							D	D	D	90	90	90			D			90	
8,0															D			90							
12,0																									
20,0																									
1,0		D	D		90	90			D			85	D	D	D	90	90	90	D	D	D	85	85	85	Group 6
1,5		D	D		90	90							D	D	D	90	90	90		D	D		85	85	
2,0			D			90							D	D	D	90	90	90		D	D		85	85	
3,0													D	D	D	90	90	90			D			85	
5,0														D	D		90	90							
8,0																									
12,0																									
20,0																									

Table: B-14 - Installation Type 2, DN ≥ 300. 1.0 vacuum, groundwater level below the pipe invert. Minimum Backfill Compaction, % Standard Proctor Density. (D = uncompacted (dumped), C = Compacted).

Type 2 DN ≥ 300	No Traffic Load – 1.0 bar Internal Vacuum – Ground Water Level below Pipe Invert																								
	Standard Trench, B_d/D = 1.8												Wide Trench, B_d/D = 3.0												<= Native Soil
Upper Backfill	SC III 85% SPD						SC III, 85% SPD or SC IV, 90% SPD						SC III 85% SPD						SC III, 85% SPD or SC IV, 90% SPD						
Backfill	SC I			SC II			SC III			SC IV			SC I			SC II			SC III			SC IV			
Pipe SN / Burial Depth, m	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	
1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85	Group 1
1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85	
2,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85	
3,0	D	D	D	90	90	90		D	D		85	85	D	D	D	90	90	90			D			85	
5,0	D	D	D	90	90	90		D	D		85	85	D	D	D	90	90	90			D			85	
8,0	D	D	D	90	90	90			D			85		D	D		90	90							
12,0		D	D		90	90									D			90							
20,0			D			90																			
1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85	Group 2
1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85	
2,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85	
3,0	D	D	D	90	90	90		D	D		85	85	D	D	D	90	90	90			D			85	
5,0	D	D	D	90	90	90		D	D		85	85	D	D	D	90	90	90			D			85	
8,0	D	D	D	90	90	90			D			85		D	D		90	90							
12,0		D	D		90	90									D			90							
20,0																									
1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85	Group 3
1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85	
2,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85	
3,0	D	D	D	90	90	90		D	D		85	85	D	D	D	90	90	90			D			85	
5,0	D	D	D	90	90	90			D			85		D	D		90	90			D			85	
8,0		D	D		90	90			D			90			D			90							
12,0			D			90																			
20,0																									
1,0	D	D	D	90	90	90		D	D		85	85	D	D	D	90	90	90		D	D		85	85	Group 4
1,5	D	D	D	90	90	90		D	D		85	85	D	D	D	90	90	90			D			85	
2,0	D	D	D	90	90	90		D	D		85	85	D	D	D	90	90	90			D			85	
3,0	D	D	D	90	90	90		D	D		85	85	D	D	D	90	90	90			D			85	
5,0		D	D		90	90			D			85		D	D		90	90							
8,0			D			90									D			90							
12,0																									
20,0																									
1,0		D	D		90	90			D			85	D	D	D	90	90	90			D			85	Group 5
1,5			D			90							D	D	D	90	90	90			D			85	
2,0			D			90							D	D	D	90	90	90			D			85	
3,0			D			90								D	D		90	90							
5,0															D			90							
8,0																									
12,0																									
20,0																									
1,0														D	D		90	90							Group 6
1,5														D	D		90	90							
2,0														D	D		90	90							
3,0															D			90							
5,0																									
8,0																									
12,0																									
20,0																									

Table: B-15 - Installation Type 2, DN ≥ 300. No Vacuum, groundwater level to ground level. Minimum Backfill Compaction, % Standard Proctor Density. (D = uncompacted (dumped), C = Compacted).

Type 2 DN ≥ 300	**No Traffic Load – No Internal Vacuum – Ground Water Level to Ground Level**																								
	Standard Trench, B_d/D = 1.8												Wide Trench, B_d/D = 3.0												
Upper Backfill	**SC III 85% SPD**						**SC III, 85% SPD or SC IV, 90% SPD**						**SC III 85% SPD**						**SC III, 85% SPD or SC IV, 90% SPD**						Soil
Backfill	**SC I**			**SC II**			**SC III**			**SC IV**			**SC I**			**SC II**			**SC III**			**SC IV**			<=Native
Pipe SN / Burial Depth, m	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	
1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 1
1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
2,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
3,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
5,0	D	D	D	85	85	85		D	D		85	85	D	D	D	90	90	85			D			90	
8,0		D	D		90	90									D			90							
12,0																									
20,0																									
1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 2
1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
2,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
3,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
5,0	D	D	D	85	85	85		D	D		85	85	D	D	D	90	90	85			D			90	
8,0		D	D		90	90									D			90							
12,0																									
20,0																									
1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 3
1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
2,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
3,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
5,0	D	D	D	85	85	85		D	D		85	85	D	D	D	90	90	85			D			90	
8,0		D	D		90	90									D			90							
12,0																									
20,0																									
1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 4
1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
2,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
3,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	90	85	85	
5,0	D	D	D	90	90	85		D	D		90	90		D	D		90	90			D			90	
8,0			D			85									D			90							
12,0																									
20,0																									
1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group 5
1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
2,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	
3,0	D	D	D	90	90	90	D	D	D	90	90	85	D	D	D	90	90	90		D	D		90	85	
5,0			D			85								D	D		90	90							
8,0																									
12,0																									
20,0																									
1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90	D	D	D	85	85	85	Group6
1,5	D	D	D	90	90	90	D	D	D	90	90	85	D	D	D	90	90	90	D	D	D	85	85	85	
2,0	D	D	D	95	90	90		D	D		90	85	D	D	D	90	90	90	D	D	D	90	85	85	
3,0			D			85							D	D	D	90	90	90		D	D		90	85	
5,0															D			90							
8,0																									
12,0																									
20,0																									

Table: B-16 - Installation Type 2, DN ≥ 300. 0.5 bar vacuum, groundwater level to ground level. Minimum Backfill Compaction, % Standard Proctor Density. (D = uncompacted (dumped), C = Compacted).

Type 2 DN ≥ 300		No Traffic Load – 0.5 bar Internal Vacuum – Ground Water Level to Ground Level																							
		Standard Trench, B_d/D = 1.8												Wide Trench, B_d/D = 3.0											
<= Native Soil	Upper Backfill	SC III 85% SPD						SC III, 85% SPD or SC IV, 90% SPD						SC III 85% SPD						SC III, 85% SPD or SC IV, 90% SPD					
	Backfill	SC I			SC II			SC III			SC IV			SC I			SC II			SC III			SC IV		
	Pipe SN / Burial Depth, m	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000
Group 1	1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85
	1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85
	2,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85
	3,0	D	D	D	90	90	90		D	D		85	85	D	D	D	90	90	90			D			85
	5,0		D	D		85	85			D			85			D			85						
	8,0			D			90																		
	12,0																								
	20,0																								
Group 2	1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85
	1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85
	2,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85
	3,0	D	D	D	90	90	90		D	D		85	85	D	D	D	90	90	90			D			85
	5,0		D	D		85	85			D			85			D			85						
	8,0			D			90																		
	12,0																								
	20,0																								
Group 3	1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85
	1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85
	2,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85
	3,0	D	D	D	90	90	90		D	D		85	85	D	D	D	90	90	90			D			85
	5,0		D	D		85	85			D			85			D			85						
	8,0			D			90																		
	12,0																								
	20,0																								
Group 4	1,0	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85
	1,5	D	D	D	90	90	90	D	D	D	85	85	85	D	D	D	90	90	90		D	D		85	85
	2,0	D	D	D	90	90	90		D	D		85	85	D	D	D	90	90	90			D			85
	3,0	D	D	D	90	90	90		D	D		85	85		D	D		90	90			D			85
	5,0			D			85									D			90						
	8,0																								
	12,0																								
	20,0																								
Group 5	1,0	D	D	D	90	90	90		D	D		85	85	D	D	D	90	90	90		D	D		85	85
	1,5		D	D		90	90			D			85	D	D	D	90	90	90			D			85
	2,0		D	D		90	90			D			85	D	D	D	90	90	90			D			85
	3,0			D			90								D	D		90	90						
	5,0																								
	8,0																								
	12,0																								
	20,0																								
Group 6	1,0			D			90							D	D	D	90	90	90			D			85
	1,5														D	D		90	90			D			85
	2,0														D	D		90	90						
	3,0															D			90						
	5,0																								
	8,0																								
	12,0																								
	20,0																								

Table: B-17 - Installation Type 2, DN ≥ 300. 1.0 bar vacuum, groundwater level to ground level. Minimum Backfill Compaction, % Standard Proctor Density. (D = uncompacted (dumped), C = Compacted).

Type 2 DN ≥ 300	No Traffic Load – 1.0 bar Internal Vacuum – Ground Water Level to Ground Level																								
	Standard Trench, B_d/D = 1.8												Wide Trench, B_d/D = 3.0												<= Native Soil
Upper Backfill	SC III 85% SPD						SC III, 85% SPD or SC IV, 90% SPD						SC III 85% SPD						SC III, 85% SPD or SC IV, 90% SPD						
Backfill	SC I			SC II			SC III			SC IV			SC I			SC II			SC III			SC IV			
Pipe SN / Burial Depth, m	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	2500	5000	10000	
1,0	D	D	D	90	90	90			D			85		D	D		90	90							Group 1
1,5	D	D	D	90	90	90			D			85		D	D		90	90							Group 1
2,0	D	D	D	90	90	90			D			85		D	D		90	90							Group 1
3,0		D	D		90	90									D			90							Group 1
5,0			D			85																			Group 1
8,0																									Group 1
12,0																									Group 1
20,0																									Group 1
1,0	D	D	D	90	90	90			D			85		D	D		90	90							Group 2
1,5	D	D	D	90	90	90			D			85		D	D		90	90							Group 2
2,0	D	D	D	90	90	90			D			85		D	D		90	90							Group 2
3,0		D	D		90	90									D			90							Group 2
5,0			D			85																			Group 2
8,0																									Group 2
12,0																									Group 2
20,0																									Group 2
1,0	D	D	D	90	90	90			D			85		D	D		90	90							Group 3
1,5	D	D	D	90	90	90			D			85		D	D		90	90							Group 3
2,0	D	D	D	90	90	90			D			85		D	D		90	90							Group 3
3,0		D	D		90	90									D			90							Group 3
5,0			D			85																			Group 3
8,0																									Group 3
12,0																									Group 3
20,0																									Group 3
1,0		D	D		90	90			D			85		D	D		90	90							Group 4
1,5		D	D		90	90			D			85		D	D		90	90							Group 4
2,0		D	D		90	90			D			85			D			90							Group 4
3,0			D			90									D			90							Group 4
5,0																									Group 4
8,0																									Group 4
12,0																									Group 4
20,0																									Group 4
1,0			D			90									D			90							Group 5
1,5															D			90							Group 5
2,0															D			90							Group 5
3,0																									Group 5
5,0																									Group 5
8,0																									Group 5
12,0																									Group 5
20,0																									Group 5
1,0																									Group 6
1,5																									Group 6
2,0																									Group 6
3,0																									Group 6
5,0																									Group 6
8,0																									Group 6
12,0																									Group 6
20,0																									Group 6

2. APPROXIMATE WEIGHTS FOR PIPES AND COUPLINGS

The data in the next two tables is intended for planning and execution of the pipe installations. They include nominal data based on the Pressure Pipe design.

dn	PN1				PN6				PN10			
	SN2500	SN5000	SN10000	Coupling	SN2500	SN5000	SN10000	Coupling	SN2500	SN5000	SN10000	Coupling
	kg/m	kg/m	kg/m		kg/m	kg/m	kg/m		kg/m	kg/m	kg/m	
300	9,4	11,8	15	6,9	8,1	10,4	12,6	11	7,9	10,2	12,6	11,2
350	12,7	16,1	20,5	8	11	14,2	17,2	12,5	10,5	13,7	17,2	12,9
400	16,4	20,9	26,7	9	14,4	18,5	22,3	14,1	13,4	17,5	22,3	14,6
450	20,7	26,4	32,9	10	18,3	23,5	28,2	15,7	16,7	21,8	28,2	16,4
500	25,7	32,9	40,9	11	22,8	29,1	34,8	17,3	20,5	26,7	34,8	18
600	35	43,5	53,3	13,1	31,4	39,3	47,9	28,8	27,5	36	47,9	29,8
700	47,8	58	72	15,9	42,3	53,2	65,6	33	37,1	48,8	65,6	34,8
800	60,5	74,3	94,5	18,7	55	68,8	85,4	37,3	48,3	63,1	85,4	40,9
900	76,9	93,9	117,8	21,5	69,4	86,7	107,3	42,8	60,8	80,6	107,3	47,1
1000	92,4	117,7	144,7	24,2	85,5	106,3	132,7	48,4	74,7	99,1	132,7	53,5
1100	111,4	139,9	174,4	26,9	103,4	128,4	160,7	53,9	89,9	119,4	160,7	60
1200	135,1	167,8	205,6	48,6	122,2	151,9	190,4	59,4	106,5	141,9	190,4	66,5
1300	155,8	195	240	53,1	143,5	179,1	223,3	64,9	124,5	166	223,3	73
1400	181	226,1	278,6	57,6	165,7	207,1	258,5	70,5	144,1	191,8	258,5	79,4
1500	209	257,1	317,5	62,2	189	238	295,5	76	164,6	219,9	295,5	86,2
1600	234,6	290,2	359,9	67	215,5	269,8	336,7	81,8	187,4	250,2	336,7	93,1
1700	266,4	328,9	407,9	71,7	244,9	304,7	378,9	87,6	211,1	281,8	378,9	100,1
1800	295,2	366,2	453,2	76,3	274	341,3	424,8	93,3	236,2	315,5	424,8	107
1900	328,5	407,6	502,6	81,1	304,1	379,3	473	99,2	262,3	351,2	473	115,9
2000	360,4	448,9	554,6	86	336,8	419,3	522,5	105,2	290,7	388,8	522,5	125,3
2100	399,3	495,9	610,1	91	370,9	462,2	576,1	111,2	320	427,9	576,1	134,7
2200	434,4	541,3	670,9	96	406,5	507	632	117,4	350,7	469,4	632	143,8
2300	473,5	591,9	731,8	101	443,9	552,9	689,6	123,4	383,3	513,4	689,6	153,2
2400	514,1	641,4	797,8	106,1	482,9	601,6	749,8	129,7	416,3	558,2	749,8	162,5
2500	559,1	691,8	0	111,4	522,4	653,5	814,5	136,1	451,7	605,4	814,5	171,8
2600	604,9	748,5	0	167,4	565,8	706	880,8	200,9	488	653,8	880,8	232,2
2700	647,8	804,1	0	175,3	609,8	759,9	949,1	210,4	525,7	704,8	949,1	243,3
2800	697,3	866,9	0	183,6	654,1	817,8	1020,6	220,3	565,2	758,1	1020,6	254
2900	743,3	926,6	0	191,8	701,6	877,4	1092,5	230,1	605,7	812,5	1092,5	264,8
3000	799	995,3	0	199,7	751,6	937,4	1170,1	239,7	648,1	869	1169,5	275,4
3100					799,9	1000,1	1247,8	261,5	690,6	928,5	1247,8	300,8
3200					852,8	1065,2	1330	272,1	735,8	988,5	1330	312,6
3300					907,4	1133	1414,7	282	782,5	1051,3	1414,7	324,2
3400					961,9	1203	1499,3	292,8	830,6	1114,4	1499,3	335,8
3500					1019,5	1272,8	0	303	879,1	1182	0	347,3
3600					1078,6	1344,9	0	314	930,4	1249,5	0	359,3
3700					1138,9	1422,9	0	324,4	982	1319,9	0	370,9
3800					1198,7	1500,2	0	334,9	1035,7	1392	0	382,6
3900					1263,7	0	0	345,5	1090,7	1465,6	0	394,4
4000					1330	0	0	355,9	1146	1540,8	0	406,3

	PN16				PN20				PN25				PN32			
dn	SN2500	SN5000	SN10000	Coupling	SN2500	SN5000	SN10000	Coupling	SN2500	SN5000	SN10000	Coupling	SN2500	SN5000	SN1000	Coupling
	kg/m	kg/m	kg/m		kg/m	kg/m	kg/m		kg/m	kg/m	kg/m		kg/m	kg/m	kg/m	
300	7,5	9,4	12,1	11,6	7,3	9,2	11,7	11,8	0	9,1	11,4	11,8			11,2	13,9
350	9,9	12,6	16,2	13,4	9,8	12,2	15,6	13,5		12,1	15,3	13,7			14,9	16,1
400	12,6	16	20,8	15,7	12,5	15,8	20,1	15,3		15,4	19,5	15,7			19	18,4
450	15,8	19,9	25,3	17,2	15,5	19,5	25,1	17,2		19,1	24,3	17,7			23,6	20,8
500	19,2	24,6	31,7	18,9	18,8	23,8	30,6	19,5		23,3	29,6	20,1			28,8	22,9
600	25,7	32,9	43,1	31,2	25,2	31,9	41,1	32,7		31,1	39,7	34,6			38,5	39,3
700	34,5	44,4	58,1	38,1	33,7	42,9	55,5	38,3		41,8	53,5	40,4			51,9	47,8
800	44,5	57,4	75,2	45,3	43,5	55,5	71,8	45,5		54,1	69,3	48,9			67,2	62,3
900	55,8	72,1	94,9	49,6	54,5	69,7	90,5	51,6		67,8	87,2	57,2			84,4	73,4
1000	68,5	88,6	116,6	56,5	66,8	85,5	111	59,4		83,3	107	72,7			103,6	90,6
1100	82,4	106,6	140,7	63,9	80,3	102,9	133,9	69		100,2	129	87,4			124,8	106,5
1200	97,6	126,3	166,9	71,5	95	121,9	158,7	82,3		118,6	153	101,2			148	121,8
1300	113,9	147,8	195	79,4	111	142,6	185,9	94,8		138,7	178,8	114,8			173	136,7
1400	131,7	171,1	226,1	89,4	128,2	164,8	215,3	107,1		160,4	206,9	128,1			200,2	151
1500	150,6	195,7	259,2	101	146,6	188,7	246,6	119,1		183,6	237	141,2			229,2	165,1
1600	170,9	222,2	294,3	112,4	166,3	214,2	280	131,2		208,4	269,1	154,1			260,2	178,9
1700	192,4	250,6	331,6	123,6	187,3	241,2	315,5	142,8		234,6	303,4	167			292,7	192,4
1800	215,3	280,2	371,6	134,4	209,5	269,9	353,3	154,6		262,4	339,5	179,4			327,4	205,9
1900	239,3	311,6	413,1	145,5	232,9	300,3	393,1	166,1		292,7	377,6	191,4			0	0
2000	264,6	345,1	457,4	156,3	257,5	332,1	434,8	178		322,9	418,9	203,3			0	0
2100	291,4	379,8	503,7	167	283,4	365,6	479	189,4		355,6	460,5	215,1			0	0
2200	319,2	416,4	552,4	177,8	310,6	400,8	525	201,2		389	504,6	226,8			0	0
2300	348,3	454,5	603,7	188,3	338,8	437,6	573,4	212,6		424	550,5	238,7			0	0
2400	378,9	494,6	656,7	199,2	367,9	475,8	623,7	224,1		463,1	599	250,3			0	0
2500	410,5	536	712,4	209,9	398,8	515,3	677,6	234,7		0	0	0			0	0
2600	443,7	579,6	769,3	267,9	430,2	557,4	730,9	305,5		0	0	0			0	0
2700	477,6	624,6	829,9	279,9	464	599,9	787,5	323,8		0	0	0			0	0
2800	513,5	671,2	891,5	292,5	498,3	645,6	846,9	342,9		0	0	0			0	0
2900	549,1	719,1	956,9	304,1	533,6	690,6	907,4	362,2		0	0	0			0	0
3000	587,8	769,5	1023	315,2	571,1	740,1	971,8	382,4		0	0	0			0	0
3100	626,9	820	1090,9	352,8	0	0	0	0		0	0	0			0	0
3200	666,5	873,5	1162,6	370,9	0	0	0	0		0	0	0			0	0
3300	710,3	928,6	1236,3	389,2	0	0	0	0		0	0	0			0	0
3400	751,8	984,7	1311,5	412,5	0	0	0	0		0	0	0			0	0
3500	0	0	0	0	0	0	0	0		0	0	0			0	0
3600	0	0	0	0	0	0	0	0		0	0	0			0	0
3700	0	0	0	0	0	0	0	0		0	0	0			0	0
3800	0	0	0	0	0	0	0	0		0	0	0			0	0
3900	0	0	0	0	0	0	0	0		0	0	0			0	0
4000	0	0	0	0	0	0	0	0		0	0	0			0	0

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