CONCRETE PIPE AND PORTAL CULVERT INSTALLATION MANUAL

P.I.P.E.S

Pipes, Infrastructural Products and Engineering Solutions Division

CONCRETE MANUFACTURERS ASSOCIATION

Quality cast in concrete

PREFACE TO THE THIRD EDITION

Concrete is possibly the most widely accepted material for storm water pipes, culverts, sewer lines and many other applications.

This acceptance stems from concrete's ability to be moulded into almost any shape and to satisfy a broad range of performance requirements in terms of size, strength and durability.

To meet these needs, the concrete pipe industry in South Africa has grown tremendously in the past sixty years.

The use of precast culverts has, in recent years, become popular as they offer many advantages over cast-in-place culverts.

Modern technology and the acceptance of SABS/SANS standards ensure that products of uniformly high quality are produced. Provided sound design and installation methods are followed concrete pipe and portal culvert will give satisfactory hydraulic and structural performance for many years.

This Manual is intended to cover all aspects of concrete pipe and portal culvert handling, installation and site testing. Being a Manual, it does not attempt to take the place of established texts, but rather to give sufficient information to enable site decisions to be taken quickly and to guide contractors along the correct paths.

This Manual has been prepared for the guidance of specifying bodies and contracting organisations using concrete pipes and portal culverts, by the PIPES division of the Concrete Manufacturers Association in consultation with its member companies.

Publications by the American Concrete Pipe Association have been freely referred to and acknowledgement is made to this Organisation

This is the third edition of the manual and it includes several additions and revisions. Constructive criticism is welcome and where relevant, will be incorporated in future editions

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1. INTRODUCTION

1.1 GENERAL

1.1.1 The interdependent relationship between design and installation requires installation practices that ensure satisfactory hydraulic and structural performance of the complete pipe or culvert line.

1.1.2 The engineering design of any project, described in the specifications and drawings, must be properly executed during construction. The Clerk of Works, as a representative of the Engineer, shares responsibility with the Contractor for ensuring that the pipe or portal culvert is installed in accordance with the contract documents. Proper inspection requires careful attention to site operation, but should not duplicate the detailed inspection and testing carried out by the pipe manufacturer.

Supervisory personnel directly associated with the installation should have a basic understanding of design principles so that the extent and limitations of the project specification and drawings can be correctly interpreted.

1.1.3 This Manual cannot, and should not, be used as a textbook, nor can it relieve the Designer and the Contractor of the need for making a thorough study of the theoretical and practical problems that occur in practice.

When in doubt, advice should be sought from a reputable manufacturer.

1.2 SCOPE

1.2.1 This Manual describes proven methods for installation of precast concrete pipes and portal culverts.

1.2.2 The selection, manufacture and installation of precast concrete pipes and culverts are covered by the following:

SANS 0102 –	The Selection of Pipes for Buried Pipelines Parts, I, II.
SANS 676 –	Reinforced Concrete Pressure Pipes.
SANS 677 –	Concrete Non-Pressure Pipes
SANS 986 -	Precast Reinforced Concrete Culverts.
ISO 974 –	Rubber Joint Rings (Non-Cellular).
SANS 1200 DB –	Civil Engineering Construction: Earthworks (Pipe Trenches).
SANS 1200 L –	Civil Engineering Construction: Low Pressure Pipelines.
SANS 1200 LB –	Civil Engineering Construction: Bedding (Pipes).
SANS 1200 LD –	Civil Engineering Construction: Sewers.
SANS 1200 LE –	Civil Engineering Construction: Stormwater Drainage.
SANS 0120 –	Code of Practice for Use with Standardised Specifications for Civil Engineering Construction and Contract Documents.

1.3 SELECTION OF PRODUCT STRENGTH

1.3.1 Once the size of product has been determined, the selection of product strength has six logical steps:

- calculate deadloads;
- calculate internal pressure;
- calculate live loads;
- choose bedding factor;
- choose safety factor;
- select required product class.

1.3.2 It is important to note that there are always a number of options, which need to be considered in order to find the optimum solution. Generally it is more economic to use a high strength pipe with a low class bedding.

1.3.3 Reference to the Concrete Pipe Handbook, published by the Concrete Manufacturers Association of Southern Africa, will be of assistance with most of the problems that can occur with pipe selection. Alternatively, Designers and Contractors should consult a concrete pipe manufacturer.

1.4 STUDY OF PROJECT SPECIFICATION

1.4.1 The drawings that are either supplied by the Engineer or from part of the contract documents should be studied thoroughly for all salient features.

1.4.2 Make a note of the locations, numbers and types of all appurtenant structures and fittings such as manholes, junctions, tees, valves (sluice, air and scour) and bends.

1.4.3 Using the information available on the drawings, determine:

- height of fill above the product;
- any superimposed or live loads;
- type of installation (i.e. trench, embankment, etc.);
- whether there are any special conditions.

1.4.4 Determine from the documents the class of bedding and type of bedding materials specified.

1.4.5 The information gleaned in the paragraphs above should be used to check the specified strength class of the pipes or culverts. This kind of check may seem superfluous, but could prevent the product from sustaining loads in excess of those permitted for the strength class used. If overload conditions occur these may lead to the pipes or culverts cracking or even collapsing.

1.4.6 Equipment and details of field testing, if required, should be established at the start of the project. It will have a direct bearing on the pipe or culvert laying programme and sufficient time should always be allowed to acquire the specialised equipment.

1.5 INSTALLATION CONDITIONS

1.5.1 The earth loads on a buried structure are significantly influenced by the installation method. The two limiting conditions are the trench and embankment.

When the fill height exceeds the outside dimension of the pipe or culvert, embankment loads can be considerably higher than trench loads.

1.5.2 The trench condition occurs when the product is placed in a trench dug into the natural earth.

1.5.3 The embankment condition occurs when the product is placed at ground level and fill placed at the sides and over the top until the required fill level is reached.

1.5.4 Many installations are intermediate between the two conditions described above.

1.5.5 As products can be installed in a trench with minimum side clearances, the difference between the loads under a trench and an embankment condition can be significant. It is, therefore, essential that products are installed in accordance with project specifications.

If there is any deviation from the installation method specified, the engineer should be informed.

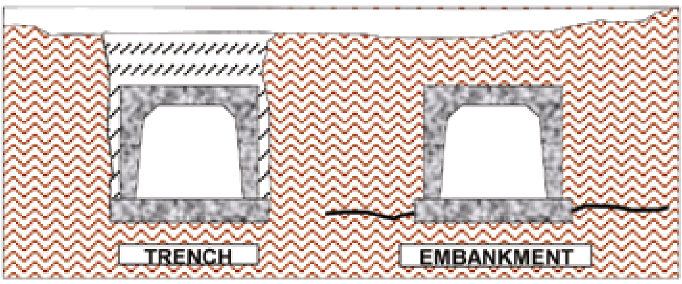

Figure 1: Installation Conditions

TABLE 1: KEY TO MATERIALS USED

Insitu Material	Lightly compacted backfill
Main backfill	Densely compacted backfill
Loose backfill	Reworked foundation
Concrete	Soilcrete
Selected granular material	Fine granular fill material
Compacted granular material	

The key to the materials used in figure 1 and the remainder of the figures is given in Table 1.

1.6 PRE-CONSTRUCTION ACTIVITIES

1.6.1 Before any site work is commenced, the Client, or his representative, and the Contractor must agree on their respective responsibilities for:

- work to be done;
- tools to be provided;
- provision of necessary materials;
- compliance with applicable laws, by-laws and regulations;
- negotiate for contract service required, such as water, electricity, etc.;
- negotiations for servitudes, rights-of-way, traffic control, etc.

1.6.2 Before ordering pipes or culverts, the Contractor should study the specifications to determine:

- sizes, lengths and strengths required;
- details of any special features;
- crossings locations in relation to water courses.

The Contractor should also prepare a delivery plan and discuss this with the Supplier to ensure that this can be met.

1.6.3 Before installation starts, the Contractor must ensure he has all the equipment required. Where specialised tools, such as turfors, are required he should refer to the manufacturer for advice.

2. ORDERING, RECEIPT AND ACCEPTANCE

2.1 INFORMATION REQUIRED

2.1.1 The information required to initiate a pipe or culvert order should be in writing and include the following:

- name and address of Contractor/Customer;
- name and location of project;
- product size, effective length and strength class;
- total length of each type and size of pipe or culvert;
- type of joint;
- size and quantity of manhole chamber sections, access shaft sections, cover slabs, adapter slabs and spacer slabs;
- lists of fittings and specials including radius pipe;
- material specifications;
- tests additional to those required by the SANS;
- jointing material and quantity;
- full and accurate delivery instructions, together with a detailed laying programme;
- invoicing instructions;
- any other special requirements or instructions.

2.2 RECEIPT AND ACCEPTANCE OF PRODUCT

2.2.1 A responsible person must always be present on site to receive product.

2.2.2 A little time spent inspecting products on arrival can save a lot of trouble at a later stage.

2.2.3 Each consignment of product is loaded, wedged and secure at the factory to avoid damage during transit.

2.2.4 A quick inspection of each load should be made before offloading commences to determine how the load has travelled and whether any damage has occurred. From this, the degree of close inspection required can be gauged.

2.2.5 Total quantities of each item should be checked against the delivery note and any damage or missing items recorded on this.

2.2.6 Once offloaded, a careful inspection of the delivered product should be made, to check:

- sizes, classes and quantities of each product against delivery note;
- cracking and chipping due to transport and handling damage;
- marking for compliance with the applicable SANS specification.

2.3 ACTION WHEN PRODUCTS DO NOT COMPLY

2.3.1 Any pipes or culverts damaged during transit or offloading should be marked and set aside. The delivery note should be endorsed with details of these unacceptable items.

2.3.2 Only when satisfied with the quantity, quality and any required endorsements made, should the responsible person sign the delivery note.

2.3.3 At this stage the ownership of the delivered goods passes from the Supplier to the Customer.

2.3.4 Damaged ends, chips or cracks which do not pass through the wall can easily be repaired. These products should be clearly marked to ensure that the necessary repairs are done before installation.

2.3.5 Pressure and sewer pipes which have damaged spigot or socket ends should not be repaired on site. They should be sent back to the Manufacturer for repair and retesting.

3. HANDLING AND OFFLOADING

3.1 CONCRETE PRODUCTS

3.1.1 When handling concrete products, it is important to remember that, as concrete is a heavy and somewhat brittle material, bumps or shock loads of any description are liable to damage the product. This applies particularly to sharp edges.

3.2 SITE ACCESS

3.2.1 The planning and executing of site preparation can significantly influence the progress of any project. This work varies considerably, depending on the location of project, topography, surface conditions and existing services.

One of the important items included in site preparations is the construction of access roads.

3.2.2 An inspection should be made before deliveries are commenced and any potential problems relating to site access resolved.

3.2.3 The access roads should be capable of carrying articulated vehicles with axle loads of 9 tonnes.

3.2.4 All offloading areas provided must be level, hard, drained and free of debris.

3.2.5 Should the access roads become impassable for the delivery vehicles, the supplier should be notified without delay so that deliveries can be suspended until further notice. This saves a great deal of time and confusion, and ensures a harmonious contract.

3.3 DISTRIBUTION

3.3.1 Co-ordination of deliveries with installation will avoid unnecessary handling and movement of equipment.

3.3.2 In the case of trench installations, the pipes or culverts should be placed on the side of the trench opposite the excavated material. The pipes or culverts should be placed so that they are protected from traffic and construction equipment, and close enough to the trench so as to permit efficient handling, but not so close that there is a danger of them falling into the trench.

3.3.3 In the case of embankment installations where the pipe or culverts are to be installed approximately the same elevation as original ground level, the pipes or culverts can be strung immediately after clearing and grading.

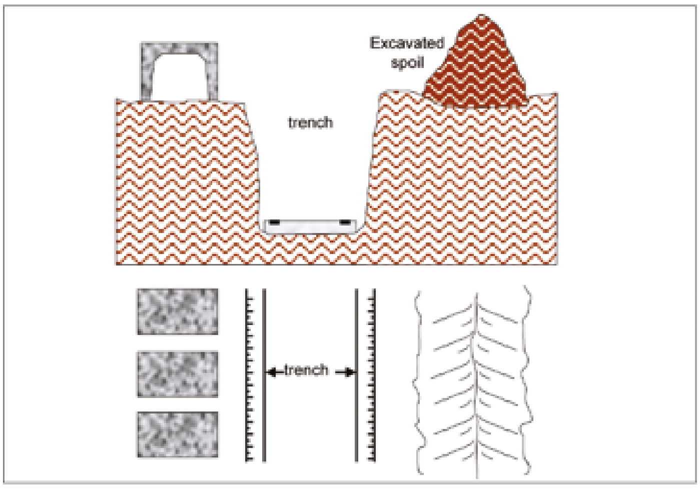

Figure 2: Distributing Culverts along Trench

3.3.4 If possible, double handling should be avoided. However, where the site conditions do not permit storing of products as described in 3.3.2 and 3.3.3 above, a storage yard away from the laying site will have to be established. The product may then be received at the storage yard and transported to the laying site when required.

3.3.5 The Contractor must ensure that he has all the necessary equipment to carry out any double handling as efficiently as possible. It is essential that a good road links the yard to the site so that the products are transported as smoothly as possible and damage eliminated.

3.4 STORAGE AREA

3.4.1 Any storage of products should be as near as possible to where the products will be installed.

3.4.2 An area clear of combustible materials and free from stormwater flooding should be selected.

3.4.3 The storage area should be level, firm and clear of any objects that may cause damage to the products.

3.4.4 Storage areas do tend to attract attention and should be made as secure as possible against theft and vandalism.

3.5 ACCEPTANCE OF PRODUCT

3.5.1 The person responsible for receiving the products must make certain before any offloading takes place that damage has not occurred during transit from factory to site.

3.5.2 Any products damaged during transit or offloading should be set aside. These products should be clearly marked to ensure that the necessary repairs are done before installation.

3.5.3 When pipes do not comply with requirements, attention is drawn to paragraphs 2.2 and 2.3.

3.6 OFFLOADING OF PIPES

3.6.1 Concrete pipe can be offloaded with conventional lifting and excavation equipment. However, specialised equipment is recommended.

3.6.2 Many transport contractors specialising in handling concrete pipe have equipped their vehicles with mechanical and/or hydraulic off-loaders.

3.6.3 Small diameter pipe was traditionally offloaded by hand, 35 to 45kg was generally accepted as the maximum mass that an individual can handle repeatedly. Today most pipes are offloaded mechanically.

3.6.4 Small to intermediate diameter pipe (i.e. up to 900 mm nominal diameter) can be offloaded by manually rolling the pipes off the truck by means of skids; the pipe should always be controlled by rope. Loosely piled soil should be banked up along the offloading point near the toe of the skids to provide a cushion and prevent runaways.

When offloading pipe by this method, the pipe is lowered all the way down to the skids and not allowed to roll free. One pipe is lowered at a time with the ropes located towards the end of the pipe and securely tied to the opposite end of the truck from which the pipe is being offloaded. Alternatively, one rope located at the centre of the pipe may be used.

3.6.5 Larger diameter pipe can also be offloaded with skids but its descent must be controlled with ropes.

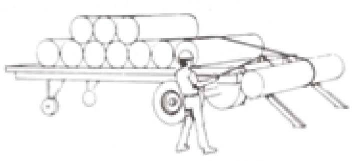

Figure 3: Offloading with Skids and Ropes

3.6.6 Mechanised equipment is recommended for off-loading larger diameter pipe. It usually simplifies and accelerates the offloading of smaller diameter pipe. When mechanical equipment is used, the lifting device must not damage the pipe.

3.6.7 Where pipe is provided with a lifting hole, the most common lifting device consists of a sling with lifting eye and spreader bar. Alternatively a lifting lug with wedge, snotter plug or spreader plate can be used.

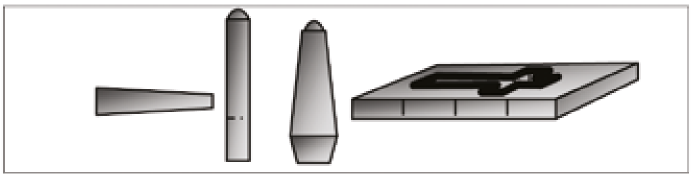

Figure 4: Lifting Equipment – (L to R) Lifting Lug with Wedge, Snotter Plug and Spreader Plate

Where lifting holes are not provided, it is normal to use a sling passing around the centre of gravity of the pipe. The sling should have a width of approximately 150 mm, and on no account should wire rope be used for the purpose.

3.6.8 The offloading of pipes must be controlled to prevent collision with other pipes or hard objects. Caution is necessary to ensure that all persons are out of the path of the pipe as it is lowered down the skid.

3.6.9 If it becomes necessary to move any pipe after offloading, the sections should be rolled or lifted, but never dragged or rolled over uneven ground.

3.7 OFFLOADING OF CULVERTS

3.7.1 Culverts can be offloaded with conventional lifting and excavating equipment. However, specialised equipment is recommended.

Many transport contractors specialising in handling concrete culvert have equipped their vehicles with mechanical and/or hydraulic cranes.

3.7.2 The culvert is provided with lifting holes. The most common lifting device consists of a sling with a lifting eye and spreader bar.

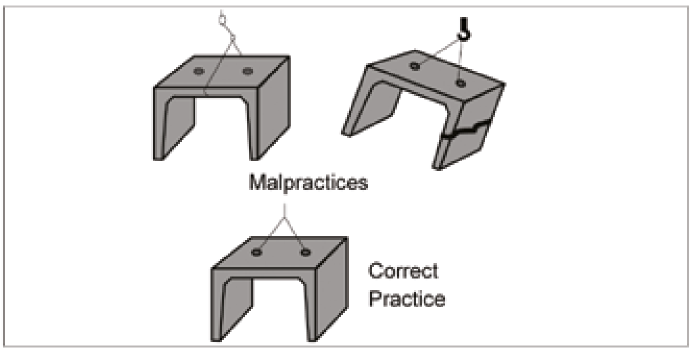

Figure 5: Lifting Culverts

3.7.3 Culverts should only be lifted using the holes provided. A single sling under the deck of a large span portal combined with rough handling can cause cracking along the top of the deck.

3.7.4 Culvert offloading must be controlled to prevent collision with other culverts or hard objects.

3.7.5 When unloading or moving culverts, care must be taken not to bump the bottom of the legs. This is very important with culverts having long legs where such action can cause haunch cracks.

3.7.6 Do not drag or push the culvert along the ground or do anything else to it, which can force the legs apart. This too can result in haunch cracks.

3.7.7 If culverts have to be moved long distances from the storage area to the site where they are to be installed, they should be transported in the same way as the cartage contractor delivered them to site. Figure 6 illustrates the recommended position during transport.

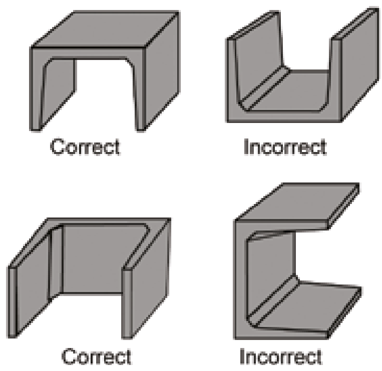

Figure 6: Orientation of Culverts During Transport

3.8 STACKING OF PIPES

3.8.1 Good housekeeping is essential with only one size and class contained in each stack.

3.8.2 Small diameter pipes should be stacked in the same manner as they were loaded on the truck. The bottom layer should be placed on a flat surface and adequately anchored to prevent movement as subsequent layers are added.

3.8.3 All pipes should be supported by their barrels so that the joint ends are free of load concentrations. Where timber runners are used, they should be placed at 1/5th of the pipe length from each end.

3.8.4 The number of layers in a stack of pipes is limited by handling and safety considerations, as well as the strength of the pipe in the bottom layer. Table 2 is a guide to stacking height.

TABLE 2: STACKING HEIGHT

Pipe diameter (mm)	No. of layers
150 - 225	6
300 – 375	4
450 – 600	3
675 – 900	2
Above 900	1

3.8.5 Pipes which are elliptically reinforced should not be stacked.

3.8.6 Each layer of spigot and socket pipes should be arrayed so that the sockets are at the same end. The sockets in the next layer should be at the opposite end and projecting beyond the spigots of the pipes in the lower layer.

Where pipes are not being stacked, the spigot and socket ends should alternate between adjacent pipes.

3.8.7 It is important to ensure that, where spigot and socket pipes are being stored, the joint ends are kept clean. In this way, the chances of a joint failing a hydraulic test due to the presence of dirt trapped between the rubber and the concrete surface are reduced.

3.8.8 Where thick-walled concrete pipes are to be exposed to the elements (especially during hot, dry weather) for a period of time, it is desirable that they are treated to prevent the chances of thermal cracking. Suggested methods for overcoming this problem are to spray with water, paint with reflective coating or shade the pipes.

3.9 STACKING OF CULVERTS

3.9.1 Good housekeeping is essential with only one size and class per stack.

3.9.2 Small culverts should be stacked in the same manner as they were loaded on the truck. The bottom layer should be placed on a flat surface.

3.9.3 Care must be taken to avoid point loads on culverts, which can result in chipping.

3.9.4 When stacking units on top of each other, do not place more load on top of a unit than one third of its specified test load.

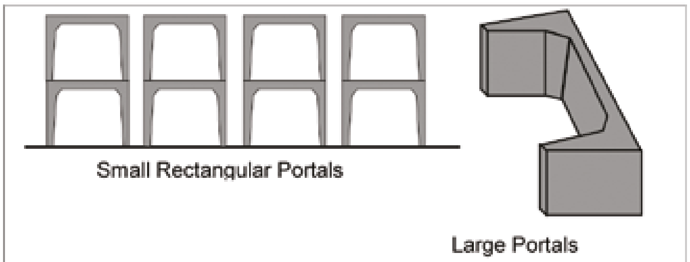

Figure 7: Stacking of Portal Culverts

3.10 REPAIRING MINOR DAMAGE

3.10.1 Repairing and patching of concrete product is permitted in terms of SANS 676 and 677 as follows:

"Occasional imperfections in a product may be rectified, provided that the repairs are sound and properly finished and cured and that the repaired product complies with the requirements of these specifications".

3.10.2 The manufacturer reserves the right to repair damaged or defective product on site provided that the Contractor has complied with paragraph 2.3 above

3.10.3 Once the Contractor has accepted delivery of items on site, he shall be responsible for any subsequent remedial work that may be required.

The Manufacturer will always be available to offer the Contractor advice or assistance with such remedial work.

3.11 STORAGE OF ANCILLARY ITEMS

3.11.1 All individual items such as rubber rings, sealing tape, jointing lubricants, fittings and accessories should be stored in a secure place.

3.11.2 Good housekeeping should be practised with these items stored in separate groups according to their type, size and class.

3.11.3 All rubber rings, jointing lubricants and flexible sealing compounds should be stored in a cool, dry place to be distributed as needed. In addition, they should be kept clean, away from oil, grease, excessive heat and out of the direct rays of the sun.

4. SURVEYING

4.1 PRELIMINARY WORK

4.1.1 Before commencing construction, the designer's requirements as given on the drawings, specifications and the relevant sections of SANS 1200 should be studied by a surveyor or other experienced person to establish:

- lines and levels of product and positions of manholes/inspection chambers;
- changes of grade and direction;
- inlets and outlets;
- junctions and junction's chambers;
- road/rail crossings;
- crossings with other services;
- other structures near the lines;
- trench base width.

4.1.2 If no trench widths are specified, trench widths given in Table 3 should be used as the maximum.

4.1.3 The trench widths given in Table 3 are based on the side allowances given in SANS 1200DB.

TABLE 3: TRENCH WIDTHS AS PER SANS 1200 DB

ND (mm)	OD (mm)	Trench Width (mm)
Up to 300	345	945
375 – 610	690	1290
675 – 825	950	1750
900 – 1200	1380	2380
1350	1620	2620
1500	1800	2800
1800	2160	3360

For nominal pipe diameters ≤ 1200mm the external diameter has been taken as 1.15 times the nominal diameter; for larger sizes 1.2 times the nominal diameter.

These trench widths correspond to the widths given in the "Concrete Pipe Handbook" and they may differ from the pay widths given on the drawings. If the latter is the case for a rough check on the load, the values given should be multiplied by the ratio of the squares of the trench widths.

Example: If the trench width in the "Concrete Pipe Handbook" for an 1800 mm ND pipe is 3360 mm and the specified trench width is 4000 mm, then the load given must be multiplied by:

$$\frac{4000^2}{3360^2} = 1.42$$

4.1.4 When a Contractor takes over a site, all the necessary datum pegs should have been installed and checked by the Engineer.

These pegs should have been given reference numbers and their co-ordinate levels listed in the drawings.

4.1.5 Great care must be taken to protect these datum pegs against disturbance by construction activities.

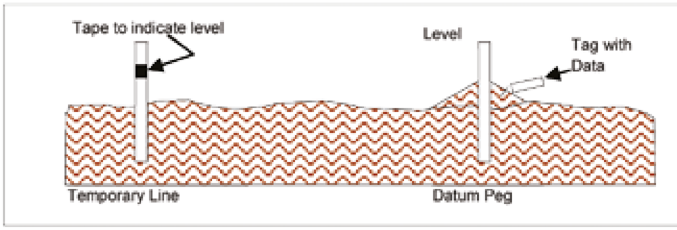

Figure 8: Survey Pegs and Markers

4.1.6 The Contractor must establish temporary line markers along the trench centre line.

4.1.7 These pegs and markers must be protected by either securing them with concrete to prevent movement or surrounding them with brightly painted rocks so that they are visible.

4.2 CENTRE LINES

4.2.1 Line markers are normally placed on or offset from the centre line position. If offset, care must be taken to establish the correct offset measurement before setting out the actual line, because once a trench is dug out of the alignment, it is costly and time-consuming to rectify the situation.

4.2.2 Once established, the centre line must be clearly marked. The distance between line markers should not exceed 50 m for straight alignment and closer for curved alignment. As these markers will be removed during excavation, it is not necessary to establish a level datum on them.

4.2.3 As stringing a line between markers during excavation is impractical, a clearly visible material such as lime, should be used to mark the centre line or edges of the excavation. The material should be placed directly onto a fish line which is subsequently removed.

4.3 LEVELS

4.3.1 The levels are transferred from the level reference pegs to the trench floor by using a dumpy level and staff. Control points are then established along the trench bottom.

4.3.2 Once the bulk excavation has been completed and the trench bottom is ready after trimming, there are various methods that can be used to transfer and monitor levels along the trench bottom:

- sight rail and boring rod;
- laser beam;
- fish line between pegs.

4.3.3 The sight rail and boning rod system (Fig. 10) is the most commonly used. The system is cheap, the materials needed readily available and easy to make.

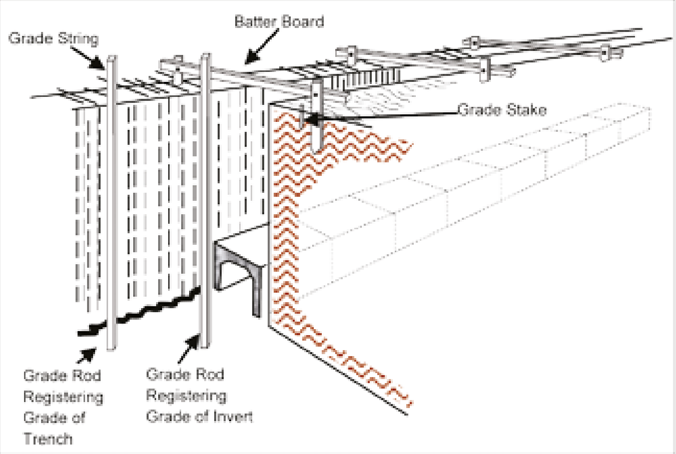

Figure 9: Sight Rail and Boning Rod

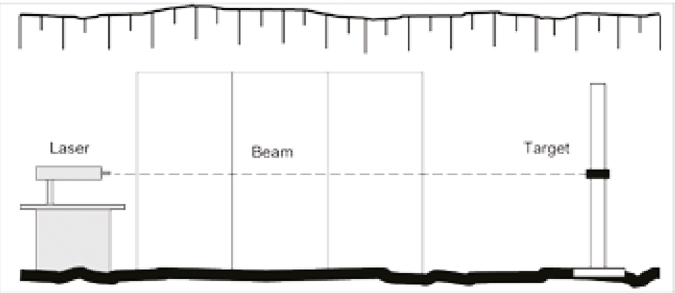

Figure 10: Use of the Laser Beam System

4.3.4 The laser beam system is expensive but very accurate and reliable. It is more complex to use than the method in 4.3.3 but with time operators gain experience and it becomes quick and easy to apply.

The setting up and operating of the laser should be done in accordance with the instruction given by the equipment supplier.

Once excavation has started, the level from the datum is transferred to the bottom of the trench using the technique described in 4.3.1. The laser beam is then set on line and level.

This level is transferred along the trench by using a marker on a boning rod as the target for the laser beam. The marker on the boning rod, which could be a nail, a narrow strip of paint or similar, is located at a distance from the end of the rod determined by the required height of the laser beam above the designed trench floor level.

4.3.5 The method of using a fish line between two pegs is not accurate when used with large spacings between pegs due to sag in the line. This system can be used only when pegs are spaced at 20 m or closer to each other.

5. EXCAVATION

5.1 GENERAL

5.1.1 The excavation, installing and backfilling operations should follow as close as possible, particularly in urban areas. Long stretches of open trench should be avoided in order to:

- minimise sheeting and shoring usage;
- reduce flooding risk;
- minimise disruption to existing utilities;
- reduce safety hazards;
- permit closer supervision of work;
- permit better quality control.

5.1.2 Culverts should be constructed so that existing surface drainage can continue.

It is therefore important, whenever possible, to install culverts as excavation progresses and immediately after the foundation has been prepared.

This will enable other construction to proceed unhindered and possibly eliminate the need to provide temporary drainage.

5.1.3 The strength of standard class portal culverts is adequate to allow legal traffic loads directly over them. It is, however, preferable to have the final road layers over the top of them providing at least 300mm of cover to give a smoother riding surface.

5.1.4 Well installed 50D pipes need at least 600 mm of cover over them before heavy traffic and/or construction equipment can pass over them.

5.1.5 In open country, cover products should be at least 600 mm to prevent damage by farm implements.

5.2 SAFETY

5.2.1 Persons responsible for excavation must adhere to the law. The statutory precautions stated in the Occupational Health and Safety Act, as amended, must be taken. When ground conditions vary from place to place, the appropriate safety measures must be taken.

5.2.2 The protection of workers in trenches is essential. Various measures can be taken to ensure the safe movement and protection of personnel and equipment from collapsing trench sides:

- trench walls can be battered;
- shoring or sheeting can be used.

5.2.3 Where the depth of excavation or the nature of material being excavated results in unstable trench walls, the walls should be supported by shoring. The structural requirements of the shoring depend on:

- depth and width or excavation;
- soil characteristics;
- bedding planes in clay or rock;
- water content of soil;
- weather conditions;
- distance from other structures;
- surcharge loads, etc.

Design and selection of shoring is complicated and beyond the scope of this manual. Typical types of shoring are given in Figure 12 below.

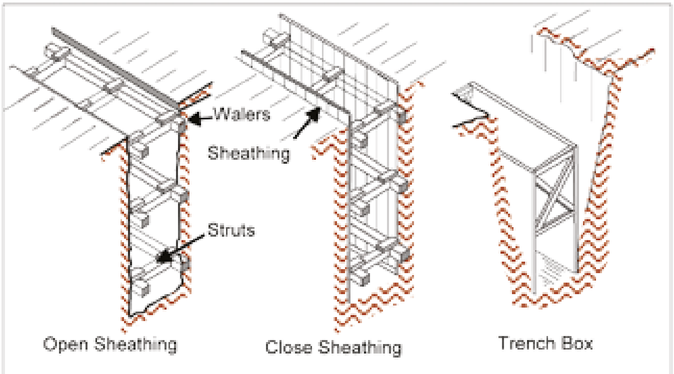

Figure 11: Types of Shoring

Trench widths should be adjusted to ensure adequate working space between the shoring used.

5.2.4 When there is sufficient space either side of the trench, the walls of the trench can be battered to a safe angle of repose for the material in question. Typical angles of repose are given in Figure 13.

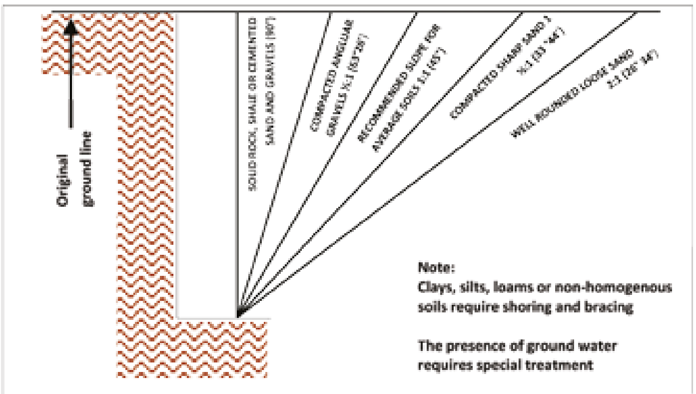

Figure 12: Approximate Angles of Repose

5.2.5 If the walls of a trench collapse, all work must cease immediately and the Engineer or Designer be informed. He must review his design to consider the effects of the increased trench width.

5.3 TRENCH WIDTHS AND DEPTH

5.3.1 The specified product trench widths should not be exceeded as the loads on a product installed in a trench are dependent upon the trench width. Over excavation could cause overloading of the structure after backfilling and commissioning.

5.3.2 When excavated material is to be used as backfill, the width of the excavation should allow clearances of at least 500 mm on either side of the conduit to ensure that the side fill can be adequately compacted.

5.3.3 If a stabilised soil or concrete is to be used as backfill, the clearance either side of the culverts can be reduced to 100 mm.

5.3.4 When excavation is in progress and the material is found to be of an inferior quality and unsuitable for backfilling, it must be removed to a dump site indicated by the Engineer.

5.3.5 If material excavated is suitable for backfilling, it should be placed adjacent to the trench. Material stockpiles will surcharge the soil adjacent to the trench and cause the trench walls to collapse. A general rule to prevent this is to ensure that the minimum distance between the trench side and the spoil exceeds half the trench depth. If the trench sides are supported, a minimum distance of one metre is recommended.

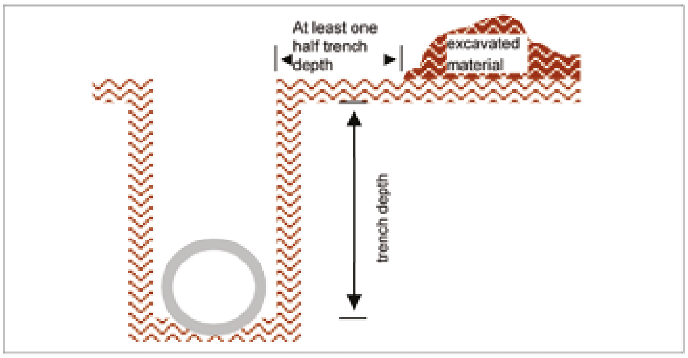

Figure 13: Placing Spoil

5.3.6 Where excavations are deep and machinery cannot reach the trench bottom or where material is unstable and requires trench sides to be battered, wide trenches with a narrow sub-trench can be used (See Figure 14). The top level of this trench should ideally be at least 300 mm above the product and its width should not exceed the specified trench width.

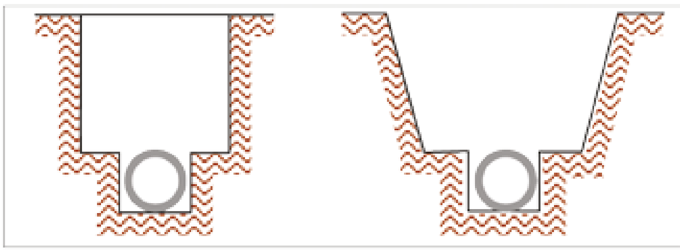

Figure 14: Wide Trench with Sub-Trench

5.4 DEWATERING

5.4.1 Water in excavations can cause several problems. Not only does it make working conditions difficult, but it hampers the progress and quality of work.

If the sides of the trench through certain materials are saturated, they could collapse without warning and cause serious injury to personnel and damage to equipment.

To avoid these problems excavations must be kept as dry as possible.

5.4.2 Storm water should be prevented from entering the excavation by forming a berm or trench around the edges to lead the water away.

Berms must be compacted or tamped down sufficiently to prevent them from being washed away.

5.4.3 When water does enter the excavations, a pump must be on hand to remove it. If this is not done, the water may soften the sides to such an extent that a collapse occurs.

Trench sides can be kept dry by placing PVC sheeting down the sides to prevent rainwater from falling directly onto them (See Figure 15). This reduces the risk of collapse.

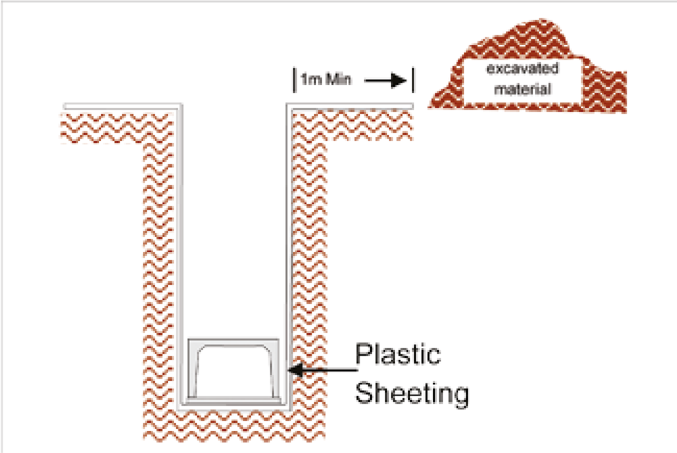

Figure 15: Protecting Trenches from Surface Runoff

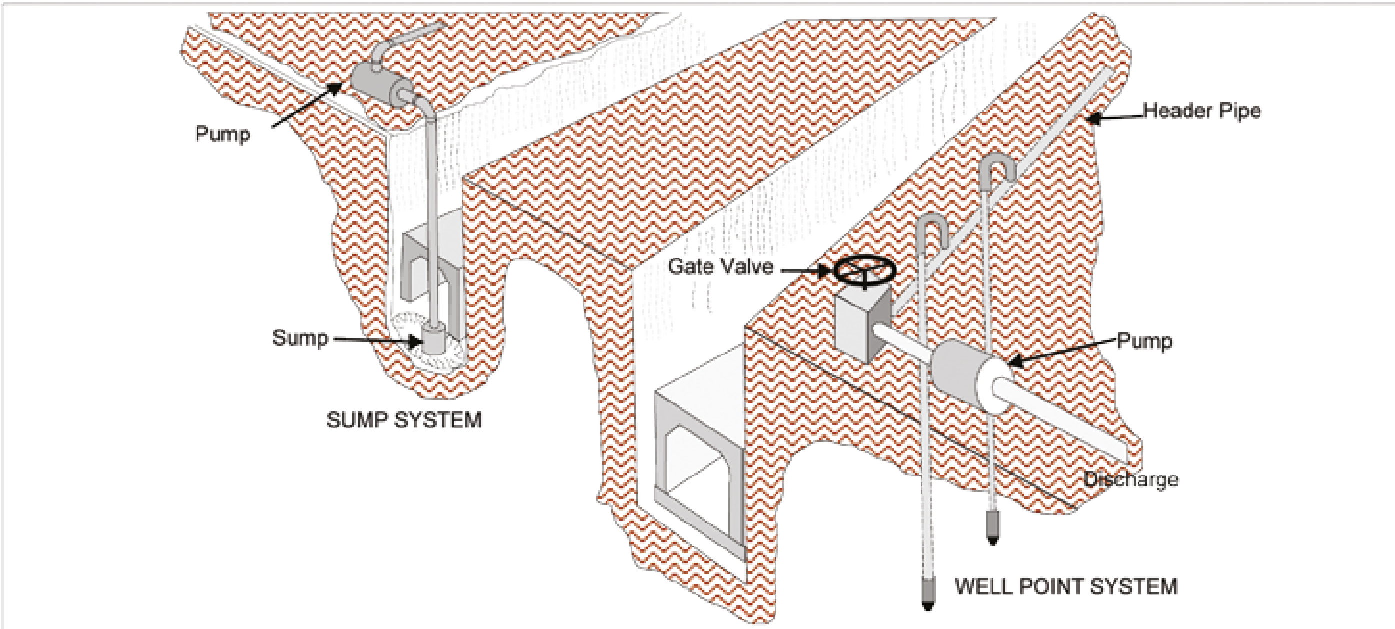

Figure 16: Dewatering Techniques

5.4.4 During the rainy season, a high water table is often encountered and water can collect in the excavation. The trench should be kept dry by pumping out any water which accumulates. Small sumps must be located at the lowest points and dug to a level below the trench floor (see figure 16). The discharge points must be well clear of the excavation so that the water does not flow back into the trench.

5.4.5 A number of different types of pumps are available for this kind of operation, but the best ones to use would be:

a) Sludge pump (Centrifugal Type). These pumps are normally self-priming and can pump very dirty water. Very little supervision is required once the pump has been started.

b) Diaphragm pump. Very reliable if properly maintained and can pump very dirty water, but with a slower pumping rate than a centrifugal type pump. Very little supervision is required once the pump has been started.

c) Air driven water pumps. They are very efficient and have a high pumping rate, but need a decent air supply. This is a drawback as this commodity is not always readily available on site.

5.4.6 As an alternative to pumps in the trench itself, a well point system (see figure 16) can be installed to suit site conditions with the points below excavated level and the discharge points well clear of the excavation area. Normally centrifugical type pumps are used for this operation.

5.4.7 Ideally any pipe or culvert installation should start at the lowest end. When possible this will reduce the reliance on the foregoing to control ground water. This starting end could be at a point where a temporary drain could be formed to lead water away from the trench.

If no outlet can be formed, the pipes or culverts already placed must be plugged or closed to prevent soil from collecting inside the line. This avoids the very costly operation of cleaning the line at a later stage.

5.5 PREPARING TRENCH BOTTOM

5.5.1 The trench bottom is the foundation for the bedding material or base slabs. It must be stable, give uniform support and have sufficient bearing capacity to maintain pipe or culvert alignment and carry the loads that will be imposed on it – it is not the bedding for the pipe or base for the culvert.

5.5.2 Mechanised means are used to removed most of the material from an excavation. The resultant width and depth is unlikely to meet the exact values specified.

5.5.3 The trench bottom should be trimmed, by hand if necessary, to ensure that the width and level are correct for installing the bedding material or base slabs.

5.5.4 The trench bottom should be checked for hard or soft sports. These could give rise to uneven settlement of bedding material or base slabs.

5.5.5 Any local hard spots should be removed and replaced with select material. This could be the material that was excavated from the trench.

The trench bottom should be levelled and compacted to meet specification requirements.

5.5.6 Any soft spots due to soil with a low bearing capacity should be modified by adding select material and working this into the subsoil until the required stability is obtained. This material can be either a granular material, lime or cement. The surface should then be trimmed to the specified level.

6. BEDDING

6.1 PURPOSE OF BEDDING

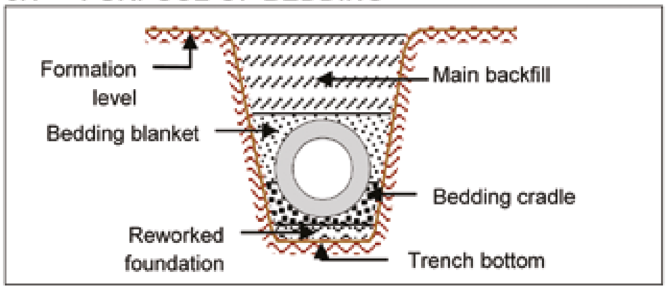

Figure 17: Terminology for Pipe Bedding

6.1.1 The terms used to describe pipe bedding are given in Figure 17.

6.1.2 The bedding serves an important function by levelling out any irregularities in the trench bottom and ensures uniform support of the barrel of each pipe.

6.1.3 The bedding is also constructed to distribute the load bearing reaction due to the weight of the backfill around the lower periphery of the pipe. The load carrying capacity of the pipe is directly related to this load distribution and several types of bedding have been established to enable designers to specify pipe strengths.

6.2 BEDDING MATERIAL

6.2.1 The material to be used for bedding should be selected such that intimate contact between the bedding and the pipe can be obtained.

6.2.2 An ideal load distribution can be realised by using granular material since it will shift to attain intimate contact as the pipe settles.

6.2.3 The granular material should be a clean, course sand or a well graded crushed rock, that flows readily into position and is free draining

6.2.4 Avoid using a well-rounded material where there is evidence of ground water, as rounded material has a tendency to flow. Hence the use of angular or uniformly graded material is recommended for high ground water conditions.

6.2.5 SANS 1200 LB states that bedding material should be granular, non-cohesive nature that is singularly graded between 0,6 mm and 19 mm.

This grading could cause a problem as surrounding natural fine material could migrate into the bedding causing the loss of support in the long term. Hence the grading of the bedding material and surrounding material should be checked to ensure that this migration will not occur.

6.2.6 When the surrounding material can migrate into the pipe bedding as shown in figure 18, due to the relative material gradings, the bedding and the pipe, should be wrapped with a geofabric to ensure that this cannot occur. This is illustrated in figure 19.

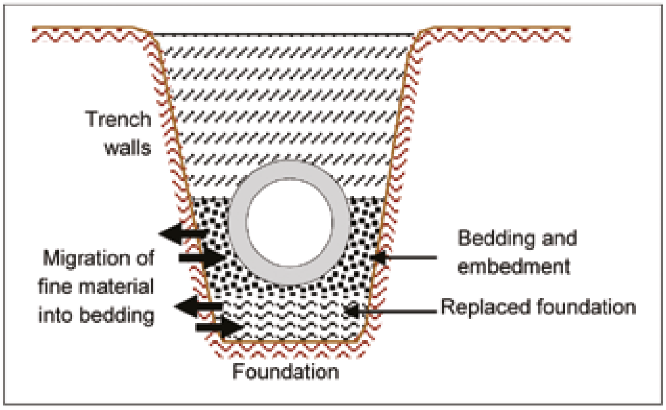

Figure 18: Horizontal Migration of Fine Material

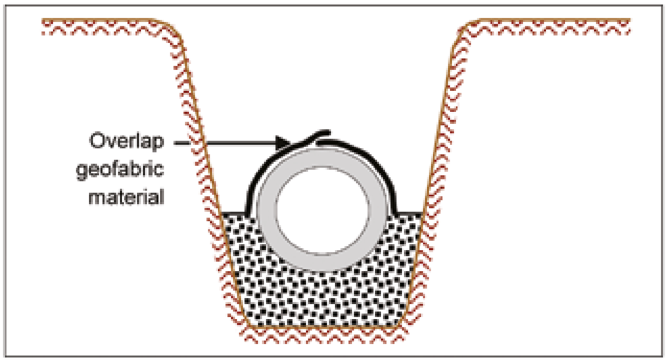

Figure 19: Geotextile Used to Prevent Migration

6.2.7 Many projects are constructed in areas where suitable bedding material as described above is difficult to obtain. In these cases the local materials should be tested to determine their compactibility factor.

6.2.8 The compactibility factor test is carried out as follows:

Apparatus

(i) Cylinder. An open-ended cylinder of length approximately 250 mm and nominal internal diameter 150 mm.

(ii) Rammer. A metal rammer of mass approximately 1 kg and having a striking face of diameter approximately 38 mm.

(iii) Rule. A steel rule graduate in millimetres

Procedure

(i) Obtain a representative sample of the material as follows:

Heap about 160 kg of the material on a clean surface, mix thoroughly, divide into two parts of approximately equal size, and discard one part.

Repeat the mixing, division, and discarding procedure until a sample of mass about 10 kg is obtained. Ensure that the moisture content of the sample is approximately the same as that of the main body of bedding material at the time that it will be used in the trench.

(ii) Place the cylinder on a firm flat surface and gently poor the sample into it, taking care not to compact the material in any way. Strike off the top surface of the material level with the top of the cylinder, and remove all the surplus material from the flat surface. Lift the cylinder up clear of its contents and place it on a fresh area of the flat surface.

(iii) Return about one-quarter of the sample material to the cylinder and tamp vigorously until no further compaction can be obtained. Repeat this procedure with each of the other quarters adding each, in turn, to the material in the cylinder and tamping the final surface as level as possible.

(iv) Measure the distance from the level of the compacted sample to the top of the cylinder and record the distance divided by the height of the cylinder as the compactibility factor of the bedding material.

6.2.9 Materials with a compactibility factor of less than 0,25 are suitable for all types of installation. Materials having higher compactibility factors require greater care in placing and compaction, and should therefore be used only with the approval of the Designer. Materials with compatibility factors greater than 0,4 should not be used.

6.3 TYPES OF BEDDING

6.3.1 The load carrying capacity of a pipe is directly related to the support given by the bedding. This support is dependent on the supporting angle of the designed bed, i.e. a support angle of 120^0 will enable a pipe to carry more load than a support angle of 40^0. It therefore follows that the Designer has a choice of many beddings. However, normal practice is to use standard beddings as given in SANS 1200 LB. The following general classification of bedding types is presented as a guideline which should be reasonably obtainable. According to current construction practice, it is generally more practical to over excavate and bed the pipe on selected material, than to shape the trench bottom to conform to the shape of the pipe.

6.3.2 Irrespective of the angle of support, or class of bedding, it is essential that the long section is uniformly supported as shown in Figure 20

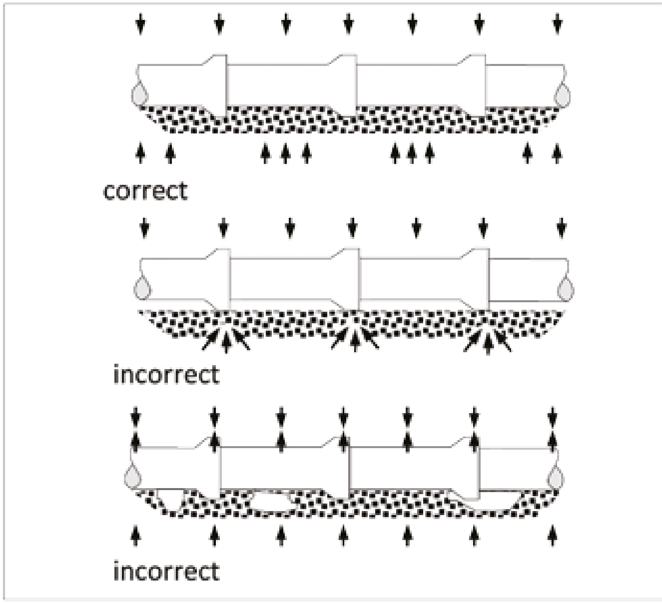

Figure 20: Uniform and Non Uniform Support

6.3.3 Bedding Class A

The pipe is normally supported on saddles or other suitable supports, spaced so that there are two supports per pipe. A soft-board strip must be placed between the pipe and the saddle. Once the line and grade have been fully checked, the concrete bedding is cast around the pipe as shown in the diagram, thus ensuring that the concrete is fully compacted under the pipe.

The concrete should be poured from one side only until it appears on the opposite side of the pipe; in this way total support of the pipe is assured. The strength of the concrete used should be 20 MPa at 28 days. Backfilling should be recommenced only once the concrete has reached a strength of 10 – 15 MPa.

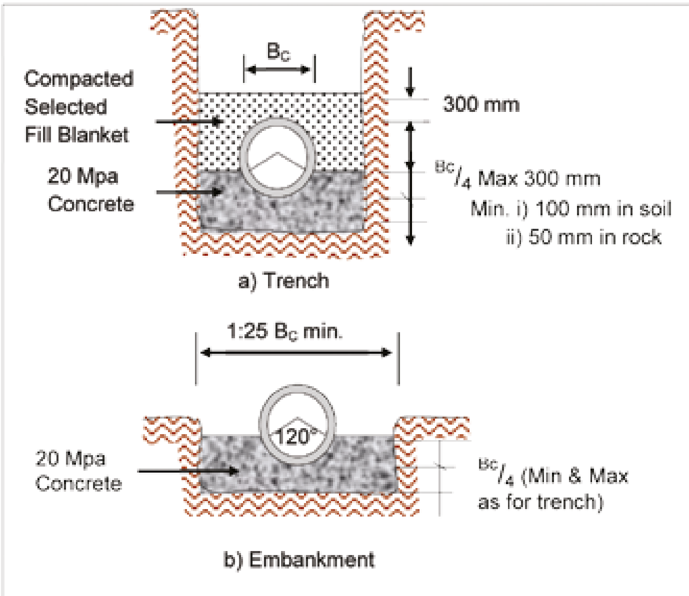

Figure 21: Bedding Class A

Embankment bedding is constructed as for a trench condition with the following additional considerations:

- the bedding should be constructed in a trench dug into the natural ground wherever this is possible;
- the projection ratio of the pipe should be kept to a minimum.

6.3.4 Bedding Class AR

The introduction of 0,4% steel reinforcement will increase the bedding factor significantly.

6.3.5 Bedding Class B

A granular bedding material should be thoroughly compacted under the pipe and around the sides of the pipe.

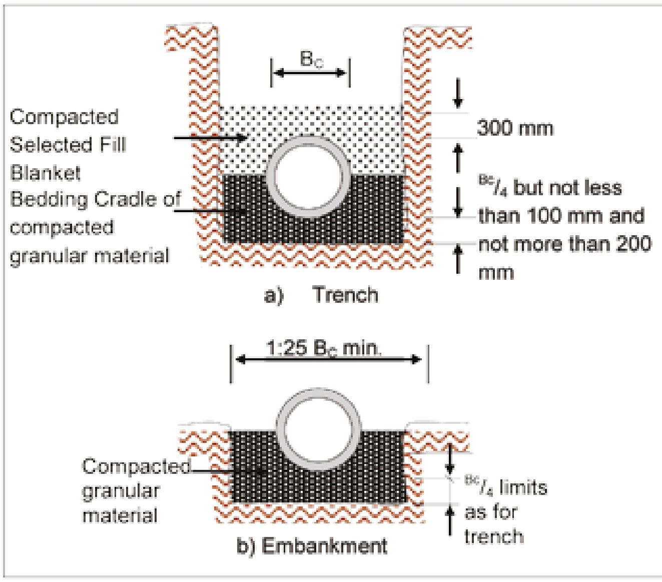

Figure 22: Bedding Class B

6.3.6 Bedding Class C

The same comments apply to Class C bedding as to Class B.

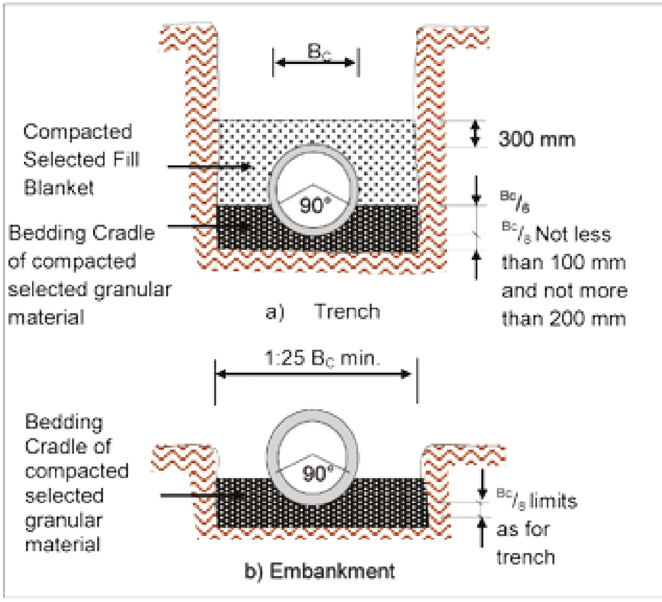

Figure 23: Bedding Class C

6.3.7 Bedding Class D

Little or no care is exercised either to shape the trench bottom to fit the lower part of the pipe exterior or to fill all spaces under and around the pipe with granular materials. However, the gradient of the line should be smooth and true to the established grade.

This class of bedding, when founded on rock, a granular cushion must be provided under the pipe. This cushion must be thick enough to protect the pipe when it settles under the influence of the vertical load, from making contact with the rock.

Before installing any pipe on a Class D bedding the Contractor should check with the Designer of the line that such a bedding was his intention.

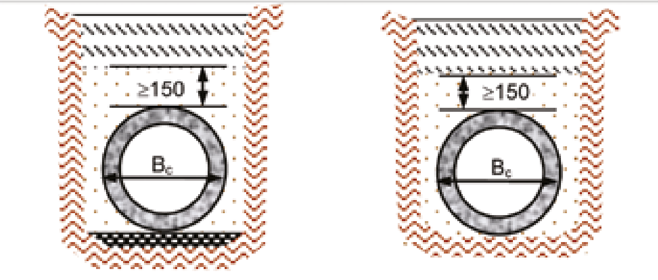

Figure 24: Class D Bedding

6.4 PLACING OF BEDDING

6.4.1 Once a stable and uniform foundation is provided, it is necessary to prepare the bedding in accordance with the requirements of the plans, specifications or standard drawings.

6.4.2 The bedding material is placed in the trench to provide the specified minimum thickness between the bottom of the pipe and the bottom of the trench.

6.4.3 This material should be checked for the presence of stones, rocks or other large particles and they should be removed.

6.4.4 The grade of the bedding should be checked for correctness and adjusted as necessary. The bedding can be brought true to grade by screeding with a straight-edge. The level of this material should be slightly higher than finally required. Once these final adjustments have been made, ensure that all the blocks or pegs used for checking the grade are removed from the bedding material.

6.4.5 With the exception of Class A Bedding, it is essential that the pipes rest uniformly on the bedding material for the full length of their barrels. To this end, the bedding material should be removed to form socket holes (refer Figure 20), ensuring that the pipes are not supported on their sockets.

6.4.6 When the pipes are placed on the bedding they will settle slightly into it. After the pipes have been placed, additional bedding material should be placed in layers not greater than 150 mm, compacted and brought up to required height around the sides of the pipe. In order to ensure uniform support along the barrel of each pipe, the bedding material is manually rammed into position beneath and around the pipes using hand-held tampers. Special care is needed to prevent the pipes from being damaged, but at the same time to ensure that no voids remain between the bedding and the pipe barrel.

6.4.7 The bedding material is compacted using equipment that is suitable to the conditions pertaining in the excavation. It is important that the compaction of the bedding material provides support around the pipe and is uniform.

6.4.8 The bedding material should be placed as shown in Figure 25a. The method shown in Figure 25b can cause severe problems because the horizontal plane is easily compacted to high density levels, and the material under the pipe is very difficult to compact, which can lead to knife-edge support.

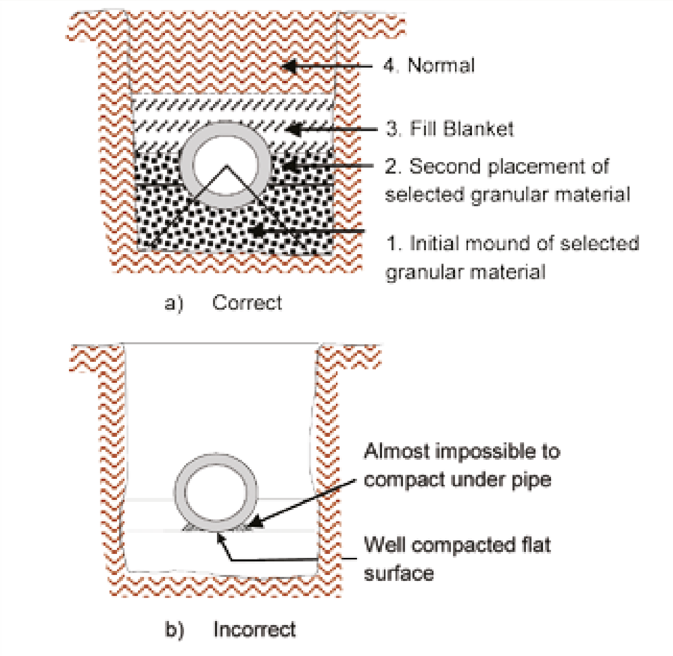

Figure 25: Construction of Bedding

6.4.9 When Class A Bedding is specified to support spigot and socket pipes, the concrete support must be discontinued at each pipe joint in order not to impair the flexibility of the pipeline. In addition, the concrete should have sufficient workability during casting to permit its flow, without excessive ramming, to all points around the pipe. This will ensure that no voids remain between the concrete and the pipe barrel.

7. PIPE LAYING

7.1 LOWERING PIPE

7.1.1 Lowering the pipe into the trench is an operation that has to be carefully planned if the laying operation is to proceed smoothly.

7.1.2 Pipes must have clear access to the trench, i.e. they must be lifted into the trench from the side away from piles of excavated material.

7.1.3 Spigot and socket pipes are normally orientated so that the spigot end enters the socket end of the last laid pipe. The lowering operation should be so organised that pipes arrive at the trench side with the correct orientation.

7.1.4 Pipes should be lowered into the trench by a lifting device, which can be controlled.

7.1.5 The most common methods are mobile cranes or pipe layers. Slings attached to excavators are also used, however, the control with this system is not as accurate as with the first two methods.

7.1.6 If mobile equipment is not available, pipes can be lowered by means of a chain block mounted on shear legs. The pipes are rolled across the trench of timbers, and the shear legs erected so that they straddle the trench. After the weight of the pipe has been taken, the timbers are removed and the pipe lowered into the trench.

7.2 LINE AND GRADE

7.2.1 Traditionally the line and grade of a pipe is determined by means of control points. These control points are usually established at 20 m centres on straight alignment and at closer centres on curves.

7.2.2 The control points are set at an equal distance from the centre line, the distance being such that the excavator can operate between them.

7.2.3 The line and level is transferred from the control point to the invert of the pipe. The transfer is normally done by measuring stick or tape.

7.2.4 Lasers are now a very common method of controlling line and grade of a pipeline. They have the advantage of providing a continuous line of light, which means that the laying can be controlled at any time.

7.2.5 The initial setting-up of the laser instrument has to be done precisely, and it is important to ensure that the instrument is carefully protected from any change due to bumping or movement. The smallest bump can cause a large deviation on a long line.

7.3 JOINTING

7.3.1 There are essentially two types of pipe joints – those incorporating a rubber sealing gasket, and those that don't.

7.3.2 The joints that do not seal are either butt-ended or Ogee-ended (self-centering with small spigot and socket ends).

7.3.3 It is sometimes required to prevent ingress of fine sand into Ogee or butt-joined pipes. This can be done by means of an external rubber collar around the joints, or by the use of a mortar coated hessian band. In the case of Ogee joints the joint gap can be filled with mortar.

7.3.4 The joints, which include a sealing gasket, are the spigot and socket, or in-the-wall joints for larger diameter pipes. Sealing gaskets can be of two types, both of which have their own method of jointing – the rolling rubber ring and the confined or sliding rubber ring joint.

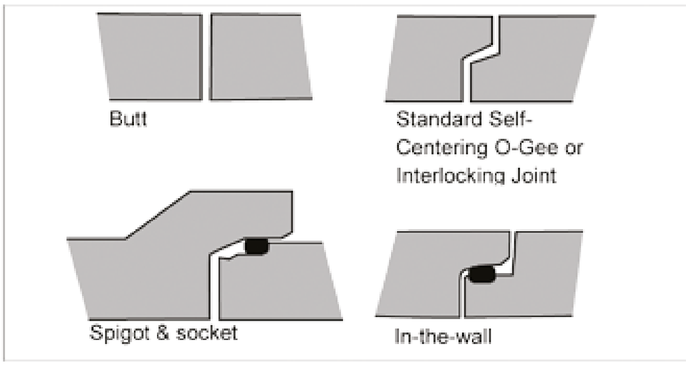

Figure 26: Standard Concrete Pipe Joints

7.3.5 Gaskets should be treated in the following manner:

i) Clean spigot, socket and the rubber ring.

ii) Stretch the rubber ring into position on the spigot end of the pipe. The ring must be seated square to the axis of the pipe, with a uniform stretch and free from kinks or twists.

iii) In the case of sliding rubber ring joints, the rubber ring should be thoroughly lubricated (with a recommended lubricant) before being placed in the groove provided for it. The socket of the pipe to be jointed should also be lubricated, paying particular attention to the lead-in taper. Only a lubricant recommended by the manufacturer should be used.

iv) On no account should lubricant be used with the rolling rubber ring joint. The spigot and socket and the rubber ring must be clean and dry to ensure that the ring rolls and does not slide.

IF THERE IS ANY DOUBT ABOUT THE TYPE OF JOINT SUPPLIED, PLEASE CONSULT THE MANUFACTURER.

v) To equalise the stretch in the rubber ring, a smooth round object, such as a screwdriver shaft, may be inserted under the ring and moved around the spigot circumference two or three times.

7.3.6 The principles of jointing all rubber gasket joints are as follows:

i) Align the axis of the pipe to be laid with that of the previous pipe and insert the spigot end slightly into the socked of the previous pipe.

ii) Pipes up to 600 mm in diameter can be assembled by means of a bar and solid wooden block across the socket of the pipe to be joined. The bar is inserted into the bedding and, using the wooden block as a fulcrum bar, is pushed forward levering the pipe into position.

Figure 27: Jointing Small Pipes

iii) Heavier pipes need to be supported by a sling at their centre of gravity in order to obtain precise vertical alignment.

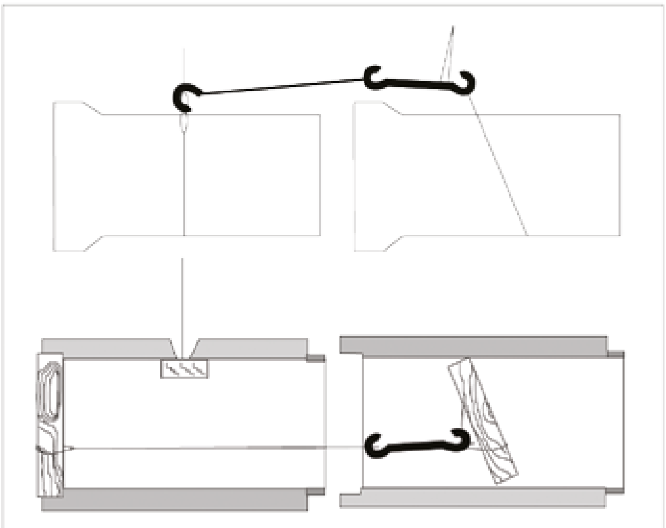

Figure 28: Jointing with Turfor

iv) Pipes are then joined by means of a Turfor or similar pulling device, again using a solid timber strongback across the socket end of the pipe, and anchored to a "deadman" timber block anchored at least four lengths, but preferably six lengths, back.

7.3.7 Where rolling rubber rings have been used, the rubber ring should have rolled back to the shoulder of the spigot, and this should be checked with a feeler gauge.

7.3.8 In order to provide flexibility to the pipeline, the pipe ends must have a uniform gap in accordance with the manufacturer's specification. If required, this gap can be filled with a flexible sealant after laying.

7.4 CURVES

7.4.1 Curves in a pipeline are normally accommodated at manholes. However, it is possible for curves of large radius to be accommodated by means of deviating the rubber ring -jointed pipes from the centre line.

7.4.2 Typical deviations and the radii of the resulting curves are given in Table 4.

7.4.3 If smaller radii of curves are required, this can be done with special pipes with deflected sockets – check with pipe manufacturer.

TABLE 4: MINIMUM RADIUS OF CURVES FOR CONCRETE PIPES

Pipe Internal diameter (mm)	Permissible angular deflection (degrees)	Minimum radius of curves for pipes 2,44 (m) long
100	6,5	21,5
150	4,5	31,0
225	3,0	46,5
300	2,0	56,0
375	2,0	70,0
450	1,5	93,0
525	1,5	93,0
600	1,25	112,0
675	1,0	140,0
900	1,0	140,0
1 050	0,75	186,0
1 200	0,75	186,0
1 350	0,5	280
and larger	0,50	280

Note: These values are for guidance and should always be checked with the manufacturer of pipes to be used.

8. PLACING PORTAL CULVERTS

8.1 GENERAL

8.1.1 The setting of line and level, and digging excavations for a portal culvert installation can be more critical then for a pipeline as deflections and changes in gradient cannot be accommodated to the same extent.

8.1.2 When the bottom of the excavations has been reached, trimmed and compacted, the base can be installed. There are two systems that can be used, namely precast or cast-in-place base slabs.

8.2 PRECAST BASE SLABS

8.2.1 The bottom of the trench should be excavated to 75 mm below the underside of the slab. This sub-grade must be compacted to the density specified and trimmed to form a true-to-grade level surface.

8.2.2 Place a layer of sand with a minimum thickness of 75 mm over this sub-grade. This sand should be levelled and lightly compacted to prevent unevenness and voids.

The base slabs are then placed on the sand true to line and level.

8.2.3 Alternatively, a wet blinding can be used as a levelling layer under the base slabs.

Prepare the sub-grade layer as described in 8.2.1 above, but in this case the level of the sub-grade should be to the underside of the base slab.

The area where the slabs are to be placed is covered with a 5:1 sand:cement mix in a slush form. The slabs are placed on this and their weight causes the slugs to be expelled from where it is not required. Once set, this slush will ensure solid and intimate contact between the underside of the slabs and the compacted sub-grade.

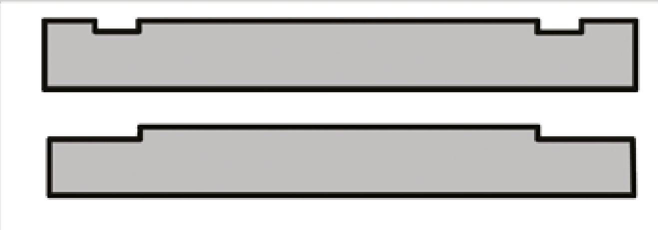

Figure 29: Precast Base Slabs

8.3 CAST-IN-PLACE BASES

8.3.1 The founding preparation for cast-in-place slabs is the same as for precast base slabs.

A layer of binding should be cast on this before placing the steel reinforcement. This prevents the soil or debris from coming into contact with it.

8.3.2 The reinforcing must be fixed as specified by the Engineer.

8.3.3 The shuttering must be erected to ensure that the specified dimensions are achieved. Provision must be made for a recess to be formed in the slab so that the bottom of the portal legs can be restrained.

8.3.4 Joints are specified at intervals in the base slabs to prevent cracking due to shrinkage and the consequent adverse effects on the culvert. Joints also allow for some flexibility should there be soil movement.

8.3.5 The type of joint and its spacing will be dependent on the founding conditions and will be specified by the Engineer.

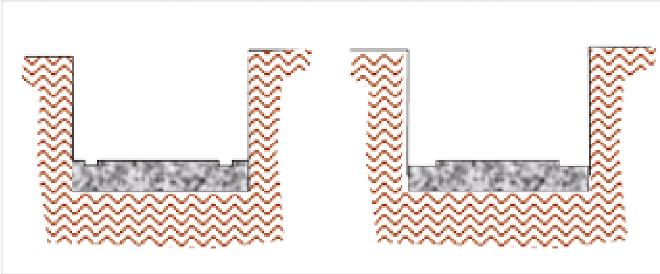

Figure 30: Cast-in-place Bases

8.3.6 Generally, culvert base slabs are cast with joints that are not watertight so that any excess water pressure (which accumulates under them) is relieved. (See Figure 30.)

8.3.7 For certain applications it may be necessary to have joints in the base slab which are watertight. This can be achieved by using a cast-in-water stop, or a mastic type sealant placed after casting.

8.3.8 Base slabs are generally cast in alternate sections to ensure discontinuity at the joints. Typically alternate sections would be cast at the same time and the intermediate sections cast when these have been stripped.

8.4 PLACING CROWN UNITS

8.4.1 Portal culverts should be aligned along their centre line and not along their legs. By doing this, the effect of any dimensional tolerances on the inside of the culvert legs will be minimised.

8.4.2 If necessary, the crown units should be marked at the centre with a chalk mark (this is seldom done).

8.4.3 The centre line can be marked along the base by using concrete nails or stringing a fishline.

8.4.4 A 3:1 sand:cement mortar should be placed in the recesses in the base slabs before the culvert is lowered.

8.4.5 The culvert should be lifted using the lifting equipment and applying the simple rules described in Clause 3.7.

8.4.6 The culvert should be lowered over the base slabs, centrally aligned and then placed onto the wet mortar. The latter will fill any level discrepancies and ensure continuous support under the portal legs. Excess mortar should then be trowelled off and made level with the base slabs.

8.4.7 The end of the culvert units must not be butted directly against each other. A gap of 10 mm should be left between each unit. If necessary, this can be sealed at a later stage.

8.4.8 When placing culverts on precast slabs, it is advisable to have the portal joints out of phase with the base joints. This gives a certain degree of interlocking between the crown and base units should there be any soil movement.

8.5 JOINT SEALING

8.5.1 Joints between crown units are generally sealed to prevent the ingress of soil and the consequent silting along the culvert invert. For certain applications, it may be necessary to make the culvert watertight.

8.5.2 Joint sealing with mortar is a proven and accepted method providing it is done correctly.

The mortar must be a dry 3:1 sand:cement mix, tamped solidly into the joint and smoothed off. Other methods of sealing joints although expensive are more effective. See figure 31 (b).

8.5.3 A heavy gauge PVC tape stuck over the outside of the culvert joints is the most frequently used alternative in SA. See figure 31 (c).

This tape is coated on one side only with a very strong adhesive and is applied after the culverts are placed. To ensure that an adequate bond is obtained the concrete surface must be clean and dry before the tape is applied.

8.5.4 Neoprene/rubber sealants have been used extensively in Europe and America. They can be applied either before or after the culverts have been placed

When fixed into the joint after the portals have been placed, it is essential that the size of joint gap be consistent so as to accept the sealant. In both in-stances the jointing material must be firmly attached to withstand external water pressure. See figure 31 (d).

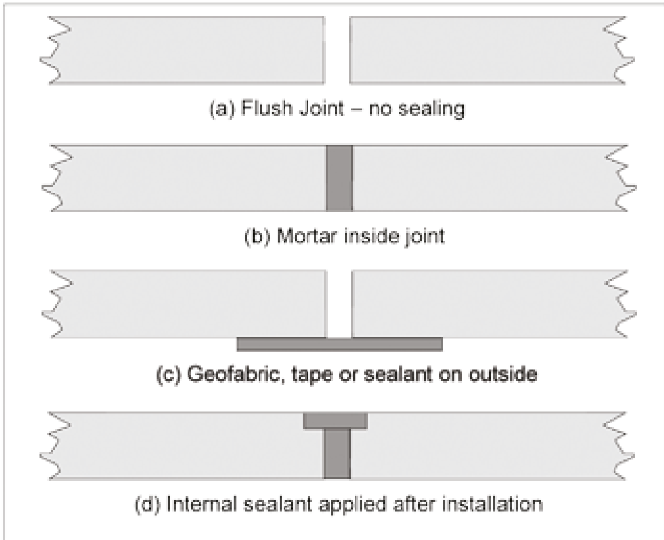

Figure 31: Culvert Joints: Sealing and Drainage

8.5.5 Self-adhesive type sealants are applied by fixing to one of the jointing faces before a culvert is placed. This method is not suited to culverts which are made with butt joints.

8.5.6 In areas with a high water table, the culvert may serve as a subsoil drain. To prevent the ingress of soil through the joints, they are covered with Bidem or a column of no fines concrete. Under these circumstances no fines blocks, which act as water collectors, should be placed on these slabs along the entire length of the culvert to act as water collectors. (See Figure 32.)

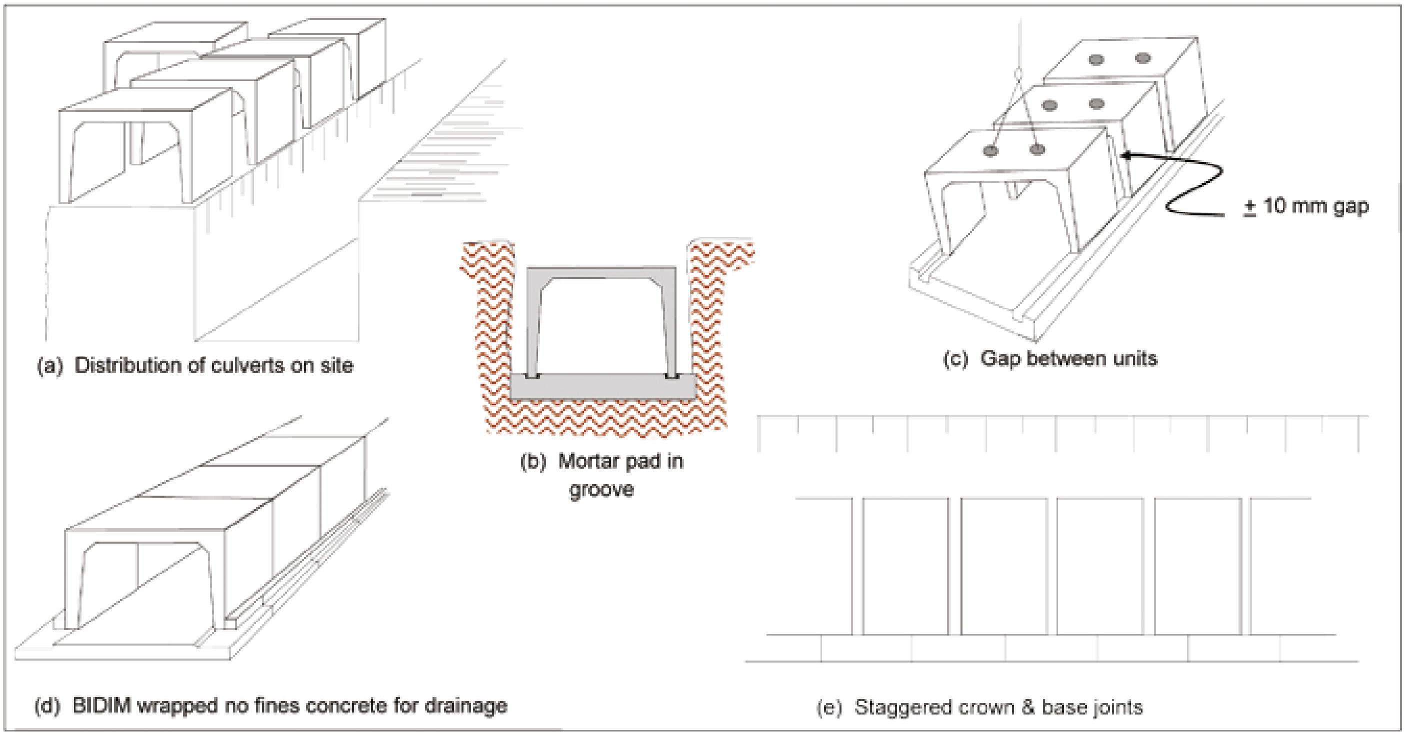

Figure 32: Placing Culvert Crown Units

9. BACKFILLING

9.1 GENERAL

9.1.1 The load carrying capacity of a pipe culvert is dependent upon the lateral support of the side fill material.

This must be carefully placed so that there are no voids in it and to a density sufficient to give the required lateral support.

9.1.2 Compaction of the side fill should be to 90% modified AASHTO. This may be achieved by hand tamping, pneumatic or mechanical compacting equipment. Impact tampers are normally used for cohesive (clay) soils, while vibration is usually more effective for granular soils. Where impact tampers are used, care must be taken to prevent damage to the pipes or culverts.

9.2 FINAL BACKFILLING

9.2.1 Once the initial backfill has been completed, the remained of the fill should be completed in layers not exceeding 300 mm in thickness compacted to specified density.

9.2.2 Where the trench crosses a road or may have to support a future structure, the backfill may be placed in layers not exceeding 150 mm in thickness and compacted in the same density as the road layers.

9.2.3 When the side fill has been completed, backfilling should continue until the selected fill blanket is placed and completed to the required thickness (usually 300 mm minimum) above the top of the pipe or culvert.

9.2.4 Heavy compacting equipment should not be used directly over the pipe or culvert until a minimum of 0,6 metre of backfill has been placed.

9.2.5 Backfilling should be completed as soon as possible after pipelaying. This will protect the pipe and reduce the risk of pipe floating if the trench becomes flooded.

9.3 TECHNIQUES FOR BACK-FILLING CULVERTS

9.3.1 When using granular backfilling, this should consist of selected granular material, placed in layers not exceeding 150 mm in thickness.

9.3.2 To avoid sway caused by unsymmetrical loading, backfilling should take place simultaneously in equal lifts on both sides of the culvert.

9.3.3 On many road projects the bulk earthworks are completed before the stormwater drainage is installed.

When this happens the trench cut through the fill should be as narrow as possible. An alternative to allow clearance either side of the culverts for compaction equipment is to dig the trench about 200 mm wider than the culverts and backfill with a soilcrete or lean mix concrete.

9.3.4 When the height of the culvert exceeds 1,5 m, props must be placed between the legs during the backfilling operation to prevent the generation of high moments and subsequent cracking along the inside of the legs (see Figure 33).

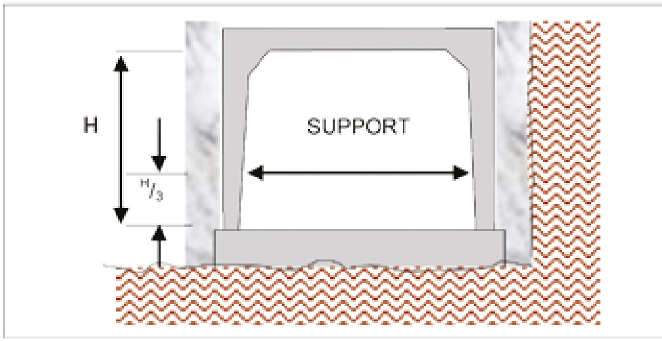

Figure 33: Support During Backfill

9.4 MULTIPLE CELL CROSSINGS

9.4.1 Multiple cell installations are used when large quantities of water have to be conveyed under a road with a low fill height.

9.4.2 The parallel barrels of culverts are placed with a space of about 100 mm between them. This is backfilled with a soilcrete or lean mix concrete to ensure that there is adequate lateral support to the culverts (see Figure 34).

9.4.3 When culverts with long legs are being backfilled, it is essential that the legs are propped as the vibrated concrete exerts considerable lateral pressure (see Figure 33).

9.4.4 If ribbed portals are installed in multiple cells, the ribs can be butted against each other to reduce the amount of backfilling required.

9.4.5 The outside edges of the multiple cell crossings are backfilled in the same manner as the single cell crossings.

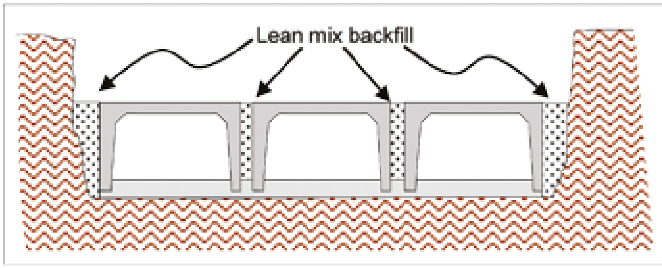

Figure 34: Multiple Cell Crossings

10. SPECIAL CONDITIONS

10.1 STEEP GRADIENTS

10.1.1 In the case of steeply inclined pipelines, it is necessary to provide transverse anchors to prevent movement. This can be done by casting concrete blocks of suitable dimensions at appropriate points along the line. The spacing of transverse anchors depends on the gradients of the pipeline and the nature of the ground.

10.1.2 Precautions should also be taken to ensure that any surface water, capable of undermining the pipes, is prevented from entering the open trench.

10.1.3 It is advisable, before backfilling the trench, to install water stops perpendicular to the pipeline axis at suitable points in the trench to prevent the bedding and backfill being washed down the slope.

10.1.4 The choice of type and spacing of anchorage and any necessary additional requirements must be determined by the pipeline designer.

10.2 UNSTABLE GROUND

10.2.1 Should the Contractor discover unstable ground in the form of running sand, etc., which was not anticipated in the specification, it is essential that the designer be informed.

10.2.2 There are a number of solutions to the problem including:

i) Continuous support on pile caps, which is expensive, but may be required where the gradient is critical.

ii) Treatment of the material beneath the trench to improve stability.

iii) The use of short length pipe which will allow for greater angular distortion.

10.3 PASSING THROUGH RIGID STRUCTURES

10.3.1 If a pipeline must pass through walls, manholes, or concrete blocks, it is desirable to ensure that the pipes are not rigidly held.

10.3.2 This is normally achieved by passing through the wall of the structure a very short length of pipe such that there are flexible joints adjacent to the wall. Short lengths should also be jointed to the main line immediately before and after passing through the wall.

10.3.3 The objective of these measures is to cater for possible differential settlement between the pipe and the structure.

10.4 ANCHOR BLOCKS

10.4.1 Suitable concrete anchor blocks should be provided in the pipeline wherever unbalanced forces occur – for example, at bends, tees, crosses and valves. These would take the form of concrete blocks cast in the trench around or under the fittings, and extending to the undisturbed trench wall.

10.4.2 The dimensions of anchor blocks will depend on the nature of the ground and the magnitude of the unbalanced forces and should always be specified by the designer.

10.5 ELLIPTICALLY REINFORCED PIPES

10.5.1 Where concrete pipes with elliptical reinforcement are used, they must be installed with the manufacturer's marks indicating the top of the pipes in the vertical direction. Once installed, the 'Top' marks should not be more than 5^0 away from the vertical.

10.5.2 Elliptically reinforced pipes are usually made with a lifting hole at top dead centre and this should be used for handling them.

10.6 FLOTATION

10.6.1 In areas with a high water table and low cover, such as when crossing flood plains or swamps, it is important to consider the possibility of flotation.

10.6.2 The mass of water displaced by the pipe is equal to the volume of water displaced by the pipe, (i.e. 1 kg water = 1 litre water). Should the mass of the pipe be less than the mass of water displaced flotation will occur.

10.6.3 Additional mass must be provided via ballast, which normally comprise concrete encasement or precast sections laid on top of the pipe.

11. FIELD TESTING

11.1 WATER TEST

11.1.1 Pipelines consist of pipes and joints. Concrete pipes used for sewers and low-pressure pipelines are load and hydrostatically tested at the factory before delivery to site to ensure that they will meet the structural requirements specified. As the pipes are jointed on site they need to be tested on site to ensure that the pipeline will meet its operating requirements. Apart from a visual inspection the only field-testing needed on a concrete pipeline is one for leakage. This gives the assurance that the installed pipeline will meet the water tightness requirements.

11.1.2 The water test is carried out as follows:

(i) Close the section of pipeline to be tested with bulkheads or plugs. As these will be subject to considerable forces they should be designed and installed to ensure that they can withstand these with an adequate safety factor.

(ii) Open the air valves and slowly fill the test section with water to ensure that all the air escapes.

(iii) Keep the test section under a slight pressure for 3 to 5 days to allow the pipes to absorb water

(iv) If pipes were exposed for more than a month additional time may be needed for this.

(v) During this period check the sealed ends and joints for leaks and the rate at which water has to be added to maintain the pressure.

(vi) When the rate of adding water stabilises increase the pressure to the required value.

11.1.3 SANS 1200-LD prescribes that sewers should be tested with a water head of not less than 1.2 m and not more than 6.0m. The period over which the loss is to be measured should be 30 minutes. The loss allowance prescribed is not more than 6 litres/100mm of pipe diameter/100m/hour.

11.1.4 Pressure pipelines are tested in the same way but the requirements are more stringent. A testing schedule that gives the pressure for each section should be compiled to ensure that the lower class pressure pipes are not overstressed.

11.1.5 The full-scale water testing of large diameter sewers and pipelines is a difficult and costly exercise. When available, special joint testing equipment that applies water pressure to one joint at a time is used. This equipment has to be used with care and it should be appreciated that it is not testing the joint that has already been factory tested, but the jointing that has been done on site. Hence the pressures used are not the same as those for which the pipeline is rated. In most cases when a sewer is man entry (≥900 mm in diameter) and below the water table as frequently occurs with this size, it can be physically inspected from inside to check for leaks.

11.1.6 Concrete has the property of autogenous healing and hair cracks or damp spots should not be cause for rejection, as this type of leakage will be stop within days of the pipe surface being exposed to a moist environment.

11.2 AIR TESTING

11.2.1 The water testing of sewers is seldom practical especially in a country as South Africa where water is scarce and may not be available for the testing of sewers. Air testing of concrete sewers is an effective way for identifying isolated sections that are leaking as poor joints or damaged pipes. As air and water have different properties this test is not an indicator of the water tightness of the pipe wall. This testing can therefore be used as an acceptance test but not as justification for rejection. If there is a dispute the final acceptance or rejection of a sewer should be based on a water test.

11.2.2 This test is conducted in a similar way to the water test. However as the intention of this is to find isolated problems the air pressure inside the section being tested is only just above atmospheric. The procedure followed is:

(i) Seal the ends of the section to be tested with bulkheads or plugs; making sure that the safety factor of blow out to test pressure is at least 2.

(ii) One of the bulkheads is fitted with connections to an air source, a pressure release valve and a pressure gauge or monometer.

(iii) Air is added to the test section to increase the internal pressure to a prescribed amount above atmospheric. This must allow sufficient time for this to stabilise, as there may be differences between the air and pipe wall temperatures.

(iv) Once the air pressure within the test section has stabilised the air supply is stopped and the time in seconds that it takes for a given pressure drop is measured. The rate of air loss is then calculated.

11.2.3 The sewer is then inspected to determine whether there are any joints or damaged

sections that are leaking. These leaks can usually be identified by the sound of escaping air. If no localised leaks are identified and the rate of pressure drop is unacceptable the exposed sewer is sprayed with soapy water to help find any problem areas. Leaking joints or damaged sections of pipe must be repaired using means that are approved by the project engineer.

11.2.4 Section 7 of SANS 1200-LD prescribes the pressures and procedures that should be used for the air testing of sewers namely:

(i) An initial pressure of 3.75kPa(375mm of water)

(ii) Once the pressure stabilises, reduce it to 2.5kPa(250mm of water)

(iii) Switch off the machine and measure how long it takes for the pressure to drop to 1.25kPa(125mm of water)

(iv) The minimum acceptable time for this drop to take place is 2 minutes/100mm diameter

11.2.5 Whenever possible defects should be repaired with the pipes in place. Only when pipes have been incorrectly installed or there has been damage due to soil movements should the replacement of pipes be considered. If this is necessary it must be done from manhole to manhole so that the whole installation is redone and the possibility of relative settlement between sections of sewer is eliminated.

11.2.6 Should the spraying of soapy water on the exposed pipe show sections of pipe were bubbles form this will probably be due the pipes having dried out as a result of being exposed for prolonged period (in excess of 6 weeks). When these pipes are exposed to the moist sewer atmosphere the concrete will take up moisture and the microstructure will seal.

11.3 SOIL DENSITY TEST

11.3.1 In South Africa where the specifications call for minimum densities of backfill or bedding material, these are normally given as a percentage of the Modified AASHTO Density. The test is carried out as follows:

(i) Samples of the material to be used are obtained

(ii) Each sample is dried and the prepared at various moisture contents

(iii) For each of the moisture contents five layers are compacted in a 0.95 litre mould

(iv) Each layer receives 25 blows from a 4.54 kg hammer falling from 457 mm

(v) Each sample is dried in an oven and the dry density calculated

(vi) A graph of moisture content versus dry density is plotted and the optimum moisture content determined

(vii) The optimum moisture content is the moisture content corresponding to maximum dry density. This maximum soil density is referred to as the Modified AASHTO Density.

11.3.2 When the material around pipes is placed it is essential that is provides the required bedding support as well as stability. This means that once the pipes are placed and the bedding and backfill compacted that there should be little or no further settlement or movement of the material in the trench. It is therefore important to understand the differences between compaction and consolidation.

11.3.3 Compaction is the pushing together of soil particles by squeezing out the air in the soil. This is done by various means, such as by rolling, ramming, or vibration that reduces the amount of air in the soil thus increasing its density. Consolidation is the gradual squeezing out of water from the pores of a saturated material by pressure with time. This is accompanied by a reduction in volume. This happens with clayey materials and the process can be reversed when this type of soil absorbs water and expands. Such materials are subject to movement and are unsuitable for pipe bedding.

11.3.4 Compaction is used to improve the desirable properties of soil surrounding pipelines. These properties are:

- High shear strength
- Low permeability and water absorption
- Minimum or no settlement under repeated loading

11.3.5 To achieve these by the compaction of a given soil at minimum cost requires knowing about the:

- Compaction of the undisturbed soil
- Maximum compaction that can be obtained
- Proportion of this maximum compaction achievable

11.3.6 A material's degree of compaction is measured by its dry density. This is given by:

$$\gamma_d = \frac{\gamma}{1+m}$$

Where γ_d - dry density

γ-bulk density of material

m – moisture content

11.3.7 When all the air has been removed from the soil and the voids are full of water the soil has reached saturation. Given the moisture content the saturated dry density can be calculated from the specific gravity of the particles. As this is an unrealistically high standard, a lower value is chosen as the maximum compaction achievable.

11.3.8 The Proctor Test was developed to measure the relationship between dry density and moisture content for a particular compactive effort. However, with the development of compaction equipment that was capable of producing high densities this test was replaced by the modified Proctor Test that was more suitable for modeling the actually sites compaction obtained. In the United States the standard Proctor and modified Proctor are the same as the standard and modified AASHTO as covered by ASTM standards. When dealing with pipelines the use of heavy compaction equipment in close proximity to the pipes can damage them, so lighter equipment is used and the Standard AASHTO densities are specified in the American literature and standards.

11.3.9 For this test samples of soil are compacted in layers in a standard mould using a standard weight dropped through a given distance and the density at several moisture contents determined. The dry density is plotted against moisture content and a curve drawn to obtain the optimum moisture content as shown in Figure 35.

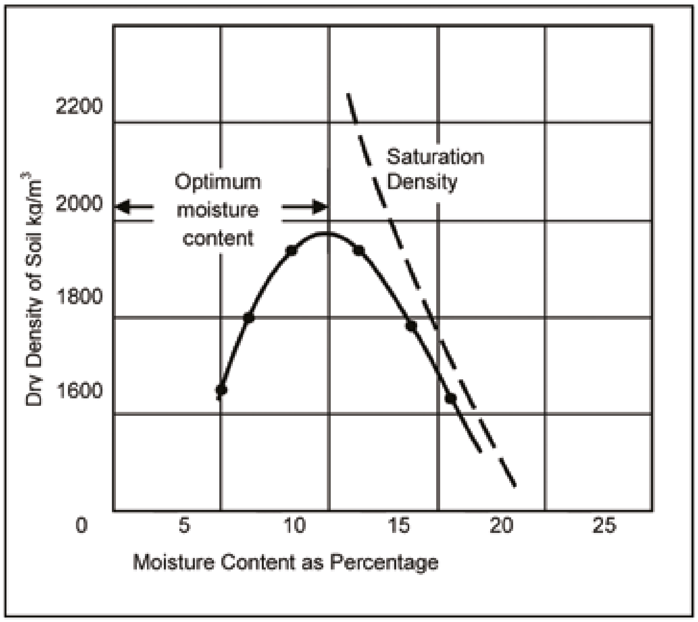

Figure 35: Moisture/Density Relationship for a Soil

11.3.10 When soil is wet it is possible for the standard number of blows to considerably reduce the few voids not filled with water. The dry density reached may thus approach the saturated dry density. On the other hand, when the moisture content is low the theoretical saturated dry density is high. No amount of compactive effort is sufficient to eliminate the air voids, as there is insufficient moisture to lubricate the particles to pack closer together. The final dry density reached may thus not be quite as low as the particles are not as close together as when the soil is wet. At an intermediate point the moisture content is optimum and the standard compaction results in a maximum dry density. This is known as the *optimum moisture content*. The maximum dry density and the optimum moisture content are not fundamental soil properties. They depend upon the compactive effort applied. The compaction required on site is expressed as a percentage of that obtained from the test.

11.3.11 Density tests are done on the compacted backfill or bedding material on the site and then compared to the Modified Proctor Density to check that these materials have been placed to the required densities.

11.3.12 It is important to appreciate that although thte standard AASHTO density test and the modified AASHTO density test are similar, that the test results are not numerically changeable. The relationship between the two test results is dependant upon both the type of material and the degree of compaction.

The 'Concrete Pipe Technology Handbook' (47p.p.4-8;4-10) gives a useful relationship between the two densities that is produced as Table 5.

TABLE 5: RELATION BETWEEEN STANDARD AND MODIFIED AASHTO DENSITIES

Specified Standard Proctor ASTM D 698 AASHTO T 99 %	Equivalent Modified Proctor ASTM D 1557 AASHTO T 180 %
Soil groups 1 and 2	
100	95
95	90
90	85
85	80
80	75
Soil group 3	
100	90
95	85
90	80
85	75
80	70

Notes:

a) Group 1 soils are graded granular sands

b) Group 2 soils are non-plastic silty sands

c) Group 3 soils are silty clays

11.3.13 Achieving the 90 % mod AASHTO density as normally specified is not a problem with the group 1 and 2 soils using light compaction equipment. However, to achieve this on the group 3 materials could prove to be difficult due to the high clay content. Cohesionless, free draining materials should be used for pipe bedding as they can be compacted in confined spaces with light equipment.

11.3.14 Such materials will remain stable once placed and compacted. With cohesive materials a great degree of compaction is needed which requires a greater compactive effort, to ensure that the material around the pipelines remains stable. Because such material is more difficult to compact the effect of this greater amount of energy needed could result in damage to the pipes.

12. SPECIAL APPLICATIONS

12.1 JACKING INSTALLATIONS

12.1.1 The jacking of pipes and culverts is becoming increasingly more important as the cost of surface disruption in cities and of major road and rail routes continues to increase (see Figure 36b).

12.1.2 Well conceived and designed jacking operations can result in the installation of concrete pipe and culvert under railway lines or highways with no disruption to the traffic flow.

12.1.3 Jacking should be undertaken only by firms with specialist experience and knowledge. For this reason those sections that could be jacked with advantage, should be identified early in the project.

12.1.4 It is important to supply the specialist Contractor with comprehensive geotechnical information and full details of the adjacent underground services.

12.1.5 Specially designed pipes or culverts are required for the jacking process and these must be discussed with the manufacturer early enough to enable modifications to be made.

12.1.6 This technique involves:

(i) Excavating a pit at beginning and end of proposed line.
(ii) Constructing a launching pad in entry pit
(iii) Pushing a jacking shield against the face of the pit
(iv) Tunnelling through the soil while being protected by the jacking shield by making an excavation slightly larger than the shield just ahead of it
(v) Pushing conduits into the tunnel as it progresses
(vi) Grouting the space left between the outside of the conduit and the tunnel.

12.1.7 With a jacked installation the vertical load on the conduits will be significantly less than that experienced in a trench installation. However the longitudinal stresses in the pipes will be much higher than those on a pipe installed in an open excavation. It may therefore be necessary to use pipes with thicker walls to handle these forces.

12.2 INDUCED TRENCH INSTALLATIONS

12.2.1 The induced trench installation is a special technique used to increase the height of the fill that can be carried by standard strength conduits under very high embankments (see Figure 36(a)). The procedure followed is to:

(i) Install the conduit as normally done in an embankment installation
(ii) Backfill over it to the required height
(iii) Dig a trench of the same width as the outside dimension of the conduit down to ± 300mm from the top of the conduit
(iv) Fill the sub-trench with a compressible material as straw or sawdust

(v) Complete backfilling up to formation level as for a standard embankment installation.

12.2.2 The yielding material in the sub-trench settles and thus produces frictional forces that reduce the load on the conduit. The deeper the sub-trench the higher the frictional forces developed and hence the greater the reduction in load to be carried by the conduit.

12.2.3 Under very high fills, where standard pipe/bedding class combinations or portal culvert classes are inadequate to cope with the earth loads standard product classes are used and the sub-trench depth is adjusted to reduce the load to the required value. An important fact to appreciate with this type of installation is that the settlement in the sub-trench must not be so great that the top of the formation settles. In other words there must be sufficient fill over the conduit to allow the plain of equal settlement to form below the top of the formation. Details of this are shown in Figure 36(a) below

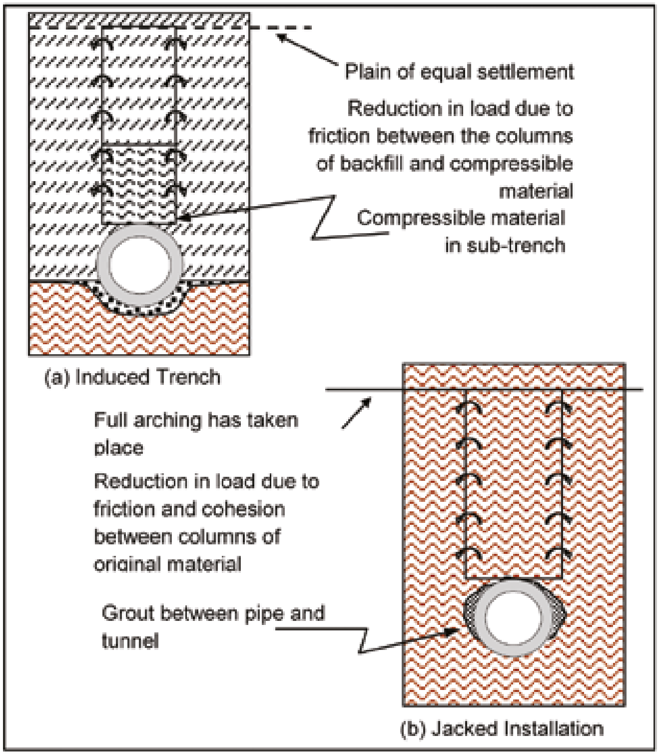

Figure 36: Special Installations

The procedure for calculating the depth of sub-trench is given in SANS 10102 Part I. The designer should not use this procedure without first doing a detailed study.

13. CONCLUDING COMMENT

The satisfactory performance of any buried conduit is dependent upon the quality of decisions made in the design office, the quality of the products supplied to site and the quality of workmanship on site.

It is essential that the designer's requirements are clearly stated in the project specifications so that the supplier knows what requirements the products must meet and the contractor knows how the products should be installed.

By correctly applying the principles stated in this handbook and its companion volume the "Concrete Pipe and Portal Culvert Handbook" precast concrete pipes and portal conduits should
14. provide a service life in excess of a 100 years

13. REFERENCES

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Photograph on front cover of 900mm diameter spigot and socket pipes with dolomitic / calcium aluminate cement sacrificial lining on the Moreleta Outfall Sewer 2009. Client – City of Tshwane; Consultant – Aurecon; Contractor – Cerimele Construction.

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