



Engineering

Technical Guideline TG0637

General Technical Information for Geotechnical Design - Pipelines

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Significant/Major Changes Incorporated in This Edition

This is the first issue of this Technical Guideline under the new numbering format. The original version of the document was last published in 2007 with the name of General Technical Information for Geotechnical Design Part J – Pipelines (TG 10j). A full version history of this document is given in Document Controls. The major changes in this revision are listed in the following table:

Section No. in TG 0637	Section No. in TG 10j	Changes
TG0637 – 3	TG 10j – 5	Major Revision
TG0637 – 4	TG 10j – 6	Minor Revision
TG0637 – 5	TG 10j – 9	Major Revision
TG0637 – 6	TG 10j – 7	Minor Revision
TG0637 – 7	N/A	New Section
TG0637 – 8	N/A	New Section
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TG0637 – 10	TG 10j – 10	Minor Revision
TG0637 – 11	TG 10j – 13	Minor Revision
TG0637 – 12	TG 10j – 15	Major Revision
TG0637 – 13	TG 10j – 16	Minor Revision
TG0637 – 14	TG 10j – 17	Minor Revision
TG0637 – 15	TG 10j – 22	Major Revision
TG0637 – 16	TG 10j – 2	Major Revision
Note: Sections 3, 4, 11, 12, 14, 18, 19, 20, 21, 23, and 24 of TG 10j are superseded by the present TG 0637.		

Document Controls

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1 Introduction

SA Water is responsible for operation and maintenance of an extensive amount of engineering infrastructure.

This guideline has been developed to assist in the design, maintenance, construction, and management of this infrastructure.

1.1 Purpose

The purpose of this guideline is to detail minimum requirements to ensure that assets covered by the scope of this guideline are constructed and maintained to consistent standards and attain the required asset life.

1.2 Glossary

The following glossary items are used in this document:

Term	Description
AHBP	Allowable Horizontal Bearing Pressure
CLSM	Controlled Low Strength Materials
MMDD	Modified Maximum Dry Density
MSCL	Mild Steel Cement Lined pipe
SA Water	South Australian Water Corporation
SMDD	Standard Maximum Dry Density
TG	SA Water Technical Guideline
TS	SA Water Technical Standard
WSAA	Water Services Association of Australia
WSCM	SA Water's Water Supply Construction Manual

1.3 References

1.3.1 Australian and International

The following table identifies Australian and International standards and other similar documents referenced in this document:

Number	Title
AS 1289.5.3.1 – 2004 (R2016)	Methods of testing soils for engineering purposes - Soil compaction and density tests - Determination of the field density of a soil - Sand replacement method using a sand-cone pouring apparatus
AS 1289.5.4.1 – 2007 (R2016)	Methods of testing soils for engineering purposes - Soil compaction and density tests - Compaction control test - Dry density ratio, moisture variation and moisture ratio
AS 1289.5.6.1 – 1998 (R2016)	Methods of testing soils for engineering purposes - Soil compaction and density tests - Compaction control test - Density index method for a cohesionless material
AS 1289 5.8.1 – 2007	Methods of testing soils for engineering purposes - Soil compaction and density tests - Determination of field density and field moisture content of a soil using a nuclear surface moisture–Density gauge - Direct transmission mode
AS 2566.1– 1998 (R2018)	Buried flexible pipelines – Part 1: Structural Design, with Amendment No. 1, August 2017
AS 2566.2 – 2002 (R2016)	Buried flexible pipelines – Part 2: Installation, with Amendment No. 1, Reconfirmed 2016
AS 3725 – 2007	Design for installation of buried concrete pipes, January 2007
WSA 03 – 2011	Water Supply Code of Australia, WSAA, Version 3.1, 2011

1.3.2 SA Water Documents

The following table identifies the SA Water standards and other similar documents referenced in this document:

Number	Title
TS 4	Packing Sand for Pipe Laying and Trench Fill
TS 0460	Liners and Floating Covers for Earth Bank Storages for Potable or Recycled Water

1.4 Definitions

The following definitions are applicable to this document:

Term	Description
SA Water's Representative	The SA Water representative with delegated authority under a Contract or engagement, including (as applicable): <ul style="list-style-type: none"> • Superintendent's Representative (e.g. AS 4300 & AS 2124 etc.) • SA Water Project Manager • SA Water nominated contact person
Responsible Discipline Lead	The engineering discipline expert responsible for TG 0637 defined on page 3 (via SA Water's Representative)

2 Scope

The scope of this document is to provide guidelines on geotechnical aspects of pipeworks for design and construction of SA Water infrastructure.

3 Pipe Embedment – How it works

Installation of pipeline in trenches is the most common way of pipe installation in SA Water assets portfolio. Figure 1 below shows the typical cross section of pipeline in trenches, taken from AS 2566.1. Selection of proper embedment materials is an important element in design and construction of pipeworks in trenches.

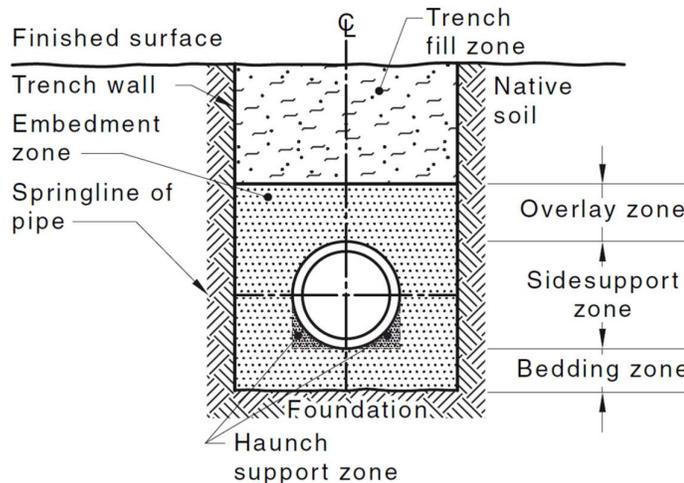


Figure 1: Terminology of buried flexible pipelines, taken from AS 2566.1

The embedment material surrounding a pipe is comprised of the following zones:

- Bedding: the zone between the foundation and the bottom of the pipe,
- Haunch support: the part of the side support below the spring line of the pipe,
- Side support: the zone between the bottom and the top of the pipe,
- Overlay: the zone between the side support and either the trench fill or the embankment fill.

Flexible pipelines rely on embedment materials to resist vertical loads (e.g. due to backfill and traffic loads) without excessive deformation of the pipe and the finished ground.

AS 2566.1 outlines the structural requirements for design of buried flexible pipelines. Flexible pipelines, included in this Standard, are listed below:

- ABS: Acrylonitrile butadiene styrene
- GRP: Glass filament reinforced plastics
- PVC: Polyvinyl chloride
- OPVC: Oriented PVC
- PE: Polyethylene
- PP: Polypropylene
- DI: Ductile iron
- MS: [Mild] Steel

Note that rigid pipes such as fibre-reinforced concrete and steel-reinforced concrete pipes are excluded from the definition of flexible pipes and AS 3725 needs to be followed for the design of this type of pipes.

The mechanism of load transfer from the pipe to the surrounding embedment materials is discussed in more details in the following sub-sections.

3.1 Vertically loaded free pipe

A flexible pipe loaded by trench fill and traffic will be squashed down vertically and bulged out sideways, as shown in Figure 1.

In the case of rigid pipes, the pipe itself could be designed to support the entire trench fill and traffic loads, but it would need to have a very thick wall.

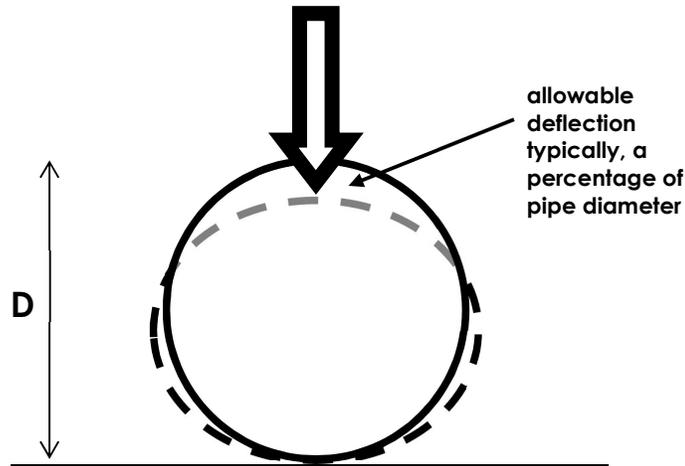


Figure 2: Pipe deflection under loads

3.2 Vertically loaded pipe with side support

It is usually more efficient to rely on the material at the sides of the pipe to provide some lateral resistance to the bulging. This is known as “side support” and its effect is shown in Figure 3 and Figure 4. Side support reduces the pipe vertical deflection for a given load and so allows a thinner pipe wall to be used.

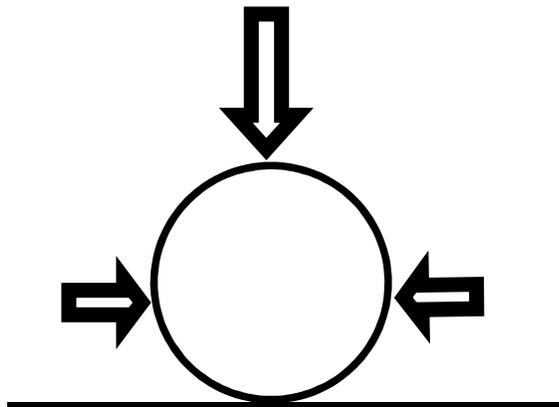


Figure 3: Reduced deflection of pipe embedded in soil

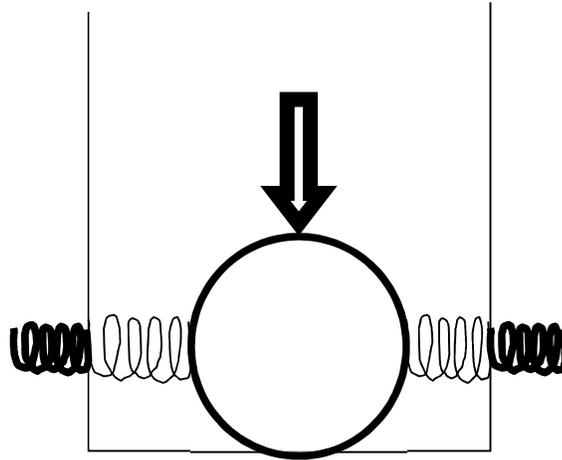


Figure 4: The Spring analogy for side support

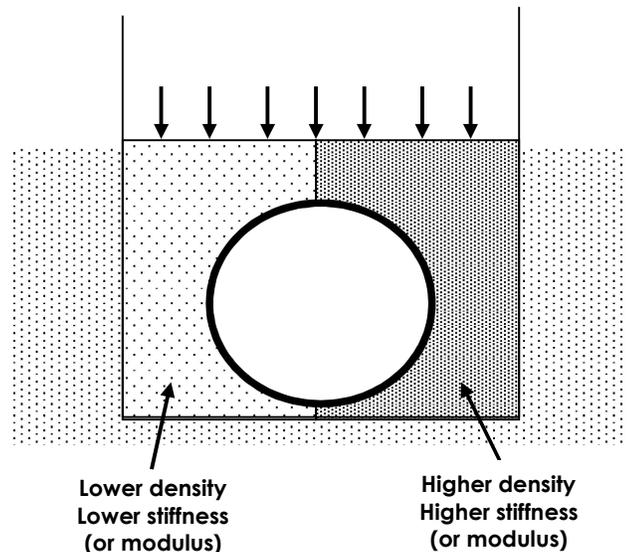


Figure 5: Pipe embedment stiffness (or modulus)

Usually little can be done about the stiffness of the trench wall material (the “native soil modulus”), so the designer is limited to specifying the stiffness of the pipe embedment material (the “embedment soil modulus”).

The embedment soil modulus depends on the nature of the material (e.g. whether it is a silty sand or a gravel) and on its density. The density of the embedment soil depends on the compaction procedures during construction.

The density of the pipe embedment material must always be sufficient that it does not settle around the pipe under its self-weight or under the trench fill or traffic loading (see Figure 5 and Figure 6). If it is loose enough to do this, it is also too loose to provide proper side support. The embedment materials therefore should be well compacted in layers to have sufficient density, as shown in Figure 7. More insights into the compaction requirements are provided in the following sections.

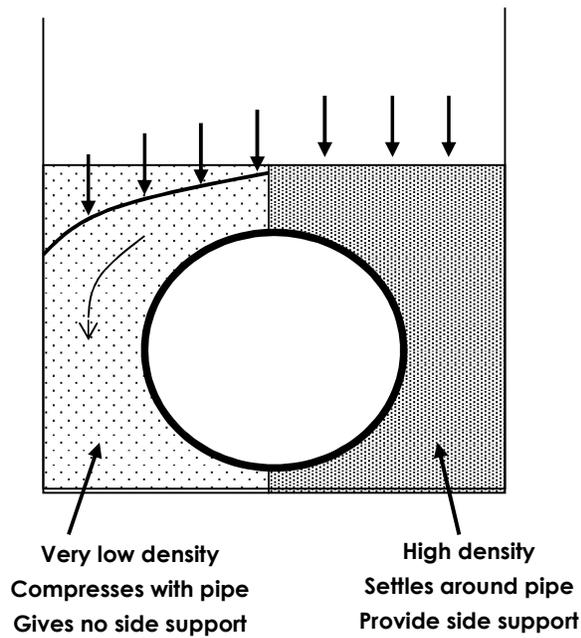


Figure 6: Minimum practical limit for density of pipe embedment

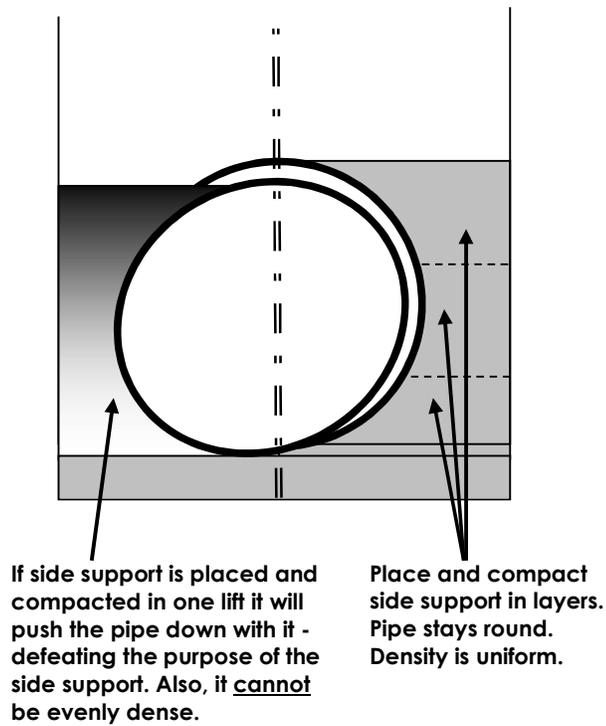


Figure 7: Illustration of why side support must be uniform and packed in lifts

3.3 What native soil modulus to design for?

- Native soil modulus is likely to be very variable.
- Little can usually be done economically to improve it.
- It is difficult to measure in the field.
- It is generally reasonable to use a conservative value from established correlations with other soil parameters.
- Table 3.2 in AS 2566.1 gives correlations between soil type, density and modulus. The type of the soil should be identified by a competent geotechnical engineer or by undertaking geotechnical investigations.
- Natural soils can have densities below the “engineering” range (i.e. less than say 90% of standard maximum dry density, SMDD), so Table 3.2 gives correlations for as low as 85% of SMDD. However, for fine-grained soils with medium to high plasticity (e.g. CH or MH), or fine-grained soils with medium to low plasticity which contain less than 25% of coarse-grained particles (e.g. CL or ML), Table 3.2 provides no reliable modulus if the compaction is less than 90% of SMDD. In many parts of Adelaide and generally in South Australia, the native soil may fall in the CL-CH category, therefore the designer needs to seek the advice of a qualified geotechnical engineer to adopt a proper evaluation technique for the modulus of these type of soils if their in-situ compaction ratio is less than 90% SMDD.

3.4 What embedment soil modulus to design for?

- Good embedment soil will improve the combined modulus of the native and embedment soils. The influence of embedment soil increases if it replaces more native soil in the side support zone. Such influence however is hard to be quantified unless a numerical modelling technique is utilized in the design to understand the soil-structure interaction.
- The embedment soil modulus can be controlled by specifying both the material and its density. It gives the designer flexibility to take account of the cost of embedment materials, availability of materials, compaction methods, degree of site supervision, etc.
- There is a minimum practical limit for embedment soil density, in that it must be at least sufficiently dense not to settle vertically down around the pipe under the loads from the trench fill or traffic.
- The embedment should also be sufficiently dense that it does not creep or permanently compress under the lateral stresses. Note that soils appear to have quite a high elastic modulus under the very low-strain cyclic loading that they are subjected to in laboratory modulus tests, but suffer creep under static loading, and permanent compression under slight overload.
- Table 3.2 in AS 2566.1 (and its section 3.4 generally) does not alert the inexperienced designer to these points and so could lead to inappropriate designs.

4 Embedment Sand – Simple Field Test

The main requirements for a good pipe embedment sand are:

1. It will be easy to compact in the restricted area around a pipe.
2. Its ease of compaction will be relatively insensitive to moisture content.
3. If in contact with metal pipe or fittings it has a low specific conductivity.

A simple field test is described here to check for the first two of these requirements – i.e. whether the sand will be easy to compact and whether its ease of compaction will be sensitive to changes in moisture content. This test method was suggested in a SA Water’s technical note dated 03/02/2002.

The test relies on the fact that a sand that is free draining will normally also be easy to compact and that its compaction will not be sensitive to changes in moisture content. This test was found to correlate well with the normal "grading" based acceptance criterion for embedment sands – namely that an embedment sand should be non-plastic and contain less than about 5 to 10% fines (5% limit for plastic fines and 10% for non-plastic fines according to AS 2566.2, where "Fines" are defined as material less than 75 micrometre in diameter).

This test checks the sands on three different criteria – drainage rate, liquefaction and penetration. The test procedure is shown in the following images. A sample table for interpretation of the test results is provided in Table 1.



Step 1 – Preparation

Take the sieve and check that the 75 micrometre mesh is firmly in place and undamaged.



Step 2 – Filling

Fill loosely with the sand to be tested up to the lower lip.



Step 3 – Saturating

Distribute 500 mL of water over the sand in one continuous, fairly quick, but smooth pour, taking care to keep the surface reasonably flat.



Step 4 – Drainage Rate

Record (in seconds) how long it takes for the water on top of the sand to disappear.

(Photographs of four examples are presented below.)



Step 5 – Liquefaction

Wait twenty seconds after the water has cleared from the surface, then gently tap the whole sieve on the ground five times.

Record how many seconds it takes for any new water that appears to disappear again.

(If none appears record zero.)



Step 6 – Penetration

Wait at least another five minutes then press the ball of the thumb into the surface of the sand, using moderate pressure.

Record whether or not the impression is more than 5 mm deep.



The picture above-left shows an impression that is less than 5 mm deep. The surface felt firm. (This sand had 5% fines.)

The picture left shows an impression that is greater than 5 mm deep. The full depth was completely sloppy (This sand had 16% fines).

**Drainage Example 1**

This sand had 0% fines in it.

It took less than 5 seconds for the water to clear the surface.

**Drainage Example 2**

This sand had 5% fines in it.

It took about 45 seconds for the water to clear the surface.

**Drainage Example 3**

This sand had 10% fines in it.

It took about 90 seconds for the water to clear the surface.

**Drainage Example 4**

This sand had 16% fines in it.

Even after 3 hours the surface was still wet.

Table 1: Embedment sand, sample test results

Sample Number	Drainage Rate		Liquefaction		Penetration		Acceptance
	Time taken for initial water to disappear		Time taken for "new" water to disappear (if none record zero)		Depth of thumbprint		
	time in seconds	<90 s <input checked="" type="checkbox"/> >90 s <input checked="" type="checkbox"/>	time in seconds	<30 s <input checked="" type="checkbox"/> >30 s <input checked="" type="checkbox"/>	depth in mm	<5 mm <input checked="" type="checkbox"/> >5 mm <input checked="" type="checkbox"/>	Three <input checked="" type="checkbox"/> = OK Two <input checked="" type="checkbox"/> or less = NG
1	70	<input checked="" type="checkbox"/>	15	<input checked="" type="checkbox"/>	3	<input checked="" type="checkbox"/>	OK
2	110	<input checked="" type="checkbox"/>	40	<input checked="" type="checkbox"/>	>10	<input checked="" type="checkbox"/>	NG

5 Embedment Compaction – Modulus vs Density

Clause 5.6 of AS 2566.2 specifies the required specifications to control the compaction of the pipeline embedment materials. Provided that the specified compaction criteria is met, Table 3.2 of AS 2566.1 can be used to obtain correlations between soil type, density and modulus.

The following table and associated discussions are taken from a SA Water's technical note prepared on 13/11/2003, to provide further insights into proper selection of elastic modulus of the materials based on other corresponding measures on site. Note that the correlations in Table 2 are rough estimates and only show an indicative field identification test.

Table 2: Field identification test of compaction

Soil Modulus (MPa)	SPT (blows per 300 mm) (Note 1)	Consistency of Sand --- Field Identification Test	Consistency of Clay --- Field Identification Test	Equivalent % of Standard Maximum Dry Density
5	24	Medium Dense (Note 2) --- takes a footprint 5 mm deep	Very Stiff (Note 3) --- readily indented with thumbnail	Approx. 95% (Note 5)
3	14	Medium Dense (Note 2) --- takes a footprint 8 mm deep	Stiff to Very Stiff (Note 4) --- readily indented with thumb but penetrated only with great effort	Approx. 90% (Note 5)
1. These numbers are based on Hobas design manual correlations, and slightly adjusted to be consistent with suggested values of AS 2566.1 2. SPT range for "medium dense" is 10 to 30 blows per 300 mm. 3. SPT range for "very stiff" is 15 to 30 blows per 300 mm. 4. SPT range for "stiff" is 8 to 15 blows per 300 mm. 5. Correlations not to be used in any manner or for any other purposes than that intended.				

The pipe side support and overlay material should be placed and compacted using methods and techniques which:

1. Will ensure that the specified density is achieved uniformly around the pipe,
2. Does not damage the pipe surface or protective coatings,
3. Does not displace the pipe from its laid position, and
4. Does not put any vertical load on the pipe until the pipe side support has been compacted to its specified density.

The pipe overlay material should not be placed until the pipe side support material has been placed and compacted.

The pipe side support and overlay material should be placed in layers, and each layer compacted to a density of not less than 95% of the standard maximum dry density of the material. The layer thickness should be appropriate to the nature of the material and the compaction techniques used. Where compaction is required, hand tampers, surface plate vibrators, vibratory rollers or internal vibrators should be used. Compacted lift thickness should not exceed 200 mm. Where hand tampers or internal vibrators are used, the lift thicknesses should not exceed 150 mm, the length of the vibrator, or half the pipe diameter, whichever is smallest.

6 Specifications for Embedment Compaction

The following notes are based on a SA Water's technical note which was prepared on 16/12/2003 and provide a basis for required specifications for the embedment compaction in pipeline trenches.

6.1 Introduction

Why use a method spec rather than a performance spec for the placement and compaction of pipe embedment sand?

A method spec says "HOW" a job should be done – it spells out the steps that need to be followed to achieve the required engineering result.

A performance spec says only "WHAT" the final result should look like – but compliance is limited to things that can be measured.

It is important to use a method spec for the placement and compaction of pipe embedment sand because:

1. It is just as important HOW the required density is achieved in pipe embedment sand as it is that the required density is achieved at all.
2. There is limited confidence in field tests for measuring the density of pipe embedment sand down the sides of a pipe in a trench.
3. It is possible to build into a method spec some feedback that instantly tells the person laying the pipe that the required engineering result has been achieved at all points. With a performance spec it is usually necessary to wait several days for the results of a few scattered density tests – which, as stated above, may not work in pipe embedment sand anyway.

6.2 Discussion

Why is it important HOW the required density is achieved in embedment sand?

Flexible pipelines as defined in Section 3 are not designed to be strong enough to support the trench fill and the future traffic load by themselves. They need a lot of help from the

embedment material around them to prevent them from being squashed out of round by these loads.

Squashing a flexible pipe out of round puts stresses in its walls that add to the hoop stress from the pressure of the water inside the pipe. Manufacturers usually design flexible pipes assuming that the embedment will be good (stiff) enough to limit the vertical deflection of the pipe to a certain limit under trench fill and traffic loads (the limit is based on pipe type, see AS 2566.2). If this deflection is exceeded, then the combined stress in the pipe walls from the oval shape and internal pressure will exceed the design stress, and the life of the pipe will be shortened.

This means that the embedment material must not only be dense enough to provide the required support for the pipe, but that the density must be achieved in such a way that the pipe is not put out of round by the compaction process. The most important place for a good density to be achieved is generally in the side support region and particularly under the haunch of the pipe.

7 Compaction testing and verification in pipeline trenches

According to AS 2566.2, direct methods of testing are required to verify compaction in pipeline trenches, except where indirect methods are permitted.

Since measurement of the modulus after placement of the embedment material in the pipe trench is not possible, the verification of the relative compaction of the embedment zone during pipe installation is the most important measure for ensuring the soil modulus will be at least equal to those assumed at the design stage.

In SA Water projects, normally two types of pipe embedment materials are used, TS4 sand for water pipes and pressurised sewer pipes, and single size coarse aggregates (10 or 14 mm) for gravity sewer pipes. The selected methods for verifying the level of compaction need to be appropriate to the type of material being tested.

For low fines soils the measurement of the field density is normally based on using density index (I_D) based on AS 1289.5.6.1. For well-graded gravel or sands, where test results in the laboratory show a well-defined compaction curve, the dry density ratio (R_D) based on AS 1289.5.4.1 is applicable.

The dry density ratio (R_D) may be used for compaction control in conjunction with a nuclear density gauge (AS 1289.5.8.1) which require calibration for site control of embedment material density. Application of the nuclear density gauge might have limitations inside the pipe trenches due to the limited space for access to the side support, or difficulty of calibration in close proximity to the pipe and trench wall.

SA Water conducted a trial compaction testing program in Port Wakefield pipe relay project in 2019 to understand the capability of the nuclear density gauge in compaction control in the trenches. The sand replacement method using sand-cone pouring apparatus (AS 1289.5.3.1) was used as the reference compaction testing method. The embedment sand (TS4) was used in a 0.9 m wide trench with DN375 mm GRP and MSCL (Sintakote) pipes inside the trench¹. The density in the side support and above the overlay zone was measured and compared using the two techniques.

Results of this comparison showed that the dry density ratios obtained using the nuclear density gauge were lower in all locations than those obtained using the sand replacement method. The difference between the two methods seemed to be more significant for tests performed in the GRP trench than the tests in the MSCL trench, the average differences

¹ For more information refer to the project records of C7589 about the GRP pipeline section between Pt Wakefield and Bowmans rail crossing, and the realigned section at the Bowmans rail crossing.

being 4.6% and 2.1% respectively. The overall range of difference between the two methods was from 1 to 6.5%.

The possible reason for the higher percentage difference in the GRP trench tests was attributed to the greater confinement of the GRP trenches compared with the MSCL trenches. The effect of reflected radiation may have been greater due to the confinement and there being less distance between the gauge, the pipe and the trench wall and thus producing a lower density reading.

In another trial testing for a pipeline in Taillem Bend, the comparison was performed at top of the overlay sand above the pipe where the location had a clear area greater than 600 mm from the long side of the gauge. The tests at Taillem Bend showed a good comparison, where both sand replacement and nuclear density gauge achieving the same field density.

In general, it seems that, for compaction testing of the side support and haunch area of the pipes inside the trench, where the nuclear density gauge might be impacted by the confinement of the trench and close proximity to the pipe, the nuclear density gauge will provide conservative results. However, application of a fixed offset to the nuclear test results to calculate the actual compaction ratio is not recommended since the trial was based on a small number of results and the confinement distances being different at each location. It is recommended that at each site, a calibration of the nuclear density gauge with sand replacement technique be conducted at the start of the project and then the calibration be frequently verified during the project.

The use of indirect compaction measurement methods such as the dynamic cone penetrometer, Perth sand penetrometer, Clegg impact soil tester, and the deflection monitoring procedure are not permitted in SA Water projects, unless approved by SA Water Engineering in a specific project.

8 Frequency of compaction testing

According to AS 2566.2, the frequency of compaction testing and location of compaction control tests in the embedment zone needs to be as specified in the design. As a minimum AS 2566.2 asks for testing the compaction of embedment material at the rate of 1 test per 2 layers per 100 linear metres of pipeline, or part thereof.

Compared with AS 2566.2, the WSAA requirement for frequency of compaction testing is slightly different. WSAA-03 (2011) states that for compacted material located in a trafficable zone, one test needs to be conducted in each 300 mm of the depth of fill and each 300 m² of area or part thereof. For compacted material located in a non-trafficable zone, one test needs to be conducted in each 900 mm of the depth of fill and each 1200 m² of area or part thereof. WSAA requirements is based on total area of the trench, rather than the length of the pipeline.

Current SA Water's further requirements for compaction testing frequency as stipulated in the supplementary document to WSAA are based on linear length of the pipe rather than the area of the trench, also with specific testing required at the location of connections.

The SA Water supplementary document to WSAA is currently under review in light of the recent experiences in capital and land development projects. In the final revision, more insights into the SA Water requirements will be provided. In interim, the following testing frequency will be required in all water and wastewater pipeline projects:

- Compaction testing needs to be undertaken to a greater frequency initially to establish a reliable compaction regime, with the frequency reduced once the methodology is established and consistent results are obtained, to the satisfaction of the Superintendent.
- In general, the compaction testing needs to be undertaken to the following frequency as a minimum:
 - Every 100 m length of pipeline.

- The interval of testing may change to every 200 m length of pipeline after the first 500 m length, if the ground condition, pipe type, and pipe diameter does not change over the entire length.
- As soon as any of these changes occur, the interval of testing reverts back to every 100 m length.
- For water mains and water connections, a minimum of one compaction test needs to be undertaken within each layer of embedment zone and the trench fill:
 - for each 100 m length of pipeline
 - in at least 20% of the trenches for connections, i.e. 1 in each group of 5 connections or part thereof (within the same project).
 - or as otherwise directed by the Superintendent's Representative.
- At every test location outlined above, the following minimum number of tests needs to be conducted on each layer:
 - Embedment layer – one test at 2/3 of the pipe depth from bottom of the pipe, and one test at top of the pipe overlay
 - Trench fill – one test every 300 mm depth of fill. At least one test mid trench fill
 - Pavement layers – one test at top of subgrade and one test at top of each pavement layer, unless the road authority specifies more stringent compaction testing frequency which needs to be followed accordingly.
- Test locations needs to be representative of the filled area.
- The Superintendent may carry out random confirmatory tests.

9 Embedment Overlay and Trench Fill

In pipe-laying practice, whether water or wastewater, the pipe overlay is that part of the pipe embedment which immediately overlays the pipe, see Figure 1 for more details about the terminology.

The function of the pipe overlay is to act as a mechanical buffer between the pipe and the trench fill above.

To act as a successful buffer, the pipe overlay must be:

1. A material that is sufficiently fine and uniform that it cannot itself damage either the pipe or any protective coating on the pipe. For example, for PVC pressure pipes, it is necessary to use sand as the overlay to prevent scratching, whereas for non-pressure PVC sewers, which are less sensitive to minor scratching, screenings can be used.
2. Easy to compact, so that the effort required to compact it does not damage the pipe. Again, sand or screenings are acceptable.
3. Sufficiently thick that any large stones in the trench fill above cannot penetrate through it to the pipe.
4. Sufficiently thick that the compactive effort put into the trench fill above cannot damage the pipe.
5. Sufficiently thick that, even if some were displaced during subsequent construction operations, there would be sufficient thickness left.
6. Sufficiently thick that the minimum thickness achieved is sufficient, even under laying conditions where the control of thickness is difficult, such as in a deep sewer trench.

If the above six criteria are applied to normal water main laying, it has been found that an overlay thickness of 100 to 300 mm (depending on the diameter of the pipe) is appropriate, according to AS 2566.2. The overlay material is sand, which is both easy to compact and

relatively difficult to displace once in place. The trench is shallow, and so it is easy to control overlay thickness. Quarry rubble is used as trench fill in reinstatement of the roads, so there are no large stones in it, and it is relatively easy to compact.

If the above six criteria are applied to normal sewer laying, it has been found that an overlay thickness of 300 mm is appropriate. Sewer overlay material is screenings which, although easy to compact, are also relatively easily displaced. A sewer trench is often deep, and so it is difficult to control the thickness of the overlay. Sewer trench fill often contains large stones and is also often difficult to compact.

For water pipe laying, SA Water specifies 95% to 100% compaction for trench fill in order to control surface settlement (for trafficable areas: 100% SMDD if TS4 sand is used, or 95% MMDD if quarried pavement material or pavement sand is used, for non-trafficable areas: 95% SMDD).

For sewer pipe laying, SA Water specifies 95% compaction for trench fill in order to control surface settlement (95% MMDD for roads, and 95% SMDD for easements).

To this point may be added the fact that the quality of the trench fill material is more likely to be at the lower end of the allowable range in easements than under roads (i.e. it may contain large stones and/or be more clayey and so require heavier compaction).

10 Controlled Low-Strength Material for Embedment

Controlled Low-Strength Material (CLSM) is one of the proposed pipe embedment materials in AS 2566.2. In SA Water projects however CLSMs are not usually used.

The following discussion provides geotechnical comments on a proposal by the contractor (Leeds) to use CLSM for pipe embedment on some sections of a pipelaying project, as was reviewed and commented on 11/11/2003.

CLSM, otherwise known as “flowable fill” or (in the past) “unshrinkable fill”, is a sand and cement based backfill material produced in a concrete batching plant and transported in a mixer truck – its transportation cost on site is therefore similar to any other concrete product.

1. The main physical characteristics of well-designed CLSM are:
 - It will be free flowing (with an almost creamy consistency) so that it fills small voids (mainly achieved with an air entraining agent and possibly also a plasticiser).
 - It will have a specific maximum strength when cured – e.g. 1 to 5 MPa. The usual mix design criteria are that it should be weak enough to allow it to be dug out by hand tools if required in the future, but firm enough to give the required lateral modulus (stiffness) for the pipe and/or vertical/horizontal load carrying capacity.
 - It will require no additional vibration or compaction after placing.
 - It will have an acceptably low shrinkage during curing.
 - It will reach its design strength in an acceptably short time.
2. The contractor considered that the advantages to him on this project would be:
 - The ability to use a narrower trench (150 mm clearance either side proposed at the time. Currently AS 2566.2 allows 50% reduction in the clearance between pipe and trench wall if CLSM is used instead of embedment sand, while still providing the same amount of side support).
 - Avoiding having operatives in the trench (for compaction of embedment, etc.).
3. Things to be wary of when using CLSM as pipe embedment are:
 - Buoyancy of the pipe in the CLSM – which is a fluid with about twice the density of water. It can be minimised by backfilling in several lifts or counter with saddle anchors.
 - Reduced side support in very weak ground because of the narrower trench. The side support given to the pipe comes from a combination of the width and modulus (stiffness) of the embedment and the modulus of the natural ground in the trench walls.
 - The time required to achieve the design strength (or, in this application, sufficient strength to enable trench backfilling can be completed).

SA Water inspected the results of the trial on 28 April 2003 (see photos below):

- The CLSM appeared to be fully cured (it had been placed on 23 April 2003).
- Its strength in-situ was such that it could be slowly fretted away with the toe of a boot or (it was estimated) dug with difficulty using a spade.
- In terms of its “strength in a hand specimen” (an engineering geologists’ method of classification) it could be “broken by hand with difficulty” indicating a compressive strength of a little over 1 MPa or a “very weak” (VW) rock.

SA Water was informed that:

- The mix contained 6% cement and had a target strength of 1.5 MPa.
- One side of the trench was vibrated after pouring, the other was not.
- It achieved a reasonable strength (sufficient to allow backfilling) within 5 to 7 hours.

- The supplier considered that CLSM can be produced using 4% cement but not less.

Based on these observations of the trial, past experience with the use of CLSM, and general knowledge of its performance, SA Water considered that CLSM would be appropriate for pipe embedment on these contracts. It was also advised that the mix should be similar to that trialled and the points listed in point (3) above should be considered in the design.

It should be noted however that current SA Water standard drawings specify application of TS4 sand or screenings for pipe embedment, therefore application of CLSM in any project will require a thorough assessment – the contractor will need to apply for dispensation with required technical submissions to SA Water for approval.



Photo 1: A concrete pipe (background) was placed in the trench and the CLSM poured to mid-height. The CLSM was vibrated on the right-hand side of the trench but not on the left. The pipe was removed when the CLSM had cured, revealing the quality of the contact.



Photo 2: The left side – not vibrated. Shows “flow banding” but otherwise full contact with the pipe.



Photo 3: The right side – was vibrated. There has been some “aggregation” of the finely entrained bubbles to give the voids visible in the photograph, but otherwise there is still full contact with the pipe. Vibration is neither necessary nor recommended.



Photo 4: The CLSM made full contact with the bottom and sides of the pipe.



Photo 5: These lumps were above half height and broke off as the pipe was removed. A lump of the cured CLSM could be “broken with difficulty by hand” indicating a compressive strength of about 1 MPa.

11 Pipe Trench Width Discussion

This section provides an explanation of differing trench widths specified for water and wastewater mains in SA Water construction manuals, based on a SA Water's technical note prepared on 09/06/2000.

- **A 600 mm minimum trench width is specified for sewers** (150, 225 and 300 mm), as sewers are generally deep, and there is a need to ensure reasonable access for personnel during placement and compaction of the embedment.
- **A narrower trench width is allowed for water mains**, as mains are generally shallow, and therefore reasonable access can be gained for placement and compaction of the embedment within a narrower trench than is required for the same size of sewer, particularly for the smaller diameter pipes.
- **No maximum trench width is specified for sewers**, as sewer pipes in the 150 to 300 mm size range (with the specified embedment) are strong enough to support all trench fill and traffic loads without relying on the shedding of some of those loads to the trench wall.
- Not specifying a maximum width allows the contractor to use battered or benched cut excavation if these are more economical.
- **A maximum trench width is specified for water mains** as it is desirable to disturb the ground for the minimum width possible. Anchors and thrust blocks must bear on undisturbed ground.
- Specifying a maximum trench width for a water main does not unduly restrict the contractor, as the mains are shallow, and contractors are unlikely to want to use wide battered cuts anyway.

12 Pipe Laying in Embankments

12.1 Pipelines within the embankment footprint

If the embankment holds water in any form, it must be considered as an embankment dam. If in such case a pipeline which conveys water (either under pressure or gravity) passes through the embankment body, within the embankment footprint the pipe will need to be encased in cement stabilized sand or reinforced concrete, depending on the risk profile of the embankment. For further discussions about the definition of the risk profile and the embankment footprint, please see Section 6.1.3.4 of TS 0460.

The embedment of the pipes for other types of embankments that do not hold water in any forms will be the same as normal trenches with special consideration for the deeper trenches that might be required and possibly more trench fill materials.

12.2 Pipelines outside of the embankment footprint

The material used for trench backfill outside the embankment footprint will need to be coarse, free flowing pit or beach sand, equivalent to SA Water Technical Standard TS4. Note that sand backfilling can only be used on trenches outside the embankment footprint. For the definition of the embankment footprint, refer to Section 6.1.3.4 of TS 0460.

12.3 Shared trench requirements

Where the pipes and other underground services are laid in the same trench, then a minimum horizontal and vertical clearance should be provided between the pipe and the other conduits. Table 5.5 of WSA 03-2011 should be followed to determine the required clearances.

13 Pipe Trench Excavation Stability – Sample Log Sheet

The following sample log sheet can be used to roughly check the stability of the pipe trenches. This sample is a guide only and does not replace the engineering judgement of a qualified person which is required in accordance with WHS Act for safe work around trenches.

Excavation Conditions Summary Sheet		Pit Number
		TP21B
Project:	Loxton Irrigation District Rehabilitation - Stage 2	
Pipe Route:	Line 28 - Anderson Road	
Chainage:	730 m E of centre of Balfour Ogilvy Rd	
Location:	5 m north of centre of road – see comments	
GPS Coordinates:	m East	m North

Depth	Water				Clay Soil				Sand Soil				Overall Rating for Trench Stability (sum of ratings to left)							
	Dry	Moist	Wet	Inflow	Stiff	Firm	Soft	very Soft	Cemented	Dense	Medium Dense	Loose	Fairly Stable	Less Stable	Unstable	Very Unstable				
Rating {	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	5	6	7	8
0.0 – 0.5	•											•					•			
0.5 – 1.0	•								•					•						
1.0 – 1.5		•									•									
1.5 – 2.0		•									•									
2.0 – 2.5			•									•							•	
2.5 – 3.0				•								•								•
3.0 – 3.5		•			•									•						
3.5 – 4.0																				
4.0 – 4.5																				
4.5 – 5.0																				

Comments: This test location is in the road shoulder on the opposite side of the road to TP21A and the irrigation channel. It was investigated because conditions at TP21A appeared to be very unstable from a depth of 1 m down.

14 Pipe Laying – Roads Over Old Mains

This section specifies the requirements for road construction works in the vicinity of SA Water existing infrastructure. This is based on a SA Water's technical note dated 2/11/2001 with reference to construction of an overtaking lane in Noarlunga – Cape Jervis Rd, Myponga.

In that particular project, SA Water had concerns about road works adjacent to and above the existing 250 mm diameter AC water main located along the Noarlunga –Cape Jervis Rd. This main was laid in 1962. The proposed road reconstruction works consisted of boxing out to a 400 mm depth along the causeway adjacent to the Myponga Reservoir and 450 mm depth further towards Myponga Township as part of the road. It was understood that the existing cover over the main was variable from 600 mm to 750 mm. SA Water requires that no heavy vibration compaction equipment be used over the pipe except where, or until, the cover over the pipe is greater than 600 mm. In that project, SA Water requirements were as listed below:

- Only plate vibrator compaction equipment should be used for all fill/road pavement materials between 300 mm and 600 mm over the pipe and within 500 mm laterally from each edge of the pipe.
- If the boxing-out comes within 300 mm of the top of the pipe, then the nature of the material over the pipe should be assessed. If it is not dense, or not uniform, or if it contains any stone larger than 50 mm, then it should be carefully removed over a width 500 mm either side of the pipe and replaced with clean, high-quality sand fill selected for its ease of compaction. Compaction of this sand should be achieved using light (hand guided) plate compaction equipment only.

In general, SA Water will not take responsibility for risks associated with works to be carried out in close proximity to its infrastructure. The road works authority will therefore be charged full actual costs for repairs to any damage to pipework etc. that might occur.

Use of approved protection slabs over the pipeline might be considered, subject to providing required technical documents to SA Water and obtaining relevant approvals from SA Water Engineering pipeline specialists.

It is recommended that a site inspection with representatives from SA Water, the relevant road work authority and its principal contractor, be arranged to discuss the appropriate course of action for working near the water mains.

15 Laying Pipeline in Reactive Soils

SA Water asset management studies have shown a correlation between circumferential cracking of the pipes and joint failures within locations of soil reactivity, for example black clays and Keswick clays. In the 2016/17 period, circumferential cracking and joint leaks accounted for 52% of water main failures across the metropolitan network in Adelaide.

Although the effects of soil reactivity on water infrastructures is still subject to more research in SA Water, in the interim the following recommendations which are mainly based on a technical note dated 19/11/2003 should be considered in future design works:

- Where a pipeline is to be laid through an area where extremely reactive soils are present, the design should incorporate details to prevent the pipe embedment or trench fill materials from conducting the infiltrated water around the site, and also to minimise, in general, the impact of potential soil movements on the pipe. Such design details might include, for example, using sand instead of screenings as the embedment material, paying additional attention to controlling the French-drain effect, ensuring that the invert of the pipe is sufficiently deep, staying well clear of native trees, or re-routing the pipe to avoid particularly reactive areas.

- When selecting discharge locations for trench drainage systems, care should be taken to ensure that there can be no backflow of water into the pipeline trench fill from the stormwater pipes or surface drains into which the trench water is being discharged when the stormwater pipes or surface drains are surcharging.

In capital projects, a thorough investigations of the soil reactivity and its effects on pipelines and water infrastructures needs to be undertaken by the appointed contractor and corresponding mitigation measures be specifically addressed in the design and during construction.

16 Pipe Anchor Block Outlets

Sometimes it is considered necessary to find alternative anchoring systems for block outlets, in particular whether the valve could be braced to the wall of the valve chamber. This section deals with such situation, mainly taken from a SA Water's technical note prepared on 28/05/1999.

The chamber is unlikely to be able to resist the thrust, particularly with the bigger pipes, unless it is designed for it. Chambers are generally designed to resist only light, uniform, external loads. They are not designed to resist local internal thrust. There would also be the difficulty of ensuring adequate compaction of the backfill outside of the chamber.

Two alternatives appear possible:

- Make the MSCL "special" longer so that the anchor can be located well away from the disturbed ground near both the chamber and the connection. The main disadvantage would be that even with this approach it might still be difficult to find undisturbed or sufficiently strong/dense ground.
- Use a cast-in-place base slab for the chamber and design the base slab to act as the anchor. The pipe would be bolted to the slab on a standard pedestal. The chamber would have a thicker base slab.