Backfill Specification

MRWA Specification No. 04-03.1

Melbourne Retail Water Agencies

(Including City West Water, South East Water & Yarra Valley Water)

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Please Note: This Specification may be periodically updated.

1 INTRODUCTION

1.1 Application

This Specification sets out the Principal's requirements for the backfill and compaction of soils in excavations associated with the construction of water supply and sewerage assets. This specification refers to the trenchfill zone and not the embedment zone. For details of embedment zone requirements, refer to the MRWA Edition of the WSAA Water Supply and Sewerage Codes.

It also applies to fill associated with assets constructed by tunnels, drives, shafts, bores and other trenchless technologies.

Deep compressible clays (Coode Island Silt) are outside the scope of this Specification.

1.2 Requirements for this Specification

Correct trench backfill and compaction is a critical success factor for the Principal's projects. Incorrect backfill and compaction by contractors causes the Principal to incur risks associated with backfill subsidence and collapse such as:

- Customer inconvenience and dissatisfaction.
- Damage to customer and council assets.
- Damage to other authorities' infrastructure.
- Hazards to road users and pedestrians.
- Costs associated with rectifying damage.
- Costs associated with litigation for damages.

Compliance with this Specification will reduce or eliminate these risks by assisting contractors to:

- Understand that soils are like any other construction material. Different soil types have differing properties, and require different construction techniques to ensure optimum performance.
- Comply with a basic standard of backfill and compaction appropriate to each soil type.

1.3 Relevant Australian Standards

AS 1289: Methods of Testing Soils for Engineering Purposes.

AS 3798: Guidelines on Earthworks for Commercial and Residential Developments.

AS 2566.2: Buried Flexible Pipelines: Part 2 - Installation.

1.4 Definitions

For the purpose of this specification, the following definitions shall apply:

Approved, Approval:

Unless otherwise specified, means approved by, or approval of, the Superintendent.

Backfill, Fill:

Terms used to describe the material used in the Embedment and Trench Fill Zones.

Compaction:

The process whereby the density of a soil mass is increased by mechanical, usually dynamic, means. This typically involves tamping, rolling, or vibration, or a combination of these processes. This results in a relocation of soil particles and the expulsion of air from the soil mass, but usually without significantly altering the amount of water in the soil.

Cohesionless Soils:

Poorly graded sand and gravel mixtures, generally with less than 5% fines (ie finer than 75 μm), which are non-plastic and which do not exhibit a well-defined moisture-density relationship when tested in accordance with AS 1289.5.1.1 or AS 1289.5.2.1. These will typically be "clean sands".

Cohesive Soils:

Those materials which have a well-defined moisture-density relationship when tested in accordance with AS 1289.5.1.1 or AS 1289.5.2.1. Whilst cohesive soils are typically clayey in nature, for the purpose of this definition these may also include well-graded granular materials such as crushed rock.

Dry Density Ratio, Relative Compaction:

The degree of compaction specified and achieved in cohesive soils is usually expressed as a dry density ratio, as described in AS 1289.5.4.1. This compares the dry density of the compacted soil with a reference density, being the peak dry density which can be achieved in a controlled laboratory compaction process, e.g. Standard Compaction, AS 1289.5.1.1. Dry Density Ratio is also sometimes referred to as Relative Compaction. This more generic term allows for other reference testing procedures such as Hilf Rapid Compaction (AS 1289.5.7.1) for clay fills and Density Index (AS 1289.5.6.1) for sands.

Embedment Zone, Trench Fill Zone:

The areas defined in MRWA Editions of WSAA Water Supply and Sewerage Codes: Standard Drawings SEW-1201-V "Embedment and

Trenchfill - Typical Arrangements", and WAT-1201-V “Embedment and Trenchfill – Typical Arrangement”.

Field Density Testing:

To allow comparison of the achieved field compaction with a laboratory reference density, it is necessary to be able to reliably determine the achieved field density and moisture content. The commonly used methods for assessing field bulk density are the sand replacement test (AS 1289.5.3.1) and the nuclear density gauge (AS 1289.5.8.1), but moisture content usually is measured in the laboratory.

Indirect measures of achieved compaction include penetrometer testing. The Perth Sand Penetrometer (PSP) is often used in clean sands, with the number of blows required to drive a blunt ended rod into the sand taken as an indicator of the relative compaction of the sands (see Perth Sand Penetrometer).

Maximum Dry Density, Optimum Moisture Content:

The peak dry density achieved in the laboratory compaction test is referred to as the Maximum Dry Density (MDD), and this occurs at the relevant Optimum Moisture Content (OMC) for that compactive effort. The MDD and OMC derived in the laboratory test are not unique properties of a soil, but are dependent upon the applied compactive effort and the nature of this effort. In the laboratory, there are Standard (AS 1289.5.1.1) and Modified (AS 1289.5.2.1) efforts. Modified compaction applies approximately 4.5 times the energy of Standard compaction. Similarly, in the field, different compaction equipment will apply different compactive effort.

Moisture Conditioning:

Although the moisture content of a soil mass usually is not significantly altered by the compaction process, the degree of compaction (density increase) which can be achieved for a given compaction effort is dependent upon the moisture content of the soil being compacted. The alteration of the moisture content prior to compaction is often referred to as moisture conditioning.

Ordinary Fill:

Material obtained from excavation or imported that contains not more than 20% by mass of rock fragments with size between 75 mm and 150 mm, with no rock or clay fragments greater than 150 mm. (Refer AS 2566.2-2002.)

Perth Sand Penetrometer:

A steel shaft which is struck by a hammer free falling on its anvil. Used for determining the resistance of a soil to penetration. Penetration resistance is in units of blows per 300 mm. (Refer A1289.6.3.3)

Reactive Soils:

Clay soils, for which a change in moisture content may result in sufficient change in volume to affect the engineering performances of any structure (including pavements) influenced by this soil.

Road Authority:

The authority that is responsible for the care and management of the road in question.

Road Reserve:

The public carriageway reserve between property boundaries which contains assets including, but not limited to, the road formation, footpaths, driveways, nature strips.

Selected Fill:

Material that is free from organic or other deleterious material, obtained from excavation or imported, with a particle size for rock not greater than 20 mm, or for other than rock not greater than 75 mm. (Refer AS 2566.2-2002.)

Settlement:

Settlement is a downwards displacement of the ground surface, relative to either the surrounding ground (differential settlement) or a stable bench mark (total settlement). It is the result of a volume reduction in the ground beneath the surface, due to any of several possible mechanisms, as described below.

Collapse Settlement:

Fill materials which have been inadequately compacted or placed excessively dry can undergo a sudden volume reduction when their moisture content is increased. This can occur without any increase in the applied stress and is often referred to as collapse. The moisture content increase can occur from surface infiltration, leaking of the installed service or groundwater.

Consolidation settlement:

Refers to the vertical displacement within a soil mass which occurs under the influence of an applied load, usually static. This volume reduction is usually time dependent and associated with expulsion of water. The applied load may be the self weight of the filling or an external load, such as a building footing or an embankment. The consolidation may occur within the filling (it usually would need to be relatively wet) or the underlying soils.

Compaction Settlement:

Typically occurs under the influence of a dynamic load. During the placement and compaction process there is a volume reduction, but this would not typically be referred to as settlement. However, under such influences as traffic, poorly compacted material will undergo further volume reduction, manifested as settlement at the surface and, in the case of trench backfill, as localised differential settlement

Subsidence:

Subsidence is often interchanged with settlement, in particular in relation to depressions left in roadways etc, following service trench construction. Subsidence may be assumed to be *"Downward movement, predominantly vertical in direction, due to removal, consolidation or displacement of the underlying strata"*.

2 BACKFILL REQUIREMENTS

2.1 General

The Contractor shall employ suitable methods to compact backfill of trenches and shafts to comply with this Specification and prevent collapse or settlement.

2.2 Contractor Responsible for Subsidence

The Contractor is responsible for monitoring for, and rectifying any, subsidence that occurs as a consequence of the works. The Contractor shall make good any damage caused as a consequence of subsidence, including (but not limited to) damage to fences, buildings, paving and/or landscaping works. "Damage" is deemed to include tilting or leaning structures.

2.3 Option to Use Alternative Backfill Materials and/or Methods

The Contractor shall request approval to use alternative backfill materials, for example sand or flowable fill in place of clay. The Contractor shall request approval to use alternative construction methods, such as trenchless methods, to reduce the work associated with backfill and compaction control.

Use of alternative backfill materials and/or construction methods will be subject to:

(a) The alternatives being approved by the Superintendent.

(b) All costs associated with transport and disposal of the excavated material that is not required being borne by the Contractor.

(c) Where the Principal requires it, the Contractor obtaining written permission from the owner of the final dump site, and providing a copy to the Superintendent for approval before transport commences.

Adoption of alternative backfill materials and/or construction methods in these circumstances shall not constitute a variation, and no additional payment shall be made for such adoption by the Principal.

2.4 Backfill Placement

2.4.1 General:

Impact loading of the pipeline, shafts, structures and appurtenances must be avoided during the placement of backfill.

2.4.2 Adjacent to Shafts and Structures:

Where fill is placed around shafts or other structures, the fill shall be placed and compacted evenly around the shaft or structure to prevent displacement. Care shall be taken to place and compact the fill evenly around the structure in thin layers, to avoid unbalanced lateral loading.

High compactive effort shall not be used against structures to ensure damage to the structure is prevented. Particular care must be taken adjacent to house sewer connection branches and retaining walls.

2.4.3 Concrete Pipeline Support:

Where a pipeline is supported on concrete, the Contractor must not place the overlay material until the concrete has obtained its initial set. Backfill must not be placed within 24 hours of placing the concrete, or longer where specified by the Design Drawings.

2.5 Provision of Safe Environment for Field Density Testing

The contractor shall provide for the safe performance of the specified testing. This shall include:

(a) Preparation, in consultation with laboratory staff, of an approved safe working procedure that complies with the requirements of all OHS legislation, regulations and codes of practice.

(b) Provision of equipment (for example trench shields) to make excavations safe at the locations selected for testing.

2.6 Compaction Control Testing - Locations

The testing shall be carried out by an independent soil testing authority with NATA accreditation for the required tests. The laboratory staff shall randomly select the test location within the relevant backfill layer using a method approved by the Water Agency. The Superintendent, or his Representative or Inspector, shall direct the laboratory staff with respect to any additional test locations that they may require.

Under no circumstances shall the Contractor or his staff or agents direct the laboratory staff where to take tests, except where the Contractor requires additional tests at its own cost. The results of the Contractor's additional tests shall be reported to the Superintendent, in addition to those obtained from the normal testing program.

No testing shall be undertaken closer than 500 mm to the top of the pipe, where such testing is performed above the pipe. For testing of backfill below 500 mm from the top of the pipe, such testing shall be carried out near to the side of the trench, such that the testing apparatus is unlikely to intercept the pipe.

2.7 Area Represented by Test

The area deemed to be represented by a test shall be determined and recorded by the Superintendent. The Superintendent shall keep records in a form satisfactory to the Water Agency for audit purposes.

2.8 Work Not To Proceed Until Tests Passed

Further backfilling of a trench over the section deemed to be represented by a test shall not be carried out unless the testing indicates that the specified minimum levels of compaction have been achieved.

2.9 Testing Required by the Water Agency

The Water Agency reserves the right to select additional locations for testing, at its own expense. Where such tests fail, the Contractor shall bear the cost of rectification works, and the cost of re-testing.

3 TRAFFIC AREAS

3.1 Application

This Clause applies to backfill material for trenches in all Traffic Areas, including:

(a) The full width of any existing or proposed road carriageway plus shoulders, and extending to one metre beyond the shoulders/kerb.

(b) The full width of any property access driveway, and extending one metre either side.

(c) The full length of any constructed footpath (including, but not limited to concrete, asphalt, crushed rock footpaths).

(d) The full width of any median strip.

(e) Any other areas that are used as Traffic Areas.

3.2 Road Authority Requirements May Prevail

The Road Authority's requirements are defined to be the requirements described in the Road Authority's standard specifications and drawings with respect to traffic areas as defined in Clause 3.1.

The backfill material for traffic areas shall be acceptable to the Road Authority, and in accordance with its standard specification and drawings.

(a) If the Road Authority's requirements for traffic areas exceed the requirements of this Specification, then the Road Authority's requirements shall take precedence.

(b) If the Road Authority's requirements for traffic areas are less than the requirements of this Specification, and the contractor can provide satisfactory documentary evidence that the road authority is prepared to accept works in accordance with the road authority's own requirements, then the Road Authority's requirements may be adopted.

(c) In all other cases, or if the Road Authority's requirements are non-existent or unclear, then this Specification shall take precedence.

3.3 Backfill Material

The backfill material in traffic areas shall comply with the following:

(a) For trenches less than 1.5 metres deep, in traffic areas other than footpaths, the backfill shall be 20 mm Class 2 Plant Mixed Wet Mix Crushed Rock, for the full depth.

(b) For trenches 1.5 metres deep or greater, in traffic areas other than footpaths, the backfill shall be:

i. 20 mm Class 2 Plant Mixed Wet Mix Crushed Rock for the top 600 mm.

ii. 20 mm Class 4 (or better) Crushed Rock for the remainder, or other backfill material specifically approved by the Road Authority.

(c) For trenches under footpaths, the backfill shall be 20 mm Class 4 (or better) Crushed Rock, or other backfill material specifically approved by the Road Authority.

(d) All crushed rock backfill material shall comply with Vic Roads Standard Specification 812.

3.4 Backfill Placement

The backfill material shall be placed and compacted in layers not exceeding 200 mm loose thickness, and shall be moisture conditioned as required to facilitate compaction to the required density (Clause 3.6).

3.5 Compaction Testing

Compaction control testing shall be undertaken in accordance with Clause 2.6, and at the following minimum frequencies.

All tests must meet or exceed the specified compaction requirements. All road crossings shall be tested.

3.5.1 Road Base Course and Sub-base:

For every 50 metre length of trench (or part thereof) three tests shall be taken:

(a) Within the top 100 mm (ie within the base course) of an existing road.

(b) In the depth range 100 mm to 300 mm depth (ie within the pavement sub-base).

3.5.2 Backfill Under Roads, Road Shoulders, Median Strips (below sub-base):

For every 40 metre length of trench (or part thereof) one test shall be taken per two layers of the backfill material:

(a) Layers to be tested shall be selected randomly, in accordance with Clause 2.6. The position of the layer to be tested, and the location of the test, shall vary from test to test.

(b) Adjacent layers shall not be selected for testing.

3.5.3 Backfill Under Footpaths:

As for roads, except that the testing shall be for every 100 metre length of trench (or part thereof).

3.6 Required Density

In terms of the Modified Compaction test (AS 1289.5.2.1) the minimum dry density ratio (AS 1289.5.4.1) required is as follows:

(a) The top 100 mm of pavement: 98% (existing roads only)

(b) Below 100 mm from surface, where crushed rock: 95%

(c) Below 300 mm from surface, where permitted to be sand min: 85% Density Index, or 10 blows/300 mm PSP (see Clause 4.4)

3.7 Road Authority and Council Requirements

If the Road Authority and/or Council have additional requirements for compaction testing that exceed the above requirements, the additional requirements must be complied with.

3.8 Test Result Outcomes

Test results shall be reviewed by the Superintendent and action shall be taken in accordance with the following table:

Modified Dry Density Ratio (%)		Density Index % / PSP Below 300 mm (where permitted to be sand)	Action Required
Top 100 mm	Below 100 mm (FCR only)		
Not less than 98.0	Not less than 95.0	Not less than 85 / 10 blows	Superintendent accepts layer under test.
97.0 to less than 98	94.0 to less than 95.0	Not less than 75 to 85 / 9 to 10 blows	Contractor to re-roll and retest (only permitted twice. A third test failure will result in rejection of the layer under test).
Less than 97.0	Less than 94.0	Less than 80 / 9 blows	Superintendent rejects layer under test.

All work associated with re-working the compacted fill after a test(s) indicating density lower than specified shall be carried out at the contractor's expense.

3.9 Rejection of Backfill Layer

In the event that a compacted layer under test is rejected, the Contractor shall re-excavate the material in that layer, and backfill with new material, re-compact and re-test in accordance with this Specification. This work shall be at the Contractor’s cost, and no additional payment shall be made by the Principal.

4 COHESIONLESS SOILS

4.1 Application

This clause applies to the use of cohesionless soil fill, in all areas except under Traffic Areas (see Clause 3.1) and other excepted areas.

Cohesionless soils, for the purpose of this Specification, are defined elsewhere in this Specification. Such soils will typically be clean sands or silty sands.

Unless specifically approved by the superintendent, cohesionless soil fill is only to be used in those areas where the natural soils within which works are being undertaken are also cohesionless. Where cohesionless soil fill is proposed in areas where the natural soils are clayey, and consequently may be reactive, special considerations may need to be applied. In such circumstances, the designer may impose additional requirements to those given in this Specification.

4.2 Use of Water

4.2.1 Flooding

Flooding of backfill as means of attempting compaction is not permitted.

4.2.2 Jetting

Jetting of backfill is only permitted where the surrounding soil is also cohesionless, as defined in Clause 1.4. Where cohesionless soil is used to backfill trenches excavated in clayey soils, jetting is not permitted and mechanical compaction is to be used.

Where jetting is to be permitted, the Contractor must:-

(a) Have an approved placement, inspection and testing work plan in place, which is used to control the process.

(b) Utilise appropriate equipment that is approved.

(c) Achieve the specified level of compaction.

(d) Pay for the water taken from the Principal's water reticulation system.

(e) Use an approved Backflow Prevention Device.

(f) Take steps to ensure that water is not wasted.

(g) Take preventive measures to contain water containing sediment, and in particular, prevent it entering drains and water courses, all in accordance with EPA Guidelines.

4.3 Backfill Placement and Compaction Requirements

4.3.1 Jetting

Where jetting is proposed as the means of achieving compaction, cohesionless soils may be placed in the trench to a depth consistent with the approved work plan, the equipment used for jetting and with the equipment available to assess compliance. Compaction of placed fill by jetting may then be undertaken. No further filling shall be permitted until testing has been undertaken and compliance indicated. A delay of at least 24 hours may be required before testing, to allow excess water to disperse.

Additional filling, jetting and testing shall then be undertaken as required.

4.3.2 Mechanical Compaction

Where mechanical compaction is proposed, backfill shall be placed in the bottom of the backfill zone and spread to provide a uniform thickness layer. The thickness of the layer will depend upon the nature of the backfill, and the compaction equipment to be used. The contractor is responsible for assessing the required layer thickness. However, the thickness of a loose material layer shall not exceed 400 mm in any circumstances.

Mechanical compaction shall be carried out on the layer, to achieve the specified level of relative compaction. Water may be added during the compaction process, to assist with compaction. The compaction equipment used and layer thickness adopted shall be such that the required relative compaction is achievable over the full depth of the layer.

Subsequent layers shall be placed and compacted as described above to backfill the trench as specified.

4.4 Required Backfill Density

Backfill shall be compacted to achieve the minimum relative compaction described below, in terms of Density Index (AS 1289.5.6.1) or penetration resistance using a Perth Sand Penetrometer (PSP) (AS 1289.6.3.3).

4.4.1 Road Reserves

In Road Reserves (other than Traffic Areas)

Minimum Density Index of 65%, or

Minimum PSP Penetration resistance of 8 blows per 300 mm

4.4.2 Other Areas

Minimum Density Index of 60%, or

Minimum PSP Penetration resistance of 7 blows per 300 mm

Note: With sands compacted using mechanical means, the surface soils may be loosened by the process. Testing of the penultimate layer is often required to assess compliance. The final layers will then require additional attention to achieve compliance, often with static rolling compaction.

4.5 Test Frequency

4.5.1 Test Performed using a PSP

Where testing is performed using the PSP, testing shall be carried out as shown in the following table.

Asset	Road Reserves	Other Areas
Sewers	Three tests per manhole length, except where the manhole length is less than 50 m where only one test is required.	One test per manhole length.
Rising Mains and Water Mains	Three tests per 80 m length or part thereof, except for lengths less than 40 m where only one test is required.	Two tests per 100 m length or part thereof.

4.5.2 Test performed using conventional field density and laboratory reference density testing.

Where testing is performed using conventional field density and laboratory reference density testing.

Asset	Road Reserves	Other Areas
All areas	1 test per two layers per 40 m length (or part thereof)	1 test per two layers per 100 m length (or part thereof)

4.5.3 Test Locations:

The layer of backfill to be tested shall be selected randomly, in accordance with Clause 2.6.

The position of the layer to be tested, and the location of the test, shall vary from test to test.

4.5.4 Additional Tests:

The Superintendent may direct that additional testing be carried out at specified locations. Costs for these tests shall be borne by:

(a) The Principle, where the test meets this Specification,

(b) The Contractor, where the test fails to meet this Specification..

4.6 Test Results Outcomes

The test results shall be reviewed by the Superintendent.

Where jetting has been used as the method of compaction, the following action shall be taken.

(a) PSP Penetration over all test intervals equals or exceeds minimum requirement:- accept zone under test.

(b) PSP Penetration over one or more test intervals is less than minimum requirement:- re-jet and re-test all of area represented by these tests.

(c) Re-jetted and re-tested area again fails to indicate compliance*:- remove backfill and replace.

** If excessive silt content, jetting may not succeed. Mechanical compaction of backfill in layers may be required.*

Where mechanical compaction has been used, testing with the PSP is permitted for several placed layers. However, should the penetration resistance over any test interval be less than the required value, removal of all backfill represented by the tests, and its replacement, recompaction and testing is required.

For testing using field density and laboratory reference density testing, if all test results equal or exceed the requirements, the test zone under consideration is accepted. Where non-compliance of any test by more than 5% Density Index is indicated by the testing, the zone under consideration shall be excavated, replaced and compacted and tested again. For non-compliance by less than 5% Density Index, the zone in question may be re-rolled at the Contractor's sole discretion and then re-tested (at the appropriate level). If compliance is indicated, the zone under consideration will be accepted. If not, excavation, replacement and recompaction before submitting for further testing shall be required.

All work associated with re-working the compacted fill after a test(s) indicating density lower than specified shall be carried out at the contractor's expense.

5 COHESIVE SOILS (CLAYS AND CLAYEY SOILS) – REQUIREMENTS

5.1 Application

This clause applies to the use of soils which are either clay or are sufficiently clayey in composition that they will behave in a clay like manner when placed and compacted as trench backfill. These soils may be placed in all areas except under traffic areas (as defined in Clause 3.1) and other excepted areas. They are cohesive soils in accordance with the definitions presented in Clause 1.4. Should well graded granular materials (eg crushed rock), which also are likely to be cohesive soils in relation to the definition in Clause 1.4, be proposed for use as backfill, this section may also be adopted. However, guidance from the Superintendent should be sought in relation to moisture conditioning, for which the requirements of Clause 5.3 may not be applicable. The use of granular material for backfill in areas where the natural soils are reactive clays (e.g. basaltic clays) will not be permitted unless specifically approved by the Superintendent. In such circumstances, special considerations may need to be adopted, and the designer may incorporate additional requirements to those of this Specification.

5.2 Use of Water

5.2.1 Flooding and Jetting Not Permitted:

Flooding or jetting of cohesive fill materials in excavations is NOT PERMITTED UNDER ANY CIRCUMSTANCES. Cohesive soil fill that has been flooded or jetted shall be rejected, and the Contractor shall replace the fill material, in accordance with this Specification, at its own cost.

5.2.2 Moisture Conditioning Prior to Backfilling:

Moisture conditioning of fill shall be carried out as required, providing the Contractor:

(a) Has an approved inspection and test plan in place, which is used to control the process.

(b) Pays for the water taken from the Water Agency's reticulation system.

(c) Uses an approved Backflow Prevention Device.

(d) Takes steps to ensure that water is not wasted.

(e) Takes preventive measures to contain water containing sediment, and in particular, prevent it entering drains and water courses.

5.3 Moisture Conditioning

The moisture content of the fill is critical to achieving the specified minimum compaction requirements. The fill should be moisture conditioned as necessary to facilitate achieving the required relative compaction, but in any case to within the range 85% to 115% of Standard Optimum Moisture Content, as determined by AS 1289.5.1.1 or AS 1289.5.7.1.

5.3.1 Field Test for OMC:

The following empirical test is provided for the information of the Contractor only. It is NOT a method statement or advice, nor is it a direction from the Principal or Superintendent or their representatives, nor is it designed to replace expert advice. This information in no way reduces the Contractor's responsibility to ensure that the backfill moisture content is correct in order to achieve the specified densities.

As a field guide to assessing whether a clayey soil is near its Optimum Moisture Content (OMC) for Standard Compaction (AS 1289 5.1.1), the following test is useful.

A representative handful of material proposed for use as backfill is squeezed in the hand. Suitable material should be wet enough so that it binds together with no more than slight crumbling when the hand is opened, and not so wet that it is at all plastic or slippery, nor exudes water when the material is well shaken in the hand. Clayey material, at about standard OMC should be able to be rolled into a worm, approximately 2 mm in diameter, but when an attempt is made to bend the worm, it should not bend but should break.

When compacted against a firm surface, the material of correct moisture content should not surge ahead of the roller or other equipment and should not rebound excessively after wheel loading. It should readily bind together under the rolling action.

Possible action to alter the moisture content of stockpiled backfill material could include:

5.3.1.1. Dry Fill:

Finely spray water and uniformly blend water through the dry fill and mix to provide a consistent moisture distribution. Allow time (say overnight) for clayey soils to cure.

5.3.1.2. Wet Fill:

Blend fill with drier material, or aerate the fill. Note if the fill is excessively wet it may be difficult, if not impossible to achieve the specified compaction, and specialized advice should be sought.

It is suggested that minimising the time between excavation and re-compaction of the excavated material is the best method of achieving the

OMC and the compaction target. It is very difficult to properly moisture condition the excavated material once it has dried out. The Contractor must therefore consider the need to limit the amount of trench excavated at any time to the amount that it can manage with the level of equipment and resources on site.

5.4 Backfill Placement and Compaction Requirements

Suitably moisture conditioned backfill material shall be loosely placed in the bottom of the backfill zone and spread to form a uniform thickness layer. The thickness of the layer will vary depending on the type of soil and on the equipment available for compaction.

The Contractor shall establish the optimum loose layer thickness to achieve the required compaction. However the thickness of a loose material layer shall not exceed 300 mm under any circumstances.

Mechanical compaction shall be carried out on the layer to achieve the specified level of compaction. The compaction equipment shall be capable of achieving the required level of density at the underside of the layer.

Subsequent layers shall be placed and compacted as described above to backfill the trench as specified.

Some Ordinary Fill may behave essentially as a cohesive material, but contain greater than 20% of rock material which is coarser than 37.5 mm. Such material may be acceptable as backfill to trenches, but will be unable to be tested using the methods of AS1289. Where such materials are proposed for use as backfill, the Contractor shall provide to the Superintendent, for his approval, a method Specification for the placement and compaction of the material. This Method Specification shall be in sufficient detail to demonstrate that the intent of this Specification will be achieved. No backfill using this material shall be permitted until the Method Specification has been approved.

5.5 Compaction Testing

Field dry density testing and laboratory compaction testing shall be carried out at test locations determined in accordance with Clause 2.6 and the table below.

The frequency of testing, and the minimum compaction requirements (relative to Standard compaction (AS 1289.5.1.1) in accordance with AS 1289.5.4.1 or AS 1289.5.7.1) shall be as shown in the following table:

Within Trenchfill Zone and Up To:	Minimum Density Ratio Required:	Moisture Content% of Standard OMC	Test Frequency Required:
Within 600 mm of finished surface level: (Use Selected Fill.)	95% (minimum)	85% to 115%	1 test* per two layers per 40 m length (or part thereof)
600 mm below the finished surface level: (Use Ordinary or Selected Fill.)	90% (minimum)	85% to 115%	1 test* per two layers per 100 m length (or part thereof)

*Note that "test" means one field test plus one laboratory test (refer Clause 5.6).

5.5.1 Test Locations:

The layer of backfill to be tested shall be selected randomly, in accordance with Clause 2.6.

The position of the layer to be tested, and the location of the test, shall vary from test to test.

5.5.2 Additional Tests:

The Superintendent may direct that additional testing be carried out at specified locations. Costs for these tests shall be borne by:

(a) Where the test meets this Specification, the Principal.

(b) Where the test fails to meet this Specification, the Contractor.

5.6 Compaction Testing – Method

The field dry density and laboratory compaction tests shall be carried out on a one to one basis. (i.e. one laboratory compaction test shall be carried out for each field dry density test).

The testing methods may include:

- AS 1289 5.1.1, AS 1289.5.1.2 Standard Compaction
- AS 1289 5.3.1 Field Dry Density – Sand Replacement Method
- AS 1289 5.4.1 Dry Density Ratio
- AS 1289 5.7.1 Hilf Density Ratio
- AS 1289 5.8.1 Nuclear Density Gauge*

*The Nuclear Density Gauge method of field dry density measurement shall only be used in a trench where it can be demonstrated that the

effects of reflected radiation from the walls of the trench are adequately compensated for.

5.7 Test Result Outcomes

Test results shall be reviewed by the Contractor, and action taken in accordance with the following table:

Density Test Result:	Action:
Meets Specification	Continue to place and compact layers of fill layers of fill
Below Specification	Report test failures and locations to Superintendent. Rip fill, re-spread, re-compact and retest all fill represented by the test. If the testing indicates low density for a third time, the material shall be re-excavated, replaced with new fill, re-compacted and re-tested.

All work associated with re-working the compacted fill after a test(s) indicating density lower than specified shall be carried out at the contractor's expense.

5.8 Compaction Trial

The Contractor shall undertake such trials as are necessary at the start of the backfilling operation to establish a suitable compaction procedure. These trials shall be used to establish:

(a) An appropriate layer thickness to suit the soil and available compaction equipment and moisture conditioning requirements.

(b) A suitable number of passes of the compaction equipment to achieve the minimum compaction requirements.

The contractor shall then advise the Superintendent of the proposed layer thickness, moisture conditioning procedure and number of compaction passes to be used as the backfill procedure for the soil type under test to meet or exceed the minimum requirements of this Specification.

5.8.1 Changing Materials:

Soil types may change within the project area, to the point where the compaction method devised during the initial trials is no longer achieving the densities required by this Specification.

Where soil properties change such that the soil is substantially different from the soil further trials shall be conducted, and the compaction procedures modified to suit the new soil properties.

6 DRIVES, SHAFTS, TUNNELS AND BORES

6.1 Drives and Tunnels

Drives and tunnels must be refilled above the embedment zone using the following materials and methods:

(a) 20 mm Class 4 crushed rock, or embedment concrete sand or 5 mm minus, pneumatically placed (blowing backfill into the excavation using compressed air through temporary piping that can be retracted as the excavation fills).

(b) Grouting, either by gravity, or under pressure. (Gravity grouting should only be used for tunnels where there is sufficient head.)

6.2 Grouting

Grout for backfilling shall be a sand-lime-cement slurry consisting of 20 parts sand to 2 parts lime to 1 part cement by volume, to which sufficient water is added to permit the mix to just flow under its own weight. An acceptable alternative is a commercially manufactured product such as Liquifill Grade PC1 or approved equivalent.

Grouting of tunnels, drives and bores must be carried out within 24 hours of pipe placement by one of the following methods. Grouting of bores is not required where the diameter of the bore exceeds the outside diameter of the pipe by less than 40 mm.

6.2.1 Gravity Grouting:

The grout is allowed to flow under gravity to fill the excavation. The grout must be placed in shafts and allowed to flow into the drives to completely fill them. Excess water must be removed progressively, Care must be taken to prevent the drives becoming air-bound and, if necessary, the Contractor shall provide riser holes for the release of entrapped air.

Riser holes shall be drilled and cleaned out prior to placement of the grout, and shall be maintained in a clear condition during the grouting operation. Riser holes shall be between 75 mm and 300 mm in diameter.

If backfilling against a bulkhead, the Contractor shall provide, at the top of the bulkhead, a horizontal proving hole not less than 50 mm diameter. The Contractor shall maintain the proving hole in a clear condition.

A substantial surcharge must be maintained above the roof of the tunnel, drive or bore throughout the placing operation. Placing shall continue without interruption until, by the presence of slurry in the risers and by the cessation of movement in the free surface, it is apparent that the tunnel, drive or bore is full, or until directed by the Superintendent that the filling be discontinued. Grout must not be permitted to rise above 600 mm below ground surface level.

6.2.2 Pressure Grouting:

The grout is forced into the excavation using air or mechanical pressure. Riser holes and proving holes must be constructed and maintained if necessary, and the grout placed to a level in the riser holes as specified for gravity grouting.

6.3 Voids Behind Timber Ground Support

In close-timbered tunnels, drives and shafts, the Contractor shall fill the voids behind the timber ground support by pressure grouting or other approved means.