<u>F/1 Specification Notes (Provisional) June 2016</u>

1. Introduction

These notes are for the guidance of designers, contract writers, contractors, consultants and road controlling authorities. They are not intended to be included in the contract documents. The numbers assigned to paragraphs in these notes correspond with the clauses in the specification to which the notes refer.

Users of these notes are also referred to the following useful references:

- *Guide to Pavement Technology, Part 41: Earthworks Materials*: Austroads, April 2009

2. Scope

Specification NZTA F/1 should be used for all road and highway earthworks. It does not directly refer to other specifications for associated works. The interrelationship with other specifications for works such as pavement construction, drainage, culvert and subsoil drain construction, fencing etc should be made in the contract documents where appropriate.

3. Definition of Key Earthwork Terms

In an engineering project the earthworks for the road formation can be constructed in a number of ways, including: (a) “box cutting”, (b) “embankment fill”, (c) in “sidling cut” and (d) by “sidling cut and fill”. These typical construction methods are illustrated in Figure 1.

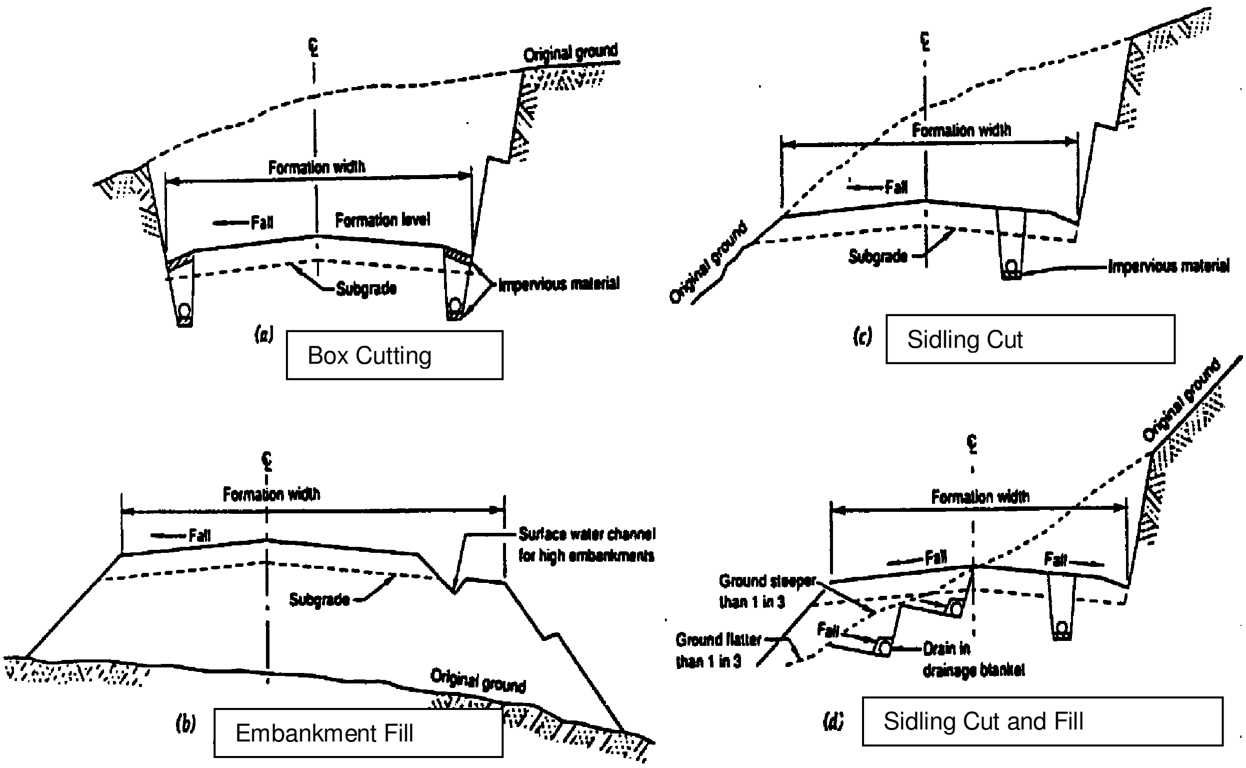

Figure 1: Typical Road Pavement Construction Methods

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To distinguish between the earthworks associated with cuts or embankment fills and the subsequent pavement materials (sub-base, basecourse) the term *top of subgrade surface* is used. The top of surface should be defined on the drawings. The designer will need to confirm under which specification (F/1 or B/2) any modification of the subgrade and subgrade surface using methods such as stabilisation will be completed.

- Most of the definitions in this specification define physical limits for individual elements within the construction

- “Granular fill” relates to the technical requirements for compaction and control of the granular fill construction

- The definitions for rock relate to the classification of materials for payment

- Soft rock materials may need to be excavated as a rock, but then compacted as a soil, as a result of the ongoing slaking and material breakdown during construction. The use of soft rock materials will require careful consideration during investigation, design and construction.

4. Earthworks Management

Effective earthworks projects include good production planning. The Contractor needs to understand the designer’s intention for earthworks in order to plan and implement the earthworks successfully. This in turn means that the designer should through the contract specification provide information that supports good understanding of the works by all parties, including access to all geotechnical investigation and laboratory test information.

5. Environmental Management

Environmental planning and good on site environmental management have become significant features in modern earthworks projects. Designers and Contractors are referred to the following references on this subject:

- *Erosion & Sediment Control: Guidelines for Soil Disturbing Activities* : Auckland Regional Council Technical Publication No 90, March 1999

- *Erosion & Sediment Control: Guidelines for Soil Disturbing Activities* : Environment Waikato Technical Report 2002/01, May 2003

6. Site Clearing

It is importance from the start of any construction work that attention is paid to the effects of the earthworks on the surrounding landscape. The haphazard removal, dumping or clearing of existing vegetation and landforms cannot be accepted, nor can the unwarranted damage of vegetation or landforms bounding the construction site.

The contract documents should carefully list and describe as necessary specific items to be protected from damage within the bounds of the site. In some cases it will be necessary to specify separate items for clearing (e.g. large trees, individual buildings of significant size) and a comprehensive schedule should be prepared.

All clearing should be carefully planned and executed with particular attention to both the short and long term effects on potential soil erosion. Any local conditions pertaining to the operation of clearing and disposal on a specific site should be specified.

The clearing of borrow and dump areas should be included in this item. In recent times even the clearing of dump areas has required the removal of topsoil and vegetation, benching as required, and the installation of subsoil drains before any dumping can take place. Any such requirements need to be specified.

7. Topsoil Management

The effective uplifting and recovery of topsoil for future use on a construction site is an important part of modern earthworks projects. Contamination by weeds, construction debris and other deleterious material can and should be carefully controlled. Wherever possible topsoil shall be transferred directly to the designated area for placement as the planting media rather than stockpiled for future use.

Topsoil or other material should not be removed from within the drip lines of established vegetation that is to be retained, except where this could result in unstable conditions. In the latter case the Engineer should be consulted before the affected land is disturbed. The root systems of existing protected plants should also be preserved wherever practicable.

Where topsoil stockpiling is required, (refer also Clause 1.9) the following provisions will assist the management of stockpile operations:

- Limiting the height of topsoil stockpile to 3 metres
- Limiting the width of the base of stockpiles to 10 metres
- Adopting batter slopes, protective covers and drainage measures which help reduce potential for erosion and/or contamination
- Limiting the period of stockpiling
- Treating the surface of stockpiles with suitable herbicide to prevent weed growth and ensuring the stockpile faces remain “weed free” prior to use.

The stripping and stockpiling of topsoil from borrow areas should be included in this item.

For calculating quantities for payment purposes, the Contractor should carry out field depth measurements of the topsoil prior to stripping. It may be necessary to calculate average depths over individual sections of the site, if the recorded depths of topsoil vary significantly. The solid volume can then be computed from the actual areas stripped. Alternatively the stripped topsoil could be measured in stockpile and an agreed bulking factor applied to arrive at the solid in place volume prior to stripping for payment purposes.

Allowance must be made for the quantity of turf and topsoil removed when calculating the earthworks quantities so that the excavation is not paid for twice and that the increase in volume of filling is allowed for.

8. Surface Drainage

Water is both a help and a hindrance. Optimum water content conditions in soils will assist compaction processes. Too much water can cause excess pore pressures, soil weaving, and soil strength loss and erosion. Too little water will create a dust nuisance, and also hinder compaction.

Earthworks need to be protected against the unplanned introduction of surface or rain water into cut and fill areas. This often involves the temporary diversion of natural drainage water away from the site works. The construction of the final culverts, subsoil drains, and side drains whilst useful may not be able to handle the incidental needs of temporary construction drainage. The planned use of shallow surface water diversions, planned soakage areas, silt detention systems with purpose built decant systems, temporary culverts etc can all be used to provide safe and effective temporary stormwater management.

Precautions should be taken to ensure that the control of surface water within the construction site does not interfere with or disrupt the water supply to downstream users. RMA consent conditions will often make reference to the consequence of drainage works on and off the site.

Good practice can include:

- retaining a low bank on the outside of sidling cuttings as finally constructed. This practice not only provides traffic with additional safety but prevents surface water from spilling over and causing batter erosion

- providing effective water energy and erosion controls on the outlets to temporary and permanent drainage systems to mitigate against erosion damage even after vegetation has been re-established.

9. Temporary Fencing

Temporary fencing must be provided to protect adjoining properties if permanent boundary fences are not first erected.

Specification NZTA F/1 does not provide design details for permanent fencing. This should be covered by a separate section in the contract documents which could be either to a relevant standard or specifically written for the particular project.

10. Earthwork Materials

The differences in the ease of excavation of type A, W and U materials is now assumed to be less significant than whether the material is “cut to fill”, “cut to waste” , “cut to stockpile”, “stockpile to fill” or “borrow to fill”.

Material classified as type R1, R2 or R3 will continue to attract extra payment for the excavation of these materials as appropriate for each type of rock. Materials classified as type W or U do not attract any extra payment for excavation. Payment for materials classified as W or U is determined not by their classification but by whether the material is “cut to fill”, “cut to waste”, “borrow to fill” etc. Approved drying operations for type W material, either in-situ drying or drying in a stockpile site, will if approved be paid for as day works using an agreed schedule of rates.

All undercut excavation below design fill foundation or subgrade surfaces, benching etc, shall be paid for as rates tendered by the Contractor under type A material and extras if appropriate.

A Contractor is not entitled to be paid at the schedule rate for type R1, R2 or R3 material if he/she elects to rip material merely for the sake of speeding up the excavation when the material could be removed by conventional earthmoving plant with reasonable facility.

Rock materials classified as R1 can usually be ripped and moved productively using modern, well maintained construction equipment at least as powerful as either a crawler tractor fitted with a twin shanked hydraulic ripper having net engine power in the range up to 100 to 120kW, or a 30 tonne tracked excavator using a ripper tipped bucket working at full power under safe operating conditions.

Rock materials classified as R2 can usually be ripped and moved productively using modern, well maintained construction equipment at least as powerful as either a crawler tractor fitted with a twin shanked hydraulic ripper having net engine power in the range up to 270 to 315kW, or a 30 tonne tracked excavator using a single ripper off the boom at full power under safe operating conditions.

With reference to the classification of R1 and R2 materials:

- Crawler tractors with net engine power in the range 100-120kW currently include but are not limited to the *Caterpillar D6C, International Harvester TD-15C, Komatsu D60 (Refer current manufacturers specifications)*

- Crawler tractors with net engine power in the range 270-315kW currently include but are not limited to the: *Caterpillar D9 (PS), Komatsu D355, Terex 82-50 (Refer current manufacturers specifications)*

- Excavators in the 30 ton class currently include but are not limited to the *Case CX330, Cat 330C, Kobelco SK330LC, Komatsu PC300LC-7, Liebherr R942 and Volvo EC330B (Refer current manufacturers specifications)*

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The Engineer shall nominate in the contract documents the target hourly production rates used to define the transition from Types A to R1, and R1 to R2, based on prior assessment and testing of the rock materials and the guidance given in the Notes to this specification.

If the actual production rate for a single crawler tractor/excavator operation working at full power is less than 300m^3/hour this would typically signal the transition between Type A and Type R1 material. This advice is based on recent experience in sedimentary rock materials in NZ.

If the actual production rate for a single crawler tractor/excavator operation working at full power is less than 75m^3/hour this would typically signal the transition between Type R1 and Type R2 material. This advice is based on evidence contained in AS 2868 – 1986 (Classification of Machinery for Earthmoving, Construction, Surface Mining and Agricultural Purposes) and the earthworks specifications listed below:

- *Main Roads Standard Specification _ General Earthworks*: Queensland Government Department of Main Roads, MRS11.04 December 06, and Errata March 07

- *RTA QA Specification R44 – Earthworks*: Roads and Traffic Authority NSW, Edition 3, Revision 7, November 2007

Ripping trials need be carried out only if there is disagreement over the classification.

Materials which have become wet due to the Contractor’s negligence, insufficient attention by the Contractor to the closing-off of cut and fill areas, or the lack of adequate and efficient drainage and especially if being excavated outside the nominated construction season shall not be paid for at a higher rate than they would have otherwise. If suitable fill material is made unsuitable by the Contractors own actions (or in-action) then the costs of removing this material and replacing it with suitable fill material will rest with the Contractor.

The nominated construction season must always be described in the contract. The limits, if any, on the construction season will take into account past experience, the local climate conditions, and the water susceptibility of the construction materials. Clays and silts cannot normally be worked under wet conditions. Water is essential for the compaction of all materials. It is the Contractor’s decision whether to work outside the construction season and carry the extra costs, if any, in so doing.

Clause 2.9 provides direction for rock blasting. This work will need to be carried out by trained and experienced staff. The planning, implementation and monitoring of all blasting works will be the Contractor’s responsibility. When preparing the blasting plan consideration will need to be given to the following issues, amongst other things: the potential for adverse effects on adjoining land and land owners, the effects of blasting operations on temporary traffic controls, the works associated with the effective removal of blast rock fall materials (including additional pulverisation of rock fall products if required), and the maintenance and remedial requirements of areas affected by blasting operations.

11. Excavation

The successful excavation of materials in an earthworks project requires the parties involved with the project (designer, Contractor and Engineer) to appreciate the geological conditions at a project site, and to understand the materials available within cut and borrow areas. The following document provides a useful reference on this subject:

- *Guideline for the Field Classification and Description of Soils and Rock for Engineering Purposes*: NZ Geotechnical Society, December 2005

The completion of an appropriate level of investigations (including in-situ and laboratory testing) before calling tenders can assist the parties to reduce unnecessary contractual risk and encourage competitive tenders. The investigations for and preparation of soil and rock material profiles (usually as material profiles plotted using the design long section) can assist the Contractor to make the best use of available materials (including selected materials for use in the subgrade construction).

Where this is available geotechnical information about a project site this should be included as support information in the tender documents. When supplying such information, the contract documents should include a clause describing the accuracy of such specialist information.

Clause 3.3 describes the undercutting required to achieve subgrade uniformity.

It is ultimately the Engineer's responsibility to determine if an existing material should be undercut or not. Testing to assist with this decision could include "in-situ" CBR or Shear Strength tests on the "undisturbed" subgrade and comparison of these test results with the results from laboratory test on remoulded samples compacted to the same level of compaction. If the in situ test strengths are greater than the remoulded strengths then undercutting could be omitted. This can occur in some sensitive materials, e.g. volcanic ash. The site production planning should also seek to ensure that sensitive in-situ materials are not reworked by normal earthworks operations.

When the cutting is not undercut generally, it is still advisable to undercut short sections at the end where they are adjacent to embankments to provide a good tie-in between the two structural forms, as shown in Figure 2 in the specification.

All unsuitable material should be excavated and replaced by suitable material in a logical, planned manner. The removal of unsuitable foundation material from areas where filling is to be placed is classed as undercutting and will usually be paid for as "cut to waste".

Where the soft condition of foundation soils (not unsuitable foundation material as described above) is due to poor drainage, such conditions should be corrected if possible rather than removing the material. Allowance may have to be made for future consolidation effects in this material. The use of sandy or granular materials in the lower portion of the embankment could greatly accelerate consolidation, as the water in the foundation spoil will be squeezed out through this more permeable layer.

Clause 3.4 describes construction batters and benching. Where the general slope of the natural ground under a proposed embankment is such that a potential zone of weakness would be created at the interface between the existing ground and any new filling, or when the presence of subsoil water could induce hydrostatic pressure behind the fill material, it is imperative that benches be cut and subsoil drainage used in the natural ground before the filling is constructed.

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The benching and slope design criterion given in the specification is for guidance only. The Contractor and Engineer, with appropriate technical support as required, should consider each foundation condition on its own merits. Benching should be shown on the construction documents wherever possible. Benches should be designed wide enough for the operation of the intended earthwork and compaction equipment.

Where it is anticipated that subsurface water will be encountered within the bench formations after the new fill is placed, special provision should be made for the installation of subsurface drains. Sufficient details showing a typical cross-section, gradient limits and the outfall method should be shown on the construction documents and all materials and workmanship requirements noted in the contract documents.

In Clause 3.5, borrow areas should be nominated and adequately described in the construction documents, or otherwise approved by the Engineer. Approval of borrow areas should include specific requirements for working limits, access restraints if any, working method and final shape characteristics. The limitation on the work area and the final reinstatement needs should take into account the whole area being utilised. All borrow areas when finally restored should conform to the adjoining land forms, in a manner that meets all RMA consent conditions. Borrow areas should not be opened up within 5 m of the edge of the formation or bottom of an embankment, unless otherwise approved. Borrow can often be obtained by widening the cuttings, preferably on the inside of curved sections. Consider obtaining resource permits in advance to avoid unnecessary delays.

In Clause 3.6, all dump areas should either be nominated in the contract documents, or the Contractor should be asked to provide suitable consented dumpsites as required in the tender documents. Disposal areas should be located so that on completion of the works they can be reinstated satisfactorily to conform to the adjoining land forms, in a manner that meets all RMA consent conditions. Surplus material can often be used effectively as Landscape Fill in widening embankments or in providing ancillary areas such as parking zones.

Side drainage, as discussed in clause 3.7, should be provided in all flat country and especially in swampy areas. Even if a road is built on an embankment it is good practice to construct a side drain clear of the toe of the embankment for slope stability reasons.

Where the formation is sufficiently wide, sufficiently deep side drains are preferred to subsoil drains in block cuttings and sidling cuts, as they can be easily maintained.

The two main objectives of side drains are to intercept natural surface water before it reaches the pavement formation and to keep the ground water level at least 1 m below the final subgrade level to guard against the rise of capillary water in cases where subsoil drains are not included. In some cases it may be necessary to use both subsoil and side drains in a complementary system.

The construction of side or cut-off drains at or near the top of cuttings is not generally regarded as a good practice as these often induce slips. In such cases bunds can be used to deflect stormwater.

All side drains should be designed to accommodate the anticipated surface and subsurface water discharge and be fully detailed on the construction documents.

No reference has been made in this specification to exposed benches used on cut or fill batters usually to control surface erosion, as this is a technical requirement specific to a particular job. Full details of this type of benching should be given in the construction documents.

12. Fill Construction

The specification requirements for fill construction provide the Contractor with considerable latitude in the use of materials. The Contractor and the Engineer have the responsibility to optimise the use of soil materials (notably achieve cut to fill balances and reduce unnecessary cut to waste) and to apply any necessary correction, if any, in the water content to facilitate soil placement and compaction to satisfy the strength and stability requirements of the fill. This approach applies in particular to all Bulk Fill and Subgrade materials.

The Engineer needs to confirm what soil material is not suitable for use in the Bulk Fill and Subgrade. Some material that would not be suitable for the Bulk Fill and Subgrade may be acceptable for Landscape Fill, where it would be able to dry out over time. Non structural fill can also be placed in one season, allowed to dry and then moved or re-used in the next season as Bulk Fill and Subgrade if the strength and stability of this material has improved sufficiently.

The Contractor is also responsible for placing the fill in layers, and with shapes and grades that facilitate compaction and strength gain, and limit water infiltration, soil erosion and contamination of the fill or adjoining land and water.

Clause 4.4 gives attention to Subgrade construction. This fill layer is given priority because of its proximity to the design traffic loads and the resultant stresses it will have to withstand as a result. The best material available should be used in the construction of the subgrade. If suitable material is not available from the excavation of the cuttings, consideration should be given to constructing the subgrade with material borrowed from another more suitable source.

13. Compaction

This specification does not attempt to nominate the type of compaction plant to be used. This choice is left to the Contractor. The distinction is made between compaction of granular fill and cohesive fill materials. Often there will not be one type of soil on a construction site. The designer and Contractor will need to consider how best to use a range of soil types (or mixtures of soil types). How the soils on a site are mixed and used will often depend both on the geology and geography of the site, and how the Contractor uses the site (production planning).

There is usually no doubt about the suitability of granular fill material (as defined in clause 1.3) for use in fill construction since the strength is usually adequate over a range of water contents.

Cohesive material (clays and some silt) may be too dry (indicated by a high dry strength followed by a marked reduction in strength when wetted at a later stage) or too wet (indicated by a lack of initial strength). If a material is rolled when it is too wet or too dry for efficient compaction, the consequences can be high air void and lower short and long term strength (soaked CBR or Shear Strength). Further rolling at water contents is of limited value, and may well in fact make the matter worse.

The optimum water content for a soil is the water content at which a pre-determined level of compaction (Field Compaction Effort) will produce a corresponding compaction outcome (maximum dry density). NZS 4402: Part 4:1986 gives methods of determining the optimum water content and maximum dry density for three levels of compaction, ranging from Standard Compaction up to Vibrating Hammer Compaction. The former is usually appropriate for assessing compaction conditions for lower fill materials, close to the foundation for embankments. The vibrating hammer compaction method is usually associated with basecourse construction, although it may be useful when specifying subgrade material compaction, provided that the formation beneath provides an adequate “anvil” on which to compact the subgrade fill materials.

An approximate determination of the optimum water content for materials with a dominant clay fraction can be made from a plastic limit test. In most normal clayey materials the optimum water content for standard compaction is approximately 5% below the plastic limit. Another rough check in most materials is to squeeze a lump in the hand and if it just holds together when the pressure is taken off, and material does not stick to the fingers, the water content will be approximately at optimum.

Instead of setting limits on the variation from optimum water content in this specification, it has been left to the Contractor (and Engineer) to determine whether soil materials are suitable for use at naturally occurring water content or whether some water content change (drying or wetting) is worthwhile.

Table 1 can be used as a guideline during compaction of granular and cohesive soils.

Table 1: Target Ranges for Field Moisture Content

Fill Material	**Target Range for Field Moisture Content**
Granular Fill	Field Moisture Content $_{\text{granular fill}}$ = OMC $\pm$ 2% *(note this figure is based on the moisture contents being in the range of say 10% up to 16%, in which case 2% either side would not be unreasonable)*
Cohesive Fill	Field Moisture Content $_{\text{cohesive fill}}$ = OMC - 5% *(note this figure is based on the moisture contents being in the range of say 15% up to above 30%, in which case 5% down would not be unreasonable)*

If the soil is wet of optimum (as indicated by the simple tests mentioned above) the strength when compacted to standard compaction is the criterion which should be used to determine the suitability for use as Bulk Fill. The shear strength should be greater than that required for stability of the fill based on the project design parameters. For this wet condition the shear strength can be approximated as being equal to half the unconfined compressive strength.

For subgrade fill materials, the in-situ CBR (measured either by in-situ CBR test, Scala Penetrometer or Shear Vane with suitable material specific correlations to CBR for that material) should be greater than the minimum design CBR (usually a soaked CBR at standard compaction) based on the project design parameters.

The air void content can be used to determine the suitability of Bulk Fill and Subgrade materials. A higher air void content can result in post construction consolidation, under both self weight and imposed load conditions. As a general rule of thumb, the air voids content for Bulk Fill and Subgrade should be less than 10%, and ideally for normal sedimentary or metamorphic based fill materials between 5% and 8%. The target air void content in volcanic soils can be closer to 10%. Local experience of the air voids peak at which a significant reduction in strength (measured as Shear Strength or possibly CBR) occurs with soaking will give a more accurate estimate for the target air void content for a particular soil or mix of soils.

In some materials a significant gain in strength is obtained if the water content is adjusted to be nearer optimum. The Engineer and Contractor should investigate the effects of changing the water content by wetting or drying the material and measuring the strength in terms described above. The feasibility and economics of changing the water content should be considered before ordering the Contractor to do this work.

In a change from the previous TNZ F/1 specification, this document now encourages the designer and Engineer/Contractor to consider the best combination of monitoring controls to be used when monitoring soil placement and compaction outcomes in the field.

For granular fill materials, the options include monitoring field water content (and comparing with OMC values for the soil or mix of soils being used) along with either stable plateau density (wet density) or stable surface deflection.

The field water content should be monitored using a Nuclear Densometer (or other suitable device) with regular back up laboratory based oven drying water content tests to confirm appropriate calibration factors for the particular Nuclear Densometer being used. The field water content should be compared with the Optimum Water content for the soil (or mix of soils) being used in the field.

The plateau density achievements should also be monitored using a calibrated Nuclear Densometer.

The use of stable surface deflections to monitor the performance of granular fill materials will require the Contractor to be able to measure the change in surface deflection under repeated loading cycles. Methods that could be used include a Benkelman Beam extended at right angles to the line of travel of the specified roller. In the TNZ F/1 1997, the resultant impression (deflection) in the trimmed surface under a smooth wheel roller having a minimum loading of 6259 kg per metre width of fill shall not be greater than 7mm for general (bulk) fill or 5mm for subgrade fill. The Engineer and Contractor will need to consider whether these deflection targets are suitable for the soil or mix of soils being used on a particular construction site.

For cohesive fill materials, the options include monitoring field water content (and comparing with OMC values for the soil or mix of soils being used) along with either (or a combination) of the following:

- Target field wet density measured using a calibrated Nuclear Densometer
- Minimum shear strength measured using a hand held shear vane

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- Maximum air voids measured using a Nuclear Densometer, along with a good understanding of material Solid Densities (based on laboratory tests) and water content measurements backed up by laboratory based oven dry water content determinations

Once it has been established that the soils are suitable for use as filling, the specification requirements described above will ensure that the filling receives adequate compaction and strength. In-situ tests including the Nuclear Densometer, Shear Vane, Scala Penetrometer, in-situ CBR and pavement deflection testing (Benkelman Beam or Falling Weight Deflectometer) can be used to monitor compaction and strength achievements. However, some care must be exercised in interpretation of test results because any change in roller compactive effort or soil type can change the target wet density, air void and strength outcomes markedly.

Since it is recognised that there is an inherent variability in the methods used for field density determination as well as in the soil, acceptance of the fill construction is based on the average of five test results rather than single results. The requirements specified in TNZ F/1 also provide a fixed protection against accepting poor construction. Each lot of construction represented by five tests should be as homogeneous as possible. The lot should consist of material which is homogeneous and representative of the recent construction works.

Once the number of passes of a particular roller required to produce the specified compaction and strength in a particular soil type has been established from compaction trials (Section 4.6.4) using Plateau Density Testing for example, control testing may be able to be reduced in that soil. However, the water content must be kept reasonably constant and each layer must be given the required number of passes in a consistent, uniformly distributed manner.

When cohesive material is being compacted on the wet side of optimum, a marked loss in strength can occur despite an increase in density, if the material is overstressed. This is evident by a tendency of the ground to heave and weave under the passage of construction equipment even before distinct ruts begin to form. If this happens, the material must either be left so that the pore pressures can dissipate be allowed to dry (or be dried mechanically or using additives such as lime) or be compacted using a smaller compactive effort, probably without vibration.

The specifications to be used when directing testing both in the field and in the laboratory are as follows:

Dry Density, Bulk Density & Air Voids.

All the parameters above can be measured using the following tests. These are the most common methods used in NZ to test subgrades, bulk fills, subgrade improvements and basecourse/subbase granular layers.

NZS 4407: 2015 Test 4.1 The density of compacted aggregate – sand replacement (compacted aggregates)
NZS 4407: 2015 Test 4.2 The field water content and field dry density of compacted materials method using a nuclear moisture-density gauge – direct transmission mode
NZS 4407: 2015 Test 4.3 The field water content and field dry density of compacted materials method using a nuclear moisture-density gauge – backscatter mode

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NZS 4402: 1986: Test 5.1.1 Sand replacement method for determination of the in situ density
NZS 4402: 1986: Test 5.1.2 Sampling Tube method for the determination of the in situ density

The methods now include air void and total void calculations if needed.

Typically “direct transmission mode” tests are used for cohesive type materials and “backscatter mode” for granular.

The “Sand Replacement” or Sample Tube methods are used to confirm the nuclear density meters (NDMs) are working correctly on the material in question and are sometimes called for in the contract only initially, say first 5 to 10 tests.

For larger projects or materials were there is little previous history of NDM use, a cross check using Sand Replacement is recommended.

The new methods strongly recommends that Oven Dry Water Content tests be taken from under the NDM especially for clay type materials to ensure best results are obtained.

Granular layers can be tested without Oven Moisture correction as water contents are generally low and have little effect on final outcome.

Soil Strength

Vane shear strength of a cohesive soil using a hand held shear vane
NZGS Guideline for hand held shear vane test 2001.

These are usually done over a 1m² area around NDM site or on their own and comprise an average of at least 4 tests. If the test results vary by more than 20% on one test location the results are reported as a range.

Determination of the California Bearing Ratio (CBR)

NZS 4402: 1986 test 6.1.1 remoulded specimens
NZS 4402: 1986 test 6.1.2 undisturbed specimens

Determination of the penetration resistance of a soil

NZS 4402: 1986 Test 6.5.2 hand method using a dynamic cone penetrometer (Scala Test)

Clegg Hammer Test
ASTM D5874 Determination of the impact value of a soil

The Clegg Hammer tests is used on granular layers as a companion to the NDM much like Shear Vanes are with cohesive soils. Good for picking up on suspect soft areas as long as the granular material isn’t too big >65mm.

14. Top of Subgrade Surface Testing

The top of subgrade surface should be checked for line and level (refer Section 5 of the specification) and for strength in accordance with the designers expectations (and as detailed in the Schedule of Job Details).

Subgrade strength testing could utilise one or more of the following:

- In-situ CBR test
- Scala Penetrometer test (usually in association with an agreed method of in-situ material specific conversion to equivalent design CBR)
- Pavement deflection test
- In-situ Pilcon Shear vane test (usually in association with an agreed method of in-situ material specific conversion to equivalent design CBR)

Whichever subgrade strength test is specified, care should be taken to ensure that the tests are calibrated for the local soil conditions.

15. Subgrade Fill Construction

The preparation of the subgrade should be completed in a manner that will allow the overlying pavement material to be spread and compacted prior to any deterioration of the subgrade surface. The forming of a smooth and even subgrade true to cross-sectional shape and free from ruts and weak spots is essential before pavement construction commences. If aggregate is laid on rutted or a misshaped subgrade, water trapped in hollows and depressions may result in subsequent pavement failure and moreover, the variations in pavement depths will ultimately reflect differing pavement reaction characteristics.

Care must be taken to ensure that the water content of the completed subgrade is not allowed to vary once compaction and final trimming has been completed. In particular clay subgrade surfaces must not be allowed to dry out to the extent that cracks develop. If the pavement layers cannot be placed before the finished subgrade is subjected to wet conditions, consideration should be given to sealing or otherwise overlaying the surface.

When maintaining the completed subgrade surface precautions must always be taken to ensure that the design profile is retained true to specification requirements. It also best practice to limit the amount of construction or normal traffic moving over an unprotected subgrade surface.

Formation surface water channels are those permanent drainage facilities constructed as part of the final subgrade construction e.g water tables or any other surface water drainage facility constructed on the highway formation. The contract documents and drawings should fully specify the location, shape, gradient and discharge method for each surface water channel. These water channels should be designed for future grader or excavator maintenance. They should function independently of any subsoil drains.

As required in clause 4.6.7, use should be made of the Benkelman Beam or a similar “strength” test to monitor the uniformity of the prepared subgrade surface, and to provide the means of comparing the strength of the as constructed subgrade surface with the design strength target. As this will often require comparison with a subgrade design CBR, the following notes provide guidance on the current best practice:

- The in-situ CBR of a prepared subgrade surface can be measured using a CBR test rig mounted on a suitable item of construction plant to provide the necessary reaction frame. It is worthwhile undertaking a second alternative test alongside the in-situ CBR test (such as a Scala Penetrometer test) to provide some across test calibration of the reported CBR outcomes, and to provide a means of undertaking a larger number of tests over a greater area than the rather slow in-situ CBR test method may allow

- The in-situ CBR can also be determined from back calculated layer moduli that are in turn determined using from measured deflection bowls from the Benkelman Beam or Falling Weight Deflectometer. Care needs to be taken when using this approach because the back calculated layer moduli are very dependant on the accuracy of the deflection measurements and the assumed layer profiles. However if a consistent approach to deflection measurement is taken, then the results of the testing can be used to measure consistency of the subgrade across the wider site. Calibration with an in-situ CBR tests can then be used to “calibrate” the CBR tests outcomes for the local soil and pavement conditions.

This testing is not intended to be a substitute for the compaction controls detailed in clauses 4.6.1 and 4.6.2.

16. Reinstatement

Clause 6.1 refers to shaping and topsoiling. Considerable emphasis should be placed on the final restoration of all disturbed areas and the establishment of the vegetation cover. The overall appearance and public acceptance of a road reconstruction project depends largely on the satisfactory completion of these works.

On completion of the formation earthworks all disturbed areas should be shaped to conform to the adjoining land and grassed as soon as possible. An early establishment of vegetation cover will assist in controlling wind and water erosion.

The depth of topsoil to be placed depends on the topsoil availability and the future of the treated area. For example, on slopes flatter than 2:1 within the highway reserve, the depth of topsoil should range between 75 mm and 150 mm, and on areas outside the road reserve on private property the depth should be similar to that of the adjoining undisturbed areas. Full use should be made of the contract documents to detail these requirements.

No extra payment should be made for the restoration of areas damaged by the Contractor's negligent operation, or for any other area disturbed by the Contractor outside the limits not specifically approved by the Engineer as a contract working area.

When grassing disturbed areas on private property or areas of road reserve which will ultimately revert to this status, the affected landowner's seed mixture preference should always be considered. Over-extravagant demands by the landowner should not be met in full, and in such cases a pro rata payment for intended works may be negotiated.

For areas within the road reserve, the grass type should be of a low growing character with a vigorous and deep rooting system. These seed requirements also apply on areas where the mulch retention system is used.

Seed mixtures and necessary fertilisers vary with soil type, and advice on suitable types and application rates should be obtained from suitable advisors.

17. Maintenance

Under clause 7, in all cases the Engineer should give specific instructions to the Contractor regarding the extent of the excavation and trimming work necessary to remove the slip and to reform the batter surface. The removal of material from a slip which occurs during the maintenance period should not be the Contractor's responsibility unless the slip is due to faulty workmanship. If it is due only to natural causes and the Contractor is asked to remove it, the work involved should be paid for.

18. Acceptance Quality Control

Fill Construction Acceptance Monitoring

The minimum acceptable frequency of testing shall be two complete set of tests (e.g. 2NDM's and 4 Shear Vanes tests as specified or directed by the Engineer) in randomly selected locations per 200m^3 of compacted fill. If the testing shows non-conformance, all subsequent filling in the Fill Zone shall stop until such time as a corrective action is confirmed by the Contractor, in accordance with the QMP. All recorded test results (including non-conforming test results) shall be supplied to the Engineer as evidence.

Normally in larger earthworks it makes sense to carry out two test set (e.g. comprising 2 x NDMs averaged and 4 x shear vanes averaged) every 200m^3 compacted. It is also sensible to have more shear vanes, or Scala tests or Clegg tests than NDMs, e.g. twice the freq. The contract specification should clearly state what tests are required, and the minimum number of tests per set.

Every NDM test carried out on cohesive clay type materials should have water content grab samples taken and the Oven Dry Water Content used to calculate Air Voids and Dry Density.

Subgrade Strength

The minimum design strength(s) of the Subgrade, as specified in the contract documents, should be verified by the Contractor to a minimum depth of 1m below the Top of Subgrade Surface (whether this is pre-existing material or made ground) as a pre-condition of Subgrade handover (refer Section 5.7).

Unless otherwise specified in the Contract documents, or instructed by the Engineer, routine testing of the Subgrade per representative, homogenous Lot (refer Section 8.1) shall be undertaken using a Scala Penetrometer[1]. Before and during earthworks construction, on-site calibration of the Scala Penetrometer test for the local soil conditions shall be tested using full scale in-Situ CBR tests completed alongside the Scala test, in the same soil material at the same conditions, or alternatively using in-situ Shear Vane, or Plate Bearing test. The pavement designer should consider what test method bests suits the intended subgrade material, and this should be specified in the contract documents.

[1] NZS 4402: 1986 Test 6.5.2 Determination of the penetration resistance of a soil – Hand method using a dynamic cone penetrometer Standards Association of New Zealand

19. Basis of Measurement and Payment

General

Allowance for all items such as supervision, on site survey control and reinstatement as required, production and environmental planning and implementation, traffic management associated with the earthworks project, quality assurance sampling and testing, conveyance of plant, construction, maintenance and reinstatement of internal access and haul roads, charges for plant, labour and materials, general overheads, administration, profit, accommodation and on-going maintenance shall be deemed to be incorporated in the unit rates listed in the pricing schedule, unless otherwise individually scheduled.

In general all material from borrow areas, all areas of material classified as type R1 or R2, and cut to waste will have to be individually measured for payment purposes as the excavation proceeds. On the other hand, the basic quantities for type A material cut to fill may be calculated from the original survey data with modifications only necessary if the scope of the contract is varied. The method of arriving at these basic quantities should be clearly stated in the contract documents. If the calculations are based on aerial survey data, the Contractor should be given the opportunity to request a ground survey before commencing earthworks if he considers the quantities could be in error.

The objective of the earthwork material classification system is to relate payment as closely as possible to the cost incurred. All material is automatically classified as type A material for payment purposes, and when no special circumstances apply, this shall be the only payment made.

Additional payments can only be made under one other type classification. The categories defined as type W, U, R1, R2 and R3 are mutually exclusive. If there are a number of significantly different leads involved, separate items should be included in the schedule.
For the wetting and drying for Bulk Fill or Subgrade It should be noted that this basis of payment does not allow for payment for any plant which is not taking part in the drying or wetting activity.

Allow a provisional sum in the schedule for daywork associated with repair of slip damage, final shaping, and landscaping and access roads for borrow and dump areas.

Avoidable and Unavoidable Factors

During the earthworks construction and compaction process, non-conforming fluctuations in specified earthwork and compaction outcomes may be either due to “unavoidable” or “avoidable” factors.

Unavoidable factors: as ratified by the Engineer following representation by the Contractor. These could be the case where materials from approved borrow sources are highly variable, and some compromise is necessary on the amount of water to be applied, or how to make best use of target outcomes, including density outcomes derived from for example plateau density testing. In such cases agreed changes to the specified outcomes may be needed to enable the works to proceed.

Avoidable factors: may be explained through:

- Poor workmanship by the Contractor

- Use of inferior or defective equipment or construction processes
- Poor site management

In such cases, liability and cost of mitigation remains with the Contractor.

Basis of Payment for Specified Works

Clearing

Payment for clearing shall be a lump sum which shall be full compensation for all grubbing, windrowing, uplifting, carting, dumping or burning and covering of the discarded waste with suitable material and for the control, use, maintenance and reinstatement of the approved or nominated dump areas as specified.

Uplift of Topsoil and Clean Topsoil to Fill

Payment for the uplift and subsequent placement of Topsoil and Clean Topsoil shall be made on the total solid in place volume in cubic metres moved as specified. The unit rate shall be in full compensation for the stripping, loading, carting and either stockpiling or placing directly, and for the maintenance and reinstatement of all stockpile areas.

Surface Drainage Control

Temporary surface drainage control is included in the earthworks operation and no separate payment shall be made.

Temporary Fencing

Payment for temporary fencing shall be made on the total length in metres erected as specified. The unit rate shall be in full compensation for erecting, maintaining and removing the temporary fencing from the site, including all associated restoration works.

Cut, Undercut and Borrow to Fill

Payment for cut, undercut and borrow to fill shall be made on the total volume in cubic metres of earthworks excavated and placed as specified in fill. The quantity for payment shall be the solid in place volume before excavation.

The unit rate shall be in full compensation for excavating, loading, carting, spreading and compacting in layers of Type A. Where the material is Type W, R1, R2 or R3, an additional payment shall also be made.

Cut, Undercut and Borrow to Nominated Stockpile

Payment for specified cut, undercut and borrow to the Principal nominated stockpile (including salvaging materials such as existing pavement aggregates) shall be made on the total volume in cubic metres of earthworks excavated and placed as specified in the stockpile. The quantity for payment shall be the solid in place volume before excavation.

Where the Contractor chooses to use a cut/stockpile/fill process rather than the preferred method of placing the excavated material directly into the fill, no additional stockpile to spread payment will be made.

The unit rate shall be in full compensation for excavating, loading, carting, spreading and placing in layers of Type A material into the stable stockpile. Where the material is Type W, R1, R2 or R3, an additional payment shall also be made.

Stockpile to Spread

Payment shall be made on the total volume in cubic metres of suitable materials uplifted from the Principal nominated stockpile and spread in accordance with Section 4. The quantity for payment shall be the solid volume in the stockpile before excavation.

The unit rate shall be in full compensation for excavating, loading, carting, spreading and placing in layers of Type A material into the fill. Where the material is Type W, R1, R2 or R3, an additional payment shall also be made.

Cut, Undercut and Borrow to Waste

Payment for cut, undercut and borrow to waste shall be made on the total volume in cubic metres of waste material excavated and carted to dump. The quantity for payment shall be the solid volume before excavation.

The unit rate shall be in full compensation for excavating, loading, carting and dumping all material Types and for the control of the dump area as specified. Where the material is Type R1, R2 or R3, an additional payment shall also be made.

Backfill of Undercut Material

Material that is excavated to waste below the top of final Subgrade surface shall be replaced with suitable material, either: (a) from surplus cut elsewhere in the works, in which case the material shall be paid for as cut to fill or (b) from borrow or stockpile, in which case payment shall also be made as cut to fill. If otherwise imported fill material is required to be used by the Engineer, this will be treated as a Variation.

Additional Rates for R1, R2 and R3 Material

Where material is classified as R1, R2 or R3 in accordance with Section 2 of this specification, payment shall be made as an addition to the payments detailed for Type A material. The quantity for payment shall be the solid in place volume in cubic metres before excavation.

For Type R1, R2 and R3 materials, a unit rate shall be paid in addition to the rate for Type A material. This shall be in full compensation for the additional work involved in excavating/removing and handling the material through all stages.

Overbreak

Where overbreak occurs that could not be prevented by the Contractor works on site, it shall be paid for as borrow to fill. No additional payment shall be made for the works required by the Contractor to repair the effects of preventable overbreak.

Finishing Construction Batters

The compaction of fill batters and finishing of cut batters in accordance with Sections 3 and 4 shall be an integral part of the earthworks and no separate payment shall be made.

Dump and Borrow Areas

No separate payment shall be made for the work of working or shaping of dump and borrow areas.

Benching

Payment for the construction of benches shall be made on the volume of material excavated in accordance with the appropriate earthworks material description.

Subgrade Surface Finishing

Payment for Subgrade surface finishing shall be made on the total area in square metres of the Subgrade finished in accordance with Section 5.

Wetting and Drying of Fill Materials

Wetting or drying of Type A, R1, R2 and R3 materials used in bulk or Subgrade to aid compaction is considered to be part of the earthworks operation and no separate payment shall be made.

Type W Material

Type W material shall qualify for payment as cut to fill with the additional use of day work rates for drying either in-situ or in place unless:

(a) the condition is due to the Contractor's neglect of adequate surface drainage control, insufficient attention to the closing-off of cut and fill areas, or the lack of adequate and efficient drainage for control of surface water within the construction site; or

(b) the excavation is being undertaken outside the nominated construction season in the construction documents; or

(c) a reasonable time has not been allowed after rainfall for the material to return to its normal condition; or

(d) the excavation can be left until later without affecting the orderly progress of the job.

In any of the above situations, and with the Engineers approval, parts of the wet material may be removed immediately so as to facilitate drainage and drying of the remainder. In this case no extra payment shall be made for the material excavated to waste and the Contractor shall supply additional make up fill, if required, at no additional cost.

Slips

Payment for the removal of slip material shall be made under the appropriate earthworks items up until Subgrade trimming is completed at the location of the slip. Thereafter payment shall be made on the total volume in cubic metres under the special schedule item for removal of slip material. The quantity for payment shall be the solid in place volume in the batter, where this can be measured. Otherwise truck measure volumes may be used, with the Engineer’s prior approval. The unit rates for the different leads for removal of slip material shall be in full compensation for all excavation, carting, spreading, filling and compacting or dumping of the material. Payment for shaping, trimming or repair of damage required as a result of a slip shall be made at daywork rates.

Where the Contractor's negligence or faulty workmanship has been the cause of the slip, no extra payment shall be made for removal of the slip material, shaping, trimming and repair of damage.

Intersecting Roads and Private Accessways

Work involved in the construction of intersecting roads and private accessways shall be paid for under the appropriate schedule items.

Trimming, Shaping and Topsoiling

Payment for trimming and shaping in accordance with Section 6 shall be made for the total area in square metres prepared except that no payment shall be made if the work is required because of the Contractor's non-compliance with other sections of the specification.

If the Principal has specified that the Topsoil or Clean Topsoil must be stockpiled in a nominated stockpile area before begin spread over the site, then payment will be covered by cut to stockpile, and then for stockpile to spread.

Vegetation and Batter Protection

For slopes of 2H:1V and flatter, payment for vegetation (usually grassing) shall be made on the total area in square metres prepared and sown as specified in Section 6. The unit rate shall be in full compensation for the cultivation of the Topsoil, supply and sowing of the seed and fertiliser, the embedment of the mix within the soil as specified, and the maintenance of the same until a successful strike is achieved.

Payment for mulching and seeding slopes steeper than 2H:1V shall be made on the total area in square metres covered as specified in Section 6. The unit rate shall be in full compensation for the supply of the mulch, seed and fertiliser and the application of the mixture as specified, and the maintenance of the same until a successful strike is achieved.

Payment for the supply, placement, protection and maintenance of specialist vegetation (other than grass) shall be as detailed in the contract documents, and in accordance with a specific schedule rate either per plant or per square metre.

Maintenance

The costs associated with all works involved in the maintenance of the site until handover shall be included under the appropriate schedule items, and no extra payment will be made, unless the Engineer approves a variation.

Miscellaneous Items

Payment for items of work such as service relocation, drainage pipe work and structures maintenance shall be as specified and under the appropriate schedule items.

Appendix

The example below shows how the information supporting Table 5 and the subgrade testing could be presented.

EARTHWORK MATERIALS			COMPACTION AND QUALITY ASSURANCE OUTCOMES[i] TO BE ACHIEVED				TOP OF SUBGRADE Strength TEST METHOD[ii]
Specified Earthwork Layer	**Intended Source of Earthwork Material**	**Field Compactive Effort**	***Field Compaction Density (Yes or No)***	***Air void content (Yes or No)***	***Surface deflection or curvature (Yes or No)***	***Strength, bearing capacity or CBR (Yes or No)***	
Subgrade fill	*Upper level sandy SILT materials in borrow site A*	*NZ Heavy Compaction Test 4.1.2*	*Yes Minimum 95% of Target Field Compaction Dry Density, confirmed by at least two groups of five random tests per 1000 m² of fill in place*	*No*	*No*	*Yes Minimum Cu of 75kPa confirmed by at least two groups of five random tests per 1000 m² of fill in place*	*Minimum in-situ CBR measured as 6%* *Note: Calibrated Scala Penetrometer test can be used as alternative with Engineers approval*

[i] If the answer is Yes, describe target outcomes to be achieved
[ii] Describe proposed test method and target outcome.