NOTES ON EARTHWORKS CONSTRUCTION SPECIFICATION TNZ F/1

These notes are for the guidance of supervising officers and must not be included in the contract documents.

The numbers assigned to paragraphs in these notes correspond with the paragraphs in the specification to which the notes refer.

1. SCOPE

Specification TNZ F/1 should be used for all highway earthworks. It does not directly refer to other specifications for associated works. The interrelationship with permanent fencing, culverts and subsoil drains should be clearly referred to in the contract documents where appropriate.

2. DEFINITION OF TERMS

To distinguish between the earthworks and the subsequent pavement materials (sub-base etc), the term final subgrade surface is used. This final subgrade surface should be defined on the drawings.

Most of the definitions define physical limits of individual elements within the construction. “Granular fill material” relates to the technical requirements for compaction and control of the fill construction. The definition of rock relates to the classification of materials for payment.

3. CLEARING

It is of paramount importance from the start of the construction work that attention be paid to the effects of the construction on the surrounding landscape. The haphazard bulldozing or dumping or cleared vegetation cannot be accepted, nor can the unwarranted damage of vegetation bounding the construction site be tolerated. The contract documents should list items to be protected within the bounds of the site.

All clearing should be carefully planned and executed with particular attention to both the short and long term effects on potential soil erosion.

In preparing the contract documents any local conditions pertaining to the operation of clearing and disposal should be specified.

In some cases it will be necessary to specify separate items for clearing (eg, large trees, individual buildings of significant size), and in such cases a more comprehensive contract documents and schedule should be prepared.

The clearing of borrow areas should be included in this item. Normally dump areas do not require clearing and this should be mentioned in the contract documents.

4. REMOVAL OF TOPSOIL

The maximum recovery of turf and topsoil from the construction site is essential in order to be able to satisfactorily reinstate the disturbed areas on completion of the earthworks.

The stripping and stockpiling of topsoil from borrow areas should be included in this item. Removal from dump areas will normally not be worthwhile unless there is a shortage of topsoil.

For calculating quantities for payment purposes, the supervising officer should carry out field depth measurements of the topsoil prior to stripping. Where appropriate it may be necessary to calculate average depths over individual sections of the site. The solid volume can then be easily 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 volume.

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 so that the increase in volume of filling is allowed for.

5. SURFACE DRAINAGE

Water is one of the main enemies of a road builder. It is important to-ensure that all necessary precautions to secure the site against the introduction of surface water are carried out. This criterion is equally important for both the cut and fill areas.

The operation frequently entails the temporary diversion of natural drainage water away from the site works. The construction of the final culverts, subsoil drains, and side drains will seldom be sufficient to handle the incidental needs of temporary construction drainage.

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. Control of runoff and diversions shall meet the requirements of the relevant District and Regional Plans prepared under the Resource Management Act and resource consents related to the job.

It is considered good policy to leave a low bank on the outside of sidling cuttings as finally constructed. This practice not only provides traffic with additional safety but enables surface water runoff to be led to a suitable discharge position instead of spilling over and causing batter erosion.

6. TEMPORARY FENCING

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

Specification TNZ F/1 does not refer to permanent fencing. This should be covered by a separate specification which could be either to a relevant-standard or specifically written for the particular job. TNZ F/4 Notes set out the main points to be covered by a fencing specification.

7. SALVAGING AGGREGATE FROM EXISTING PAVEMENT

On the rare occasion where there is a high class aggregate available for salvage, full details of the extent of the work and proposed utilisation should be included in the contract documents. The minimum practical layer thickness is about 150 mm. The work activity is payable. The cartage involved should be stated and if there are a number of significantly different leads involved, the schedule item should include these leads.

8. CLASSIFICATION OF MATERIALS FOR PAYMENT

8.1 Material classified as type R1 or R2 will continue to attract extra rates as appropriate for each type of rock. Material classified as type W or U does 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. Drying operations approved by the engineer will be paid for as dayworks.

8.2 The difference in 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” or “borrow to fill”. All undercut excavation below fills, benching etc, shall be paid for as rates tendered by the Contractor under type A material and extras where appropriate. Thus there is no longer any need to define what constitutes "conventional plant".

8.3 A contractor is not entitled to be paid at the schedule rate for type R1 material if he 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.

The following crawler tractors have net engine power in the range 100-115kW for use in determining type R1 material:
(a) Caterpillar D6C (PS, DD or SA),
(b) International Harvester TD-15C (PS, GD or CA),
(c) Komatsu D60 (6, E6, P6 or PL6).

8.4 The following crawler tractors have net engine power in the range 270-310kW for use in determining type R2 material:

(a) Caterpillar D9 (PS),
(b) Komatsu D355,
(c) Terex 82-50.

8.5 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 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.

The nominated construction season must always be included in the contract documents. The limits, if any, on the construction season will depend entirely on past experience, the local climate conditions, and the moisture susceptibility of the construction materials. Clays and silts cannot be worked under wet conditions, whereas moisture is essential for the compaction of sands and gravels. It is the contractor's decision whether to work outside the construction season and carry the extra costs, if any, in so doing.

9. EXCAVATION

9.1 Management

The supervising officer should familiarise himself with the material available within cut and borrow areas and where possible identify and retain the high strength materials for the upper layers of the bulk filling and the subgrade layer. It is the responsibility of the supervising officer to ensure the adoption of procedures for economic and technically sound use of materials.

Consideration should always be given to defining in the contract documents any better class of material which is known to exist within the earthworks and which should be reserved for use in the subgrade.

The need for comprehensive investigations before calling tenders is stressed as a means of reducing unnecessary contractual risk and ensuring competitive tenders. Adequate soil survey and testing should be carried out before preparing the contract. Samples should be taken by digging or boring, and the soils identified. Soil profiles should be prepared for all significant highway works. Knowledge of the soils to be encountered influences location, permits the best use to be made of available materials and enables the grade line to be appropriately defined.

Rock, gravel and coarse sand can be identified by inspection. However, the correct classification of soils containing fine grained material involves mechanical analysis and other laboratory tests. Where these tests are not available, the following descriptions will serve as a guide in identifying the general soil types:

Fine sand may have slight cohesion when damp. Dry lumps of fine sand may also have slight cohesion, but they can be easily powdered between the fingers. The particles are visible and have a distinctly gritty feel.

Silt is most easily identified by the "dilatancy" test. If a pat of moist silt is shaken horizontally in the palm of the hand, moisture will come to the surface, but will recede again when the pat is pressed with the fingers.

Clay does not exhibit the property of dilatancy. It is very cohesive, smooth and greasy to touch, and sticks to the fingers when moist.

Where possible, information as to the technical classification of the material likely to be encountered should be provided in the contract documents. It is important, however, that when supplying such information, the contract documents includes a clause as to the accuracy of the information.

9.2 Undercutting

The undercutting in cuts is desirable from the point of view of uniformity of subgrade. All cuttings, except where the material is such that the strength reduces with reworking, should be undercut approximately 400 mm.

It is the Engineer's responsibility to determine if a material should not be undercut. Where he has had no past experience with the material, and suspects that it should not be undercut, he should take CBR tests "in situ" on the uncompacted subgrade and compare them with CBR tests on remoulded samples of the same material compacted to standard compaction. If the in situ CBR is greater than that of compacted imported material and there is a marked drop after reworking, then undercutting should be omitted. However, excavation plant must be closely controlled so that the material is not reworked by this operation.

When the cutting is not undercut generally, it is still advisable to undercut short sections at the end where they are adjacent to deep embankments to ensure a good bond between the two.

All unsuitable material should be excavated and replaced by suitable material. 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". Unsuitable foundation materials include materials which contain a high percentage of organic matter (ie, peat), and soft plastic clays. Organic soils are distinguished by a distinctive odour of decaying vegetation which can be intensified by heating the soil.

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 subsidence of the embankment. The use of sandy or granular materials in the lower portion of the embankment will greatly accelerate consolidation, as the water in the foundation spoil will be squeezed out through this porous layer.

9.4 Dump Areas

All dump areas should be nominated in the contract documents. If additional areas are required during the currency of the contract then these should be nominated by the Engineer when required. Disposal areas should be located so that on completion of the works they can be reinstated satisfactorily to conform with the adjoining land form. Surplus material can often be used effectively in widening embankments or in providing parking areas.

9.5 Borrow Areas

Borrow areas should be described in the contract documents. 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 stage requirements should relate to the ultimate utilisation of the area. All borrow areas when finally restored should conform to the adjoining landform. Borrow areas should not be opened up within 5 m of the edge of the formation or bottom of an embankment. Borrow can often be obtained by widening the cuttings, preferably on the inside of curved sections. Consider obtaining resource permits in advance as leaving it to the contractor may cause unacceptable delays.

9.6 Benching

This clause deals only with embankment foundation 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, or when the presence of subsoil water could induce hydrostatic pressure behind the fill material, it is imperative that niches be cut in the natural ground before the filling is constructed. The slope criterion given in specification TNZ F/1 is for guidance only and the supervising officer must consider each foundation condition on its own merits. Benching should be shown on the drawings. Benches should be designed wide enough for the operation of compaction equipment.

Where it is anticipated that subsurface water will be encountered within the bench formations, special provision should be made for the installation of a full drainage facility.

Though the actual extent of a bench drainage system cannot be specified at the time of preparing the contract documents, sufficient details showing a typical cross-section, gradient limits and the outfall method should be shown on the drawings and all materials and workmanship requirements noted in the contract documents.

No reference has been made in TNZ F/1 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 contract documents and drawings.

9.7 Side Drains

Side drainage 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.

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 influence of the highway formation and to keep the ground water level at least 1 m below the final subgrade level to guard against the rise of capillary moisture 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.

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

10. FILLING

10.1 General

The requirements for fill construction in the TNZ F/1 specification allow considerable latitude in the use of materials. The supervising officer has the responsibility to decide the best use of each material and what correction, if any, is needed in the moisture content to satisfy the strength and stability requirements of the fill. It may be possible, by correct utilisation of materials, to achieve subgrade strengths in excess of the design values which would enable a reduction in the quality and/or quantity of the higher cost pavement layers.

Using the methods described below it should be possible to reduce “cut to waste” to a minimum and to use material at its natural moisture content in many cases.

It is the responsibility of the Engineer to indicate material which is not suitable for use in fills. Some material that would not be suitable for the subgrade filling may be acceptable for bulk filling and should only be banned from being used in the subgrade layers. The Engineer must also technically classify the filling material so that the Contractor can apply the appropriate compactive effort to achieve the specified end result.

10.2 Subgrade Filling

Extreme care must be taken in constructing the subgrade because of its proximity to the design load and the 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 form the excavation of the cuttings, the subgrade should be constructed with material borrowed from another more suitable source.

10.3 Compaction and Size Control Methods

The nomination of the type of compaction plant has been left with the Contractor. The decision will depend on the plant available.

10.4 Compaction

There is usually no doubt about the suitability of granular fill material (as defined in TNZ F/1) for use in fillings since the strength is usually adequate whatever the moisture content. However, cohesive material (and silts) may be too dry (indicated 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, a low dry density and long term strength (soaked CBR) is achieved and the rolling is of limited value.

The optimum moisture content is the moisture content at which a specified amount of compaction will produce a maximum dry density.

NZS 4402:Part 4:1986, gives methods of determining the optimum moisture content for standard compaction. The compaction obtained in this test is comparable with that obtained by the type of compaction equipment in current use in New Zealand. A rough determination of the optimum moisture content can be made for materials of a clayey nature from a plastic limit test. In most normal clayey materials the optimum moisture 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, the moisture content will be approximately at optimum.

Instead of setting limits on the variation from optimum moisture content in specification TNZ F/1, it has been left to the supervising officer to determine whether the material is suitable for use at its naturally occurring moisture content or whether some moisture content change is worthwhile.

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 filling. For bulk filling the shear strength should be greater than that required for stability of the fill. For this wet condition the shear strength is equal to half the unconfined compressive strength. For subgrade filling, the unsoaked CBR at standard compaction should be greater than the value required for pavement design. A penetration test such as the Proctor needle could be used in fine grained cohesive soil instead of both unconfined compressive strength and CBR if suitable correlations are available.

If the soil looks to be dry of the optimum moisture content for standard compaction, there is a possibility that a marked decrease in strength will occur if the moisture content is later increased. Ideally the soaked CBR value should be determined for subgrade filling using dry material and this checked against the value required for pavement design. However, since this procedure takes a number of days, a guide as to the suitability of the material can be obtained from the air voids. The air voids may also be used for determining the suitability of dry bulk filling as they indicate the amount of settlement which can take place. In general the air voids should be less than 10 for both subgrade and bulk filling. Local experience of the air voids at which a significant reduction in CBR occurs with soaking will give a more accurate estimate.

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

Once it has been established that the material is suitable for use as filling, the specification requirement comparing the field wet density with the wet density at standard compaction will ensure that the filling receives adequate compaction. A penetration test such as the Proctor needle could be used to extend the control given by measuring densities. In this case the reading for the field compacted material should generally be greater than that for the sample compacted to standard compaction. However, some care must be exercised in interpretation since not all rollers produce the same penetration resistance/density relationship as that obtained from standard compaction, particularly for high degrees of saturation. Whether density or penetration resistance is used to measure compaction, the reference sample compacted to standard compaction must be at the same moisture content as the material in the construction at the time of testing.

Recommended methods for measuring the in-sit density of the compacted filling include the conventional sand replacement and seed replacement methods for measuring the volume of the hole from which a sample to be weighed has been taken, and the Washington densometer which uses a water inflated balloon to fill the hole. Seed replacement can be used where there is difficulty in obtaining a uniformly graded sand. The Washington densometer gives an accurate and quick determination of hole volume in fine grained soils showing at least some cohesion.

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 basically the one soil type, at what appears to be a constant moisture content, and which has received a uniform number of roller passes.

Once the number of passes of a particular roller required to produce the specified compaction in a particular soil type has been established, compaction testing can be reduced to a minimum in that soil. However, the moisture content must be kept reasonably constant and each layer must be given the required number of passes uniformly distributed.

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 compaction vehicles to weave even before distinct ruts begin to form. If this happens, the material must either be left so that the pore pressures can dissipate or be dried before completing compaction. For the same reason earthmoving plant must not be allowed to follow the same tracks repeatedly on cohesive soils.

11. SUBGRADE SURFACE FINISHING

11.1 Trimming and Rolling

The preparation of the subgrade should be completed in such lengths as will permit the sub-base or basecourse 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 moisture content of the completed subgrade is not allowed to vary once compaction and final trimming has been completed. Clay subgrades 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 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.

11.3 Subgrade Uniformity Testing

Full use should be made of the Benkelman beam or a similar test to control the uniformity of the subgrade surface. The aim of this test should be to provide a quantitative measure of the subgrade consistency. It is not intended to be a substitute for the compaction requirements as detailed in specification TNZ F/1.

No definitive uniformity standard is stated in specification TNZ F/1. Custom standards for individual contracts may be given in the contract documents. In some cases, for example where the performance of a particular fill material is fully appreciated, the maximum mean deflection within statistical control ranges, may be included. This approach could be further extended to include separate values for cut and fill areas.

Test rolling as a final acceptance test for subgrade construction has been deleted from the specification. In the past it sometimes overstressed a satisfactorily constructed subgrade and the results were frequently misinterpreted. It is now considered that the Benkelman beam test is of greater significance and more readily adaptable as a routine procedure.

As the test roller was often heavier than the rollers used during construction, test rolling could easily give rise to serious subgrade weaving if the moisture content was high. This could happen on a subgrade that had met the requirements of the specification in all respects and which would perform quite satisfactorily in service.

The removal of the test rolling clause does mean that more care will have to be taken during construction to ensure that compaction standards are met. There is no substitute for frequent density testing but careful observation of normal compaction operations will help pinpoint areas of inadequate compaction.

If care is taken to ensure that the subgrade will not be overstressed, a test rolling clause may be added in the contract documents as a uniformity test. It should, however, be so worded that subgrades meeting the specified density requirements are not rejected at the contractor’s expense.

11.4 Surface Water Channels

Formation surface water channels are those permanent drainage facilities constructed as part of the final subgrade construction, eg, 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 grader maintenance. They should function independently of any subsoil drains.

12. SLIPS

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.

13. INTERSECTING ROADS AND PRIVATE ACCESSWAYS

It is expected that many jobs will require a special clause in the contract documents to deal adequately with the construction of intersecting roads and private accessways.

In the past the importance of the private accessways has often been neglected and as a result inadequate, and in some cases unsafe facilities have been provided. In designing and constructing private accessways the following conditions must always be satisfied:

(a) Adequate site distance and visibility must be provided for both the highway and private access traffic.

(b) The geometric properties of private accessways should be such that all types of vehicles servicing the property are able to enter onto or leave the highway in a single manoeuvre.

(c) The number of private access points should be kept to a minimum.

14. 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 with the adjoining land and grassed as soon as possible. An early establishment of a 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 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.

15. GRASSING AND BATTER PROTECTION

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 the local farm advisory officer of the Ministry of Agriculture and Fisheries.

16. TRAFFIC CONTROL

The legal responsibility for the maintenance of the traffic route through the construction site is clearly defined in the general conditions of contract and specification TNZ G/1.

As the nature and degree of interference is particular to each individual contract, specification TNZ F/1 does not give any further requirements. These should be included in the contract documents. The need for any temporary metal should be described and the basis for payment.

All temporary roading and short term traffic deviations should be approved by the Engineer prior to their implementation. Particular attention must be paid to the adequacy of the physical dimensions of any temporary traffic routes and the proposed surface treatment.

18. METHOD OF MEASUREMENT

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.

19. BASIS OF PAYMENT

19.1 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 and R2 are mutually exclusive. If there are a number of significantly different leads involved, separate items should be included in the schedule.

19.15 Wetting and Drying Fill Material

It should be noted that this basis of payment does not involve payment for any plant which is not taking part in the drying or wetting activity.

19.18 Slips

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.