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Transport Infrastructure Ireland

## TII Publications

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# Notes for Guidance on the Specification for Road Works Series NG 600 - Earthworks (including Erratum No. 1, dated June 2013)

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March 2013

## About TII

Transport Infrastructure Ireland (TII) is responsible for managing and improving the country's national road and light rail networks.

## About TII Publications

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## Document Attributes

Each document within TII Publications has a range of attributes associated with it, which allows for efficient access and retrieval of the document from the website. These attributes are also contained on the inside cover of each current document, for reference. For migration of documents from the NRA and RPA to the new system, each current document was assigned with new outer front and rear covers. Apart from the covers, and inside cover pages, the documents contain the same information as previously within the NRA or RPA systems, including historical references such as those contained within NRA DMRB and NRA MCDRW.

## Document Attributes

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## NRA DMRB and MCDRW References

For all documents that existed within the NRA DMRB or the NRA MCDRW prior to the launch of TII Publications, the NRA document reference used previously is listed above under 'historical reference'. The TII Publication Number also shown above now supersedes this historical reference. All historical references within this document are deemed to be replaced by the TII Publication Number. For the equivalent TII Publication Number for all other historical references contained within this document, please refer to the TII Publications website.

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## National Roads Authority

### Manual of Contract Documents for Road Works (NRA MCDRW)

#### ERRATUM No. 1 (June 2013) to the Notes for Guidance to the NRA Specification for Road Works Series 600 - Earthworks Dated March 2013

The Notes for Guidance to the NRA Specification for Road Works (NRA MCDRW), Series 600 – Earthworks, dated March 2013 is amended as follows:-

1. Page 3, Clause NG 601.11, Paragraph 2

Insert the text “for approval” at the end of the second last sentence of this paragraph.

2. Page 3, Clause NG 601.11, Paragraph 2

Delete the text of the final sentence of this paragraph, which was “The Employer’s Representatives’ approval will then be required in advance of incorporating these materials into the works”.

3. Page 3, Clause NG 601.11, Paragraph 4

Delete the text “to the satisfaction” within the first sentence of this paragraph, and replace with alternative text “with the written approval”

4. Page 3, Clause NG 601.11

Insert two new paragraphs at the end of this clause, as set out below;

“Where the Contractor wishes to use materials approved by the Employer’s Representative as set out above, but outside the limiting values included in sub-Clauses 601.11 and 601.12, the use of such materials would only be accepted under an Approved Departure in accordance with NRA GD 100 Departures from Standards and Specification (Volume 0, Section 3, Part 2 of the NRA DMRB).

TRL 447 available from the Transport Research Laboratory ([www.trl.co.uk](http://www.trl.co.uk)), provides further background to these requirements should a particular aggregate source require close consideration in this regard.”

# ***EARTHWORKS***

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# EARTHWORKS

## NG 600 Introduction

- 1 The Notes for Guidance on this Series are intended to assist in the preparation of the Contract. The design of the earthworks and selection of limits for soil properties for their construction will follow the ground investigation. Certain materials may be utilised as 'acceptable' materials although processing, where appropriate, will be necessary to render unacceptable materials 'acceptable'. The Designer should describe in Appendix 6/1 the requirement for processing of unacceptable material where this has been identified as appropriate. Unless there are specific reasons, the Designer should leave the means of processing to the Contractor. The aim should be to minimise the import of materials both for economic and environmental reasons. The Designer should therefore match, for use in fill areas, those materials likely to arise in the cuttings as far as the earthworks design permits. The Contract should not normally indicate from where on Site materials are to be obtained for the various zones of fill. Certain selected fills will normally have to be imported.
- 2 The term 'rock' is used in the Specification to describe a constituent of certain selected fills having durability and strength requirements and also to describe material in cutting faces and formations requiring special methods of trimming or regulation.
- 3 Particular requirements, not specifically stated in the Specification, for the Class of fill materials to be used or permitted, or for work to be undertaken, should be included in Appendices 6/1 to 6/13. Additional Appendices may be used if necessary (see NG 000).
- 4 It is necessary to show the full extent of formation and where there is capping, the sub-formation. Most road configurations will be catered for by the appropriate cross-section and edge detail drawings contained in the NRA Road Construction Details. These drawings should normally be used without modification and incorporated in the Contract by reference (in Appendix 0/4). In cases where they do not cover the work involved, Contract-specific drawings may be necessary which should be discussed with the NRA.
- 5 The Designer when preparing Appendix 6/1 should list only the properties needed to meet his design requirements, omitting those which are unnecessary, e.g. either mc or MCV, not both. Where the Designer selects mc, it should be expressed in terms of one of the following:
  - (i) moisture content:
  - (ii) moisture content related to plastic limit; or
  - (iii) moisture content related to optimum moisture content.Determination of moisture content should be made from that part of the material passing the 20 mm BS sieve.
- 6 Tenderers should be given the fullest available information about the materials to be excavated. The following should be included:

- (i) any strata or deposits designated as Hard Material;
- (ii) the in situ material properties, relate as far as possible to the general material description and the properties used for acceptability in Table 6/1, taken from the borehole logs, which may be re-plotted on the drawings of the long-sections of cuttings and below embankments where excavation will be required.

**NG 601 Classification, Definition and Uses of Earthworks Materials and Table 6/1: Acceptable Earthworks Materials: Classification and Compaction Requirements**

- 1 The key to the use of materials both arising on Site and imported lies in Table 6/1. These materials have been classified into 7 principal Classes and sub-divided for compaction purposes or because of particular properties or applications.
- 2 Classes 1 and 2, general fills, comprise the greater part of the materials normally encountered and which are satisfactory as fill in most embankment construction.
- 3 Classes 4 and 5 are for landscaping and top-soiling respectively.
- 4 Classes 6 to 8 selected fills all have a special role.
- 5 Class 6F3 material should be considered for use only if 6F1 or 6F2 materials are not economically available, and only with the express permission of the NRA.
- 6 Many schemes will use only a few of the Classes in Table 6/1 and it will be unusual for every Class of material to be used on an individual scheme.
- 7 The Designer may further sub-divide the Classes in Table 6/1 e.g. 1A into 1A1 and 1A2 in order to obtain the better use of materials by zoning.
- 8 Appendix 6/1 must include the relevant limits of acceptability for fill materials referred to in Table 6/1.
- 9 Materials, which would otherwise be classified as unacceptable, may be rendered acceptable by remediation techniques such as treatment with lime or air drying etc. However, in advance of this material being incorporated into the Works the Contractor shall ensure that all pertinent legislation and guidelines are complied with. In addition, the use of this material should be discussed with the Employer's Representative in advance of any works.
- 10 The use of argillaceous material as defined in Clause 601.5 may be permitted for use in the Works as described in Table 6/1, provided the material meets the durability requirements therein. Where no minimum acceptable limits are included in Table 6/1, the Designer shall assess the intended end-use of the material and determine the minimum acceptable limits to ensure the material performs adequately throughout the required design life. The testing required in Table 6/1 shall be carried out in advance of incorporating this material into the Works and the results provided to the Employer's Representative.

**11** The limiting values in sub-Clauses 601.11 and 601.12 have been chosen to ensure that problems do not occur due to oxidation of reduced sulfur compounds such as pyrite. The oxidation of pyrite results in the production of sulphuric acid, which can attack concrete and/or exposed metallic elements, and lead to the formation of gypsum, which may result in heave. However, the limiting values only take account of the total amount of sulfur in each form, and do not allow consideration of factors such as grain size, mineralogy and access to air and water that affect the actual amount of oxidation that will take place in any given situation. As a result, the limiting values for oxidisable sulfides (OS) and total potential sulfate (TPS) are conservative, and may exclude materials that have been shown to perform satisfactorily as structural backfill. Examples of situations where materials may exceed the limiting values for select granular fill but still be acceptable include the following:

- (i) Pyrite present as large cubic crystals visible to the naked eye, as opposed to the fine grained and therefore more reactive framboidal pyrite. This will give high values of TPS and OS, but the rate of oxidation will be very slow because of the low specific surface area of the pyrite crystals (eg sample TR8, Plate 8.3 of TRL Report 447).
- (ii) Unreactive sulfates such as barytes present as vein material or as a cement. This will give high values of TPS and OS, because the unreactive sulfate will be detected by the total sulfur (TS) test but not by the acid soluble sulfate (AS) test (eg sample TR28 of TRL Report 447). However, such samples would give low values of total reduced sulphur (TRS). If OS is calculated directly from TRS for these materials, a more accurate value will be obtained.

Where this occurs, enquiries should be made by the Contractor to the supplier as to whether there is any history of corrosion problems or sulphate attack of concrete problems or pyrite related heave problems with the material. A programme of detailed testing should be carried out on the material, using the new test methods, to establish its chemistry and mineralogy and ascertain more clearly its potential to cause corrosion, sulphate attack or heave. The results of this testing should be provided to the Employer's Representative for approval<sup>1, 2</sup>.

Mineralogical methods may include petrographic description using thin sections, X-ray diffraction or Scanning Electron Microscopy (SEM). If pyrite is present in framboidal form (Plates 8.1 and 8.2, sample TR11D of TRL Report 447), the material should be classified as unacceptable as structural backfill, because of the known tendency of this form of pyrite to oxidise rapidly in engineering situations.

The use of the material may be permitted as structural backfill if it can be established with the written<sup>3</sup> approval of the Employer's Representative that:

- (i) the material has been used in the past as structural backfill without leading to problems with sulfur compounds; and
- (ii) the reason why the material will not cause a problem is known, based on an understanding of its chemistry and mineralogy.

Where the Contractor wishes to use materials approved by the Employer's Representative as set out above, but outside the limiting values included in sub-Clauses 601.11 and 601.12, the use of such materials would only be accepted under an Approved Departure in accordance

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<sup>1</sup> Amended as per Erratum No. 1, item 1

<sup>2</sup> Amended as per Erratum No. 1, item 2

<sup>3</sup> Amended as per Erratum No. 1, item 3

with NRA GD 100 Departures from Standards and Specification (Volume 0, Section 3, Part 2 of the NRA DMRB).

TRL 447 available from the Transport Research Laboratory ([www.trl.co.uk](http://www.trl.co.uk)) provides further background to these requirements should a particular aggregate source require close consideration in this regard.<sup>4</sup>

## **NG 602      General Requirements**

- 1** Special requirements for determining acceptability, e.g. who classifies (Designer or Contractor) and where, and whether, trial pits are required, should be stated in Appendix 6/1. (see also NG 631). The Designer should retain the obligations for classification of earthworks materials unless, following consultation with the NRA, the Designer decides that the Contractor should have the obligations for classifying earthworks materials; these obligations include sampling and testing in accordance with the contract.
- 2** All topsoil above cuttings and below embankments less than 3 metres in height should normally be stripped for re-use with the average depths of excavation given in Appendix 6/8 verified when stripping. There is frequently less topsoil in wooded areas than expected and this should be recognised when estimating volumes of topsoil. The local authority should be consulted concerning requirements for surplus topsoil, which should be stored whenever practicable rather than disposed of by the Contractor. Storage areas should be shown on the Drawings and details given in Appendix 6/8.
- 3** The Drawings should indicate where battering of excavations for foundations and trenches is permitted and details should be given in Appendix 6/3. It should not be unnecessarily restricted; in some instances it might be preferable so as to avoid leaving a wedge of material loosened by excavation. Where battering is permitted, the requirements for benching prior to backfilling and compaction should be shown on the Drawings and details given in Appendix 6/3.
- 4** Where groundwater is to be lowered as a design requirement, or to make wet unacceptable material into acceptable material where a shortfall in earthworks volumes is likely, the location and extent of such operations should be shown on the Drawings. These should be cross-referenced in Appendix 6/1.
- 5** The requirements of Clause 602.6 have been developed in accordance with the provisions of “Best Practice Guidelines on the Preparation of Waste Management Plans for Construction and Demolition Projects (Department of the Environment, Heritage and Local Government, July 2006)” and apply to surplus materials, Class U1 materials not required to be processed or used in the Works and Class U2 materials. This document should be consulted as part of the requirements under Clause 602.6

## **NG 603      Forming of Cuttings and Cutting Slopes**

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<sup>4</sup> Amended as per Erratum No. 1, item 4

- 1 The Drawings should show all changes in cross-section for cuttings and any requirements for limiting the extent of undercutting of slopes and toes of cuttings, making use of Appendix 6/3 as necessary.
- 2 Requirements for pre-split blasting, a technique for minimising overbreak and instability, should be stated in Appendix 6/3 for any substantial rock cuttings, where blasting will be permitted. (See NG 607.) Requirements for exposed cutting faces should be described in Appendix 6/3.

The design rock trap dimensions and locations should be indicated on the drawings. Notwithstanding this, all rock cuttings should be assessed by the designer upon completion and consideration given to the need for additional rock traps or alternative appropriate rock containment system.

#### **NG 604 Excavation for Foundations**

- 1 The lines and levels of foundation excavations should be shown on the Drawings together with any blinding concrete, and its mix reference, to Clause 2602.
- 2 The Drawings should indicate where the requirement in Clause 602 for not battering excavations for foundations can be relaxed and details should be given in Appendix 6/3 (see NG 602).

#### **NG 606 Watercourses**

- 1 Cross-sections for all work in connection with existing or new watercourses (which includes all ditch work) should show the extent of all treatment and other requirements. See NG Sample Appendix 6/3.

#### **NG 607 Explosives and Blasting for Excavation**

- 1 Blasting needs should be considered in relation to the likely disturbance to the environment and remaining material beyond the cutting face. Where blasting is likely to lead to savings in excavation costs, pre-construction consultation with all who may be affected is a pre-requisite to permitting blasting in Appendix 6/3. Further guidance will be found, including benefits of pre-contract blasting trials during ground investigations, in TRL report RR 53.
- 2 Blasting should only proceed where permitted in the Contract and when all the required permissions and approvals are obtained. The Contractor should consider the impact of the approvals and notification process on the overall programme and make allowances for same.
- 3 For clarity, a summary of the notification requirements that must be met by the Contractor in advance of any blasting or trial blasting activities is provided in table NG 6/1. In addition, the Contractor will also need to consider and comply with the requirements of the Garda Síochána.

<b>Time (no later than)</b>	<b>Requirement</b>
28 days	The Employer's Representatives' written consent shall be obtained by the Contractor.
14 days	Public Notification (written and published).
10 days	Written notification to Employer's Representative before any blasting commences.
12 hours	Written notice of each blasting event.

**Table NG 6/1 – Blasting Notification Requirements**

**NG 608 Construction of Fills**

- 1 The Drawings should show locations and particular requirements for selected fills and general fills in specific zones including any additional sub-divisions of Classes in Table 6/1.
- 2 The Drawings should also show how, if per-mitted, embankments may be initially constructed other than to their full width and to steeper batter slopes. These should be cross-referenced in Appendix 6/3.
- 3 Staged construction and any surcharging of embankments and benching should also be shown, with requirements for any instrumentation in Appendix 6/12. Surcharge in this specification refers to material placed in the contract. Surcharge material placed in previous works should be treated as excavation material under the appropriate heading.
- 4 The Drawings should show each change in cross-section of fills.
- 5 The use of light-weight fill in the Works requires the written permission of the Employer's Representative. Where lightweight fill materials such as expanded polystyrene, expanded clay or foamed concrete are used, the possibility of buoyancy effects should be considered. The designer should also consider differential icing effects on the pavement, chemical durability of the lightweight fill including the possibility of accidental spillage of hydrocarbons, and stability of the lightweight fill embankment.

**NG 609 Geotextiles Used to Separate Materials**

- 1 This Clause includes minimum properties for geotextiles used to separate materials to an acceptable standard.

- 2 The minimum design life stated in Appendix 6/5 should relate to the main function of the geotextile. For example, if used beneath an embankment it should exceed the time for primary consolidation of the underlying soil. Rate of sampling should be given in Appendix 6/5 together with any other requirements.
- 3 The tests in this Clause may be used for specifying geotextiles for other purposes, using appropriate values of properties, by means of a different Appendix, e.g. if used in strengthened embankments to Clause 621, Appendix 6/9 should be used. The requirements for a separating layer may however be quite different from those for other uses and the tests may need modification or extension.

#### **NG 610      Fill to Structures**

- 1 The required or permitted alternative Classes of material to be used should be stated in Appendix 6/6 for each structure together with their locations and extent, and any requirements for benching, cross-referring to Drawings where necessary. The acceptable limits of material properties for these Classes should be stated in Appendix 6/1. Choice of acceptable limits, e.g. c' and Ø') should depend on design assumptions and where they are used, values for moisture content or MCV may be unnecessary.
- 2 Class 6N material of Table 6/1 has been subdivided to allow the designer to adjust the acceptable limits of the material depending on the intended use. For example, backfill behind a structure (6N1) may be required to exhibit different properties to that of backfill at the base of a structure (6N2).
- 3 The use of argillaceous material as defined in Clause 601.5 may be permitted for use in the Works as described in Table 6/1, provided the material meets the durability requirements therein.

#### **NG 611      Fill above Structural Concrete Foundations**

- 1 Full details of extent and type of permitted materials for filling above structural concrete foundations should be shown in Appendix 6/6.

#### **NG 612      Compaction of Fills**

- 1 Method compaction will be used for the majority of earthworks. Table 6/4 compaction should produce a minimum state of compaction equal to 10% air voids at a mc at the dry limit for acceptability. The mc at which 10% air voids or less would be achieved is roughly equivalent to a maximum MCV of 12.5 for cohesive soils (Classes 2 and 7); air voids of 5% or less will be achieved at MCV 11.5 or less. With granular soils the equivalent MCV will be higher e.g. for a well graded sand an MCV of 14.5 will achieve 10% air voids or less.
- 2 End product compaction is restricted to some selected fills to structures including corrugated steel buried structures. Density testing of the materials to be used will be necessary in order to comply with an end-product specification.

### **NG 613 Sub-formation and Capping**

- 1 The Contract, either on Contract-specific Drawings or in Appendix 6/7, should state if capping is required and in which locations. They should also show the required thicknesses of capping (including any details of sub-formation having a different slope to the formation above it e.g. at flat areas of transition). Also permitted options for Classes of capping related to the properties of the material likely to form the sub-formation should be described.
- 2 The lateral extent of capping/sub-formation should be shown.
- 3 Appendix 6/7 should show the minimum thickness of capping or sub-base to be placed for weather protection, where the fill characteristics do not require the full thickness immediately.
- 4 The need for a demonstration area should be carefully considered. It will afford an opportunity for adjusting construction procedures and gaining experience of the materials to be used. Wherever possible suitable locations should be made available which may form part of the Permanent Works if the material meets the requirements of the Contract.

### **NG 614 Lime and Cement Improvement to Form General Fill**

- 1 Unacceptable Class U1 material may be rendered acceptable by the addition of an additive in the form of lime, cement or both. This process can be particularly effective on natural cohesive material that is deemed to be wet of the optimum moisture content.
- 2 Consideration will need to be given to the Class U1 material's suitability for this type of treatment, particularly in terms of the materials organic and sulfate content.
- 3 Additional tests for the rate of spread may be required to ensure that no less than the minimum lime quantity required is provided at any point on the material being treated. If adopted, the requirements should be included in Appendix 6/13.
- 4 Careful consideration should be given to the acceptability earthworks testing for this treated material, particularly in terms of the frequency of testing. Additional requirements in this regard should be included in Appendix 6/13.
- 5 A demonstration area is required if this approach is to be applied and should inform the contents of the Demonstration Area Report to be submitted to the Employer's Representative in advance of incorporating the treated soils into the Permanent Works. The demonstration area will afford an opportunity for adjusting construction procedures, additive quantities and testing methods. Wherever possible suitable locations should be made available which may form part of the Permanent Works if the material meets the requirements of the Contract.

### **NG 616 Preparation and Surface Treatment of Formation**

- 1 Where it is known that formations of rock will arise which cannot achieve the tolerances of sub-Clause 1 of Clause 616 the requirement to meet sub-Clause 4 should be stated in Appendix 6/7 and located on the Drawings.

### **NG 617 Use of Sub-formation or Formation by Construction Plant**

- 1 The Designer may permit construction plant for the supply and deposition of sub-base to use formations of capping or of materials having similar characteristics.

- 2 Remediation action may need to be taken by the Contractor to reinstate the quality of the sub-formation or formation following use by construction plant. This might involve grading off a protection layer or replacing material that has degraded in quality.

#### **NG 618 Topsoiling, Grass Seeding and Turfing**

- 1 See Clause 602 and NG 602 relating to stripping, use and storing of topsoil.
- 2 Where the ground investigation indicates that existing topsoil which is to be stripped for topsoiling, has a high clay content, the requirements of sub-Clause 618.3 to limit excavation etc. from topsoil stockpiles which have been open to prolonged rainfall should be invoked in Appendix 6/8 to prevent degradation. The 100 mm rainfall figure in sub-Clause 618.3 may also need to be revised but it should not be over-restrictive.
- 3 The seed mixture in Table 6/5 should not be changed without prior consultation with the NRA.
- 4 Weed control treatment should be carried out during a period of active growth before plants commence seeding and should not take place at times when rain is forecast during the next 24 hours.

#### **NG 619 Earthwork Environmental Bunds**

- 1 Earthwork environmental bunds may, depending on land availability and height, be constructed in various ways, e.g. normal embankment, strengthened embankment, reinforced earth structure, anchored earth structure, or be treated as a landscape area utilising Class 4 fills to Clause 620. In the latter case no reference to an earthwork environmental bund should be made so as to avoid confusion.
- 2 Full details of earthwork environmental bunds should be shown on the Drawings with any requirements for early construction shown in Appendix 6/9 and Sectionalised in the Appendix to the Form of Tender.
- 3 Consideration should be given to the maintenance of earthwork environmental bunds, and their construction should take account of the practicalities of maintaining the bund.

#### **NG 620 Landscape Areas and Screening Mounds**

- 1 Landscape areas and screening mounds are areas where the standards of construction of fills and their material quality can afford to be of a lower standard than for normal embankment construction. Notwithstanding this, these features should be geotechnically stable and not pose a risk to road users.
- 2 General or selected fills should be allowed for Class 4 landscape fill with appropriate limits on material properties being stated in Appendix 6/1. These limits should draw on those materials, listed within Class UI unacceptable material in Clause 601, which would be acceptable as landscape fill.
- 3 Landscape areas and screening mounds should be shown on the Drawings cross-referenced in Appendix 6/9.
- 4 Environmental bunds should not be constructed on landscape fill (Class 4) unless special foundations are provided or the fill is improved.
- 5 Consideration should be given to the maintenance of these areas, and their construction should take account of the practicalities of maintaining them.

### **NG 621            Strengthened Embankments**

- 1        Strengthening by interlayering geotextiles or geomeshes into an embankment or an embankment shoulder will resist the tendency for the outer edges to soften and slip after considerable time. This technique will reduce future maintenance costs and enable steeper slopes to be built. Embankments including, for example, earthwork environmental bunds may thus be built to a greater height within the available base width. The properties of geotextiles (see NG 609) and geomeshes should be described in Appendix 6/9 together with construction requirements, cross-referring to Drawings where necessary. It should be noted that the requirements of geotextile used in a strengthened embankment may however be quite different from those described in Clause 609 and the tests will need modification and extension to take account of this.
- 2        BS 8006-1:2010 and IS EN 14475:2006 should be consulted for further advice.

### **NG 622            Earthworks for Reinforced Earth and Anchored Earth Structures**

- 1        Classes of fill required or permitted and acceptability limits for their material properties, as referred to in Table 6/1, should be stated in Appendix 6/1 and identified on the Drawings. The thickness and types of drainage layer required or permitted should also be shown.
- 2        Drawings should show the maximum height to which fill may be placed above the wall during construction.
- 3        Further details on the requirements for earthworks associated with reinforced soil and anchored earth structures are given in BS 8006-1:2010.

### **NG 623 Earthworks for Corrugated Steel Buried Structures**

- 1        Acceptability limits for MCV, if required, for Class 6K (lower bedding) and Class 6M (surround) fills, as referred to in Table 6/1, should be stated in Appendix 6/1.
- 2        Where ground investigations have shown that the existing material adjacent to the location of the corrugated steel buried structure has a constrained soil modulus less than the value assumed in the design, or a corrosivity classification determined in accordance with BD 12 as implemented by NRA addendum at which corrosion of metal components could occur, the extent of additional width etc. of excavation should be shown on the Drawings. The Drawings should also show the extent of selected fill materials to be used for the construction of embankments over the structure.
- 3        Further details on the requirements for earthworks associated with corrugated steel buried structures are given in BD 12 as implemented by NRA addendum.

### **NG 624            Ground Anchorages**

- 1        Unless there are special reasons, the Designer should design ground anchorages for anchored structures. Full requirements should be shown on the Drawings and described in Appendix 6/10. The Designer should specify proof loading and/or design calculations to enable the design to be validated.
- 2        BS 8081 can give further advice.

- 3 Where the designed retained height exceeds 1.5m the structure shall be subject to and comply with NRA BD 2.
- 4 Consideration should be given to the risk of grout used in anchor installation leaching into groundwater or surface water bodies. In such circumstances the Designer should indicate how this risk is to be addressed in the design and installation methodology to be adopted.

#### **NG 625 Crib Walling**

- 1 Outlines shown on the Drawings should allow for the full range of alternative systems. Design requirements should be given in Appendix 6/10 and the Designer should ensure that the NRA is consulted in formulating these.
- 2 Where the design retained height exceeds 1.5 m, an outline Approval in Principle form should be included in Appendix 6/10.
- 3 Where the designed retained height exceeds 1.5m the structure shall be subject to and comply with NRA BD 2.

#### **NG 626 Gabions**

- 1 If extensive use is to be made of gabions Clause 626 may need extending by means of Appendix 6/10.
- 2 The Drawings should allow for the full range of alternative systems, except that plastic materials should not be permitted where there is a risk of damage by fire unless further protection is provided.
- 3 Gabions are not permitted to be incorporated as part of a road structure (ie a structural element carrying a permanent vertical load) and should only be used to function as a gravity retaining wall.
- 4 Where the designed retained height exceeds 1.5m the structure shall be subject to and comply with NRA BD 2.

#### **NG 627 Swallow Holes and Other Naturally Occurring Cavities**

- 1 In areas prone to karstification or in other locations where swallow holes and/or other naturally occurring cavities are likely to occur, special consideration should be given to the treatment of these areas and the performance of the treatments throughout the design life of the road.
- 2 Requirements for treatment of areas prone to karstification or where other naturally occurring cavities are likely to occur should be described in Appendix 6/11.
- 3 Requirements for the treatment of swallow holes or other naturally occurring cavities should be described in Appendix 6/11.
- 4 Requirements, including location, probing to determine extent, filling methods and materials, any grouting and details of mass reinforced concrete caps should be described in appendix 6/11 where required.

- 5 Consideration should be given to the inclusion of sinkhole treatments which accommodate drainage in preference to treatment measures which block or alter natural drainage patterns.
- 6 Consideration should be given to the risk of new sinkholes forming post construction.
- 7 Details in Appendix 6/11 should be updated as construction progresses and the extent of karstification is better understood.

#### **NG 628 Disused Mine Workings**

- 1 Full requirements, including location, probing to determine extent, filling methods and materials, any grouting and details of mass or reinforced concrete caps should be described in Appendix 6/11.

#### **NG 629 Instrumentation and Monitoring**

- 1 Full requirements including all details of equipment position, depths, protection to pipe or cable connections, installation techniques, and methods of calibration and reading should be described in Appendix 6/12.
- 2 Consideration should be given to the positioning of instrumentation to protect it from damage from plant during construction.
- 3 To maximise the benefit of the instrumentation, readings should be taken at frequencies that will permit the Designer to validate the assumptions made during design.

#### **NG 630 Ground Improvement**

- 1 Only one system of dynamic compaction, end-product or method, should be used in the Contract and the appropriate requirements should be listed in Appendix 6/13.
- 2 Other methods of ground improvement such as vertical drains, vibro-flotation and stone or lime columns should be detailed on the Drawings and listed in Appendix 6/13, where they are required.
- 3 Prior to the selection of an appropriate ground improvement technique, consideration should be given to the effect of the technique on the design life of that element and any associated additional maintenance requirements. These considerations should be assessed based on the Contract requirements.
- 4 The extents of ground improvement techniques should be clearly outlined on the Drawings.

#### **NG 631 Earthworks Materials Tests**

- 1 Where the limiting values of acceptability are determined from tests which are relatively time consuming, other tests may be considered for rapid evaluation during construction. If the Designer is satisfied that simpler tests will produce equivalent and consistent results they should describe the acceptable tests and apparatus in Appendix 6/1 and, from preliminary trials, obtain equivalent values of acceptability which should be monitored during construction by carrying out the definitive test periodically. For example moisture content determination may be obtained using quicker drying methods than are required by BS 1377 : Part 2 or nuclear moisture gauges may be permitted. See also NG 633.

- 2 Appendix 6/1 should state whether the Contractor or the Designer will be responsible for testing and, where the Contractor, the testing details and minimum frequencies should be given in Appendix 1/5 and cross-referenced in Appendix 6/1.
- 3 Where the Designer is carrying out testing he should list in Appendix 1/1 the apparatus and materials he requires, and in Appendix 1/6, details of samples. For some unusual tests such as 300 mm and 60 mm shear box tests, redox potential and resistivity it may be more appropriate for testing to be carried out by an approved testing laboratory. The 300 mm shear box should not normally be required on Site.
- 4 See also NG 602.1.

**NG 632 Determination of Moisture Condition Value (MCV) of Earthworks Materials**

- 1 The Designer should state in Appendix 6/1 whether the MCV/mc relationship of all imported material requiring an MCV property should also be plotted.

**NG633 Determination of Undrained Shear Strength of Remoulded Cohesive Material**

- 1 Where shear strength is used as the acceptability criterion, routine site testing may be more conveniently carried out by e.g. hand vane or hand penetrometer monitored by periodic triaxial test comparison to give adequate correlation. However, the Designer must be satisfied that the alternative testing approach is capable of allowing for an accurate determination of undrained shear strength by validating the alternative testing against the testing described in Clause 633. Notwithstanding this, the testing described in Clause 633 should continue to be carried out at a reduced frequency to validate the alternative testing methods. (See NG 631.)

**NG 636 Determination of Effective Angle of Internal Friction ( $\phi'$ ) and Effective Cohesion ( $c'$ ) of Earthworks Materials**

- 1 For granular Class 6N1, 6N2, 6P, 6I and 6J materials, consistency of supply may be checked by comparing samples with the grading, particle shape, plasticity and other characteristics of the material used for the shear box test.

**NG637 Determination of Resistivity ( $r_s$ ) to Assess Corrosivity of Soil, Rock or Earthworks Materials**

- 1 When laboratory tests are required, Appendix 6/1 (1/5), should state which of the three types of test described in BS 1377 : Part 3 should be employed.
- 2 Appendix 6/1 should consider the following for in-situ testing to determine Resistivity:
  - (i) In order to achieve meaningful results it is essential that proper contact between the electrodes and the fill should be obtained particularly where the electrode penetration is shallow.
  - (ii) Tests should be carried out at the anticipated maximum natural moisture content in order to obtain the lowest resistivity.
  - (iii) The locations should be chosen so as to cover the entire area of the structure, cutting, borrow pit or stockpile. The distance between locations should exceed three times the maximum spacing of the electrodes but not be more than 50 m.

- (iv) The field testing procedure is not suitable for massive rock material which is to be crushed before use in the Permanent Works. In this case laboratory tests should be carried out on samples of crushed material using a procedure given in Appendix 6/1.
- (v) Unexpected variations in resistivity with depth should be investigated. Typical values of the resistivity likely to be obtained for various types of strata are shown in BS 7430:2011.

**NG 638      Determination of Redox Potential ( $E_h$ ) to Assess Corrosivity of Earthworks Materials for Reinforced Earth and Anchored Earth Structures**

**1**      Appendix 6/1 should consider the following for in-situ testing to determine Redox Potential:

- (i) The number of tests to be carried out on each soil type and the locations within the area of the cutting or of the proposed borrow pit or stockpile. A minimum of five locations should be included.. It is normally sufficient to test material at a depth of 1 m below original ground level. However, it will be necessary to test at lower levels where the type of material is known to vary with depth.
- (ii) When possible, tests should be carried out at the anticipated maximum natural moisture content in order to obtain the lowest redox potential.
- (iii) It is advisable to determine the pH of the fill at the location before measuring redox potential. Where the pH lies outside the range 5.5 to 9.5, and it is known that it will remain so for the life of the structure, redox potential measurements need not be made since it is considered that micro-biological corrosion is unlikely to occur under these conditions.
- (iv) The field testing procedure is not suitable for massive rock material which is to be crushed before use in the Permanent Works. In this case laboratory tests should be carried out on samples of crushed material using a procedure given in Appendix 6/1.

**NG639      Determination of Coefficient of Friction and Adhesion between Fill and Reinforcing Elements or Anchor Elements for Reinforced Earth and Anchored Earth Structures**

**1**      The test for reinforcing elements should be carried out for each type of element and each fill material proposed to be used.

**NG 640      Determination of Permeability of Earthworks Materials**

**1**      Details of tests for the permeability of soils and fills are given in BS 1377 : Part 5 and Part 6. Details of a test for the horizontal permeability of road drainage layers are given in UK Department of Transport Advice Note HA 41.

**NG 642      Determination of the Constrained Soil Modulus ( $M^*$ ) of Earthworks Materials**

**1**      Determination of  $M^*$  from Standard Penetration Test results and/or from the coefficient of volume compressibility is normally carried out during the ground investigation stage of a scheme from tests in and/or specimens obtained from boreholes through the existing ground.

The ground investigation should be designed to ensure that sufficient information is provided to determine the  $M^*$  of the existing ground. The plate loading test is the preferred method for determining the  $M^*$  of granular fill, during the construction stage to validate the design, but can also be used on existing ground of various soil types.

### **NG 643      Determination of Sulfate Content**

- 1** Tests for sulfate and total sulfur are mandatory for structural backfills, some select granular fills and all fill materials placed within 500 mm or other stated distance of concrete or metallic elements, because of the risk of attack on construction materials. However, the oxidation of pyrite and leaching of sulfate, metals and acidity from fill materials can also cause environmental damage to surface water and groundwater, and can lead to clogging of drains with precipitates of ochre. Furthermore the oxidation of pyrite within a calcareous fill may lead to the growth of gypsum and therefore pyrite related heave within constrained granular fills.
- 2** A highway embankment is a very favourable environment for the oxidation of pyrite and other sulfides. Experience from embankment dams has shown that the oxidation of even a small proportion of the pyrite in a fill material can lead to the drainage from the embankment requiring treatment before it can be discharged to watercourses downstream.
- 3** Consideration should be given to the possibility of environmental problems with bulk fill at design stage, and expert geochemical advice taken if necessary. If a potential problem is identified, based on the known properties of the proposed fill material and experience elsewhere, the tests outlined in IS EN 1744: Part 1 Sections 10, 11 and 12 should be employed to assess the situation.
- 4** The correct chemical form of sulfate is  $SO_4$  and this form is used in BRE Special Digest 1. However, results reported following the convention in BS 1377 : Part 3 are reported as  $SO_3$ . Results may be converted from  $SO_4$  to  $SO_3$  using the following factors:  
$$SO_4 (\%, \text{ mg/l}) = 1.2 \times SO_3 (\%, \text{ mg/l})$$
$$SO_3 (\%, \text{ mg/l}) = 0.83 \times SO_4 (\%, \text{ mg/l})$$
- 5** The form in which sulfate is determined should be clearly stated in the analytical report, to avoid confusion and possible misclassification. A discussion of the different forms of sulfur and conversion factors between them is given in TRL Report 447.
- 6** Because of the variability of sulfur compounds in natural and artificial materials, it is important that a sufficient number of samples are tested and that the values selected for comparison with the limiting values are based on the highest values. The requirements set out in Clause 601 and 643 follow the principles set out in BRE Special Digest 1.
- 7** Limiting values for WS, OS and TPS are based on values in BRE Special Digest 1. This was revised in June 2005 and as a result the limiting values for WS and OS for materials within 500mm of concrete, cement bound materials, or other cementitious materials forming part of the Works have been reduced. Also, the units for sulfate in solution have been changed from g/l to mg/l.

## NG SAMPLE APPENDIX 6/1: REQUIREMENTS FOR ACCEPTABILITY AND TESTING ETC. OF WORKS MATERIALS

*[Note to Compiler: This should include]*

1. Acceptable limits for the fills in Table 6/1 appropriate to the Contract [Table 6/1, 602.1 and 608.1] and including:
  - (i) permitted Classes where alternatives are listed in the Specification;
  - (ii) those materials, which may be used for landscape fill Class 4;
  - (iii) cross-references to Drawings showing location of 'zoning' of general and selected fills;
  - (iv) additional sub-divisions of Classes in Table 6/1 required for the Contract;
  - (v) alternative and additional requirements for triaxial and shear box tests [633 and 636].
2. Special requirements for determining acceptability, who classifies and where, and whether trial pitting is required [See NG 602.1]. Where the Contractor is responsible for testing, the tests required should be scheduled in Appendix 1/5 and cross-referenced here.
3. Any requirement for processing to render unacceptable material Class U1 acceptable, cross-referring to Drawings where necessary, for each type of material to be processed and class of material to be produced [Wherever possible the means of processing should be left to the Contractor [6.
4. Requirements for groundwater lowering or other treatment.
5. MCV and additional testing requirements for material to be improved by the addition of lime and/or lime cement.
6. Details of testing (type and rate) to be undertaken during the completion of a lime and/or cement improvement demonstration area.
7. Any permitted use of the rapid assessment procedure for material acceptability.
8. Requirements (if any) for removal off site of excavated acceptable material or unacceptable material requiring processing [602.3] or retention of surplus material on site [602.5].
9. Requirements for In Situ Resistivity Tests [637.2].
10. Requirements for In Situ Redox Potential Tests [638.2 and 638.5].
11. Requirements for the assessment of the effects of water soluble (WS) sulfate, oxidisable sulfides and total potential sulfate in accordance with TRL Report 447, Test Nos. 1 to 5 [643.1].
12. Requirements for the magnesium sulfate (MS) soundness test [635.2].

## **NG SAMPLE APPENDLX 6/2: REQUIREMENTS FOR DEALING WITH CLASS U2 UNACCEPTABLE MATERIAL**

*[Note to Compiler: This should include]*

1. Drawing references for excavation and disposal of known Class U2 material.
2. Pre-agreed environmental requirements for disposal including specific sites (DOE, EPA, Local Authority, etc. as required).
3. Reference to the Construction and Demolition Waste Management Plan [602.6].
4. List of known hazardous materials likely to be encountered.
5. Methods of excavation, precautions and requirements for handling.
6. Special requirements for dealing with leachate and contaminated water.
7. Requirements for special drainage and for sealing exposed surfaces of contaminated materials.
8. Test methods to be used for chemical analysis of hazardous materials, leachate and contaminated water should be scheduled in Appendix 1/5.

### NG SAMPLE APPENDIX 6/3: REQUIREMENTS FOR EXCAVATION, DEPOSITION, COMPACTION (OTHER THAN DYNAMIC COMPACTION)

*[Note to Compiler: This should include]*

1. The drawing numbers of all drawings which give related earthworks requirements including line and level.
2. Blasting for excavation:
  - (i) Locations where blasting is permitted [607.2].
  - (ii) Time limits when blasting can take place [607.4]. [Ensure compatibility with Clause 109 and Appendix 1/9 requirements for noise and vibration].cross-references to Drawings showing location of 'zoning' of general and selected fills;
  - (iii) Pre-split blasting requirements [603.4].
  - (iv) Details of noise and vibration monitoring in property off Site during blasting operations and proposed limiting values.
  - (v) Trial explosion requirements.
3. Cutting faces requirements for:
  - (i) Undercutting restrictions - extent and limitations for sequential excavation and backfilling, where Contractor is required to undercut slopes or toes of cuttings [603.2]. *[Note that where similar requirements exist for embankments e.g. where drainage excavations are close to the toe, these should also be covered in this Appendix].*
  - (ii) Clearing loose material, where no topsoiling is required, by airline hose or water hose including maximum pressure and nozzle arrangements [603.5(iv)];
  - (iii) Making face stable, where no topsoiling is required, including depth of cut-back and thickness of cementitious material to be applied if different from Clause 603, location and type of reinforcement and details of weep holes. [Rock bolting should be described in Appendix 6/10.
  - (iv) Protecting face of soft or insecure material interlayered with rock, where no topsoiling is required, including depth of back and details of masonry infill.
  - (v) Making good prior to topsoiling *[indicating which, if any, of the measures in 603.7 are required, and where.]*
4. Watercourses including ditches etc.
  - (i) Locations where blasting is permitted [607.2].
  - (ii) Redundant where draining and clearing required, extent of excavation and Classes of fill for their infilling ][606.4].

5. Embankment Construction:
  - (i) Limits on oversteepening or in increase in width [608.5].
  - (ii) Stage construction of fills details and rates of controlled filling [606.6].
  - (iii) Surcharging details including time period, type of surcharge material, initial level of top of surcharge above designed formation or sub-formation [608.7].
  - (iv) Description of location, class and thickness of starter layers [608.2].
  
6. Compaction [612]:
  - a. General:
    - i. Requirements if compaction not to comply with Clause 612 [612.1].
  - b. Method compaction:
    - i. Locations where extra compaction in top 600 mm for Classes 1A, 1B, 2A, 2B, 2C1, 2C2 and 2D is not required for full width of embankment or between outer extremities of verges..
    - ii. Requirements for compaction of drainage materials other than Class 6H.
  - c. End-product compaction:
    - i. Whether a nuclear surface density gauge is to be used or is permitted for measuring field dry densities [612.15].
  
7. Limiting distance for deposition of materials referred to in sub-Clause 601.6 or 601.7.
  
8. Locations of excavations that are permitted to be battered and requirements for benching prior to backfilling and compaction [602.13].
  
9. Locations where excavation supports are to be left in position [602.13].
  
10. Requirements for benching or shaping to natural or earthworks slope faces to receive fill [608.10]. Location of and benching requirements for cutting slopes to receive Treatments I or II [618.5].

**NG SAMPLE APPENDIX 6/4: NOT USED**

### **NG SAMPLE APPENDIX 6/5: GEOTEXTILES USED TO SEPARATE EARTHWORKS MATERIALS**

*[Note to Compiler: This should include]*

1. Drawing references for locations where geotextiles are to be used in separation layers [609.1].
2. Whether the geotextiles are to be of synthetic or other fibres [609.1].
3. Minimum life expectancy [609.2].
4. Numbers of samples for subsequent testing. [609.4].
5. Additional testing criteria not included Clause 609.
6. Details of laying and lapping if other than as in sub-Clause 609.5.
7. Number of tests on samples. [609.8]

### **NG SAMPLE APPENDIX 6/6: FILL TO STRUCTURES, FILL ABOVE STRUCTURAL FOUNDATIONS AND FILL BELOW STRUCTURAL FOUNDATIONS.**

*[Note to Compiler: This should include]*

1. Drawing references for fill to structures and fill above structural foundations.
2. Whether Classes 6N1, 6N2 or 6P require full scale determination of stable slope, and value of slope if not 1 to 1.5 [610.6].

### **NG SAMPLE APPENDIX 6/7: SUB-FORMATION AND CAPPING AND PREPARATION AND SURFACE TREATMENT OF FORMATION**

*[Note to Compiler: This should include]*

1. Drawing references which show locations where capping is required and its thickness [613.1] for each type of pavement.
2. Allowable surface level tolerances.
3. Permitted Classes of capping.
4. Requirements for a demonstration area or areas [613.9] including location and protection [613.10]. Requirements for removal and reinstatement of demonstration area if not forming part of the permanent works [613.11].
5. Locations where treatment of formation is required [613.4 and 613.7].

## NG SAMPLE APPENDIX 6/8: TOPSOILING, GRASS SEEDING AND TURFING

*[Note to Compiler: This should include]*

1. Whether imported topsoil Class 5B is required. [618.2].
2. Whether the requirements of sub-Clause 618.3 apply *[only when majority of topsoil (Class 5A) to be stripped for re-use has high clay content, to avoid degradation following prolonged rainfall]*. Cumulative rainfall if not 100 mm.
3. References to drawings which show the areas to receive Treatments I, II or III. [618.4].
4. Thickness of topsoil to be deposited in Treatments I and II and when a tracked vehicle may not be used for spreading. [618.6(i)].
5. When hydraulic mulch seeding is not permitted for Treatment I. [618.4(i)].
6. List of areas of cutting slopes which do not need harrowing or harrowing depth if not 50 mm. [618.5(ii)]
7. Rate of distribution of fertiliser to be raked in, if other than 75g/m\ [618.6(iv)(b)].
8. Rate of distribution of seed if different from sub-Clause 618.7(h).
9. Measures for retaining turf on slopes. [618.8(iv)].
10. Requirements for glass fibre or other material to form a retaining agent in hydraulic mulch seeding. [618.9].
11. Drawing references which show areas of grass not to be mown or to be mown three times. [618.10].
12. Mowing plant requirements, if any. [618.10].
13. Seed mixture requirements which differ from those listed in Table 6/5 and drawing references showing areas where required [618.13].
14. Whether surplus topsoil is to be stored or disposed of by the Contractor. Details of topsoil storage areas such as location, height, contours and batter slopes [602.12].
15. Drawing references which show the locations where topsoil and vegetation is to be left in place [602.10].
16. Drawing references which show average depths to which topsoil is to be stripped [602.10].

## **NG SAMPLE APPENDIX 6/9: EARTHWORK ENVIRONMENTAL BUNDS, LANDSCAPE AREAS, SCREENING MOUNDS, STRENGTHENED EMBANKMENTS**

*[Note to Compiler: This should include]*

1. Earthwork Environmental Bunds
  - (i) References to Drawings which show locations and which state type of construction [619]:
    - (a) a normal embankment to Clause 608; if so whether method compaction to Clause 612 is required and which Method in Table 6/4 to adopt and Classes of fill permitted or required;
    - (b) a strengthened embankment to Clause 621; if so requirements as listed in 3 below;
    - (c) a reinforced or anchored earth structure to Clause 622; if so full details of construction.
  - (ii) Requirements for early construction.
  - (iii) Requirements for topsoiling and seeding/turfing.
  
2. Landscape Areas and Screening Mounds
  - (i) References to Drawings which show locations
  - (ii) If compaction to be 'method' to Clause 612 and if so which method in Table 6/4 to adopt.
  - (iii) Details of contouring required.
  - (iv) Locations where landscape areas may be constructed simultaneously with adjoining embankments.
  - (v) Requirements for topsoiling and seeding/turfing.
  
3. Strengthened Embankments
  - (i) Reference to Drawings which show locations, details of construction and Classes of fill.
  - (ii) Requirements for strengthening materials.

## **NG SAMPLE APPENDIX 6/10: GROUND ANCHORAGES, CRIB WALLING AND GABIONS**

*[Note to Compiler: This should include]*

1. Ground Anchorages [624]
  - (i) Details of ground anchor type;
  - (ii) Reference to drawings showing layout and typical anchor details;
  - (iii) Construction requirements
  - (iv) Specification for anchor, tendons, grouting, tensioning and corrosion protection;
  - (v) Testing requirements (loading, frequency of test, reporting)
  - (vi) Trial installations
  
2. Crib Walling [625]
  - (i) Reference to drawings showing locations and outline;
  - (ii) Specification for component parts;
  - (iii) Foundation treatment requirements
  - (iv) Construction requirements and methodology
  
3. Gabions [626].
  - (i) References to drawings showing locations and layout;
  - (ii) Type of mesh required (core diameter, opening sizes etc.);
  - (iii) Specification for infill material;
  - (iv) Foundation treatment requirements;
  - (v) Gabion wall backfill details;
  - (vi) Permanent drainage details.

## **NG SAMPLE APPENDIX 6/11: SWALLOW HOLES AND CAVITIES**

*Note to Compiler: This should include]*

1. Drawing references showing locations of voided ground;
2. Drawing references showing locations prone to karstification or where swallow holes or other naturally occurring cavities are likely to occur over the design life of the road.
3. Methodology for inspecting voids where required;
4. Requirements for filling and method of material placement;
5. Grouting type and procedure;
6. Details of other permitted treatments;
7. Requirements for concrete caps to voids (visible at formation or otherwise) or soft areas;
8. Requirements to mitigate risk to Road Works from the potential for voids to form over the life of the Road Works.

## **NG SAMPLE APPENDIX 6/12: INSTRUMENTATION AND MONITORING**

*Note to Compiler: This should include]*

1. Drawing references showing locations and extent of instrumentation including that required for staged construction. *Note: instrumentation and monitoring for blasting should be covered in Appendix 6/3 and for dynamic compaction in Appendix 6/13;*
2. Schedules of instruments by type and description with alternatives where possible;
3. Details of protection measures, connections and housing;
4. Installation timing and techniques;
5. Calibration requirements;
6. Details of responsibility for instrumentation installation and monitoring.
7. Frequency of readings and method of reporting readings where the Contractor is required to carry out these tasks.
8. Trigger values, limits and actions required if trigger levels are approached or exceeded.

## NG SAMPLE APPENDIX 6/13: GROUND IMPROVEMENT

*Note to Compiler: This should include]*

1. Dynamic Compaction
  - (i) Drawing references showing locations where dynamic compaction is required.
  - (ii) For end-product: performance requirements in terms of tolerable further settlement after the process has been completed.
  - (iii) For method, the following where applicable:
    - (a) Special; drainage requirements;
    - (b) Class and thickness of granular layer;
    - (c) Mass, shape and contact area of pounder;
    - (d) Height(s) of drop and spacing of imprints;
    - (e) Number of drops;
    - (f) Arrangements and number of passes;
    - (g) Requirements, including class of material, for filling of imprints;
    - (h) Requirements for instrumentation, monitoring and testing.
  
2. Other Methods

For other methods of approved ground improvement:

  - (i) Drawing references showing locations where each method is to be applied;
  - (ii) Typical details for the treatment proposed;
  - (iii) Details of spacing, depth, size etc.
  - (iv) Specification details.
  - (v) Testing requirements.





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