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Special backfill material for cable installations

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Issue 1 published, 1997.

Amendments since publication

Issue	Date	Amendment
Issue 2	February 2016	Major revision of Issue 1: (i) to reflect changes made to the standards referenced (ii) to allow the option for alternative cable backfill materials to be introduced by specifying the performance characteristics required for backfills materials (iii) to retain the specific requirements for the three 'selected sand' backfills and 'stabilised' backfills, updated to reflect changes in national standards. *NOTE: To avoid confusion due to the re-numbering of existing clauses and addition of new clauses, the Clause numbering below refers to this revised version, Issue 2. The Clause numbers of Issue 1 are given in brackets, where relevant, for cross referencing.* This issue includes the following principal technical changes. Foreword: Revised due to the expanded content of TS 97-1. Clause 1 (Issue 1, Clause 1.1): Scope expanded to describe the increased scope and to define that the Specification applies to backfill materials that are intended for open trench applications and including cables both directly buried and installed in ducts but not requirements for thermal grouts or Bentonite mixture in cable ducts. Clause 2 (Issue 1, Clause 1.2): References updated, deleted or added as relevant. Clause 3: Clause added with relevant terms and definitions included. Clause 4 (Issue 1, Clause 1.3): Amended to state that the backfills referred to are classified into two groups: (i) Traditional backfills, retained from Issue 1, which have defined composition and properties. (ii) Alternative (non-traditional) backfill materials.

		Clause 6 (Issue 1, Section 2, 3 and 4): Units have been inserted to follow the values stated for dry relative density. These units are Mg/m^3. Clause 6.1.1 (Issue 1, Clause 2.1), Paragraph 2: Wording "…about 50 per cent of possible sources..." amended to "…an adequate number of sources…" to reflect the reduced availability of selected sands. Clause 6.1.5 (Issue 1, Clause 2.5): (i) Paragraph 2, item ii: Reference to "Clause 1.1.1 of BS 1377" updated to "Clause 2.2.4 of BS 1377-1". (ii) Last paragraph: Text expanded and Table 1 added to clarify the required tests and assessment requirements. Technical requirements unchanged. Clause 6.1.6 (Issue 1, Clause 2.6): Frequency of samples for routine tests changed from every 50 m length of trench to '50 m when possible but not exceeding 100 m length of trench'. Clause 6.2.3 (Issue 1, Clause 3.3): (i) Sentence 1: Requirement "…10 mm coarse aggregate as defined in BS 882 with particle size not exceeding 14 mm…" revised to "…10 mm single size coarse aggregate with particle size not exceeding 14 mm, meeting the requirements of BS EN 12620 aggregate size 4/10…" to align with the specification in BS EN 12620. (ii) Sentence 2: Requirement added that acceptance of gravel shall be subject to agreement between the Engineer and the Contractor. Technical intent unchanged. Clause 6.2.5 (Issue 1, Clause 3.5): Reference to withdrawn BS 874 updated to BS EN ISO 8990. NOTE: BS EN ISO 8990 includes only 2 methods of determination of thermal conductance compared to 7 in BS 874. However, no technical consequence to TS 97-1. Clause 6.2.7 (Issue 1, Clause 3.7): (i) Paragraph 2, item ii: Reference to "Clause 1.1.1 of BS 1377" updated to "Clause 2.2.4 of BS 1377-1". (ii) Last paragraph: Text expanded and Table 2 added to clarify the required tests and assessment requirements. Technical requirements unchanged. Clause 6.2.8 (Issue 1, Clause 3.8): Frequency of samples for routine tests changed from every 50 m length of trench to '50 m when possible but not exceeding 100 m length of trench'. Clause 6.3.2 (Issue 1, Clause 4.2): (i) Reference to "BS 882 Zone 2 to Zone 3" updated to "BS 12620". (ii) Requirement "…cement to BS 12…" revised to "…Portland cement EN 97-1 - CEM 1 32.5 N to BS EN 197-1 …" to align with the specification in BS EN 197-1. Technical intent unchanged. Clause 6.3.3 (Issue 1, Clause 4.3): Reference to withdrawn BS 874 updated to BS EN ISO 8990. NOTE: BS EN ISO 8990 includes only 2 methods of determination of thermal conductance compared to 7 in BS 874. However, no technical consequence to TS 97-1. Clause 6.3.5 (Issue 1, Clause 4.5): (i) Paragraph 2, item ii: Reference to "Clause 1.1.1 of BS 1377" updated to "Clause 2.2.4 of BS 1377-1". (ii) Last paragraph: Text expanded and Table 3 added to clarify the required tests and assessment requirements. Technical requirements unchanged.

		Clause 6.3.6 (Issue 1, Clause 4.6): 2nd paragraph: Frequency of samples for routine tests changed from every 50 m length of trench to '50 m when possible but not exceeding 100 m length of trench'. 3rd paragraph: Requirement that individual results of the set of dry relative density to be less than "...0.5 below the specified minimum value…" amended to "…0.05 below the specified minimum value…". Clause 7: Alternative (non-traditional) backfill materials. New section. Added to allow the option for alternative cable backfill materials to be introduced into use. Provides the specification characteristics required for such backfills materials by specifying the functional and performance requirements. Includes following clauses: • 7.2 General requirements (composition, mechanical strength, thermal characteristics, compatibility with cables, environmental compatibility and health and safety); • 7.3 Type assessment (sample size, sample preparation, type test sequence and acceptance criteria); • 7.4 Sample tests (sampling procedure, sample test sequence and acceptance criteria); • 7.5 Routine tests (sampling procedure, sample test sequence and acceptance criteria). Clause 8: On-site handling. New section to provide guidance on procedures and requirements for the installation of the backfill to clarify responsibilities and provide quality control. Includes the following clauses: • 8.1 Preliminaries. Guidance on: Obtaining certification for the backfill material; Working practices by the Contractor and Engineer to expedite the work. • 8.1.1 Test documentation Formal requirement for the Contractor to submit test documentation for the backfill material. This is a Hold Point. • 8.2 Installation procedures Installation to conform to ENA TS 09-2 unless otherwise agreed. • 8.2.1 Compaction techniques Guidance on compaction of the backfill. • 8.2.2 Trench Bedding Requirements for the bedding layer. • 8.2.3 Blinding of cables Requirements for the blinding. Routine tests after blinding are a Hold Point. • 8.2.4 Completion of joints and terminations Requirements for the joints and terminations. Annex A.2 (Issue 1, Appendix A2): Requirement "…dry relative density shall be determined in accordance with the Soil Compaction Test Number 11 of BS 1377..." revised to "…dry relative density shall be determined in accordance with the soil compaction test procedure in BS 1377-4 Clause 3.5…". Technical intent unchanged. Annex B.1.2 (Issue 1, Appendix B part A): 4th paragraph: The method for drying loose granular type backfills amended to be "The tray shall be heated for a period sufficient to thoroughly dry the sample" i.e. deletion of the requirement that the minimum period of heating be 10 minutes.

		Annex B.2 (Issue 1, Appendix B, Part B): Requirement "…method to be used shall be the first of the two in Test 14(A) of BS 1377..." revised to "…method to be used shall be that given in BS 1377-9 Clause 2.1…". Technical intent unchanged. Annex C.1 (Issue 1, Appendix C1), Apparatus, Item b): Specific reference to "Speedy' moisture tester" amended to "moisture tester with an accuracy of ± 3% or better e.g. GE Protimeter 'Speedy' tester or Delta-T devices ThetaProbe". Annex F (Issue 1, Appendix G): (i) Wording "sand" amended to "sand/fine aggregate" to align with the allowed composition of cement-bound sand in Clause 6.3.2. (ii) Clause F.3, 2nd equation: Corrected to read "Volume of voids". Annex H (Issue 1, Appendix H): Additional column added to Test sheet table to require entry of the details of the particle size distribution. Annex J: New Annex. Test sheet for recording the results of a sample test Annex K: New Annex. Test sheet for recording the results of a routine test. Annex L: New Annex. Table of the Hold Points. Bibliography: Clause added and references included of 'Management of Health and Safety at Work Regulations 1999', 'Environmental Protection Act, 1990', 'Water Resources Act, 1991' and 'Burceanu & Van Der Boerght "Study of thermal backfill materials for directly buried HV cables" 9th International Conference on Insulated Power Cables, Versailles, 2015'. Details of all other technical, general and editorial amendments are included in the associated Document Amendment Summary for this Issue (available on request from the Operations Directorate of ENA).

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Foreword

This Technical Specification (TS) is published by the Energy Networks Association (ENA) and comes into effect from the date of publication. It has been prepared under the authority of the ENA Engineering Policy and Standards Manager and has been approved for publication by the ENA Electricity Networks and Futures Group (ENFG). The approved abbreviated title of this engineering document is “ENA TS 97-1”.

This document replaces and supersedes Technical Specification 97-1 Issue 1 1997.

In the design of naturally cooled cable circuits of relatively high power transfer capacity extensive use is being made of special backfill materials in the immediate vicinity of the cable. These materials are characterised by having thermal resistivities in the fully dried-out state that do not exceed specified values. In using these materials it is no longer necessary to impose a limiting external cable surface temperature during summer to minimize the danger of moisture migration in the cable surround. The quantity and disposition of these backfill materials in a cable trench is in general chosen to allow the maximum permissible conductor temperature to be attained throughout the year; to enable designated ratings for the cable to be applicable at all times.

The purpose of this Technical Specification is to ensure that any backfill materials placed in a cable trench have thermal resistivities in the dried-out state that do not exceed the limiting values assigned by the Contractor or specified by the Network Owner in the design of the cable installation. The Specification includes specific details for currently accepted backfill materials, which are described as traditional backfills, being designated 'selected sand' backfills and 'stabilised' backfills and have thermal resistivities in the fully dried-out state not exceeding 2.7 Km/W and 1.2 Km/W respectively. Their composition, properties and test requirements are defined in detail and provide baseline options that provide an assured performance. Direct measurement of thermal resistivity presents difficulties; consequently reliance is placed upon the control of associated properties which are more readily determinable, viz. particle size distribution, void ratio, cohesion and dry relative density.

In addition, this Specification allows the option for alternative cable surround materials to be offered either by Contractors or to be specified by a Network Owner. Such backfill materials are required to demonstrate that they either meet the baseline thermal resistivity requirements specified in this Specification or have thermal properties that achieve values stipulated for the cable system design, which may require enhanced performance requirements.

Where the term “shall” or “must” is used in this document it means the requirement is mandatory. The term “should” is used to express a recommendation. The term “may” is used to express permission. Where the term “shall” is used in this document it expresses a requirement. The term “may” is used to express permission.

NOTE: Commentary, explanation and general informative material is presented in smaller type, and does not constitute a normative element.

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1 Scope

This Technical Specification sets out general requirements for special backfill materials listing both currently acceptable types of stabilised backfill materials and the option for alternative cable surround materials to be offered either by Contractors or to be specified by a Network Owner, which allow the designated ratings for the cable to be applied.

The Specification applies to backfill materials that are intended for open trench applications, where the cable is either directly buried in the backfill or installed in ducts laid in the backfill, and, as such, the backfills are required to be load bearing, resist settlement, erosion, impact and frost heave.

This Specification does not cover the requirements for thermal grouts or Bentonite mixture that may be specified for use in cable ducts and HDD situations. Refer to ENA TS 09-2 [N1] for information on their use.

2 Normative references

The following referenced documents, in whole or part, are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Standards publications

BS EN 197-1:2011, *Cement. Composition, specifications and conformity criteria for common cements*)

BS EN ISO 8990:1996, *Thermal insulation. Determination of steady-state thermal transmission properties. Calibrated and guarded hot box*

BS EN 12620:2002+A1:2008, *Aggregates for concrete*

BS 1377-1:1990, *Methods of test for soils for civil engineering purposes. General requirements and sample preparation*

BS 1377-4:1990, *Methods of test for soils for civil engineering purposes. Compaction-related tests*

BS 1377-9:1990, *Methods for test for soils for civil engineering purposes. In-situ tests*

Other publications

[N1] ENA TS 09-2, Specification for the supply, delivery & installation of power cables with operating voltages in the range 11 kV to 400 kV and associated auxiliary cables

[N2] Waste Framework Directive (2008/98/EC). Published at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/218586/l_31220081122en00030030.pdf

[N3] Guidance on the classification and assessment of waste (1st edition 2015) Technical Guidance WM3. Published by Environment Agency, Natural Resources Wales/Cyfoeth Naturiol Cymru, Scottish Environment Protection Agency (SEPA), Northern Ireland Environment Agency (NIEA)

[N4] Hazardous waste Interpretation of the definition and classification of hazardous waste (3rd Edition 2013). Published by Environment Agency, Natural Resources Wales/Cyfoeth Naturiol Cymru, Scottish Environment Protection Agency (SEPA), Northern Ireland Environment Agency (NIEA)

[N5] Classify different types of waste. Published by UK government at https://www.gov.uk/how-to-classify-different-types-of-waste

[N6] Control of Substances Hazardous to Health Regulations (COSHH) 2002 (as amended) (SI 2002/1689)

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
Contractor
person or person's firm or company, including personal representatives, successors and permitted assigns, commissioned to carry out a cable installation

3.2
Engineer
person nominated by the Purchaser to manage the cable installation contract

3.3
Hold Point
stage in the material procurement or fabrication and/or workmanship process beyond which work shall not proceed without the documented approval of the Engineer

3.4
Network Owner
Company licenced to develop, operate and maintain local electricity distribution networks

3.5
Purchaser
person or person's firm or company accepting the Contract

3.6
routine tests
tests that may be required on backfill materials brought to site to ensure that the quality of the backfill material is being maintained during a contract

3.7
sample tests
tests that may be required before installation is commenced to ensure that the backfill material which is to be used on the contract meets the requirements

3.8
type test
series of one-off tests to ensure the satisfactory performance of the backfill material

4 Types of backfill

The special backfill materials specified in this Specification are classified into two groups.

a) Traditional backfills having defined composition and properties

These are designated selected sands and stabilised backfills and attain the baseline thermal resistivity requirements defined in this Specification. At present the stabilised materials are further divided into gavel/sand and cement-bound sand mixes, and consequently the traditional backfill materials are divided into three categories, as follows:

- Selected Sands, maximum dried-out thermal conductivity 2.7 Km/W;

- Gravel/Sand, maximum dried-out thermal conductivity 1.2 Km/W;
- Cement-bound Sand, maximum cured dried-out thermal conductivity 1.2 Km/W.

Each clause describing these types is entirely self-contained to reduce cross-referencing that would have otherwise been necessary.

b) Alternative (non-traditional) backfill materials

The inclusion of the traditional backfill materials in this Specification does not preclude Contractors or a Network Owner putting forward alternative backfill materials. This may include materials that offer the same baseline thermal properties of the traditional backfills or alternatives that provide enhanced thermal properties. These must satisfy the fundamental requirements of this Specification. Acceptance on a new material will depend on satisfactory results being obtained from the tests given in Clause 7.

The non-traditional backfill materials may be divided into the following general groups.

- Quarried or recycled granular material, e.g. crushed granite, limestone or Whinstone, pulverised fuel ash, recycled foundry sand.
- Alternative formulations of traditional cement-bound sand.
- Fluidised thermal backfills intended for use in open trench applications.

NOTE: The example lists are provided as illustrative examples and are not intended to be restrictive or to be interpreted as guidance.

5 Application to contracts

The extent to which this Specification shall apply will be as stated in the Contract between the Purchaser and the Contractor.

6 Traditional backfill materials

6.1 Selected sand backfill

6.1.1 General

The designation 'selected sands' applies to sands obtained from approved selected sources chosen on the basis of density and cohesion characteristics so that the in-situ thermal resistivity in the dried-out state is not greater than 2.7 Km/W.

The category of selected sand has been arrived at from consideration of the availability in Great Britain of naturally occurring sand with good cohesion properties and of the general relationship between thermal resistivity and density of such sands in the dry state. The selection criteria have been so chosen that an adequate number of sources throughout the country can be expected to yield acceptable sand.

6.1.2 Composition of selected sand

The material shall be of consistent composition and shall not contain readily visible foreign matter, such as pieces of clay or organic detritus. Not less than 95% by weight of the material shall pass a British Standard 5 mm sieve. The material shall not contain sharp stones or flints.

6.1.3 Dry relative density

The dry relative density of the selected sand determined in accordance with the compatibility test method given in Annex A shall not be less than 1.6 Mg/m^3. After installation and when tested in accordance with Annex B, the dry relative density for any set of three samples shall have a mean value not less than 1.45 Mg/m^3.

6.1.4 Cohesion

The selected sand shall possess an adequate measure of cohesion as demonstrated by compliance with the test requirements of Annex C.

6.1.5 Sample tests on selected sand backfill

Before installation is commenced on a particular contract the Contractor shall satisfy the Engineer that the backfill material which is to be used on the Contract meets the requirements of 6.1.1 to 6.1.4 above.

The sampling procedure and test requirements for selected sand backfill materials covered by this Specification are given below.

i. A batch of at least 1 m^3 of sand shall be taken from each of four widely spaced positions in the quarry, or section of the quarry, from which the sand for the contract is to be obtained.

ii. Three samples shall be obtained from each batch of sand by the process of quartering (see Clause 2.2.4 of BS 1377-1) each being of sufficient quantity to enable both the determination of compatibility (Annex A) and the determination of cohesion (Annex C) to be carried out.

The samples shall be subjected to the tests and assessment criteria in Table 1.

Test No.	Test procedure	Clause	Result to be recorded	Assessment
1	Dry relative density	6.1.3	Measured value	All samples ≥ 1.6
2	Cohesion	6.1.4	'Pass' or 'Fail'	2 of 3 samples per batch to Pass

Table 1 – Sample tests on selected sand backfill

The results shall be recorded on a test sheet that provides the information as shown in the example test sheet in Annex D. Where material is to be supplied from more than one quarry, a separate test sheet shall be supplied for batches obtained from each quarry. Copies of each test sheet shall be supplied to the Engineer.

6.1.6 Routine tests on selected sand backfill

Approval of a backfill material on the basis of sample tests as described in 6.1.5 above does not necessarily imply approval for its unlimited use on a large contract. It will be necessary to establish by means of the routine testing described below that the quality of the backfill material is being maintained.

The frequency of testing shall be such that one set of three tests is made for each 50 m when possible but not exceeding 100 m length of trench in which the backfill is installed, samples being taken at reasonably regular intervals along the cable route or as the Engineer may reasonably require.

The in-situ dry relative density for selected sand backfills shall be determined by the method described in Annex B1. Where practical difficulties preclude the use of the core-cutter, the sand replacement method described in Annex B2 shall be employed. The mean value obtained for any set of three samples shall be not less than the value specified in 6.1.3 of 1.45 Mg/m^3 and no individual result of the set shall be more than 0.05 below the specified minimum value.

In the event of a section of backfill being initially judged unacceptable, the Contractor shall have the right to attempt additional compaction and thereafter to make a repeat set of three tests. If the acceptability criteria are still not met then the section of backfill shall be replaced.

The results shall be recorded on a test sheet that provides the information as shown in the example test sheet in Annex E; copies of each test sheet shall be supplied to the Engineer. The results of the tests shall also be entered on the appropriate trench cross-section of the Route Records.

6.2 Gravel/sand backfill

6.2.1 General

The stabilised backfill shall be well mixed in a suitable mixer to give substantially homogeneous material. The composition of the stabilised backfill shall be such as to be without injurious or deleterious effect upon the cable serving both during installation and subsequent operation of the cable throughout its service life.

6.2.2 Selected sand for gravel/sand backfill

The material shall be of consistent composition, and shall not contain readily visible foreign matter, such as pieces of clay or organic detritus. Not less than 95% by weight of the material shall pass a British Standard 5 mm sieve. The material shall not contain sharp stones or flints. The selected sand shall possess an adequate measure of cohesion as demonstrated by compliance with the test requirements given in Annex C.

6.2.3 Gravel for gravel/sand backfill

The gravel shall be 10 mm single size coarse aggregate with particle size not exceeding 14 mm, meeting the requirements of BS EN 12620 aggregate size 4/10, and may contain not more than 50% of crushed material. The aggregate shall preferably be of a rounded nature and shall not contain sharp stones or flints. Acceptance shall be subject to agreement between the Engineer and the Contractor.

6.2.4 Composition of gravel/sand backfill

A mixture of a sand which meets the requirements of 6.2.2 together with an equal part by weight of gravel which meets the requirements of 6.2.3 and a water content as required to achieve adequate compatibility, i.e. approximately (10 ±2)% of the dry weight.

6.2.5 Thermal resistivity

The thermal resistivity/dry relative density characteristic of the backfill material shall be established, the thermal resistivity being determined, as agreed between the Engineer and the Contractor in accordance with BS EN ISO 8990 or by another method, and the density measured in accordance with the appropriate method described in Annex A. The determination of this characteristic shall be made on a once and for all basis in order to enable appropriate density values to be assigned in 6.2.6 below.

6.2.6 Dry relative density

In order that a value of thermal resistivity in the dried-out state of 1.2 Km/W can justifiably be used for design purposes, it is necessary to ensure that the particular mix to be used on any contract shall not only be characterized by adequate compactibility, but that it shall be sufficiently compacted in the cable trench. To that end, the dry relative density shall be not less than 1.8 Mg/m^3 for sample tests referred to in 6.2.7 below and shall be not less than 1.7 Mg/m^3 for in-situ tests when tested in accordance with Annex B2.

6.2.7 Sample tests on gravel/sand backfills

Before installation is commenced on a particular contract, the Contractor shall satisfy the Engineer, by means of the following tests, that the backfill material which is to be used on the Contract meets the requirements of 6.2.1 to 6.2.6.

The sampling procedure and test requirements for gravel/sand backfill materials covered by this section of the Specification are given below.

i. A batch of at least 1 m^3 of the sand to be used in the gravel/sand backfill shall be taken from each of four widely-spaced positions in the quarry, or section of the quarry from which the sand for the contract is to be obtained.

iii. Three samples shall be obtained from each batch of sand by the process of quartering (see Clause 2.2.4 of BS 1377-1), each being of sufficient quality to enable the determination of cohesion (Annex C) to be carried out.

iv. The unused sand in each batch shall be retained and mixed with an equal part by weight of gravel in accordance with the requirements of 6.2.4 above.

v. Three samples shall be obtained from each batch of gravel/sand backfill by the process of quartering (see Clause 2.2.4 of BS 1377-1) each being of sufficient quantity to enable the determination of dry relative density (Annex A) to be carried out.

The samples shall be subjected to the tests and assessment criteria in Table 2.

Test No.	Test procedure	Sample material	Clause	Result to be recorded	Assessment
1	Cohesion	Sand	6.1.4	'Pass' or 'Fail'	2 of 3 samples per batch to Pass
2	Dry relative density	Gravel/sand	6.2.6	Measured value	All samples ≥ 1.8

Table 2 – Sample tests on selected gravel/sand backfill

The results of the measurements of dry relative density on the gravel/sand backfill and of cohesion on the constituent sand shall be recorded on a test sheet that provides the information as shown in the example test sheet in Annex D. Where material is to be supplied from more than one quarry, a separate test sheet shall be supplied for batches obtained from each quarry. Copies of each test sheet shall be supplied to the Engineer.

6.2.8 Routine tests on gravel/sand backfill

Approval of a backfill material on the basis of sample tests as described in 6.2.6 above does not necessarily imply approval for its unlimited use on a large contract. It will be necessary to establish by means of the routine testing described below that the quality of the backfill material is being maintained.

The frequency of testing shall be such that the set of three tests is made for each 50 m when possible but not exceeding 100 m length of trench in which the backfill is installed, samples being taken at reasonably regular intervals along the cable route or as the Engineer may reasonably require.

The core-cutter method shall not be used for gravel/sand mixes and therefore the in-situ relative dry density shall be determined by the method given in Annex B2.

The mean value obtained for any set of three samples shall be not less than the value specified in 6.2.6 above of 1.7 Mg/m^3 and no individual result of the set shall be more than 0.05 below the specified minimum value.

In the event of a section of backfill being initially judged unacceptable, the Contractor shall have the right to attempt additional compaction and thereafter to make a repeat set of three tests. If the acceptability criteria are still not met then the section of backfill shall be replaced.

The results shall be recorded on a test sheet that provides the information as shown in the example test sheet in Annex E; copies of each test sheet shall be supplied to the Engineer. The results of the tests shall also be entered on the appropriate trench cross- section of the Route Records.

6.3 Cement-bound backfill

6.3.1 General

The stabilised backfill shall be well mixed in a suitable mixer to give a substantially homogeneous material. The composition of the stabilised backfill shall be such as to be without injurious or deleterious effect upon the cable serving both during installation and subsequent operation of the cable throughout its service life.

To ensure by direct determination or otherwise, that particle size distributions are consistent with the attainment of a dried-out thermal resistivity not exceeding 1.2 Km/W, it is required that the sands embodied in cement-bound sand stabilised backfill shall be strictly in accordance with the description given below.

6.3.2 Composition of cement-bound sand

Sand or fine aggregate as defined in BS 12620 with not less than 95% by weight of the material passing a 5 mm sieve, shall be bound with Portland cement EN 97-1 - CEM 1 32.5 N to BS EN 197-1 in the ratio of 14 parts to 1 part by volume (approximately in the range 18 to 20 parts by weight), with water added in the requisite amount, dependent upon the initial water content of the sand, to enable adequate compaction to be achieved. This is provided for by a total water/cement ratio of approximately 2:1 by weight.

6.3.3 Thermal resistivity/maximum void ratio

The thermal resistivity/dry relative density characteristic of the backfill material shall be established, the thermal resistivity being determined, as agreed between the Engineer and the Contractor, in accordance with BS EN ISO 8990 or by another method.

Because of the differences between hand-mixed samples and bulk supplies it is preferable in a sample test to assess the dry relative density of cement-bound sand backfill be measuring the void ratio of the sand which forms the basis of the backfill. The method to be used is described in Annex F; the maximum void ratio shall not exceed 0.54. The determination of this characteristic shall be made on a once and for all basis in order to enable appropriate density values to be assigned in 6.3.5 below.

6.3.4 In-situ dry relative density

In order that a value of thermal resistivity in the dried-out state of 1.2 Km/W can justifiably be used for designed purposes, it is necessary to ensure that the particular mix to be used on any contract shall not only be characterized by adequate compactibility but that it shall be sufficiently compacted in the cable trench. To that end, the in-situ dry relative density for any set of three samples shall have a mean value not less than 1.6 Mg/m^3 when determined by the tests described in Annex G.

6.3.5 Sample tests on cement-bound sand backfill

Before installation is commenced on a particular contract, the Contractor shall satisfy the Engineer, by means of the following tests that the backfill material which is to be used on the contract meets the requirements of 6.3.1 to 6.3.4.

The sampling procedure for the sand to be used in the cement-bound sand backfill covered by this section of the Specification is given below.

i. A batch of at least 1 m^3 of the sand to be used in the cement-bound sand backfill shall be taken from each of four widely spaced positions in the quarry, or section of the quarry, from which the sand for the contract is to be obtained.

ii. Three samples shall be obtained from each batch of sand by the process, of quartering (see Clause 2.2.4 of BS 1377-1) each being of sufficient quality to enable both the determination of void ratio (Annex F) and the determination of particle size distribution in accordance with the requirements of BS EN 12620 to be carried out.

The samples shall be subjected to the tests and assessment criteria in Table 3.

Test No.	Test procedure	Sample material	Clause	Result to be recorded	Assessment
1	Particle size distribution	Sand/fine aggregate	6.3.2	'Pass' or 'Fail'	All samples ≥95% by weight of material passing a 5 mm sieve
2	Void ratio	Sand/fine aggregate	6.3.3	Measured value	All samples ≤ 0.54

Table 3 – Sample tests on cement bound sand backfill

The results of the determinations of void ratio and particle size distribution shall be recorded on a test sheet that provides the information as shown in the example test sheet in Annex H. Where material is to be supplied from more than one quarry, a separate test sheet shall be supplied for batches obtained from each quarry. Copies of each test sheet shall be supplied to the Engineer.

6.3.6 Routine tests on cement-bound sand backfill

Approval of a backfill material on the basis of sample tests as described in 6.3.5 above does not necessarily imply approval for its unlimited use on a large contract. It will be necessary to establish by means of the routine testing described below that the quality of the backfill material is being maintained.

The frequency of testing shall be such that one set of three tests is made for each 50 m when possible but not exceeding 100 m length of trench in which the backfill is installed, samples being taken at reasonably regular intervals along the cable route or as the Engineer may reasonably require.

The in-situ dry relative density shall be determined by the core-cutter method detailed in Annex B1, and Annex G. The mean value obtained for any set of three samples shall be not less than the value specified in 6.3.4 above and no individual result of the set shall be more than 0.05 below the specified minimum value.

Where practical difficulties preclude the use of the core-cutter, the sand replacement method described in Annex B2 shall be employed.

In the event of a section of backfill being initially judged unacceptable, the Contractor shall have the right to attempt additional compaction and thereafter to make a repeat set of three tests. If the acceptability criteria are still not met then the section of backfill shall be replaced.

The results shall be recorded on a test sheet that provides the information as shown in the example test sheet in Annex I; copies of each test sheet shall be supplied to the Engineer. The results of the tests shall also be entered on the appropriate trench cross- section of the Route Records.

7 Alternative (non-traditional) backfill materials

7.1 General

The designation ‘alternative (non-traditional) cable surround materials' is intended to apply to cable surround materials other than the selected sand and stabilised backfills specified in Clause 6, although it may apply also to alternative formulations of these traditional backfills.

This Specification is not intended to preclude the use of any material but it shall be demonstrated that the material can meet the requirements in this Specification.

7.2 General requirements

7.2.1 Composition

The composition shall be stated in sufficient detail to uniquely identify it. Where relevant, the source of the material shall be included in the detail. Where the backfill is composed of two or more constituents, the source of each component shall be stated.

The material shall be of consistent composition and shall not contain readily visible foreign matter, organic detritus and shall not contain sharp stones or flints.

Where the backfill material is of a loose granular type nature, the granular size shall be defined by the British Standard sieve size(s) through which not less than 95% by weight of the material shall pass. Where the material is composed of two or more components, which are mixed together to form the backfill, the British Standard sieve size for each component shall be defined.

The backfill material shall be cable of being well mixed during installation to give a substantially homogeneous material and to provide an adequate degree of cohesion and stability to ensure stable support for the cable and environs of the cable installation. Instructions shall be provided on a suitable method(s) to ensure correct mixing of the backfill.

7.2.2 Mechanical strength

The mechanical performance of backfill must be compatible with its intended environment, and must provide structural support and resist settlement, erosion, impact and frost heave.

7.2.3 Thermal characteristics

The material shall, as a minimum, be capable of providing a backfill where thermal resistivity, in the dried out state, does not exceed the value stated on the type test certificate.

In many cable installations contracts, the baseline values of 2.7 Km/W or 1.2°C Km/W will apply. Otherwise, the material will be required to satisfy the thermal resistivity values designated by the Contractor or a value specified in a Contract to enable designated ratings for the cable to be attained.

Confirmation that the material meets the thermal requirements shall be provided for each contract by supply of the results of the type and sample tests specified in this Specification. In addition, the backfill material supplied to site shall be subjected to on-site sample tests, as specified in this Specification.

7.2.4 Compatibility with cables

The composition of the backfill material shall be such as to be without injurious or deleterious effect upon the cable serving both during installation and subsequent operation of the cable throughout its service life.

It shall not be abrasive to the cable sheath and be free of sharp edges that could damage the cable sheath.

7.2.5 Environmental compatibility

The composition of the backfill material shall not constitute a danger to the environment and water courses [2, 3]. It shall not contain hazardous waste material as defined by the EU Waste Framework Directive [N2]. Guidance on interpreting the Directive and classification codes is provided by the Environment Agency [N3, N4, N5].

In exceptional cases, consideration may be given to the use of backfill materials that contain hazardous materials, as defined by the Waste Framework Directive [N2], subject to the agreement of all parties involved. In these cases, instructions on the safe handling, installing and disposal of the material shall be provided by the Contractor and agreed by all parties involved.

7.2.6 Health and safety

The composition of the backfill material shall not constitute a hazard to the health and safety of workers involved in installation [1]. Where risks are identified the Contractor shall provide instructions to enable the risk to be properly managed. The backfill material shall not contain any substance classified as dangerous by the COSHH regulations [N6].

Where there is the possibility of risk to public health and safety during cable installation, e.g. dust clouds from offloading backfill material in vicinity to public areas, then steps shall be taken to prevent exposure of the public to that risk. The measures to be taken shall be agreed between the Engineer and Contractor.

7.3 Type assessment

The material shall meet the requirements of the type assessment tests as specified below. The composition of the material, as defined in Clause 7.2.1, shall be stated on the test report.

The type test acceptance shall apply only to this material and, if relevant, its source and shall not be taken as a generic approval for materials of a similar nature or from an alternative non-approved source. Where agreed between the Engineer and Contractor this restriction may be relaxed and acceptance extended to similar materials or identical materials from alternative sources, on a particular contract.

7.3.1 Procedure

7.3.1.1 General

The Contractor shall be responsible for arranging and managing the type assessment testing. A type test report shall be prepared which includes reference to all tests identified in Table 4 of this Technical Specification.

On successful completion of the tests, the Contractor shall submit copies of the type test report to the Purchaser.

The Purchaser shall confirm acceptance, of the type assessment of the material, on receipt of a satisfactory type test report.

NOTE: This type test assessment procedure ensures that any new backfill material is correctly tested to confirm that it has the requisite properties. The consequences of cable failures in service from use of an unsatisfactory backfill are severe for the Network Owner.

7.3.1.2 Sample size

For type assessment, the sample sizes and sequence of tests given in Table 4 shall be used. The total number of samples required for type assessment is fifteen. Samples used for the testing shall be prepared according to Clause 7.3.2. Twelve samples shall be subjected to the tests in Table 1. This allows three spare samples which permits a repeat test to cover a failure in a test. The number of failed samples tolerated per test is given in Table 4.

Test No.	Test procedure	Clause	Sample size	Number failed samples
1	Thermal resistivity	7.3.3.1	12	0
2	Dry relative density	7.3.3.2	12	0
3	Homogeneity	7.3.3.3	12	0
4	Cohesion	7.3.3.4	12	2

Table 4 – Sequence of tests for type approval

In the event of one failure in tests no. 1 to 3, or three failures in test no. 4, a repeat test may be made using the spare samples up to the maximum of three. If there are no failures in the repeat tests, the type assessment can be accepted subject to the agreement of the Purchaser.

7.3.2 Sample preparation

i. A representative example of backfill material shall be obtained from the source supplier of sufficient volume to carry out steps ii to vi.

ii. Where the backfill material is of a loose granular type nature, the granular size shall be confirmed by demonstrating that the material (or each constituent, if relevant) meet the British Standard sieve size(s) requirements specified in Clause 7.2.1.

iii. Where the backfill is composed of and supplied as two or more constituents, the constituent parts shall be mixed appropriately to provide the stated composition.

iv. Five batches of at least 1 m^3 of backfill material shall be taken from widely spaced positions in the representative example,

v. Three test samples shall be obtained from each batch, each being of sufficient quantity to enable the tests below to be carried out. The samples shall be prepared by the process of quartering (see Clause 2.2.4 of BS 1377-1) unless the make-up does not permit this, e.g. cured or semi-solidified material, where a sample shall be taken from the top, middle and bottom of the batch by a technique agreed with the Purchaser.

vi. Twelve test samples shall be selected and the remaining three retained as spare samples.

7.3.3 Type tests to be carried out

7.3.3.1 Thermal resistivity

The fully dried thermal resistivity characteristic of the backfill material shall be established. The thermal resistivity shall be determined in accordance with BS EN ISO 8990, using either the guarded hot box or calibrated hot box apparatus. Where the calibrated hot box apparatus is used, details of the calibration method shall be supplied.

Measurements of the characteristic shall be made using backfill material taken from the twelve test samples (Clause 7.3.2). Each test piece shall be treated to achieve a dried-out state. The method adopted will be dependent on the backfill category.

- For loose granular type backfills
  Heated for a period sufficient to thoroughly dry the sample;
- For backfills that are cured or semi-solidified
  Heated for a period sufficient to thoroughly dry the sample or, if not possible, until moisture content is < 1%.

For a backfill material which includes trapped moisture as a property; a suitable method of preparation, other than achieving a fully dried state, shall be demonstrated for measuring thermal resistivity and agreed by the Purchaser.

The thermal resistivity shall be measured using a temperature difference across the sample of 80 °C/m unless an alternative temperature differential has been agreed between the Purchaser and Contractor.

NOTE: Retain the measurements of specimen surface temperature taken for the measurements of thermal resistivity (refer to Clause 2.7.1 of BS EN ISO 8990 for information). These are required for assessment of sample homogeneity in Clause 7.3.3.3.

From the results from the twelve measurements of thermal resistivity, the declared value of fully dried thermal resistivity shall be determined as follows.

i. Calculate the Mean value of the twelve readings.
ii. Calculate the Standard Error of the Mean.
iii. Calculate the declared value of fully dried thermal resistivity as.
Mean value + 2.0 x Standard Error of the Mean.

Acceptance criterion: No individual value of the set of fully dried thermal resistivity values shall differ from the Mean value by more than 10%.

NOTE: The acceptance criterion has been adopted to ensure that the level of scatter among the individual readings is low i.e. to ensure uniformity of performance of the backfill. BS EN ISO 8990 states that for homogeneous specimens, accuracy within ± 5% can generally be achieved for measurement of thermal resistivity. Combining this with a requirement that the variability of the thermal resistivity of the backfill should not exceed ± 10%, statistically gives an expected variability of 11% in individual test readings on a set of 12 measurements. This has been rounded down to 10%.

The declared value of fully dried thermal resistivity shall be stated on the type test report.

7.3.3.2 Dry relative density

The dry relative density characteristic of the backfill is used as the means to characterise the dry thermal resistivity of backfill material on-site by routine tests during installation. Therefore, it is necessary to establish a definitive reference value by the type test.

Measurements of the characteristic shall be made using backfill material taken from the twelve test samples (Clause 7.3.2). The method adopted will be dependent on the backfill category.

- For loose granular type backfills
  Method given in Annex A;
- For backfills that are cured or semi-solidified
  Core-cutter method detailed in Annex B1, and Annex G. Where practical difficulties preclude the use of the core-cutter, the sand replacement method described in Annex B2 shall be employed.

From the results from the twelve measurements of thermal resistivity, the declared value of fully dried thermal resistivity shall be determined as follows.

i. Calculate the Mean value of the twelve readings.

ii. Calculate the Standard Error of the Mean.

iii. Calculate the declared value of dry relative density as.
Mean value - 2.0 x Standard Error of the Mean.

Acceptance criterion: No individual value of the set of dry relative density values shall differ from the Mean value by more than 10%.

The declared value of dry relative density shall be stated on the type test report.

7.3.3.3 Homogeneity

The degree of homogeneity shall be assessed using the temperature measurements taken of specimen surface temperature in accordance with Clause 2.7.1 of BS EN ISO 8990, during the twelve measurements of thermal resistivity (Clause 7.3.3.1).

Acceptance criterion: The back fill material shall be classed as homogeneous if the local differences in surface temperature are less than 20% of the mean surface-to-surface temperature difference in each of the twelve tests carried out.

7.3.3.4 Cohesion

Loose granular type backfills are required to demonstrate an adequate level of cohesion in order to ensure stability during and after installation.

Determination of the cohesion shall be made of backfill material taken from the twelve test samples (Clause 7.3.2) using the test apparatus and procedure of Annex C1 and C2.

Acceptance criterion: The material shall be deemed to have met the requirement if ten of twelve samples withstand the application of 4 kg load.

7.4 Sample tests

Before installation is commenced on a particular contract the Contractor shall satisfy the Engineer, by means of the following tests, that the backfill material which is to be used on the Contract meets the requirements of Clauses 7.4.2.1 to 7.4.2.4 below. The results of the measurements of sample tests shall be recorded on a test sheet that provides the information as shown in the example test sheet in Annex J; copies of each test sheet shall be supplied to the Engineer.

7.4.1 Sampling procedure

The sampling procedure is given below.

i. A representative example of backfill material(s) shall be obtained from the source supplier of sufficient volume to carry out steps ii to v.

ii. Where the backfill material is of a loose granular type nature, the granular size shall be confirmed by demonstrating that the material (or each constituent, if relevant) meet the British Standard sieve size(s) requirements specified in Clause 7.2.1.

iii. If relevant, the materials shall be mixed appropriately to provide the composition stated in Clause 7.2.1.

iv. Four batches of at least 1 m^3 of backfill material shall be taken from widely spaced positions in the representative example

v. Three test samples shall be obtained from each batch, each being of sufficient quantity to enable tests on thermal resistivity, dry relative density, homogeneity and cohesion to be carried out. The samples shall be prepared by the process of quartering (see Clause 2.2.4 of BS 1377-1) unless the make-up does not permit this,

e.g. cured or semi-solidified material, where a sample shall be taken from the top, middle and bottom of the batch by a technique agreed with the Engineers.

7.4.2 Sample tests to be carried out

7.4.2.1 Thermal resistivity

The fully dried thermal resistivity characteristic of the backfill material shall be measured using the method described in Clause 7.3.3.1. The mean value of the 3 measurements for each test sample shall be less than or equal to the declared value of fully dried thermal resistivity stated on the type test certificate and no individual value of the set shall differ from the declared value by more than 10%.

7.4.2.2 Dry relative density

The dry relative density of the backfill material shall be measured using the method described in Clause 7.3.3.2. The mean value of the 3 measurements for each test sample shall be not less than the declared value of dry relative density stated on the type test certificate and no individual value of the set shall differ from the declared value by more than 10%.

7.4.2.3 Homogeneity

The homogeneity of the backfill material shall be measured using the method and shall meet the requirements described in Clause 7.3.3.3.

7.4.2.4 Cohesion

The cohesion of a loose granular type backfill material shall be measured using the method and shall meet the requirements described in Clause 7.3.3.4.

7.5 Routine tests

Approval of a backfill material on the basis of sample tests as described in 7.4.2 above does not necessarily imply approval for its unlimited use on a large contract. It will be necessary to establish by means of the routine testing described below that the quality of the backfill material is being maintained.

The frequency of testing shall be such that one set of three tests is made for each 50 m when possible but not exceeding 100 m length of trench in which the backfill is installed, samples being taken at reasonably regular intervals along the cable route or as the Engineer may reasonably require.

The in-situ dry relative density for the backfill shall be determined by the method described in Clause 7.3.3.2. The mean value obtained for any set of three samples shall be not less than 90% of the value of the declared value of fully dried thermal resistivity stated on the type test certificate and no individual result of the set shall differ from the 90% value of the declared value by more than 10%.

In the event of a section of backfill being initially judged unacceptable, the Contractor shall have the right to attempt remedial action, as agreed with the Engineer, and thereafter to make a repeat set of three tests. If the acceptability criteria are still not met then the section of backfill shall be replaced.

The results shall be recorded on a test sheet that provides the information as shown in the example test sheet in Annex K; copies of each test sheet shall be supplied to the Engineer. The results of the tests shall also be entered on the appropriate trench cross-section of the Route Records.

8 On-site procedures

8.1 Preliminaries

Delays can arise when the proposed suppliers of the backfill material do not have the relevant certification and/or test documentation for the materials to satisfy the sample test requirements of this Specification, e.g. it is out-of-date or the materials are to be supplied from a newly developed area of the site. Therefore, in accordance with Clause 8.1.1, the status of the documentation should be checked in advance of starting the cable installation and if sample tests are required, these should be initiated as soon as possible. Where disputes arise over the validity of the certification provided by the supplier, these shall be resolved by agreement between the Contractor, Purchaser and material supplier.

Where the Highways Authority places a restriction on work in a highway regarding the length of an individual trench and/or a time limit on the work, there may be a need to ensure that arrangements are agreed between the Contractor and Engineer to expedite the work, where interaction between the two parties is required, e.g. to move beyond the Hold Points. For example, an arrangement to use electronic notification, exchange of test data and approval for Hold Points between the Contractor and Engineer may be established. Reference should also be made to Annex L for the schedule of Hold Points.

8.1.1 Test documentation

Prior to commencing the contract, the Contractor shall submit to the Engineer or Purchaser the relevant test documentation to demonstrate conformance to the requirements for the type test specified in Clause 7.3.3, where relevant, and the sample tests specified in Clause 6.1.5, Clause 6.2.7, Clause 6.3.5 or Clause 7.4, as relevant, for the backfill to be used on the contract. This is a Hold Point.

8.2 Installation procedures

The overall cable installation shall conform to the installation methods laid down in ENA TS 09-2 [N1]. Where the Contractor or the Purchaser or the Engineer propose changes to the installation practice that do not conform to ENA TS 09-2 [N1] or to existing industry norms, these shall be subject to agreement between the Contractor and the Purchaser during contract discussions or between the Contractor and the Engineer during the installation stage.

The following sub-clauses highlight issues that are relevant to the installation of compacted special backfill and are intended to complement the procedures in ENA TS 09-2 [N1].

8.2.1 Compaction techniques

Adequate compaction of the backfill is essential in order for the special backfill to achieve the specified value thermal resistivity in the fully dried-out and requisite mechanical properties. Hence, quality control of the installation method is necessary and the inclusion of requirements in this Specification for on-site routine tests to be carried out after installing the backfill.

Compaction shall be by hand or vibrating plate compactor. An adequate level of compaction can be achieved by several passages of a compactor or the hand compacting method. The required number of passes to achieve the necessary level of compaction may be based on the installation knowledge and experience of the Contractor.

Experience indicates the necessary compaction level is difficult to achieve for the 'traditional' selected sand and sand/gravel backfills if they are too dry, e.g. < 1% water content. Where such backfills is received on-site in a dry state from the supplier, it is recommended that water is added to achieve a water content of (say) 10%. Tests [1] suggest that at least four passages of the vibrating plate are necessary to achieve the required compaction level at this level of water content.

At this time, experience on the handling and compaction of alternative (non-traditional) backfill materials is too limited to be able to provide guidance. Obtaining this information should form part of the development work for a new backfill material, in order to develop the installation practice.

8.2.2 Trench bedding

The trench depth shall be sufficient to ensure that the required minimum depth of bedding and subsequent cable cover is achieved.

Unless otherwise agreed in the contract or by the Engineer, the base of the trench shall be lined with a bedding layer of special backfill, which shall be compacted to a depth of 75 mm and be installed covering the full width of the trench. This shall apply for both direct buried cables and cables installed in ducts. Compaction shall be by hand or vibrating plate compactor.

NOTE: Where required by the Purchaser, cables having an insulated oversheath shall be subject to oversheath tests as specified in ENA TS 09-2 [N1] Clause 7.18.10 prior to commencing the cable installation, to confirm that the oversheath has not been damaged during transport/unloading.

8.2.3 Blinding of cables

After installation, cables and joints in trenches shall be surrounded by a layer of compacted, special backfill material. After compaction, the layer shall measure, at any point, not less than 100 mm thickness above the topmost cable, cable duct or joint. Compaction generally shall be by hand or vibrating plate compactor. However, all blinding material over and around the cable, cable duct and the joint(s) in joint bays shall be compacted by hand to minimise the risk of damage and to ensure adequate compaction close to and, if relevant, between cables.

Bags filled with backfill shall be used to support cables, joints or ancillary equipment when necessary.

After blinding, the routine tests specified in Clause 6.1.6, Clause 6.2.8, Clause 6.3.6 or Clause 7.5, as relevant, shall be carried out and satisfactory conformance documented by the Contractor and Engineer. This is a Hold Point.

NOTE: Where required by the Purchaser, cables having an insulated oversheath shall be subject to oversheath tests as specified in ENA TS 09-2 [N1] Clause 7.18.10 after blinding, to confirm that the oversheath has not been damaged during pulling in and blinding.

8.2.4 Completion of joints and terminations

Joints and terminations shall be completed in accordance with the manufacturer's instruction and shall be fully supported for their complete length. This support shall have a thermal resistivity of at least equal to that of the bedding and blinding used in the trench.

NOTE: Where required by the Purchaser, cables having an insulated oversheath and where the new cable circuit comprises one or more new cable sections, the new circuit shall be subject to oversheath tests as specified in ENA TS 09-2 [N1] Clause 7.18.10 after jointing of all the new cable sections but prior to being connected to the existing network.

Annex A
(normative)

Determination of dry relative density by soil compaction measurement

A.1 Introduction

The dry relative density of a backfill is not a specific property of the material but is dependent upon the degree of compaction applied. In order to assess the compatibility of a backfill material, which will largely influence the dry density when installed, it is necessary to specify the test procedure to be adopted in the preparation of samples for the determination of dry relative density. It is further necessary to specify a test procedure for the backfill, taking account of the degree of compaction which can reasonably and consistently be achieved in an actual cable installation.

A.2 Test procedure

The dry relative density shall be determined in accordance with the soil compaction test procedure in BS 1377-4 Clause 3.5 but with the following modifications to the test procedure.

i. The material shall not be sieved prior to making the test.

ii. The material under test shall be compacted at a moisture content within the range of moisture contents at which it is to be installed (for selected sand this would normally be (10±2)%.

iii. In compacting the material in the mould each of the three equal layers shall be given nine blows from the rammer dropped from a height of 305 mm above the test sample.

Annex B
(normative)
Routine determination of in-situ dry relative density

B.1 By the core-cutter method

B.1.1 Apparatus

a) Core-cutter - as shown in Figure B1 attached.

b) Open Metal Tray.

c) Scales - to be suitable for weighing up to 150 g with an accuracy of ± l g.

B.1.2 Procedure

The sample shall be taken from the backfill after compaction and smoothing, as specified in Clause 8.2.2 and Clause 8.2.3.

The core-cutter, suitably lubricated, shall be inserted gradually into the backfill at right angles to the surface with a slight motion until the lower surface of the flange is coincident with the surface of the backfill. Lubrication applied to the inner and outer surfaces assists in insertion of the cutter and subsequent sample removal but care must be taken not to contaminate the sample. A suitable method is to lubricate the cutter by wiping it with a cloth containing lubricating oil, e.g. a vegetable or silicon based oil.

The cutter shall be rotated three times and then slowly withdrawn. If the lower surface of the sample is concave it shall be rejected and a new sample taken. In the event of five consecutive samples being taken and rejected due to the concavity of the lower surface, the backfill shall be further compacted before fresh samples are taken. If the lower surface is convex, the surplus material shall be scraped clear by use of a straight edge. Any material adhering to the outer surface of the cutter shall be cleared away.

The complete sample shall be removed from the core-cutter and spread on the open metal tray. The tray shall be heated for a period sufficient to thoroughly dry the sample.

The sample shall then be weighted to an accuracy of ± 1 g.

B.1.3 Assessment

The dry density is given by: W_D/V

Where: W_D = Measured dry weight (g)

V = Volume of sample in core cutter (ml) = 70

B.2 By the sand replacement method

The method to be used shall be that given in Clause 2.1 of BS 1377-9 except that the moisture content determined shall be made in the following manner.

i. From the excavated backfill take a sample of approximately 70 ml spread on an open metal tray and weigh with scales.

ii. Dry the sample and re-weigh in accordance with the procedure specified.

iii. Record the result as 'Moisture Content', i.e. percentage ratio of Weight Loss to Dry Weight.

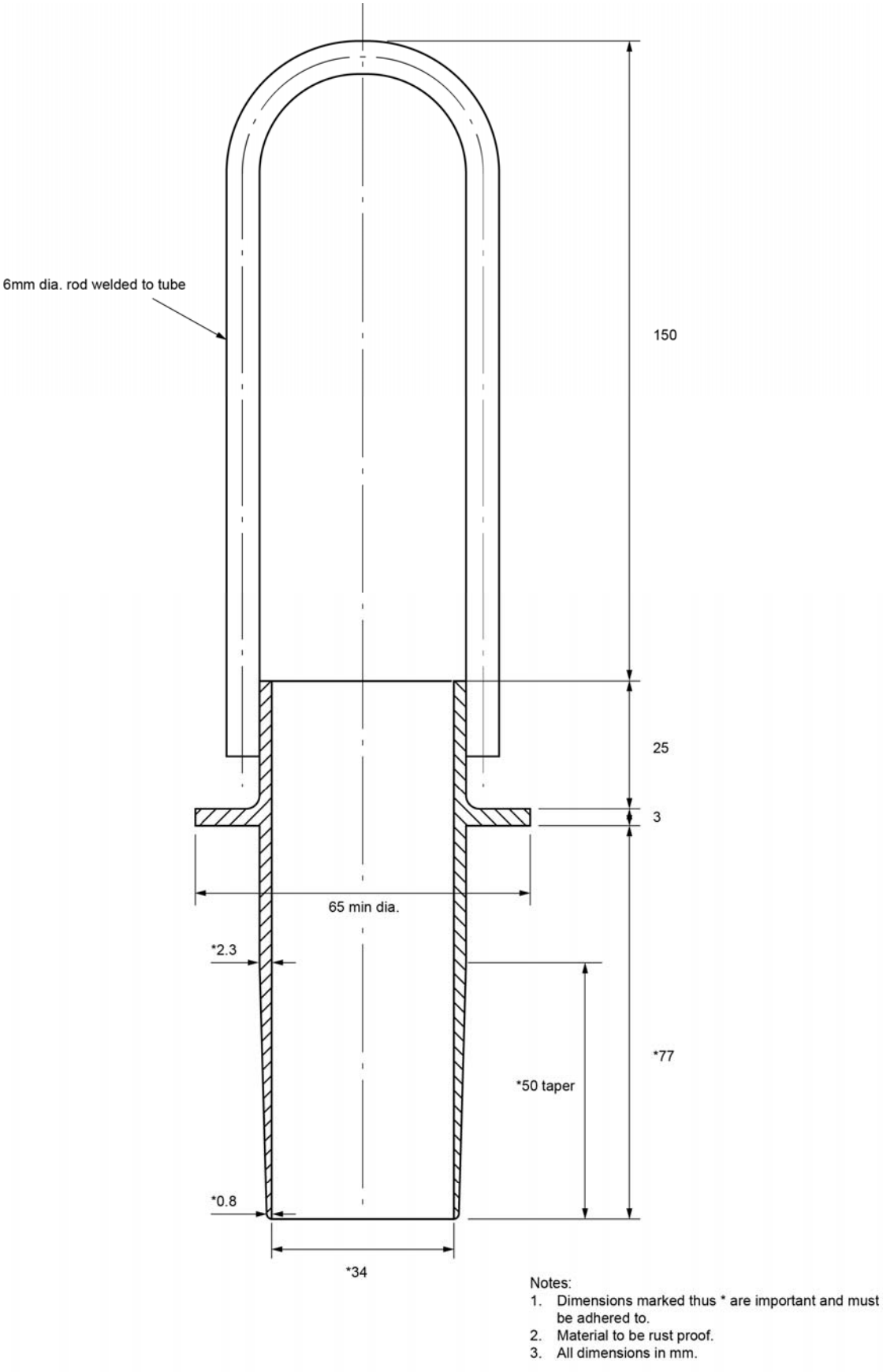


Figure B1 – Core cutter for sampling of backfill

Annex C
(normative)
Determination of cohesion

Cohesion is not readily measured directly, but an acceptable indirect assessment shall be made by the following crushing strength test:

C.1 Apparatus

a) American Foundry men's Society standard sand rammer with two pedestal cups, specimen tube and metal stripping post.

b) A moisture tester with an accuracy of ± 3% or better e.g. GE Protimeter ‘Speedy’ tester or Delta-T devices ThetaProbe.

c) An oven controlled at 105 to 110 °C.

d) A balance readable and accurate to l g.

e) A 4 kg weight. (Diameter not less than 50 mm).

f) A metal tray, approximately 300 mm x 300 mm.

C.2 Procedure

Adjust the moisture content of a sample for testing to (10±2)% with the aid of the moisture tester or other suitable means of measurement.

The quality of sand required for the test is found by trial and is such that the compacted cylinder of sand within the tolerance limits for height as shown on the sand rammer, i.e. 50 mm ±1 mm.

Weigh out a suitable sample and transfer to the specimen tube fitted with a pedestal cup. Compact with three blows of the rammer and carefully remove the compacted cylinder of sand using the metal stripping post and transfer to the metal tray.

Prepare three compacted cylinders of sand and dry these in the oven for 18 hours at 105 to 110 °C.

Remove after 18 hours, allow to cool and carefully place the 4 kg weight on the top of each cylinder of sand in tum and report whether the cylinder withstands the weight.

C.3 Assessment

The material should be deemed to have met the requirement if two of three samples withstand the application of 4 kg load.

Annex D
(normative)
Example test sheet for sample tests on selected sand and gravel/sand backfills

Record of Sample Tests in accordance with EA Technical Specification 97-1 Contract

Contract Reference:

Contractor:

Detail of Special Backfill

Source of Supply* Subcontractor:

County:

Parish:

Name of Quarry:

*These details relate to the sand component of the compounded backfill

Date of Tests:

Batch No.	Sample No.	Dry Relative Density	Cohesion †
1	1		
	2		
	3		
2	1		
	2		
	3		
3	1		
	2		
	3		
4	1		
	2		
	3		

† Indicates ‘Pass’ or ‘Fail’

Signature of Contractors Engineer:

Signature of Purchaser's Representative:

Annex E
(normative)
Example test sheet for routine tests on selected sand and gravel/sand backfills

Record of Routine Tests in accordance with EA Technical Specification 97-1

Contract Reference:

Contractor:

Details of Special Backfill

Source of Supply* Sub-contractor:

County:

Parish:

Name of Quarry:

* These details relate to the sand component of the compounded backfill

Date of Test Routine																			
Location on Route																			
Dry Relative Density †																			
Initials of Contractor's Engineer																			
Initials of Purchaser's Representative																			
Date of Test Routine																			
Location on Route																			
Dry Relative Density †																			
Initials of Contractor's Engineer																			
Initials of Purchaser's Representative																			

† Top half of row to show the individual values of each set of 3 samples.
Bottom half of row to show mean of 3 results.

Annex F
(normative)
Determination of dry relative density by void ratio measurement

The dry relative density of a compounded backfill is not a specific property of the material but is dependent on the degree of compaction applied. In order to assess the compactibility of a backfill material, which largely influence the dry density when installed, it is necessary to specify the test procedure to be adopted in the preparation of samples for the determination of dry relative density.

Because of the difference between hand-mixed samples and bulk supplies it is preferable in a sample test to assess the compactibility of cement-bound sand backfill by measuring, in the manner described below, the void ratio of the sand/fine aggregate which forms the basis of the backfill.

F.1 Apparatus

100 millilitre measuring glass

Burette

Distilled water

F.2 Procedure

Fill the measuring glass with 50 millilitres of distilled water using the burette. Add approximately 60 millilitres of dry sand/fine aggregate.

Cork the glass and shake it rapidly with small amplitude until no change in the bulk volume of the sand suspension is apparent.

Allow the contents to settle and then take the following measurements:

a = volume of saturated sand/fine aggregate

b = volume of saturated sand/fine aggregate plus water

c = volume of water above the sand/fine aggregate

F.3 Assessment

Calculate the void ratio as follows:

$$\text{Void ratio} = \frac{\text{volume of voids}}{\text{volume of solids}}$$

$$\text{Volume of voids} = 50 - c$$
$$= 50 - (b - a)$$
$$= a + (b - 50)$$

$$\text{Volume of solids} = a - (a + (b - 50))$$
$$= b - 50$$

$$\text{Void ratio} = \frac{a + (b - 50)}{(b - 50)}$$

(The void ratio shall not exceed the value given6.3.3).

Annex G
(normative)
Determination of in-situ dry cured relative density

G.1 General

The Apparatus and Procedure for this test shall be as given in Annex B1. The assessment of the dry cured relative density shall be as given below.

G.2 Assessment of dry cured relative density

The dry cured relative density shall be calculated from the following formula:

$$\text{Dry cured relative density}^* = W_D \frac{1 + \frac{0.25}{1 + A}}{V}$$

where: W_D = Dry uncured weight (g)

A = Proportion of sand by weight to that of cement in the mix

V = Volume of wet sample in core cutter (ml) = 70

* In deriving the dry cured relative density the term $1 + \frac{0.25}{1 + A}$ is introduced to make allowance for moisture lost by rapid drying which would otherwise become chemically combined if normal curing occurred.

Annex H
(normative)
Example test sheet for sample tests on sand to be used in cement-bound sand backfill

Record of Sample Tests in accordance with EA Technical Specification 97-1 Contract

Contractor reference:

Contractor:

Detail of sand/fine aggregate used in Backfill

Source of Supply* Subcontractor:

County:

Parish:

Name of Quarry:

*These details relate to the sand/ fine aggregate component of the cement-bound sand backfill

Date of Tests:

1.	2	3	4	5	6
Batch No.	**Sample No.**	**Particle size distribution †**	**Volume of Solids b - 50**	**Volume of Voids a - (b - 50)**	**Void Ratio Col. 5 / Col.4**
1	1				
	2				
	3				
2	1				
	2				
	3				
3	1				
	2				
	3				
4	1				
	2				
	3				

Signature of Contractors Engineer:

Signature of Purchaser's Representative:

† Indicates ‘Pass’ or ‘Fail’

Annex I
(normative)
Example test sheet for routine tests on sand to be used in cement-bound sand backfill

Record of Routine Tests in accordance with EA Technical Specification 97-1

Contract Reference:

Contractor:

Details of Cement-bound Sand

Description (i.e. proportions of sand, cement and water)

Source of Supply* Sub-contractor:

County:

Parish:

Name of Quarry:

* These details relate to the sand component of the compounded backfill

Dry cured relative density $= WD \frac{1+\frac{0.25}{1+A}}{V}$

V =

A =

Date of Test Routine					
Location on Route					
Dry Cured Relative Density †					
Initials of Contractor's Engineer					
Initials of Purchaser's Representative					
Date of Test					
Location on Route					
Dry Relative Density †					
Initials of Contractor's Engineer					
Initials of Purchaser's Representative					

† Top half of row to show the individual values of each set of 3 samples.
Bottom half of row to show mean of 3 results.

Annex J
(normative)
Example test sheet for sample tests on non-traditional backfills

Record of Sample Tests in accordance with EA Technical Specification 97-1 Contract

Contractor reference:

Contractor:

Detail of Backfill

Description:

Source of Supply:

Type test values

Fully dried thermal resistivity:

Dry (cured) relative density:

Date of Tests:

Batch No.	Sample No.	Thermal Resistivity			Relative Density			Homogeneity†	Cohesion†
		Value	Mean	†	Value	Mean	†		
1	1								
	2								
	3								
2	1								
	2								
	3								
3	1								
	2								
	3								
4	1								
	2								
	3								

† Indicate ‘Pass’ or ‘Fail’

Signature of Contractors Engineer:

Signature of Purchaser's Representative:

Annex K
(normative)
Example test sheet for routine tests on non-traditional backfills

Record of Routine Tests in accordance with EA Technical Specification 97-1 Contract Reference: Contractor:					
Detail of Backfill Description: Source of Supply: Type test values Dry (cured) relative density:					
Date of Routine test					
Location on Route					
Dry Relative Density †					
Initials of Contractor's Engineer					
Initials of Purchaser's Representative					
Date of Routine test					
Location on Route					
Dry Relative Density †					
Initials of Contractor's Engineer					
Initials of Purchaser's Representative					

† Top row to show the individual values of each set of 3 samples
Middle row to show mean of 3 results
Bottom row too show ‘Pass’ or ‘Fail’

Annex L
(informative)
Schedule of Hold Points

Clause Reference	Hold Points
8.1.1 Test documentation	Prior to commencing the contract, submission of the relevant test documentation to demonstrate conformance to type assessment tests (if relevant) and sample tests for the backfill to be used on the contract.
8.2.3 Blinding of cables	Conformance to the routine test requirements on the installed backfill after blinding.

Bibliography

Legislation

[1] The Management of Health and Safety at Work Regulations 1999

[2] Environmental Protection Act, 1990

[3] Water Resources Act, 1991

Other publications

[4] Burceanu & Van Der Boerght "*Study of thermal backfill materials for directly buried HV cables*" 9th International Conference on Insulated Power Cables, Versailles, 2015

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