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Zemeljska dela - 5. del: Kontrola kakovosti

Earthworks - Part 5: Quality control

Erdarbeiten - Teil 5: Qualitätskontrolle und Überwachung

Terrassement - Partie 5: Contrôle qualité et surveillance

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European foreword

This document (EN 16907-5:2018) has been prepared by Technical Committee CEN/TC 396 "Earthworks", the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2019, and conflicting national standards shall be withdrawn at the latest by June 2019.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document is one of the European Standards within the framework series of EN 16907 on *Earthworks*, as follows:

— *Part 1: Principles and general rules;*

— *Part 2: Classification of materials;*

— *Part 3: Construction procedures;*

— *Part 4: Soil treatment with lime and/or hydraulic binders;*

— *Part 5: Quality control* (this document);

— *Part 6: Land reclamation earthworks using dredged hydraulic fill;*

— *Part 7: Hydraulic placement of extractive waste.*

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1 Scope

This European Standard provides recommendations and guidance on the quality assurance and quality control of earthworks construction forming part of general civil engineering and building works. It provides guidance on the techniques to be used to give clients, contractors and designers confidence that the earthworks have been constructed in accordance with their requirements.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

EN 1997-1:2004, *Eurocode 7: Geotechnical design - Part 1: General rules*

EN 16907-1, *Earthworks - Part 1: Principles and general rules*

EN 16907-2, *Earthworks - Part 2: Classification of materials*

EN 16907-3, *Earthworks - Part 3: Construction procedures*

EN 16907-4, *Earthworks - Part 4: Soil treatment with lime and/or hydraulic binders*

EN 16907-6, *Earthworks - Part 6: Land reclamation earthworks using dredged hydraulic fill*

CEN/TS 17006, *Earthworks - Continuous Compaction Control (CCC)*

EN ISO 18674 (all parts), *Geotechnical investigation and testing – Geotechnical monitoring by field instrumentation*

EN ISO 22476-1, *Geotechnical investigation and testing - Field testing - Part 1: Electrical cone and piezocone penetration test (ISO 22476-1)*

EN ISO 22476-2, *Geotechnical investigation and testing - Field testing - Part 2: Dynamic probing (ISO 22476-2)*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

Note See also Clause 3 in EN 16907-1:2018 for general terms and definitions for use in earthworks.

3.1
quality assurance
all those planned and systematic actions necessary to provide confidence that the earth-structure will perform satisfactorily in service i.e. that it has been constructed to the specified requirements

3.2
quality control
system used to monitor, assess and adjust construction/execution processes to ensure that the final product will meet the specified level of quality

4 Quality Assurance Programme

Quality Assurance [QA] refers to the overall system for assuring project quality with Quality Control [QC] being one element of a comprehensive Quality Assurance programme.

A comprehensive construction QA programme consists of the following core elements:

i) Quality Control: See Definition in 3.2;

ii) acceptance: All factors [i.e. sampling, testing and inspection] to evaluate the degree of compliance with contract requirements;

iii) resolution of non-conformances: A process for resolution of non-conformances should be unbiased and timely. To address disputes related to testing, use of retained samples used in the acceptance decision, alternate or third party laboratories, and a well-defined decision process to determine the outcome of the dispute are advisable.

NOTE An independent quality assurance may be required – i.e. an unbiased and independent evaluation of all the sampling and testing procedures used in the acceptance programme.

5 Quality Control Plan

A Quality Control Plan for earthworks shall as a minimum include:

1) sampling and test procedures, including:
   - test locations;
   - frequency of testing;
   - test methods and standards to be adopted;
   - extent of data to be collected and storage requirements thereafter;
   - methods and criteria for acceptance;
2) an organization chart identifying all relevant personnel and key tasks; in particular who is responsible for quality overall and for individual elements such as testing;
3) procedures for reviewing samples, certificates etc.;
4) visual observations and inspections;
5) document control procedures;
6) procedures for recording non-conformance and what corrective actions are to be undertaken.

A plan should take cognisance of the risk of non-compliance and the potential effects of any consequential structural failure if such non-compliance is either not identified or not corrected having been identified.

Information should be collected for each non-conformance and prompt action taken to identify the reasons behind such an event and to identify appropriate corrective action(s) to prevent a recurrence.

All works specified for the project should be checked, tested and monitored as appropriate with records being fully documented and maintained throughout the construction period and afterwards if required.

6 Material checking

Prior to any bulk earthworks being undertaken, materials characterization should be carried out in accordance with EN 16907-2 to ensure that the design assumptions are still valid and the excavation, transportation and compaction requirements in the contract documents/specification are appropriate.

Compliance sampling and testing should be carried out at the point of excavation for on-site materials unless the character of the material is likely to change between excavation and deposition, in which case further sampling and testing should be carried out at deposition.

Imported materials should be sampled and tested for compliance at the point of deposition where practical and may also be tested at source, especially for initial approval.

All material testing shall be carried out in accordance with the test procedures agreed in the Quality Control plan.

Where specified in the contract, the results of the classification testing shall be submitted for review/approval prior to the start of filling.

Testing and recording of materials should be continuously reviewed as excavation and filling progresses. Test results should be made available before permanent deposition and compaction, as far as is practicable.

Additional chemical testing may be required when manufactured or recycled materials are incorporated within the earthworks.

Guidance on the appropriate testing for stabilized soils can be found in EN 16907-4.

Further information on a number of the common tests used across Europe can be found in EN 1997-2:2007, Clause 5 and associated Annexes and in EN 16907-2.

Routine chemical testing in earthworks is usually limited to organic content, carbonate content, sulfur and sulfate content, pH value and chloride content and further information is found in EN 1997-2:2007 Subclause 5.6.

7 Approaches to Compaction Control

7.1 General

Two main approaches of specifying compaction exist across Europe, which are Method specification and End product specification, as described below and in EN 16907-3 and as summarized in EN 16907-1.

Land reclamation by dredged hydraulic fill shall be specified by end product specifications.

NOTE This clause gives a brief summary of each specification approach and provides recommendations for aspects that are specifically relevant to Quality Control.

7.2 Method Specification

Method Specifications require the production and placement of earthworks using specified materials, specific types of equipment and methods stated in the contract.

If a method specification is used, acceptance shall be controlled by one or a combination of the following:

— checking visually and manually recording the conformity of the execution with the method specifications (i.e. number of passes, layer thickness, acceptability of fill material, type and weight of compactor, speed of compactor, and frequency of vibration (where required));

— checking and recording the compacted volume (Q) and the total compacted surface covered by the compactor to compact that volume (S, controlled by a tachograph) – see Q/S method in Annex B;

— checking and recording the number of compacted passes, layer thickness and speed of compactor using a compactor equipped with full Global Navigation Satellite System recording and documentation systems (see CEN/TS 17006).

It is beneficial to construct a trial embankment at an early stage in the earthworks to demonstrate that with the proposed materials, methods and equipment the specified criteria (if any) can be achieved. The trial embankment should also be used to validate the effectiveness of the proposed recording regime specifically and quality control procedures generally and refinements made where necessary.

NOTE Method Specifications have been used for many years both with or without selected checking in a number of countries and the practice is well developed and understood. They are based on extensive research and practice into compaction methods and soils.

7.3 End product Specification

End product Specifications require earthworks to be constructed to achieve specified engineering criteria. In this form of specification the earthworks practitioner responsible for construction has responsibility and latitude in determining the materials, procedures and equipment used to produce the product.

NOTE The Quality Control sampling and testing requirements often depend on the form of contract. Commonly a minimum level of testing will be set. In some cases the Quality Control testing regime is at the discretion of the earthworks practitioner responsible for construction and acceptance is based on sampling and testing of the final in-place product. Normally in end product specification the compliance testing is undertaken as the embankment is constructed (e.g. on each layer of placed fill).

It is beneficial to construct a trial embankment at an early stage in the earthworks to demonstrate that the proposed materials, methods and equipment are capable of achieving the specified criteria, prior to implementation of the routine rate of testing in the Quality Assurance system.

Compliance can be demonstrated by various means, including *in situ* density testing, plate load testing, or Continuous Compaction Control, all of which should be supported by contemporary records maintained by the earthworks practitioner responsible for construction to provide evidence that the specified requirement(s) have been achieved in each layer of the embankment. The type and extent of the contemporary records and the responsibility for their production should be an integral part of the Quality Control Plan.

See also 12.2 in EN 16907-1:2018.

8 Compliance testing

8.1 General

Fill should be inspected and/or tested to ensure that the material, compaction procedures and procedures of construction comply with the specification (see EN 1997-1:2004, 5.3.4).

The selection of material properties should consider the feasibility of performing compliance testing relative to the selected acceptability criteria and the constraints imposed by the contract and construction operations.

It is important to understand that earthworks testing needs to produce rapid results in order that construction/execution is not delayed. On the majority of civil engineering projects, the rate of earthworks construction is a critical activity. Related to this is the need for rapid turnaround of the results from the compliance testing as any delays will increase the volume of material placed and compacted for which compliance is unproven. When assessing the appropriate form of compliance testing the earthworks practitioner should be aware of these testing limitations.

Where appropriate, relationship testing should be used to determine the correlation between the results of compliance tests that will be used to control the earthworks and the fundamental soil properties upon which the earthworks design is based. Such testing should be carried out in advance of the main earthworks programme. See also 6.3.5 in EN 16907-1:2018.

Compliance testing at the point of deposition generally falls into two main classes i.e.:

— tests for *in situ* density;

— stiffness and bearing capacity tests.

8.2 *In situ* density testing

In situ density testing may be required for the compacted fill to ensure that the specification requirements have been achieved. The density testing can be carried out using one of the methods set out below:

— nuclear density testing;

— sand replacement;

— core cutter;

— rubber balloon;

— liquid replacement;

— gypsum replacement.

In situ density testing should be undertaken and the results obtained should be assessed against an appropriate reference percentage of the maximum dry density derived from laboratory compaction testing or by another method. The *in situ* test results obtained during earthworks compaction should exceed this reference value. For fills with a significant fines content, both *in situ* density and water content should be determined at the time of placement to confirm that the air voids content in the compacted fill is acceptable – see 6.3 in EN 16907-1:2018.

There are a number of issues associated with the common/traditional *in situ* density tests i.e.;

— it is time consuming to conduct a sufficient number of tests for a statistical analysis of the compaction test results;

— oversize particles need to be accounted for;

— determination of water content may take time which may delay works;

— accurate determination of the volume of the excavated material needs to be done.

Nuclear density testing is proven for bulk density measurements but not for water content measurement; dry density should be calculated or calibrated from the water content obtained in the laboratory from a soil sample taken at the testing location.

Nuclear methods have one main advantage over traditional techniques i.e. tests can be conducted rapidly and results can be obtained in minutes. However they need to be calibrated correctly and appropriate health and safety precautions need to be adopted. Also, in a similar way to other *in situ* density tests, they are not appropriate for materials with oversize particles or for heterogeneous materials. Nuclear density testing relies on penetration of radiation rays through the compacted fill between a radiation source and a receiver. This can provide fast results for dry density although a separate measurement of the water content is to be recommended. For *in situ* density testing of compacted fills, nuclear density testing should be carried out using the direct transmission method.

8.3 Stiffness and bearing capacity testing

8.3.1 General

Stiffness and bearing capacity tests can generally be divided into three main types i.e.;

— plate loading tests;

— deflectometer tests;

— penetration tests;

8.3.2 Plate loading tests

A plate loading test is the loading of a stiff circular plate to determine the deformation modulus from the measured vertical displacement of the plate under the load.

The common tests are:

— static plate;

— dynamic plate, which enables faster measurement of the dynamic deformation modulus on site;

— zone loading test: This is a variation on the static test which embraces a significantly larger rectangular area and tends to be restricted to larger projects or where hydraulic fill has been placed (see EN 16907-6).

NOTE 1 Plate loading tests are widely used across Europe and the majority of countries have developed their own standards, with widely varying specifications (plate diameter, loads and loading procedure, method of determination of modulus, etc.). This can lead to considerable differences in the resulting modulus which is obtained. As well as being used for measurement of subgrade stiffness in both embankments and cuttings they are also used in several countries to check the quality of fill as the material is being placed.

When using plate loading tests to check the compaction quality of a fill the ratio of the modulus of deformation for the first loading cycle to the modulus of deformation for the second loading cycle is often used. The ratio of the moduli in most cases should not exceed an appropriate value but it should be noted that practice varies across Europe with respect to evaluation.

NOTE 2 A range of national standards for dynamic plate loading testing, e.g., Lightweight Deflectometers (LWD) as well as some heavier dynamic plate loading tests have been developed in Europe. As with static plate load tests, there are several variations on the equipment and test methodology.