SLOVENSKI STANDARD
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Zemeljska dela - 3. del: Postopki izvajanja zemeljskih del

Earthworks - Part 3: Construction procedures

Erdarbeiten - Teil 3: Ausführung von Erdarbeiten

Terrassement - Partie 3 : Procédés de construction

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Earthworks - Part 3: Construction procedures

Terrassement - Partie 3 : Procédés de construction

Erdarbeiten - Teil 3: Ausführung von Erdarbeiten

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European foreword

This document (EN 16907-3:2018) 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of an identical text or by endorsement, at the latest by June 2019, and conflicting national standards shall be withdrawn at the latest by June 2019.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* (this document)*;*

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

— *Part 5: Quality control;*

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

— *Part 7: Hydraulic placement of waste.*

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1 Scope

This European Standard provides execution procedures for excavating, transporting and placing soils and rocks for the construction of earth-structures and guidance for the work. Additionally, it includes excavation and placement of rock materials underwater.

Dredging of soils and the associated hydraulic placement of fills are covered by EN 16907-6 and EN 16907-7.

Execution of earthworks follows the conclusions of the earthworks design and optimization phase (EN 16907-1), which should anticipate soil and rock specificities and their suitability. In case some events could not be foreseen, additional design is performed during the execution of works.

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

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

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

3 Terms and definitions

For the purposes of this document, the terms, definitions and symbols given in EN 16907-1 and the following 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

3.1
trafficability
ability of a material surface to support the passage of earthworks

3.2
compaction
process of removing air from a soil normally by mechanical means

3.3
compactive effort
energy applied to achieve compaction

3.4
over compaction
condition that arises during compaction when sufficient air has been expelled from a fill such that further compactive effort results in elevated pore water pressures causing the fill surface to become unstable as the material "mattresses"

Note 1 to entry: Over compaction of granular soils can also result in the crushing of individual particles thereby modifying the particle size distribution.

3.5
density index
density state of a granular soil (natural or compacted) determined by comparing its void ratio (e) with the minimum (e_{min}) and maximum (e_{max}) attainable for the particular material

Note 1 to entry: The minimum and maximum void ratios correspond to the densest state (I_D = 100 %) and loosest state (I_D = 0 %) respectively (=[e_{max} − e/ e_{max} - e_{min}] × 100 %).

3.6
fine soil
soil with at least 15 % fines content, depending on national practices

3.7
fine active soil
water-sensitive fine soil which exhibits specific shrinking/swelling properties to be taken into consideration for earthworks

4 General considerations

4.1 Prerequisites to execution of earthworks

Before the beginning of construction, all geotechnical design issues should be solved, including temporary and permanent stability, erosion and settlements. All unresolved issues during design shall be identified to all parties and highlighted before the commencement of construction. In this case, the responsibility for closing out shall be made clear.

Before the commencement of each part of works, the design of each part of the earthworks shall have been completed, including the assessment of the available materials and their suitability (see EN 16907-1 and EN 16907-2).

4.2 Climatic conditions

Before commencing earthworks, the prevailing climatic conditions at the construction site shall be considered. Seasonal climatic variations can impose limiting factors on earthworks.

During periods of rainfall, consideration should be given to suspending earthworks operations in wet sensitive materials. When necessary, the earth surfaces should be sealed to prevent the ingress of water.

In dry climatic conditions, consideration should be given to preventing evaporative losses by covering the exposed earth surfaces with non-sensitive materials.

NOTE Seasonal climatic considerations will vary depending on different regions. For example, a frozen ground surface may provide a temporary working platform that can enhance the excavation of soft soil.

4.3 Environmental factors

All earthworks should comply with the relevant environmental legislation.

Earthworks have the potential to harm the natural and built environment and therefore they should be planned in such a manner so as to minimize the potential for harm.

The environmental factors to be considered during earthworks construction commonly include the following:

Noise – European and national regulations should be considered. It is applying for receptors, e.g. domestic dwellings which are affected by the increase of noise beyond legal limits. Assessments should be made of the noise emissions of the various types of earthwork machinery and background noise level readings taken prior to commencement of the earthwork operations.

Consideration should be given to restricted working hours and to the construction of temporary noise barriers utilizing earth bunds or fencing.

Contamination – if there are areas of contamination within an excavation, the activities should be controlled so as to prevent further contamination of the surrounding soil. Contaminated materials should be handled separately and if they are to be stockpiled, the surface upon which they are to be placed should be sealed and shaped to prevent the potential run-off of contaminated water. The potential effect on workers should also be considered and appropriate protective equipment provided.

Appropriate equipment should be selected, to deal with the contaminated material.

Dust – Earthwork operations have the potential to cause dust, particularly in fine graded soils in dry weather conditions.

Dust should be controlled by spraying water onto the exposed surfaces. The potential for dust generation is limited if the exposed surfaces are covered with topsoil and seeded as works progress.

Water courses protection – The most likely cause of pollution from earthworks is the siltation of surface water by uncontrolled silt laden run-off. Consideration shall therefore be given when planning the earthwork operation to the proposed dewatering system. Control measures can include the establishment of settlement ponds and the use of silt fences.

Vibration shall be considered especially sensitivity of existing structures, or building or utilities to vibrations and sound shock waves.

Normal earthwork operations are unlikely to cause harmful vibration levels, however blasting operations can cause considerable vibration and therefore have the potential to damage either the works or adjoining properties. In cases where vibration caused by blasting is likely to cause damage, blasting should be prohibited and replaced by ripping and/or hydraulic breaking.

4.4 Use of secondary manufactured materials and recycled materials

For reasons of economy and environmental sustainability, the Earthworks Practitioner should consider the use of recycled materials and industrial by-products. These will typically include demolition arisings (crushed concrete, etc.) and industrial by-products such as pulverized fuel ash, burnt colliery shale, biomass ashes, slag, foundry sand and cement kiln dust, as well as quarrying processing by-products.

The use of by-products and recycled materials presents special considerations for the Earthworks Practitioner. These considerations fall into two principle categories: legislative and geotechnical.

Legislative considerations concern the environmental and waste licensing legislation that governs the use of such recycled materials and by-products. In order to prevent environmental harm, strict national legislative controls are normally applied to the use of such products. It should be noted that such materials are often considered as a “waste” and legislation governing such materials is often complex. The use of such materials should be carefully evaluated because of their potential to cause environmental harm during both the construction phase and the operation phase of the earthwork. Such harm is often associated with the creation of airborne pollution by dust and ground/surface water pollution by leachate.

Geotechnical concerns relate to the unique characteristics of the recycled material and secondary manufactured products. These materials will often behave in a different manner to natural materials and due consideration shall be taken of this in their specification and use. Particular consideration should be given to the long-term durability of the materials in both the physical and chemical context as, particularly in the case of industrial secondary manufactured products, they may be susceptible to gradual chemical deterioration which can lead to failure of the earthwork. Testing regimes should be established to identify the nature of the material and to validate its consistency during use.

Processing by way of sizing or blending/mixing with other by-products or natural materials is often a means to achieve an environmentally and geotechnically suitable material. These activities should be subject to the same controls and considerations described above.

5 Excavation

5.1 General

Excavation for earthworks is the process of forming cuttings or other excavations, normally by mechanical means, and includes the loading of the excavated material into transportation equipment. Excavation and loading is an integrated process. This section identifies the key considerations relating to excavation (and loading).

The aim of the excavation process is to create the designed excavated earthworks profile. In so doing, the excavation should be planned not only to ensure that the excavated materials are maintained/protected during their excavation such that they are suitable for their intended use, but also to ensure that the excavation can be carried out safely and efficiently while ensuring that the excavation formation level/subgrade and the surrounding ground are undamaged by the excavation process.

Excavation should not commence until the area to be filled is suitable for accepting material or that an appropriate temporary stockpile area is available.

For colder climates, if the material in the cutting is sensitive to frost heave and if the frost will penetrate more than 0,5 m in the material in the final profil, boulders should be removed.

5.2 Material type and excavation techniques

The type and nature of the material to be excavated is the most important consideration for the excavation process. The group of material (see informative Annex B) will determine the manner and the rate of excavation. It is therefore of fundamental importance to identify the material types to be excavated prior to the commencement of excavation.

If an excavation contains mixed materials, consideration should be given to the need to separate the different grades during excavation or to mix them (e.g.: Frontal excavation).

Table 1 identifies the main material types (described in Annex B) and their appropriate methods of mechanical excavation.

Table 1 — Material types

Material type	Possible excavation method	Possible pre-processing
Fine graded (all states)	Backacter excavator Face shovel excavator Wheeled front loader Tracked front loader Push-loaded scraper	Wet soils may require treatment with binder to permit scraper excavation.
Granular (all grades)	Backacter excavator Face shovel excavator Wheeled front loader Tracked front loader Push-loaded scraper	None Dewatering may be necessary to permit excavation or to assist drying of materials.
Rock – Weak	Backacter excavator Face shovel excavator Wheeled front loader Tracked front loader Push-loaded scraper	Scraper excavation will normally require ripping or blasting. Ripping or loosening by blasting will also aid other excavation methods.
Rock – Strong	Backacter excavator Face shovel excavator Wheeled front loader	Blasting with explosives and/or breaking with hydraulic hammers. For some strong rocks heavy ripping can be considered.
Chalk	Backacter excavator Face shovel excavator Wheeled front loader Tracked front loader Push-loaded scraper	The use of scrapers on some types of chalk may lead to disaggregation and instability of the material possibly necessitating the use of treatment with binder. If the need for the possible use of binders is to be avoided other means of excavation should be considered. For hard chalk ripping can be necessary.

The excavation methods (machine types) listed in the preceding table are described in Annex C.

Large excavators have a high break out force and can avoid blasting.

Specialist excavation equipment such as long reach/low ground pressure excavators or draglines are often required for excavations in very poor soils or soils containing organic material. The former also have benefits in undertaking excavations in areas of difficult access, and in ground conditions imposing limitations regarding stability.

It is possible to treat the excavated materials (e.g. with lime) during the excavation process (see Annex J of EN 16907-4:2018).

5.3 Special considerations when excavating in rock

Excavation in rock places special demands on the earthworks, which do not exist when excavating in soil.

Predicting the ease of excavation of rock and rock masses is very important in earthworks. In order to describe the excavation of rocks, different terms have been used, related to the principle of excavation and the mechanics of fracture. In this document, the term excavatability is used as a broad term that refers to the ease of excavation of rock and rock masses and includes the following methods:

a) digging, when easy/very easy excavation conditions exist (soil or loose rocks);

b) ripping, for moderate to difficult excavation conditions, (weak rocks, and weathered part of strong rocks);

c) blasting for very difficult excavation conditions (strong rocks).

The assessments to determine the ease or difficulty with which a rock mass may be excavated are based upon the consideration of:

d) the rock materials forming the rock blocks within the *in situ* rock mass (because excavation entails fragmentation and rupture of the rock materials when the block volume is large);

e) the nature, extent and orientation of the fractures;

f) the geological structure with respect to folding and faulting and schistosity.

Indirect assessment of these parameters can be based upon:

— rock description (see EN 16907-2);

— seismic velocity of P-wave and nature of the rock;

— discontinuity spacing index and point load test;

— geological strength index.

NOTE Examples of such indirect methods can be found in Caterpillar tables (ref), Pettifer and Fookes, Quarterly Journal of Engineering Geology, 27, 145–164; Bull eng Geol Environ (2010) 69:13–27 – Excavatability assessment of rock masses using the Geological Strength Index.

In addition, the following information could be relevant:

— relevant parameters on rock hardness, fractures, faulting and folding (direct or indirect);

— information on the weathering, karstification, hydrogeology.

In order to choose the appropriate method of excavation, the following information should be made available:

— assessed geology of the rock mass;

— performed boreholes with logs, lab testing and photos;

— all constraints on existing structures, buildings, utilities, ... which could influence the choice of the method of excavation.

If blasting is anticipated, then additional information should be gathered:

— presence of water if any;

— sensitivity of existing structures, or building or utilities to vibrations and sound shock waves;

— for adjacent sensitive soil: restrictions regarding vibrations and direct impact from blasting.

In addition, the following information could be relevant:

— maximum particular speed for each range of frequency;

— results of trial blasting, if any;

— anticipated variation of the top of the rock mass to be blasted;

— maximum size of blocks allowed in fill or other specifications on the grading curve;

— environmental and neighbourhood sensitivity.

5.4 Influence of excavated material end use

The proposed use of the excavated material will influence the excavation method. Materials which are to be used in a structural fill area (e.g. embankment or platform) will need to be excavated in such a manner to optimize the reuse while ensuring that their quality is not deteriorated and they do not become unsuitable for compaction in the fill area.

Materials which are sensitive to behavioural changes during the earthworks process (excavate, "load", transport, deposit and compact) should be excavated in such a manner to ensure that their properties are maintained during handling.

Care will be required to identify a method that will achieve effective and consistent mixing with regards to the type and distribution of material.

NOTE On the other hand, materials which are to be placed in non-structural fills (e.g. landscape areas or disposed of offsite) do not have to be excavated in such a manner so as to maintain their quality.

Normally, material types required to be deposited separately should be excavated separately. However, it is sometimes beneficial to deliberately mix varying grades of material as part of the excavation process to improve material quality and therefore render material acceptable which would otherwise be unacceptable or optimize the characteristics of acceptable material.

5.5 Protection of cuts during construction

5.5.1 Stability during construction

It is important that the determination of the face height and inclination shall focus on the consideration of the actual ground conditions for each excavation.

Temporary slopes created as the excavation of the cutting progresses should not be steeper than the permanent design slope unless stability implications are assessed. Excavation faces created by backacter/face shovel/loader excavation are normally vertical and should therefore not be left for long periods. If excavation is not to be a continuous process, the vertical excavation faces should be cut to a safe slope to prevent collapse until excavation recommences. In any event, vertical excavation faces should not normally exceed 5m in height for soils and at all times should be protected along the top edge by temporary fencing or earth bunds.

The bench height should be considered for each excavation and may exceed 5 m in some rock excavations.

NOTE Vertical or steep faces may be strictly limited in clays, where height limitations of 2 m or 3 m are quite common.

The excavation shall not extend beyond the designed profile. If excavation inadvertently exceeds the designed profile, the design shall be reviewed. If the resultant void requires filling, this shall be carried out as if it were an earthworks embankment with material of adequate engineering properties. Where trenches (for drainage and the like) are to be excavated at the base of slopes, these should be excavated in such a manner so as not to undermine the adjacent slope. They should be backfilled/reinstated as soon as possible.

Consideration should be given to the need to monitor the stability of excavations or adjacent structures.

5.5.2 Water control/drainage

Excavations should be planned to prevent the materials to be excavated from deterioration or the final formation from being damaged by water. Water will arise from two sources: ground-water where the excavation extends below water table and rainwater ("surface water"). In some cases groundwater will be encountered above water table level where lenses of water-bearing soils occur within otherwise non-water bearing soils. This is commonly described as "perched water". Care must be taken about artesian aquifer which is a confined aquifer containing groundwater under positive pressure. If water is not controlled in the excavation, it can damage or erode soils.

In any case the effect of such operations on neighbouring activities (e.g. existing well, settlement on building due to water table lowering) shall be assessed.

In all cases, care shall be taken to ensure that suitable discharge arrangements are in place in order to prevent environmental damage.

NOTE Water control is normally undertaken by ensuring that the excavation is shaped to discourage ponding and by the installation of ditches/grips/drains and the like. In some cases, these gravity systems will be supported by positive drainage, i.e. pumps.

In excavations that extend below water table level, it will often be necessary to artificially lower the water table before excavation commences. Systems such as perimeter well-pointing exist for such purposes. Advance installation of permanent drains may also assist. This prior dewatering not only enables efficient excavation but also will improve, in most cases, the behavioural characteristics of the materials to be excavated.

5.5.3 Erosion

Excavated slopes, particularly those in excavations containing fine granular soils, are prone to erosion caused by rainfall or wind. Exposed slopes should be protected as soon as practicable to prevent erosion by the application of the specified protection measures, e.g. by covering with topsoil or gravel and seeding/vegetating. Otherwise, a temporary protective layer should be left on the slope in order to prevent erosion of the final slope and this should only be removed immediately prior to the application of the protection measure.

Erosion may also occur due to outbreak of ground water in a slope with layered soil. Proper drainage and erosion protection should be applied.

5.5.4 Protection of subgrade

The sub-grade of the cutting or excavation should not be exposed to wet weather or frost without some form of protection or remediation.

After the frost season, the subgrade shall be inspected and any necessary remedial measure undertaken (recompaction, soil treatment, excavation and replacement, …).

During the construction it is normal to leave a protection/sacrificial layer on the floor of the cutting immediately above subgrade to prevent damage to the subgrade. Excavation should not proceed beyond this layer until the subgrade is ready to be prepared. Trafficking of the protection layer should be restricted.

5.6 Excavation under water

5.6.1 General

The work described in this chapter applies to removal of soft soil prior to embankment construction in water, and to other kinds of underwater excavation of limited size. This includes removal of obstacles in fairways and navigation channels by blasting and/or excavation.

For dredging in general, reference is made to the EN 16907-6.

Special information on site conditions, in addition to ground conditions, relevant for planning under water excavation are:

— geometry of the site including boundary conditions;

— topography,access;

— slopes and headroom restrictions;

— water depth and under water slope and topography with specified tolerances;

— existing underground structures, pipes and cables, services, known contaminants and archaeological constraints;

— environmental restrictions.

5.6.2 Equipment

Excavation under water can either be performed from dry land or from a barge or from a jack-up platform.

When performed from land it is especially important to make sure that the reach of the equipment is sufficient taking into account the water depth, the excavation depth and the slope of the excavation/embankment in order to be able to work in a safe manner. For this case, it is very important to be aware of the stability of the embankment/excavation slope during excavation execution of the works. Temporary stability is as important as permanent stability.

Where large boulders might be found, it is important that the equipment is adequate to handle even the largest boulders. Very large boulders might be blasted.

NOTE Normally, excavation is executed by backacter excavator or by wire operated grab/dredger.

5.6.3 Tolerance requirement

The slope of the excavation and tolerances in level shall be in accordance with the design.

Special requirements in areas for ship traffic shall be specified.

5.6.4 Underwater blasting

When the ground (soil or rock) is too solid to be loosened and excavated by mechanical equipment, blasting may be performed.

The rock shall be cleaned from loose material before blasting. Design considerations for the blasting shall be based on bedrock mapping, and the blasting plan, drilling and blasting agent shall be adapted to the site conditions.