SLOVENSKI STANDARD
SIST EN 15237:2007

01-julij-2007

Izvedba posebnih geotehniļ nih del - Navpiļ no odvodnjavanje

Execution of special geotechnical works - Vertical drainage

Ausführung von besonderen geotechnischen Arbeiten (Spezialtiefbau) - Vertikaldräns

Exécution des travaux géotechniques spéciaux - Drains verticaux

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EUROPEAN STANDARD

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EN 15237

February 2007

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English Version

Execution of special geotechnical works - Vertical drainage

Exécution des travaux géotechniques spéciaux - Drains verticaux

Ausführung von besonderen geotechnischen Arbeiten (Spezialtiefbau) - Vertikaldräns

This European Standard was approved by CEN on 7 January 2007.

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Foreword

This document (EN 15237:2007) has been prepared by Technical Committee CEN/TC 288 “Execution of special geotechnical works”, 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of an identical text or by endorsement, at the latest by August 2007, and conflicting national standards shall be withdrawn at the latest by August 2007.

The document has been prepared to stand alongside EN 1997–1, *Eurocode 7: Geotechnical design — Part 1: General rules*, and EN 1997–2 *Eurocode 7: Geotechnical design — Part 2: Ground investigation and testing*. This standard expands on design only where necessary, but provides full coverage of the construction and supervision requirements.

This document was drafted by a working group comprising delegates from 10 European countries. Experts from Japan have taken part in the meetings of the working group and contributed to the formulation of the final draft. The working group commenced work in March 2002.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

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1 Scope

This European Standard establishes general principles for the execution, testing, supervision and monitoring of vertical drain projects.

This European Standard includes the application of prefabricated vertical drains and sand drains and deals with requirements to be placed on design, drain material and installation methods. This European Standard applies to the improvement of low-permeability, highly compressible soils by vertical drainage and preloading. Information regarding loading (embankment, vacuum or ground water lowering) and preloading is given in informative Annexes A and B.

Vertical drainage is used both in on land and in marine constructions for the following purposes:

— (pre-)consolidation and reduction of post-construction settlements;

— speeding up the consolidation process by decreasing the path lengths for pore water dissipation;

— increase of stability (by increasing effective stresses in the soil);

— groundwater lowering;

— mitigation of liquefaction effects.

In each case there is an overall treatment of the soil (the volume of the drains is small in relation to the soil volume treated).

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This European Standard does not include soil improvement by means of wells, gravel and stone columns, large-diameter geotextile enclosed columns or reinforcing elements.

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Vertical drainage can also be combined with other foundation or ground improvement methods, e.g. electro-osmosis, piles and compacted sand piles, dynamic compaction and deep mixing.

Guidance on practical aspects of vertical drainage, such as investigation of drain properties, execution procedures and equipment, is given in Annex A. Investigation of soil characteristics and assessment of design parameters, which are affected by drain properties and execution, are presented in Annex B.

2 Normative references

The following referenced documents 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.

EN 1997–1, *Eurocode 7: Geotechnical design — Part 1: General rules*

EN 1997–2, *Eurocode 7: Geotechnical design — Part 2: Ground investigation and testing*

EN 13252:2000, *Geotextiles and geotextile-related products — Characteristics required for use in drainage systems*

EN ISO 9862, *Geosynthetics — Sampling and preparation of test specimens (ISO 9862:2005)*

EN ISO 10319, *Geotextiles — Wide-width tensile test (ISO 10319:1993)*

EN ISO 10320, *Geotextiles and geotextile-related products — Identification on site (ISO 10320:1999)*

EN ISO 10321, *Geotextiles — Tensile test for joints/seams by wide-width method (ISO 10321:1992)*

EN ISO 11058, *Geotextiles and geotextile-related products — Determination of water permeability characteristics normal to the plane, without load (ISO 11058:1999)*

EN ISO 12956, *Geotextiles and geotextile-related products — Determination of the characteristic opening size (ISO 12956:1999)*

EN ISO 12958:1999, *Geotextiles and geotextile-related products — Determination of water flow capacity in their plane (ISO 12958:1999)*

EN ISO 14688 (all parts), *Geotechnical investigation and testing*

3 Terms and definitions

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

3.1
auger installation method
fr: installation à la tarière
de: Schneckeneinbauverfahren
installation method of sand drains by means of screw type auger or continuous flight hollow stem auger

3.2
band drain[1)]
fr: drain plat
de: Streifendrän
prefabricated drain with a rectangular cross-section, usually consisting of a central core with a channel system surrounded by a filter sleeve

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3.3
cylindrical prefabricated drain
fr: drain tubulaire
de: zylindrischer Drän
drain consisting of an annular-corrugated and perforated open core, surrounded by a filter sock

3.4
discharge capacity q_w
fr: capacité de décharge
de: Durchflusskapazität
discharge capacity of a drain well is equal to the cross-sectional area of the drain multiplied by its overall permeability in longitudinal direction (the volume of water which flows out of the drain per time unit under a hydraulic gradient equal to unity)

3.5
displacement installation method
fr: installation par fonçage refoulant
de: Verdrängungseinbauverfahren
installation method of drains by means of a closed-end steel tube/mandrel

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1) The terms “wick drains” and “prefabricated vertical drains” (PVD) are also used.

3.6
drain anchor
fr: sabot d'ancrage
de: Dränschuh
anchor fixed at the end of band drains before installation and which prevents soil from intruding into the mandrel during installation and the band drain from being dragged up when the mandrel is withdrawn

3.7
drainage blanket
fr: tapis drainant
de: Dränndecke
upper high-permeability drainage layer, which has good contact with the drains and prevents the creation of backpressure in the drains

3.8
dynamic installation method
fr: méthode d'installation par battage ou vibrofonçage
de: dynamische Dräneinbauweise
drain installation method using dynamic action (impact or vibratory hammer)

3.9
geotextile enclosed sand drain
fr: drains de sable dans une gaine de géotextile
de: geotextilumschlossener Sanddrän
sand drains enclosed in some type of filter fabric made of geotextile

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3.10
jet installation method
fr: méthode d´installation par lançage
de: Einbau mittels Hochdruckinjektion
installation method of sand drains by means of internal jetting or rotary jet

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3.11
sand drain
fr: drain de sable
de: Sanddrän
drain with circular cross-section, built up of granular material (sand, gravel) with high permeability

3.12
static installation method
fr: méthode d´installation par fonçage
de: statisches Einbauverfahren
drain installation method by means of static load (pushing)

3.13
vibro installation method
fr: méthode d´installation par vibrofonçage
de: Vibrationseinbauverfahren
installation method of sand drains by means of a top vibrator mounted on a hollow mandrel or by a depth vibrator

3.14
working platform
fr: plateforme de travail
de: Arbeitsebene
platform created for access of the drain installation machines to the location of the vertical drains

4 Information needed for the execution of the work

4.1 Prior to the execution of the work, all necessary information shall be available.

4.2 This information shall include:

a) relevant information regarding the site conditions;

b) the location of main grid lines for setting out;

c) drawings with the location and length of the drains;

d) any legal or statutory restrictions;

e) method statement for the vertical drain installation (see 8.1);

f) characteristics of the drains (physical and hydraulic characteristics), accompanying document for CE-marking;

g) specification for the drains and other materials to be used (see Clause 6) and the schedule of any testing and acceptance procedures for materials incorporated in the works;

h) description of a suitable quality management system, including supervision and monitoring.

4.3 The information regarding the site conditions shall cover, where relevant:

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a) the geometry of the site (boundary conditions, topography, access, slopes, headroom restrictions etc.);

b) the ground properties of the site which may influence the execution of the vertical drains:

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- soil description (soil type, soil stratification and existence and frequency of sand and silt layers, hard layers);
- penetration resistance (e.g. results of penetration tests);
- composition, lateral extent, thickness and firmness of the surface stratum, tree roots, fill etc.;
- presence of cobbles or boulders or cemented layers that can cause difficulties for the execution or can require special installation equipment;

c) the following climatic and environmental information:

- weather information in areas with extreme climatic conditions;
- marine conditions (currents, tidal movements, wave heights etc.);
- environmental hazards (any water and subsoil contamination, which could affect the execution method, the safety of the work or the discharge of excavation material from the site shall be documented, including the presence of hazardous gas and occurrence of unexploded ammunition);

d) the existing underground structures, services, known contamination and archaeological constraints;

e) the environmental restrictions, including noise, vibration and pollution;

f) planned or ongoing construction activities, such as dewatering, tunnelling and deep excavations;

g) previous experience from drain installation work adjacent to the site;

h) the characteristics of the working platform and the drainage layer (physical and hydraulic properties);

i) the conditions of structures, roads, services etc. adjacent to the work.

4.4 For the loading operation the following information shall be available:

a) construction programme for loading;

b) preloading (temporary and permanent loading);

c) time schedule for loading and possible preloading;

d) unit weight of fill used for preloading;

e) notice of any restrictions such as construction phasing required in the design;

f) monitoring programme.

4.5 The following instructions shall also be given:

a) reporting procedure for unforeseen circumstances, or conditions revealed that appear to be different from those assumed in the design;

b) reporting procedure, if an observational method of design is adopted.

4.6 Any additional or deviating requirements falling within the permission clauses given in this European Standard shall be established and agreed upon before the commencement of the works.

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5 Geotechnical investigations

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5.1 General

5.1.1 The geotechnical investigations carried out for the design of vertical drainage work following the requirements of EN 1997 shall provide information for the installation of the vertical drains, see 4.3 b).

5.1.2 The geotechnical investigation report shall be available in sufficient time to allow for planning and execution of the vertical drainage works.

5.1.3 If the geotechnical investigations carried out are deemed insufficient, a supplementary investigation should be conducted.

5.2 Specific requirements

5.2.1 Apart from the general geological description and the details listed in EN 1997-1, the site investigation report shall contain information regarding ground conditions for the execution of vertical drain installations and for loading, see Annex A and Annex B.

5.2.2 Information about ground conditions shall comprise:

a) piezometric levels of groundwater, its variation and possible deviation from hydrostatic pressure conditions;

b) undrained shear strength.

5.2.3 The ground level and location at any point of investigation or testing should be established relative to the recognised national datum or to a fixed reference point.

6 Materials and product

6.1 General

6.1.1 Vertical drainage involves the use of prefabricated drains and/or sand drains.

NOTE A variety of prefabricated drains exists on the market. Most of them consist of the core and a geotextile filter.

6.1.2 Prefabricated drains consisting of a core and a geotextile filter are subjected to CE marking. The following specific properties shall be given.

a) tensile strength, in kN according to EN ISO 10319;

b) elongation at maximum tensile force, in % according to EN ISO 10319;

c) tensile strength of filter, in kN/m according to EN ISO 10319;

d) tensile strength of seams and joints, in kN/m according to EN ISO 10321;

e) velocity index of filter (v_{h50}), in mm/s according to EN ISO 11058;

f) characteristic opening size of filter (O_{90}), in μm according to EN ISO 12956;

g) discharge capacity of the drain, in m^3/year according to EN ISO 12958 (see also Annex A);

h) durability, in years (EN 13252:2000, Annex B).

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NOTE The dynamic perforation resistance (cone drop test, EN 918) as mentioned in EN 13252 is not compulsory for this application.

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6.2 Raw materials of prefabricated drains

6.2.1 A prefabricated drain usually comprises a geotextile or geotextile-related product.

6.2.2 The product is used in applications that do not involve reinforcement of soil and where long-term strength is not a significant parameter and in natural soils with a pH-value between 4 and 9 and at a soil temperature less than 25 °C according to EN 13252. A service lifetime of up to 5 years is applicable.

6.2.3 The use of 5 % internal regenerate (e.g. raw material made out of unused core) for the production of the core is permitted. The composition should be known and the material be processed in the same way as the original product. The use of recycled material is only permitted provided that it can be verified that it is not causing pollution of the soil or ground water.

6.2.4 Materials used to manufacture the drains shall not cause pollution of the soil or the groundwater.

6.2.5 Biodegradable drains can be used if they fulfil the drainage requirements during the lifetime of the project.

6.3 Band drains

6.3.1 Shape and structure of band drains

6.3.1.1 The band drain is a prefabricated drain with a rectangular cross-section, usually consisting of a central core with a channel system surrounded by a filter. The width of the core of the band drains is typically 100 mm and the thickness is between 2 mm and 10 mm.

6.3.1.2 The core should consist of a profiled strip, with or without perforation, or a profiled mat with an open or closed structure. It should have a structure that provides regular hydraulic flow capacity.

6.3.1.3 Tears and/or other defects shall not be allowed to occur. Visual inspections for damage shall be made regularly as part of the production quality control.

6.3.2 Measurements

6.3.2.1 The roll length, width and thickness of the core at any given place should comply with the dimensions given by the manufacturer (within allowable deviations given by the manufacturer). See accompanying document for CE-marking (EN 13252).

6.3.2.2 The measurements should comply with EN ISO 9863-1.

6.3.3 Durability

6.3.3.1 The durability of the drain shall comply with the durability aspects given in EN 13252 (weathering, required service lives up to five years or more when the drains are installed to mitigate soil liquefaction).

6.3.3.2 The drains should be protected against weathering during storage on the site.

6.3.3.3 The product shall not be exposed longer than the time announced by the producer for CE Marking (EN 13252) unless the product is protected by a wrapping material or stored in-house. The recommendations of the supplier shall be followed.

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6.3.4 Tensile strength and elongation

6.3.4.1 The required tensile strength of the band drain is very dependent upon the type of installation machine, installation technique and depth of the drain. Tensile strength of the band drains in the longitudinal direction shall be high enough to prevent breakage during and after installation.

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6.3.4.2 Testing of tensile strength and elongation of the band drain should be made in accordance with EN ISO 10319 (to be modified with regard to the width of the product).

6.3.4.3 The following characteristics of a band drain are recommended:

a) elongation ≥ 2 % at failure of the weakest element;

b) elongation ≤ 10 % at a tensile force of 0,5 kN (20 % if exposed to frost);

c) minimum tensile force > 1,5 kN at failure of the weakest element. The seam should not fail during the test.

NOTE These values depend on the installation equipment and procedure and may need to be adjusted accordingly.

6.3.4.4 The strength of the seam, measured according to EN ISO 10321 in a range of temperatures, which apply to the project site, shall be at least 1 kN/m.

6.3.5 Discharge capacity

6.3.5.1 The discharge capacity and the filtration characteristics are the most important properties. The following factors influence the discharge capacity:

a) due to increasing lateral effective pressure during the consolidation process the filter is squeezed into the channel system of the core, which reduces the channel area;

b) the vertical compression of the soil taking place during the consolidation process may lead to buckling of the relatively incompressible band drains, which may reduce the channel area;

c) fines may intrude through the filter into the core and cause blocking of the channel system;

d) soil temperature has an influence on the compression resistance and creep of the drains and thus on the discharge capacity.

6.3.5.2 The required discharge capacity of the band drain is largely dependent upon the purpose of ground improvement, the consolidation parameters of the soil, the drain spacing and the depth of drain installation (see Annex B).

6.3.5.3 The discharge capacity shall be high enough to satisfy the design requirements.

6.3.5.4 The recommended value of the discharge capacity is given in Annex B.

6.3.5.5 The discharge capacity test should be carried out in accordance with EN 12958 with the modifications given in A.4.1.2 in Annex A.

6.3.5.6 For usual applications, the discharge capacity test should be performed at the laboratory temperature and then the test report should be referred to a temperature of 20 °C. For applications in tropical environment, the discharge capacity test should be performed at a temperature corresponding to the soil temperature at the place of drain installation and then the test report should be referred to that specific temperature.

6.3.5.7 The test period should be long enough to yield a constant value of discharge capacity, preferably at least two days at the maximum static pressure stipulated by the designer.

6.3.6 Filter of band drains

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6.3.6.1 The filter sleeve should be composed of a non-woven material consisting of fibres that are mechanically, chemically or thermally bonded.

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6.3.6.2 The filter sleeve should have a regular structure.

6.3.6.3 The occurrence of creases, tears, holes and/or other defects shall not be allowed. The seams of the filter sleeve shall be constructed in such a way that fines cannot intrude into the core of the band drain.

6.3.6.4 Visual inspections for damage shall be made regularly during production in accordance with the factory production control plan.

6.3.7 Tensile strength per unit width of filter

6.3.7.1 The tensile strength of the filter shall be sufficient to prevent breakage during and after installation.

6.3.7.2 Testing should be carried out in accordance with EN ISO 10319. The average of the individually measured values for the tensile strength should not be lower than 3 kN/m in the longitudinal direction. For installations deeper than 25 m or in difficult soil conditions, a minimum tensile strength of 6 kN/m in the longitudinal direction is recommended.

6.3.8 Velocity index of filter

Testing should be carried out in accordance with EN ISO 11058. The average of the individually measured values of the velocity index (v_{h50}) should be higher than 1 mm/s. In case of drain installation for liquefaction problems, the filter pore size should be adapted to ensure adequate permeability of the filter for this application, see 6.4.

6.3.9 Pore size of filter

6.3.9.1 The pore size of filter shall be selected to ensure sufficient discharge capacity and avoid serious loss of discharge capacity due to clogging of the filter and/or the core by soil particles. The seams of the filter shall not have an opening size bigger than that of the geotextile filter.

6.3.9.2 Primarily, the requirements for the filter sleeve characteristics shall be given in the project, considering the soil properties at the site and the installation conditions (dry or wetland, offshore).

6.3.9.3 The value of the characteristic opening size O_{90}, measured in accordance with EN ISO 12956 should not be higher than 80 μm.

NOTE The value of O_{90} may be influenced by project-specific requirements and higher values may be acceptable.

6.3.9.4 In silty soils and silt the characteristic opening size O_{90} of the filter should be adapted to the soil conditions according to the following criteria:

a) $< d_{85,soil}$ in silty soils, which are problematic from the point of view of filtering technique;

b) $< 1,5\ d_{50,soil}$ to $2,8\ d_{50,soil}$ in soils, which are difficult from the point of view of filtering technique, mainly medium and coarse silt.

6.3.10 Quality control

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6.3.10.1 The band drain shall comply with all European requirements and conformity assessment procedures that apply to it. The properties shall be within the limits announced in the accompanying document accredited by a Notifying Body.

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6.3.10.2 The filter and drain characteristics and corresponding testing methods, as well as the proposed testing frequency, are given in Table 1, adapted from EN 13252. The sampling procedure for the different testing methods shall comply with EN ISO 9862.

NOTE The on-site testing frequency should be decided between the parties involved.

Table 1 — Proposed testing frequency for fabrication control

Property	Proposed test frequency	Required standard
Filter:		
Thickness	25 000 m^2	EN 9863-1
Mass per unit area	25 000 m^2	EN 9864
Pore size	200 000 m^2	EN 12956
Velocity index	200 000 m^2	EN 11058
Tensile strength in the longitudinal direction	200 000 m^2	EN 10319
Tensile strength in the cross direction	200 000 m^2	EN 10319
Drain composite:		
Width and thickness	25 000 m	EN 9863-1
Mass per unit length	25 000 m	EN 9864
Tensile strength in the longitudinal direction	100 000 m	EN 10319
Elongation at maximum tensile force	100 000 m	EN 10319
Discharge capacity straight	500 000 m	Annex A
Discharge capacity buckled	500 000 m	Annex A
Tensile strength of filter seam	100 000 m	EN 10321
Durability	500 000 m	EN 13252

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6.4 Prefabricated cylindrical drain

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6.4.1 Shape and structure of cylindrical drains

6.4.1.1 A cylindrical drain consists of an annular-corrugated and perforated open core, surrounded by a filter sock. The drain diameter is typically 50 mm in outer diameter and 45 mm in inner diameter.

6.4.1.2 Tears and/or other defects shall not be allowed to occur. Visual inspections for damage shall be made regularly as part of the production quality control.

6.4.2 Measurements

The diameter and thickness of the core should comply with the dimensions given by the manufacturer (within allowable deviations given by the manufacturer).

6.4.3 Durability

6.4.3.1 The durability of the drain shall comply with the durability aspects given in EN 13252 (Annex B, B.1 weathering, and B.2, required service lives up to five years or more when the drains are installed to mitigate soil liquefaction).

6.4.3.2 The drains should be protected against weathering during storage on the site.

6.4.3.3 The product shall not be exposed longer than the time announced by the producer for CE Marking (EN 13252) unless the product is protected by a wrapping material or stored in-house. The recommendations of the supplier shall be followed.