SLOVENSKI STANDARD
SIST EN 12715:2002

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Izvedba posebnih geotehniļ nih del - Injektiranje

Execution of special geotechnical work - Grouting

Ausführung von besonderen geotechnischen Arbeiten (Spezialtiefbau) - Injektionen

Exécution des travaux géotechniques spéciaux - Injection

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EUROPEAN STANDARD
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English version

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Ausführung von besonderen geotechnischen Arbeiten (Spezialtiefbau) - Injektionen

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Contents

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 188 "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of an identical text or by endorsement, at the latest by January 2001, and conflicting national standards shall be withdrawn at the latest by January 2001.

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

This standard has been prepared by the Working Group (WG 6) of the CEN/TC 288. The general remit of TC/288 is the standardisation of the execution procedures for geotechnical works (including testing and control methods) and of the required material properties. WG 6 has been charged with the subject area of grouting, including compaction grouting.

The document has been prepared to stand alongside ENV 1997 part 1: EUROCODE 7: Geotechnics, Geotechnical Design, General Rules. This standard expands on design only where necessary, but provides full coverage of the construction and supervision requirements.

It has been drafted by a working group comprising delegates from 9 countries and against a background of more than ten pre-existing grouting standards and codes of practice, both national and international. In view of the different construction methods used internationally and the respective experience it may be necessary to supplement this standard, or parts of it, by National Application Documents to cater for specific or local situations.

The annexes A, B and C are informative.

1 Scope

This standard is applicable to the execution, testing and monitoring of geotechnical grouting work. Specific aspects concerning design are provided since ENV 1997-4 has been abandoned.

Grouting for geotechnical purposes (geotechnical grouting) is a process in which the remote placement of a pumpable material in the ground is indirectly controlled by adjusting its rheological characteristics and by the manipulation of the placement parameters (pressure, volume and the flow rate).

The following principles and methods of geotechnical grouting are covered by this standard :

— displacement grouting (compaction grouting, hydraulic fracturing) ;

— grouting without displacement of the host material (permeation, fissure grouting, bulk filling).

Specialised grouting activities, generally associated with structural and/or emergency works, are not covered by this standard.

2 Normative references

This European Standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited in the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 196-1, *Methods of testing cement – Part 1: Determination of strength.*

EN 196-2, *Methods of testing cement – Part 2: Chemical analysis of cement.*

EN 196-3, *Methods of testing cement – Part 3: Determination of setting time and soundness.*

ENV 196-4, *Methods of testing cement – Part 4: Quantitative determination of constituents.*

EN 196-5, *Methods of testing cement – Part 5: Pozzdanicity test for pozzolanic cement.*

prEN 196-8 :1997, *Methods of testing cement – Part 8: Determination of heat of hydration.*

prEN 196-9 :1997, *Methods of testing cement – Part 9: Determination of heat of hydration – Semi-adiabatic method.*

prEN 197-1 :2000, *Cement – Part 1: Composition, specifications and conformity criteria for common cements.*

prEN 197-2:2000, Cement – Part 2: Conformity evaluation.

ENV 451, Methods of testing fly ash.

EN 480-1, *Admixtures for concrete, mortar and grout - Test methods – Part 1 : Reference concrete and reference mortar for testing.*

EN 480-2, *Admixtures for concrete, mortar and grout - Test methods – Part 2 : Determination of setting time.*

prEN 480-3 :1991, *Admixtures for concrete, mortar and grout - Test methods – Part 3 : Determination of shrinkage and expansion.*

EN 480-4, *Admixtures for concrete, mortar and grout - Test methods – Part 4 : Determination of bleeding of concrete.*

EN 480-5, *Admixtures for concrete, mortar and grout - Test methods – Part 5 : Determination of capillary absorption.*

EN 480-6, *Admixtures for concrete, mortar and grout - Test methods – Part 6 : Infrared analysis.*

prEN 480-7 :1991, *Admixtures for concrete, mortar and grout - Test methods – Part 7 : Determination of the density of liquid admixtures.*

EN 480-8, *Admixtures for concrete, mortar and grout - Test methods – Part 8 : Determination of the conventional dry material content.*

prEN 480-9 :1991, *Admixtures for concrete, mortar and grout - Test methods – Part 9 : Determination of the pH value.*

EN 480-10, *Admixtures for concrete, mortar and grout - Test methods – Part 10 : Determination of water soluble chloride content.*

EN 480-11, *Admixtures for concrete, mortar and grout - Test methods – Part 11 : Determination of air void characteristics in hardened concrete.*

EN 480-12, *Admixtures for concrete, mortar and grout - Test methods – Part 12 : Determination of the alkali content of admixtures.*

prEN 934-1 :1998, *Admixtures for concrete, mortar and grout - General definitions and general requirements for all types of admixtures.*

prEN 934-3 :1998, *Admixtures for concrete, mortar and grout – Part 3 : Admixtures for masonry mortar – Definitions, requirements and conformity.*

EN 934-4, *Admixtures for concrete, mortar and grout – Part 4 : Admixtures for grout for prestressing tendons – Definitions, requirements and conformity.*

EN 934-6, *Admixtures for concrete, mortar and grout – Part 6 : Sampling, quality control, evaluation of conformity and marking and labelling.*

ENV 1997-1 :1994, *EUROCODE 7 : Geotechnical design – Part 1: General rules*

3 Definitions and symbols

3.1 Definitions

The definitions given in this chapter cover only the most important terms involved in geotechnical grouting. Further definitions are given in the glossary in annex B.

3.1.1
bulk filling
fr : injection de comblement
de : Hohlraumverfüllung
bulk filling is the placement of grout with a high particulate content to fill substantial voids

3.1.2
compaction grouting
fr : injection solide
de : Verdichtungsinjektion (Kompaktionsinjektion)
a displacement grouting method which aims at forcing a mortar of high internal friction into the soil to compact it without fracturing it

3.1.3
contact grouting
fr : injection de contact
de : Kontaktinjektion
the injection of grout into the interface between man-made structures and the ground

3.1.4
displacement grouting
fr : injection avec déplacement des terrains
de : Verdrängungsinjektion
injection of grout into a host medium in such a manner as to deform, compress, or displace the ground

3.1.5
effective pressure
fr : pression effective
de : wirksamer Druck
the actual grout pressure acting in the ground

3.1.6
fissure grouting
fr : injection de fissure
de : Kluftinjektion
the injection of grout into fissures, joints, fractures and discontinuities, particularly in rock

3.1.7
gravity grouting
fr : injection gravitaire
de : drucklose Verfüllung
grouting under no applied pressure other than the height of grout fluid. Sometimes referred to as tremie grouting

3.1.8
grout
fr : coulis
de : Injektionsgut
a pumpable material (suspension, solution, emulsion or mortar), injected into soil or rock, which stiffens and sets with time

3.1.9
grouting pressure
fr : pression d'injection
de : Injektionsdruck
a pressure applied during the grouting process and measured at defined locations (usually at the pump or the borehole collar)

3.1.10
hydraulic fracturing (hydraulic fracture, claquage grouting)
fr : fracturation hydraulique (injection de claquage)
de : Hydraulische Rissbildung (Claquage)
the fracturing of a ground initiated by the injection of water or grout under a pressure in excess of the local tensile strength and confining pressure; also called hydrofracturing, hydrosplitting, hydrojacking or claquage

3.1.11
penetration grouting
fr : injection de pénétration
de : Eindringinjektion
grout injection of joints or fractures in rock, or pore spaces in soil, without displacing the ground. The term includes permeation (impregnation), fissure and contact grouting

3.1.12
permeation (impregnation) grouting
fr : injection d'imprégnation
de : Poreninjektion (Imprägntion durch Porenverfüllung)
the replacement of interstitial water or gas of a porous medium with a grout at injection pressures low enough to prevent displacement

3.1.13
non-displacement grouting

fr : injection sans déplacement des terrains
de : Verdrängungsfreie Injektion (Injektion ohne Baugrundverdrängung)

substitution of the natural interstitial fluid in the accessible existing voids of the ground by a grout or mortar without any significant displacement of the ground. The term includes penetration grouting and bulk filling

3.1.14
stable suspension

fr : suspension stable
de : stabile Suspension

stable suspensions exhibit in 2 hours less than 5 per cent bleeding of clear water at the top of a 1 000 ml cylinder with an internal diameter of 60 mm at a temperature of 20 °C

3.2 Symbols and units

The following symbols and units are used in this standard :

Symbols	Denomination	Unit
T	Temperature	[°C]
V	Volume injected	[m³]
P	Injection pressure	[Pa]
Q	Injection or flow rate	[m³/s] or [l/s]
k	Intrinsic (absolute) permeability[1)]	[m²]
K	Coefficient of hydraulic conductivity	[m/s]
i	Hydraulic gradient	[dimensionless]
d_{10}, d_{15}	Largest particle size of the smallest 10, 15 % of grout	[mm]
D_{85}, D_{90}	Largest grain size of the smallest 85, 90 % of the medium	
t	Setting time	[s]
σ_c	Compressive strength	[Pa]
τ_f	Shear strength	
σ	Normal stress	[Pa]
τ	Shear stress	
ε	Strain	[dimensionless]
$\dot{\gamma}$	Shear rate	[s^{-1}]
μ_{app}	Viscosity (apparent)	[Pa.s], [kg/m.s]
η	(dynamic)	[Pa.s]
ν	(kinematic)	[m²/s]
c	Cohesion	[Pa]
τ_0	Yield shear stress	[Pa]
ρ	Density	[kg/m³]
γ	Specific or unit weight	[kN/m³]
t_M	Outflow time (Marsh)	[s]
R	Action radius	[m]

1 Pa = 1 N/m² = 10^{-5} bar

1) It is common practice in geotechnical engineering to use k for hydraulic conductivity. Nevertheless, this refers to the parameters generally used in rock and fluid mechanics.

4 Information needed

4.1 All information relevant to the execution of the grouting works should be provided with the work specifications.

4.2 The following technical information shall be available on site before the commencement of the works :

— site conditions and limitations, e.g. size, gradients, access ;

— working restrictions, including any environmental, legal or statutory restrictions ;

— any underground contamination or hazard which could affect the method of execution or the safety of the working environment ;

— design and specifications for the works.

4.3 The following technical information should be available on site before the commencement of the works :

— geological and geotechnical conditions (see Chapter 5) ;

— the co-ordinate locations of the site with respect to the national grid ;

— existence, location and conditions of any adjacent structures, e.g. buildings, roads, utilities or services, underground structures and their foundations ;

— any concurrent or subsequent activities which could affect the works (e.g. groundwater extraction or recharge, tunnelling, other deep excavations) ;

— any previous experience with grouting or other underground works on or adjacent to the site, or relevant experience in the execution of comparable works under similar conditions ;

— any information relevant for the production of drawings and method statements (where required) ;

— any additional requirements for the supervision, monitoring or testing of the works.

4.4 The following aspects shall be established before the commencement of the works and shall be available in written form on site :

— the requirement, and assignment, for any survey of the condition of adjacent structures, roads, services, etc. to be carried out prior to, during and after the works ;

— specific procedures and criteria for the verification, control and acceptance of the grouting works ;

— the clear division of tasks with respect to the design, execution, interpretation of results and approval of the works.

5 Site investigation

5.1 General

5.1.1 The general requirements for site investigation are contained in ENV 1997-1 :1994, chapters 3 and 7 and the relevant national documents.

5.1.2 For design purposes, the site investigations should :

— provide a comprehensive geotechnical report ;

— establish the ground susceptibility to grout ;

— furnish a basis for selecting the grout types.

5.1.3 For the execution, the ground investigation report should contain the following specific information :

— the relevant physical and chemical characteristics of the ground ;

— the ground level at investigation and testing locations relative to a recognised datum ;

— the location, founding level and condition of existing or envisaged structures ;

— the presence of any anisotropies or permeable horizons which could influence the grouting works ;

— the orientation, frequency, and width of rock joints and the composition and nature of any infill material ;

— the location and nature of filled or open cavities ;

— the presence of obstructions that require special drilling and grouting methods or equipment ;

— the presence and characteristics of ground that is likely to loosen, soften or become unstable, dissolve, collapse or swell as a result of drilling or grouting ;

— the groundwater levels and gradients and their variation with time ;

— strata with high groundwater velocities and permeabilities ;

— the temperature, chemical composition, organic and bacteriological content of the groundwater or ground, if problems are expected.

5.1.4 The geological and geometrical model, and the void structure and its anticipated evolution should be described in the investigation report. The precision and limits of the model should be highlighted.

5.1.5 Where relevant, the following specific drilling information should be recorded :

— location and cause of core losses ;

— unstable zones and stabilisation measures taken ;

— water level at the beginning and end of a run, zones of water loss and gain, measurements of return water, water colour and changes in colour ;

— action of the drill rig (jerky, rough, smooth, steady motion) ;

— recording of drill parameters in the case of destructive boreholes ;

— rate of advance.

5.1.6 Special care shall be taken when investigating for injections in high stress regions and in polluted ground :

— for injections in high stress regions, the in situ state of stress shall be investigated before designing a grouting project ;

— for the injection of organic gels into polluted soils, a bacteriological investigation of the groundwater and ground shall be carried out.

5.1.7 Site investigation boreholes shall be suitably backfilled when no longer required.

5.2 Permeability testing

5.2.1 The hydraulic conductivity of the ground may be :

— determined from in situ permeability tests or large scale pumping tests ;

— estimated from laboratory tests on samples of undisturbed soil or recompacted soil ;

— estimated from the particle size distribution of the soil, and/or density of the ground.

5.2.2 Suitable correlations with actual field permeabilities should be established.

5.2.3 Each site investigation hole in rock should be tested to determine the water take and to identify the water bearing or open zones in the hole. The hole should be either tested as it is drilled or tested by the use of packers after drilling is completed.

5.2.4 Special care shall be taken to isolate artesian zones before testing.

5.2.5 Lugeon tests are used in rock to obtain a general impression of the transmissivity of the ground. They do not necessarily provide a reliable correlation with the absorption of a specific grout.

5.3 Field grouting trials and grouting tests

5.3.1 Field grouting trials are executed in order to define or validate a grouting method. Field grouting trials should be considered as part of the initial site investigation. They should be conducted during the final design phase, or the first part of the construction phase if they did not form part of the site investigation. They should be executed where initial investigations and local or comparable experience is insufficient to support or justify the effectiveness of the grouting project. The trials should provide information on borehole spacing, grouting pressure and grout take and type.

5.3.2 Grouting trials shall be planned and executed in close collaboration with the designer of the final grouting program.

5.3.3 The limit criteria for the properties of the proposed grout should be established on the basis of experience gained during the trial grouting.

5.3.4 Detailed records shall be kept of each operation performed during the grouting trials.

5.3.5 An indication of in situ conditions may be obtained by permeating reconstituted soil samples with trial grouts, under laboratory conditions. Permeability measurements made before and after grouting the sample may provide indicative information which will facilitate decisions on the frequency of injection points, the desired properties of the grout mix, and the required grout volume.

6 Materials and products

6.1 General

6.1.1 All grout components and grouts shall comply with the specifications for the works and the relevant EN or national standards.

6.1.2 The compatibility of all grout constituents shall be evaluated. Similarly, an assessment shall be made of the possible interaction between the grout and the ground.

6.1.3 Once established, the sources of grout materials shall not be changed without prior compliance verification or testing.

6.1.4 Materials that do not meet agreed quality standards, shall promptly be removed from the site.

6.2 Grout materials

6.2.1 Hydraulic binders and cements

6.2.1.1 Hydraulic binders include all cements and similar products used in water suspension for making grouts.

6.2.1.2 Microfine (ultra-fine) hydraulic binders or cements are characterised by a particle size d_{95} of less than 20 µm.

6.2.1.3 The granulometric curve, especially of the microfine products used, shall be known.

6.2.1.4 When selecting the type of hydraulic binder for grout, its grain size distribution should be considered in relation to the dimensions of the fissures or voids of the ground to be treated.

6.2.1.5 Cements are subject to prEN 197-1 :2000 and prEN 197-2 :2000. Methods for testing of cements are subject to EN 196. Properties and methods different from those mentioned in those standards and specific to grouting are subject of this standard.

6.2.2 Clay materials

6.2.2.1 Natural clays, activated or modified bentonites can be added to cement based grouts in order to reduce bleeding and filtration under pressure, to vary the viscosity and cohesion (yield) of the grout, or to improve the pumpability of the grout.

6.2.2.2 The mineralogy, particle size, water content, and Atterberg liquid limit of the clay should be known.

6.2.3 Sands, gravels and fillers

6.2.3.1 Sand and fillers are commonly used in cement grouts or clay suspensions as bulking agents or as a means of varying the consistency of the grout, its resistance to wash-out, or its mechanical strength and deformability.

6.2.3.2 Natural sands or gravels may be added to grouts, provided that they do not contain any harmful components.

6.2.3.3 The granulometry of sands and fillers used in grouts shall be known.

6.2.4 Water

6.2.4.1 Water obtained from natural sources on-site should be tested (particularly for chlorides, sulphates and organic matter) and approved.

6.2.4.2 Sea water can be used provided that the properties of the grout mix are not impaired.

6.2.5 Chemical products and admixtures

6.2.5.1 Chemical products such as silicates and their reagents, lignin based materials, acrylic or epoxy resins, polyurethanes or others can be used in grouting work subject to compliance with environmental legislation.

6.2.5.2 The effects of all products and by-products resulting from reaction of the chemical products with other components of the grout or with the surrounding ground shall be considered.

6.2.5.3 Admixtures are organic or inorganic products added in small quantities during the mixing process in order to modify the properties of the grout and to control grout parameters such as viscosity, setting time, stability, and strength, resistance, cohesion and permeability after placement.

6.2.5.4 Admixtures to grout such as superplasticizers, water retaining agents, air entrainers and others are subject of parts 1, 3, 4 and 6 of prEN 934 and prEN 480-1 to 480-12.

6.2.6 Other materials

6.2.6.1 Calcareous or siliceous fillers, pulverised fuel ash (pfa), pozzolans and fly ash from thermal power plants or any inert or reactive components may be used in grouts, provided that they are chemically compatible with each other and satisfy immediate and long term environmental requirements.

6.2.6.2 Methods for testing of fly-ash are subject to ENV 451. Methods different from those mentioned in that standard and specific to grouting are subject of this standard.

6.3 Grouts

6.3.1 General

6.3.1.1 Grouts are classified as :

— suspensions: either particulate or colloidal suspensions ;

— solutions: either true or colloidal solutions ;

— mortars.

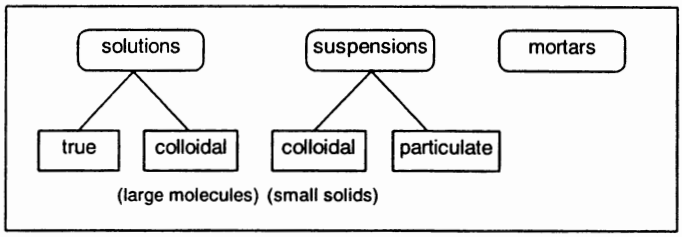

Figure 1 — Grout classification

6.3.1.2 The following intrinsic properties shall be considered when choosing a grout :

— rheology (viscosity, cohesion, etc.), Setting time, Stability ;

— particle size, if applicable ;

— strength and durability ;

— toxicity.

6.3.1.3 The main parameters that define the properties of grouts before and after setting are listed below :

Table 1 — Parameters characterising grout properties

	Solutions	suspensions	mortars
Before setting	setting time, density, pH, surface tension, pot life, film time, gel time, viscosity, cohesion, thixotropy	setting time, density, pH, grain size distribution, viscosity, cohesion, yield, thixotropy, stability, water retention capacity	setting time, density, pH, grain size distribution, viscosity, workability, water retention capacity
After setting	hardening after setting, final strength, pH, deformability, durability, shrinkage, expansion, shear strength, syneresis (silicate based solutions)	hardening time, final strength, deformability, durability, shrinkage, expansion, density, shear strength	hardening time, final strength, deformability, durability, shrinkage, expansion

6.3.2 Suspensions

6.3.2.1 Suspensions are characterised by :

— the grain size distribution of the solid particles ;

— their water/solid ratio ;

— the rate of sedimentation and bleeding ;

— their water retention capacity under pressure filtration ;

— their rheological properties and behaviour with time.

6.3.2.2 The granulometric curve of microfine suspensions should be determined with a laser granulometer or equally precise instrument.

6.3.2.3 The tendency of suspended solids to flocculate (particularly in microfine suspensions) shall be taken into account.

6.3.2.4 The tendency of solids in suspension to settle in water due to gravity forces, and their tendency to bleed under pressure, shall be considered in relation with the nature and properties of the host medium.

6.3.2.5 Colloidal clay suspensions should be prepared so that the clay particles are thoroughly deflocculated and hydrated before injecting.

6.3.3 Solutions

6.3.3.1 Some types of silicate grout are not stable with time and their use should be carefully assessed.

6.3.3.2 Organic silicate gels may lead to the proliferation of bacteria in the ground.

6.3.3.3 The effect of syneresis on the properties of the treated ground and on the environment, particularly their long term effect, shall be evaluated prior to treatment.

6.3.3.4 The effect of temperature differences on the grout behaviour during production and placement shall be taken into account.

6.3.3.5 Special attention shall be paid to :

— the toxicity of individual resin grout components ;

— the risk of dilution of the grout mixture in the groundwater leading to prolongation of the setting time or even inhibition of the chemical reaction ;

— the toxicity of any substance released into the groundwater if the chemical reaction is not fully achieved or modified by the host medium.

6.3.3.6 Resins are usually applied under the circumstances given in Table 2 :

Table 2 — Application of resin grouts

Resin type	Ground type	Use/Application
Acrylic	granular soil finely fissured rock	Reduction of permeability Improvement of strength
Polyurethane	large voids	Foaming to block water inflow (aquareactive resins) Stabilisation or local void filling (two component resins)
Phenolic	fine sand and sandy gravel	Tightening and consolidation
Epoxy	fissured rock	Improvement of strength Reduction of permeability

6.3.4 Mortars

6.3.4.1 Mortars showing high internal friction are used for compaction grouting or for the filling of voids. Their rheological behaviour is usually determined by slump tests (workability, see Table A.1).

6.3.4.2 Mortars flowing under their own weight are generally used for filling cavities, large cracks, open fissures and voids in granular soils. They shall be stable and their rheological behaviour (similar to suspensions) is usually characterised with suitably selected flow cones.