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ΕΛΛΗΝΙΚΗ ΤΕΧΝΙΚΗ ΠΡΟΔΙΑΓΡΑΦΗ

HELLENIC TECHNICAL SPECIFICATION

Ενεματώσεις εδαφών και βράχων

Soil and rock grouting

Pricing class: **12**

Preamble

This Hellenic Technical Specification revises and replaces ELOT TS 1501-11-03-05-00:2009.

This Hellenic Technical Specification was prepared by Experts and checked and evaluated in its field by a Supervisor/Specialist - Expert, who assisted the work of the Technical Committee ELOT/TE 99 “Specifications of Technical Works”, the secretariat of which belongs to the Directorate for Standardisation of the Hellenic Organization for Standardization (ELOT).

The text of this Hellenic Technical Specification ELOT TS 1501-11-03-05-00 was adopted on 17.03.2023 by ELOT/TE 99 in accordance with the Regulation on the drafting and publication of Hellenic Standards and Specifications.

The European, international and national standards referred to in the standardisation references are available by ELOT.

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Content

Introduction

This Hellenic Technical Specification (HTS) is part of the technical texts originally prepared by the Ministry for the Environment, Spatial Planning and Public Works and the Institute for Constructions Economy (IOK) and was subsequently edited by ELOT in order to be applied to the construction of national public technical works, with a view to produce works that are robust and capable of meeting and satisfying the needs which have dictated their construction, and be beneficial for the society as a whole.

Under a contract between NQIS/ELOT and the Ministry for Infrastructure and Transport (online publication number 6ΕΟΒ465ΧΘΞ-02Τ), ELOT was assigned the editing and update as 2nd Edition of three hundred fourteen (314) Hellenic Technical Specifications (HTS), in accordance with the applicable European Standards and Regulations and the procedures laid down in the Regulation on the drafting and publication of Hellenic Standards and Specifications and in the Regulation on the establishment and operation of Technical Standardization Instruments.

This Hellenic Technical Specification was prepared by the contractor of the restricted tender No 1/2020 for the award of the work “Revision of the 1st edition of 314 HTS” (online publication number ΩΕΕΑΟΞΜΓ-ΞΗΔ), checked and evaluated in its field by a Supervisor/Specialist - Expert and submitted for Public Consultation. It was approved by the Technical Committee ELOT/TE 99 “Specifications of Technical Works”, which was set up by the Decision of the Managing Director of the NQIS, Δν.Σ. 285-19/08-02-2019 (ΑΔΑ6ΩΛΡΟΞΜΓ-15Ξ).

This HTS covers the requirements arising from the EU law, the relevant New Approach Directives currently in force and the National Law, and refers to and is compatible with harmonised European standards.

Soil and rock grouting

1 Objective

Objective of this Technical Specification is the execution of special geotechnical grouting operations.

This Technical Specification covers the following soil and rock grouting operations:

a) emitting by displacement of the geomaterial (e.g. condensation grouting, hydraulic soil fracture grouting).

b) grouting without displacement of the geomaterial (e.g. sealing grouting, fissure filling grouting, void fill grouting).

The specialised grouting works related to the protection and operation of underground works are not included herein, but are the subject of Technical Specification ELOT TS 1501-12-07-02-00.

2 Standardization references

This Technical Specification incorporates –by way of references– provisions of other publications, whether dated or not. These references refer to the respective parts of the text and a list of these publications is presented thereafter. In case of references to dated publications, any subsequent amendments or revisions thereof shall apply to this document when incorporated in it by means of amendment or revision. With regard to references to undated publications, their latest version shall apply.

ELOT EN 197-1	*Cement - Part 1: Composition, specifications and conformity criteria for common cements -- Τσιμέντο. Μέρος 1: Σύνθεση, προδιαγραφές και κριτήρια συμμόρφωσης για τα κοινά τσιμέντα*
ELOT EN 450-1	*Fly ash for concrete - Part 1: Definition, specifications and conformity criteria -- Ιπτάμενη τέφρα για σκυρόδεμα - Μέρος 1: Ορισμοί, προδιαγραφές και κριτήρια συμμόρφωσης*
ELOT EN 1008	*Mixing water for concrete - Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete -- Νερό ανάμιξης σκυροδέματος - Προδιαγραφή για δειγματοληψία, έλεγχο και αξιολόγηση της καταλληλότητας του νερού, συμπεριλαμβανομένου του νερού που ανακτάται από διεργασίες στη βιομηχανία σκυροδέματος, για τη χρήση του ως νερό ανάμιξης σκυροδέματος*
ELOT EN 1997-1	*Eurocode 7: Geotechnical design - Part 1: General rules -- Ευρωκώδικας 7: Γεωτεχνικός σχεδιασμός - Μέρος 1: Γενικοί κανόνες*
ELOT EN 12715	*Execution of special geotechnical work – Grouting -- Εκτέλεση ειδικών γεωτεχνικών έργων - Ενεματώσεις*
ELOT EN 13139	*Aggregates for mortar -- Αδρανή κονιαμάτων*
ELOT EN 13242	*Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction -- Αδρανή υλικών σταθεροποιημένων με υδραυλικές κονίες ή μη σταθεροποιημένων για χρήση στα τεχνικά έργα και την οδοποιία*

ELOT EN ISO 13500	*Petroleum and natural gas industries - Drilling fluid materials - Specifications and tests -- Βιομηχανίες πετρελαίου και φυσικού αερίου - Ρευστά υλικά εξόρυξης - Προδιαγραφές και δοκιμές*
ELOT EN ISO 22282-1	*Geotechnical investigation and testing - Geohydraulic testing - Part 1: General rules -- Γεωτεχνικές έρευνες και δοκιμές - Δοκιμές διαπερατότητας - Μέρος 1: Γενικοί κανόνες*
ELOT EN ISO 22282-2	*Geotechnical investigation and testing - Geohydraulic testing - Part 2: Water permeability tests in a borehole using open systems Γεωτεχνικές έρευνες και δοκιμές - Δοκιμές διαπερατότητας - Μέρος 2: Δοκιμές υδατοπερατότητας σε γεώτρηση με ανοιχτό σύστημα*
ELOT EN ISO 22282-3	*Geotechnical investigation and testing - Geohydraulic testing - Part 3: Water pressure tests in rock -- Γεωτεχνικές έρευνες και δοκιμές - Δοκιμές διαπερατότητας - Μέρος 3: Δοκιμές πίεσης νερού σε βράχους*
ELOT EN ISO 22282-4	*Geotechnical investigation and testing - Geohydraulic testing - Part 4: Pumping tests -- Γεωτεχνικές έρευνες και δοκιμές - Δοκιμές διαπερατότητας - Μέρος 4: Δοκιμές άντλησης*
ELOT EN ISO 22282-5	*Geotechnical investigation and testing - Geohydraulic testing - Part 5: Infiltrometer tests -- Γεωτεχνικές έρευνες και δοκιμές - Δοκιμές διαπερατότητας - Μέρος 5: Δοκιμές διήθησης*
ELOT EN ISO 22282-6	*Geotechnical investigation and testing - Geohydraulic testing - Part 6: Water permeability tests in a borehole using closed systems -- Γεωτεχνικές έρευνες και δοκιμές - Δοκιμές διαπερατότητας - Μέρος 6: Δοκιμές υδατοπερατότητας σε γεώτρηση με κλειστό σύστημα*

3 Terms and definitions

The following terms and definitions are used in this Technical Specification:

3.1 Soil and rock grouting

Means the process by which a fluid material is injected into the geomaterial with simultaneous control and regulation of flow characteristics and intrusion parameters (pressure, volume and flow rate). This process is analysed in the standard ELOT EN 12715.

3.2 Void fill grouting

Grouting is carried out in order to fill major voids within the geomaterial.

3.3 Condensation grouting

Grouting of geomaterial displacement, in order to condense it without causing hydraulic fracture.

3.4 Contact grouting

Grouting into the interface between construction and geomaterial.

3.5 Displacement grouting

Grouting is carried out, while grouting is infiltrated into the geomaterial, causing its deformation, compression, even though its own full displacement.

3.6 Fissure grouting

Grouting into existing cracks, divisions and discontinuities of the geomaterial (rock mass).

3.7 Gravity grouting

Injection grouting (tremie grouting), i.e. without applying additional pressure, in addition to the pressure head of the fluid of the grouting.

3.8 Permeation grouting

Grouting into rock-mass gaps or cracks or into void soil mass resources, without displacement of the corresponding geomaterial. The term includes sealing grouting, fissure filling grouting and contact grouting.

3.9 Grout

Material (suspension, solution, emulsion or mortar) which is ingested into the geomaterial and over time occurs its deposition, coagulation and hardening.

3.10 Grouting pressure

The pressure exerted during the grouting process and measured at specified positions (usually at the pump opening or at the beginning of the drilling).

3.11 Hydraulic fracture

Fracture of the geomaterial, which is caused by the injection of water or grout due to the excess of its local tensile strength and the current stress of the hole.

4 Requirements

4.1 General requirements for planning work during the Study phase

The application of geomaterials is carried out in accordance with a special study, based on those laid down in ELOT EN 12715, which must take into account the following:

(1) The prevailing conditions in the area where the grouting are carried out, i.e. terrain (topographical mapping) and accessibility to the application sites.

(2) The findings of the geotechnical investigation

(3) The existence of structures in the nearest area of execution of grouts (e.g. buildings, roads, civil works utilities) that can suffer stress or damage.

(4) Any underground pollution and/or other factors that may affect the method of implementation or the safety of the surrounding area.

(5) The existence of obstacles which require the application of specific techniques for drilling and performing grouting (i.e. the use of special equipment).

(6) Simultaneous or subsequent activities which may affect enclosure operations (e.g. groundwater drainage, groundwater recharging, underground excavations, open deep excavations, etc.)

(7) Procedures and criteria for the confirmation, control and acceptance of emulsion work.

(8) Data from the grouting procedure under similar conditions.

4.2 Geotechnical Investigation Requirements at the Study Phase

4.2.1 General

The execution of geotechnical surveys must comply with the general requirements and principles set out in Eurocode 7 (ELOT EN 1997-1).

The main objectives of geotechnical investigation are:

a) the control of the “groutability” of the soil; and

b) the identification of the appropriate types of grout for the specific application.

Particular attention should be paid to the following conditions and geotechnical properties of the grouting area:

(1) The physical and chemical characteristics of geomaterials.

(2) The presence of any uneven or permeable surfaces, which may affect the grouting work.

(3) The orientation, frequency and width of the discontinuities of rock formations, as well as the composition and nature of their filling geomaterials.

(4) The location and nature of filled or void hollows.

(5) The presence and characteristics of geomaterials, the behaviour of which may be influenced by drilling or embroidery operations with the possible occurrence of phenomena of relaxation, instability, collapse of structure or swelling.

(6) Changes with the time of groundwater level (if any).

(7) The existence of layers within which it is possible to develop an underground flow regime with large hydraulic gradients.

(8) The chemical composition, organic and bacteriological content of groundwater or geomaterials, if problems are expected.

Particular attention should be paid when investigating zones characterised either by conditions of pollution or contamination of geomaterials or by high trends.

When organic clots (GELs) are intended to be carried out, a bacteriological examination of the geomaterial and groundwater injected is required.

The following information must be systematically recorded when performing the required drilling:

i. Location and cause of loss of the grout.

ii. Instability zones and stabilisation measures taken.

iii. Areas of water loss and inflows, measurements of the water returned, the color of the water and its possible changes.

iv. Characteristics of the movement of the piercing strains (i.e. spasmodic, sharp, layered, steady movement).

v. Recording of drilling parameters in the case of “destructive” drilling.

4.2.2 Permeability tests

The permeability of geomaterials may be determined:

a) by on-site permeability tests or large-scale pumping tests;

b) by laboratory testing on representative samples;

c) indirectly through particle gradient and geomaterial density.

It is recommended that each research hole in rock be identified through appropriate tests, water absorption as well as aquifer zones and possible bulks. The above tests may be carried out either during the opening of the hole or by the use of gaskets after the drilling has been completed.

These tests shall be carried out in accordance with ELOT EN ISO 22282-1, ELOT EN ISO 22282-2, ELOT EN ISO 22282-3, ELOT EN ISO 22282-4, ELOT EN ISO 22282-5 and ELOT EN ISO 22282-6.

Particular attention shall be paid to the existence of Artesian aquifers before the permeability tests are carried out.

By performing Lugeon tests on rock, an overview of its water permeability can be obtained, but it is not possible to establish a reliable correlation with the absorption potential of a particular grout.

4.2.3 Performance of grouting tests

The execution of grouting tests is aimed at establishing or confirming the principles of a method of grouting. These tests are part of the initial geotechnical investigation and must be carried out when initial surveys and local relevant experience cannot adequately support/justify the effectiveness of this grouting method.

These tests determine the distance of the boreholes, the applied emitting pressure, but also the type and quantity of the grout. Alternatively, they can be performed during the study phase or even at the beginning of the relevant work. Decisions on how to carry out test injections must be taken in cooperation with the Geotechnical Designer with the Competent Authority.

Indications of the prevailing conditions in the area of application of the injections may also be obtained by appropriate laboratory tests for filtration of grouting tests on mixed samples of the geomaterials of that area.

The permeability measurements before and after the insertion of the above samples may provide information which facilitates decisions on the nozzle of the grouting holes, the properties of the mixture used and the required volume of the grouting.

4.3 General requirements for preparation materials for grouting

Cement, water, bentonite, natural clays, additives, admixtures (e.g. fly ash) and aggregates of various grades (sand, gravel) shall be used for the manufacture of all grouting types (suspensions, natural clays, additives, fly ash) and aggregates of various grades (sand, gravel) in the appropriate proportions to ensure the characteristics of the mixture provided for in the Study (see paragraph 4.2 above).

Cement, fly ash and aggregates must meet the requirements of harmonised standards ELOT EN 197-1, ELOT EN 450-1, ELOT EN 13139 (sand) and ELOT EN 13242 (steals), respectively, and mandatory:

a) bear the CE marking;

b) be accompanied by a declaration of performance under Delegated Regulation (EU) No 574/2014 (OJ EEL159/41/28.05.2014) and a safety data sheet in accordance with the provisions of Regulation (EC) No 1907/2006, where necessary.

In addition, cement and fly ash must be accompanied by a certificate of constancy of performance while aggregates (see Bibliography [10]) must be accompanied by a certificate of conformity of factory production control. These certificates shall be issued by a body notified in the EU and presented at the request of the Competent Authority.

4.4 More specific requirements for mortar preparation materials

4.4.1 Hydraulic binders

Hydraulic binders are cement and other hydraulic mortars (fly ashes, pozzolanes, etc.) mixed with fine grained aggregates form the basis of aqueous suspension.

The mortar produced must be fine grained with a grain size d_{95} < 20 mm and the particle size of the aggregates shall be selected according to the dimensions of the existing cracks or gaps of the geomaterial being implanted.

4.4.2 Clay materials

The addition of natural clays and activated bentonites to concretes aims to reduce their penetration under pressure, change their viscosity or improve their pumpability. The suitability of materials in this category to be added to cement depends on their mineralogical composition and physical characteristics (e.g. natural moisture and Atterberg limits).

When there is an increased underground flow, it is possible to use bentonite activated or not in the form of suspension, water-bentonite, in the cement-water injection.

The bentonite used in cement grouts must be accompanied by a test report from a specialised laboratory in accordance with ELOT EN ISO 13500.

The water content of bentonite must be greater than 350 % (average of three tests).

It is also possible to add to the cement-water liquidators, plasticisers, etc., additives.

4.4.3 Sands, gravel

Sands and gravel are commonly used in cements or bentonic suspensions to change their mechanical strength and deformability.

The incorporation of natural sands or carpets as additional materials to the injections may be provided that they do not contain components harmful to the mixture and that their particle size meets the composition requirements of the grout.

4.4.4 Water

Water from natural sources on site must be checked in particular for its content of chlorates, sulphates and organic ingredients, in accordance with the requirements of ELOT EN 1008.

The use of seawater is not excluded as long as the properties of the injection used are not altered and as long as it is approved by the competent authority.

4.4.5 Chemicals and contaminants

The incorporation of reactive chemicals (e.g. acrylic or epoxy resins, polyurethanes, etc.) into the composition of injections requires documentation of their compatibility with the applicable environmental legislation.

The addition of organic or inorganic impurities in small quantities during the mixing process is intended to regulate the properties of the grout (e.g. viscosity, coagulation time, strength, consistency, etc.) and its penetrability.

It is possible to add calcite and silicate materials, pulverised fuel ash, pozzolans and fly ash as components if they are chemically compatible with each other and meet environmental requirements.

Fly ash must generally meet the requirements of ELOT EN 450-1.

In Greece it comes from the thermal power stations of Megalopolis and Ptolemaida and is calcareous. Since the production of these stations is not stable and there is so far no Greek or European standard for these materials, only the National Technical Specification “Greek Fly Ashes” approved by Decision No. DIPAD/οικ. 281/Φ200 (Government Gazette, 551/B/18-4-2007), it is necessary to ensure a sufficient quantity of ash from the same production plant with stable characteristics during the preparation of construction. Fly ash does not have to be processed; on the contrary, the aim must be to have as much free CaO as possible, which is the most active ingredient in stabilising clay soil materials.

4.5 Requirements for grouts

4.5.1 Grouting types and their characteristics

(a) Solid particle suspensions and colloidal suspensions

Suspensions are characterised by:

- the particle gradient of solid particles
- the ratio of water/solid particles
- the rate of sedimentation
- water retention capacity
- their rheological properties and their general behaviour over time.

The determination of the particle gradient of solid particles in fine suspensions shall be done by means of appropriate high-precision instruments.

The flocculation tendency of suspended solids (especially in fine suspensions) must be taken into account. Colloidal clay suspensions before embedding must undergo a decidification treatment of clay particles.

In addition, the tendency of suspended solid particles to settle due to gravity must be considered in relation to the nature and properties of the geomaterial being embedded.

Silicate groutings should be used after careful assessment of their behaviour over time. Account must also be taken of the effect of temperature variations in their production and application on their behaviour.

Please note that implantations of geomaterials with organic silicate gels may have adverse environmental effects (e.g. spread of bacteria within geomaterials).

(b) Mortars

Mortars which are characterised by high internal friction are used in condensation or void fill groutings.

The workability of mortars must be determined by seating tests on flow cones (Table in Annex C to ELOT Standard EN 12715, see also Annex B hereto).

The introduction of gravitational mortars is applied to fill cavities, large and open cracks as well as gaps in granular soils.

In particular, in mortars used in condensation injections, the minimum percentage of fine grains passing a 0.1 mm sieve shall be 15 %.

(c) Resin grouting

In order to be implemented it is necessary to pay particular attention to the following:

(1) The toxicity of the resin components of the groutings.

(2) The risk of dissolving the grouting in groundwater, which may lead to an elongation of the clotting time or even to the non-occurrence of the chemical reaction.

(3) The toxicity of substances that may enter the underground aquifer if the chemical reaction is not carried out successfully.

The uses of the different types of resin injections are summarised in Table 1 below:

Table 1 – Uses of resin injections

Resin type	Terrain type	Use/Application
Acrylic	granular soil fine-cracked rock	Permeability reduction Improving endurance
Polyurethane	major voids	Creating foam to prevent water inflow Stabilisation or filling of local voids (two-component resins)
Phenolic	fine sand and gravel	Tightening of structure
Epoxy	cracked rock	Improving endurance Permeability reduction

4.5.2 Selection factors for grouting type

In order to select a grout, the following basic properties should be considered:

a) rheology (viscosity, consistency, etc.), coagulation time

b) particle size (where applicable)

c) strength and durability

d) toxicity.

The main parameters defining the properties of pre- and post-coagulation injections are presented in the following Table 2:

Table 2: Parameters characterising the properties of injections

(Table B.2 of ELOT EN 12715:2021)

	Solutions	Suspensions	Mortars
Before the coagulation	Coagulation time, density, pH, tensile surface tension, coagulation time, viscosity, consistency, thixotropy	Coagulation time, density, pH, particle gradient, viscosity, cohesion, leakage, thixotropy, water retention capacity	Coagulation time, density, pH, particle gradient, viscosity, workability, water retention capacity
After the coagulation	Post-coagulation hardening, final strength, pH, deformability, durability, systolicity, dilativity, shear strength, aggregation (silica solutions)	Hardening time, final strength, deformability, durability, systolicity, expansion, density, shear strength	Hardening time, endurance, deformability, durability, systolicity, dilativity

4.5.3 Scope of different types of injections

Compatibility between all used components of the grout and the interaction of grout and soil are important factors for successful integration.

Table 3 provides indicative information on the suitability of grouts for different types of geomaterials.

Table 3 – Indicative types of grout for different types of geomaterials

Geomaterial/ Conditions under application	Scope of application	Grouting without displacement			Grouting with displacement
		Sealing	Fissure or contact grouting	Void fill grouting	
Granular soil	Gravel, coarse sands and gravel $K>5 \times 10^{-3}$ m/s	Suspensions of pure cement (mainly cement)			
	Sands $5 \times 10^{-5}<K<5 \times 10^{-3}$ m/s	Very fine suspensions, solutions			Cement suspensions, mortar
	Medium to fine-grained sands $5 \times 10^{-6}<K<1 \times 10^{-4}$ m/s	Very fine suspensions, solutions, special chemicals			
Cracked rock	Faults, cracks, karst forms e > 100 mm		Mortars with a main component of cement, suspensions whose main component is cement	Mortars, cement suspensions with short coagulation time. Expanded polyurethanes. Products that react with water.	
	Cracks, divisions 0.1 mm < e < 100 mm		Cement-based suspensions, Fine-grained suspensions		
	Small cracks e < 0.1mm		Very fine-grained suspensions, Silica gels, Specific chemicals		
Hollows	Major voids			Mortars, cement suspensions with short coagulation time. Expanded polyurethanes. Products that react with water	

(e = crack width)

4.5.4 Requirements for checking grouting

In order to determine the degree of success of the injections, appropriate control tests should be carried out as soon as possible, so as to allow immediate corrective action to be taken if deviations from the forecasts of the study are detected.

The characteristics of the grouts must be tested at an ambient temperature of 20 °C. However, if the temperature conditions of the area of application of the grouts differ significantly from those of the laboratory, field tests shall also be carried out during which any changes in temperature must be recorded.

The table in Annex C to ELOT standard EN 12715 summarises the testing methods of the most important parameters of all types of injections (see Anne B to this Decision).

The grouting control tests depend on the type of grouts and the purpose they serve and include permeability tests, on-site and laboratory tests to determine the mechanical characteristics of the implanted geomaterials, test excavations, etc.

The data recorded during drilling can be used to check that the objectives of the integration work have been met.

4.6 Measurement and recording requirements

Manifest territorial movements and/or movements of adjacent structures must be accurately recorded with the installation of the instruments provided for in the Study in order to determine in a timely manner whether such movements exceed the tolerable limits laid down in the study.

Specific computer-connected recording systems shall be used for:

a) The monitoring of the perforations of the insertion holes, which includes measurements, controls and interpretation of the drilling parameters.

b) Measurements and controls of the embedding parameters for the different types of grouts, which are infused at each stage of the work.

In particular, the following parameters may be recorded automatically during the drilling of the insertion holes:

1) The rate of penetration
2) Pressure and flow of liquids
3) The reflected energy (in case of impact drilling)
4) The rotation speed
5) The applied torque
6) The exercised force
7) The length of the drilling

The evaluation of the above records provides useful information in relation to possible alternations of geological and geotechnical conditions.

The following documents must be drawn up and kept at the construction site:

1) Daily recording of observations regarding to perforation and grouting
2) Monthly recording showing daily progress and grout consumption
3) Final report – reference with the necessary technical and quantitative details to be signed by the responsible engineer of the construction site and representative of the competent authority
4) A report after completion of the works, in which the Contractor and the Competent Authority confirm in signature the achievement of the criteria for acceptance of the works, as predetermined according to the Study.

All the above-mentioned documents are considered to be essential elements of the implementation work.

5 Methodology for the execution of works

5.1 Equipment

The grouting execution must be carried out by qualified and experienced staff.

For the execution of geomaterial grouts, the following equipment is necessary:

(1) Drilling and piling equipment
(2) Mixing and stirring equipment.
(3) Pumping equipment

(4) Grouting piping

(5) Gaskets

(6) Equipment for recording and checking the properties of grouting.

In particular, it should be noted that grouting equipment must safely withstand the maximum expected grouting pressure.

The maintenance of the above-mentioned equipment during the grouting work must be carried out by qualified and experienced staff.

5.2 Perforation of grouting hole

The opening of the grouting holes may be carried out by:

- rotary drilling
- percussion (whether or not lined)
- drilling accessories such as drills, grabs, etc.

Successful drilling of holes in unstable geomaterials requires the support of their walls using:

- supporting perforating fluids (e.g. bentonite, water, foams, etc.)
- temporary tubing
- techniques for progressively supporting the walls of holes during drilling.

Drilling below the surface of the subterranean aquifer (with or without artesianism) shall be made by maintaining an opposite constant overpressure of water or other supporting perforation fluid.

The choice of drilling techniques of the holes must be made on the basis of not preventing the subsequent application of grouts (especially with regard to possible changes in the initial permeability of the geomaterials at the point of application).

The opening of new holes is necessary to replace those which have been blocked and those with unacceptable geometrical deviations from their intended positions.

Rock insert holes must be washed immediately after opening to remove debris and other loose materials, but also to further loosen the existing cracks and breaks, provided that the rock mass in question cannot be adversely affected by this process.

5.3 Manufacture of grout

The components of grouts must be stored in such a way that they are adequately protected from weather conditions (especially from temperature and humidity), but also from possible pollution.

The storage of prepared grouts in tanks must ensure that their rheological and other properties are not significantly different.

Measurement of doses of component materials of grouts shall be carried out by calibrated dosing devices according to the prescribed ratios and within the limits of their tolerances.

The mixers used must ensure that the final mixture is as homogeneous as possible.

For the uninterrupted delivery of grouts with solid suspended particles and to avoid separation and/or premature coagulation, a stirring tank is required, located between the mixing tanks and the pump assembly.

Grouts with a minimum coagulation time shall be mixed as close as possible to the point of inhalation.

It is recommended that the pumps have the following characteristics:

(1) adjustable supply of the grout

(2) Adjustable pressure rate of the grout

(3) easy cleaning and maintenance

(4) adjustment of the valves according to the viscosity of the inhaled injection.

The injection pressure within the geomaterials shall be measured as close as possible to the injection point.

It should be noted that the injection systems used must be able to smooth changes in the pressures imposed, thereby reducing the risk of undesirable and incomprehensible hydraulic breakages of geomaterials.

Injection pipes shall withstand the maximum expected application pressure with an adequate safety factor.

The inside of the injection tubes should be cleaned at the end of each injection phase.

Stirring the suspensions is necessary until they are injected into the geomaterials in order to avoid sedimentation.

5.4 Injection of the grout

The main methods of channelling the grouts are the following:

(1) Intrusion into holes into stable geomaterials with unsupportable walls.

(2) Intrusion into temporarily tubular holes, which have been drilled into unstable geomaterials.

(3) Injecting through an appropriate device of the drilling hole. This phase is generally considered as pre-consolidation and may be followed by methods (1) or (2).

(4) Intrusion through a tubing recovered in ascending steps.

The ways in which geologic applications are carried out are summarised in Table 4. The concept of step is defined as the predetermined injection length of the injection, the two limits of which are determined either by using two gaskets in specific (each time) positions, or by using a gasket continuously moving from the bottom of the hole to its orifice.

Table 4 – Methods for applying geomaterials

	ROCK			SOIL		
	Stable	Unstable				
	Open hole		Valve tube	Perforation Staff	Valve tube	Stem or tubing
Single step	X			X	X		X
Multiple steps			X			X	
Ascending steps	X		X	X	X	X	X
Descending steps		X	X			X	X

Soil material injections can be achieved by means of pipes, mounting liquids and valve tubes.

Valve tubes, the valves of which are “sealed” into the ground using a supporting liquid (e.g. bentonic suspension), allow repeated injection of injection due to the low strength of the created filter layer at the interface between the pipes and the walls of the holes.

When emitting soil materials, water can also be applied through the adjacent valve tubes to prevent leakage of the grout.

Large openings (vacuums, openings, etc.) can be filled with grouts, either directly or through a pipe extending until the end of them.

Gaskets must be used to isolate each injection step. The gaskets may be passive, mechanical, pneumatic and must be long enough to avoid bypassing the grout through the geomaterial being implanted. In addition, the gaskets shall ensure an absolute “sealing” between the walls of the hole and the injection tube when applying the maximum injection pressure.

The maximum step of the grafting on a rock must not exceed 10 m. However, under conditions of severely fragmented and disturbed rock mass, the above-mentioned length must be adjusted appropriately. The maximum impregnation step in earth materials shall not exceed 1.0 m.

During injections under underground flow conditions, measures shall be taken to prevent dilution or total loss of the grout. These measures depend on the geomaterial being applied, the purpose of the embedding and the provision of the underground flow and are:

(1) The use of a grout with very short coagulation time (such as resins reacting with water, or cements with sodium silicate).

(2) The use of large viscosity grout.

(3) The use of additives to limit the dilution of the grout.

The pressure, volume and injection supply of the injections shall be regulated during grouts to avoid unwanted movements and deformations of the geomaterial being implanted, unless this is the pursuit of the whole process. It should be noted that particular attention should be paid to areas in the vicinity of vulnerable structures.

The supply of the grout used when performing multi-step sealing is dependent on its viscosity and the lengths of the application steps.

5.5 Sequencing of grouts

The general grouting planning a continuous process, throughout which systematic monitoring is required. Possible decisions related to changes in the method or parameters of the applied grouts, as well as the continuation or termination of grouts, should be taken jointly with the Competent Authority.

Grouts in descending steps are usually used to improve unstable rocking and, if performed in descending steps through different holes, the upper stage in all holes should be injected before the next (lower) stage is perforated and injected into all adjacent holes.

Grouts in ascending steps are applied only to open holes in fixed rock or when the target is condensation.

Multi-stage grouts using valve tubes are commonly used on earthy soils and sometimes in unstable rocks.

The application of grouts using the method of gradual densification of the distance between the grouting holes is summarised as follows:

1) Firstly, the primary holes are opened and implanted.
2) The secondary holes are then opened and implanted between the primary holes.
3) The densification of the network of the above-mentioned insertion holes may include openings and grouts of tertiary or quaternary holes.

This method may be applied:

a) to ensure uniform integration of a zone;

b) in order to establish, on the basis of experience gained, zones which require close-ordered holes for their successful integration.

When a hole is classified as primary, it must also be an exploratory grout hole. Primary is defined as holes opened outside areas where injection tests have been preceded.

In order to limit lateral diffusion of the grout, outside the boundaries of the predetermined enclosure area, inhalations shall start at the perimeter of the zone under remediation and proceed progressively to its interior. However, this procedure should not be applied where there is a risk of the groundwater being trapped or if the purpose of the operations concerned is to extract the water from the enclosure zone.

6 Criteria for accepting completed works

Compliance with the construction methodology described above is essential for the successful integration of geomaterials. This requires systematic supervision of the work at all stages of its execution in order to take any necessary corrective measures immediately.

Acceptance of completed operations requires full verification of the data of the records referred to in paragraph 4.6 of this Decision.

7 Method of measurement of works

7.1 Hole drilling

The measurement of the opening of grouting holes is done in meters of hole length that were perforated and accepted according to the terms of this and the Study.

The measurement is distinguished according to the diameter of the hole and/or by grading the length.

Account shall be taken of the diameter of the hole provided for in the Study for its entire length, irrespective of any intermediate enlargements required to achieve the ultimately desired diameter.

The above-mentioned measured units of works include:

(1) The supply of all necessary materials (water or other perforated liquid), micromaterials and consumables

(2) Transport from any distance and temporary storage

(3) Wear and deterioration of materials and depreciation and stoppage of equipment

(4) The provision of the necessary personnel and equipment for drilling holes

(5) The fitting and extraction of piping that may be required during drilling

(6) Cleaning and rinsing of the hole

(7) Loading and unloading, transportation at any distance, paving of drilling products

(8) Carrying out all required tests, checks and records in accordance with this Specification, as well as taking corrective measures (work and materials), if non-conformities are detected, during tests and checks.

The remaining line in the hole following a special order from the Competent Authority, or when provided for in the Study, shall be measured in particular in kilograms.

7.2 Grouting with or without displacement of the geomaterial

The measurement of grouting with or without geomaterial displacement shall be carried out in cubic meters of grout, which was injected and accepted in accordance with the terms of this Technical Specification, with distinction according to the pressure applied, according to the provisions of the Contractual Issues of the Project. (e.g. a pressure of less than 5 MPa, a pressure of 5 to 20 MPa and a pressure greater than 20 MPa).

The above-mentioned measured units of works include:

(1) The supply of water, various other micromaterials and consumables

(2) Transport from any distance and temporary storage

(3) The transport from any distance and temporary storage of all necessary materials for the composition of the cement

(4) Wear and deterioration of materials and depreciation and stoppage of equipment

(5) The provision of the necessary personnel and equipment for mixing, transporting and injecting the grout

(6) The connection of the grout line to the holes to perform the grouting

(7) The caulking and sealing of the cracks from which it leaks

(8) The removal of the pipes of the orifices from the insertion holes, the control and discharge of unclean water and waste grout

(9) Carrying out the required tests, checks and records in accordance with this Law, as well as taking corrective measures (work and materials), if non-conformities are found, during the tests and checks.

All components in the production of the injection except water and admixtures shall be measured in particular by species, according to the approved mixing ratios, on the basis of the acceptable amount of perfusion.

The permeability tests and test injections referred to in this Technical Specification shall be measured in particular, in accordance with the provisions of the Contractual Issues of the Project.

Annex A
(informative**)**

Health, safety and protection of the environment

A.1 General

During the execution of the works, the applicable provisions on Occupational Health and Safety Measures shall be met and employees shall be equipped with the necessary Personal Protective Equipment (PPE), as appropriate, which must comply with the provisions of Regulation (EU) 2016/425.

The requirements laid down in the approved SAF/FAY of the project must also be strictly observed, in accordance with the Ministerial Decisions SGDE/DIPAD/οικ/889 (Government Gazette, Series II, No 16/14-01-2003) and the SGPR/DIPAD/οικ/177 (Government Gazette, Series II, No 266/14-01-2001).

A.2 Hazard sources in the execution of works

(1) Powders of powdered chemicals that are toxic to the skin, eyes or respiratory system

(2) Vapours released from liquid mixtures of grouts

(3) Components of grouts or grouts that are harmful to skin contact

(4) Groundwater contamination

(5) Mixing chemicals that can cause an explosion

(6) Disposal of waste or waste water

(7) Transport, deposition and handling of materials, where all procedures for the use of lifting machines apply.

(8) Perform the drilling with the drilling rig.

(9) Process of cementing and injecting through the flexible pipes.

(10) Possible movements of soil and adjacent structures

(11) Changes in the groundwater level

(12) Spread of the grout

(13) Risk of transporting heavy objects.

(14) Working in noise conditions.

A.3 Health and safety measures

It is mandatory to comply with Directive 92/57/EU, which refers to the “Minimum Health and Safety Requirements for Temporary and Mobile Works” (as transposed into Greek legislation by Presidential Decree 305/96) and with the Greek Health and Safety Legislation (Presidential Decree 17/96 and Presidential Decree 159/99, etc.).

The work requires the use of heavy equipment and electro-tools or compressed air tools. This equipment will only be handled by an experienced licensed crane.

When chemicals are used, the use of protective measures is required, as appropriate, by the personnel performing the works, as specified in the Material Safety Data Sheet of the respective material producer.

Workers must in all cases be equipped with the required personal protective equipment (PPE), depending on the object and location of the work to be carried out and the type of equipment used. The PPE must be in good condition, free of damage, bear a CE marking and a declaration of conformity in accordance with the provisions of Regulation (EU) 2016/425 and fall under the following Standards:

Table A.1 — Requirements for PPE

Type of PPE	**Relevant Standard**
Breathing protection – Full face masks – Requirements, testing, marking	ELOT EN 136
Breathing protection – Gas filters and combination filters – Requirements, testing, marking	ELOT EN 140
Breathing protection – Particulate filters – Requirements, testing, marking	ELOT EN 143
Respiratory protective devices – Filtering half masks to protect against particles — Requirements, testing, marking	ELOT EN 149
Protective gloves against mechanical risks	ELOT EN 388
Industrial safety helmets	ELOT EN 397
Hearing protectors – General requirements – Part 1: Earplugs	ELOT EN 352-1:
Hearing protectors – General requirements – Part 2: Ear plugs	ELOT EN 352-2:
Hearing protectors – General requirements – Part 3: Earplugs attached to head and/or face protection devices	ELOT EN 352-3:
Hearing protectors – Safety requirements – Part 4: Noise-dependent earplugs with attenuation	ELOT EN 352-4:
Breathing protection – Valve filters for protection against gases or particulates – Requirements, testing, marking	ELOT EN 405
Protective clothing – General requirements	ELOT EN ISO 13688
Personal protective equipment – Safety footwear	ELOT EN ISO 20345
Protective clothing – Guidelines for selection, use, care and maintenance of chemical protective clothing	CEN/TR 15419

All individual mechanical devices shall comply with applicable Machine Safety Standards

Specific requirements of the transport equipment of the fluids used due to the development of high pressures.

Management and removal of outgoing waste materials and avoiding pollution of the environment.

Drilling rigs shall meet the requirements of ELOT Standard EN 791.

The provisions in force, as amended and adapted to technical progress, will apply to the management of all materials used.

Please note that for all implantation operations and during their execution staff must wear protective clothing and gloves, as most chemical grouts contain some ingredients, which are toxic to the skin. In addition, face masks should be available for workers working in closed areas where vapours from the grouts or dust from the components of the injections can be inhaled. Protective helmets must be available for all construction site workers. Safety glasses must be available for all workers in areas where injections are carried out. It is stressed that large pieces of epoxy or polyester resins often produce significant amounts of heat and should therefore be handled with caution.

Annex B
(informative)
Indicative types of injections for different types of geomaterials

Table B.1 — Indicative grouts for different types of ground

Host medium	**Range**	**Non-displacement grouting**			**Displacement Grouting**
		Permeation	**Rock or contact grouting**	**Bulk filling**	**Compaction, fracture and compensation grouting**
Granular soil	Gravel, coarse sand and sandy gravel	Pure cement suspension, Cement based suspensions	n/a	n/a	Cement based grouts, Mortar
	Coarse to medium sand	Microfine or ultrafine suspensions, Silicate gels	n/a	n/a	Cement based grouts, Mortar
	Fine sand	Silicate gels Special chemicals	n/a	n/a	Cement based grouts, Mortar
Fissured/ jointed rock	Faults, cracks, joints, voids or channels with openings e > 50 mm	n/a	Cement based mortars, Cement based suspensions (clay filler), polyurethane grouts	Mortars, Cement based Suspensions Polyurethane grouts	n/a
	Fissures/joints 1 mm < e < 50 mm	n/a	Cement and fine cement-based suspensions	n/a	Cement and fine cement-based suspensions
	Fissures/joints 0,1 mm < e < 1 mm	n/a	Fine and microfine cement-based suspensions	n/a	Cement and fine cement-based suspensions
	Micro fissures/joints e < 0,1 mm	n/a	Microfine/ultrafine suspensions Silicate gels, Special chemical grouts	n/a	Cement and fine cement-based suspensions
Cavity	Large voids or karst features	n/a	n/a	Cement based mortars Cement based, suspensions with short setting time Expansive polyurethane, Other water reactive products	n/a
NOTE e = fissure aperture (mm)					

Measurements of grout parameters according to Table C.1 of ELOT EN 12715:2021

	Parameter	Unit	Measuring apparatus/method	Applicable standard	Application	Chemical grout	Cement suspension	Mortar	Remarks
1	Density	[g/cm3]	Mud Balance	EN ISO 10414-1	Lab and site	N	A	N	
		[g/cm3]	Pycnometer and scale	N/A	Lab	A	A	N	
		[g/cm3]	Hydrometer (suitable graduation)	N/A	Lab and site	A	N	N	
2	Marsh Apparent Viscosity	[s/l] [s/qt]	Marsh funnel (standard, orifice diameter = 4,75 mm)	EN ISO 10414-1	Lab and site	N	A	N	*see R1-R2*
3	Modified Marsh Apparent Viscosity	[s/l] [s/qt]	Modified Marsh funnel, other nozzles (orifice diameter = 8, 10, 12 mm)	N/A	lab and site	N	A	N	*see R1-R2*
4	Flow Cone (Apparent viscosity)	[s]	Flow Cone (orifice 12,75mm)	ASTM C939	Lab and site	N	N	A	*see R1-R3*
5	Viscosity (apparent and plastic)	[cP = mPa*s]	Coaxial viscometer (Rheometers)	EN ISO 10414-1	Lab	A	A	N/A	*see R1 and R4*
6	Cohesion (Yield point, Yield stress)	[Pa]	Rheometer (direct indicating viscometer, coaxial viscometer)	EN ISO 10414-1	Lab	A	A	N	*see R1 and R4*
		[mm]	Cohesion Plate or equivalent Vane Shear Test	N/A	Lab and site				*see R1 and R5*
7	Bleeding rate (Sedimentation rate)	[%]	Graduated transparent cylinder	N/A	Lab and site	N	A	A	*see R6*
8	Stability under pressure (Water retention capacity)	[kpf = min-0,5]	Filter press (low pressure)	EN ISO 10414-1	Lab and site	N/A	A	A	*see R7*
9	Consistency (slump)	[mm]	Slump cone test set (Abrams cone)	EN 12350-2	Lab and site	N	N	A	*see R8*

	Parameter	Unit	Measuring apparatus/method	Applicable standard	Application	Chemical grout	Cement suspension	Mortar	Remarks
10	Setting time	[hr/min/s]	Overturned glass beaker	N/A	Lab and site	A	A	N	*see R9*
			Gel-meter	N/A	Lab	A	A	N	
			Vicat or Gillmore apparatus	N/A	Lab	N	A	N	
11	Mechanical Resistance	[hr/min/s]	Vane test, Unconfined compression test, Triaxial Compression Test	N/A	Lab	A	A	A	*see R10*
12	Durability	N/A	Pin-hole test, permeability test vs. time, Chemical analysis	N/A	Lab	A	A	A	*see R11*
13	Filtration Stability	mm	Suction filtration device, etc.	EN 14497	Lab	N	A	N	*see R12*

N/A = Not Available

N = Not applicable/not generally used

A = Applicable

Bibliography

[1] Law 1568/85 (Government Gazette, No. 177A/18.10.85), *"On the health and safety of workers".*

[2] Presidential Decree 17/96 (Government Gazette, No. 11A/96*), "Implementation of measures to promote improvements in the health and safety of workers" in compliance with Directive 89/391/EEC and 91/383/EEC, as amended by Presidential Decree 159/99*

[3] Presidential Decree 105/95 (Government Gazette, No. 67A/95*), "Minimum requirements for safety and/or health marking at work, in compliance with Directive 92/58/EEC".*

[4] Presidential Decree 305/96 (Government Gazette, No 212/29.8.96), *"Minimum safety and health requirements to be applied to temporary or mobile construction sites, in compliance with Directive 92/57/EEC", in conjunction with Circular No 130159/7.5.97 of the Ministry of Labour and Circular No 11 (Protocol No. Δ16α/165/10/258/ΑΦ/ 19.5.97) of the Ministry of the Environment, Public Works and Public Works, concerning the above Presidential Decree*

[5] Presidential Decree 338/2001 (Government Gazette, No. 227/A/2001), *Protection of workers' health and safety at work from risks arising from chemical agents.*

[6] Presidential Decree 396/94 (Government Gazette, No. 220A/94), *"Minimum safety and health requirements for the use by workers of personal protective equipment at work, in compliance with Directive 89/656/EEC"*

[7] Presidential Decree 397/94 (Government Gazette, No. 221/A/94), *Minimum safety and health requirements for the manual handling of loads involving a risk in particular to the back and back of workers in compliance with Council Directive 90/269/EEC.*

[8] Regulation (EU) 2016/425 *of the European Parliament and of the Council of 9 March 2016 on personal protective equipment and repealing Council Directive 89/686/EEC.*

[9] National Technical Specification "Greek Fly Ashes" (Decision No. ΔΙΠΑΔ/οικ. 281/Φ200. Government Gazette, No. 551/B/18-4-2007)

[10] Ministerial Decision 269357/1-9-2022 *Aggregates intended for use in public works' (B' 4823).*