

KCS 11 30 30 : 2019

Consolidation Process

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Foreword

- This standard was organized and integrated as the code by comparing and reviewing duplicate or contradictory content within the existing construction standards (design standards, standard specifications) due to the transition of the construction standards code system.
- This standard is established by integrating and organizing the parts that are related to cement grouting in existing Building Construction Standard Specifications, Road Construction Standard Specifications and Harbor and Fishing Ports Construction Standard Specifications. The history of the standards are as follows:

Construction Standard	Main Content	Enacted or Revised (Year.Month)
Road Construction Standard Specification	· Established by the Korean Society of Civil Engineers commissioned by the Ministry of Construction	Establishment (Dec. 1967)
Road Construction Standard Specifications	· The specifications were improved and revised to become general specifications of overall road work by reviewing the related existing specifications and guidelines that were used and being developed.	Revision (Dec. 1985)
Road Construction Standard Specifications	· The specifications were improved and revised to be better specifications by advancing and complying with the currently used specifications and guidelines, along with the introduction of new theories.	Revision (May 1990)
Road Construction Standard Specifications	· The specifications were revised to enhance the international competitiveness and to promote quality improvements of road works by reorganizing the system to cope with the openness of the construction market as a result of the launch of the World Trade Organization (WTO).	Revision (July 1996)
Road Construction Standard Specifications	· The specifications were re-organized to establish a system of national standards and to reflect the revision of contents and other standards, such as the Korean Industrial Standard (KS) and the Standard Specification of Concrete according to the Construction Standard Organization Guideline, and to improved and revise standards to address the problems.	Revision (Nov. 2003)

Construction Standard	Main Content	Enacted or Revised (Year.Month)
Road Construction Standard Specifications	· The specifications were revised to improve the problems produced during the road construction and to induce reliable constructions through consistency with other standards such as the KS, Standard Specification of Concretes , and Standard Specifications of Tunnels, ensuring the prevention of shoddy and faulty construction thorough quality control.	Revision (Mar. 2009)
Road Construction Standard Specifications	· The specifications were revised to reflect the recommendations from the Central Construction Technology Deliberation Committee and changed the standard specifications, specialized specifications, and design drawings.	Revision (Sep. 2015)
Road Construction Standard Specifications	· Partial revision, including overview, forest and tree protection materials, and general construction works.	Revision (May 2016)
Standards Specifications of Harbor Construction	· Establishment of the Standards Specifications for Harbor Construction	Establishment (Dec. 1976)
Standards Specifications of Harbor Construction	· Revision of the Standards Specifications for Harbor Construction	Revision (Dec. 1977)
Standards Specifications of Harbor Construction	· The specifications added various design conditions for harbor construction, and included general policies and standards of designs in relation to harbor facilities, counter facilities, and other facilities for harbor construction.	Revision (Dec. 1986)
Standards Specifications of Harbor Construction	· The standards were significantly revised to provide a basis to apply the re-estimation of deep-sea waves, the estimation of wind speeds, and load coefficient to improve the safety of harbor facility and equipment, including coastal maintenance facilities.	Revision (Dec. 1996)
Standard Specifications of Harbor and Fishing Port Construction	· The standards were completely revised to include preemptive countermeasure against climate changes and to reflect the changing port construction conditions.	Revision (Nov. 2005)
Standard Specifications of Harbor and Fishing Port Construction	· The specifications were significantly revised to reflect the modified contents in the upper technical standards and other fields standards, improving related specifications, such as mass concrete and cap concrete and other related specifications such as filter mats, ships, quay walls, and other attached facilities, and added specifications concerning marina facilities.	Revision (Dec. 2012)

Construction Standard	Main Content	Enacted or Revised (Year.Month)
KCS 11 30 05 : 2016	· Integrated and organized the code system due to the transition to the code system of construction standards.	Establishment (Jun. 2016)
KCS 11 30 05 : 2016	· Modified to satisfy the Korean Industrial Standards and Construction Standards.	Modification (Jul. 2018)





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1. General

1.1 Scope of Application

- (1) This standard is applied to construction methods that aim to improve or reinforce ground through setting, hardening, or consolidation by means of chemical grouting, mixing, and stabilization inside soft ground.
- (2) Other construction methods not specified in (1) in the above may be applied if the stability of the ground and the facility can be ensured after obtaining approval from the construction supervisor.

1.2 Documents to be submitted

1.2.1 Construction plan document

- (1) The constructor shall create the construction plan documents according to the construction plan and submit them.

1.2.2 Mix design document

- (1) The mix design documents including mix design and mix proportions that can achieve the specified requirements shall be created and submitted.

1.2.3 Grouting plan document

- (1) Chemical grouting plan document
- (2) Stability management plan document

1.2.4 Test samples

- (1) Samples are put into sealed containers and delivered to the test room.

1.3 Reference standards

1.3.1 Related laws

No contents.

1.3.2 Related standards

- KCS 11 20 10 Ground cutting (earth cut)
- KCS 11 20 25 Refilling and backfill
- KS F 2303 Test methods of soil's liquid and plastic limits
- KS F 2324 Engineering classification method of soils
- KS F 2328 Test methods of soil cement compressive strength

- KS F 2331 Test methods of water content and density relationship of soil-cement mixture
- KS F 2528 Soil-aggregate materials for unpaved roads
- KS L 5201 Portland cement
- KS L 5210 Blast-furnace slag cement
- KS L 9501 Industrial lime

1.4 Construction environment requirements

- (1) The mixed materials during ground stabilization shall not be installed if the wind speed is more than 15 km/h and the temperature is below 4 °C.

2. Material

2.1 Grouts

2.1.1 Review items

- (1) Grouts shall be investigated comprehensively in terms of stability, constructability, and economic feasibility in addition to the purpose of ground improvements, ground conditions, and site conditions.

2.1.2 Grout type

- (1) A grout type shall be selected according to the construction specifications. If the construction specifications are not available, it shall be approved by the construction supervisor before use.

2.1.3 Classification and selection of grouts

- (1) Ground grouts can be largely classified into water-glass and polymer-based chemicals, cement, and clay-based non-chemical grouts. Since there are many types of grouts, their performance shall be verified by test grouting before the final selection.

2.2 Mixed and additive materials

2.2.1 Mixed materials

- (1) Cements and limes are used as additives in the mixing method. Other additives used in liquid water-glass type, composite water-glass type, and specialized silica type shall follow the rules specified in the construction specifications.
- (2) The following materials are used.
 - ① Coarse aggregates
 - ② Fine aggregates

- ③ In-situ soils
- ④ Cements
- ⑤ Limes
- ⑥ Accessory
- ⑦ Others

2.2.2 Soil-lime mixture

- (1) In-situ soils, limes, and aggregates are mixed and used.
- (2) For in-situ soils, the following materials shall be used.
 - ① Available materials after excavation, and net embankment materials
 - ② Good grade materials
 - ③ Materials without soil clod whose diameter is larger than 75 mm and stones or detritus whose diameter is larger than 50 mm
 - ④ Materials that belong to the CL classification according to KS F 2303
- (3) Limes shall be appropriate to the soil's stabilization.
- (4) Coarse aggregates shall comply with KS F 2528, and shall be coarse soil materials mixed with fine soils whose liquid limit is 25 or smaller, and the plasticity index is less than 5.
- (5) Fine aggregates shall be clean and natural river sands without silt, clay, mud, easily breakable or soluble materials, and organic matter. They shall be classified into SW or SP according to KS F 2324, and their maximum grain size shall be less than 5 mm, having a uniformity coefficient of 1.0, and coefficient of curvature shall be within the range of 2.0 to 2.5.
- (6) An indoor mix test according to mix proportion of each material shall be conducted, and a mix proportion that satisfies the purpose shall be determined.
- (7) A weight of limes shall not exceed 10% of the dried mixed material's weight.
- (8) For earth and sand used in the mix, soils that are available in the site are employed.
- (9) Lime-based (quicklime, slaked lime), cement-based, and gypsum-based materials are used for additives.
- (10) The approval of the construction supervisor shall be acquired before the mixture is poured.

2.2.3 Soil-cement mixture

- (1) Excavated soil, cements, and aggregates are mixed and used.
- (2) For excavated soil, the following materials shall be used.
 - ① Available materials after excavation, and net embankment materials
 - ② Good grade materials
 - ③ Materials without soil lump whose diameter is larger than 75 mm and stones or detritus whose diameter is larger than 50 mm
 - ④ Materials that belong to CL classification according to KS F 2303

- (3) KS L 5201 Portland cements, normal cements, or sulfate resistant cements are to be used.
- (4) Coarse aggregates shall comply with KS F 2528, and shall be coarse soil materials mixed with fine soils whose liquid limit is 25 or less, having a plasticity index smaller than 5.
- (5) Fine aggregates shall be clean and natural river sands without silt, clay, mud, easily breakable or soluble materials, and organic matter. They shall be classified into SW or SP according to KS F 2324, and their maximum grain size shall be less than 5 mm having a uniformity coefficient of 1.0, and the coefficient of curvature shall be within the range of 2.0 to 2.5.
- (6) A weight of cements shall not exceed 10% of the dried mixed material's weight.
- (7) An indoor mix test according to mix proportion of each material shall be conducted to determine a mix proportion that satisfies the purpose.
- (8) The compressive strength of the mixture shall ensure the value proposed in the design drawings, and determined in consultation with the construction supervisor is achieved.
- (9) Water is put into the mixture to make a wet and homogeneous mixture without clod, which shall not become a wet plastic material.
- (10) The approval of the construction supervisor shall be acquired before the mixture is poured.

2.3 Used water

- (1) Water shall be fresh and clean, and shall not include harmful materials such as as clay, mud, or alkalis.

2.4 Material inspection

- (1) The approval of the construction supervisor shall be acquired before the mixture is poured.

3. Construction

3.1 Overview

- (1) The construction conditions may differ depending on site and soil conditions. However, KCS 11 30 05 shall be followed under general construction conditions.

3.2 Construction plan

3.2.1 Construction plan document

- (1) The construction plan document shall be created based on the design drawings, and construction specifications, or the results obtained in the tests prior to start of construction, and be submitted to the construction supervisor to acquire approval.

3.2.2 Grouting plan

- (1) For grouting work, the purpose of the grouting shall be understood, and the conditions of the target ground shall be identified prior to the start of construction.
- (2) Investigation boring shall be conducted according to the instruction of the construction supervisor prior to the start of grouting, and the results shall be reported immediately.
- (3) Chemical grouting plan
 - ① The above item(s) of (2) shall be determined considering the purpose of the ground improvements, in-situ ground conditions, and the construction equipment functions.
- (4) Equipment operation plan
 - ① The transportation and layout plans of construction equipment and measures against soil settlement occurred due to the weight or the vibration of equipment during construction shall be arranged.

3.2.3 Stabilization plan

- (1) The optimum mix proportion shall be selected, and mix tests shall be conducted prior to the start of construction. The type of hardeners and mix plans shall follow the design documents or other specifications, but it shall be approved by the construction supervisor in advance.

3.2.4 Mixing plan

- (1) The mixing construction plan document shall be created based on the results obtained in the test construction or construction specifications and the design drawings prior to the start of construction, and submitted to the construction supervisor to obtain approval. The following items shall be included in the construction plan document.
 - ① Mixing method of earth and sand and additives
 - ② Types and mix proportion of additives
 - ③ Equipment operation plan
 - ④ Axial revolution of turning vane for mixing
 - ⑤ Continuity of work
 - ⑥ Inflow of underground water, in particular sea water
 - ⑦ Safety and environmental impacts
 - ⑧ Other instructions from construction supervisor

3.3 Test construction

- (1) Test construction shall be conducted according to the instruction of construction supervisor due to changes in site conditions, importance of upper structures, and the purpose of ground improvement prior to construction start.

3.3.1 Grouting test construction

(1) Indoor and site tests shall be conducted prior to the start of construction, and the test method shall comply with the instructions of the construction supervisor. The indoor test is to verify the chemical consolidation effects, and the site test is to verify the chemical grouting effects. The test results shall contain the following items.

- ① Chemical solution type and mix proportion
- ② Infiltration effect
- ③ Injection mode
- ④ Injection tube type and installation method (spacing, length, diameter of grouting borehole, and quantity)
- ⑤ Grouting amount, speed, and pressure
- ⑥ Other instructions from construction supervisor

3.3.2 Mix test construction

(1) Mix proportion test shall be conducted prior to the start of construction. More than three types of mix proportions shall be selected to conduct the mix test. The mix test method shall comply with the instructions of the construction supervisor. The mix test results shall contain the following items.

- ① Water content of the samples
- ② Compaction
- ③ Curing conditions
- ④ Sample's strength

3.3.3 Mixing test construction

(1) The most effective additive type and amount shall be determined by the mix test prior to the start of construction.

(2) Test construction shall be conducted according to the instruction of the construction supervisor prior to the start of construction if precision construction is required due to changes in site conditions, the importance of upper structures, and the purpose of the ground improvement. The test construction results shall include the following items.

- ① Types of the used additives
- ② Mix proportion of earth and sand and additive
- ③ Performance of the used equipment (penetrator, mixer, and grouter, etc.)

3.4 Grouting hole drilling

(1) Once drilling is complete, slime inside the borehole is cleansed with pure water to facilitate smooth grouting work until the pure water is all discharged.

3.5 Construction preparation

- (1) The construction supervisor shall be a person who is fully equipped with skills and experience of construction methods and high-pressure jet grouting methods.
- (2) The machine, tools, equipment, and temporary materials shall be prepared to execute the construction smoothly and safely according to the construction plan document.
- (3) The machine installation shall maintain safety, and machines shall be arranged appropriately considering the site conditions and working circumstances.
- (4) In principle, grouts shall be suitable for the construction purpose and satisfy the related regulations.

3.6 Grouting

- (1) The injection amount and pressure must be managed by using equipment.
- (2) A back-flow of grouts shall be prevented during injection, and no soil arching or damage shall be incurred to surrounding structures.
- (3) If a large fluctuation of the grouting amount occurs, it shall be reported quickly to the construction supervisor.
- (4) Data that can verify the material use amount and the grouting amount shall be submitted.
- (5) The grouting pressure and amount shall be constantly monitored during chemical grouting work. When unexpected changes occur, grouting shall be immediately suspended and required actions shall be taken after investigating the cause.
- (6) A constant pressure is preferable to fixed amount grouting according to the target soil quality and underground water characteristics.
- (7) The grouting model tests shall be conducted for chemical grouting not to dilute or lose the chemical solution due to underground streams in the aquifer or by hydraulic ground, thereby adjusting gel time, grouting amount, speed, concentration, and grouting rate according to the flow level of the underground water.
- (8) When the grouting width is thick due to a large permeability coefficient, the gap of the grouting hole shall be reduced, and the grouting rate shall be increased.

3.7 Mixing

- (1) If grass or tree roots are found in the target region, they shall be removed beforehand, and if stagnant water is at the construction site, it shall be drained as to not obstruct the construction. A trench shall be excavated on the surface, which will be constructed, during the surface drainage work, and water content on the surface layer shall be reduced to ensure the trafficability of construction machines.
- (2) The improved ground shall have a certain depth and cross-section area.
- (3) The work ground is arranged and reinforced to prevent the construction equipment from tilting

during the deep cement mixing method.

- (4) The pre-set amount of grout material is mixed with a certain amount of soil. Once a grout material is dissolved in water, it becomes a strong alkali and emits heat. Thus, much care should be taken to not affect the surrounding environment or people. Efforts shall be made to prevent dusting or the exudation of grout material.
- (5) In the cement mixing method or lime mixing method, grout material and ground soil are mixed and pressure is applied to obtain the required density.
- (6) Excessive loads shall not be applied to the improved ground until the ground reaches the required strength, and appropriate temperature and humidity shall be maintained.
- (7) Materials such as cements and limes shall be stored not to be exposed moisture. The safety of workers shall be ensured against heat generation during the use of lime (quicklime etc.) additives.
- (8) The stabilization due to additives shall be deep and uniform in the mixture as much as possible to improve the ground with a constant density.
- (9) If compaction is needed, the following items shall be kept.
 - ① Even layering and sufficient compaction shall be conducted to have 300 mm or thinner of single layer and completion thickness.
 - ② The spreading work shall be conducted not to have cavities in the stabilized soils when compaction does not take place.
- (10) Curing shall be conducted if necessary until a certain strength is acquired once the compaction and spreading work is complete.

3.8 Stabilization

3.8.1 Ground cutting

- (1) The surrounding structures shall be protected not to be damaged by the work.
- (2) The in-situ soil shall be cut to the specified depth.
- (3) Test rolling shall be conducted to verify the soft sections and the soft section shall be cut.
- (4) The ground cutting shall not surpass a 45° support angle from the foundation structure.
- (5) Soil clods, gravels, and rocks whose volume is less than 0.25 m³ shall be pulled out and removed, and larger rocks shall be dug out, according to the demolition requirements.
- (6) Unexpected ground conditions shall be reported to the construction supervisor, and the work shall be suspended until the resumption of work is approved.
- (7) Over-cut sections shall be corrected to be level with the site soil height or higher to not cause stability problems.
- (8) The cut soils are temporarily piled up at a designated place, and the remaining soil shall be removed from the site.

3.8.2 Soil handling and re-filling

- (1) Non-woven fabric is laid on the ground. A lap joint method shall be used for connection.
- (2) Refilling shall be conducted while compacting the excavated soil in the site. The processed soils are well mixed to have the right mix proportion, and the required stabilization shall be achieved.
- (3) The mixture shall be spread to have a successive layer with a 200mm thickness or thinner during mixing.
- (4) In the deep mixing, at least 16 hours shall be monitored after mixing, and pouring shall be conducted within 72 hours.
- (5) The mixture shall maintain the optimum water content to achieve the required stabilization.
- (6) The pouring of the adjacent mixtures shall not exceed 30 min for soil-cement stabilization, and the pouring of the adjacent mixtures for lime stabilization shall begin within 60 min.
- (7) The compaction of the mixture during soil-cement stabilization shall start within 30 min after pouring, and the compaction of the mixture during lime stabilization shall start within 60 min after pouring.
- (8) The mixture for lime stabilization shall be compacted according to KS F 2331.
- (9) The gradient shall be 2% or steeper from buildings or structures unless otherwise specified.
- (10) The compaction shall be done in accordance with the required survey line, foundation level, and cross section.
- (11) The gradient shall be gradually changed until it reaches a horizontal surface.
- (12) A construction joint of a vertical straight line shall be made after the completion of the daily work.
- (13) For the filling of the damaged part, it shall be replaced with the new mixture up to the original depth.
- (14) The remaining mixture shall be removed from the site.

3.9 Curing

- (1) During curing, rapid drying should be paid attention to, and passage of heavy loads shall be avoided as much as possible.
- (2) After the mixture is compacted, the surface shall be sealed with a curing membrane or a fascine immediately.
- (3) The surface is sealed during lime stabilization and no traffic shall be allowed for 72 hours.

3.10 Allowable tolerance

- (1) The filled surface during stabilization shall be within ± 25 mm from the expected elevation.

3.11. Equipment

- (1) The construction equipment shall be selected considering the design conditions, geological

features, underground water conditions, construction conditions, and economic feasibility.

- (2) The equipment during stabilization process shall be suitable equipment for soil cutting, mixing, mixed material pouring, spraying, collecting, and compaction. The equipment shall be approved by the construction supervisor.
- (3) The grouting equipment shall be able to record grouting pressure, grouting amount, and grouting time automatically.

3.12 Construction conditions

- (1) Refilling shall not be conducted in ground which were frozen or softened during stabilization.

3.13 Construction and site quality control

3.13.1 Grouting construction management

- (1) The grouting construction method shall be conducted according to the construction plan after the purpose of the construction and grouting work are fully understood.
 - ① A location of grout injection shall be selected not to contaminate the surrounding environment, and used materials and water shall not be spilled.
 - ② For the storage of grout materials, safety measures are needed according to the related regulations, depending on site conditions.
 - ③ Grouts shall be managed fully by gauges, flow meters, and other required instruments.
 - ④ A variety of required materials shall be collected at the site during construction and used to create formal documents.
 - ⑤ Surface elevation measurements
 - ⑥ The verticality and construction depth shall be carefully managed during construction. In particular, much care should be taken to prevent damage to existing facilities.
 - ⑦ Other instructions from the construction supervisor

3.13.2 Mixing construction management

- (1) The pouring location and stirring shaft's verticality shall be checked prior to pouring.

3.13.3 Stabilization and site quality control

- (1) In-situ testing shall be conducted in accordance with the requirements of quality control.
- (2) The compressive strength test and analysis of the hardened materials shall follow the requirements of KS F 2328.
- (3) If the test results do not satisfy the specified requirements, the corresponding construction shall be removed and replaced at the expense of the constructor, and re-tests shall be done.

3.14 Verification of the improvement effect

3.14.1 Determination of the grouting effect

- (1) If the permeability coefficient is less than $K = \alpha \times 10^{-4}$ mm/sec in the in-situ permeability testing, it is considered as passed.
- (2) The standard penetration test compares the ground N value before and after grouting and determines pass or fail.
- (3) If red color reaction is revealed in the unaided eye observation and verification (pigment determination method), it means good, and grout infiltration condition is verified with unaided eyes directly.
- (4) The inspection of the ground improvement results shall be conducted by dividing them into initial inspection, mid-inspection, and final inspection phases.
- (5) The criteria of pass or fail shall follow the criteria proposed in the construction specifications.

3.14.2 Investigation and measurement of the improvement effects

- (1) The designated locations are marked prior to the construction, and the soil settlement displacement is measured, and in-situ testing is conducted to determine the construction progress. Furthermore, effects on the surrounding ground and facilities are also investigated according to the construction.
- (2) The in-situ testing and soil tests are conducted to verify the ground improvement effects when the construction is complete.
- (3) If a load is applied at a well-point, the discharged water amount is measured as well as installing observatory wells to measure the underground water level. If the effect is not sufficient, it shall be consulted reported to the construction supervisor.
- (4) If a load is applied using the atmospheric pressure, the state of maintaining the vacuum is measured, and if it is not sufficient, it shall be reported to the construction supervisor.

3.14.3 Verification test after construction

- (1) The verification test shall be conducted after construction to check whether the purpose is met by grouting.
- (2) For verification, the reinforced regions are divided uniformly to check and verify the reinforced target areas equally and complexly by referring to the following methods so verifying whether the grouts are well distributed over the ground and these shall be inspected by the construction supervisor.
 - ① Verification through bare eyes after excavation
 - ② Verification through geotechnical investigation and tests
 - ③ Verification through non-destructive inspection via geophysical survey

- ④ Indirect verification through grouting circumstances or records

3.15 Preventive measures against environmental contamination

- (1) The treatment of the surplus soil produced from the ground where chemical solution was injected shall not contaminate underground water and public water preventing underground water pollution.
- (2) The transportation and handling of slime shall be processed lawfully, according to the environment-related acts such as waste management law.

3.16 Construction record

- (1) The construction records during construction are produced and submitted to the construction supervisor.

3.17 Processing during and after construction

- (1) When something abnormal occurs in the improved and surrounding regions of ground improvement, the causes are investigated, and measures shall be established and executed after consulting with the construction supervisor.
- (2) The surface water due to rainfall or water discharged from the improved ground shall be handled with a drainage for construction. Thus, no damage shall be incurred inside or outside the work place.
- (3) The high-pressure spraying of grouting is an ultra-high-pressure spraying construction method. Thus, if relaxation and uplift occur it shall be investigated and required measures shall be provided. In addition, the measures shall be executed after obtaining the approval of the construction supervisor.
- (4) When chemical grouting is constructed nearby underground utilities, required measures shall be taken to prevent the inflow of the chemical solution to the underground utilities.

3.18 Establishment of modification and improvement measures

- (1) With regard to the investigation on the ground consolidation effects during or after improvement, if the conditions defined in the design are not satisfied, it shall be reported to the construction supervisor and measures regarding the improvement period, loading weight, changes in loading method, or re-consolidation shall be addressed.
- (2) The revised and improved countermeasures shall be established for the following cases, and reported to the construction supervisor, and executed upon the instruction of the construction supervisor.
 - ① Cases in which the improvement strength does not satisfy the standard set in the drawings and construction specifications.
 - ② Cases in which serious environmental problems occur.

- ③ Cases in which the grouting work is not conducted consecutively due to the interruption of construction.
- ④ Cases in which the elevation difference in the ground surface exceeds the allowable limit set in the construction specifications.

