Korean Construction Standard

KCS 11 30 35 : 2019

Compaction Works

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국토교통부

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 compaction works in the Standard Specifications of Sewage Pipes and Harbor and Fishing Ports Construction Standard Specifications based on existing Road Construction Standard Specifications and Standard Specifications for General Civil Works. 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 compaction works that improves ground density by applying compaction using materials whose permeability is good for soft ground.

1.2 Documents to be submitted

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

(2) The constructor shall submit the quality conformity certificates of the materials used.

2. Material

2.1 Materials and equipment

(1) The materials used in soft ground treatment work shall comply with the requirements specified in the detailed approved construction drawings and contract drawings, and shall be ones that passed a certain test.

(2) The larger the particle diameter of the materials for compaction, the better, but if sands or gravels that do not exceed 50 mm of particle diameter at most are used, and materials shall not be applied to grounds that contain more than 20% of silt, or more than 5% of clay.

(3) Since the compaction effects of compaction equipment varies depending on the ground type and water content, the amount of compaction works shall be determined through site tests.

(4) The applicability of grouts injected to the ground shall be determined according to ground type.

2.2 Material quality

(1) The tests for the specifications and qualities of each material shall be conducted according to the test methods specified in the construction specifications, and additional test items that are deemed necessary in light of reasonable construction management shall follow the instruction of the construction supervisor after consultation between the contractor and the construction supervisor.

(2) A frequency of management test execution shall follow the number of tests specified in the construction specifications.

(3) Since the specification and quality inspections of materials cannot be checked after construction, they shall be tested prior to construction and only the approved products shall be used.

2.3 Material inspection

(1) If the construction supervisor deems it necessary, the construction supervisor may dispatch

inspectors at any time to the required production facility to test the products or inspect the production process.

(2) The inspection of the ground improvement results shall be conducted by dividing it into initial inspection, mid-inspection, and final inspection phases.

(3) The criteria of pass or fail shall follow the criteria proposed in the construction specifications.

3. Construction

3.1 Surface compaction

(1) When soil is compacted on the surface, the depth of the compaction effect is limited. Thus, soils shall be piled and spread evenly with a constant thickness and compacted by layer by layer, using static or dynamic equipment. Cohesive soil shall be compacted with static rollers, and sandy soil ground or ground that contain only a small amount of cohesive soils shall be compacted with vibration rollers or vibration plates. Dynamic compaction is needed with vibro-flotation when deep compaction is required.

3.2 Deep compaction

(1) Deep compaction shall be done by applying a large drop energy or dynamic energy or installing structural members such as piles. The deep compaction method is a construction method that improves ground density by forcibly pushing good permeability materials (sands, oyster shells, and crushed stones, etc.) into soft ground or by applying compaction.

3.2.1 Overview

(1) Application Scope

① It is applied to construction that install piles whose diameter is large by pressing sands (or similar materials) to increase bearing capacity and horizontal resistance, reduce settlement, and prevent liquefaction in soft grounds consisting of sands or clays.

(2) Submission documents

① The construction plan document shall be created and submitted in accordance with the construction plan according to this standard.

② The following items shall be submitted additionally.

A. Measurement plan document

B. Construction report

3.2.2 Materials

(1) Materials shall comply with the material criteria of this standard 2, and the design requirements shall be satisfied if other materials are used.

(2) The fine-grained soil content in sands shall be less than 3% to expect superior drainage effects in the sand pile, and shall not exceed 15% under any circumstance.

(3) The maximum dimension and particle-size distribution of the used crushed stones shall follow the regulations of additional construction specifications and the crushed stone material criteria in the horizontal drainage work shall be satisfied. In particular, in case that horizontal drainage is considered by the placement of crushed stone compaction piles in cohesive soil, the reduction in drainage performance due to the clogging effect shall not occur.

(4) When using mixed aggregates, particle sizes and qualities shall follow the regulations in the construction specifications.

3.2.3 Construction

(1) The driving machine of the compaction piles shall be equipped with devices that can record the driving length and input material amount by itself. The following items shall be inspected by the construction supervisor after conducting a test construction: determination of construction depth, penetration capability, precision, and bucket capacity of the automatic recorder.

(2) A replacement ratio of input materials, pile's gap, array, diameter, and input amount shall comply with the design drawings.

(3) The following standards are applied for pull-out height and re-penetration depth of the casing tube when driving compaction piles. Note that if reasonable alternatives are made through test constructions, they may be applied after acquiring approval from the construction supervisor. In addition, 1m-pullout and re-penetration shall be conducted one more time at 1m of depth.

① When depth is 3 m or shallower

A. Pullout height of the casing tube: 3 m

B. Re-penetration depth: 2 m

② Surface - depth 3 m

A. Pullout height of the casing tube: 1.5 m

B. Re-penetration depth: 1.0 m

(4) At least 1.5 m of difference in height of material filled inside the casing and the casing tip shall be maintained.

(5) The material input to the casing shall follow Section 3.2.2 of this standard.

(6) Since the placement of compaction piles may damage surrounding structures, due to the soil arching, the construction from the outside to the inner direction (inside) of the placement site shall be employed in principle.

(7) The construction management record follows Section 3.5 in this standard.

(8) The dust, noise, and water pollution, etc. shall follow the standards set by related laws including noise and vibration management acts, and legislations concerning the conservation of water quality and aquatic ecosystems.

(9) The investigation and test items, methods, and quantities during construction shall follow the standards set in the construction specifications. The setup location of drilling investigation to verify the improvement effects shall follow the decisions made by the construction supervisor.

(10) The corrective actions and countermeasures shall be established for the following cases, and shall 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 or construction specifications.

② Cases in which unexpected changes in strata occur during construction.

③ Cases in which piles are cut or the material input amount is not sufficient.

④ Cases in which the placement location of piles and the inclination exceeds the allowable range.

3.3 Sand (crushed stone) compaction pile method

(1) Steel pipe casing is penetrated and sands, oyster shells, and crushed stones are filled inside the steel pipe casing to construct compaction piles. This construction method can be applied to all earth and sand types.

(2) The penetration equipment with automatic record devices shall be used for the penetration of the steel pipe casing.

(3) The construction plan document is created prior to the start of construction, and submitted and is approved by the construction supervisor. The following items shall be contained in the construction plan document.

① Penetration plan of steel pipe casing: Type of steel pipes, penetration equipment (vibration size), penetration spacing, penetration depth, penetration order (longitudinal or lateral direction), and the allowable verticality.

② Material input plan: Transportation routes, stockpile location, input amount, input order, input method, replacement ratio

③ Compaction plan: Compaction method, compaction equipment operation

(4) The construction range, replacement ratio, sand input amount, and improvement strength shall follow the design drawings or construction specifications.

(5) The material input and compaction shall be conducted consistently using the same method in the compaction pile construction.

(6) The following items shall be recorded during the construction, and submitted to the construction supervisor.

① Penetration velocity of steel pipes

② Input material amount by depth

③ Variation of upper end height of input materials inside the steel pipe

④ Pile's length

(7) The dust, noise, and water pollution, etc. shall follow the standards set by related laws including noise and vibration management acts and legislation concerning the conservation of water quality and aquatic ecosystems.

(8) The investigation and test items, methods, and quantities during construction shall follow the standards set in the construction specifications. The setup of location of drilling investigation to verify the improvement effects shall follow the decision made by the construction supervisor.

(9) The corrective actions and 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 or construction specifications.

② Cases in which piles are cut or the material input amount is not sufficient.

③ Cases in which the location of the pile exceeds the allowable errors set by the construction specification.

3.4 Vibro-flotation method

(1) It is a construction method that constructs a sand pile by excavating the ground through high-pressure water spraying and filling the excavated hole with sand. This method is suitable of sandy soil.

(2) The construction plan document containing the following construction plans is created prior to the start of construction, and is submitted to and approved by the construction supervisor.

① Excavation plan: Performance of excavation equipment, excavation spacing, and excavation order

② Material (sands or crushed stones, etc.) input plan: Transportation routes, stockpile location, input amount, input order, input method, replacement ratio

③ Compaction plan: Compaction method (water or air supply), compaction equipment operation

(3) The ground excavation equipment where automatic recording devices are attached shall be used.

(4) The placement and size of sand piles as well as construction range, replacement ratio, material input amount, and improvement strength shall follow the design drawings or construction specifications.

(5) The following items shall be recorded during the construction, and submitted to the construction supervisor.

① Excavation velocity of the excavator

② Input material amount

③ Variance of the upper end height of filling sands and input amount by depth

(6) The construction management items are as follows:

① Elevation measurement of the ground

A. The ground height shall be measured in the middle of the construction or after construction in case of soil arching or settlement.

B. The measurement method and location shall follow the instruction specified in the drawings or construction specifications.

C. The measurement time, frequency, and range shall be approved by the construction supervisor prior to the start of construction.

② Environmental impact: The dust, noise, and water pollution shall follow the criteria set in environment conservation laws.

③ Pile verticality

④ Other instructions from the construction supervisor: The investigation and test items, methods, and quantities during construction shall follow the standards set in the construction specifications. The setup of location of drilling investigation to verify the improvement effect shall follow the decision made by the construction supervisor.

(7) 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 or construction specifications.

② Cases in which piles are cut or the material input amount is not sufficient.

③ Cases in which the location of the piles exceed the allowable error set by the construction specification.

3.5 Dynamic compaction method

(1) It is a construction method that compacts the ground using heavy weights. It is suitable for sandy soil, waste landfills, or heterogeneous ground where a large amount of large rocks are mixed. In some cases, aggregates are filled inside the compaction space.

3.5.1 Overview

(1) It applies to a dynamic compaction (dynamic consolidation) method that causes compaction effects up to the deep layer of the ground by the free fall of a heavy weight from a high location, and the dynamic replacement method that forms a large diameter pile underground by hitting materials such as crushed stones or sand gravels directly to increase the strength of the ground.

(2) The submitted documents are as follows:

① In addition to the construction plan document according to KCS 11 30 05 (3.2), safety

management plan documents, the following items shall be made and submitted additionally.

A. The test construction planned in the design according to ground conditions, construction conditions, and improvement purpose is executed after consultation with the construction supervisor. The test construction results shall contain the following items.

(A) Drop phase and drop energy size by phase

(B) Arrangement of drop locations and drop order

(C) Setting time

B. If a ground volume is significantly reduced due to the compaction, supplemental materials shall be added as much as the reduced volume after obtaining approval the from construction supervisor.

C. The construction plan document is created prior to the start of construction, and is submitted to and approved by the construction supervisor. The following items shall be contained in the construction plan document.

(A) The performance inspection and transportation methods of the equipment are determined through the equipment operation plan.

(B) The compaction plan is determined through weight's weight, drop height, and the number of hitting.

(C) For the compaction order, three-dimensional compaction order diagrams are made in both the horizontal and vertical directions.

(D) Safety measures of surrounding facilities

D. Construction management items

(A) Vibration's harmful effects

(B) Elevation measurement of the ground

(C) Measurement of pore water pressure (cohesive soil ground)

(D) Other instructions from the construction supervisor

E. Facilities required for safety management shall be placed during construction.

3.5.2 Materials

(1) Sand gravels or ripraps are used as replacement materials. Thorough quality control is enforced during transportation to prevent foreign matter from being introduced.

3.5.3 Construction

(1) The following items shall be specified in the dynamic compaction work.

① This construction method is applied for the increase in density by compaction, increased and uniform bearing capacity, reduction in residual settlement, prevention of liquefaction after earthquake, settlement facilitation, forced replacement, and compaction of underwater

crushed stone mound.

② The dynamic compaction work facilitates ground compression by cracks in the vertical direction and the dissipation of pore water pressure as tensile stress in the horizontal direction occurs after applying an impact load to the ground.

③ Since the impact energy due to dynamic compaction is applied to each drop spot, the number of drops shall be determined as much as needed by the compaction effect during compaction.

④ Much care should be taken during construction as no significant effects are obtained even if hitting energy is applied once the pore water pressure inside the ground increases and a liquefied state is reached depending on the depth where hitting is applied in the case of an impermeable layer or saturated ground.

⑤ For hitting spacing, one-time hitting energy and required total energy for improvement are compared so that hitting shall be made by creating a mesh to supply the required energy evenly over the entire area.

⑥ To determine the dynamic compaction spacing and one-time hitting energy (weight's weight and drop height) that are suitable to the characteristics of the improvement target ground, test constructions shall be conducted, and the compaction effects shall be verified.

⑦ The deep part is compacted and improved at first, and then upper part is improved sequentially until the ground surface is completely compacted.

⑧ For improvements of saturated cohesive soil and saturated sandy soil with a large amount of fine material, a setting period is placed until the excessive pore water pressure is dissipated. If a drainage method is used, the setting time may shorten.

⑨ The effects on the stability of surrounding structures and environmental impact of noise and vibration on adjacent regions shall be taken into consideration.

⑩ In case that construction is difficult due to high underground water level or the presence of soft cohesive soil near the surface, the presence of soft cohesive soil ground, thick organic ground, a drainage handling plan prior to the start compaction shall be established.

(2) The construction work general items of dynamic replacement shall follow the above (1) section, and other items not included shall follow the related construction specifications.