KCS 11 70 05 : 2019

Nails

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국토교통부

Foreword

- To address needs that were caused by changes in the construction standards code system, the overlaps and conflicts between existing construction standards (design standards, standard specification) were compared and reviewed and then integrated into a new document that can be maintained as a standard code.

- These standards were revised and enacted as standards by integrating the Construction Work Slope Surface Standard Specification and the corresponding parts of Road Work Standard Specification, Temporary Construction Standard Specification, and Utility Tunnel Standard Specification. Major matters related to the enactment and revision of these standards are as follows:

Construction Standard	Major Contents	Enactment · Revision (Month, Year)
Construction Work Slope Surface Standard Specification	• Construction Work Slope Surface Design Standards enacted.	Enactment (May 2006)
Construction Work Slope Surface Standard Specification	• Construction Work Slope Surface Design Standards revised.	Revision (Dec 2011)
KCS 11 70 05 : 2016	• Integrated and maintained as a code according to changes in the construction standard code system.	Enactment (June .2016)
KCS 11 70 05 : 2016	• Revised to harmonize Korean Standards with Construction Standards.	Revision (July 2018)

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1. General Matters

1.1 Scope of Application

(1) These standards are applied to nailing works for reinforcing slopes.

1.2 Reference Standards

- KS D 3504 Steel bars for concrete reinforcement.
- KS L 5201 Portland cement.
- KS D 7002 Uncoated stress-relieved steel wires and strands for prestressed concrete.
- KS D 3505 Steel bars for prestressed concrete.

2. Materials

2.1 Materials

2.1.1 Nails

(1) The deformed bar used for nails shall be PS materials conforming to the KS D 3504 (steel bars for concrete reinforcement), KS D 7002, and KS D 3505. A material having no applicable KS standard shall be tested by an certified testing institute, and only one of which material appropriateness is recognized by a procedure equivalent to the procedure for the materials already certified may be used to guarantee the quality.

(2) If the corrosion of nail steel materials may affect the future stability of the structure, materials that have undergone zinc plating or equivalent corrosion protection treatment shall be used to prevent corrosion.

(3) Nails shall not include any defects and shall be well attachable to grout. Therefore, soil or oil that may hinder the attachment shall be removed from nails before application.

2.1.2 Anchor plate

(1) Anchor plates shall be of a material that may support the load on the nail for a long time

(2) The area of an anchor plate shall be over 150 ㎜ × 150 ㎜. The thickness of an anchor plate shall be over 9 ㎜. The thickness shall be over 12 ㎜ if an anchor plate is installed on expandable ground or if the area of the anchor plate is over 300 ㎜ × 300 ㎜. The anchor plate shall allow the control of the angle between the anchor plate and the nail so that the nuts may be fastened even if the nails and the anchor plate are not perpendicular with each other.

(3) An anchor plate shall undergo zinc plating or an equivalent corrosion protection

treatment to prevent corrosion.

2.1.3 Grout

(1) The cement used for grout injection shall basically be the common portland cement or rapid hardening cement according to KS L 5201. When an admixture is added according to such need, it shall be used after being subject to objective validation and after approval from the construction supervisor has been obtained.

(2) Grout transfers the load from the nails to the surrounding ground and protects the nails from the invasion of corrosive materials. Grout shall have the sufficient strength and durability and shall tightly fill the gap between the nails and the ground.

(3) The mixing of grout shall be designed to secure a 28-day strength of approximately 24 MPa, and the water/cement ratio (W/C) shall be in a range between 40 and 50%. A hardening accelerator agent and an expansion agent may be used to secure the strength rapidly and to tightly fill the gap between the nails and the ground. The aforementioned W/C range satisfies the requirements of general grout materials. However, since grout quality increases as W/C decreases in a range that does not damage constructability, such admixtures as a superplasticizer and a water-reducing agent may be used.

(4) The water used in grout shall not contain a significant amount of any materials that affect the grout quality, such as oils, acids, salts, and organic matters.

3. Construction

3.1 Verification of Construction Conditions

3.1.1 Verification of Ground Conditions

(1) Before construction of the nailing work, the conformity between the ground conditions specified in the design drawings and those of the actual site shall be verified. If there is nonconformity or if the construction according to the design plan is considered inappropriate, a counteraction shall be taken immediately, including changes of the design. In addition, if the weak part of the cutting surface requires additional treatment, such as removal or reinforcement, the treatment shall be carried out according the construction supervisor's instructions.

3.1.2 Construction Plan and Drawings

(1) The work schedule, construction sequence, construction method, number of workers, equipment utilization plan, and the material import plan shall be reviewed, including the

nail installation range, construction area, and construction date and time.

(2) If the design drawings are not in accordance with the site conditions, the modified design plan, calculation sheet, and review report prepared by an executive senior engineer in the field shall be reviewed to prepare countermeasures.

(3) The cross-sectional drawings for each part, including the spatial relationship between nailing holes and the surrounding structure and the soil work finishing plan for the top of the retaining wall, shall be reviewed.

(4) A construction development drawing (drawing of longitudinal section) prepared by considering the topography of the installation ground shall be reviewed.

(5) The detailed installation drawings for the edges, corners, parts with a changing slope, and curves shall be reviewed.

3.2 Construction Standard

3.2.1 Cutting

(1) The cutting surface is often used as the main structure in nailing construction. Therefore, cutting shall be carried out at the accurate position and shape. The cutting depth and the time of the following cutting step shall be determined by considering a cutting depth allowing for self-standing of the ground depending on the soil type and the curing time needed to obtain the sufficient strength of the injected grout or the sprayed concrete.

(2) Although it depends on the ground conditions, the vertical cutting depth of each step in soil is limited to a maximum of 2 m. The cutting depth shall be maintained at least one or two days of self-standing under the same conditions.

(3) Cutting shall start from the top of the slope surface, and cutting and nail installation shall be alternatively repeated on the individual nail installation steps in the direction of top to bottom. The reference line for one-step cutting shall be the midline between the upper nail and the lower nail directly.

(4) If self-standing is difficult due to the presence of an aquifer in the middle of the stratum or a sand or soft layer with no adhesiveness, a reinforcing material, a berm, or an existing panel may be used.

(5) If the cutting surface is partially collapsed during the cutting work, a separate countermeasure shall be established to secure the stability of the cutting surface according to the range of the collapse.

3.2.2 Boring and Nail Inserting

(1) Boring shall be carefully performed to avoid movement of the surrounding facilities or

severe disturbance of the ground.

(2) Boring shall be performed after sufficiently investigating the surrounding facilities, including underground utilities and buildings, and by choosing boring equipment appropriate for the site conditions. A compressed air-based drill is effectively used in general, but a hydraulic drill or a boring facility exclusively for nailing shall be employed for clay ground or loose reclamation soil ground.

(3) Boring shall be performed according to the position, boring diameter, length, and direction specified in the design drawings. The boring angle shall conform to the value provided by the design drawings. The bored holes shall be kept empty for at least several hours. If the hole wall is not retained, casing shall be performed.

(4) Boring may be performed either immediately after cutting or after concrete spraying for the stabilization of the cutting surface. In the case where concrete spraying is performed before boring, boring shall be carefully performed not to cause cracking of the concrete spraying surface.

(5) After boring is completed, the presence of impurities inside the hole shall be checked before inserting the nail. If there is a residual impurity, the inside of the hole shall be cleaned. When cleaning the inside of the hole, the use of water shall be avoided because the hole wall may collapse. The impurity may be pushed by compressed air to the end of the hole or raked out by using a rake.

(6) One piece of nail without a seam may be used without modification. However, if nails shall unavoidably be connected due to the long insertion length, they may be connected by using a coupler or by welding. When a coupler is used for connection, the cross-sectional area of the reinforcing material shall not be reduced by the processing of the screw coupling. The material of the coupler shall have a strength equal to or higher than that of the reinforcing material, and shall have a structure that does not cause the loss of the tensile force.

(7) When inserting a nail, a spacer shall be used to locate the nail at the center of the bored hole. The spacer shall be prepared by deforming a PVC pipe according to the boring diameter or an exclusive spacer shall be employed. The spacer installation interval shall be within 2.5 m, and at least two spacers shall be installed.

3.2.3 Grout Injection

(1) The cement paste shall be mixed to have strength, W/C, and admixture content higher than the values provided in the design drawings. A hardening accelerator and an expansion agent are often used, and their mixing ratios shall be determined by performing test mixing.

(2) After nail installation, grout is injected. The cement paste is injected to the inside of the

hole without pressure. In cases where a casing is installed and the casing is to be recovered, the casing shall be removed after the grout injection and before the complete curing of the grout, avoiding the collapse of the hole wall.

(3) If pressure is applied in the grout injection, damage to the slope surface stability may occur due to the cleavage cracks depending on the ground conditions. Therefore, the appropriate maximum injection pressure shall be verified through test work before commencing construction work each time the ground conditions are changed, and the construction work shall be performed after obtaining approval from the construction supervisor.

(4) Grout injection shall be undertaken to completely fill the inside of the hole. Grout injection shall be performed several times according to the infiltration of the grout to the surrounding ground. The number of times of grout injection shall be sufficient for a dry sandy soil ground. At the final step, the injection shall be performed by capping the hole inlet with a cloth or a lid to prevent the overflow of the grout.

(5) At least two injection hoses shall be installed. The outlet of the first injection hose shall be placed at the bottom of the borehole, while that of the second injection hose shall be at about 3/4 of the hole length from the hole inlet for the injection of the second or later steps. The injection hoses shall be separately marked for management.

(6) The first grout injection shall be performed from the hole bottom to the hole inlet until the grout overflows. The injection shall be performed several times at an interval of 3 to 4 hours. The final injection shall be performed at the hole inlet.

(7) After the completion of the injection, no tensile force or impact shall be applied to the nail during the curing period, which shall be at least one week to obtain the necessary strength. However, when a curing accelerator is used, the work of the next step may be carried out according to the experimental results after the strength reaches about 80% of the necessary strength (about 1 to 3 days).

(8) If there are many cracks or gaps on the ground, the grout may be consumed in an amount more than expected due to the infiltration of the grout. Therefore, it is recommended to install a cloth packer to the nail or to use mortar or an admixture before injecting the grout.

3.2.4 Installation of Anchor Plate

(1) Before installing an anchor plate, grout paste shall be additionally filled or mortar shall be applied to the borehole to avoid the exposure of the nail at the bottom of the anchor plate installation surface. For the junction of the nail head and the facing, a steel anchor plate and a nut are used to fix the nail head.

(2) When a facing is constructed by concrete spraying, two steel wires of at least D16

shall be used to bind the nail up and down and left and right with an adjacent nail in order to connect nail heads together by adding a wire mesh.

(3) When a facing is not constructed, mortar or other materials shall be filled to make the surface in contact with the anchor plate plane, so that there may be no gap between the anchor plate and the slope surface. The nuts shall be tightened by using a wrench to avoid manual loosening of the nuts.

3.2.5 Construction of Facing

(1) The facing is constructed by performing concrete spraying and using concrete walls and concrete grid blocks to make sure that the adjacent nail heads are tightly connected with each other.

(2) The construction of a facing by concrete spraying shall be performed as specified in KCS 11 73 10 Concrete Spraying.

(3) Concrete walls and concrete grid blocks shall be reinforced by using steel reinforcements. When a concrete spray is applied as a facing, the facing shall be reinforced by using a wire mesh of at least ϕ4.8 ㎜ × 100 ㎜ × 100 ㎜.

3.2.6 Drainage Facilities

(1) Drainage facilities shall be able to prevent high groundwater level fluctuating depending on the season, unexpected groundwater flow, infiltration of rainwater, and sudden inflow of external water. In particular, surfaces exposed after cutting works at a construction site shall be checked in the construction steps to concentrate the drainage facilities, planned to be installed in a certain interval or type, on the necessary areas, or to cancel installation in unnecessary areas through review.

(2) General types of drainage facilities are shown below. It is reasonable to select the drainage facilities appropriate to the conditions in the construction stage rather than in the design stage.

① Weep holes connected with possible drainage facilities

② Drain pipes with holes installed beneath the ground surface

③ Drainage facilities installed between a concrete spray and a ground (perforated pipes, non-woven fabric for drainage, sand or aggregates, etc.)

④ Facilities that may suppress the water flow on a slope surface top or on a wall (surface drain in a slope surface, front-end drain of a slope surface, etc.)

(3) Wall surface drainage facilities

① On a ground with a high groundwater level, necessary drainage facilities shall be installed before concrete spraying following cutting work. The drainage facilities mentioned above may be applied.

② A drain shall be installed to discharge the water from a drain pipe.

③ Drainage facilities installed between an anchor plate and the ground shall be aligned with the protruding weep hole of the anchor plate.

(4) In the rainy season where the cutting surface may collapse due to rainwater infiltration to the ground, a cut-off facility shall be installed to prevent rainwater permeation and rainwater inflow to the cutting surface.

3.3 Allowable Construction Error

(1) A nail shall be accurately inserted to the predetermined position and shall not be moved until the grout is settled. Generally, the error range shall be ± 3° for the boring angle and 0.2 m for the boring position with reference to the values specified in the design drawings.

3.4 Site Quality Control

3.4.1 Pull-out Test

(1) The pull-out test shall be performed as a pull-out test performed with testing nails and a proof test performed with the construction nails specified in the design drawings.

(2) The number of times of performing the test shall be as specified in the design drawing. The pull-out test shall be performed with at least two products out of 30 products (with two products if the total number of products is less than 30) to verify whether the tensile force satisfies the design tensile force standard. The test position or part may be modified according to the site conditions through review by the construction supervisor. If the tensile force fails to satisfy the design tensile force standard, reconstruction shall be performed, or an action shall be taken to maintain the standard tensile force.

(3) If a proof test is impossible or unreasonable according to the conditions, the result of the proof test may be replaced by the rest of the pull-out test through the review by the construction supervisor.

(4) Proof test

① A proof test shall be performed by selecting one of the nails constructed on each layer. It is recommended to select he nails on the individual layers alternately.

② The tester shall provide before the test a method of determining the displacement of the tested nail relative to the grout while the pulling load is applied.

③ The tester shall record the measurements during the test, and submit the result sheet.

④ The length of the nail protruding from the anchor plate shall be at least 0.15 m.

For a nail used in a pull-out test, the grout shall be injected only to 0.3 m from the wall, and then the test is performed before re-injection.

⑤ The load is measured by using a pressure gauge or a load gauge.

⑥ Pulling is performed to measure the test load applied to the nail and the nail tip displacement at each loading step.

⑦ The load is increased in steps from 12.5% of the design load to 25% to 125% by 12.5% increments in each step, and gradually removed after the completion of the test.

⑧ The increasing of the load shall be carried out within 1 minute and shall never exceed 2 minutes. However, the loading duration is 10 minutes exceptionally at 50% of the design load.

⑨ While the loading continues, the nail tip displacement shall be recorded at 1, 2, 3, 4, 5, and 10 minutes. If the displacement measured at 1 to 10 minutes is less than 2 mm in a loading step, the next step follows.

⑩ If the allowable displacement (2 ㎜) is reached within 10 minutes at the application of 50% of the design load, the application of the load shall be continued for 50 minutes more. The measurement shall be performed at 15, 20, 25, 30, 45, and 60 minutes, and the next step follows after 65 minutes.

⑪ If the pull-out test result is smaller than the design value, the design shall be modified according to the test result. After the pull-out test, the nail shall be cut on the concrete spray face. If there is a particular instruction from the construction supervisor or if the site conditions are poor, an additional test shall be performed to obtain a better test result. After the test, the protruding part around the nail settlement support shall be finished by concrete spraying, and the anchor plate shall be replaced by a new one.

(5) Pull-out test

① The pull-out test is to verify the extreme pulling resisting force of the ground before the nail construction after cutting works. The boring and nailing length shall be at least 2 m, and the test shall be performed uniformly on a layer.

② If the stability or constructablity of the entire nail structure is affected by the pulling at the originally planned position, the pull-out test may be performed at the immediate adjacent ground.

③ The tester shall provide before the test a method of determining the absolute displacement of the tested nail while the pulling load is applied.

④ The tester shall record the measurements during the test, and submit the result sheet.

⑤ The length of the nail protruding from the anchor plate shall be at least 0.15 m.

For a nail used in a pull-out test, the grout shall be injected only to 0.3 m

⑥ The load is measured by using a pressure gauge or a load gauge.

⑦ Pulling is performed to measure the test load applied to the nail and the nail tip displacement at each loading step.

⑧ Since the tested nail is short and thus the frictional force rapidly becomes apparent, the loading shall be increased in steps at 10%, 20%, 30%, ····· of the design load up to the yielding load of the nail reinforcing material.

⑨ The increasing of the load shall be carried out within 1 minute and shall never exceed 2 minutes.

⑩ While the loading continues, the nail tip displacement shall be recorded every 5 minutes. If the sum of the displacement measured is less than 2 mm in a loading step, the next step follows. The loading shall continue for 30 minutes at the final loading step.

⑪ After the completion of the pull-out test, the nail may be removed manually or by using a simple tool, if possible, or cut off if it is not easily removed.

⑫ A load-displacement curve, a load-time curve, and a displacement-time curve shall be prepared on the basis of the measurement data obtained from the test. The extreme pullout resistance force, obtained from the load-displacement curve, is divided by the skin friction area to which grout is injected to calculate the extreme skin friction resistance. If the obtained extreme skin friction resistance value is significantly different from the value assumed in the design stage, an additional test shall be performed to verify, and the result shall be reported to the construction supervisor to change the design.

⑬ If the extreme skin friction resistance obtained by the pull-out test is very large, the nail tension member may be fractured. Therefore, the yield tensile strength of the nail shall be checked before the start of the construction work to avoid the application of a load higher than the yield strength, and appropriate actions shall be taken to prevent workers and equipment from being placed directly behind the tension jack.

3.4.2 Grout Quality Control

(1) The test of the grout quality is performed by preparing a specimen for an unconfined compression strength test. The strength of the grout shall be higher than the strength required by the design.

3.4.3 Measurement Management

(1) Measurement management shall basically be performed to determine the nail stability,

to manage the construction works, and to prepare future maintenance works. The items for measurement management include slope, steel reinforcement strain, and groundwater level. The necessary item for nail measurement management is the measurement of the deformation of the nail facing.

(2) For the tiltmeter that is generally used to measure the deformation of the nail facing, the lower end of the tiltmeter pipe shall be inserted and installed to a stable ground that is not affected by the cutting work.

(3) Generally, the maximum horizontal displacement that does not affect the stability of the nail facing is about 1/300 of the cutting depth. If the horizontal displacement exceeds this value, the construction works shall be performed in consultation with an executive senior engineer of the field while carefully monitoring the variation of the measurement value.