Korean Design Standard

KCS 11 44 00 : 2019

Utility Tunnel

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KC CODE

국토교통부

Foreword

•In accordance with the change to the construction standards code system, the duplications and conflicts between existing construction standards (design standards, standard specifications) were compared and reviewed and then integrated into this standard as a standard code.

•This standard was established by integrating the parts corresponding to the general aspects and principles of the existing utility tunnel standard specification. The history of the standard and its revisions is as follows.

Construction Standard	Main Contents	Enacted or revised (Year.Month)
Utility Tunnel Standard Specification	• Established utility tunnel standard specification	Enacted (2010.2)
KCS 11 44 00 : 2016	• Integrated and maintained as code in accordance with the changes to the construction standards code system	Enacted (2016.6)
KCS 11 44 00 : 2018	• Amended according to Korean Industry Standards and Construction Standards	Revised (2018.7)
KCS 11 44 00 : 2019	• Amended through the conformity assessment of ground construction standards	Revised (2019.12)

Table of Contents

1. General

1.1 General provisions

(1) This standard is a standard specification which provides the basic requirements that must be satisfied with regard to the materials, construction, and quality of the construction work for utility tunnels.

(2) The construction specification for utility tunnels shall be prepared based on the provisions of this standard. In such cases, the standard specification may be applied or modified according to the construction concerned.

(3) If the provisions specified in this standard differ from those specified in the relevant construction specification, the provisions of the relevant construction specification shall take precedence.

(4) This standard includes basic requirements of various facilities such as civil engineering, electrical, mechanical, fire prevention, and control facilities for the construction of utility tunnels. For all other matters, follow the relevant specifications.

1.2 Reference standard

1.2.1 Related laws and regulations

(1) Laws related to construction contracts

- Act on Contracts to which the Nation is a Party
- Regulations on Special Cases Concerning the Enforcement Decree of the Act on Contracts to which the State is a Party in Specific Procurement

(2) Laws related to construction management

- Act on Special Measures for Designation & Management of Development Restriction Zones
- Framework Act on the Construction Industry
- Construction Technology Promotion Act
- Building Act
- Regulations on the fire safety management of public institutions
- Labor Standards Act
- Clean Air Conservation Act
- Road Act
- Act on Urban Parks, Green Areas, Etc.
- Urban Gas Business Act
- Cultural Heritage Protection Act
- Framework Act on Forestry
- Occupational Safety and Health Act
- Industrial Accident Compensation Insurance Act

- Industrial Standardization Act
- Noise and Vibration Control Act
- Framework Act on Fire-fighting Services
- Fire-fighting System Installation Business Act
- Act on Fire Prevention and Installation, Maintenance, and Safety Control of Fire-fighting Systems
- Water Quality and Aquatic Ecosystem Conservation Act
- Special Act on the Safety Control and Maintenance of Establishments
- Act on the Safety Control of Hazardous Substances
- Natural Parks Act
- Natural Environment Conservation Act
- Electric Utility Act
- Electric Technology Management Act
- Electrical Construction Business Act
- Groundwater Act
- Act on the Safety Management of Guns, Swords, Explosives, Etc.
- Land Survey Act
- Housing Site Development Promotion Act
- Soil Environment Conservation Act
- Wastes Control Act
- Electrical Appliances and Consumer Products Safety Control Act
- River Act
- Environmental Impact Assessment Act
- Framework Act on Environmental Policy
- Act on the Promotion of the Conversion into Environment-friendly Industrial Structure
- Special Act on Underground Safety Management
- Countermeasures against Earthquake and Volcano Disaster Act

1.2.2 Related standards

- KCS 11 20 10 Cutting
- KCS 11 20 15 Excavation
- KCS 11 20 20 Banking (Filling)
- KCS 11 20 25 Refilling and backfilling
- KCS 11 20 30 Soil disposal and surplus soil handling
- KCS 11 30 05 Soft ground improvement construction general
- KCS 11 30 10 Replacement method
- KCS 11 30 30 Consolidation process
- KCS 11 30 35 Compaction

- KCS 11 30 40 Lightweight material filling
- KCS 11 30 45 Ground grouting
- KCS 14 20 01 Concrete construction general
- KCS 14 20 10 Conventional concrete
- KCS 14 20 12 Form and shore
- KCS 14 20 30 Watertight concrete
- KCS 14 20 40 Cold weather concrete
- KCS 14 20 41 Hot weather concrete
- KCS 14 20 43 Underwater concrete
- KCS 14 20 50 Preplaced concrete
- KCS 14 20 52 Precast concrete
- KCS 21 50 05 Form-shore work general
- KCS 27 10 05 Tunnel construction general
- KCS 27 10 10 Construction plan
- KCS 27 10 15 Investigation and survey
- KCS 27 20 00 Tunnel excavation
- KCS 27 25 00 TBM
- KCS 27 30 00 Tunnel support
- KCS 27 40 00 Tunnel lining
- KCS 27 40 05 Cast-in-place lining
- KCS 27 40 10 Segment lining
- KCS 27 50 05 Drainage and waterproofing
- KCS 27 50 10 Instrumentation
- KCS 27 50 15 Auxiliary method
- KCS 27 60 00 Work environment
- KCS 41 40 01 Waterproof work general
- KCS 41 40 13 Underground structure external waterproof work
- KDS 14 20 30 Concrete structure usability design standard
- KDS 14 20 40 Concrete structure durability design standard
- KDS 14 20 50 Concrete structure reinforcement details design standard
- KS F 2312 Test method for soil compaction using a rammer
- KS F 4009 Ready-mixed concrete
- KS F 4935 Sealder of injection type for water leakage maintenance of adhesive flexible rubber asphalt series
- KS D 3503 Rolled structural steel
- KS D 3504 Steel for reinforced concrete
- KS D 3536 Mechanical structure stainless steel pipe

- KS D 7014 Stainless steel coated electrode

1.3 Definition of terms

No content

1.4 Design drawing review and detailed drawing preparation

(1) In order to build the structure presented in the design drawing, the contractor of the utility tunnel must review the site conditions in detail and check for errors in the various calculation sheets and design drawings, then prepare detailed design documents according to the site conditions and obtain approval from the construction supervisor.

1.5 Excavation work

1.5.1 Selecting the excavation method

(1) The scope of application is the excavation work during the construction of utility tunnels by open cut and non-open cut methods.

(2) Excavation methods are classified into open cut and non-open cut methods, and the excavation method required by the corresponding construction method should be selected.

(3) The open cut method is a general construction method in which the surface is excavated using natural slope excavation, retaining walls, and cofferdams, and is refilled after constructing structures such as cast-in-place utility tunnels and precast utility tunnels, and should consider matters related to the earthwork.

(4) Non-open cut methods refer to construction methods other than the general open cut method, such as the blasting method, TBM method(open TBM, shield TBM), shield method, shield TBM method, and special methods to pass through rivers, railways, and bridges. This method should consider conditions such as the ground conditions, groundwater, soil, environment, size of the inner section, shape, and extension.

(5) Excavation methods include mechanical, blasting, and crushing excavation, the details of which shall be in accordance with KCS 27 20 00.

(6) Details of construction plan, tunnel support, tunnel concrete lining, drainage and waterproofing, auxiliary methods, and instrumentation shall be in accordance with KCS 27 10 10, KCS 27 30 00, KCS 27 40 05, KCS 27 40 10, KCS 27 50 05, KCS 27 50 15 and KCS 27 50 10, respectively.

(7) The detailed specifications for vertical shafts for the use of access holes and branch connections shall be in accordance with KCS 27 60 00.

1.6 Excavation by the open cut method

1.6.1 Earthwork

(1) In the excavation of ground with high permeability or sandy and soft grounds, consider the collapse of the slope and the retention of the retaining wall, as well as the drainage in the work environment and auxiliary methods.

(2) Apply the most appropriate method according to the site conditions to transport and discharge the excavated earth.

(3) When the joint condition of rocks is greatly developed during excavation, apply an auxiliary method to cope with the large-scale activity phenomenon.

(4) Create an accurate map of the ground, underground utilities and yearly constructions (sidewalk block, boundary stone, protective stone, and road sign) during the construction.

(5) Start road excavation after relocating roadside trees, electric poles, and artifacts.

(6) Perform road excavation in accordance with the slope of the conventional road so that the lining surface does not cause flooding during the construction.

(7) The specifications for structure excavation, slope cutting, and banking shall be in accordance with KCS 11 20 15, KCS 11 20 10, and KCS 11 20 20, respectively.

(8) The contractor must develop safety measures in order to protect the obstacles discovered during road excavation. In particular, the next process should be performed only after visually inspecting underground utilities such as gas pipes and water pipes through a precision excavation.

1.6.2 Refilling

(1) Prior to refilling, prepare a results table of various tests related to the construction plan and road recovery.

(2) Refill between the outer surface of the structure and lagging with sand or high-quality soil.

(3) Refill immediately after waterproofing the structure and the waterproof protection work.

(4) If there are concerns of ground settlement during refilling, perform refilling according to the results of the test embankment.

1.6.3 Soft ground improvement general

(1) If there is soft ground in the route of the utility tunnel, apply a soft ground improvement method in accordance with KCS 11 30 05. For soft ground improvement, apply an appropriate method according to the ground and site conditions, and follow the relevant improvement standard for each construction method.

1.7 Excavation by non-open cut methods

(1) Matters related to excavation, muck hauling, and transport by non-open cut methods shall be in

accordance with KCS 27 20 00.

(2) Excavation by the TBM method shall be in accordance with KCS 27 25 00.

(3) Details of construction plan, tunnel supports, auxiliary methods, and instrumentation shall be in accordance with KCS 27 10 10, KCS 27 30 00, KCS 27 50 15, and KCS 27 50 10, respectively.

1.8 Cast-in-place concrete work

1.8.1 Scope of application

(1) This shall be applied to the transport, placing, and curing of cast-in-place concrete during the construction of utility tunnels, and matters related to the manufacture and assembly of rebars, formwork, and the quality control of concrete shall follow KCS 14 20 11 and KCS 14 20 12.

(2) When constructing concrete lining, follow KCS 27 40 05.

1.8.2 Materials to submit

(1) Follow KCS 14 20 10.

1.8.3 Construction records

(1) Follow KCS 14 20 10.

1.8.4 Quality assurance

(1) Follow KCS 14 20 10.

1.9 Precast concrete work

1.9.1 Scope of application

(1) In terms of the construction of utility tunnels, this applies to the manufacture, transportation, and installation of prefabricated P.C. utility tunnels with joints.

(2) For TBM of non-open cut utility tunnels, follow KCS 27 40 10.

1.9.2 Manufacturing process

(1) See Figure 1.9-1 for the general manufacturing process. Additional processes may be added.

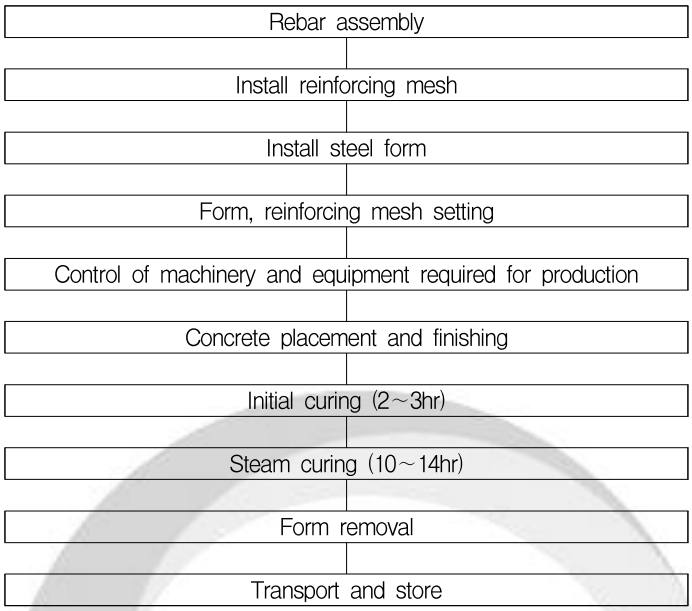

Figure 1.9-1 Precast concrete manufacturing process

1.9.3 Concrete mixture

(1) The concrete shall be mixed in accordance with KS F 4009 based on the concrete mix design for the design strength in the presence of the mixing manager.

(2) The unit quantity of the concrete mixture shall be as small as possible within the range of required strength, durability, water tightness, crack resistance, performance to protect rebars and steel, and workability according to the work.

(3) To ensure proper workability, as shown in Table 1.9-1, the concrete should be easy to place and fill every corner of the form according to the size and shape of the member and the method of tamping the concrete, and at the same time, the materials should not be separated.

Table 1.9-1 Concrete quality

Compressive strength	Slump value	Maximum size of coarse aggregate	Remarks
Equal to or greater than 40MPa	100mm ±20mm	25mm	Prefabricated utility tunnel

1.9.4 Fabrication and assembly of rebars

(1) The details of fabricating, connecting, and fixing rebars shall be in accordance with KDS 14 20

50 and KDS 14 20 52, and other details related to the fabrication and assembly of rebars shall follow KCS 14 20 11.

1.9.5 Fabrication and installation of steel forms

(1) The forms and shores shall be able to withstand the loads during construction, the lateral pressure of concrete, and the vibration and impact while pouring. In addition, forms must be fabricated and assembled so that the concrete does not exceed the construction tolerance.

(2) Consult with the relevant agencies about the various openings and underground utilities related to the works concerning facilities and electricity. In addition, install forms firmly in the required location to prevent movement during the concrete work. Other details related to steel formwork shall be in accordance with KCS 21 50 05.

1.9.6 Reinforcing mesh erection and production machinery control

(1) Install the assembled reinforcing mesh precisely inside the steel form and maintain a certain effective depth and cover, and reassemble the rebars if the cover and effective depth are not maintained.

(2) After installing the reinforcing mesh, assemble the form in accordance with the installation of the steel form.

(3) Before placing the concrete, level the form to avoid eccentricity when pouring the concrete.

1.9.7 Steam curing

(1) Steam curing shall be performed according to KCS 14 20 52.

1.9.8 Removing the form and storing

(1) General

① The strength of the concrete shall be at least 15 MPa when removing the form, so check the strength using the test piece at the time of placing the concrete before removing the form.

② Use an insert beam to remove the form properly. Be careful not to damage or deform the mold before or after removing the form.

③ Be careful not to damage or deform the mold and product when removing the form, and avoid shrinkage cracks caused by sudden changes in temperature.

④ Products that have been inspected shall be transferred and stored by type according to the order of shipment.

⑤ After removing the form, products shall be fully repaired if they have damaged parts before inspection. Select and store acceptable products by accurately measuring the error range specified in the section above.

⑥ In storing, the position of the supports shall be on the same line so that there is no damage to the products.

⑦ When removing the form, remove any hazardous substances such as loose aggregate on the surface of the precast member, poor quality concrete laitance, mud, and oil, and make sure that the joints are firmly connected.

⑧ Cure the concrete by maintaining a wet condition from the time of removing the form to the time of storage, and do not expose the concrete to the atmosphere in a dry state.

1.9.9 Transporting the products

(1) Matters related to transporting the products shall follow KCS 14 20 52.

1.10 Waterproofing work

1.10.1 Scope of application

(1) Waterproofing work shall be performed to prevent the penetration of water on the outer surface of the cut-and-cover cast-in-place concrete utility tunnel, the outer surface of the PC utility tunnel structure, and joints, and matters related to non-cut-and-cover utility tunnels shall follow KCS 27 50 05.

① Since the utility tunnel is influenced by the water pressure from the outside, the utility tunnel should be constructed for waterproof to prevent leaks from the outer wall of the structure, the upper slab, the bottom, joints, special sections, and the connection between different structures.

② To prevent leaks from the outside of the structure, waterproofing of the utility tunnel shall be carried out according to the purpose, structure, shape, and environmental conditions.

③ The utility tunnel shall be waterproofed using materials and methods according to the physical and chemical environmental conditions of the installation site.

1.10.2 Waterproofing work: General

(1) To waterproof the utility tunnel safely, quickly, and economically, investigate the following in the surroundings of the site before the waterproofing work.

① Existing waterproofing materials and construction methods, application cases to similar structures, leakage cases, types and conditions of nearby structures

② Ground composition status, soil condition and classification, ground condition, etc.

③ Variation of groundwater level, aquifer characteristics (permeability coefficient, percolation rate, rectification factor, etc.), water quantity, area of influence, etc.

④ Review and analyze the results of the investigation thoroughly and organize the data required to plan and perform the waterproofing work, and store the data for reference to

other construction works in the future.

(2) Carry out the construction by referring to the following, since the shape and structure of the utility tunnel affects the movement of the waterproofing layer and the groundwater affects the hydraulic resistance and chemical stability of the waterproofing materials.

① If the differential settlement or behavior of the ground in the area where the structure is to be installed is expected to be more than 50 mm, perform work to prevent damage to the waterproof layer, and if necessary, perform a structural behavior response test to select the proper waterproofing materials and construction method.

② Prevent the waterproof layer from being damaged by changes in the groundwater level due to the quality of groundwater (chemical effects such as salinity) and rainfall.

③ Examine the influence of structures neighboring the utility tunnel (vibration and behavior effects of subways and underground roads, the settlement of buildings, etc.) to prevent damage to the waterproof layer or degradation of waterproofing performance.

④ In locations such as special sections, variable joints, connections between different structures, expansion joints, and wall penetrations (piping penetration, etc.), make sure that the waterproofing material does not damage the behavior of each special section.

⑤ Since pile heads such as H-beams, steel pipes, and concrete piles used to improve the ground in the area where the utility tunnel is to be installed affect leaks at the bottom of the utility tunnel, use waterproofing seals to prevent the penetration of groundwater along the gaps.

⑥ Make sure that the groundwater is not contaminated by the waterproofing material.

⑦ The waterproof layer should not be damaged or separated by seasonal and temperature changes.

⑧ Be fully aware of the specific construction method of the waterproofing work according to the construction area (structural upper slab, outer wall, floor, separated-placement joint, expansion joint, etc.), construction method, and construction order before starting the construction (mock-up test, etc.)

(3) Make sure that the climate, temperature, humidity, wind, and chemical components in the atmosphere (salt, carbon dioxide, acid rain concentration, etc.) near the construction site of the utility tunnel do not damage the waterproofing layer.

(4) Construction and quality control of the utility tunnel waterproofing work shall be performed in accordance with the contents and procedures of the relevant standards (Korean Industrial Standards, etc.), guidelines (specifications related to waterproofing, etc.), and regulations.

(5) Consider the following when selecting the waterproofing materials and construction method.

① Performance of the materials and construction method

A. Long-term leakage safety against ground settlement

B. Response to the behavior of structures including subsidence and vibration

C. Stability of adhesion to the structural surface under wet conditions
D. Watertightness of the waterproofing layer
E. Stability against changes in the air temperature
F. Crack resistance in joints (connections) and cracks
G. Long-term durability in groundwater conditions
H. Chemical safety in groundwater quality (salinity, acid, and alkaline), polluted water (salt water and sulfate)

② Constructability
A. Simplicity of surface treatment method
B. Use of solvent-based materials
C. Simplicity of construction process and shortened curing time
D. Safety and simplicity of adhesion between sheets
E. Safety and simplicity of adhesion between substrates (materials)
F. Safety against earth pressure during refilling
G. Safety related to the previous and next civil engineering work

③ Technical aspects of material production
A. Status of production plant
B. Certification of nationally approved technology
C. Performance of field application at home and abroad

④ Maintenance
A. Follow-up maintenance (A/S period, leakage treatment method)
B. Specification standard of waterproofing method

(6) The types of waterproofing materials and construction methods commonly used for utility tunnels are shown in Table 1.7-1 below. Select the materials and construction methods according to the environmental conditions of the utility tunnel to be installed by considering 1.7.2 (5) above.

Table 1.10-1 Types of waterproofing materials and construction methods

Classification by form	Classification by material	
Liquid applied waterproofing membranes	Synthetic polymer-based spray coating waterproofing	
	Rubber asphalt-based spray coating waterproofing	
Sheet based waterproofing membranes	Synthetic polymer sheets	Self-adhesive rubber sheets
		Concrete pre-applied sheets
		HDPE sheets
		EVA vinyl sheets
		Polyurethane sheets
	Bentonite sheets	
Composite waterproofing	Synthetic polymer coating waterproofing + sheet waterproofing	
	Adhesive flexible rubber coating waterproofing + sheet waterproofing	
	Other double composite waterproofing	
Joint(waterproofing)	Adhesive flexible rubber waterproof seals	
	Adhesive flexible rubber coating waterproofing + sheet waterproofing	

(7) As condensation can be caused in the utility tunnel by the difference between internal and external temperature, install ventilation facilities. Consider the application of anti-condensation paint.

2. Materials

2.1 General provisions

No content

2.2 Excavation work

No content

2.3 Excavation by the open cut method

2.3.1 Selecting the excavating machine

(1) Select the excavating machine by considering the ground conditions, surrounding environment, the size of the utility tunnel, shape, extension, excavation method, and muck hauling method, and choose an economical model based on the characteristics of the ground.

2.3.2 Refilling

(1) The material used for refilling shall be of low compressibility and the strength should not be degraded by the penetration of water. Use materials that are easy to compact and not affected by frost.

2.3.3 Soft ground improvement

(1) All of the materials used in the construction shall be of the prescribed quality, and shall be inspected by the construction supervisor.

(2) You may send an inspector to the manufacturing site to inspect the testing and manufacturing process of the products.

2.4 Excavation by non-open cut methods

No content

2.5 Cast-in-place concrete work

2.5.1 Materials: General

(1) The materials of concrete shall conform to KCS 14 20 10.

(2) The concrete curing agent shall meet or exceed the specifications of the Korean Industrial Standards.

(3) Since concrete is highly vulnerable to damage in the event of fire, consider the application of fire-resistant mortar.

2.5.2 Transportation equipment

(1) The transportation equipment and conditions are as follows and conform to KCS 14 20 10.

① Transport vehicle

A. Truck mixer or truck agitator

(A) Used for long hauls or for high slump concrete.

(B) The transport vehicle should be capable of maintaining the mixed concrete in a uniform state, and should completely discharge the concrete without separating the materials. When samples are taken from the 1/4 and 3/4 sections of the concrete for testing, the difference between the slumps on both sides should be within 30 mm.

B. Dump truck

(A) Used for transporting stiff consistency concrete with a slump less than 25 mm for a distance below 10 ㎞ or a period of under 1 hour.

(B) The bottom of the dump truck's loading bay shall be flat, wide, and waterproof, and

if necessary, be equipped with a cover for protection against direct sunlight and rainfall.

C. Hand truck

(A) Hand trucks may be used when it is possible to prevent the concrete materials from being separated by making a flat transport route less than 100 m.

② Concrete pump

A. Use a piston or squeeze-type pump. Obtain the approval of the construction supervisor before using other types of pumps.

B. Determine the type of concrete pump, the diameter of the conveyance pipe, and piping after testing the pump. However, the minimum nominal size of the conveyance pipe for the maximum size of coarse aggregate shall be in accordance with Table 2.5-1 below.

Table 2.5-1 Minimum nominal size of conveyance pipe for the maximum size of coarse aggregate

Maximum size of coarse aggregate(㎜)	Nominal size of conveyance pipe(㎜)
20	≥ 100
25	≥ 100
40	≥ 125

C. Install the conveyance pipe using supports or fixed steel to prevent adverse effects such as vibration on the form, arrangement of bars, and poured concrete.

D. Before conveying the concrete, convey rich-mix mortar to prevent any change in concrete quality.

E. Dispose of concrete that has deteriorated in quality due to the deterioration of mortar quality according to (4) from the outlet of the conveyance pipe and by clogging from the pumping.

F. The concrete pump should be cleaned in advance and tested if necessary.

③ Tremie

A. If using tremies, the model, type, and method of use must be approved by the construction supervisor.

B. The tremies should be watertight with a size that allows concrete to fall freely.

④ If using a concrete placer, the model, type, and method of use must be approved by the construction supervisor.

⑤ If using a belt conveyor, refer to KCS 14 20 10 for the precautions.

⑥ If using a chute, refer to KCS 14 20 10 for the precautions.

2.5.3 Compaction equipment

(1) If compacting the concrete, the performance and compaction method of the vibrating machine shall comply with KCS 14 20 00.

2.6 Precast concrete work

2.6.1 Materials: General

(1) The materials of concrete shall be in accordance with KCS 14 20 52.

2.7 Waterproofing work

2.7.1 Waterproofing materials

(1) The waterproofing materials used in the utility tunnel shall adhere to the concrete surface and materials, and the quality of the product must meet the specifications of the Korean Industrial Standards.

(2) The waterproofing materials shall meet the requirements for durability, toughness, and flexibility, and the material should not be damaged during the joint construction of the utility tunnel body.

(3) The waterproofing materials used in the utility tunnel shall satisfy the performance requirements such as stability in reaction to and deposition of the chemical components (seawater, salt water, and other chemically contaminated water) of groundwater, resistance to changes in water pressure and flow velocity, safety and response to the influence of structural behavior, response to changes in temperature and humidity, safety of construction in a wet and underwater environment, and safety of construction according to seasonal changes.

(4) Perform composite waterproofing by using waterproof seal materials (hereinafter referred to as waterproof seal) which is flexible on the concrete's surface to prevent damage to the waterproofing layer for joint construction sections, joints, and connections to other structures. The waterproof seal must be flexible, adhesive to a wet surface, responsive to behavior, and should not separate under water.

(5) Use the waterproofing materials after confirming the required performance through an evaluation (test) before the construction or during the design process.

2.7.2 Selecting the waterproofing materials

(1) Select the appropriate waterproofing materials for the utility tunnel according to the evaluation of Table 2.7-1 to Table 2.7-5 with regard to the considerations for selecting the waterproofing method described in 1.7.2(5) above and the types of waterproofing materials and methods in 1.7.2(6) above. At this point, the material to be evaluated must meet the quality standards set by Korean Industrial Standards, or the quality standards in the specifications.

(2) The designer or the contractor should perform an evaluation on the waterproofing materials and construction method in the design stage or before the waterproofing work, or may entrust such work to a national or public quality testing institute, a quality inspection institute, or a research institute related to waterproofing technology.

Table 2.7-1 Performance evaluation of utility tunnel waterproofing materials and construction methods

No.	Category	Evaluation	Evaluation index	Rating	Remarks
1	Chemical deposition stability	Evaluate the stability of the waterproof layer (degradation such as separation) after depositing chemical water (salt water) around the utility tunnel for 3 weeks for each material (system+construction method).	No degradation		Evaluate the overall performance by giving ratings (weight and score) for each evaluation index during the design or construction stage
			Partial degradation		
2	Structural behavior responsiveness	Evaluate the waterproofing layer for tearing and leakage after performing behavior tests of more than 10㎜ on 5 specimens for each material (system+construction method). (Partial leaks are considered to be construction defects)	No leaks at all		
			Leak in 1 specimen		
			Leaks in 2 specimens		
			Leaks in 3 specimens		
			Leaks in 4 specimens		
3	Wet surface adhesion stability	Evaluate the adhesion stability on the concrete surface under wet conditions for 3 weeks for each material (system + construction method).	Stable in all aspects		
			Separation at the edge		
			Separation at the edge & center		
4	Watertightness	Evaluate the watertightness after various performance evaluations for each material (system+construction method).	No penetration		
			Penetration		
5	Temperature dependency	Evaluate the adaptability according to the changes in temperature (high & low) for each material (system + construction method).	Low strain rate		
			Average strain rate		
			High strain rate		
6	Crack resistance	Evaluate the product that has the best performance by measuring the crack resistance performance of each material (system+construction method).	Top 20% performance		
			Mid 60% performance		
			Bottom 20% performance		
7	Durability	Evaluate the durability of each material (system+construction method) for 40 days.	Top 20% performance		
			Mid 60% performance		
			Bottom 20% performance		
8	Low temperature adhesion stability	Evaluate the adhesion stability on the concrete surface after placing each material (system+construction method) and concrete at low temperature.	Stable in all aspects		
			Separation at the edge		
			Separation at the edge & center		

Table 2.7-2 Evaluation of waterproofing construction technology (common aspects)

Category			Evaluation	Evaluation index	Rating	Remarks
Common	Surface treatment method (Step treatment, separated placement and EJ joints, crack repair and reinforcement are basically performed)		Evaluate the surface treatment such as the treatment of laitance, honeycomb, and pinhole on the concrete surface to simplify the construction.	Construction method that does not require surface treatment		Evaluate the overall performance by giving ratings (weight and score) for each evaluation index during the design or construction stage
				Construction method that involves a general surface treatment (water cleaning, drying)		
				Construction method that involves a precise surface treatment (honeycomb and pinhole treatment, and application of surface conditioning agent)		
	Use of solvent-based materials		Evaluate the use of solvents (xylene, toluene, and gasoline) to apply primers for surface treatment, mix coating materials, and use adhesives for fire & environmental safety.	Use of inorganic solvent components		
				Use of organic solvent components		
	Number of processes (Excluding surface treatment)		Evaluate the total number of processes in the waterproofing work to ensure simplicity of construction management and precision of construction.	Method with less than 3 processes		
				Method with 4 processes		
	Basic process	Primer application Waterproofing Protective layer installation		Method with more than 5 processes		
	Curing period		Evaluate the number of days (per unit area) required for the basic process from the start to the end (completely dry) of waterproofing for the relevant construction method to ensure construction quality & manage the construction period.	1 day		
				2 days		
				More than 3 days		

Table 2.7-3 Evaluation of construction technology (by series)

Category			Evaluation	Evaluation index	Rating	Remarks
Series	Coating	Application method	Evaluate whether the waterproofing method used for the coating (roller, spatula) material is spraying type or coating type considering the thickness uniformity and constructability.	Spraying-type		Evaluate the overall performance by giving ratings (weight and score) for each evaluation index during the design or construction stage
				Coating-type		
		Thickness uniformity	Evaluate the thickness uniformity from applying the coating material to drying.	Uniform		
				Inconsistent		
	Sheets	Adhesion between sheets	Evaluate the simplicity of the construction technology to ensure the watertightness of the joints between sheets.	Self-adhesive		
				Heat-fused		
				Adhesive		
		Adhesion to substrate	Evaluate the simplicity of the construction technology to ensure watertightness & adhesion safety between the sheets and surface.	Self-adhesive		
				Heat-fused		
				Adhesive		
	Composite	Adhesion between sheets	Evaluate the simplicity of the construction technology to ensure watertightness & adhesion safety between the surface and the waterproofing material.	Self-adhesive		
				Heat-fused		
				Adhesive		
		Adhesion between materials	Evaluate the simplicity of the construction technology to ensure watertightness & adhesion safety between waterproofing materials.	Self-adhesive		
				Heat-fused		
				Adhesive		

Table 2.7-4 Evaluation of production technology

Item	Evaluation	Evaluation index		Rating	Remarks
Production plant	Evaluate the reliability of supply & production quality control of the relevant products.	In-house production			Evaluate the overall performance by giving ratings (weight and score) for each evaluation index during the design or construction stage
		Consigned production	1 product		
			More than 2 products		
Technical certification	Evaluate the possession of government approved technology for the relevant waterproofing material and method.	New construction technology + patent technology			
		New construction technology			
		Patent technology			
		N/A			
Application results	Evaluate the application results at home and abroad for the relevant waterproofing material and method.(excluding sites with leakage)	More than 10 locations (Including overseas results)			
		5~9 locations			
		Less than 4 locations			

Table 2.7-5 Evaluation of waterproofing work specifications and maintenance guidelines

Category	Evaluation	Evaluation index	Rating	Remarks
Specification & maintenance guideline	Evaluate the level of preparation for the construction technology guidelines (specifications, maintenance guidelines, etc.) to ensure the on-site quality of the relevant waterproofing technology.	Good		Evaluate the overall performance by giving ratings (weight and score) for each evaluation index during the design or construction stage
		Average		
Leakage repair measures	Evaluate the waterproof layer management during the construction, and the leak repair measures after completion (after refilling) of the relevant waterproofing technology.	O		
		X		

3. Construction

3.1 General provisions

No content

3.2 Excavation work

No content

3.3 Excavation by the open cut method

3.3.1 Excavating machines: General

(1) Excavation through the open cut method can be divided into manual and mechanical excavation. Mechanical excavation is performed using heavy equipment such as shovels and breakers to minimize the relaxation of the ground and maintain the stability of the excavated surface.

(2) Apply mechanical excavation to rock or soil ground with highly developed joints where blasting and manual excavation is impossible.

3.3.2 Operation of excavating machines

(1) Excavation machines shall be operated in accordance with KCS 27 20 00.

3.3.3 Refilling

(1) For refilling the outer section of the structure, use high-quality soil to prevent damage to the waterproof layer, and make sure that each layer is well pressed. If it is difficult to compact, perform water binding by filling more sand, or perform compaction with small equipment.

(2) Construct with high-quality soil to prevent declinating pressure and impact around the underground utilities, scaffold, and shores.

(3) When refilling the upper section of the underground utilities, avoid directly injecting from the transportation vehicle to prevent damage to the underground utilities.

(4) If the excavated materials are suitable for refilling, the materials may be used selectively.

(5) After completing compaction of the first layer of backfill, the thickness shall be less than 200 mm. In addition, maintain 95% of the maximum dry density obtained by methods D & E of KS F 2312 for every three layers and 90% of A compaction for the embankment on the original ground.

(6) Perform refilling work immediately after completing the waterproofing and waterproofing protection work on the utility tunnel. If there are concerns of ground settlement, perform tests and carry out refilling according to the results.

3.3.4 Soft ground improvement

(1) Matters related to soft ground improvement shall comply with KCS 11 30 35. Depending on the site situation, the application of replacement method, consolidation process, lightweight filling method, ground grouting, etc. can be considered following KCS 11 30 10, KCS 11 30 30, KCS 11 30 35, KCS 11 30 40, and KCS 11 30 45.

3.3.5 Earthwork

(1) In performing soil excavation, avoid loosening the surrounding ground by considering the excavation length, width, height, and slope according to the quality of the soil.

3.4 Excavation by non-open cut methods

(1) Excavation by non-open cut methods shall be in accordance with KCS 27 20 10.

3.5 Cast-in-place concrete work

3.5.1 Preparation for construction

(1) The preparation for construction shall follow KCS 14 20 10.

3.5.2 Transportation

(1) Matters related to transportation shall follow KCS 14 20 10.

3.5.3 Placement

(1) Matters related to placement shall follow KCS 14 20 10.

3.5.4 Pumping

(1) Matters related to pumping and relevant equipment shall follow KCS 14 20 10.

3.5.5 Cold weather Concrete placement

(1) Matters related to cold weather concrete placement shall follow KCS 14 20 40.

3.5.6 Hot weather concrete placement

(1) Matters related to hot weather concrete placement shall follow KCS 14 20 4.

3.5.7 Concrete placement under water

(1) Matters related to concrete placement under water shall follow KCS 14 20 43.

3.5.8 Compaction

(1) Matters related to compaction shall follow KCS 14 20 10.

3.5.9 Construction joints

(1) Matters related to construction joints shall follow KCS 14 20 10.

3.5.10 Expansion joints

(1) Insulate both sides of the expansion joint which are in contact with the structure and arrange joints and cut-off plates if necessary.

(2) Other matters related to expansion joints shall follow KCS 14 20 10.

3.5.11 Crack control joints

(1) The location and structure of crack control joints shall follow KCS 14 20 10.

3.5.12 Curing and protection

(1) Concrete curing and protection shall be in accordance with KCS 14 20 10.

3.5.13 Construction tolerance

(1) To ensure the durability of the reinforced concrete structure, the allowable crack width shall be in accordance with KDS 14 20 30 and KDS 14 20 40.

(2) The tolerance of dimensions shall be in accordance with KCS 21 50 05.

3.5.14 Concrete waterproofing, damp proofing, and disaster prevention

(1) After completing the concrete work, perform waterproofing according to the design drawing.

(2) After completing the concrete work, perform damp proofing according to the design drawing.

(3) After completing the concrete work, perform fire resistance (retardation work) according to the design drawing.

3.6 Precast concrete work

3.6.1 Precast concrete: General

(1) General details of precast concrete work shall be in accordance with KCS 14 20 52.

3.7 Waterproofing work

3.7.1 Waterproofing work: General

(1) Waterproofing work of the utility tunnel shall be in accordance with KCS 27 50 05, KSC 41 40 01, and KCS 41 40 13.

3.7.2 Preparation

(1) Before starting the waterproofing work, smooth out the bumps on the concrete surface to prevent damage to the waterproofing membrane and excessive pores between the waterproofing material and concrete during the construction.

3.7.3 Waterproofing work

(1) After determining the materials and construction method for the waterproofing work, prepare a comprehensive construction plan and develop prompt countermeasures considering the various construction conditions.

① Waterproofing work considering the structural details of the utility tunnel

A. If there are structural joints, penetrations, and connections between two structures due to the shape of the utility tunnel (square, cylindrical, etc.), perform appropriate waterproofing on these areas from the initial stage.

② Waterproofing work considering the stability and subsidence of the ground condition

A. To prevent damage to the waterproof layer due to the structure sinking because of the ground conditions in the area where the utility tunnel is to be installed, thoroughly examine the ground settlement and perform waterproofing work to ensure stable long-term performance in the behavior of the structure. In particular, when the settlement or behavior is measured to be more than 50 mm, check and confirm whether the waterproofing materials and construction method provide the corresponding performance before starting the construction.

③ Waterproofing work considering the surface condition of the structure

A. When waterproofing the utility tunnel, the surface of the concrete structure is often under wet conditions due to the influence of rainfall and groundwater. In such cases, it is difficult to secure the quality of the waterproof layer due to the reduced adhesion between the concrete surface and waterproofing material. For this reason, it is essential to determine whether the waterproofing materials and construction method can be applied under wet conditions while maintaining quality standards before starting the waterproofing work.

④ Waterproofing special sections

A. In terms of sections such as the variable joints, connections between two structures, expansion joints between structures, and wall penetrations in the utility tunnel, consider each of the structural characteristics. In addition, perform waterproofing work so that the waterproofing material can follow the design displacement with respect to the behavior of the variable section.

⑤ Waterproofing pile heads such as H-beams

A. Pile heads such as H-beams, steel pipes, and concrete piles used to improve the ground

in the area where the utility tunnel is to be installed affect leaks in the bottom of the utility tunnel, so perform waterproofing work to prevent this from happening.

⑥ Construction joints and expansion joints

A. The waterproof layer in the construction and expansion joints can be easily damaged by the settlement of the structure as well as by expansion and contraction due to temperature changes. These areas should be constructed in parallel with double-reinforced waterproof treatment or flexible waterproof seals that can safely cope with the behavior of the structure.

⑦ Waterproofing work considering seasonal changes

A. When installing the utility tunnel, ensure stable constructability through using waterproofing materials that can cope with all four seasons.

(2) Since waterproof sheets lack surface conformability at curves such as corners and protrusions, it is difficult to maintain the watertightness of the joints between the sheets, so manage these carefully and comprehensively.

(3) Manage the quality of coating materials during construction because they are significantly affected by the climate, and there are also concerns about uneven thickness, pinholes, and stability of the waterproof layer.

(4) For defects such as leaks in the waterproof layer during and after the waterproofing work, clarify the assurance of quality and limitations of liability before starting the work.

(5) When waterproofing the outer surface of the utility tunnel, establish an appropriate construction plan for the selected waterproofing materials by considering the conditions and constructability of the construction site such as the performance required for the environment of the structure (behavior and vibration, groundwater conditions), the status of the structure's surface, and groundwater conditions.

① Develop a comprehensive construction plan for the materials, equipment, facilities, and construction method according to the construction conditions such as the size of the construction, surface conditions, and leakage.

② If necessary, conduct waterproofing work under the guidance of a waterproofing engineer (expert) who has sufficient experience and skills.

③ For storing and handling the waterproofing materials, protect the adhesive surface from foreign substances and physical damage, and avoid fires.

④ Treating the structural surface and leaks

A. Take care of any honeycombs, protrusions, and foreign substances which may interfere with the waterproofing work in advance, and secure a stable waterproof surface by draining the inflow of groundwater to prevent contact with the waterproof surface. Repair any leaks before starting the waterproofing work.

⑤ Temporary resources and equipment

A. Use the proper resources and equipment for the waterproofing work considering safety and constructability.

⑥ Work tools

A. Use the appropriate tools for waterproofing work to ensure safe and reliable results.

⑦ Precautions for the construction that follows the waterproofing work

A. To prevent damage to the constructed waterproof layer, consider the following when performing construction work after waterproofing.

(A) Be careful not to damage the waterproof layer when assembling the rebars on the floor.

(B) Be careful not to damage the waterproof layer when using vibrators.

3.7.4 Quality test and management of waterproofing materials

(1) If necessary, test and manage the waterproofing material selected in section 2.2 according to the quality standards specified in the Korean Industrial Standards (KS) or the design drawing, and if necessary, you may request testing from national and public quality testing institutes and quality inspection institutes.

(2) Store the waterproof sheets in an indoor warehouse to prevent direct contact with the ultraviolet rays in sunlight and to prevent degradation due to damage caused by rainwater or groundwater around the site.

(3) Confirm the accuracy of the waterproofing design, construction management, quality of materials, and maintenance before performing the waterproofing work, and conduct a mock-up to check for any problems that may occur during the construction process.

(4) In the event of defects such as leaks in the waterproof layer during and after the waterproofing work, clarify the assurance of quality and limitations of liability before starting the work.

(5) For quality control, review the interference with other processes, the order of construction, and the effect on other processes related to the waterproofing work before starting the waterproofing work.

(6) Inspecting and repairing the waterproof layer

① Confirm the safety of the waterproof layer after completing the waterproofing work and repair any areas where there are concerns over leaks, damage, and separation.

(7) Protecting the waterproof layer

① Install a protective layer to ensure the safety of the waterproof layer according to subsequent works such as refilling after completing the waterproofing work. The protective material used for the protective layer should be specified in the design drawing or supplied by the waterproofing material manufacturer or the waterproofing contractor as a product suitable for protecting the waterproofing material used in the construction.

3.7.5 Refilling

(1) Perform refilling within the time limit specified by the manufacturer of the waterproofing material after completing the waterproofing work.

(2) Use soil or gravel that does not contain any impurities for the refilling work, and remove aggregates with sharp edges, such as boulders, gravel, bricks, wood, and rebars with a size of more than 100 mm, as these may damage the waterproof sheets.

(3) If the drop height of backfill soil is high, use a chute to prevent direct impact on the waterproof layer.

3.7.6 Safety and fire prevention

(1) During the waterproofing work, the workers should check and manage the solvents, inflammables, and tools in advance to prevent safety and health problems.

(2) To prevent fires, establish sufficient heat source management measures and check matters related to fire control, evacuation, rescue, and safety education before construction.

3.7.7 Maintenance during construction

(1) For leaks that occur after waterproofing the outer surface of the utility tunnel, minimize damage to the structure and internal facilities from groundwater and establish repair or reinforcement measures for economic maintenance.

(2) For leaks in the utility tunnel, aim to fundamentally block the water at the point of inflow.

(3) Determine the appropriate repair materials and construction method to repair leaks in the utility tunnel by considering the behavior of the structure and cracks, durability, constructability, safety under water, and adhesion to wet surfaces.

(4) Apply leak repair methods such as the crack infusion repair method, back infusion repair method, and waterproof layer reconstruction method, but select repair materials according to the evaluation method (refer to KS F 4935, etc.) in Table 3.7-1 based on the requirements of the leakage environment of the main structure.

Table 3.7-1 Performance standards for injection-type sealing materials to repair leaks

Category			Performance standard	Remarks
Permeability resistance performance			No penetration	KS F 4935
Adhesion to wet surface			Bottom plate of the specimen should not fall in 60s	
Performance against structural behavior			No penetration	
Underwater loss resistance performance (※)			Weight change rate should be within -0.1%	
Chemical resistance performance (※)	Acid treatment	H_2SO_4	Weight change rate should be within -0.1%	
		HCl		
		HNO_3		
	Sodium chloride treatment			
	Alkali treatment			
Temperature dependence performance(heat/cold)			No penetration	

Note) Some sealing materials increase in weight when reacting with water (H_2O) or chemicals due to expansion, but this is usually not a factor that indicates degraded performance (underwater loss), so we only evaluate weight loss.

(5) Repair work management

① Develop a comprehensive construction plan for the materials, equipment, facilities, and construction method according to the construction conditions such as the conditions of the leaks and the size of construction.

② Repair the leaks under the guidance of a waterproofing engineer with sufficient experience and skill.

③ Develop a plan to store and handle repair materials and other subsidiary materials.

④ Ensure the correct methods are employed to use and manage the materials to maintain quality.

(6) Quality control of repair materials

① The contractor shall submit a warranty for major construction materials, and the construction supervisor shall extract samples of the materials to confirm the quality.

(7) Repair work on special sections

① In the event of leaks in the following areas of the utility tunnel, conduct repair work by selecting the proper repair materials and methods considering the structural characteristics.

A. The right angles and corners of the structure

B. Expansion joints

C. Structure penetrations