KCS 11 40 10 : 2019

Corrugated Steel Plate Culvert

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KC CODE

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 reinforced concrete culverts in each standard based on the existing Road Construction Standard Specifications. The history of the standards are as follows:

Construction Standard	Main Content	Enacted or Revised (Year.Month)
Road Construction Standard Specifications	• Established by the Korean Society of Civil Engineers commissioned by the Ministry of Construction	Enacted (1967.12)
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.	Revised (1985.12)
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	Revised (1990.05)
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)..	Revised (1996.07)
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.	Revised (2003.11)

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.	Revised (2009.03)
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.	Revised (2015.09)
Road Construction Standard Specifications	• Partial, revision including overview, forest and tree protection materials, and general construction works.	Revised (2016.05)
KCS 11 40 10 : 2016	• Integrated and organized to accommodate the code system due to the transition to the code system of construction standards.	Enacted (2016.06)
KCS 11 40 10 : 2018	• Modified to satisfy the Korean Industrial Standards and Construction Standards.	Revised (2018.07)
KCS 11 40 10 : 2019	• Modified to satisfy the Korean Industrial Standards and Construction Standards.	Revised (2019.11)

Table of Contents

1. Generals

1.1 Scope of Application

(1) This standard is applied to the construction of corrugated steel plate structures, such as passage and canal culverts, small bridges, and temporary facilities using corrugated steel plates.

1.2 Reference standards

1.2.1 Related laws

No contents.

1.2.2 Related standards

- KCS 10 10 10 Public administration requirements
- KCS 11 20 25 Refilling and backfill
- KS B 1002 Hexagon head bolts and hexagon head screws
- KS B 1012 Hexagon nuts and nuts and low type hexagon nuts
- KS B 1016 Foundation bolts
- KS D 0210 Macro-structure detecting method for steel
- KS D 3503 Rolled steels for general structure
- KS D 3506 Hot-dip zinc-coated steel sheets and coils
- KS F 2312 Test method for soil compaction using a rammer

1.3 Definition of Terms

- Corrugated steel plates: Steel plate for structures molded to have a corrugated pattern with specified standards.
- Corrugated steel plate structures: Structures that support external loads based on soil-structure interaction after connecting corrugated steel plates by bolts to form sections and then compacting the surrounding ground and upper part with engineered backfill materials.
- Span (S) and rise (R): The maximum width and height of the corrugated steel plate structure (refer to Figure 3.1-7 for span and rise by cross-section shape).
- Soil cover: Soil filled portion from the top of the corrugated steel plate structure to the ground surface.
- Minimum depth of soil cover: Minimum soil cover depth that guarantees the stable behavior of corrugated steel plate structure.
- Engineered backfill: Compaction and filling of high-quality soil or other filling materials according to given criteria at a certain area around the structure to ensure ductile behaviors of the corrugated steel plate structure.

- Bedding: To form a compaction earth and sand layer (bed) that plays a cushioning role between the closed-section of the corrugated steel plate structure and the foundation ground.
- Arching: Phenomenon of inter-transfer of pressure on a structure due to the relative displacement between soil masses around corrugated steel plate structure.

1.4 Submission documents

1.4.1 Requirements and procedure of documents to be submitted

(1) The requirements and procedure of document submission follow the corresponding requirements in KCS 10 10 10.

1.4.2 Items required in the construction plan document

The contractor shall create the construction plan document including the following items.

1.4.3 Shop Drawing

A detailed construction plan describing each items below shall be submitted.

(1) Detailed construction plan for Temporary facility required for construction.
(2) Construction sequence
(3) Standard drawings of layering
(4) Methodology of compaction
(5) Construction drawings required by construction supervisor

The contractor shall create the construction plan document including the following items.

(1) Construction overview
(2) Detailed process schedule (materials, human resource, and equipment plan included)
(3) Process plan by construction work type
(4) Quality control plan (quality control organization, management goals and execution methods, corrective actions taken when the goals are not satisfied, etc.)
(5) Safety management plan and environmental management plan
(6) Items that require consultation and adjustment with other construction and work types
(7) Items that require adjustment and modifications of design drawings
(8) Other items

① The construction plan document may be divided according to the construction progress after acquiring the approval of the construction supervisor. When the construction plan document is modified, the revised construction plan document shall be created and approved by the construction supervisor.

2. Materials

2.1 Materials

2.1.1 Steel plates

(1) The corrugated steel plate materials shall employ steel materials for structures that comply with the corresponding requirements in KS D 3590 or SS275, SS315 of KS D 3503, or equivalent or higher standard products, and that are hot dip zinc coated according to 2type 45 of KS D 8308.

Table 2.1-1 Requirements of source material of corrugated steel plates (KS D 3503, 3506)

Material Symbol	Chemical composition					Mechanical properties				
	C (%)	Si (%)	Mn (%)	P (%)	S (%)	Zinc Coating weight (g/m^2)[2]	Yield strength (MPa)[3]	Tensile strength (MPa)	Elongation rate (%)	
									≤0.05	5<t≤16
SS275 (SS400)	≤0.25	≤0.45	≤1.40	≤0.050	≤0.050	900≤	275≤	410 ~550	21≤	18≤
SS315 (SS490)[1]	≤0.28	≤0.50	≤1.50	≤0.050	≤0.050	900≤	315≤	490 ~630	19≤	16≤
SS410 (SS540)	≤0.30	≤0.55	≤1.60	≤0.040	≤0.040	900≤	410≤	540≤	16≤	14≤
SS450 (SS590)	≤0.30	≤0.55	≤1.80	≤0.040	≤0.040	900≤	450≤	590≤	14≤	12≤

Note 1) Grade40(275 MPa or higher yield strength, 380 MPa or higher tensile strength) of ASTM A1018 can be applicable

2) Based on two sides of steel plate

3) This value is applied for the strength during design (Test value may be applied if separated test result is available.)

(2) The specification of corrugation is divided into standard and deep types. The features of sections depending on the thickness, and the arrangement of bolt holes shall follow the standards and design drawings of the manufacturer.

(3) Steel plates must be molded to have the final shape unless otherwise specified, and the bolt holes shall be hot dip zinc coated after the holes are punched. After coating, the plates shall not be cut or have their shapes changed arbitrarily.

2.1.2 Bolts and others

(1) Bolts and nuts used in the steel plate assembly shall be products that are specified in the standard specifications, and anchor bolts and base channel for concrete connection shall comply with the material standards of bolts and steel plates.

(2) The above metal accessory material must be zinc-plated or non-rusting materials, and shall be used unless steel plates are used for temporary structures.

2.2. Equipment

2.2.1 Crane

(1) The process of crane lifting plan for layering culvert shall be submitted to construction supervisor.

2.2.2 Mixer for grout injection

(1) A mixer for grout injection shall be capable of continuous injection work at least at one place.

3. Construction

3.1 Construction standards

3.1.1 Foundation and backfill

A corrugated steel plate structure exhibits the structural performance through interaction between the steel plate and the surrounding ground. Thus, care should be taken to select backfilling materials and to construct structure foundation.

(1) Foundation ground

① The foundation ground where steel plate structures are placed shall have sufficient bearing capacity against the entire upper load, including the structure and the backfill load, and shall not cause excessive settlement. Thus, if the in-situ ground does not satisfy the above conditions, the ground is replaced with high quality fill materials or improved and reinforced as much as necessary.

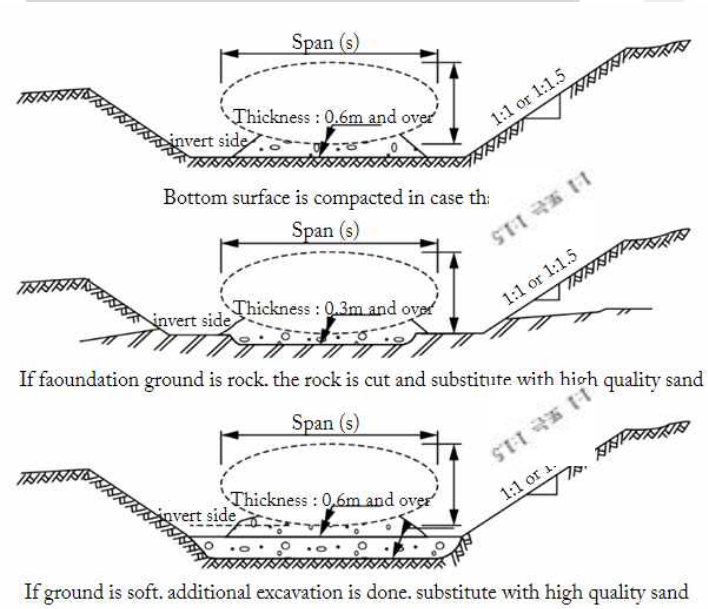


Figure 3.1-1 Example of processing method according to foundation ground conditions

② If structures are installed after excavating foundation ground, an excavation width shall be 3.0 m wider than the width of steel plate structure. If steel plate bottom surface is exposed to rock mas, the ground is replaced with high quality cobbled sands up to 300 mm in depth from the bottom surface.

③ The ground where a structure is installed shall avoid soft layers and rock masses as much as possible. The soft layer shall be compacted with high quality sand and gravel, while sandy gravel is loosely laid in the rock mass section to minimize the relative displacement over the entire section.

④ A certain amount of camber may be placed in the structure bottom surface, expecting unequal settlement of the structure according to changes in soil cover depth above the structure. Here, the amount of camber is set within 1% of the total structure length.

(2) Bedding

① When closed section structures are constructed, bedding shall be installed using sandy soils that have good permeability between foundation ground and steel plate in the structure bottom surface. The maximum dimension of the bedding material shall not exceed 1/2 of the plate corrugation pitch (75mm in standard corrugated steel plate and 190 to 200mm in deep corrugated steel plate).

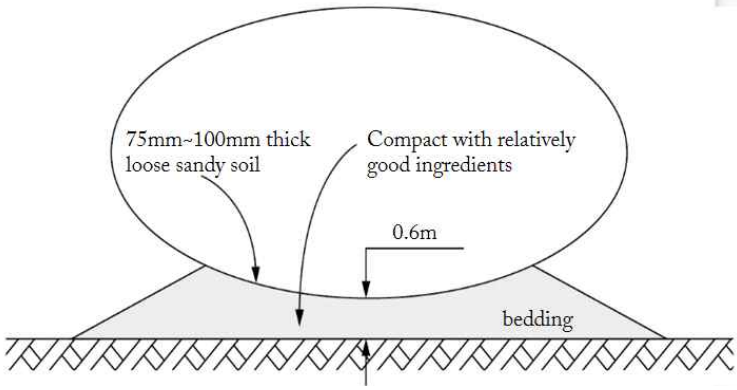


Figure 3.1-2 Bedding construction

② A thickness of bedding shall be 0.6m or thicker from the center of the structure, and an approximately 100 mm-thick layer of sand (less than 15 mm diameter) is loosely created at a place that is contacted with the steel plate thereby filling the corrugation space in the steel plate with soil completely.

③ A width of bedding is determined as the distance between spots where a radius of curvature of the lower steel plate changes, although it depends on the structure shape. It is preferable for a circular shape structure to form a bedding layer that does not make compaction in the lower part (haunch) of the steel plate difficult.

④ The following items shall be inspected during bedding construction to ensure sufficient bearing capacity.

A. Whether the location of structure is matched with the location in the design.

B. Identification of the ground conditions, such as soft groundor rocky ground.

C. Whether the ground bearing capacity specified in the design is secured.

D. Bedding formation status that is significant to the shape of the lower curvature of the corrugated steel plate structure.

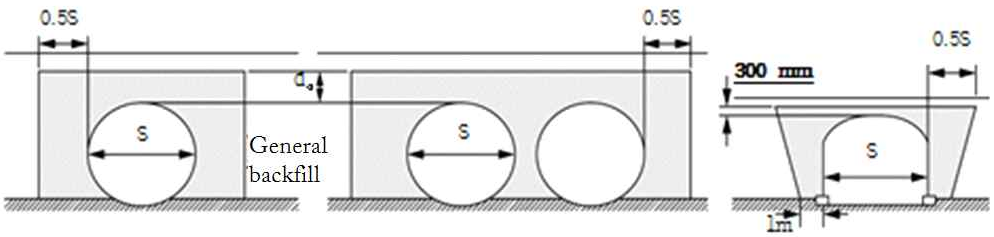
(3) Backfilling

① Backfilling shall be done with uniform compaction using granular materials whose compressibility is small, or materials with high quality gradation. The materials used in foundation ground and backfilling shall be the same material or materials that are not significantly different to make earth pressure uniformly applied to the structure.

② The backfilling portion of the underground steel plate structure is divided into an engineered backfilling portion that directly affects the behaviors of the steel plate structure, and a general backfilling portion around the engineered backfilling portion.

③ When structures are installed in the banking section (including excavation after banking), the engineered backfilling section shall ensure a space of more than 1/2 of the structure width from the outermost side of the steel plate wall laterally, and a space of the minimum depth of soil cover (dc) from the crown of the steel plate wall vertically as shown in Figure 3.1-3.

④ When in-situ ground is excavated, and structures are installed, excavation shall ensure 1.5 m or longer space from the outermost side of the steel plate wall, and a range of more than 1/2 of the structure width from the outermost side of the steel plate wall laterally and a range of more than minimum depth of soil cover (dc) vertically are regarded as the engineered backfilling section as shown in Figure 3.1-4.



(a)All cross-sections except for box type (b)Parallel construction(excluding box)

Figure 3.1-3 Engineered backfilling section when underground steel plate structure is installed in the banking section

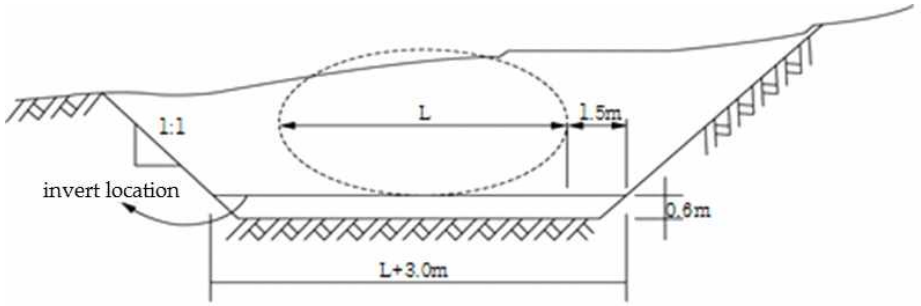


Figure 3.1-4 Engineered backfilling section when foundation ground is excavated and steel plate structure is installed

⑤ The engineered backfilling materials or mixtures shall be crushed stones or gravels with good durability and small compressibility after compaction, and sands with good grain size distribution, which shall be approved by the construction supervisor. They shall have the quality of subgrade materials or higher as presented in Table 3.1-1. If subgrade-quality materials in Table 3.1-1 are used, anti-freeze measures shall be taken during winter.

Table 3.1-1 Quality criteria of engineered backfilling materials of underground steel plate structures

Grade / Category	Subbase material quality (SB-1, SB-2)	Subgrade material quality
percentage against No. 200 sieve	Less than 10%	Less than 25%
Plastic index (PI)	NP	Less than 10%
Unified classification symbol	GW, SW, GP, SP	SM, SP

⑥ When a soil cover section is relatively thin, or loading conditions are disadvantageous, in particular, with the following conditions, filling materials with subbase material quality or higher shall be used as presented in Table 3.1-2.

A. When a soil cover depth is thinner than the minimum depth of soil cover,
B. When the structure section conditions are ones presented in Table 3.1-2,
C. Regions where underground water springs to the surface,
D. When the lower ground of structure is very soft (maybe excluded in case of ground improvement),
E. Regions where aconfined aquifer is present close to the surface.

Table 3.1-2 Cross-section conditions of structures that shall employ subbase quality materials

Category	Cross-section condition
Standard type	When cross-section width (span) is more than 10 m,
	The upper radius of curvature of low or high arch type is more than 4.5 m,
Deep type	When a cross-section shape is box-girder bridge,
	All cases using deep type steel plates,

⑦ The engineered backfilling materials shall be higher grades than presented in the design drawings (subgrade quality or higher). The maximum grain size shall not exceed 1/2 of the corrugation depth of steel plate (75 mm of diameter). The filling material at the directly contacted portion to the steel plate structure shall use aggregates whose grain size is less than 15 mm. Aggregates may be laid within 1 m of the steel plate to reduce the earth pressure depending on the site.

⑧ General backfilling materials may employ materials around the site for filling materials (up to 80 mm aggregate size) other than engineered backfilling materials in accordance with the design, and shall, while being sure to avoid large rocks. They shall not be placed within the range of the engineered backfilling if it can be avoided.

⑨ Flowable mortar mixture consisting of granular soil, water, fly ash, and cement, controlled low strength material (CLSM), and other special material may be used instead of general earth and sand materials in the engineered backfill section.

⑩ When the earth and sand in the lower part of internal pavement of foundationless structure is compacted, the adjacent steel plate section is compacted using a small compacter to prevent damage to the steel plate, and the center portion is compacted using a general compacter. Note that if the compaction work is difficult to be done, concretes may be used in place of earth and sand in the lower part of the internal pavement.

⑪ The construction of engineered backfilling portion shall follow KCS 11 20 25. Accordingly, a thickness of one layer after compaction completion shall be less than 200㎜, and the density shall be more than 95% of the maximum dry density calculated using C, D, or E method in KS F 2312.

⑫ The compaction thickness of one layer may be adjusted after approval from the construction supervisor and a senior engineer in the geotechnical engineering field if standard compaction management can be found to be achievable through test compaction.

⑬ For backfilling portions, if a soil cover height is less than 3.5m, subbase materials are not used, and if it is more than 3.5m, subgrade soils may be used.

⑭ The traffic of heavy equipment must be controlled strictly except for compaction equipment

within 0.6m from the steel plate wall during the backfilling compaction work. The compaction equipment during lateral side compaction shall run in parallel with the longitudinal direction, and it shall be run in perpendicular direction during upper side compaction.

⑮ A difference in compaction height at both sides of the structure shall be less than one-layer compaction thickness (200 ㎜), and re-compaction shall be done if the structure is deformed due to the biased earth pressure.

⑯ For structure's backfilling, a layer thickness shall be marked every200mm on the side of the corrugated steel plate structure prior to backfilling material placement to check the layer compaction progress, and compaction tests are conducted in every three layers.

⑰ Basically, large rollers are used for backfilling compaction in the side portion. However, if the work using large compaction equipment is difficult, small compaction equipment shall be used within 0.6m from the steel plate wall.

⑱ Since sufficient compaction force shall be secured for the haunch portion of foundationless structure, compaction by watering or rodding of high density sand is a method of placing lightweight concrete up to the haunch height if the compaction of the haunch portion is difficult.

⑲ The section from the crown to the minimum depth of soil cover during the upper part of backfilling of the corrugated steel plate structure shall be constructed with engineered backfilling.

⑳ Vibrating compaction shall not be executed until the minimum depth of soil cover is secured during upper part compaction, and the traffic of heavy equipment shall not be allowed except for compaction equipment. Heavy weight objects shall not be allowed as well.

(4) Soil cover portion

① The section from the crown of steel plate structure to the minimum depth of soil cover shall be constructed by following the standards of engineered backfilling.

② The equipment shall be run in a direction perpendicular to the axis of the structure during the compaction of the soil cover section, and vibrating compaction shall not begin until the minimum depth of soil cover is ensured.

③ When the minimum depth of soil cover is not ensured, heavy equipment, except for compaction equipment shall not pass the upper side of the structure, and heavyweight objects shall not be allowed either.

(5) Backfilling of intersection and banking/cut sections

① The banking and cut slopes that border with the backfilling portion shall be compacted using saw-toothed or stepped bench cut in line with the compaction thickness as shown in Figure 3.1-5, and loose portions shall be removed prior to the start of construction.

② Particular care should be taken for the backfilling section of first and second divisions when division conxstruction is used.

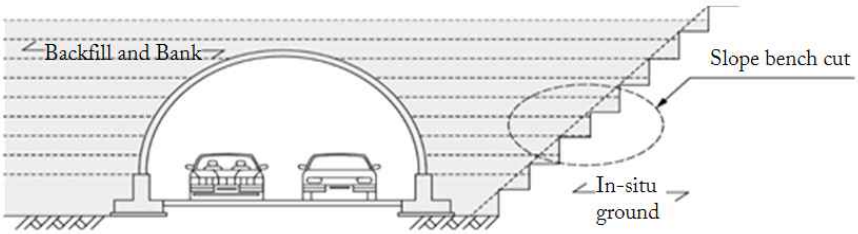


Figure 3.1-5 Backfilling of intersection and banking and cut sections

(6) Backfilling of longitudinal slope section

① For the banking section of a foundationless structure, the bearing capacity of the foundation ground must be ensured, and backfilling shall be conducted according to the conceptual diagram of Figure 3.1-6 to integrate the foundation ground and backfilling into the banking body.

② Backfilling shall be complete as soon as possible to prevent disturbances between the foundation ground and backfilling banking materials due to rainfalls.

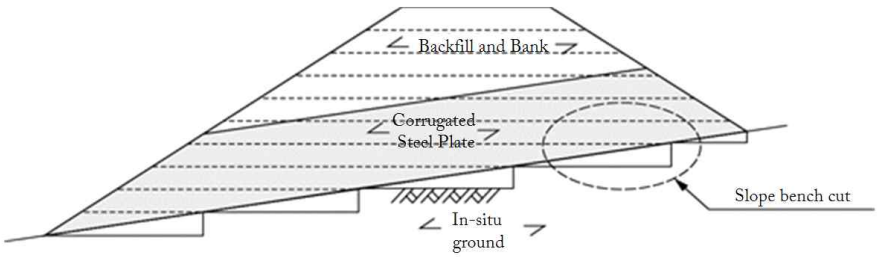


Figure 3.1-6 Backfilling of structure with longitudinal slope

(7) Equipment operation during compaction

① The compaction equipment shall be run parallel with the length direction of the structure for lateral side compaction, and shall be run perpendicular to the longitudinal direction of the structure for upper side compaction.

② During backfilling work, when backfilling materials are laid on the lateral side of the corrugated steel plate structure, the work shall be performed at a distance of 2m to minimize the effect on the structure.

3.1.2 Foundation of open section structures

(1) Concrete foundation

① For open-section (arch-type section) structures, concrete foundation structures that can support the steel plate walls shall be installed at the precise location, and a base channel gap shall be verified through measurement.

(2) Connection of steel plate and foundation

① The steel plate and foundation concretes are connected using a base channel.

② A base channel shall be installed together with the burial anchor prior to concrete placement. If concrete is placed first, a buried anchored connection angle shall be used.

③ A channel shall be connected to be perpendicular to the steel plate.

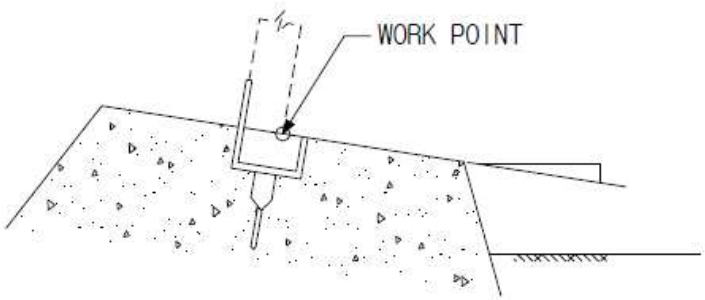


Figure 3.1-7 Foundation connecting portion using a base channel

3.1.3 Assembly of steel plates and others

(1) Inspection of materials and site preparation

① The contractor shall verify the following items in the presence of the construction supervisor, and have only suitable materials delivered to the site. Here, test result reports (issued by professional quality inspection organization) of the zinc coating weight according to weight method (direct method) or the antimony chloride method (indirect method) specified in KS D 0210 shall be attached with regard to the zinc-coated steel plate materials and accessory materials, and plating thickness shall be verified using a coating thickness gauge when materials are delivered to the site.

A. Thickness and quantity of steel plates

B. Quality of finishes of steel plate end sand bolt holes

C. Steel plate coating quality and coating weight

D. Whether access or ies such as bolt sand nuts satisfy the specifications.

② At the site where the structure will be installed, the storage location of delivered materials, the location of the required equipment such as cranes, and entry of the construction equipment during backfilling work shall be determined beforehand.

③ The steel plates shall be transported and handled with care as to not cause deformation or surface damage. When the steel plates are installed, no impact shall be exerted on the steel

plates with heavy or hard objects.

④ Damaged steel plates or steel plates whose zinc-coat is peeled off shall be replaced.

(2) Assembly of steel plates

① The assembly of steel plates shall be conducted according to the design drawings or construction plan document, and starts from the downstream side (lower side) to the upstream (higher side). The design section shape shall be maintained using supports or steel wires if necessary.

② The steel plates delivered to the site have different curvature and specification generally. Thus, the order and position must be kept carefully without change in accordance with the installation drawings.

③ When steel plates are stacked, the gap between plates shall be minimized, and more than four plates shall not be stacked at a single location. A gasket or packing shall be used in the connecting portion.

④ Other than locations where the radius of curvature changes, the location of the joint portion shall not be laid consecutively in the length direction during assembly.

⑤ The nominal tightening torque of bolts shall be 200 N·m - 400 N·m, and uniform torque shall be applied overall during assembly. A quantity of 3% of the total number of bolts used in the joint portions in the length and circumferential directions shall be selected randomly and inspected using a torque gauge in the presence of the construction supervisor after steel plate assembly is complete. If the number of bolts that are out of the nominal torque range exceeds 10% of the total number of inspected bolts, fastening shall be done again for all bolts.

3.1.4 Measurement of changes in cross-section

(1) For corrugated steel plate structures, changes in shape size of the cross-section shall be measured ① immediately after assembly, ② in the middle of backfilling (including soil cover), and ③ immediately after the completion of construction.

(2) Once the assembly is complete, a cross-section size is measured prior to the start of backfilling. If the measured result is more than 5% of the designed shape, bolts shall be released loosely to correct the shape and the structure shall be reassembled.

(3) Once the backfilling starts, a cross-section size inside the structure shall be measured immediately after compaction at each layer (more than three places measured) thereby identifying any deformation. The criteria of the deformation allowed in the middle of and after construction are presented in Table 3.1-3. If the cross-section deformation exceeds the criteria in Table 3.1-3, construction shall be immediately stopped, and the cause shall be identified to find the reinforcement measure thereby reducing the deformation.

Table 3.1-3 Allowable range of deformation in structures in the middle of and after construction

Category	Allowable cross-section deformation
When standard type steel plate is applied,	Within 5% of the structure height (rise, R) defined in Figure 3.1-8
When deep type steel plate is applied,	Within 2% of the structure height (rise, R) defined in Figure 3.1-8

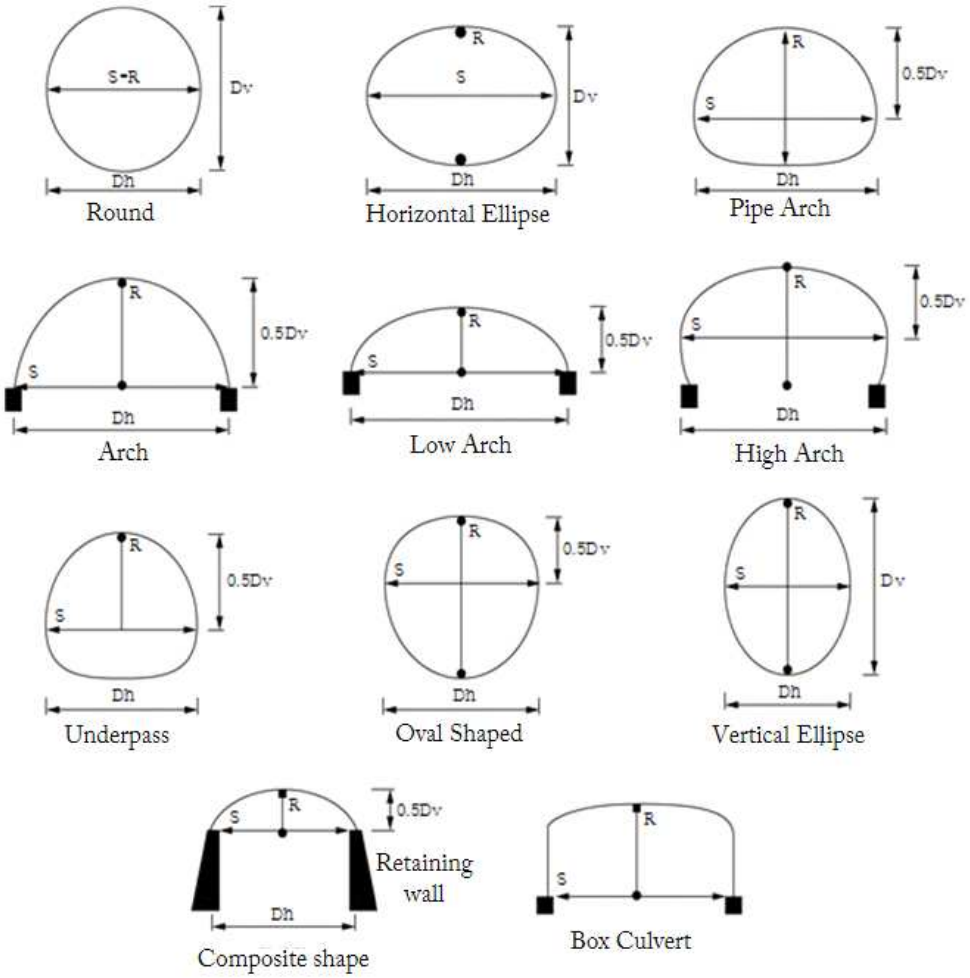


Figure 3.1-8 Applied cross-section of corrugated steel plate structure (S=width-span, R=height-rise)

3.1.5 Other items

(1) Appropriate surface waterproof treatment, such as asphalt bituminous material coating shall be applied to the joint portion of the steel plate to prevent water infiltration through the joint portion or bolt holes. If necessary, waterproof film shall be buried at the soil cover and backfilling portions.

(2) If buoyancy is applied due to the rise of the surrounding water level, the uplift pressure shall be investigated, and increase if structure's self-weight or measures such as anchor installation shall be provided if needed.

(3) When structures are constructed in an environment where corrosion or damage to steel plate members are expected, measures of increasing the thickness of the steel plate or the coating of the protective film shall be taken.

(4) When steel plate structures are constructed by connecting them to rigid bodies such as concrete structures, suitable method of joint installation or reinforcement shall be provided through stress investigation on the structure bonding portion.

(5) SB-1(2) materials are used as backfilling materials with composite type building structures.

3.1.6 Reinforcement of cross-section of corrugated steel plates

(1) Structures may be reinforced to increase the load carrying capacity of corrugated steel plate underground structures.

(2) Reinforcing materials shall have the same radius of curvature with that of the main structure and be installed at regular spacing in the length direction of the structure.

(3) If concrete are filled between main structure and reinforcing material, the stiffness calculation in the reinforced cross-section for load carrying capacity shall be based on non-composite cross-section. Note that additional investigation is needed if the calculation is based on composite cross-section.