Chapter 6 Port Transportation Facilities

(English translation of this section from Japanese version is currently being prepared.)

1 General

(English translation of this section from Japanese version is currently being prepared.)

1.1 Traffic Signs and Markings

(English translation of this section from Japanese version is currently being prepared.)

2 Port Roads

(English translation of this section from Japanese version is currently being prepared.)

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(English translation of this section from Japanese version is currently being prepared.)

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(English translation of this section from Japanese version is currently being prepared.)

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(English translation of this section from Japanese version is currently being prepared.)

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(English translation of this section from Japanese version is currently being prepared.)

3 Underwater Tunnels

[Ministerial Ordinance] (Performance Requirements for Roads)

Article 36

1 The performance requirements for roads shall be as prescribed in the following items:

(1) Roads shall satisfy the requirements specified by the Minister of Land, Infrastructure, Transport and Tourism so as to ensure the safe and smooth flow of traffic within ports,and between ports, and their hinterlands in consideration of the traffic characteristics in the ports.

(2) Damage due to surcharge loads, etc. shall not adversely affect the continous use of the roads without impairing their functions.

2 In addition to the provisions of the preceding paragraph, the performance requirements for roads with tunnel sections shall be as prescribed in the following items:

(1) Damage due to self-weight, earth pressure, water pressure, Level 1 earthquake ground motions, etc shall not adversely affect the continous use of the roads without impairing their functions.

(2) Damage due to Level 2 earthquake ground motions, flames and heat due to fires, etc. shall not adversely affect the restoration of their functions through minor repair works.

[Public Notice] (Performance Criteria of Underwater Tunnels)

Article 78

1 The performance criteria of underwater tunnels shall be as prescribed in the following items:

(1) Underwater tunnels shall be covered with appropriate materials of required thicknesses to secure the integrity of the structural members and the stability of their structures against the dropping and dragging of ship anchors, scouring of seabed by waves and currents, etc.

(2) Underwater tunnels shall be equipped with the management facilities necessary for their safe and smooth use.

(3) The degree of damage under accidental situation, in which the dominating actions are Level 2 earthquake ground motions, flames, and heat due to fires shall be equal to or less than the threshold level.

2 In addition to the provisions of the preceding paragraph, the performance criteria of underwater tunnels shall be as prescribed in the following items:

(1) The risk of failure due to the insufficient bearing capacity of the foundation ground under the permanent state, in which the dominating action is self-weight, shall be equal to or less than the threshold level.

(2) The risk of impairing the integrity of structural members under the permanent state, in which the dominating action is earth pressure, shall be equal to or less than the threshold level.

(3) The risk of the floating-up of immersed tunnel elements, ventilation facilities and shafts ,under the variable situation in which the dominating action is water pressure, shall be equal to or less than the threshold level.

(4) The risk of impairing the integrity of structural members and losing the stability of immersed tunnel elements, ventilation facilities, shafts, joint sections, etc. under the variable situation in which the dominating action is Level 1 earthquake ground motion, shall be equal to or less than the threshold level.

[Interpretation]

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(2) Performance Criteria of Underwater Tunnels (Article 36 paragraph 2 of the Ministerial Ordinance and the interpretation related to Article 78 of the Public Notice)

① The required performance of underwater tunnels shall be serviceability. Serviceability is defined as follows:

a) The quality and thickness of materials covering underwater tunnels shall be appropriately set with careful consideration to the stability against the uplift of underwater tunnels, the effects of the penetration of cast and dragged anchors by ships navigating over underwater tunnels, and the scouring of covering sections owing to waves and currents.

b) Underwater tunnels shall be provided with appropriate management facilities and equipment necessary for their safe and smooth use.

② The required performance of underwater tunnels under the accidental situation in which the dominating actions are Level 2 earthquake ground motions, flames, and heat due to fires shall be restorability. **Attached Table 12-3** shows the performance verification items and standard indexes for determining limit values with respect to the actions. In this table, the term "damage" is used for the performance verification item as a comprehensive expression of verification items that differ depending on the types of underwater tunnels.

Attached Table 12-3 Performance Verification Items and Standard Indexes for Determining the Limit Values of Underwater Tunnels under an Accidental Situation

<table>
<tr><th colspan="3">Ministerial ordinance</th><th colspan="3">Public notice</th><th rowspan="2">Performance requirements</th><th colspan="3">Design situation</th><th rowspan="2">Verification item</th><th rowspan="2">Standard index for determining the limit value</th></tr>
<tr><th>Article</th><th>Paragraph</th><th>Item</th><th>Article</th><th>Paragraph</th><th>Item</th><th>State</th><th>Dominating action</th><th>Non-dominating action</th></tr>
<tr><td>35</td><td>2</td><td>–</td><td rowspan="2">78</td><td rowspan="2">1</td><td rowspan="2">3</td><td rowspan="2">Restorability</td><td rowspan="2">Accidental</td><td>Flames and heat due to fires</td><td>–</td><td rowspan="2">Damage</td><td rowspan="2">–</td></tr>
<tr><td>36</td><td>2</td><td>2</td><td>Level 2 earthquake ground motions</td><td>Self-weight, earth pressure, water pressure, surcharge</td></tr>
</table>

③ In the performance verification of underwater tunnels under the accidental situation of flames and heat due to fires, the actions of the flames and heat due to fires shall be appropriately set in accordance with the types of vehicles passing through the underwater tunnels. Furthermore, the members constituting underwater tunnels shall be coated with fire-resistant materials when necessary.

④ The performance criteria of immersed and shield tunnels shall be applied mutatis mutandis to those of underwater tunnels. In addition to the provision above, **Attached Table 12-4** shows the performance verification items and standard indexes for determining the limit values with respect to the actions on immersed and shield tunnels under the permanent action situation in which the dominating action are self-weight and earth pressure and under the variable situation in which the dominating actions are water pressure and Level 1 earthquake ground motions.

Attached Table 12-4 Performance Verification Items and Standard Indexes for Determining the Limit Values of Immersed and Shield Tunnels under Respective Design Situations

Ministerial ordinance			Public notice			Performance requirements	Design state			Verification item	Standard index for determining the limit value
Article	Paragraph	Item	Article	Paragraph	Item		State	Dominating action	Non-dominating action		
35 36	2 2	– 1	78	2	1	Usability	Permanent	Self-weight	Water pressure, earth pressure, and surcharge	Bearing capacity of the foundation ground	Action–resistance ratio with respect to bearing capacity
					2			Earth pressure	Self-weight, water pressure, and surcharge	Soundness of members	–
					3		Variable	Water pressure	Self-weight, earth pressure, and surcharge	Uplifting of immersed tunnel elements, ventilation facilities, and shafts	–
					4			Level 1 earthquake ground motion	Self-weight, earth pressure, water pressure, and surcharge	Stability of immersed tunnel elements, ventilation facilities, and shafts	–
										Soundness of members	–
										Stability of joint sections	–

⑤ In the performance verification of the soundness of members constituting tunnels (**Attached Table 12-4**), the standard indexes for determining the limit values shall be appropriately set in accordance with the structures of tunnels and the materials of the members.

⑥ In the performance verification of the stability of the immersed tunnel elements, ventilation facilities, and shafts (**Attached Table 12-4**), the standard indexes for determining the limit values shall be appropriately set in accordance with the structures of tunnels.

⑦ In the performance verification of the stability of the joint sections of tunnels (**Attached Table 12-4**), the standard indexes for determining the limit values shall be appropriately set in accordance with the structures of tunnels, materials, and joint sections. The stability of joint sections shall ensure the strength, deformation performance, and waterproof property of the joint sections.

3.1 General

(1) Tunnels as port transportation facilities are classified into road, railroad, and other tunnels in terms of intended use. They are also classified into mountain, open-cut, shield, and immersed tunnels in terms of construction method.

(2) The explanations in this section can be applied to the performance verification of underwater tunnels as port road facilities constructed using the submerged tunneling method (hereinafter immersed tunnels) and those constructed using the shield tunneling method (hereinafter shield tunnels). For the performance verification of tunnels for other uses or with different structural types, the standards relevant to the respective tunnels should be followed.

(3) In the performance verification of underwater tunnels, refer to the **Road Structure Ordinance** (Cabinet Order No. 424 on December 26, 2011) for items that are not specified in the following sections.

(4) **Fig. 3.1.1** shows the definitions of terms related to the immersed tunnels used in this section.

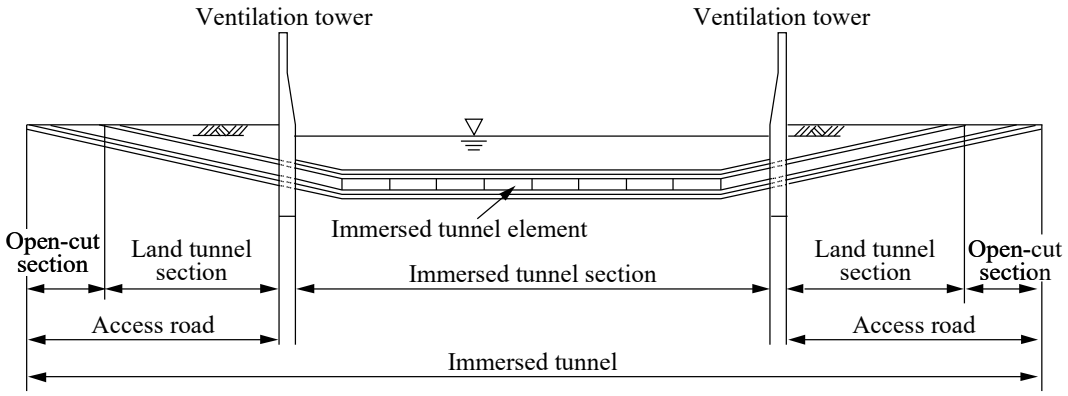

Fig. 3.1.1 Definitions of terms on Immersed Tunnel

(5) The standards related to underwater and other types of tunnels are as follows.

① The **Technical Standard for Road Tunnels** (Official Notice by the Director-General, City Bureau and the Director-General, Road Bureau, Ministry of Construction, May 19, 1988)

② The **Technical Standard and Commentaries for Road Tunnels (Ventilation)** (The Japan Road Association, June 2015)

③ The **Technical Standard and Commentaries for Road Tunnels (Structure)** (The Japan Road Association, December 2003)

④ The **Installation Standard for Road Tunnel Emergency Facilities** (Official Notice by the Director-General, City Bureau and the Director-General, Road Bureau, Ministry of Construction, April 21, 1981)

⑤ The **Installation Standard and Commentaries for Road Tunnel Emergency Facilities** (The Japan Road Association, October 2001)

⑥ The **Installation Standard and Commentaries for Road Lighting Facilities** (The Japan Road Association, October 2007)

⑦ The **Standard Specifications for Tunneling-2016: Mountain Tunnels** (The Japan Society of Civil Engineers, August 2016)

⑧ The **Standard Specifications for Tunneling-2016: Cut-and-Cover Tunnels** (The Japan Society of Civil Engineers, August 2016)

⑨ The **Standard Specifications for Tunneling-2016: Shield Tunnels** (The Japan Society of Civil Engineers, August 2016)

(6) In the performance verification of immersed tunnels as port road facilities, the **Technical Manual for Immersed Tunnels**[1)] can be used as a reference. **References 2)** to **7)** can be used as a general reference for the design and construction of immersed tunnels. Furthermore, **References 8)** and **9)** can be used as references for the examination of the earthquake resistance of immersed tunnels.

3.2 Fundamentals of Performance Verification

(1) The locations, alignments, and cross-sectional shapes of underwater tunnels shall be appropriately set in accordance with the use conditions, plans of related facilities, such as future deepening plans of the navigation channels, and the natural conditions of water areas where tunnels are constructed. Port districts have particularly high composition rates of heavy vehicles; therefore, it is necessary to give appropriate consideration to ventilation methods and road alignments.

(2) Past examples of construction can be used as references in selecting the locations and deciding the alignments and the cross sections of underwater tunnels.

(3) One of the general methods for reducing the construction costs of underwater tunnels is to shorten the tunnel lengths by increasing the longitudinal gradients in consideration of the design speeds of roads. However, the soot

concentration in the exhaust gas of vehicles sharply increases when the gradients increase, thereby increasing the costs for ventilation facilities (installation and maintenance costs). Furthermore, the longitudinal gradients affect smoke control on the occurrence of fires inside tunnels. Therefore, the longitudinal gradients of underwater tunnels shall be determined by taking these factors into consideration.

(4) The cross sections of underwater tunnels shall be determined with consideration to the traffic volumes of vehicles, the composition ratios of large vehicles, the needs for pedestrian and bicycle tracks, the evacuation passages, the types of cables and pipes in utility ducts, with or without restriction on traffic carrying hazardous materials, the presence or absence of toll gates, and the connections with other roads.

The future utilization plans of underwater tunnels should be adequately studied because it is difficult to add additional functions, such as the widening of widths, after their completion. Furthermore, in the case of the necessity to provide immersed tunnel sections with curved geometry in planar view, the inner cross sections of the immersed tunnel sections shall be appropriately set to avoid interference with clearance limits.[3)]

(5) If pedestrian and bicycle tracks and evacuation passages will be installed, due consideration shall be given to their usability for elderly and physically handicapped persons.

(6) Underwater tunnel elements shall have fire-resistant structures, fire-safety facilities, and evacuation passages. Furthermore, underwater tunnel elements shall have other safety facilities as required such as evacuation passages and emergency telephones in case of accidents and disasters. For the fire-resistant design of tunnels with concrete structures, steel members, and joint sections, **References 10)** and **11)** can be used as references.

(7) On the basis of the provisions in Article 46 of the **Road Act**, underwater tunnels can be planned and designed with a ban or restriction on vehicles loaded with volatile or combustible articles and other dangerous goods.

(8) Management facilities and equipment

Management facilities and equipment include the facilities and equipment for ventilation, emergency, lighting, electric power, security and measurement, monitoring and control, and drainage.

In cases wherein ventilation towers are constructed as ventilation facilities, it is necessary to functionally allocate ventilation, electrical, control, and ancillary equipment. It is also necessary to install inlet ports, exhaust ports, and connection ducts that connect the ventilation towers with the elements of tunnels to achieve efficient ventilation.

(9) Immersed tunnel elements (Immersed tunnel sections)

① The structural types of immersed tunnel elements are classified into steel shell type, concrete types (reinforced concrete and prestressed concrete types), and composite (hybrid) types. The most appropriate structures shall be selected with consideration to the characteristics of the respective types.

② Composite-type immersed tunnels are further classified into an open-sandwich type with a structural member comprising steel plates and reinforced concrete and a full-sandwich type with steel plates on both surfaces of the structural members.

③ For the design and construction of composite-type immersed tunnels, particularly open-sandwich type, refer to **References 12)** to **14)**.

④ Concrete types are generally constructed in dry docks, and steel and composite types are generally constructed in shipyards.

(10) The maintenance and management plans of underwater tunnels shall be established as a standard practice to efficiently and reliably implement the management of underwater tunnels. The maintenance and management plans shall also be established in accordance with the installation conditions of underwater tunnels and by referring to **Part I, Chapter 2, 4 Maintenance of Facilities Subjected to Technical Standards** and Past Cases (for example, **References 15)** and **16)**).

3.3 Determination of Basic Cross Sections

(1) Underwater sections of tunnel elements

① The top surfaces of immersed tunnel elements shall be covered with appropriate materials of the required thickness to ensure the structural safety of tunnel elements by taking into consideration the penetration depths of the anchors cast and dragged by navigating ships, the frequencies of casting and dragging of anchors, the buoyancy of tunnels, and the scouring due to waves and water flows. In principle, it is preferable that the

thickness of the cover layers, including the thickness of the concrete layers to protect the upper slabs, should be 1.5 m or greater. The elevations of the top surfaces of the cover layers shall be set in consideration of the construction errors associated with dredging or backfilling work.[4)]

② The immersion depths of tunnel elements shall be appropriately set by taking into consideration any future plans to deepen the water areas above and around the tunnel elements.

③ The structural types and lengths of immersed tunnel elements shall be determined giving due consideration to sectional force, joint structures, size of fabrication yards, tunnel element installation and joint construction methods, and economical efficiency of the immersed tunnel elements, including joints. In general, the lengths of immersed tunnel elements are set at approximately 100 m, but there are cases of longer lengths so that the number of installation operations and joint locations can be reduced.[5)]

The dimensions of the inner cross section of immersed tunnel elements shall be set by taking into consideration the margins for the installation of fire-resistant materials, allowance rooms, and construction errors when fabricating and installing immersed tunnel elements.[3)]

(2) Ventilation towers

① The structures of the ventilation towers for immersed tunnels need to be studied with appropriate methods corresponding to the characteristics of the facilities and grounds on the basis of the evaluated actions.

② Ventilation machines, electrical facilities and their equipment, and control facilities and their equipment should be functionally arranged in a ventilation tower. Furthermore, the ventilation towers shall have structures with inlet ports, exhaust ports, and connection ducts that connect the ventilation towers with the tunnel elements to achieve efficient ventilation.

③ Sufficient spaces should be provided inside ventilation towers so that the monitoring, inspection, and minor repair of the installed equipment can be performed smoothly. In particular, large machines, such as ventilation machines, shall have structures that enable them to be easily carried in and out of ventilation towers.

④ The locations and structures of inlet ports shall enable the exhausting of the intake volume of the air from the exhaust ports or shall minimize the entrances of the tunnels.

⑤ The locations of exhaust ports shall ensure that the concentration of exhaust gas at ground levels remains within a allowable level.

⑥ Generally, shafts double as ventilation towers, but they can be separated.

⑦ Ventilation towers shall have a ventilation function and shall be designed giving scenery consideration to the surrounding landscapes.

⑧ The locations of ventilation towers shall be set by taking into consideration the relative displacement between the ventilation towers and tunnels owing to consolidation settlement and earthquake ground motions.

(3) Access roads

① The structures of access roads shall be generally designed with due consideration to the usage plans, natural conditions, social conditions, construction methods, and construction costs.

② The road surface elevations of the entry and exit sections of access roads shall be determined by taking into consideration the connection with other roads, the elevations of the neighboring grounds, the inflow of seawater or river water during storm surges, the water depths on the occurrence of tsunamis, and the longitudinal gradients of underwater tunnels.

③ Access roads generally comprise open-cut sections and land tunnel sections. The structures of the open-cut sections are classified into concrete and earth slope types, and concrete type is generally used. The land tunnel sections are generally constructed with the open-cut method.

3.4 Performance Verification

(1) Stability of underwater tunnels

① Considering that tunnels are considerably long in longitudinal directions, the examination of the structural stability of underwater tunnels shall be performed for both the longitudinal and transverse directions of the tunnels.

② The structural stability of underwater tunnels can be generally examined in a manner that analyzes the stability in the transverse directions on the basis of rigid frames (in the case of immersed tunnels) and the stability in the longitudinal directions on the basis of beams on elastic ground with ground reaction modeled as springs or in a manner that analyzes the entire stability, including the ground surrounding the tunnels, by using the finite element method.

③ The foundations of underwater tunnels shall be examined in terms of their bearing capacity against the weights of the tunnels and covering soil, consolidated settlement, elastic settlement, and liquefaction.[6)]

④ Although earthquake ground motions may act on underwater tunnels in all directions, the performance verification can be generally performed in two directions: the transverse directions, in which tunnels are subjected to maximum flexural moment and shear force, and the longitudinal directions, in which tunnels are subjected to maximum axial force.

⑤ It is preferable to select the appropriate types and quality of backfill materials to ensure the safety against settlement and uplift of tunnel elements, mitigate the possibility of liquefaction due to the actions of earthquake ground motions, and facilitate maintenance dredging to maintain navigation channel depths.

⑥ Given that underwater tunnels are bottom-seabed facilities, many cases of construction of underwater tunnels on soft ground have been reported. Therefore, the influence of soft ground on the cracks in concrete and water leaks through joints, which may impair the functions of underwater tunnels, need to be fully studied.

⑦ In the earthquake-resistant design, verification shall be performed on the stability against earthquake ground motions in harbors (**Part II, Chapter 6 Earthquakes**), the possibility of liquefaction, and lateral flows when ventilation towers are installed close to revetments.

⑧ In cases wherein underwater tunnels are constructed on soft ground, it is necessary to confirm that underwater tunnels do not cause the slide failures of surrounding ground owing to the actions of earthquake ground motions.

(2) Stability of the structural members of underwater tunnels

① The structural members of underwater tunnels shall have safe structures in terms of the following factors:

(a) Watertightness

(b) Cracks in concrete

(c) Uplift of structure elements due to buoyancy after installation

(d) Ventilation and disaster prevention functions

(e) Other additional functions.

② Additional functions may include waterworks, power cables, and gas conduit pipes.[7)]

③ Immersed tunnel elements

It is preferable to install waterproof-coated layers on the outside surface of immersed tunnel elements to ensure watertightness. The typical materials for waterproof-coated layers are steel plates, synthetic rubber (butyl system), and asphalt. According to the recent domestic construction of concrete immersed tunnels, steel plates are frequently used for the lower faces of floor slabs and outer faces of side walls, and synthetic rubber or steel plates are frequently used for the top faces of upper slabs. Moreover, sufficient waterproof treatment is necessary around anchor bolts that penetrate waterproof-coated layers.

(3) Underwater tunnel joints

① The joints of underwater tunnels shall have safe structures against stresses and displacement due to the actions of earthquake ground motions, settlement of surrounding ground, and temperature fluctuations.

② The locations and structural types of joints on underwater tunnels are normally determined giving due consideration to the size of fabrication yards, shifting of waterways, capacity of construction machines during construction, uneven settlement of ground and foundations, and influence of temperature variations after construction. In the assessment of the earthquake resistance of underwater tunnels, the locations and structural types of joints are also important factors. Therefore, the earthquake resistance of joints needs to be adequately examined when determining the locations and structural types of joints.

③ The joints between tunnel elements and ventilation towers shall also have safe structures against stresses and displacement due to the actions of earthquake ground motions.

④ The joint structures are largely classified into two types: a continuous structure (rigid joint) that has the same stiffness and strength as those of the cross sections of the immersed tunnel elements so that it can endure deformation, strain during permanent actions, earthquake ground motions, and other actions; a flexible structure (flexible joint) that has sufficient flexibility to absorb deformations during permanent actions, earthquake ground motions, and other actions.

⑤ Immersed tunnel elements

The popular methods for executing underwater joining and primary water sealing between immersed tunnel elements are water pressure connection and underwater concrete methods. In recent years, the water pressure connection method has become more popular than the underwater concrete method.

The flexible joint structures combining rubber gaskets and PC cables have been used in many cases, and they are classified into bellows and crown seal joints.[17] It is preferable to select the appropriate types of joints by taking into consideration the effects of uneven settlement, behavior of tunnel elements during earthquakes, locations, structures, workability, and economic efficiency of the joints. Conventionally, joints have been used only at the junctions between immersed tunnel elements. However, in recent years, they have been installed in immersed tunnel elements (other than junctions) to enable them to cope with uneven settlement and earthquake ground motions. For the mechanical property and durability of rubber gaskets, refer to **References 18)** to **20)**.

The methods for installing joints at the locations to be immersed at the very end are classified into dry work, water sealing panel, terminal block, V-block, and key element methods. It is preferable to select appropriate methods by taking into consideration their locations, structures, construction methods, and workability.

3.5 Structural Details

(1) Underwater tunnels shall be provided with the following facilities as necessary:

① Ventilation facilities

② Emergency facilities

③ Lighting facilities

④ Electric power related facilities

⑤ Security and measurement facilities

⑥ Monitoring and control facilities

⑦ Drainage facilities

(2) Ventilation is essential for underwater tunnels to prevent the adverse effects of exhaust gas from motor vehicles from accumulating inside the tunnels. Although natural ventilation may be sufficient for short tunnels, ventilation facilities shall be installed for the immersed tunnels of roads in a port.

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4 Parking Lots

(English translation of this section from Japanese version is currently being prepared.)

4.1 General

(English translation of this section from Japanese version is currently being prepared.)

4.2 Examination of Sizes and Locations

(English translation of this section from Japanese version is currently being prepared.)

4.3 Performance Verification

(English translation of this section from Japanese version is currently being prepared.)

5 Bridges

(English translation of this section from Japanese version is currently being prepared.)

5.1 General

(English translation of this section from Japanese version is currently being prepared.)

5.2 Fundamentals of Performance Verification

(English translation of this section from Japanese version is currently being prepared.)

5.3 Ensuring Durability

(English translation of this section from Japanese version is currently being prepared.)

5.4 Performance Verification of Fenders

(English translation of this section from Japanese version is currently being prepared.)

6 Canals

(English translation of this section from Japanese version is currently being prepared.)

6.1 General

(English translation of this section from Japanese version is currently being prepared.)

6.2 Performance Verification

(English translation of this section from Japanese version is currently being prepared.)

7 Railroads

(English translation of this section from Japanese version is currently being prepared.)

7.1 General

(English translation of this section from Japanese version is currently being prepared.)

7.2 Performance Verification

(English translation of this section from Japanese version is currently being prepared.)

8 Heliports

(English translation of this section from Japanese version is currently being prepared.)

8.1 General

(English translation of this section from Japanese version is currently being prepared.)