8 Boat Lift Yards and Landing Facilities for Air Cushion Craft

Ministerial Ordinance

Performance Requirements for Boat Lift Yards

Article 32
The performance requirements for boat lift yards shall be as specified in the subsequent items in consideration of its structure type:

(1) The requirements specified by the Minister of Land, Infrastructure, Transport and Tourism shall be satisfied so as to enable the safe and smooth lifting and launching of boats.

(2) Damage due to self weight, earth pressure, water pressure, variable waves, berthing and traction of boats, Level 1 earthquake ground motions, imposed loads, and/or other actions shall not impair the function of the boat lift yards nor affect their continued use.

Public Notice

Performance Criteria of Boat Lift Yard

Article 58
1 The performance criteria of boat lift yards shall be as specified in the subsequent items:

(1) The boat lift yard shall have the necessary water depth and length corresponding to the dimensions of the design ships.

(2) The boat lift yard shall have the necessary ground elevation in consideration of the tidal range, the dimensions of the design ships, and the usage conditions.

(3) The boat lift yard shall have the necessary ancillary equipment in consideration of the usage conditions.

2 The provisions of Article 49 through Article 52 shall be applied with modification as necessary to the performance criteria of the front wall portion of the boat lift yard in consideration of the structural type.

3 The performance criteria of the pavement of the boat lift yard shall be as specified in the subsequent items:

(1) The pavement of the boat lift yard shall have the dimensions required for enabling the safe and smooth handling of boats.

(2) The risk of impairing the integrity of the pavement under the variable action situation, in which the dominant action is imposed load, shall be equal to or less than the threshold level.

(3) The risk of impairing the integrity of the pavement under the variable action situation, in which the dominant actions are water pressure and variable waves, shall be equal to or less than the threshold level.

[Technical Note]

8.1 Boat Lift Yards

8.1.1 Fundamentals of Performance Verification

(1) A boat lift yard is a facility used to retrieve ships to the land and launch to the sea for such purposes as repair, refuge from storm waves and storm surges, and land storage of ships during winter.

(2) In many cases, rails or cradles are employed in the retrieving and launching of ships of 30 tons or larger in gross tonnage, but the provisions in this section can be applied to the performance verifications of the facilities used to lift and launch ships smaller than 30 tons in gross tonnage directly over the slope of slipway.

(3) **Fig. 8.1.1** Notations of Various Parts of boat lift yard.

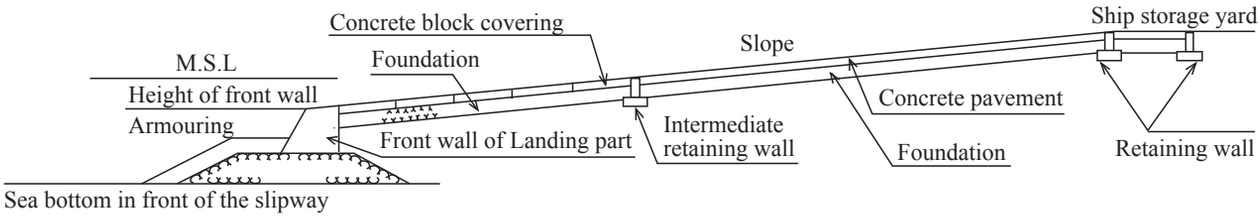


Fig. 8.1.1 Boat Lift Yard

8.1.2 Location Selection of Boat Lift Yard

Location of boat lift yards needs to be determined in such a way that the following requirements are satisfied:

① The front water area is calm.

② The front water area is free from siltation or scouring.

③ Navigation and anchorage of other ships are not hindered.

④ There is an adequate space in the background for the work for ship lifting and launching as well as for ship storage.

8.1.3 Dimensions of Each Part

[1] Requirements for Usability

① Water depth and length

(a) Length
In setting the length of slipways for the performance verification, the dimensions of the design ships shall be appropriately considered.

(b) Water depth
In setting the water depth of slipways for the performance verification of boat lift yards, the dimensions of the design ships and the envisaged conditions of use of the facility shall be appropriately considered.

② Crown height
In setting the crownt height of slipways for the performance verification of boat lift yards, the dimensions of the design ships and the envisaged conditions of use of the facility shall be appropriately considered to enable the slipway to be safely and efficiently used.

③ Slope angle of the slipway
In the performance verification of boat lift yards having slipways, the slope angle of the slipway shall be appropriately set considering the dimensions and shape of the design ships, the ground conditions, the tidal range, and the envisaged conditions of the use of the facility in order to enable smooth retrieving and launching of ships.

[2] Height of Each Part

(1) It is preferable that the crown height of the front wall of the slipway section be located at a level lower than the mean monthly-lowest water level (LWL) by the draft of the design ships. This requirement indicates that it is necessary lift ships even at the low water of neaps. The draft of the ship should be the light draft for the case of repair, refuge, and wintertime storage, and should be the full-load draft for the case of lifting small fishing boats filled with catches. For boat lift yards that are to be constructed in the areas where tidal ranges are small or for the boat lift yards that are to be used even at the low water springs during high waves, it is possible to lower the crest height of the front wall further.

(2) The ground elevation of the ship storage yard can be determined by applying **2.1.1 Dimensions of Quaywalls**. However, when the ship storage area is located adjacent to a quaywall, the crown height of the ship storage area can be set equal to the crown height of the quaywall to facilitate ease of use. In cases where waves are high in the water area in front of the boat lift yard, consideration of the wave runup height is preferable.

(3) It is preferable not to change the gradient of the slipways considering the convenience of retrieving and launching of ships.

(4) If providing a point at which the gradient changes on the slipways is unavoidable, due to the deep depth of water or constraint of available ground area, it is preferable that the position of the point of gradient change be set considering the heights of the following:

① When the slipway consists of two different surfaces
Near M.S.L. - H.W.L.

② When the slipway consists of three different surfaces
First point Near L.W.L.
Second point Near H.W.L.

[3] Front Water Depth

The depth of water in front of the slipway may be determined referring to the sum of the draft of the design ship and a margin of 0.5 m.

[4] Gradient of Slipway

(1) The gradient of slipway shall be determined appropriately in consideration of the shape of the design ships, the characteristics of foundation, and the tidal range, so that the lifting and launching of ships can be performed smoothly.

(2) When the slipway is to be utilized by small ships, it is preferable to have a slope with a single-gradient. Single-gradient slopes are frequently used in slipways for human power-based ship lifting in shallow waters. For this type of slipways, a slope inclination of 1:6 to 1:12 may be used as a reference.

(3) When the water in front of the slipway is deep or the area of the construction site is limited, the slipway may be built with two or more gradients. When this is the case, a two-gradient slipway may be adopted when the crown elevation of the front wall is about-2.0 m, and a three-gradient slipway may be adopted when the crest height of the front wall is lower than-2.0 m. The following values may be used as reference gradients:

① When the slipway consists of two different surfaces:
Front slope: 1:6 to 1:8
Rear slope: 1:8 to 1:12

② When the slipway consists of three different surfaces:
Front slope: an inclination steeper than 1:6
Central slope: 1:6 to 1:8
Rear slope: 1:8 to 1:12

[5] Area of Front Basin

(1) The basin in front of a boat lift yard shall have an appropriate area that allows for efficient operation of ship retrieving and launching without damage to the ships, and safe and efficient navigation of nearby ships.

(2) When the ship is launched to the sea by sliding over the slipway, the ship runs over a certain distance after touching the water with the speed gained during the launch. This distance is more than about five times of the ship's length overall, although it varies depending on the gradient of slope, slipway friction, and launching distance. However, because the ship attains its maneuverability after moving a distance about 4 to 6 times of its length, it is sufficient to secure a distance about five times of the ship's length overall from the waterfront line of the slipway to the other end of the basin. When strong tidal currents exist, it is preferable to add an appropriate margin.

(3) When the ship is launched to the sea gently by wire ropes, a distance of about three times of the ship's length overall will suffice to secure the required width of water area.

8.2 Landing Facilities for Air Cushion Craft

8.2.1 Fundamentals of Performance Verification

(1) Air cushion craft landing facilities shall be located at an appropriate location and have an appropriate structure for the safe boarding of passengers and safe and smooth landing of the craft.

(2) Air cushion craft landing facilities are normally constructed on the shore. These facilities usually use slopes similar to those of slipways as described in **8.1 Boat Lift Yards** to land and glide down air cushion crafts.

(3) **Fig. 8.2.1** illustrates an air cushion craft.

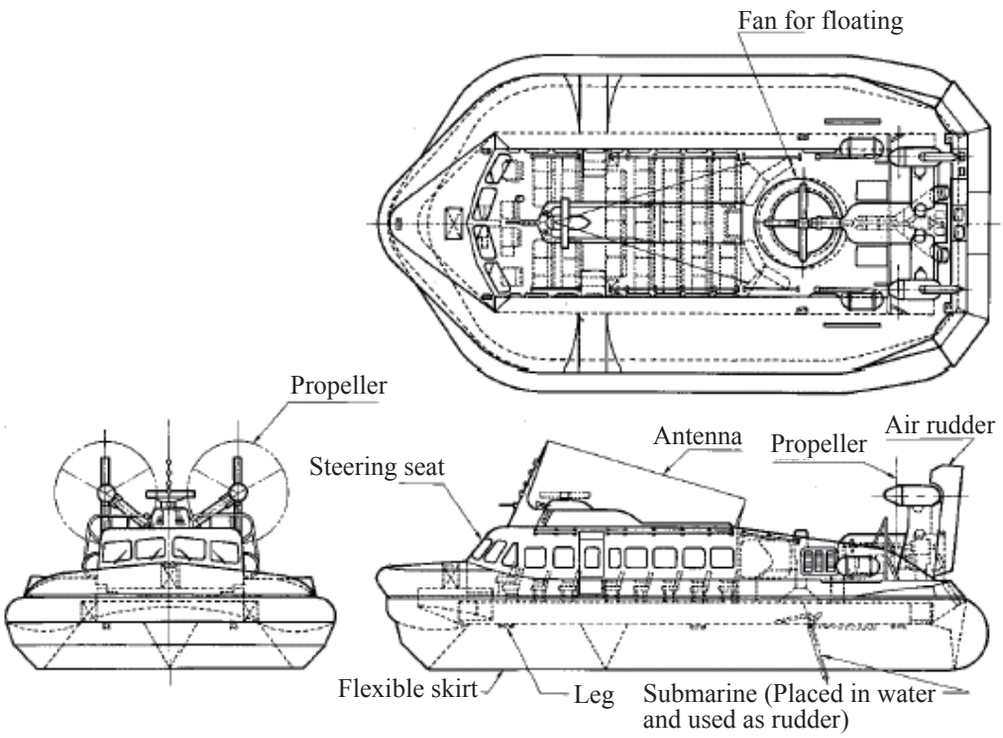


Fig. 8.2.1 Example of Air Cushion Craft

(4) An example of the main dimensions of air cushion craft is shown in **Table 8.2.1**.

Table 8.2.1 Example of Dimensions of Air Cushion Craft

	Total length (m)	Total width (m)	Total height (m)	Skirt depth (m)	Boarding capacity (persons)	Total mass (t)	Maximum speed (kt)
a	18.2	8.6	4.4	1.2	75	14	45
b	24.7	12.7	7.9	1.6	115	50	65
c	23.1	11.0	6.5	1.2	105	51	50
d	14.8	7.0	4.6	1.2	38	9.1	60

8.2.2 Selection of Location

(1) In determining the location, the following requirements shall be considered:
① The water basin in front of the facility shall be calm.
② The effects of strong winds and beam winds on the craft shall be minimum.
③ Operation of the crafts shall not hinder navigation and mooring of other ships.
④ Influences of noise and water spray from the operation of crafts upon other navigation ships and neighboring area shall be minimum.

(2) Air cushion crafts are excellent for stability in high-speed operation, but they are susceptible to influences of winds during low-speed operation such as approaching and leaving to/from a landing facility. In the determination of the location of air cushion craft facilities, therefore, it is preferable to give careful consideration to the level of calmness of the basin in front of the facilities and the direction of the prevailing wind.

(3) As noises from an air cushion craft may be as high as 100 dB at a distance of 50 m from the craft, it is preferable to locate air cushion craft landing facilities far enough away from hospitals, schools and housing areas, or to shut off the noises by surrounding the facilities with sound-proof walls.

8.2.3 Dimensions of Each Part

The air cushion landing facilities shall be provided with a slipway, apron, and passenger boarding facilities. In

addition, lighting facilities, hangers, sound-proof walls, oil supply facilities and repair facilities and others shall be provided as necessary.

[1] Slipway

(1) The structure of the slipway can be determined by referring to the slipway structure described in **8.1.3 Dimensions of Each Part**.

(2) The width of the slipway should be determined considering of the lateral movement of the air cushion craft during the landing or gliding-down operation due to beam winds. Usually a width of about three times the width of the craft is adopted.

(3) The gradient of the slipway needs to be determined considering its psychological effect on passengers, performance of the air cushion craft, and use of land. Usually a gradient of 1:10 or gentler is adopted.

[2] Apron

In many cases the apron width is the same as that of the slipway and the apron length is about two times the length of the air cushion craft. In cases where two or more air cushion crafts use the landing facility simultaneously, a parking space should be provided alongside the apron.

[3] Hangar

When a hangar is to be constructed, it is preferable to locate it adjacent to the apron to facilitate the servicing and maintenance of air cushion craft and to provide the refuge space of air cushion craft in rough weather. The dimensions of the hangar are preferably as follows:

Width: .5 times the width of the air cushion craft (per one craft)
Length: 1.2 times the length of the air cushion craft (per one craft)
Height: There should be a clearance of about 0.5 m from the ceiling to the top of the air cushion craft when the craft is lifted afloat.

References

1) Kimura., K.: Design method of plastering blocks for slipway, Journal of Public Works Research Institute (PWRI), Hokkaido Regional Development Bureau, No. 369、1984

9 Ancillary of Mooring Facilities

Ministerial Ordinance

Performance Requirements for Ancillary Facilities of Mooring Facilities

Article 33

1 The performance requirements for ancillary facilities of mooring facilities shall be as specified in the subsequent items in consideration of the type of facilities:

(1) The requirements specified by the Minister of Land, Infrastructure, Transport and Tourism shall be satisfied so as to facilitate the safe and smooth use of mooring facilities.

(2) The damage due to self weight, earth pressures, Level 1 earthquake ground motions, berthing and traction of ship, imposed loads, collision with vehicles, and/or other damage shall not impair the function of the ancillary facilities nor affect their continued use.

2 In addition to the provisions of the previous paragraph, the performance requirements for the ancillary facilities for mooring facilities which are classified as high earthquake-resistance facilities shall be such that the damage due to Level 2 earthquake ground motions and other actions do not affect the restoration through minor repair works of the functions required of the piers concerned in the aftermath of the occurrence of Level 2 earthquake ground motions. Provided, however, that as for the performance requirements for the ancillary facilities of the mooring facilities which require further improvement in earthquake-resistant performance due to the environmental conditions, social or other conditions to which the pier concerned is subjected, the damage due to said actions shall not adversely affect the restoration through minor repair works of the functions of the facilities concerned and their continued use.

9.1 Mooring Posts and Mooring Rings

Public Notice

Performance Criteria of Mooring Posts and Mooring Rings

Article 59

The performance criteria of mooring posts and mooring rings shall be as specified in the subsequent items:

(1) Mooring posts and mooring rings shall be appropriately placed so as to enable the safe and smooth mooring of ships and cargo handling works by taking into account the positions of the mooring lines for the ships using the mooring facilities concerned.

(2) The risk of impairing the integrity of the members of mooring posts and mooring rings and losing their structural safety shall be equal to or less than the threshold level under the variable action situation in which the dominant action is the traction by ships.

[Commentary]

(1) Performance Criteria of Mooring Posts and Mooring Rings

① Stability of Facilities (serviceability)

(a) **Attached Table 54** shows the setting on the performance criteria and design situations, except accidental situations, of mooring posts and mooring rings.

Attached Table 54 Setting on the Performance Criteria and Design Situations (excluding accidental situations) of Mooring Posts and Mooring Rings

Ministerial Ordinance			Public Notice			Performance requirements	Design situation			Verification item	Index of standard limit value
Article	Paragraph	Item	Article	Paragraph	Item		Situation	Dominating actions	Non-dominating actions		
33	1	2	59	1	2	Serviceability	Variable	Traction by ships		Soundness of mooring post and mooring ring components	–
								Traction by ships	Self weight	Stability of mooring post and mooring ring structures (sliding of superstructures)	Limit value on sliding
										Stability of mooring post and mooring ring structures (overturning of superstructures)	Limit value on overturning

(b) Soundness of Structural Members (serviceability)
For the performance verification of mooring posts and mooring rings, the performance criteria for the soundness shall be set properly according to the kind of materials.

(c) Stability of Structures (serviceability)
The verification of structural stability shall verify the sliding and overturning of superstructures under the variable situations where dominating action is the traction by ships

[Technical Note]

9.1.1 Position of Mooring Posts and Mooring Rings

(1) The performance verification of mooring posts and mooring rings shall require their proper layout to allow the safe and smooth mooring of ships and cargo handling, considering the positions of the mooring lines of the ships using the mooring facilities concerned.

(2) In general, mooring posts are installed at around both ends of the berth and away from waterlines as far as possible for the mooring of ships in a storm, whereas bollards are installed close to the berth faceline for the mooring or the berthing and leaving of ships in ordinary conditions.

(3) The positioning and names of the mooring lines of ships during berthing may refer to **2.1.1 (2) Length, Water Depth and Layout of Berths.**

(4) The distance intervals between bollards and their minimum number of installation per berth may refer to the values given in **Table 9.1.1**.

Table 9.1.1 Placement of Bollards

Gross tonnage of design ship (t)	Maximum interval between bollards (m)	Minimum number of installation per berth (unit)
Less than 2,000	10-15	4
2,000 or more and less than 5,000	20	6
5,000 or more and less than 20,000	25	6
20,000 or more and less than 50,000	35	8
50,000 or more and less than 100,000	45	8

(5) In the cases where mooring lines are not pulled upward at such mooring facilities for small ships mooring posts at intervals of 10 - 20 m are installed without bollards. Instead of bollards, small ship mooring facilities may be installed with mooring rings or similar with equivalent strengths to bollards at intervals of 5 - 10 m.

(6) For some small ship mooring facilities, mooring rings or equivalents may be installed to moor small ships. Mooring rings or similar shall be installed at a proper height taking tide levels into consideration. Small ships are

often tied to mooring rings with the mooring lines from their bows and sterns, and hence mooring rings or similar may be placed at intervals of 5 - 10 m.

(7) Mooring posts are installed according to use conditions by ships. They are often installed in such manner that angles between ship axes and mooring lines would be set closely to a right angle as much as possible so that they could react effectively against the forces perpendicular to the ship axes. In many cases, one mooring post is installed at each end of a berth.

The angles of bow lines and stern lines with respect to their ship axes are set to be small to control the movement of ships in the ship axes direction. It is preferable to install bollards so that these angels are kept larger than 25 - 30°. **Fig. 9.1.1** shows the typical installment examples of mooring posts.

(8) There are cases where the mooring lines stretched from two adjacently moored ships are tied to one mooring post installed at the junction of two berths. Since the lines are stretched from different directions and their resultant force is not larger than the tractive force from either of the ships, there is no need to install larger-size mooring posts at the junctions of two berths. However, in some cases, it would take time to release mooring lines for unberthing, resulting in accidents. Two bollards shall be hence installed at an interval of several meters in the junction. In the case of large mooring facilities, sometimes four or more lines are tied from each of bow and stern of the both sides of ships. In such a case, it is preferable to install two bollards at an interval of several meters at the places to tie these lines.

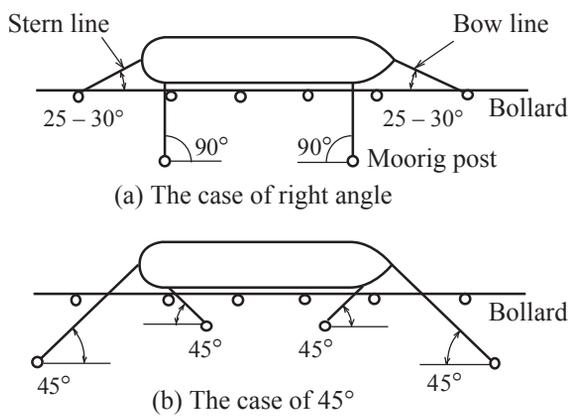


Fig. 9.1.1 Typical Arrangements of Mooring Posts and Bollards

9.1.2 Actions

(1) Tractive Force of Design Ship

① The tractive forces by ships shall be calculated appropriately considering the berthing and mooring conditions of ships.

② The tractive forces by ships can be calculated in accordance with **Part II, Section 8, 2.4 Actions due to Traction by Ships**.

(2) The verification of the sliding and overturning of superstructures shall be performed on tractive forces from the most dangerous traction angles. The traction angles of the most dangerous tractive forces can be calculated from equations **(9.1.1)** and **(9.1.2)**. The expected ranges of traction angles depending on conditions such as the dimensions of design ships and tide levels shall be considered.

① The case of sliding (See **Fig. 9.1.2 (a)**)

$$\theta_k = 2\tan^{-1}\left\{\frac{1}{(T-P_h)}\left(W + P_v - \sqrt{W^2 + 2WP_v + P_v^2 - T^2 + P_h^2}\right)\right\} \tag{9.1.1}$$

where

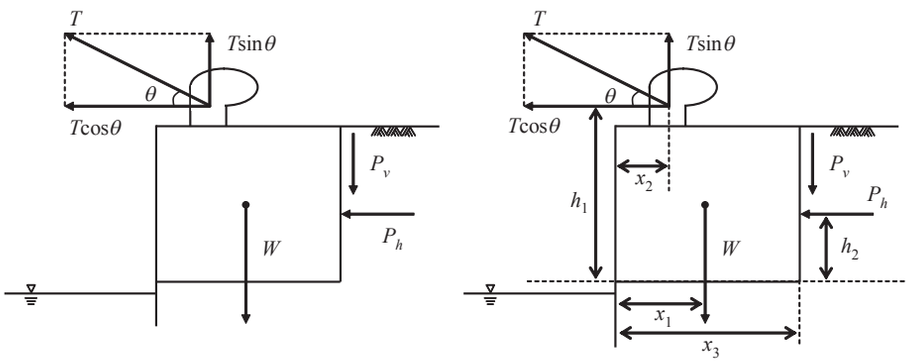
θ : traction angle (rad)
T : tractive force (kN/m)
P_v : resultant vertical earth pressure acting on superstructure (kN/m)
P_h : resultant horizontal earth pressure action on superstructure (kN/m)
W : weight of superstructure (kN/m)

② The case of overturning (See **Fig. 9.1.2 (b)**)

$$\theta_k = \tan^{-1}\left(\frac{x_2}{h_1}\right) \tag{9.1.2}$$

where

θ : traction angle (rad)
x_2 : distance from faceline of quaywall to tractive force acting point (m)
h_1 : distance from bottom of superstructure to tractive force acting point (m)



(a) Sliding (b) Overturing

Fig. 9.1.2 Actions caused by Tractive Forces

9.1.3 Performance Verification

(1) Examination on the Stability of the Superstructures on which Mooring Posts and Mooring Rings are Installed

① Examination on sliding
The following equation may be used for examining the stability of the superstructures on which mooring posts and mooring rings are installed. The subscript *d* indicates design value.

$$f_d(W_d + P_{v_d} - T_d \sin\theta_d) \geq \gamma_a(T_d \cos\theta_d + P_{h_d}) \tag{9.1.3}$$

where

f : friction coefficient
W : weight of superstructure (kN/m)
θ : traction angle (rad) (see **9.1.2 Actions**)
T : tractive force (kN/m)
P_v : resultant vertical earth pressure acting on superstructure (kN/m)
P_h : resultant horizontal earth pressure acting on superstructure (kN/m)
γ_a : structural analysis factor

The design values in the equation can be calculated from the following equation, where the symbol γ is the partial factor corresponding to its subscript, where suffix k and d indicate the characteristic values and design values, respectively.

$$f_d = {}_f f_k\,,\quad T_d = {}_T T_k\,,\quad W_d = {}_W W_k\,,\quad {}_d = {}_\theta {}_k\,,\quad P_{h_d} = {}_{P_h} P_{h_k}$$

$$P_{v_d} = {}_{P_v} P_{v_k} \text{ (it can be shown as } P_{v_d} = {}_{P_v} P_{h_k} \tan(\delta + \psi) \text{ by using horizontal components)} \tag{9.1.4}$$

where

δ : wall friction force
ψ : angle between wall and vertical line (°)

② The following equation may be used for examining the stability of the superstructures on which mooring posts and mooring rings are installed. The subscript *d* indicates design value.

$$x_1 W_d + x_3 P_{v_d} \geq \gamma_a(h_1 T_d \cos\theta_d + x_2 T_d \sin\theta_d + h_2 P_{h_d}) \tag{9.1.5}$$

where

W : weight of superstructure (kN/m)

θ : traction angle (rad) (see **9.1.2 Actions**)
T : tractive force (kN/m)
P_v : resultant vertical earth pressure acting on super structure (kN/m)
P_h : resultant horizontal earth pressure action on super structure (kN/m)
x_1 : distance from the faceline of quaywall to superstructure weight acting point (m)
x_2 : distance from faceline of quaywall to tractive force acting point (m)
x_3 : distance from faceline of quaywall to acting point of resultant vertical earth pressure (m)
h_1 : distance from bottom of superstructure to tractive force acting point (m)
h_2 : distance from bottom of superstructure to acting point of resultant horizontal earth pressure (m)
γ_a : structural analysis factor

The design values in the equation can be calculated from equation **(9.1.4)**.

③ Partial Factors

In examining the stability of the sliding and overturning of the superstructures on which mooring posts and mooring rings are installed, the values shown in **Table 9.1.2** may be used as standard partial factors. These partial factors are determined taking account of the setting used in previous design methods.

Table 9.1.2 Partial Factors used in the Performance Verification of the Stability of Superstructures

			γ	α	μ/X_k	V
Sliding	γ_f	Friction coefficient	1.00	–	–	–
	γ_{Pv}	Resultant vertical earth pressure	1.00	–	–	–
	γ_{Ph}	Resultant horizontal earth pressure	1.00		–	–
	γ_W	Weight of superstructure	1.00	–	–	–
	γ_T	Tractive force	1.00	–	–	–
	γ_θ	Traction angle	1.00	–	–	–
	γ_a	Structural analysis factor	1.20	–	–	–
Overturning	γ_{Pv}	Resultant vertical earth pressure	1.00	–	–	–
	γ_{Ph}	Resultant horizontal earth pressure	1.00		–	–
	γ_W	Weight of superstructure	1.00	–	–	–
	γ_T	Tractive force	1.00	–	–	–
	γ_θ	Traction angle	1.00	–	–	–
	γ_a	Structural analysis factor	1.20	–	–	–

α: sensitivity coefficient, μ/X_k: deviation of average (average value/characteristic value), V: coefficient of variation

9.2 Fender Equipment

Public Notice

Performance Criteria for Fender System

Article 60

The performance criteria for fender system shall be as specified in the subsequent items:

(1) The fender system shall be properly installed and provided with the function satisfying the necessary specifications so as to enable the safe and smooth berthing and mooring in consideration of the environmental conditions to which the system concerned are subjected, the berthing and mooring conditions of ships, and the structure type of mooring facilities.

(2) The risk that the berthing energy of ships may exceed the absorption energy of the fender system under the variable action situation, in which the dominant actions is ship berthing, shall be equal to or less than the threshold level.

[Commentary]

(1) Performance Criteria of Fender Equipment

① Stability of Facilities (Usability)

(a) **Attached Table 55** shows the setting on the performance criteria and design situations except accidental situations, of fender equipment.

Attached Table 55 Setting on the Performance Criteria and Design Situations (excluding accidental situations) of Fender Equipment

Ministerial Ordinance			Public Notice			Performance requirements	Design situation			Verification item	Index of standard limit value
Article	Paragraph	Item	Article	Paragraph	Item		Situation	Dominating action	Non-dominating action		
33	1	2	60	1	2	Serviceability	Variable	Variable Ship berthing	–	Berthing energy of fender equipment	Absorption energy

(b) Variable Situations where Dominating Actions are Ship Berthing (Serviceability)

The verification of ship berthing is such that the risk of the berthing energy of ships exceeding the absorption energy of fender equipment shall be equal to or less than the limit value when ships are berthing.

[Technical Note]

9.2.1 Fundamentals of the Performance Verification of Fender Equipment

(1) When a ship is berthed to a wharf or when a moored ship moves owing to wind and wave forces, berthing force and friction force are generated between the ship and the mooring facility. To prevent damages to the ship's hull and mooring facility due to these forces, fender equipment are installed on the mooring facility. However, in case that ships are provided with fender equipment such as ship fenders or tires for small ships or certain types of ferries and the maneuvering of such a ship is done very carefully considering the energy absorption capacity of the fender equipment, the mooring facility does not necessarily have to be equipped with fender equipment, because the berthing force to the mooring facility is relatively low.

(2) For fender systems used as fender equipment, rubber and pneumatic fenders are commonly selected. Other types such as foam types, water pressure types, oil pressure types, suspended weight types, pile types, and timber types are also used.[2)]

(3) The performance verification procedure of rubber fenders, pneumatic fenders, and pile type fenders is as shown in **Fig. 9.2.1**.

(4) The performance of fenders has significant effects on the construction costs of mooring facilities, the maintenance costs after construction, and berthing efficiency. It is preferable for the section of fenders to consider not only their construction costs but also comprehensive costs of all aforementioned factors. In the cases of piled piers and dolphins, the effects of the reaction forces of fender systems are normally relevant, and hence in some cases

selection of high-performance fender systems, even if they are expensive, results in reducing the construction costs of quaywalls as a whole. In the cases of gravity-type quaywalls and sheet pile quaywalls on which the reaction forces of fender systems have no effects on the structural dimensions, the performance of fender system does not affect the construction costs of quaywalls. In some cases, however, selection of easy maintenance type fender system, even if they are expensive, results in cost saving in the long run, due to their maintenance costs after completion. There are also cases in which high-performance fender systems are selected to reduce the delay of ship berthing due to oceanographic and meteorological phenomena. Because this results in improving cargo handling efficiency.

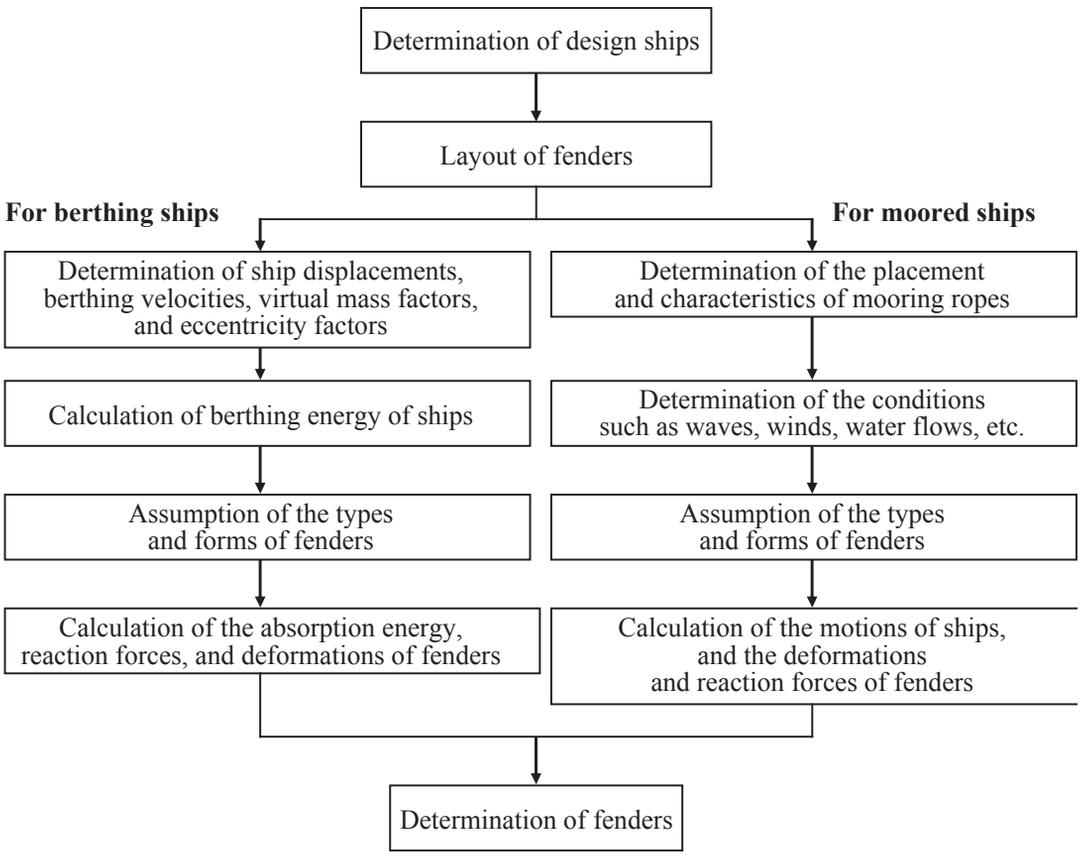


Fig. 9.2.1 Example of Performance Verification Procedures of Fenders

9.2.2 Actions

(1) Berthing Energy of Ships

① For calculating the berthing energy of ships in the performance verification of fenders, refer to **Part II, Chapter 8, 2.2 Actions Caused by Ship Berthing**.

② The partial factors used for calculating the berthing energy of ships in the performance verification of fenders shall be set at 1.0 for all the parameters.

(2) The calculation of berthing force is performed in general by obtaining the load-absorption energy curve of mooring facility and then preparing the load-absorption energy curve of a whole fender system at a certain point. As shown in **Fig. 9.2.2**, the berthing force P for a given berthing energy E_f can be obtained based on the load-absorption energy curve prepared by adding the absorption energy E_{f1} caused by fender deformation and the absorption energy E_{f2} caused by quaywall deformation.

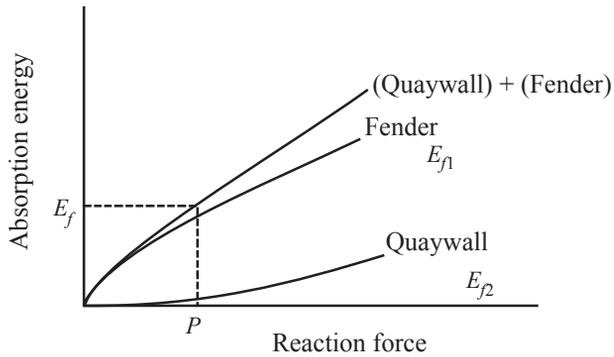


Fig. 9.2.2 Calculation of Berthing Force

(3) In case of mooring facilities that are exposed to wave actions, ships move in both the horizontal and vertical directions. The ship's motions may cause excessive shear deformation in fenders in addition to the normal compressive deformation, which sometimes leads to breakage of fenders. If the shearing force is assumed to be the friction force, the force is estimated at about 30% to 40% of the reaction force of the fender.

(4) Contact panels and similar means shall be installed on fender equipment as necessary to reduce surface pressure and thus to prevent berthing forces from acting on ships as a concentrated load. Synthetic resin plates or other materials are sometimes fixed in front of contact panels to reduce the shearing forces acting on fender systems.

9.2.3 Layout of Fenders [2), 7)]

(1) The layout and specification setting in the performance verification of fender equipment need to be appropriately performed to allow the safe and smooth berthing and mooring of ships, considering the natural conditions where the facilities concerned are placed, the berthing and mooring conditions of ships, and the structure type of mooring facilities.

(2) Fender equipment need to be appropriately placed so that ships have no direct contact with mooring facilities before the fender equipment absorb the berthing energy of design ships.

(3) Rubber fenders are normally placed at intervals of 5 to 20m. When a ship berths, a part near the bow or stern contacts the quaywall at first. It should be noted that since the ship has a curved surface at aforementioned contact parts, excessively wide fender intervals cause the ship to directly contact the quaywall, to which fenders are not placed, before the fenders sufficiently absorb the berthing energy. The intervals of about 5m normally cause no problem, but in the case that the intervals are 10m or more and thus, the part of the ship might directly contact the part of the quaywall to which fenders are not placed, it is preferable to construct the coping of fender placing parts projected out 0.2 to 0.5m from other parts. Another method is to hang a wood block in front of a rubber fender to make the block projected from other parts.

(4) In the cases of large quaywalls where fenders are placed at wide intervals and the fenders for small ships are placed in between them, it is preferable to adjust the front surfaces of the fenders for small ships backward of those for large ships to some extent. If the front surfaces of the fenders for small ships are inadequately adjusted, large ships may contact the fenders with a small energy absorption capacity before the fenders for large ships sufficiently absorb the berthing energy of the ships, causing the serious increase in the reaction forces of the fenders for small ships.

9.2.4 Performance Verification

[1] General

(1) It is preferable to appropriately select the types of fenders taking account of the following:

① Structural characteristics of mooring facilities and ships using them

② For mooring facilities subject to the effect of waves, the motions of moored ships and ship berthing conditions such as berthing angles.

③ Effects of the reaction forces of fender systems generated during ship berthing on the structures of mooring facilities

④ Variation ranges of the physical characteristics of fenders due to manufacturing errors, dynamic characteristics and thermal characteristics.

[2] Performance Verification

(1) The energy absorption due to the deformation of mooring facility is as follows:

① It can be generally assumed that there is no energy absorption due to the deformation of the main bodies of such rigid mooring facilities as gravity-type quaywalls, sheet pile quaywalls, quaywalls with relieving platform, and cellular-bulkhead type quaywalls.

② Detached piers, dolphins, piled piers, open-type wharves are classified into two types: one is the type with a rigid structure and the other with a flexible structure. There is no energy absorption due to the deformation of the former type facilities. On the other hand, there is energy absorption due to the deformation of the latter type facilities because of their flexibility, and the energy absorption is generally given by equation **(9.2.1)**.

$$E_1 = \int_0^{Y_1} g(y_1)dy_1 \tag{9.2.1}$$

where

E_1 : absorption energy due to the deformation of main body of mooring facility (Nm)
Y_1 : maximum displacement of main body of mooring facility (m)
$g(y_1)$: characteristics of reaction force caused by the deformation of main body of mooring facility (N)

Flexible facilities are normally made of steel materials. Since their performance required for the actions caused by the berthing forces of ships is serviceability and the responses are within an elastic limit, the relationship between the deflection and reaction forces of such mooring facilities is linear. When a mooring facility and its fender systems completely absorb the berthing energy of a ship, the absorption energy of the mooring facility is expressed by equation **(9.2.2)**, where C denotes the spring constant of the quaywall.

$$E_1 = \frac{1}{2}CY_1^2 \tag{9.2.2}$$

The same shall apply to the absorption energy of pile type fenders.

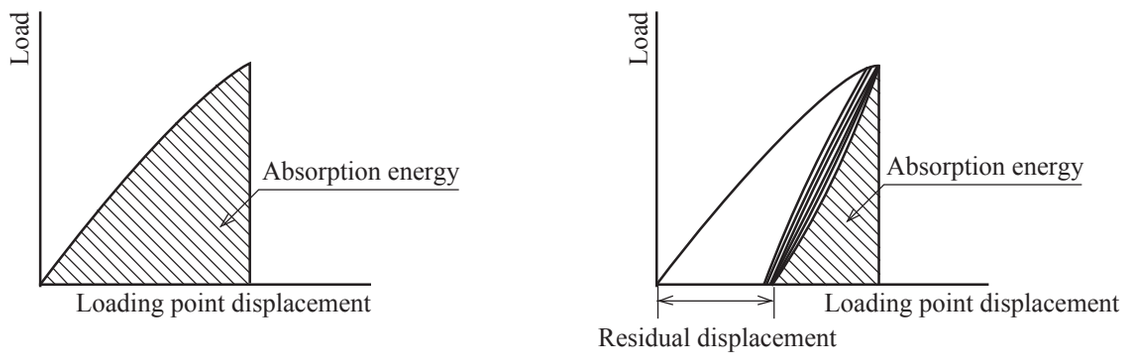
③ The single pile structure (SPS) is a type of structure that absorbs the berthing energy by the deformation of piles made of high tensile strength steel. In the performance verification of berthing dolphins that use SPS, it is preferable to evaluate the amount of energy absorption considering the residual deformation of the piles due to repeated berthing. As shown in **Fig. 9.2.3**, the amount of energy absorbed by piles is calculated from the displacement obtained by subtracting the residual displacement from the loading point displacement.[8)]
The loading point displacement with the residual displacement is calculated from equation (**9.2.3**).

$$y_{top} = A_1 y_0 + A_2 i_0 h + \frac{Ph^3}{3EI} \tag{9.2.3}$$

where

y_{top} : displacement of the pile at loading point, considering residual displacement (m)
y_0 : pile displacement at sea bottom at the time of initial loading (m)
i_0 : pile deflection angle at sea bottom at the time of initial loading (rad)
P : horizontal load (N)
h : height of loading point (m)
EI : flexual rigidity of pile (Nm^2)
A_1, A_2 : influence coefficients due to repeated loading

The time of initial loading indicates the situation where the largest load is initially applied among the past loadings.



(a) Absorption energy at the time of initial loading (b) Absorption energy at the time of ship berthing

Fig. 9.2.3 Absorption Energy by Deformation of Piles

The values of influence coefficients due to repeated loading based on the result of an in situ full-scale loading experiment [9] and a model test [10] are proposed in **Table 9.2.1**.

Table 9.2.1 Values of Influence Coefficients due to Repeated Loading [8]

	For obtaining the maximum displacement	For obtaining the energy absorbed by the deformation of piles	For obtaining the residual displacement
A_1	1.4	0.4	0.8
A_2	1.2	0.6	0.5

(2) Calculation of the Absorption Energy by Fenders

In the cases of rigid structures where there is no energy absorption due to the deformation of the main bodies of mooring facilities, the absorption energy by fenders may be calculated from the following equation, where the subscript *d* indicates design value:

$$E_{s_d} = \phi E_{cat} \geq E_{f_d} \tag{9.2.4}$$

where

E_s : absorption energy by fender (kNm)
ϕ : manufacturing error of fender (tolerance)
E_{cat} : specified value of the absorption energy by fender (kNm)
E_f : berthing energy of ship (kNm)

The characteristic value of the berthing energy of a ship E_{fk} can be expressed by equation **(2.2.1)** in **Part II, Chapter 8, 2.2 Actions Caused by Ship Berthing.** Since the partial factors used for calculating the berthing energy of a ship are set at 1.0 for all parameters, the design value of the berthing energy of the ship E_{fd} is equal to its characteristic value E_{fk}.

(3) Energy Absorption by Fenders

There are various types of rubber fenders such as V-shaped, circular hollow, and rectangular hollow. Each of these types differs from others in terms of the relationship between the reaction force and deformation as well as the energy absorption rate. Manufacturers' catalogs show diagrams of the amount of energy absorption versus the deformation, and those of the reaction force versus the deformation for each type of fenders. It is convenient to use these diagrams.

Constant-reaction force type fenders such as V-shaped fenders are characterized with low reaction forces and high energy absorption rates. It should be borne in mind, however, that the total reaction force to the mooring facility may become large when a ship comes in contact with two to three fenders simultaneously. This is because of the fact that the reaction force level rises nearly to the maximum value when the energy absorption rate reaches to 1/3 of the design capacity on each fender.

(4) Consideration of Variation in Characteristics of Rubber Fenders

Factors that cause variations in characteristics of fenders include the product deviations from the standards,

aging in quality, dynamic characteristics i.e. velocity-dependent characteristics, creep characteristics, repetition characteristics i.e. compression frequency-dependent characteristics, oblique compression characteristics, and thermal characteristics. In the fenders for floating structures, these factors are important in the evaluation of the safety of the mooring equipment. In the fenders for mooring facilities, it is necessary to verify the performance of the fenders in consideration of the product deviations, dynamic characteristics, oblique compression characteristics and thermal characteristics. For example, when the product deviation (tolerance) of the fender is ±10%, it is preferable to employ the energy absorption characteristics lowered by 10% from the catalog value and to use the reaction force characteristics raised by 10% from the catalog value in the performance verification of the fenders and the mooring facility. With regard to dynamic characteristics, it is preferable to confirm that the reaction force of the fender at the time of ship berthing shall not exceed the standard value shown in the catalog in consideration of the berthing velocity of ships. It should also be borne in mind that the fender reaction force becomes higher in a low-temperature environment than in the standard temperature environment.

It has been recommended by a working group of the International Navigation Association (PIANC) to perform correction on the absorption energy and reaction force by applying correction coefficients of velocity and temperature in the selection of fender, in order to reflect changes in characteristics due to the environment in which the fender is used such as the ship's berthing velocity and the temperature [11]. The guideline [12] for the selection of fenders by using these correction coefficients is published. Actual values of these correction coefficients should be checked with the manufacturer, as they vary depending on the berthing velocity, temperature, and kind of rubber used for the fender. It should also be borne in mind that the reaction force exerts on the quaywall may become larger when a small ship is berthing at a high berthing velocity than when a large ship is berthing at a low berthing velocity.

(5) The berthing forces of ships may cause a permanent deformation of ship hull, and hence the type of fender systems should be carefully selected.[13), 14)] It is preferable to fix contact panels in front of fenders as necessary to reduce loads on ship hull.

Since damage to ship hull is affected by not only the magnitude of berthing force but also structural strength of the ship hull, it is preferable to widen the contact area of each fender system so that the fender contacts two ribs of the ship hull at the same time. Nagasawa [15] assumed that actions at the maximum berthing forces distributed over a sufficiently wide area are uniform over more than the rib space. He proposed to calculate the critical berthing forces causing plastic hinges to form at both ends of ship hull plate between ribs assumed as fixed condition. The report [16] of PIANC's Fender Committee includes the results of analyzing the effects of fender reaction forces on the strengths of ship hull structures. Kawakami et al.[13] performed the stress analysis of the ship hull structures on which the reaction forces of fender systems were acted. The results indicate that when a fender system contacts two or more ribs at the same time, the stresses exerted on the ship hull and the ribs are not greater than the yield points if the surface pressure is 290 kN/m^2 or less.

(6) A fender system should also be safe against the shearing force due to the friction between the fender and the ship hull generated by oblique berthing of ships. This force can be normally calculated by the equation suggested by Vasco Costa [17]. When a ship is berthing to the quaywall at an angle of 6 to 14º with the face line of the berth, this force becomes 10% to 25% of the berthing force of the ship.

9.3 Lighting Facilities

Public Notice

Performance Criteria of Lighting Facilities

Article 61

The performance criterion of lighting facilities shall be such that appropriate lighting facilities are installed so as to enable the safe and smooth utilization of the mooring facilities where cargo handling works, berthing and unberthing of ships, and going-in and going-out of people are taking place in consideration of the utilization conditions of the mooring facilities concerned.

[Technical Note]

9.3.1 Fundamentals of Performance Verification

(1) Appropriate lighting facilities shall be provided at the wharves and related areas where cargo handling works such as loading, unloading and transfer, berthing / leaving of ships, and use by passengers and others are carried out at night, in consideration of the use conditions of the concerned mooring facilities.

(2) The description here may be applied to the installation, improvement, and maintenance of the lighting facilities at the wharves where cargo handling, berthing and leaving, passenger use, etc. are performed at night.

(3) Many lighting facilities are designed these days to highlight the night views of structures, parks, watersides, etc. in urban fringes and tourist sites in particular to meet social needs for the lighting and other facilities in port facilities. In these cases, not only illumination but also light colors and color rendering properties are needed to give people pleasure, familiarity, and peace of mind. On the other hand, as lighting facilities have come into wide use, it has become essential to consider at the adverse effects of lighting of lighting on the surroundings and energy saving. The performance verification of lighting facilities should fully take account of these demands. It is preferable for the places where people interact such as amenity-oriented revetments, marinas, parks, promenades, etc. to properly examine lighting functions and individually take necessary measures suited to individual facilities.

9.3.2 Standard Intensity of Illumination

[1] General

(1) Standard intensity of illumination is an average horizontal-plane illumination and defined as the minimum value to safely and effectively use the facilities concerned. The objective generally used in designing lighting facilities is illumination. The horizontal illumination means the illumination of a floor surface or a ground surface. The average horizontal illumination is the average value.

(2) The illumination of lighting facilities shall be properly determined to enable the safe and smooth use of the facilities concerned, depending on the varieties and systems of work.

(3) The International Commission on Illumination (CIE) has been examining the criteria of illumination and published the **Lighting Guide** for outdoor work areas. The criteria include the recommendations for the regulation values of the uniformity ratios of illumination and glare as well as average illumination.

[2] Standard Intensity of Illumination for Outdoor Lighting

The values shown in **Table 9.3.1** may be used for the standard intensity of illumination of each type of outdoor facilities.

Table 9.3.1 Standard Intensity of Illumination for Outdoor Lighting

Facility			Standard intensity of illumination (lx)
Wharf	Apron	Passenger facilities, vehicle facilities, mooring facilities for pleasure boats, general cargo berths, container berths	50
		Slipways for pleasure boats, aprons for handling dangerous goods using pipelines	30
		Simple work aprons using pipelines and belt conveyors	20
	Yard	Container storage spaces, general cargo storage spaces, cargo handling yards, cargo transfer yards	20
	Path	Passenger gates, vehicle gates	75
		Passenger paths, vehicle paths	50
		Other paths	20
	Security	All facilities	1–5
Road and Park	Road	Main roads	20
		Other roads	10
	Parking lot	For ferries	20
		Others	10
	Park Green space	Garden paths	3

[3] Standard Intensity of Illumination for Indoor Lighting

The values shown in **Table 9.3.2** can be used for the standard intensity of illumination of each type of indoor facilities.

Table 9.3.2 Standard Intensity of Illumination of Indoor Lighting

Facility		Standard intensity of illumination (lx)
Passenger terminal	Waiting rooms	300
	Passenger boarding paths and gates	100
Shed and Warehouse	Cargo handling spaces for fishing boat berths	200
	Container freight stations, sheds exclusive use of cars	100
	Rough work sheds and warehouses	70
	Other sheds and warehouses	50

9.3.3 Selection of Light Sources

(1) Light source for wharf lighting is preferably selected considering the following requirements:

① The light source shall be of a high efficiency and long service life.

② The light source shall be stable against the variations of ambient temperature.

③ The light source shall provide a good light color and good color rendering performance.

④ The time of the stabilization of the light after turning-on shall be short.

(2) Any light source other than a light bulb shall be used together with an appropriate stabilizer.

9.3.4 Selection of Apparatuses

[1] Outdoor Lighting

It is preferable to select lighting for outdoor illumination in consideration of the following requirements:

① Lighting equipment shall be rainproof. When a large amount of flammable dangerous goods is to be handled in the proximity of the lighting equipment, lighting equipment shall be explosion-proof.

② Materials for the lamp, reflector surface, and illumination cover shall be of good quality and have high durability and good resistance against deterioration and corrosion.

③ Sockets shall be of appropriate type for the respective light source.

④ Stabilizers and the internal wiring shall be capable of withstanding the expected increase in the temperature of the equipment.

⑤ Lighting equipment shall be of high-efficiency type.

⑥ Luminous intensity distribution shall be controlled appropriately in consideration of the use of the equipment.

[2] Indoor Lighting

Lighting for indoor illumination shall be selected in consideration of the following requirements:

① Luminous intensity distribution shall be controlled appropriately in consideration of the use of the equipment.

② Sockets shall be of appropriate type for the respective light source.

③ Stabilizers and the internal wiring shall be capable of withstanding the expected increase in the temperature of the equipment.

④ Lighting equipment shall be of high-efficiency type.

9.3.5 Performance Verification

In the designing of lighting, the layout of lighting facilities shall be determined considering the items listed below for the lighting method, light source, and equipment selected, in consideration of the characteristics of the area where the equipment is to be installed. Those equipment whose influence area extends to the sea shall be deployed in such a way that they do not hinder the navigation of nearby ships.

① Standard intensity of illumination

② Distribution of intensity of illumination

③ Glare

④ Adverse effects of light and energy conservation considerations

⑤ Light color and color rendering performance

9.3.6 Maintenance

[1] Inspection

(1) Inspection shall be periodically performed on the following:

① Lighting status

② Stain and damage to apparatuses

③ Flaking of paint

(2) Illumination intensity should be measured at several selected points in the typical places of each facility.

9.4 Lifesaving Facilities

Public Notice

Performance Criterion of Lifesaving Equipment

Article 62
The performance criteria of lifesaving equipment shall be such that appropriate lifesaving equipment is provided and readily available as necessary so as to secure the safety of human beings on the mooring facilities to serve for passenger ships with the gross tonnage being equal to or larger than 500 tons.

9.5 Curbings

Public Notice

Performance Criteria of Curbing

Article 63
The performance criteria of curbing shall be as specified in the subsequent items:

(1) Curbing shall be installed at appropriate locations and provided with the dimensions necessary for ensuring the safe utilization of the mooring facilities while not hindering ship mooring and cargo handling in consideration of the structure types and the utilization conditions of the mooring facilities concerned.

(2) The risk of impairing the integrity of curbing shall be equal to or less than the threshold level under the variable action situation in which the dominant action is collision of vehicles.

[Commentary]

(1) Performance Criteria of Curbings

① Stability of Facilities (serviceability)
Attached Table 56 shows the setting on the performance criteria and design situations except accidental situations of curbings.

Attached Table 56 Setting on the Performance Criteria and Design Situations (excluding accidental situations) of Curbings

Ministerial Ordinance			Public Notice			Performance requirements	Design situation			Verification item	Index of standard limit value
Article	Paragraph	Item	Article	Paragraph	Item		Situation	Dominating action	Non-dominating action		
33	1	2	63	1	2	Serviceability	Variable	Car crash	–	Soundness of curbing	–

[Technical Note]

9.5.1 Fundamentals of Performance Verification

The structure, shape, layout, and materials of curbing shall be set properly in such a way that the safety of users is ensured and cargo handling work is not hindered, in consideration of the structural characteristics and the conditions of use of the mooring facilities.

9.5.2 Performance Verification

The distance intervals between curbings need to be shorter than the wheel treads of the cargo handling equipment and vehicles. They may be set at about 30cm in general to drain rainwater from the aprons. It is preferable, however, to set the intervals of curbings, which are installed at both side of mooring posts, at 1.5 - 2.5m. In the cases where vehicles are not expected to pass because fences or other barriers are set up to prohibit the passage of vehicles, there is no need to install curbings.

9.6 Vehicle Loading Facilities

Public Notice

Performance Criteria of Vehicle Ramps

Article 64
The performance criteria of vehicle ramps shall be such that they satisfy the necessary specifications corresponding to the dimensions and characteristics of vehicles which use the ramps.

[Technical Note]

(1) A proper value not less than those given in **Table 9.6.1** may be used as the widths of vehicle loading facilities. Regarding movable bridges, it is preferable, however, to properly take account of the characteristics of their structures. Small facilities means loading facilities exclusively used for small and light vehicles.

(2) A proper value not more than those given in **Table 9.6.1** may be used as the slopes of vehicle loading facilities. Regarding extension lengths of the horizontal parts, 7m and 4m are used for general type facility and small facility, respectively. It is preferable to properly set the slopes of the facilities frequently used for loading large container cars, taking account of the safety and conditions of use of large container car loading.

(3) The radii of the center lanes of curved sections may refer to the **Enforcement Regulations for Road Structures**. A proper radius of 15m or more may be generally used for the curve radii.[24)]

(4) The range of vertical movement distance of the movable part of small and general facilities is frequently determined by adding 1m to tidal range.

(5) It is preferable to properly install signs and marks depending on the characteristics and use conditions of the structures of the facilities concerned.

Table 9.6.1 Widths and Gradient of Vehicle Loading Facilities

Type of facility	Number of lanes	Width (m)	Gradient (%)	
			Fixed part	Movable part
Facility exclusively used for loading vehicles with a width of not more than 1.7m (small facility)	1	3.00	12	17
	2	5.00		
Facility exclusively used for loading	1	3.75	10	12
Vehicles with a width of not more than 2.5m	2	6.50		
Facility frequently used for loading large container cars	1	4.00	–	–
	2	7.00		

9.7 Water Supply Facilities

Public Notice

Performance Criteria of Water Supply Facilities

Article 65
The provisions in Article 89 shall be applied to the performance criteria of water supply facilities with modification as necessary.

9.8 Drainage Facilities

Public Notice

Performance Criteria of Drainage Facilities

Article 66
The performance criteria of the drainage facilities shall be such that they are installed at appropriate locations and provided with the necessary functions and dimensions in consideration of the quality of water to be drained at and the structural characteristics of the mooring facilities as well as and their utilization conditions.

[Technical Note]

Mooring facilities shall be provided with drainage facilities such as drains and drainage holes, as necessary, taking account of the drainage quality and the structural characteristics and conditions of use of the mooring facilities concerned.

9.9 Fueling Facilities and Electric Power Supply Facilities

Public Notice

Performance Criteria of Fueling Facilities and Electric Power Supply Facilities

Article 67
The performance criteria of fueling facilities and electric power supply facilities shall be as specified in the subsequent items:

(1) The fueling facilities and electric power supply facilities shall be installed at appropriate locations and provided with the required fueling capacity or electric power supply capacity so as to enable the safe and smooth fueling and electric power supply to ships and others in consideration of the structural characteristics and the utilization conditions the mooring facilities concerned.

(2) In the cases where oil pipes are laid under pavements, the risk of impairing the integrity of oil pipes shall be equal to or less than a threshold level under the variable action situation in which the dominant action is imposed load.

[Commentary]

(1) Performance Criteria of Fueling Pipes

① Stability of Fueling Pipes (serviceability)
Attached Table 57 shows the setting on the performance criteria and design situations (except accidental situations) of fueling pipes.

Attached Table 57 Setting on the Performance Criteria and Design Situations (excluding accidental situations) of Fueling Pipes

Ministerial Ordinance			Public Notice			Performance requirements	Design situation			Verification item	Index of standard limit value
Article	Paragraph	Item	Article	Paragraph	Item		Situation	Dominating actions	Non-dominating actions		
33	1	2	67	1	2	Serviceability	Variable	Surcharge	–	Soundness of fueling pipes	–

[Technical Note]

(1) A mooring facility shall be provided, as necessary, with fueling and/or electric power supply facilities that allow safe and efficient fueling and power feeding, in consideration of the size of ships to moor at the facility, situation of the cargo handling, and structural characteristics of the mooring facility.

(2) Fueling and electric power supply facilities shall safely and efficiently supply a required quantity within the mooring time of ships without disturbing cargo handling work, considering the scales of the ships at berth.

9.10 Passenger Boarding Facilities

Public Notice

Performance Criteria of Passenger Boarding Facilities

Article 68
The provisions in Articles 91 or 92 shall be applied to the performance criteria of passenger boarding facilities with modification as necessary.

9.11 Fences, Doors, Ropes, etc.

Public Notice

Performance Criteria of Fences, Doors, and Ropes

Article 69
The performance criteria of fences, doors, ropes, and others shall be such that they are installed at appropriate locations as necessary and provided with the necessary dimensions so as to secure the safety of passengers, to reserve the space for passenger paths, to prevent the intrusion of vehicles, and others in the mooring facilities and the related facilities.

9.12 Monitoring Equipment

Public Notice

Performance Criteria of Monitoring Equipment

Article 70
The performance criteria of monitoring equipment shall be as specified in the subsequent items:

(1) The monitoring equipment shall be installed at appropriate locations as necessary and satisfy the necessary specifications so as to secure the safety of passengers, to maintain the public security, to prevent the intrusion of vehicles, and others in the mooring facilities and the related facilities.

(2) The monitoring equipment shall be provided with the functions necessary for preserving the monitoring records.

[Technical Note]

[1] Fundamentals of Performance Verification

(1) International port facilities such as quaywalls and basins used by international ships shall provide and maintain equipment to ensure security in compliance with the **Law on Ensuring the Security of International Ships and Port Facilities (Law No. 31 of 2004).** International ships mean the passenger ships engaged in international voyage, i.e. voyage from a port in a country to a port in another country, and the cargo ships with a gross tonnage of 500 tons or more.

(2) Monitoring equipment needs to be installed to enable monitoring in restricted areas considering the conditions of use of the mooring facilities concerned and natural conditions in its vicinities.

(3) Monitoring equipment means monitoring cameras and related equipment.

9.13 Signs

Public Notice

Performance Criteria of Signs

Article 71
The performance criteria of signs shall be such that they are installed at appropriate locations as necessary and satisfy the specifications required for indicating the locations of various facilities, guiding users, and warning possible dangers, and others with the objectives of securing the safety and convenience of users and preventing accidents and disasters.

[Technical Note]

9.13.1 Placement of Signs and Marks

(1) In order to ensure the safety of port users and convenient use of ports, it is preferable to place signs and marks in the following cases:

① When it is necessary to ensure that port users could arrive at their destinations smoothly and safely and to provide guideboards for the location of port facilities.

② When it is necessary to warn port users about dangers associated with the use of facilities and cargo handling works.

③ When it is necessary to provide instructions to port users about methods to use facilities and guide them to ensure safe and smooth use of facilities.

④ When it is necessary to regulate the behavior of port users to ensure their safety and smooth activities, to prevent disasters such as fire and falling accident, and to prevent environmental pollution by littering.

9.13.2 Forms and Installation Sites of Signs

The forms of signs shall be such that those used for ordinary roads. It is preferable to properly determine the sizes, colors, and character sizes so that port users can easily recognize them.

9.14 Aprons

Public Notice

Performance Criteria of Aprons

Article 72
The performance criteria of aprons shall be as specified in the subsequent items:

(1) Aprons shall be provided with the necessary dimensions for enabling the safe and smooth cargo handling works.

(2) The surface of aprons shall be provided with the gradient necessary for draining rainwater and other surface water.

(3) Aprons shall be paved with appropriate materials in consideration of imposed load and the usage conditions of the mooring facilities.

(4) The risk of incurring damage to the pavement to the extent of affecting cargo handling works shall be equal to or less than a threshold level under the variable action situation in which the dominant action is imposed load.

[Commentary]

(1) Performance Criteria of Aprons

① Width (usability)
Apron widths shall be properly set to allow safe and smooth cargo handling.

② Gradient (usability)
Gradient of apron shall be properly set to drain water and other surface waters.

③ Pavement Materials (usability)
Aprons shall be paved with proper materials taking account of the surcharges and the conditions of use of mooring facilities.

④ Pavements (serviceability)
Attached Table 58 shows the setting on the performance criteria and design situations (except accidental situations) of apron pavements.

Attached Table 58 Setting on the Performance Criteria and Design Situations (excluding accidental situations) of Apron Pavements

Ministerial Ordinance			Public Notice			Performance requirements	Design situation			Verification item	Index of standard limit value
Article	Paragraph	Item	Article	Paragraph	Item		Situation	Dominating action	Non-dominating action		
33	1	2	72	1	4	Serviceability	Variable	Surcharge	–	Soundness of pavement	–

[Technical Note]

9.14.1 Specifications of Aprons

[1] Apron Widths

(1) The apron widths of ordinary mooring facilities may generally refer to the values shown in **Table 9.14.1**.

Table 9.14.1 Apron Widths

Berth water depth (m)	Apron width (m)
Less than 4.5	10
4.5 or more and less than 7.5	15
7.5 or more	20

(2) The determination of apron widths of general cargo wharves shall normally take account of the spaces for cranes, temporary storage, cargo handling, and traffic paths. It is preferable to set the widths at not less than 15 - 20m when sheds are installed at the back and fork lifts are used, and not less than 10 - 15m when roads are at the back and open storage yards are in the immediate vicinity and trucks are allowed to drive into the aprons for cargo handling operations.

[2] Gradient of Apron

(1) Aprons are where cargo handling is performed and closely related to the conditions of cargo handling operation at the backyards, and hence cross slopes need to be properly determined taking these conditions into consideration.

(2) Aprons normally have a down slope of 1 - 2% toward the sea. Shallow draft wharves have steep slopes. Aprons in snowy places often have relatively steep slopes. In some cases, reverse slopes are used depending on the conditions of use of aprons and environmental consideration.

(3) Since the settlement of backfilling may cause slopes to be reversed, construction should be carefully performed.

[3] Countermeasures for Apron Settlement

(1) For aprons, appropriate countermeasures need to be taken to prevent excessive settlement due to sand washing-out or consolidation of the lower landfill material that would hinder cargo handling operation and the traffic of vehicles.

(2) In general, the material below the subgrade of apron pavement is subject to settlement due to consolidation. There is also a risk of settlement due to washing-out of the landfill material used as part of the layers below the subgrade through joint sections of quaywall, or compression of the backfilling material behind the quaywall. There are many cases of the failure of pavement that are thought to be attributable mainly to these types of settlement. Therefore, it is preferable to consider measures for preventing these types of settlement such as the provision of countermeasure against sand washing-out and the compaction of the backfilling material behind the quaywall.

9.14.2 Performance Verification

[1] General

The types of apron pavements shall be properly selected in a comprehensive judgment taking account of the soil properties below the subgrade, constructability, surrounding pavement conditions, cargo handling methods, economic efficiencies, and maintenance.

[2] Fundamentals of Performance Verification

(1) The performance verification of apron pavements shall be such that pavement structures are stable under the surcharges by cargo handling vehicles and related equipment.

(2) **Fig. 9.14.1** shows an example of the performance verification procedures of apron pavements.

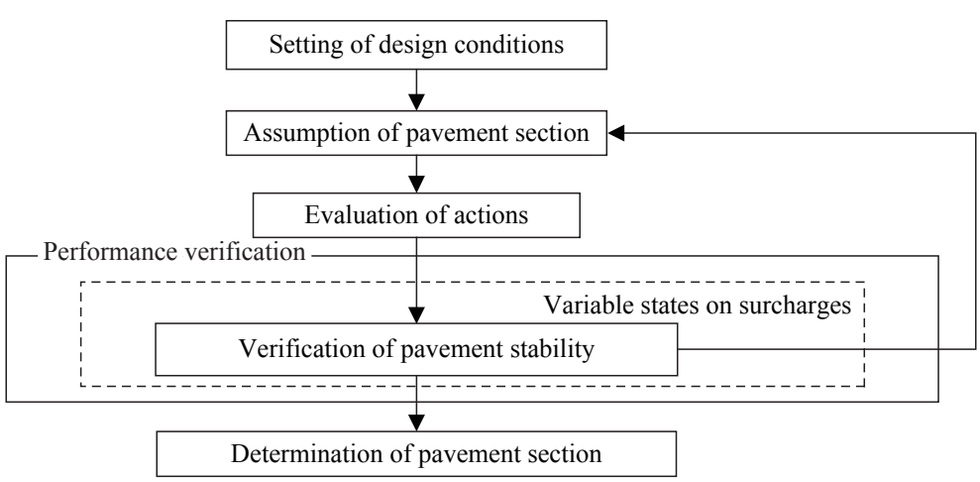


Fig. 9.14.1 Example of Procedures for the Performance Verification of Apron Pavements

[3] Actions

(1) Actions to be considered in the performance verification of apron pavements are generally the surcharges by trucks, truck cranes, rough terrain cranes, all terrain cranes, fork lift trucks, straddle carriers, etc., depending on the types of cargoes and cargo handling methods. Here, truck cranes, rough terrain cranes, and all terrain cranes are denoted as the movable cranes. The performance verification of apron pavements normally takes account of the ground contact areas on which surcharges are applied, setting the maximum surcharges and the ground contact pressures to make the pavement thickness become maximum.

(2) The characteristic values of the surcharges used for the verification of apron pavements may refer to **Table 9.14.2**.[27] Outriggers are applied to the cases of movable cranes, where a wheel means a single wheel or dual wheels i.e. two wheels are laterally connected. In the cases where the loads of actually used cargo handling equipment can be precisely set, this table may not be used.

Table 9.14.2 Characteristic Values of the Actions considered in the Performance Verification of Apron Pavements

Type of action (cargo handling equipment load)		Maximum load of an outrigger or a wheel (kN)	Ground contact area of an outrigger or a wheel (cm^2)	Ground contact pressure (N/cm^2)
Movable crane truck crane, rough terrain crane, all terrain crane	Type 20	220	1,250	176
	Type 25	260	1,300	200
	Type 30	310	1,400	221
	Type 40	390	1,650	236
	Type 50	470	1,900	247
	Type 80	690	2,550	271
	Type 100	830	3,000	277
	Type 120	970	3,350	290
	Type 150	1170	3,900	300
Truck	25 ton class	100	1,000	100
Tractor trailer	for 20ft	50	1,000	50
	for 40ft	50	1,000	50
Fork lift truck	2t	25	350	71
	3.5t	45	600	75
	6t	75	1,000	75
	10t	125	1,550	81
	15t	185	2,250	82
	20t	245	2,950	83
	25t	305	3,600	85
	35t	425	4,950	86
Straddle carrier		125	1,550	81

[4] Performance Verification for Concrete Pavements

(1) Procedures of Performance Verification

① **Fig. 9.14.2** shows an example of the procedures of the performance verification for concrete pavements.

② It is preferable to perform the verification of concrete pavements both on base course thickness, and concrete slab thickness considering, cyclic numbers of actions, conditions of the bearing capacities of roadbeds.

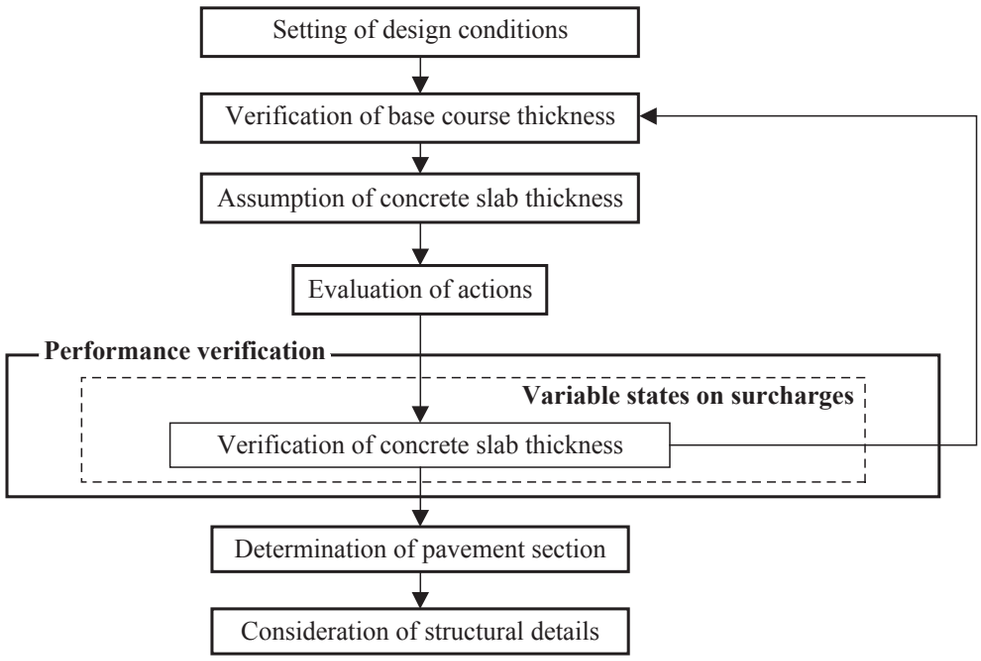


Fig. 9.14.2 Example of the Procedures of Performance Verification for Concrete Pavements

(2) Design Conditions

① The design conditions considering the performance verification are generally as follows:

(a) Design working life
(b) Conditions of Action
(c) Cyclic numbers of actions
(d) Subgrade bearing capacity
(e) Materials used

② Design working life
The design working life of concrete pavements shall be properly set considering the conditions of use and other related conditions of mooring facilities. The design working life of concrete pavements used for the aprons of quaywalls and other facilities may be generally set at 20 years.

③ Action conditions
The design action conditions are those requiring the maximum concrete slab thickness among the types of actions to be considered. The characteristic values of actions may be set referring to **Table 9.14.3**. The partial factors used for calculating design values may be set at 1.0. The "Action classification" in **Table 9.14.3** is the classification needed when using **(3)** ② **(d) Empirical method of setting concrete slab thickness**.

Table 9.14.3 Reference Values for the Action Conditions of Concrete Pavements used for the Aprons of Quaywalls and Other Facilities

Action classification	Type of action		Action (kN)	Ground contact radius (cm)
CP_1	Fork lift truck	2t	25	10.6
	Tractor trailer	for 20ft, 40ft	50	17.8
	Fork lift truck	3.5t	45	13.8
CP_2	Fork lift truck	6t	75	17.8
CP_3	Truck	25 ton class	100	17.8
	Fork lift truck	10t	125	22.2
	Straddle carrier		125	22.2
	Fork lift truck	15t	185	26.8
CP_4	Mobile crane (truck crane, rough terrain crane, all terrain crane)	Type 20	220	19.9
	Fork lift truck	20t	245	30.7
	Mobile crane (truck crane, rough terrain crane, all terrain crane)	Type 25	260	20.3

④ Roadbed bearing capacity

The performance verification of concrete pavements may set the subgrade bearing capacity using the design bearing capacity coefficient K_{30}.

(a) The design bearing capacity coefficient K_{30} of the subgrade can be obtained from the results of the plate loading test specified. The design bearing capacity coefficient K_{30} is generally set as the value corresponding to a settlement of 0.125cm. It is preferable to perform plate loading tests at one or two locations per 50m in the faceline directions of quaywalls.

(b) When setting the design bearing capacity coefficientK_{30} in an area of subgrade made of the same materials, it is preferable to calculate the values of K_{30} from equation **(9.14.1)** using the measured values of three or more points excluding extreme values.

(Bearing capacity coefficient K_{30} of subgrade)=
(Average of bearing capacity coefficients of multiple points)

$$-\left\{\frac{\text{(Maximum value of bearing capacity coefficient)} - \text{(Minimum value of bearing capacity coefficient)}}{C}\right\} \tag{9.14.1}$$

where

C : coefficient used for calculating bearing capacity coefficients. The values in **Table 9.14.4** may be used.

Table 9.14.4 Reference Values for the Coefficient C

Number of test points (n)	3	4	5	6	7	8	9	10 or more
C	1.91	2.24	2.48	2.67	2.83	2.96	3.08	3.18

(c) When the subgrade has already been constructed, the bearing capacity coefficient should be obtained by performing a plate load test on the subgrade at the condition of maximum moisture content. When it is not possible to conduct a plate loading test in such condition, the bearing capacity coefficient should be obtained by correcting the value using equation (**9.14.2**). The CBR values in equation should be obtained from undisturbed soil samples.

Bearing capacity coefficient of subgrade (corrected value)
=Bearing capacity coefficient calculated from measured value

$$\times \frac{\text{CBR (immersed in water for 4 days)}}{\text{CBR (natural moisture content)}} \tag{9.14.2}$$

⑤ Calculation of the cyclic numbers of actions
The following methods are used for calculating the cyclic numbers of loading during design working life:

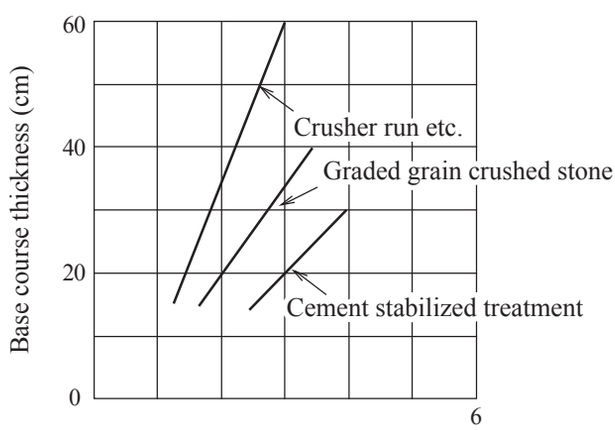
(a) To estimate the cyclic numbers from the past records of similar-scale ports

(b) To estimate the cyclic numbers from the cargo handling volumes of the ports concerned
The method [27] (b) to estimate the cyclic numbers from the cargo handling volumes of the ports may refer to the cyclic number calculation method [30] to verify the performance of the fatigue limit states of the superstructures of piled piers proposed by Nagao et al.

(3) Performance Verification

① Verification of base course thickness

(a) It is preferable to prepare a test base course and set base course thickness at value which makes the bearing capacity coefficient equal to 200N/cm^3. In the cases where the preparation of a test base course is difficult, the base course thickness may be directly set using the design curves shown in **Fig. 9.14.3**. The minimum base course thickness is generally set at 15cm.



$$\frac{\text{Bearing capacity coefficient of base course}}{\text{Bearing capacity coefficient of subgrade}} = \frac{K_1}{K}$$

K_1 is the bearing capacity coefficient of base course K_{30} (200N/cm^3).
K_2 is the bearing capacity coefficient of subgrade K_{30}

Fig. 9.14.3 Design Curves of Base Course Thickness [28]

(b) The base course thickness of concrete pavements may be set referring to **Table 9.14.5** prepared based on the past records.

Table 9.14.5 Reference Values for Base Course Thickness of Concrete Pavements

Design condition	Base course thickness				
Design bearing capacity coefficient of base course K_{30} (N/cm3)	Upper subbase course		Lower subbase course		Total base course thickness
	Cement stabilized base	Graded grain material	Graded grain material	Crusher run etc.	
50 or more and less than 70	–	40	–	20	60
	20	–	20	–	40
	25	–	–	30	55
70 or more and less than 100	–	20	15	–	35
	–	20	–	20	40
	15	–	15	–	30
	15	–	–	15	30
100 or more	–	20	–	–	20
	15	–	–	–	15

② Verification of concrete slab thickness

(a) Bending strengths of concrete slabs
The bending strengths of concrete slabs may be set at 450N/cm^2 for 28 days test piece.

(b) **Fig. 9.14.4** shows the relation between concrete slab thickness and bending stress. The bending stresses are calculated using an equation called Arlington formula. The symbols CP_1 - CP_4 in **Fig. 9.14.4** are the classification names needed for using **(d) Empirical method of setting concrete slab thickness**.

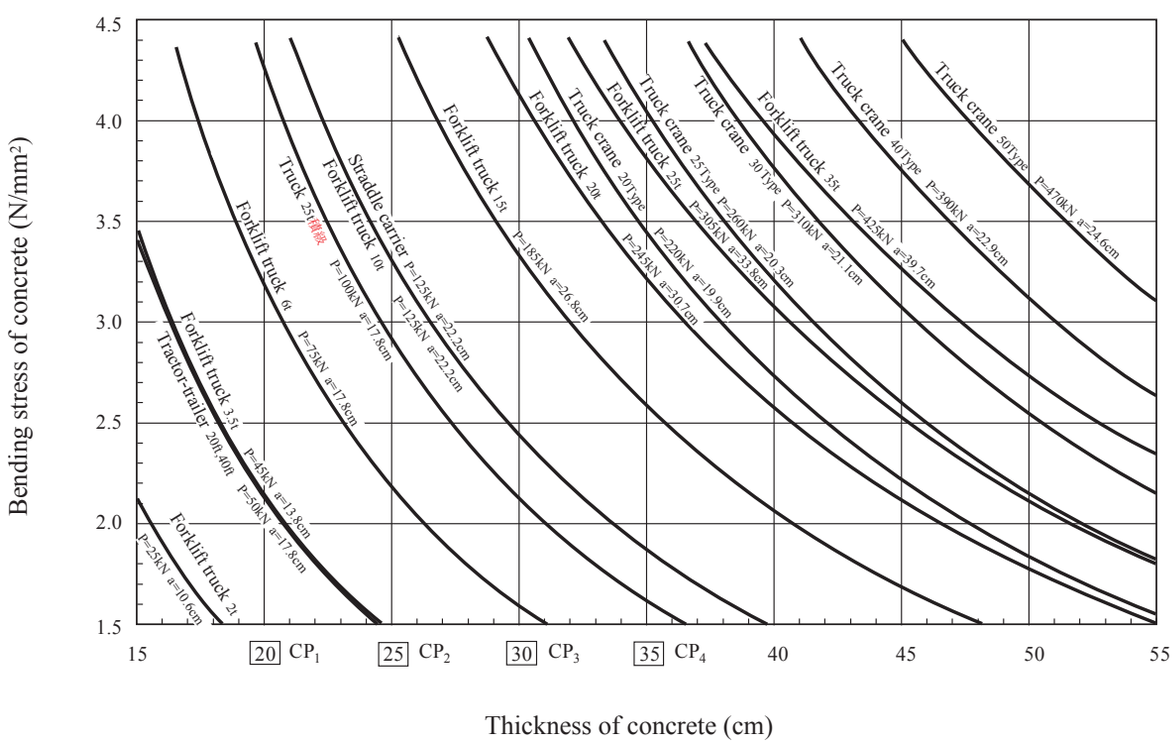


Fig. 9.14.4 Relation between Concrete Slab Thickness and Bending Stress

(c) Setting of concrete slab thickness
The method of setting the thickness of concrete slabs in compliance with the concept of **Pavement Design and Construction Guide** [28] has been proposed.[27] In this method, the fatigue characteristics of concrete slabs are calculated based on the wheel load stresses imposed on concrete slabs and their cyclic numbers during design working life. And the relation between the above mentioned characteristics and the degree of fatigue as a failure criterion is proposed to set the thickness of concrete slabs.[27] The following outlines the method:

1) Allowable cyclic numbers of wheel load stresses are calculated from the fatigue equation **(9.14.3)**.

$$N_i = 10^{\{(1.000-SL)/0.044\}} \qquad 1.0 \geq SL > 0.9$$
$$N_i = 10^{\{(1.077-SL)/0.077\}} \qquad 0.9 \geq SL > 0.8$$
$$N_i = 10^{\{(1.224-SL)/0.118\}} \qquad 0.8 \geq SL \qquad (9.14.3)$$

where

N_i : allowable cyclic number of wheel load stress imposed on concrete slab

SL : wheel load stress/design reference bending strength (= 450N/cm^2).

2) Calculation of the Degree of Fatigue

The degree of fatigue of a concrete slab is calculated from equation **(9.14.4)**.

$$FD = \sum \left(\frac{n_i}{N_i} \right) \qquad (9.14.4)$$

where

FD : degree of fatigue

n_i : cyclic number of wheel load i

N_i : allowable cyclic number of wheel load stress imposed on concrete slab

3) Setting of Concrete Slab Thickness

Using the degree of fatigue as the failure criterion of a concrete slab, concrete slab thickness is set so that the degree of fatigue FD is equal to 1.0 or less.

(d) Empirical method of setting concrete slab thickness

1) The concrete slab thickness set referring to the empirical values given in **Table 9.14.5** may be considered to have the same performance as the one set using the method of **(c) Setting Concrete Slab Thickness**.

Table 9.14.6 Reference Values for Concrete Slab Thickness

Action classification	Concrete slab thickness (cm)
CP_1	20
CP_2	25
CP_3	30
CP_4	35
Applied to piled pier slab	10

2) The "Action classification" in **Table 9.14.6** corresponds to the one given in **Table 9.14.3**. It should be noted in classifying actions that there are cases where the maximum loads are not equivalent to the value shown in **Table 9.14.2**. In such cases, the classification with the closest and larger value is used. For example, if the maximum load per outrigger of a truck crane is 120kN, it is regarded as a type 20 truck crane; if the maximum load per wheel of a fork lift truck is 64kN, it is regarded as a 6 ton fork lift truck.

3) In **Fig.9.14.4**, it is preferable to verify the concrete slab thickness by separately, for the load plotted at the right side of a curve of type 25 truck crane.

4) Regarding the setting of concrete slab thickness based on the values given in **Table 9.14.6**, it is preferable to take account of PC pavement and continuously reinforced concrete pavement for the design load exceeding CP_4, because non-reinforced concrete pavement needs a very thick slab. Since cranes such as truck cranes have larger ground contact pressures than other cargo handling equipment, it is preferable to lay iron plates or the like under the outriggers to reduce pressure when using them on aprons.

(4) Structural Details

① Layer preventing frost penetration

In the design of pavement in the cold regions where the pavement is subject to freezing and thawing, layer preventing frost penetration should be provided.

② Iron mesh

(a) It is effective to bury iron mesh in a concrete slab structure to prevent cracking.

(b) It is preferable to overlap the junctions of reinforcing bars. The overlap length and the depth of the reinforcing bars from the surface need to be properly set considering the thickness of the concrete slab.

③ Joints

It is preferable to place joints on concrete pavements to allow the concrete slabs to expand, shrink, and warp freely to some extent, reducing stresses.

(a) Joints of the concrete pavement of apron shall be arranged appropriately, considering the size of apron, structure of mooring facilities, the type of joint and load condition. In addition, joints shall have a structure that is appropriate for the type of joint.

(b) Longitudinal joint

1) Longitudinal construction joints shall generally be press-type structured and made of tie bars. Tie bars are, however, not used for piled pier slabs. It is preferable for the longitudinal joints adjoining the superstructures of quaywalls and sheds to have a structure using both joint sealing compounds and joint fillers. It is preferable to set longitudinal joints at proper intervals depending on paving machines used, total pavement widths, and traveling crane beds. It is preferable to place longitudinal joints on the shoulder of backfill, the joints of quaywalls, and the position of sheet-pile anchorages to reduce the effects of change in bearing capacity of and below base courses and the joints of quaywalls.

2) Tie-bars are provided to prevent adjoining slabs from separating, and sinking / rising of either slab at joints. Tiebars also serve as a reinforcement to transfer the sectional force. Because the apron pavement has a relatively small width and is physically constrained by the main structure of the quaywall or sheds, separation of apron concrete slabs at joints rarely occurs. However, it is necessary to provide tie-bars at longitudinal construction joints to prevent sinking / rising of either slab at joints due to differential settlement of layers below the base course, and to accommodate a wide variety in the directions of traffic load that is not observed on ordinary roads.

(c) Transverse joints

1) Transverse shrinkage joints
Transverse shrinkage joints shall generally be dummy-type structured and made of dowel bars. On piled pier slabs, however, dowel bars are not used. It is preferable for shrinkage joints to be placed on the joints of quaywalls.

2) Transverse construction joints
Transverse construction joints shall generally be press-type and made of dowel bars. On piled pier slabs, however, dowel bars are not used. Transverse construction joints are placed at the end of daily work or inevitably placed due to rain during construction or the failures of construction machines or other equipment. It is preferable for transverse construction joints to fit position with transverse shrinkage joints.

3) Transverse expansion joints
It is preferable for transverse expansion joints to generally have a structure using both joint sealing compounds and joint fillers in upper and lower parts and use dowel bars. On piled pier slabs, however, dowel bars are not used. It is preferable to set transverse expansion joints at proper intervals depending on construction conditions. Expansion joints are the weakest points of pavements, hence, consideration is needed for reducing the number of their placement points as much as possible.

4) Dowel bars
Dowel bars have a function to transfer loads and prevent the unevenness of adjoining slabs. In either case of transverse shrinkage joints, transfer construction joints, or transfer expansion joints, dowels bars are placed to fully transfer loads.

(d) Joint structures

Fig. 9.14.5 - 9.14.8 show standard joint structures.

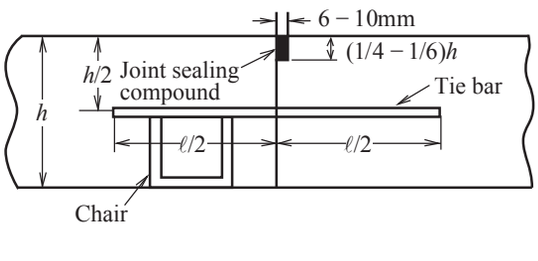


Fig. 9.14.5 Longitudinal Construction Joint

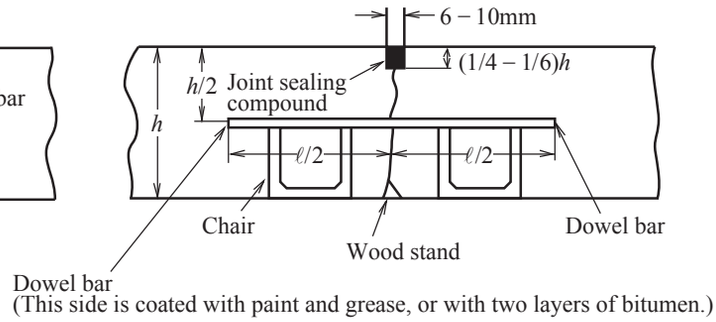


Fig. 9.14.6 Transverse Shrinkage Joint

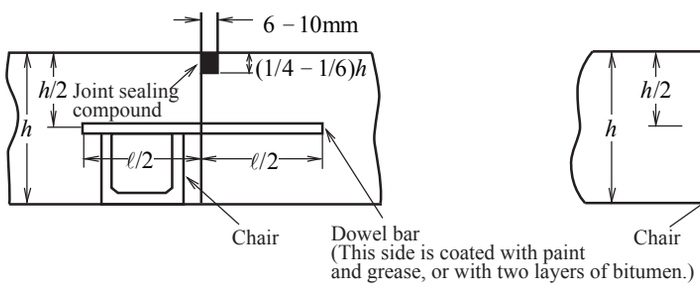


Fig. 9.14.7 Transverse Construction Joint

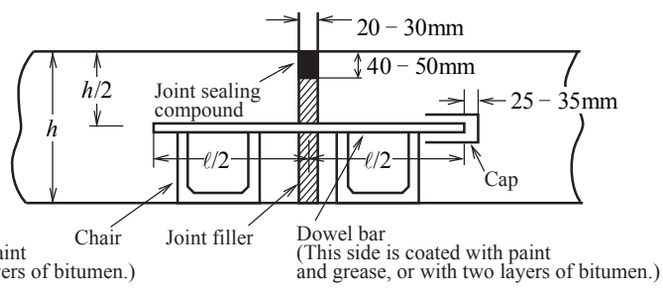


Fig. 9.14.8 Transverse Expansion Joint

④ Tie bars and dowel bars

(a) Tie bars and dowel bars shall be properly selected considering the traveling loads imposed on apron pavements in all directions.

(b) The specifications and placement intervals of tie bars and dowel bars may refer to the values shown in **Table 9.14.7**.

Table 9.14.7 Reference Values for the Specifications and Placement Intervals of Tie Bars and Dowel Bars

Action classification	Slab thickness (cm)	Tie bar			Dowel bar		
		Diameter (cm)	Length (cm)	Interval (cm)	Diameter (cm)	Length (cm)	Interval (cm)
CP_1	20	25	80	45	25	50	45
CP_2	25	25	100	45	25	50	45
CP_3	30	32	100	40	32	60	40
CP_4	35	32	100	40	32	60	40

Note: The values of tie bars and dowel bars are those of SD295A (deformed steel bar) specified in JIS G 3112 and of SS400 (round steel bar) specified in JIS G 3101, respectively.

⑤ End protection

An end protection work along the landward side of pavement shall be provided at a location where there is a risk of destruction of the base course due to infiltration of rain water or destruction of the concrete slab and base course due to heavy loading.

[5] Performance Verification of Asphalt Pavements

(1) Procedures of Performance Verification

Fig. 9.14.9 shows an example of the procedures of the performance verification for asphalt pavements.

(2) Design Conditions

① The design conditions considered in the performance verification are generally as follows:

(a) Design working life
(b) Action conditions
(c) Cyclic numbers of actions
(d) Bearing capacity of subgrade
(e) Materials used

② Design working life
The design working life of asphalt pavements shall be properly set considering the usage conditions of mooring facilities. The design working life of asphalt pavements used for the aprons of quaywalls and may be generally set at 10 years.

③ Conditions of action
Among the kinds of subject actions, the conditions of action shall be those requiring the maximum asphalt pavement thickness.

④ Calculation of the cyclic numbers of actions
For calculating of the cyclic numbers of actions, refer to **9.14. [4] (2) ⑤ Calculation of the cyclic numbers of actions**.

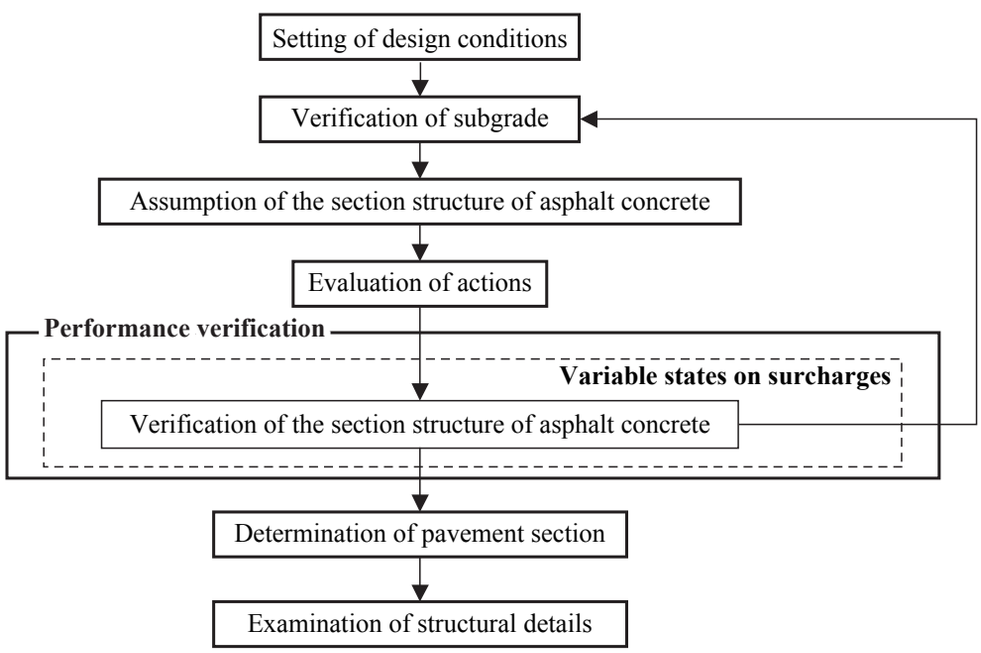


Fig. 9.14.9 Example of Procedures of Performance Verification for Asphalt Pavements

⑤ Subgrade bearing capacity
The design *CBR* of the subgrade in the pavement area subject to the performance verification is determined by tamping down subgrade soil containing natural moisture and immersing it in water for four days to obtain the CBR.

$$\text{CBR (corrected)} = \text{On-site CBR} \times \frac{\text{CBR (immersed in water for 4 days)}}{\text{CBR (natural moisture content)}} \tag{9.14.5}$$

Design CBR can be obtained from equation **(9.14.6)** using the above-defined CBR excluding extreme values.

$$\text{Design CBR} = \text{Average CBRs for all test points} - \frac{\text{Maximum CBR} - \text{Minimum CBR}}{C} \tag{9.14.6}$$

where C is given in **Table 9.14.4**.

(4) Performance Verification

① Verification of asphalt concrete pavement structure

(a) Setting of pavement sections
Pavement structure is determined so that the equivalent conversion asphalt concrete sections of the assumed pavement sections are not less than required equivalent conversion sections.

(b) Required equivalent conversion asphalt concrete pavement thickness
Required equivalent conversion asphalt concrete pavement thickness T_A is calculated from equation **(9.14.7)**. The variables subscripted with d mean design values.

$$T_{Ad} = \frac{3.84 N_d^{0.16}}{CBR^{0.3}} \tag{9.14.7}$$

where
T_A : required equivalent conversion asphalt concrete pavement thickness (cm)
N : the value of cyclic number of action during design working life n_i converted to 49kN wheel load. It is calculated from the following equation. The partial factors can be set at 1.0.

$$N_d = \sum_{i=1}^{m} \left[\left(\frac{\gamma_{P_i} P_i}{49} \right)^4 n_i \right] \tag{9.14.8}$$

where
P_i : wheel load (kN)
n_i : cyclic number of wheel load P_i
m : setting number of loaded state

(c) Equivalent conversion asphalt concrete pavement thickness of assumed section
The equivalent conversion asphalt concrete pavement thickness T_A of the assumed section can be calculated from equation **(9.13.9)**.

$$T_A' = \sum_{i=1}^{n} [a_i h_i] \tag{9.14.9}$$

where
T_A : equivalent conversion asphalt concrete pavement thickness of assumed section (cm)
h_i : thickness of layer i (cm)
a_i : equivalent conversion factor of material and work method used for pavement layer i. It may be referred to **Table 9.14.8**.
n : number of layers

Table 9.14.8 Equivalent Conversion Factor of Asphalt Concrete

Layer	Construction method / material	Requirements	Equivalent conversion factor	Remark
Surface and binder courses	Hot asphalt mixture for surface and binder courses	–	1.00	AC I – AC IV
Base course	Bituminous stabilization	Marshall stability level 3.43kN or greater	0.80	A-treated material II
		Marshall stability level 2.45 to 3.43kN	0.55	A-treated material I
	Grading adjustment	Corrected CBR 80 or greater	0.35	Grading adjusted material
Subbase course	Crusher-run, slag, sand, etc.	Corrected CBR 30 or greater	0.25	
		Corrected CBR 20 to 30	0.20	Grain material

② Example of empirical verification of asphalt concrete pavement composition
Table 9.14.10 shows an example of empirical verification of asphalt concrete pavement composition. The table is prepared referring to the action conditions shown in **Table 9.14.9**. The symbols H and T_A' in **Table 9.14.10** express total pavement thickness and the equivalent conversion asphalt concrete pavement thickness of the assumed section, respectively. If the design CBR of a subgrade is 2 or more and less than 3, it is preferable to

replace it with one using good quality materials or to add a water sealing layer. If it is less than 2, it is preferable to replace it with good quality materials and set the pavement thickness once again.

Table 9.14.9 Reference Values for Action Conditions of Action for Asphalt Pavements on Aprons of Quaywalls

Action classification	Cargo handling machine	
AP_1	Tractor trailer	20ft, 40ft
AP_2	Fork lift truck	2t
	Fork lift truck	3.5t
	Fork lift truck	6t
AP_3	Fork lift truck	10t
	Fork lift truck	15t
	Truck	25 ton class
	Straddle carrier	
	Mobile crane (truck crane, rough terrain crane, all terrain crane)	Type 20
AP_4	Mobile crane (truck crane, rough terrain crane, all terrain crane)	Type 25

③ The type and material quality of asphalt concrete can be set as listed in **Table 9.14.11**

Table 9.14.11 Type and Material Quality of Asphalt Concrete

Type	AC I	AC II	AC III	AC IV
Use	For surface course		For binder course	
Number of blows for Marshall stability test	50times	75times	50times	75times
Marshall stability (kN) Flow value (1/100cm) Porosity (%) Degree of saturation (%)	4.9 or greater 20–40 3–5 75–85	8.8 or greater 20–40 2–5 75–85	4.9 or greater 15–40 3–6 65–80	8.8 or greater 15–40 3–6 65–85

Note: The columns of "number of blows 75 times" apply to cases where the ground contact pressure of tire with the design load is 70 N/cm^2 or greater, or where the traffic of large vehicles is heavy and rutting is expected.

(5) Structural Details

The placement of frost-heaving suppression bed is needed in cold regions where freezing and thawing, may occur if pavement thickness is less than freezing depth.

Table 9.14.10 Examples of Composition of Asphalt Pavement

Condition of actions		Composition of pavement								
Classification of actions	Design CBR of subgrade (%)	Surface course		Binder course		Base course		Subbase course	Total thickness	
		Type	h_1 (cm)	Type	h_2 (cm)	Type	h_3 (cm)	h_4 (cm)	H (cm)	T'_A (cm)
AP_1	Equal to or above 3 and less than 5	AC I	5	AC III	5	Grading adjusted material	25	35	70	25.8
		AC I	5	–	–	A-treated material I	25	35	65	25.8
	Equal to or above 5 and less than 8	AC I	5	AC III	5	Grading adjusted material	20	25	55	22.0
		AC I	5	–	–	A-treated material I	20	30	55	22.0
	Equal to or above 8 and less than 12	AC I	5	AC III	5	Grading adjusted material	15	20	45	19.3
		AC I	5	–	–	A-treated material I	15	30	50	19.3
	Equal to or above 12 and less than 20	AC I	5	AC III	5	Grading adjusted material	15	15	40	18.3
		AC I	5	–	–	A-treated material I	15	20	40	17.3
	Equal to or above 20	AC I	5	AC III	5	Grading adjusted material	15	15	40	18.3
		AC I	5	–	–	A-treated material I	15	15	35	16.3
	On the deck slab of open-type wharf	AC I	5	AC III	4 or greater	–	–	–	9 or greater	–
AP_2	Equal to or above 3 and less than 5	AC II	5	AC IV	5	Grading adjusted material	25	35	70	25.8
		AC II	5	–	–	A-treated material I	25	35	65	25.8
	Equal to or above 5 and less than 8	AC II	5	AC IV	5	Grading adjusted material	20	25	55	22.0
		AC II	5	–	–	A-treated material I	20	30	55	22.0
	Equal to or above 8 and less than 12	AC II	5	AC IV	5	Grading adjusted material	15	20	45	19.3
		AC II	5	–	–	A-treated material I	15	30	50	19.3
	Equal to or above 12 and less than 20	AC II	5	AC IV	5	Grading adjusted material	15	15	40	18.3
		AC II	5	–	–	A-treated material I	15	20	40	17.3
	Equal to or above 20	AC II	5	AC IV	5	Grading adjusted material	15	15	40	18.3
		AC II	5	–	–	A-treated material I	15	15	35	16.3
	On the deck slab of open-type wharf	AC II	5	AC IV	4 or greater	–	–	–	9 or greater	–
AP_3	Equal to or above 3 and less than 5	AC II	5	AC IV	15	Grading adjusted material	30	45	95	40.0
		AC II	5	AC IV	10	A-treated material II	20	45	80	40.0
	Equal to or above 5 and less than 8	AC II	5	AC IV	15	Grading adjusted material	25	30	75	34.8
		AC II	5	AC IV	10	A-treated material II	20	20	55	35.0
	Equal to or above 8 and less than 12	AC II	5	AC IV	15	Grading adjusted material	15	20	55	29.3
		AC II	5	AC IV	10	A-treated material II	15	15	45	30.0
	Equal to or above 12 and less than 20	AC II	5	AC IV	15	Grading adjusted material	15	15	50	28.3
		AC II	5	AC IV	10	A-treated material II	15	15	45	30.0
	Equal to or above 20	AC II	5	AC IV	15	Grading adjusted material	15	15	50	28.3
		AC II	5	AC IV	10	A-treated material II	15	15	45	30.0
	On the deck slab of open-type wharf	AC II	5	AC IV	4 or greater	–	–	–	9 or greater	–
AP_4	Equal to or above 3 and less than 5	AC II	5	AC IV	15	Grading adjusted material	40	60	120	46.0
		AC II	5	AC IV	10	A-treated material II	20	70	105	45.0
	Equal to or above 5 and less than 8	AC II	5	AC IV	15	Grading adjusted material	30	45	95	39.5
		AC II	5	AC IV	10	A-treated material II	20	40	75	39.0
	Equal to or above 8 and less than 12	AC II	5	AC IV	15	Grading adjusted material	25	30	75	34.8
		AC II	5	AC IV	10	A-treated material II	15	35	65	34.0
	Equal to or above 12 and less than 20	AC II	5	AC IV	15	Grading adjusted material	15	25	60	30.3
		AC II	5	AC IV	10	A-treated material II	15	15	45	30.0
	Equal to or above 20	AC II	5	AC IV	15	Grading adjusted material	15	15	50	28.3
		AC II	5	AC IV	10	A-treated material II	15	15	45	30.0
	On the deck slab of open-type wharf	AC II	5	AC IV	4 or greater	–	–	–	9 or greater	–

Note: In case of the deck slab of piled pier, the boxes of the binder course in Table 9.14.10 refer to the value for the total of filling material and binder course. This does not necessarily have to be asphalt concrete.

9.15 Foundations for Cargo Handling Equipment

Public Notice

Performance Criteria of Foundations for Cargo Handling Equipment

Article 73

1 The performance criteria of the foundations for cargo handling equipment shall be as specified in the subsequent items in consideration of the types of cargo handling equipment and the structural type of foundations:

(1) The foundations shall have the dimensions necessary for enabling the safe and smooth operations of cargo handling works, traveling of cargo handling equipment, and others.

(2) The foundations shall satisfy the following criteria under the variable action situation in which the dominant actions are Level 1 earthquake ground motions and imposed load:

(a) In the case of pile-type structures, the risk that the axial force acting on a pile may exceed the resistance stress caused by ground failure shall be equal to or less than the threshold level.

(b) In the case of pile-type structures, the risk that the stress in a pile may exceed the yield stress shall be equal to or less than the threshold level.

(c) The risk of impairing the integrity of beam components shall be equal to or less than the threshold level.

(d) In the cases of pile-less structures, the risk of beam sliding shall be equal to or less than the threshold level.

(3) The amount of beam deflection shall be equal to or less than the threshold level under the variable action situation in which the dominant actions is imposed load.

2 In addition to the provisions in the preceding paragraph, the performance criteria for the foundations of cargo handling equipment to be installed on the high earthquake-resistance facilities shall be such that the degree of damage owing to the action of Level 2 earthquake ground motions, which is the dominant action of the accidental action situation, is equal to or less than the threshold level corresponding to the performance requirement.

[Commentary]

(1) Performance Criteria of the Foundations for Cargo Handling Equipment

① The specifications of the foundations for cargo handling equipment shall be properly set according to the types of cargo handling equipment and the structural types of foundations to allow safe and smooth cargo handling operations and the safe and smooth traveling and other operations of cargo handling equipment.

② Piles and Beams (Serviceability)

(a) **Attached Table 59** shows the setting on the performance criteria and design situations (except accidental situations) of the foundations for cargo handling equipment.

Attached Table 59 Setting on the Performance Criteria and Design Situations (excluding accidental situations) of the Foundations for Cargo Handling Equipment

Ministerial Ordinance			Public Notice			Performance requirements	Design situation			Verification item	Index of standard limit value
Article	Paragraph	Item	Article	Paragraph	Item		Situation	Dominating action	Non-dominating action		
33	1	2	73	1	2a	Serviceability	Variable	L1 earthquake ground motion (Surcharge*3))	Self weight, earth pressure	Axial force acting on pile*1)	Resistance force against ground failure (push in, pull out)
					2b					Yield of pile*1)	Design yield strength
					2c					Section failure of beam	Design section resistance (ultimate limit state)
					2d					Sliding of beam*2)	Limit value on sliding
					3			(Surcharge*3))	Self weight, earth pressure	Deflection of beam	Limit value of deflection

*1) Limited to the structures where foundation piles are used for the foundations for cargo handling equipment
*2) Limited to the structures where foundation piles are not used for the foundations for cargo handling equipment
*3) It is an action applied from a cargo handling machine to its foundation and is properly set according to design situations.

(b) Axial Forces Acting on Piles in the Cases of Pile-type Structures
The verification of axial forces acting on piles in the cases of pile-type structures shall be such that the risk of the axial forces acting on piles being greater than the resistance forces against ground failure is not more than a limit value.

(c) Yield of Piles in the Cases of Pile-type Structures
The yield verification of piles in the cases of pile-type structures shall be such that the risk of the stress generated in a pile being greater than the yield is not more than the limit value.

(d) Section Failure of Beams
The section failure verification of beams shall be such that the risk of the design section force generated in a beam component being greater than the design section resistance is not more than the limit value.

(e) Beam Sliding in the Cases of Pile-less Structures
The verification of beam sliding in the cases of pile-less structures shall be such that the risk of beam sliding is not more than the limit value.

(f) Beam Deflection
The verification of beam deflection shall be such that the amount of deflection generated in a beam being greater than the limit value of deflection is not more than the limit value under the variable situations where dominating action is surcharge.

③ Foundations for Cargo Handling Equipment Installed in High Earthquake-Resistance facilities (Restorability)
Restorability shall be ensured under the accidental situations in respect of Level 2 earthquake ground motions.

Attached Table 60 Setting on the Performance Criteria and Design Situations limited to Accidental Situations of the Foundations for Cargo Handling Equipment in High Earthquake-resistance Facilities

Ministerial Ordinance			Public Notice			Performance requirements	Design situation			Verification item	Index of standard limit value
Article	Paragraph	Item	Article	Paragraph	Item		Situation	Dominating action	Non-dominating action		
33	1	2	73	2	–	Restorability	Accidental	L2 earthquake ground motion	Self weight, surcharge, earth pressure	Damage	–

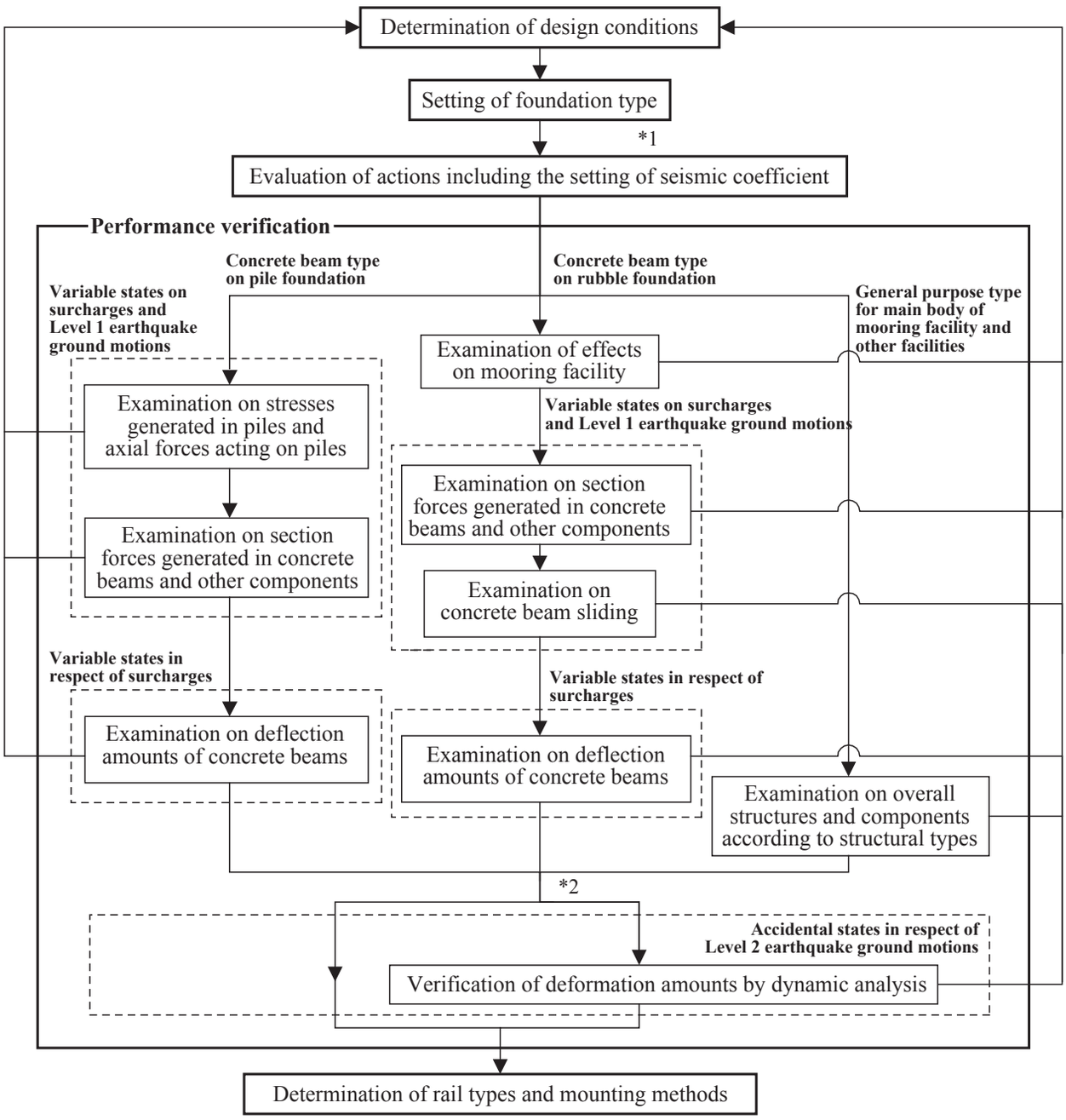
[Technical Note]

9.15.1 Fundamentals of Performance Verification

(1) The specifications of the foundations for cargo handling equipment shall be properly set according to the types of cargo handling equipment and the structural types of foundations to allow safe and smooth cargo handling operations and the safe and smooth traveling of cargo handling equipment.

(2) The foundation for rail-type traveling cargo handling equipment needs to be designed appropriately in consideration of the external forces that act on the foundation, allowable displacement for the foundation, degree of difficulty of maintenance, effects on the wharf structure, and construction and maintenance costs.

(3) **Fig. 9.15.1** shows an example of the procedures for the performance verification of the foundations for cargo handling equipment.



*1 Since the evaluation of the effects of liquefaction is not included in this chart, it should be considered separately.
*2 The foundations for cargo handling equipment installed in high earthquake-resistance facilities are verified on Level 2 earthquake ground motions.

Fig. 9.15.1 Example of Procedures of the Performance Verification for the Foundations for Cargo Handling Equipment

(4) Types of Foundations for Rail Traveling Equipment

① Foundation type that connects piles by reinforced concrete beams on pile foundations
This type is used for soft ground where uneven settlement is expected. It is also used for the foundations for large cargo handling equipment on good quality sand ground.

② Foundation type that uses other facilities such as the main bodies of mooring facilities
This type uses the reinforced concrete beams of piled piers, the main bodies of mooring facilities, such as the superstructures of caisson-type quaywalls or the wall anchorages of sheet-pile quaywalls as the foundation for the cargo handling equipment. The performance verification of facilities shall be conducted in advance considering the actions caused by cargo handling equipment. In such cases, overall construction costs are

often reduced. When one leg is on the main body of a mooring facility and the other leg is on an independent foundation, caution is needed to avoid uneven settlement. It should be noted that ground motions may cause the displacement of crane foundations, resulting in the displacement or derailing of crane legs. Rigid legs of gantry cranes are normally not placed on piled piers. Since the tip of jetty-type piled piers are weak to the actions caused by ship berthing or tractive forces or earthquakes, special reinforcement is needed.

③ Foundation type that places concrete beams on rubble foundations
This type is used for relatively good quality ground with a small possibility of settlement.

(5) Limit Value of Displacement of Rails
The displacement of rails is small at the time of completion of construction, but it increases with the lapse of time. Therefore, it is general practice to make construction errors as small as possible. Tolerance of the displacement differs somewhat among manufacturers of equipment. **Table 9.15.1** [31] indicates the installation and maintenance standards that are commonly employed.

Table 9.15.1 Examples of Technical Standards of Rail Truck Laying and Maintenance

Item	Installation standards	Maintenance requirements (upper limits for operation)
Rail span	±10 mm or less for the entire rail length	±15 mm or less for the entire rail length
Lateral and vertical warps of rail	5 mm or less per 10 m of rails	15 mm or less per 10m of rails
Elevation difference between seaward and landward rails	1/1000 of rail span or less	1/500 of rail span
Gradient in the travelling direction	1/500 or less	1/250 or less
Straightness	±50 mm or less for the entire rail length	±80 mm or less for the entire rail length
Rail joints	Vertical and lateral differences: 0.5 mm or less	Vertical and lateral differences: 1mm or less
	Gap: 5 mm or less	Gap: 5 mm or less
Wear of the head of rail	–	10% or less of the original dimension

9.15.2 Actions

(1) Forces that act on the foundation for cargo handling equipment shall be determined appropriately in due consideration of the type, and operation conditions.

(2) The forces are assumed to act on the entire length of rails during operation or earthquakes. At the time of storms, the forces assumed to act on the section where the crane is stationed.

(3) For the wheel loads that act on the rails when the crane is operational, a traveling load that is equal to 120% of the maximum static wheel load can be considered. However, this can be considered to be 110% of the maximum static wheel pressure of the crane when the traveling speed is less than 60 m/min.[34]

9.15.3 Performance Verification of Pile-type Foundations

[1] Concrete Beams

(1) The performance verification of concrete beams placed on pile foundations may be conducted assuming that they are continuous beams supported by pile heads. The effects of beams contacting the ground are ignored.

(2) Concrete beams constructed on pile foundation need to be stable against the contact pressure between the rail and concrete, and against the stress transmitted from the rail.

(3) The rail stress is usually calculated by assuming that the rail is an infinite continuous beam supported by elastic foundation. This method is often used for the cases where the wheel loads are spread over the beam by inserting an elastic material such as rubber pads between the rail and the concrete beam to prevent crushing of concrete.

(4) Solving Method of the Infinite Continuous Beam Supported by Elastic Foundation
The rail stress and the contact pressure between the rail and concrete can be calculated using the method described in **9.15.4 [2]Concrete Beams**. In this case, the symbols *Ec*, *Ic*, and *K* in equation (**9.15.4**) should be replaced as follows:s

Ec : modulus of elasticity of the rail

Ic : moment of inertia of the rail
K : modulus of elasticity of the material placed under the rail, when tie pads are used, use the modulus of elasticity of the tie pad

When the bearing stress is too high, it should be reduced by inserting elastic plates under the rail.

(7) The fastening force between the rail and the foundation can be calculated by using the beam theory on elastic foundation,[36] but it is necessary to have a sufficient allowance to avoid the effect of impact. For calculation of the fastening force for the cases where the double elastic fastening method is employed, refer to Minemura's study.[37] In many cases, bolts with a diameter of about 22 mm are used at intervals of about 50 cm.

[2] Maximum Static Resistance Forces of Piles

(1) Piles shall be stable against the actions caused by cargo handling equipment and foundations.

(2) The action that exerts on the piles should be the reaction force at each supporting point calculated in accordance with **[1] Concrete Beams.**

(3) The maximum static resistance forces of piles may be calculated referring to **Part III, Chapter 2, 2.4 Pile Foundations**.

(4) In the cases where piles are affected by the surfaces of rupture of active earth pressures, the performance verification of bearing piles described in **2.8 Quaywalls with Relieving Platforms** may be referred to.

(5) When piles are under the influence of the active earth pressure failure plane, the required embedment length differs between the seaward piles and landward piles. However, it is common practice to use foundation piles of the same length for both the seaward and landward, to avoid a differential settlement of the foundation. When the piles are driven into the bearing stratum, there is no need to use the same embedded length.

9.15.4 Performance Verification in the Cases of Pile-less Foundation

[1] Analysis of Effect on Quaywall [38]

(1) When no pile is used to support the foundation for cargo handling equipment, the effect of the actions of the cargo handling equipment and its foundation on the main structure of mooring facilities shall be examined.

(2) Application of surcharge on the area behind a gravity-type structure increases the earth pressure and may cause forward sliding of the quaywall. The influence of a concentrated load on the earth pressure is large in the zone at the levels immediately below the loading point. But the influence becomes smaller as the depth increases. When the quaywall height is small and the quaywall lengthis short, care should be given because of strong influence of concentrated load. When the load is applied directly on a quaywall, the subsoil reaction force increases. In particular, when the load is applied on the quaywall at its front end, the subsoil reaction force at the front toe becomes significantly large. In a quaywall of small width and short length, this tendency of reaction force increase is amplified and thus care should be given.

(3) In ordinary sheet pile quaywalls, the maximum stress occurs between the tie member installation point and the sea bottom. However, when a concentrated load is expected to act on the area behind the sheet pile wall, the maximum stress may occur at the level near the tie member installation point. The concentrated load, however, rarely causes an adverse effect on the embedded part of the sheet pile. It is preferable to provide a sufficient causes earth covering thickness for the tie members to avoid adverse effects on the tie members.

[2] Concrete Beams

(1) The reinforced concrete beams placed on the rubble foundations laid on the ground shall ensure stability against flexural moments, shear forces and deflection, and their amounts of settlement shall be less than a limit value of settlement.

(2) The characteristic values of the flexural moments, shear forces and deflection of the reinforced concrete beams placed on rubble foundations can be obtained from equations **(9.15.1) - (9.15.6)**. The variables subscripted with k denote characteristic values.

① In the cases where loads act near the middle of beam

$$M_k = \sqrt[4]{\frac{E_c I_c}{64K}} \sum W_i e^{-\beta x_i} (\cos \beta x_i - \sin \beta x_i) \tag{9.15.1}$$

$$S_k = \frac{1}{2}\sum W_i e^{-\beta x_i} \cos \beta x_i \tag{9.15.2}$$

$$y = \sqrt[4]{\frac{1}{64 E_c I_c K^3}} \sum W_i e^{-\beta x_i} (\cos \beta x_i + \sin \beta x_i) \tag{9.15.3}$$

② In the cases where loads act on beams ends or junctions

$$M = \sum \frac{W_i}{\beta} e^{-\beta x_i} \sin \beta x_i \tag{9.15.4}$$

$$S = \sum W_i e^{-\beta x_i} (\sin \beta x_i - \cos \beta x_i) \tag{9.15.5}$$

$$y = \sum \frac{2 W_i \beta}{K} e^{-\beta x_i} \cos \beta x_i \tag{9.15.6}$$

where

M : flexural moment at subject section (N - mm)
S : shear force at subject section (N)
y : amount of deflection at subject section (mm)

$$\beta = \sqrt[4]{\frac{K}{4 E_c I_c}}$$

E_c : modulus of elasticity of concrete (N/mm^2)
W_i : wheel load (N)
l_c : inertia moment of concrete foundation (mm^4)
K : modulus of elasticity of ground $K = C_b$
C : pressure needed to settle a unit area of ground by unit depth (N/mm^3)
b : bottom width of concrete beam (mm)
x_i : distance from wheel load point to subject section (mm)

(3) The reinforced concrete beams placed on rubble foundations are assumed to be supported by continuous elastic foundations of a uniform section over the entire length. In other words, it is assumed that the reaction forces of loaded beams are continuously distributed and their strengths are directly proportional to the amount of deflection at each point. Assuming the moment generated at a point of a distance X from the traveling wheel as M and the deflection as y, M and y are expressed by equations **(9.15.7)** and **(9.15.8)**, respectively, by an elastic theory.[39), 49)]

$$M_k = W \sqrt[4]{\frac{E_c I_c}{64K}} e^{-\beta x} (\cos \beta x - \sin \beta x) = W \sqrt[4]{\frac{E_c I_c}{64K}} \phi_1 \tag{9.15.7}$$

$$y = \frac{W}{\sqrt[4]{64 E_c I_c K^3}} e^{-\beta x} (\cos \beta x + \sin \beta x) = \frac{W}{\sqrt[4]{64 E_c I_c K^3}} \phi_2 \tag{9.15.8}$$

When two or more wheels are close to each other, the flexural moment directly under an arbitrary wheel is obtained from equation **(9.15.9)**.

$$M_{1k} = W_1 \sqrt[4]{\frac{EI}{64K}} \tag{9.15.9}$$

Expressing the distance between another wheel as x_2 and ϕ_1 for βx_2 as ϕ_{12}, the flexural moment is calculated from equation **(9.15.10)**.

$$M_{2k} = W_2 \sqrt[4]{\frac{EI}{64K}} \phi_{12} \tag{9.15.10}$$

The resultant moment directly under the first wheel can be determined from $M = M_1 + M_2$. Equation **(9.15.1)** can be derived from this expression. Deflection can be obtained in the same way. The values given by the following expression may be used for the values of C.[39), 41)]

$C = 5.0 \times 10^{-2} \sim 0.15$ (N/mm^2)

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