# **Chapter 3 Waterways and Basins**

# 1 General

# **Ministerial Ordinance**

# General Provisions

# Article 8

- 1 Waterways and basins shall be provided in appropriate locations in light of geotechnical characteristics, meteorological characteristics, sea states and other environmental conditions, as well as ship navigation and other usage conditions of the water area around the facilities concerned.
- 2 In the waterways and basins where it is necessary to maintain the calmness of the water area, measures shall be taken to mitigate the impact of waves, water currents, winds, and/or other actions.
- 3 In waterways and basins in which there is risk of siltation by sediments, measures shall be taken to prevent the occurrence thereof.

# **Ministerial Ordinance**

Necessary Items concerning Waterways and Basins

## Article 12

The necessary matters for the enforcement of the performance requirements for waterways and basins as specified in this chapter by the Minister of Land, Infrastructure, Transport and Tourism and other requirements shall be provided by the Public Notice.

## Public Notice

### Waterways and Basins

## Article 29

The items to be specified by the Public Notices under Article 12 of the Ministerial Ordinance concerning with the performance requirements of waterways and basins shall be as provided in the subsequent article through Article 32.

## [Technical Note]

- (1) In selecting the locations for basins exclusively used by dangerous cargo ships, the following should be considered:
  - (a) To minimize an encounter with general ships, especially passenger ships.
  - (b) To isolate them from the facilities of which surrounding environment should be protected, such as housing areas, schools and hospitals.
  - (c) To be capable of encountering against accidents including hazardous goods spill.
- (2) From the viewpoint of safety and efficiency in navigation and cargo handling, it is preferable to separate the basins for passenger ships, ferries, and fishing boats and small craft basins from those for other types of ships.
- (3) In principle, it is preferable to separate timber handling facilities as a specialized terminal from other general facilities.

# 2 Waterways

# Ministerial Ordinance

Performance Requirements for Waterways

### Article 9

The performance requirements for waterways shall be such that the requirements specified by the Minister of Land, Infrastructure, Transport and Tourism are satisfied in light of geotechnical characteristics, waves, water currents, and wind conditions along with the usage conditions of the surrounding water areas, for securing the safe and smooth use by ships.

# Public Notice

### Performance Criteria of Waterways

## Article 30

The performance criteria of waterways shall be as specified in the subsequent items:

- (1) The waterways shall have an appropriate width that is equal to or greater than the length of the design ship in waterways where there is a possibility of ships passing each other and equal to or greater than one-half of the length of the design ship in waterways where there is no possibility of passing each other, in light of the length and width of the design ship, the traffic volume of ships, the conditions of geotechnical characteristics, waves, water currents, and winds, as well as the usage conditions of the surrounding water areas. Provided, however, that where the mode of navigation is special, the width of the waterway can be reduced to the width that shall not hinder the safe navigation of ships.
- (2) The waterways shall have an appropriate depth that is greater than the draft of the design ship in consideration of the trim and the degree of ship motions of the design ship due to waves, water currents, winds, and others.
- (3) The alignment of waterways shall be such that the safe ship navigation is not hindered, in light of the geotechnical conditions, waves, water currents, and winds as well as the usage conditions of the surrounding water areas.
- (4) In waterways where ship navigation is remarkably congested, waterways shall be provided with the lanes separated by the direction of movement or by the size of ships.

## [Technical Note]

## 2.1 General

(1) Concept of Waterways

Waterways are considered to be a water area whose existence is clearly identified to navigators by buoys or other means in order to contribute to safe and smooth ship navigation subject to entrance channels and passage channels in shallow water area.

(2) Classification of Verification Methods

Verification methods for waterways can be classified as follows, depending on whether a design ship or navigation environment is designated or not.

- (a) Class 1: Case where the design ship and navigation environment cannot be designated.
- (b) Class 2: Case where the design ship and navigation environment can be designated.
- (3) In performance verification of waterways, the methods described in **2.2 Depth of Navigation Channel** to **2.4 Alignment of Navigation Channel (Bends)** which are proposed by Japan Institute of Navigation Standard Committee and National Institute for Land and Infrastructure Management Port and Harbour Department <sup>1</sup>), <sup>2</sup>) can be used.
- (4) Performance Criteria of Waterways
  - ① Depth of navigation channels (usability)
  - (a) Case where the design ship and navigation environment cannot be designated
    - In performance verification of waterways in cases where the design ship and navigation environment cannot be designated, the following values can be used as an appropriate depth which is greater than the maximum draft of the design ship.

- In waterways in harbors, where the effects of waves such as swells are not expected, 1.10 times the maximum draft.
- In waterways outside of harbors, where the effects of waves such as swells are expected, 1.15 times the maximum draft.
- In waterways in the open sea, where the effects of waves such strong swells are expected, 1.20 times the maximum draft.
- (b) Case where the design ship and navigation environment can be designated

In setting the water depth of waterways in performance verification of waterways in cases where the design ship and navigation environment can be designated, appropriate consideration shall be given to the maximum draft of the design ship, ship squatting due to ship waves or swells, and keel clearance.

(c) Case of special methods of navigation

In setting the water depth in performance verification of waterways for entry/egress at drydocks and waterways for use in special methods of navigation such as routes where half-loaded operation (unloading at more than one port) is normal, notwithstanding the items mentioned in (a) and (b), the water depth shall be set appropriately, considering the anticipated condition of use of the objective waterway.

2 Width of navigation channels (usability)

(a) Case where the design ship and navigation environment cannot be designated

- Appropriate width of waterway with possibility of ships passing each other In performance verification of waterways where there is a possibility of ships passing each other in cases where the design ship and navigation environment cannot be designated, the following values can be used as appropriate widths greater than the length overall of design ship.
  - When the distance of the waterway is comparatively long, 1.5 times the length overall of design ship.
  - When design ships will frequently pass each other during navigation of the waterway, 1.5 times the length overall of design ship.
  - When design ships will frequently pass each other during navigation of the waterway and it is comparatively long, 2.0 times the length overall of design ship.
- 2) Appropriate width of navigation channel with no possibility of ships passing each other In performance verification of waterways where there is no possibility of ships passing each other in cases where the design ship and navigation environment cannot be designated, the appropriate width shall be 0.5 times the length overall of design ship or greater. Provided, however, that in cases where the width of the navigation channel is less than the length overall of design ship, adequate countermeasures to ensure safe navigation of ships, such as provision of facilities to support ship navigation shall be examined.
- (b) Case where the design ship and navigation environment can be designated In setting the width of navigation channels in performance verification of waterways in cases where the design ship and the navigation environment can be designated, appropriate consideration shall be given to the basic ship maneuvering width, width necessary to cope with the effects of the side walls of the waterways, width necessary to cope with the effects of ships passing, width necessary to cope with the effects of ships overtaking other ships.
- (c) Case of special navigation situation Case of special navigation situation include cases where it is necessary to consider the use of tugboats or provision of a waiting basin, cases where the extended length of the waterway is extremely short. Cases where the extended length of the waterway is extremely short include cases where the total length of the waterway is extremely short and cases where one part of the total length is extremely short.
- ③ Direction of navigation channels (usability)
  - (a) Whenever possible, the direction of navigation channels shall be linear. Provided, however, that in cases where a bend must unavoidably be included in a waterway, the angle of intersection of the centerlines of the waterway at the bend shall not exceed roughly 30°.
  - (b) Case where the angle intersection of the centerlines of the waterway at a bend exceeds 30°
    - Case where the design ship and the navigation environment cannot be designated In performance verification of waterways in cases where the angle of intersection of the centerlines of the waterway at a bend exceeds 30° and the design ship and the features of the navigation environment such as the rudder angle cannot be designated, the corner cut at the inner side of the bend shall be set appropriately,

and the radius of curvature of the centerline of the waterway at the bend shall be set to roughly four times the length between perpendiculars of the design ship or greater.

- 2) Case where the design ship and navigation environment such as rudder angle can be designated In performance verification of waterways in cases where the angle of intersection of the centerlines of the waterway at a bend exceeds 30° and the design ship and the features of the navigation environment such as the rudder angle can be designated, the corner cut at the inner side of the bend shall be set appropriately, and the radius of curvature of the centerline of the waterway at the bend shall be set appropriately, considering the maneuverability index of turning, which shows the turning performance of the design ship.
- (c) As the shape of widened parts of width of navigation channels at bends, curved shapes other than corner cuts can be used, considered installation of buoys.

### 2.2 Depth of Navigation Channel

### 2.2.1 Bases for Verification

(1) Verification for Class 1 (Empirical approach)

When the dimension of design ship, navigational environments such as weather and sea condition and ship speed are not specified, the depth of navigation channel can be basically determined as follows.<sup>1), 2)</sup>

Waterway in a port where waves including swell does not affect ship motion : D=1.10dWaterway out of a port where waves including swells affect ship motion : D=1.15d (2.2.1)Waterway in open water where waves including swells exist : D=1.20d

where

D : depth of navigation channel

- d: full draft of design ship in still water
- (2) Verification for Class 2 (performance-based approach <sup>1), 2)</sup>)

When the dimension of design ship, navigational environments such as weather and sea condition and ship speed are specified, the necessary depth of navigation channel can be calculated by the following equation.

$$D=d+D_1+ Max (D_2,D_3)+D_4$$

where

D : depth of navigation channel

- $D_1$  : squat (bow sink during underway)
- $D_2$ : bow sink due to heaving and pitching motion (in case of  $\lambda$ >0.45*Lpp*)
- $D_3$ : bilge keel sink due to heaving and rolling motion (in case of TR = TE)
- $D_4$  : allowance of depth
- $\lambda$  : length of wave including swell
- *Lpp* : length between perpendiculars of design ship
- *TR* : natural rolling period of design ship
- TE : encounter period of design ship and design wave

At the actual design stage and the actual operation, the following elements should be taken into consideration.

- ① Swell : Wavelength is fixed with the depth of navigation channel
- <sup>(2)</sup> Tide : Generally, tide height is above the chart datum during navigation, this tide height is considered as additional depth of water in actual operation.
- ③ Accuracy of depth of water : the err of depth of chart gives some risk for navigation, but usually the dredged bottom is deeper than planned bottom. This additional dredging that is confirmed by sufficient sounding survey can be considered as the additional depth of water in actual operation.
- ④ Others : Air pressure, bottom nature, obstruction in water, density of seawater and etc. should be taken into consideration if necessary.
  - (a) Calculation of  $D_1$

 $D_1$  is calculated as follow.<sup>3</sup>)

$$D_{1} = \left(0.75 + 1.5\frac{d}{D}\right) \cdot \left(\frac{C_{b}}{Lpp/B}\right) \cdot \frac{U^{2}}{g} + 15\frac{d}{D} \cdot \left(\frac{C_{b}}{Lpp/B}\right)^{3} \cdot \frac{U^{2}}{g}$$
(2.2.3)

where

- d : full draft of design ship in still water
- D : depth of navigation channel
- B : breadth of design ship
- $C_b$  : block coefficient of design ship
- U : ship speed
- g : acceleration of gravity

When  $C_b$  is unknown, following values may be referred.

(2.2.2)

| Design ship                        | 50% value | Standard deviation |
|------------------------------------|-----------|--------------------|
| Cargo vessels                      | 0.804     | 0.0712             |
| Container ships                    | 0.668     | 0.0472             |
| Tankers                            | 0.824     | 0.0381             |
| Roll on/Roll off vessels           | 0.667     | 0.0939             |
| Pure Car Carrier ships             | 0.594     | 0.0665             |
| LPG ships                          | 0.737     | 0.0620             |
| LNG ships                          | 0.716     | 0.0399             |
| Passenger ships                    | 0.548     | 0.0452             |
| Ferries (short-to-medium distance) | 0.516     | 0.0295             |
| Ferries (long distance)            | _         | _                  |

#### Table 2.2.1 Block Coefficient Cb 4)

#### (b) Calculation of $D_2$

Maximum of  $D_2$  (Bow sink due to heaving and pitching motion) and maximum of  $D_3$  (Bilge keel sink due to heaving and rolling motion) do not occur at the same time. Therefore large value of  $D_2$  or  $D_3$  shall be adopted.  $D_2$  in case of  $\lambda$ >0.45*Lpp* can be calculated by the value of  $D_2/h_0$  taken from Fig. 2.2.1)



Note: This figure shows only the case of  $C_b$  =0.7 and  $F_n$ =0.1, but covers the case of deep sea where ship motion is bigger than one in shallow water. Therefore this figure can apply to all cases regardless of  $C_b$  and  $F_n$ .

#### Fig. 2.2.1 Ratio of having Motion and Wave Amplitude 5)

where

$$h_0$$
 : amplitude of wave ( $h_0=H/2$ )  
H : wave height

(c) Calculation of  $D_3$ 

In case where TR and TE is nearly equal,  $D_3$  can be calculated by the following equation.<sup>6)</sup>

$$D_3 = 0.7 \cdot \left(\frac{H_{1/3}}{2}\right) + \left(\frac{B}{2}\right) \cdot \sin\theta \tag{2.2.4}$$

where

 $\begin{aligned} \theta &= \mu \gamma \phi \\ \mu \gamma &= 7 \\ \phi &= 360 \; (0.35 H_{1/3} / \; \lambda \;) \sin \phi \end{aligned}$ 

TR and TE can be calculated by the following equation.

$$TR = 0.8B / (GM)^{0.5}$$

$$TE = \lambda / (\lambda / TW + U\cos\phi)$$
(2.2.5)



Fig. 2.2.2 Encounter Angle  $\varphi$ 

It is appropriate that GM is nearly equal to B/25. However, GM can be calculated by the following equation because real value of GM varies depending on ship condition.

(2.2.6)

$$GM=a(B/25)$$

where

GM : distance between the center of gravity of ship and metacenter (m)

- TW : wave period (s)
- $H_{1/3}$  : significant wave height (m)
  - B : breadth of design ship (m)
  - $\theta$  : maximum rolling angle of design ship (°)
  - $\mu$  : ratio of rolling induced by regular waves
  - $\gamma$  : effective wave slope coefficient
  - $\phi$  : maximum wave slope angle (°)
  - $\varphi$  : encounter angle between ship's head and wave direction (°)
  - *a* : 0.2–0.5
- (d) Calculation of  $D_4$

 $D_4$  is allowance of depth for sink of ship by large rudder angle to alter her course and can be calculated by the following equation.

$$D_4 = 0.5 \text{m} \quad d \leq 10 \text{m}$$
 (2.2.7)  
 $D_4 = 0.05 d \quad d > 10 \text{m}$ 

(e) Convergence of calculation for design depth of a new navigation channel

*D*, depth of navigation channel, is as the input data in the calculation equation of  $D_1$ , squat, that is a basic element for calculation of *D*. Therefore convergence of calculation is necessary until the value of *D* calculated by equation (2.2.2) becomes the same value of *D* in the calculation for new design depth of navigation channel.

(f) Application to design change of existing waterway In case of design change of existing waterway, existing depth of water is used as input data of D for calculation of  $D_1$  and performance requirement for depth of navigation channel can be evaluated by the following equation.

$$D$$
 (Existing depth of navigation channel)  $\geq D (=d+D_1+Max(D_2,D_3)+D_4)$  (2.2.9)

In case that the above equation is unsatisfied, it is necessary to change navigational environment such as change of initial ship speed or deepening of depth of navigation channel to be acquired by convergence of calculation.

### 2.3 Performance Verification of Width of Navigation Channel

### 2.3.1 Verification for Class 1 (Empirical Approach)

(1) As the necessary width for Class 1 navigation channels, the following values can generally be used.<sup>1), 2)</sup>

- (1) In waterways where two-way navigation is not expected, an appropriate width of  $0.5L_{oa}$  or more can generally be used. However, when the width is less than  $1.0L_{oa}$ , it is preferable to take adequate safety measures, such as provision of facilities to support navigation.
- (2) In waterways where two-way navigation is expected, an appropriate width of  $1.0L_{oa}$  or more can generally be used. Provided, however, that;

where

W : width of navigation channel (m)

 $L_{oa}$  : length overall of design ship (m)

### 2.3.2 Verification for Class 2 (Performance-based Approach) 1), 2)

In the verification for class 2, the well-established calculations of the ship maneuvering motion <sup>3), 4)</sup> are fully utilized, with which versatile performance predictions can be made with sufficient accuracy. From a view point of the practical use at the concept design phase, simple linear calculations and estimate equations are provided, which are derived from the fully nonlinear motion equations. Furthermore, for the following typical 15 ships covering a wide range of ship types and sizes, computations with respect to the width for the wind forces and the interaction forces are made and summarized in the following tables. The 15 ships are selected as the ship types, principal particulars of which are given in **Table 2.3.1** together with hydrodynamic derivatives. Making use of these computations together with the above simple linear calculations and estimate equations, the determination of width of navigation channel (estimations of the width elements) can practically and easily be made without computers.

|    | Ship Type                            | GT/GWT                   | $L_{oa}(\mathbf{m})$ | $L_{pp}(\mathbf{m})$ | <i>B</i> (m) | do(m) | Cb(m)  | Y'v    | N'v    | Υ΄δ     | $N'\delta$ |
|----|--------------------------------------|--------------------------|----------------------|----------------------|--------------|-------|--------|--------|--------|---------|------------|
| 1  | Cargo Ship                           | 5,000 GT                 | 109.0                | 103.0                | 20.0         | 7.0   | 0.7402 | -1.688 | -0.590 | -0.0723 | 0.0362     |
| 2  | Small Cargo Ship                     | 499 GT                   | 63.8                 | 60.4                 | 11.2         | 4.2   | 0.5395 | -1.653 | -0.597 | -0.0881 | 0.0441     |
| 3  | Container Ship (Over Panamax)        | 77,900 <i>DWT</i>        | 299.9                | 283.8                | 40.0         | 14.0  | 0.6472 | -1.340 | -0.457 | -0.0720 | 0.0360     |
| 4  | Container (Panamax)                  | 59,500 DWT               | 288.3                | 273.0                | 32.2         | 13.3  | 0.6665 | -1.312 | -0.449 | -0.0781 | 0.0391     |
| 5  | Very Large Bulk Carrier              | 172,900 DWT              | 289.0                | 279.0                | 45.0         | 17.8  | 0.8042 | -1.612 | -0.562 | -0.0699 | 0.0350     |
| 6  | Large Bulk Carrier (Panamax)         | 74,000 <i>DWT</i>        | 225.0                | 216.0                | 32.3         | 13.5  | 0.8383 | -1.587 | -0.553 | -0.0696 | 0.0348     |
| 7  | Sm all Bulk Carrier                  | 10,000 DWT               | 125.0                | 119.2                | 21.5         | 6.9   | 0.8057 | -1.551 | -0.519 | -0.0773 | 0.0387     |
| 8  | VLCC                                 | 280,000 DWT              | 333.0                | 316.0                | 60.0         | 20.4  | 0.7941 | -1.658 | -0.564 | -0.0880 | 0.0440     |
| 9  | Small Tanker                         | 6,000 DWT                | 100.6                | 92.0                 | 20.0         | 7.0   | 0.7968 | -1.835 | -0.640 | -0.0811 | 0.0406     |
| 10 | Large Pure Car Carrier               | 21,500 DWT               | 199.9                | 190.0                | 32.2         | 10.1  | 0.6153 | -1.417 | -0.484 | -0.0731 | 0.0365     |
| 11 | Pure Car Carrier                     | 18,000 <i>DWT</i>        | 190.0                | 180.0                | 32.2         | 8.2   | 0.5470 | -1.287 | -0.427 | -0.0753 | 0.0376     |
| 12 | LNG Ship                             | 69,500 DWT               | 283.0                | 270.0                | 44.8         | 10.8  | 0.7000 | -1.213 | -0.382 | -0.0762 | 0.0381     |
| 13 | Refrigerated Cargo Carrier           | 10,000 GT                | 152.0                | 144.0                | 23.5         | 7.0   | 0.7526 | -1.372 | -0.451 | -0.0705 | 0.0353     |
| 14 | Passenger Ship (2shafts 2propellers) | ellers) 28,700 <i>GT</i> |                      | 160.0                | 24.7         | 6.6   | 0.6030 | -1.214 | -0.387 | -0.1000 | 0.0500     |
| 15 | Ferry Boat (2shafts 1propellers)     | 18,000 GT                | 192.9                | 181.0                | 29.4         | 6.7   | 0.5547 | -1.125 | -0.354 | -0.0875 | 0.0437     |

(1) Basic Formulae for Determination of Width of Navigation Channel

The width of navigation channel  $W_{TOTAL}$  may generally be determined by the following basic equation.

$$W_{TOTAL} = W_{BM} + W_{IF}$$

where

 $W_{BM}$  : width of basic maneuvering lane

 $W_{IF}$ : additional width requisite against interaction forces

(2.3.1)

The width of basic maneuvering lane  $W_{BM}$  consists of four basic elements as follows;

$$W_{BM} = a \left( W_{WF} + W_{CF} + W_{YM} + W_{DD} \right)$$
(2.3.2)

where

 $W_{WF}$ : width requisite against wind forces  $W_{CF}$ : width requisite against current forces  $W_{YM}$ : width requisite against yawing motion  $W_{DD}$ : width requisite for drift detection.

Furthermore the additional width requisite against interaction forces consists of the following three elements.

$$W_{IF} = W_{BA} + bW_{PA} + cW_{OV}$$
(2.3.3)

where

 $W_{BA}$  : width requisite against bank effect forces  $W_{PA}$  : width requisite against two-ship interaction in passing  $W_{OV}$  : width requisite against two-ship interaction in overtaking.

Coefficients a, b and c in equations (2.3.2) and (2.3.3) are given as

a = 1 and b = c = 0 : for one-way channel a = 2, b = 1 and c = 0 : for two-way channel a = 4, b = 1 and c = 2 : for four-way channel

(2) Estimation of Basic Maneuvering Lane

① Width requisite against wind and current forces

In order to keep on a straight line in the waterway center under external forces, the ship should be operated by the check helm to run in an oblique condition with some drift angle with respect to its heading as shown in **Fig. 3.1**, so that the forces acting on the ship, namely the hull forces, the rudder forces and the external forces, can be balanced.



Fig. 2.3.1 W<sub>WF</sub>+W<sub>CF</sub>:Width Requisite against Wind and Current Forces

The width requisite against the wind and current forces  $(W_{WM} + W_{CF})$  may be calculated with the use of the drift angle  $\beta$  as follows;

$$W_{WF} + W_{CF} = L_{OA} \sin\beta + B\cos\beta$$
(2.3.4)

where,  $L_{OA}$  and B denote the over all length of ship and the breadth of ship respectively, and the drift angle  $\beta$  may be given as

$$\beta = \beta_1 + \beta_2 \tag{2.3.5}$$

where

 $\beta_1$  : drift angle due to wind forces

 $\beta_2$  : drift angle due to current forces.

② Drift angle due to wind forces

**Table 2.3.2** gives the drift angle due to the wind forces together with its corresponding check helm for the 15 ship types selected in **Table2.3.1**, which are obtained by the calculation of drift angle due to wind forces for the shallow water of H/d=1.2 (*H*: water depth *d* : ship draft). In **Table 2.3.2**, computations are given at each 15 degree of the relative wind direction from 0 degree (the head wind) to 180 degree (the tail wind).

|    | 01: T                      |    |          |       |       |       |       | Rel   | ative Wi | nd Direc | tion (deg | ree)  |       |       |       |       |
|----|----------------------------|----|----------|-------|-------|-------|-------|-------|----------|----------|-----------|-------|-------|-------|-------|-------|
|    | S nip Type                 |    |          | 0     | 15    | 30    | 45    | 60    | 75       | 90       | 105       | 120   | 135   | 150   | 165   | 180   |
| 1  | Cargo Ship                 | β1 | (degree) | 0.000 | 0.003 | 0.007 | 0.011 | 0.014 | 0.017    | 0.017    | 0.015     | 0.011 | 0.007 | 0.003 | 0.001 | 0.000 |
|    |                            | δ1 | (degree) | 0.000 | 0.017 | 0.049 | 0.102 | 0.169 | 0.233    | 0.276    | 0.284     | 0.257 | 0.204 | 0.138 | 0.068 | 0.001 |
| 2  | Small Cargo Ship           | β1 | (degree) | 0.000 | 0.006 | 0.011 | 0.017 | 0.021 | 0.024    | 0.024    | 0.021     | 0.016 | 0.011 | 0.006 | 0.003 | 0.000 |
|    |                            | δ1 | (degree) | 0.000 | 0.028 | 0.069 | 0.128 | 0.199 | 0.267    | 0.313    | 0.325     | 0.300 | 0.245 | 0.170 | 0.087 | 0.001 |
| 3  | Container Ship             | β1 | (degree) | 0.000 | 0.019 | 0.036 | 0.049 | 0.056 | 0.059    | 0.056    | 0.049     | 0.040 | 0.029 | 0.019 | 0.009 | 0.000 |
|    | (Over Panamax)             | δ1 | (degree) | 0.000 | 0.082 | 0.178 | 0.293 | 0.425 | 0.559    | 0.671    | 0.736     | 0.732 | 0.648 | 0.485 | 0.261 | 0.002 |
| 4  | Container (Panamax)        | β1 | (degree) | 0.000 | 0.015 | 0.029 | 0.038 | 0.042 | 0.043    | 0.040    | 0.036     | 0.030 | 0.023 | 0.016 | 0.008 | 0.000 |
|    |                            | δ1 | (degree) | 0.000 | 0.070 | 0.143 | 0.220 | 0.303 | 0.387    | 0.461    | 0.510     | 0.517 | 0.468 | 0.357 | 0.195 | 0.002 |
| 5  | Very Large Bulk Carrier    | β1 | (degree) | 0.000 | 0.002 | 0.005 | 0.008 | 0.010 | 0.012    | 0.012    | 0.010     | 0.008 | 0.005 | 0.003 | 0.001 | 0.000 |
|    |                            | δ1 | (degree) | 0.000 | 0.015 | 0.039 | 0.077 | 0.124 | 0.169    | 0.199    | 0.206     | 0.189 | 0.153 | 0.105 | 0.053 | 0.000 |
| 6  | Large Bulk Carrier         | β1 | (degree) | 0.000 | 0.002 | 0.004 | 0.006 | 0.008 | 0.009    | 0.009    | 0.008     | 0.006 | 0.004 | 0.002 | 0.001 | 0.000 |
|    | (Panamax)                  | δ1 | (degree) | 0.000 | 0.015 | 0.036 | 0.067 | 0.104 | 0.139    | 0.162    | 0.167     | 0.153 | 0.124 | 0.085 | 0.043 | 0.000 |
| 7  | 7 Small Bulk Carrier       | β1 | (degree) | 0.000 | 0.006 | 0.012 | 0.018 | 0.024 | 0.027    | 0.026    | 0.023     | 0.018 | 0.012 | 0.006 | 0.003 | 0.000 |
|    |                            | δ1 | (degree) | 0.000 | 0.027 | 0.070 | 0.135 | 0.217 | 0.296    | 0.351    | 0.367     | 0.340 | 0.278 | 0.194 | 0.099 | 0.001 |
| 8  | VLCC                       | β1 | (degree) | 0.000 | 0.002 | 0.005 | 0.008 | 0.011 | 0.013    | 0.013    | 0.011     | 0.008 | 0.005 | 0.002 | 0.001 | 0.000 |
|    |                            | δ1 | (degree) | 0.000 | 0.008 | 0.027 | 0.059 | 0.102 | 0.143    | 0.170    | 0.174     | 0.157 | 0.123 | 0.082 | 0.040 | 0.000 |
| 9  | Small Tanker               | β1 | (degree) | 0.000 | 0.003 | 0.007 | 0.011 | 0.014 | 0.017    | 0.017    | 0.015     | 0.011 | 0.007 | 0.003 | 0.001 | 0.000 |
|    |                            | δ1 | (degree) | 0.000 | 0.015 | 0.044 | 0.095 | 0.160 | 0.223    | 0.264    | 0.272     | 0.245 | 0.193 | 0.129 | 0.064 | 0.001 |
| 10 | Large Pure Car Carrier     | β1 | (degree) | 0.000 | 0.041 | 0.076 | 0.103 | 0.118 | 0.122    | 0.115    | 0.100     | 0.080 | 0.059 | 0.038 | 0.019 | 0.000 |
|    |                            | δ1 | (degree) | 0.000 | 0.159 | 0.340 | 0.556 | 0.806 | 1.067    | 1.298    | 1.450     | 1.470 | 1.324 | 1.006 | 0.546 | 0.005 |
| 11 | Pure Car Carrier           | β1 | (degree) | 0.000 | 0.051 | 0.097 | 0.132 | 0.152 | 0.158    | 0.149    | 0.130     | 0.104 | 0.076 | 0.048 | 0.024 | 0.000 |
|    |                            | δ1 | (degree) | 0.000 | 0.161 | 0.353 | 0.593 | 0.877 | 1.176    | 1.440    | 1.609     | 1.626 | 1.458 | 1.104 | 0.598 | 0.006 |
| 12 | LNG Ship                   | β1 | (degree) | 0.000 | 0.033 | 0.063 | 0.087 | 0.103 | 0.109    | 0.105    | 0.091     | 0.072 | 0.052 | 0.032 | 0.015 | 0.000 |
|    |                            | δ1 | (degree) | 0.000 | 0.092 | 0.211 | 0.374 | 0.573 | 0.780    | 0.952    | 1.049     | 1.040 | 0.914 | 0.680 | 0.364 | 0.003 |
| 13 | Refrigerated Cargo Carrier | β1 | (degree) | 0.000 | 0.008 | 0.015 | 0.023 | 0.028 | 0.032    | 0.031    | 0.028     | 0.022 | 0.015 | 0.008 | 0.004 | 0.000 |
|    |                            | δ1 | (degree) | 0.000 | 0.036 | 0.089 | 0.164 | 0.255 | 0.342    | 0.405    | 0.425     | 0.397 | 0.328 | 0.231 | 0.119 | 0.001 |
| 14 | Passenger Ship             | β1 | (degree) | 0.000 | 0.008 | 0.015 | 0.023 | 0.028 | 0.032    | 0.031    | 0.028     | 0.022 | 0.015 | 0.008 | 0.004 | 0.000 |
|    | (2shafts 2propellers)      | δ1 | (degree) | 0.000 | 0.174 | 0.363 | 0.578 | 0.826 | 1.097    | 1.361    | 1.561     | 1.629 | 1.507 | 1.169 | 0.643 | 0.006 |
| 15 | 15 Ferry Boat              | β1 | (degree) | 0.000 | 0.053 | 0.100 | 0.136 | 0.158 | 0.164    | 0.155    | 0.135     | 0.108 | 0.078 | 0.050 | 0.024 | 0.000 |
|    | (2shafts 1propellers)      |    | (degree) | 0.000 | 0.113 | 0.253 | 0.438 | 0.662 | 0.900    | 1.111    | 1.244     | 1.257 | 1.126 | 0.851 | 0.460 | 0.004 |

 $\beta_1$ : Drift Angle (degree)

 $\delta_l: Check \; Helm \; (degree)$ 

For the concept design use, the drift angle  $\beta_1$  and its corresponding check helm  $\delta_1$  may practically and easily be estimated by employing figures of the similar ship to the design ship given in **Table 2.3.2**. It is noted that the figures in **Table 2.3.2** are computed for the case of K=1.0, where K is defined as

$$K = \frac{U_W}{U} \tag{2.3.6}$$

where  $U_W$  and U denote the relative wind speed and the ship speed respectively.

For an arbitrary value of *K*, the drift angle due to the wind forces  $\beta_1(K)$  and its corresponding check helm  $\delta_1(K)$  can be obtained by the following equations.

$$\beta_1 (K) = K^2 \times \beta \text{ (figure given in Table 2.3.2 for } K=1.0)$$
(2.3.7)

 $\delta_1 (K) = K^2 \times \delta \text{ (figure given in Table 2.3.2 for } K=1.0\text{)}. \tag{2.3.8}$ 

In the above drift angle estimation, it should be confirmed that the check helm  $\delta_1$  corresponding to each drift angle  $\beta_1$  be less than the maximum rudder angle (35 degree for the conventional rudder), because the ship handling can not be made in the case of the rudder angle greater than the maximum one.

In addition to the above type-ship method, when the principal dimensions of the design ship are known, more accurate estimations of the drift angle  $\beta_1$  and the check helm  $\delta_1$  can be made by the direct calculation as follows;

③ Drift angle and check helm

The drift angle due to the wind forces  $\beta$  can be obtained theoretically by solving the equilibrium equations with respect to the drift angle and the check helm in the course keeping motion under the wind forces, which are derived from the coupled motion equations of sway and yaw.<sup>3), 4</sup>) The solutions of the above equilibrium equations (algebraic equations), namely the drift angle  $\beta$  and the check helm  $\delta$ , can be given by the following equations.

$$\beta = \mu \frac{Y'_{W}(\theta_{W})N'_{\delta} - N'_{W}(\theta_{W})Y'_{\delta}}{Y'_{v}{}^{*}N'_{\delta} - N'_{v}{}^{*}Y'_{\delta}}$$
(2.3.9)

$$\delta = \mu \frac{Y'_W(\theta_W) N'_v * - N'_W(\theta_W) Y'_v}{Y'_v * N'_\delta - N'_v * Y'_\delta}$$
(2.3.10)

(4) Linear derivatives of hull forces and rudder forces

In equations (2.3.9) and (2.3.10),  $Y'_{\nu}$  and  $N'_{\nu}$  denote the linear static derivatives of hull lateral force and hull yaw moment respectively, and they can be estimated by the following equations 2), 4) in which the shallow water effects are well taken into consideration.

$$Y'_{\nu}^{*} \left(= Y'_{\nu} + \gamma Y'_{\delta}\right) = -\left[\frac{1}{2} \frac{\pi k}{\frac{1}{2} k d_{H} + \left\{\frac{1}{2} \pi d_{H} \cot\left(\frac{1}{2} \pi d_{H}\right)\right\}^{2.3} + 1.4 \frac{C_{B}B}{L}}\right] + 0.4Y'_{\delta}$$

$$N'_{\nu}^{*} \left(= N'_{\nu} + \gamma N'_{\delta}\right) = -\frac{\pi k}{\frac{1}{2} k d_{H} + \left\{\frac{1}{2} \pi d_{H} \cot\left(\frac{1}{2} \pi d_{H}\right)\right\}^{1.7}} + 0.4N'_{\delta}$$
(2.3.11)
$$\left(\frac{1}{2} \lambda d_{H} + \left\{\frac{1}{2} \pi d_{H} \cot\left(\frac{1}{2} \pi d_{H}\right)\right\}^{1.7}\right\}^{1.7} + 0.4N'_{\delta}$$

where

$$k \left(=\frac{2d}{L}\right): \text{ aspect ratio of ship}$$

$$L : \text{ length of ship (between perpendiculars)}$$

$$B : \text{ breadth of ship}$$

$$d : \text{ draft of ship}$$

$$C_B: \text{ block coefficient}$$

$$d_H \left(=\frac{d}{H}\right): \text{ ratio of ship draft to water depth}$$

H: water depth

 $\gamma (= 0.4)$  : flow-straightening coefficient

In equations (2.3.9) - (2.3.12),  $Y'\delta$  and  $N'\delta$  denote the linear derivative of rudder lateral force and rudder yaw moment respectively, and they can be estimated by the following equations.<sup>2), 4)</sup>

$$Y'_{\delta} = -\varepsilon (1 + a_H) \frac{6.13\lambda_R}{\lambda_R + 2.25} \cdot \frac{A_R}{Ld}$$

$$N'_{\delta} = -\frac{1}{2} Y'_{\delta}$$
(2.3.13)

where

 $\lambda_R$  : aspect ratio of rudder  $A_R$  : rudder area.

In equations (2.3.13) and (2.3.14),  $\varepsilon$  denotes the coefficient of rudder inflow speed and the followings are practically employed in the computation.

\*  $\varepsilon$  =1.1 for both ships with a single propeller and single rudder arrangement

and with a twin propeller and twin rudder arrangement.

\*  $\varepsilon = 0.7$  for a ship with a twin propeller and single rudder arrangement.

In addition,  $a_H$  denotes the coefficient of hydrodynamic force induced on the ship hull by the rudder deflection, and  $a_H$  can be estimated with the use of Fig. 2.3.2 given as a function of  $C_{B.5}$ 

(2.3.14)

(2.3.12)



Fig. 2.3.2 Hydrodynamic Coefficient a<sub>H</sub>

#### (5) Wind force coefficients

In equations (2.3.9) and (2.3.10), the coefficient with respect to the wind forces  $\mu$  is given in the following form.

$$\mu = \left(\frac{\rho_W}{\rho}\right) \left(\frac{A_S}{Ld}\right) \left(\frac{U_W}{U}\right)^2 \tag{2.3.15}$$

where

$$p_W$$
 : density of air

 $\rho$  : density of water

 $A_s$ : projected lateral area above water line

 $U_W$ : relative wind speed at gravity center of ship

U : ship speed.

In addition,  $Y'_{W}(\theta_{W})$  and  $N'_{W}(\theta_{W})$  denote the coefficients of wind lateral force and wind yaw moment respectively as functions of  $\theta_{W}$  which indicates the angle of relative wind direction at the center of gravity of the ship. On the basis of the wind tunnel tests,  $Y_{W}(\theta_{W})$  and  $N_{W}(\theta_{W})$  may practically be obtained by the following expressions with the trigonometric series.<sup>6</sup>

$$Y'_{W}(\theta_{W}) = \sum_{n=1}^{5} C_{Y_{n}} \sin(n\theta_{W})$$
(2.3.16)

$$N'_{W}(\theta_{W}) = \sum_{n=1}^{3} C_{Nn} \sin(n\theta_{W}).$$
(2.3.17)

In the above equations, the regression coefficients  $C_{Yn}$  and  $C_{Nn}$  are estimated by the following equations, for which the coefficients  $C_{Yn0}$ ,  $C_{Yn1}$ ,  $C_{Nn0}$ ,  $C_{Nn1}$  etc. are given in **Table 2.3.3** 

$$C_{Yn} = C_{Yn0} + C_{Yn1} \frac{A_S}{L^2} + C_{Yn2} \frac{x_S}{L} + C_{Yn3} \frac{L}{B} + C_{Yn4} \frac{A_S}{A_F}$$
(2.3.18)

$$C_{Nn} = C_{Nn0} + C_{Nn1} \frac{A_S}{L^2} + C_{Nn2} \frac{x_S}{L} + C_{Nn3} \frac{L}{B} + C_{Nn4} \frac{A_S}{A_F}$$
(2.3.19)

where

 $A_F$ : projected front area above water line

- $A_S$  : projected lateral area above water line
- $x_s$ : distance between FP (fore perpendicular) and figure center of  $A_s$ .

| Су           | Const. | $A_S/L_2$ | $x_S/L$ | L/B    | $A_S/A_F$ | Cm  | Const. | $A_S/L_2$ | $x_S/L$ | L/B    | $A_S/A_F$ |
|--------------|--------|-----------|---------|--------|-----------|-----|--------|-----------|---------|--------|-----------|
| <i>C y</i> 2 | 0.509  | 4.904     | -       | _      | 0.022     | Cm1 | 2.650  | 4.634     | -5.876  | -      | _         |
| С у3         | 0.0208 | 0.230     | -       | _      | _         | Cm2 | 0.105  | 5.306     | -       | -      | 0.0704    |
| <i>C y</i> 4 | -0.357 | 0.943     | -0.075  | 0.0381 | _         | Cm3 | 0.616  | _         | -1.474  | 0.0161 | _         |

Table 2.3.3 Regression Coefficients of Wind Forces

(6) Drift angle due to current forces

The drift angle due to the current forces  $\beta_2$  can be obtained by

$$\beta_2 = \arctan\left(\frac{U_C}{U}\right) \tag{2.3.20}$$

where

 $U_C$ : current speed perpendicular to channel center line

U : ship speed.

(7) Width requisite against the yawing motion caused by unsteady external forces  $W_{YM}$  may be defined as the maximum deviation (double amplitude) due to the yawing as shown in **Fig. 2.3.3**, and  $W_{YM}$  may be calculated by the following equation.

$$W_{YM}\left(=2U\int_{0}^{\frac{T_{y}}{4}}\sin\psi(t)dt\right) = \frac{1}{2}UT_{y}\sin\psi_{0}$$
(2.3.21)

where

$$\psi(t)(=\psi_0 \sin\left(\frac{2\pi}{T_y}t\right))$$
: yawing angle

In equation (2.3.21),  $T_y$  (the yawing period) = 12 sec and  $\psi_0$  (the yawing amplitude) = 4 degree may empirically be employed in the computation.



Fig. 2.3.3 WYM:Width requisite against Yawing Motion

(8) Width requisite for drift detection

In general, a ship sailing in the waterway more or less makes some amount of lateral deviation from its course line even if the ship handler does believe that his ship is running on the right course line. This drift may hardly be detected within a small amount of deviation. However the ship handler can recognize the drift when the lateral deviation from the waterway center line becomes a considerable amount as shown in **Fig. 3.4**. The drift detection should be considered with respect to both sides of the waterway center line. Estimations of the width requisite for the drift detection are provided for the following three types of on-board navigation equipment, which are currently available in the actual ship operation.

- \* Drift detection by observing light buoys with naked eyes.
- \* Drift detection by observing light buoys with RADAR.
- \* Drift detection by GPS or D-GPS.



Fig. 2.3.4 Width Requisite for Drift Detection

(9) Drift Detection by observing light buoys with naked eyes

The width requisite for the drift detection in this case  $W_{DD}$  (NEY) may be defined as the maximum deviation that almost all ship handlers are supposed to be able to recognize by observing light buoys ahead on both sides of the waterway with naked eyes. Referring to **Fig. 2.3.5**,  $W_{DD}$  (NEY) can be calculated by

$$W_{DD}(NEY) = 2L_F \tan \alpha_{\max}$$
(2.3.22)

where  $L_F$  denotes the distance for the drift detection between the ship and the light buoys ahead along the waterway center line, and  $L_F = 7 \times L_{OA}$  ( $L_{OA}$ : the over all length of ship) may empirically be employed in the computation. The maximum intersecting angle corresponding to the above maximum deviation  $\alpha_{max}$ may be estimated with the use of an empirical formula developed on the basis of statistical data by full scale experiments, and it is given by

$$\alpha_{\rm max} = 0.00176\theta^2 + 0.0008\theta + 2.21372\,(^\circ) \tag{2.3.23}$$

In equation (2.3.23),<sup>7</sup>)  $\theta$  denotes the intersecting angle by two lines from the ship to the two buoys ahead on both sides of the waterway as shown in Fig. 2.3.5, and it is defined as

$$\theta = 2 \arctan\left(\frac{W_{BUOY}}{2L_F}\right) \tag{2.3.24}$$

where

 $W_{BUOY}$ : clearance between two buoys.



Fig. 2.3.5 Drift Detection by observing Light Buoys with Naked Eyes or RADAR

10 Drift detection by observing light buoys with RADAR

The width requisite for the drift detection in this case  $W_{DD}(RAD)$  may be calculated by the following equation.

$$W_{DD}(RAD) = 2 \frac{W_{BUOY}}{\sin \theta} \sin \gamma$$
(2.3.25)

where  $\gamma$  denotes the observation error of direction by RADAR, and equation (2.3.25) is rewritten for the two cases of  $\gamma=2^{\circ}$  and  $\gamma=1^{\circ}$  as follows.

$$W_{DD}(RAD) = 0.0698 \frac{W_{BUOY}}{\sin \theta} \quad (\gamma = 2^\circ)$$
(2.3.26)

$$W_{DD}(RAD) = 0.0349 \frac{W_{BUOY}}{\sin \theta} \quad (\gamma = 1^{\circ})$$
(2.3.27)

① Drift detection by GPS

It is assumed that the perception error of GPS information on the display by naked eyes be a half of the ship breadth, and in addition that the error of GPS information itself be 30 meters for the usual GPS and none for the D-GPS. Then the following equations may be given with respect to the width requisite for the drift detections by GPS and D-GPS respectively, where the errors are considered for both sides of the waterway center line.

$$W_{DD}(GPS) = B + 60$$
 (m) (2.3.28)

$$W_{DD}(D - GPS) = B \quad (m). \tag{2.3.29}$$

#### (3) Estimation of Additional Width for Interaction Forces

/

The width requisite against the interaction forces may be estimated with the use of a concept of the requisite clearance between the ship and bank wall or between two ships, in which the ship can keep a straight course line against the interaction forces with the rudder angle predetermined from a view point of the actual ship operation. Making use of the calculation of check helm against interaction force, the requisite clearance may be obtained in the following manner. Namely check helm computations are made first for some values of the clearance between the ship and bank wall or between ships, and then the requisite clearance can be obtained by determining the clearance corresponding to the predetermined rudder angle through interpolations.

① Width requisite against bank effect forces

The check helm against the bank effect forces  $\delta$  together with the drift angle  $\beta$  can be given by the following equations in the similar way to equations (2.3.9) and (2.3.10).

$$\delta = \frac{Y'_B(\eta')N'_v - N'_B(\eta')Y'_v}{Y'_v N'_\delta - N'_v Y'_\delta}$$
(2.3.30)

$$\beta = \frac{Y'_B(\eta')N'_{\delta} - N'_B(\eta')Y'_{\delta}}{Y'_v N'_{\delta} - N'_v Y'_{\delta}}$$
(2.3.31)

where

 $\eta' = \frac{\eta}{I}$  ( $\eta$ : clearance between ship longitudinal center line and bank wall).

In equations (2.3.30) and (2.3.31),  $Y'_B(\eta')$  and  $N'_B(\eta')$  denote the coefficients of lateral force and yaw moment due to bank effects respectively. The coefficients of  $Y'_B(\eta')$  and  $N'_B(\eta')$  may practically be estimated with the use of computed results<sup>8</sup> shown in **Fig. 2.3.6**, where  $C_F$  and  $C_M$  as functions of  $S_P(=\eta)$  in the ordinate denote  $Y'_B(\eta')$ and  $N'_B(\eta')$  respectively and  $S'_T$  in the abscissa denotes dimensionless distance (divided by the ship length) from the midship to the bank entrance in the longitudinal direction. It is noted that the peak values in the force and moment variations should be employed for the estimations of  $Y'_B(\eta')$  and  $N'_B(\eta')$  by **Fig. 2.3.6** 



Fig. 2.3.6 Lateral Force and Yaw moment due to Bank Effects 8)

**Table 2.3.4** gives the requisite clearance with respect to the bank effect forces for the 15 ship types, which are obtained with the predetermined rudder angle of 5 degree. In **Table 2.3.4** together with **Fig. 2.3.7**, the requisite clearance is denoted by the term of "bank clearance" with a symbol of  $W_{bi0}$ . It is noted that the figures of bank clearance are obtained for the canal section with the upright wall.

|    | Ship Type                            | $L_{pp}$ | В     | $W_{bio}$ | $W_{bio}/B$ |
|----|--------------------------------------|----------|-------|-----------|-------------|
| 1  | Cargo Ship                           | 103.0    | 20.0  | 17.4      | 0.87        |
| 2  | Small Cargo Ship                     | 60.4     | 299.9 | 9.8       | 0.87        |
| 3  | Container Ship (Over Panamax)        | 283.8    | 40.0  | 55.5      | 1.39        |
| 4  | Container (Panamax)                  | 273.0    | 32.2  | 55.2      | 1.71        |
| 5  | Very Large Bulk Carrier              | 279.0    | 45.0  | 52.6      | 1.17        |
| 6  | Large Bulk Carrier (Panamax)         | 216.0    | 32.3  | 41.9      | 1.30        |
| 7  | Small Bulk Carrier                   | 119.2    | 215.0 | 20.3      | 0.95        |
| 8  | VLCC                                 | 316.0    | 60.0  | 49.7      | 0.83        |
| 9  | Small Tanker                         | 92.0     | 20.0  | 13.8      | 0.69        |
| 10 | Large Pure Car Carrier               | 190.0    | 32.2  | 34.3      | 1.06        |
| 11 | Pure Car Carrier                     | 180.0    | 32.2  | 31.2      | 0.97        |
| 12 | LNG Ship                             | 270.0    | 44.8  | 47.7      | 1.07        |
| 13 | Refrigerated Cargo Carrier           | 144.0    | 23.5  | 26.6      | 1.13        |
| 14 | Passenger Ship (2shafts 2propellers) | 160.0    | 24.7  | 25.9      | 1.05        |
| 15 | Ferry Boat (2shafts 1propellers)     | 181.0    | 29.4  | 30.5      | 1.04        |

#### Table 2.3.4 Bank Clearance

(unit:meter)



Fig. 2.3.7 Width Requisite against Bank Effect Forces

For practical use at the concept design, the width requisite against the bank effect forces for the canal section  $W_{BA0}$  may simply be estimated by employing figures of the similar ship to the design ship given in **Table 2.3.4**, namely

$$W_{BA0} = W_{bi0}$$
 (figure given in **Table 2.3.4**). (2.3.32)

Taking the bank effects on both sides of the waterway into consideration, the width for the dredged waterway shown in Fig. 2.3.8  $W_{BA}$  may be obtained by

$$W_{BA} = (C_{DS}^{L} + C_{DS}^{R}) W_{BA0}$$
(2.3.33)

In the above equation,  $C_{DS}^{L}$  and  $C_{DS}^{R}$  denote corrections of the dredged waterway configuration to the canal section for the left and right side banks respectively, and  $C_{DS}$  is given by the following equation.

$$C_{DS} = \exp\left(-\frac{2h_1}{1-h_1}\right)$$
(2.3.34)

#### where

$$h_1 = \frac{D_{OUT}}{D} = \frac{1}{2} \frac{D + D_{OUT}}{D}$$

 $D_{OUT}$ : depth of outer navigation channel D: depth of inner navigation channel



Fig. 2.3.8 Width for the Dredged Navigation Channel

2 Width requisite against Two-ship Interaction in Passing

The check helm against the two-ship interaction  $\delta$  may be given by the following simple equation on the assumption of zero drift angle ( $\beta$ =0) due to relatively short-time interaction.

$$\delta = -\frac{N'_{SI}(\eta')}{N'_{\delta}}$$
(2.3.35)

where

$$\eta' = \frac{\eta}{L}$$
 ( $\eta$ : clearance between longitudinal centerlines of two-ships).

The coefficient of yaw moment due to the two-ship interaction  $N'_{SI}(\eta')$  in equation (2.3.35) may practically be estimated with the use of computed results <sup>9), 10)</sup> shown in **Fig. 2.3.9** and **Fig. 2.3.10**. In these figures,  $C_{Mi}$  (*i*=1,2) as a function of  $S_{P12}$  (= $\eta$ ) in the ordinate denotes  $N'_{SI}(\eta')$  and  $S_{T12}$  in the abscissa denotes the midship to midship distance of two ships in the longitudinal direction. **Fig. 2.3.9** shows  $N'_{SI}(\eta')$  for the meeting condition, and **Fig. 2.3.10** shows  $N'_{SI}(\eta')$  for the overtaking condition. In the similar way to the bank effect forces, it is noted that the peak value in the moment variation should be employed for the estimations of  $N'_{SI}(\eta')$  by **Fig. 2.3.9** and **Fig. 2.3.10**.



Fig. 2.3.9 Yaw Moment due to Two-ship Interaction in Passing 9)



Fig. 2.3.10 Yaw Moment due to Two-ship Interaction in Overtaking <sup>10)</sup>

**Table 2.3.5** shows the requisite clearance with respect to the two-ship interaction in the passing for the 15 ship types, which are obtained with the predetermined rudder angle of  $15^{\circ}$ . In **Table 2.3.5** together with **Fig. 3.11**, the requisite clearance is denoted by the term of "passing distance" with a symbol of  $W_C$ .

|    | Ship Type                            | L <sub>pp</sub> | В     | $W_C$ | W <sub>C</sub> /B |
|----|--------------------------------------|-----------------|-------|-------|-------------------|
| 1  | Cargo Ship                           | 103.0           | 20.0  | 32.6  | 1.63              |
| 2  | Small Cargo Ship                     | 60.4            | 299.9 | 17.6  | 1.57              |
| 3  | Container Ship (Over Panamax)        | 283.8           | 40.0  | 105.0 | 2.63              |
| 4  | Container (Panamax)                  | 273.0           | 32.2  | 103.6 | 3.22              |
| 5  | Very Large Bulk Carrier              | 279.0           | 45.0  | 98.8  | 2.20              |
| 6  | Large Bulk Carrier (Panamax)         | 216.0           | 32.3  | 79.0  | 2.45              |
| 7  | Small Bulk Carrier                   | 119.2           | 215.0 | 38.2  | 1.77              |
| 8  | VLCC                                 | 316.0           | 60.0  | 91.0  | 1.52              |
| 9  | Small Tanker                         | 92.0            | 20.0  | 25.2  | 1.26              |
| 10 | Large Pure Car Carrier               | 190.0           | 32.2  | 64.6  | 2.01              |
| 11 | Pure Car Carrier                     | 180.0           | 32.2  | 58.4  | 1.81              |
| 12 | LNG Ship                             | 270.0           | 44.8  | 90.7  | 2.03              |
| 13 | Refrigerated Cargo Carrier           | 144.0           | 23.5  | 50.5  | 2.15              |
| 14 | Passenger Ship (2shafts 2propellers) | 160.0           | 24.7  | 47.7  | 1.93              |
| 15 | Ferry Boat (2shafts 1propellers)     | 181.0           | 29.4  | 57.1  | 1.94              |

| Table | 2.3.5 | Passing | Distance |
|-------|-------|---------|----------|
|-------|-------|---------|----------|

(unit:meter)



Fig. 2.3.11 Width Requisite against Two-ship Interaction in Passing

For the practical design use, the width requisite against the two-ship interaction in passing  $W_{PA}$  may easily be estimated with the use of figures of the similar ship to the design ship given in **Table 2.3.5**, namely

$$W_{PA} = W_C \text{ (figure given in Table 2.3.5).}$$
(2.3.36)

③ Width requisite against two-ship interaction in overtaking

In the same way as the above, **Table 2.3.6** shows the requisite clearance with respect to the two-ship interaction in the overtaking for the 15 ship types, which are obtained with the predetermined rudder angle of  $15^{\circ}$ . In **Table 2.3.6** together with **Fig. 2.3.12**, the requisite clearance is denoted by the term of "overtaking distance" with a symbol of  $W_{ov}$ .

|    | Ship Type                            | $L_{pp}$ | В     | $W_{ov}$ | $W_{ov}/B$ |
|----|--------------------------------------|----------|-------|----------|------------|
| 1  | Cargo Ship                           | 103.0    | 20.0  | 55.7     | 2.79       |
| 2  | Small Cargo Ship                     | 60.4     | 299.9 | 30.0     | 2.68       |
| 3  | Container Ship (Over Panamax)        | 283.8    | 40.0  | 169.1    | 4.23       |
| 4  | Container (Panamax)                  | 273.0    | 32.2  | 163.2    | 5.07       |
| 5  | Very Large Bulk Carrier              | 279.0    | 45.0  | 162.2    | 3.60       |
| 6  | Large Bulk Carrier (Panamax)         | 216.0    | 32.3  | 128.4    | 3.98       |
| 7  | Small Bulk Carrier                   | 119.2    | 215.0 | 64.2     | 2.98       |
| 8  | VLCC                                 | 316.0    | 60.0  | 155.7    | 2.60       |
| 9  | Small Tanker                         | 92.0     | 20.0  | 44.9     | 2.24       |
| 10 | Large Pure Car Carrier               | 190.0    | 32.2  | 106.9    | 3.32       |
| 11 | Pure Car Carrier                     | 180.0    | 32.2  | 98.2     | 3.05       |
| 12 | LNG Ship                             | 270.0    | 44.8  | 150.1    | 3.35       |
| 13 | Refrigerated Cargo Carrier           | 144.0    | 23.5  | 83.2     | 3.54       |
| 14 | Passenger Ship (2shafts 2propellers) | 160.0    | 24.7  | 78.3     | 3.17       |
| 15 | Ferry Boat (2shafts 1propellers)     | 181.0    | 29.4  | 94.7     | 3.22       |

#### Table 2.3.6 Overtaking Distance

(unit:meter)



Fig. 2.3.12 Width Requisite against Two-ship Interaction in Overtaking

For the practical design use, the width requisite against the two-ship interaction in the overtaking  $W_{OV}$  may easily be estimated with the use of figures of the similar ship to the design ship given in **Table 2.3.4**, namely

$$W_{OV} = W_{ov} \text{ (figure given in Table 2.3.6)}. \tag{2.3.37}$$

In addition to the above type-ship method, in the similar way to the drift angle due to the wind forces, when the principal dimensions of the design ship are known, more accurate estimations of the width requisite against the interaction forces may be made by the direct application of the check helm calculation.

#### (4) Determination of Width of Navigation Channel

The total width of navigation channel can be determined by the basic formulae described in 2.3.2 (1) Basic Formula for Determination of width of Navigation Channel. However it is noted that  $W_{DD}$  (*NEY*) in equation (2.3.22) and  $W_{DD}$  (*RAD*) in equation (2.3.25) are given as functions of  $W_{BUOY}$  (the clearance between two buoys ahead on both sides) which should be identical to the design target of the width of navigation channel.

For this reason, iteration computations are needed for the cases of the drift detection by observing light buoys either with the naked eyes or with RADAR, and the iteration procedure is briefly given as follows. Assuming some amount of  $W_{BUOY}$  and substituting it into equation (2.3.22) or equation (2.3.25), then  $W_{DD}$  (NEY) or  $W_{DD}$ (RAD) are computed, where the computed  $W_{TOTAL}$  by equation (2.3.1) should be identical to the assumed  $W_{BUOY}$ . Some steps of iterations, not one-time computation but some few steps or more, may usually be needed in order to attain a satisfactory convergence for the difference between the assumed  $W_{BUOY}$  and the computed  $W_{TOTAL}$ . The convergence may be judged by

$$|assumed W_{BUOY} - computed W_{TOTAL}| \prec \varepsilon$$
(2.3.38)

where  $\varepsilon = 1.0$  meter may be taken. In addition, regarding the assumption of  $W_{BUOY}$  at the first step computation, quick convergent iteration may be expected by employing a value of  $L_{OA}$  for the one-way channel and  $2L_{OA}$  for the two-way channel.

Regarding the drift detection by GPS or D-GPS, the total width of navigation channel can easily be determined simply by summing up the necessary elements given in equations (2.3.1) - (2.3.3).

### 2.4 Alignment of Navigation Channel (Bends)

### 2.4.1 Fundamentals of Performance Verification

(1) In class 1 waterways, in cases where a bend exceeds 30° and the design ship and the features of the navigation environment such as the rudder angle, ship speed cannot be designated, it is preferable that the centerline of the bend in the waterway be an arc having a radius of curvature roughly 4 times the length overall of the design ship  $L_{oa}$  or more, and that the width of navigation channel be equal to or greater than the necessary width. When the angle of intersection of the centerlines is 30° or greater, in two-way waterways having its width of W, it is preferable that the corner cut be designed as shown in **Fig. 2.4.1**. Furthermore, depending on the design ship and the navigation environment, the length between perpendiculars  $L_{pp}$  can be used instead of the length overall  $L_{pa}$ .



Fig. 2.4.1 Corner Cut at Bend Section of Width W of Navigation Channel

(2) In class 2 waterways, in cases where a bend exceeds 30° and the design ship and the features of the navigation environment such as the rudder angle, ship speed can be designated, the radius of curvature can be calculated based on the manoeuverability index of turning, which shows the turning performance of ships. In the bend, it is desirable that the width be greater than that required by corner cut, etc.

It may also be noted that in cases other than corner cut, a curved shape, etc. can be used, considering the installation of buoys, etc., based on adjustment with the parties concerned with maritime affairs. In particular, providing a corner cut is not necessarily effective in cases where the angle of intersection between the center lines is large; therefore, study of a curved shape is preferable.

#### 2.4.2 Performance Verification for Class 2

The radius of curvature which is necessary in class 2 waterways can be calculated by the following method.

The curvature of bend which joins two straight line channel legs should be determined by considering both aspects of the ship turning ability and the rudder angle to be taken, and the bend radius (= the ship turning radius) R may be calculated by the following equation.<sup>1), 2)</sup>

$$R = \frac{L}{K'\delta_0}$$
(2.4.1)

where

L : length of ship (between perpendiculars) (m)

K : non-dimensional index of turning ability

 $\delta_0$  : rudder angle (rad)

**Table 2.4.1** gives the non-dimensional index of the turning ability *K* for 13 ship types, which are obtained by analyzing the motion trajectories of 90 degree turning computed with the use of fully nonlinear equations of the ship maneuvering motion.<sup>3), 4)</sup> The computations are made for the turning motion with 20 degree rudder in the shallow water of H/d = 1.2 under non-external forces.

For the concept design use, the turning ability index *K* may practically and easily be estimated by employing figures of the similar ship to the design ship given in **Table 2.4.1** as follows.

$$K = K'$$
 (the figure given in Table 2.4.1). (2.4.2)

It is noted that *K* is not given for the 2 types of PCCs in **Table 2.4.1**, for which careful attention and consideration should be paid from a view point of the large wind force effects.

|    | Ship Type                            | <i>K'</i> |
|----|--------------------------------------|-----------|
| 1  | Cargo Ship                           | 0.58      |
| 2  | Small Cargo Ship                     | 0.47      |
| 3  | Container Ship (Over Panamax)        | 0.42      |
| 4  | Container (Panamax)                  | 0.52      |
| 5  | Very Large Bulk Carrier              | 0.52      |
| 6  | Large Bulk Carrier (Panamax)         | 0.49      |
| 7  | Small Bulk Carrier                   | 0.62      |
| 8  | VLCC                                 | 0.62      |
| 9  | Small Tanker                         | 0.60      |
| 10 | LNG Ship                             | 0.75      |
| 11 | Refrigerated Cargo Carrier           | 0.63      |
| 12 | Passenger Ship (2shafts 2propellers) | 0.66      |
| 13 | Ferry Boat (2shafts 1propellers)     | 0.55      |

| Table 2.4.1 | Non-dimensional | Index of | f Turnina         | Ability   |
|-------------|-----------------|----------|-------------------|-----------|
| 10010 2.1.1 | Non annonoiona  | mack o   | i i ai i iii i ig | 7 (Dilley |

### References

- 1) Yoshimura, Y.: Mathematical model for the maneuvering ship motion in shallow water, Journal of the Kansai society of naval architects, Japan, No.200, March 1986
- Takahashi, H., A. Goto and M. Abe: Study on ship dimensions by statistical analysis-standard of main dimensions of design ship (Draft), Research Report of National Institute for Land and Infrastructure Management, No.28, March 2006
- 3) VLCC Study Group: 10 sections regarding VLCC, SEIZANDOSHOTEN
- 4) Honda, K.: Outline of ship handling (5th edition), SEIZANDOSHOTEN, 1998
- Takagi, M.: On the ship motion in shallow water No.3, Transactions of the West-Japan Society of Naval Architects, Vol. 54, 1977
- 6) Ohtsu, K., Yoshimura, Y., Hirano, M., Tsugane, M and Takahashi, H.: Design Standards for Fairway in Next Generation, Asia Navigation Conference 2006, No.26, 2006
- 7) The Japan Port and Harbour Association: Technical Standards and Commentaries for Port and Harbour Facilities in Japan
- Inoue, S., Hirano, M., Kijima, K. And Takashina, J.: A Practical Calculation Method of Ship Maneuvering Motion, ISP (International Shipbuilding Progress), Vol.28, No.325, 1981
- 9) Principle of Naval Architecture (2nd Revision), Vol.3, SNAME, 1989
- Kose, K., Yumuro, A. And Yoshimura, Y.: Mathematical Model of Ship Maneuvering Motion-Interactions among Hull, Propeller and Rudder, and its Expressions, The 3rd Ship Maneuverability Symposium Text, The Society of Naval Architects of Japan, 1981
- 11) Yamano, T. and Saito, Y.: An Estimation Method of Wind Force Acting on Ship's Hull, Journal of the Kansai Society of Naval Architects, No.228, 1997
- 12) Kijima, K. and Lee, M/: On the Safe Navigation Including the Interaction Forces between Ship and Ship, Transactions of the West-Japan Society of Naval Architects, No.104, 2002

# 3 Basins

# Ministerial Ordinance

Performance Requirements for Basins

### Article 10

The performance requirements for basins shall be such that the requirements specified by the Minister of Land, Infrastructure, Transport and Tourism are satisfied in light of geotechnical characteristics, waves, water currents, and wind conditions along with the usage conditions of the surrounding water areas, for securing the safe and smooth use by ships.

# Public Notice

Performance Criteria for Basins

## Article 31

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

- (1) The size of a basin shall satisfy the following standards. Provided, however, that the standards shall not be applied to basins for design ships with the gross tonnage less than 500 tons:
  - (a) Basins which are provided for use in anchorage or mooring of ships excluding the basins in front of quaywalls, mooring piles, piers, and floating piers shall have an area greater than a circle that has a radius obtained by adding an appropriate value to the length of the design ship, in light of the conditions of geotechnical characteristics, waves, water currents, and winds as well as the usage condition of the surrounding water areas. Provided, however, that in cases where that the area specified above is not required owing to the mode of anchorage or mooring, the basin size can be reduced to the area that shall not hinder the safe anchorage or mooring of ships.
  - (b) Basins which are provided for use in anchorage or mooring of ships in front of quaywalls, mooring piles, piers, and floating piers shall have an appropriate area of which the length and width are greater than the length and width of the design ship, respectively, in light of the conditions of geotechnical characteristics, waves, water currents, and winds, the usage condition of the surrounding water areas, and the mode of anchorage or mooring.
  - (c) Basins which are provided for use in ship turning by the bow shall have an area greater than a circle that has a radius obtained by multiplying the length of the design ship by 1.5. Provided, however, that in cases where that the area specified above is not required owing to the method of ship turning by the bow, the basin size can be reduced to the area that shall not hinder the safe ship turning by the bow.
- (2) The basin shall have an appropriate depth that is greater than the draft of the design ship, in light of the degree of the motions of the design ship due to waves, water currents, winds, and others.
- (3) Basins which are provided for use in anchorage or mooring of ships in front of quaywalls, mooring piles, piers, and floating piers shall in principle secure the harbor calmness which enables the working rate of cargo handling operation at equal to or greater than 97.5% in terms of time throughout the year. Provided, however, that this rate shall not be applied to the basins where the mode of utilization of mooring facilities or the water areas in front of them are regarded as special.
- (4) In a basin which is provided as a harbor of refuge during stormy weather, the wave conditions during stormy weather shall remain below the level that is admissible for refuge of the design ship.
- (5) In a basin which is provided for anchorage or mooring of ships for the main purpose of timber sorting, measures shall be taken to prevent drifting of timbers.

## [Technical Note]

## 3.1 Performance Criteria

- (1) Area of Basins (usability)
  - 1 Basins provided for use in anchorage or mooring of ships
    - (a) Basins other than those in front of quaywalls.In basins which are provided for use in anchorage or mooring of ships, basins other than basins in front of quaywalls, mooring piles, piers, and floating piers means basins which are provided for use in anchoring

### TECHNICAL STANDARDS AND COMMENTARIES FOR PORT AND HARBOUR FACILITIES IN JAPAN

and buoy mooring. In determining the area of the basin in performance verification of the basin concerned, appropriate consideration shall be given to the properties of the sea-bed, the effect of wind, the water depth, depending on the functions required in the objective facilities and the expected condition of use of the facilities. Cases where that area is not necessary due to the method of anchorage or mooring are defined as cases of buoy mooring. In determining the area of the basin in the performance verification of basins in this case, appropriate consideration shall be given to the expected condition of use of the objective facilities and the amount of horizontal movement of buoys due to the effect of differences in sea level.

(b) Basins in front of quaywalls

In determining the proper area of basins greater than the length overall of the design ship and greater than the width of the design ship in the performance verification of basins in front of quaywalls, mooring piles, piers, and floating piers, when determining the length of the basin, appropriate consideration shall be given to the necessary extension in alongside mooring of the design ship in the length overall of the design ship, and in determining the width of the basin, appropriate consideration shall be given to safety in berthing and unberthing of the design ships.

- <sup>(2)</sup> Basins provided for use in turning of bow
  - (a) Basins provided for use in turning of the bow (hereinafter called "ship turning") means the turning basins. In determining the scale of the basin, turning basin, in the performance verification of the basin concerned, appropriate consideration shall be given to the method of turning of the design ship, the turning performance of the design ship, the arrangement of the mooring facilities and waterways. Methods of turning in cases where that area is not necessary mean turning employing a tugboat, turning using thrusters having adequate thrust and turning using an anchor.
  - (b) Area which does not hinder safe turning
    - 1) In determining the area of a basin in the performance verification of the basin, the following values can be used as areas which do not hinder safe turning.
      - Turning using thrusters having adequate thrust may be equivalent to turning using a tugboat.
      - When turning under the ship's own power, a circle having a diameter 3 times the length overall of the design ship
      - When turning using a tugboat, a circle having a diameter 2 times the length overall of the design ship
    - 2) Special cases in connection with small craft

In basins provided for use in turning of small crafts, in cases where the area of the basin must unavoidably be reduced due to topographical conditions, the following values can be used as an area which does not hinder safe turning, with the use of a mooring anchor, winds, or tidal currents.

Turning utilizing thrusters having adequate thrust may be equivalent to turning using a tugboat.

- When turning under the ship's own power, a circle having a diameter 2 times the length overall of the design ship
- When turning using a tugboat, a circle having a diameter 1.5 times the length overall of the design ship
- (c) Mooring/unmooring basins

In determining the scale of basins in the performance verification of mooring/unmooring basins, appropriate consideration shall be given to the method of turning of the design ship, whether the ship is equipped with thrusters or not, the effects of winds and tidal currents, ease of maneuvering.

### (2) Water Depth of Basins (usability)

- (1) An appropriate water depth greater than the draft of the design ship is a value obtained by adding a keel clearance, which is set corresponding to the maximum draft, to the assumed maximum draft of the design ship, such as the load draft. In determining the water depth of a basin in the performance verification of the basin, an appropriate depth greater than the draft of the design ship under the datum level for port management shall be secured. Provided, however, that this shall not apply to basins for use in fitting of ships and other basins provided for use in special anchorage or mooring of ships.
- ② Turning using thrusters

In determining the keel clearance in the performance verification of the basins with the use of special turning methods such as turning using thrusters by ferries shall set approximately 10% larger than the general maximum draft, taking consideration of the special turning method.

### (3) Calmness of Basins (usability)

Calmness of basins means the percentage of time when the basin concerned is in a condition in which ships can use the basin safely and smoothly. In verification of calmness in the performance verification of the basins, when necessary, the condition of waves which may hinder anchorage and mooring of ships and cargo handling in the basin shall be evaluated appropriately. In the verification of the calmness of the basin, the wave height in the basin can generally be used as an index; however, when necessary, appropriate consideration shall be given to the direction and period of waves affecting ship motion of the design ship while moored, and to the mooring method of the design ship.

### (4) Condition of Waves in Basin During Rough Weather (usability)

In the verification of the condition of waves during rough weather in the performance verification of the basins, the allowable range of the condition of waves during rough weather shall be set appropriately giving appropriate consideration to the height, direction, and period of waves in the objective basin, depending on the type and principal dimensions of the design ship and sheltering method.

# 3.2 Performance Verification

## [1] Location and Area

(1) Area of Basins Provided for Use in Anchorage or Mooring

- ① A single anchoring, see Fig. 3.2.1(a) and a dual anchoring, see Fig. 3.2.1(b), are the most popular mooring methods. A two anchoring method and a bow-and-stern anchoring method are also applied.
- <sup>(2)</sup> It is necessary to determine the chain length in such a way that the holding powers of the mooring anchor and the chain lying on the sea bottom can resist the actions exerted on the ship under such conditions as the type of ship, anchorage method, and meteorological and marine conditions. In general, the stability of the mooring system increases as the length of the anchor chain increases.
- ③ The area of anchorage area is defined as a circle having a radius equivalent to the sum of the ship's length and the horizontal distance between the bow and the center of rotation of the laying chain.
- (4) When the conditions required to calculate the length of the anchor chain are unknown, **Table 3.2.1** may normally be used as a reference.
- (5) Fig. 3.2.1(c) shows a single-buoy mooring, and Fig. 3.2.1(d) shows a dual-buoy mooring with the buoys located in the bow and stern of the ship. In this double-buoy mooring, it is necessary to locate the buoys in such a way that the line connecting the two buoys become parallel with the directions of tidal currents and winds. In the determination of the area of these types of buoy mooring, Table 3.2.2 may be used as a reference.
- (6) The width of basins between multiple parallel piers can be set referring to the values specified below.  $(L_{oa}: \text{ length overall of design ship})$ 
  - (a) When the number of piers on one side of a groin is approximately 3 or less:  $1.0 L_{oa}$
  - (b) When the number of berths on one side of a pier is approximately 4 or more: 1.5 L<sub>oa</sub> In cases where the back of the pier is to be used as a small craft basin, and when used by bunkering ships or barges, it is preferable to consider those use conditions.
- $\bigcirc$  In determining the anchoring method and scale in rough weather, References 1) 4) can be used as reference.



(c)Single buoy mooring

Fig. 3.2.1 Concept of Scale of Basin (Per Ship)

Table 3.2.1 Anchorage Basins

| Purpose of use            | Method of use    | Bottom soil or wind velocity | Diameter (m)           |  |
|---------------------------|------------------|------------------------------|------------------------|--|
| Offshore waiting or cargo | Single anchoring | Good anchoring               | $L_{oa}$ +6D           |  |
| handling                  |                  | Poor anchoring               | L <sub>oa</sub> +6D+30 |  |
|                           | Dual anchoring   | Good anchoring               | $L_{oa}$ +4.5D         |  |
|                           |                  | Poor anchoring               | $L_{oa}$ +4.5D+25      |  |

Note)  $L_{oa}$ : length overall of design ship (m), D: water depth (m)

### Table 3.2.2 Size of Basins for Buoy Mooring

| Method of use       | Area   |  |  |
|---------------------|--|--|--|
| Single buoy mooring | Circle with radius $(L_{oa}+25)$                           |  |  |
| Dual buoy mooring   | Rectangle with sides of $(L_{oa} + 50)$ (m) and $L_{oa}/2$ |  |  |

Note)  $L_{oa}$ : length overall of design ship (m)

- (3) Area of Basins Provided for Use in Maneuvering Mooring/unmooring basins
  - (1) In general, the mooring/unmooring water area and waterways can be planned at the same water area from the viewpoints of efficient layout and the use of the port facilities. Provided, however, that it is preferable to separate the two in cases where ship traffic is congested.
  - <sup>(2)</sup> When examining the size of a mooring/unmooring basin using tugboats, References 5) and 6) can be used as reference.

## [2] Water Depth

"Appropriate depth" in the water depth of basins shall be a water depth which secures keel clearance corresponding to the maximum draft in the expected maximum draft such as the full load draft below the datum level used in construction.

### [3] Harbor Calmness

- (1) In conducting the performance verifications in connection with harbor calmness, **Part II**, **Chapter 2**, **4.5 Concept of Harbor Calmness** can be used as reference.
- (2) Determination of the threshold wave height for cargo handling works in the performance verifications in connection with harbor calmness must be conducted properly based on the type and dimensions of the design ship, the features of cargo handling works, and the direction and period of the waves considered. In determining the critical wave height for cargo handling, Environmental Assessment Manual of Long Period Waves in Harbors<sup>7</sup>) can be used as reference. In determining the threshold wave height for cargo handling works in cases where there is no danger of cargo handling problems caused by ship motion of the design ship due to swell, or long period waves, the values shown in Table 3.2.3 can be used as reference.

Table 3.2.3 Reference Values of Threshold Wave Height for Cargo Handling Works not Affected by Swell, or Long Period Waves

| Ship type         | Threshold wave height for cargo handling works $(H_{1/3})$ |  |  |
|-------------------|--|--|--|
| Small craft       | 0.3m   |  |  |
| Medium/large ship | 0.5m   |  |  |
| Very large ship   | 0.7–1.5m   |  |  |

Note) Here, the small craft means ships of roughly  $\leq$ 500GT class which mainly use the small craft basin, the very large ship means ships of roughly  $\geq$ 50,000GT class which mainly use large-scale dolphins or offshore berths, and the medium/large ship means ships other than the small craft and the very large ships.

### References

- 1) Iwai, A.: New Edition Ship maneuvering theory, Kaibun-do Publishing, 1977
- 2) Honda, K.: Ship maneuvering theory (Enlarged 5th Edition), Seizan-do Publishing, 1978
- 3) Japan Association for Maritime Safety Edition: Maneuvering of Guideline for Very Large ships, Seizan-do Publishing, 1975
- 4) Suzuki, Y.: Study on the Design of Single Point Buoy Mooring, Technical Note of PHRI No.829,1996
- 5) Nakajima, T.: Maneuvering of tug boats- Technique-, Kaibun-so Publishing, 1979,
- 6) Yamagata, H.: Tug boats and their utilization method, Seizan-do Publishing, 1992
- 7) Coastal Development Institute of Technology (CDIT): Impact Evaluation Manual for long-period waves in ports, Coastal Technology Library No. 21, CDIT, 2004, 86p.

# 4 Small Craft Basin

# **Ministerial Ordinance**

Performance Requirements for Small Craft Basins

### Article 11

The performance requirements for small craft basins shall be such that the requirements specified by the Minister of Land, Infrastructure, Transport and Tourism are satisfied in light of geotechnical characteristics, waves, water currents, and wind conditions along with the usage conditions of the surrounding water areas, for securing the safe and smooth use by small crafts.

# Public Notice

Performance Criteria for Small Craft Basins

## Article 32

The requirement specified in item (2) of the preceding article shall be applied to the performance criteria for small craft basins with modification as necessary.

2 In addition to the provisions in the preceding item, the performance criteria for the small craft basins shall be such that the basins have the shape, area, and calmness necessary for the safe and smooth use of ships.

## [Technical Note]

As the scale of rest facilities, it is preferable to calculate the necessary extended length by adding an appropriate width clearance, mutual clearance between ships, based on consideration of the actual condition of use. In rest facilities used by small craft such as fishing boats, **Table 4.1** can be used as reference for the width clearance in case of mooring by longitudinal mooring.

| Table 4.1 | Relationship | between | Ship | Width | and | Width | Clearand | e |
|-----------|--------------|---------|------|-------|-----|-------|----------|---|
|           |              |         |      |       |     |       |          |   |

| Ship width | Width clearance |  |  |
|------------|-----------------|--|--|
| <2m        | 1.0-2.0m        |  |  |
| 2m to <4m  | 1.5–2.5m        |  |  |
| 4m or more | 2.0-3.0m        |  |  |