## 5. Analysis of Height Above Surface ($H_{st}$) by Ship Type – 1

A value which is a practical necessity when designing bridges over fairways, arranging the relationship with the obstacle assessment level (OAS) at maritime airports, etc. is the height from the sea surface to the highest point on a ship, in other words, the height above surface ($H_{st}$). Here, the height above surface ($H_{st}$) is calculated by the following equation.

$$H_{st} = H_{kt} - \beta d \quad (4)$$

where,

$H_{kt}$: Total height
$H_{st}$: Height above surface
$\beta$ : Draft factor
d: Full load draft

The total height ($H_{kt}$) and full load draft (d) of an assumed design ship are basically invariable. However, the actual draft of a ship changes during navigation depending on the cargo loading condition and other factors, and as a result, the height above the sea surface ($H_{st}$) will also vary. Because the height above the surface ($H_{st}$) obtained here by subtracting the full load draft (d) from the total height ($H_{kt}$) is only the minimum value, the height of bridge girders and OAS at maritime airports will be evaluated in way which invites risk if studied using this value.

Therefore, a parameter which termed the “draft factor” ( $\beta$ ) is introduced as an index of the draft condition, which varies depending on cargo loading condition, etc. That is, the draft factor ( $\beta$ ) will be the maximum value, 1.0, when the design ship is in a fully-loaded condition, and will be less than 1.0 under conditions other than full load. Naturally, as shown in **Figure29**, the height above surface ($H_{st}$) will increase as $\beta$ decreases, in other words, as the ship’s draft becomes shallower, and may pose a danger to structures of interest such as bridges.

The following **Table12-19** show the results when height above surface ($H_{st}$) was calculated by ship type for cases assuming the total height ($H_{kt}$) shown in **Ch. 4**, the full load draft (d) shown in the results of previous research,[12] and draft factors ( $\beta$ ) from 1.0 to 0.8 (in increments of 0.05) using coverage rates of 50%, 75%, and 95%. However, due to the large effect of ballast conditions in cargo ships and container ships, calculations were made assuming $\beta$ in the range of 1.0 to 0.5 (increments of 0.1) limited to these two types of ships.

When setting concrete values for $\beta$, appropriate setting is necessary based on the points for attention in the analysis method described in section **3.3**, the actual and planned cargo loading conditions, the bow trim and stern trim of the ship while sailing, and other relevant factors.

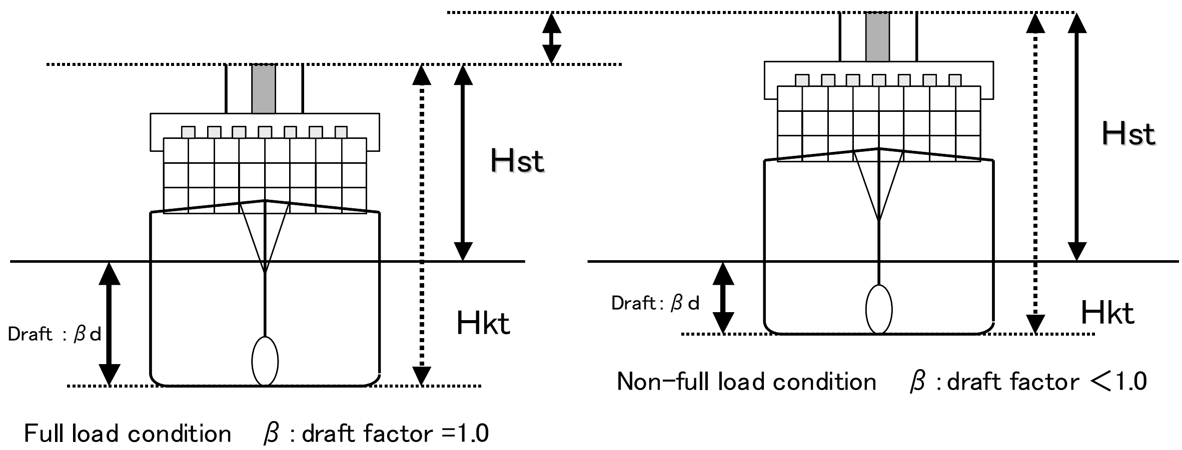



**Figure29** Height above surface ($H_{st}$) and draft factor

**Table12** Cargo ship: Height above surface ($H_{st}$) corresponding to draft factor ( $\beta$ )

| Coverage rate | DWT (t) | $H_{kt}$ (m) | d (m) | $H_{st}=H_{kt}-\beta d$ (m) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | $\beta$=1.0 | $\beta$=0.9 | $\beta$=0.8 | $\beta$=0.7 | $\beta$=0.6 | $\beta$=0.5 |
| 50% | 1,000 | 20.2 | 3.4 | 16.8 | 17.1 | 17.5 | 17.8 | 18.1 | 18.5 |
| | 2,000 | 24.8 | 4.3 | 20.5 | 20.9 | 21.3 | 21.8 | 22.2 | 22.6 |
| | 3,000 | 27.5 | 4.9 | 22.6 | 23.0 | 23.5 | 24.0 | 24.5 | 25.0 |
| | 5,000 | 30.8 | 5.8 | 25.0 | 25.6 | 26.2 | 26.8 | 27.3 | 27.9 |
| | 10,000 | 35.4 | 7.3 | 28.1 | 28.8 | 29.6 | 30.3 | 31.0 | 31.8 |
| | 12,000 | 36.6 | 7.8 | 28.8 | 29.6 | 30.4 | 31.2 | 31.9 | 32.7 |
| | 18,000 | 39.3 | 8.9 | 30.4 | 31.3 | 32.2 | 33.1 | 34.0 | 34.8 |
| | 30,000 | 42.7 | 10.0 | 32.7 | 33.7 | 34.7 | 35.7 | 36.7 | 37.7 |
| | 40,000 | 44.6 | 11.0 | 33.6 | 34.7 | 35.8 | 36.9 | 38.0 | 39.1 |
| | 55,000 | 46.7 | 12.2 | 34.5 | 35.7 | 36.9 | 38.1 | 39.4 | 40.6 |
| | 70,000 | 48.3 | 13.2 | 35.1 | 36.4 | 37.7 | 39.0 | 40.4 | 41.7 |
| | 90,000 | 49.9 | 14.3 | 35.6 | 37.1 | 38.5 | 39.9 | 41.4 | 42.8 |
| | 120,000 | 51.8 | 15.7 | 36.1 | 37.7 | 39.3 | 40.9 | 42.4 | 44.0 |
| | 150,000 | 53.3 | 16.9 | 36.4 | 38.1 | 39.8 | 41.5 | 43.2 | 44.9 |
| 75% | 1,000 | 22.3 | 3.8 | 18.5 | 18.9 | 19.3 | 19.7 | 20.0 | 20.4 |
| | 2,000 | 26.9 | 4.8 | 22.1 | 22.6 | 23.1 | 23.5 | 24.0 | 24.5 |
| | 3,000 | 29.6 | 5.4 | 24.2 | 24.7 | 25.3 | 25.8 | 26.3 | 26.9 |
| | 5,000 | 33.0 | 6.4 | 26.6 | 27.2 | 27.8 | 28.5 | 29.1 | 29.8 |
| | 10,000 | 37.5 | 8.1 | 29.4 | 30.2 | 31.1 | 31.9 | 32.7 | 33.5 |
| | 12,000 | 38.7 | 8.6 | 30.1 | 31.0 | 31.9 | 32.7 | 33.6 | 34.4 |
| | 18,000 | 41.4 | 9.8 | 31.6 | 32.6 | 33.6 | 34.6 | 35.5 | 36.5 |
| | 30,000 | 44.8 | 10.5 | 34.3 | 35.3 | 36.4 | 37.4 | 38.5 | 39.5 |
| | 40,000 | 46.7 | 11.5 | 35.2 | 36.4 | 37.5 | 38.7 | 39.8 | 41.0 |
| | 55,000 | 48.8 | 12.8 | 36.0 | 37.3 | 38.6 | 39.8 | 41.1 | 42.4 |
| | 70,000 | 50.4 | 13.8 | 36.6 | 38.0 | 39.4 | 40.7 | 42.1 | 43.5 |
| | 90,000 | 52.1 | 15.0 | 37.1 | 38.6 | 40.1 | 41.6 | 43.1 | 44.6 |
| | 120,000 | 54.0 | 16.5 | 37.5 | 39.1 | 40.8 | 42.4 | 44.1 | 45.7 |
| | 150,000 | 55.4 | 17.7 | 37.7 | 39.5 | 41.3 | 43.0 | 44.8 | 46.6 |
| 95% | 1,000 | 25.4 | 4.4 | 21.0 | 21.4 | 21.9 | 22.3 | 22.7 | 23.2 |
| | 2,000 | 30.0 | 5.5 | 24.5 | 25.0 | 25.6 | 26.1 | 26.7 | 27.2 |
| | 3,000 | 32.6 | 6.3 | 26.3 | 27.0 | 27.6 | 28.2 | 28.9 | 29.5 |
| | 5,000 | 36.0 | 7.4 | 28.6 | 29.4 | 30.1 | 30.8 | 31.6 | 32.3 |
| | 10,000 | 40.6 | 9.3 | 31.3 | 32.2 | 33.2 | 34.1 | 35.0 | 35.9 |
| | 12,000 | 41.8 | 9.9 | 31.9 | 32.9 | 33.9 | 34.9 | 35.9 | 36.9 |
| | 18,000 | 44.5 | 11.3 | 33.2 | 34.3 | 35.4 | 36.6 | 37.7 | 38.8 |
| | 30,000 | 47.9 | 11.2 | 36.7 | 37.8 | 38.9 | 40.0 | 41.1 | 42.3 |
| | 40,000 | 49.8 | 12.3 | 37.5 | 38.7 | 39.9 | 41.2 | 42.4 | 43.6 |
| | 55,000 | 51.9 | 13.7 | 38.2 | 39.5 | 40.9 | 42.3 | 43.6 | 45.0 |
| | 70,000 | 53.5 | 14.8 | 38.7 | 40.1 | 41.6 | 43.1 | 44.6 | 46.1 |
| | 90,000 | 55.1 | 16.0 | 39.1 | 40.7 | 42.3 | 43.9 | 45.5 | 47.1 |
| | 120,000 | 57.0 | 17.6 | 39.4 | 41.2 | 42.9 | 44.7 | 46.5 | 48.2 |
| | 150,000 | 58.5 | 18.9 | 39.6 | 41.5 | 43.4 | 45.3 | 47.2 | 49.0 |

**Table13** Container ship: Height above surface ($H_{st}$) corresponding to draft factor ( $\beta$ )

| Coverage rate | DWT (t) | $H_{kt}$ (m) | d (m) | $H_{st}=H_{kt}-\beta d$ (m) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | $\beta$=1.0 | $\beta$=0.95 | $\beta$=0.9 | $\beta$=0.85 | $\beta$=0.8 |
| 50% | 10,000 | 40.5 | 7.6 | 32.9 | 33.3 | 33.7 | 34.1 | 34.5 |
| | 20,000 | 46.6 | 9.5 | 37.1 | 37.5 | 38.0 | 38.5 | 39.0 |
| | 30,000 | 50.1 | 10.8 | 39.3 | 39.8 | 40.4 | 40.9 | 41.4 |
| | 40,000 | 52.6 | 11.7 | 40.9 | 41.5 | 42.0 | 42.6 | 43.2 |
| | 50,000 | 54.5 | 12.3 | 42.2 | 42.8 | 43.4 | 44.1 | 44.7 |
| | 60,000 | 56.1 | 13.1 | 43.0 | 43.6 | 44.3 | 45.0 | 45.6 |
| | 100,000 | 60.5 | 14.6 | 46.0 | 46.7 | 47.4 | 48.2 | 48.9 |
| 75% | 10,000 | 42.5 | 7.9 | 34.6 | 35.0 | 35.4 | 35.8 | 36.2 |
| | 20,000 | 48.6 | 9.9 | 38.7 | 39.2 | 39.7 | 40.2 | 40.6 |
| | 30,000 | 52.1 | 11.2 | 40.9 | 41.4 | 42.0 | 42.6 | 43.1 |
| | 40,000 | 54.6 | 12.1 | 42.5 | 43.1 | 43.7 | 44.3 | 44.9 |
| | 50,000 | 56.5 | 12.7 | 43.9 | 44.5 | 45.1 | 45.8 | 46.4 |
| | 60,000 | 58.1 | 13.4 | 44.7 | 45.4 | 46.1 | 46.8 | 47.4 |
| | 100,000 | 62.5 | 14.7 | 47.9 | 48.6 | 49.3 | 50.1 | 50.8 |
| 95% | 10,000 | 45.4 | 8.3 | 37.1 | 37.6 | 38.0 | 38.4 | 38.8 |
| | 20,000 | 51.5 | 10.4 | 41.1 | 41.6 | 42.1 | 42.6 | 43.1 |
| | 30,000 | 55.0 | 11.9 | 43.1 | 43.7 | 44.3 | 44.9 | 45.5 |
| | 40,000 | 57.5 | 12.7 | 44.8 | 45.5 | 46.1 | 46.7 | 47.4 |
| | 50,000 | 59.4 | 13.2 | 46.3 | 46.9 | 47.6 | 48.2 | 48.9 |
| | 60,000 | 61.0 | 13.7 | 47.3 | 48.0 | 48.7 | 49.3 | 50.0 |
| | 100,000 | 65.4 | 14.9 | 50.6 | 51.3 | 52.1 | 52.8 | 53.5 |

**Table14** oil tanker: Height above surface ($H_{st}$) corresponding to draft factor ( $\beta$ )

| Coverage rate | DWT (t) | $H_{kt}$ (m) | d (m) | $H_{st}=H_{kt}-\beta d$ (m) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | $\beta$=1.0 | $\beta$=0.9 | $\beta$=0.8 | $\beta$=0.7 | $\beta$=0.6 | $\beta$=0.5 |
| 50% | 50,000 | 39.1 | 10.9 | 28.2 | 29.3 | 30.4 | 31.5 | 32.6 | 33.7 |
| | 70,000 | 43.9 | 12.3 | 31.6 | 32.9 | 34.1 | 35.3 | 36.5 | 37.8 |
| | 90,000 | 47.5 | 13.5 | 34.0 | 35.4 | 36.7 | 38.1 | 39.4 | 40.8 |
| | 100,000 | 49.0 | 14.0 | 35.0 | 36.4 | 37.8 | 39.2 | 40.6 | 42.0 |
| | 150,000 | 54.8 | 16.4 | 38.4 | 40.0 | 41.7 | 43.3 | 44.9 | 46.6 |
| | 300,000 | 64.7 | 21.3 | 43.4 | 45.5 | 47.6 | 49.8 | 51.9 | 54.0 |
| 75% | 50,000 | 41.1 | 12.0 | 29.1 | 30.3 | 31.5 | 32.7 | 33.9 | 35.1 |
| | 70,000 | 45.9 | 12.9 | 33.0 | 34.3 | 35.6 | 36.9 | 38.2 | 39.5 |
| | 90,000 | 49.5 | 14.2 | 35.3 | 36.7 | 38.2 | 39.6 | 41.0 | 42.4 |
| | 100,000 | 51.0 | 14.8 | 36.2 | 37.7 | 39.2 | 40.7 | 42.1 | 43.6 |
| | 150,000 | 56.8 | 17.2 | 39.6 | 41.3 | 43.0 | 44.8 | 46.5 | 48.2 |
| | 300,000 | 66.7 | 22.4 | 44.3 | 46.5 | 48.8 | 51.0 | 53.2 | 55.5 |
| 95% | 50,000 | 44.1 | 13.8 | 30.3 | 31.6 | 33.0 | 34.4 | 35.8 | 37.2 |
| | 70,000 | 48.9 | 13.8 | 35.1 | 36.4 | 37.8 | 39.2 | 40.6 | 42.0 |
| | 90,000 | 52.4 | 15.2 | 37.2 | 38.8 | 40.3 | 41.8 | 43.3 | 44.8 |
| | 100,000 | 53.9 | 15.8 | 38.1 | 39.7 | 41.3 | 42.9 | 44.5 | 46.0 |
| | 150,000 | 59.7 | 18.5 | 41.2 | 43.1 | 44.9 | 46.8 | 48.6 | 50.5 |
| | 300,000 | 69.6 | 24.0 | 45.6 | 48.0 | 50.4 | 52.8 | 55.2 | 57.6 |

**Table15** RORO ship: Height above surface ($H_{st}$) corresponding to draft factor ( $\beta$ )

| Coverage rate | GT (t) | $H_{kt}$ (m) | d (m) | $H_{st}=H_{kt}-\beta d$ (m) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | $\beta$=1.0 | $\beta$=0.95 | $\beta$=0.9 | $\beta$=0.85 | $\beta$=0.8 |
| 50% | 3,000 | 28.5 | 3.9 | 24.6 | 24.8 | 25.0 | 25.2 | 25.4 |
| | 5,000 | 32.4 | 4.7 | 27.7 | 28.0 | 28.2 | 28.4 | 28.7 |
| | 10,000 | 37.7 | 5.9 | 31.8 | 32.1 | 32.4 | 32.7 | 33.0 |
| | 20,000 | 42.9 | 7.4 | 35.5 | 35.9 | 36.3 | 36.7 | 37.0 |
| | 40,000 | 48.2 | 9.5 | 38.7 | 39.2 | 39.7 | 40.1 | 40.6 |
| | 60,000 | 51.3 | 9.5 | 41.8 | 42.3 | 42.7 | 43.2 | 43.7 |
| 75% | 3,000 | 31.7 | 4.6 | 27.1 | 27.4 | 27.6 | 27.8 | 28.1 |
| | 5,000 | 35.6 | 5.5 | 30.1 | 30.4 | 30.7 | 30.9 | 31.2 |
| | 10,000 | 40.9 | 6.9 | 34.0 | 34.3 | 34.7 | 35.0 | 35.4 |
| | 20,000 | 46.1 | 8.7 | 37.4 | 37.9 | 38.3 | 38.7 | 39.2 |
| | 40,000 | 51.4 | 9.7 | 41.7 | 42.2 | 42.7 | 43.1 | 43.6 |
| | 60,000 | 54.5 | 9.7 | 44.8 | 45.3 | 45.7 | 46.2 | 46.7 |
| 95% | 3,000 | 36.3 | 5.9 | 30.4 | 30.7 | 31.0 | 31.3 | 31.6 |
| | 5,000 | 40.2 | 7.0 | 33.2 | 33.6 | 33.9 | 34.3 | 34.6 |
| | 10,000 | 45.5 | 8.8 | 36.7 | 37.1 | 37.6 | 38.0 | 38.4 |
| | 20,000 | 50.7 | 11.0 | 39.7 | 40.3 | 40.8 | 41.4 | 41.9 |
| | 40,000 | 56.0 | 9.9 | 46.1 | 46.6 | 47.1 | 47.6 | 48.1 |
| | 60,000 | 59.1 | 9.9 | 49.2 | 49.7 | 50.2 | 50.7 | 51.1 |

**Table16** PCC: Height above surface ($H_{st}$) corresponding to draft factor ( $\beta$ )

| Coverage rate | GT (t) | $H_{kt}$ (m) | d (m) | $H_{st}=H_{kt}-\beta d$ (m) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | $\beta$=1.0 | $\beta$=0.95 | $\beta$=0.9 | $\beta$=0.85 | $\beta$=0.8 |
| 50% | 3,000 | 26.9 | 4.2 | 22.7 | 23.0 | 23.2 | 23.4 | 23.6 |
| | 5,000 | 30.8 | 4.8 | 26.0 | 26.2 | 26.5 | 26.7 | 27.0 |
| | 12,000 | 37.4 | 6.1 | 31.3 | 31.6 | 31.9 | 32.3 | 32.6 |
| | 20,000 | 41.3 | 7.1 | 34.2 | 34.6 | 34.9 | 35.3 | 35.6 |
| | 30,000 | 44.4 | 7.9 | 36.5 | 36.9 | 37.3 | 37.7 | 38.1 |
| | 40,000 | 46.5 | 8.8 | 37.7 | 38.2 | 38.6 | 39.1 | 39.5 |
| | 60,000 | 49.6 | 9.9 | 39.7 | 40.2 | 40.7 | 41.2 | 41.7 |
| 75% | 3,000 | 29.6 | 4.7 | 24.9 | 25.2 | 25.4 | 25.6 | 25.9 |
| | 5,000 | 33.5 | 5.4 | 28.1 | 28.4 | 28.6 | 28.9 | 29.2 |
| | 12,000 | 40.1 | 6.8 | 33.3 | 33.7 | 34.0 | 34.3 | 34.7 |
| | 20,000 | 44.0 | 7.9 | 36.1 | 36.5 | 36.9 | 37.3 | 37.7 |
| | 30,000 | 47.0 | 8.8 | 38.2 | 38.7 | 39.1 | 39.6 | 40.0 |
| | 40,000 | 49.2 | 9.3 | 39.9 | 40.4 | 40.9 | 41.3 | 41.8 |
| | 60,000 | 52.3 | 10.4 | 41.9 | 42.4 | 42.9 | 43.4 | 44.0 |
| 95% | 3,000 | 33.5 | 5.5 | 28.0 | 28.3 | 28.5 | 28.8 | 29.1 |
| | 5,000 | 37.3 | 6.4 | 30.9 | 31.3 | 31.6 | 31.9 | 32.2 |
| | 12,000 | 44.0 | 8.1 | 35.9 | 36.3 | 36.7 | 37.1 | 37.5 |
| | 20,000 | 47.8 | 9.3 | 38.5 | 39.0 | 39.5 | 39.9 | 40.4 |
| | 30,000 | 50.9 | 10.4 | 40.5 | 41.0 | 41.5 | 42.1 | 42.6 |
| | 40,000 | 53.1 | 10.0 | 43.1 | 43.6 | 44.1 | 44.6 | 45.1 |
| | 60,000 | 56.2 | 11.2 | 45.0 | 45.5 | 46.1 | 46.6 | 47.2 |

**Table17** LPG ship: Height above surface ($H_{st}$) corresponding to draft factor ($\beta$)

| Coverage rate | GT (t) | $H_{kt}$ (m) | d (m) | $H_{st}=H_{kt}-\beta d$ (m) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | $\beta$=1.0 | $\beta$=0.95 | $\beta$=0.9 | $\beta$=0.85 | $\beta$=0.8 |
| 50% | 3,000 | 29.8 | 5.7 | 24.1 | 24.4 | 24.7 | 25.0 | 25.2 |
| | 5,000 | 33.5 | 6.6 | 26.9 | 27.2 | 27.5 | 27.8 | 28.2 |
| | 10,000 | 38.4 | 8.0 | 30.4 | 30.8 | 31.2 | 31.6 | 32.0 |
| | 20,000 | 43.4 | 9.7 | 33.7 | 34.1 | 34.6 | 35.1 | 35.6 |
| | 30,000 | 46.3 | 10.9 | 35.4 | 35.9 | 36.4 | 37.0 | 37.5 |
| | 40,000 | 48.3 | 11.9 | 36.4 | 37.0 | 37.6 | 38.2 | 38.8 |
| | 50,000 | 49.9 | 12.6 | 37.3 | 37.9 | 38.6 | 39.2 | 39.8 |
| 75% | 3,000 | 31.2 | 6.3 | 24.9 | 25.3 | 25.6 | 25.9 | 26.2 |
| | 5,000 | 34.9 | 7.3 | 27.6 | 28.0 | 28.3 | 28.7 | 29.0 |
| | 10,000 | 39.8 | 8.9 | 30.9 | 31.4 | 31.8 | 32.3 | 32.7 |
| | 20,000 | 44.8 | 10.8 | 34.0 | 34.5 | 35.1 | 35.6 | 36.2 |
| | 30,000 | 47.7 | 12.1 | 35.6 | 36.2 | 36.8 | 37.4 | 38.0 |
| | 40,000 | 49.8 | 13.1 | 36.7 | 37.3 | 38.0 | 38.6 | 39.3 |
| | 60,000 | 51.3 | 14.0 | 37.3 | 38.0 | 38.7 | 39.4 | 40.1 |
| 95% | 3,000 | 33.3 | 7.3 | 26.0 | 26.4 | 26.7 | 27.1 | 27.5 |
| | 5,000 | 37.0 | 8.4 | 28.6 | 29.0 | 29.4 | 29.8 | 30.2 |
| | 10,000 | 41.9 | 10.3 | 31.6 | 32.1 | 32.6 | 33.2 | 33.7 |
| | 20,000 | 46.9 | 12.5 | 34.4 | 35.0 | 35.6 | 36.2 | 36.9 |
| | 30,000 | 49.8 | 14.0 | 35.8 | 36.5 | 37.2 | 37.9 | 38.6 |
| | 40,000 | 51.8 | 15.2 | 36.6 | 37.4 | 38.1 | 38.9 | 39.7 |
| | 60,000 | 53.4 | 16.2 | 37.2 | 38.0 | 38.8 | 39.6 | 40.5 |

**Table18** LNG ship: Height above surface ($H_{st}$) corresponding to draft factor ($\beta$)

| Coverage rate | GT (t) | $H_{kt}$ (m) | d (m) | $H_{st}=H_{kt}-\beta d$ (m) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | $\beta$=1.0 | $\beta$=0.95 | $\beta$=0.9 | $\beta$=0.85 | $\beta$=0.8 |
| 50% | 80,000 | 54.0 | 11.0 | 43.0 | 43.5 | 44.1 | 44.6 | 45.2 |
| | 100,000 | 60.9 | 11.6 | 49.3 | 49.9 | 50.5 | 51.1 | 51.7 |
| | 120,000 | 66.6 | 12.1 | 54.5 | 55.1 | 55.7 | 56.3 | 56.9 |
| 75% | 80,000 | 58.3 | 11.5 | 46.8 | 47.4 | 48.0 | 48.5 | 49.1 |
| | 100,000 | 65.2 | 12.1 | 53.1 | 53.8 | 54.4 | 55.0 | 55.6 |
| | 120,000 | 70.9 | 12.6 | 58.3 | 58.9 | 59.6 | 60.2 | 60.8 |
| 95% | 80,000 | 64.5 | 12.3 | 52.2 | 52.8 | 53.5 | 54.1 | 54.7 |
| | 100,000 | 71.5 | 13.0 | 58.5 | 59.1 | 59.8 | 60.4 | 61.1 |
| | 120,000 | 77.1 | 13.5 | 63.6 | 64.3 | 65.0 | 65.7 | 66.3 |

**Table19** Passenger ship: Height above surface ($H_{st}$) corresponding to draft factor ( $\beta$ )

| Coverage rate | GT (t) | $H_{kt}$ (m) | d (m) | $H_{st}=H_{kt}-\beta d$ (m) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | $\beta$=1.0 | $\beta$=0.95 | $\beta$=0.9 | $\beta$=0.85 | $\beta$=0.8 |
| 50% | 3,000 | 28.2 | 3.4 | 24.8 | 25.0 | 25.1 | 25.3 | 25.5 |
| | 5,000 | 32.7 | 4.0 | 28.7 | 28.9 | 29.1 | 29.3 | 29.5 |
| | 10,000 | 38.8 | 5.0 | 33.8 | 34.1 | 34.3 | 34.6 | 34.8 |
| | 20,000 | 45.0 | 7.0 | 38.0 | 38.3 | 38.7 | 39.0 | 39.4 |
| | 30,000 | 48.6 | 7.0 | 41.6 | 41.9 | 42.3 | 42.6 | 43.0 |
| | 50,000 | 53.1 | 7.0 | 46.1 | 46.4 | 46.8 | 47.1 | 47.5 |
| | 70,000 | 56.1 | 8.0 | 48.1 | 48.5 | 48.9 | 49.3 | 49.7 |
| | 100,000 | 59.2 | 8.0 | 51.2 | 51.6 | 52.0 | 52.4 | 52.8 |
| 75% | 3,000 | 32.4 | 4.3 | 28.1 | 28.3 | 28.5 | 28.7 | 29.0 |
| | 5,000 | 36.9 | 5.0 | 31.9 | 32.2 | 32.4 | 32.7 | 32.9 |
| | 10,000 | 43.1 | 6.4 | 36.7 | 37.0 | 37.3 | 37.6 | 37.9 |
| | 20,000 | 49.2 | 7.8 | 41.4 | 41.8 | 42.2 | 42.6 | 42.9 |
| | 30,000 | 52.8 | 7.8 | 45.0 | 45.4 | 45.8 | 46.1 | 46.5 |
| | 50,000 | 57.3 | 7.8 | 49.5 | 49.9 | 50.3 | 50.7 | 51.1 |
| | 70,000 | 60.3 | 8.1 | 52.2 | 52.6 | 53.0 | 53.4 | 53.8 |
| | 100,000 | 63.4 | 8.1 | 55.3 | 55.7 | 56.1 | 56.5 | 56.9 |
| 95% | 3,000 | 38.5 | 6.1 | 32.4 | 32.7 | 33.0 | 33.3 | 33.6 |
| | 5,000 | 43.0 | 7.2 | 35.8 | 36.1 | 36.5 | 36.9 | 37.2 |
| | 10,000 | 49.1 | 9.1 | 40.0 | 40.5 | 40.9 | 41.4 | 41.8 |
| | 20,000 | 55.2 | 8.9 | 46.3 | 46.8 | 47.2 | 47.7 | 48.1 |
| | 30,000 | 58.8 | 8.9 | 49.9 | 50.4 | 50.8 | 51.3 | 51.7 |
| | 50,000 | 63.4 | 8.9 | 54.5 | 54.9 | 55.3 | 55.8 | 56.2 |
| | 70,000 | 66.3 | 8.3 | 58.0 | 58.4 | 58.9 | 59.3 | 59.7 |
| | 100,000 | 69.5 | 8.3 | 61.2 | 61.6 | 62.0 | 62.4 | 62.8 |

## 6. Analysis of Height Above Surface ($H_{st}$) by Ship Type – 2

**Chapter 5** presented a procedure for estimating height above surface ($H_{st}$) using the values of total height ($H_{kt}$) and full load draft (d), which were analyzed separately. Here, in contrast, the height above surface (Hst) in a fully-loaded condition is first calculated directly from the total height ($H_{kt}$) and full load draft (d) of individual ships, and the height above surface ($H_{st}$) is then estimated directly by applying the statistical analysis method proposed in **Ch. 3** to the data obtained in the first step.

Therefore, unification of the fundamental data was performed by IMO No. for the LRF Data, which comprises the data on total height ($K_{kt}$) and LMIU Data, which comprises the data on full load draft (d). The numbers of ships for which data are available on total height ($K_{kt}$) and full load draft (d) as the objects of this analysis are shown by ship type in **Table20**. Based on this fundamental data, fundamental data on $H_{st}$ ( = $H_{kt}$ – d) were constructed independently.

Considering the points regarding the analysis procedure discussed in section **3.3** and the fact that the $H_{st}$ given here is a minimum value, when this method is used practically in the design of bridges over fairways and setting of the OAS for maritime airports, a safety factor $\gamma$ ($\geqq$1.0) based on the ratio of the full load draft of the design ship and the actual draft during navigation must be applied. The result of the simple $H_{st}$ (= $H_{kt}$ – d) here is the same concept as the results when the draft factor ( $\beta$ ) discussed in **Ch. 5** equals 1.0. In order to compare the two, a comparison with the results when $\beta$ = 1.0 is shown on the *x*-axis. Although inconsistencies can be seen in large-scale and small-scale ships with some ship types, rough agreement can be confirmed.

The following presents the results of an analysis by ship type in the same manner as in **Ch. 4**.

**Table20** Number of ships for which total height ($H_{kt}$) and full load draft (d) data are available

| Type | N of ship |
|---|---|
| Cargo Ship | 568 |
| Container Ship | 304 |
| Oil Tanker | 1,140 |
| RORO Ship | 310 |
| PCC | 84 |
| LPG Ship | 357 |
| LNG Ship | 73 |
| Passenger Ship | 73 |

### 6.1 Cargo ship

A distribution diagram of the height above surface ($H_{st}$) data for cargo ships is shown in **Figure1**. Next, the results of a semilog regression analysis to exclude the data for the region exceeding ±2σ are shown in **Figure30–2**. The results of a regression analysis obtained by applying the semilog regression analysis method to the data being analyzed after excluding the region exceeding ±2 σ are shown in **Figure30–3**. The results when the log expressions on the *x*-axis in **Figure30–3** are expressed as antilogs are shown in **Figure30–4**. These **Figure30–3, –4** show the results of regression equations for coverage rates of 50%, 75%, and 95%, and **Figure30–3** also shows the value of the coefficient of determination (0.721) and the coefficients of the regression equation for each coverage rate. From this **Figure 30–4**, it can be concluded that meaningful regression equations for cargo ships have been obtained.

Accordingly, based on the regression equations obtained here, the values for total height ($H_{kt}$) were calculated for coverage rates of 50%, 75%, and 95%, corresponding to ship classes set in the same manner as in the "Technical Standards." The results are shown in **Table21**.

The results in this **Table21** show the same concept as the results when the draft factor ( $\beta$ ) in **Ch. 5** equals 1.0. In order to compare the two, **Figure30-5** shows the results when the draft factor ( $\beta$ ) = 1.0 on the *x*-axis and the results in **Table21** on the *y*-axis. To clarify the distinction between the two, in contrast to the expression $H_{kt}$ – 1.0d on the *x*-axis, the *y*-axis shows ($H_{kt}$ – d).

**Table21** Results of analysis of height above surface ($H_{st}$) (cargo ship)

| Dead Weight Tonnage (t) | 50% (m) | 75% (m) | 95% (m) |
|---|---|---|---|
| 1,000 | 18.8 | 20.9 | 23.9 |
| 2,000 | 21.4 | 23.5 | 26.6 |
| 3,000 | 22.9 | 25.0 | 28.1 |
| 5,000 | 24.8 | 27.0 | 30.0 |
| 10,000 | 27.5 | 29.6 | 32.6 |
| 12,000 | 28.1 | 30.3 | 33.3 |
| 18,000 | 29.7 | 31.8 | 34.9 |
| 30,000 | 31.6 | 33.7 | 36.8 |
| 40,000 | 32.7 | 34.8 | 37.9 |
| 55,000 | 33.9 | 36.0 | 39.1 |
| 70,000 | 34.8 | 36.9 | 40.0 |
| 90,000 | 35.8 | 37.9 | 40.9 |
| 120,000 | 36.8 | 39.0 | 42.0 |
| 150,000 | 37.7 | 39.8 | 42.9 |

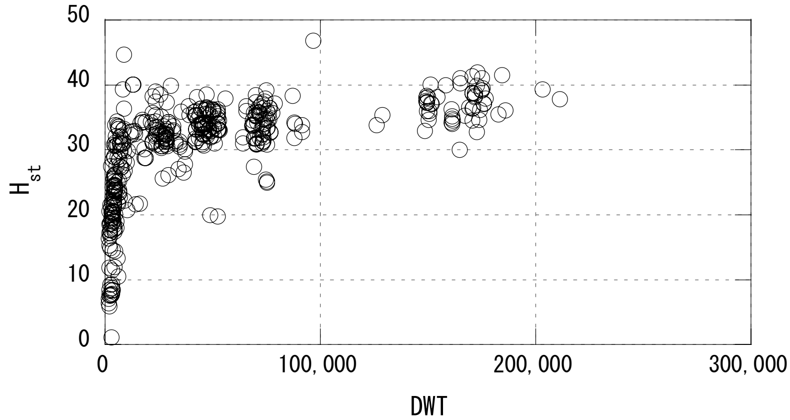



**Figure30–1** Distribution of $H_{st}$ data (cargo ship)

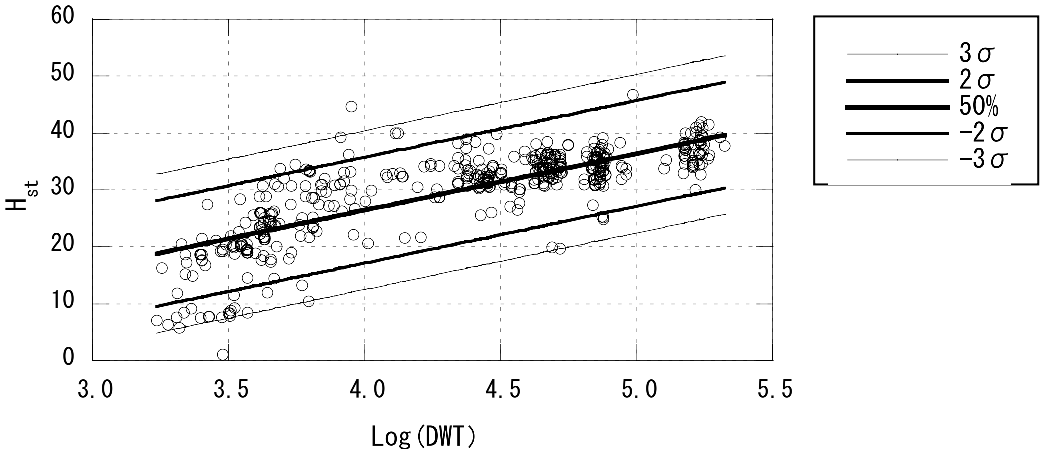
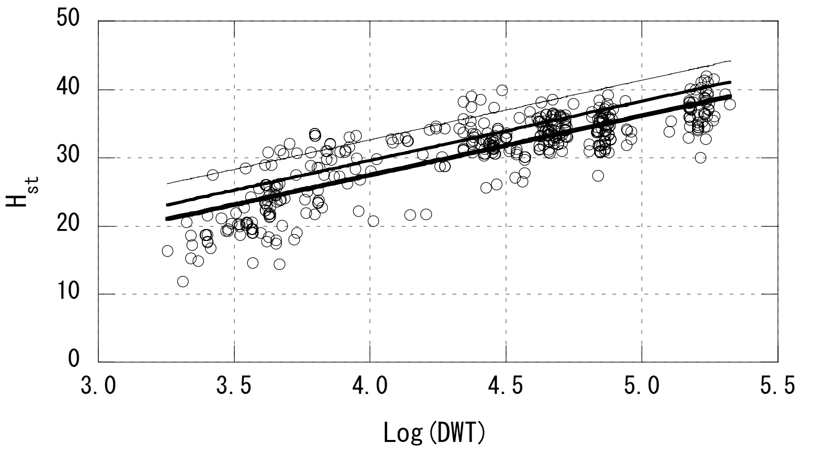



**Figure30–2** $H_{st}$ – semilog regression analysis (cargo ship)




Y=alogX+b

( $R^2$= 0.721 , σ= 3.149 )

| | 50% | 75% | 95% |
|---|---|---|---|
| a | 8.70 | 8.70 | 8.70 |
| b | -7.33 | -5.21 | -2.15 |

**Figure30–3** Results of $H_{st}$ – semilog regression analysis ①: After exclusion of data exceeding ±2σ (cargo ship)

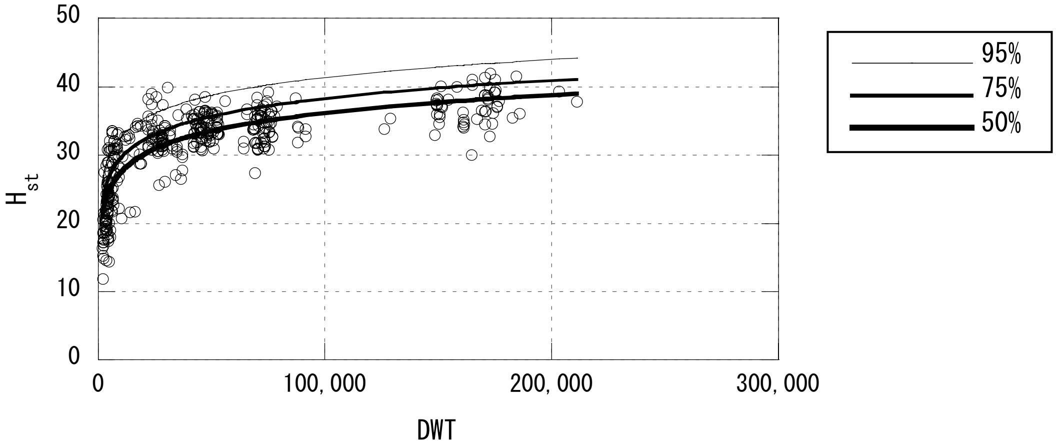



**Figure30–4** Results of $H_{st}$ – semilog regression analysis ②: After exclusion of data exceeding ±2σ (cargo ship)

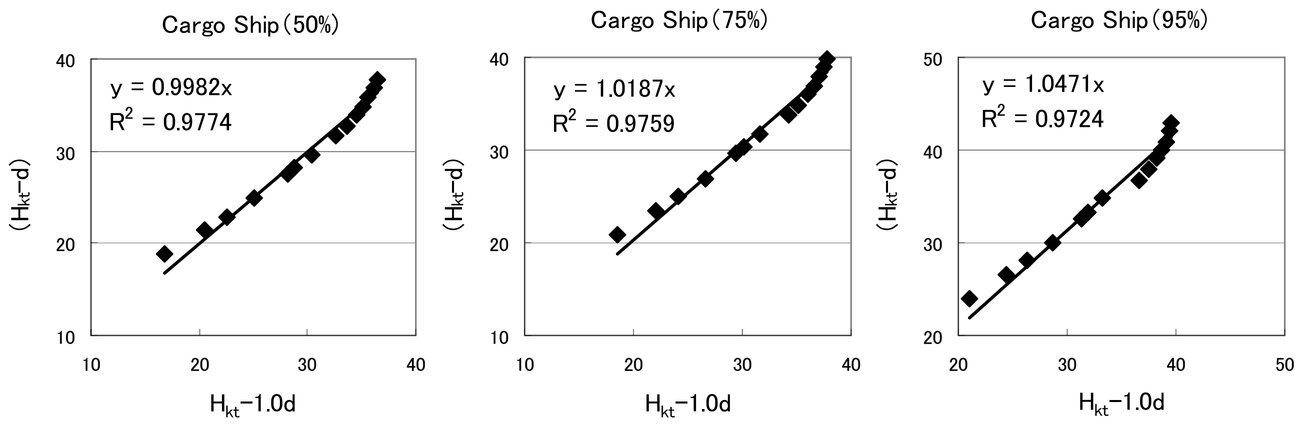



**Figure30–5** Comparison with draft factor ( $\beta$ ) = 1.0

**6.2 Container ship**

A distribution diagram of the height above surface ($H_{st}$) data for container ships is shown in **Figure31–1**. Next, the results of a semilog regression analysis to exclude the data for the region exceeding ±2σ are shown in **Figure31–2**. The results of a regression analysis obtained by applying the semilog regression analysis method to the data being analyzed after excluding the region exceeding ±2 σ are shown in **Figure31–3**. The results when the log expressions on the *x*-axis in **Figure 31–3** are expressed as antilogs are shown in **Figure31–4**. These **Figure31–3, –4** show the results of regression equations for coverage rates of 50%, 75%, and 95%, and **Figure31–3** also shows the value of the coefficient of determination (0.724) and the coefficients of the regression equation for each coverage rate. From this **Figure31–4**, it can be concluded that meaningful regression equations for container ships have been obtained.

Accordingly, based on the regression equations obtained here, the values for total height ($H_{kt}$) were calculated for coverage rates of 50%, 75%, and 95%, corresponding to ship classes set in the same manner as in the "Technical Standards." The results are shown in **Table22**.

The results in this **Table22** show the same concept as the results when the draft factor ( $\beta$ ) in **Ch. 5** equals 1.0. In order to compare the two, **Figure31-5** shows the results when the draft factor ( $\beta$ ) = 1.0 on the *x*-axis and the results in **Table22** on the *y*-axis. To clarify the distinction between the two, in contrast to the expression $H_{kt}$ – 1.0d on the *x*-axis, the *y*-axis shows ($H_{kt}$ – d).

**Table22** Results of analysis of height above surface ($H_{st}$) (container ship)

| Dead Weight Tonnage (t) | 50% (m) | 75% (m) | 95% (m) |
|---|---|---|---|
| 10,000 | 32.6 | 34.5 | 37.4 |
| 20,000 | 36.7 | 38.7 | 41.5 |
| 30,000 | 39.1 | 41.1 | 43.9 |
| 40,000 | 40.8 | 42.8 | 45.6 |
| 50,000 | 42.1 | 44.1 | 47.0 |
| 60,000 | 43.2 | 45.2 | 48.0 |
| 100,000 | 46.2 | 48.2 | 51.1 |

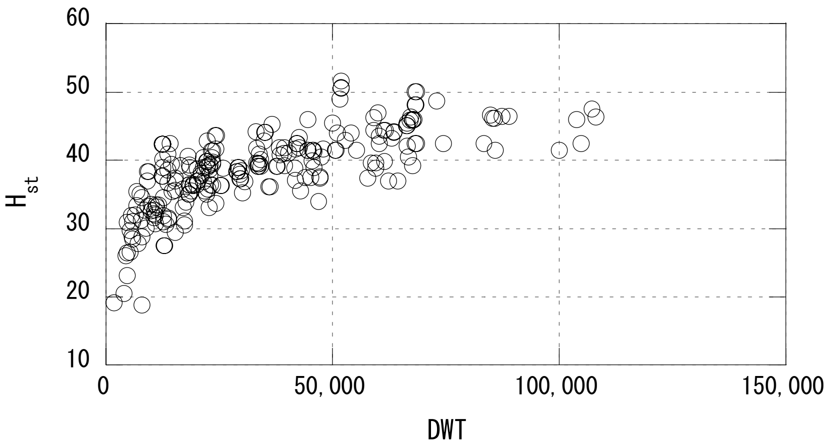



**Figure31–1** Distribution of $H_{st}$ data (container ship)

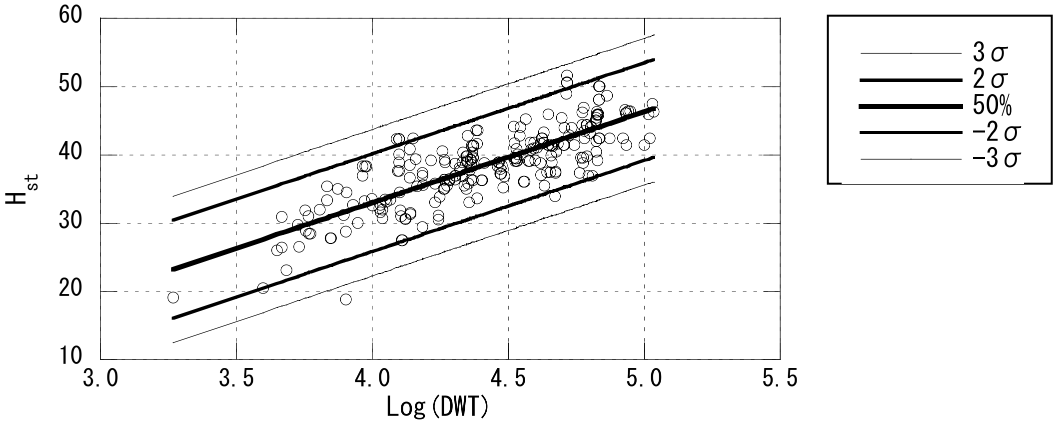
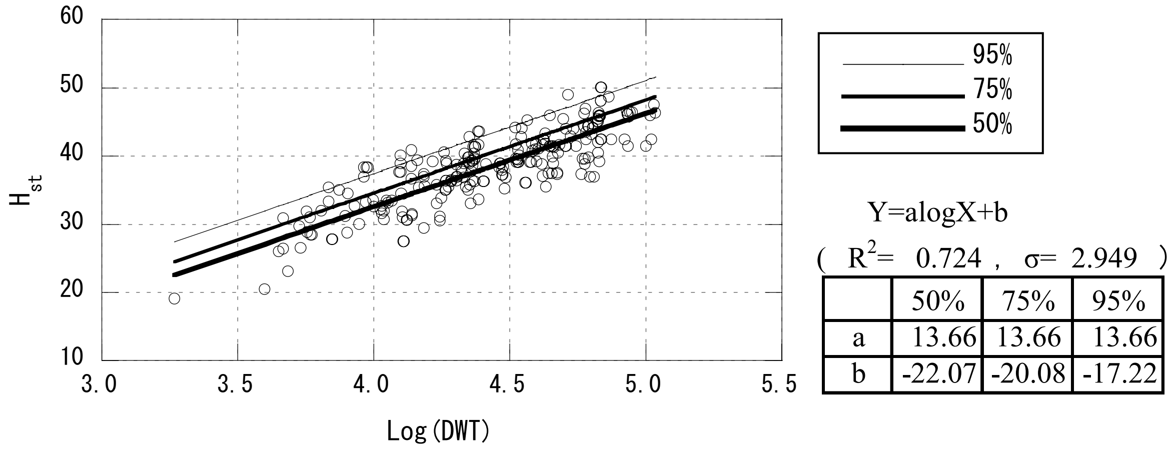



**Figure31–2** $H_{st}$ – semilog regression analysis (container ship)




| | 50% | 75% | 95% |
|---|---|---|---|
| a | 13.66 | 13.66 | 13.66 |
| b | -22.07 | -20.08 | -17.22 |

**Figure31–3** Results of $H_{st}$ – semilog regression analysis ①: After exclusion of data exceeding ±2σ (container ship)

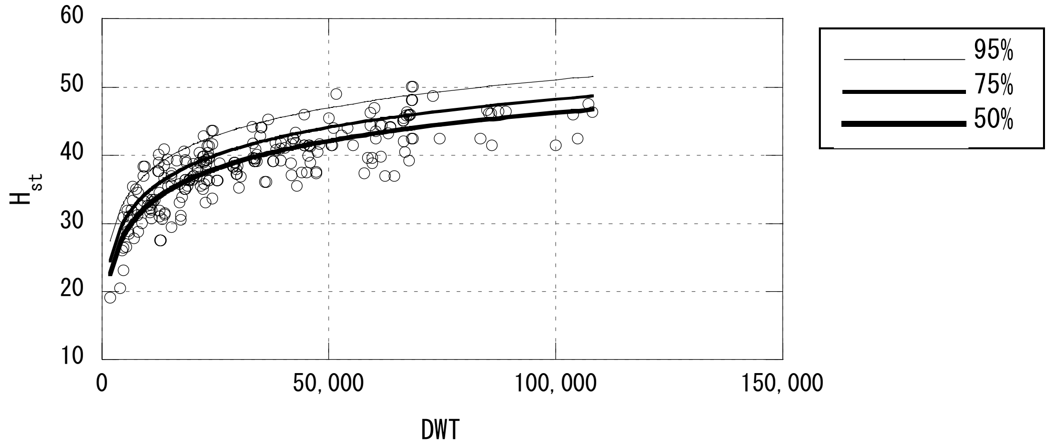



**Figure31–4** Results of $H_{st}$ – semilog regression analysis ②: After exclusion of data exceeding ±2σ (container ship)

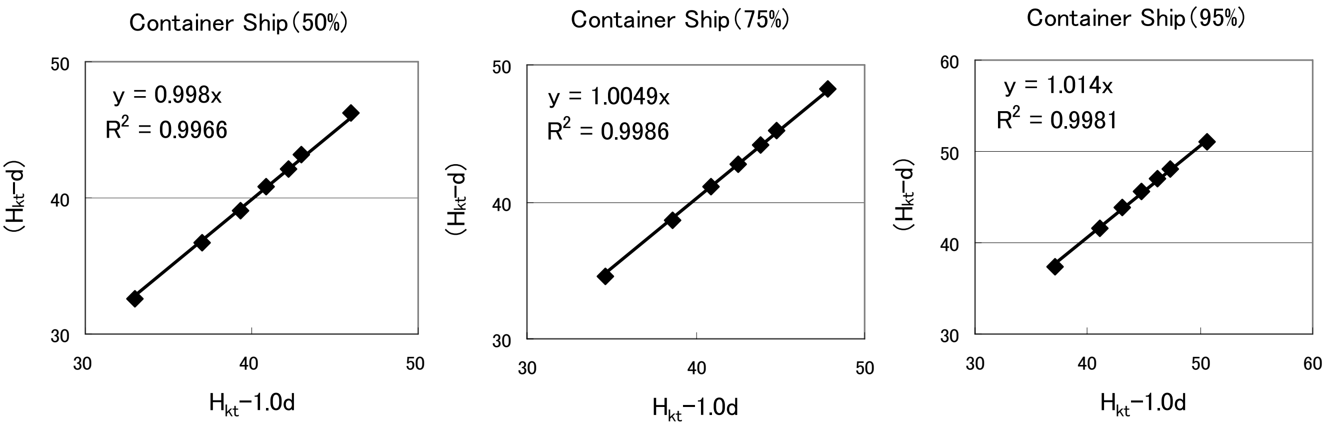



**Figure31–5** Comparison with draft factor ( $\beta$ ) = 1.0

**6.3 Oil tanker**

A distribution diagram of the height above surface ($H_{st}$) data for oil tankers is shown in **Figure32–1**. Next, the results of a semilog regression analysis to exclude the data for the region exceeding ±2σ are shown in **Figure32–2**. The results of a regression analysis obtained by applying the semilog regression analysis method to the data being analyzed after excluding the region exceeding ±2 σ are shown in **Figure32–3**. The results when the log expressions on the *x*-axis in **Figure 32–3** are expressed as antilogs are shown in **Figure32–4**. These **Figure32–3, –4** show the results of regression equations for coverage rates of 50%, 75%, and 95%, and **Figure32–3** also shows the value of the coefficient of determination (0.673) and the coefficients of the regression equation for each coverage rate. From this **Figure32–4**, it can be concluded that meaningful regression equations for oil tankers have been obtained.

Accordingly, based on the regression equations obtained here, the values for total height ($H_{kt}$) were calculated for coverage rates of 50%, 75%, and 95%, corresponding to ship classes set in the same manner as in the "Technical Standards." The results are shown in **Table23**.

The results in this **Table23** show the same concept as the results when the draft factor ( $\beta$ ) in **Ch. 5** equals 1.0. In order to compare the two, **Figure32-5** shows the results when the draft factor ( $\beta$ ) = 1.0 on the *x*-axis and the results in **Table23** on the *y*-axis. To clarify the distinction between the two, in contrast to the expression $H_{kt}$ – 1.0d on the *x*-axis, the *y*-axis shows ($H_{kt}$ – d).

**Table23** Results of analysis of height above surface ($H_{st}$) (oil tanker)

| Dead Weight Tonnage (t) | 50% (m) | 75% (m) | 95% (m) |
|---|---|---|---|
| 50,000 | 29.3 | 31.2 | 34.0 |
| 70,000 | 32.0 | 33.9 | 36.6 |
| 90,000 | 33.9 | 35.8 | 38.6 |
| 100,000 | 34.7 | 36.6 | 39.4 |
| 150,000 | 37.9 | 39.8 | 42.6 |
| 300,000 | 43.4 | 45.3 | 48.0 |

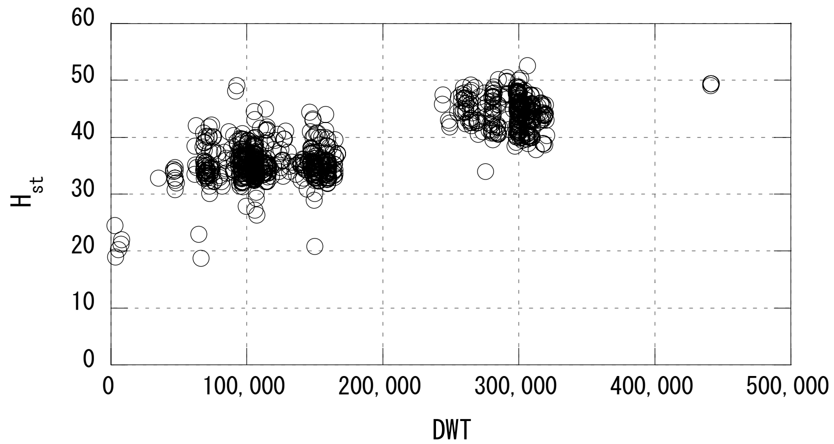



**Figure32–1** Distribution of $H_{st}$ data (oil tanker)

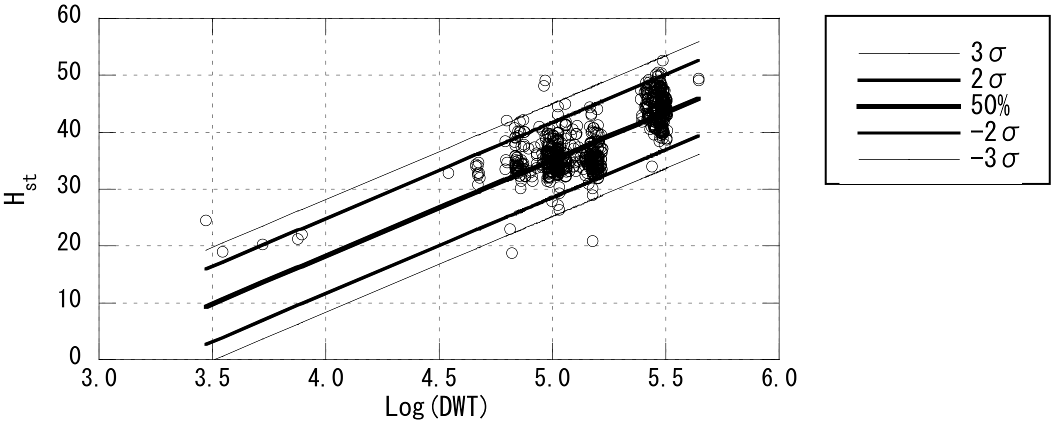
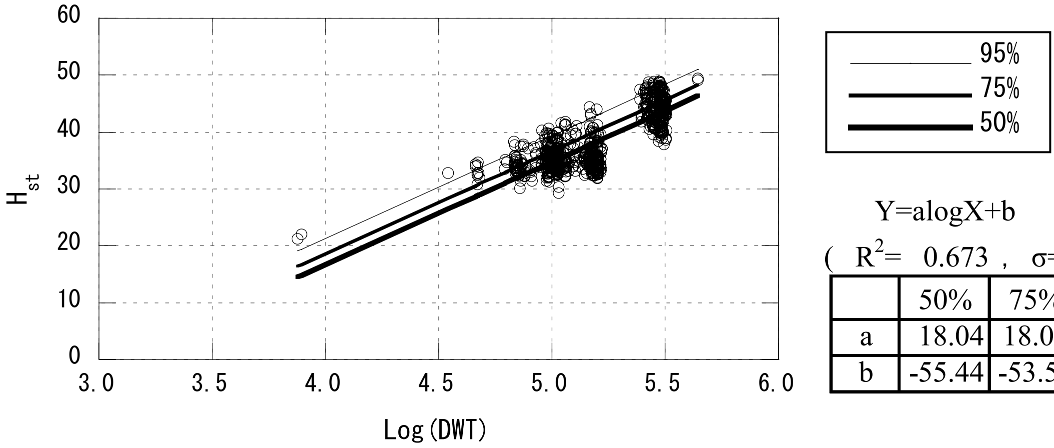



**Figure32–2** $H_{st}$ – semilog regression analysis (oil tanker)




Y=alogX+b

( $R^2$= 0.673 , $\sigma$= 2.817 )

| | 50% | 75% | 95% |
|---|---|---|---|
| a | 18.04 | 18.04 | 18.04 |
| b | -55.44 | -53.54 | -50.81 |

**Figure32–3** Results of $H_{st}$ – semilog regression analysis ①: After exclusion of data exceeding $\pm 2\sigma$ (oil tanker)

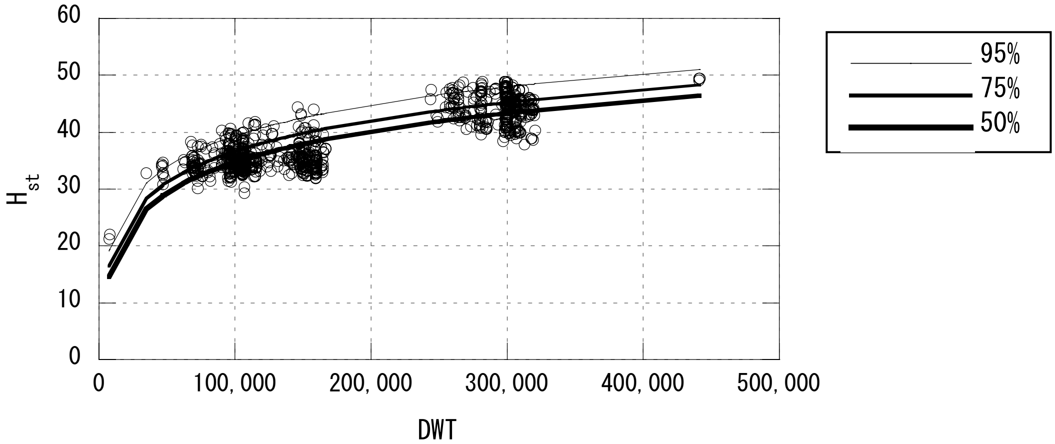



**Figure32–4** Results of $H_{st}$ – semilog regression analysis ②: After exclusion of data exceeding $\pm 2\sigma$ (oil tanker)

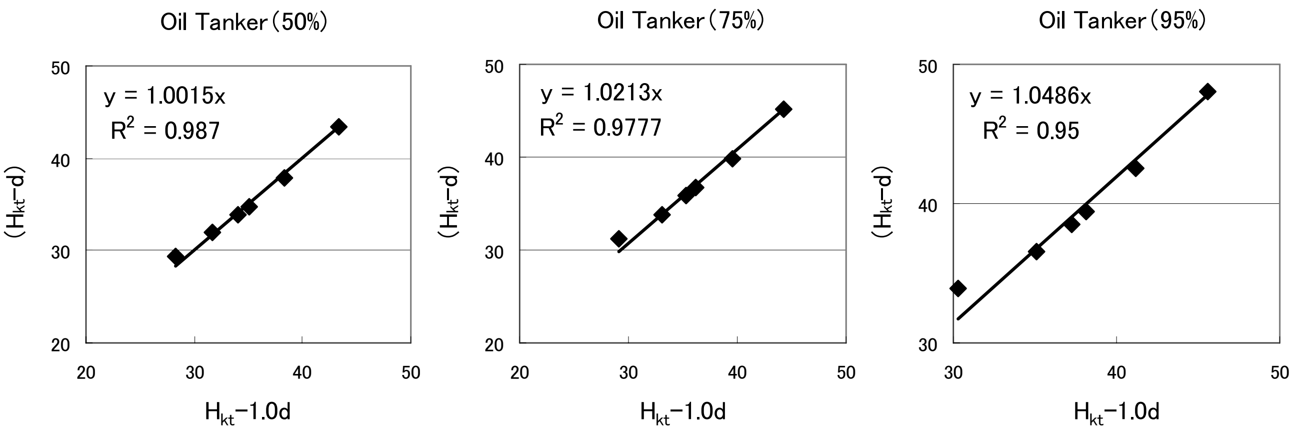



**Figure32–5** Comparison with draft factor ( $\beta$ ) = 1.0

### 6.4 RORO ship

A distribution diagram of the height above surface ($H_{st}$) data for RORO ships is shown in **Figure.33–1**. Next, the results of a semilog regression analysis to exclude the data for the region exceeding ±2σ are shown in **Figure33–2**. The results of a regression analysis obtained by applying the semilog regression analysis method to the data being analyzed after excluding the region exceeding ±2 σ are shown in **Figure33–3**. The results when the log expressions on the *x*-axis in **Figure33–3** are expressed as antilogs are shown in **Figure33–4**. These **Figure33–3, –4** show the results of regression equations for coverage rates of 50%, 75%, and 95%, and **Figure33–3** also shows the value of the coefficient of determination (0.725) and the coefficients of the regression equation for each coverage rate. From this **Figure33–4**, it can be concluded that meaningful regression equations for RORO ships have been obtained.

Accordingly, based on the regression equations obtained here, the values for total height ($H_{kt}$) were calculated for coverage rates of 50%, 75%, and 95%, corresponding to ship classes set in the same manner as in the "Technical Standards." The results are shown in **Table24**.

The results in this **Table24** show the same concept as the results when the draft factor ( $\beta$ ) in **Ch. 5** equals 1.0. In order to compare the two, **Figure33-5** shows the results when the draft factor ( $\beta$ ) = 1.0 on the *x*-axis and the results in **Table24** on the *y*-axis. To clarify the distinction between the two, in contrast to the expression $H_{kt}$ – 1.0d on the *x*-axis, the *y*-axis shows ($H_{kt}$ – d).

**Table24** Results of analysis of height above surface ($H_{st}$) (RORO ship)

| Gross Tonnage (t) | 50% (m) | 75% (m) | 95% (m) |
|---|---|---|---|
| 3,000 | 23.7 | 26.6 | 30.9 |
| 5,000 | 26.7 | 29.7 | 33.9 |
| 10,000 | 30.8 | 33.7 | 38.0 |
| 20,000 | 34.9 | 37.8 | 42.1 |
| 40,000 | 39.0 | 41.9 | 46.2 |
| 60,000 | 41.4 | 44.3 | 48.6 |

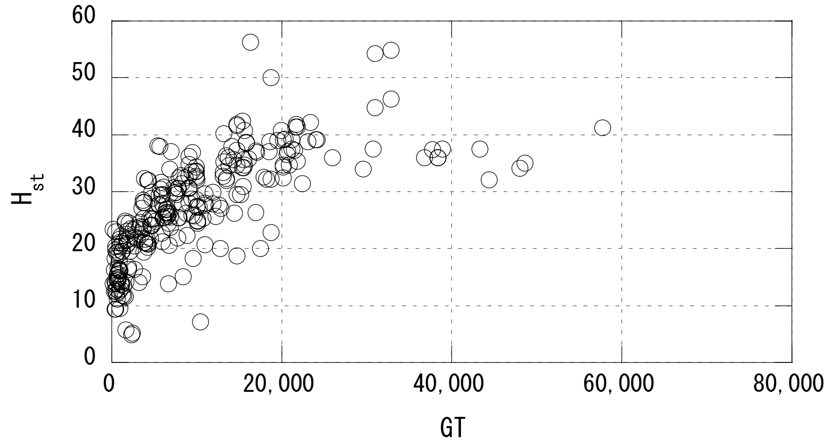



**Figure33–1** Distribution of $H_{st}$ data (RORO ship)

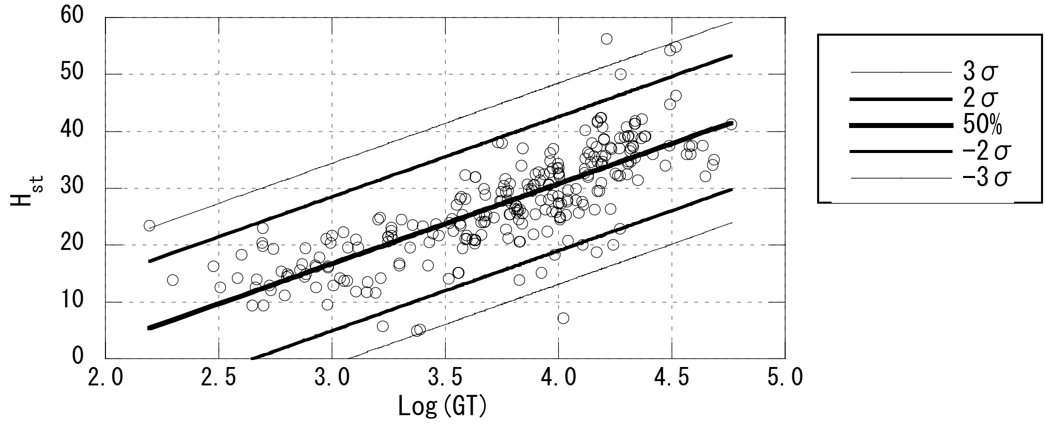
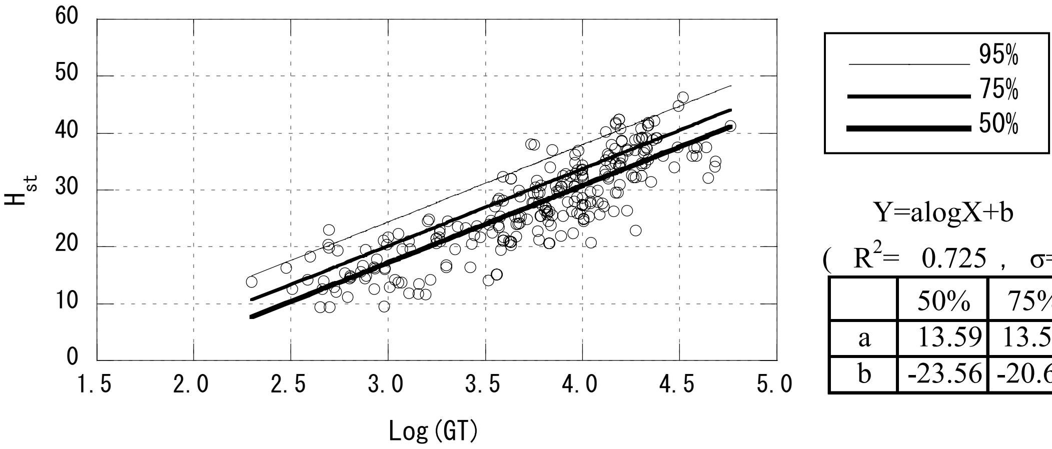



**Figure33–2** $H_{st}$ – semilog regression analysis (RORO ship)




Y=alogX+b

( $R^2$= 0.725 , σ= 4.374 )

| | 50% | 75% | 95% |
|---|---|---|---|
| a | 13.59 | 13.59 | 13.59 |
| b | -23.56 | -20.62 | -16.37 |

**Figure33–3** Results of $H_{st}$ – semilog regression analysis ①: After exclusion of data exceeding ±2σ (RORO ship)

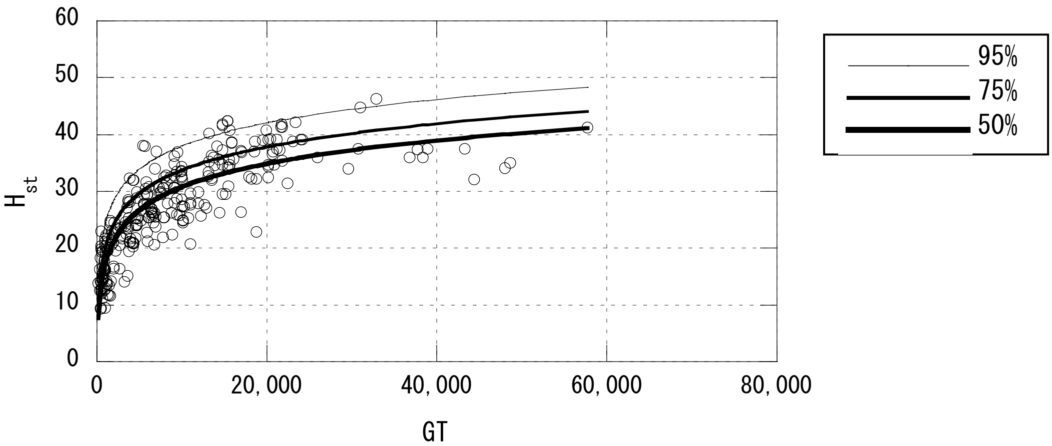



**Figure33–4** Results of $H_{st}$ – semilog regression analysis ②: After exclusion of data exceeding ±2σ (RORO ship)

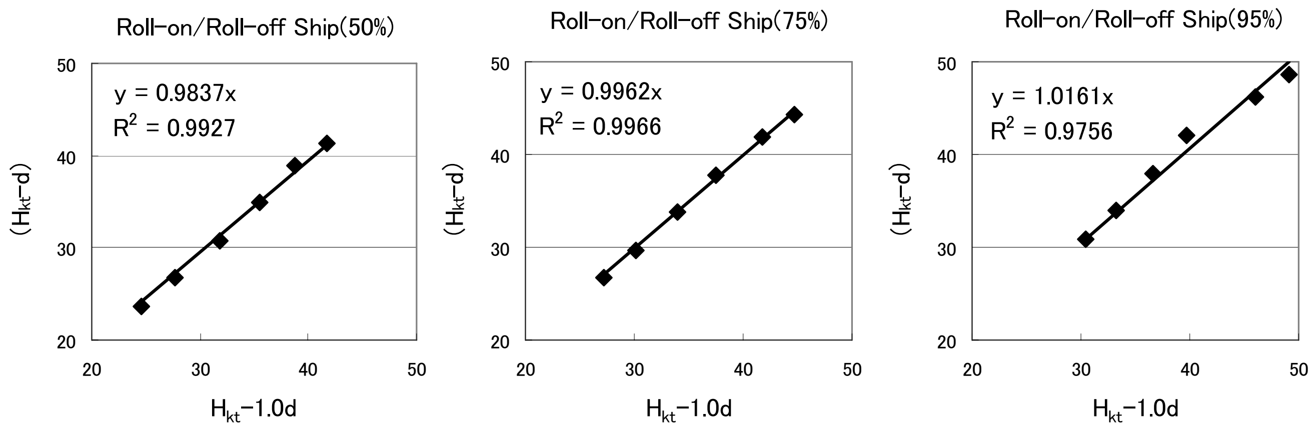



**Figure33–5** Comparison with draft factor ( $\beta$ ) = 1.0

**6.5 PCC**

A distribution diagram of the height above surface ($H_{st}$) data for PCC ships is shown in **Figure34–1**. Next, the results of a semilog regression analysis to exclude the data for the region exceeding ±2σ are shown in **Figure34–2**. The results of a regression analysis obtained by applying the semilog regression analysis method to the data being analyzed after excluding the region exceeding ±2 σ are shown in **Figure34–3**. The results when the log expressions on the *x*-axis in **Figure34–3** are expressed as antilogs are shown in **Figure34–4**. These **Figure34–3, –4** show the results of regression equations for coverage rates of 50%, 75%, and 95%, and **Figure34–3** also shows the value of the coefficient of determination (0.573) and the coefficients of the regression equation for each coverage rate. From this **Figure34–4**, it can be concluded that meaningful regression equations for PCC ships have been obtained.

Accordingly, based on the regression equations obtained here, the values for total height ($H_{kt}$) were calculated for coverage rates of 50%, 75%, and 95%, corresponding to ship classes set in the same manner as in the "Technical Standards." The results are shown in **Table25**.

The results in this **Table25** show the same concept as the results when the draft factor ( $\beta$ ) in **Ch. 5** equals 1.0. In order to compare the two, **Figure34-5** shows the results when the draft factor ( $\beta$ ) = 1.0 on the *x*-axis and the results in **Table25** on the *y*-axis. To clarify the distinction between the two, in contrast to the expression $H_{kt}$ –1.0d on the *x*-axis, the *y*-axis shows ($H_{kt}$ – d).

**Table25** Results of analysis of height above surface ($H_{st}$) (PCC)

| Gross Tonnage (t) | 50% (m) | 75% (m) | 95% (m) |
|---|---|---|---|
| 3,000 | 24.0 | 26.5 | 30.2 |
| 5,000 | 26.6 | 29.2 | 32.9 |
| 12,000 | 31.1 | 33.7 | 37.4 |
| 20,000 | 33.7 | 36.3 | 40.0 |
| 30,000 | 35.8 | 38.4 | 42.1 |
| 40,000 | 37.3 | 39.8 | 43.5 |
| 60,000 | 39.4 | 41.9 | 45.6 |

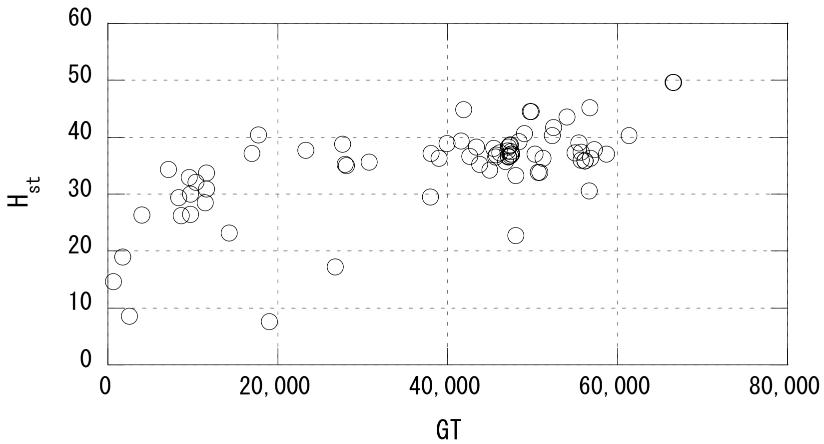



**Figure34–1** Distribution of $H_{st}$ data (PCC)

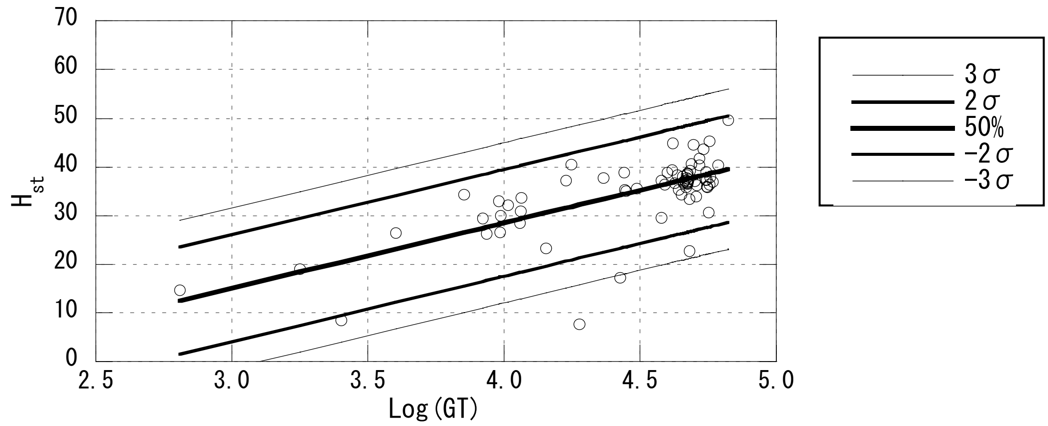
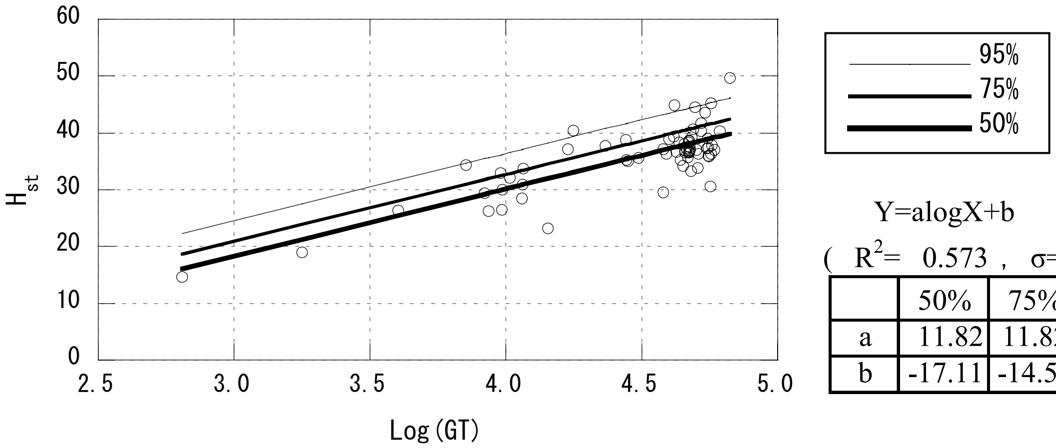



**Figure34–2** $H_{st}$ – semilog regression analysis (PCC)




Y=alogX+b

( $R^2$= 0.573 , σ= 3.801 )

| | 50% | 75% | 95% |
|---|---|---|---|
| a | 11.82 | 11.82 | 11.82 |
| b | -17.11 | -14.55 | -10.86 |

**Figure34–3** Results of $H_{st}$ – semilog regression analysis ①: After exclusion of data exceeding ±2σ (PCC)

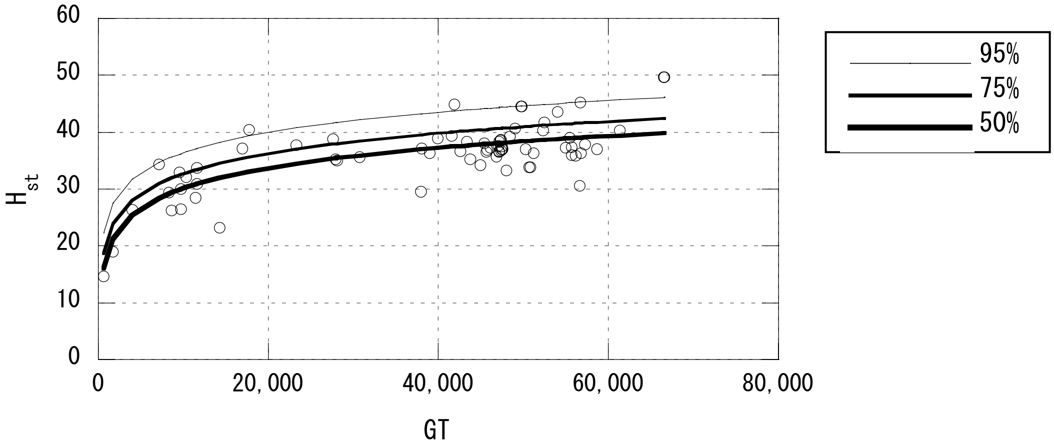



**Figure34–4** Results of $H_{st}$ – semilog regression analysis ②: After exclusion of data exceeding ±2σ (PCC)

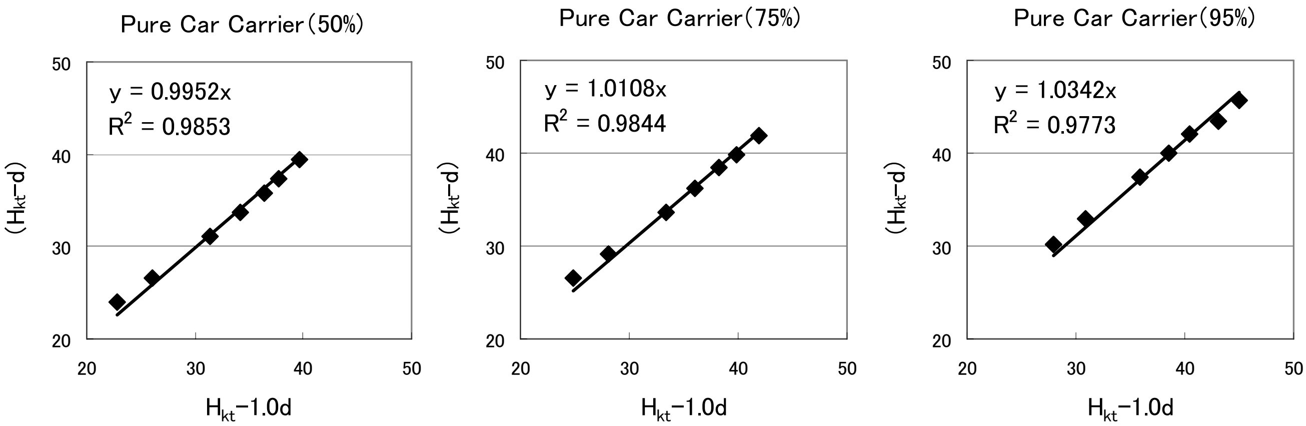



**Figure34–5** Comparison with draft factor ( $\beta$ ) = 1.0

**6.6 LPG ship**

A distribution diagram of the height above surface ($H_{st}$) data for LPG ships is shown in **Figure35–1**. Next, the results of a semilog regression analysis to exclude the data for the region exceeding ±2σ are shown in **Figure35–2**. The results of a regression analysis obtained by applying the semilog regression analysis method to the data being analyzed after excluding the region exceeding ±2 σ are shown in **Figure35–3**. The results when the log expressions on the *x*-axis in **Figure35–3** are expressed as antilogs are shown in **Figure35–4**. These **Figure35–3, –4** show the results of regression equations for coverage rates of 50%, 75%, and 95%, and **Figure35–3** also shows the value of the coefficient of determination (0.878) and the coefficients of the regression equation for each coverage rate. From this **Figure35–4**, it can be concluded that meaningful regression equations for LPG ships have been obtained.

Accordingly, based on the regression equations obtained here, the values for total height ($H_{kt}$) were calculated for coverage rates of 50%, 75%, and 95%, corresponding to ship classes set in the same manner as in the "Technical Standards." The results are shown in **Table26**.

The results in this **Table26** show the same concept as the results when the draft factor ( $\beta$ ) in **Ch. 5** equals 1.0. In order to compare the two, **Figure35-5** shows the results when the draft factor ( $\beta$ ) = 1.0 on the *x*-axis and the results in **Table26** on the *y*-axis. To clarify the distinction between the two, in contrast to the expression $H_{kt}$ – 1.0d on the *x*-axis, the *y*-axis shows ($H_{kt}$ – d).

**Table26** Results of analysis of height above surface ($H_{st}$) (LPG ship)

| Gross Tonnage (t) | 50% (m) | 75% (m) | 95% (m) |
|---|---|---|---|
| 3,000 | 24.4 | 25.7 | 27.6 |
| 5,000 | 26.8 | 28.2 | 30.1 |
| 10,000 | 30.2 | 31.6 | 33.5 |
| 20,000 | 33.6 | 34.9 | 36.9 |
| 30,000 | 35.6 | 36.9 | 38.8 |
| 40,000 | 37.0 | 38.3 | 40.2 |
| 50,000 | 38.0 | 39.4 | 41.3 |

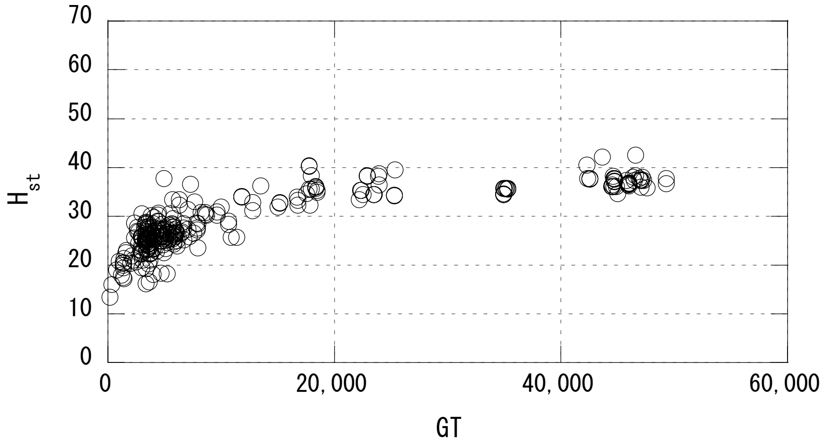



**Figure35–1** Distribution of $H_{st}$ data (LPG ship)

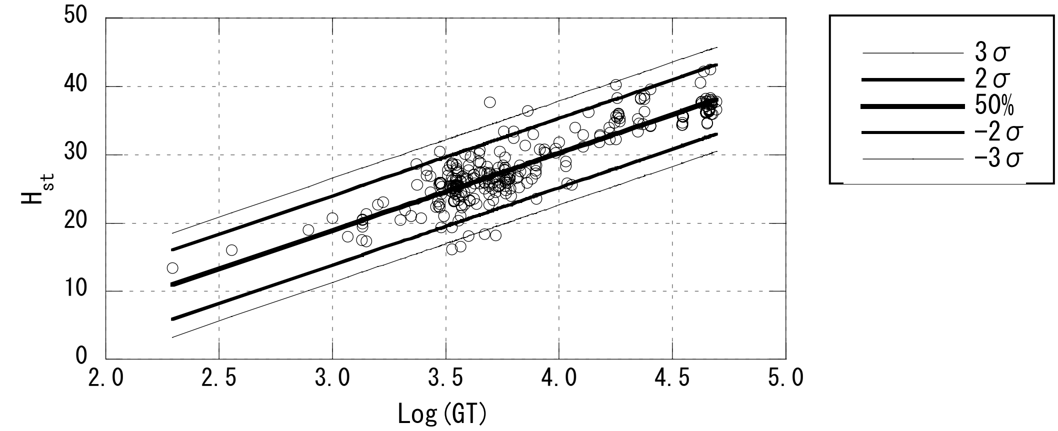
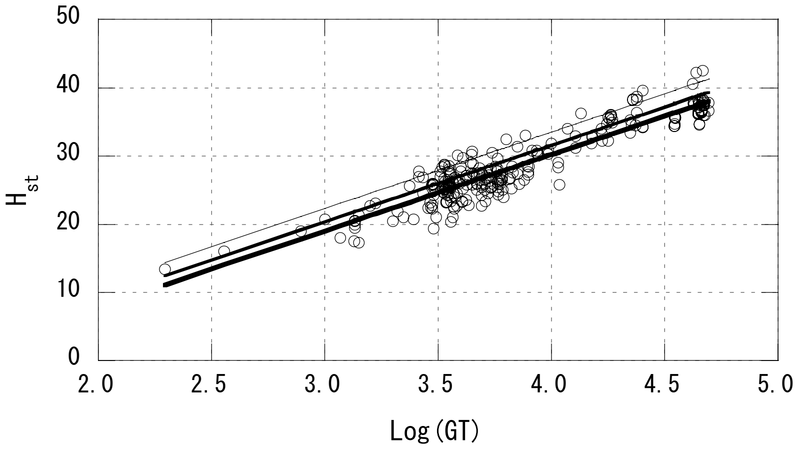
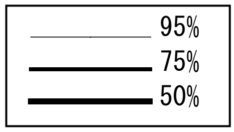



**Figure35–2** $H_{st}$ – semilog regression analysis (LPG ship)




Y=alogX+b

( $R^2$= 0.878 , σ= 1.994 )

| | 50% | 75% | 95% |
|---|---|---|---|
| a | 11.21 | 11.21 | 11.21 |
| b | -14.62 | -13.27 | -11.34 |

**Figure35–3** Results of $H_{st}$ – semilog regression analysis ①: After exclusion of data exceeding ±2σ (LPG ship)

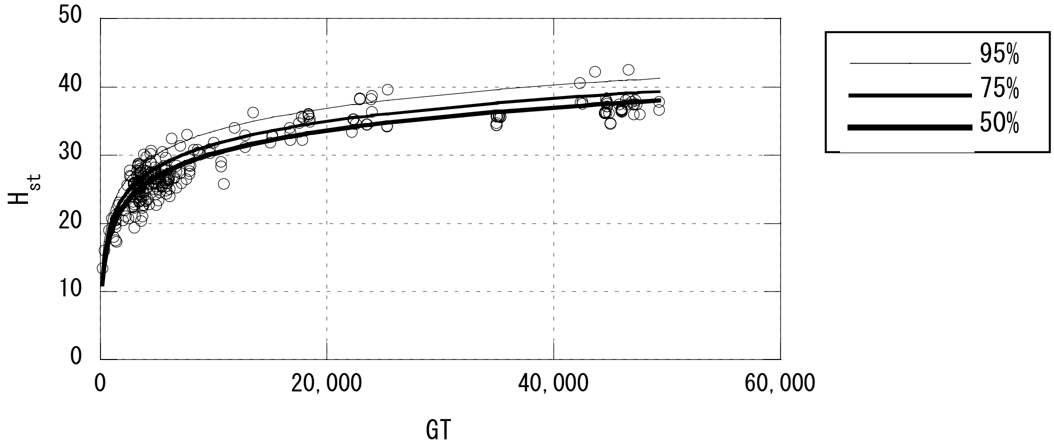



**Figure35–4** Results of $H_{st}$ – semilog regression analysis ②: After exclusion of data exceeding ±2σ (LPG ship)

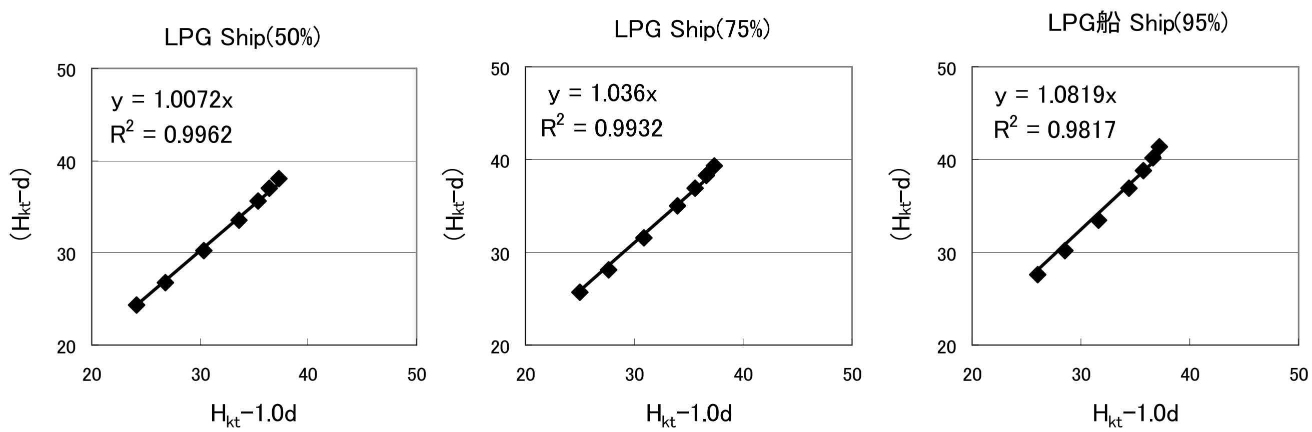



**Figure35–5** Comparison with draft factor ( β ) = 1.0

**6.7 LNG ship**

A distribution diagram of the height above surface ($H_{st}$) data for LNG ships is shown in **Figure36–1**. Next, the results of a semilog regression analysis to exclude the data for the region exceeding ±2σ are shown in **Figure36–2**. It may be noted that ships of 50,000GT and less were excluded due to the small number of data. The results of a regression analysis obtained by applying the semilog regression analysis method to the data being analyzed after excluding the region exceeding ±2 σ are shown in **Figure36–3**. The results when the log expressions on the *x*-axis in **Figure36–3** are expressed as antilogs are shown in **Figure36–4**. These **Figure36–3, –4** show the results of regression equations for coverage rates of 50%, 75%, and 95%, and **Figure36–3** also shows the value of the coefficient of determination (0.192) and the coefficients of the regression equation for each coverage rate. In spite of the fact that the coefficient of determination is low here, unlike that for the other ship types, it is thought that these results reflect the special characteristics of this region.

Accordingly, based on the regression equations obtained here, the values for total height ($H_{kt}$) were calculated for coverage rates of 50%, 75%, and 95%, corresponding to ship classes set in the same manner as in the "Technical Standards." The results are shown in **Table27**.

The results in this **Table27** show the same concept as the results when the draft factor ( $\beta$ ) in **Ch. 5** equals 1.0. In order to compare the two, **Figure36-5** shows the results when the draft factor ( $\beta$ ) = 1.0 on the *x*-axis and the results in **Table27** on the *y*-axis. To clarify the distinction between the two, in contrast to the expression $H_{kt}$ – 1.0d on the *x*-axis, the *y*-axis shows ($H_{kt}$ – d).

**Table27** Results of analysis of height above surface ($H_{st}$) (LNG ship)

| Gross Tonnage (t) | 50% (m) | 75% (m) | 95% (m) |
|---|---|---|---|
| 80,000 | 42.3 | 46.6 | 52.8 |
| 100,000 | 49.4 | 53.7 | 59.9 |
| 120,000 | 55.2 | 59.5 | 65.7 |

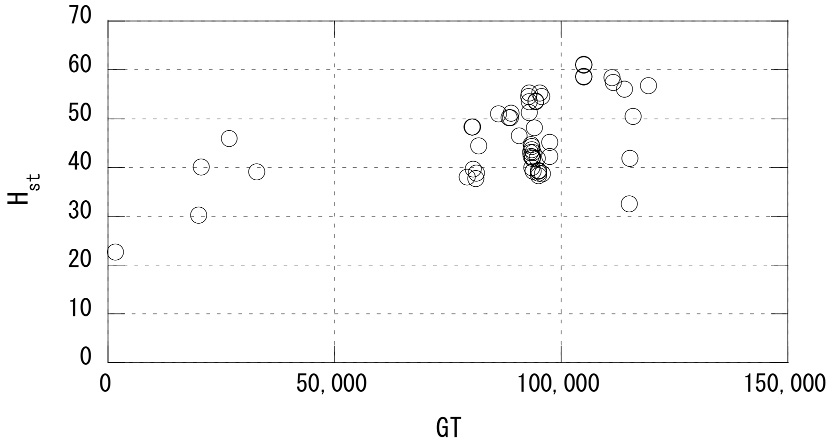



**Figure36–1** Distribution of $H_{st}$ data (LNG ship)

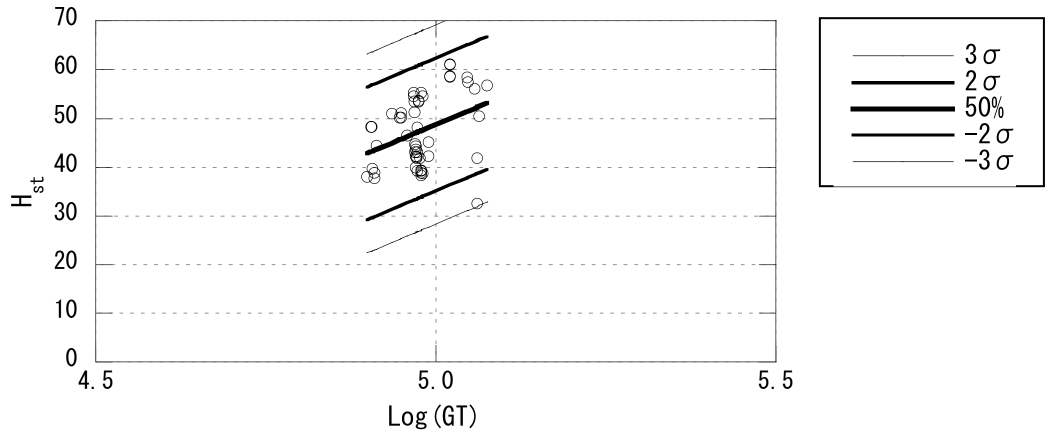
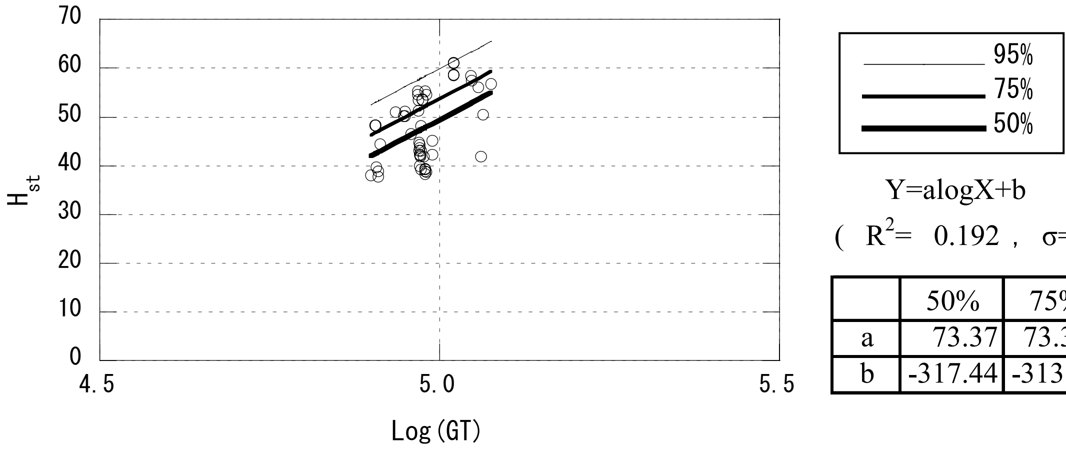



**Figure36–2** $H_{st}$ – semilog regression analysis (LNG ship)




Y=alogX+b

( $R^2$= 0.192 , σ= 6.374 )

| | 50% | 75% | 95% |
|---|---|---|---|
| a | 73.37 | 73.37 | 73.37 |
| b | -317.44 | -313.14 | -306.95 |

**Figure36–3** Results of $H_{st}$ – semilog regression analysis ①: After exclusion of data exceeding ±2σ (LNG ship)

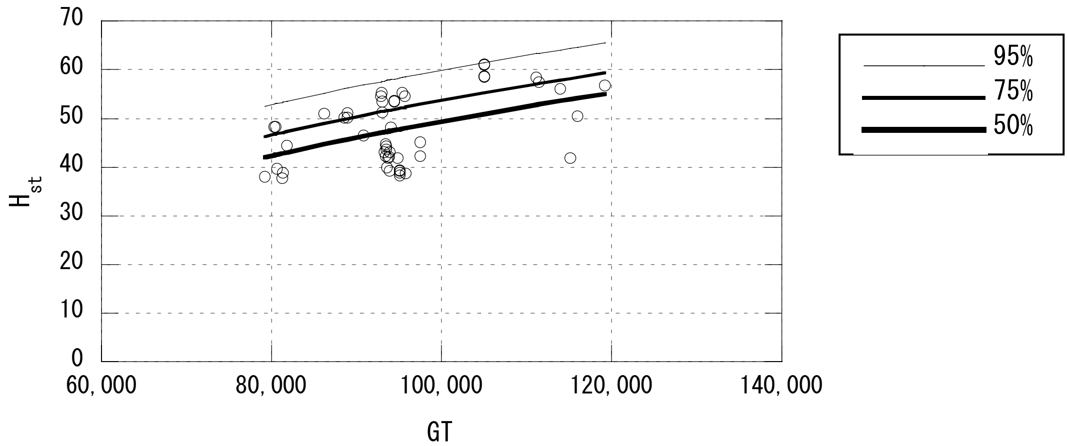



**Figure36–4** Results of $H_{st}$ – semilog regression analysis ②: After exclusion of data exceeding ±2σ (LNG ship)

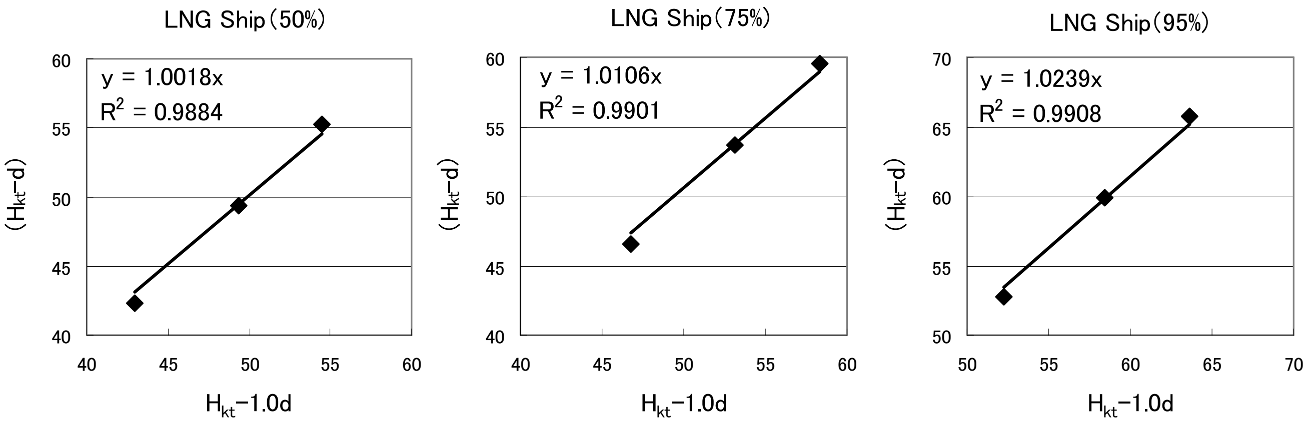



**Figure36–5** Comparison with draft factor ( β ) = 1.0

**6.8 Passenger ship**

A distribution diagram of the height above surface ($H_{st}$) data for passenger ships is shown in **Figure37–1**. Next, the results of a semilog regression analysis to exclude the data for the region exceeding ±2σ are shown in **Figure37–2**. The results of a regression analysis obtained by applying the semilog regression analysis method to the data being analyzed after excluding the region exceeding ±2 σ are shown in **Figure37–3**. The results when the log expressions on the *x*-axis in **Figure37–3** are expressed as antilogs are shown in **Figure37–4**. These **Figure37–3, –4** show the results of regression equations for coverage rates of 50%, 75%, and 95%, and **Figure37–3** also shows the value of the coefficient of determination (0.678) and the coefficients of the regression equation for each coverage rate. From this **Figure37–4**, it can be concluded that meaningful regression equations for passenger ships have been obtained.

Accordingly, based on the regression equations obtained here, the values for total height ($H_{kt}$) were calculated for coverage rates of 50%, 75%, and 95%, corresponding to ship classes set in the same manner as in the "Technical Standards." The results are shown in **Table28**.

The results in this **Table28** show the same concept as the results when the draft factor ( $\beta$ ) in **Ch. 5** equals 1.0. In order to compare the two, **Figure37-5** shows the results when the draft factor ( $\beta$ ) = 1.0 on the *x*-axis and the results in **Table28** on the *y*-axis. To clarify the distinction between the two, in contrast to the expression $H_{kt}$ – 1.0d on the *x*-axis, the *y*-axis shows ($H_{kt}$ – d).

**Table28** Results of analysis of height above surface ($H_{st}$) (passenger ship)

| Gross Tonnage (t) | 50% (m) | 75% (m) | 95% (m) |
|---|---|---|---|
| 3,000 | 25.7 | 30.3 | 37.0 |
| 5,000 | 29.2 | 33.9 | 40.5 |
| 10,000 | 34.0 | 38.6 | 45.3 |
| 20,000 | 38.8 | 43.4 | 50.0 |
| 30,000 | 41.6 | 46.2 | 52.8 |
| 50,000 | 45.1 | 49.7 | 56.3 |
| 70,000 | 47.4 | 52.0 | 58.6 |
| 100,000 | 49.8 | 54.5 | 61.1 |

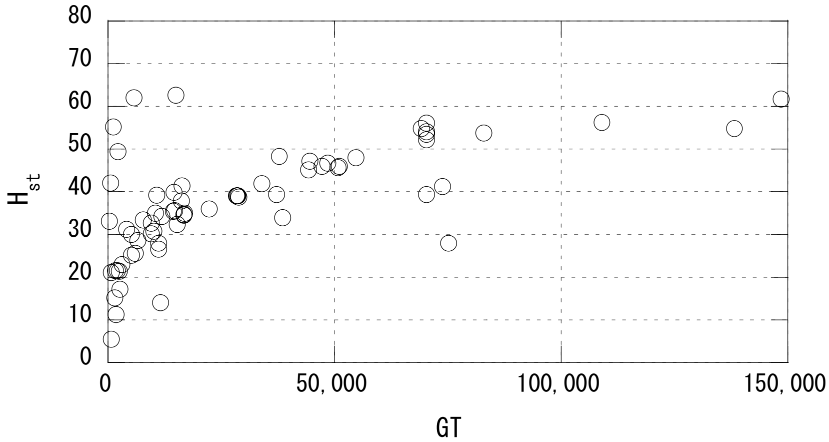



**Figure37–1** Distribution of $H_{st}$ data (passenger ship)

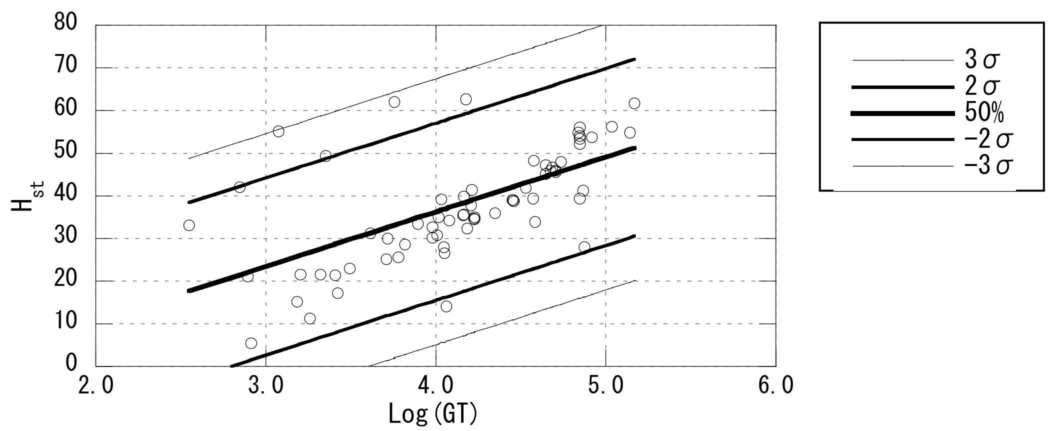
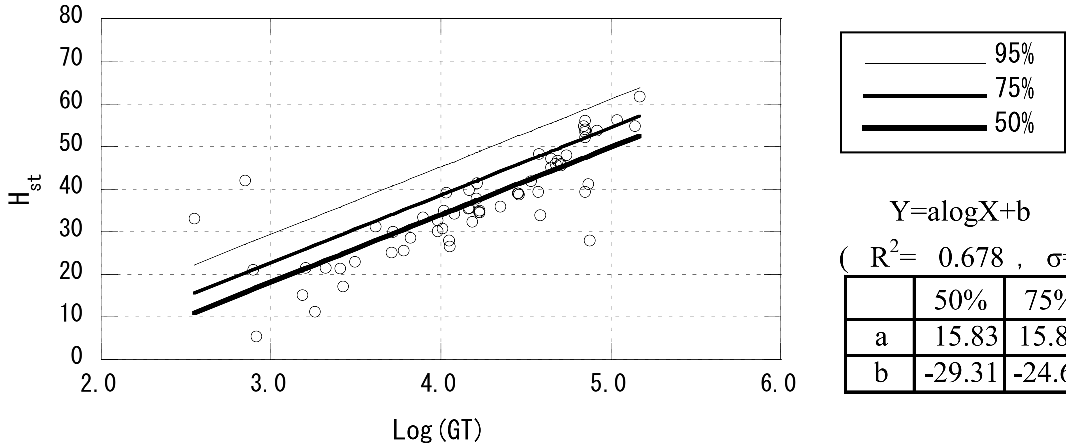



**Figure37–2** $H_{st}$ – semilog regression analysis (passenger ship)




Y=alogX+b

( $R^2$= 0.678 , σ= 6.843 )

| | 50% | 75% | 95% |
|---|---|---|---|
| a | 15.83 | 15.83 | 15.83 |
| b | -29.31 | -24.69 | -18.05 |

**Figure37–3** Results of $H_{st}$ – semilog regression analysis ①: After exclusion of data exceeding ±2σ (passenger ship)

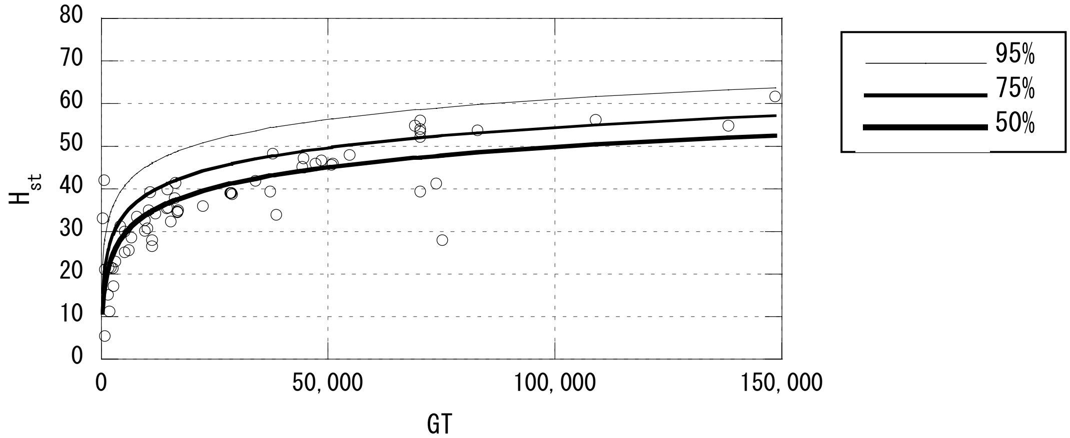



**Figure37–4** Results of $H_{st}$ – semilog regression analysis ②: After exclusion of data exceeding ±2σ (passenger ship)

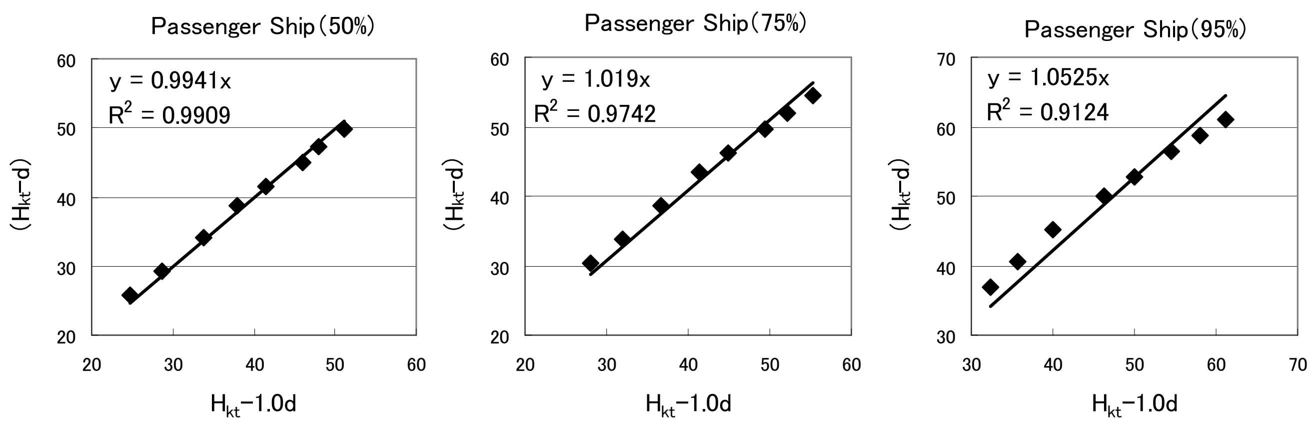



**Figure37–5** Comparison with draft factor ( β ) = 1.0

## 7. Conclusion

Based on an examination of the reasons why dimensional values related to the height of ships were not given in the existing "Technical Standards for Port and Harbour Facilities" (Ministry of Land, Infrastructure and Transport), the first objective of this research was to propose dimensions for the height of ships with accuracy equal to that of the ship main dimensions, such as length over all, full load draft, etc., in the "Technical Standards."

Concretely, this research included:

① Comparative analysis of the dispersion with data on main dimensions by ship class.

② Exclusion of statistically anomalous values from data in the fundamental data.

③ Application of a new statistical analysis method.

Based on the above, the values of total height (height from keel to top) for coverage ratios of 50%, 75%, and 95% were calculated for ship classes set in the same manner as in the "Technical Standards," and the results were presented in table form.

The second objective was to propose ship height dimensions with the same accuracy as main dimensions such as length over all, full load draft, etc. in the "Technical Standards" for the height from the sea surface to the highest point on the ship, which is necessary when designing bridges over fairways, arranging the relationship with the obstruction assessment surface (OAS) in maritime airports, etc.

This research focused on:

① Technique for estimating height above surface ($H_{st}$) using the values of total height ($H_{kt}$) and full load draft (d), which are analyzed separately.

② Technique for estimating height above surface ($H_{st}$) in a fully-loaded condition directly from total height ($H_{kt}$) and full load draft (d) for individual ships.

Using these techniques, the values of the height above the sea surface for coverage ratios of 50%, 75%, and 95% were calculated for ship classes set in the same manner as in the "Technical Standards," and the results were presented in table form.

Because examples which present dimensional value tables of this type for ship height cannot be found elsewhere, including non-Japanese sources, reflection of these results in a future revision of the "Technical Standards" is expected. On the other hand, it is also necessary to present these results in various forums for external evaluation. In order to base such a revision on these evaluations and respond to changes in the circumstances surrounding the "Technical Standards," it will be necessary to carry out an analysis of ship height in combination with the other main ship dimensions such as length over all, full load draft, etc. in the future.

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**(* Note): Outline of Lloyd's Register Fairplay Ltd.**

Lloyd's Register Fairplay Ltd. (LRF) is a company which was established in 2001 by merging the maritime information publishing division of Lloyd's Register (LR) and Fairplay Publications Limited.

As the origin of Lloyd's Register of Shipping, the company was established in 1760 at a London coffee shop owned by Edward Lloyd for the main purpose of classifying merchant ships from the viewpoints of their structures and seakeeping capabilities. The first Register of Ships was published in 1764. In 1975, LR was registered as a philanthropic organization, i.e., a non-profit organization. Today, LR has offices in approximately 120 countries and determines the class of merchant ships worldwide.

On the other hand, Fairplay Publications Limited was established by its founder, Tomas Hope Robinson, in 1883 as a publishing house. The company published weekly magazines, and LRF continues to publish the Fairplay International Shipping Weekly even today. Subsequently, in the 1970s, Fairplay was sold to the Pearson Group, which publishes the Financial Times.

In 2001, the maritime information publishing division of LR and Fairplay were merged, creating Lloyd's Register-Fairplay Ltd. as a company specializing in providing information to the world shipping industry. The company is headquartered in England and has opened offices in Singapore, Sweden, and the United States.

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