Chap 7. Harbor Tranquility

7.1 Parameters Governing Harbor Tranquility

• Fundamental functions of a harbor
  - Safety of passengers, cargos, and vessels
  - Efficiency of port operation (loading and unloading of cargos)

• Approaches to estimate harbor tranquility
  - Estimate wave height distribution in a harbor (by numerical analysis or hydraulic model tests) for given offshore wave conditions. But the effect of wave action on ships is different depending on the size of ships. In general, large ships are influenced by long-period swells, while small boats are influenced by short-period wind waves.
  - Ship motions are to be analyzed (Effects of mooring lines, fenders, and local winds should be included)

• Other factors
  - Ship navigation at harbor entrance
  - Ship refuge during storms
  - Efficiency of cargo handling and ship demurrage
  - Construction cost of harbor facilities

7.2 Estimation of the Probability of Wave Height Exceedance within a Harbor

7.2.1 Estimation Procedure (See Fig. 7.2)

number of days of wave height exceedance per year
= exceedance probability × 365 days

7.2.2 Joint Distribution of Significant Wave Height, Period and Direction Outside a Harbor

- Harbor operations under normal conditions
- Need wave data (outside a harbor) several times a day at least 3 years (rough, normal, moderate)
- A large number of data points → represent each sea state by significant wave height and period
- Data on wave directions are rare at present → need to estimate using wind data and visual observation.

Table 7.1 Example of exceedance probability of wave height in different directions.

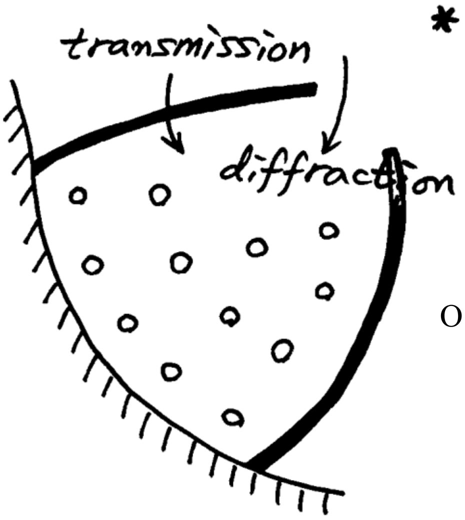
–Akita Port (1974)–

Wave Direction	Percentage (%)	Significant Wave Height $H_{1/3}$ Over 0 m	Over 1 m	Over 2 m	Over 3 m	Over 4 m	Over 5 m	Over 6 m
SW	1.4	1.4	0.4	0.1	0	0	0	0
WSW	29.0	29.0	9.2	2.5	1.2	0.5	0.3	0.1
W	68.2	68.2	21.6	6.2	2.8	1.2	0.7	0.2
WNW	1.4	1.4	0.4	0.1	0	0	0	0
Total	100.0	100.0	31.6	8.9	4.0	1.7	1.0	0.3
Prevailing period $T_{1/3}$			7.0 s		9.0 s		11.0 s	

number of days of wave height exceedance per year
= exceedance probability × 365 days

e.g., $\frac{31.6}{100} \times 365 = 115$ days (wave heights over 1 m outside this harbor)

7.2.3 Selection of the Points for the Wave Height Estimation



* Given exceedance probability of wave height for different incident wave directions outside a harbor

O Predict exceedance probability of wave height at selected points inside the harbor (important and representative points)

7.2.4 Estimation of Wave Height in a Harbor Incident through an Entrance

For each set of significant wave height, period, and direction, predict significant wave heights at selected locations by applying directional random wave diffraction (Sec. 3.3) and transmission over a breakwater (Sec. 3.9).

Table 7.2 Diffraction coefficient of random sea waves at the location under study.

	Diffraction Coefficient		
Wave Direction	$T = 7$ s	$T = 9$ s	$T = 11$ s
SW	0.101	0.116	0.130
WSW	0.277	0.290	0.303
W	0.508	0.587	0.595
WNW	0.849	0.852	0.855

Note: K_d is independent on wave height.

7.2.5 Estimation of Waves Transmitted over a Breakwater (Sec. 3.9)

Transmission coefficient, $K_T = \dfrac{H_T}{H_i}$ ← assume normal incidence to the breakwater.

Table 7.3 Estimated height of transmitted waves.

Incident height H_I (m)	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**
Transmitted height H_T (m)	**0.03**	**0.06**	**0.09**	**0.24**	**0.45**	**0.81**

7.2.6 Estimation of the Exceedance Probability of Wave Height within a Harbor

At a given location within a harbor,

$H_d = K_d H_i$ due to diffraction

H_T = transmitted significant wave height

Combined height $H_s = \sqrt{H_d^2 + H_T^2}$ (addition of wave energy)

Table 7.4 Superposition of diffracted and transmitted wave height.

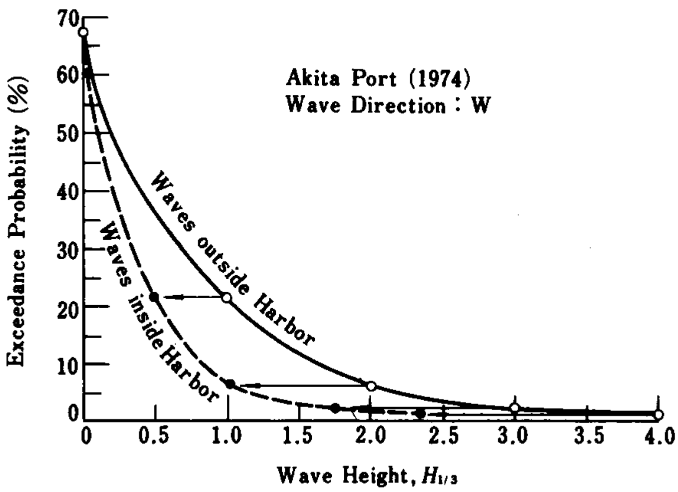
Wave Direction		H_I (m) 1.0	2.0	3.0	4.0	5.0	6.0
SW	H_d	0.10	0.20	0.35	0.46	0.65	0.78
	H_T	0.03	0.06	0.09	0.24	0.45	0.81
	H_S	0.10	0.21	0.36	0.52	0.80	1.12
WSW	H_d	0.28	0.55	0.87	1.16	1.52	1.82
	H_T	0.03	0.06	0.09	0.24	0.45	0.81
	H_S	0.28	0.55	0.87	1.18	1.59	1.99
W	H_d	0.51	1.02	1.76	2.35	2.98	3.57
	H_T	0.03	0.06	0.09	0.24	0.45	0.81
	H_S	0.51	1.02	1.76	2.36	3.01	3.66
WNW	H_d	0.85	1.70	2.56	3.41	4.28	5.13
	H_T	0	0	0	0	0	0
	H_S	0.85	1.70	2.56	3.41	4.28	5.13

Note: Transmitted waves were assumed to arrive at the site without dissipation for the direction of SW to W, but not to arrive for the direction of WNW.

Also check $H_d = K_d H_i$

$$\left.\begin{aligned} &\text{for } H_i = 1,\, 2 \text{ m:} \;\; T_{1/3} = 7 \text{ s} \\ &\text{for } H_i = 3,\, 4 \text{ m:} \;\; T_{1/3} = 9 \text{ s} \\ &\text{for } H_i = 5,\, 6 \text{ m:} \;\; T_{1/3} = 11 \text{ s} \end{aligned}\right\} \text{with } K_d \text{ given in Table 7.2 for different } T_{1/3}$$

Find exceedance probability of H_s for each wave direction, e.g., Fig. 7.3 for wave direction W:



exceedance prob. ($H_i >$ specified H_i) = exceedance prob. ($H_s >$ corresponding H_s) assuming 1 to 1 correspondence between H_i and H_s for given wave direction.

Interpolate exceedance probability versus H_s to find exceedance probability for given $H_s = 0.5, 1.0, 1.5, 2.0, \cdots$ m.

Table 7.5 Result of estimation of the exceedance probability of wave height inside the harbor (percent).

Direction of Offshore Waves	Interior Wave Height H_s					
	Over 0 m	Over 0.5 m	Over 1.0 m	Over 1.5 m	Over 2.0 m	Over 2.5 m
SW	1.4	0	0	0	0	0
WSW	29.0	3.0	0.8	0.4	0.1	0
W	68.2	21.5	6.5	3.0	2.0	1.2
WNW	1.4	0.4	0.1	0	0	0
Total (all directions)	100.0	24.9	7.4	3.4	2.1	1.2

Similar tables at different locations inside the harbor.

Exceedance probability of H_s can be used for:

1) exceedance probability of amplitude of ship motions at a particular berth
2) expected number of workable days of ship operation at a berth
3) comparison of different breakwater alignments

7.2.7 Examination of Storm Wave Height in a Harbor

Port operation under normal wave conditions

versus

Safe anchorage for vessels during storms (rare events)

↑	↑
(H_s = 1 m or less?)	· limited data (several years)
no real quantitative guideline	· may need hindcasting

7.3 Graphical Solution of the Distribution of Wave Height in a Harbor

- Applications of Sec. 3.3 Wave Diffraction
- Read Sec. 3.7 Wave Reflection and Dissipation

The graphical method (subjective + accuracy?) may be useful in interpretation of experimental or computed results.

7.4 Some Principles for Improvement of Harbor Tranquility

(i) The harbor should have a broad interior

- Minimize intrusion of waves from entrance
- Incident wave energy disperses over a large area (less energy at a given location)

(ii) The portion of the waterfront from where the outer sea can be viewed through the harbor entrance should be left as a natural beach or be provided with wave-absorbing revetments (See Figs. 7.7 and 7.8).

(iii) Small craft basins should be located in an area which cannot be viewed directly from the harbor entrance (protected waterfront → avoid direct penetration of waves).

(iv) A portion of the waterfront of a harbor should be reserved as an area of wave energy dissipation to avoid multi-reflection (See example shown in Fig. 7.9).

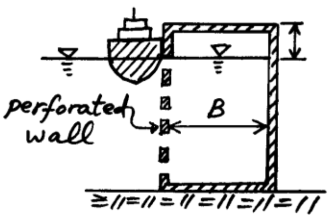
(v) Precautions should be taken against the reflection of waves from the back (reflective) faces of vertical breakwaters (See Fig. 7.10 and Layout of Ulsan New Port).

- Suppress the intrusion of waves into the harbor by modifying the entrance.
- Re-design the breakwater so that the back faces are not reflective.

(vi) Comments on quay walls of the energy dissipating type:

Concrete caissons with perforated or slit front walls

Sudden expansion → eddies → energy dissipation



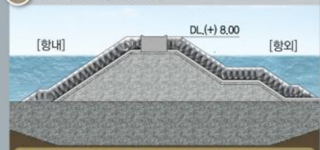
Enough clearance is needed

Width (B) is important: $B/L \cong 0.2$

울산신항 조감도

울산신항은
다양한 형상의 방파제 전시장

1 중앙방파제(삼성물산)

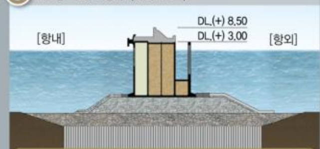


사석경사제 (2000. 01~2005. 06)
- S-berm type (국내 최초)

2 남방파제 1공구(현대건설)

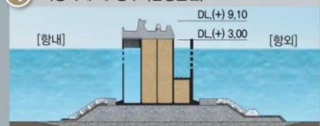
소파블록 피복 케이슨제 (2004. 12~2009. 05)
- 반원형 슬릿케이슨 (국내 최초)

3 남방파제 2공구(대우건설)



케이슨식 혼성제 (2004. 12~ 2009. 05)
- Open 슬릿케이슨 (국내 최초)

4 북방파제 제1공구 (삼성물산)



케이슨식 혼성제 (2008. 12~2011. 09)
- 양면 횡슬릿 (국내 최대 케이슨)
- 다단계 소파형 상치구조 (세계 최초)