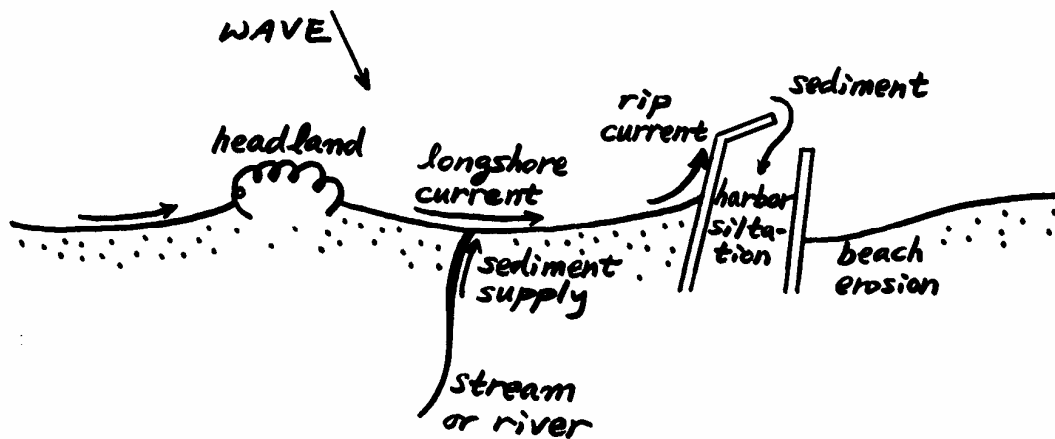
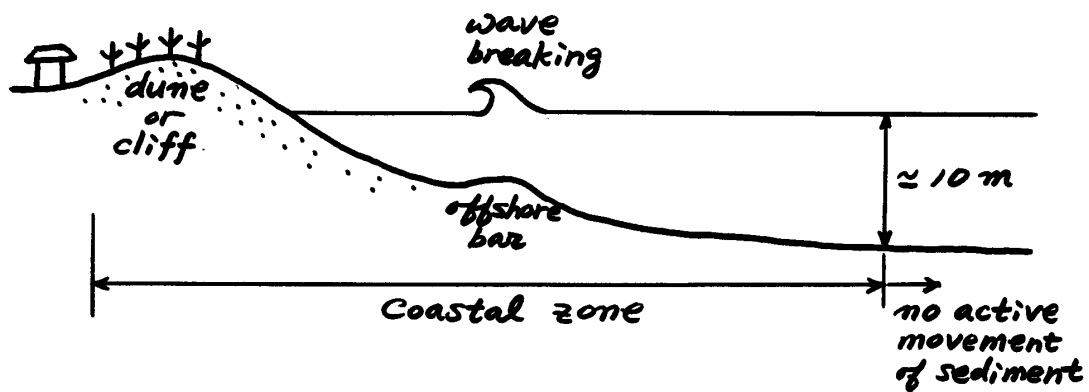


Chapter 8. Coastal Zone Processes

8.0 Introduction



- Stability of beach depends on:
 - (1) sediment supply
 - (2) onshore-offshore transport of sediment
 - (3) longshore transport of sediment
- Equilibrium beach: A beach which is subject to short-term change, but remains stable for a long-term period (over several years).

- Coastal development (construction of structures, dredging, beach nourishment, etc)



Violation of equilibrium state



Beach evolution towards a new equilibrium state

- Effects of coastal development on a beach:
 - (1) Change of sediment supply to the beach
 - Construction of dam or reservoir
 - Change of river passage
 - Beach nourishment or sand mining
 - (2) Change of wave energy flux to the beach
 - Construction of offshore structures or submerged breakwater
 - (3) Interruption of longshore transport
 - Construction of shore-connected structures (e.g., groins or jetties)

8.1 Beach Sediment Properties and Analysis

- Physical properties of sediment
 - Particle size and size distribution
 - Particle shape
 - Specific gravity (ρ_s / ρ) $\cong 2.6$ for sand
 - Fall velocity = f (size, shape, ρ_s / ρ)
- Sediment sampling
 - Beach: shovel or corer
 - Underwater: Grab

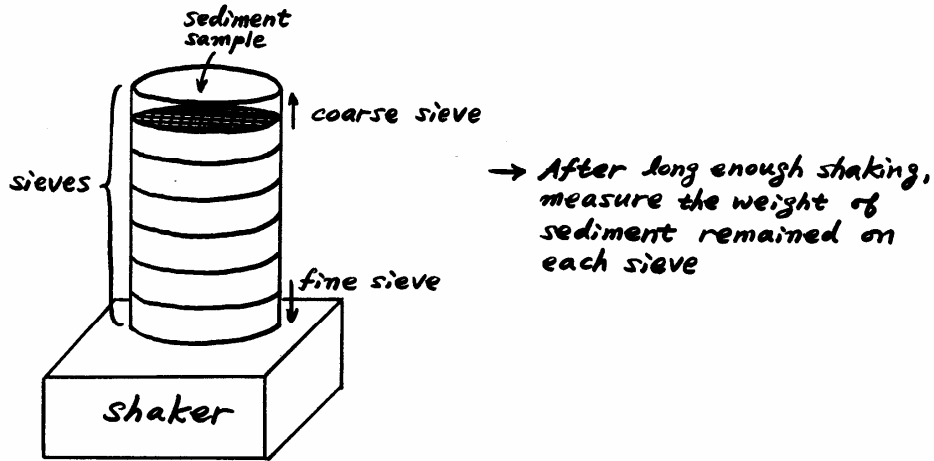
Size and size distribution

- Sediment classification:

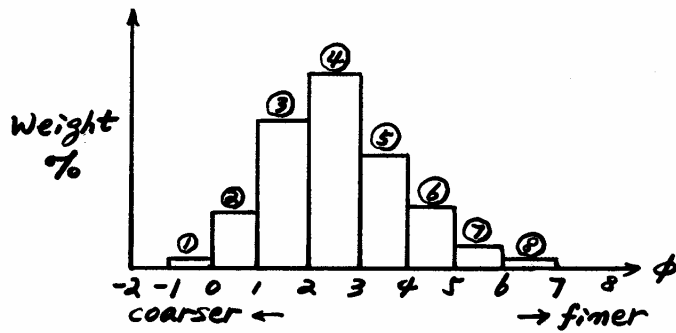
See Table 8.1 of textbook (Wentworth) and SPM Fig. 4-7 (Wentworth and Unified)
- Unit: diameter (d , mm) or ϕ

$$\phi = -\log_2 d(\text{mm}) \rightarrow d = \frac{1}{2^\phi}; \quad \phi \uparrow \text{ as } d \downarrow \text{ and } \phi \text{ can be negative.}$$

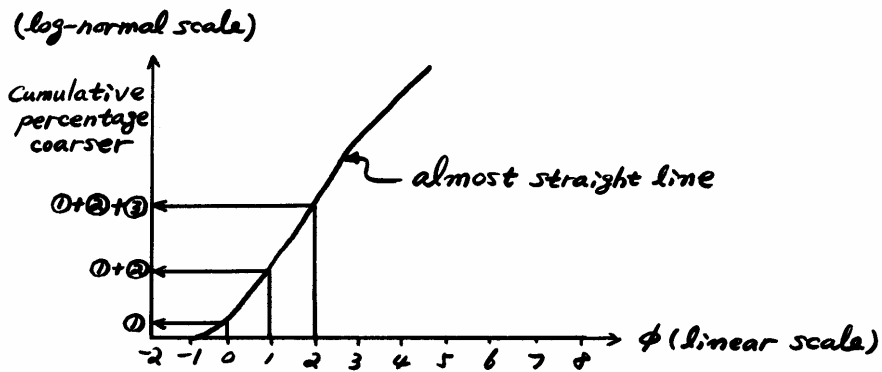
- Size distribution



Histogram of weight percent



Cumulative weight percent curve



- Useful parameters

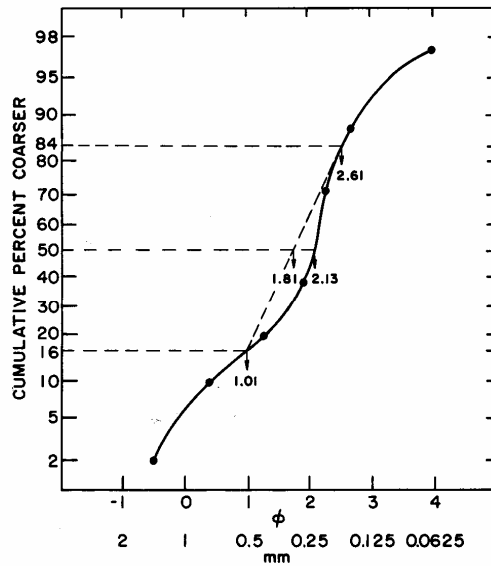


Figure 8.1. Plot of typical sand sample size analysis.

- Median diameter ($M_{d\phi}$; 中央粒徑) = ϕ_{50}
- Mean diameter (M_{ϕ} ; 平均粒徑) = $\frac{1}{2}(\phi_{16} + \phi_{84})$
- Standard deviation (σ_{ϕ} ; 標準偏差) = $\frac{1}{2}(\phi_{84} - \phi_{16})$

small σ_{ϕ} : well sorted, large σ_{ϕ} : poorly sorted

- Skewness (α_{ϕ} ; 歪度) = $\frac{M_{\phi} - M_{d\phi}}{\sigma_{\phi}}$

중앙입경($M_{d\phi}$)을 중심으로 size distribution의 비대칭성

Perfectly symmetric distribution (straight line) $\rightarrow M_{\phi} = M_{d\phi} \rightarrow \alpha_{\phi} = 0$

Note: It is meaningful to convert $M_{d\phi}$ and M_{ϕ} to mm unit, but it is meaningless to

convert σ_{ϕ} and α_{ϕ} to mm unit.

8.2 Beach Profiles and Profile Change

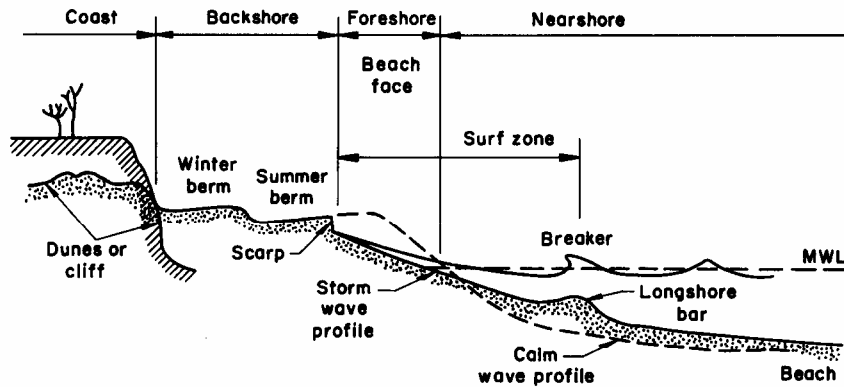


Figure 8.2. Typical beach profiles (vertical scale exaggerated) and terminology.

- Seasonal variation of beach profile

- Storm (or winter) profile:

Storm (high, steep waves) → Erosion of beach face → Offshore movement of sand
 → Offshore bar is formed

- Normal (or summer) profile:

Normal (low, mild waves) → Sediment at offshore bar is transported onshore gradually → Recovery of beach

- Overall beach slope is $\begin{cases} \text{mild for storm profile} \\ \text{steep for normal profile} \end{cases}$

- Large tide area → water level fluctuation → Change of location of wave breaking

→ no prominent offshore bars

- Parameters related to storm/normal profiles

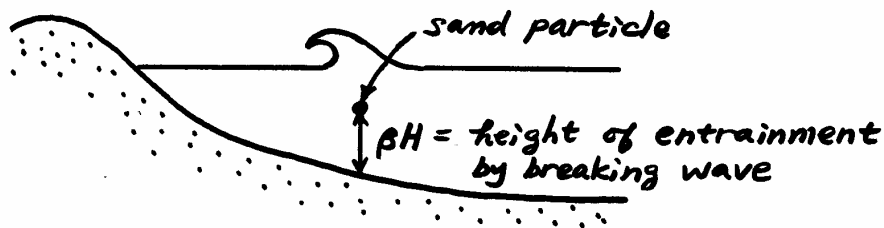
- Wave steepness (H_0 / L_0)

$H_0 / L_0 > 0.025$: Storm profile

$H_0 / L_0 < 0.025$: Normal profile

No consideration on sediment characteristics

- Dean number, $D = \frac{H_0}{V_f T}$; V_f = fall velocity of sediment for median diameter

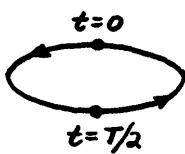


$$\text{Time to fall to bottom} = \frac{\beta H}{V_f}$$

Wave orbital motion

Sand particle w/o wave

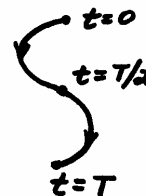
Sand particle under wave



+



=



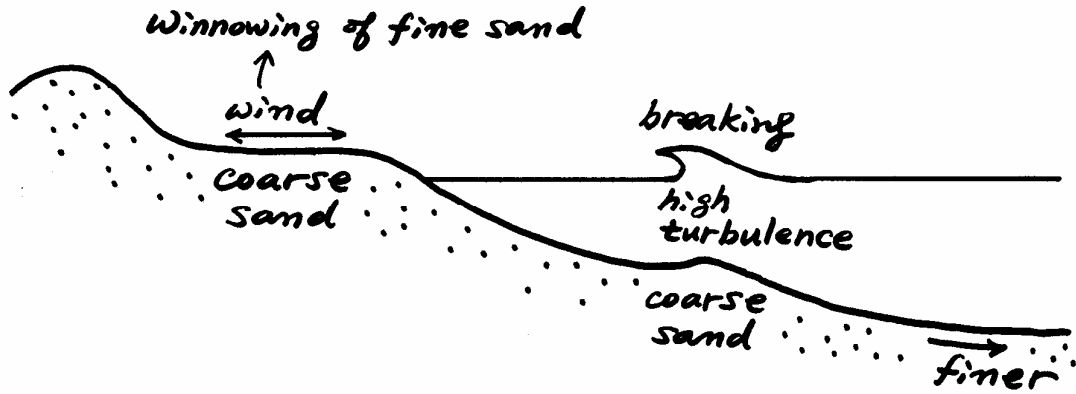
If $\frac{\beta H}{V_f} < \frac{T}{2}$ or $\frac{2\beta H}{V_f T} < 1 \rightarrow$ Onshore transport of sand \rightarrow Normal profile

If $\frac{\beta H}{V_f} > \frac{T}{2}$ or $\frac{2\beta H}{V_f T} > 1 \rightarrow$ Offshore transport of sand \rightarrow Storm profile

β is unknown, which should be determined empirically.

$$D \equiv \frac{H_0}{V_f T} \begin{cases} < 1 & \text{normal profile} \\ > 1 & \text{storm profile} \end{cases}$$

- Sand size variation along beach profile



- Beach slope versus sand size

Coarser sand → Steeper beach slope

Normal profile → Steeper slope

↓

Smaller $\frac{H_0}{V_f T}$ → Larger V_f → Coarser sand

Storm profile → Milder slope

↓

Larger $\frac{H_0}{V_f T}$ → Smaller V_f → Finer sand

8.3 Nearshore Circulation

- Nearshore currents
 - wind-generated currents (吹送流)
 - river outflow
 - tidal currents (潮流)
 - longshore currents (沿岸流): most important for nearshore sediment transport
 - undertow (海向底流)
- Generation mechanism of longshore currents

1) Obliquely incident breaking waves

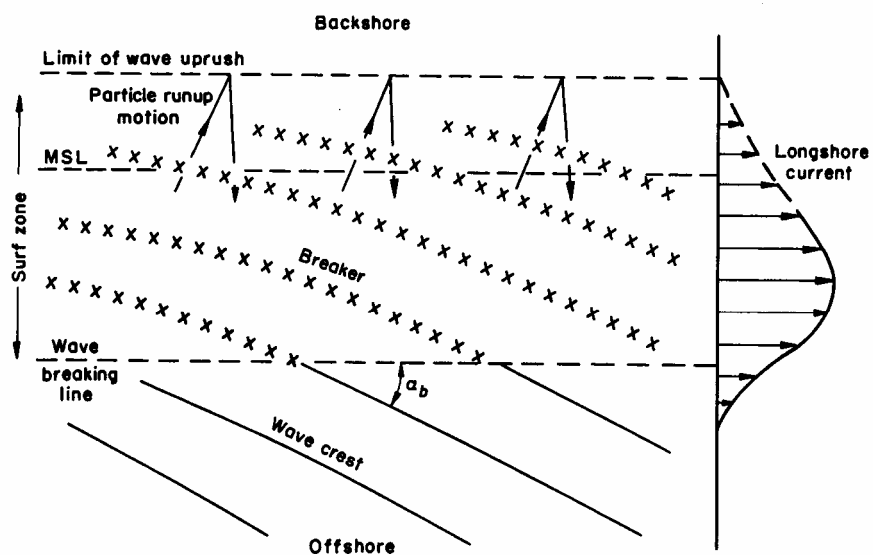


Figure 8.4. Wave-generated longshore current.

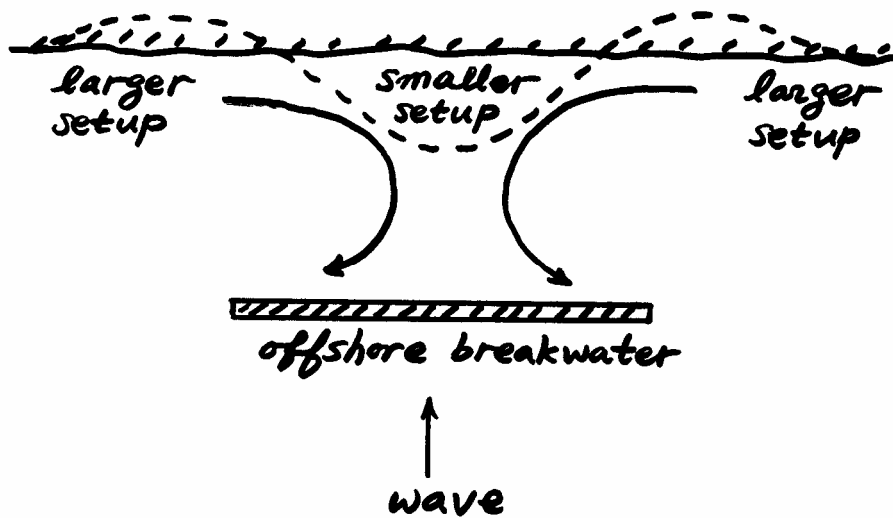
Average longshore current velocity:

$$U = 20.7m\sqrt{gH_b} \sin 2\alpha_b; \quad m = \text{beach slope}$$

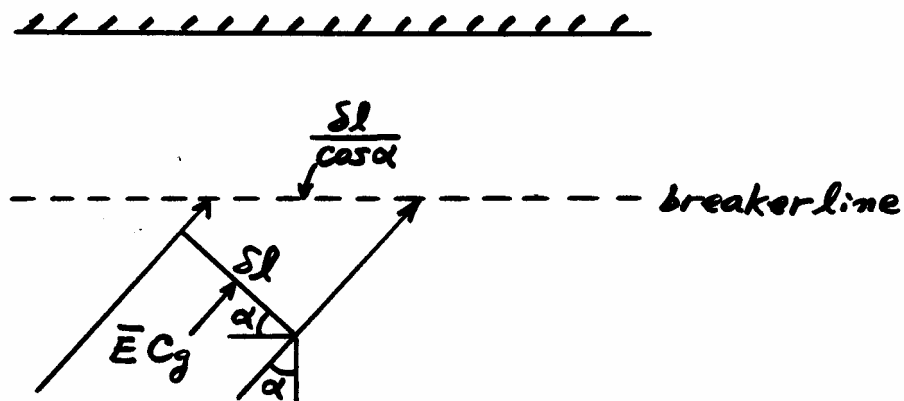
2) Longshore variation of wave setup

In general, larger $H_b \rightarrow$ larger setup \rightarrow increase mean water level. Therefore, the gradient of mean water level generates longshore currents from high water level region to low water level region.

Example)



8.4 Alongshore Sediment Transport Processes and Rates



Q_l = volumetric longshore transport rate [L^3/T]

I_l = immersed weight longshore transport rate [ML/T^3], which has the same dimension as wave energy flux per unit length of beach

$I_l = Q_l(\rho_s - \rho)g(1 - p)$; p = porosity of sand ~ 0.4

Energy flux per δl of crest length = $\overline{EC}_g \delta l$

Energy flux per unit length of beach = $\overline{EC}_g \cos \alpha$

Longshore component of energy flux per unit length of beach = $\overline{EC}_g \cos \alpha \sin \alpha \equiv P_l$

Since I_l and P_l have the same dimension, assume

$$I_l = KP_l$$

where K = empirical constant (~ 0.58 for field data and smaller for laboratory data)

$$Q_l = \frac{KP_l}{(\rho_s - \rho)g(1 - p)}$$

At breaker line,

$$\begin{aligned}
 P_l &= \bar{E}_b C_{gb} \cos \alpha_b \sin \alpha_b \\
 &= \frac{1}{8} \rho g H_b^2 \sqrt{g d_b} \frac{1}{2} \sin 2\alpha_b \\
 &= \frac{1}{16} \rho g H_b^2 \sqrt{g \frac{H_b}{\gamma}} \sin 2\alpha_b \\
 &= \frac{1}{16} \rho \frac{g^{3/2}}{\sqrt{\gamma}} H_b^{5/2} \sin 2\alpha_b
 \end{aligned}$$

$$\therefore Q_l = \frac{K}{(\rho_s - \rho)g(1-p)} \frac{1}{16} \rho \frac{g^{3/2}}{\sqrt{\gamma}} H_b^{5/2} \sin 2\alpha_b$$

We can write

$$Q_l = \Gamma K H_b^{5/2} \sin 2\alpha_b$$

where

$$\Gamma = \frac{\sqrt{g}}{16(s-1)(1-p)\sqrt{\gamma}}; \quad s = \frac{\rho_s}{\rho} = \text{specific gravity of sand}$$

More general equation:

$$Q_l = \Gamma H_b^{5/2} \left[K_1 \sin 2\alpha_b - K_2 \frac{\partial H_b}{\partial x} \cot \beta \cos \alpha_b \right]$$

where $\tan \beta$ = beach slope. The first term represents sediment transport due to oblique incidence of waves, while the second term is due to different wave setup which is important where diffraction effect is dominant. K_1 and K_2 are empirical constants, but they can be used as model calibration parameters for a shoreline evolution model.

8.5 Shore Response to Coastal Structures

- Groin (突堤): 해안에 직각 방향으로 제방을 축조하여 해안에 평행한 방향의 표사 이동을 억제함으로써 해안의 안정성을 도모하는 구조물

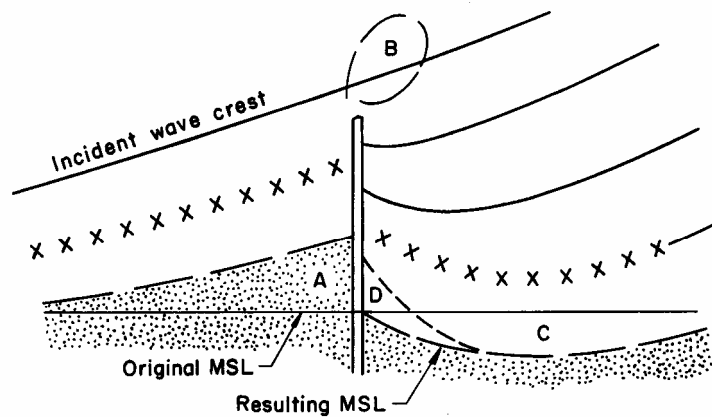


Figure 8.6. Shore response to placement of a shore-perpendicular structure.

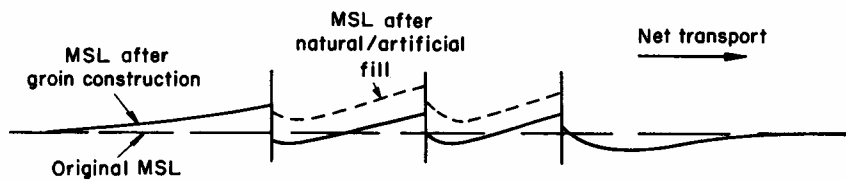


Figure 8.7. Shore response to a series of shore-perpendicular structures.

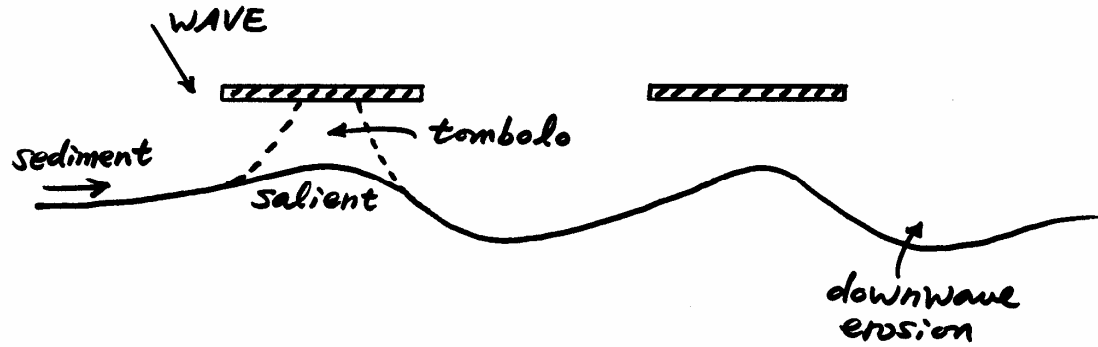


주문진항 남쪽 해안에 설치된 돌제군

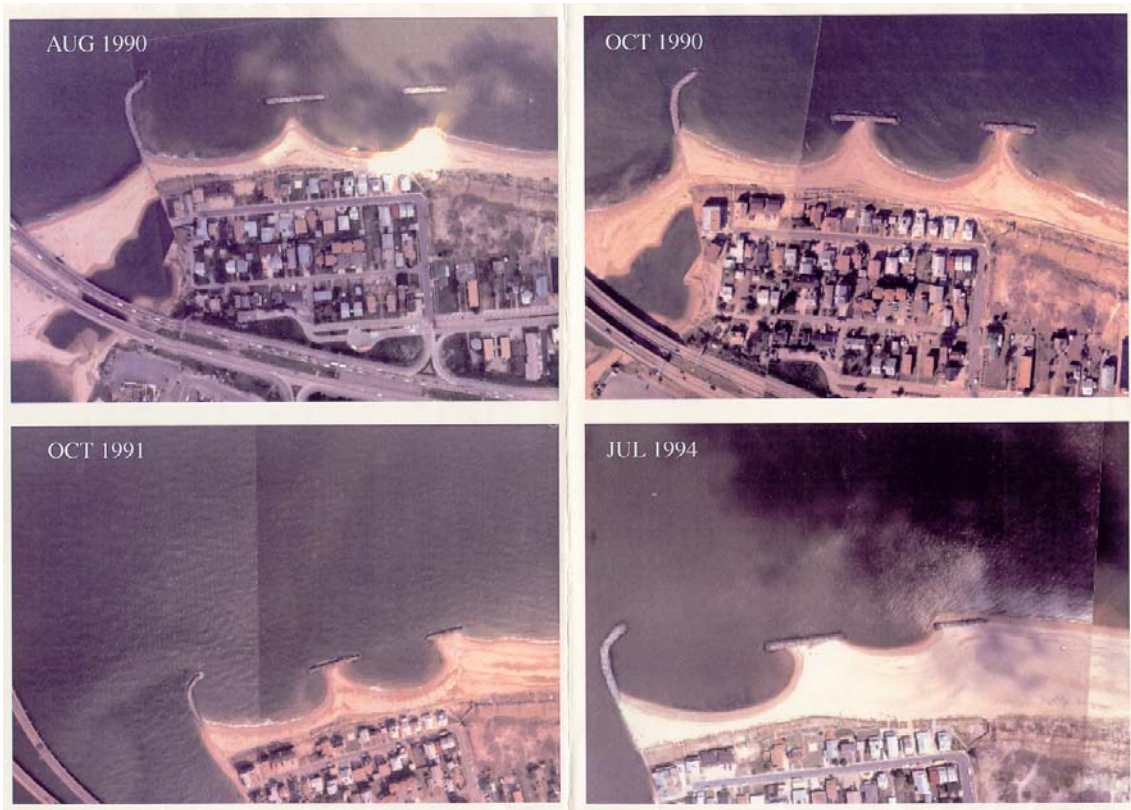
- Jetty (導流堤): 돌제와 마찬가지로 해안에 직각 방향으로 축조하지만 강의 하구 또는 조석 수로 (tidal inlet) 등에 설치하여 선박의 항로 유지 및 매몰 방지를 목적으로 하는 구조물. 돌제에 비해 규모가 훨씬 큼.
- Offshore breakwater (離岸堤): 해안에서 바다 쪽으로 어느 정도 떨어진 거리에 해안에 평행한 방향으로 제방을 축조하여 제방 배후에서의 회절 현상에 의해 표사 이동을 억제함으로써 해안의 안정성을 유지하기 위한 구조물. 구조물의 상부가 수면보다 낮게 축조하는 경우 潛堤(submerged breakwater)라고 부름



Figure 2-27. Wave diffraction at Channel Islands Harbor breakwater, California.

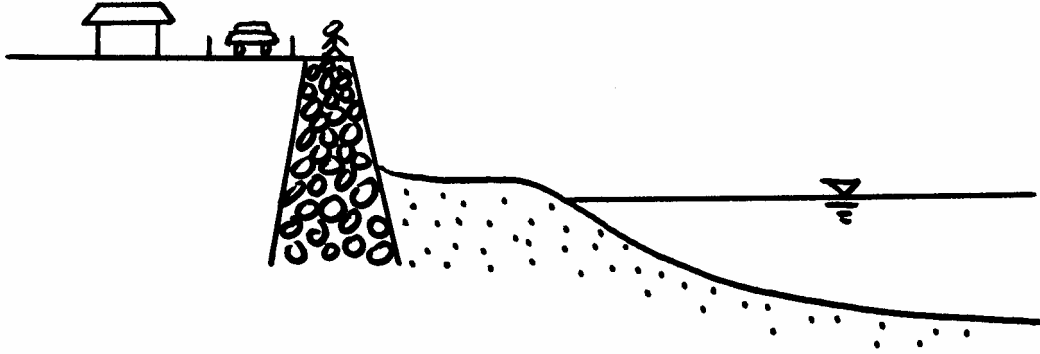


이안제 배후에서 해안선이 전진한 형태를 'salient'라고 부르며, salient가 더욱 성장하여 이안제와 연결된 상태를 'tombolo'라고 부른다.



미국 버지니아주 Willoughby Spit의 이안제 설치후 해안선 변화

- Seawall (護岸): 해안을 따라 제방을 축조하여 해안의 가옥이나 도로 등을 파랑의 직접적인 침입이나 범람으로부터 보호하기 위한 구조물



호안의 경사가 급한 경우 반사파로 인해 호안 전면의 파고가 증가하고 standing wave가 발생하여 호안 전면의 해안이 침식되는 경우가 많으므로 설계 시 주의가 요망됨.

- 해안 보호 구조물의 세계적인 추세

- Line defense: 주로 호안이나 돌제 등을 이용하여 해안선을 따라 구조물을 축조하여 해안을 보호하는 방안

- Zone defense: 이안제, 잠제 등을 이용하여 외해 측에서 파랑 에너지를 감소시켜 해안을 보호하는 방안

Line defense는 육상의 가옥이나 해안도로 등을 보호할 수는 있으나 해안 보호 또는 일반인의 해안 접근 등에서는 바람직하지 않음. 반면에 zone defense는 파랑의 침입을 외해 측에서 차단시킴으로써 해안을 보호하고 일반인의 해안 접근을 용이하게 할 수 있음. 따라서 현재 세계적인 해안 보호 추세는 line defense보다는 zone defense 개념을 도입하는 추세임. 실제로 일본의 경우 최근 통계에 의하면 호안이나 돌제에 비해 이안제의 사용이 급증하고 있음.

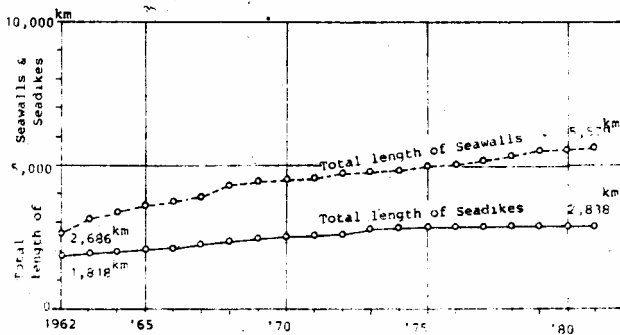


Fig. 1 Increase of seawalls and seedikes in Japan.

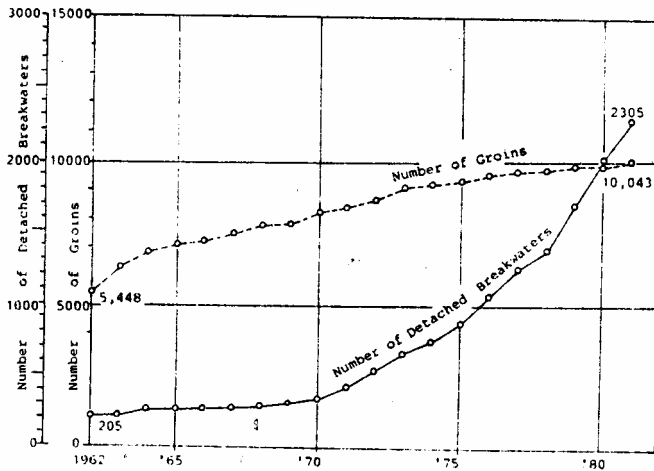


Fig. 2 Increase of groins and detached breakwaters.

8.6 Numerical Models of Shoreline Change

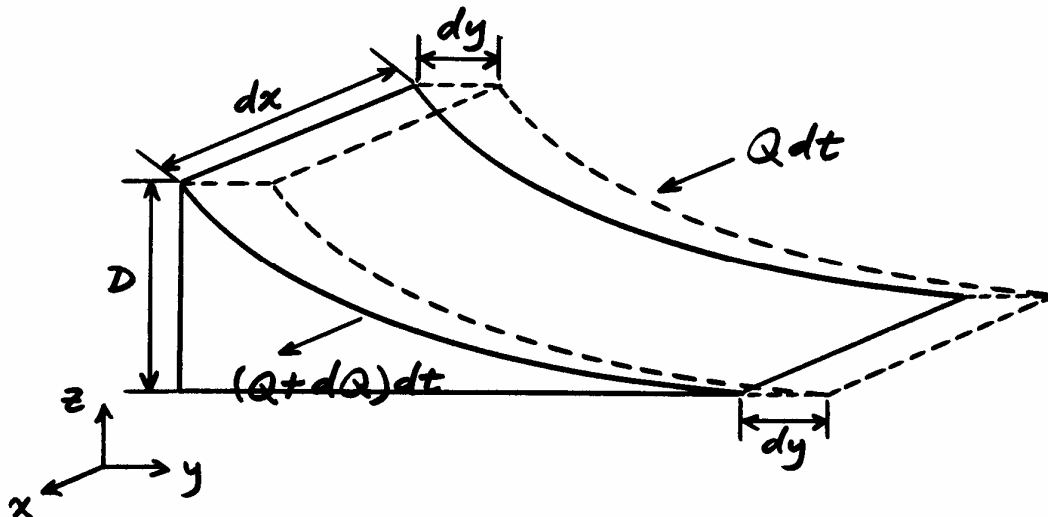
Calculation of H_b and α_b from wave transformation numerical model



Calculation of shoreline change due to longshore transport of sediment

Assumptions:

- (1) The beach profile always has the same shape determined by the equilibrium profile. Therefore, all bottom contour lines are parallel.
- (2) The beach has a fixed depth, D , within which erosion or accretion of beach occurs, and which is called depth of closure and is about 10 m.



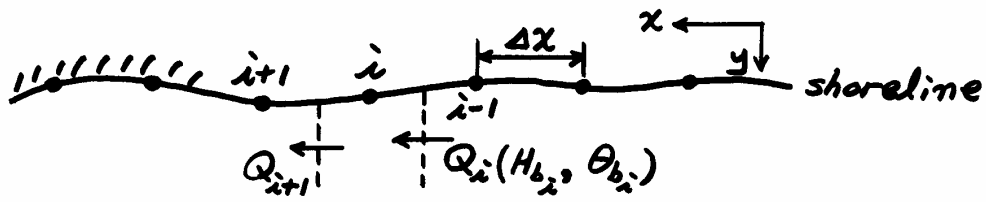
Conservation of sand:

$$D dx dy = Q dt - (Q + dQ) dt = -dQ dt$$

or

$$\frac{dy}{dt} = -\frac{1}{D} \frac{dQ}{dx}$$

which can be solved numerically.



$$\frac{y' - y}{\Delta t} = -\frac{1}{D} \frac{Q_{i+1} - Q_i}{\Delta x}$$

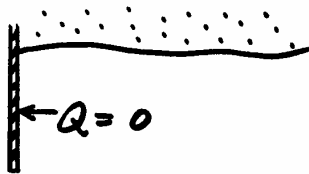
or

$$y' = y - \frac{\Delta t}{D} \frac{Q_{i+1} - Q_i}{\Delta x}$$

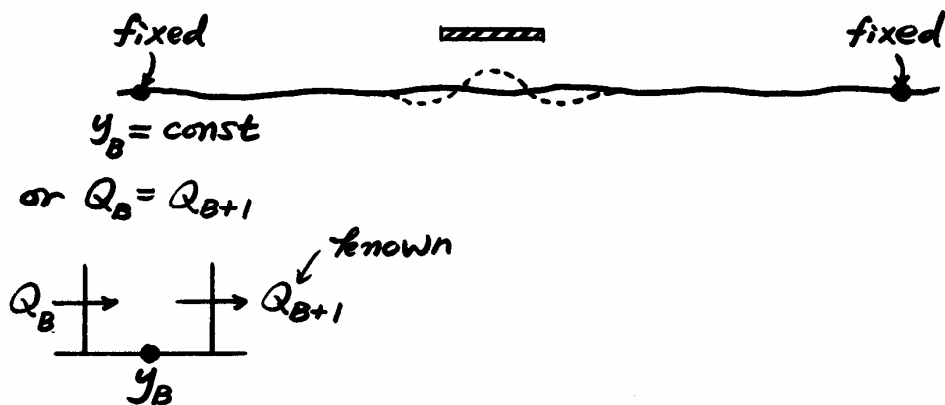
where the prime indicates a new value of shoreline position.

Boundary conditions:

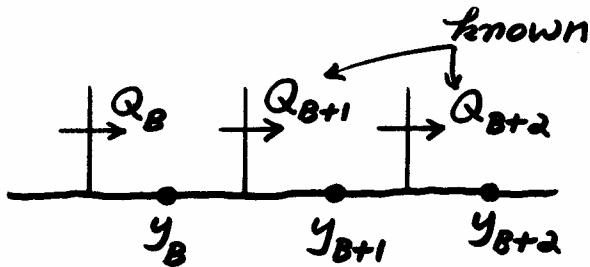
(1) No flux boundary condition (groin or jetty)



(2) Fixed boundary condition: If the boundary is far enough from the source of beach change, assume that the shoreline does not change at the boundary.



(3) Floating boundary condition: Assume linear variation of Q in the vicinity of the boundary.



$$Q_{B+1} - Q_B = Q_{B+2} - Q_{B+1}$$

$$Q_B = 2Q_{B+1} - Q_{B+2}$$

Calculate y_B using Q_B and Q_{B+1} .

8.7 Beach Nourishment and Sediment Bypassing (read text)



미국 플로리다주 Dade 해안의 양빈 전후의 모습

시민 1명당 1000원씩 거둬 백사장 복원 해운대 '모래 트러스트 운동'

부산 해운대구가 시민 1명당 1000원씩의 돈으로 백사장 모래를 복원하는 '샌드 트러스트(Sand Trust)' 운동을 펼친다.

해운대구는 "날로 좁아져 가고 있는 해운대해수욕장 백사장을 살리기 위해 '모래 복원 1000원 샌드 트러스트(Sand Trust)운동'을 전개하기로 했다"고 2일 밝혔다. '샌드 트러스트 운

동'이란 국민의 자발적 헌금이나 기부로 보전할 가치가 있는 자연과 문화유산을 사들이는 '내셔널 트러스트 운동'을 벤치마킹한 것이다. 전국 최고의 해수욕장인 해운대의 백사장은 1947년 폭 70m에 면적 8만9000㎡였으나 57년 뒤인 2004년 폭 38m에 면적 4만8000㎡로 폭과 면적이 절반 가까이 줄었다. 이에 따라 해운대구는 해

수욕장 모래를 복원하기 위해 1990년부터 매년 여름 해수욕장 개장 직전 2800㎡의 모래를 퍼붓고 있다. 지금까지 든 모래값만 6억6000만원에 이른다.

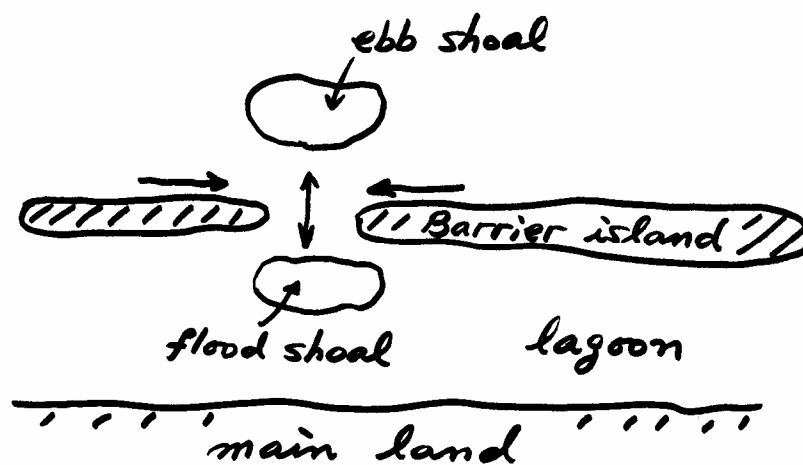
해운대구는 2004년부터 2년 동안 실시한 '해운대 모래복원 사업 타당성 및 기본계획 용역'에서 "미포와 동백섬에 수중 방파제를 설치해야 모래 유실을 막을 수 있다"는 등의 결론을 내렸다. 수중방파제 조성 등에 드는 돈은 492억원. 여기 들어가는 돈을 '샌드 트러스트 운동'을 통해 마련하겠다는 게 해운대구 계획이다.

부산=박주영 기자 park21@chosun.com

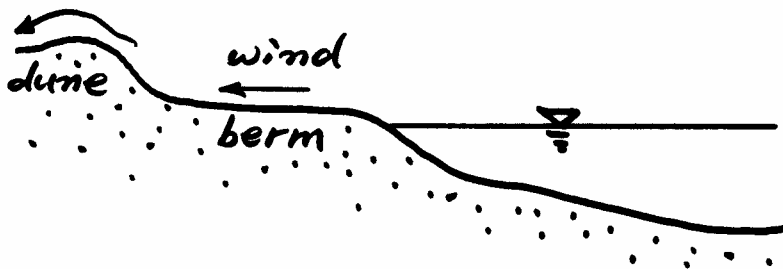
8.8 Wind Transport and Dune Stabilization (read text)

8.9 Sediment Budget Concept and Analysis

- Sources of sand
 - (1) River
 - (2) Coast erosion
 - (3) Beach nourishment
- Sinks of sand
 - (1) Tidal inlets



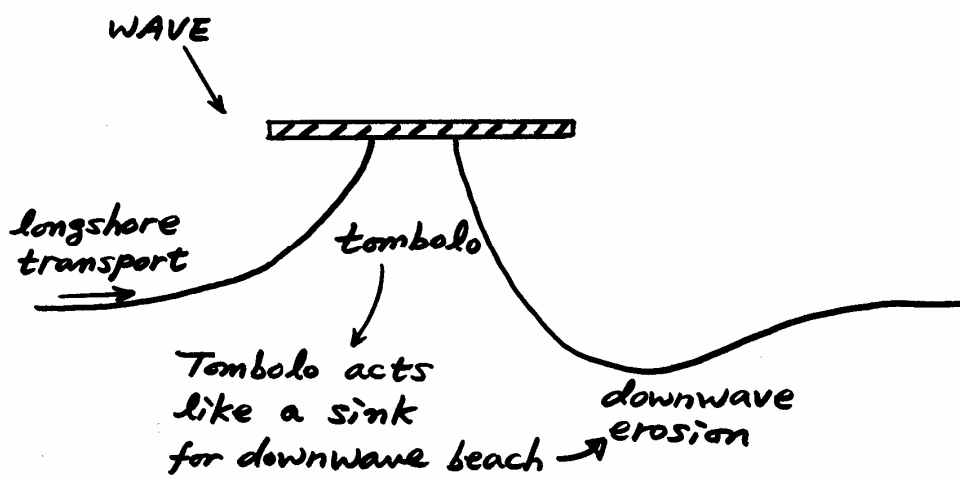
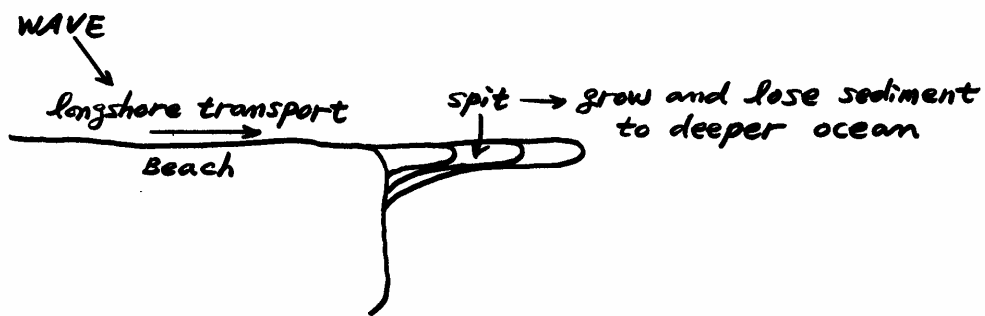
- (2) Wind-driven sand (飛砂)



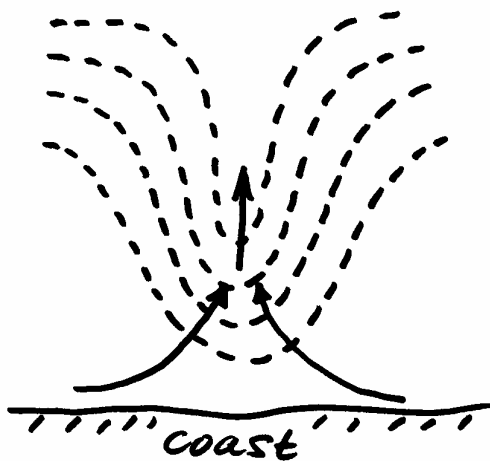
- (3) Offshore deposition

Severe erosion during storms → offshore transport of sand → Not 100% of eroded sand return to the beach during mild wave condition.

- (4) Spits, tombolos, etc.



(5) Submarine canyon



(6) Sand mining: construction material, etc.