# CE 498
# Coastal and Harbor Engineering

*Recitation #4 - Solutions*

A rubble mound breakwater will be constructed at a depth of 7m. Deep water design characteristics are given as $H_{s0}$=6 m and $T_s$=9 sec. The selected damage level for the breakwater is 0-5 percent (S=2). Sea bed slope is 1:20 with straight line parallel bottom contours. The design storm duration is 6 hours.

Find the armor stone weight (W) of the rubble mound breakwater using both Hudson and Van der Meer approaches.

Parameters:

Face slope of the breakwater= 1:2

Refraction coefficient $K_r$ = 1.0

Notional Permeability=0.4

$\gamma_s$= 2.7 t/m$^3$, $\gamma_w$ = l.0 t/m$^3$

$K_{DNB}$ = 4, $K_{DB}$ = 2

# Hudson's Methodology

**CASE 1: NON-BREAKING WAVES**

- $\frac{H_{s,toe}}{d_s} < 0.6 \Rightarrow$ **Non Breaking Waves**
- $H_{design} = H_{1/10,toe} = 1.27 H_{s,toe}$
- $K_D = K_{D,non-breaking}$
- Use Hudson Equation: $W = \frac{\gamma_s H_{design}^3 \tan\alpha}{(S_r - 1)^3 K_{D,non-breaking}}$

**CASE 2: BREAKING WAVES**

- $\frac{H_{s,toe}}{d_s} \geq 0.6 \Rightarrow$ **Breaking Waves**
- $H_{design} = H_b = H_{breaking}$

  $H_{breaking}$ is calculated using depth-limited approach.

  $H_{breaking} = \gamma_{break} d_s$

  where $\gamma_{break}$ is the breaker index can be taken as $0.78$.
- $K_D = K_{D,breaking}$
- Use Hudson Equation: $W = \frac{\gamma_s H_{design}^3 \tan\alpha}{(S_r - 1)^3 K_{D,breaking}}$

# Find $H_{s,toe}$: Regular Wave Transformation

$$H_{s,toe} = H_{s0} \cdot K_s \cdot K_r$$

$$L_0 = 1.56 \cdot T_s^2 = 1.56 \cdot 9^2 = 126.36\,m$$

$$\frac{h}{L_0} = \frac{7}{126.36} = 0.055$$

$$from\ \ GWT \quad K_s = 1.006 \qquad \& \qquad K_r = 1\ \left(given\right)$$

$$H_{s,toe} = H_{s0} \cdot K_s \cdot K_r = 6 \cdot 1.006 \cdot 1 = 6.04\,m$$

# Check the Design Condition

$$\frac{H_{s,toe}}{h} = \frac{6.04}{7} = 0.86$$

$$As \quad \frac{H_{s,toe}}{h} \geq 0.6 \quad \rightarrow \text{ Breaking Condition}$$

# Calculate Stone Size

Breaking Condition $\rightarrow$ $H_{design} = H_b = H_{breaking}$ & $K_D = K_{D,breaking}$

$$H_{design} = H_b = \gamma_{break} \cdot d_s = \gamma_{break} \cdot h = 0.78 \cdot 7 = 5.46m$$

$$W = \frac{\gamma_s \ H^3_{design} \ tan(\alpha)}{(S_r - 1)^3 \ K_{D,breaking}}$$

$$W = \frac{(2.7)(5.46)^3 (0.5)}{\left(\frac{2.7}{1.0} - 1\right)^3 \cdot 2} = 22.4 \ t$$

# Van der Meer's Methodology

- Type of breaking

$$\xi_m = \tan\alpha / \sqrt{(2\pi / g) \times H_{s,toe} / T_m^2)} \qquad \xi_{cr} = \left[6.2P^{0.31}\sqrt{\tan\alpha}\right]^{\frac{1}{P+0.5}}$$

- Plunging: $\xi_m < \xi_{cr}$

$$\frac{H_{s,toe}}{\Delta \; D_{50}} = 6.2P^{0.18}\left(\frac{S}{\sqrt{N}}\right)^{0.2}(\xi_m)^{-0.5}$$

- Surging: $\xi_m \geq \xi_{cr}$

$$\frac{H_{s,toe}}{\Delta \; D_{50}} = 1.0P^{-0.13}\left(\frac{S}{\sqrt{N}}\right)^{0.2}\sqrt{\cot\alpha}(\xi_m)^{P}$$

# Find $H_{s,toe}$: Energy Decay Charts (Van der Meer, 1990)

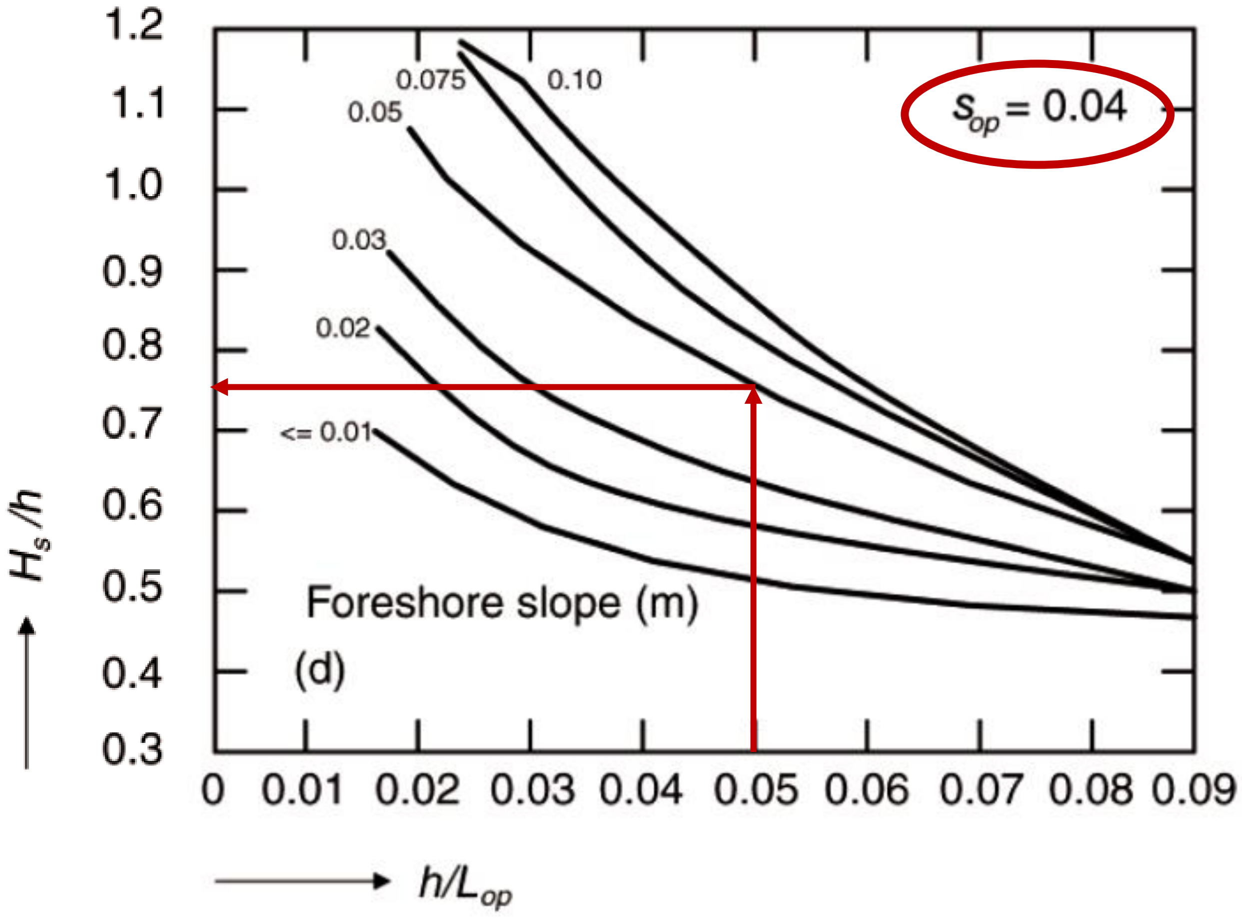
$$T_p = 1.05 \cdot T_s = 9.45\,sec$$

$$L_{op} = 1.56 \cdot T_p^2 = 139.3\,m$$

$$S_{op} = \frac{H_{s0}}{L_{op}} = 0.043$$

$$\frac{h}{L_{op}} = \frac{7}{139.3} = 0.0502 \approx 0.05$$

$$\frac{H_{s,toe}}{h} = 0.76 \text{ from } \mathrm{S_{op}} = 0.04 \text{ graph}$$



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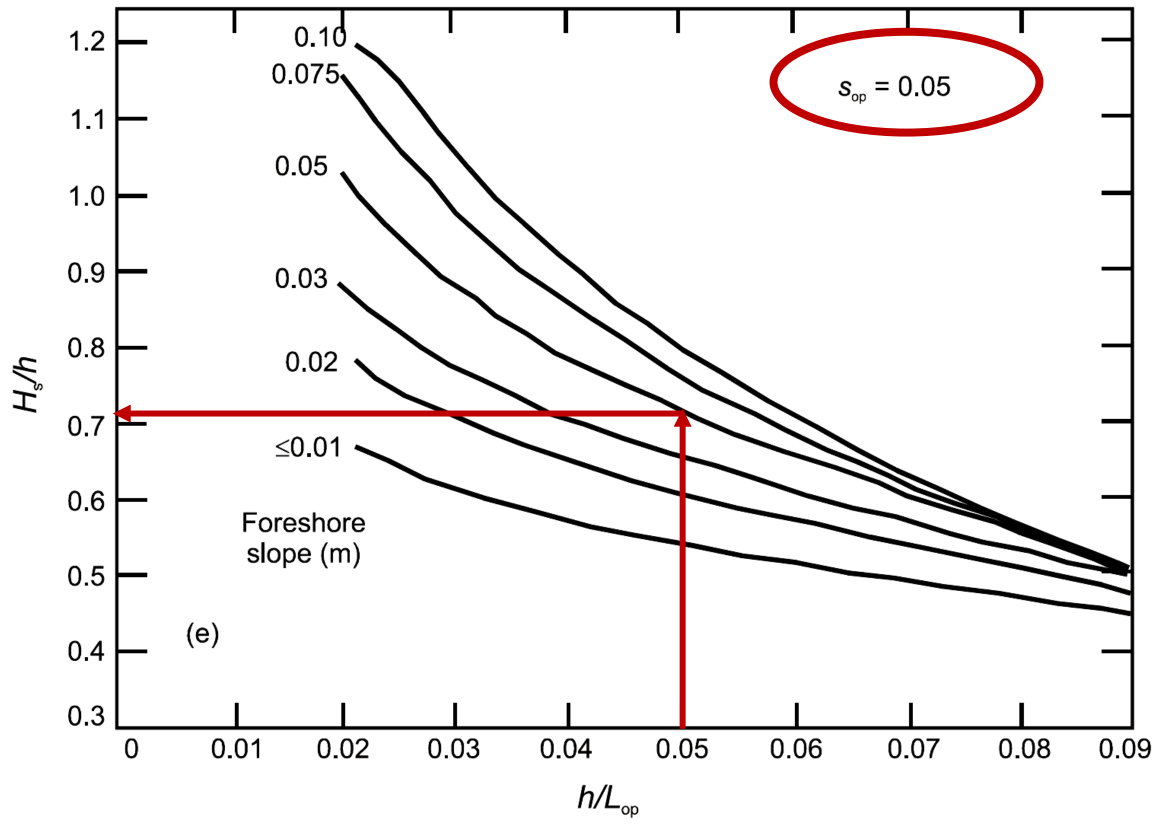

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$\frac{H_{s,toe}}{h} = 0.71$ from $S_{op}=0.05$ graph

$\rightarrow$ By interpolation $\rightarrow \frac{H_{s,toe}}{h} = 0.745 \rightarrow H_{s,toe} = 5.22\,m$

$\frac{h}{H_{s,toe}} = 1.34 \rightarrow$ Although, it is smaller than 3, let's see the results with Van der Meer's Approach to see how to apply the formula!

# Check the Type of Breaker

$$T_m = 0.81 \cdot 9 = 7.29s$$

$$\xi_m = \frac{\tan\alpha}{\sqrt{(2\pi / g) \times H_{s,toe} / T_m^2)}} = \frac{0.5}{\sqrt{(2\pi / 9.81) \times 5.22 / 7.29^2)}} = 1.99$$

$$\xi_{cr} = \left[6.2P^{0.31}\sqrt{tan\,\alpha}\right]^{\frac{1}{P+0.5}} = \left[6.2\left(0.4\right)^{0.31}\sqrt{0.5}\right]^{\frac{1}{0.4+0.5}} = 3.77$$

As $\xi_m < \xi_{cr} \rightarrow$ Plunging

# Calculate Stone Size

$$\frac{H_{s,toe}}{\Delta\ D_{50}} = 6.2P^{0.18}\left(\frac{S}{\sqrt{N}}\right)^{0.2}(\xi_m)^{-0.5}$$

$$N = \frac{\text{storm duration}}{T_m} = \frac{6 \cdot 3600}{7.29} = 2963 \text{ waves}$$

$$\frac{5.22}{\left(\frac{2.7}{1.0} - 1\right)\ D_{50}} = 6.2\,(0.4)^{0.18}\left(\frac{2}{\sqrt{2963}}\right)^{0.2}(1.99)^{-0.5}$$

$$D_{50} = 1.6\ m \quad \rightarrow \quad W_{50} = \gamma_s\ D_{50}^3 = 11.1\, tons$$

# Results

- Hudson’s Approach: 22.4  tons
- Van der Meer’s Approach: 11.1 tons