**NANYANG TECHNOLOGICAL UNIVERSITY**

**SEMESTER 2 EXAMINATION 2015-2016**

**CV4116 - COASTAL ENGINEERING**

**April / May 2016** Time Allowed: 2½ hours

**INSTRUCTIONS**

1. This paper contains **FOUR (4)** questions and comprises **FOUR (4)** pages.
2. Answer **ALL** questions.
3. All questions carry equal marks.
4. All answers must be written in the answer book provided.
5. This is a Restricted Open Book Examination. Only **ONE (1) Sheet** of A4 paper with handwritten notes on both sides is allowed.
6. A separate booklet of tables and charts is issued together with the paper. Do not write on this booklet.

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1. (a) A beach is constantly under attack by deepwater waves with a period of 10 s approaching at an angle $\alpha_o$ of 15°. The beach slope is generally linearly varying, and the sand particle is rather coarse with a $d_{50}$ of 1 mm corresponding to a settling velocity of 0.15 m/s. The densities for sand ($\rho_s$) and seawater ($\rho$) are 2650 and 1030 kg/m³, respectively. Given that the maximum bottom velocity before the sand particles begin to move is:

$$U_{max(-d)} = [8(\rho_s/\rho - 1)gd_{50}]^{0.5}$$

What is the minimum deepwater wave height, $H_o$, in order to initiate the sand motion at a depth of 10 m? (12 Marks)

(b) (i) The above beach has in fact been experiencing erosion over the years. Based on Dean's criteria, what would be the minimum $H_o$ that is attacking the beach?

(ii) Two different protection options, namely headland breakwaters and detached breakwaters, are being considered. Discuss their differences and sketch the layouts with these two options.

(iii) Instead of the hard options in b(ii), the soft measure of beach nourishment is also being considered. Discuss the concept of "Working with Nature" as compared to what is being done at present for beach nourishment.

(13 Marks)



Settling V = 0.15 m/s

1)(a) $U_{max(-d)} = [8(\rho_s/\rho - 1) g d_{50}]^{0.5} = \left[8\left(\frac{2650}{1030} - 1\right) g (0.001)\right]^{0.5} = 0.35$ m/s

T = 10 s

d = 10 m

$\frac{d}{gT^2} = \frac{10}{g(10)^2} = 0.0101$ , $\theta_o = 15°$

$K_r K_s = 0.97$

$H = K_r K_s H_o$

$H = 0.97 H_o$

$1.667 = 0.97 H_o$

$H_o = 1.718$ m

~~$L = L_o = \frac{gT^2}{2\pi} = \frac{g(10)^2}{2\pi} = 156.13$~~

Deep water

$u = \frac{\pi H}{T} e^{\left(\frac{2\pi z}{L}\right)} \cos\theta$

$0.35 = \frac{\pi H}{10} e^{\frac{2\pi(-10)}{156.13}}$

$H = 1.667$

(b)(i) Dean: $F_o = \frac{H_o}{V_f T}$

For erosion: $F_o > 2 \Rightarrow \frac{H_o}{V_f T} > 2$

$\therefore H_o > 2 V_f T$

$H_o > 2(0.15)(10)$

$H_o > 3$ m

(ii) Part 2 lec 4 (pg 15)

2) (a)





2. (a) Show, by derivation from first principle, that the potential energy density due to the wave motion is equal to $\rho g H^2/16$.

(7 Marks)

(b) Two pressure sensors are located as shown in Figure 2b below. For an 8 s progressive wave, the maximum dynamic pressure (the portion induced by the wave motion) at Sensors 1 and 2 are $1.04\times10^3$ N/m$^2$ and $1.28\times10^3$ N/m$^2$, respectively. What are the water depth d, wave height, and wave length? The following values may be used: g = 9.81 m/s$^2$, ρ=1025 kg/m$^3$.

(10 Marks)

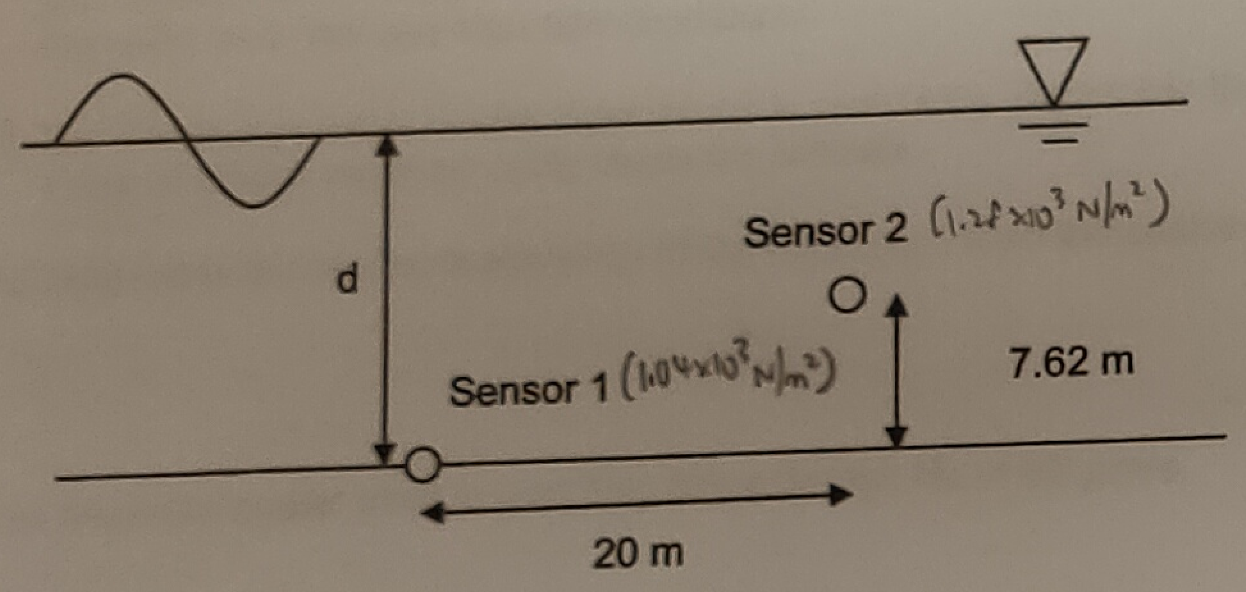


Figure 2b

(c) Given the values of water depth d and wave height in 2(b), if Sensor 2 is now moved to an area with a 5 degree slope in the sea bed as shown in Figure 2c, what will be the maximum and minimum pressures recorded by Sensor 2?

(8 Marks)

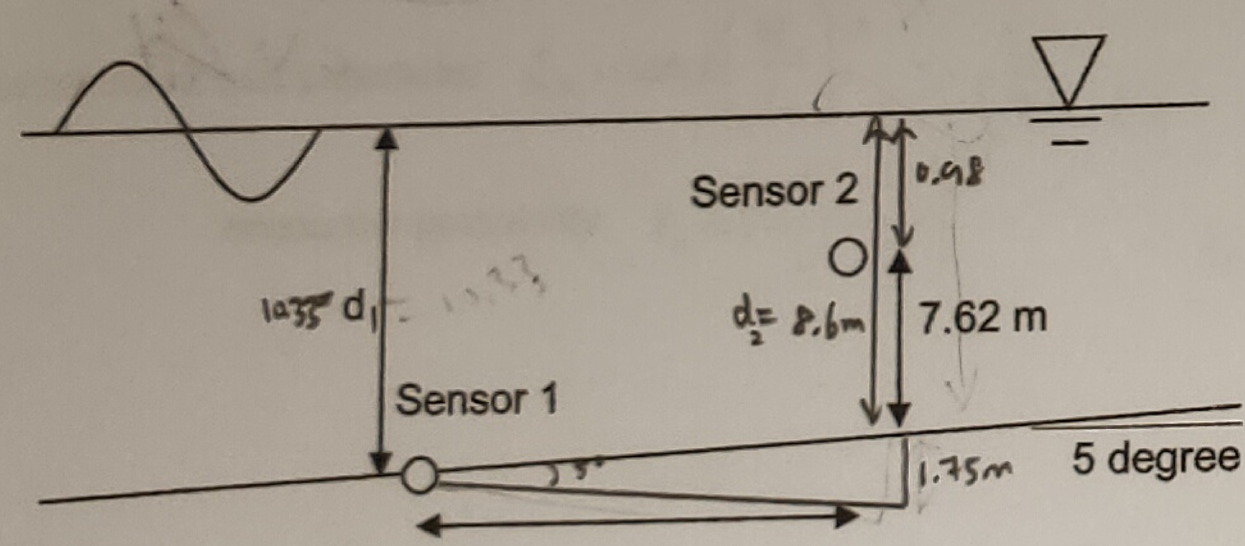


Figure 2c

$\tan 5 = \frac{y}{20}$

$y = 1.75$m





$p = \rho g \eta \frac{\cosh[\frac{2\pi}{L}(z+d)]}{\cosh(2\pi d/L)} - \rho g z = \frac{\rho g H}{2}\frac{\cosh(k(z+d))}{\cosh(kd)} \cancel{- \rho g z}$

$k = \frac{2\pi}{L}$

No need minus $\rho g z$ ?

2) (b) Sensor 1: $y=-d$, max dynamic pressure, $p_1 = \frac{\rho g h}{2}\left(\frac{1}{\cosh(kd)}\right) \cancel{-\rho g(-d)}$ ? ①

Sensor 2: $y = -d+7.62$, $p_2 = \frac{\rho g h}{2}\frac{\cosh(7.62k)}{\cosh(kd)} - \cancel{\rho g(-d+7.62)}$ ?

thus $\frac{p_2}{p_1} = \cosh(7.62k) = \frac{1.28\times10^3}{1.04\times10^3}$

$7.62k = 0.6669$

$k = 0.0875$

$\frac{d}{L} =$

$\frac{2\pi}{L} = 0.0875$

$L = 71.78$ m

T=8s, $L = \frac{gT^2}{2\pi}\tanh\left(\frac{2\pi d}{L}\right)$

$71.78 = \frac{g(8)^2}{2\pi}\tanh\left(\frac{2\pi d}{71.78}\right)$

$0.7183 = \tanh\left(\frac{2\pi d}{71.78}\right)$

$\frac{2\pi d}{71.78} = 0.904$

$d = 10.33$ m

From ①

$1.04\times10^3 = \frac{\rho g H}{2}\frac{1}{\cosh(kd)}$ ? 10.33 0.0875

H=0.297m

H=0.3m

(c) At sensor 2: $z = -0.98$m $kd = \left(\frac{2\pi}{L}\right)d = \frac{2\pi}{66.8}(8.6) = 0.8089$

$L = \frac{gT^2}{2\pi}\tanh\left(\frac{2\pi d}{L}\right) = \frac{g(8)^2}{2\pi}\tanh\left(\frac{2\pi(8.6)}{L}\right) = 66.8$m

• $K_s = \sqrt{\frac{1}{\tanh(kd)\left[1+\frac{2kd}{\sinh(2kd)}\right]}} = 0.92$ where $kd = \left(\frac{2\pi}{L}\right)d = \frac{2\pi}{\cancel{66.8}\ 71.3}(10.33) = 0.9772$ ($d_1$)

No refraction: $H_1 = K_s H_0$

$0.3 = 0.92 H_0$

$H_0 = 0.325$m

• At $d_2 \rightarrow kd = \left(\frac{2\pi}{L}\right)d = \frac{2\pi}{66.8}(8.6) = 0.808 \rightarrow$ get $K_s = 0.93$

$H = K_s H_0$

$= 0.95(0.325)$

$= 0.30875$m

At sensor 2: $P_{wavg} = \rho g \frac{H}{2}\frac{\cosh(2\pi(z+d)/L)}{\cosh(2\pi d/L)}$

$= 1025(9.81)\left(\frac{0.30875}{2}\right)\frac{\cosh(2\pi(-0.98+8.59)/66.8)}{\cosh[2\pi \times 8.59/66.8]}$

$= 1.463\times10^3$

Max pressure $= 1.463\times10^3 - \rho g z = (1.463\times10^3) - \rho g(-0.98) = 11.22\times10^3$ N/m$^2$

Min P $= -1.463\times10^3 - \rho g z = -1.463\times10^3 - \rho g(-0.98) = 8.29\times10^3$ N/m$^2$

3\. (a) A quarrystone revetment is used to protect a small offshore island created by reclamation and on which a power generation plant is proposed to be built. The sea at this site has a mean water depth of 4 m and a semi-diurnal tidal range of 2 m. The significant wave height is 2 m and the wave period is 8 s. The density of the rough quarrystones available for construction is 2600 kg/m³ and that of seawater is 1025 kg/m³. The revetment has a design slope of 1V:3H and uses stones of 2 units thick.

(i) Considering the type of installation proposed, what is the design wave height you would use in sizing the stones for the revetment? Provide brief reasons. Consider both low and high tide conditions.

(ii) For the design wave height determined in part (a)(i), determine the minimum mass of stones required using Hudson's formula.

(iii) Determine the minimum elevation of the revetment from the seabed.

(17 Marks)

(b) The proposed power plant in part 3(a) has a design life of 60 years.

(i) What is the return period of the wave would you need to consider if the encounter probability of this wave is not to exceed 5% over the 60 year design life?

(ii) The design life is sufficiently long that climate change effects need to be considered. Describe two possible effects which may impact on the design of the revetment.

(8 Marks)

Useful formulas: surf parameter $\xi_{om} = \tan\beta\left(\frac{H_s}{L_o}\right)^{-\frac{1}{2}}$

encounter probability $P_e = 1-\left(1-\frac{1}{T_r}\right)^L$



3(a) $H_s = 2\text{m}$, $T = 8\text{s}$

Mean depth $d = (4 \pm 1) = (3, 5)$

(i) Design $H_{1/10} = 1.27 H_s = 1.27(2) = 2.54\text{ m}$

check breaking:

low tide $= \frac{H_{1/10}}{d} = \frac{2.54}{3} = 0.847$ (breaking)

use $H_b = 0.78 d_s = 0.78(3) = 2.34\text{m}$

high tide $= \frac{H_{1/10}}{d} = \frac{2.54}{5} = 0.508$ (x breaking)

use $H_{1/10} = 2.54$

(ii) Hudson: $M = \frac{\rho_s H^3}{K_D\left(\frac{\rho_s}{\rho_w}-1\right)^3 \cot\alpha}$

SPM Table 7.8 → Rough quarry stone, 2 unit

$\tan\theta = \frac{1}{3}$

$\cot\theta = \frac{3}{1}$

$\boxed{\text{Slope} = \cot\alpha = 3}$

$K_D = ?$ $\rho_w$

| | Breaking (Low tide) | x breaking (High tide) |
|---|---|---|
| Structure Trunk | $M = \frac{2600(2.34)^3}{2\left(\frac{2600}{1025}-1\right)^3(3)} = 1530$ kg | $M = \frac{2600(2.54)^3}{4\left(\frac{2600}{1025}-1\right)^3(3)} = 979$ kg |
| Structure Head | $M = \frac{2600(2.34)^3}{1.3(2.6-1)^3(3)} = 2085$ kg | $M = \frac{2600(2.54)^3}{2.3(2.6-1)^3(3)} = 1508$ kg |

high tide ↓

(iii) Crest elevation $= 5 + R$

CEM Fig VI-5-12: $\tan\beta = \frac{1}{3}$

$L_o = \frac{gT^2}{2\pi} = \frac{g(8)^2}{2\pi} = 99.92$

$\xi_{om} = \tan\beta\left(\frac{H_s}{L_o}\right)^{-\frac{1}{2}} = \frac{1}{3}\left(\frac{2}{99.92}\right)^{-\frac{1}{2}} = 2.36$

Assume $p = 0.1$, little overtopping allowed ⇒ use $R_{2\%}$

$\therefore \frac{R_{2\%}}{H_s} = 1.6$

$R_{2\%} = 1.6 \times H_s = 3.2\text{m}$

$\therefore$ Crest elevation $= 5 + 3.2 = 8.2\text{m}$

(b) (i) $P_e < 0.05$

$1 - \left(1 - \frac{1}{T_R}\right)^{60} < 0.05$

$\left(1 - \frac{1}{T_R}\right)^{60} > 0.95$

$1 - \frac{1}{T_R} > 0.999$

$-\frac{1}{T_R} < 0.000854$

$T_R > 1170$

(b)(ii)

4. A vertical wall breakwater is proposed to protect a coastal harbour. The design water depth is 2.5 m and the nearshore slope in the area is 1:50 with depth contours being parallel to the trunk of the breakwater. It is initially determined that deep water waves with wave height $H_o$ 1.7 m and period 9 s propagating at normal incidence towards the breakwater trunk will result in breaking waves at the breakwater.

$\theta = 90°$ ?

(a) Using the breaker depth index and CEM Figure II-4-2, determine the breaking wave height $H_b$ and show that this $H_b$ is consistent with the design depth used. (6 Marks)

(b) Calculate the maximum total force on the breakwater using Minikin's method for breaking waves. Assume calm wave water conditions on the lee side of the breakwater and a seawater density of 1025 kg/m³. (10 Marks)

(c) Calculate the surf parameter and briefly describe the characteristics of the expected breaker type. (4 Marks)

(d) Briefly discuss on the suitability of using Minikin's method versus using Goda's method for determining the maximum wave force in this case. (5 Marks)

Useful formulas: Breaker depth and height indices and surf parameter

$$\gamma_b = H_b / d_b \quad ; \quad \Omega_b = \frac{H_b}{H_o} = 0.56\left(\frac{H_o'}{L_o}\right)^{-\frac{1}{5}} \quad ; \quad \xi_o = \tan\beta\left(\frac{H_o}{L_o}\right)^{-\frac{1}{2}}$$

0.02 $-\frac{1}{2}$

**END OF PAPER**





4) $H_{design} = 2.5$ m

$d = 2.5$ m

Slope : 1:50 , $\tan\beta = 0.02$

$H_o = 1.7$ m, $T = 9$ s

(a)

| Iteration | $H_b$ | $\frac{H_b}{gT^2}$ | get $\frac{H_b}{d_b}$ | $H_b = \_ \times d_b$ (2.5) |
|---|---|---|---|---|
| 1 | 3m | 0.0038 | 0.85 | 2.125m |
| 2 | 2m | 0.0025 | 0.86 | 2.15m |
| 3 | 2.1m | 0.0026 | 0.86 | 2.15m |

$H_b \approx 2.1$ m

(a) $\Omega_B = 0.56\left(\frac{H_o'}{L}\right)^{-0.2} = \frac{H_b}{H_o}$

CEM Fig II-3-6

$H_o' = K_R H_o$

CEM Fig II-3-6

- $\frac{d}{gT^2} = \frac{2.5}{g(9)^2} = 0.00315$, $\theta = 0°$

- $K_R = 1.0$

$H_o' = K_R H_o = (1.0)(1.7) = 1.7$ m

Deep water wavelength, $L_o = \frac{gT^2}{2\pi} = \frac{g(9)^2}{2\pi} = 126.47$ m

$\Omega_B = 0.56\left(\frac{H_o'}{L_o}\right)^{-0.2} = 0.56\left(\frac{1.7}{126.47}\right)^{-0.2} = \frac{H_b}{H_o}$

$1.33 = \frac{H_b}{1.7}$

$H_b = 2.25$ m (continue)

Fig II-4-2

$\frac{H_b}{gT^2} = 0.00283$,

$\frac{H_b}{d_b} = 0.9$

$H_b = 0.9(2.5)$

$= 2.25$ m

(b) Minikin's method

SPM Fig 7-100 : $\frac{d}{gT^2} = \frac{2.5}{g(9)^2} = 0.0031$

$m = 0.02 \, \frac{1}{50}$

$\frac{3R_m}{\rho g H_b^2} = 8.5$

$\frac{3R_m}{1025(9.81)(2.25)^2} = 8.5$

$R_m = 144.23$ kN

(c) $\xi = \tan\beta\left(\frac{H_o}{L_o}\right)^{-\frac{1}{2}}$

$= 0.02\left(\frac{1.7}{126.47}\right)^{-\frac{1}{2}} = 0.173 < 0.5$ (Spilling)

Spilling = Crest becomes unstable & cascades down shoreward face ; mild breaking

(d) Minikin's Method will be very conservative & costly, b/c it accounts for peak pressures (air pockets) & wave slamming force.

For this breaking case of spilling, use Goda's method which calcs for slower breaking.