UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: August-September 2018

Module Number: CE 7251

Module Name: Coastal Engineering Applications and Management

[Three Hours]

[Answer **all questions**, each question carries TWELVE marks, Use wave table given in the Appendix]

Q1 (a) Explain how (i) longshore currents (ii) tidal currents are generated using sketches if necessary. Describe why they are important for coastal engineering ?.

[4 marks]

(b) Choose appropriate coastal defence policy option/s from Shoreline Management Plan (SMP) for the following areas where there is severe coastal erosion ?. Explain the reasons for your choice.

(i) Galle face, Colombo
(ii) An unpopulated coastal area in the eastern province

[4 marks]

(c) (i) Define the Coastal Zone of Sri Lanka (ii) Describe the statutory functions of the Department of Coast & Coastal Resources Conservation.

[4 marks]

Q2 As shown in Figure Q2, a platform supported on a cylindrical monopole with diameter, D=3.0m, to gather metocean data is planned in the coastal sea at h=10m water depth. Design environmental data are provided below.

Wave height, H= 4m, wave period, T= 8 seconds
Maximum tidal current speed (U_c): 1 m/s
Wind speed (U_w): 40 m/s

(a) Linearised form of the velocity potential of a surface gravity wave is given by:

$$\phi = \frac{gH}{2\omega}\frac{\cosh k(z+h)}{\cosh(kh)}\sin(kx - \omega t) \quad \text{-------------Eq. 2.1}$$

Derive horizontal wave orbital velocity (U) and acceleration (a_x) at the mid-depth, i.e., z = - 0.5h for (kx-ωt) = π/4.

[4 marks]

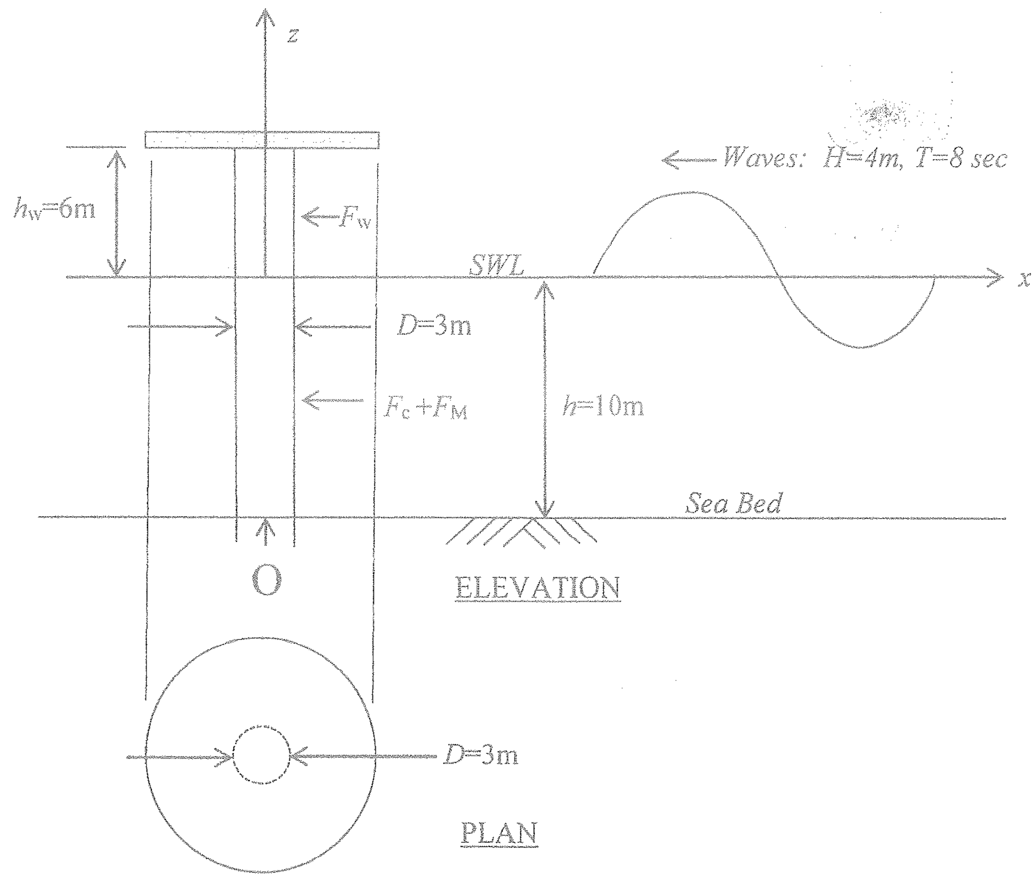


Figure Q2 Side view and plan of the monopile

(b) Calculate drag and inertia forces and total wave force ($F_M = F_D + F_I$) on the monopile for $(kx-\omega t) = \pi/4$. Assume horizontal wave orbital velocity and acceleration at the mid-depth are applicable to the full submerged part of the monopile.

Drag force, $F_D = \frac{1}{2}\rho C_D A U^2$ ---------------Eq. 2.2

Inertia force, $F_I = \rho C_M \forall a_x$ ---------------Eq. 2.3

Where, A= cross sectional area = $D \times h$ and the displaced volume of water, $\forall = \frac{\pi D^2}{4} h$, C_D=0.7, C_M=2.0, density of water, ρ=1030 kg/m³.

[3 marks]

(c) Calculate drag force (F_c) due to tidal current (U_c) using C_D=0.7 in Equation 2.4. Assume Inertia force is negligible.

Drag Force, $F_c = \frac{1}{2}\rho C_D A U_c^2$---------------Eq. 2.4

[1 mark]

(d) Calculate wind induced drag force (F_w) on the pile. Use C_D=1.0 and density of air, ρ_a=1.1703 kg/m³ in Equation 2.5.

Drag force, $F_w = \frac{1}{2}\rho_a C_D A U_w^2$---------------Eq. 2.5

[1 mark]

(e) Calculate the total restoring moment (KNm) required to resist overturning by the lateral forces. Assume total wave force and tidal drag force act at the mid water depth, wind force acts 3m above the still water level, SWL. Non-linear enhancement of velocity due to wave/current interaction is neglected. Assume drag on the platform is also negligible.

[3 marks]

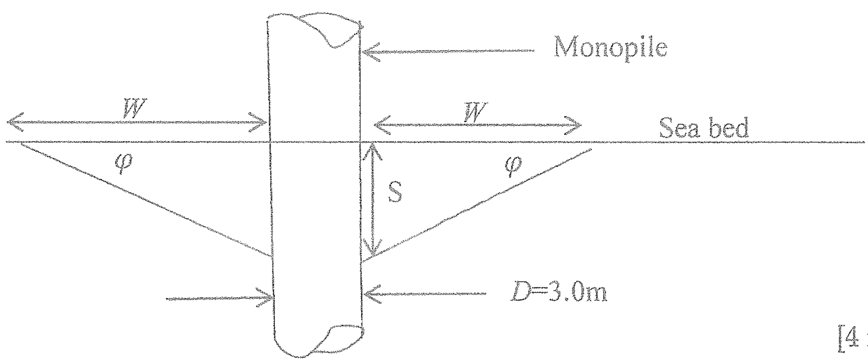
Q3 (a) For the location described in Question Q2 calculate peak orbital velocity (U_b) at the sea bed. Use parameters given in Q2.

[4 marks]

(b) A scour hole around the monopole (described in Q2) will be created few weeks after the construction in the sandy sea bed as shown in Figure Q3. Calculate the scour depth (S) and width (W) of the scour hole using the relationship:

$\frac{S}{D} = 1.3$ --------Eq. 3.1

Angle of repose/friction of sand is φ=30 deg.



[4 marks]

Figure Q3 Scour hole around the monopile

(c) To prevent scour it is planned to construct a rock scour protection around the monopile. If the first (threshold) movement of a rock particles occur when Shields critical shear stress, $\theta c = 0.05$, calculate (i) nominal rock diameter (d) and (ii) mass of rock to be used in the scour protection apron.

$\theta = \frac{\tau}{(\rho_s - \rho) g d}$ ---------------- Eq. 3.2

$\tau = \frac{1}{2} f_w \rho U_b^2$ ---------------- Eq. 3.3

Where wave friction factor, f_w=0.3, density of rock, ρ_s=2650kg/m^3, density of seawater, ρ=1030kg/m^3. Assume, mass of rock = $\rho_s d^3$

[4 marks]

Q4 A beach nourishment program has been planned for an eroded beach frontage. Existing sand has a median grain diameter of d=0.2mm. The beach profile is represented by the equation, $y = -Ax^{2/3}$ as shown in Figure Q4. $A = 0.067w^{0.44}$ where w(m/s) is the sediment settling velocity given by $w=14d^{1.1}$ with d to be substituted in millimetres.

(a) Explain the importance of median sand particle size in beach nourishment.

[3 marks]

(b) If the new sand material to be dumped on the beach is of median diameter, d=0.3mm, and design beach width is 60m, calculate the volume of sand required per metre length of the beach.

[9 marks]

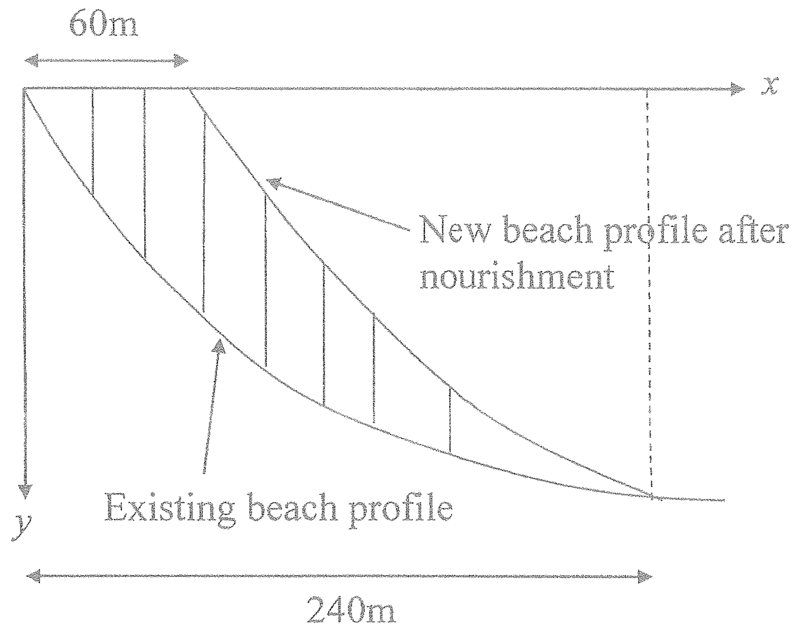


Figure Q4. Cross-shore beach profile

Q5 Assume that you have been tasked to design a rock breakwater consisting of an armour layer, secondary (under-layer) and a core made of quarry run to protect the basin of a fishery harbour (see Figure Q5).

(a) Show on a sketch a typical cross section of a breakwater. Explain the functions of (i) armour layer (ii) secondary/under layer (iii) core (iv) footing

[4 marks]

(b) Determine the crest level of the breakwater for 2% exceedance probability providing a 0.6m freeboard for settlement and water level/wave exceedance.

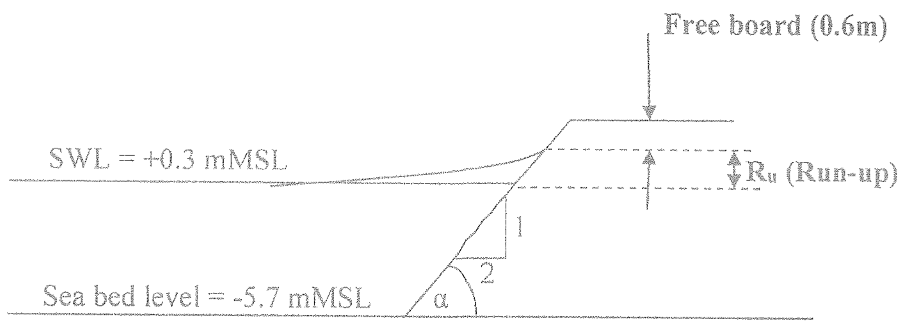


Figure Q5. Breakwater seaward slope

Maximum wave run-up height (R_u) is given by:

$$\frac{R_{ui\%}}{H_s} = A\xi_{0m} \text{ for } 1.0<\xi_{0m} \leq 1.5 \qquad \text{Eq. 5.1}$$
$$= B(\xi_{0m})^C \text{ for } 1.5<\xi_{0m} \leq (D/B)^{1/C} \qquad \text{Eq. 5.2}$$
$$= D \text{ for } (D/B)^{1/C} \leq \xi_{0m} < 7.5 \qquad \text{Eq. 5.3}$$

$$\xi_{0m} = \frac{\tan\alpha}{\sqrt{S_{0m}}} \qquad \text{Eq. 5.4}$$

$$S_{0m} = \frac{H_{s0}}{L_0} \qquad \text{Eq. 5.5}$$

Assume a breakwater slope of 1:2. Design water level (SWL) is +0.3mMSL. Bed level at the toe of the structure is -5.7mMSL. Deep water wave height, H_{s0}=3.0m, and wave period, T_m=8 sec. Nearshore transformed wave height, H_s=3.3m. Assume a breaker index, γ_b=0.78.

[4 marks]

Table Q5. Coefficients A, B, C, D for Run-up calculation (for use in Eq 5.1 – 5.3)

Table VI-5-5
Coefficients in Equations VI-5-12 and VI-5-13 for Runup of Irregular Head-On Waves on Impermeable and Permeable Rock Armored Slopes

Percent [1]	A	B	C	D [2]
0.1	1.12	1.34	0.55	2.58
2.0	0.96	1.17	0.46	1.97
5	0.86	1.05	0.44	1.68
10	0.77	0.94	0.42	1.45
(significant)	0.72	0.88	0.41	1.35
50 (mean)	0.47	0.60	0.34	0.82

[1] Exceedence level related to number of waves
[2] Only relevant for permeable slopes

(c) Use Van der Meer equation to calculate median rock armour size (D_{n50}) and mass (M_{50}).

Assuming plunging waves, the equation reads:

$$\frac{H_s}{\Delta D_{n50}} = 6.2S^{0.2}P^{0.18}N_z^{-0.1}\xi_{0m}^{-0.5} \text{ ------- Eq. 5.6}$$

Where, S is relative eroded area equal to 2 for initial damage. P is porosity equal to 0.3. Number of waves in a storm N_z=5000. Significant wave height, H_{s0}=3.0m, H_s=3.3m, wave period T=8 sec, $S_{om}=H_{s0}/L_0$. Breakwater slope is tan α, $\Delta=[(\rho_s/\rho)-1]$ where density of rock, ρ_s=2650kg/m^3 and density of seawater, ρ=1030kg/m^3. Assume a rock can be considered as a cube with the side length of D_{n50} in the calculation of rock mass.

$$\xi_{0m} = \frac{\tan \alpha}{\sqrt{S_{0m}}} \quad \text{----------Eq. 5.7}$$

[4 marks]

APPENDIX:

Table 1. Wave table

h/L0	h/L	Sinh($2\pi h/L$)	Cosh($2\pi h/L$)
0.030	0.07135	0.4634	1.1021
0.031	0.07260	0.4721	1.1059
0.032	0.07385	0.4808	1.1096
0.033	0.07507	0.4894	1.1133
0.034	0.07630	0.4980	1.1171
0.035	0.07748	0.5064	1.1209
0.036	0.07867	0.5147	1.1247
0.037	0.07984	0.5230	1.1285
0.038	0.08100	0.5312	1.1324
0.039	0.08215	0.5394	1.1362
0.040	.08329	0.5475	1.1401
0.041	.08442	0.5556	1.1440
0.042	.08553	0.5637	1.1479
0.043	.08664	0.5717	1.1518
0.044	.08774	0.5796	1.1558
0.060	0.1043	0.7033	1.2225
0.061	0.1053	0.7110	1.2270
0.062	0.1063	0.7187	1.2315
0.063	0.1073	0.7256	1.2355
0.064	0.1082	0.7335	1.2402
0.095	.1366	0.9677	1.3917
0.096	.1375	0.9755	1.3970
0.097	.1384	0.9832	1.4023
0.098	.1392	0.9908	1.4077
0.099	.1401	0.9985	1.4131
0.1000	.1410	1.006	1.4187
0.1010	.1419	1.014	1.4242
0.1020	.1427	1.022	1.4297
0.1030	.1436	1.030	1.4354
0.1040	.1445	1.037	1.4410

Symbols:

h= water depth, *L*= wave length, L_0=deep water wave length = $gT^2/2\pi$