UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: March 2021

Module Number: CE 7251 **Module Name: Coastal Engineering Applications and Management**

[Three Hours]

[Answer **all questions**, each question carries TWELVE marks]

Q1 (a) Referring to physics, explain how (i) refraction and shoaling (ii) diffraction occur using sketches if necessary. Describe why these coastal processes are important for coastal engineering ?.

[3 marks]

(b) (i) Describe the statutory functions of the Department of Coast & Coastal Resources Conservation (ii) Explain why mangroves are important as a soft coastal defence ?

[3 marks]

(c) It is proposed to construct a vertical quay wall in a harbour for berthing of vessels using a reinforced vertical concrete wall as shown in Figure Q1. Incoming wave height, $Hinc$=1.5m and wave period, T=8 seconds, density of sea water ρ= 1030kg/m³. Use Wave Table given in the Appendix and assume usual (x,z) coordinate system where z is measured positive upwards from SWL.

(i) What is the height of the reflected wave (H_r) ?

[2 marks]

(ii) Calculate the hydrostatic pressure and **peak** dynamic wave pressure (P_w) at the sea bed ? Calculate $P\ max$= (hydrostatic pressure + wave pressure).

$$P_w = \frac{\rho g H_r \cosh[k(z+h)]}{2\cosh(kh)} \cos(kx - \omega t)$$

[2 marks]

(iii) Calculate dynamic wave pressure P_0 at SWL. Assume $Hoc = \frac{\pi H_{inc}^2}{L} \coth \frac{2\pi h}{L}$

[2 marks]

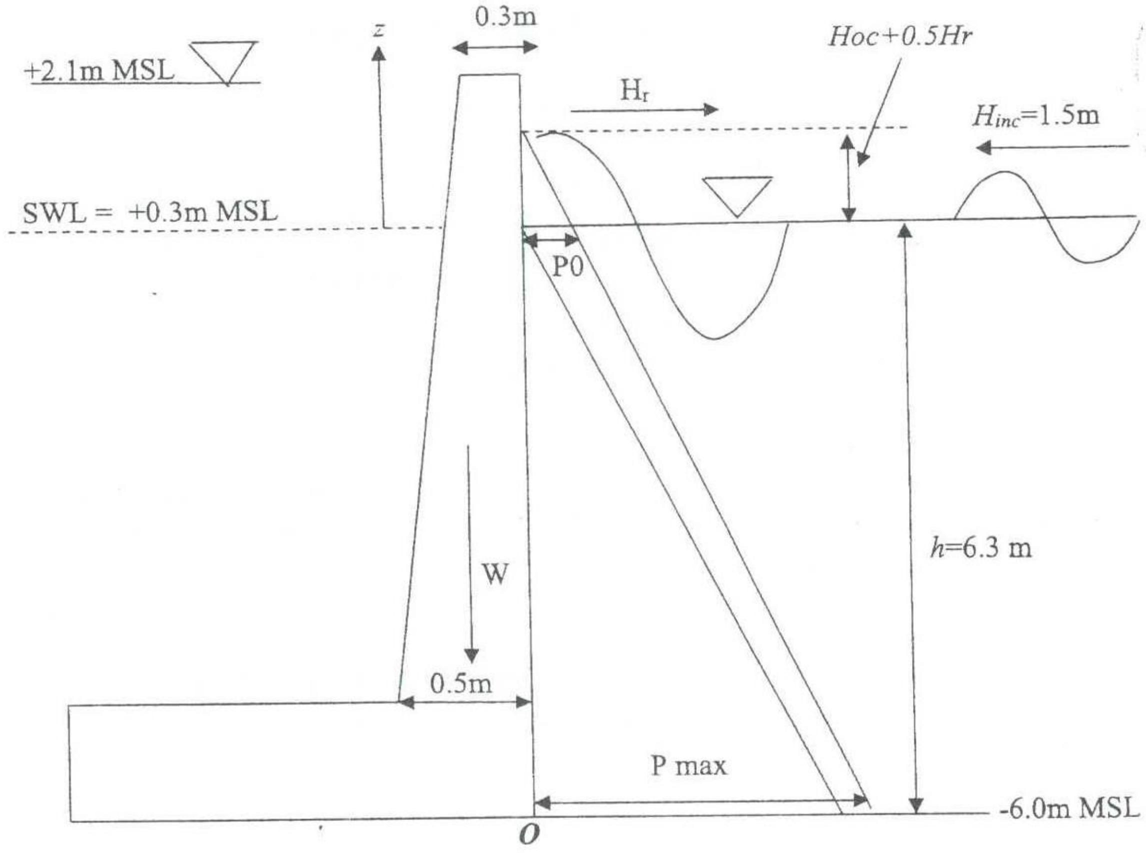


Figure Q1. Vertical Quay Wall Structure

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 Wave height, H= 3m, wave period, T= 8 seconds. Use wave table given in the Appendix.

(a) Explain how inertia and drag forces on a solid object are generated referring to fluid flow behaviour around the object and Newtonian mechanics.

[4 marks]

(b) 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 orbital velocity (U) and acceleration (a_x) at the mid-depth, i.e., z = - 0.5h for (kx-ωt) = $\pi/3$.

[4 marks]

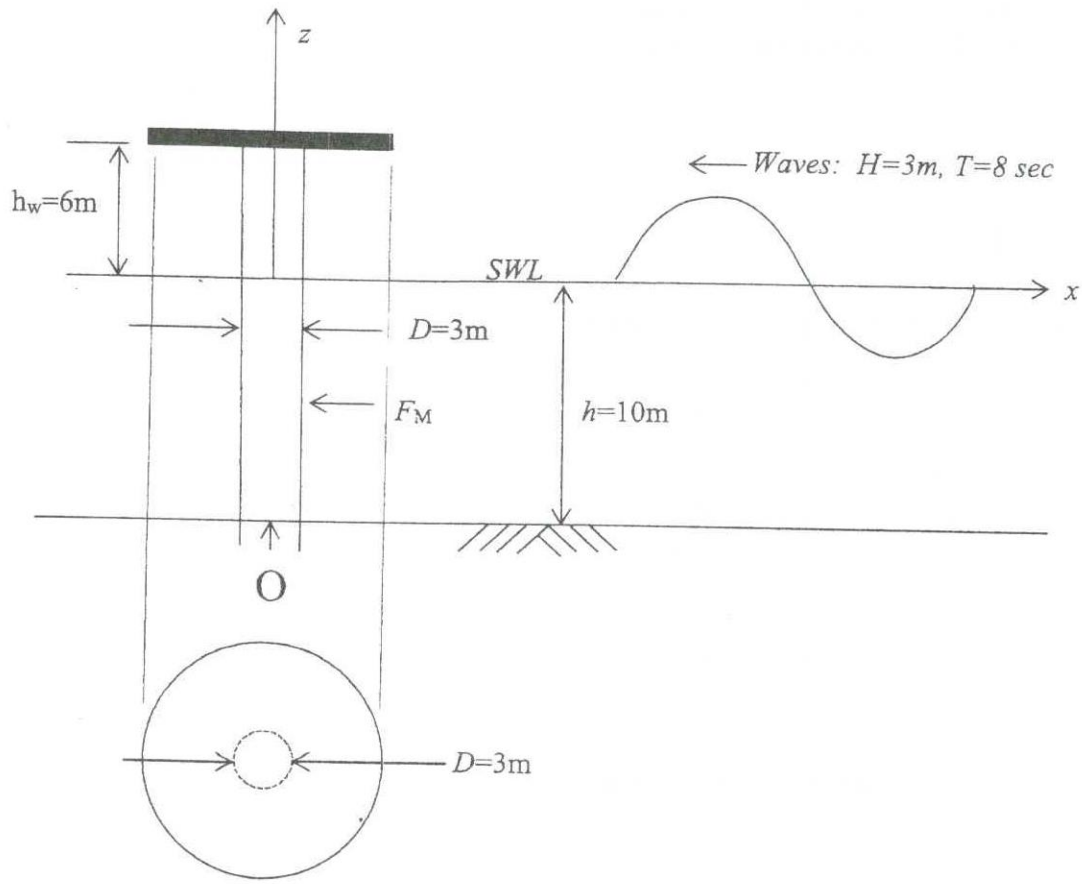


Figure Q2 Side view and plan of the monopile

(c) Calculate drag and inertia forces and total wave force ($F_M = F_D + F_I$) on the pile for $(kx\text{-}\omega t) = \pi/3$. Assume 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/m^3.

[4 marks]

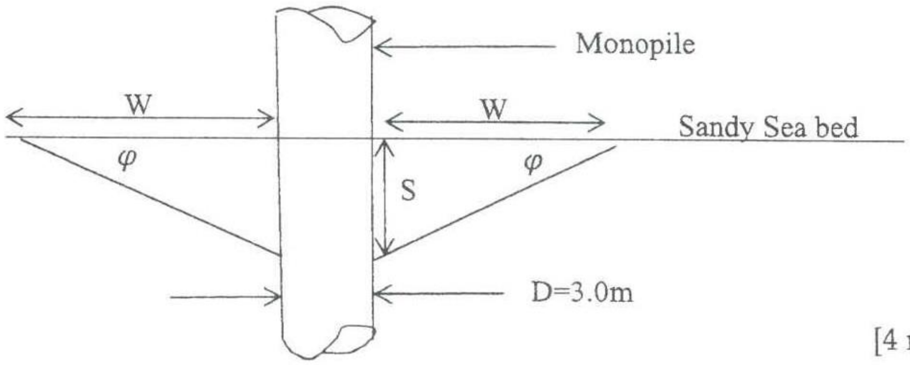
Q3 (a) For the monopole described in Q2 (i.e., wave height, H=3m, wave period, T=8 sec and water depth, h=10m) calculate **peak** orbital velocity (U_b) at the sea bed. Use same definition sketch and parameters as in Q2.

[4 marks]

(b) Calculate the 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

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

$\theta = \frac{\tau}{(\rho_s - \rho)gd}$ ---------------- 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 = $\rho_s d^3$

[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 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]

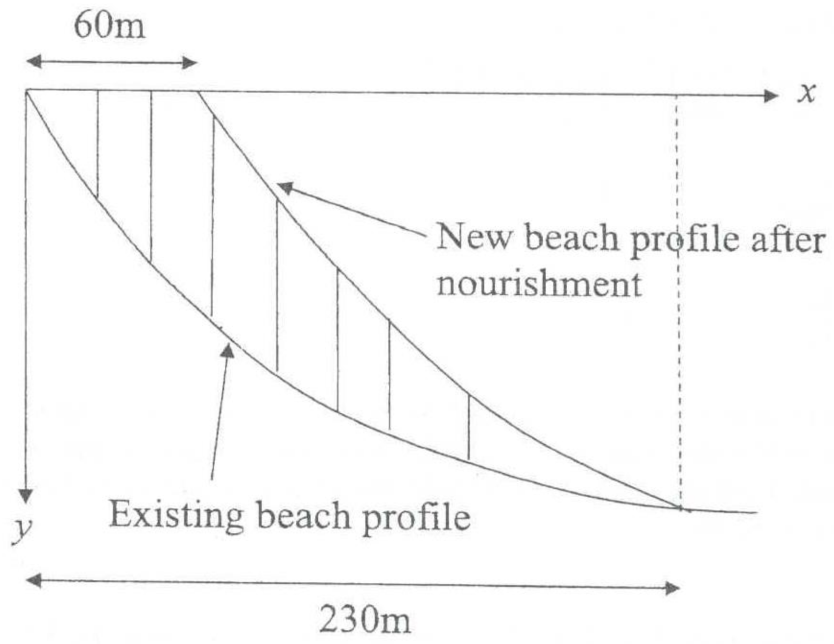


Figure Q4. Cross-shore beach profile

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.

(a) Draw 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.

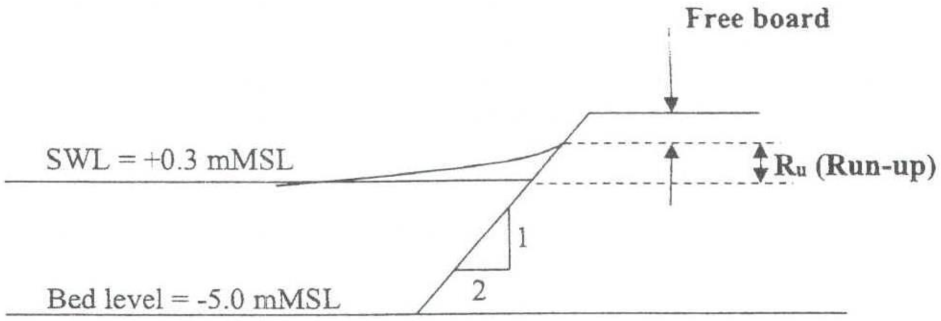


Figure Q5. Definition sketch of breakwater slope

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 -5.0mMSL. Deep water wave height, H_{s0}=2.5m, and wave period, T_m=8 sec. Nearshore transformed wave height, H_s=2.8m. 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)

Percent exceedance	A	B	C	D
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

(c) Use Van der Meer equation to calculate median rock armour diameter and mass.

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_s=2.8m, wave period T=8 sec, S_m=H_s/L_0. Breakwater slope is $\tan\alpha = 1/2$. $\Delta=[(\rho_s/\rho)-1]$ where density of rock ρ_s=2650kg/m^3 and density of seawater ρ=1030kg/m^3.

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

[4 marks]

APPENDIX:

Table 1. Wave table

h/L0	h/L	Sinh(2πh/L)	Cosh(2πh/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 = $gT^2/2\pi$