UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: October 2019

Module Number: CE 7251

Module Name: Coastal Engineering Applications and Management

[Three Hours]

[Answer all questions, each question carries TWELVE marks]

Q1 (a) Use physics behind coastal processes to explain how (i) wave-induced longshore currents (ii) tidal currents are generated with the aid of sketches if necessary. Describe why these processes are important for coastal engineering ?.

[4 marks]

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

(i) North of Port City, Colombo
(ii) An unpopulated coastal area in the southern province

[4 marks]

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

[4 marks]

Q2 As shown in Figure Q2 an underwater spherical tank to store natural gas is proposed. The diameter of the sphere, D=10m. Design environmental data are provided below.

Wave height, H= 6m, wave period, T= 8 seconds, Water depth, h=20m, density of seawater = 1030 kg/m^3. Use wave table given in the Appendix.

(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 a relationship for dynamic wave pressure using:

$$p(x,z,t) = -\rho\frac{\partial\phi\,(x,z,t)}{\partial x} \quad \text{-----------------Eq. 2.2}$$

[4 marks]

(b) Calculate peak (maximum) pressure p_1, p_2, p_3 on elements at a radius $r=D/2$ at the following positions M_1, M_2, M_3 assuming diffraction effects are negligible.

(i) Pont M_1 at $\varphi = \frac{\pi}{12}$, $\theta = \frac{\pi}{4}$

(ii) Point M_2 at $\varphi = \frac{\pi}{4}$, $\theta = \frac{\pi}{4}$

(iii) Point M_3 at $\varphi = \frac{5\pi}{12}$, $\theta = \frac{\pi}{4}$

[4 marks]

(c) Calculate the maximum force, F_1, F_2, F_3, on the surface area with width LN and length RS along an arc of the first quadrant of the top half-sphere bounded by the angles:

(i) Force F_1: from $\theta = \frac{\pi}{6}$ to $\theta = \frac{\pi}{3}$ and from $\varphi = 0$ to $\varphi = \frac{\pi}{6}$

(ii) Force F_2: from $\theta = \frac{\pi}{6}$ to $\theta = \frac{\pi}{3}$ and from $\varphi = \frac{\pi}{6}$ to $\varphi = \frac{\pi}{3}$

(iii) Force F_3: from $\theta = \frac{\pi}{6}$ to $\theta = \frac{\pi}{3}$ and from $\varphi = \frac{\pi}{3}$ to $\varphi = \frac{\pi}{2}$

Assume pressures p_1, p_2 and p_3 calculated in Q2(b) are the average peak pressure on surface elements formed by the angle $\Delta\varphi$ =30 deg.

[4 marks]

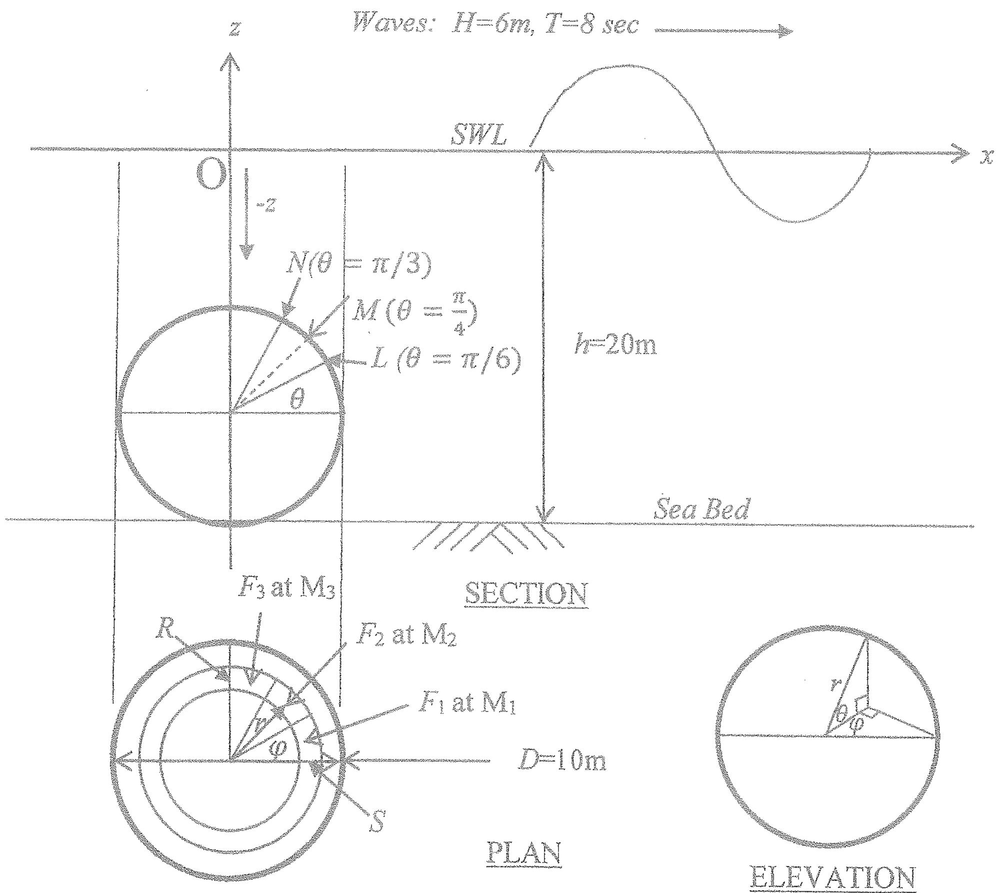

Figure Q2 Elevation, section and plan views of the underwater gas tank

Q3 (a) When a hard engineering solution such as a groyne is given to a coastal erosion problem the problem may be shifted to down coast. Explain this phenomenon with the aid of sketches.

[6 marks]

(b) Time evolution of 2 km long and 100m wide rectangular beach fill is given by the following equation.

$$y = Y_0\left\{erf\left[\frac{\lambda}{4\sqrt{Gt}}\left(\frac{2x}{\lambda}+1\right)\right] - erf\left[\frac{\lambda}{4\sqrt{Gt}}\left(\frac{2x}{\lambda}-1\right)\right]\right\} \quad \text{-------- Eq. 3.1}$$

Where y is the distance to shoreline from a datum, y=0.

Original beach fill is shown with a broken line. Calculate the shoreline position y at x=0, 2 years after the construction (Note – time, t should be substituted in seconds in Equation 3.1).

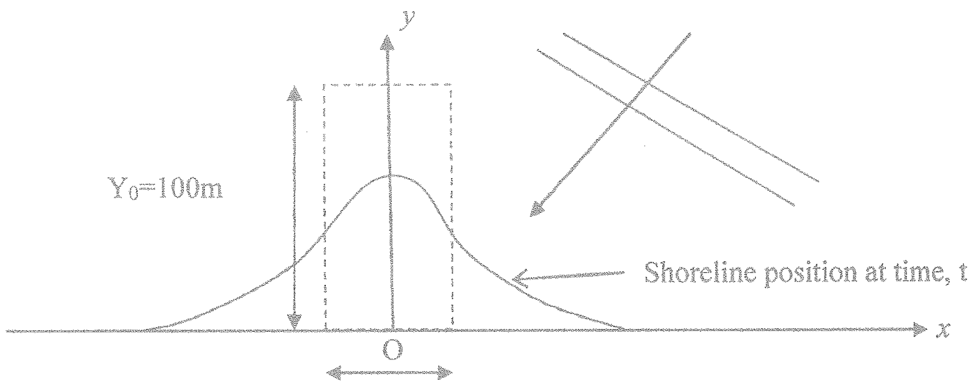

Figure Q 3.1 Beach planform

$$G = \frac{K H_b^{\frac{5}{2}} \sqrt{\frac{g}{\gamma_b}}}{8\frac{(\rho_s-\rho_w)}{\rho_w} a (h_* + B)} \quad \text{------------ Eq. 3.2}$$

K=0.7, $\gamma_b = 0.78$, $a = 1 - porosity = 0.6$, B=3m, h_*=4m, h_b=3m, ρ_s=2650kg/m^3, ρ=1030kg/m^3. G is alongshore diffusivity. Obtain error function value from the graph shown in Figure Q 3.2.

[6 marks]

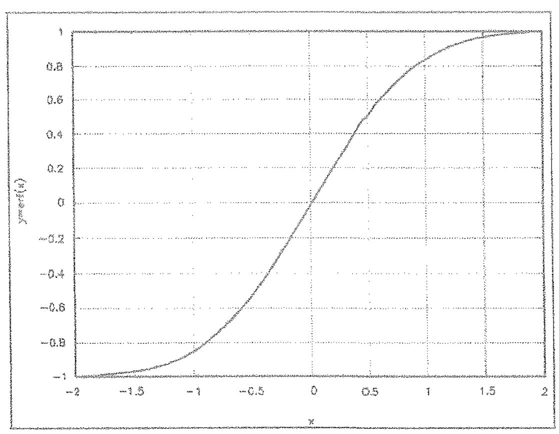

Figure Q 3.2 Graph of error function y=erf(x)

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=0.32mm, and design beach width is 50m, calculate the volume of sand required per metre length of the beach.

[9 marks]

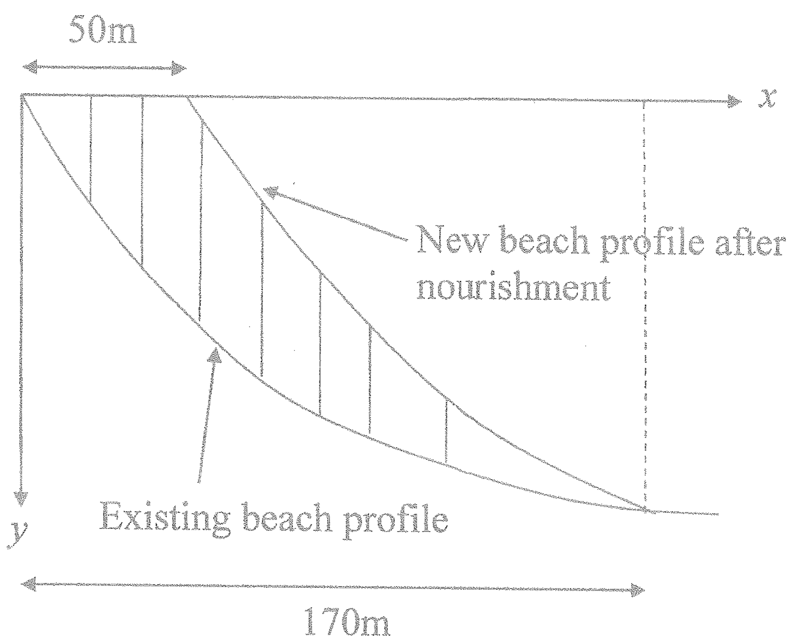

Figure Q4. Cross-shore beach profile

Q5 (a) 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. Show 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) Figure Q5 shows a sectional view of a caisson breakwater supported on a rock foundation. The design wave height H= 3m and wave period T=8 sec. Water depth, h_s=10m. Height of the caisson, h_w=6m. The caisson structure projects 1m above the still water level (h_c=1m). The water depth in front of the Caisson, d=5m. Calculate dynamic wave pressure on the seaward face of the caisson p_1, p_2, p_3 and uplift pressure p_u using relationships given below. Assume the caisson box width is 3m and length is 6m. Angle of wave incidence is zero ($\beta = 0$). Density of sea water, ρ_w =1030 kg/m^3. Use wave table given in the Appendix.

$\eta^* = 0.75\,(1+\cos\beta)H$ ---------- Eq. 5.1

$p_1 = 0.5\,(1+\cos\beta)\,(\alpha_1 + \alpha_2\cos^2\beta)\rho_w g H$ ---------- Eq. 5.2

$p_3 = \alpha_3 p_1$ ---------- Eq. 5.3

$p_u = 0.5\,(1+\cos\beta)\,\alpha_1\alpha_3\,\rho_w g H$ ---------- Eq. 5.4

$\alpha_1 = 0.6 + 0.5\left[\frac{4\pi h_s/L}{\sinh(4\pi h_s/L)}\right]^2$ ---------- Eq. 5.5

$\alpha_2 = \text{smallest of } \frac{h_b - d}{3h_b}\left(\frac{H}{d}\right)^2 \text{ and } \frac{2d}{H}$ ---------- Eq. 5.6

$\alpha_3 = 1 - \left(\frac{h_w - h_c}{h_s}\right)\left[1 - \frac{1}{\cosh(2\pi h_s/L)}\right]$ ---------- Eq.5.7

$h_b = h_s$ ---------- Eq. 5.8

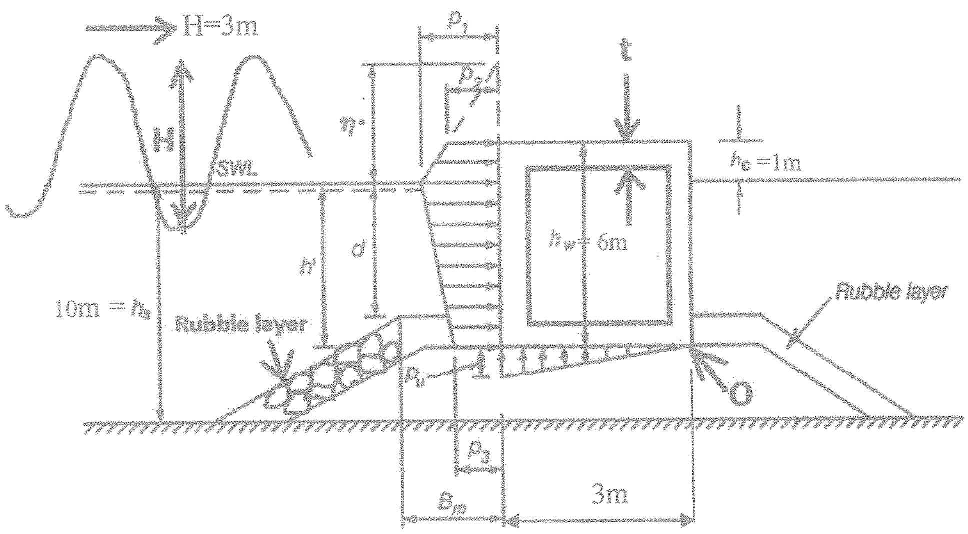

Figure Q5. Cross-section of a caisson breakwater

[4 marks]

(c) Calculate the total horizontal (F_H) and uplift (F_U) forces on the caisson and the position of their line of action. By considering moments around point "O" calculate the thickness of the caisson box (t). Assume that the caisson box, having six sides made with reinforced concrete of which the wall thickness is t, is empty (hollow). Density of concrete is 2650 kg/m^3.

[4 marks]

APPENDIX:

Table 1. Wave table

h/L0	h/L	Sinh(2πh/L)	Cosh(2πh/L)
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
0.1950	0.2209	1.879	2.128
0.1960	0.2218	1.890	2.138
0.1970	0.2226	1.901	2.148
0.1980	0.2234	1.913	2.158
0.1990	0.2243	1.924	2.169
0.2000	0.2251	1.935	2.178
0.2010	0.2260	1.947	2.189
0.2020	0.2268	1.959	2.199
0.2030	0.2277	1.970	2.210
0.2040	0.2285	1.982	2.220

Symbols:

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