Table (3-2) Diffraction Coefficients (k_d), Wiegel, (1962).

	β (Degrees)												
r/L	0	15	30	45	60	75	90	105	120	135	150	165	180
						θ = 15°							
1/2	0.49	0.79	0.83	0.90	0.97	1.01	1.03	1.02	1.01	0.99	0.99	1.00	1.00
1	0.38	0.73	0.83	0.95	1.04	1.04	0.99	0.98	1.01	1.01	1.00	.100	1.00
2	0.21	0.68	0.86	1.05	1.03	0.97	1.02	0.99	1.00	1.00	1.00	1.00	1.00
5	0.13	0.63	0.99	1.04	1.03	1.02	0.99	0.99	1.00	1.01	1.00	1.00	1.00
10	0.35	0.58	1.10	1.05	0.98	0.99	1.01	1.00	1.00	1.00	1.00	1.00	1.00
						θ = 30°							
1/2	0.61	0.63	0.68	0.76	0.87	0.97	1.03	1.05	1.03	1.01	0.99	0.95	1.00
1	0.50	0.53	0.63	0.78	0.95	1.06	1.05	0.98	0.98	1.01	1.01	0.97	1.00
2	0.40	0.44	0.59	0.84	1.07	1.03	0.96	1.02	0.98	1.01	0.99	0.95	1.00
5	0.27	0.32	0.55	1.00	1.04	1.04	1.02	0.99	0.99	1.00	1.01	0.97	1.00
10	0.20	0.24	0.54	1.12	1.06	0.97	0.99	1.01	1.00	1.00	1.00	0.98	1.00
						θ = 45°							
1/2	0.49	0.50	0.55	0.63	0.73	0.85	0.96	1.04	1.06	1.04	1.00	0.99	1.00
1	0.38	0.40	0.47	0.59	0.76	0.95	1.07	1.06	0.98	0.97	1.01	1.01	1.00
2	0.29	0.31	0.39	0.56	0.83	1.08	1.04	0.96	1.03	0.98	1.01	1.00	1.00
5	0.18	0.20	0.29	0.54	1.01	1.04	1.05	1.03	1.00	0.99	1.01	1.00	1.00
10	0.13	0.15	0.22	0.53	1.13	1.07	0.96	0.98	1.02	0.99	1.00	1.00	1.00
						θ = 60°							
1/2	0.40	0.41	0.45	0.52	0.60	0.72	0.85	1.13	1.04	1.06	1.03	1.01	1.00
1	0.31	0.32	0.36	0.44	0.57	0.75	0.96	1.08	1.06	0.98	0.98	1.01	1.00
2	0.22	0.23	0.28	0.37	0.55	0.83	1.08	1.04	0.96	1.03	0.98	1.01	1.00
5	0.14	0.15	0.18	0.28	0.53	1.01	1.04	1.05	1.03	0.99	0.99	1.00	1.00
10	0.10	0.11	0.13	0.21	0.52	1.14	1.07	0.96	0.98	1.01	1.00	1.00	1.00
						θ = 75°							
1/2	0.34	0.35	0.38	0.42	0.50	0.59	0.71	0.85	0.97	1.04	1.05	1.02	1.00
1	0.25	0.26	0.29	0.34	0.43	0.56	0.75	0.95	1.02	1.06	0.98	0.98	1.00
2	0.18	0.19	0.22	0.26	0.36	0.54	0.83	1.09	1.04	0.96	1.03	0.99	1.00
5	0.12	0.12	0.13	0.17	0.27	0.52	1.01	1.04	1.05	1.03	0.99	0.99	1.00
10	0.08	0.08	0.10	0.13	0.20	0.52	1.14	1.07	0.96	0.98	1.01	1.00	1.00
						θ = 90°							
1/2	0.31	0.31	0.33	0.36	0.41	0.49	0.59	0.71	0.85	0.96	1.03	1.03	1.00
1	0.22	0.23	0.24	0.28	0.33	0.42	0.56	0.75	0.96	1.07	1.05	0.99	1.00
2	0.16	0.16	0.18	0.20	0.26	0.35	0.54	0.69	1.08	1.04	0.96	1.02	1.00
5	0.10	0.10	0.11	0.13	0.16	0.27	0.53	1.01	1.04	1.05	1.02	0.99	1.00
10	0.07	0.07	0.08	0.09	0.13	0.20	0.52	1.14	1.07	0.96	0.99	1.01	1.00
						θ = 105°							
1/2	0.28	0.28	0.29	0.32	0.35	0.41	0.49	0.59	0.72	0.85	0.97	1.01	1.00
1	0.20	0.20	0.24	0.23	0.27	0.33	0.42	0.56	0.75	0.95	1.06	1.04	1.00
2	0.14	0.14	0.13	0.17	0.20	0.25	0.35	0.54	0.83	1.08	1.03	0.97	1.00
5	0.09	0.09	0.10	0.11	0.13	0.17	0.27	0.52	1.02	1.04	1.04	1.02	1.00
10	0.07	0.06	0.08	0.08	0.09	0.12	0.20	0.52	1.14	1.07	0.97	0.99	1.00
						θ = 120°							
1/2	0.25	0.26	0.27	0.28	0.31	0.35	0.41	0.50	0.60	0.73	0.87	0.97	1.00
1	0.18	0.19	0.19	0.21	0.23	0.27	0.33	0.43	0.57	0.76	0.95	1.04	1.00
2	0.13	0.13	0.14	0.14	0.17	0.20	0.26	0.16	0.55	0.83	1.07	1.03	1.00
5	0.08	0.08	0.08	0.09	0.11	0.13	0.16	0.27	0.53	1.01	1.04	1.03	1.00
10	0.06	0.06	0.06	0.07	0.07	0.09	0.13	0.20	0.52	1.13	1.06	0.98	1.00
						θ = 135°							
1/2	0.24	0.24	0.25	0.26	0.28	0.32	0.36	0.42	0.52	0.63	0.76	0.90	1.00
1	0.18	0.17	0.18	0.19	0.21	0.23	0.28	0.34	0.44	0.59	0.78	0.95	1.00
2	0.12	0.12	0.13	0.14	0.14	0.17	0.20	0.26	0.37	0.56	0.84	1.05	1.00
5	0.08	0.07	0.08	0.08	0.09	0.11	0.13	0.17	0.28	0.54	1.00	1.04	1.00
10	0.05	0.06	0.06	0.06	0.07	0.08	0.09	0.13	0.21	0.53	1.12	1.05	1.00
						θ = 150°							
1/2	0.23	0.23	0.24	0.25	0.27	0.29	0.33	0.38	0.45	0.55	0.68	0.83	1.00
1	0.16	0.17	0.17	0.18	0.19	0.22	0.24	0.29	0.36	0.47	0.63	0.83	1.00
2	0.12	0.12	0.12	0.13	0.14	0.15	0.18	0.22	0.28	0.39	0.59	0.86	1.00
5	0.07	0.07	0.08	0.08	0.08	0.10	0.11	0.13	0.18	0.29	0.55	0.99	1.00
10	0.05	0.05	0.05	0.06	0.06	0.07	0.08	0.10	0.13	0.22	0.54	1.10	1.00
						θ = 165°							
1/2	0.23	0.23	0.23	0.24	0.26	0.28	0.31	0.35	0.41	0.50	0.63	0.79	1.00
1	0.16	0.16	0.17	0.17	0.19	0.20	0.23	0.26	0.32	0.40	0.53	0.73	1.00
2	0.11	0.11	0.12	0.12	0.13	0.14	0.16	0.19	0.23	0.31	0.44	0.68	1.00
5	0.07	0.07	0.07	0.07	0.08	0.09	0.10	0.12	0.15	0.20	0.32	0.63	1.00
10	0.05	0.05	0.05	0.06	0.06	0.06	0.07	0.08	0.11	0.11	0.21	0.58	1.00
						θ = 180°							
1/2	0.20	0.25	0.23	0.24	0.25	0.28	0.31	0.34	0.40	0.49	0.61	0.78	1.00
1	0.10	0.17	0.16	0.18	0.18	0.23	0.22	0.25	0.31	0.38	0.50	0.70	1.00
2	0.02	0.09	0.12	0.12	0.13	0.18	0.16	0.18	0.22	0.29	0.40	0.60	1.00
5	0.02	0.06	0.07	0.07	0.07	0.08	0.10	0.12	0.14	0.18	0.27	0.46	1.00
10	0.01	0.05	0.05	0.06	0.06	0.07	0.07	0.08	0.10	0.13	0.20	0.36	1.00

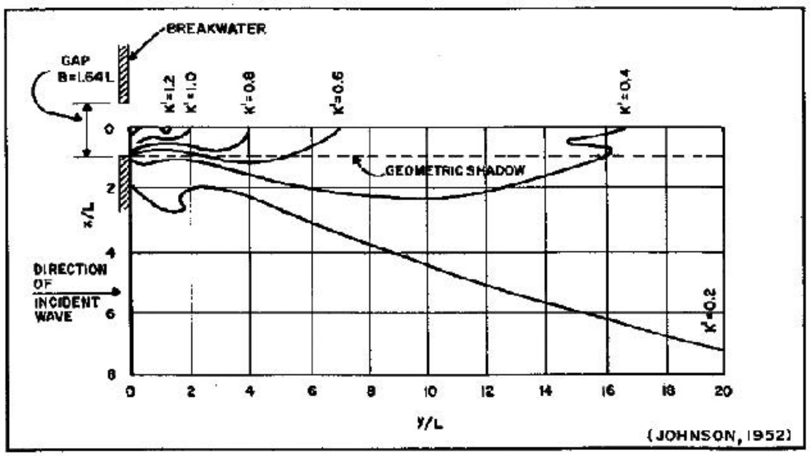


FIGURE 27
Contours of Equal Diffraction Coefficient for B = 1.64 L (B/L = 1.64)

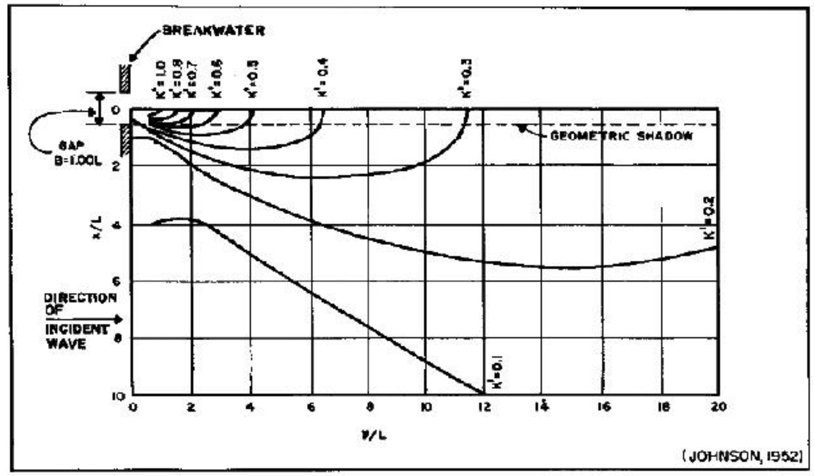


FIGURE 25
Contours of Equal Diffraction Coefficient for B = 1.00 L (B/L = 1.00)

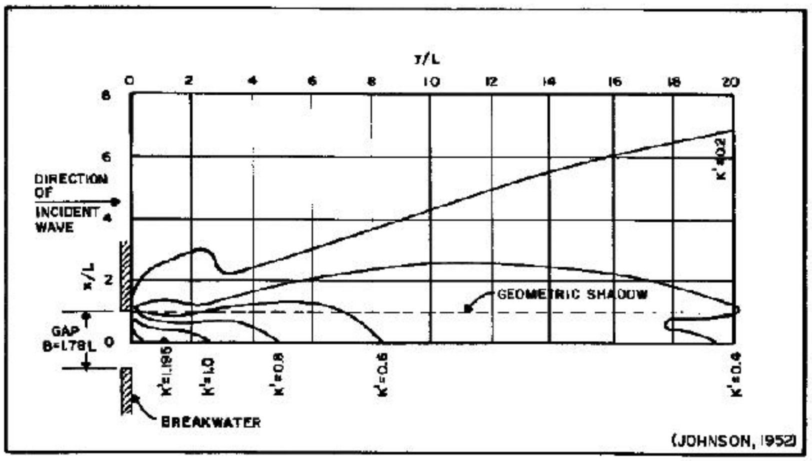


FIGURE 28
Contours of Equal Diffraction Coefficient for B = 1.78 L (B/L = 1.78)

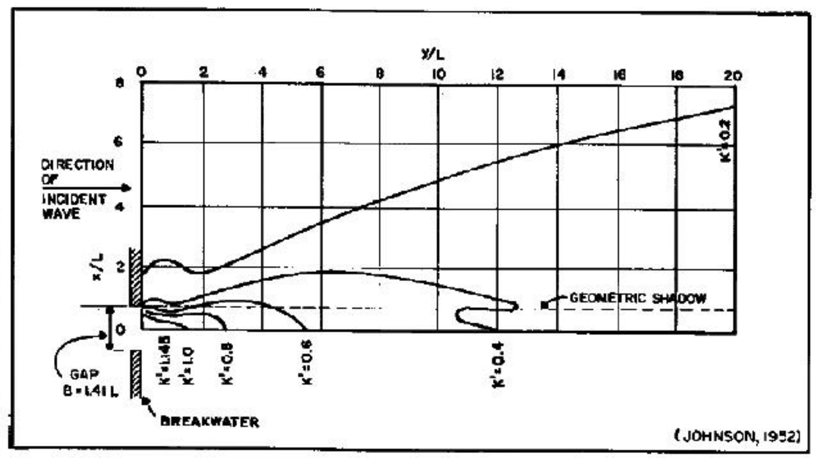


FIGURE 26
Contours of Equal Diffraction Coefficient for B = 1.41 L (B/L = 1.41)

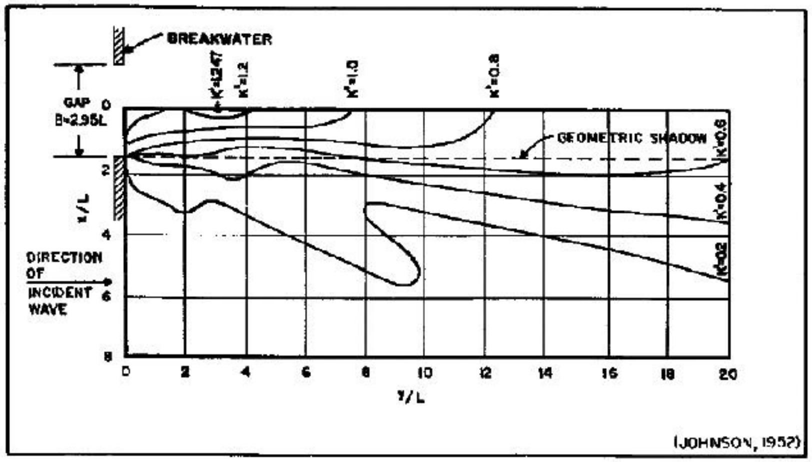


FIGURE 31
Contours of Equal Diffraction Coefficient for B = 2.95 L (B/L = 2.95)

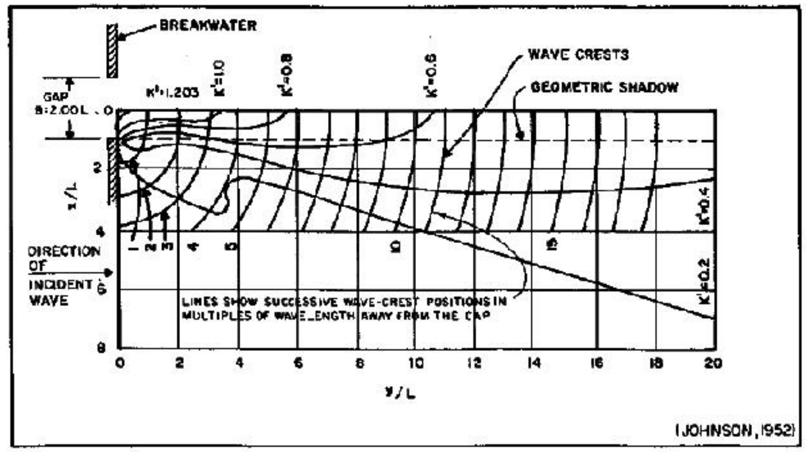


FIGURE 29
Contours of Equal Diffraction Coefficient for B = 2.00 L (B/L = 2.00)

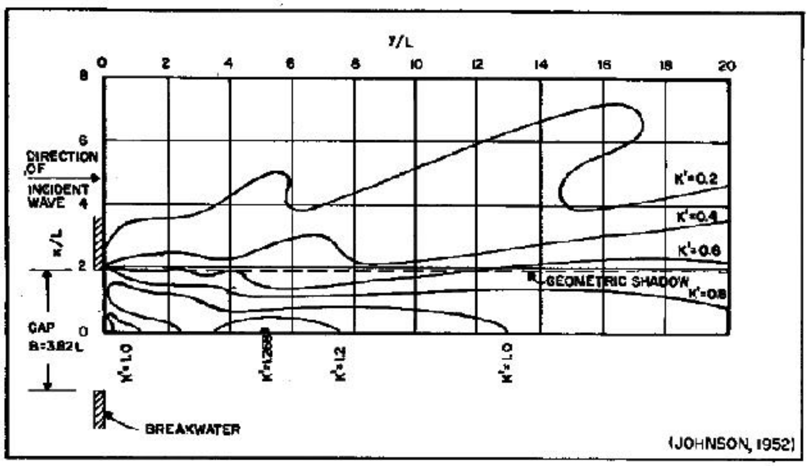


FIGURE 32
Contours of Equal Diffraction Coefficient for B = 3.82 L (B/L = 3.82)

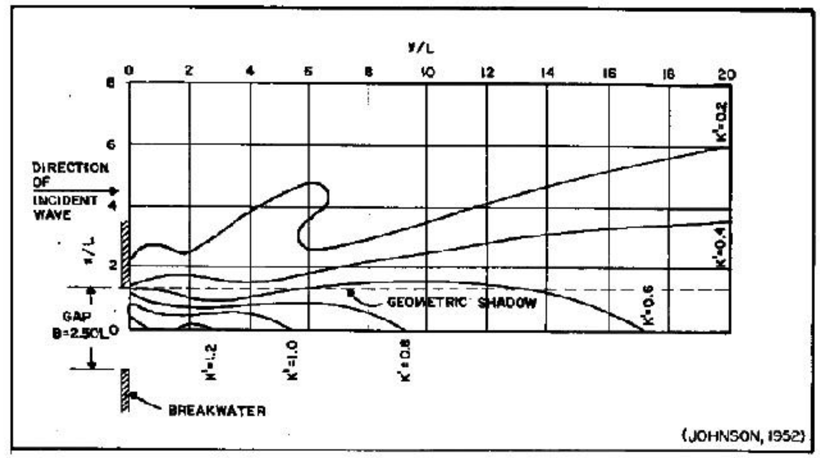
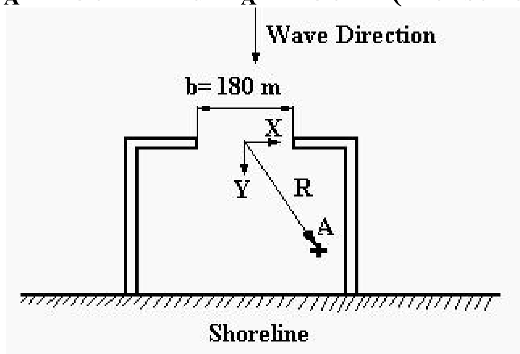


FIGURE 30
Contours of Equal Diffraction Coefficient for B = 2.50 L (B/L = 2.50)

Example (3-4):

For a harbor which protected by the shown breakwater system in the following figure, subject to normal waves with 2 m wave height and 8 sec wave period. The water depth at the breakwater gap is 7 m. Calculate the wave height at the point A with coordinates of X_A = 150 m and Y_A = 250 m (measured from the gap center).



SOLUTION

$L_o = 1.56\ T^2 = 1.56 * 8^2 = 100$ m

$d / L_o = 7 / 100 = 0.07$ from Table (3-1)

$d / L = 0.1139$ the $L = 61.5$ m

$b / L = 180 / 61.5 = 2.93 < 5$ (Double Breakwater)

$X / L = 150 / 61.5 = 2.44$

$Y / L = 250 / 61.5 = 4.1$

From chart of b = 2.95 L ➡ $k_d = 0.35$ then

$H_A = k_d * H_i = 0.35 * 2$

$H_A = 0.7$ m

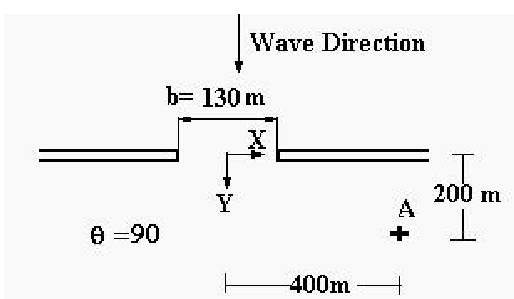
Example (3-5):

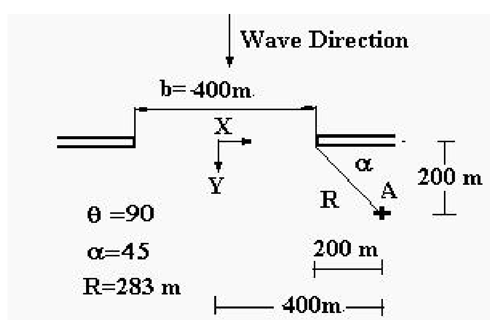
Waves with a period of T= 8 sec and height of H = 2.5 m strike upon a double breakwater at an angle of 90°. The water depth at the head of the breakwater is 8 m. Find the wave height at point A with coordinates of X = 400 m and Y = 200 m (measured from the gap center) when:

- **The breakwater gap is 400 m.**
- **The breakwater gap is 130 m.**

SOLUTION

For Breakwater Gap of 130 m





$L_o = 1.56\ T^2 = 1.56 * 8^2 = 100$ m

$d / L_o = 8 / 100 = 0.08$ from table

$d / L = 0.1232$ the $L = 65$ m

$b / L = 130 / 65 = 2 < 5$ (Double Breakwater)

$X / L = 400 / 65 = 6.2$

$Y / L = 200 / 65 = 3.1$

From chart of $b = 2.0\ L$ ➡ $k_d = 0.1$ then

$H_A = k_d * H_i = 0.1 * 2.5$

<u>$H_A = 0.25$ m</u>

<u>For Breakwater Gap of 400 m</u>

$b / L = 400 / 65 = 6.2 > 5$ (Single Breakwater)

$\alpha = 45^o$, $R = 282$ m and $\theta = 90^o$

$R / L = 282 / 65 = 4.34$

From chart of $\theta = 90^o$ or Table (3-2) ➡ $k_d = 0.145$ then

$H_A = k_d * H_i = 0.145 * 2.5$

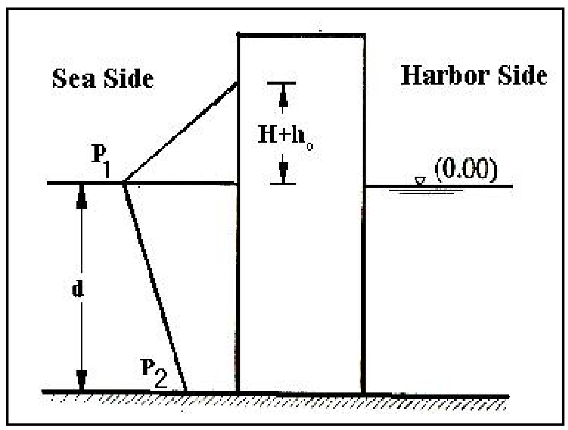
<u>$H_A = 0.36$ m</u>

Wave Forces ٤-٣ قوة الأمواج على الحوائط الراسية:

I- Non-Breaking Zone

$$\frac{H}{d} < 1.0$$

<u>Sainflou Formula</u>



$$h_o = \frac{kH^2}{2\tanh(kd)} \quad , \quad k = 2\pi/L$$

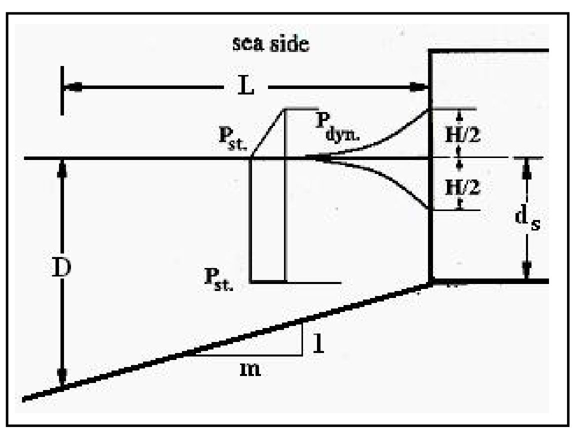
$$P_2 = \frac{\gamma H}{\cosh(kd)}$$

$$P_1 = (\gamma d + P_2)\left(\frac{H + h_o}{H + h_o + d}\right)$$

II- Breaking Zone:

$$\frac{H}{d_s} \geq 1.0$$

<u>Miniken Formula</u>



$$P_{dyn} = 101\gamma \frac{H_b}{L_D}\frac{d_s}{D}(D + d_s)$$

$$P_{st.} = \frac{\gamma H_b}{2}$$

$$D = m*L + d_s$$

L : طول موجي عند الحاجز على عمق d_s

L_D: طول موجي على عمق D