EWCE 471 — SA

L01

14/06

Basic Coastal Engg.

Lec 01 :

Lec 3: wave theory – Small amplitude

Time period (T) remains constant for a definite wave.

$\omega = \frac{2\pi}{T}$ [T sec → 2π, 1 sec → 2π/T]

wave number, $K = \frac{2\pi}{L}$

Phase velocity or wave celerity, $C = \frac{L}{T} = \frac{\omega}{K}$

wave steepness, $\varepsilon = H/L$

Relative depth = d/L

Relative wave height = H/d

Irrotational fluid motion

Small amplitude theory assumptions

Small Amplitude wave Theory

$$C = \frac{gT}{2\pi} \tanh \frac{2\pi d}{L}$$

$$L = \frac{gT^2}{2\pi} \tanh \frac{2\pi d}{L}$$

} dispertion eq^n

$d/L \geq 0.5$ → deep water cond.

≤ 0.05 → shallow water → $c = \sqrt{gd}$; $L = \sqrt{gd}\, T$

In-between → transitional zone

$$c_0 = \sqrt{\frac{gL_0}{2\pi}}$$

$$\frac{c}{c_0} = \frac{L}{L_0} = \tan \frac{2\pi d}{L}$$

$$c_0 = \frac{gT}{2\pi}$$

$$L_0 = \frac{gT^2}{2\pi}$$

Linear wave theory

$$\frac{C}{C_0} = \frac{L}{L_0} = \tanh \frac{2\pi d}{L}$$

Ex. 3 : Depth = 10 m

T = 10 s

92

$$L_0 = \frac{gT^2}{2\pi} = 156.13$$

$$d/L_0 = \frac{10}{156.13} = 0.06 \rightarrow \text{transitional}$$

$$\frac{L}{L_0} = \tanh \frac{2\pi \times 10}{L}$$

Let, L $\quad$ $L_0 \times \tanh \frac{2\pi \times 10}{L}$

P10/ $T = 10s$ | Find C, L

$d = 200m$ to $d = 3m$

For $d = 200m$:

$$L_0 = \frac{gT^2}{2\pi} = 156.13$$

$$d/L_0 = \frac{200}{156.13} = 1.28 \longrightarrow \text{deep water}$$

$$C = C_0 = \frac{gT}{2\pi}$$

$d = 3m$:

Local fluid particle accelerations

(eq be provided)

Lec 5

water particle displacements

(eq not be provided)
(derivation may be asked)
(draw figure)

$\frac{\xi^2}{A^2} + \frac{\zeta^2}{B^2} = 1$ ← show that in shallow water particle moves in elliptical path

Example P12

$T = 8s \qquad d = 15m \qquad H = 5.5\,m$

$L_0 = 1.56\,T^2 = 1.56 \times 8^2 = 99.84\,m$

At $d = 15m$

$d/L_0 = \frac{15}{99.84} = 0.15$ [transitional]

$L = 81.7\,m$

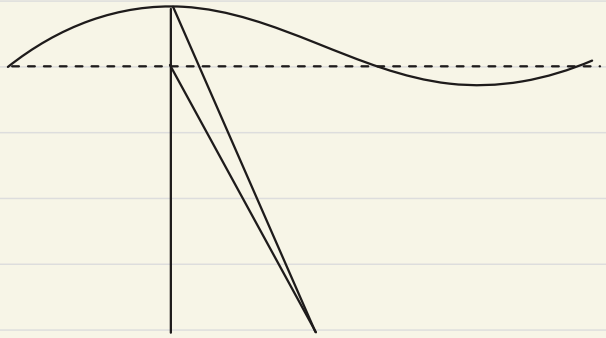
$$w = \frac{H}{2}\frac{gT}{L}\frac{\sinh\left[\frac{2\pi(z+d)}{L}\right]}{\cosh\frac{2\pi d}{L}}\sin\theta$$

$$= \frac{5.5}{2} \times \frac{9.81 \times 8}{81.7} \times \frac{\sinh\left[\frac{2\pi(-5+15)}{81.7}\right]}{\cosh\frac{2\pi \times 15}{81.7}}\sin\frac{\pi}{3}$$

$\doteq$

Linear wave theory: wave pressure

Deep water wave dynamic pressure distribution



> 1.0

1.025

$$\eta = \frac{N(\rho + \rho g z)}{\rho g k_2}$$

Application example: P22

$p = 144 \ KN/m^2$

$T = 1/f = 1/0.066 = 15s$

...

$$z = -(12 - 0.6) = -11.4 \ m$$

CT → lec 5, 6

Chapter 7—8: Wave energy

Two types energy → kinetic, potential

$$\bar{E}_K = \int_x^{x+L} \cdots$$ [not needed to memo]

$$\bar{E}_K = \frac{1}{16}\rho g H^2 L$$

$$\bar{E}_P = \frac{1}{16}\rho g H^2 L$$

} memo

Power: ...

memo

$$n = \frac{1}{2}\left(1 + \frac{2kd}{\sinh 2kd}\right) \qquad P = \left(\frac{nE}{T}\right)_1 = \left(\frac{nE}{T}\right)_2 = \text{const}$$

Wave power:

$$E = \frac{\rho g H^2 L}{8} \; ; \qquad \frac{B_1 \times n_1 \times \rho g H_1^2 \times L_1}{8T} = \frac{B_2 \times n_2 \times \rho g H_2^2 \times L_2}{8T}$$

$$\Rightarrow \quad - - -$$

~~Graph of P08~~

Specific energy → energy per unit surface area

$$\bar{E} = \frac{E}{L \times 1} = \frac{\rho g H^2}{8}$$

wave energy flux → $\bar{P} = \frac{1}{T}\int_t^{t+n} \cdots$ [not needed to memo]

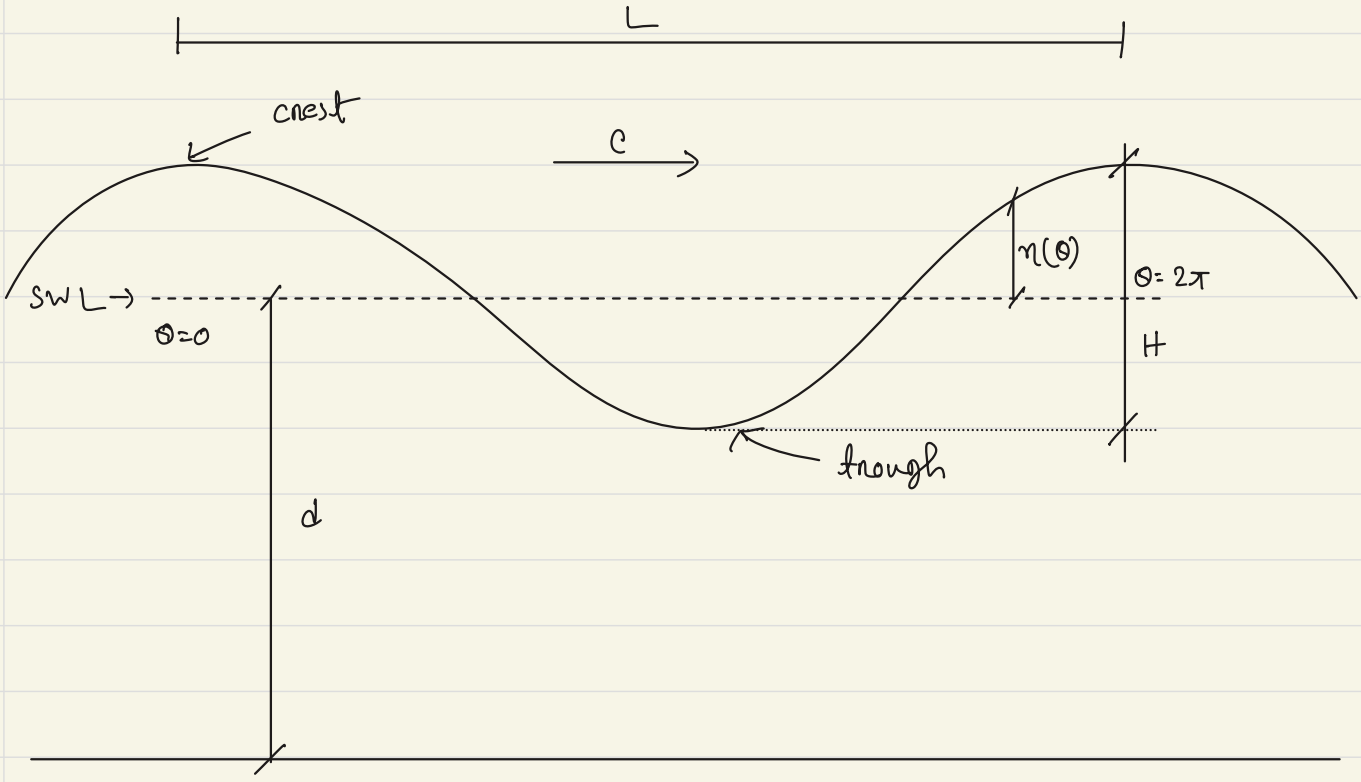
$$\bar{P} = \bar{E}\, nC = \bar{E} C_g \qquad \text{[memo]}$$

($C = L/T$)

$$= \bar{E}\, n \frac{L}{T}$$

Lec 5-6: Small Amplitude Wave Theory & Application Examples

Wave parameters:



$\omega = \frac{2\pi}{T}$; $K = \frac{2\pi}{L}$ T = Time period

$C = \frac{L}{T} = \frac{\omega}{K}$ [wave celerity = speed of wave (crest/trough/..)

Relative depth = $\frac{d}{L}$ Relative steepness = $\frac{H}{L}$

Relative wave ht = $\frac{H}{d}$

Amplitude = $H/2$ [for small amplitude waves (compared to wave len)]

Celerity of propagation,

$$c = \frac{L}{T} \quad \text{or} \quad c = \frac{\omega}{k} \quad (\omega \to \frac{2\pi}{T},\ k \to \frac{2\pi}{L})$$

General formula, $c = \sqrt{\frac{gL}{2\pi} \tanh\left(\frac{2\pi d}{L}\right)}$

$$\Rightarrow c^2 = \frac{gcT}{2\pi} \tanh\left(\frac{2\pi d}{L}\right) \qquad c = \frac{L}{T} \Rightarrow L = cT$$

$$\Rightarrow c = \frac{gT}{2\pi} \tanh\left(\frac{2\pi d}{L}\right)$$

$$\rightarrow L = \frac{gT^2}{2\pi} \tanh\left(\frac{2\pi d}{L}\right)$$

Wave classification:

Deep water: $\frac{d}{L} > 0.5$; at depth > 0.5 (wave length), wave don't touch channel bed (no friction, full circular)

$$\tanh(2\pi x) \approx 1 \quad \text{for} \quad x > 0.5$$

$$L_0 = \frac{gT^2}{2\pi}$$

$$c_0 = \frac{gT}{2\pi}$$

Intermediate: $d/L \rightarrow [0.05, 0.5]$

$$c = c_0 \tanh\frac{2\pi d}{L} \quad ; \quad c_0 = \frac{gT}{2\pi}$$

$$L = L_0 \tanh\frac{2\pi d}{L} \quad ; \quad L_0 = \frac{gT^2}{2\pi}$$

Shallow: $\frac{d}{L} < 0.05$

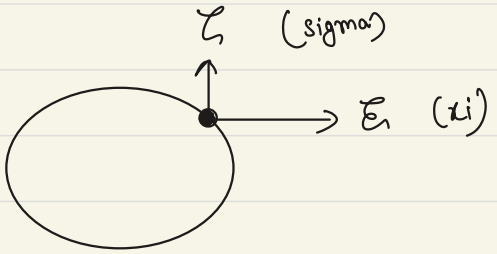
$C = \sqrt{gd}$

$L = \sqrt{gd}\,T$

$\left[\frac{\tanh(2\pi x)}{2\pi} \approx x \text{ for } x \leq 0.05\right]$

Deep water	Intermediate water	Shallow water
$C_0 = \frac{gT}{2\pi}$	$C = C_0 \tanh\frac{2\pi d}{L}$	$C = \sqrt{gd}$
$L_0 = \frac{gT^2}{2\pi}$	$L = L_0 \tanh\frac{2\pi d}{L}$	$L = \sqrt{gd}\,T$

water particle displacement:



$$\xi = -\frac{H}{2}\,\frac{\cosh\left(\frac{2\pi(z+d)}{L}\right)}{\sinh\frac{2\pi d}{L}}\sin\theta$$

$$\zeta = \frac{H}{2}\,\frac{\sinh\left(\frac{2\pi(z+d)}{L}\right)}{\sinh\left(\frac{2\pi d}{L}\right)}\cos\theta$$

Show that in shallow water depth, particles move in elliptical orbit:

Using simplified equation of particle displacement:

$$\xi = -\frac{H}{2} \frac{\cosh \frac{2\pi(d+z)}{L}}{\sinh \frac{2\pi(d)}{L}} \sin\theta$$

$$\zeta = \frac{H}{2} \frac{\sinh \frac{2\pi(z+d)}{L}}{\sinh \frac{2\pi d}{L}} \cos\theta$$

Now, $\sin^2\theta = \left[\frac{\xi}{a} \frac{\sinh \frac{2\pi d}{L}}{\cosh \frac{2\pi(z+d)}{L}} \right]^2$ $\quad \left[\frac{H}{2} = a\right]$

$$\cos^2\theta = \left[\frac{\zeta}{a} \frac{\sinh \frac{2\pi d}{L}}{\sinh \frac{2\pi(z+d)}{L}} \right]^2$$

And, $\sin^2\theta + \cos^2\theta = \frac{\xi^2}{A^2} + \frac{\zeta^2}{B^2}$; $A = \cdots$

$B = \cdots$

Ans / Show that in shallow water depth, particles move in elliptical orbit:

Using simplified eqn of water particle displacement:

$$\xi = -\frac{H}{2}\frac{\cosh\frac{2\pi(z+d)}{L}}{\sinh\frac{2\pi d}{L}}\sin\theta$$

$$\zeta = \frac{H}{2}\frac{\sinh\frac{2\pi(z+d)}{L}}{\sinh\frac{2\pi d}{L}}\cos\theta$$

Let, $A = \frac{H}{2}\frac{\cosh\frac{2\pi(z+d)}{L}}{\sinh\frac{2\pi}{L}}$; horizontal semi-orbital axis

$$B = \frac{H}{2}\frac{\sinh\frac{2\pi(z+d)}{L}}{\sinh\frac{2\pi d}{L}}$$; vertical semi-orbital axis

Now, $\xi = -A\sin\theta \Rightarrow \frac{\xi}{A} = -\sin\theta$

$\zeta = B\cos\theta \Rightarrow \frac{\zeta}{B} = \cos\theta$

$$\Rightarrow \sin^2\theta + \cos^2\theta = \frac{\xi^2}{A^2} + \frac{\zeta^2}{B^2}$$

$$\Rightarrow \frac{\xi^2}{A^2} + \frac{\zeta^2}{B^2} = 1 \longrightarrow \text{elliptical}$$

At deep-water, $A = B$

shallow-water, $z \to -d$; $\cosh 0 = 1$

$\sinh 0 = 0$

$\therefore B > A \longrightarrow$ flattens $\rightarrow$ horizontal

velocities:

$$\text{Horizontal, } u = \frac{H}{2}\frac{gT}{L}\frac{\cosh\frac{2\pi(z+d)}{L}}{\cosh\frac{2\pi(d)}{L}}\cos\theta$$

$$\text{vertical, } w = \frac{H}{2}\frac{gT}{L}\frac{\sinh\frac{2\pi(z+d)}{L}}{\cosh\frac{2\pi(d)}{L}}\sin\theta$$

Ex. P12 / $T = 8s$; $d = 15m$; $H = 5.5m$

$$\frac{L}{L_0} = \tanh\frac{2\pi d}{L} \quad ; \qquad L_0 = \frac{gT^2}{2\pi} = \frac{9.8\times 8^2}{2\pi} = 99.82$$

$\Rightarrow L = 81.73$ m

Trial & error:

L	$L_0 \tanh\frac{2\pi d}{L}$
50	95.32
100	73.5
80	82.54
81	82.07
81.5	81.84
81.7	81.74
81.73	81.73

Now, $d/L = \frac{15}{81.73} = 0.18 \in [0.05, 0.5]$ [intermediate]

At $\theta = \pi/3$, $z = -5m$:

$$v_x = \frac{H}{2}\frac{gT}{L}\frac{\cosh\frac{2\pi(z+d)}{L}}{\cosh\frac{2\pi d}{L}}\cos\theta$$

in rad

$$= \frac{55}{2}\frac{9.81\times 8}{81.73}\frac{\cosh\frac{2\pi(-5+15)}{81.73}}{\cosh\frac{2\pi\times 15}{81.73}}\cos\pi/3 = 0.993 \text{ m/s}$$

$$v_y = \frac{H}{2}\frac{gT}{L}\frac{\sinh\frac{2\pi(z+d)}{L}}{\cosh\frac{2\pi(d)}{L}}\sin\theta$$

$= \ldots$

$a_x = \ldots$

$a_y = \ldots$

$$\xi = -\frac{H}{2}\frac{\cosh\frac{2\pi(z+d)}{L}}{\sinh\frac{2\pi d}{L}}\sin\theta$$

$= \ldots$

$$\zeta = \frac{H}{2}\frac{\sinh\frac{2\pi(z+d)}{L}}{\sinh\frac{2\pi d}{L}}\cos\theta$$

$= \ldots$

Linear wave theory: wave pressure

Subsurface pressure:

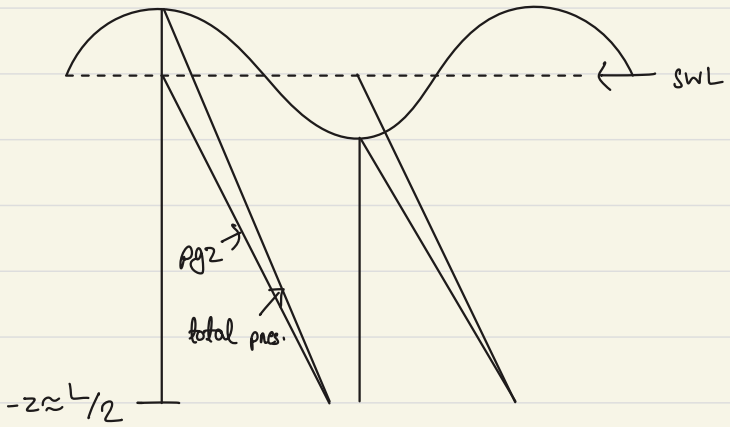
$$p = \frac{H}{2}\rho g \frac{\cosh \frac{2\pi(z+d)}{L}}{\cosh \frac{2\pi d}{L}} \cos\theta - \rho g z$$

$$= \rho g \eta k_2 - \rho g z$$

$$\Rightarrow p = \rho g (\eta k_2 - z)$$

$$\eta = \frac{H}{2}\cos\theta$$

$$k_2 = \frac{\cosh \frac{2\pi(z+d)}{L}}{\cosh \frac{2\pi d}{L}}$$



$$\eta = \left(\frac{p}{\rho g} + z\right)\frac{1}{k_2}$$

$$= \frac{p + \rho g z}{\rho g k_2} \rightarrow \frac{N(p+\rho g z)}{\rho g k_2}$$

$\rho > 1000\ kg/m^3$ for seawater

P22/ $p = 124\ kN/m^2$

$z = -(12 - 0.6) = -11.4\ m$

$T = \frac{1}{0.066} = 15\ s$

$\frac{L}{L_0} = \tanh \frac{2\pi d}{L}$

$L_0 = \frac{gT^2}{2\pi} = 351.29\ m$

$\therefore L = 156.9\ m$

$K_2 = \frac{\cosh \frac{2\pi(z+d)}{L}}{\cosh \frac{2\pi d}{L}}$

$= 0.895$

$\eta = \frac{p + \rho g z}{\rho g K_2}$

$= \frac{124 + 1.025 \times 9.81 \times (-11.4)}{1.025 \times 9.81 \times 0.895}$

$= 1.04$

$\Rightarrow \frac{H}{2} = 1.04 \Rightarrow H = 2.08\ m$

Recap:

$$c = \frac{gT}{2\pi} \tanh\left(\frac{2\pi d}{L}\right)$$

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

wave classification: deep-water $\rightarrow \frac{d}{L} > 0.5$

$$c_0 = \frac{gT}{2\pi}$$

$$L_0 = \frac{gT^2}{2\pi}$$

Intermediate $\rightarrow \frac{d}{L} \rightarrow [0.05, 0.5]$

$$c = c_0 \tanh \frac{2\pi d}{L}$$

$$L = L_0 \tanh \frac{2\pi d}{L}$$

Shallow $\rightarrow \frac{d}{L} < 0.05$

$$c = \sqrt{gd}$$

$$L = \sqrt{gd}\, T$$

wave particle displacement:

vertical, $\xi = -\frac{H}{2} \frac{\cosh \frac{2\pi(d+z)}{L}}{\sinh \frac{2\pi d}{L}} \sin\theta$

Horizontal, $\zeta = \frac{H}{2} \frac{\sinh \frac{2\pi(d+z)}{L}}{\sinh \frac{2\pi d}{L}} \cos\theta$

velocity:

$$v_x = \frac{H}{2} \frac{gT}{L} \frac{\cosh \frac{2\pi(d+z)}{L}}{\cosh \frac{2\pi(d)}{L}} \cos\theta \; ; \; v_y = \frac{H}{2} \frac{gT}{L} \frac{\sinh \frac{2\pi(d+z)}{L}}{\cosh \frac{2\pi d}{L}} \sin\theta$$

Show: in shallow water depth, particle move in elliptical orbit

Hor. displacement, $\xi = -\frac{H}{2} \frac{\cosh \frac{2\pi(z+d)}{L}}{\sinh \frac{2\pi d}{L}} \sin\theta$

Vert. " , $\zeta = \frac{H}{2} \frac{\sinh \frac{2\pi(z+d)}{L}}{\sinh \frac{2\pi d}{L}} \cos\theta$

Let, hor. semi-orbital axis, $A = \frac{H}{2} \frac{\cosh \frac{2\pi(z+d)}{L}}{\sinh \frac{2\pi(d)}{L}}$

vert. " " , $B = \frac{H}{2} \frac{\sinh \frac{2\pi(z+d)}{L}}{\sin \frac{2\pi d}{L}}$

Hence, $\xi = -A\sin\theta \Rightarrow \sin^2\theta = \frac{\xi^2}{A^2}$

$\zeta = B\cos\theta \Rightarrow \cos^2\theta = \frac{\zeta^2}{B^2}$

$\Rightarrow \frac{\xi^2}{A^2} + \frac{\zeta^2}{B^2} = 1 \longrightarrow$ elliptical

At shallow water depth, $z \to -d$; $\cosh(0) = 1$

$\sinh(0) = 0 \rightarrow B \to 0$

$\therefore A > B \rightarrow$ flattens $\rightarrow$ horizontal

Linear wave theory: wave pressure

$$p = \frac{H}{2} \rho g \frac{\cosh\left(\frac{2\pi(z+d)}{L}\right)}{\cosh\left(\frac{2\pi d}{L}\right)} \cos\theta - \rho g z$$

$$\eta = \frac{H}{2} \cos\theta$$

$$K_z = \frac{\cosh \frac{2\pi(z+d)}{L}}{\cosh \frac{2\pi d}{L}}$$

$$\therefore p = \rho g \eta K_z - \rho g z$$

$$= \rho g (\eta K_z - z)$$

$$\eta = \frac{N\left(p + \rho g z\right)}{\rho g K_z}$$

P12/ $T = 8$ sec

$d = 15$ m

$H = 5.5$ m

$$L_0 = \frac{gT^2}{2\pi} = \frac{9.81 \times 8^2}{2\pi} = 99.92 \text{ m}$$

$L = 81.79$ m

$d/L_0 = \frac{15}{99.92} = 0.15$ (intermediate)

$$\therefore L = L_0 \tanh \frac{2\pi d}{L}$$

L	$L_0 \tanh \frac{2\pi d}{L}$
50	95.42
100	73.58
80	82.62
81.5	81.92
81.7	- - -

$$\xi = -\frac{H}{2} \frac{\cosh \frac{2\pi(d+z)}{L}}{\sinh \frac{2\pi d}{L}} \sin\theta =$$

$$\zeta = \frac{H}{2} \frac{\sinh \frac{2\pi(d+z)}{L}}{\sinh \frac{2\pi d}{L}} \cos\theta =$$

P22/

$p = 124\ kN/m^2$

$\rho = 1025\ kg/m^3$

$d = 12\ m$

$z = -(12 - 0.6) = -11.4\ m$

$T = 1/0.066 = 15\ s$

$$\eta = \frac{N(p + \rho g z)}{\rho g K_2}$$

$$= \frac{124 + 1.025 \times 9.81 \times (-11.6)}{1.025 \times 9.81 \times 0.90}$$

$$= 1.04$$

$$\therefore H = 2.08\ m$$

$$K_2 = \frac{\cosh \frac{2\pi(d+z)}{L}}{\cosh \frac{2\pi d}{L}}$$

$$= 0.90$$

$$L_0 = \frac{gT^2}{2\pi} = 351.29\ m$$

$$d/L_0 = 0.034 < 0.05$$

$$\therefore L = \sqrt{gd}\, T = 162.75\ m$$

Lec 7/ P11

P12/ #6

$$\frac{L}{L_0} = \tanh \frac{2\pi d}{L}$$

$$\Rightarrow L = 156 \tanh\left(\frac{2\pi \times 10}{L}\right)$$

$$\Rightarrow L = 92.34$$

$T = 10$ sec

$L_0 = 1.56 T^2 = 156$ m

$$H/H_0 = \sqrt{\frac{L_0}{2nL}}$$

$$\Rightarrow H = 2\sqrt{\frac{156}{2 \times 0.874 \times 93.3}} =$$

$$n = \frac{1}{2}\left(1 + \frac{2kd}{\sin 2kd}\right)$$

$$= \frac{1}{2}\left(1 + \frac{2(0.0673)(10)}{\sinh(2(0.0673)(10))}\right)$$

$$= 0.876$$

Log

20/08

Linear wave theory - group velocity

$$c_g = \frac{1}{2}\frac{L}{T}\left[1 + \frac{\frac{4\pi d}{L}}{\sinh\frac{4\pi d}{L}}\right] = nC$$

Deep-water, $c_{g_0} = \frac{1}{2} c_0$

Shallow water, $C = \sqrt{gD}$

P22/ $L_0 = 1.56\,T^2 = \cdots$

Mid → Lec 7, 8

Wave transformation

Processes:

Wave shoaling: $d \approx \frac{1}{2}L$ or less

$$\frac{H}{H_0} = \underbrace{\sqrt{\frac{L_0}{2nL}}}_{K_s} \underbrace{\sqrt{\frac{B_0}{B}}}_{K_r}$$

Green's law

$$Hd^{1/4} = \text{const}$$

↳ theoretically reach ∞ but breaks earlier

\# $d_1 = 10\,m$, $H_1 = 1\,m$, $d_2 = 1\,m$

$$H_1 d_1^{1/4} = H_2 d_2^{1/4}$$

$$\Rightarrow H_2 = 1.78\,m$$

Rough / Midterm

27/08

Lec 7-8: Linear Wave Theory — Wave Energy

Total energy of wave system:

$$E = E_K + E_P$$
$$= \frac{1}{16}\rho g H^2 L + \frac{1}{16}\rho g H^2 L$$
$$= \frac{1}{8}\rho g H^2 L$$

wave power:

$$P = \frac{\rho g H^2 L}{16T}\left(1 + \frac{2kd}{\sinh 2kd}\right) \quad ; \quad k = \frac{2\pi}{L} \qquad \left[\omega = \frac{2\pi}{T};\ C = \frac{L}{T} = \frac{\omega}{k}\right]$$

$$= \frac{E}{T} n = \frac{nE}{T} \quad ;$$

$$n = \frac{1}{2}\left[1 + \frac{2kd}{\sinh 2kd}\right] \rightarrow 0.5 \text{ @ DW}, \quad 1 \text{ @ S.W}$$

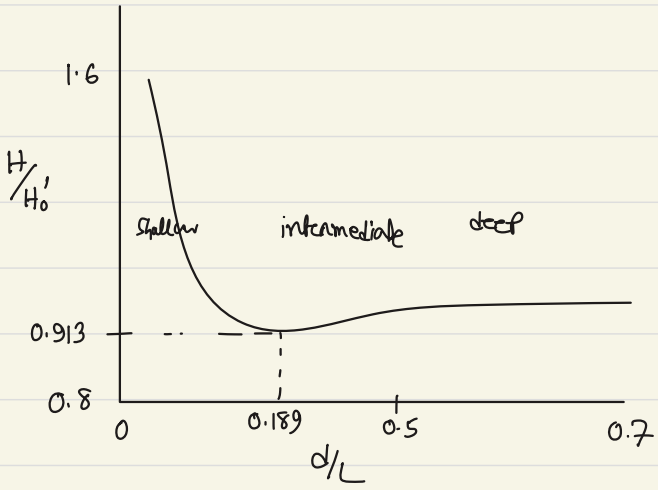
$$E = \frac{1}{8}\rho g H^2 L$$

Specific energy:

$$\bar{E} = \frac{E}{A \rightarrow L \times 1}$$
$$= \frac{\rho g H^2}{8}$$

P8/

As waves enters intermediate water depth from deep water, its wave heigh decreases. It (H/H_0') reaches minimum value of 0.913 at $d/L = 0.189$. Shoreward of this point, wave ht increases rapidly until it breaks.



wave energy flux:

$$\bar{P} = \bar{E} n C = \bar{E} C_g ;$$

$$\bar{E} = \frac{\rho g h^2}{8}$$

$$n = \frac{1}{2}\left[1 + \frac{2kd}{\sinh 2kd}\right] ; \qquad k = \frac{2\pi}{L}$$

$$C = \frac{gT}{2\pi} \tanh \frac{2\pi d}{L}$$

$$\bar{P}_0 = \frac{1}{2} \bar{E}_0 C_0$$

$$P_{shallow} = E \bar{C}$$

P11/

- when crest parallel to contour: energy is conserved

$$\bar{E}_0 n_0 C_0 = \bar{E} n C$$

$$\Rightarrow \frac{1}{2} \bar{E}_0 C_0 = \bar{E} n C$$

- If crest is at an angle, above no longer applies
- Group velocity determines how fast energy is moving towards shoreline.
- Shoaling coeff. determines ht of wave in relation to wave ht at deep water (H/H_0).

P12/

$$C_0 = \frac{gT}{2\pi}; \quad L_0 = \frac{g T^2}{2\pi}$$

$$C = C_0 \tanh \frac{2\pi d}{L}; \quad L = L_0 \tanh \frac{2\pi d}{L}$$

$$H/H_0 = \sqrt{\frac{L_0}{2nL}}$$

$d = 10\ m$

$L_0 = 156\ m$

$H_0 = 2\ m$

$$L = L_0 \tanh \frac{2\pi d}{L}$$

$$\Rightarrow L = 92.34\ m$$

$$H = H_0 \sqrt{\frac{L_0}{2nL}}; \qquad n = \frac{1}{2}\left[1 + \frac{2kd}{\sinh 2kd}\right]; \qquad k = \frac{2\pi}{L} = 0.068$$

$$= 2 \times \sqrt{\frac{156}{2 \times 0.874 \times 92.34}} \qquad = \frac{1}{2}\left[1 + \frac{2 \times 0.068 \times 10}{\sinh(2 \times 0.068 \times 10)}\right]$$

$$= 1.97\ m \qquad = 0.874$$

$$u_x = \frac{H}{2}\frac{gT}{L}\frac{\cosh\frac{2\pi(d+z)}{L}}{\cosh\frac{2\pi d}{L}}\cos\theta \;; \qquad L_0 = \frac{gT^2}{2\pi} \Rightarrow T = 10\,s$$

$$= 1\ m/s$$

$$p = \frac{H}{2}\rho g\frac{\cosh\frac{2\pi(d+z)}{L}}{\cosh\frac{2\pi d}{L}}\cos\theta - \rho g z$$

$$= \cdots$$

Group vel → C_g

Individual vel → C (phase vel / celerity)

$C_g > C$ may happen due to surface tension.

$$C_g = nC \;; \quad C = \frac{L}{T} \;;$$

$$n = \frac{1}{2}\left[1 + \frac{2kd}{\sinh 2kd}\right]$$

deep water → $C_g = \frac{1}{2}C_0$

shallow water → $C_g = C = \sqrt{gd}$

P22/

$T = 10\,s$

$d_1 = 200\,m$; $d_2 = 3\,m$

$L_o = \frac{gT^2}{2\pi} = 156.13\,m$;

At $d = 200\,m$:

$\frac{d}{L_o} = 1.28 > 0.5$; deep

$C_g = \frac{1}{2}C = \frac{1}{2}\left(\frac{gT}{2\pi}\right) = 7.8\,m/s$

At $d = 3\,m$

$\frac{d}{L_o} = 0.019 < 0.05$; shallow

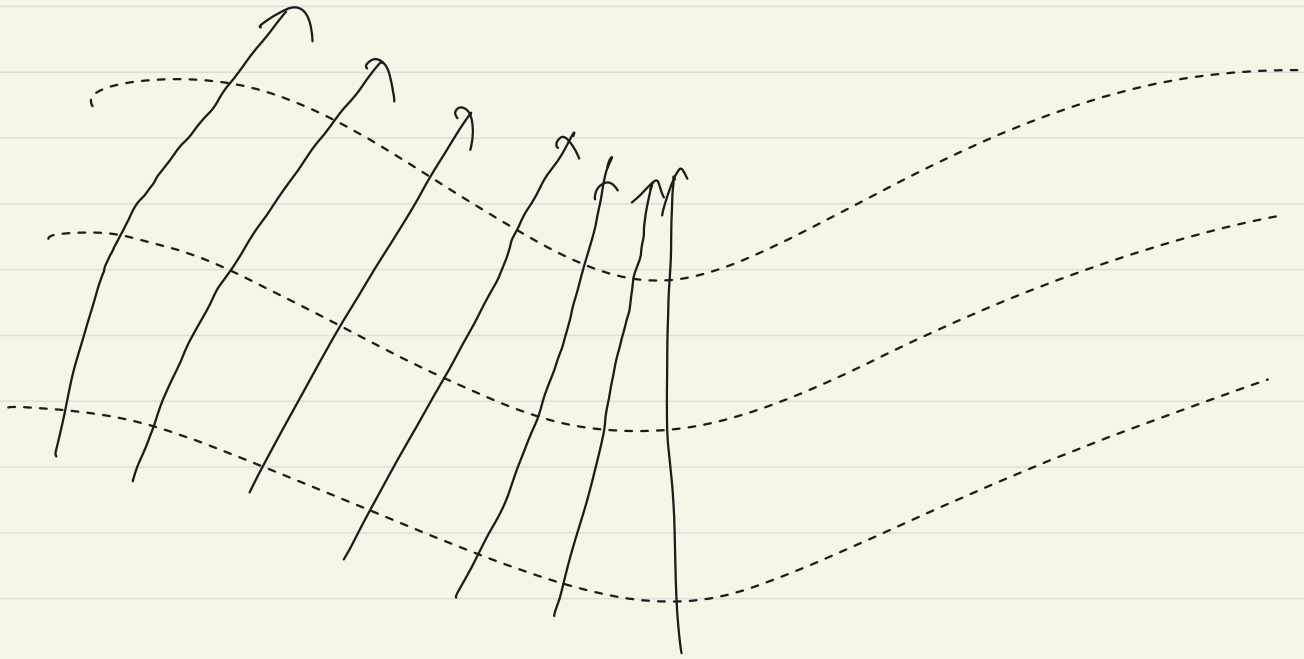
$\therefore C_g = C = \sqrt{gd} = 5.42\,m/s$

L11

03/09

Wave Refraction

wave tries to move vertical to contour line



Math/ P17

$H_0 = 2m$

$T = 10\,s$

$\theta = 35°$

$C_0 = 15.6\ m/s$

$d = 2.3\ m$

$C = 4.75\ m/s$

L12

06/09

P16/

$c_0 = 15.6$ m/s

$d = 2.3$ m

$c = \sqrt{gd} = 4.75$ m/s

Wave diffraction

P24/ $T = 6$s

$d = 10$ m

$L_0 = \frac{gT^2}{2\pi} = 56.21$

$L = L_0 \tanh \frac{2\pi d}{L} \Rightarrow L = 48.41$ m

L13

07/09

Spilling
Plunging
collapsing
Surging
} all 4

why waves breaks

L14 10/09

Breaker types

ε_n → be given bathymetry → bed profile

P19/

(a) $L_0 = 1.5(8)^2 = 99.84$ m $m = 0.05$

$\frac{H_0}{L_0} = \frac{4.5}{99.84} = 0.045$

From Nomograph, Slope = 0.05

shoaling factor = 1.16

$\therefore H_b = 4.5 \times 1.16 = 5.22$ m

$\varepsilon_0 = \tan\beta \left(\frac{H_0}{L_0}\right)^{-1/2}$

Instead of what kind of breaker it may be asked — what'll be the breaking Ht for spilling breaker

P21/ $L_0 = 156\,m$

$H_0/L_0 = 3/156 = 0.019$

From Nomograph 1, for slope = 0.05, shoaling fact. = 1.4 } $K_R = 1.05$

$H_b = H_0 \times K_R \times K_S = 3 \times 1.05 \times 1.4 = 4.41\ m$

$H_b/gT^2 = \frac{4.41}{9.81 \times \dots}$

P22/

Radiation stress

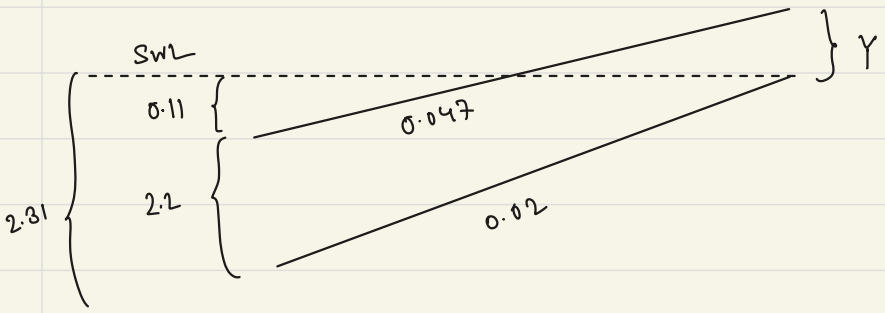
$$\eta_d = -\frac{H^2}{16d} \qquad \text{[set-down]}$$

P35/ $H = 2m$

$d = 2.2\,m$

$$\eta_d = -\frac{H^2}{16d} = -0.114\ m$$

$$\frac{dd'}{dx} = \left(1 + \frac{8}{\cdots}\right)^{-1} \Rightarrow \cdots$$



Y = set up = $0.425\ m$

---

wave swash

wave run-up

ØØ math

50+10
+20 b

P44/

white capping
wave overtopping
wave reflection

Rough / Final

03/11

Lec 3

$\omega = \frac{2\pi}{T}$; $k = \frac{2\pi}{L}$

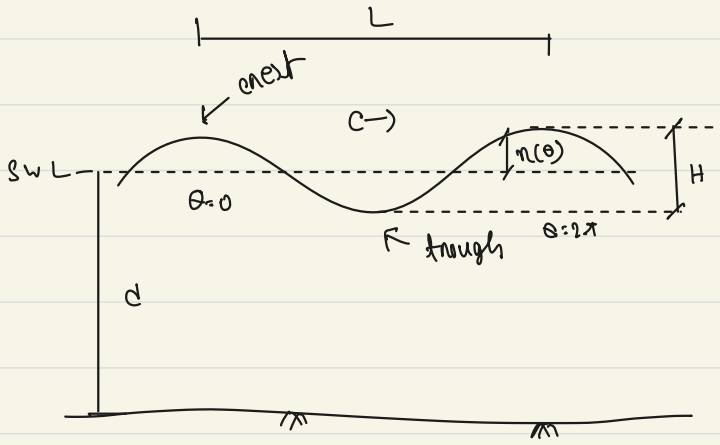
$C = \frac{L}{T} = \frac{\omega}{k}$

Relative depth = $\frac{d}{L}$

" wave ht = $\frac{H}{d}$

steepness = $\frac{H}{L}$

Amplitude = $H/2$



Small amplitude wave theory:

Dispersion eqn:

$$C = \frac{gT}{2\pi} \tanh \frac{2\pi d}{L}$$

$$L = \frac{gT^2}{2\pi} \tanh \frac{2\pi d}{L}$$

$C = \frac{L}{T} \Rightarrow L = CT$

Assumptions:

1. Incompressible fluid
2. Irrotational fluid motion
3. Pressure const at water–air interface
4. Impermeable flat btm
5. very small amplitude

when $\frac{d}{L} \geq 0.5$ → deep water

$$C_0 = \frac{gT}{2\pi}$$

$$L_0 = \frac{gT^2}{2\pi}$$

$\frac{d}{L} \leq 0.05$ → shallow water

$$C = \sqrt{gd}$$

$$L = \sqrt{gd}\,T$$

In btwn → Intermediate

$$\frac{C}{C_0} = \frac{L}{L_0} = \tanh \frac{2\pi d}{L}$$

Lec 4

P09/ $d = 10\,m$

$T = 10\,s$

$H = 2\,m$

Assume deep water,

$$C_0 = \frac{gT}{2\pi} = 15.61\ m/s$$

$$L_0 = C_0 T = 156.13\ m$$

$$d/L = {}^{10}/_{156.13} = 0.064 < 0.5 \quad \text{[intermediate]}$$

$$\frac{L}{L_0} = \tanh \frac{2\pi d}{L}$$

L	$L_0 \tanh \frac{2\pi d}{L}$
100	86.95
90	94.17
92	92.65
92.3	92.43
92.37	92.38

P10/

$T = 10s$

$d = 200\,m, \quad d = 3m$

$$C_0 = \frac{gT}{2\pi} = 15.61\ m/s$$

$$L_0 = C_0 T = 156.1\ m$$

$d = 200m$: $\quad d/L_0 = \frac{200}{156.1} = 1.28 > 0.5 \longrightarrow$ deep

$C = C_0$

$L = L_0$

$d = 3\,m$; $\quad d/L_0 = 0.019 \leq 0.05$; $\quad C = \sqrt{gD} = 5.42\ m/s$

$L = CT = 54.2\,m$

---

velocity:

$$u = \frac{H}{2}\frac{gT}{L}\frac{\cosh\frac{2\pi(z+d)}{L}}{\cosh\frac{2\pi d}{L}}\cos\theta$$

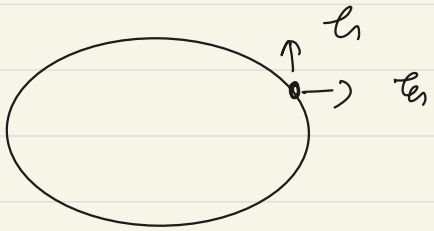
$$w = \frac{H}{2}\frac{gT}{L}\frac{\sinh\frac{2\pi(z+d)}{L}}{\cosh\frac{2\pi d}{L}}\sin\theta$$

Accelenation:

$$\alpha_x = \frac{g\pi H}{L}\frac{\cosh\frac{2\pi(z+d)}{L}}{\cosh\frac{2\pi d}{L}}\sin\theta$$

$$\alpha_z = \frac{g\pi H}{L}\frac{\sinh\frac{2\pi(z+d)}{L}}{\cosh\frac{2\pi d}{L}}\cos\theta$$

Lec 5



Displacement:

$$\xi = -\frac{HgT^2}{4\pi L}\,\frac{\cosh\frac{2\pi(z+d)}{L}}{\cosh\frac{2\pi d}{L}}\,\sin\theta$$

$$\zeta = +\frac{HgT^2}{4\pi L}\,\frac{\sinh\frac{2\pi(z+d)}{L}}{\cosh\frac{2\pi d}{L}}\,\cos\theta$$

Simplified: Show that is in shallow water depth particle moves in elliptical orbit:

$$\xi = -\frac{H}{2}\,\frac{\cosh\frac{2\pi(z+d)}{L}}{\sinh\frac{2\pi d}{L}}\,\sin\theta$$

$$\zeta = +\frac{H}{2}\,\frac{\sinh\frac{2\pi(z+d)}{L}}{\sinh\frac{2\pi d}{L}}\,\cos\theta$$

Let, $A = \frac{H}{2}\,\frac{\cosh\frac{2\pi(d+z)}{L}}{\sinh\frac{2\pi d}{L}}$; $B = \frac{H}{2}\,\frac{\sinh\frac{2\pi(z+d)}{L}}{\sinh\frac{2\pi d}{L}}$

$\Rightarrow \xi = -A\sin\theta$, $\zeta = B\cos\theta$

$\Rightarrow \sin\theta = -\frac{\xi}{A}$; $\cos\theta = \frac{\zeta}{B}$

$$\sin^2\theta + \cos^2\theta = 1 = \frac{\xi^2}{A^2} + \frac{\zeta^2}{B^2}$$

$$A = \frac{H}{2} \frac{\cosh \frac{2\pi(d+z)}{L}}{\sinh \frac{2\pi d}{L}} \quad ; \quad B = \frac{H}{2} \frac{\sinh \frac{2\pi(z+d)}{L}}{\sinh \frac{2\pi d}{L}}$$

At deep, $A = B$

shallow, $z = -d \rightarrow \cosh(0) = 1$

$\sinh(0) = 0$

$B > A \rightarrow$ flattens $\rightarrow$ horizontal

P12/ $T = 8s$

$d = 15\,m$

$H = 5.5\,m$

$$u = \frac{H}{2}\frac{gT}{L}\frac{\cosh\frac{2\pi(z+d)}{L}}{\cosh\frac{2\pi d}{L}}\cos\theta =$$

$$w = \frac{H}{2}\frac{gT}{L}\frac{\sinh\frac{2\pi(z+d)}{L}}{\cosh\frac{2\pi d}{L}}\sin\theta$$

$$p_n = -\frac{\rho g H}{L}\frac{\cosh\square}{\cosh\square}\sin$$

$$p_2 = \frac{\rho g H}{L}\frac{\sinh}{\cosh}\cos$$

$$\xi_3 = -\frac{H}{2}\frac{\cosh\frac{2\pi(z+d)}{L}}{\sinh\frac{2\pi(z+d)}{L}}\sin\theta$$

$$\xi_3 = +\frac{H}{2}\frac{\sinh\square}{\sinh\square}\cos\theta$$

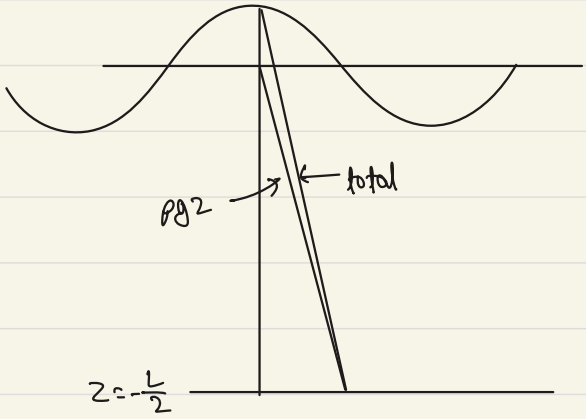
Subsurface pressure:

$$p = \frac{H}{2}\rho g \frac{\cosh \frac{2\pi(z+d)}{L}}{\cosh \frac{2\pi d}{L}} \cos\theta - \rho g z$$

$$= \rho g \eta K_2 - \rho g z$$

$$\eta = \frac{H}{2}\cos\theta$$

$$K_2 = \frac{\cosh \frac{2\pi(z+d)}{L}}{\cosh \frac{2\pi d}{L}}$$



$$\Rightarrow p = \rho g (\eta K_2 - z)$$

$K_2 \rightarrow$ pressure resp. factor

$$\eta = \left(\frac{p}{\rho g} + z\right)\frac{1}{K_2}$$

$$= \frac{p + \rho g z}{\rho g K_2} \rightarrow \frac{N(p+\rho g z)}{\rho g K_2}$$

P22/

$p = 124\ KN/m^2$

$z = -12 + 0.6 = -11.4\ m$

$f = 0.0666\ Hz \rightarrow T = 15\ s$

$k_2 = \dfrac{\cosh \frac{2\pi(z+d)}{L}}{\cosh \frac{2\pi d}{L}}$

① $= 0.902$

$\eta = \dfrac{N(p+\rho g z)}{\rho g k_2}$

② $= \dfrac{124 + 1.025 \times 9.81 \times (-11.4)}{1.025 \times 9.81 \times 0.902} = 1.03$

$\eta = \dfrac{H}{2}\cos\theta$

③ $\Rightarrow H = 2.06\ m$

$L_0 = \dfrac{gT^2}{2\pi} = 351.29\ m$

$d/L_0 = \dfrac{12}{351.29} = 0.034 \lesssim 0.05$

$\therefore L = \sqrt{gD}\,T = 162.75\ m$

Recap:

$$p = \frac{H}{2}\rho g \frac{\cosh \frac{2\pi(z+d)}{L}}{\cosh \frac{2\pi d}{L}} \cos\theta - \rho g z$$

$$\eta = \frac{H}{2}\cos\theta; \quad \eta = \frac{N(p+\rho g z)}{\rho g k_2}$$

$$k_2 = \frac{\cosh \frac{2\pi(z+d)}{L}}{\cosh \frac{2\pi d}{L}}$$

Lec 7-8 : Wave Energy

Total energy, $E = E_K + E_P$

$$= \frac{1}{16}\rho g H^2 L + \frac{1}{16}\rho g H^2 L$$

$$= \frac{1}{8}\rho g H^2 L$$

Energy density or specific energy :

$$\bar{E} = \frac{E}{A} = \frac{\rho g H^2}{8} \qquad [A = L \times 1]$$

Power: Energy transmitted per unit time in the direction of wave propagation.

$$P = \frac{1}{2}\frac{E}{T}\left(1 + \frac{2kd}{\sinh 2kd}\right) \quad ; \quad k = \frac{2\pi}{L}$$

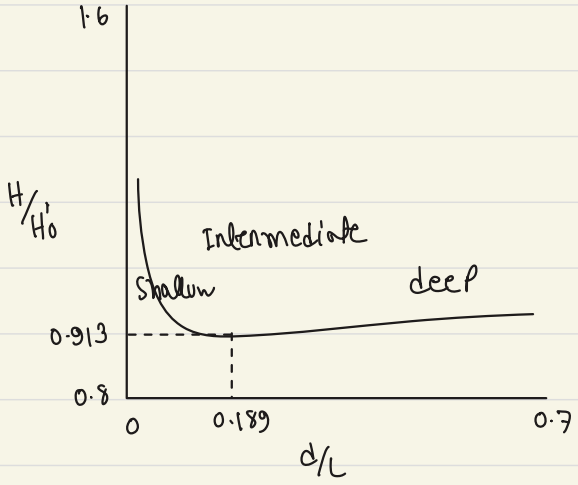
$$n = \frac{1}{2}\left(1 + \frac{2kd}{\sinh 2kd}\right)$$

$$P = \frac{nE}{T} \quad ; \quad n \to 0.5 \text{ at deep}$$

$$\to 1.0 \text{ at shallow}$$

P8/

As water moves shorewards, its wave ht decrease until it reaches the lowest at intermediate zone.
After that it starts increasing until the waves become unstable & breaks.



---

wave energy flux:

Rate at which energy is transmitted in the direction of wave across a perpendicular plane extending down the entire depth.

$$\bar{P} = \bar{E}\, n C = \bar{E} C_g$$

$\bar{P} \rightarrow$ wave power

Deep water, $\bar{P}_0 = \frac{1}{2} \bar{E}_0 C_0$; $n_0 = 1/2$ at deep

shallow " , $\bar{P} = \bar{E} C_g = \bar{E} C$ 1 at shallow

P11/

→ when crest is parallel to contour, energy is conserved,

$$\bar{E}_0 n_0 C_0 = \bar{E} n C \Rightarrow \frac{1}{2}\bar{E}_0 C_0 = \bar{E} n C$$

→ If not above breaks

→ Group vel. determines how fast energy is moving to shore.

→ Shoaling coeff dets rel^n of ht of wt w.r.n to deep water wave ht (H/H_0)

P12/ $d = 10m$

$L_0 = 156\ m$

$H_0 = 2m$

$$\frac{H}{H_0} = \sqrt{\frac{L_0}{2nL}}\sqrt{\frac{B_0}{B}}$$

$$\frac{H}{H_0} = \sqrt{\frac{L_0}{2nL}}\sqrt{\frac{B}{B_0}}$$

$$\Rightarrow H = 2 \times \sqrt{\frac{156}{2 \times 0.874 \times 92.33}}$$

$$= 1.97\ m$$

$$d/L_0 = 0.064 > 0.05$$

$$L = L_0 \tanh\frac{2\pi d}{L}$$

$$= 92.33\ m$$

$$n = \frac{1}{2}\left(1 + \frac{2kd}{\sinh 2kd}\right); \quad k = \frac{2\pi}{L}$$

$$= 0.068$$

$$= 0.874$$

$$L_0 = \frac{gT^2}{2\pi} \Rightarrow T = 10s$$

$$u_x = \frac{H}{2}\frac{gT}{L}\frac{\cosh\frac{2\pi(z+d)}{L}}{\cosh\frac{2\pi d}{L}}\cos\theta$$

$$= 1.0\ m/s$$

$$P = \frac{H}{2}\rho g \frac{\cosh\frac{2\pi(z+d)}{L}}{\cosh\frac{2\pi d}{L}}\cos\theta - \rho g z = \cdots$$

Group vel → C_g

Individual vel / phase vel → C

$$C_g = nC \; ; \qquad C = \frac{L}{T}$$

$$n = \frac{1}{2}\left[1 + \frac{2kd}{\sinh 2kd}\right]$$

deep water → $C_g = \frac{1}{2}C_0 \qquad \left[C_0 = \frac{gT}{2\pi}\right.$

shallow water → $C_g = C$

$= \sqrt{gd}$

P22 / $T = 10s$

$d = 200\,m$, $d = 3\,m$

$C_g = nC \; ; \quad n = \frac{1}{2}\left(1 + \frac{2kd}{\sinh 2kd}\right) ; \quad k = \frac{2\pi}{L}$

$$L_0 = \frac{gT^2}{2\pi} = 156.13\ m$$

At $d = 200\,m$; $\frac{d}{L_0} = 1.28 > 0.5$

$C = \frac{gT}{2\pi} = 15.61\ m/s$

$C_g = \frac{1}{2}C = 7.81\ m/s$

At $d = 3\,m$: $\frac{d}{L_0} = 0.019 < \frac{1}{20}$

$C = \sqrt{gd} = 5.42\ m/s$

$= C_g$

Lec 9-10 wave transformation

Shoaling:

Deformation of wave which starts when depth less than half of wave length.

$d/L \leq 0.5 \longrightarrow$ intermediate

$$H/H_0 = \underbrace{\sqrt{\frac{L_0}{2nL}}}_{K_s} \underbrace{\sqrt{\frac{B_0}{B}}}_{K_r}$$

K_s = Shoaling coeff

K_r = refraction coeff.

$$K_s = \frac{H}{H_0} = \sqrt{\frac{C_0}{2nC}}$$

At shallow, $n = 1$, $C = \sqrt{gd}$

$$\Rightarrow K_s = \frac{H}{H_0} = \sqrt{\frac{C_0}{2\sqrt{gd}}}$$

$\Rightarrow H \propto d^{-1/4} \Rightarrow H\, d^{1/4} = \text{const}$ [Green's Law]

$\rightarrow$ shallower $\rightarrow$ $d \downarrow$

$H \uparrow$

theoretically wave ht to reach infinite but practically, breaking occur.

P08/

$d_2 = 1\,m$

$d_1 = 10\,m$

$H_1 = 2\,m$

$$H_1 d_1^{1/4} = H_2 d_2^{1/4}$$

$$\Rightarrow H_2 = 1.78\,m$$

Wave refraction:

Turning of wave propagation direction when it comes at an angle with bottom contour.

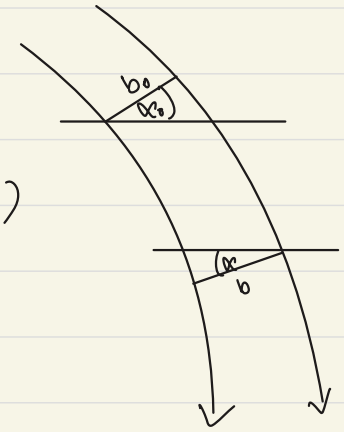
Snell's Law:

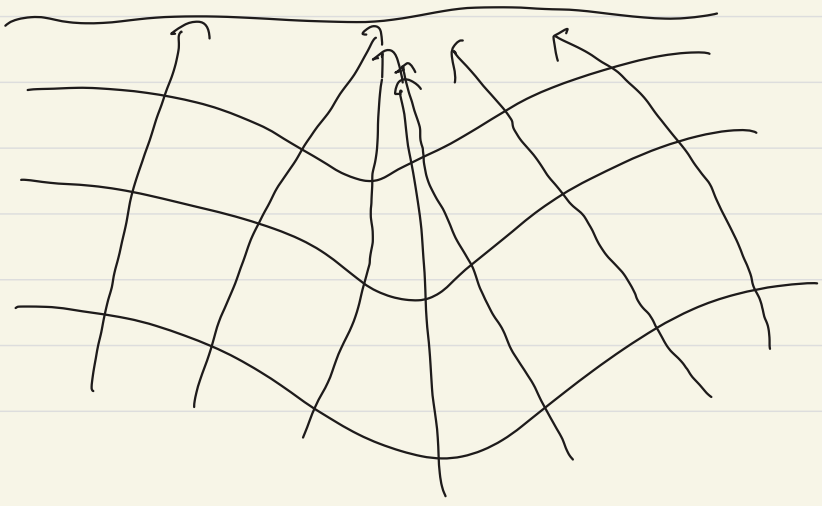
$$\frac{\sin\alpha}{C} = \text{const} = \frac{\sin\alpha_0}{C_0}$$

straight coast w/ parallel contours

Refraction coeff.:

$$K_R \equiv \frac{H}{H_0} = \sqrt{\frac{b_0}{b}} = \sqrt{\frac{\cos\alpha_0}{\cos\alpha}} \quad (< 1 \text{ always})$$





Bottom contour straight & parallel:

$$\frac{\sin\alpha_0}{L_0} = \frac{\sin\alpha}{L} = \frac{1}{n}$$

$$\frac{B_0}{\cos\alpha_0} = n = \frac{B}{\cos\alpha}$$

$$K_n = \sqrt{\frac{b_0}{b}} = \sqrt{\frac{\cos\alpha_0}{\cos\alpha}}$$

$$\alpha = \sin^{-1}\left(\frac{C}{C_0}\sin\alpha_0\right)$$

P16/ $H_0 = 2\,m$ $\quad H_1 = ?$

$T = 10\,s$ $\quad \alpha_1 = ?$

$\alpha_0 = 35°$

$d = 2.3\,m$

$C_0 = \frac{gT}{2\pi} = 15.61\,m/s$; $C = \sqrt{gd} = 4.75\,m/s$

$\alpha = \sin^{-1}\left(\frac{C}{C_0}\sin\alpha_0\right) = 10.1°$ $\qquad K_n = \sqrt{\frac{\cos\alpha_0}{\cos\alpha}} = 0.912$

$$\frac{H}{H_0} = \sqrt{\frac{L_0}{2nL}}\,K_n$$

$$\Rightarrow H = 2 \times \sqrt{\frac{156.1}{2\times1\times47.5}} \times 0.912 = 2.33\,m$$; $n=1$ of shallow

wave diffraction:

Process by which wave propagates into the lee zone behind a struct; caused by lateral transmittance of wave energy along crest.

P24/

$T = 6s$

$\theta = 60°$

$d = 10m$

$\beta = 30°$

$r = 96.6\ m$

$H_0 = 2.2\ m$

θ = incidence angle

β = defracted angle

r = dist from head

$$L_0 = \frac{gT^2}{2\pi} = 56.21\ m \; ; \quad d/L = 0.18$$

$\therefore L = 48.4\ m$

$r/L = 2$

$\therefore K_r = 0.28$

$H = 2.2 \times 0.28 = 0.62\ m$

Lec 11-12 wave transformation

Bottom friction
Depth induced wave breaking

wave breaking :

As wave moves towards shallower water, its wave len decreases and ht and steepness increase. At shallower region, the bottom friction causes the bottom part to move slower while the upper part cont to move faster.

At a time, the top outpaces the btm and spills over.

wave breaks when it reaches a limiting steepness which is a func of H/L and beach slope $\tan\beta$

Breaker types!

1. spilling
2. plunging
3. collapsing
4. surging

Spilling: Over gradual, simply sloping bed
wave crest becomes unstable and spills over
At $d = 1.671$

Plunging: Abrubt or moderate transition from deep to shallow
Base decelerate faster than top

Collapsing: The wave crest remain largly unbroken.
Lower portion collapses into beach slope.
Insignificant

Surging: Along very steep coastlines
The wave never actually breaks offshore; instead it surges directly up the beach face.

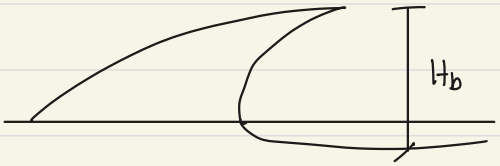
<u>wave breaking criteria:</u>

Two indices:

Breaker depth index: $\gamma_b = \frac{H_b}{d_b}$; depth at breaking

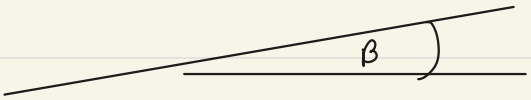
" ht index: $\Omega_b = \frac{H_b}{H_0}$; deep water wave ht

Identify breaker type:



$$\xi_0 = \tan\beta \left(\frac{H_0}{L_0}\right)^{-1/2}$$

$$\xi_b = \tan\beta \left(\frac{H_b}{L_0}\right)^{-1/2}$$



	ξ_0	ξ_b
spilling	$(\cdots, 0.5)$	$(\cdots, 0.4)$
Plunging	$(0.5, 2.3)$	$(0.5, 1.5)$
collapsing	$(2.3, 3.2)$	$(1.5, 2)$
surging	$(3.2, \cdots)$	$(2, \cdots)$

P19/

a) $H_0 = 4.5$ m

$T = 8$ s

$m = 0.05$

Deep water wave steepness

$$= \frac{H_0}{L_0} = 0.045$$

$$L_0 = \frac{gT^2}{2\pi} = 99.92$$

S.F = 1.16

∴ Shoaling breaking ht = 1.16×4.5

$= 5.22$ m

Breaker steepness $= \frac{H_b}{gT^2} = \frac{5.22}{9.81 \times 8^2}$

$= 0.00831$

Breaking depth coeff = 1.09

∴ Breaking depth $= 1.09 \times 5.22 = 5.69$ m

$$\xi_0 = \tan\beta \left(\frac{H_0}{L_0}\right)^{-1/2}$$

(β in radians)

$$= \tan(0.05)\,(0.045)^{-1/2} = 0.236$$

∴ Spilling

b) $L_0 \rightarrow \cdots$; $\frac{H_0}{L_0} \rightarrow \cdots$; SF $\rightarrow \cdots$; $\frac{H_b}{gT^2} \rightarrow \cdots$; $\cdots$

P21/ $m = 1/20$

$H_0 = 3.0\ m$

$K_R = 1.05$

$T = 10\ s$

$\frac{H_0}{L_0} = 0.019$ $\qquad L_0 = 156.13\ m$

$K_S = 1.4$ $\qquad \frac{H}{H_0} = K_S K_R$

$\therefore H_b = 3.0 \times 1.4 \times 1.05 = 4.41\ m$

$\frac{H_b}{gT^2} = 0.0045 \rightarrow 1$

$\therefore$ breaking depth $= 4.41\ m$

P22/ (a) $H_0 = 3\ m$

$T = 8\ s$

$d_1 = 8\ m$

Assume, $m = 0.05$

$\frac{H_0}{L_0} = 0.03 \rightarrow K_S = 1.26$

$H_b = 3 \times 1.26 \rightarrow 3.78$;

$\frac{H_b}{gT^2} = 0.006 \longrightarrow \cdots \rightarrow 3.99\ m$

$\therefore$ no break at 8m & 6m

$L_0 = 99.92\ m$

Energy principle:

$$\frac{\rho g H_0^2 L_0}{8} = \frac{\rho g H_1^2 L_1}{8}$$

$$\Rightarrow \frac{3^2 \times 99.91}{8} = \frac{H_1^2 \times 64.9}{8}$$

$\Rightarrow H_1 = \cdots$

$\frac{d}{L_0} = 0.08$ $\quad [0.05, 0.5]$

$L = 64.9\ m$

$n = \frac{1}{2}\left(1 + \frac{2kd}{\sinh 2kd}\right)$

$\therefore 0.845$ $\qquad k = \frac{2\pi}{L} = 0.0968$

Radiation stress / wave setup and set-down :

Excess flow of momentum due to presence of waves which is exerted on mean flow.

Lec 13 – 14 wave forces & coastal structure

wave ht at wall, $H_w = H_i + H_R$

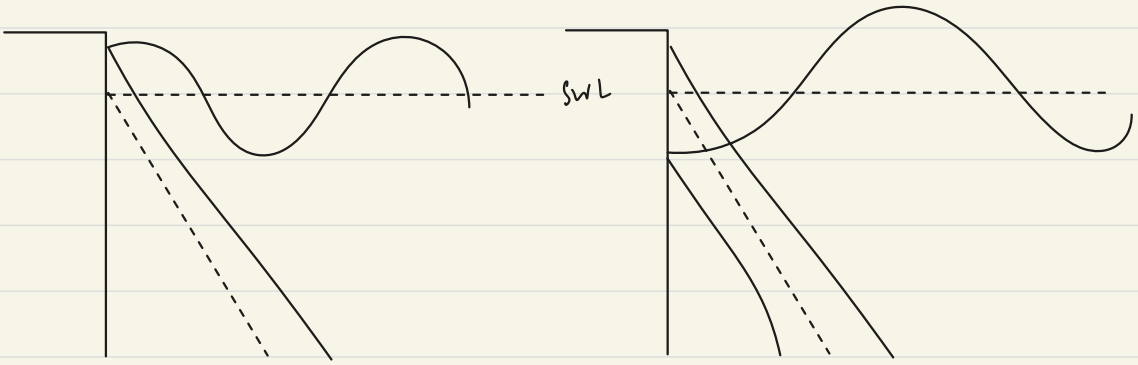
$= (1+\kappa) H_i$; $\kappa = \frac{H_R}{H_i}$ ← reflc coeff.

ht of clapotis crest,

$$\eta_c = d + h_0 + \left(\frac{1+\kappa}{2}\right) h_i$$

trough, $\eta_t = d + h_0 - \left(\frac{1+\kappa}{2}\right) h_i$

Pressure distn. :



$$p = \frac{1+\kappa}{2} \quad \frac{w H_i}{\cosh \frac{2\pi d}{L}}$$

Non-breaking wave forces on coastal struct:

$\frac{h_0}{H_i}$ from $\frac{H_i}{d}$ & $\frac{H_i}{gT^2}$

$F_{total} = \frac{wd^2}{2} + F_{wave}$; $w = 9.81\ N/m^3$

$M_{total} = \frac{wd^3}{6} + M_{wave}$

P15/ $H_i = 2m$ $d = 4m$ $T = 8s$ & $12s$

$K_R = 2 = \alpha$

$\frac{H_i}{d} = 0.5$ $\frac{H_i}{gT^2} = 0.0032$ & 0.0014

From graph, $\frac{h_0}{H_i} = 0.79$ & 0.9

$\therefore h_0 = 1.58\ m$ & $1.8\ m$

$y_c = d + h_0 + \left(\frac{1+\alpha}{2}\right) H_i = 7.58\ m$ & $7.8\ m$

$y_c = d + h_0 - \left(\frac{1+\alpha}{2}\right) H_i = 3.58m$ & $3.8\ m$

Force: $\frac{F_c}{wd^2} = 0.65$ & 0.68

$\frac{F_t}{wd^2} = -0.30$ & -0.33

$\therefore F_c = 0.65 \times wd^2 = 101.92$ KN/m &

- - - 106.6 KN/m

$F_t = -0.30 \times wd^2 = -47.04$ KN/m &

-51.7 KN/m

$\therefore F_{c\,total} = F_c + \frac{wd^2}{2} = 180.32$ KN/m &

185 - - -

$F_{t,\,total} =$ - - - $= 31.36$ KN/m &

26.7 KN/m

Moment: $\frac{m_c}{wd^3} =$ ...

$\frac{m_t}{wd^3} =$ ...

$m_c =$ ... KN-m/m

$m_t =$ ...

$m_{c,\,total} = m_c + \frac{wd^3}{6}$

$m_{t,\,total} =$ ...

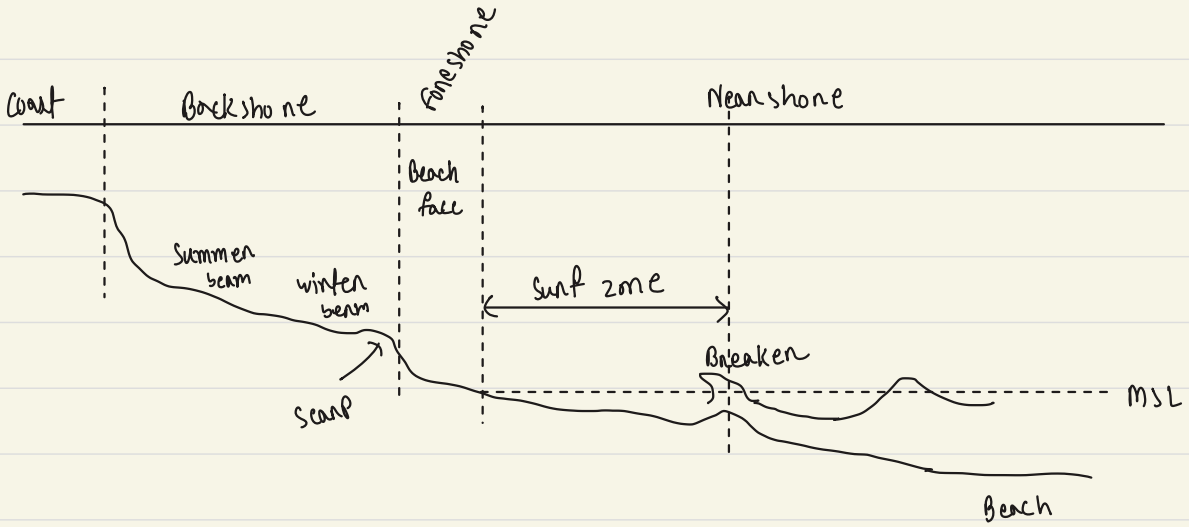
Critical cond.: Same SWL on both sides of wall
wave crest on one side, trough on other

$F_{net} = 101.92 - (-47.04) = 148.9$ (ignore hydrostatic cancels out)

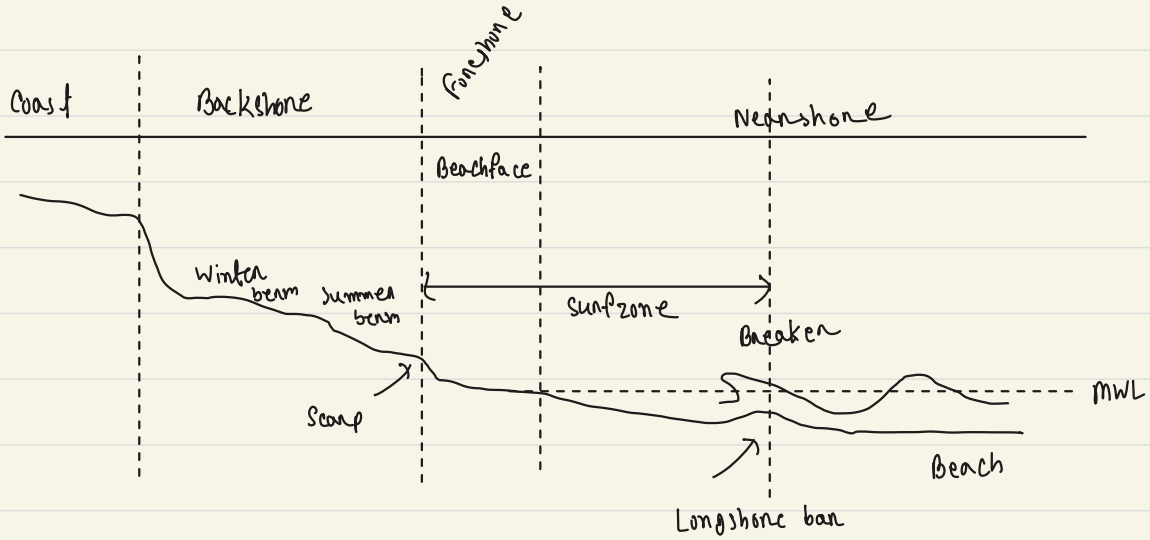
$m_{net} =$ ...

lec 17–18

Typical cross-section of beach profile:



Recap:



Nearshore waves & current system:

→ waves normal to shoreline

Refraction

Shoaling

Diffraction

mass transport

Longshore transport

Erosion

Deposition

Reflection

very strong Rip current

Estuary:

Semi-enclosed water body open to sea within which seawater is nearly diluted w/ fresh water.

classification:

Based on tide dominance:

1. Tide dominated
2. wave "
3. River "
4. mixed estuarine sys

Based on geomorphology:

1. Drowned river valley
2. Bar-built
3. Fjord type
4. Tectonically produced

Based on salinity:

1. well mixed
2. Partially "
3. salt wedge
4. Inverse
5. Intermittent
6. Highly stratified