Hydraulics Structures

Civil Engineering Department

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Lane's Weighted Creep Theory

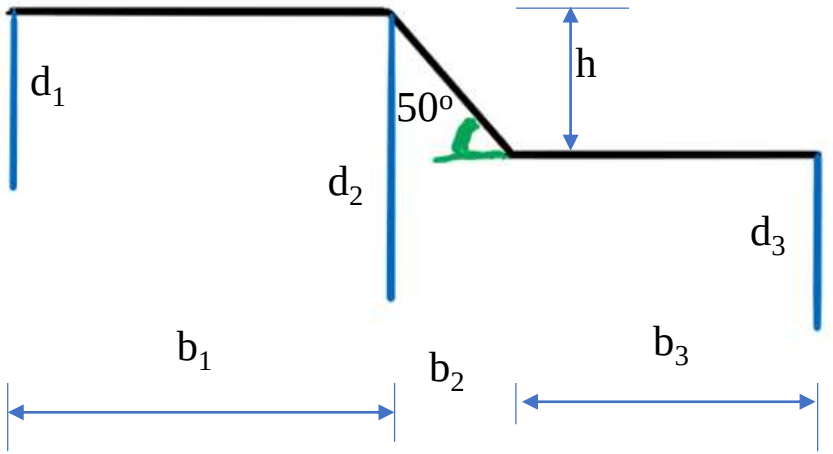
Lane, on the basis of his analysis carried out on about 200 dams all over the world, stipulated that the horizontal creep is less effective in reducing uplift (or in causing loss of head) than the vertical creep. He, therefore, suggested a weightage factor of 1/3 for the horizontal creep, as against 1.0 for the vertical creep.

Creep line $= L.W. = \frac{1}{3} H + 2 * V$

H = The summation of all HORIZONTAL distance + The slope contact LESS THAN 45°.

V = The summation of all VERTICAL distance + The slope contact HIGHER THAN 45°.

$$L.W. = \frac{1}{3}(b_1 + b_3) + 2(d_1 + d_2 + d_3) + h \qquad The\ slope > 45^o$$



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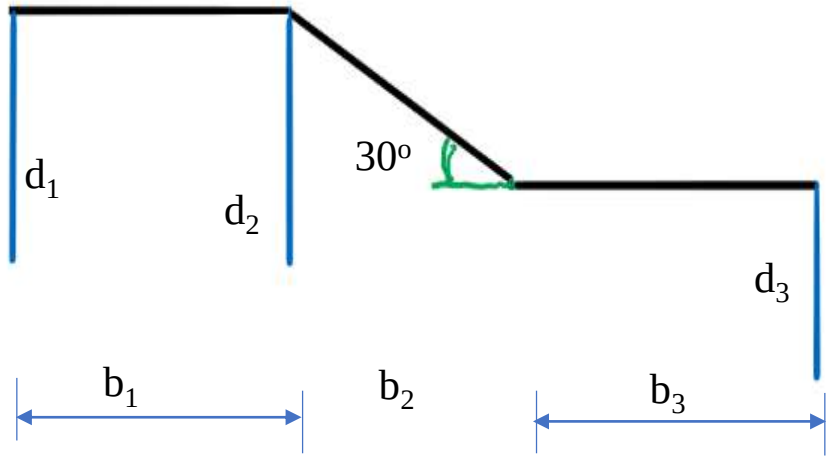
$$L.W. = \frac{1}{3}(b_1 + b_2 + b_3) + 2(d_1 + d_2 + d_3) \qquad The\ slope < 45^o$$



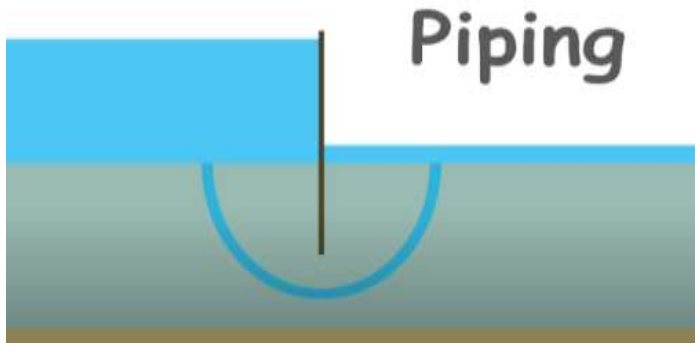
Safety Against Piping

$L.W. = H * C$ $\qquad\qquad$ $C = \frac{L.W.}{H}$

H = U/S Water Level – D/S Water Level

C … is the safety coefficient. This coefficient has to be kept HIGHER than the soil safety coefficient limit to ensure safety against the piping failure. The table below listed the soil types and their coefficient limits.

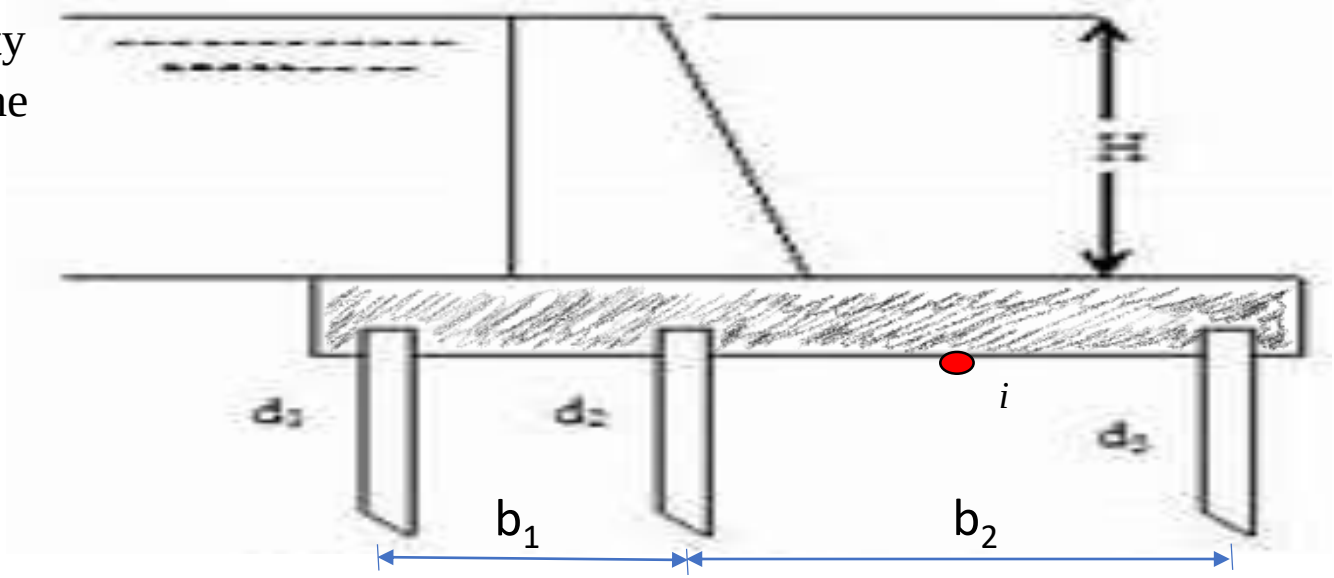
The safe limit of soils is given in the following table:



No.	Soil type	C	Safe limit of hydraulic gradient
1	Very Fine Sand or Silt	8.5	1/8.5
2	Fine Sand	7	1/7
3	Coarse Sand	5	1/5
4	Gravel and Sand	3.5 – 5	1/5 – 1/3.5
5	Boulder and Gravel Sand	2.5 – 3	1/3 – 1/2.5

Safety Against Uplift Pressure

The same criteria are used herein to estimate the safety against Uplift Pressure by taking into consideration the change in calculating L.W. as was explained in the piping failure portion.



$$\text{Hydraulic Gradient } (i) = \frac{H}{L.W.}$$

H = U/S Water Level – D/S Water Level

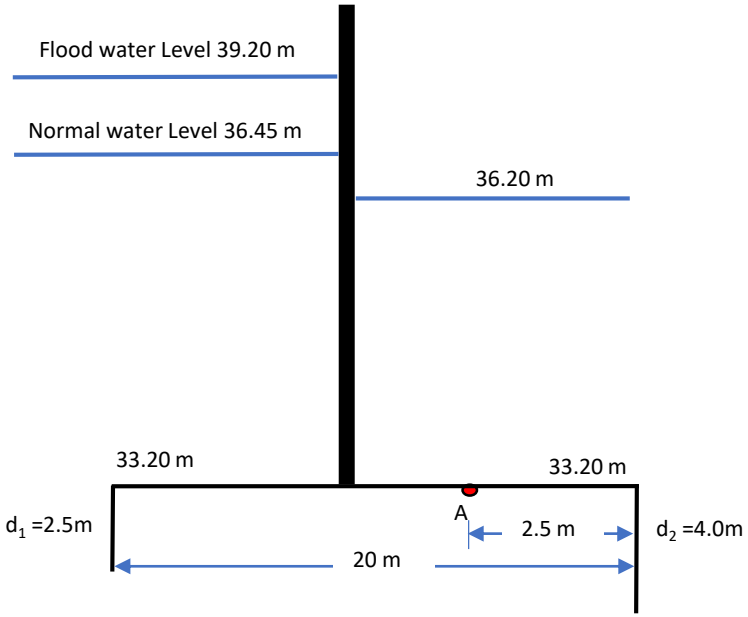
$$t = \frac{H}{G-1} * \frac{4}{3}$$

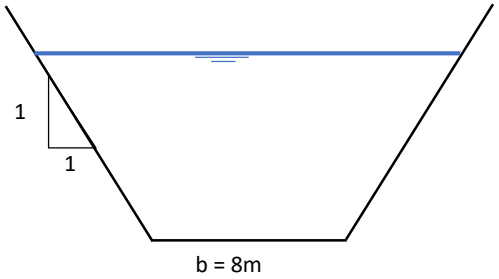
G = 2.4 ton/m^3 ····· For Concert

$$t = \frac{h_i}{G-1} * \frac{4}{3}$$

$$h_i = H\ (1 - \frac{\text{L.Wi}}{\text{L.W}})$$

Example: By using Lane's Theory and for the given information in the previous example, check if the structure is safe against the piping failure.





Solution:

From the Table Coarse Sand …… C = 5

$$L.W. = \frac{1}{3} H + 2 * V$$

$$L.W. = \frac{1}{3} (20) + 2(2.5 + 4) = 19.67m.$$

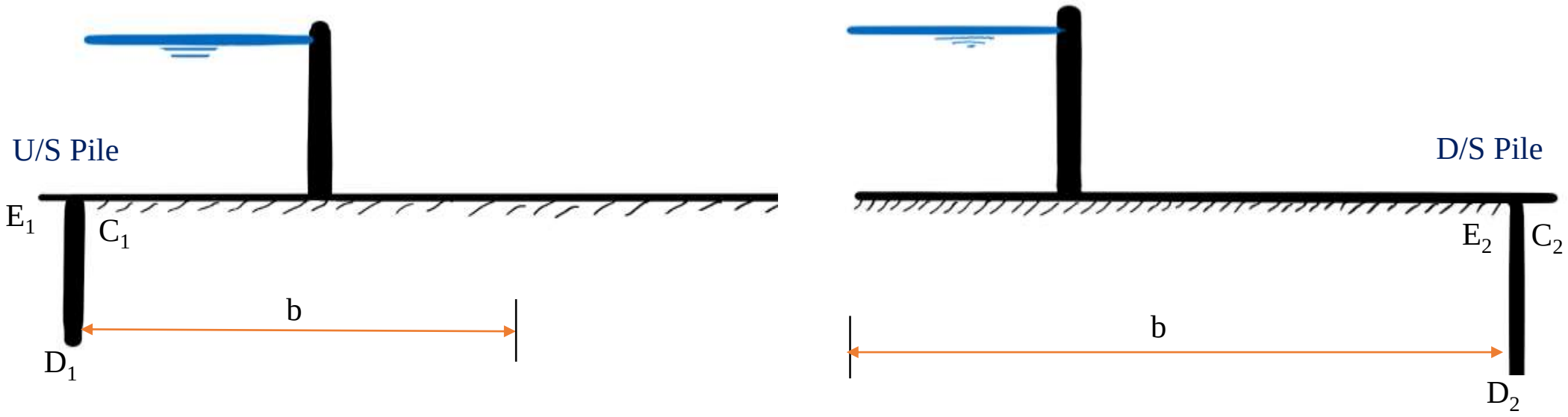
$$L.W. = H * C$$

$$Thus, \quad C = \frac{L.W.}{H}$$

Khosla's Theory

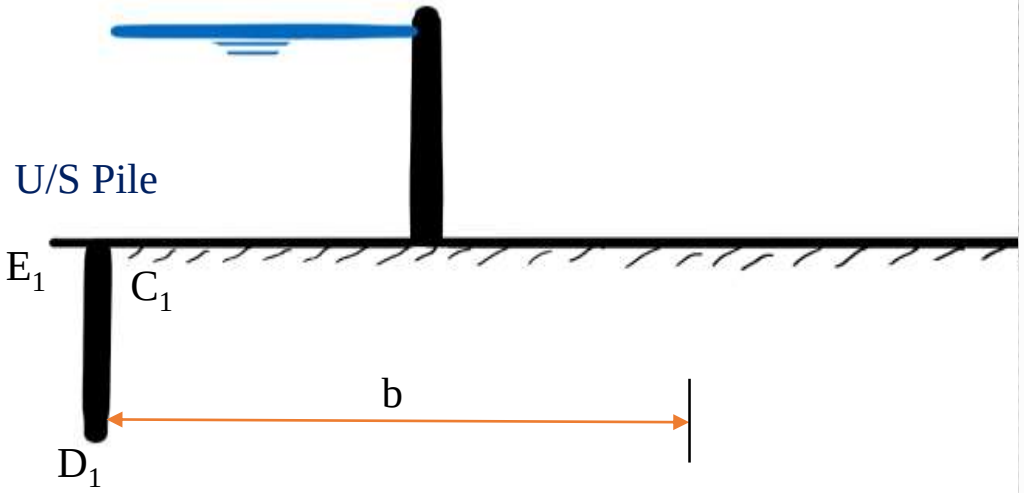
For the determination of seepage below the foundation of hydraulic structure developed the method of independent variable. The following specific cases of general form were considered in Khosla's Theory.

- ***Straight horizontal flow of negligible thickness with pile at either end, <u>upstream</u> or at <u>downstream</u> end***



Khosla's Theory

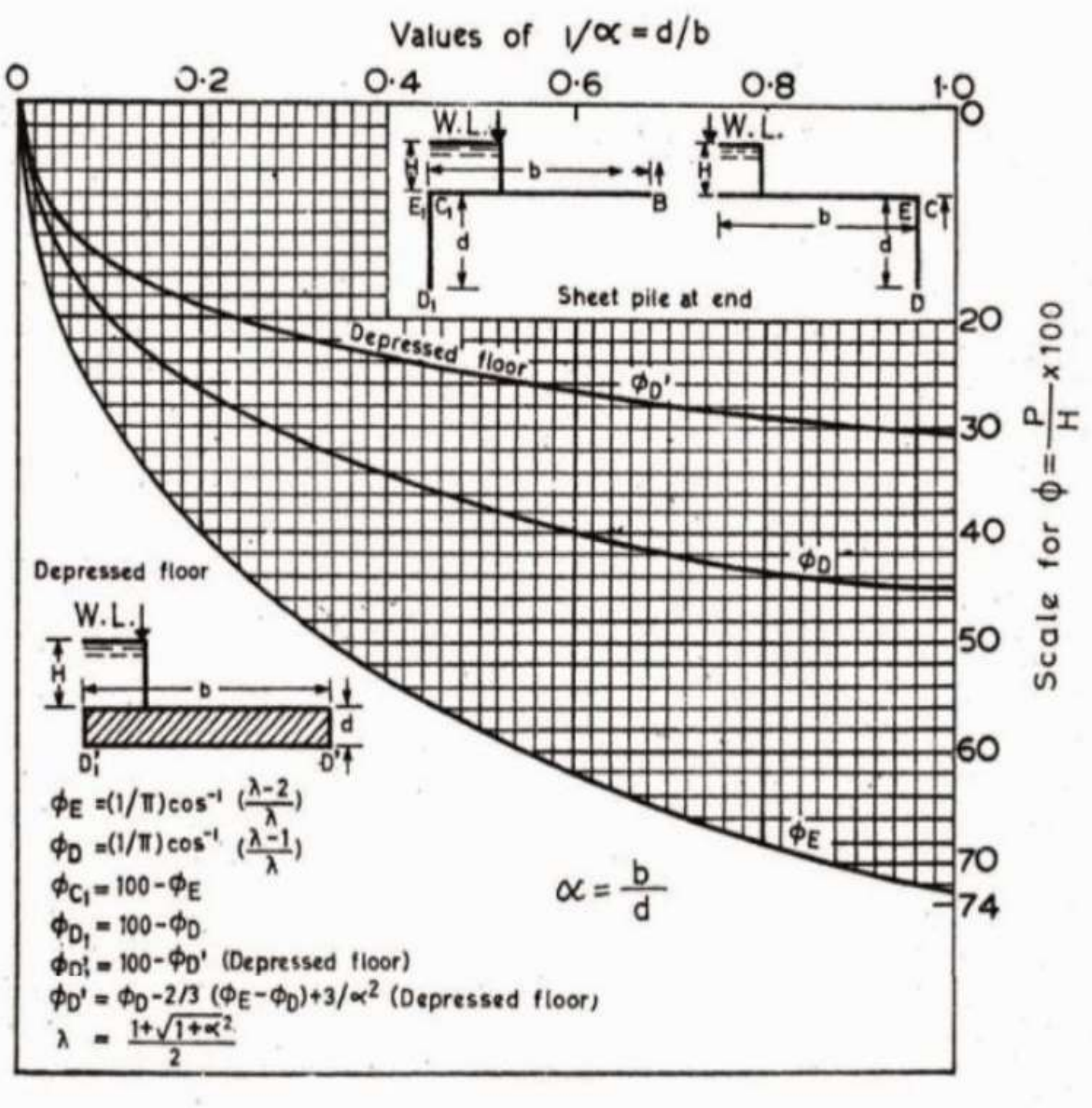
- ***Upstream End***



$\emptyset E_1 = 100\%$

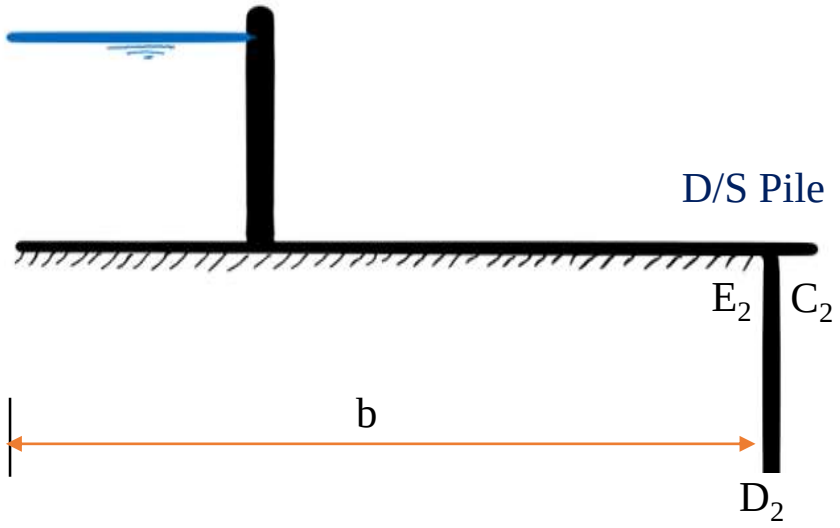
$\emptyset D_1 = 100\% - \emptyset D$ (From Curve)

$\emptyset C_1 = 100\% - \emptyset E$ (From Curve)



Khosla's Theory

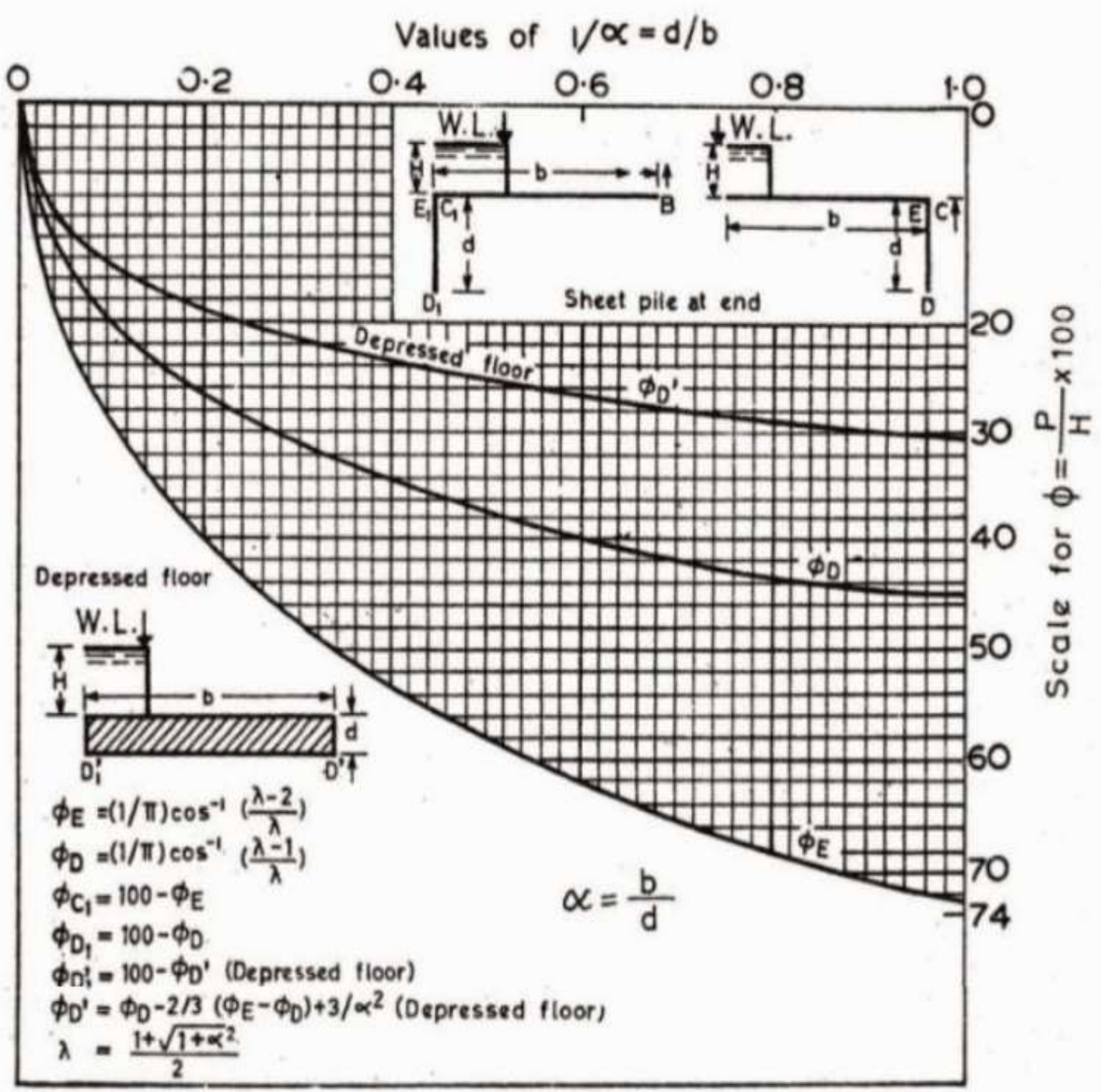
- ***Downstream End***



$\emptyset E_2 = \emptyset E$ (From Curve)

$\emptyset D_2 = \emptyset D$ (From Curve)

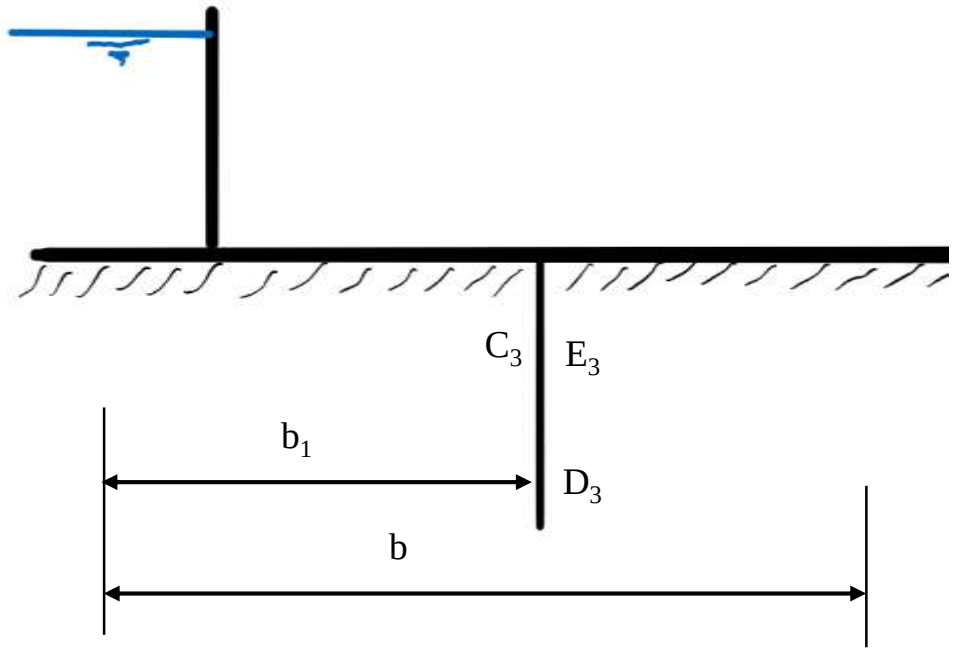
$\emptyset C_2 = 0\%$

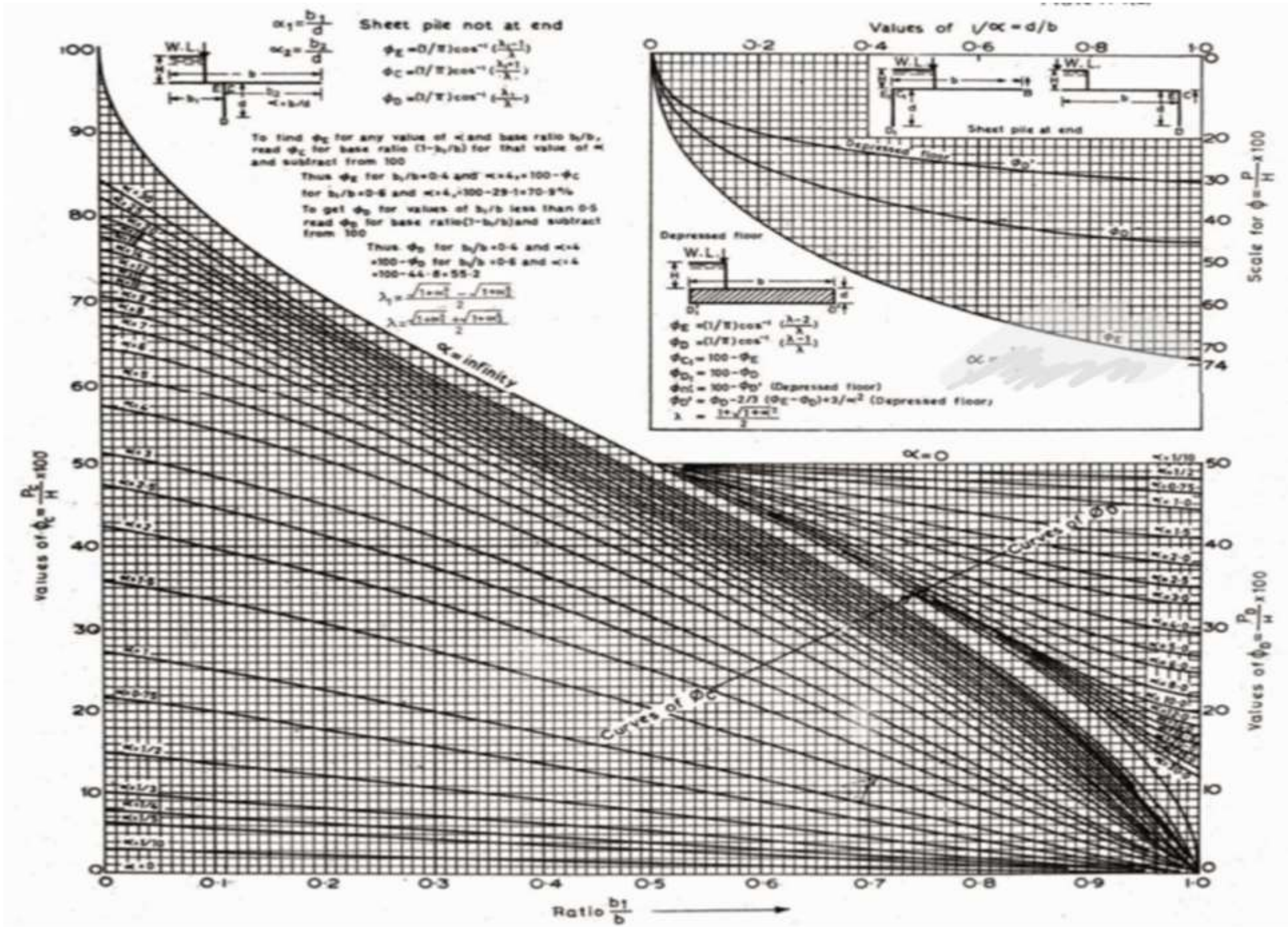


Khosla's Theory

For the determination of seepage below the foundation of hydraulic structure developed the method of independent variable. The following specific cases of general form were considered in Khosla's Theory.

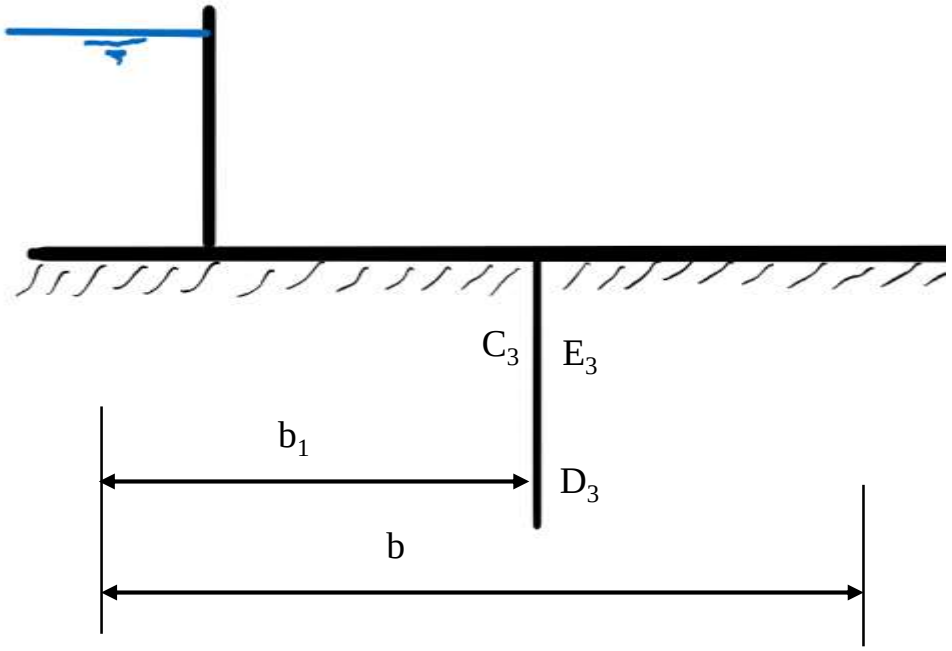
- ***Straight horizontal floor of negligible thickness with pile at some <u>intermediate</u> point.***




Sheet pile not at end
Values of √∝ = d/b
Sheet pile at end
Depressed floor
Curves of Φc
Curves of Φd
∝ = infinity
∝ = 0
Values of Φc = Pc/H x 100
Values of Φd = Pd/H x 100
Scale for Φ = P/H x 100
Ratio b1/b

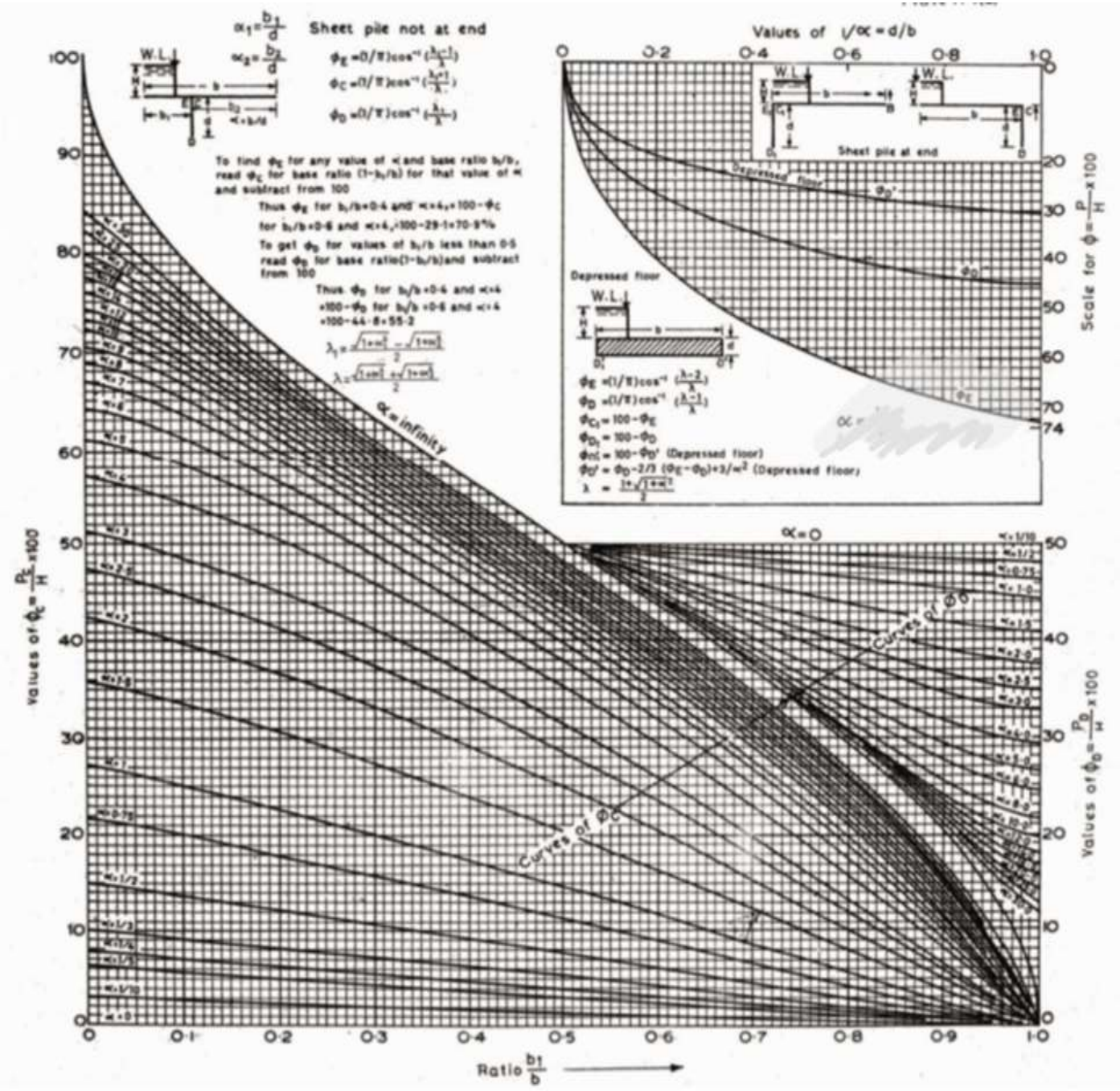
Khosla's Theory

- ***Intermediate Point***



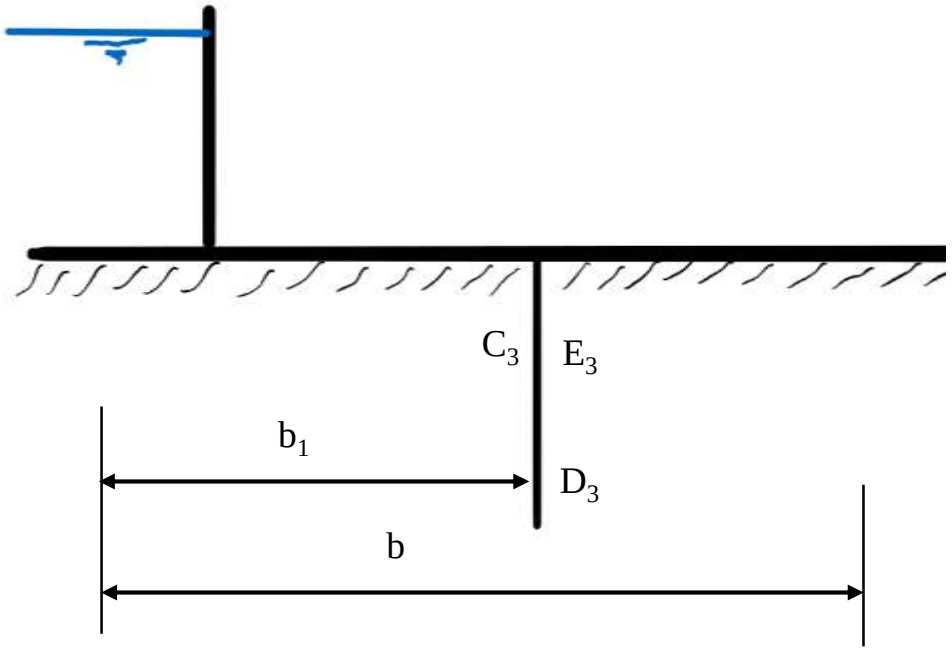
- To get $\emptyset C_3$
  - Read $\emptyset C$ for the base ($\frac{b_1}{b}$) and α (From Curve)

$$\emptyset C_3 = \emptyset C$$



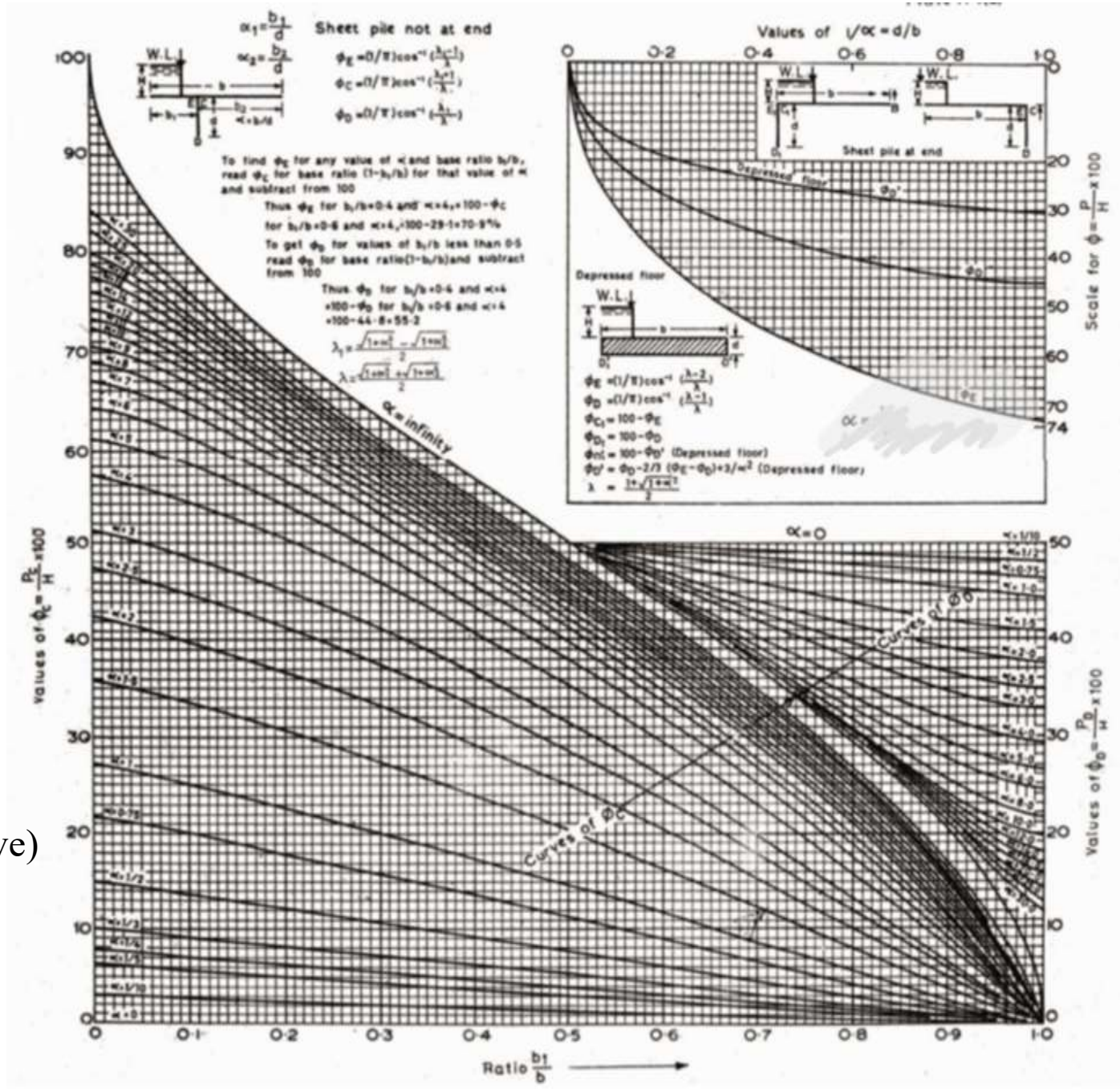
Khosla's Theory

- ***Intermediate Point***



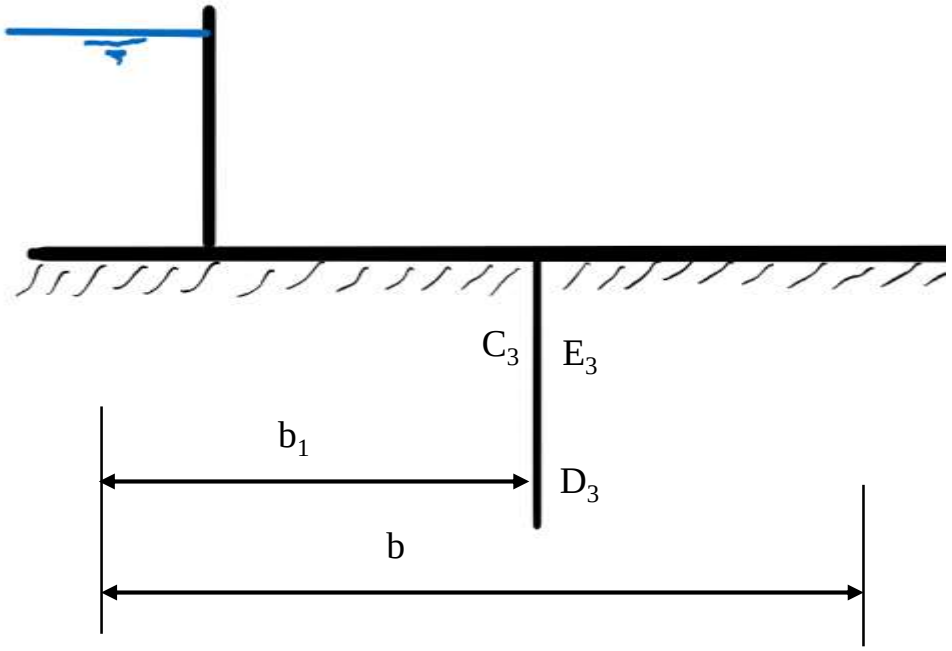
- To get $\emptyset E_3$
  - Read $\emptyset C$ for the base $(1-\frac{b_1}{b})$ and α (From Curve)

$$\emptyset E_3 = 100\% - \emptyset C$$



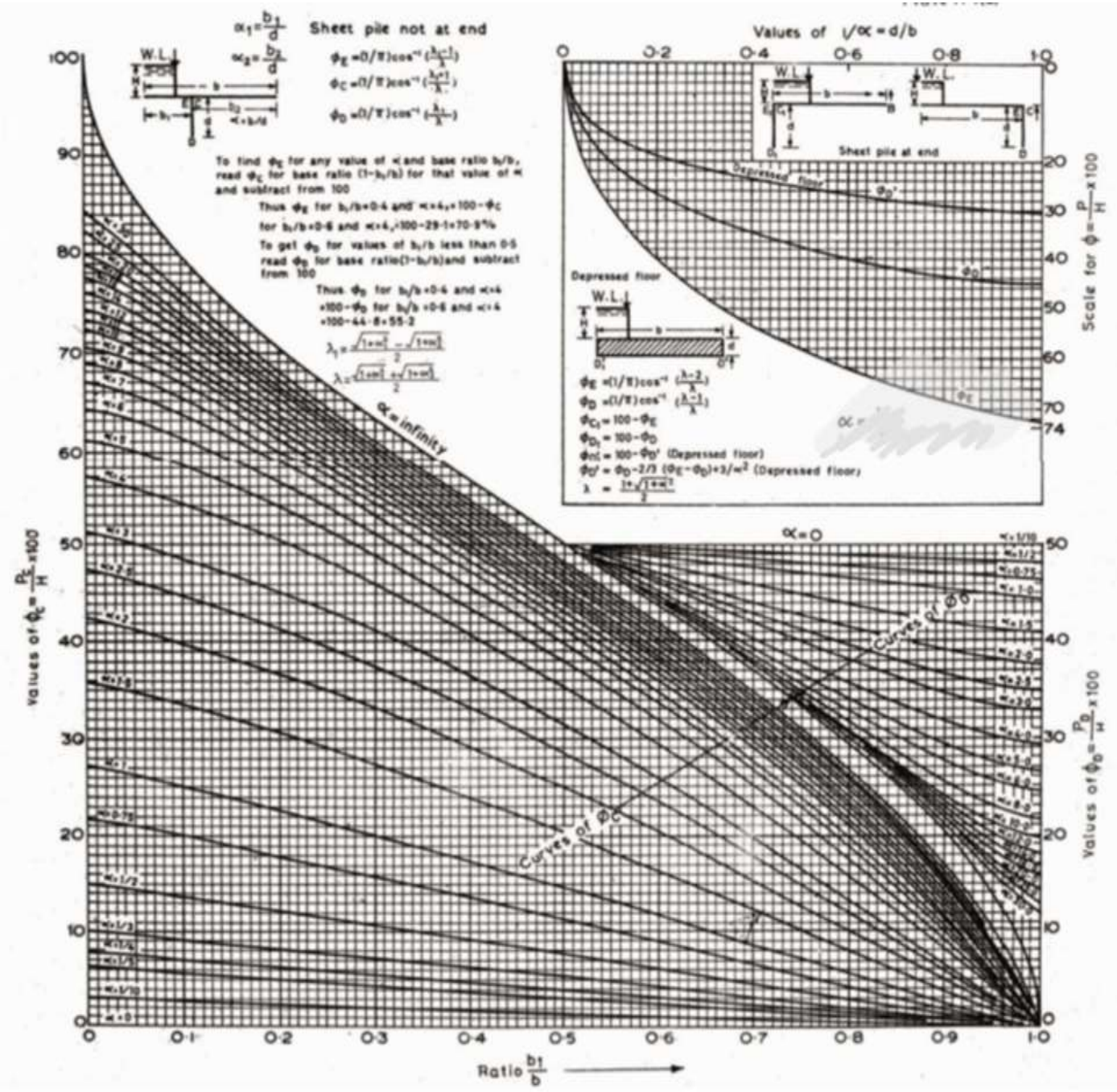
Khosla's Theory

- ***Intermediate Point***



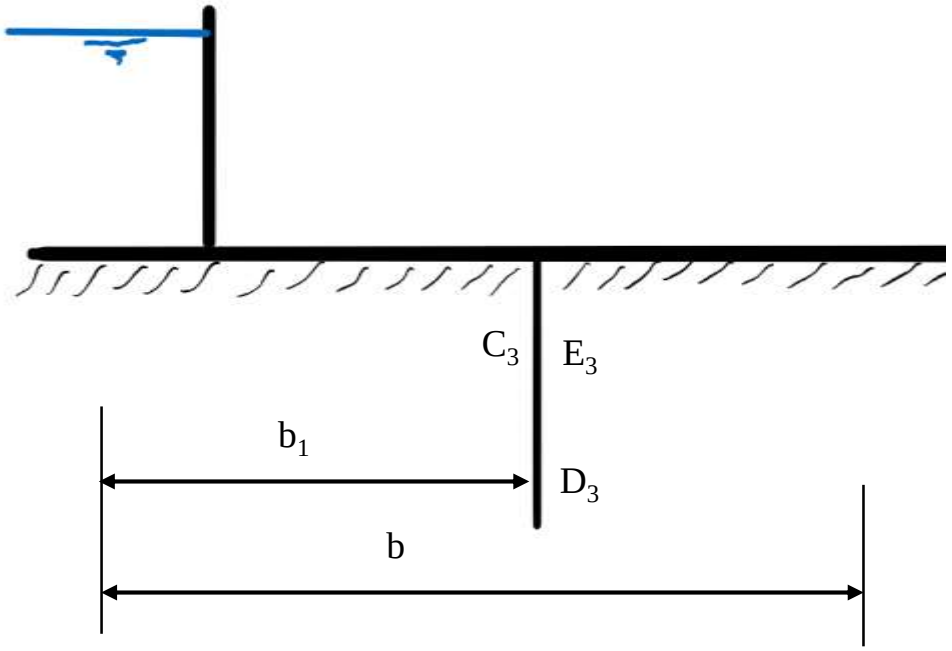
- To get $\emptyset D_3$ *When* $\frac{b_1}{b} > 0.5$
  - Read $\emptyset D$ for the base ($\frac{b_1}{b}$) and α (From Curve)

$$\emptyset D_3 = \emptyset D$$



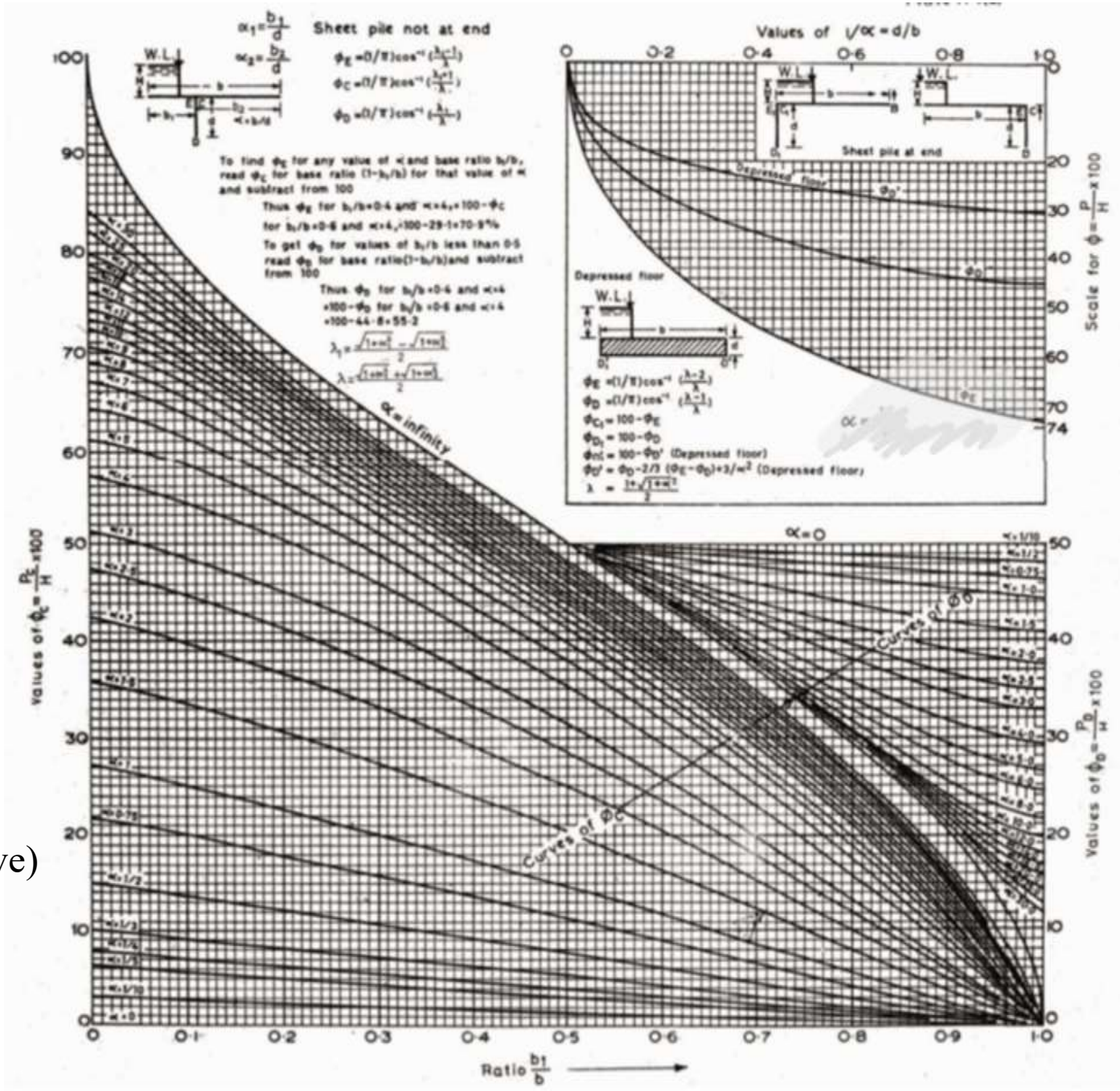
Khosla's Theory

- ***Intermediate Point***



- To get $\emptyset D_3$ *When* $\frac{b_1}{b} < 0.5$
  - Read $\emptyset D$ for the base $(1-\frac{b_1}{b})$ and α (From Curve)

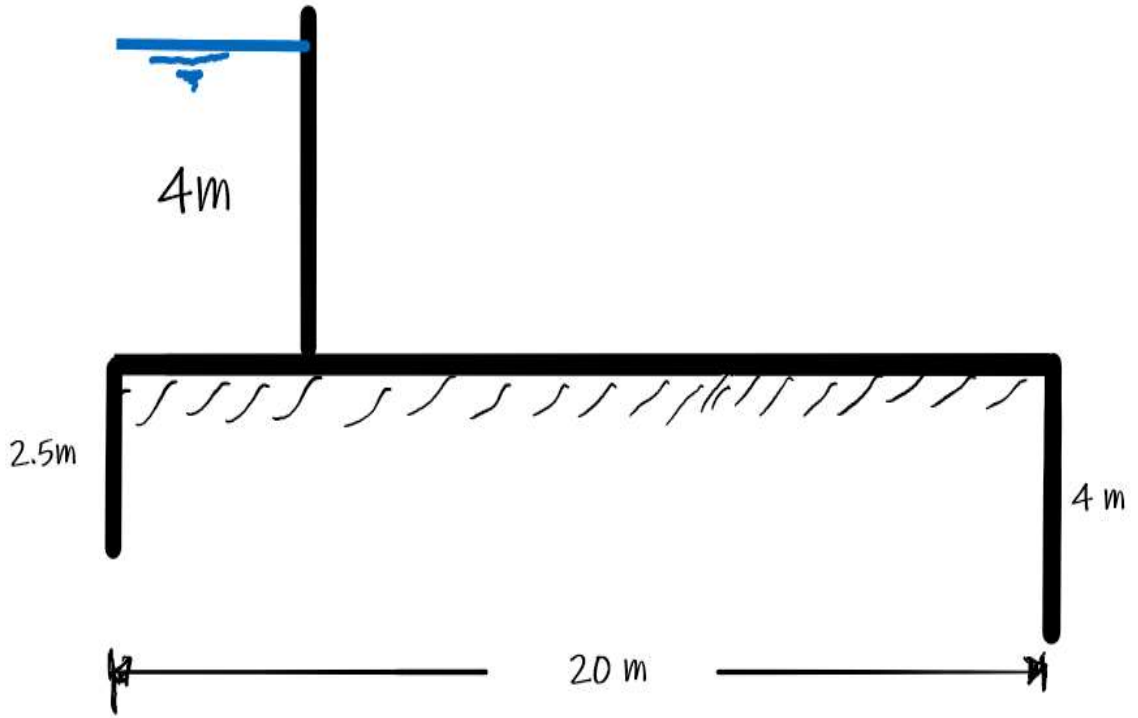
$$\emptyset D_3 = 100\% - \emptyset D$$



Example: - For the given information in the figure below, b=20m, d_1= 2.5m, d_2=4m, H=4m, find ØE_1, ØD_1, ØC_1, ØE_2, ØD_2, and ØC_2.

Solution:

$$H = 4m$$



For U/S Pile

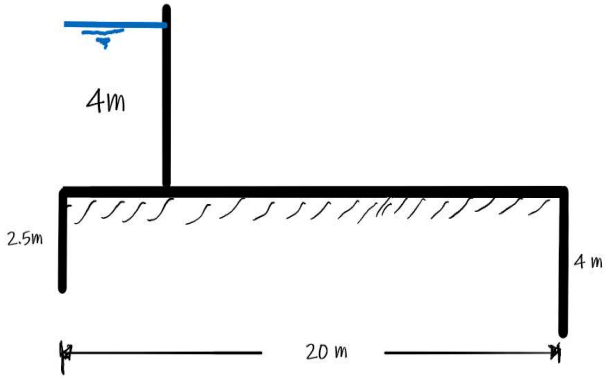
$$\frac{1}{\propto} = \frac{d_1}{b} \longrightarrow \frac{2.5}{20} = \frac{1}{8} = 0.125$$

ØE_1 = 100%

ØD_1= 100% - ØD (from curve)

ØC_1= 100% - ØE (from curve)

Example: - For the given information in the figure below, b=20m, d_1= 2.5m, d_2=4m, H=4m, find $\emptyset E_1$, $\emptyset D_1$, $\emptyset C_1$, $\emptyset E_2$, $\emptyset D_2$, and $\emptyset C_2$.



Solution: $\frac{1}{\alpha} = 0.125$

$\emptyset E_1 = 100\%$

$\emptyset D_1 = 100\% - \emptyset D$ (from curve)

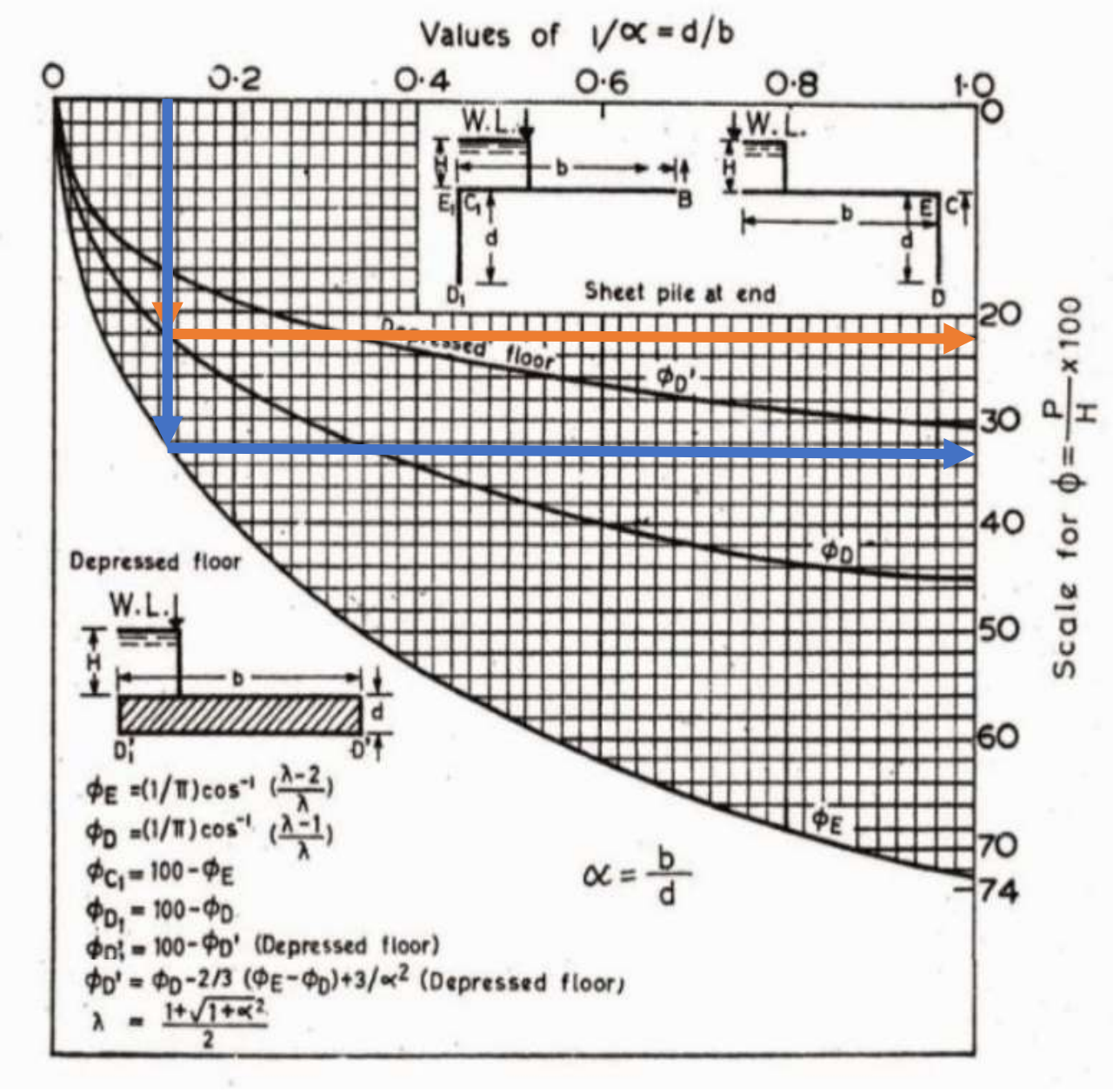
$\emptyset D$ (from curve) = 22%

$\emptyset D_1 = 100\% - 22\% = 78\%$

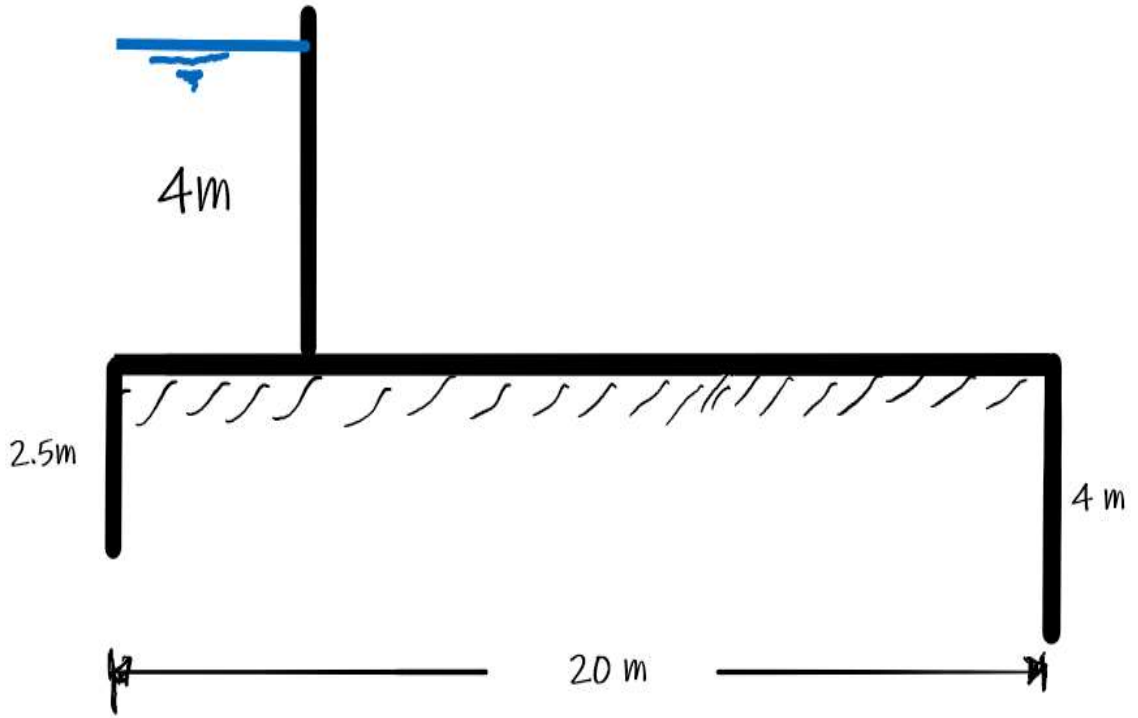
$\emptyset C_1 = 100\% - \emptyset E$ (from curve)

$\emptyset E$ (from curve) = 33%

$\emptyset C_1 = 100\% - 33\% = 67\%$



Example: - For the given information in the figure below, b=20m, d_1= 2.5m, d_2=4m, H=4m, find $\emptyset E_1$, $\emptyset D_1$, $\emptyset C_1$, $\emptyset E_2$, $\emptyset D_2$, and $\emptyset C_2$.



Solution:

$$H = 4m$$

For D/S Pile

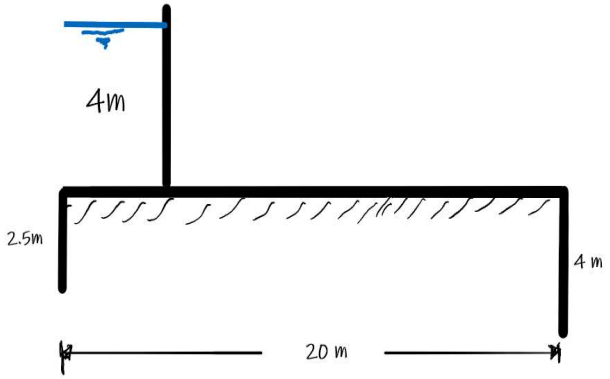
$$\frac{1}{\propto} = \frac{d_2}{b} \longrightarrow \frac{4}{20} = \frac{1}{5} = 0.2$$

$\emptyset E_2 = \emptyset E$ (from curve)

$\emptyset D_2 = \emptyset D$ (from curve)

$\emptyset C_2 = 0\ \%$

Example: - For the given information in the figure below, b=20m, d_1= 2.5m, d_2=4m, H=4m, find $\emptyset E_1$, $\emptyset D_1$, $\emptyset C_1$, $\emptyset E_2$, $\emptyset D_2$, and $\emptyset C_2$.



Solution: $\frac{1}{\alpha} = 0.2$

$\emptyset C_2 = 0\%$

$\emptyset D_2 = \emptyset D$ (from curve)

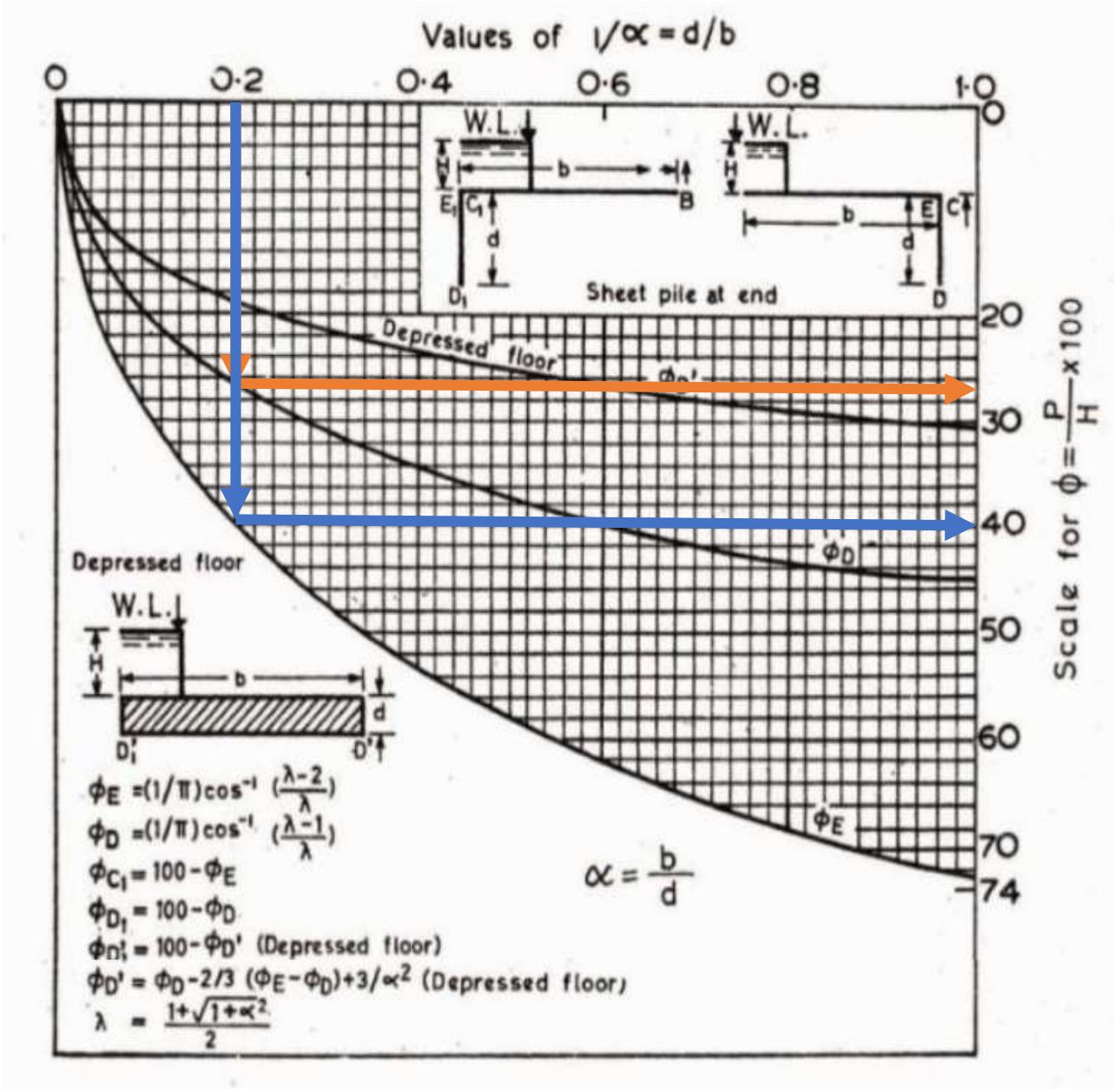
$\emptyset D$ (from curve) = 26.2%

$\emptyset D_2 = 26.2\%$

$\emptyset E_2 = \emptyset E$ (from curve)

$\emptyset E$ (from curve) = 40%

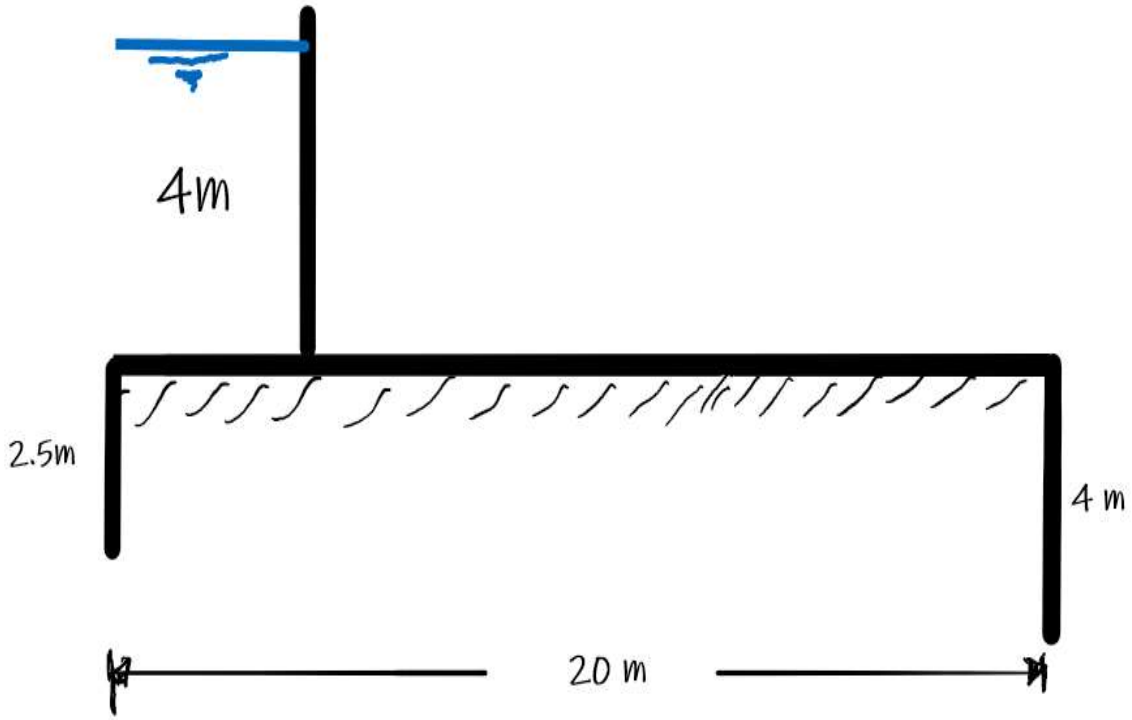
$\emptyset E_2 = 40\%$



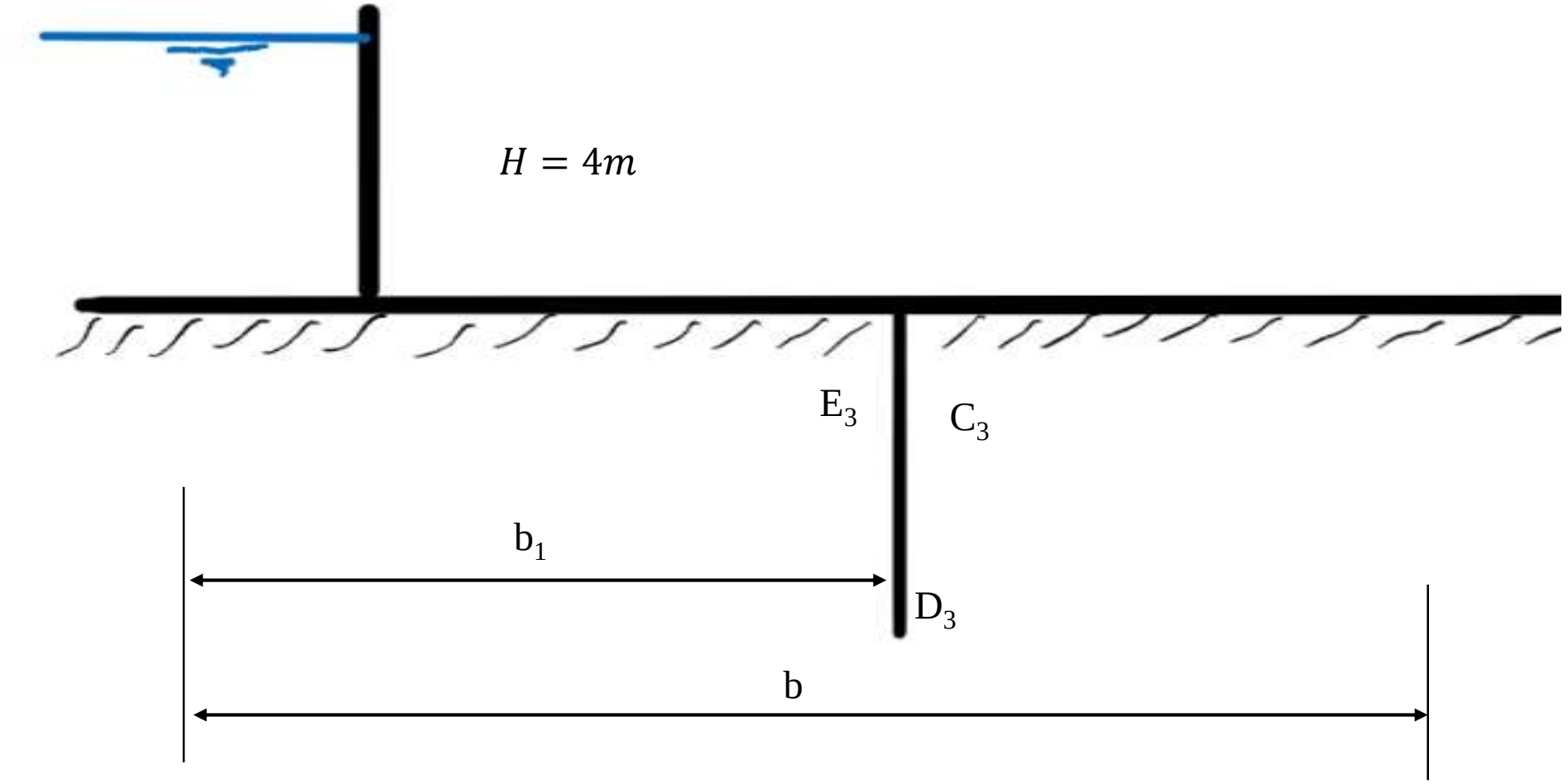
Example: - For the given information in the figure below, b=20m, d_1= 2.5m, d_2=4m, H=4m, find ØE_1, ØD_1, ØC_1, ØE_2, ØD_2, and ØC_2.

Solution: $H = 4m$

Ø	%	Uplift Pressure (m)
E_1	100	4.0
D_1	78	3.12
C_1	67	2.68
E_2	40	1.6
D_2	26.2	1.048
C_2	0	0

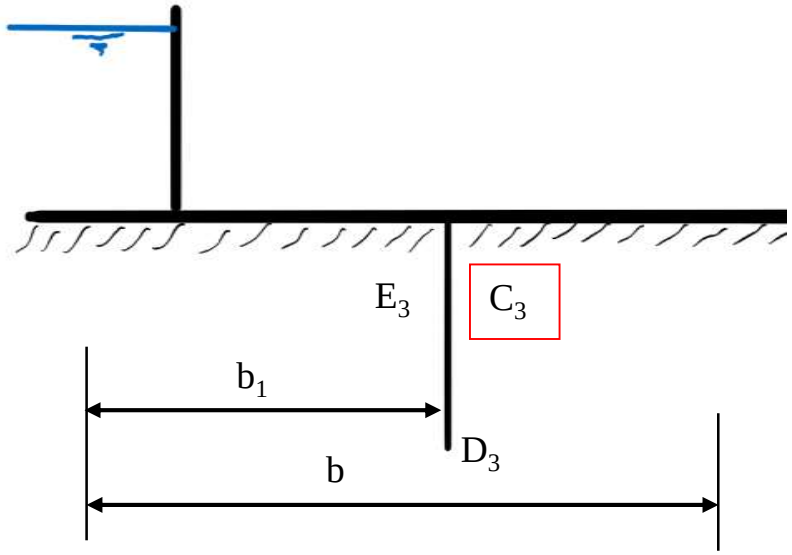


Example: - For the given information, b_1 =8m, b= 20m, d=5m, find ØE_3



Solution: $H = 4m$

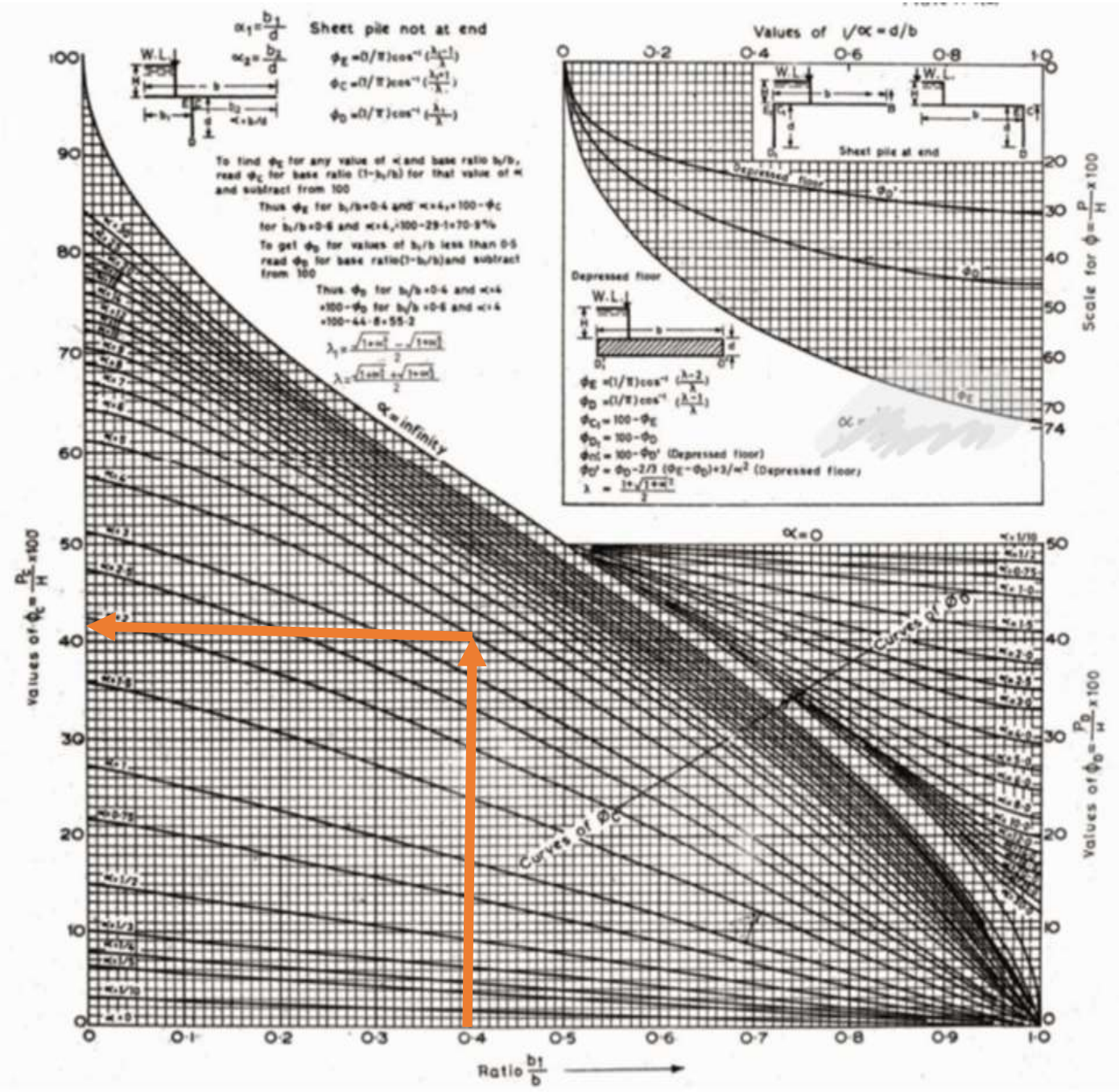
$$\propto = \frac{b}{d_1} = \frac{20}{5} = 4 \qquad \frac{b_1}{b} = \frac{8}{20} = 0.4$$



- To get $\emptyset C_3$
- Read $\emptyset C$ for the base $(\frac{b_1}{b})$ and α

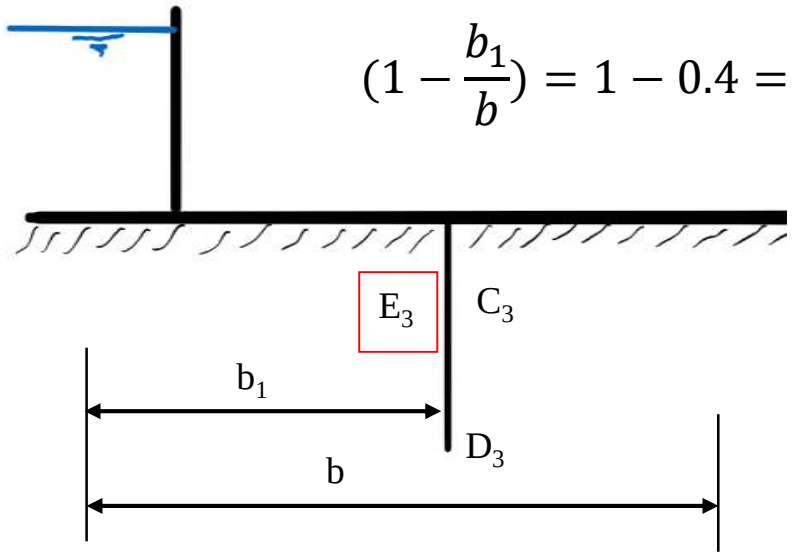
$\emptyset C$ (From Curve) = 41%

$\emptyset C_3 = \emptyset C = 41\%$



Solution: $H = 4m$

$$\propto = \frac{b}{d_1} = \frac{20}{5} = 4 \qquad \frac{b_1}{b} = \frac{8}{20} = 0.4$$



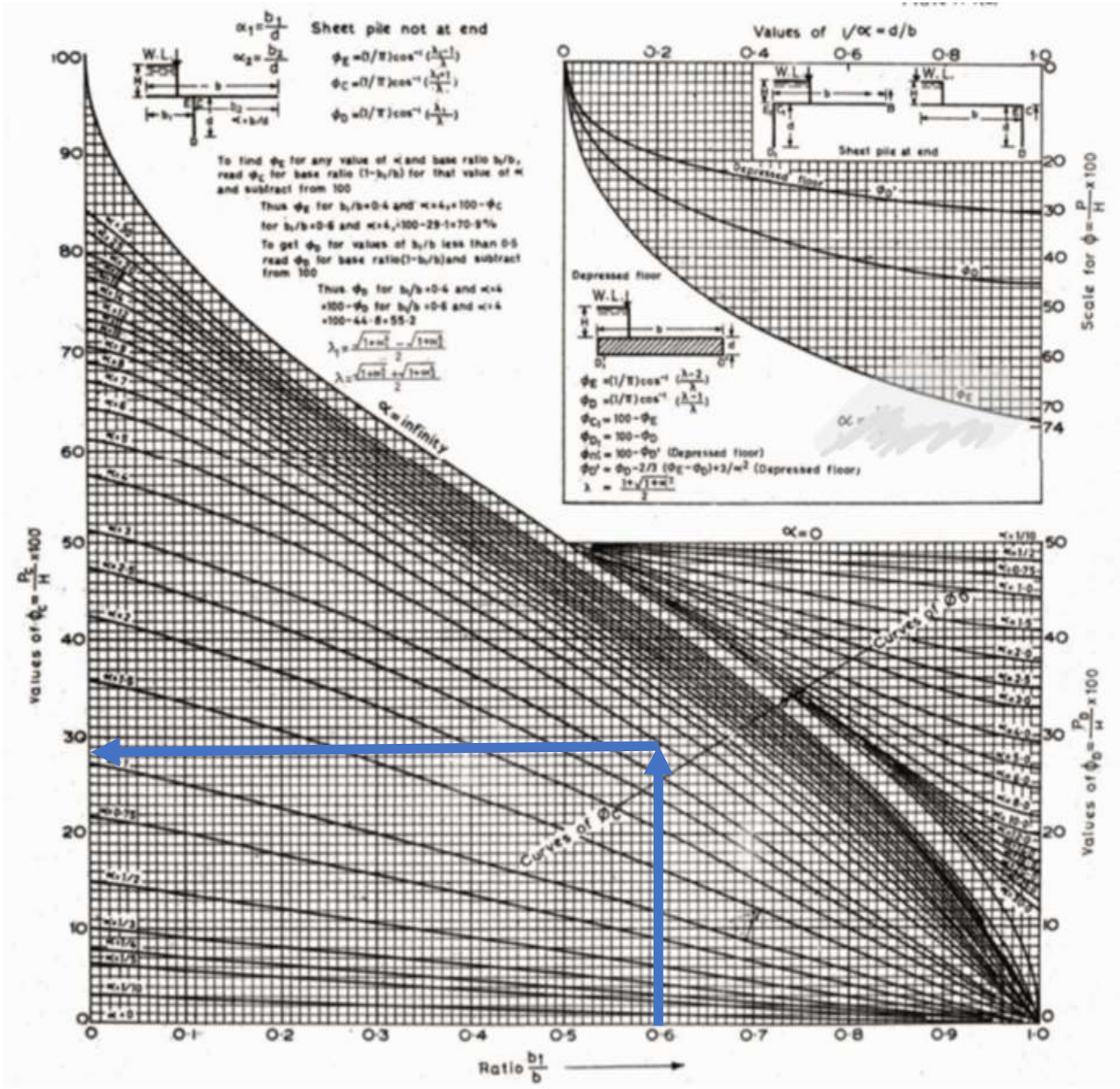
$$(1 - \frac{b_1}{b}) = 1 - 0.4 = 0.6$$

- To get $\emptyset E_3$
  - Read $\emptyset C$ for the base $(1-\frac{b_1}{b})$ and α

$\emptyset C$ (From Curve) = 29.2%

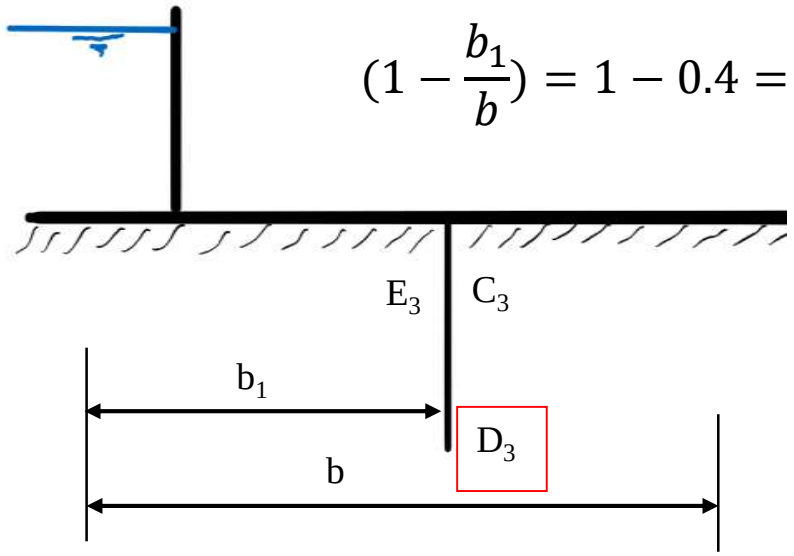
$\emptyset E_3 = 100\% - \emptyset C$

$\emptyset E_3 = 100\% - 29.2\% = 70.8\%$



Solution: $H = 4m$

$$\propto = \frac{b}{d_1} = \frac{20}{5} = 4 \qquad \frac{b_1}{b} = \frac{8}{20} = 0.4$$



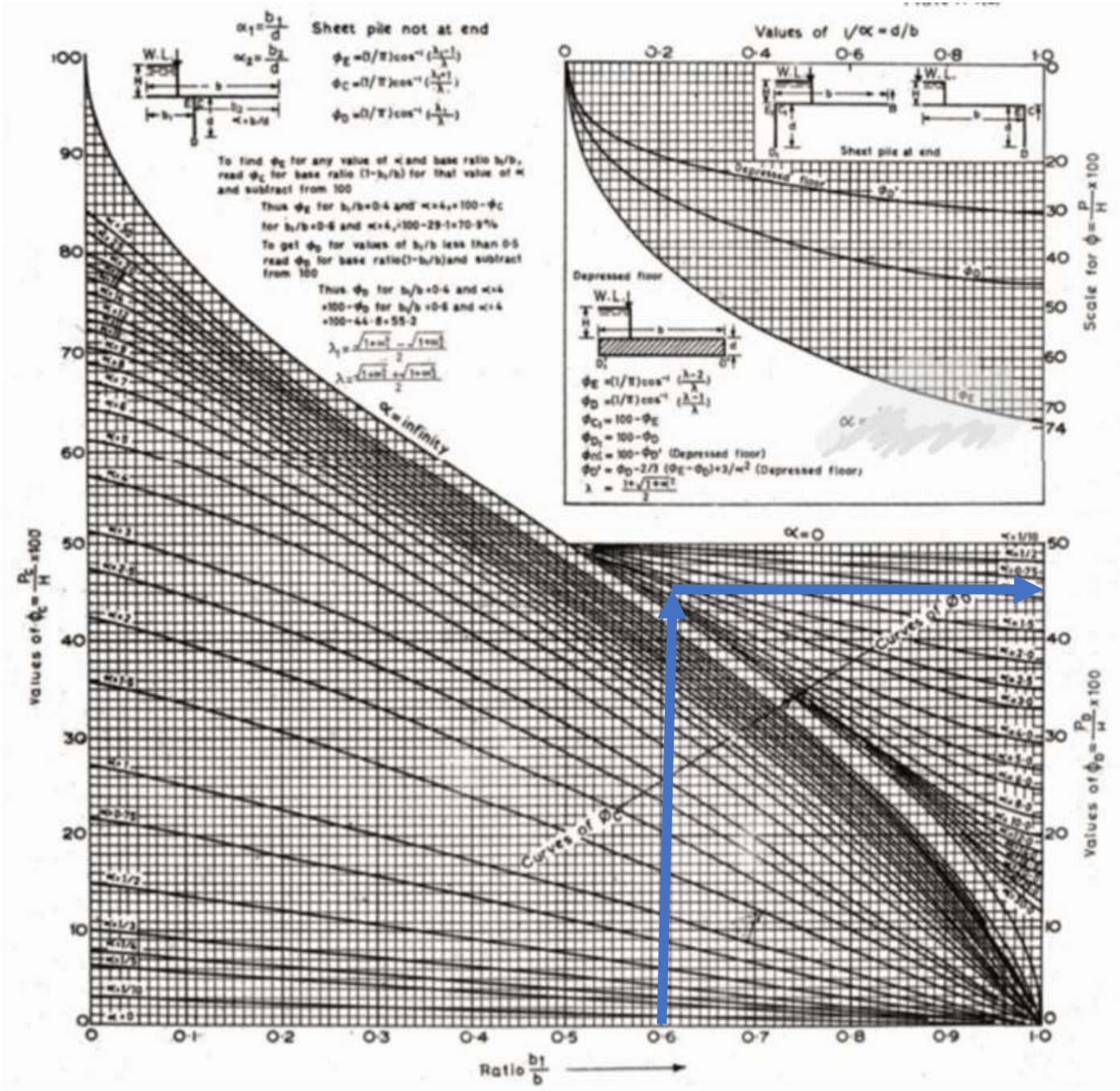
$$(1 - \frac{b_1}{b}) = 1 - 0.4 = 0.6$$

- To get $\emptyset D_3$
  - Read $\emptyset D$ for the base $(1-\frac{b_1}{b})$ and α

$\emptyset D$ (From Curve) = 45.3 %

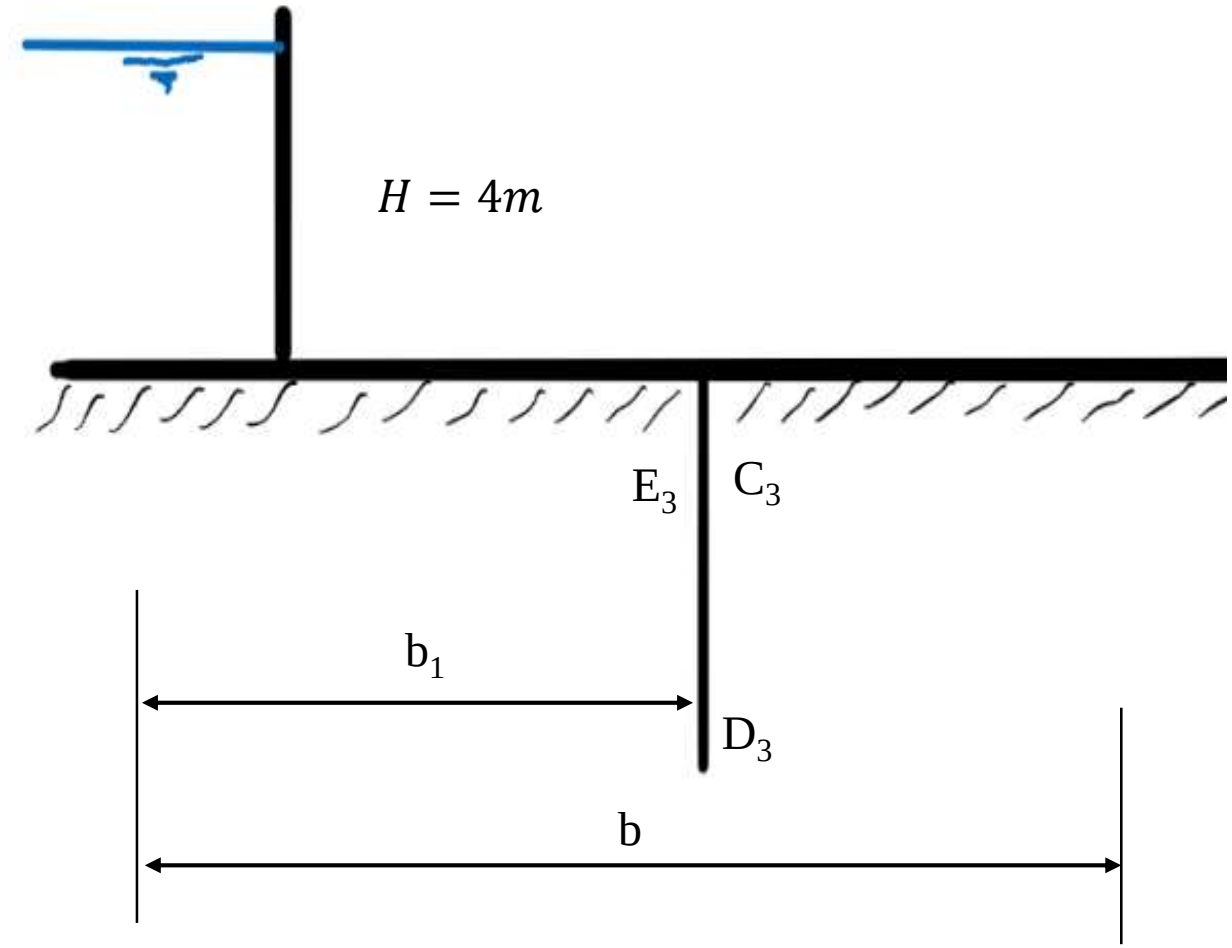
$$\emptyset D_3 = 100\% - \emptyset D$$

$$\emptyset D_3 = 100\% - 45.3\% = 54.7\%$$



Example: - For the given information, b_1 =8m, b= 20m, d=5m, find ØE_3

Ø	%	Uplift Pressure (m)
E_3	70.8	2.832
D_3	54.7	2.188
C_3	41	1.64



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