GEOTECHNICAL ENGINEERING

Topic : settlement in shallow and pile foundation

_ Numericals _

Settlement in foundation :

1. Immediate Settlement (S_i)
2. Consolidation or Primary settlement (S_c)
3. Secondary consolidation settlement or creep (S_s)

1. Immediate Settlement (S_i) :

It is also called as *volume distortion* settlement . it causes due to compression of air in voids. Essentially, this is the rearrangement of grains due to changing stress, resulting in a reduction in void ratio and instant settlement. hence, it is considered to be an elastic process . Therefore the settlement can be calculated from elastic theory. Immediate Settlement take place immediately after the construction of structure within the time period of 7 days. Immediate Settlement analysis are used for all fine grained soil including silt and clay with degree of saturation and all coarse grained soil with large coefficient of permeability.

Immediate Settlement is given by following expression :

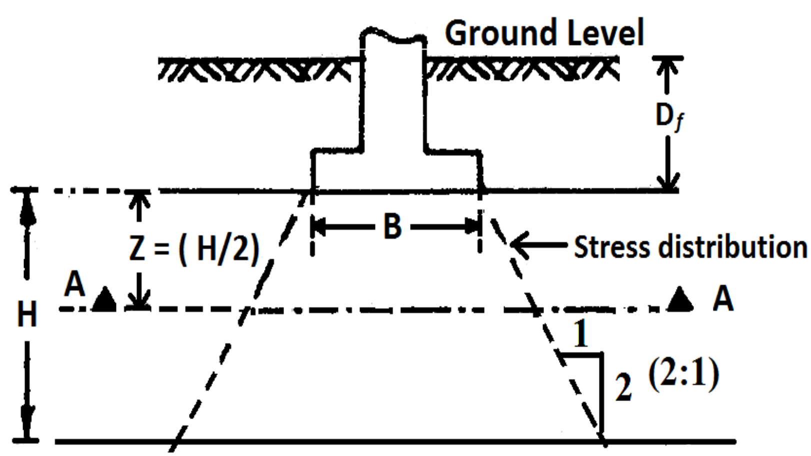
$$S_i = q\ B\left(\frac{1-\mu^2}{E_S}\right) I$$

Where, B = width of the footing in mt. μ – Poisson's ratio ;

E_S = modulus of elasticity or deformation modulus in KN/m^2

q – Pressure intensity in KN/m^2

I – Influence factor as per table given in IS 8009 – Part I – 1976, Page 20 ;



Influence Factor (I) :

table shown below (IS 8009 – Part I – 1976 , Page 20) gives the value of **Influence Factor (I)** for flexible and rigid footing according to various shapes of footing .

Shape of the footing	Flexible footing			Rigid Footing
	Center	Corner	Average	
Circle	1.0	0.64 (edge)	0.85	0.79
Square	1.12	0.56	0.95	0.82
Rectangle				
$L/B = 1.5$	1.36	0.68	1.20	1.06
$L/B = 2.0$	1.53	0.77	1.31	1.20
$L/B = 2.0$	1.78	0.89	1.52	1.42
$L/B = 5.0$	2.10	1.05	1.83	1.70
$L/B = 10.0$	2.52	1.26	2.25	2.10
$L/B = 100.0$	3.38	1.69	2.96	3.40

Important Note :

Students are expected to remember all values which are highlighted in red color shown in the table.

2. Consolidation or Primary settlement (S_c) :

it causes due to gradual expulsion of water from soil mass due to due to gradual dissipation of pore pressure induced by compressive forces . hence there is reduction in volume of soil mass. In short, It is the gradual re-arrangement of soil grains as water is expelled and thus attain closer packing causing reduction in volume. This component of settlement is usually dominant in fine-grained saturated clays.

Consolidation settlement is given by ;

$$S_C = \frac{C_C}{1 + e_0} \; x \; H \; x \; \log \left[\frac{\overline{\sigma_0} + \Delta\,\bar{\sigma}}{\overline{\sigma_0}} \right]$$

Where, C_C = Compression Index = 0.009 ($W_L - 10$)

W_L – Water content at liquid state i.e liquid limit

e_0 = Initial void ratio = $\frac{\text{w G}}{\text{S}}$

H – Thickness of the layer of stress distribution

$\overline{\sigma_0}$ = Surcharge or overburden pressure at Section A – A

= Unit weight of the soil (γ) x depth ($D_f + Z$)

Note : *It is always computed w.r.t. Ground Level*

$$\Delta\,\bar{\sigma} = \Delta\,\bar{\sigma} = \left[\frac{\text{Load}}{\text{Area of distributed pressure at Section A} - \text{A}} \right]$$

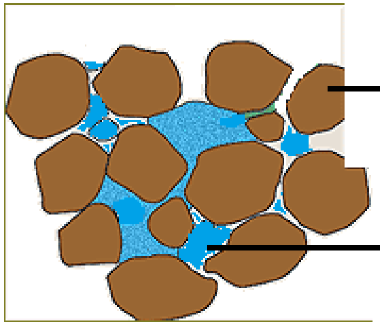
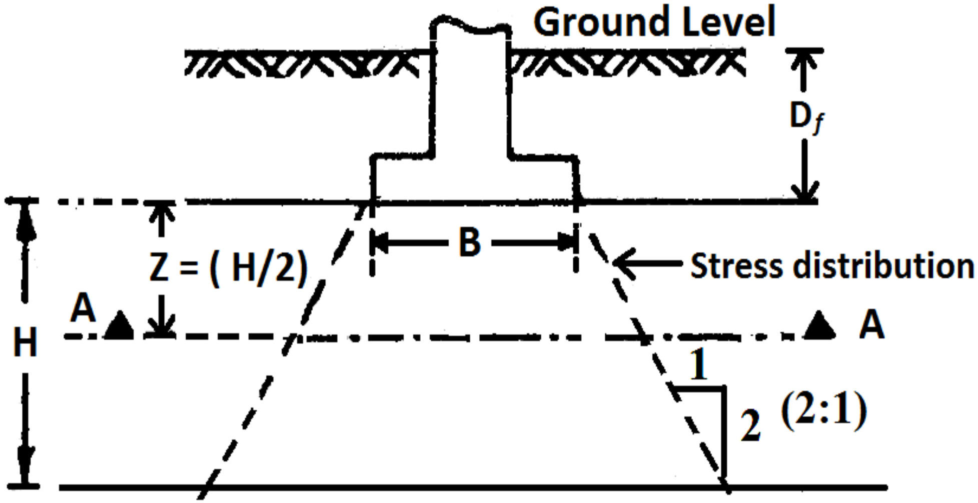


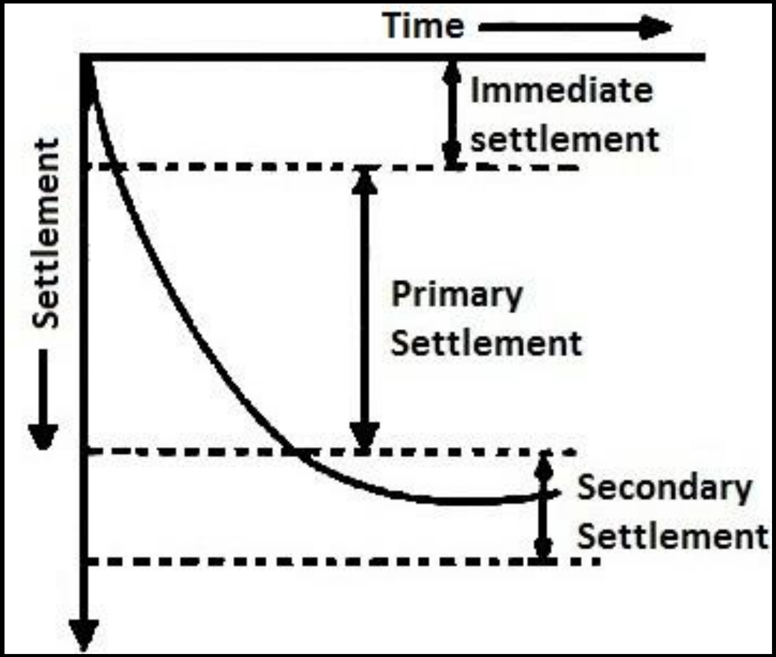
Figure : Structure of the soil



3. Secondary consolidation settlement or creep (S s)

The secondary settlement, Ss represents time-dependent settlement, or creep, that occurs under a *constant effective stress*. It starts with the completion of consolidation. During this stage of settlement, the pore water pressure is zero and the settlement is only due to distortion of soil grains. It is fairly easy to separate this component of settlement from the other two since it occurs when effective stress does not change.

Hence , Total Consolidation settlement is given by S = **(S i + S c + S s)**



Problem 1. A 2.0 x 3.0 mt. Footing rest on the surface of soil strata having modulus of elasticity as 60,00000 KN/m2 and poisons ratio as 0.3. If the same soil is subjected to a vertical load of 1000 KN, what will be the immediate settlement ? Take the influence factor as 0.80 . **[SGBAU,W-16, W-17/7 m]**

Solution :

Given , width of footing (B) = 2.0 $mt.$ (least value)

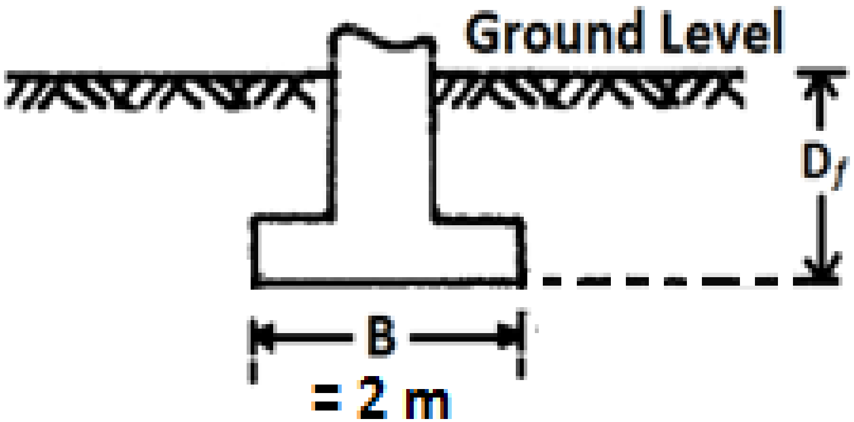
Poisson's ratio (μ) = 0.3 ; $E_S = 6 \; x \; 10^6 \; KN/m^2$

Influence factor (I) = 0.80

Load = 1000 KN

$\therefore$ Pressure (q) = Load/Area

$= 1000/(2 \, x \, 3) = 166.67 \; KN/m^2$



Immediate Settlement is given by ;

$$S_i = q \; B \left(\frac{1 - \mu^2}{E_S} \right) I$$

$$\therefore \; S_i = \left[116.67 \; x \; 2 \; x \left(\frac{1 - 0.3^2}{6 \; x \; 10^6} \right) x \; 0.80 \right] = 4 \; x \; 10^{-5} \; mt. = 0.04 \; mm$$

Problem 2. Determine immediate settlement below the corner of Flexible footing from the following data :

i) Modulus of Elasticity = 50000 KN/m2 ii) Poisons ratio = 0.3

iii) Size of footing = 3.0 m x 3.0 m iv) Load = 1000 KN **[SGBAU,S-18/7 m]**

Solution :

Given, width of footing (B) = 3.0 m

Poisson's ratio (μ) = 0.3

and $E_S = 50000 \quad KN/m^2$

Now, Pressure (q) = Load/Area

$= 1000/(0.3 \; x \; 0.3)$

$= 111.12 \quad KN/m^2$

As per table given in

IS 8009 – Part I – 1976 pg. 20 ;

At corner of Flexible footing,

Influence factor (I) = 0.56

Shape of the footing	Flexible footing Center	Corner	Average	Rigid Footing
Circle	1.0	0.64 (edge)	0.85	0.79
Square	1.12	0.56	0.95	0.82
Rectangle				
L/B = 1.5	1.36	0.68	1.20	1.06
L/B = 2.0	1.53	0.77	1.31	1.20
L/B = 2.0	1.78	0.89	1.52	1.42
L/B = 5.0	2.10	1.05	1.83	1.70
L/B = 10.0	2.52	1.26	2.25	2.10
L/B = 100.0	3.38	1.69	2.96	3.40

Immediate Settlement is given by ;

$$S_i = q \; B \left(\frac{1 - \mu^2}{E_S} \right) I$$

$$\therefore \; S_i = \left[111.12 \; x \; 3 \; x \left(\frac{1 - 0.3^2}{50000} \right) x \; 0.56 \right] = 3.4 \; x \; 10^{-3} \quad mt. = 3.4 \; mm$$

Problem 3. The Circular footing of 20 m diameter ground level oil tank transmits an uniform pressure of 300 at 2.8 mt. Depth. Determine immediate settlement under the canter of foundation from the following data : **[SGBAU,W-15,S-17/7 m]**

$E_S = 60{,}00000\ KN/m^2$; $\gamma = 22\ KN/m^3$; $\mu = 0.45$

Solution :

Given , diameter of footing (d) = B = 20 m

Poisson's ratio (μ) = 0.45 ;

$E_S = 6\ x\ 10^6\ KN/m^2$ and

pressure $q = 300\ KN/m^2$

As per table given in

IS 8009 – Part I – 1976 , Page 20 ;

At the centre of Flexible Circular footing ,

Influence factor (I) = 1

Immediate Settlement is given by ;

$$S_i = q\ B \left(\frac{1-\mu^2}{E_S} \right) I$$

$$\therefore\ S_i = \left[300\ x\ 20\ x \left(\frac{1-0.45^2}{6\ x\ 10^6} \right) x\ 1 \right] = 8\ x\ 10^{-4}\ mt. = 0.8\ mm$$

Shape of the footing	Flexible footing			Rigid Footing
	Center	Corner	Average	
Circle	1.0	0.64 (edge)	0.85	0.79
Square	1.12	0.56	0.95	0.82
Rectangle				
L/B = 1.5	1.36	0.68	1.20	1.06
L/B = 2.0	1.53	0.77	1.31	1.20
L/B = 2.0	1.78	0.89	1.52	1.42
L/B = 5.0	2.10	1.05	1.83	1.70
L/B = 10.0	2.52	1.26	2.25	2.10
L/B = 100.0	3.38	1.69	2.96	3.40

Problem 4. A 0.6 m square plate is placed on the surface sand and loaded to 200 **KN/m2**. determine the total deformation modulus if the plate settles by 4 mm . what will be the immediate settlement of rigid footing 2.5 *m* x 2.5 *m* if it is loaded to the same intensity of pressure ? assume Poisson ratio = 0.3 and Combined Influence factor = 0.88

[SGBAU,S-15/7 m]

Solution :

Case 1] Given that , width of plate (B) = 0.6 m ; Influence factor (I) = 0.88

Poisson's ratio (μ) = 0.3 ; pressure (q) = 200 KN/m^2

Immediate Settlement (S_i) = 4 mm = 4 x 10 $^{-3}$ mt. and

deformation modulus or Modulus of Elasticity (E_S) = ?

Immediate settlement is given by :

$$S_i = q\ B \left(\frac{1 - \mu^2}{E_S} \right) I$$

$$\therefore\ 4\ x\ 10^{-3} = \left[200\ x\ 0.6\ x \left(\frac{1 - 0.3^2}{E_S} \right) x\ 0.88 \right]$$

$$\therefore\ E_S = 24024\ \ KN/m^2$$

Case 2] width of footing (B) = 2.5 m ; Influence factor (I) = 0.88

Poisson's ratio (μ) = 0.3 ; pressure (q) = 200 KN/m^2

Immediate Settlement (S_i) = 4 mm = $4 \ x \ 10^{-3}$ $mt.$ and

deformation modulus or Modulus of Elasticity (E_S) = 24024 KN/m^2

Immediate settlement is given by :

$$S_i = q \ B \left(\frac{1 - \mu^2}{E_S} \right) I$$

$$\therefore \ S_i = \left[200 \ x \ 2.5 \ x \left(\frac{1 - 0.3^2}{24024} \right) x \ 0.88 \right] = 0.0167 \ mt. = 16.67 \ mm$$

Consolidation or Primary settlement (S_c) :

it causes due to gradual expulsion of water from soil mass due to due to gradual dissipation of pore pressure induced by compressive forces . hence there is reduction in volume of soil mass. In short, It is the gradual re-arrangement of soil grains as water is expelled and thus attain closer packing causing reduction in volume. This component of settlement is usually dominant in fine-grained saturated clays.

Consolidation settlement is given by ;

$$S_C = \frac{C_C}{1 + e_0} \; x \; H \; x \log \left[\frac{\overline{\sigma_0} + \Delta \bar{\sigma}}{\overline{\sigma_0}} \right]$$

Where, C_C = Compression Index = $0.009 \, (W_L - 10)$

W_L – Water content at liquid state i.e liquid limit

e_0 = Initial void ratio = $\dfrac{\text{w G}}{\text{S}}$

H – Thickness of the layer of stress distribution

$\overline{\sigma_0}$ = Surcharge or overburden pressure at Section A – A

= Unit weight of the soil (γ) x depth ($D_f + Z$)

Note : *It is always computed w.r.t. Ground Level*

$$\Delta \bar{\sigma} = \Delta \bar{\sigma} = \left[\frac{\text{Load}}{\text{Area of distributed pressure at Section A} - \text{A}} \right]$$

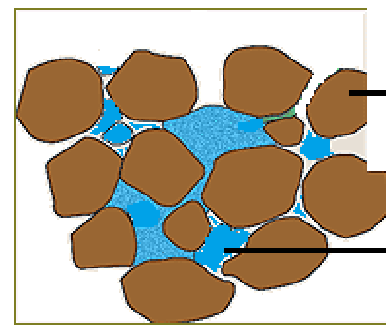
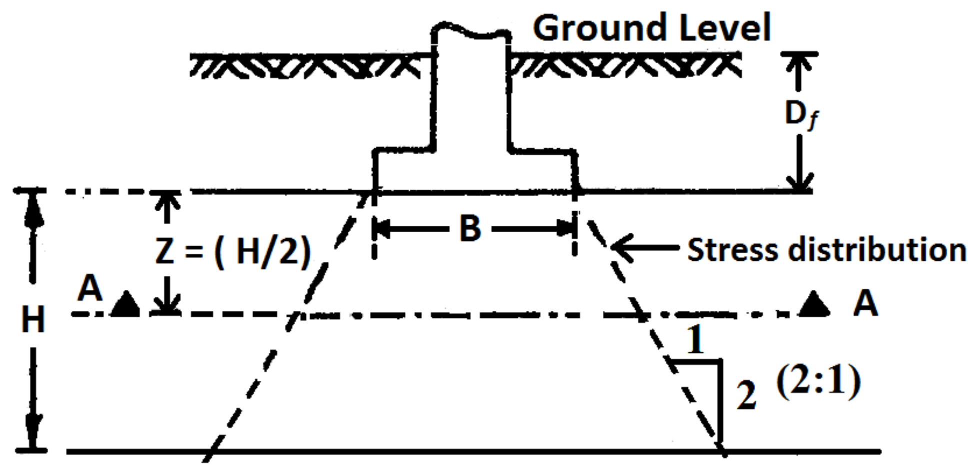
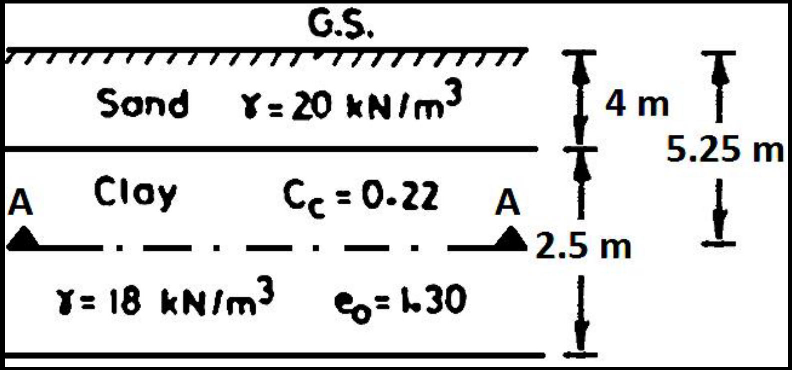


Figure : Structure of the soil



Problem 1. Determine Consolidation settlement in clay layer as a shown in figure due to increase of pressure 30 KN/m2 at the mid height of clay layer ? Also determine the settlement when the water table rises to ground surface ?



Solution :

Case 1] When water table does not exist :

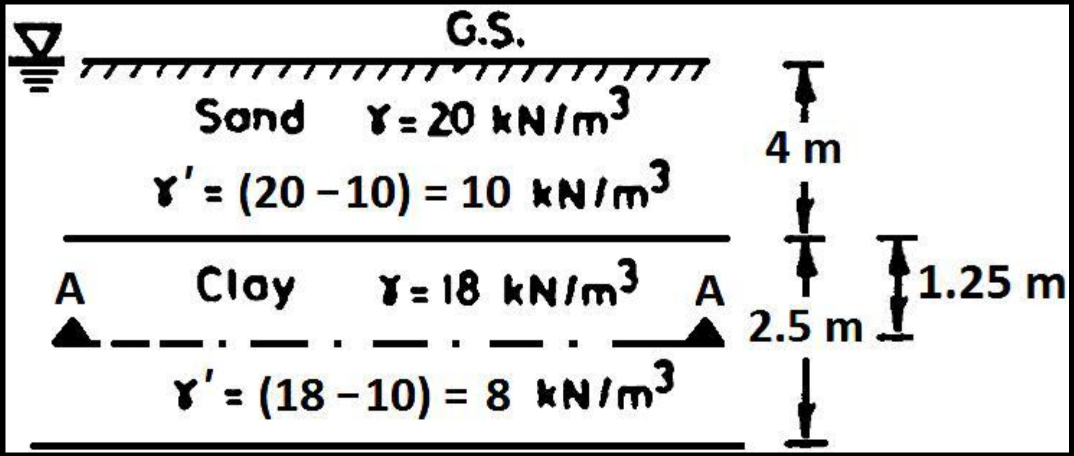
The Surcharge or Overburden pressure at the center of clay layer (at Section A-A) :

$\overline{\sigma_0}$ = (unit wt. x depth) = [(20 x 4) + (18 x 1.25)] = 102.5 KN/m^2

Consolidation settlement is given by ;

$$S_f = \frac{C_c}{1+e_0} \, x \, H \, x \log\left[\frac{\overline{\sigma_0}+\Delta\bar{\sigma}}{\overline{\sigma_0}}\right] = \frac{0.22}{1+1.3} \, x \, 2.5 \, x \log\left[\frac{102.5+30}{102.5}\right] = 0.0263 \ mt. = 2.63 \ cm$$

Case 2] When water table rises to ground surface :



The Surcharge or Overburden pressure at the center of clay layer (at section A-A) :

$$\overline{\sigma_0} = (20 - 10)\ x\ 4 + (18 - 10)\ x\ 1.25 = 50\ \ KN/m^2$$

Consolidation settlement is given by ;

$$S_C = \frac{C_C}{1 + e_0}\ x\ H\ x\ \log\left[\frac{\overline{\sigma_0} + \Delta\bar{\sigma}}{\overline{\sigma_0}}\right] = \frac{0.22}{1 + 1.3}\ x\ 2.5\ x\ \log\left[\frac{50 + 30}{50}\right] = 0.0488\ \ mt. = 4.88\ \ cm$$

Problem 2. A soft normally consolidated clay layer is 18 m thick. The natural water content is 42 % . The Saturated unit weight of soil is 18 KN/m3. The grain specific gravity is 2.7 and liquid limit is 63 % . vertical stress increment at the centre of the layer is 9 KN/m2. The ground water table is at the surface of ground level. Determine the settlement of the foundation ? **[SGBAU,W-16/7 m]**

Solution :

Water content at liquid state i.e liquid limit $(W_L) = 63\ \%$

Compression Index $(C_c) = 0.009\ (W_L - 10) = 0.009\ x\ (63 - 10) = 0.477$

Since the soil is fully saturated; degree of saturation (S) = 100 % = 1

Water content at natural state (w) = 42 % = (42/100) = 0.4

specific gravity of Clay soil (G) = 2.7

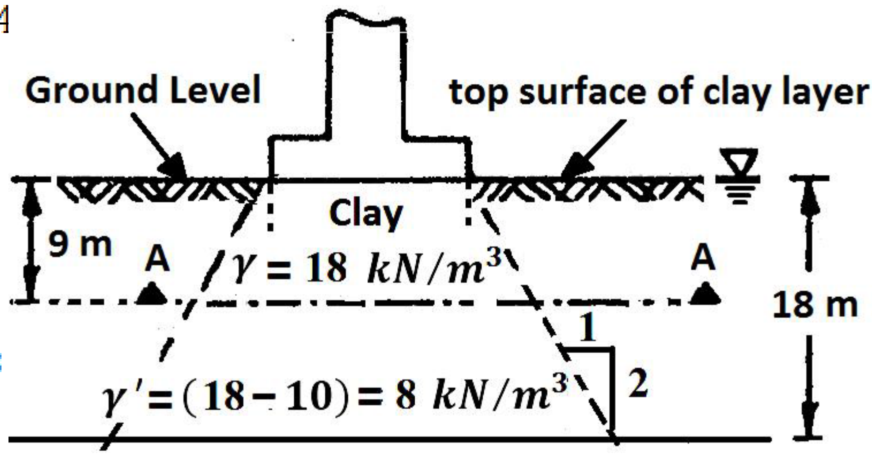
void ratio (e_0) is given by

$$e_0 = \frac{w\,G}{S} = \left(\frac{0.42\ x\ 2.7}{1}\right) = 1.134$$

Saturated unit weight of soil $(\gamma_{sat}) = 18\ KN/m^3$

Submerged unit weight $(\gamma') = (\gamma_{sat} - \gamma_w) = (18 - 10) = 8$

Where, γ_w – unit weight of water $= 9.81 \approx 10\ KN/m^3$



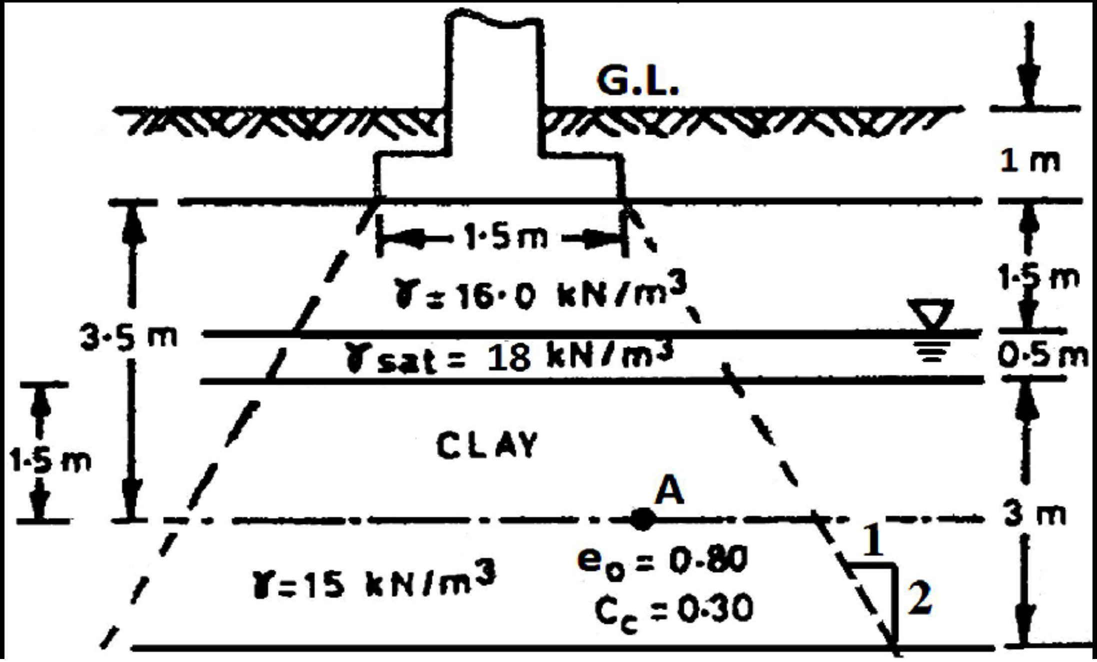
The Surcharge or Overburden pressure at the center of clay layer :

$$\overline{\sigma_0} = (18 - 10)\ x\ 9 = 72\ KN/m^2$$

Consolidation settlement of clay layer is given by ;

$$S_f = \frac{C_c}{1 + e_0}\ x\ H\ x \log\left[\frac{\overline{\sigma_0} + \Delta\bar{\sigma}}{\overline{\sigma_0}}\right] = \frac{0.477}{1 + 1.134}\ x\ 18\ x \log\left[\frac{72 + 9}{72}\right] = 0.206\ mt. = 20.6\ cm$$

Problem 3. A footing has size of 3.0 mt. x 1.5 mt. causes pressure increment of 200 KN/m2. at its base as shown in figure. Determine the consolidation settlement of the at the middle of the clay layer. Assume 2 : 1 pressure distribution. Consider the variation of pressure across the depth of clay layer ?



Solution :

The footing is rectangular of size (L x B) = 3.0 mt. x 1.5 mt.

The Surcharge or Overburden pressure at the center of clay layer (S/C A-A) :

$$\overline{\sigma_0} = (16 \ x \ 1) + (16 \ x \ 1.5) + (18 - 10) \ x \ 0.5 + (15 - 10) \ x \ 1.5 = 51.5 \ KN/m^2$$

Now, Pressure = (Load/Area) ∴ Load = Pressure x Area = [200 x (3 x 1.5)] = 900 KN

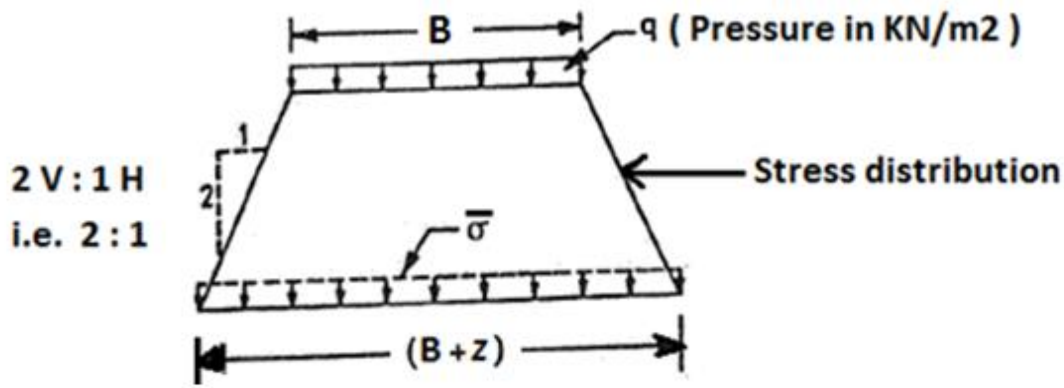
Let Z be the distance from the level where the distribution of pressure is developed to the center of clay layer (Section A – A)

∴ Z = 3.5 mt.

Important Note :

These Formulae are only applicable for stress distribution of 2 V : 1 H i.e. 2 : 1

Computation of $\Delta\bar{\sigma}$ for stress distribution 2 V : 1 H i.e. 2 : 1 only

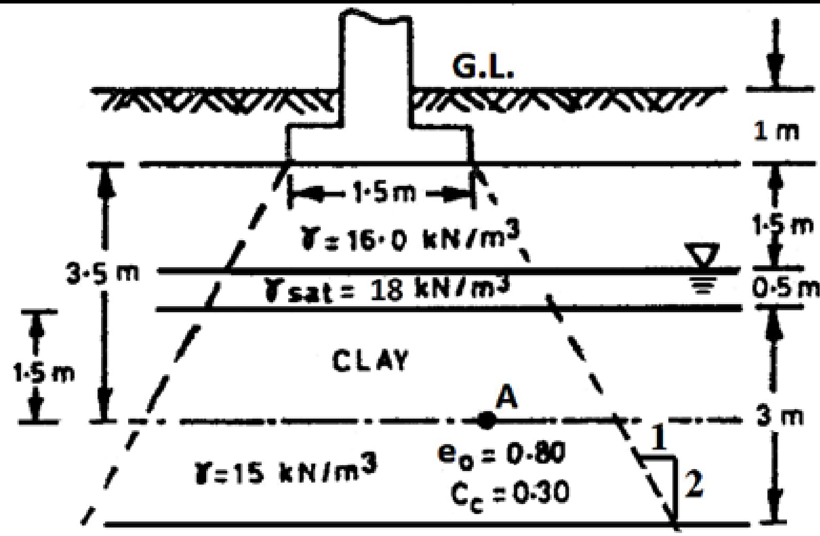


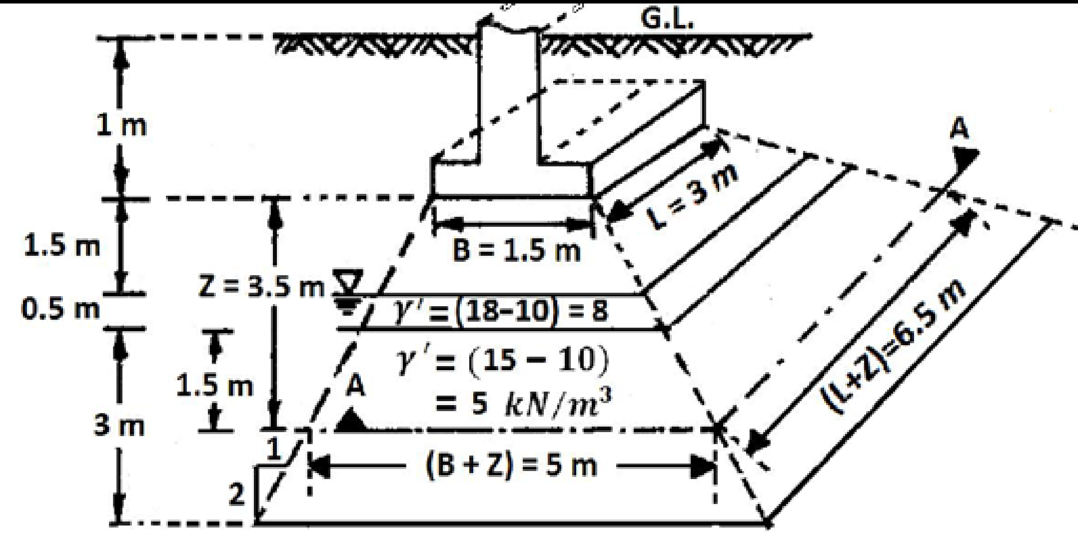
(1) Square area (B x B) : $\Delta\bar{\sigma}_z = \dfrac{q\,B^2}{(B+z)^2} = \dfrac{\text{Load}}{(B+z)^2}$

(2) Rectangular area (B x L) : $\Delta\bar{\sigma}_z = \dfrac{q\,(B \times L)}{(B+z)\,(L+z)} = \dfrac{\text{Load}}{(B+z)\,(L+z)}$

(3) Strip area (Width B, unit length) ; $\Delta\bar{\sigma}_z = \dfrac{q\,(B \times 1)}{(B+z) \times 1} = \dfrac{\text{Load}}{(B+z) \times 1}$

(4) Circular area (diameter d) ; $\Delta\bar{\sigma}_z = \dfrac{q\,d^2}{(d+z)^2} = \dfrac{\text{Load}}{(d+z)^2}$





the pressure distribution is 2 V : 1 H (given) , hence the formula of $\Delta\,\bar{\sigma}$ which we had discussed earlier in the note can be appli

$$\therefore\ \Delta\,\bar{\sigma} = \left[\frac{\text{Load}}{\text{Area of distributed pressure at Section A} - \text{A}}\right] = \left[\frac{\text{Load}}{(\text{B} + \text{Z})\ x\ (\text{L} + \text{Z})}\right]$$

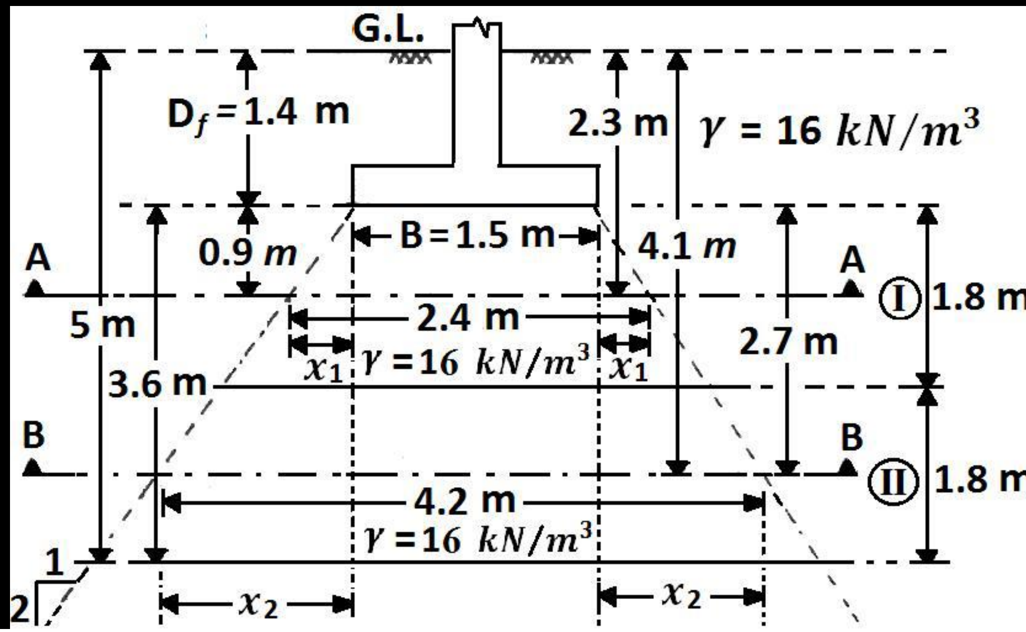
$$\therefore\ \Delta\,\bar{\sigma} = \left[\frac{900}{(1.5 + 3.5)\ x\ (3 + 3.5)}\right] = 27.70\quad KN/m^2$$

Consolidation settlement of clay layer is given by ;

$$S_f = \frac{C_C}{1 +\ e_0}\ x\ H\ x\ \log\left[\frac{\overline{\sigma_0} + \Delta\,\bar{\sigma}}{\overline{\sigma_0}}\right] = \frac{0.30}{1 +\ 0.80}\ x\ 3\ x\ \log\left[\frac{51.5 + 27.7}{27.7}\right] = 0.228\ \ mt. = 22.8\ \ cm$$

Problem 4. A square footing of size 1.5 m x 1.5 m rest at depth of 1.4 m in saturated clay layer of 5 m deep. The unconfined compression strength of clay is 38 KN/m2 , liquid limit = 35 %. Saturated unit weight = 16 KN/m3. water content = 30 % and G = 2.7. Determine consolidation settlement of footing for 120 KN load by dividing clay deposit into two layers below footing . **[SGBAU,S -18/7 m]**

Solution :



Water content at liquid state i.e liquid limit (W_L) = 35 %

Compression Index $(C_C) = 0.009\ (W_L - 10) = 0.009\ x\ (35 - 10) = 0.225$

Since the soil is fully saturated; degree of saturation (S) = 100 % = 1

Water content at natural state (w) = 30 % = (30/100) = 0.30

specific gravity of Clay soil (G) = 2.7 and void ratio (e_0) is given by

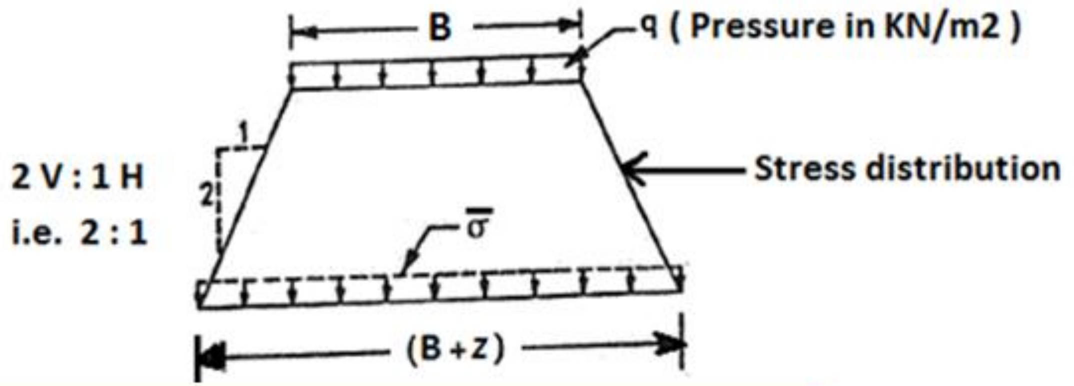
$$e_0 = \frac{w\,G}{S} = \left(\frac{0.30\ x\ 2.7}{1}\right) = 0.81$$

Saturated unit weight of soil $(\gamma_{sat}) = 16\ KN/m^3$ throughout 5 mt depth.

Important Note :

These Formulae are only applicable for stress distribution of 2 V : 1 H i.e. 2 : 1

Computation of $\Delta\bar{\sigma}$ for stress distribution 2 V : 1 H i.e. 2 : 1 only



(1) Square area (B x B) : $\boxed{\Delta\bar{\sigma}_z = \dfrac{q\,B^2}{(B+z)^2} = \dfrac{\text{Load}}{(B+z)^2}}$

(2) Rectangular area (B x L) : $\Delta\bar{\sigma}_z = \dfrac{q\,(B \times L)}{(B+z)\,(L+z)} = \dfrac{\text{Load}}{(B+z)\,(L+z)}$

(3) Strip area (Width B, unit length) ; $\Delta\bar{\sigma}_z = \dfrac{q\,(B \times 1)}{(B+z) \times 1} = \dfrac{\text{Load}}{(B+z) \times 1}$

(4) Circular area (diameter d) ; $\Delta\bar{\sigma}_z = \dfrac{q\,d^2}{(d+z)^2} = \dfrac{\text{Load}}{(d+z)^2}$

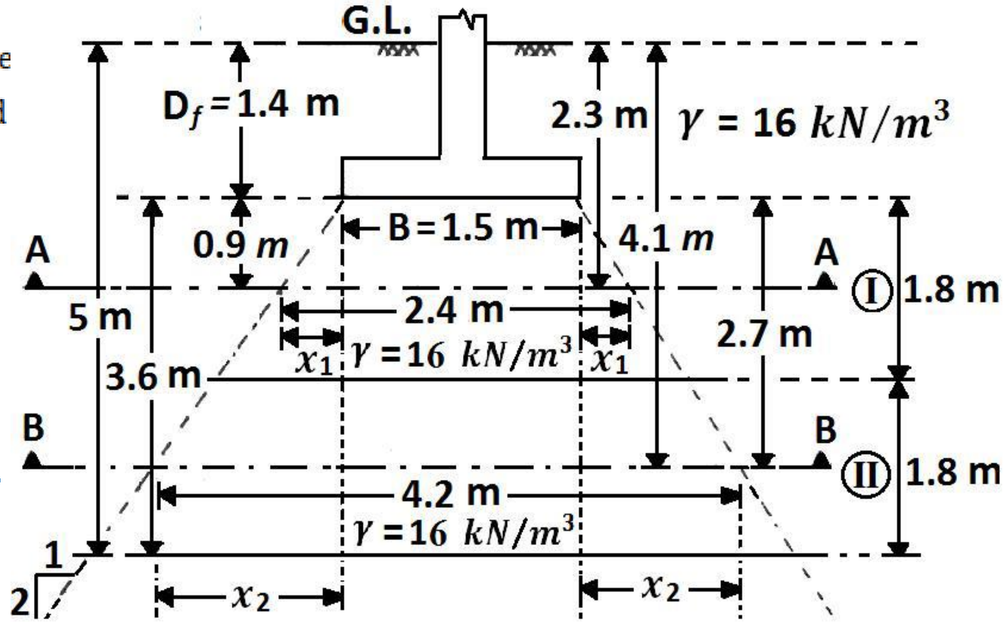
1] Calculation of Surcharge or Overburden pressure $\overline{\sigma_0} = (\gamma \; x \text{ depth})$:

For layer I (considering Section A – A); $\overline{\sigma_0} = (16 \; x \; 2.3) = 36.8 \;\; KN/m^2$

For layer II (considering Section B – B); $\overline{\sigma_0} = (16 \; x \; 4.1) = 65.6 \;\; KN/m^2$

2] Calculation of $\Delta\,\overline{\sigma}$:

For layer I (considering Section A – A) :



Assume the pressure distribution as 2 : 1 i.e. 2 V : 1 H. hence formula of $\Delta\,\overline{\sigma}$ which we **seen** earlier in note can be applied

$$\therefore \; \Delta\,\overline{\sigma} = \left[\frac{\text{Load}}{(\text{B} + \text{Z})^2}\right] = \left[\frac{120}{(1.5 + 0.9)^2}\right] = 20.84 \;\; KN/m^2$$

Alternative method :

$$\frac{H}{V} \rightarrow \frac{1}{2} = \frac{x_1}{0.9} \;\; ; \;\; \therefore \; x_1 = 0.45 \;\; mt.$$

width at section A – A; $B_I = [\,1.5 + (\,2 \; x \; x_1\,)\,]$

$= [\,1.5 + (\,2 \; x \; 0.45\,)\,] = 2.4 \;\; mt.$

$$\therefore \; \Delta\,\overline{\sigma} = \left[\frac{\text{Load}}{B_I \;\; x \;\; B_I}\right] = \left[\frac{120}{(2.4 \; x \; 2.4)}\right] = 20.84 \;\; KN/m^2$$

For layer II (considering Section B – B) :

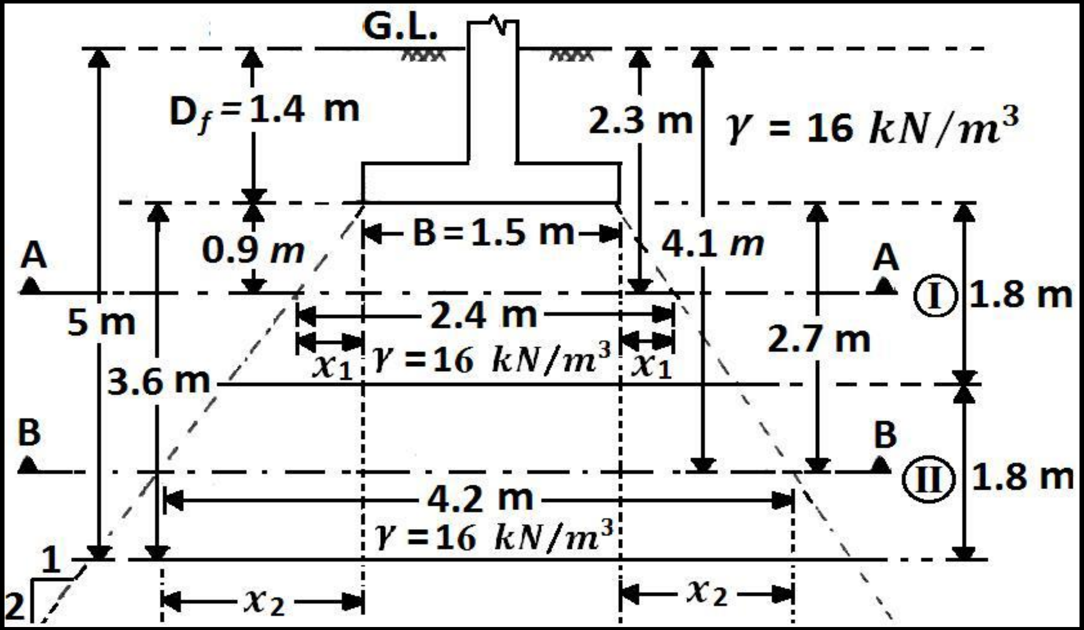
$$\therefore \; \Delta\,\overline{\sigma} = \left[\frac{\text{Load}}{(\text{B} + \text{Z})^2}\right] = \left[\frac{120}{(1.5 + 2.7)^2}\right] = 6.80 \;\; KN/m^2$$

Alternative method :

$$\frac{H}{V} \rightarrow \frac{1}{2} = \frac{x_2}{2.7} \;\; ; \;\; \therefore \; x_2 = 1.35 \;\; mt.$$

width at section B – B; $B_{II} = [\,1.5 + (\,2 \; x \; x_2\,)\,] = [\,1.5 + (\,2 \; x \; 1.35\,)\,] = 4.2 \;\; mt.$

$$\therefore \; \Delta\,\overline{\sigma} = \left[\frac{\text{Load}}{B_{II} \;\; x \;\; B_{II}}\right] = \left[\frac{120}{(4.2 \; x \; 4.2)}\right] = 6.80 \;\; KN/m^2 \ldots\ldots\ldots\ldots \textit{square footing}$$

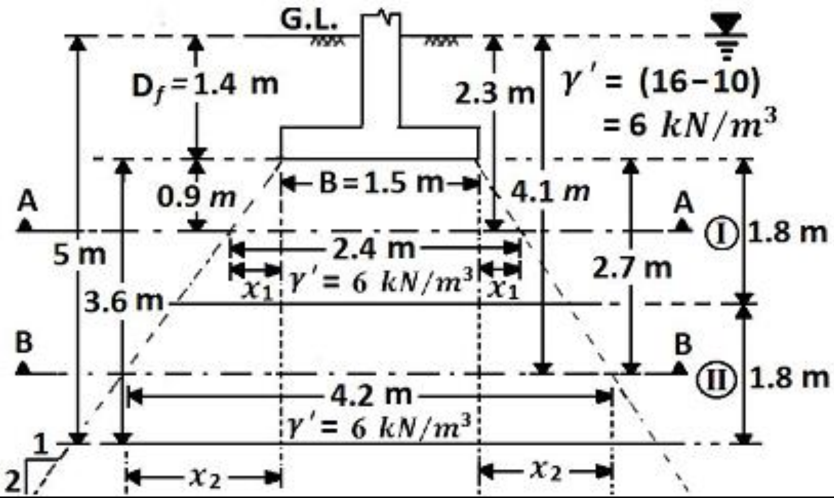


Consolidation settlement is given by ;

$$S_f = \frac{C_c}{1 + e_0} \; x \; H \; x \log \left[\frac{\overline{\sigma_0} + \Delta\,\overline{\sigma}}{\overline{\sigma_0}} \right]$$

Layer No.	Thickness (H) mt.	C_c	e_0	S/C	$\overline{\sigma_0}$	$\Delta\,\overline{\sigma}$	S_f
I	1.8 mt.	0.225	0.81	A - A	36.8	20.84	0.0436 mt.
II	1.8 mt.	0.225	0.81	B - B	65.6	6.80	0.0095 mt
∴ Total Consolidation Settlement $(S_f) = \sum = 0.0531\ mt = 5.3\ cm$							

Problem 5. Solve problem No. 4 when the water table is located at ground surface.



1] Calculation of Surcharge pressure $\overline{\sigma_0} = (\gamma\ x\ \text{depth})$:

For layer I (considering Section A - A) ;

$\overline{\sigma_0} = (16 - 10)\ x\ 2.3 = 13.8\ \ KN/m^2$

For layer II (considering Section B - B) ;

$\overline{\sigma_0} = (16 - 10)\ x\ 4.1 = 24.6\ \ KN/m^2$

2] Calculation of $\Delta\,\bar{\sigma}$:

Same as in Problem No. 04

Final Consolidation settlement is given by :

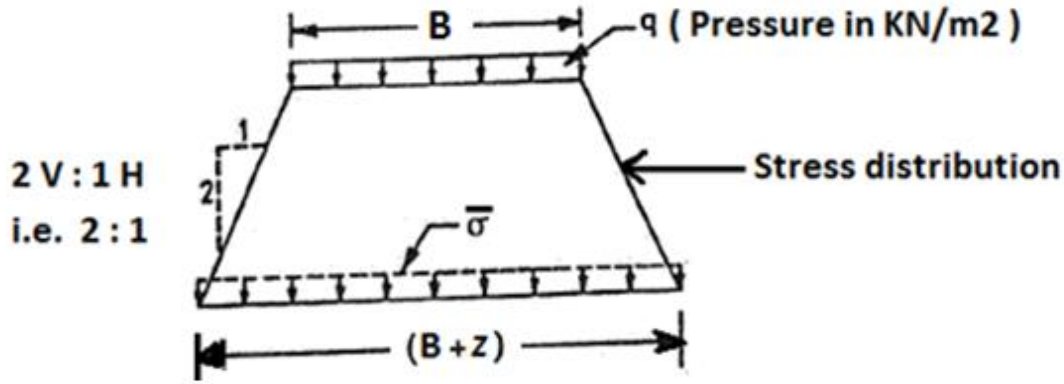
$$S_f = \frac{C_C}{1 + e_0}\ x\ H\ x\ \log\left[\frac{\overline{\sigma_0} + \Delta\,\bar{\sigma}}{\overline{\sigma_0}}\right]$$

Layer No.	Thickness (H) mt.	C_C	e_0	S/C	$\overline{\sigma_0}$	$\Delta\,\bar{\sigma}$	S_f
I	1.8 mt.	0.225	0.81	A - A	13.8	20.84	0.0497 mt.
II	1.8 mt.	0.225	0.81	B - B	24.6	6.80	0.0131 mt.
∴ Total Consolidation Settlement $(S_f) = \sum = 0.0628\ \ mt = 6.3\ \ cm$							

Important Note :

These Formulae are only applicable for stress distribution of 2 V : 1 H i.e. 2 : 1

Computation of $\Delta\bar{\sigma}$ for stress distribution 2 V : 1 H i.e. 2 : 1 only



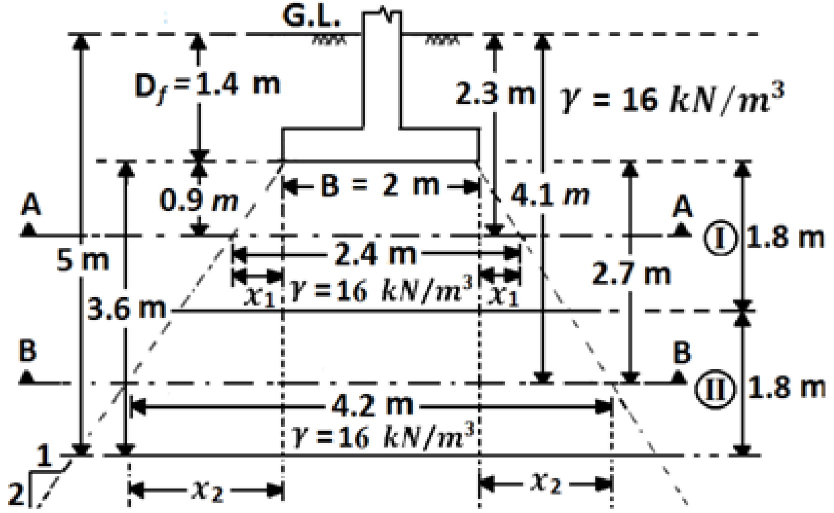
(1) Square area (B x B) : $\Delta\bar{\sigma}_Z = \dfrac{q\,B^2}{(B+Z)^2} = \dfrac{\text{Load}}{(B+Z)^2}$

(2) Rectangular area (B x L) : $\Delta\bar{\sigma}_Z = \dfrac{q\,(B \times L)}{(B+Z)\,(L+Z)} = \dfrac{\text{Load}}{(B+Z)\,(L+Z)}$

(3) Strip area (Width B, unit length) ; $\Delta\bar{\sigma}_Z = \dfrac{q\,(B \times 1)}{(B+Z) \times 1} = \dfrac{\text{Load}}{(B+Z) \times 1}$

(4) Circular area (diameter d) ; $\Delta\bar{\sigma}_Z = \dfrac{q\,d^2}{(d+z)^2} = \dfrac{\text{Load}}{(d+z)^2}$

Problem 6. Solve the above problem (problem No. 4) for the rectangular footing of 2 mt. x 3 mt



Assume that the pressure distribution is 2 : 1 i.e. 2 V : 1 H.

Hence the formula of $\Delta \bar{\sigma}$ in the note can be applied

Calculation of $\Delta \bar{\sigma}$:

For layer I (considering Section A – A):

$$\therefore\ \Delta \bar{\sigma} = \left[\frac{\text{Load}}{(B+Z)(L+Z)}\right] = \left[\frac{120}{(2+0.9)(3+0.9)}\right]$$

$$= 10.61\ KN/m^2$$

For layer II (considering Section B – B):

$$\therefore\ \Delta \bar{\sigma} = \left[\frac{\text{Load}}{(B+Z)(L+Z)}\right] = \left[\frac{120}{(2+2.7)(3+2.7)}\right]$$

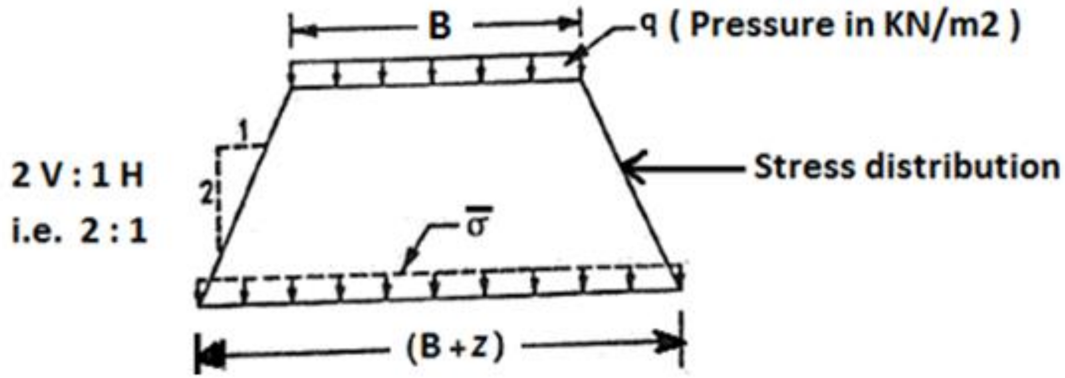
$$= 4.48\ KN/m^2$$

Layer No.	Thickness (H) mt.	C_c	e_0	S/C	$\overline{\sigma_0}$	$\Delta \bar{\sigma}$	S_f
I	1.8 mt.	0.225	0.81	A - A	36.8	10.61	0.0246 mt.
II	1.8 mt.	0.225	0.81	B - B	65.6	4.48	0.0064 mt.
$\therefore$ Total Consolidation Settlement (S_f) = $\sum = 0.031\ mt = 3.1\ cm$							

Important Note :

These Formulae are only applicable for stress distribution of 2 V : 1 H i.e. 2 : 1

Computation of $\Delta\bar{\sigma}$ for stress distribution 2 V : 1 H i.e. 2 : 1 only



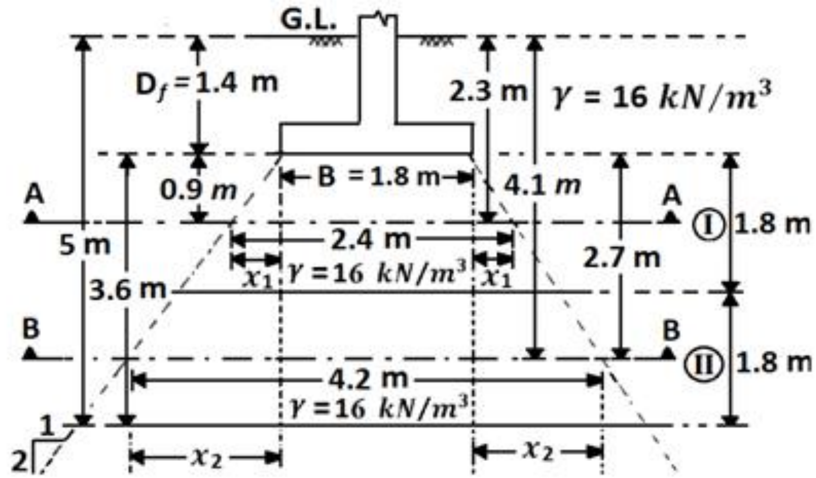
(1) Square area (B x B) : $\Delta\bar{\sigma}_z = \dfrac{q\,B^2}{(B+z)^2} = \dfrac{\text{Load}}{(B+z)^2}$

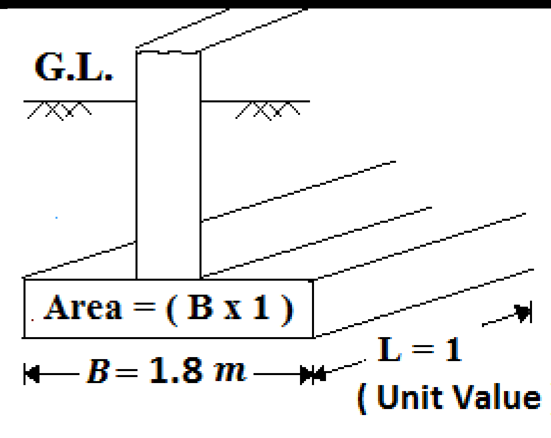
(2) Rectangular area (B x L) : $\Delta\bar{\sigma}_z = \dfrac{q\,(B \times L)}{(B+z)\,(L+z)} = \dfrac{\text{Load}}{(B+z)\,(L+z)}$

(3) Strip area (Width B, unit length) ; $\Delta\bar{\sigma}_z = \dfrac{q\,(B \times 1)}{(B+z) \times 1} = \dfrac{\text{Load}}{(B+z) \times 1}$

(4) Circular area (diameter d) ; $\Delta\bar{\sigma}_z = \dfrac{q\,d^2}{(d+z)^2} = \dfrac{\text{Load}}{(d+z)^2}$

Problem 7. Solve the problem No. 4 for the strip footing of 1.8 mt width.





Assume that the pressure distribution is 2 : 1 i.e. 2 V : 1 H.

Hence the formula of $\Delta\bar{\sigma}$ in the note can be applied

Calculation of $\Delta\bar{\sigma}$:

For layer I (considering Section A – A):

$$\therefore\ \Delta\bar{\sigma} = \left[\frac{\text{Load}}{(B+Z)\,x\,1}\right] = \left[\frac{120}{(1.8+0.9\ )\,x\,1}\right] = 44.45\ \ KN/m^2$$

For layer II (considering Section B – B):

$$\therefore\ \Delta\bar{\sigma} = \left[\frac{\text{Load}}{(B+Z)\,x\,1}\right] = \left[\frac{120}{(1.8+2.7\ )\,x\,1}\right]$$

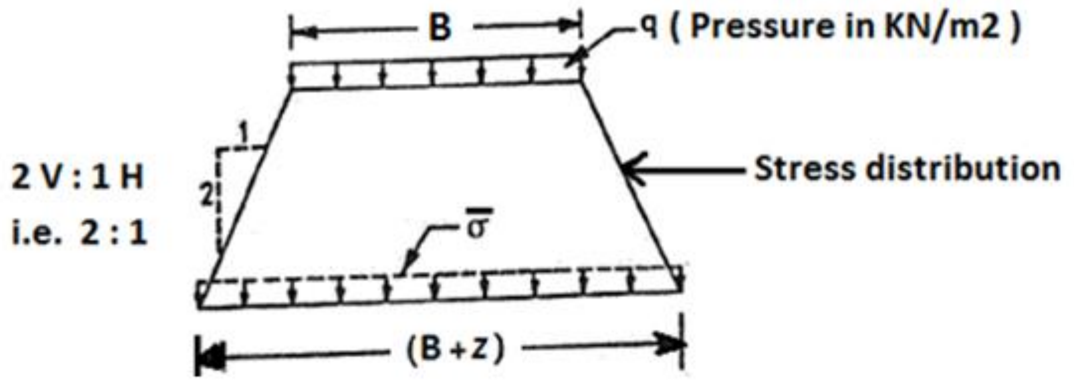
$$= 26.67\ \ KN/m^2$$

Layer No.	Thickness (H) mt.	C_C	e_0	S/C	$\overline{\sigma_0}$	$\Delta\bar{\sigma}$	S_f
I	1.8 mt.	0.225	0.81	A - A	36.8	44.45	0.077 mt.
II	1.8 mt.	0.225	0.81	B - B	65.6	26.67	0.033 mt
∴ Total Consolidation Settlement (S_f) = $\sum = 0.110\ mt = 1.1\ cm$							

Important Note :

These Formulae are only applicable for stress distribution of 2 V : 1 H i.e. 2 : 1

Computation of $\Delta\bar{\sigma}$ for stress distribution 2 V : 1 H i.e. 2 : 1 only



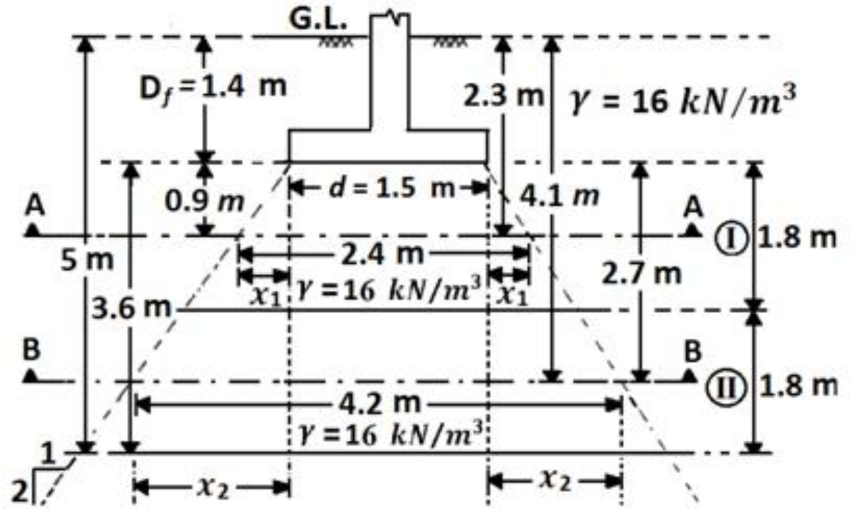
(1) Square area (B x B) : $\Delta\bar{\sigma}_z = \dfrac{q\,B^2}{(B+z)^2} = \dfrac{\text{Load}}{(B+z)^2}$

(2) Rectangular area (B x L) : $\Delta\bar{\sigma}_z = \dfrac{q\,(B \times L)}{(B+z)\,(L+z)} = \dfrac{\text{Load}}{(B+z)\,(L+z)}$

(3) Strip area (Width B, unit length) ; $\Delta\bar{\sigma}_z = \dfrac{q\,(B \times 1)}{(B+z) \times 1} = \dfrac{\text{Load}}{(B+z) \times 1}$

(4) Circular area (diameter d) ; $\Delta\bar{\sigma}_z = \dfrac{q\,d^2}{(d+z)^2} = \dfrac{\text{Load}}{(d+z)^2}$

Problem 8. Solve the problem No. 4 for the circular footing of 1.5 mt diameter .



Assume that the pressure distribution is 2 : 1 i.e. 2 V : 1 H.

Hence the formula of $\Delta\bar{\sigma}$ in the note can be applied

Calculation of $\Delta\bar{\sigma}$:

For layer I (considering Section A – A) :

$$\therefore\ \Delta\bar{\sigma} = \left[\frac{\text{Load}}{(\text{dia} + Z)^2}\right] = \left[\frac{120}{(1.5 + 0.9)^2}\right]$$

$$= 20.84\ KN/m^2$$

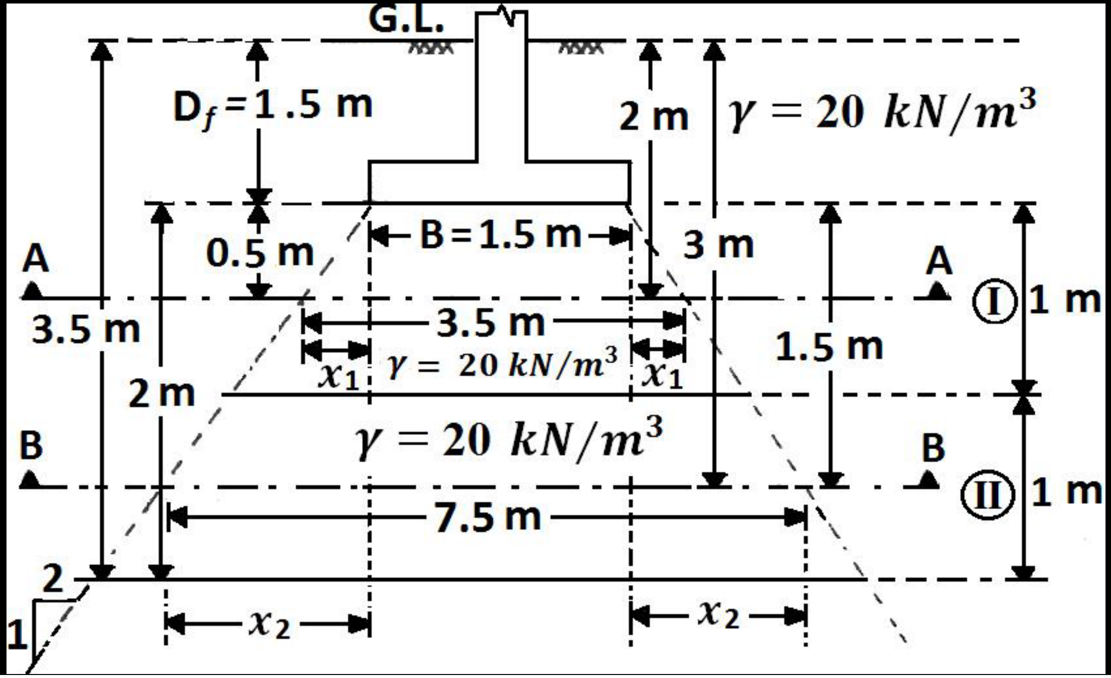
For layer II (considering Section B – B):

$$\therefore\ \Delta\bar{\sigma} = \left[\frac{\text{Load}}{(\text{dia} + Z)^2}\right] = \left[\frac{120}{(1.5 + 2.7)^2}\right] = 6.802\ KN/m^2$$

Layer No.	Thickness (H) mt.	C_c	e_0	S/C	$\overline{\sigma_0}$	$\Delta\bar{\sigma}$	S_f
I	1.8 mt.	0.225	0.81	A - A	36.8	20.84	0.0436 mt.
II	1.8 mt.	0.225	0.81	B - B	65.6	6.802	0.0095 mt
$\therefore$ Total Consolidation Settlement $(S_f) = \sum = 0.0531\ mt = 5.31\ cm$							

Problem 9. Compute the primary consolidation settlement of uniform soil deposit subjected to load of 225 KN through the square footing of 1.5 m located at 1.5 m depth. the thickness of compressible soil layer is 3.5 m followed by rock layer . the unit weight of soil is 20 KN/m3 , initial void ratio is 0.8 and compression index as 0.07 . The stress distribution shall be taken as 2 H : 1 V and consider two layers ? **[SGBAU,S -17/7 m]**

Solution :



Unit weight of soil (γ) = 20 KN/m^3 throughout 3.5 mt depth is same.

1] Calculation of Surcharge or Overburden pressure $\overline{\sigma_0}$ = (γ x depth) :

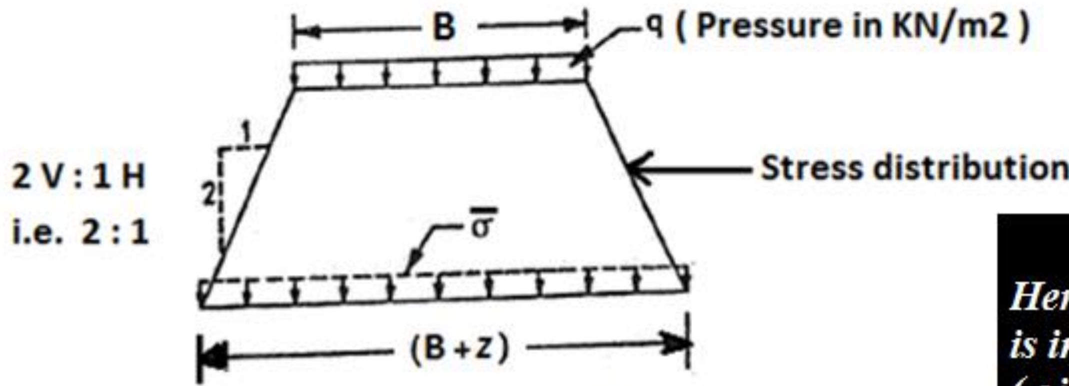
For layer I (considering Section A – A) ; $\overline{\sigma_0} = (2 \ x \ 20) = 40 \ \ KN/m^2$

For layer II (considering Section B – B) ; $\overline{\sigma_0} = (3 \ x \ 20) = 60 \ \ KN/m^2$

Important Note :

These Formulae are only applicable for stress distribution of 2 V : 1 H i.e. 2 : 1

Computation of $\Delta\bar{\sigma}$ for stress distribution 2 V : 1 H i.e. 2 : 1 only



Here the stress distribution is in the order of 2 H : 1 V (given in the question) hence these furmulae are not applicable ....

(1) Square area (B x B) : $\Delta\bar{\sigma}_z = \dfrac{q\,B^2}{(B+z)^2} = \dfrac{\text{Load}}{(B+z)^2}$

(2) Rectangular area (B x L) : $\Delta\bar{\sigma}_z = \dfrac{q\,(B \times L)}{(B+z)\,(L+z)} = \dfrac{\text{Load}}{(B+z)\,(L+z)}$

(3) Strip area (Width B, unit length) ; $\Delta\bar{\sigma}_z = \dfrac{q\,(B \times 1)}{(B+z) \times 1} = \dfrac{\text{Load}}{(B+z) \times 1}$

(4) Circular area (diameter d) ; $\Delta\bar{\sigma}_z = \dfrac{q\,d^2}{(d+z)^2} = \dfrac{\text{Load}}{(d+z)^2}$

2] Calculation of $\Delta\bar{\sigma}$:

Note : the pressure distribution is 2 H : 1 V.

hence the formula of $\Delta\bar{\sigma}$ which we have seen in the note can not be applied.

For layer I (considering Section A – A):

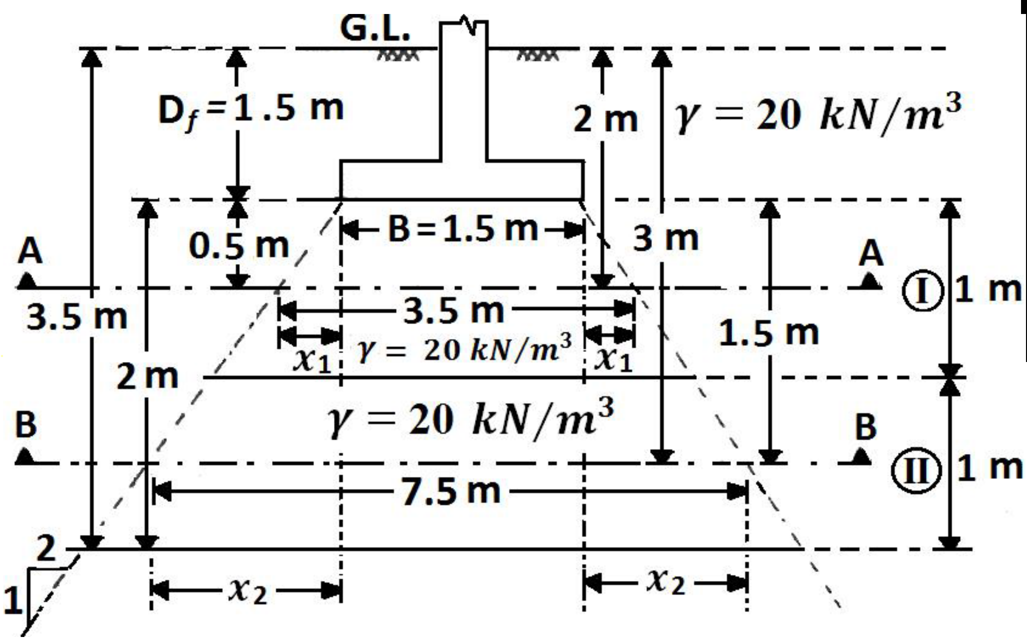
$$\frac{H}{V} \rightarrow \frac{2}{1} = \frac{x_1}{0.5} \quad ; \quad \therefore x_1 = 1 \ mt.$$

width at section A – A; $B_I = [1.5 + (2 \ x \ x_1)]$

$$= [1.5 + (2 \ x \ 1)] = 3.5 \ mt.$$

$$\therefore \Delta\bar{\sigma} = \left[\frac{\text{Load}}{B_I \ x \ B_I}\right] = \left[\frac{225}{(3.5 \ x \ 3.5)}\right] = 18.37 \ KN/m^2$$

……………… *square*



For layer II (considering Section B – B):

$$\frac{H}{V} \rightarrow \frac{2}{1} = \frac{x_2}{1.5} \quad ; \quad \therefore x_2 = 3 \ mt.$$

width at section B – B; $B_{II} = [1.5 + (2 \ x \ x_2)]$

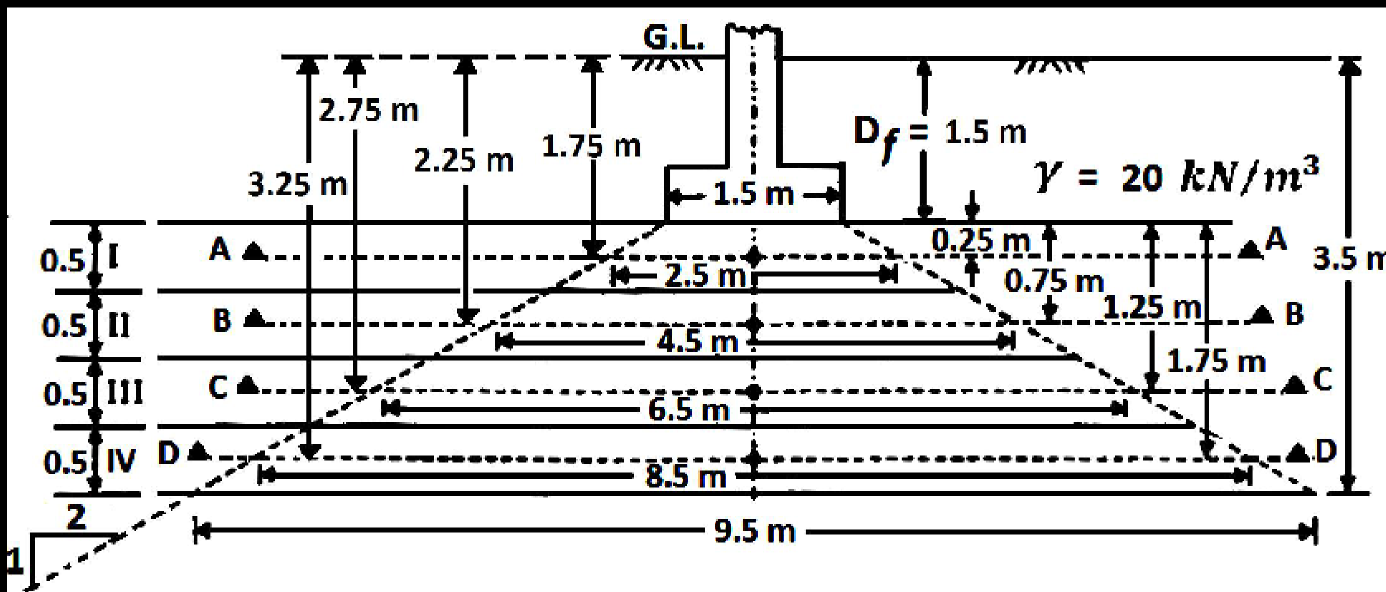
$$= [1.5 + (2 \ x \ 3)] = 7.5 \ mt.$$

$$\therefore \Delta\bar{\sigma} = \left[\frac{\text{Load}}{B_{II} \ x \ B_{II}}\right] = \left[\frac{225}{(7.5 \ x \ 7.5)}\right] = 4 \ KN/m^2$$

Layer No.	Thickness (H) mt.	C_c	e_0	S/C	$\bar{\sigma}_0$	$\Delta\bar{\sigma}$	$S_f = \frac{C_c}{1+e_0} \ x \ H \ x \log\left[\frac{\bar{\sigma}_0 + \Delta\bar{\sigma}}{\bar{\sigma}_0}\right]$
I	1 mt.	0.07	0.8	A - A	40	18.37	0.0064 mt.
II	1 mt.	0.07	0.8	B - B	60	4	0.00109 mt
$\therefore$ Total Consolidation Settlement (S_f)					=		$\sum = 0.0075 \ mt = 7.5 \ mm$

Problem 10. Compute the primary consolidation settlement of uniform soil deposit subjected to load of 225 KN through the square footing of 1.5 m located at 1.5 m depth. the thickness of compressible soil layer is 3.5 m followed by rock layer . the unit weight of soil is 20 KN/m3, initial void ratio is 0.8 and compression index as 0.07 . The stress distribution shall be taken as 2 H : 1 V and consider four layers ? **[GATE 1992]**

Solution :



unit weight of soil (γ) = 20 KN/m^3 throughout 3.5 mt depth is same.

1] Calculation of Surcharge or Overburden pressure $\overline{\sigma_0}$ = (γ x depth) :

For layer I (considering Section A – A); $\overline{\sigma_0} = (1.75\ x\ 20) = 35\ \ KN/m^2$

For layer II (considering Section B – B); $\overline{\sigma_0} = (2.25\ x\ 20) = 45\ \ KN/m^2$

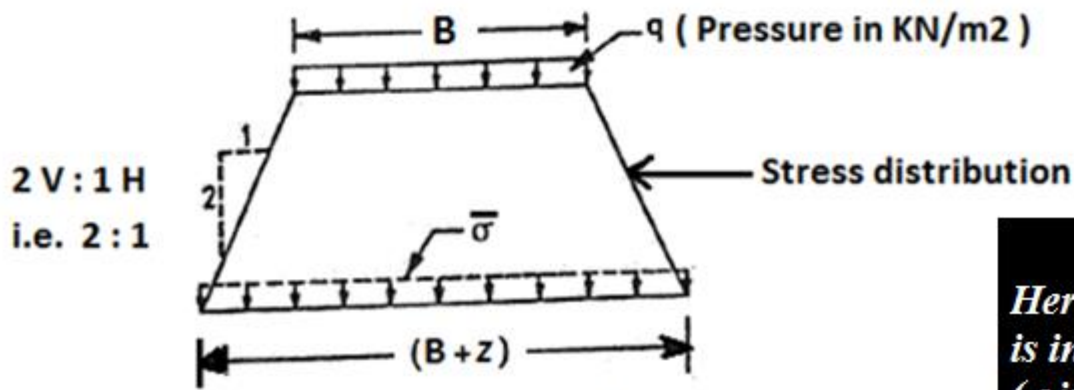
For layer III (considering Section C – C); $\overline{\sigma_0} = (2.75\ x\ 20) = 55\ \ KN/m^2$

For layer IV (considering Section D – D); $\overline{\sigma_0} = (3.25\ x\ 20) = 65\ \ KN/m^2$

Important Note :

These Formulae are only applicable for stress distribution of 2 V : 1 H i.e. 2 : 1

Computation of $\Delta\overline{\sigma}$ for stress distribution 2 V : 1 H i.e. 2 : 1 only



Here the stress distribution is in the order of 2 H : 1 V (given in the question) hence these furmulae are not applicable ....

(1) Square area (B x B) : $\Delta\overline{\sigma}_z = \dfrac{q\,B^2}{(B+z)^2} = \dfrac{\text{Load}}{(B+z)^2}$

(2) Rectangular area (B x L) : $\Delta\overline{\sigma}_z = \dfrac{q\,(B \times L)}{(B+z)\,(L+z)} = \dfrac{\text{Load}}{(B+z)\,(L+z)}$

(3) Strip area (Width B, unit length) ; $\Delta\overline{\sigma}_z = \dfrac{q\,(B \times 1)}{(B+z) \times 1} = \dfrac{\text{Load}}{(B+z) \times 1}$

(4) Circular area (diameter d) ; $\Delta\overline{\sigma}_z = \dfrac{q\,d^2}{(d+z)^2} = \dfrac{\text{Load}}{(d+z)^2}$

For layer I (considering Section A – A):

$$\frac{H}{V} \rightarrow \frac{2}{1} = \frac{x_1}{0.25} \quad ; \quad \therefore x_1 = 0.5 \ mt.$$

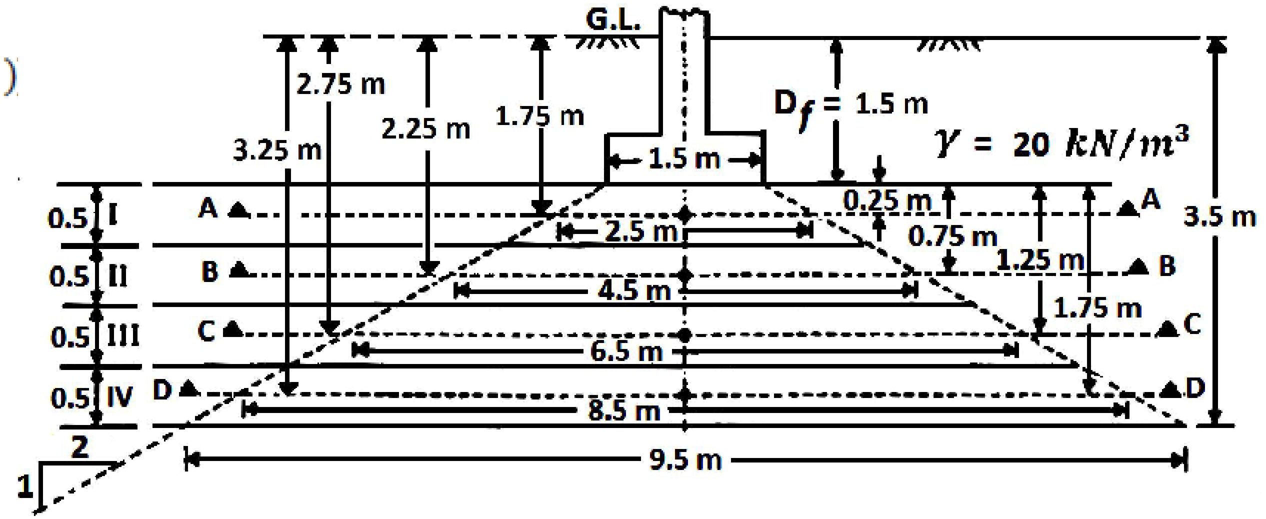
Width at section A – A ;

$$B_I = [1.5 + (2 x x_1)] = [1.5 + (2 x 0.5)$$

$$= 2.5 \ mt.$$

$$\therefore \ \Delta\bar{\sigma} = \left[\frac{\text{Load}}{B_I \ x \ B_I}\right] = \left[\frac{225}{(2.5 x 2.5)}\right]$$

$$= 36 \ KN/m^2$$



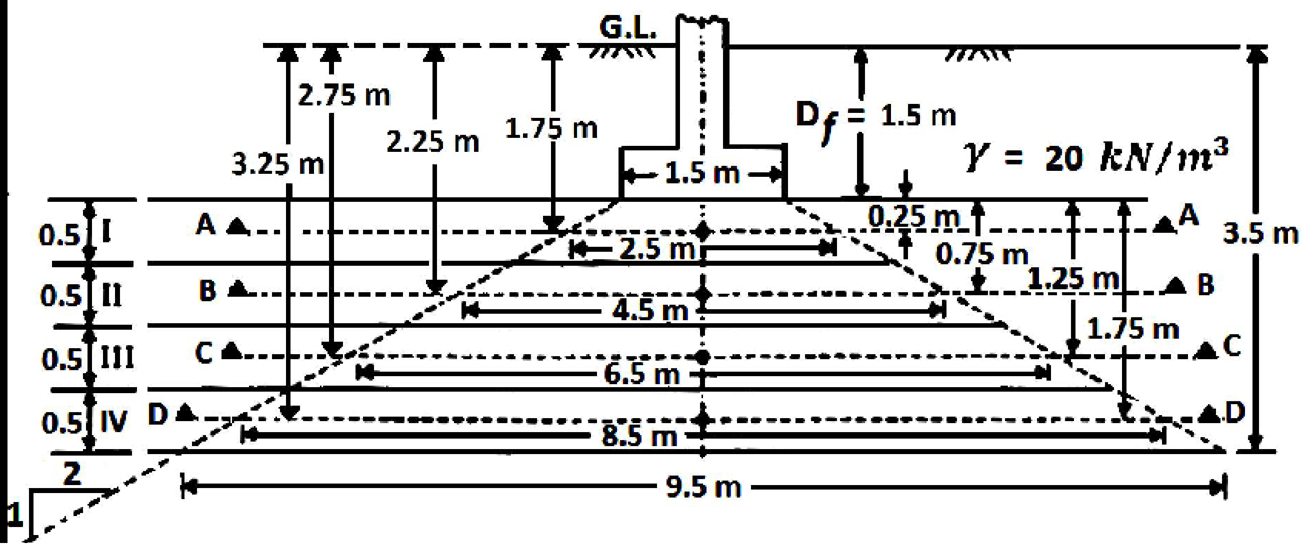
For layer II (considering Section B – B):

$$\frac{H}{V} \rightarrow \frac{2}{1} = \frac{x_2}{0.75} \quad ; \quad \therefore x_2 = 1.5 \ mt.$$

Width at section B – B ;

$$B_{II} = [1.5 + (2 x x_2)] = [1.5 + (2 x 1.5)] = 4.5 \ mt$$

$$\therefore \ \Delta\bar{\sigma} = \left[\frac{\text{Load}}{B_{II} \ x \ B_{II}}\right] = \left[\frac{225}{(4.5 x 4.5)}\right] = 11.11 \ KN/m^2$$



For layer III (considering Section C – C):

$$\frac{H}{V} \rightarrow \frac{2}{1} = \frac{x_2}{1.25} \; ; \; \therefore x_3 = 2.5 \ mt.$$

Width at section C – C ; $B_{III} = [\, 1.5 + (\, 2 \, x \, x_3) \,]$

$$= [\, 1.5 + (\, 2 \, x \, 2.5 \,)\,] = 6.5 \ mt.$$

$$\therefore \ \Delta \bar{\sigma} = \left[\frac{\text{Load}}{B_{III} \ x \ B_{III}} \right] = \left[\frac{225}{(6.5 \, x \, 6.5)} \right] = 5.325 \ KN/m^2$$

...square footing

For layer IV (considering Section D – D):

$$\frac{H}{V} \rightarrow \frac{2}{1} = \frac{x_4}{1.75} \; ; \; \therefore x_4 = 3.5 \ mt.$$

Width at section B – B ; $B_{IV} = [\, 1.5 + (\, 2 \, x \, x_4) \,]$

$$= [\, 1.5 + (\, 2 \, x \, 3.5)\,] = 8.5 \ mt.$$

$$\therefore \ \Delta \bar{\sigma} = \left[\frac{\text{Load}}{B_{IV} \ x \ B_{IV}} \right] = \left[\frac{225}{(8.5 \, x \, 8.5)} \right] = 3.114 \ KN/m^2$$

...square footing

Layer No.	Thickness (H) mt.	C_C	e_0	S/C	$\overline{\sigma_0}$	$\Delta \bar{\sigma}$	$S_f = \frac{C_C}{1+e_0} \, x \, H \, x \log \left[\frac{\overline{\sigma_0} + \Delta \bar{\sigma}}{\overline{\sigma_0}} \right]$
I	0.5 mt.	0.07	0.8	A - A	35	36	0.006 mt.
II	0.5 mt	0.07	0.8	B - B	45	11.11	0.00186 mt
III	0.5 mt	0.07	0.8	C – C	55	5.32	0.00078 mt
IV	0.5 mt	0.07	0.8	D –D	65	3.11	0.00039 mt
$\therefore$ Total Consolidation Settlement (S_f)					=		$\sum = 0.009 \ mt = 9 \ mm$

Consolidation or Primary settlement (S_c) in group of Piles :

To find Consolidation or Primary settlement in group of Piles , Load is assumed to be act at an distance of [2/3 x Length of the pile] with stress distribution of 2 V : 1 H i.e. 2 : 1

Consolidation settlement is given by ;

$$S_C = \frac{C_C}{1 + e_0} \; x \; H \; x \; \log \left[\frac{\overline{\sigma_0} + \Delta\,\bar{\sigma}}{\overline{\sigma_0}} \right]$$

Where, C_C = Compression Index = $0.009\,(W_L - 10)$

W_L – Water content at liquid state i.e liquid limit

e_0 = Initial void ratio = $\frac{w\,G}{S}$

H – Thickness of the layer of stress distribution

$\overline{\sigma_0}$ = Surcharge or overburden pressure at Section A – A

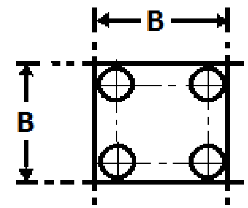
= Unit weight of the soil (γ) x depth **[(2/3 x L) + Z]**

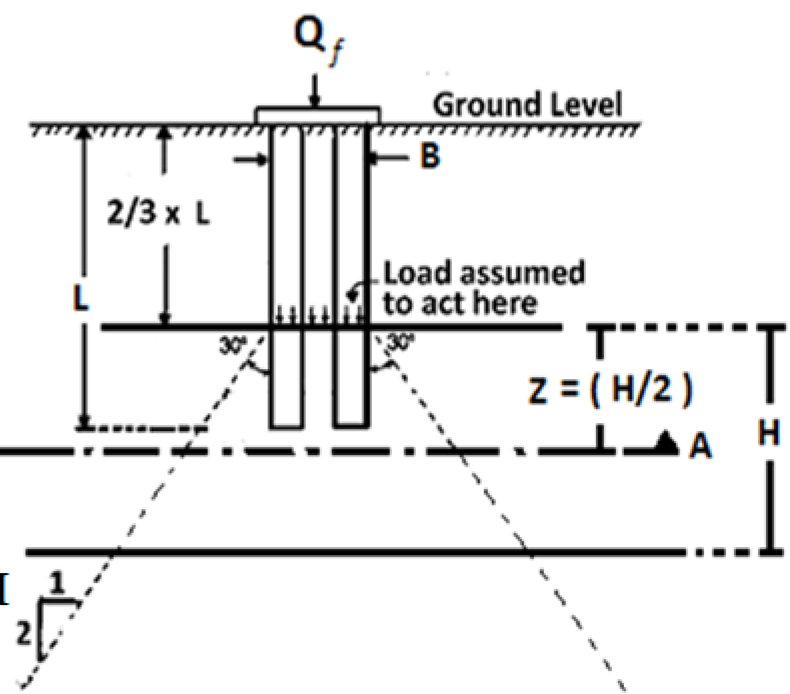
Note : *It is always computed w.r.t. Ground Level*

$$\Delta\,\bar{\sigma} = \Delta\,\bar{\sigma} = \left[\frac{\text{Load}}{\text{Area of distributed pressure at Section A} - \text{A}} \right]$$

2 V : 1 H

2 : 1



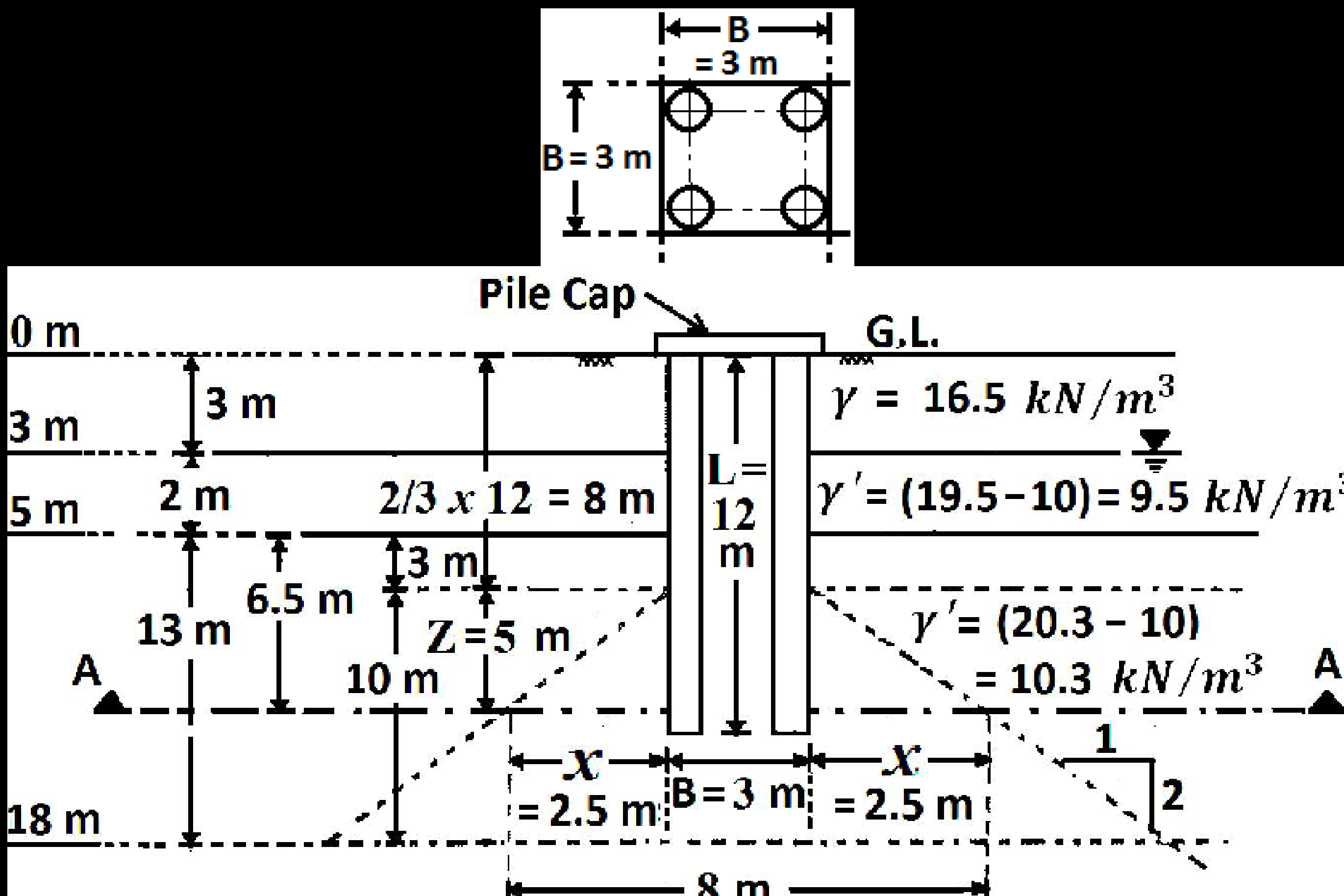


Problem 1. Determine consolidation settlement of Square pile group of width 3.0 mt. And carrying net load of 2100 KN. The water table is at 3 m below ground surface. The load of pile is transmitted at 2/3 length of the pile . The length of the pile is 12 m . the slope of dispersion of load to the foundation is 1 H : 2 V . The soil properties are given below :

[SGBAU,W-13,S -14/7 m]

Layer Depth	Unit weight in KN/m^3	For soil 5 – 18 mt.
0 – 3 mt.	$\gamma = 16.5$	$C_c = 0.25$
3 – 5 mt.	$\gamma_{sat} = 19.5$	$e_0 = 0.78$
5 – 18 mt.	$\gamma_{sat} = 20.3$	

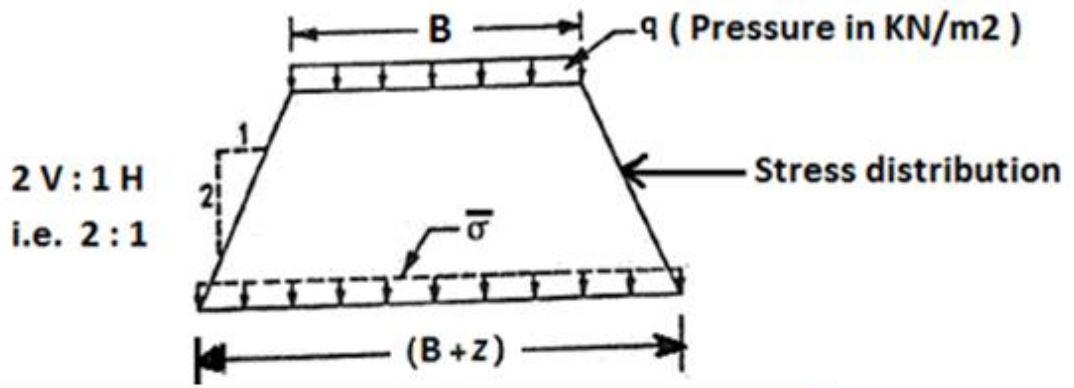
Solution :



Important Note :

These Formulae are only applicable for stress distribution of 2 V : 1 H i.e. 2 : 1

Computation of $\Delta\overline{\sigma}$ for stress distribution 2 V : 1 H i.e. 2 : 1 only



(1) Square area (B x B) : $\Delta\overline{\sigma}_z = \dfrac{q\,B^2}{(B+z)^2} = \dfrac{\text{Load}}{(B+z)^2}$

(2) Rectangular area (B x L) : $\Delta\overline{\sigma}_z = \dfrac{q\,(B \times L)}{(B+z)\,(L+z)} = \dfrac{\text{Load}}{(B+z)\,(L+z)}$

(3) Strip area (Width B, unit length) ; $\Delta\overline{\sigma}_z = \dfrac{q\,(B \times 1)}{(B+z) \times 1} = \dfrac{\text{Load}}{(B+z) \times 1}$

(4) Circular area (diameter d) ; $\Delta\overline{\sigma}_z = \dfrac{q\,d^2}{(d+z)^2} = \dfrac{\text{Load}}{(d+z)^2}$

1] Calculation of Surcharge or Overburden pressure $\overline{\sigma_0} = (\gamma \ x \ \text{depth})$:

Considering Section A – A;

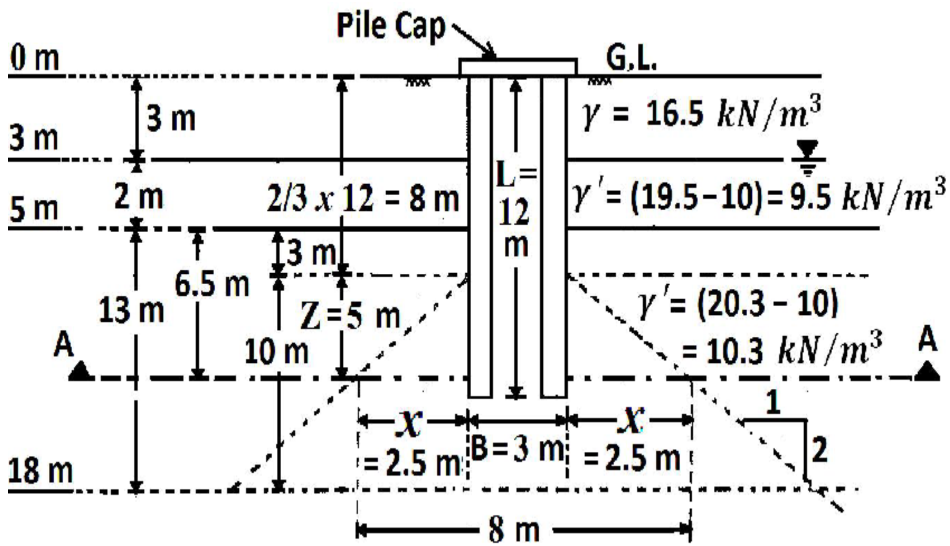
$$\overline{\sigma_0} = [\ (16.5 \ x \ 3) + (19.5 - 10) \ x \ 2 + (20.3 - 10) \ x \ 6.5\ ]$$

$$= 135.45 \quad KN/m^2$$

2] Calculation of $\Delta\,\overline{\sigma}$: considering Section A – A :

Note: the pressure distribution is 2 V : 1 H.

Hence the formula of $\Delta\,\overline{\sigma}$ which we have seen in the note can be applied.



$$\therefore \ \Delta\,\overline{\sigma} = \left[\frac{\text{Load}}{B_I \ x \ B_I}\right] = \left[\frac{2100}{(8 \ x \ 8)}\right] = 32.812 \quad KN/m^2$$

Alternative method:

$$\frac{H}{V} \rightarrow \frac{1}{2} = \frac{x}{5} \ ; \quad \therefore \ x = 2.5 \ mt.$$

Width at section A – A; $\quad B_I = [\,3 + (2 \ x \ x)\,]$

$$= [\,3 + (2 \ x \ 2.5)\,] = 8 \quad mt.$$

$$\therefore \ \Delta\,\overline{\sigma} = \left[\frac{\text{Load}}{(\text{B} + \text{Z})^2}\right] = \left[\frac{2100}{(3+5)^2}\right] = 32.812 \quad KN/m^2$$

Final Consolidation settlement is given by ;

$$S_f = \frac{C_c}{1 + e_0} \ x \ H \ x \log\left[\frac{\overline{\sigma_0} + \Delta\,\overline{\sigma}}{\overline{\sigma_0}}\right]$$

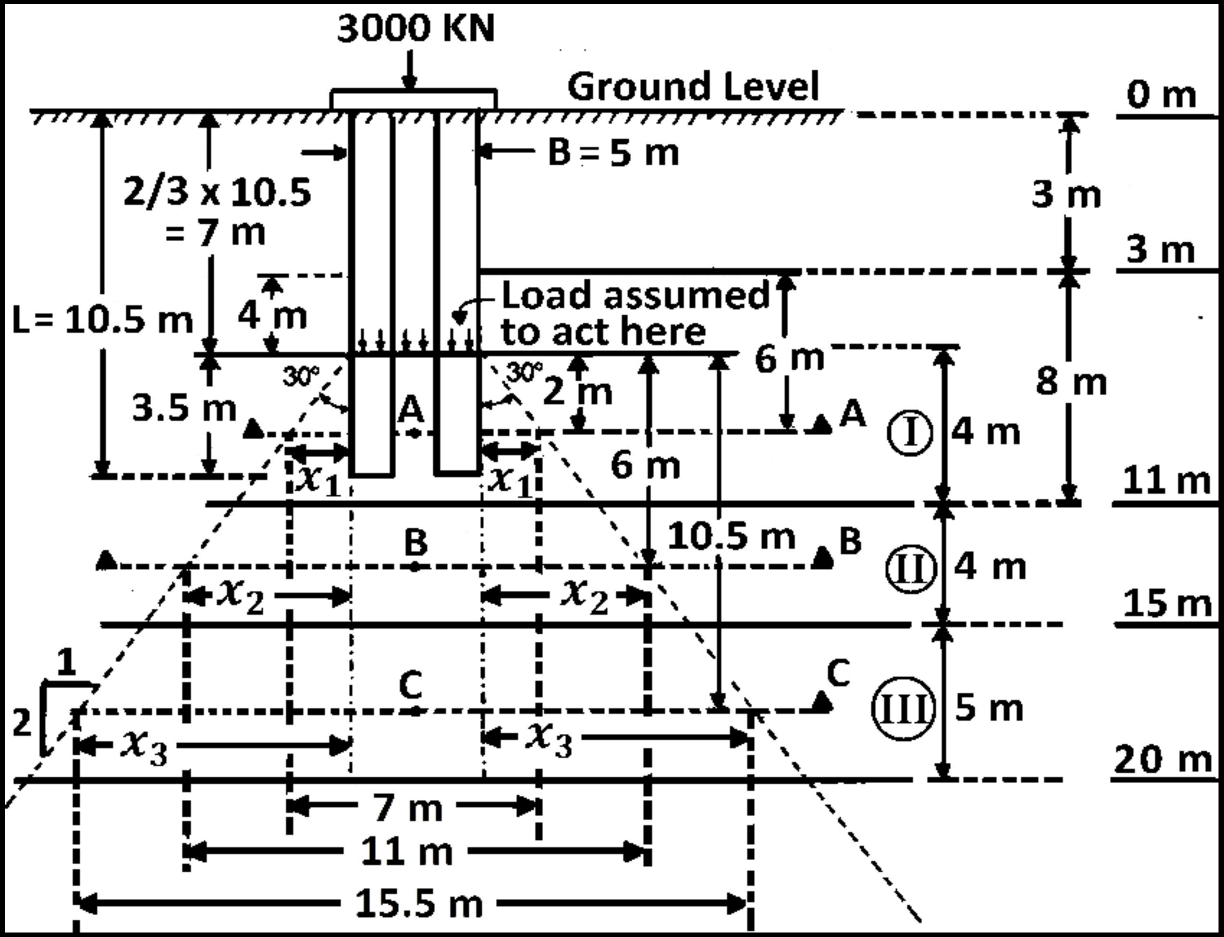
$$= \frac{0.25}{1 + 0.78} \ x \ 10 \ x \log\left[\frac{135.45 + 32.812}{135.45}\right]$$

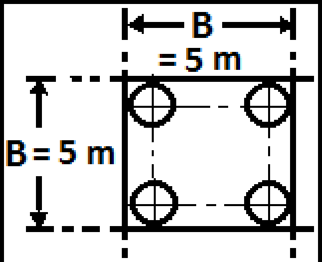
$$= 0.132 \quad mt. = 13.2 \quad cm$$

Problem 2. Determine consolidation settlement of Square pile group of width 5.0 mt. And carrying net load of 3000 KN. The length of the pile is 10.5 m . the slope of dispersion of load to the foundation is 1 H : 2 V . The soil properties are given below :

Layer Depth	Unit weight in KN/m^3	C_C	e_0
0 – 3 mt.	16.5	0.25	0.80
3 – 11 mt.	20	0.20	0.76
11 – 15 mt.	19	0.22	0.65
15 – 20 mt.	18	0.27	0.70

Solution :

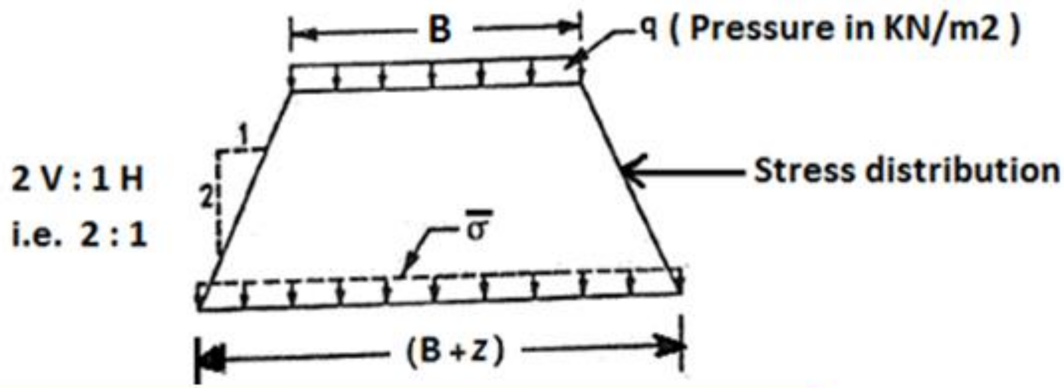




Important Note :

These Formulae are only applicable for stress distribution of 2 V : 1 H i.e. 2 : 1

Computation of $\Delta\bar{\sigma}$ for stress distribution 2 V : 1 H i.e. 2 : 1 only



(1) Square area (B x B) : $\boxed{\Delta\bar{\sigma}_z = \dfrac{q\,B^2}{(B+z)^2} = \dfrac{\text{Load}}{(B+z)^2}}$

(2) Rectangular area (B x L) : $\Delta\bar{\sigma}_z = \dfrac{q\,(B \times L)}{(B+z)\,(L+z)} = \dfrac{\text{Load}}{(B+z)\,(L+z)}$

(3) Strip area (Width B, unit length) ; $\Delta\bar{\sigma}_z = \dfrac{q\,(B \times 1)}{(B+z) \times 1} = \dfrac{\text{Load}}{(B+z) \times 1}$

(4) Circular area (diameter d) ; $\Delta\bar{\sigma}_z = \dfrac{q\,d^2}{(d+z)^2} = \dfrac{\text{Load}}{(d+z)^2}$

1] Calculation of Surcharge or Overburden pressure $\overline{\sigma_0} = (\gamma\ x\ \text{depth})$:

For layer I (considering Section A – A);

$\overline{\sigma_0} = [\,(3\ x\ 16.5\,) + (\,20\ x\ 6\,)\,] = 169.5\ \ KN/m^2$

For layer II (considering Section B – B);

$\overline{\sigma_0} = [\,(3\ x\ 16.5\,) + (\,20\ x\ 8\,) + (\,19\ x\ 2\,)\,] = 247.5\ \ KN/m^2$

For layer III (considering Section C – C);

$\overline{\sigma_0} = [\,(3\ x\ 16.5\,) + (\,20\ x\ 8\,) + (\,19\ x\ 4\,) + (\,18\ x\ 2.5\,)\,]$

$= 330.5\ \ KN/m^2$

Layer Depth	Unit weight in KN/m^3	C_C	e_0
0 – 3 mt.	16.5	0.25	0.80
3 – 11 mt.	20	0.20	0.76
11 – 15 mt.	19	0.22	0.65
15 – 20 mt.	18	0.27	0.70

2] Calculation of $\Delta\,\overline{\sigma}$: Its square group of piles.

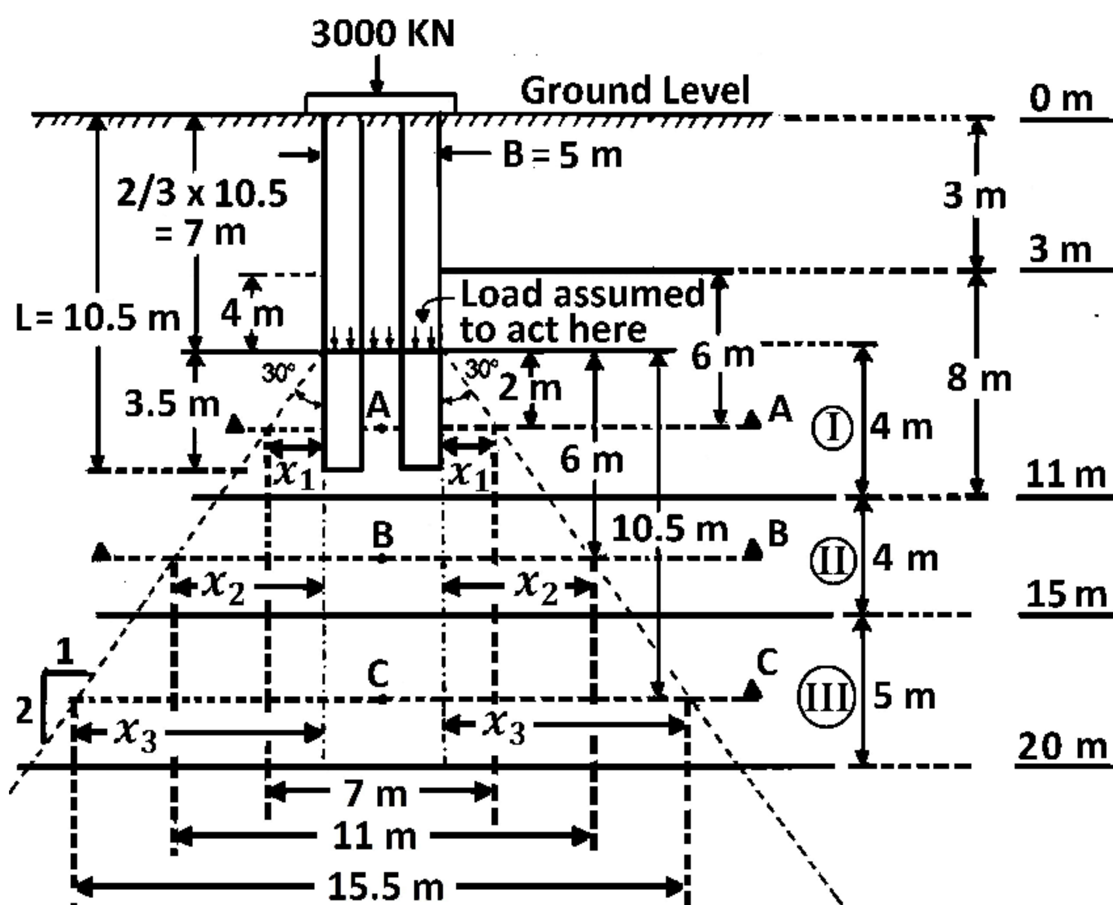
For layer I (considering Section A – A):

Here, the pressure distribution is 2 V: 1 H.

Hence the formula

of $\Delta\,\overline{\sigma}$ which we had in the note can be applied.

$$\therefore\ \Delta\,\overline{\sigma} = \left[\frac{\text{Load}}{(B+Z)^2}\right] = \left[\frac{3000}{(5+2)^2}\right] = 61.22\ \ KN/m^2$$



Alternative method:

$$\frac{H}{V} \rightarrow \frac{1}{2} = \frac{x_1}{2}\ \ ;\ \ \therefore\ x_1 = 1\ mt.$$

width at section A – A; $B_I = [\,5 + (\,2\ x\ x_1)\,]$

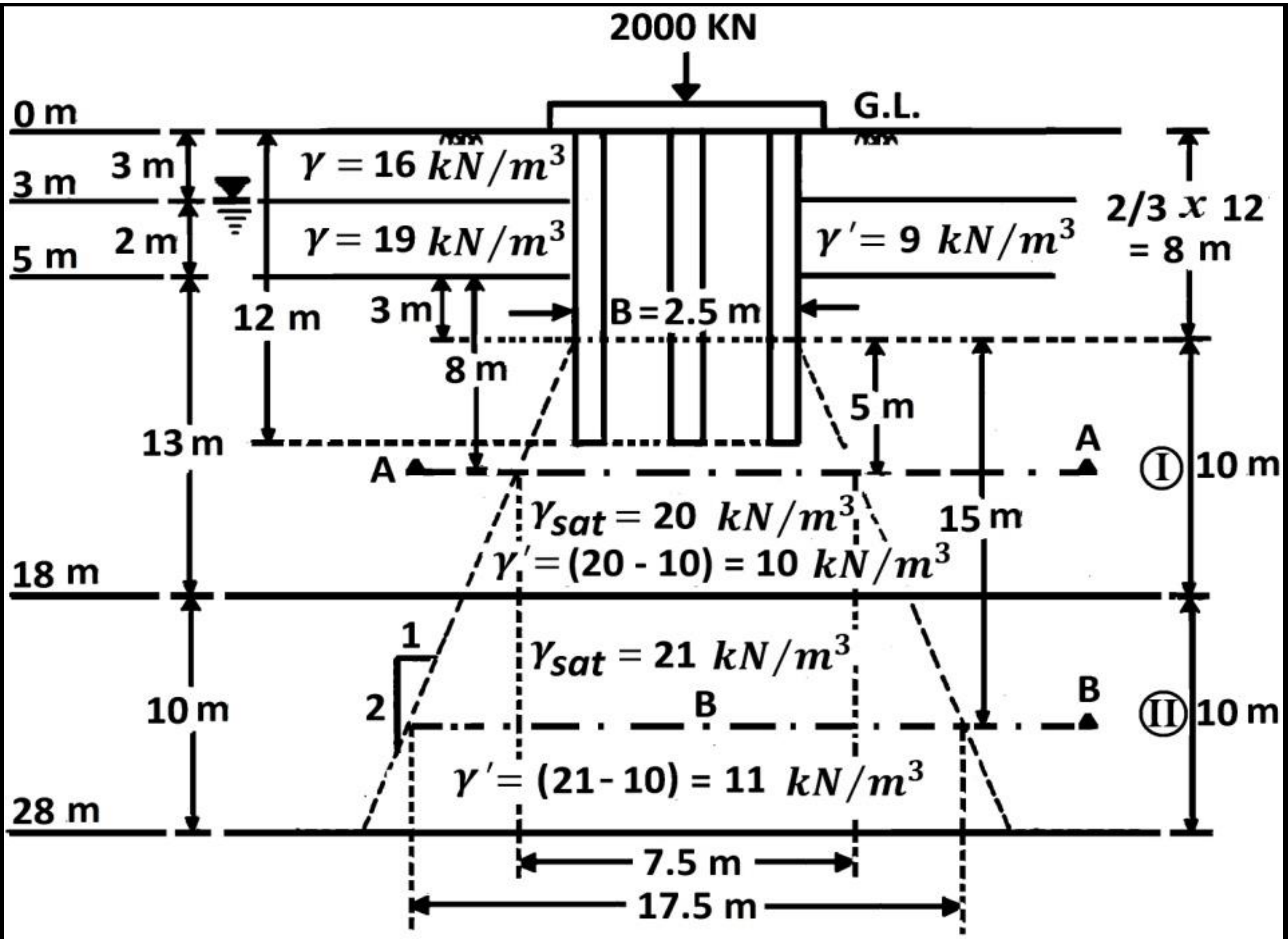
$= [\,5 + (\,2\ x\ 1)] = 7\ mt.$

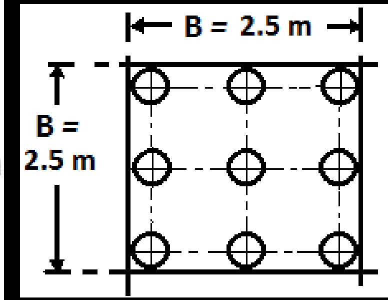
$$\therefore\ \Delta\,\overline{\sigma} = \left[\frac{\text{Load}}{B_I\ x\ B_I}\right] = \left[\frac{3000}{(7\ x\ 7)}\right] = 61.22\ \ KN/m^2$$

Problem 3. Determine consolidation settlement of Square pile group of width 2.5 mt. And carrying net load of 2000 KN. The length of the pile is 12 m . The water table is at 3 m below ground surface. the slope of dispersion of load to the foundation is 1 H : 2 V . The soil properties are given below :

Layer Depth	Unit weight in KN/m^3	C_c	e_0
0 – 3 mt.	$\gamma = 16$	0.23	0.80
3 – 5 mt.	$\gamma_{sat} = 19$	0.21	0.76
5 – 18 mt.	$\gamma_{sat} = 20$	0.25	0.75
18 – 28 mt.	$\gamma_{sat} = 21$	0.20	0.65

Solution :

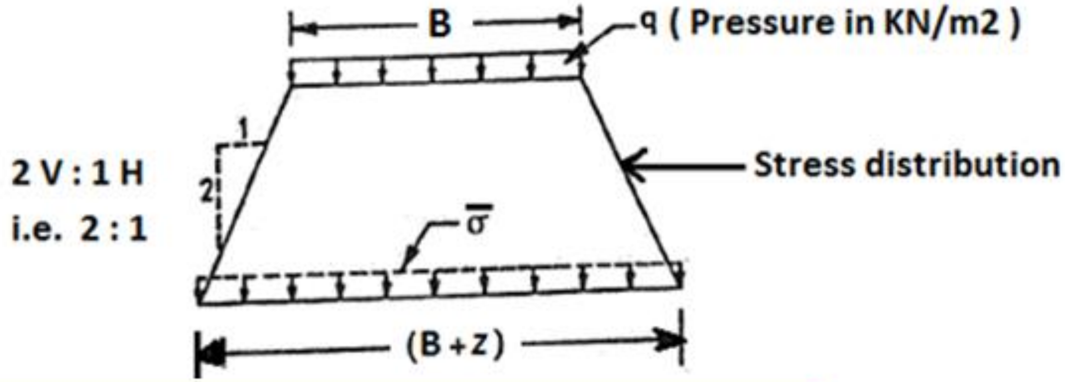




Important Note :

These Formulae are only applicable for stress distribution of 2 V : 1 H i.e. 2 : 1

Computation of $\Delta\bar{\sigma}$ for stress distribution 2 V : 1 H i.e. 2 : 1 only



(1) Square area (B x B) : $\Delta\bar{\sigma}_z = \dfrac{q\,B^2}{(B+z)^2} = \dfrac{\text{Load}}{(B+z)^2}$

(2) Rectangular area (B x L) : $\Delta\bar{\sigma}_z = \dfrac{q\,(B \times L)}{(B+z)\,(L+z)} = \dfrac{\text{Load}}{(B+z)\,(L+z)}$

(3) Strip area (Width B, unit length) ; $\Delta\bar{\sigma}_z = \dfrac{q\,(B \times 1)}{(B+z) \times 1} = \dfrac{\text{Load}}{(B+z) \times 1}$

(4) Circular area (diameter d) ; $\Delta\bar{\sigma}_z = \dfrac{q\,d^2}{(d+z)^2} = \dfrac{\text{Load}}{(d+z)^2}$

1] Calculation of Surcharge or Overburden pressure $\overline{\sigma_0} = (\gamma\ x\ \text{depth})$:

For layer I (considering Section A – A);

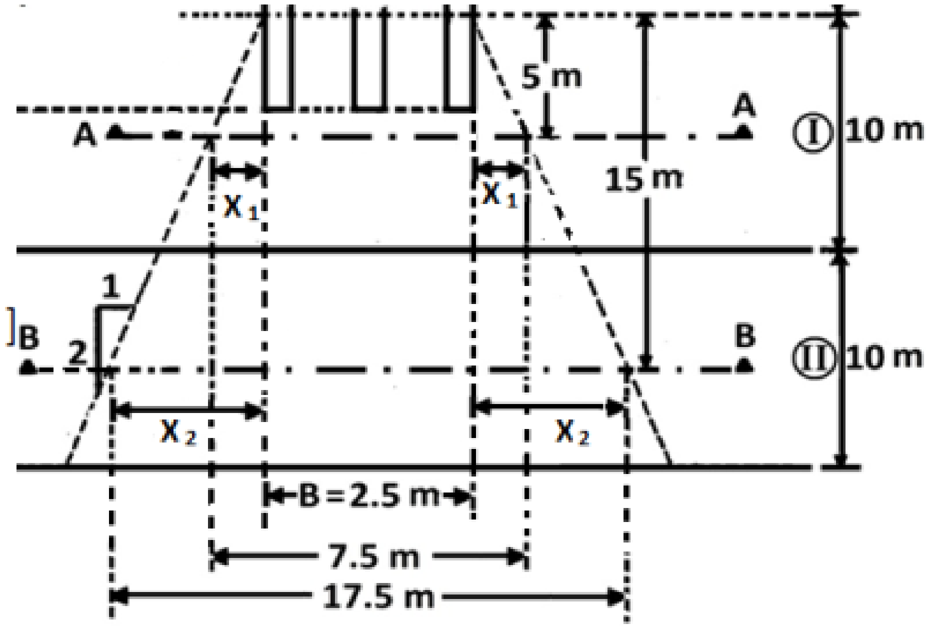
$$\overline{\sigma_0} = [\,(3\ x\ 16) + (19-10)\ x\ 2 + (20-10\ )\ x\ 8\,]$$

$$= 146\quad KN/m^2$$

For layer II (considering Section B – B);

$$\overline{\sigma_0} = [\,(3\ x\ 16) + (19-10)\ x\ 2 + (20-10\ )\ x\ \mathbf{13} + (21-10)\ x\ \ 5\,]$$

$$= 251\quad KN/m^2$$



2] Calculation of $\Delta\,\bar{\sigma}$: Its square group of piles.

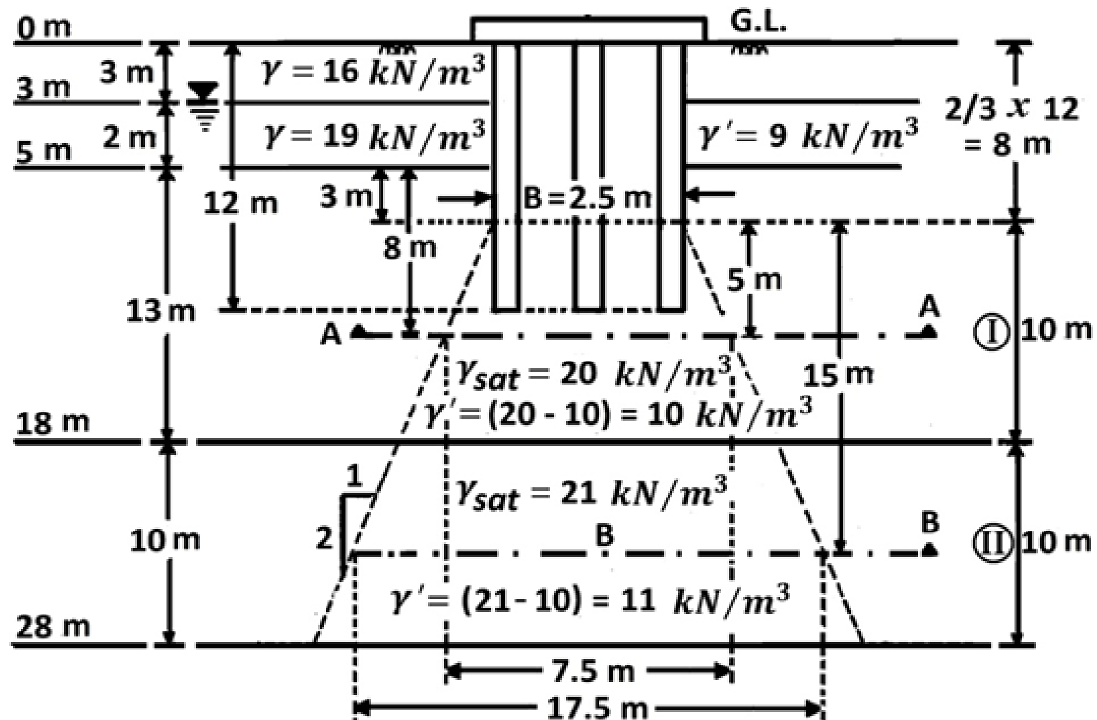
For layer I (considering Section A – A):

Here, the pressure distribution is 2 V : 1 H.

hence the formula of

$\Delta\,\bar{\sigma}$ which we seen in note can be applied.

$$\therefore\ \Delta\,\bar{\sigma} = \left[\frac{\text{Load}}{(B+Z)^2}\right] = \left[\frac{2000}{(2.5+5)^2}\right] = 35.56\ \ KN/m^2$$



Alternative method:

$$\frac{H}{V} \rightarrow \frac{1}{2} = \frac{x_1}{5}\quad ;\quad \therefore\ x_1 = 2.5\ \ mt.$$

Width at section A – A; $B_I = [\,2.5 + (\,2\ x\ x_1)\,]$

$$= [\,2.5 + (\,2\ x\ 2.5\,)] = \ 7.5\ \ mt.$$

$$\therefore\ \Delta\,\bar{\sigma} = \left[\frac{\text{Load}}{B_I\ \ x\ \ B_I}\right] = \left[\frac{2000}{(\,7.5\ x\ 7.5\,)}\right] = 35.56\ \ KN/m^2$$

For layer II (considering Section B – B):

$$\therefore\ \Delta\bar{\sigma} = \left[\frac{\text{Load}}{(B+Z)^2}\right] = \left[\frac{2000}{(2.5+15)^2}\right] = 6.53\ KN/m^2$$

Alternative method:

$$\frac{H}{V} \rightarrow \frac{1}{2} = \frac{x_2}{15}\ ;\ \therefore x_2 = 7.5\ mt.$$

Width at section B – B; $B_{II} = [\,2.5 + (\,2\ x\ x_2\,)\,]$

$= [\,2.5 + (\,2\ x\ 7.5\,)\,] = 17.5\ mt.$

$$\therefore\ \Delta\bar{\sigma} = \left[\frac{\text{Load}}{B_{II}\ x\ B_{II}}\right] = \left[\frac{2000}{(\,17.5\ x\ 17.5\,)}\right] = 6.53\ KN/m^2$$

Final Consolidation settlement is given by;

$$S_f = \frac{C_C}{1+e_0}\ x\ H\ x\ \log\left[\frac{\overline{\sigma_0}+\Delta\bar{\sigma}}{\overline{\sigma_0}}\right]$$

Layer No.	Thickness (H) mt.	C_C	e_0	S/C	$\overline{\sigma_0}$	$\Delta\bar{\sigma}$	S_f
I	10 mt.	0.25	0.75	A - A	146	35.56	0.135 mt.
II	10 mt.	0.20	0.65	B - B	251	6.53	0.014 mt.
$\therefore$ Total Consolidation Settlement $(\,S_f\,) = \sum = 0.149\ mt.$