Mat foundation design

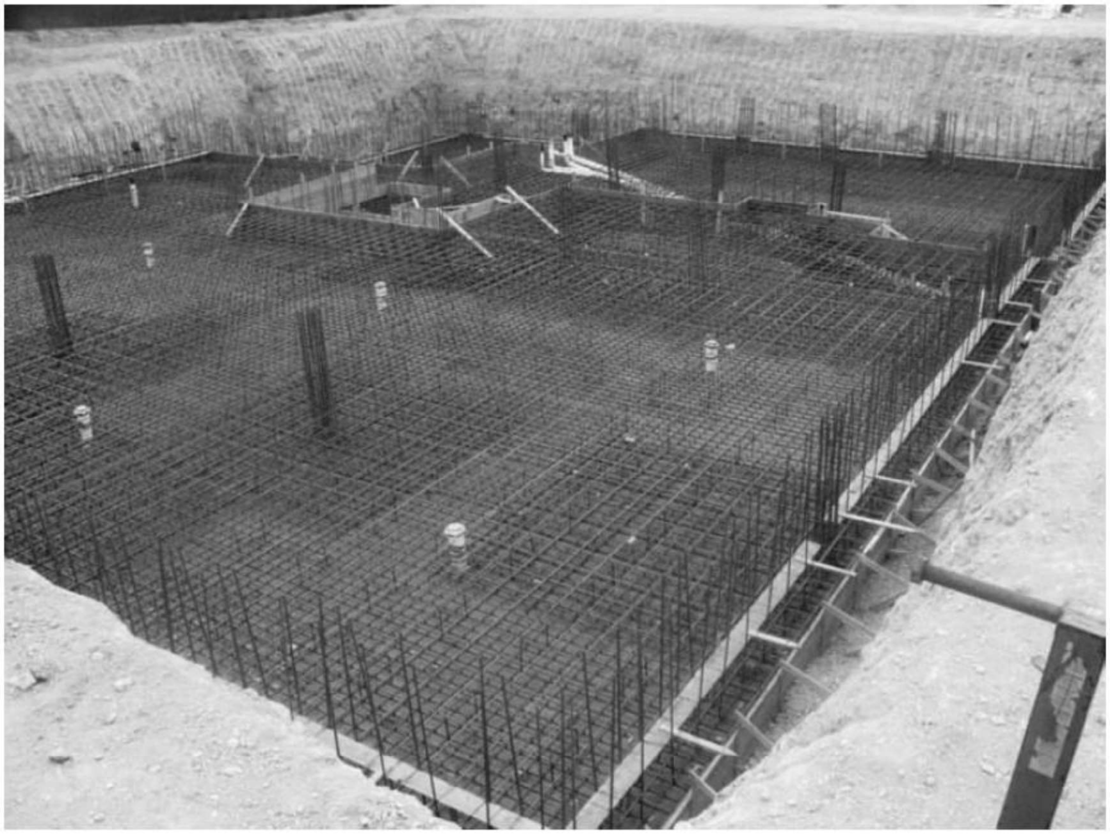


Fig.1 Mat foundation under construction

Structural design of mat foundation

Step 1. Figure 1 shows mat dimensions $B * L$ of the mat foundation and column loads of $Q_1, Q_2, Q_3, \dots \dots \dots \dots Q_n$

Locate the centerlines of the footing by drawing the x & y axis as shown in Fig.2

Calculate the total column load as

Referring to Fig.2

$$\boldsymbol{Q = Q_1 + Q_2 + Q_3 + \cdots \dots \dots \dots . . + Q_n} \qquad (1)$$

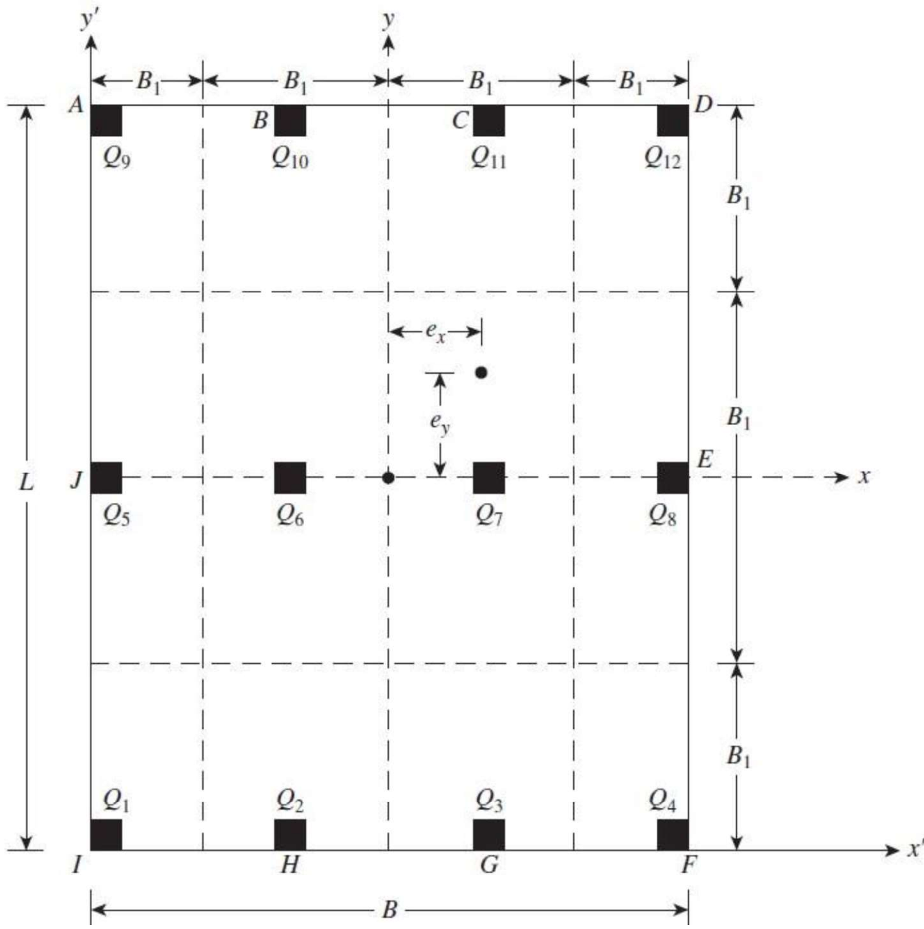


Fig.2 Mat dimensions and columns load

Step 2. Determine the pressure on the soil, q_O, below the mat at points A, B, C, D,……. by using the equation

$$q_o = \frac{Q}{BL} \mp \frac{M_x y}{I_x} \mp \frac{M_y X}{I_y} \qquad (2)$$

Where

M_x : moment of the total load about the X − axis , $M_x = Qe_y$

M_y: moment of the total load about the Y- axis $M_y = Qe_x$

I_x: Moment of inertia about the X-axis

I_y: Moment of inertia about the Y-axis

It is easily to use

$q_o = \frac{Q}{BL} - \frac{M_x y}{I_x} - \frac{M_y X}{I_y}$ **and substitute x and y with their signs**

The load eccentricities, e_x and e_y in the x and y directions can be determined by using coordinates:$(\acute{x}, \acute{y})$

$\acute{X} = \frac{Q_1 \acute{X}_1 + Q_2 \acute{X}_2 + \cdots .....Q_n \acute{X}_n}{Q}$, $e_x = \acute{X} - \frac{B}{2}$

$\acute{y} = \frac{Q_1y_1+Q_2y_2+\cdots\ldots Q_ny_n}{Q}$, $e_y = \acute{y} - \frac{L}{2}$

Step 3. Compare the values of the soil pressures determined in Step 2 with the net allowable soil pressure to determine whether $q_o \leq q_{all}$

Step 4. Divide the mat into several strips in the x and y directions. (See Fig.2). Let the width of any strip be B1.

Step 5. Draw the shear, V, and the moment, M, diagrams for each individual strip (in the x and y directions). For example, the average soil pressure of the bottom strip in the x direction of Fig.2 is

$$q_{ave} = \frac{q_I + q_F}{2}$$

where $q_I$and q_F soil pressures at points I and F, as determined from Step 2.

The total soil reaction is equal to $q_{ave}B1B$.

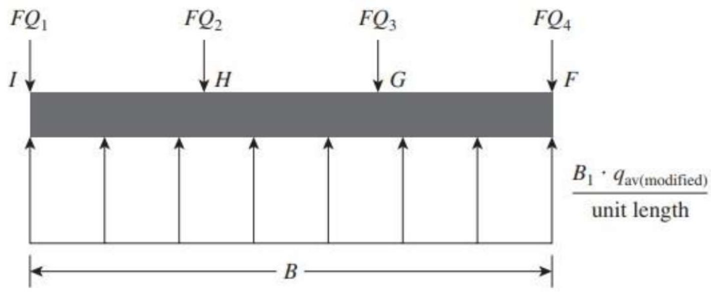


Fig.3

Now obtain the total column load on the strip as:

Q1+ Q2 + Q3+ Q4.

The sum of the column loads on the strip will not equal because the shear between the adjacent strips has not been taken into account. For this reason, the soil reaction and the column loads need to be adjusted, or

$$Average\ load = \frac{q_{ave}B_1B + (Q1 + Q2 + Q3 + Q4)}{2}$$

Now, the modified average soil reaction becomes

$$q_{ave(modified)} = q_{ave(}\frac{average\ load}{q_{ave}B1B}$$

and the column load modification factor is

$$F = \frac{Average\ load}{Q1 + Q2 + Q3 + Q4}$$

So the modified column loads are $FQ_1, FQ_2, FQ_3, FQ_4$and This modified loading on the strip under consideration is shown in Fig.3. The shear and the moment diagram for this strip can now be drawn, and the procedure is repeated in the x and y directions for all strips.

Step 6. Determine the effective depth d of the mat by checking for diagonal tension shear near various columns. According to ACI Code 318-95 (Section 11.12.2.1c, American Concrete Institute, 1995), for the critical section,

$$U = b_o d\emptyset(0.34)\sqrt{f_{\acute{c}}}$$

U: Factored column load

$\emptyset$: reduction factor =0.85

$f_{\acute{C}}$: Compression strength of concrete at28 days in MN/m^2

The units of $b_O$and d

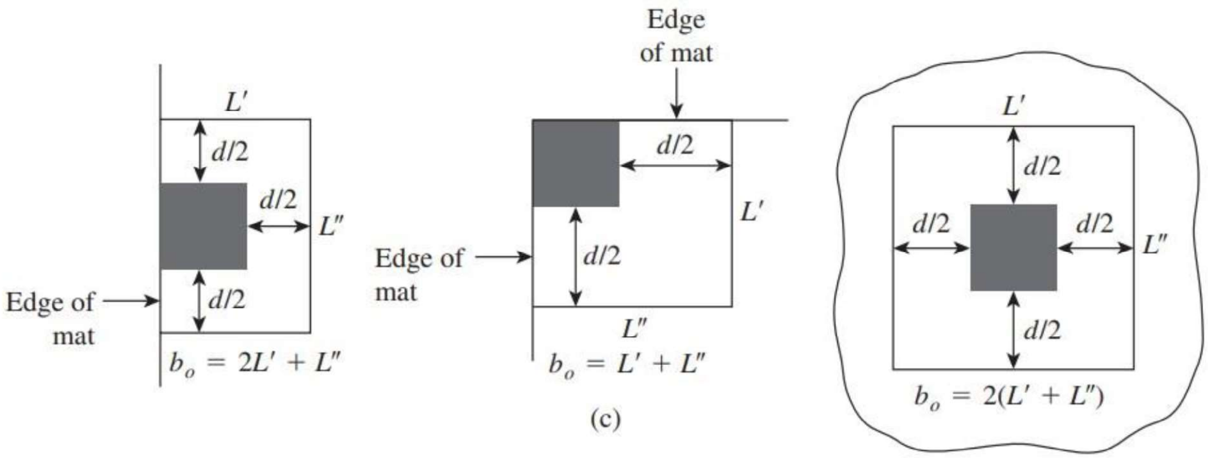


Fig.4 critical shear

The expression for b_O in terms of d, which depends on the location of the column with respect to the plan of the mat, can be obtained from Fig.4.

Step 7. From the moment diagrams of all strips in one direction (x or y), obtain the maximum positive and negative moments per unit width (i.e., $\acute{M} = \frac{M}{B1}$)

Step 8. Determine the areas of steel per unit width for positive and negative reinforcement in the x and y directions. We have

$$M_U = \acute{M}(load\ factor) = \emptyset A_S f_y (d - \frac{a}{2})$$

and

$$a = \frac{A_S F_y}{0.85 f_{\acute{C}} b}$$

Where

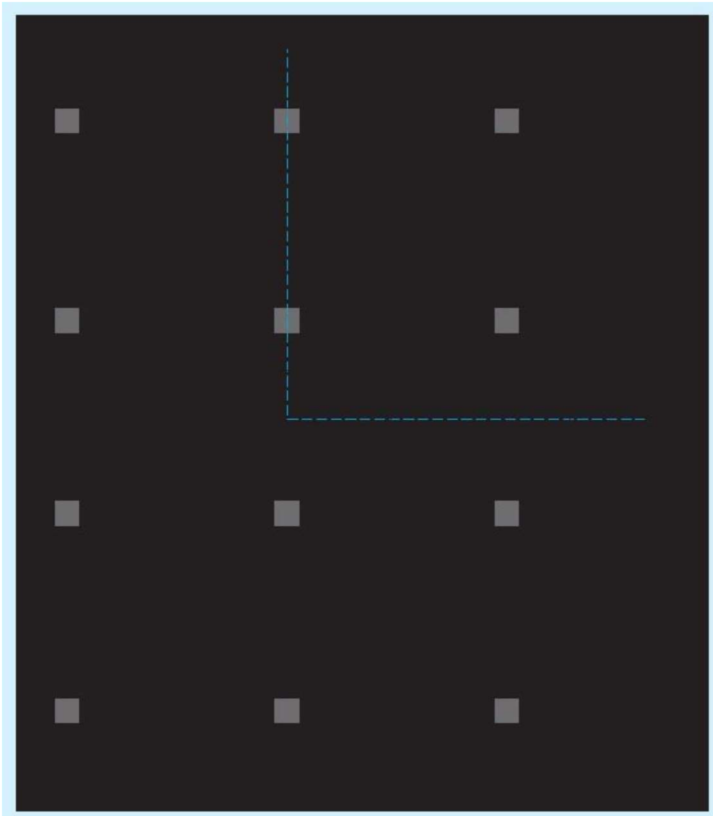
A_S: area of steel per unit width

$\emptyset = 0.9$ reduction factor

M_U: Factored moment

f_y: Yield stress of reinforcement in tension

Design Example: The plan of a mat foundation is shown in Figure 5. Calculate the soil pressure at points A, B, C, D, E, and F. (Note: All column sections are planned to be (0.5 m * 0.5 m.)



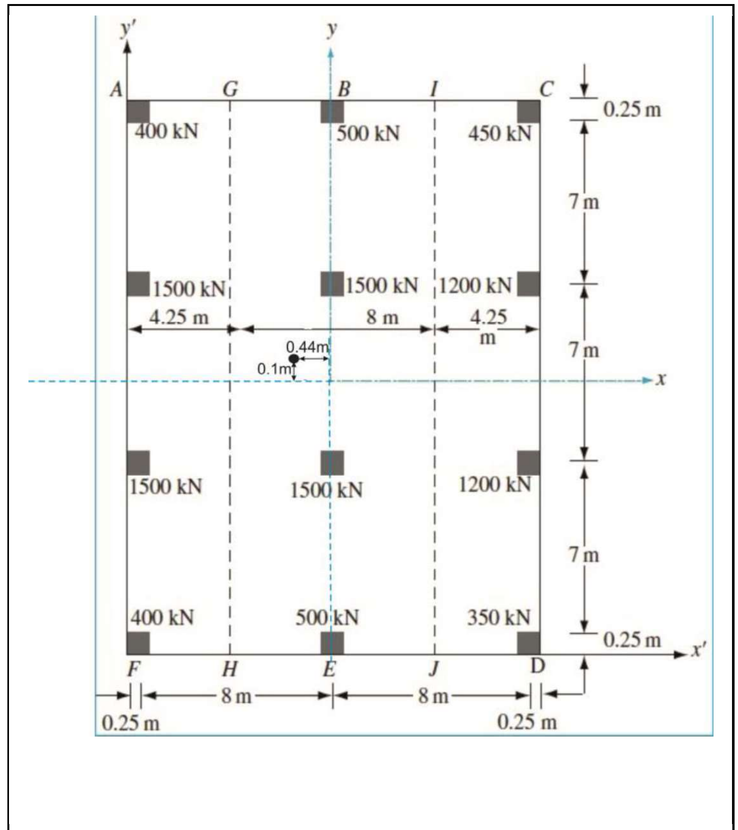


Fig. 5 plan map of mat foundation

$$q = \frac{N}{BL} \pm \frac{M_y X}{I_y} \pm \frac{M_x Y}{I_x}$$

$$BL = 15.5 * 21.5 = 354.75 m^2$$

Moment of inertia

$$I_x = \frac{BL^3}{12} = \frac{16.5*21.5^3}{12} = 13{,}665 m^4$$

$$I_y = \frac{LB^3}{12} = \frac{21.5*16.5^3}{12} = 8050 m^4$$

Resultant

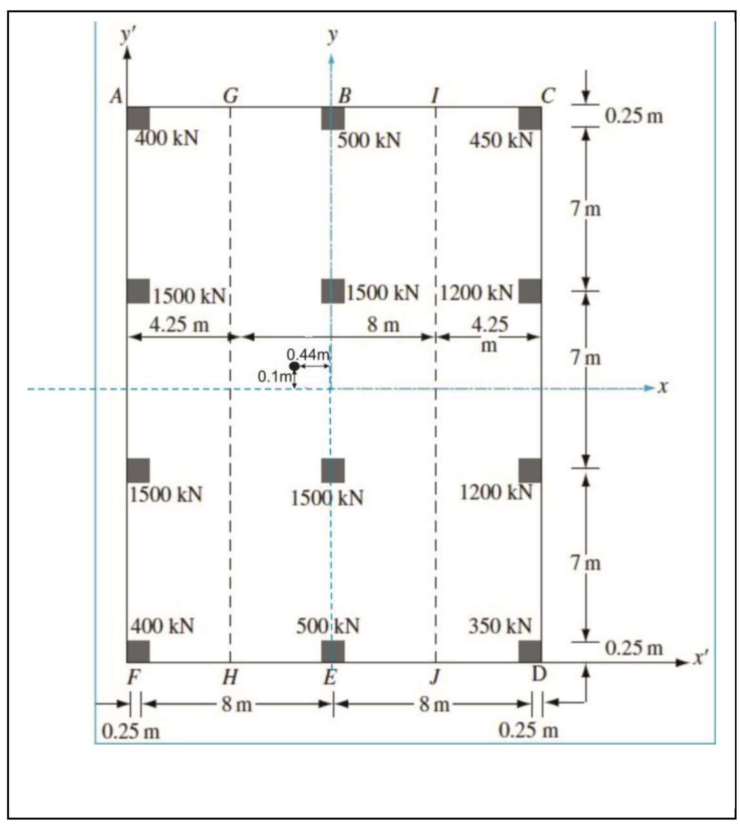
$$Q = 350 + 2*400 * +450 + 2*500 +$$

$$2*1200 + 4*1500 = 11000 \text{ kN}$$

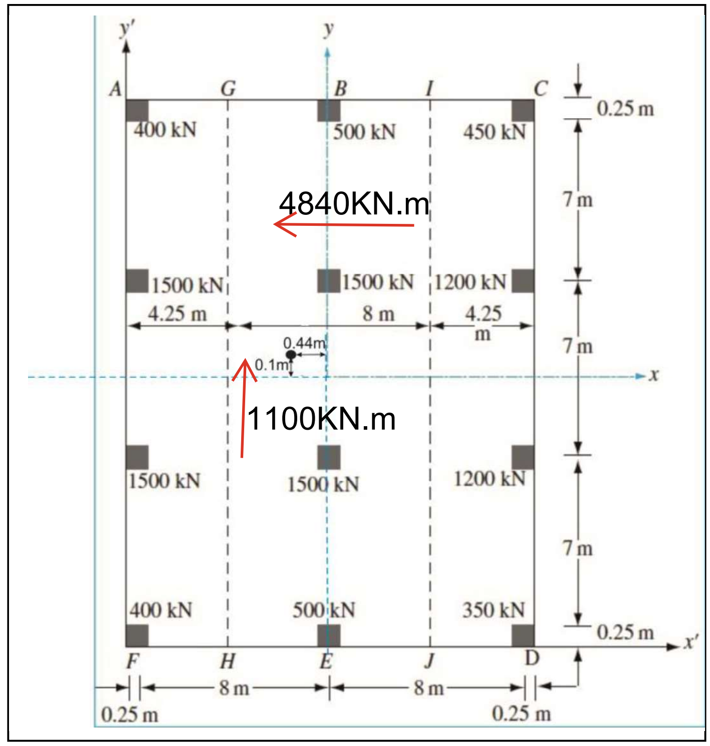
$$M_y = Qe_x\ , \quad e_x = \acute{X} - \frac{B}{2}$$

$$M_x = Qe_y\ , \quad e_y = \acute{y} - \frac{L}{2}$$

Centroid and eccentricity



$\bar{X} = \frac{Q_1\bar{X}_1 + Q_2\bar{X}_2 + \cdots .....Q_n\bar{X}_n}{Q} = \frac{1}{Q}(Q_1\bar{X}_1 + Q_2\bar{X}_2 + \cdots .....Q_n\bar{X}_n)$



$$\bar{X} = \frac{1}{11000}[0.25(400 + 1500 + 1500 + 400) +$$

$$8.25(500 + 1500 + 1500 + 500) +$$

$$16.25(350 + 1200 + 1200 + 450)]$$

=7.814m

$$e_x = \bar{X} - \frac{B}{2} = 7.814 - \frac{16.5}{2} = -0.436 \approx 0 - 0.44m$$

Hence, the resultant line of action is located to the left of the center of the mat. So ↻

$M_y = Qe_x = 11000 * (-0.44m) = -4{,}840\ KN.m$,

similarly

$$\bar{y} = \frac{1}{11000}[0.25(400 + 500 + 350) +$$

$$7.25(1500 + 1500 + 1200) + 14.25(1500 + 1500 + 1200) + 21.25(400+500+450)]$$

=10.85m

$e_y = \bar{y} - \frac{L}{2} = 10.85 - \frac{21.5}{2} = -0.1m$ ↺

$M_x = Qe_y = 11000 * (-0.1m) = -1100KN.m$

Distributed load

$$\boldsymbol{q = \frac{N}{BL} \pm \frac{M_yX}{I_y} \pm \frac{M_xY}{I_x}}$$

$$q = \frac{11000}{16.5 * 21.5} \pm \frac{4{,}840X}{8050} \pm \frac{1100Y}{13{,}665}$$

$\boldsymbol{q = 31 \pm 0.6x \pm 0.08Y}$ **(KN/m^2)**

$\boldsymbol{q\ at\ A = 31 + 0.6 * 8.25 + 0.08 * 10.75 = 36.81}$**KN/m^2**

$\boldsymbol{q\ at\ B = 31 + 0.6 * 0 + 0.08 * 10.75}$

$= 31.86\ \mathrm{KN/m^2}$

$q\ at\ C\ =\ 31 - 0.6 * 8.25 + 0.08 * 10.75$

$= 26.91\ \mathrm{KN/m^2}$

$q\ at\ D =\ 31 - 0.6 * 8.25 - 0.08 * 10.75$

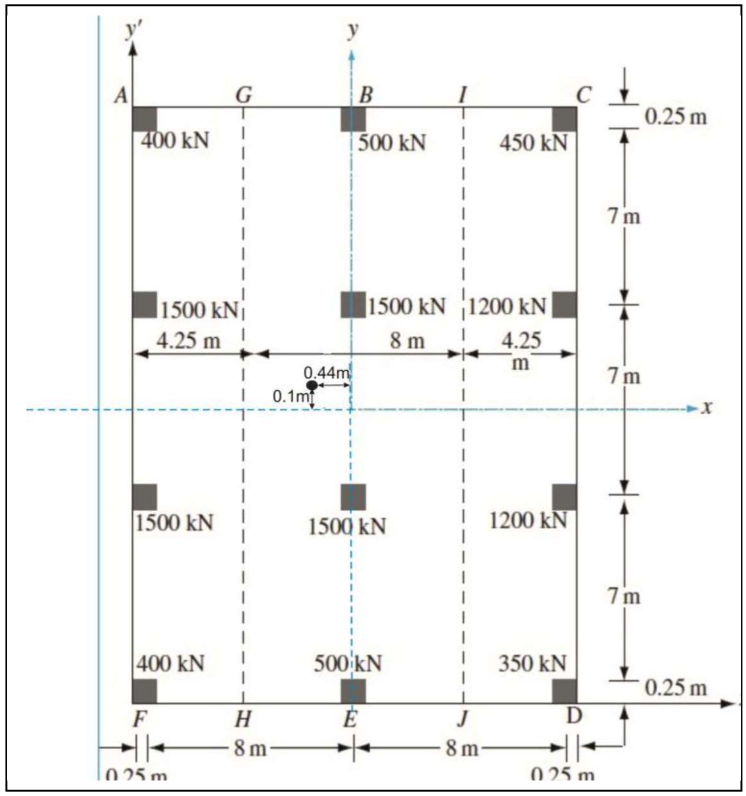
$= 25.19\ \mathrm{KN/m^2}$

$q\ at\ E\ =\ 31 - 0.6 * 0 - 0.08 * 10.75$

$= 30.16\ \mathrm{KN/m^2}$

$q\ at\ F\ =\ 31 + 0.6 * 8.25 - 0.08 * 10.75$

$= 35.09\ \mathrm{KN/m^2}$



Divide the mat shown in the figure into three strips, such as *AGHF* (*B*1 = 4.25 m), *GIJH* (*B*1= 8 m), and *ICDJ* (*B*1= 4.25 m). Determine the reinforcement requirements in the *y* direction. Here, *fc* = 20.7 $\mathrm{MN/m^2}$, *fy* = 413.7 MN/m2, and the load factor is F=1.7.

SFD & BMD

Strip AGHF

Average soil pressure $q_{av} = q_A + q_F = \frac{36.81+35.09}{2} = 35.95\ KN/m2$

Total soil reaction $q_{av}B_1L = 35.95 * 4.25 * 22.5 = 3285\ KN$

$Average\ loads = \frac{Total\ soil\ reaction+Column\ load}{2} = \frac{3285+3800}{2} = 3542.5\ KN$

Modified average soil pressure

$q_{av(modified)} = q_{av}(\frac{3542.5}{3285}) = 35.95\left(\frac{3542.5}{3285}\right) = 38.768\ KN/m2$

$qL = 38.768 * 4.25 = 164.674 KN/m$

The column loads can be modified in a similar manner by multiplying factor

$F = \frac{3542.5}{3800} = 0.9322$

$-331.83 + 164.674X1 = 0$, $x1 = 2.015\ m$

$-577.11 + 164.674x2 = 0$, **x2 = 3.5 m**

$-822.4 + 164.674x3 = 0$, **x3 = 5 m**

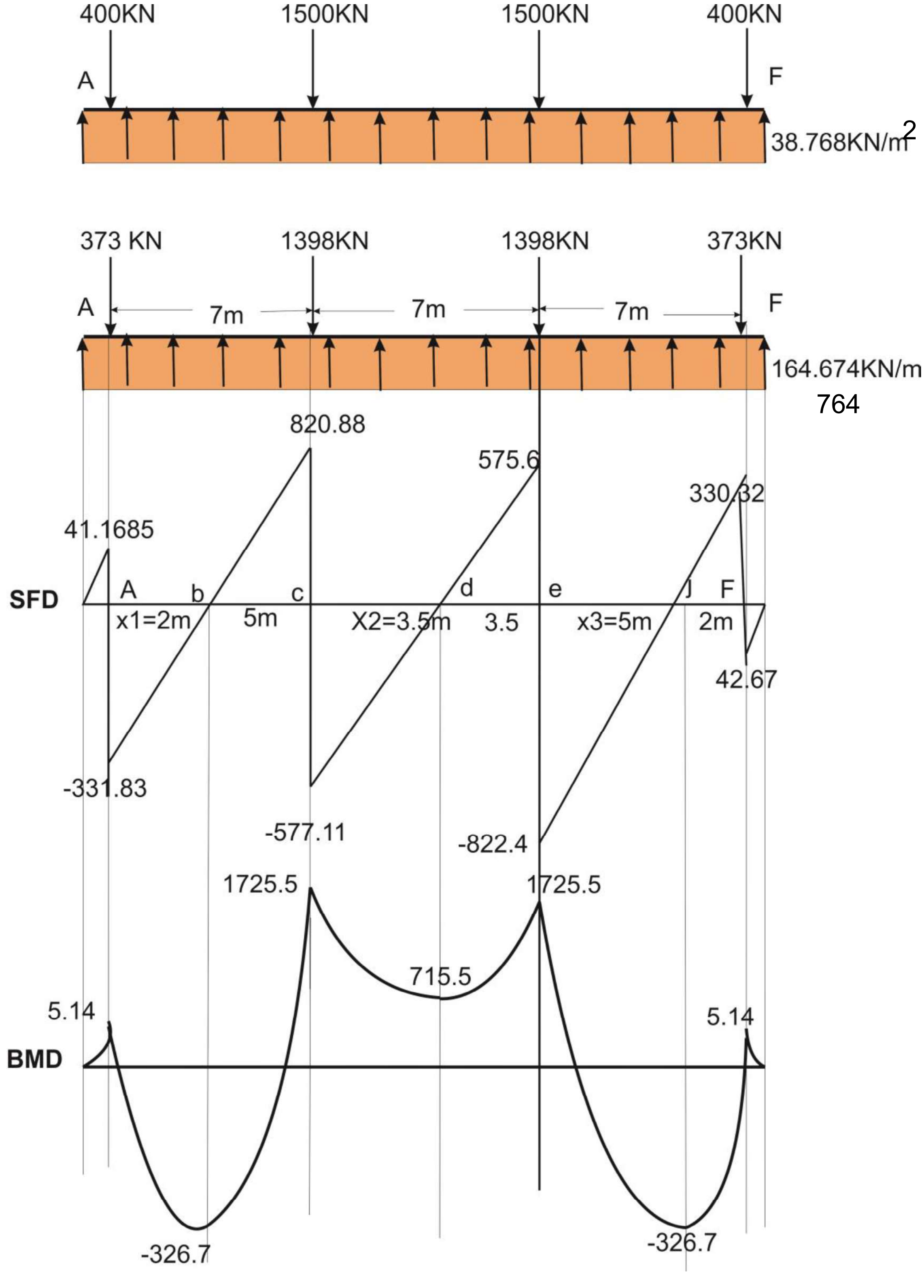


Fig.6 SFD & BMD of strip AGHF

Strip GIJH

$$q_{av} = \frac{q_B + q_E}{2} = \frac{31.86 + 30.16}{2}$$

$$= 31kN/m2$$

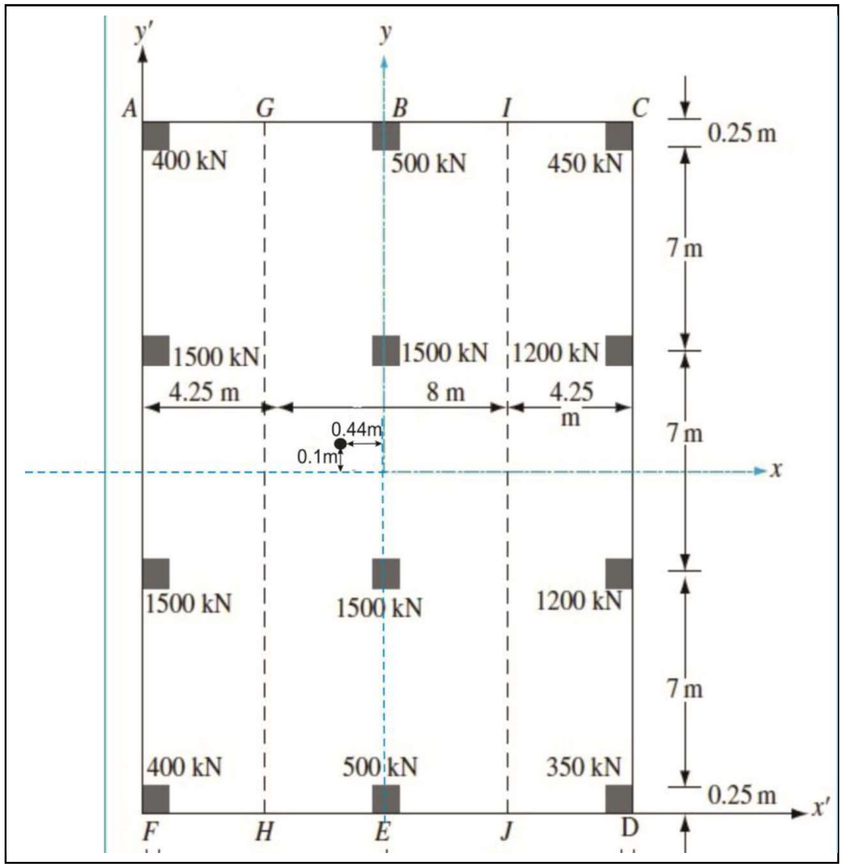
Total Load = 4000 kN

Total soil load = 31*8*21.5= 5,332 KN

Average load = (4000+5332)/2 =4666KN

$$q_{av(modified)} = 31\left(\frac{4666}{5332}\right) = 27.12\frac{KN}{m2}$$

$$F = \frac{4666}{4000} = 1.1665$$



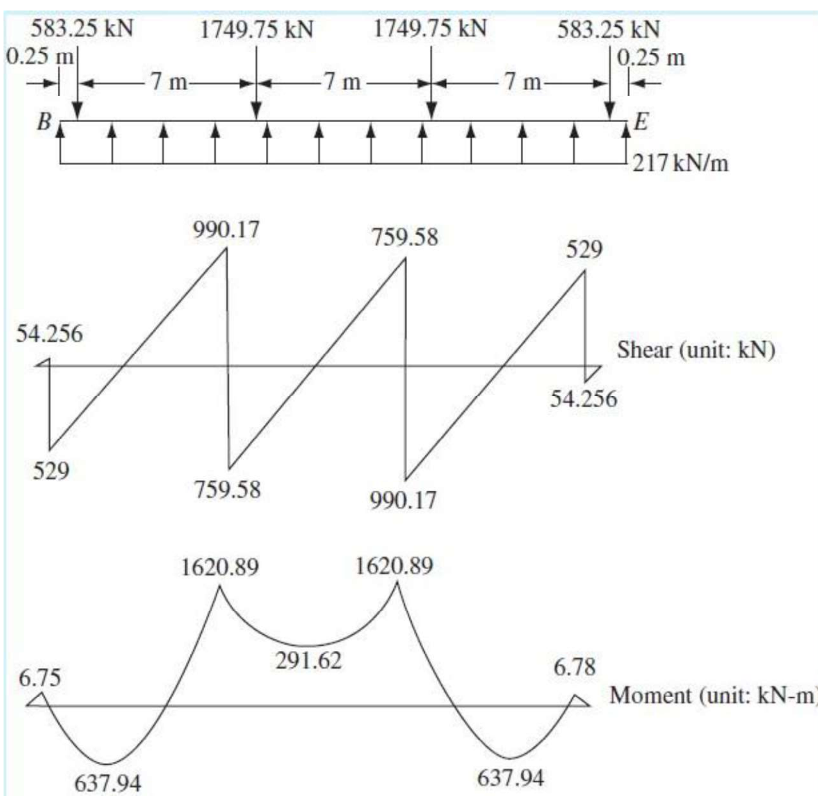


Fig.7 SFD & BMD of strip GIJH