Design of Mat/Raft Foundation

- Mat or raft foundation is a large concrete slab supporting several columns in two or more rows.
- It is used where the supporting soil has low bearing capacity.
- The bearing capacity increased by combining all individual footings in to one mat –since bearing capacity is proportional to width and depth of foundations.
- In addition to increasing the bearing capacity, mat foundations tend to bridge over irregularities of the soil and the average settlement does not approach the extreme values of isolated footings.
- Thus mat foundations are often used for supporting structures that are sensitive to differential settlement.

- **Design of uniform mat**
- Design Assumptions
  - mat is infinitely rigid
  - planner soil pressure distribution under mat

- **Design Procedure**

I. Determine the line of action of the resultant of all the loads acting on the mat

II. Determine the contact pressure distribution as under
  - If the resultant passes through the center of gravity of the mat, the contact pressure is given by

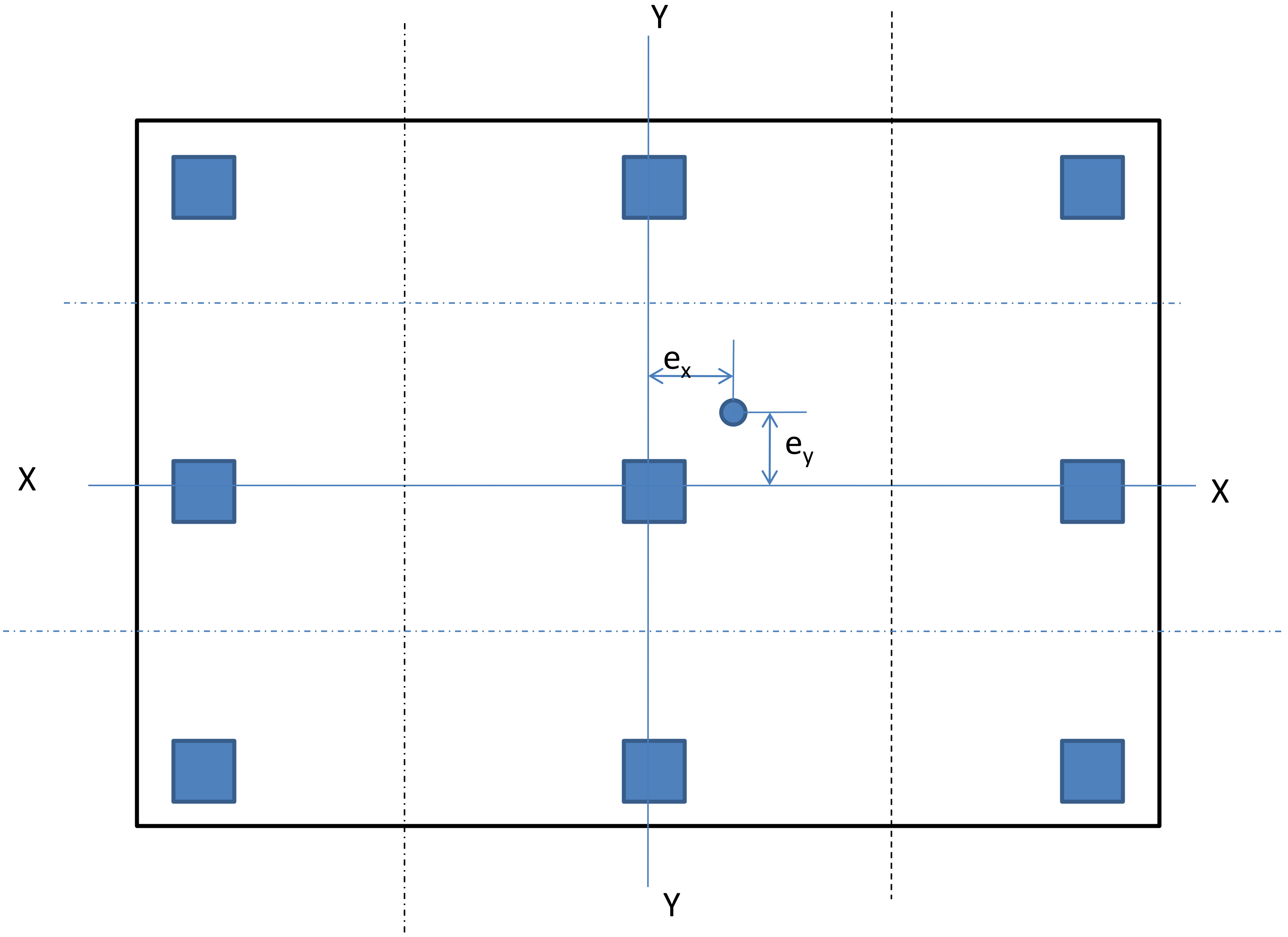
$$\sigma = \frac{Q}{A}$$

- If the resultant has an eccentricity of e_x and e_y in the x and y direction

$$\sigma_{\max/\min} = \frac{Q}{A} \pm \frac{Qe_x}{Iyy} x \pm \frac{Qe_y}{Ixx} y$$

The maximum contact pressure should be less than the allowable soil pressure

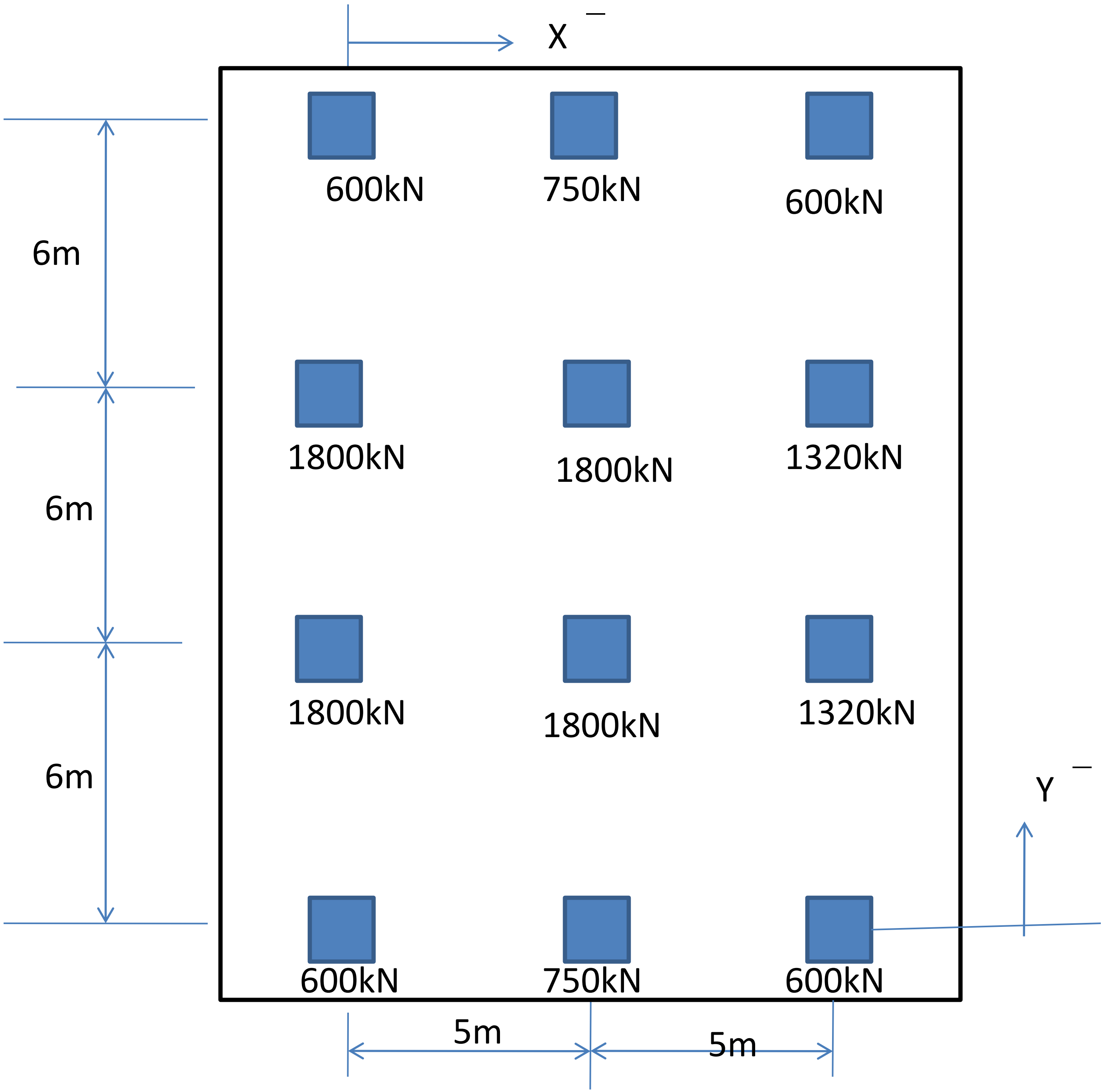
- Divide the slab mat into strips in x and y directions. Each strip is assumed to act as independent beam subjected to the contact pressure and the columns loads.
- Determine the modified column loads
- Draw the shear force and bending moment diagrams for each strip.
- Select depth of mat for shear requirement
- Select steel reinforcement for moment requirement


Y
e_x
e_y
X
X
Y

• Example

- A mat foundation is to be design by the conventional method (rigid method) for the loadings shown in Fig. below.

  - All columns are 40X40cm
  - Ultimate soil bearing pressure , q_{ult} = 100kPa
  - f_{yk} = 300MPa $\Rightarrow$ f_{yd} = 300/1.15 = 260.87 Mpa
  - C25 $\Rightarrow f_{ck}$= 20MPa $\Rightarrow f_{ctk}$ = 1.5 MPa,


X
600kN
750kN
600kN
6m
1800kN
1800kN
1320kN
6m
1800kN
1800kN
1320kN
6m
Y
600kN
750kN
600kN
5m
5m

- Location of c.g. of loads
- $\sum P$ = (600 +750+ 600)*2 +(1800+1800+1320)*2 =13740kN

- 13740 $\bar{X}$ = (750 +1800+1800+750)*5 + (600 +1320+1320+600)* 10

  $\bar{X}$ = 4.65m

  e_x = 5-4.65 = 0.35

  X' = 5 +0.35 = 5.35m
- B_{min} = 2*(5.35 +0.20+0.15) =11.40m
- 13740 $\bar{Y}$ = (600 +750+600)*18 + (1800 +1800+1320)* 12 + (1800 +1800+1320)* 6

  $\bar{Y}$ = 9m

  e_y = 6+ 6/2 -9 = 0
- L_{min} = 2* (9+0.20+0.15) = 18.70m
- Dimension of Mat 11.40 X 18.70m

- Actual contact pressure

$\sigma = \Sigma P/(BL) = 13740/(11.40*18.70) = 64.45kPa < \sigma_{ult} = 100kPa$

- Thickness of the mat
- Punching shear
- Punching shear under 1800kN load

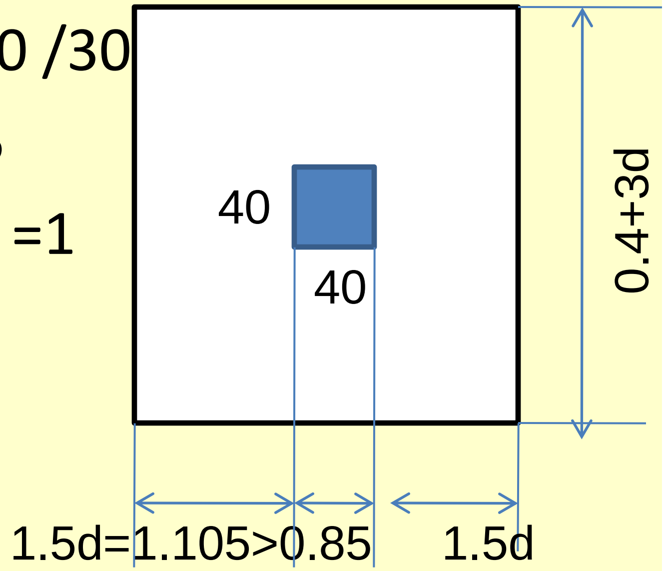
Take d= 0.70m and $\rho = \rho_{min} = 0.50/f_{yk} = 0.50 /30$

$k_1 = (1+50\rho) = (1 +50*0.0017) = 1.085$

$k_2 = 1.6 - d = 1.6 - 0.70 = 0.90$, Take $K_2 = 1$

$P_r = (0.85+0.4+1.105)2+(0.4+3(0.70)$

$= 7.21m$



- Net shear force developed
- $V_d = 1800 - \sigma*(2.355* 2.50)$, $\sigma = 64.45kP$
- $V_d = 1800 - 64.45*(2.355* 2.50) = 1420.55kN$

- Punching shear resistance

$$V_{up} = 0.25 f_{ctd} k_1 k_2 ud \quad (MN)$$

- V_{up} = 0.25 *1000* 1.085*1.00*7.21*0.70

  =1369.00kN < V_d .. NOT OK! Increase the depth

Take d= 0.75m and $\rho = \rho_{min} = 0.50/f_{yk} = 0.50 /300 = 0.0017$

$k_1 = (1+50\rho) = (1 +50*0.0017) = 1.085$

$k_2 = 1.6 – d = 1.6 - 0.75 = 0.85$, Take $K_2 = 1$

P_r =(0.85+0.4+1.125)2+(0.4+3(0.75)

=7.40m

- Net shear force developed
- V_d= 1800 -σ*(2.375* 2.65) , σ =64.45kP
- V_d= 1800 -64.45*(2.375* 2.65)=1394.37kN

- Punching shear resistance

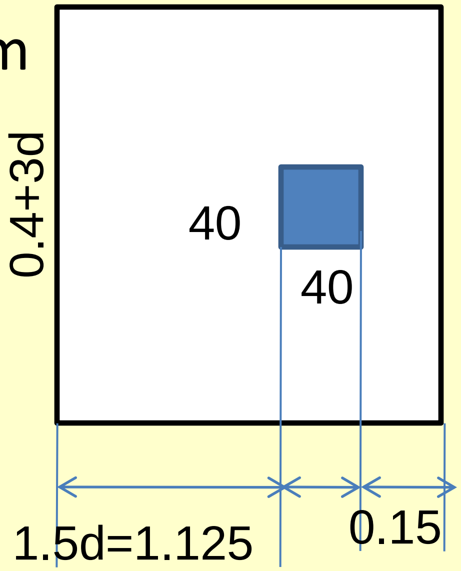
$$V_{up} = 0.25 f_{ctd} k_1 k_2 ud \quad (MN)$$

- V_{up} = 0.25 *1000* 1.085*1.00*7.40*0.75

  =1505.44kN >V_d .. OK!

- Check punching shear under 1320kN

P_r =(1.125 +0.15+0.4)2+(0.4+3(0.75)) =6.00m



- Net shear force developed
- V_d= 1320 -64.45*(1.675*2.65)=1033.92kN
- Punching shear resistance

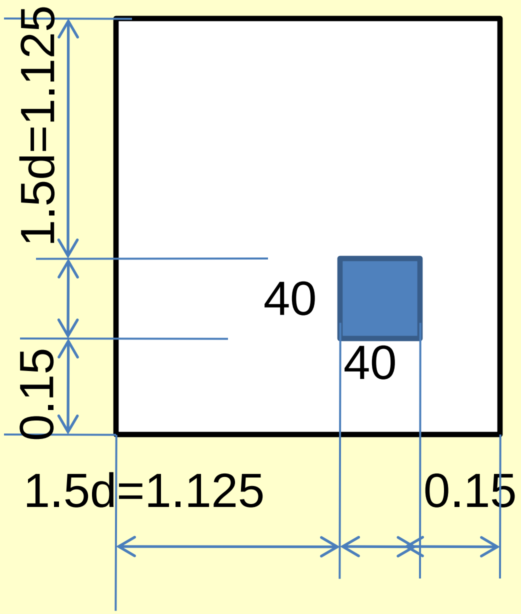
$$V_{up} = 0.25 f_{ctd} k_1 k_2 ud \quad (MN)$$

- V_{up} = 0.25 *1000* 1.085*1.00*6.00*0.75

  =1220.63kN > V_d .. OK!

- Check punching shear under 600kN
- P_r =(1.125+0.15+0.4) +(1.125+0.15+0.4)

  =3.35m



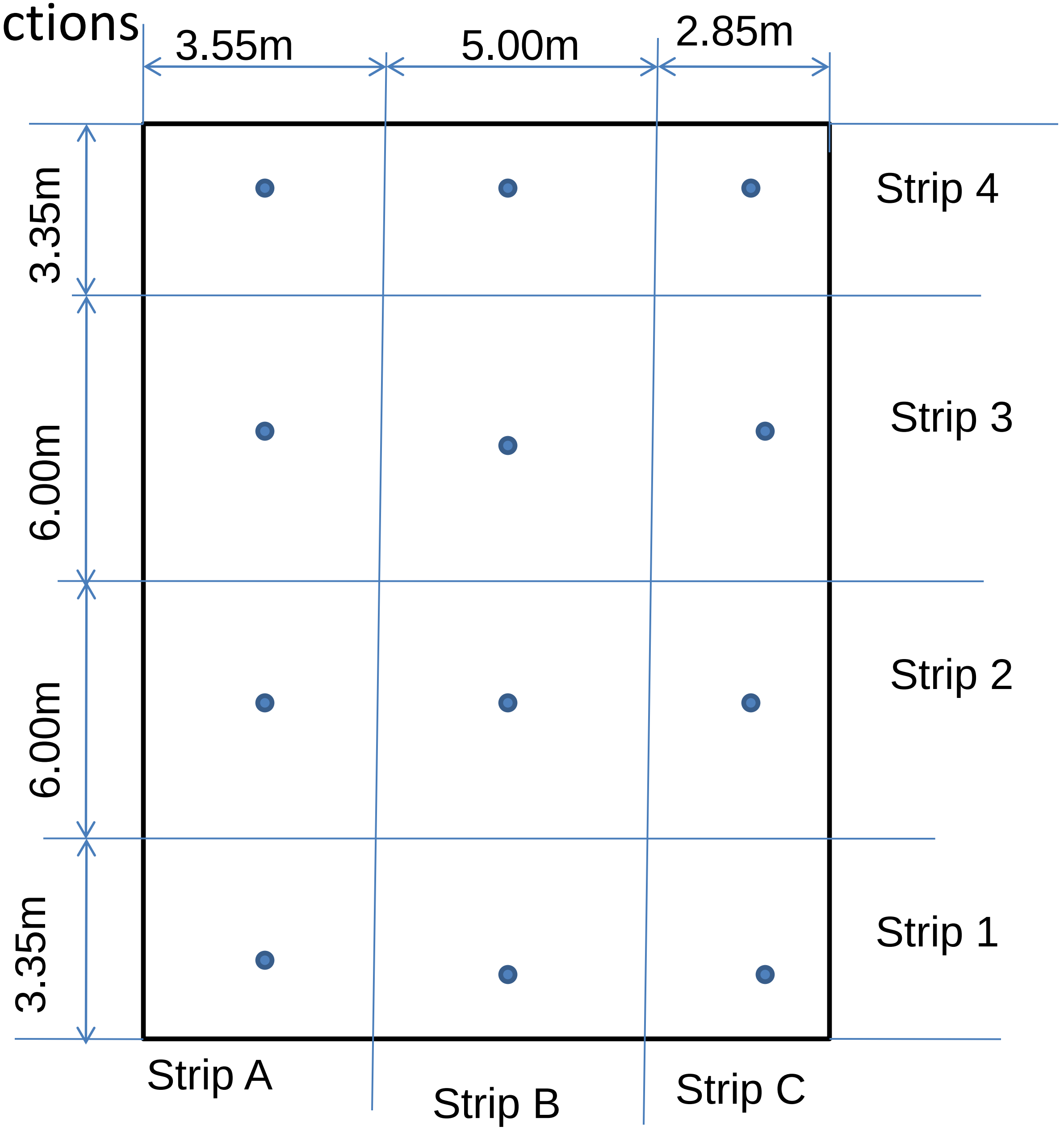
- Net shear force developed
- V_d= 600 -64.45*(1.675*1.675)=419.18kN
- Punching shear resistance

  $V_{up} = 0.25 f_{ctd} k_1 k_2 ud$ (MN)

- V_{up} = 0.25 *1000* 1.085*1.00*3.35*0.75

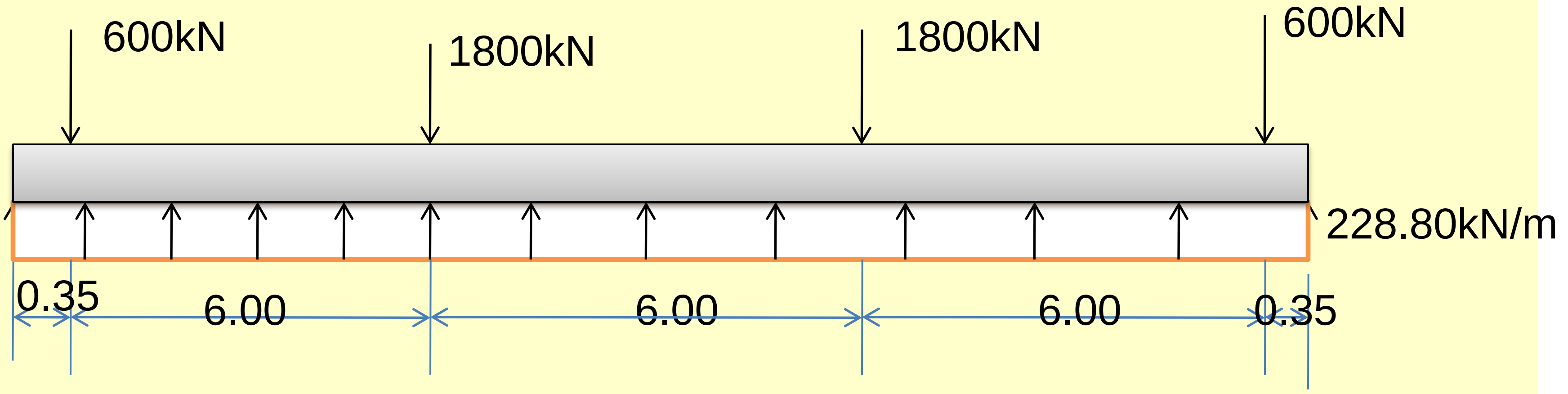
  =681.52kN > V_d .. OK!

- Soil reaction analysis:- Divide the slab mat into strips in x and y directions



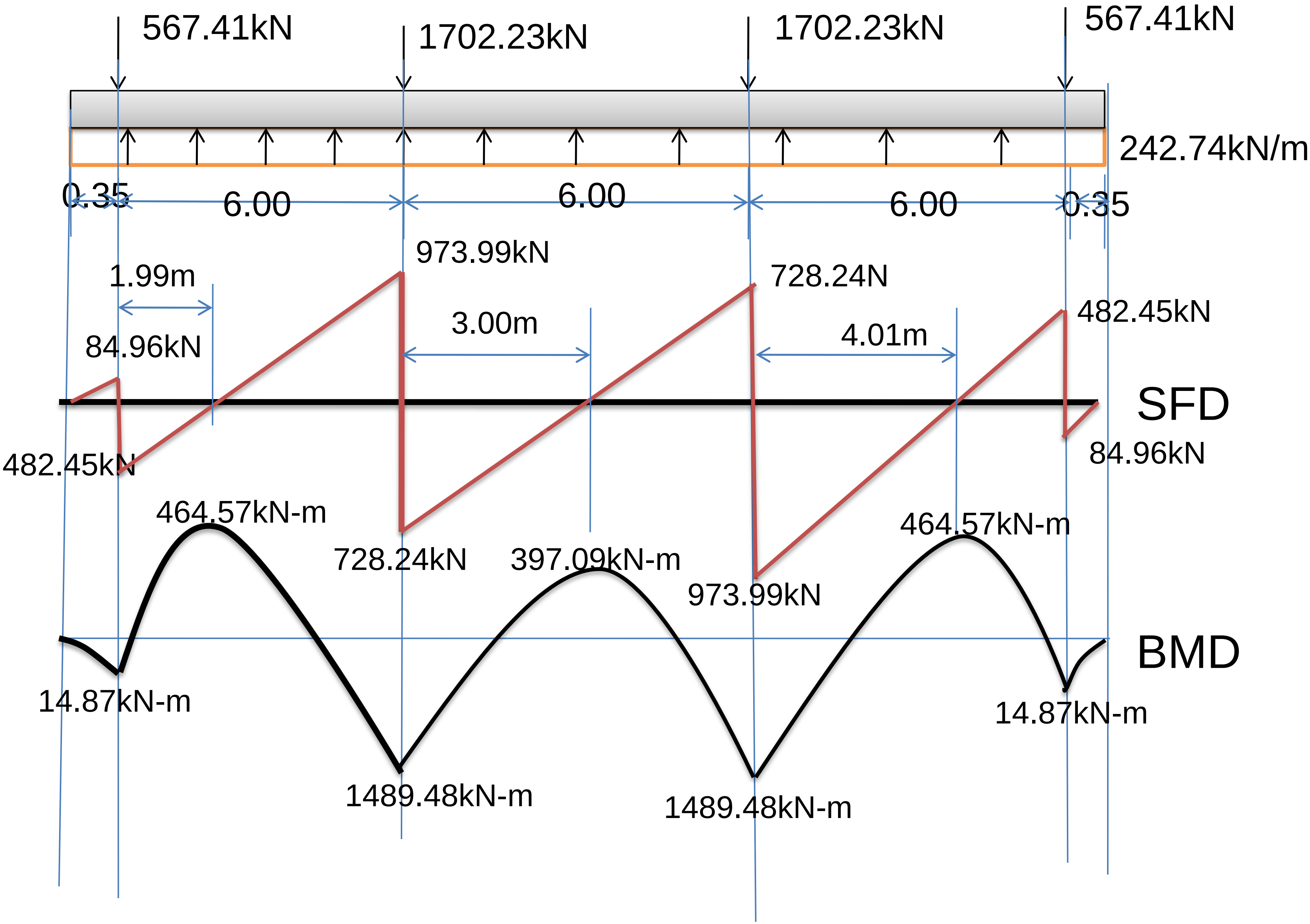
- Strip A, (64.45)*3.55 = 228.80kN/m
- Strip B , (64.45)*5.00 = 322.25kN/m
- Strip C, (64.45)*2.85 = 183.68kN/m
- Strip 1 &Strip 4, (64.45)*3.35 = 215.91kN/m
- Strip 2 & Strip 3 (64.45)*6.00 = 386.70kN/m

- Shear force and Bending moment diagrams for each strip
- Strip A

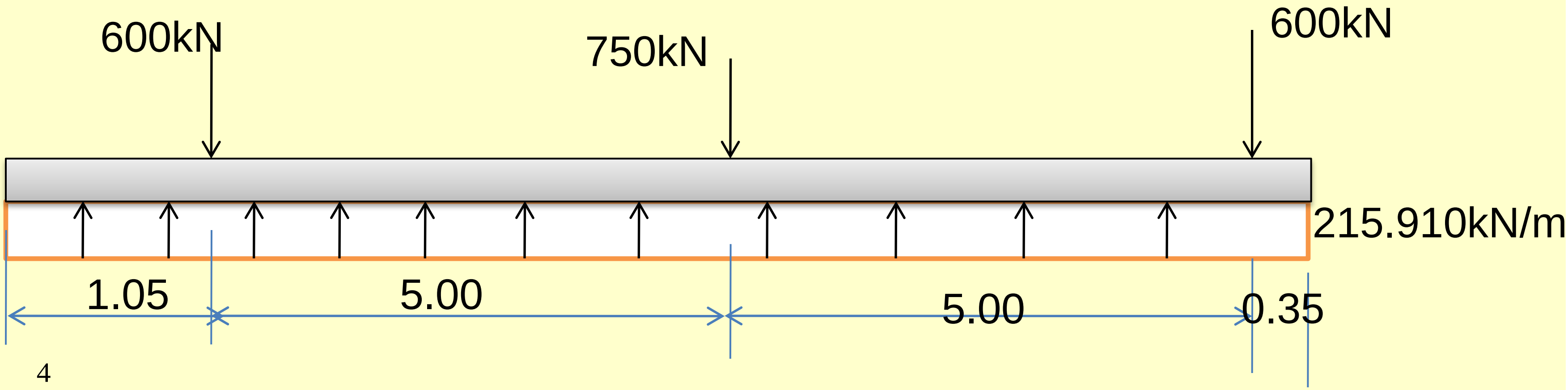


$$\sum_{i=1}^{4} P_i = 600 + 1800 + 1800 + 600 = 4800 \ kN$$

- ΣR = 228.80* 18.70 =4278.56kN
- ΣV = ΣP- ΣR = 4800-4278.56 =521.44 $\neq$ 0
- Hence take average of ΣP and ΣR
- I.e., (4800 +4278.56)/2 =4539.28kN
- σ_{avg} = (4539.28)/18.70 =242.74kN/m
- P_{1avg} = P_{4avg} = (4539.28/4800) *600 =567.41kN
- P_{2avg} = P_{3avg} = (4539.28/4800) *1800 =1702.23kN

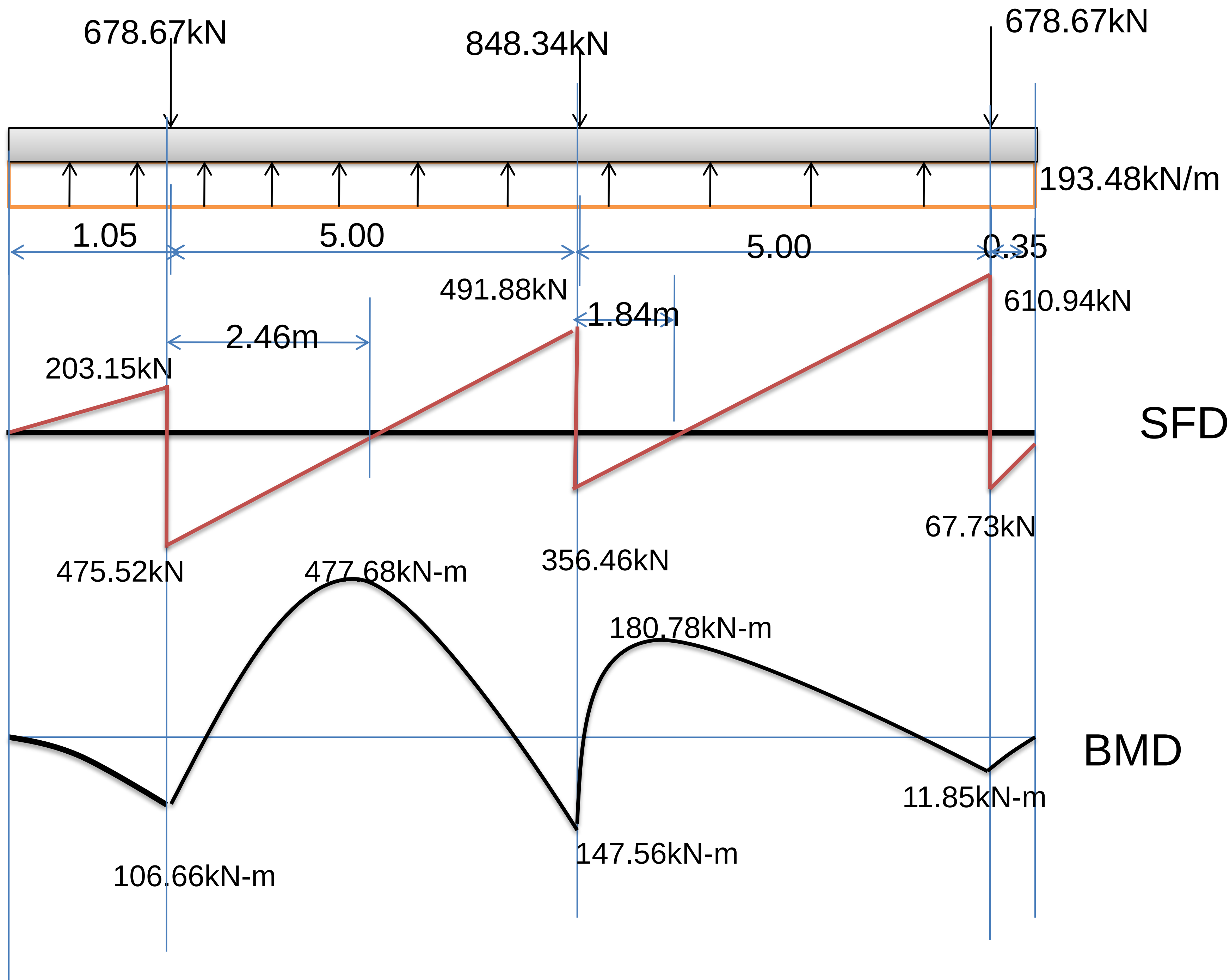

567.41kN
1702.23kN
1702.23kN
567.41kN
242.74kN/m
0.35
6.00
6.00
6.00
0.35
973.99kN
1.99m
728.24N
482.45kN
3.00m
4.01m
84.96kN
SFD
482.45kN
84.96kN
464.57kN-m
464.57kN-m
728.24kN
397.09kN-m
973.99kN
BMD
14.87kN-m
14.87kN-m
1489.48kN-m
1489.48kN-m

- Strip 1 &Strip 4, (64.45)*3.35 = 215.91kN/m



$$\sum_{i=1}^{4} P_i = 600 + 750 + 600 = 1950 \ kN$$

- ΣR = 215.91* 11.40=2461.37kN
- $\Sigma V = \Sigma P - \Sigma R$ = 1950-2461.37 = -511.37 $\neq 0$
- Hence take average of ΣP and ΣR
- I.e., (1950+2461.37)/2 =2205.69kN
- σ_{avg} = (2205.69)/11.40 =193.48kN/m
- $P_{1avg} = P_{3avg}$ = (2205.69/1950) *600 =678.67kN
- P_{2avg} = (2205.69/1950) *750 =848.34kN


678.67kN
848.34kN
678.67kN
193.48kN/m
1.05
5.00
5.00
0.35
491.88kN
1.84m
610.94kN
2.46m
203.15kN
SFD
67.73kN
475.52kN
477.68kN-m
356.46kN
180.78kN-m
BMD
11.85kN-m
147.56kN-m
106.66kN-m