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PREFACE

B. Singh (Ex. IES)

For each and every aspirant in the preparation for any competitive exam, consolidating what is learnt and to get the flavour & feel of actual exam are among the top list of desiderata. With the students' expression of interest for a book to prepare effectively for State Level exams , this conventional book is debut of MADE EASY in exclusive State Level Services study material which will definitely fulfil all the requirements of aspirants.

This book covers conventional questions from various papers of 11 different PSCs across the country (BPSC, RPSC, OPSC, MPSC, GPSC, MPPSC, JPSC, UKPSC, KPSC, Kerala PSC and HPSC); which will certainly be a path for students to achieve their goal.

Reasonable efforts are been taken to make sure that answers are framed and transcribed accurately. With key formulae, relevant theory and graphical/pictorial representations this book will not only give questions of various PSCs over the years but also will equip students with concepts, knowledge and understanding of the subject. I hope this book will prove to be an efficient tool to prepare for subjective exams of different PSCs. This book will also come handy for ESE Mains and SSC conventional exams.

It is impossible to acknowledge all the individuals who helped us, but would like to sincerely thank all authors, editors and reviewers for putting their painstaking efforts to publish this book.

B. Singh (Ex. IES)
Chairman and Managing Director
MADE EASY Group

Contents

BPSC 2012

Bihar Public Service Commission

Assistant Engineer

Exam held in 2012 **Paper-V (Section-II)**

1. (a) Two-plate load tests with square plates were performed on a soil deposit. For 30 mm settlement, the loads obtained are as follows:

Width of square plate(in mm)	Load(in kN)
300	38.2
600	118.5

Determine the width of square footing which would carry a net load of 1500 kN for a limiting settlement of 30 mm.

[10 Marks]

Sol: Given,

Width of square plate(in mm)	Load(in kN)
300	38.2
600	118.5

Settlement recorded = 30 mm

As per Housel's equation,

We know that $Q = A_p \cdot m + P_p \times n$

where, Q = Load applied on given plate

A_p = Contact area of plate

P_p = Perimeter of plate

m = a constant corresponding to the bearing pressure

n = another constant corresponding to perimeter shear

Hence, for the two plate load test, we may write

$$Q_1 = A_{p1}m + P_{p1}m$$

$$A_{p1} = (0.3)^2\text{m}^2 = 0.09\text{ m}^2,\ P_{p1} = 4 \times 0.3 = 1.2\text{ m}$$

$$38.2 = 0.09\text{ m} + 1.2\text{ n} \quad ...(1)$$

$$A_{p2} = (0.6)^2\text{m}^2 = 0.36\text{ m}^2,\ P_{p2} = 4 \times 0.6 = 2.4\text{ m}$$

$$118.5 = 0.36\text{ m} + 2.4\text{ n} \quad ...(2)$$

Operating equation (2) – equation (1) × (4)

$$118.5 - 4 \times (38.2) = 2.4n - 4.8n$$

$$-34.3 = -2.4n$$

$$n = 14.29$$

Put the value of n in eq. (1)

$$38.2 = 0.09 \times m + 1.2 \times 14.29$$

$$m = 233.91$$

For prototype foundation, we may write

$$Q_f = 233.91A_f + 14.29\ P_f$$

Let size of footing, be ($B \times B$),

$$A_f = B^2,\ P_f = 4B,\ Q_f = 1500 \text{ kN}$$

$$1500 = 233.91B^2 + 14.29 \times 4B$$

$$233.41B^2 + 57.16B - 1500 = 0$$

$$B = 2.41 \text{ m} \simeq 2.4 \text{ m}$$

$\therefore$ The size of footing $= 2.4 \text{ m} \times 2.4 \text{ m}$

1. (b) **For the simply-supported beam shown in figure 1, determine the deflection at centre point C and slopes at ends A and B. [$E = 2.05 \times 10^5$ N/mm^2 and $I = 80 \times 10^6$ mm^4]**

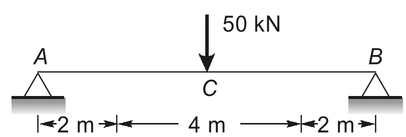


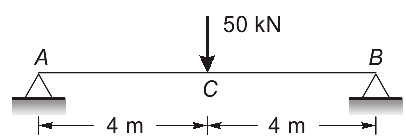
Fig. 1

[10 Marks]

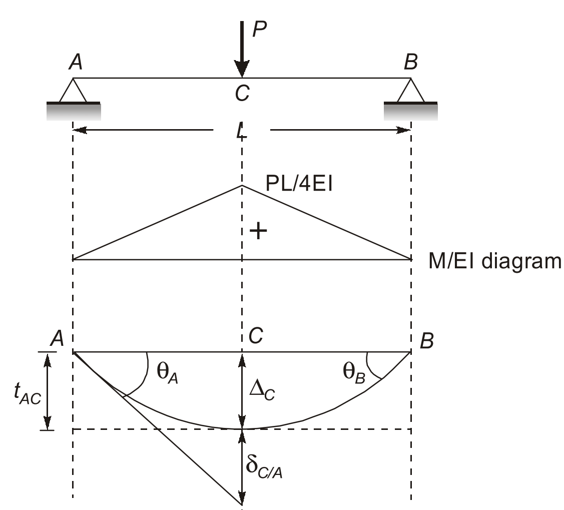
Sol: Given, SSB

$$E = 2.05 \times 10^5 \text{ N/mm}^2$$

$$I = 80 \times 10^6 \text{ mm}^4$$



To find deflection at centre point C, and slope at point A and B,
Let us find it by using moment area method.



At C, slope will be zero,

i.e. $\theta_C = 0$

So, considering part AC only,

For slope at A,

Change of slope from A to C = Area of M/EI diagram between A and C

$$\theta_C - \theta_A = \frac{1}{2} \times \frac{L}{2} \times \frac{PL}{4EI}$$

$$\theta_A = \frac{-PL^2}{16EI}$$

$$\theta_A = \frac{PL^2}{16EI} (\circlearrowright)$$

By symmetry

$$\theta_B = \frac{PL^2}{16EI} (\circlearrowleft)$$

Deflection at C,

$\Delta_C = t_{AC}$ = moment of area of M/EI diagram between A and C taken about A.

$$\Delta_C = \left(\frac{1}{2}\times\frac{L}{2}\times\frac{PL}{4EI}\times\frac{2(L/2)}{3}\right) = \frac{PL^3}{48EI}$$

$\therefore$ Deflection at $C = \frac{PL^3}{48EI}(\downarrow \text{ward})$

Given,

$P = 50$ kN

$E = 2.05 \times 10^5$ N/mm^2

$I = 80 \times 10^6$ mm^4

$$EI = 1.64 \times 10^{13} \text{ Nmm}^2 = 1.64\times\frac{10^{13}\times 10^{-6}}{10^3} \text{ kNm}^2 = 1.64 \times 10^4 \text{ kNm}^2$$

Now,

$$\theta_A = \frac{PL^2}{16EI} = \frac{50\text{kN}\times(8)^2\text{ m}^2}{16\times 1.64\times 10^4 \text{ kNm}^2}$$

$$\theta_A = 0.01219 \text{ radian } (\circlearrowright)$$

$$\theta_B = 0.01219 \text{ radian } (\circlearrowleft)$$

$$\Delta_C = \frac{PL^3}{48EI} = \frac{50\text{kN}\times(8)^2\times\text{m}^2}{48\times 1.64\times 10^4\text{ kNm}^2} = 0.03252 \text{ m}$$

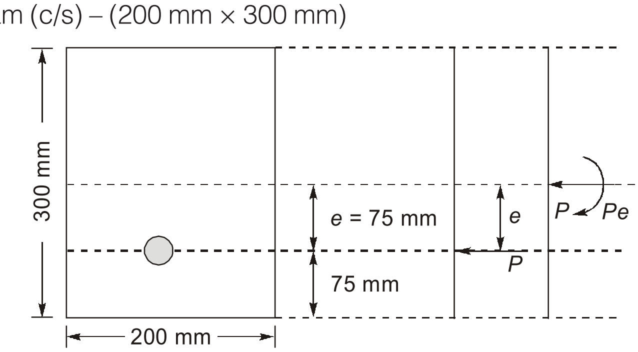
$$\Delta_C = 0.03252 \text{ m } \downarrow \text{Ward}$$

1. (c) A post-tensioned beam, 200 mm × 300 mm, prestressed with tendon 520 mm^2 area stretched to a stress of 1000 N/mm^2. The tendon passes through a hole 50 mm wide and 75 mm deep left in the beam, having the centre of the hole at 75 mm from the bottom. The loss at the time of prestressing is 5%. Find the stresses in concrete immediately after prestressing.

[10 Marks]

Sol: Given:

Post tensioned beam (c/s) – (200 mm × 300 mm)



Cross section area of tendon = 520 mm^2

Initial stress = 1000 N/mm^2

Initial prestressing force,

$$P = 520 \times \frac{1000}{1000} \text{ kN} = 520 \text{ kN}$$

$$\text{Loss of prestress} = 5\%,\ k = \left(1 - \frac{P_L\%}{100}\right) = \left(1 - \frac{5}{100}\right) = 0.95$$

Eccentricity of prestressing force = 75 mm

Stresses in concrete just after (immediately after) prestressing,

i.e. At transfer stage,

No losses is considered here,

At ends,

$$f_{t/b} = \frac{P}{A} \mp \frac{Pe}{I} y_{t/b}$$

$$f_{t/b} = \frac{P}{A} - \frac{Pe}{I} y_t$$

$$f_t = \frac{520 \times 10^3}{(200 \times 300)} - \frac{520 \times 10^3 \times 75}{\frac{200 \times (300)^3}{12}} \times 150$$

$$f_t = -4.33 \text{ N/mm}^2$$

$$f_b = \frac{P}{A} + \frac{Pe}{I} y_b$$

$$= \frac{520 \times 10^3}{200 \times 300} + \frac{520 \times 10^3 \times 75}{\frac{200 \times (300)^3}{12}} \times 150$$

$$f_b = 21.67 \text{ N/mm}^2$$

SECTION - A

2. (a) Analyze the frame shown in fig. 2 and draw the BM and SF diagram. [EI is constant for all the members].

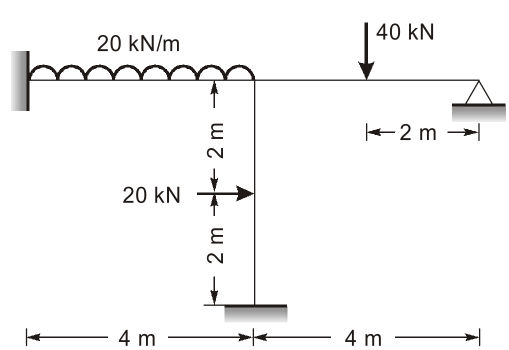
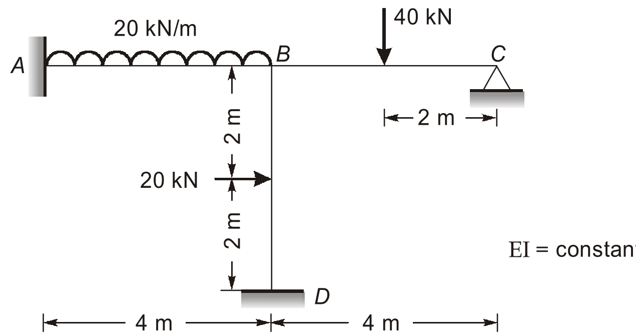


Fig. 2

[10 Marks]

Sol:



Let us do it, by using slope deflection method,

Unknown joint displacements,

$$(\theta_B, \theta_C)$$

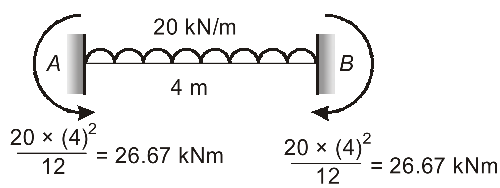
If we use modified slope deflection equation for span BC, then there is no need to consider θ_C, hence unknown reduces to only θ_B.

Hence, joint equilibrium equations required is:

$$M_{BA} + M_{BC} + M_{BD} = 0 \qquad ...(1)$$

Fixed end moments:

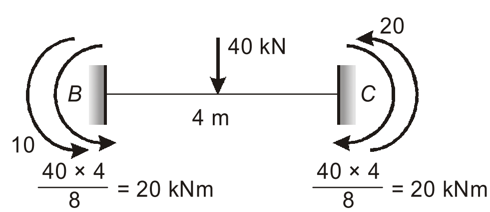
Span *AB*



$$M_{FAB} = -26.67 \text{ kNm}$$

$$M_{FBA} = 26.67 \text{ kNm}$$

Span *BC*

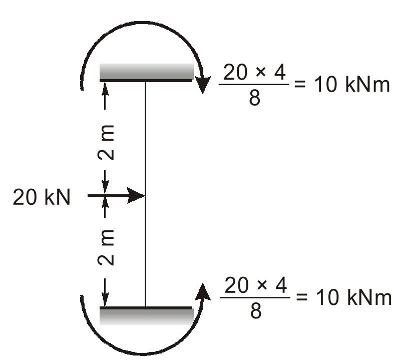


$$M_{FBC} = -20 \text{ kNm}$$

$$M_{FCB} = 20 \text{ kNm}$$

$$\bar{M}_{FBC} = -20 - 10 = -30 \text{ kNm}$$

Span *BD*



$$M_{FBD} = 10 \text{ kNm}$$
$$M_{FDB} = -10 \text{ kNm}$$

Now, using slope deflection eq.

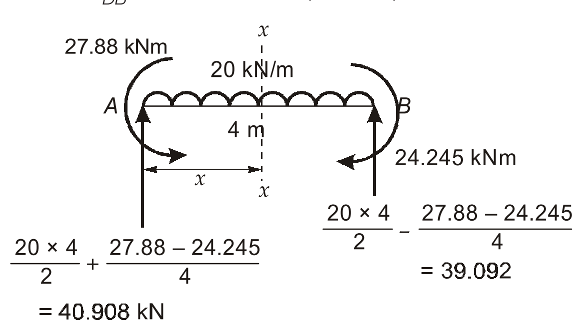
Span *AB*,
$$M_{AB} = M_{FAB} + \frac{2EI}{L}\left(2\theta_A + \theta_B - \frac{3\Delta}{L}\right) \qquad \{\theta_A = 0, \Delta = 0\}$$
$$= -26.67 + \frac{2EI}{4}\theta_B = -26.67 + 0.5EI\theta_B \qquad \text{...(A)}$$
$$M_{BA} = M_{FBA} + \frac{2EI}{L}\left(2\theta_B + \theta_A - \frac{3\Delta}{L}\right)$$
$$= 26.67 + \frac{2EI}{L}2\theta_B = 26.67 + EI\theta_B \qquad \text{...(B)}$$

Span *BC*,
$$M_{BC} = \bar{M}_{FBC} + \frac{3EI}{L}\left(\theta_B - \frac{\Delta}{L}\right)$$
$$= -30 + \frac{3EI}{4}\theta_B \qquad \text{...(C)}$$

Span *BD*,
$$M_{BD} = M_{FBD} + \frac{2EI}{L}\left(2\theta_B + \theta_D - \frac{3\Delta}{L}\right) \qquad \{\theta_D = 0, \Delta = 0\}$$
$$= 10 + \frac{2EI}{4}2\theta_B = 10 + EI\theta_B \qquad \text{...(D)}$$
$$M_{DB} = M_{FDB} + \frac{2EI}{L}\left(2\theta_D + \theta_B - \frac{3\Delta}{L}\right)$$
$$= -10 + \frac{2EI}{4}2\theta_B = -10 + 0.5EI\theta_B \qquad \text{...(E)}$$

Now, using eq. (1)
$$M_{BA} + M_{BC} + M_{BD} = 0$$
$$26.67 + EI\theta_B + \left(-30 + \frac{3EI}{4}\theta_B + 10 + EI\theta_B\right) = 0$$
$$2.75EI\theta_B + 6.67 = 0$$
$$EI\theta_B = \frac{-6.67}{2.75} = -2.425$$

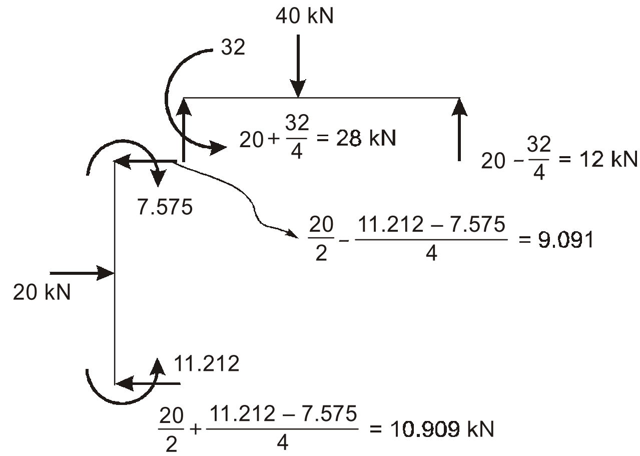
Now,
$$M_{AB} = -26.67 + 0.5 \times (-2.425) = -27.88 \text{ kNm}$$
$$M_{BA} = 26.67 - 2.425 = 24.245 \text{ kNm}$$
$$M_{BC} = -30 + 0.75 \times (-2.425) = -31.818 \text{ kNm} \simeq -32 \text{ kNm}$$
$$M_{BD} = 10 - 2.425 = 7.575$$
$$M_{DB} = -10 + 0.5 \times (-2.425) = -11.212 \text{ kNm}$$



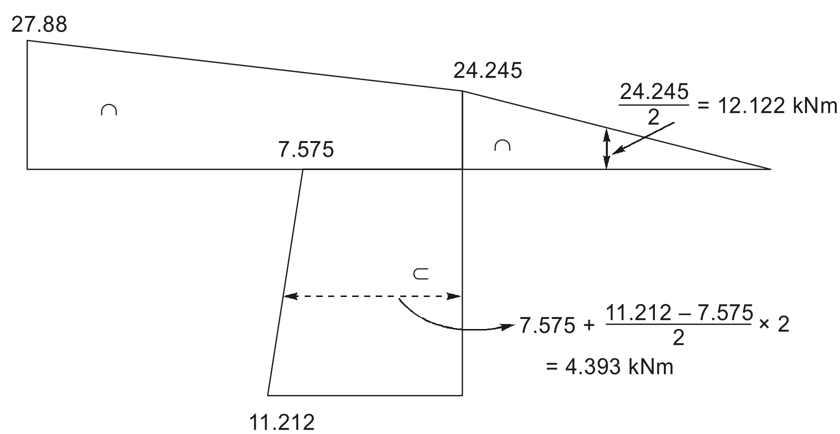
$$SF_{xx} = 0$$
$$40.908 - 20x = 0$$

$$x = \frac{40.908}{20} = 2.045 \text{ m}$$

$$M^{max} = -27.88 + 40.908 \times 2.045 - \frac{20 \times (2.045)^2}{2} = 13.956 \text{ kNm}$$

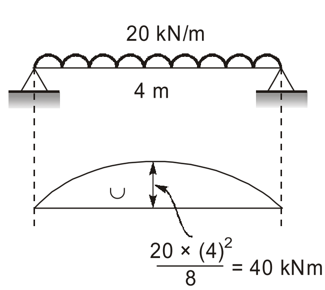


End moment diagram:

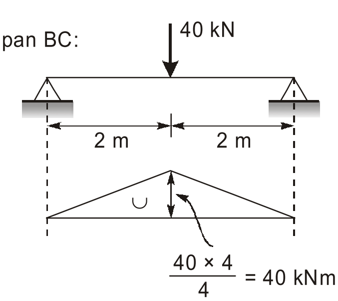


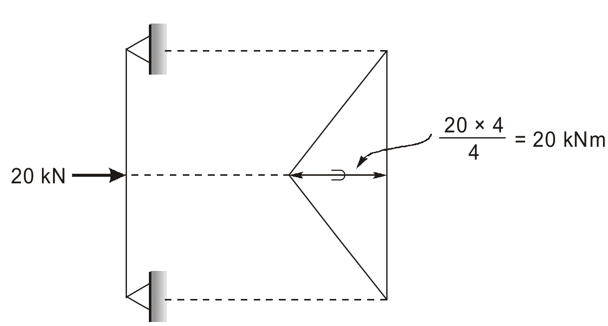
Free moment diagram:

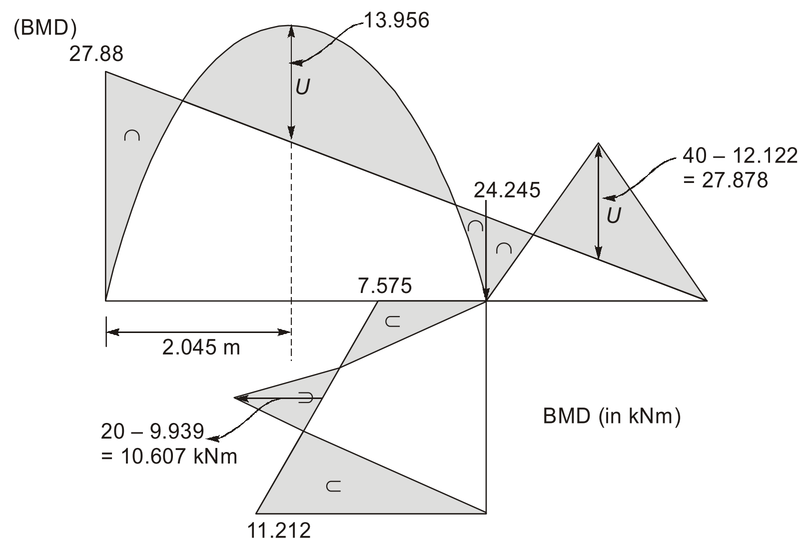
Span AB:

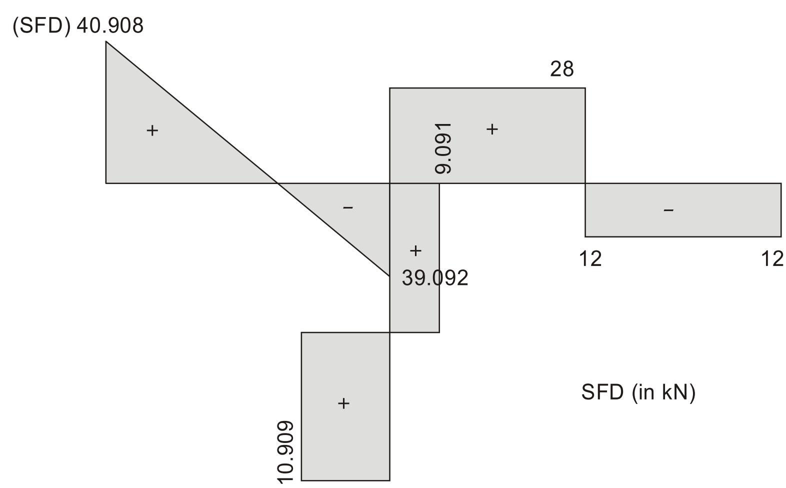


Span BC:





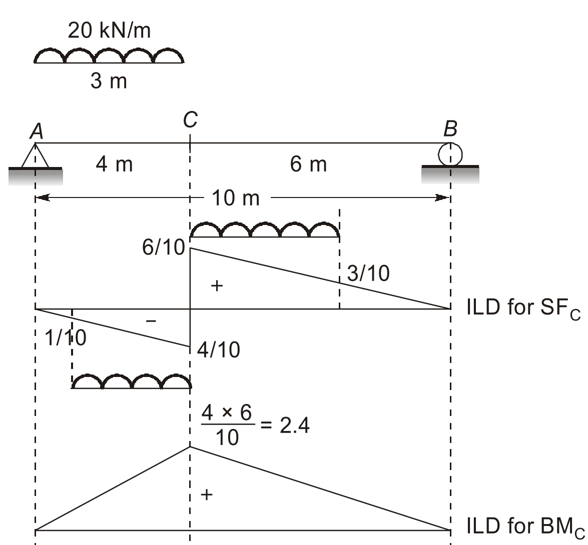




2. (b) A uniformly distributed load of 20 kN/m covering a length of 3 m crosses a girder of span 10 m. Find the maximum shear force and bending moment at a section 4 m from left-hand support.

[10 Marks]

Sol:



for maximum +ve *SF* at *C*,

Tail of udl is placed just to the right of *C*.

$$\text{Maximum +ve } SF = \text{Load intensity} \times \text{area under udl}$$

$$= 20 \times \frac{1}{2}\left(\frac{6}{10}+\frac{3}{10}\right)\times 3 = 27 \text{ kN}$$

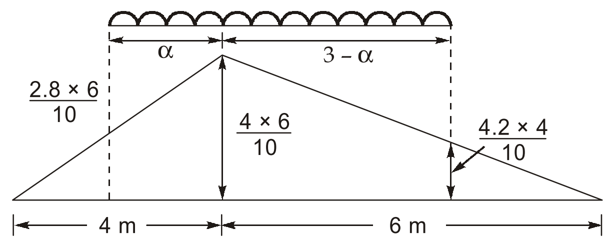
For maximum –ve SF at *C*,

Head of udl is placed just to the left of *C*

$$\text{maximum –ve } SF = \text{Loading intensity} \times \text{area under udl}$$

$$= -20\left(\frac{1}{2}\left(\frac{4}{10}+\frac{1}{10}\right)\times 3\right) = -15 \text{ kN}$$

For maximum B.M. at *C*, udl should be placed so that the section divides the udl in the same ratio as it divides the span.



$$\frac{\alpha}{3-\alpha} = \frac{4}{6}$$

$$6\alpha = 12 - 4\alpha$$

$$10\alpha = 12$$

$$\alpha = 1.2 \text{ m}$$

Maximum B.M. at C, M^{max} = Loading intensity × Area under udl.

$$= 20\times\left[\frac{1}{2}\left(\frac{2.8\times 6}{10}+\frac{4\times 6}{10}\right)\times 1.2\right]+20\left[\frac{1}{2}\left(\frac{4\times 6}{10}+\frac{4.2\times 4}{10}\right)\times 1.8\right]$$

$$= 122.4 \text{ kNm}$$

3. (a) Design a lap joint to connect two plates of size 250 mm × 12 mm to mobilize full-plate tensile strength. The permissible tensile stress in plate is 225 N/mm² and permissible shear stress in weld is 180 N/mm². The size of weld is limited to 8 mm. Draw the details.

[10 Marks]

Sol: Given, size of plates = (250 mm × 12 mm)

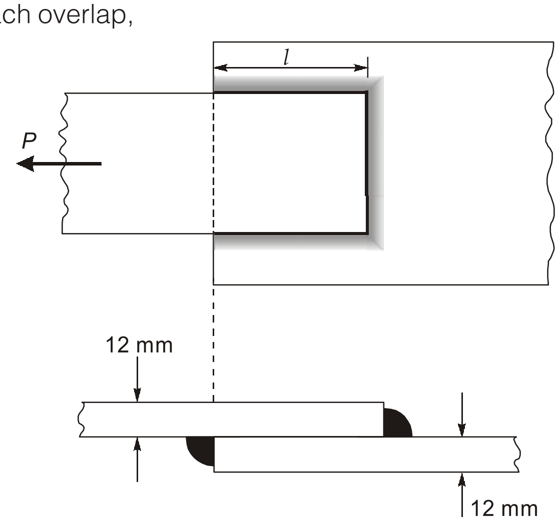
Permissible tensile stress of plate = 225 N/mm^2

Permissible shear stress of weld = 180 N/mm^2

size of weld = 8 mm

Assuming welding is done on all sides

Let *l* be the length of each overlap,



Tensile strength of plate for full strength

$$T_{dg} = \text{(Permissible tensile stress)} \times \text{Area of plate}$$
$$= 225 \times (250 \times 12)\, 10^{-3} = 675 \text{ kN}$$

For full mobilization of strength,

$$\text{strength of weld} = T_{dg}$$

$$\text{(Permissible shear stress)} \times (L_{eff} \times t_t) = 675 \times 10^3 \text{ N}$$

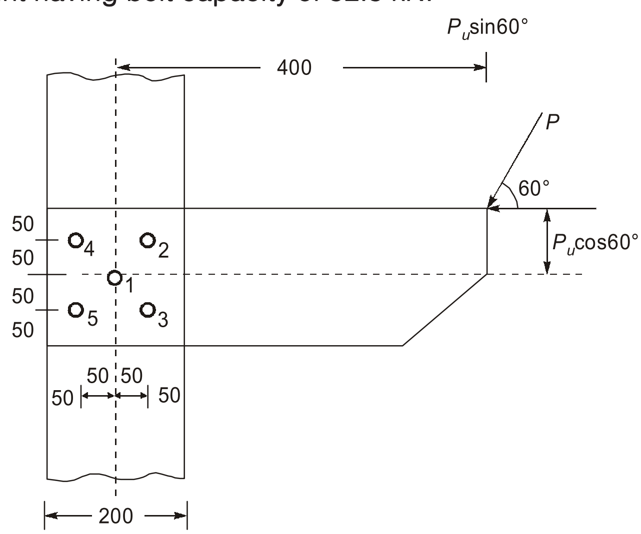
$$t_t = \text{throat thickness} = 0.7S$$
$$= 0.7 \times 8 = 5.6 \text{ mm}$$

Now, $$180 \times (2l + 2 \times 250) \times 5.6 = 675 \times 10^3$$
$$l = 84.82 \simeq 85 \text{ mm}$$
$$\text{Overlap, } l = 85 \text{ mm} \nless (4t \text{ or } 40 \text{ mm})_{max}$$
$$= (4 \times 12 \text{ or } 40 \text{ mm})_{max} = 48 \text{ mm (OK)}$$

Thus, provide 8 mm size fillet weld of length (2 × 85 + 500)

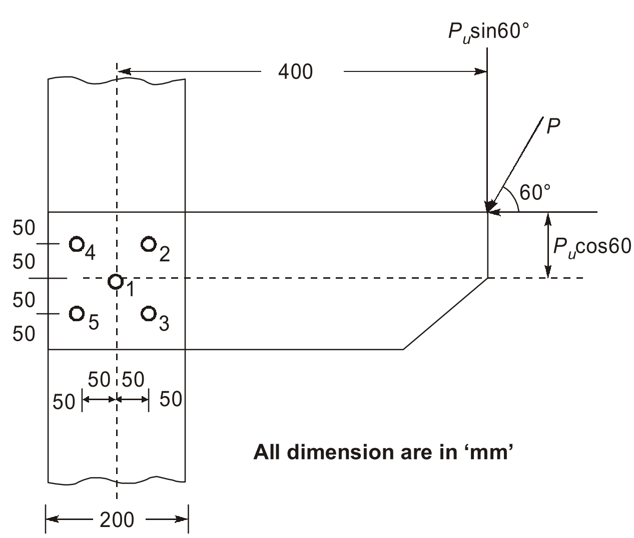
= 670 mm all round the joint to develop the full strength.

3. (b) **Find the maximum load (P) shown in fig. 3 for 20 mm diameter bolts connecting 10 mm thick bracket plate for nonslip joint having bolt capacity of 52.5 kN.**



[10 Marks]

Sol:



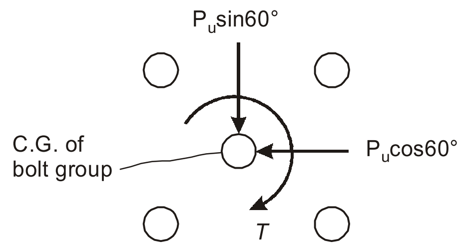
Given, diameter of bolt = 20 mm

Thickness of bracket plate = 10 mm

Bolt capacity or strength of bolt, V_{db} = 52.5 kN

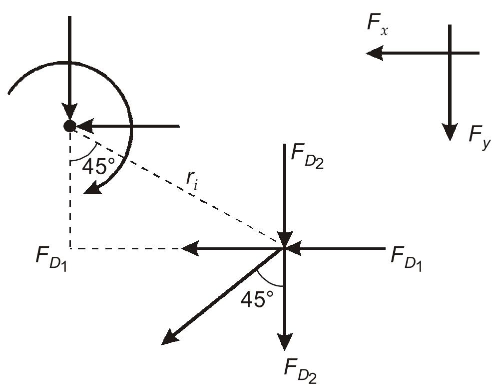
Let P_u be the ultimate load (in kN)

Bolt '3' is critical bolt,



Torsional moment on the weld group

$$T = -P_u \cos 60° \times 0.100 + P_u \sin 60 \times 0.400 = 0.2964\ P_4 \text{ kNm}$$



$$F_{D_1} = \frac{P_u \cos 60°}{5} = 0.1\ P_u$$

$$F_{D_2} = \frac{P_u \sin 60°}{5} = 0.173\ P_u$$

$$r_i = \sqrt{(50)^2 + (50)^2} = 50\sqrt{2} \text{ mm}$$

$$\sum r_i^2 = 4\left[(50\sqrt{2})^2\right] = 20000 \text{ mm}^2$$

Now, F_t = torsional shear force in the bolt

$$= \frac{Tr_i}{\Sigma r_i^2} = \frac{0.2964 P_4 \times 10^6 \text{ N-mm} \times 50\sqrt{2} \text{ mm}}{20000}$$

$$= 1047.932\ P_u\ N = 1.047\ P_u (\text{kN})$$

Direct shear force in the bolt

$$F_{D1} = 0.1 P_u \text{ kN};\ F_{D2} = 0.173\ P_u \text{ kN}$$

$$F_x = F_{D2} + F_t \sin 45°$$

$$= 0.173 P_u + 1.047 P_u \times \frac{1}{\sqrt{2}} = 0.914 P_u$$

$$F_y = F_{D1} + F_t \cos 45°$$

$$= 0.1 P_4 + 1.047 P_u \times \frac{1}{\sqrt{2}} = 0.84 P_u$$

Resultant stress on the weld

$$F_r = \sqrt{F_x^2 + F_y^2} = \sqrt{(0.914 P_u)^2 + (0.84 P_u)^2} = 1.241 P_4$$