To: Sir Haider Ali

PROJECT REPORT

Group Members:

M. USMAN 241202

TOUSEEF 241196

AREEBA 241253

SECTION: BEME-F-24-B

MECHANICS OF MATERIAL-I

DMAE-Air University Islamabad

STRUCTURAL ANALYSIS AND DESIGN OF A SIMPLE SUPPORTED STEEL VEHICLE/PEDESTRIAN BRIDGE

Introduction

This project focuses on the design of a simply supported bridge for pedestrian and light vehicle use. The bridge is analyzed under dead load, live load, and environmental effects such as wind. Structural analysis is performed to determine reactions, shear forces, bending moments, and deflections, and the main beams are designed to satisfy strength and serviceability requirements using either structural steel or reinforced concrete. The final design includes a schematic layout and a brief evaluation of its performance and limitations.

Problem defination

This project involves the analysis and design of a simply supported bridge subjected to various loading conditions using Mechanics of Materials principles. The aim is to evaluate stresses and deflections in the structure and ensure that the design is safe, stable, and within allowable limits for the selected material

Assumptions

- The beam is rectangular beam
- Assume that we take the value of FOS (factor of safety) as 1.67.
- And dimensions of the beam are
  Length=50m, Width=5m
- Loads acts perfectly Vertical
- Pedestrian Load = 5kN/m
- Dead load = 25kN/m
- Concentrated Loads = (25, 50 and 25) kN
- Wind Load = 2kN/m

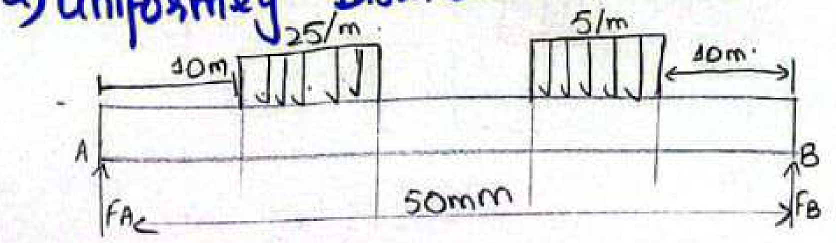
Material Properties

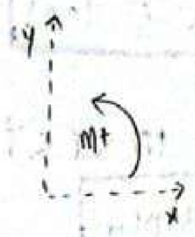
- Structural Steel (E = 200 GPa)
- Yield Strength = 250 MPa
- Density = 2500 kg/m³
- Compressive Strength = 40 MPa
- Maximum Stress = 150MPa

Formulas

$$M_{max} = \frac{PL}{4} \qquad M_{max} = \frac{wL^2}{8} \qquad \sigma = \frac{Mc}{I} \qquad I = \frac{1}{12}bh \qquad \delta = \frac{PL}{AE}$$

a) Uniformly Distributed Loads:-





Calculations:-

$\Sigma F_y = 0.$

$F_A + F_B - 125 - 25 = 0.$

$F_A + F_B = 150\ kN. \quad — (1).$

$\Sigma M_A = 0.$

$125(12) - 25(38) + F_B(50) = 0.$

$F_B = 51.5\ kN.$

Now putting the value of F_B in (1).

$F_A + 51.5 = 150.$

$F_A = 98.5\ kN.$

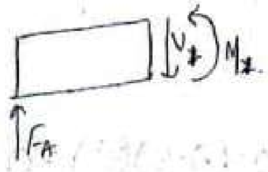
- Calculations of shear forces & moments:-

$\Sigma F_{y_1} = 0.$

$+F_A - V_1 = 0.$

$98.5 - V_1 = 0$

$\boxed{V_1 = +98.5}$

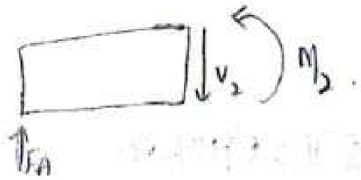


$\Sigma M_1 = 0.$

$\boxed{M_1 = 0}$

$\Sigma F_{y_2} = 0.$

$\boxed{V_2 = 98.5}$

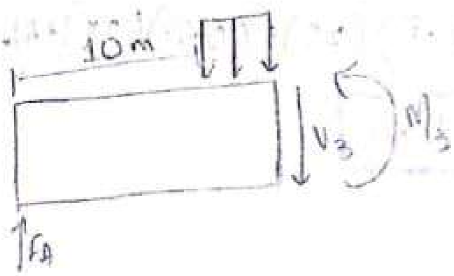


$\Sigma M_2 = 0.$

$-(98.5)(10) + M_2 = 0.$

$\boxed{M_2 = 985\ kNm}$

$\Sigma F_{y_3} = 0.$



$F_A - 25(3) - V_3 = 0.$

$\therefore 98.5 - 25 \times 3 = V_3.$

$\boxed{V_3 = 23.5\ kN}$

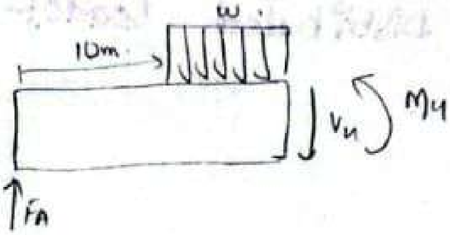
$\Sigma M_3 = 0.$

$-(98.5)(13) - 12.5(3)^2$

$\boxed{M_3 = 1168\ kNm}$

* $98.5 - 25(5) - V_4 = 0$.

$\boxed{V_4 = -26.5\ kN}$



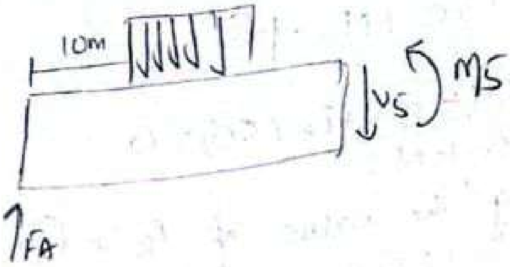
$\Sigma M_4 = 0$.

$(98.5)(15) - 12.5(5)^2$.

$\boxed{M_4 = 1165\ kNm}$.

* $98.5 - 25(5) - V_5 = 0$.

$\boxed{V_5 = -26.5\ kN}$.

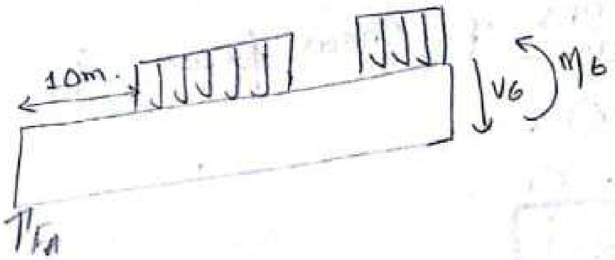


$\Sigma M_5 = 0$

$(98.5)(35) - 12.5(5)^2 = 0$.

$\boxed{M_5 = 3135\ kN\ m}$.

* $\Sigma Fy_6 = 0$



$F_A - 125 - 15 - V_6 = 0$.

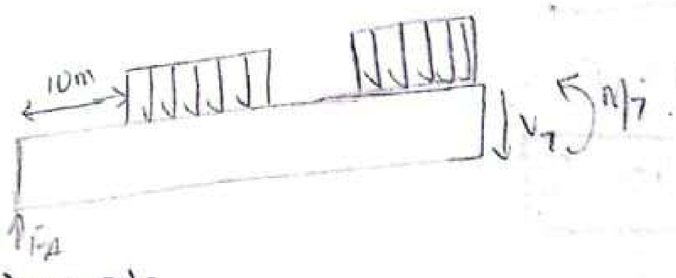
$98.5 - 125 - 15 - V_6 = 0$.

$\boxed{V_6 = -41.5}$.

$\Sigma M_6 = 0$.

$-(98.5)(38) + ((12.5)(25) + M_6 \cancel{=0} \cdot (2.5)(3^2) = 0$.

$\boxed{M_6 = 3408\ kNm}$.



$\Sigma Fy_7 = 0$

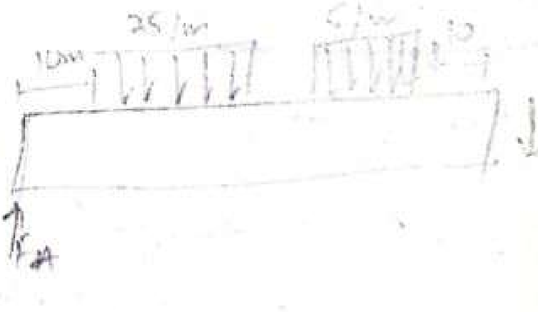
$F_A - 125 - 25 - V_7 = 0$.

$\boxed{V_7 = -51.5\ Nm}$.

$\Sigma M_7 = 0$.

$-(98.5)(40) + ((12.5)(25) + (2.5)(25) + M_7 = 0$.

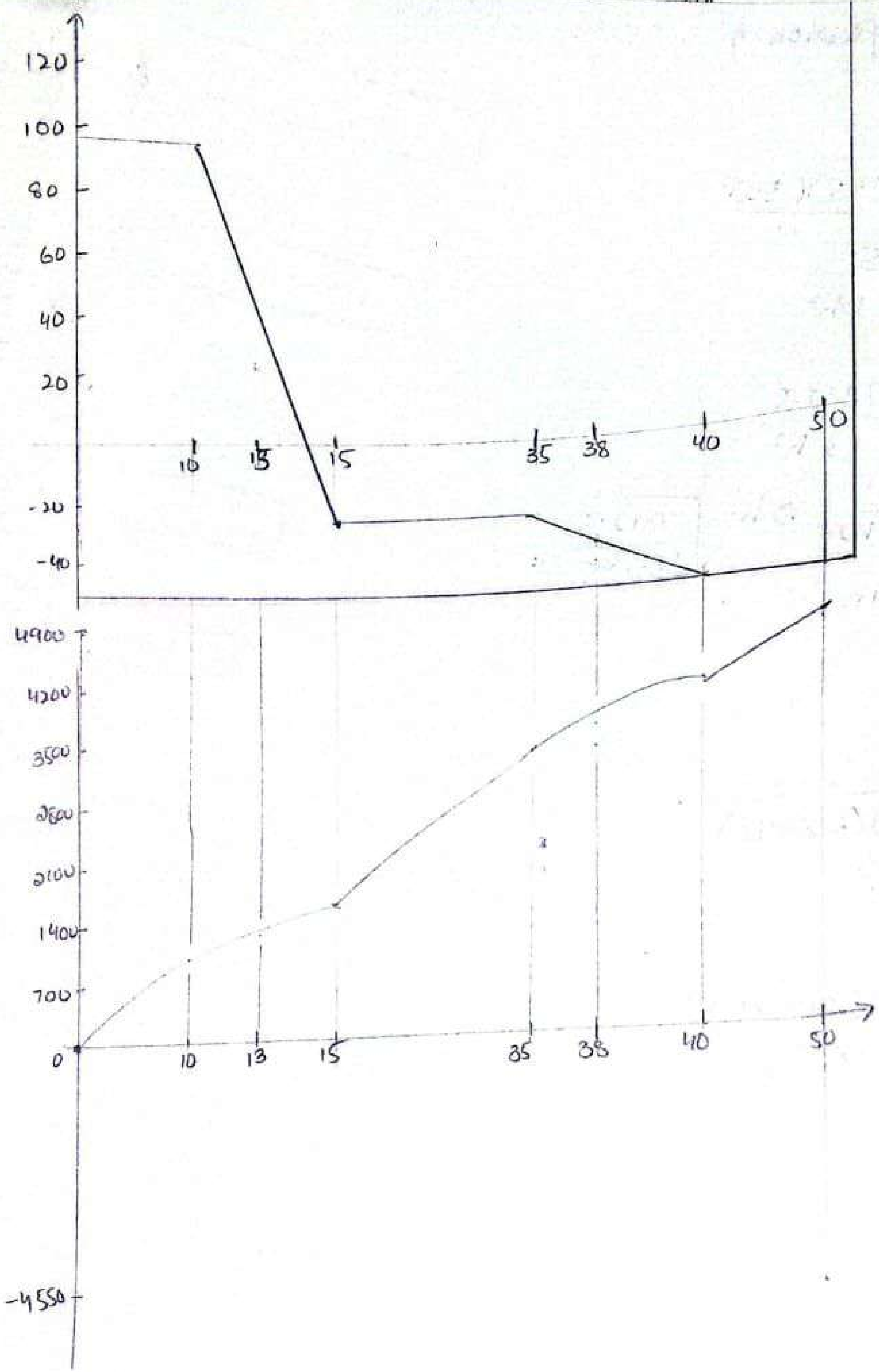
$\boxed{M_7 = 3565\ kN\ m}$.



$\Sigma M_8 = 0$.

$-(98.5)(50) + ((12.5)(25) + (2.5)(25) + M_8 = 0$.

$\boxed{M_8 = -4550\ kN\ m}$


120
100
80
60
40
20
10
13
15
35
38
40
50
-20
-40
4900
4200
3500
2800
2100
1400
700
0
10
13
15
35
38
40
50
-4550

*** Calculating Deflection ;**

$w = 25$

$l = 50$.

$M_{max} = \frac{wl^2}{8} = \frac{(25)(50)^2}{8}$.

$M_{max} = 7812.5$

$\sigma = \frac{Mc}{I}$, $I = \frac{1}{2} bh^3$.

$\sigma = \frac{M}{bh^2} = \frac{7812.5}{5 \times h^2}$

$\frac{150 \times 5}{7812.5} = \frac{1}{h^2} \Rightarrow h = \sqrt{\frac{7812.5}{150 \times 5}}$.

$h = 0.102m$.

* Deflection :-

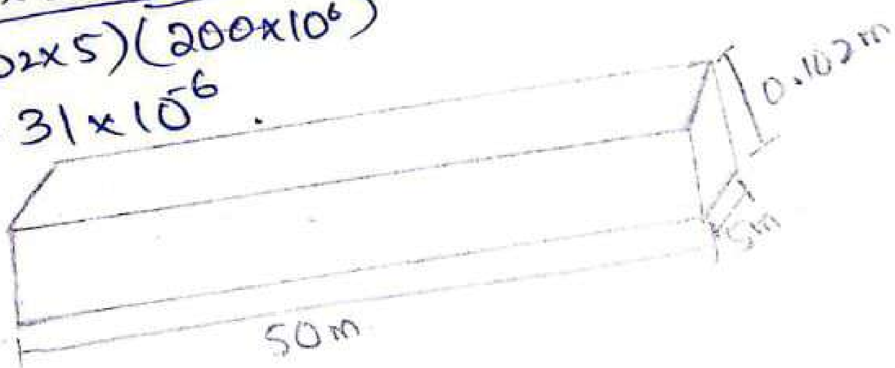
$\delta = \int \frac{PL}{AE}$.

$\delta_c = \frac{125 \times 13}{(0.102 \times 5)(200 \times 10^6)}$.

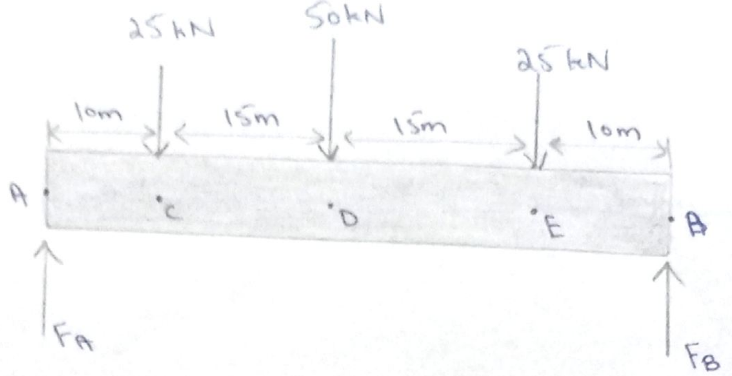
$= 1.59 \times 10^{-5}$.

$\delta_D = \frac{25 \times 38}{(0.102 \times 5)(200 \times 10^6)}$

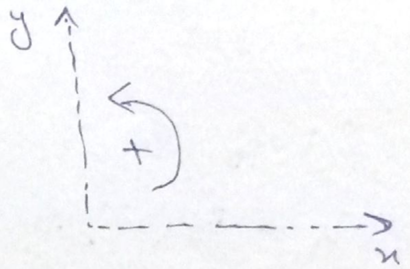
$= 9.31 \times 10^{-6}$.



b) Concentrated Load at mid span



Reaction Forces:



$\sum F_y = 0$

$F_A - F_C - F_D - F_E + F_B = 0$

$F_A + F_B = 100\ kN$

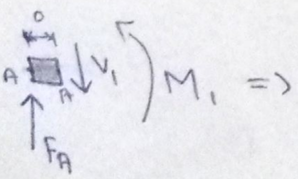
$\sum M_A = 0$

$-(25 \times 10) - (50 \times 25) - (25 \times 40) + F_B(50) = 0$

$F_B = 50kN$

So, $F_A = 50kN$

Calculating Shear Force and Moments:



$\Rightarrow$

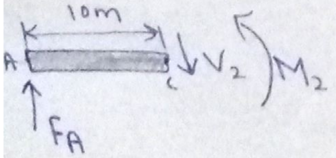
$\sum F_y = 0$

$F_A - V_1 = 0$

$\boxed{V_1 = 50kN}$

$\sum M_A = 0$

$\boxed{M_1 = 0}$



$\Rightarrow$

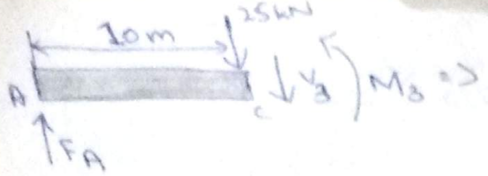
$\sum F_y = 0$

$\boxed{V_1 = 50kN}$ $\longrightarrow$ because no additional force applied

$\sum M_c = 0$

$M_1 - F_A(10) = 0$

$\boxed{M_1 = 500kNm}$



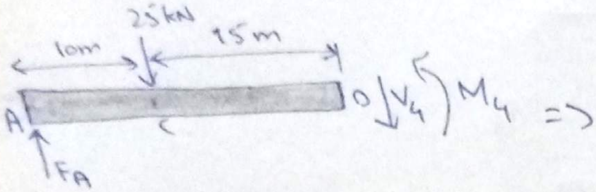
$\Rightarrow \sum F_y = 0$

$F_A - V_3 - 25 = 0$

$\boxed{V_3 = 25 \text{ kN}}$

$\sum M_c = 0$

$\boxed{M_3 = 500 \text{ kNm}}$ → because no change in x



$\Rightarrow \sum F_y = 0$

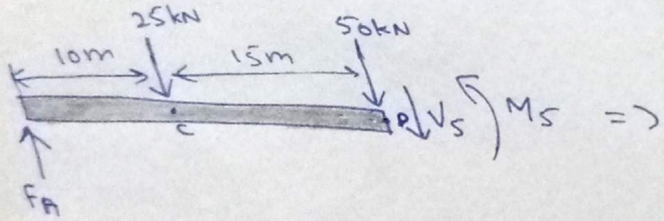
$F_A - V_4 - 25 = 0$

$\boxed{V_4 = 25 \text{ kN}}$

$\sum M_D = 0$

$M_4 - F_A(25) + 25(15) = 0$

$\boxed{M_4 = 875 \text{ kNm}}$



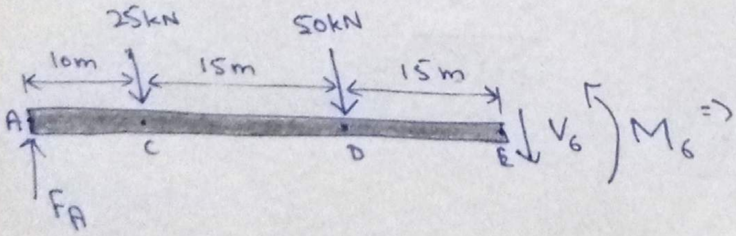
$\Rightarrow \sum F_y = 0$

$F_A - V_5 - 25 - 50 = 0$

$\boxed{V_5 = -25 \text{ kN}}$

$\sum M_D = 0$

$\boxed{M_5 = 875 \text{ kNm}}$ → because no change in x



$\Rightarrow \sum F_y = 0$

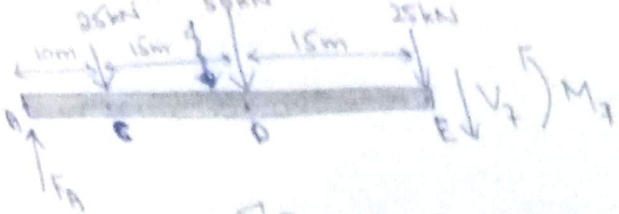
$F_A - V_6 - 25 - 50 =$

$\boxed{V_6 = -25 \text{ kN}}$

$\sum M_E = 0$

$M_6 - F_A(40) + 25(30) + 50(15) = 0$

$\boxed{M_6 = 500 \text{ kNm}}$



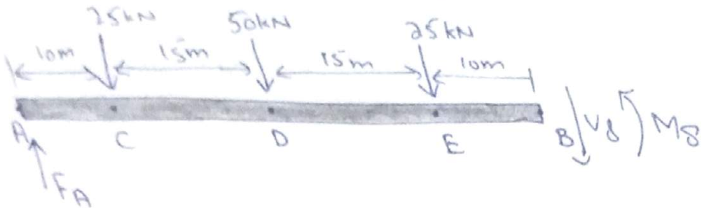
$\sum F_y = 0$

$F_A - V_7 - 25 - 50 - 25 = 0$

$\boxed{V_7 = -50 \text{ kN}}$

$\sum M_E = 0$

$\boxed{M_7 = 500 \text{ kNm}}$ → because no change in x

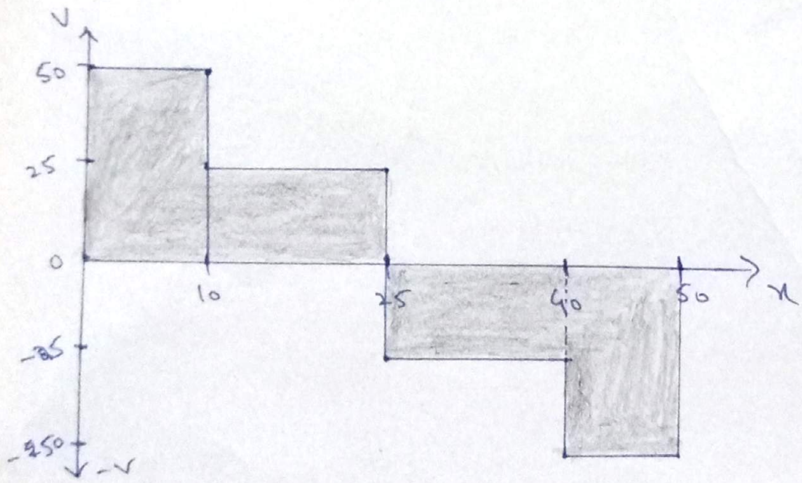


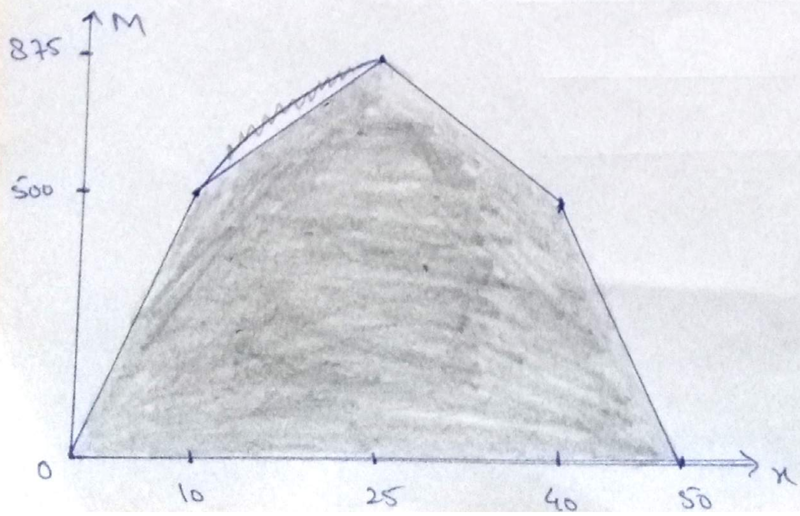
$V_8 = V_7 = -50 \text{kN}$ } → because no additional force applied.

$\sum M_B = 0$

$M_8 - F_A(50) + 25(40) + 50(25) + 25(10) = 0$

$\boxed{M_8 = 0 \text{ kNm}}$





$\sigma_{max} = 150\ MPa = 150 \times 10^6\ Pa$ or Nm^{-2}

$$\sigma_{max} = \frac{M_{max}\, c}{I}$$

$$\boxed{c = h/2}$$

$$\boxed{I = \tfrac{1}{12} bh^3}$$

$$\sigma_{max} = \frac{M_{max}\,(h/2)}{\tfrac{1}{12} bh^3}$$

$$\sigma_{max} = \frac{M_{max}}{bh^2}$$

$$\boxed{M_{max} = \frac{PL}{4}}$$

$$\sigma_{max} = \frac{6PL}{\cancel{6\times}4 \times bh^2}$$

$$h = \sqrt{\frac{6PL}{\cancel{6}4\, b\, \sigma_{max}}}$$

$$h = \sqrt{\frac{6 \times 50 \times 10^3 \times 50}{\cancel{6\times}4 \times 5 \times 150 \times 10^6}}$$

$$\boxed{h = 0.029\,m}$$

$$\text{Area} = b \times h$$
$$\text{''} = 5 \times 0.029$$
$$\text{Area} = 0.144\ m^2$$

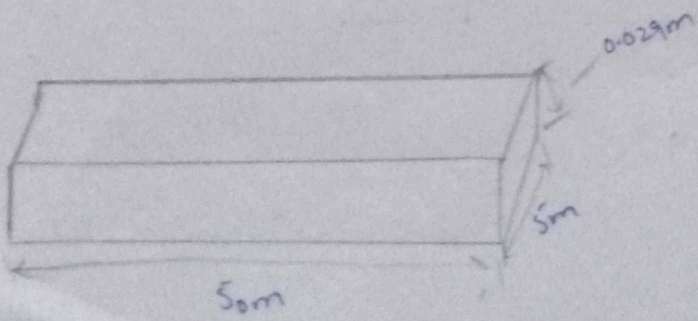
$$\delta = \sum \frac{PL}{AE}$$

$$\delta = \frac{P_c L_c}{A_c E} + \frac{P_D L_D}{A_D E} + \frac{P_E L_E}{A_E E}$$

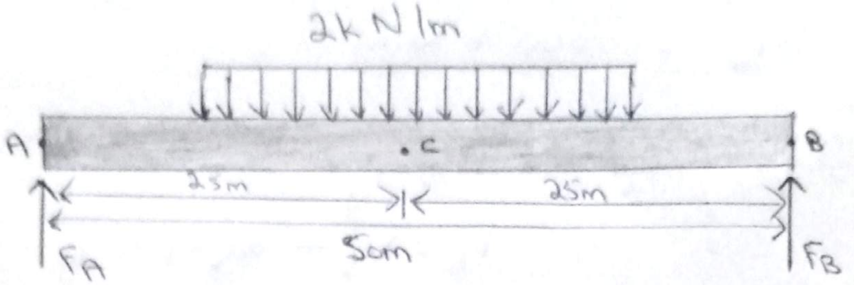
$$\delta = \frac{25 \times 10^3 \times 10}{0.144 \times 200 \times 10^9} + \frac{50 \times 10^3 \times 25}{0.144 \times 200 \times 10^9} + \frac{25 \times 10^3 \times 50}{0.144 \times 200 \times 10^9}$$

$$\delta = 8.68 \times 10^{-6} + 4.34 \times 10^{-5} + 4.34 \times 10^{-5}$$

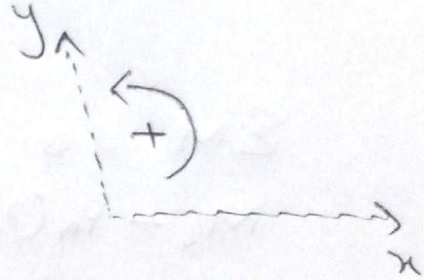
$$\boxed{\delta = 9.55 \times 10^{-5}\ m}$$



c) Wind Load or lateral load effect



Reaction forces:



$$\sum F_y = 0$$

$$F_A + F_B = 2(30)$$

$$F_A + F_B = 60 \quad \text{—— (1)}$$

$$\sum M_A = 0$$

$$-60(25) + F_B \times 50 = 0$$

$$F_B = \frac{60 \times 25}{50}$$

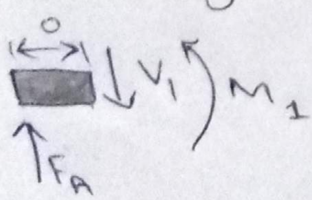
$$\boxed{F_B = 30\,kN}$$

Put in (1)

$$F_A = 60 - 30$$

$$\boxed{F_A = 30\,kN}$$

Calculating Shear force and Moments:

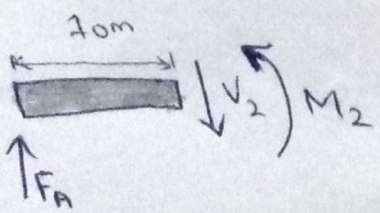


$$\Rightarrow F_A - V_1 = 0$$

$$\boxed{V_1 = 30\,kN}$$

$$\sum M = 0$$

$$\boxed{M_1 = 0}$$



$$\Rightarrow F_A - V_2 = 0$$

$$\boxed{V_2 = 30\,kN}$$

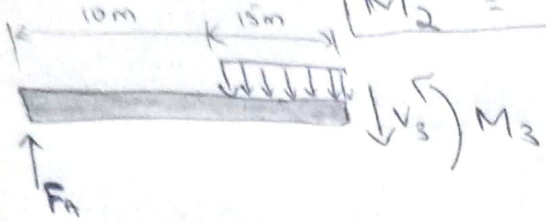
Shear force eq $= -2x$

Moment $\rightarrow -x^2$

$$\Sigma M = 0$$

$$M_2 - 30(10) = 0$$

$$\boxed{M_2 = 300 \text{ kNm}}$$



$\Rightarrow$

$$\Sigma F_y = 0$$

$$F_A - V_3 - 2(x) = 0$$

$$V_3 = 30 - 2(15)$$

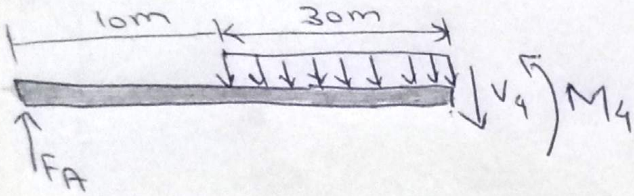
$$\boxed{V_3 = 0}$$

$$\Sigma M = 0$$

$$M_3 - F_A(25) + (15)^2 = 0$$

$$M_3 = 30(25) - (15)^2$$

$$\boxed{M_3 = 525 \text{ kNm}}$$



$\Rightarrow$

$$\Sigma F_y = 0$$

$$F_A - V_4 - 2(x) = 0$$

$$V_4 = 30 - 2(30)$$

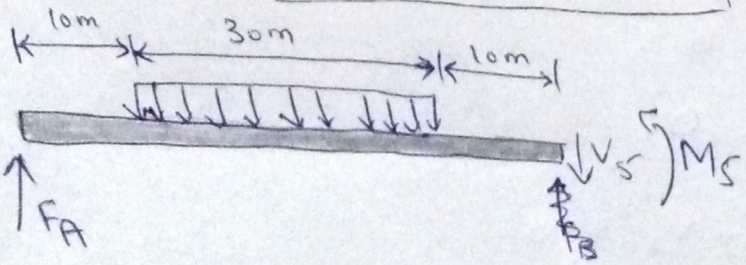
$$\boxed{V_4 = -30 \text{kN}}$$

$$\Sigma M = 0$$

$$M_4 - F_A(40) + (30)^2 = 0$$

$$M_4 = 30(40) - (30)^2$$

$$\boxed{M_4 = 300 \text{kNm}}$$



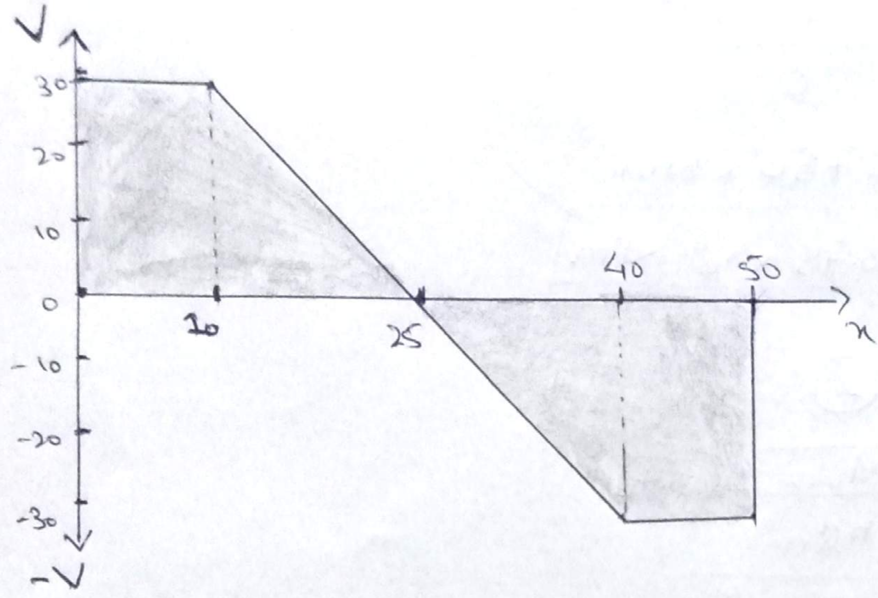
$\Rightarrow$ $\boxed{V_5 = -30 \text{kN}}$

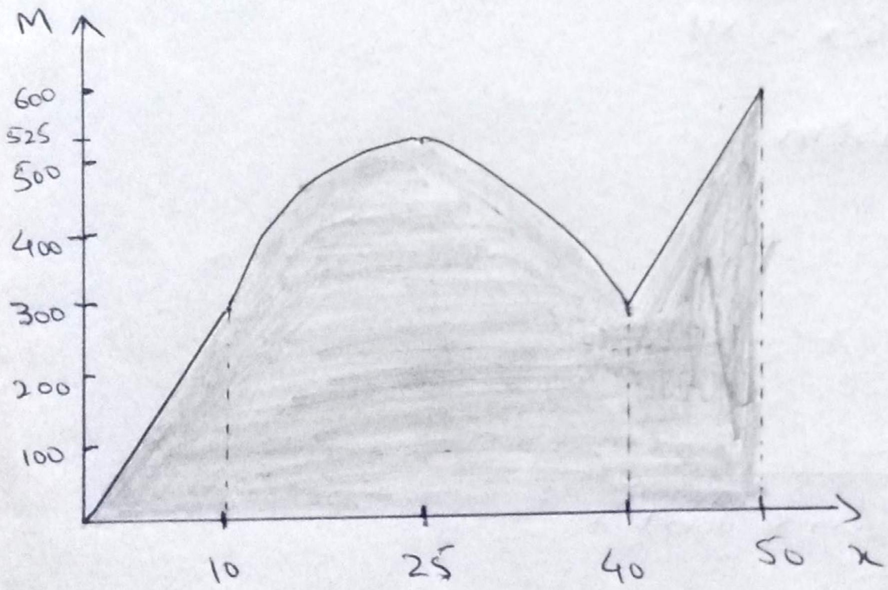
$$\Sigma M = 0$$

$M_S - F_A(50) + (30)^2 = 0$

$M_S = 30(50) - (30)^2$

$\boxed{M_S = 600 \text{ kNm}}$





$\sigma_{max} = 150 \text{ MPa} = 150 \times 10^6 \text{ Nm}^{-2}$

$\sigma_{max} = \dfrac{M_{max}\, c}{I}$

$c = h/2$

$I = \frac{1}{12} b h^3$

$\sigma_{max} = \dfrac{M_{max} \times h/2}{\frac{1}{12} b h^3}$

$\sigma_{max} = \dfrac{M_{max}}{1/6\, b h^2}$ —— 2

$\Rightarrow \quad M_{max} = \dfrac{wL^2}{8}$

Put values, we get

$$M_{max} = \frac{60 \times (50)^2}{8}$$

$$M_{max} = 18750 \text{ kNm}$$

or $\boxed{M_{max} = 18.75 \times 10^6 \text{ Nm}}$

Put values in (2), we get

(2) $\Rightarrow \quad h = \sqrt{\dfrac{6 \times M_{max}}{b\,\delta_{max}}}$

$$h = \sqrt{\frac{6 \times 18.75 \times 10^6}{5 \times 150 \times 10^6}}$$

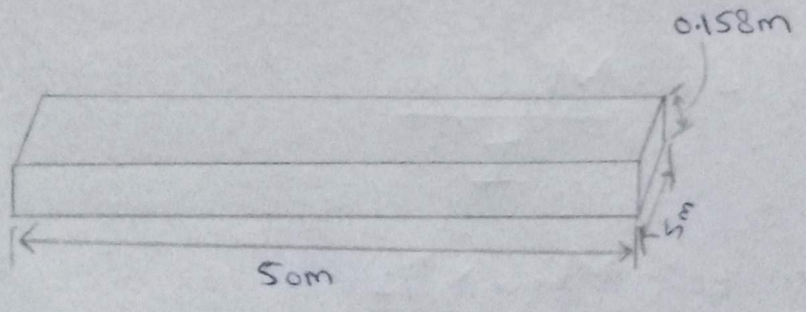
$$\boxed{h = 0.158 m}$$

at point c:

$$\delta_c = \frac{P_c L_c}{A_c E_c} = \frac{P_c L_c}{b \times h \times E_c}$$

$$\delta_c = \frac{60 \times 10^3 N \times 25 m}{5m \times 0.158m \times 200 \times 10^9 Nm^{-2}}$$

$$\boxed{\delta_c = 9.49 \times 10^{-6} m}$$



Advantages

- **Simplicity:** Simply supported design is easy to analyze, construct, and maintain.
- **Cost-effective:** Requires less material and labor compared to continuous or cantilever bridges.
- **Versatility:** Can accommodate both pedestrian and light vehicle traffic.
- **Predictable behavior:** Structural responses (shear, bending, deflection) are straightforward to calculate.

Limitations

- **Limited span:** Simply supported beams are not ideal for long spans without intermediate supports.
- **Higher deflection:** Longer spans may experience larger deflections compared to continuous bridges.
- **Stress concentration:** Maximum bending occurs at mid-span, which may require stronger sections.
- **Limited redundancy:** Failure of one beam can affect overall bridge performance.

Possible Improvements

- **Use continuous or composite beams** for longer spans and reduced deflection.
- **Optimize material selection** to reduce weight while maintaining strength (e.g., high-strength steel or prestressed concrete).
- **Add lateral bracing or stiffeners** to improve stability under wind or vehicle loads.
- **Incorporate modular design** for easier construction and maintenance.

Summary

This project focused on the design and analysis of a simply supported bridge for pedestrian and light vehicle traffic. The bridge was evaluated under multiple loading scenarios, including dead load, live load, and environmental effects. Structural analysis was performed to determine reactions, shear forces, bending moments, and deflections. The main beams were designed using either structural steel or reinforced concrete to satisfy strength and serviceability criteria. The final design provides a safe, practical, and cost-effective solution, with potential improvements identified for longer spans, material optimization, and enhanced stability.