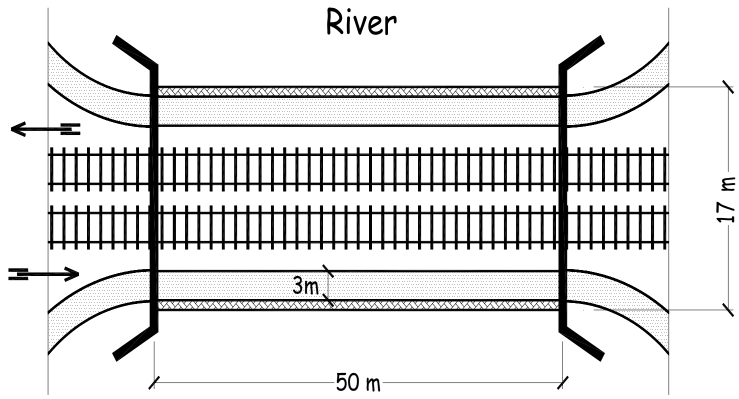
Material of construction is **steel 52** and Live load is according to the Egyptian Code of Practice.
Data not given may be reasonably assumed./

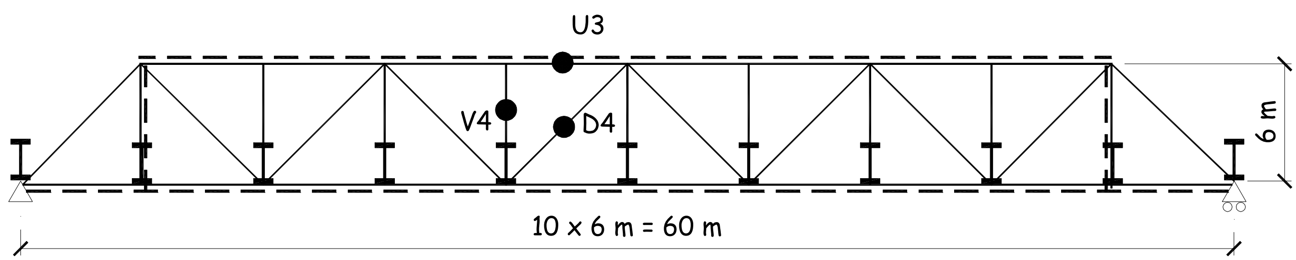
Question (1): 35%

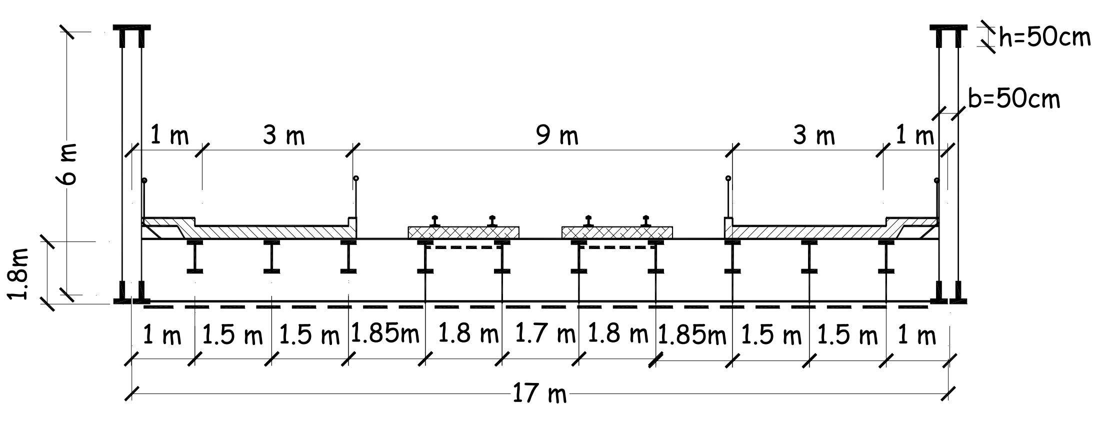
A combined road-railway bridge is to be constructed to cross a river of width 50 m. The total bridge width is 17 m including 1.0 m side walk at each side. The high water levels of the river is (+40.0). Top level of the roads is (+51.0). The minimum clearance required for navigation at the river is 5.0 m. Using a suitable scale, draw a complete general layout (for the 50 m span between the piers) showing the arrangement of the main elements of the bridge, floor beams and bracing systems in different views.



Question (2): 80%

A combined rail-roadway pony welded truss bridge of the shown cross section has a span of 60 m and is divided into 10 equal panels 6.0 m each. The main trusses are spaced 17 m apart. Depth of the main truss is 6.0 m. The inner spacing between the gusset plates is 50 cm, and depth of the upper and lower truss chords is taken as 50 cm. Depth of the welded cross girder is taken as 1.8 m. It is required to;





AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
STRUCTURAL ENGINEERING D

DESIGN OF STEEL BRIDGES
Fourth Year Civil – (Structural Eng. Sec.)
COURSE NO. CES 452
١St Term, December 2014
Time : 3 Hrs

1- Calculate the maximum B.M. and maximum S.F. of in intermediate cross-girder due to live load and impact only. I+1= $0.73 + \frac{2.16}{\sqrt{L_i}-0.2}$, where L_i = Effective Length for designed member **(15%)**

2- Design a welded built-up section for an intermediate cross-girder knowing that;

$M_{D.L.}$ = 110 m.t $Q_{D.L.}$ = 32 t F_{sr} = 1.26 t/cm^2 **(15%)**

3- Check the tendency of web buckling due to pure shearing stresses in the critical panel of the cross girder (Consider $Q_{Mid\text{-}Panel} = 0.94\ Q_{D+L+I}$).

[k_q=5.34+ (4/α^2), for α>1 & k_q=4+ (5.34/α^2), for α<1, $\lambda_q = \frac{d/t_w}{57}\sqrt{\frac{F_y}{k_q}}$ for $\lambda_q \le 0.8$ $q_b = 0.35F_y$,

for $0.8 < \lambda_q < 1.2$ $q_b = (1.5-0.625\ \lambda_q)\ 0.35F_y$, and for $\lambda_q \ge 1.2$ $q_b = (0.9/\lambda_q)\ (0.35F_y)$]. **(5%)**

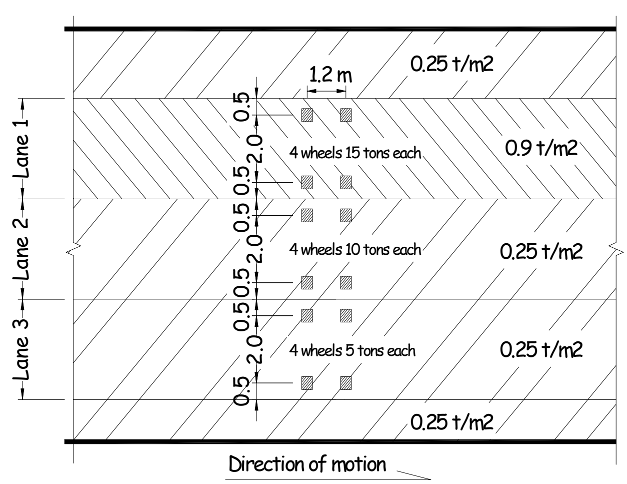
4- Design an intermediate transverse stiffener for the welded cross girder, consider $Q_{stiffener} = 0.9\ Q_{D+L+I}$

where: $C_s = 0.65\ [(0.35F_y/q_b)-1]\ Q_{stiffener}$ **(5%)**

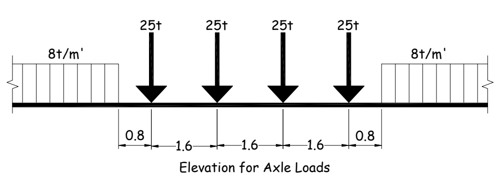
5- Find maximum and minimum forces in marked members U3, D4 and V4 due to live loads and impact only. **(20%)**

6- Design suitable sections for the marked members U1, D4 and V4, knowing that;
For U3: F_D= -527 t (Comp.), D4: F_D= -31 t (Comp.),
Note: for member (U3), consider the flexibility of U-frame action δ= 0.08 cm/ton **(20%)**

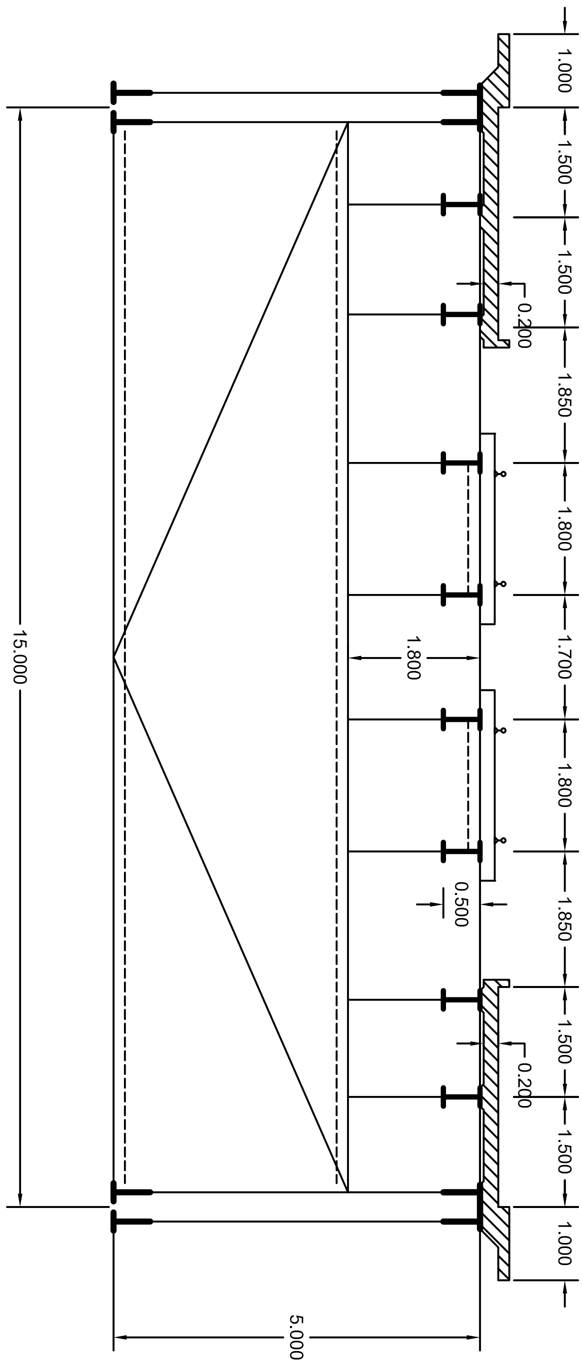
Roadway Load Pattern



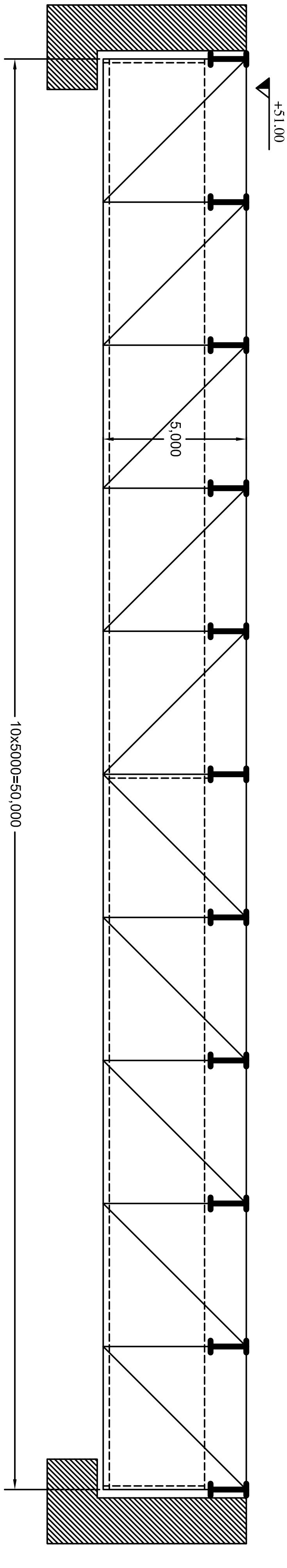
Railway Load Pattern



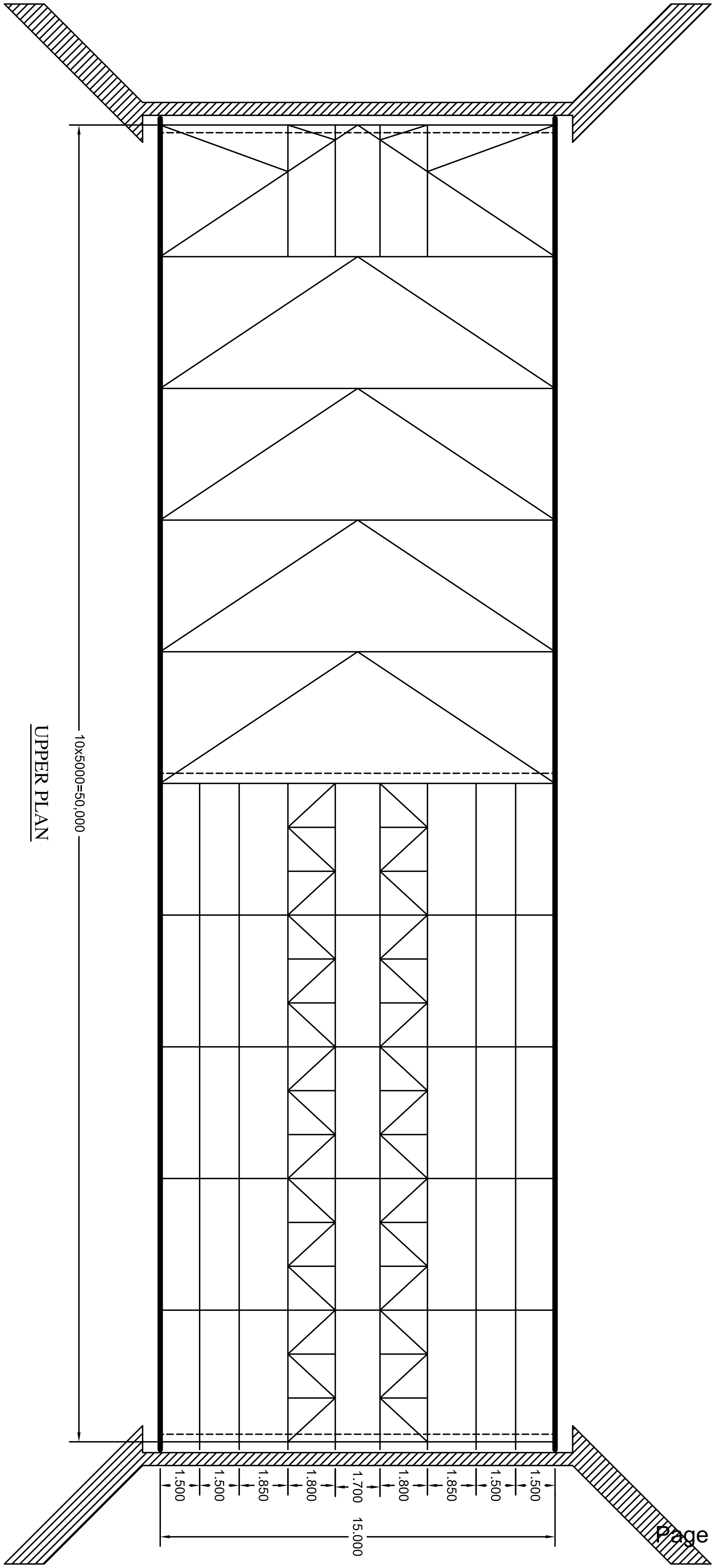
--- GOOD LUCK ---



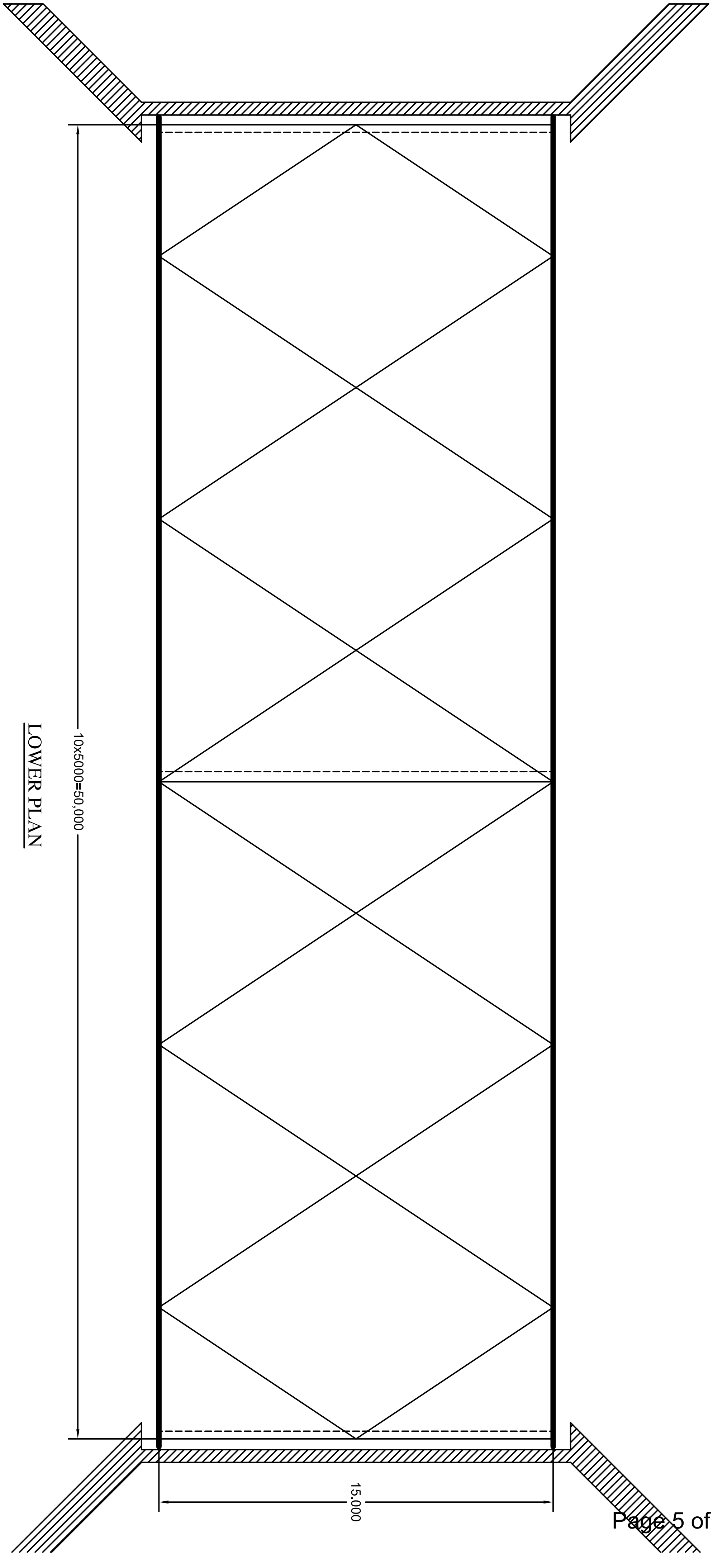
CROSS SECTION



ELEVATION


10x5000=50,000
1.500
1.500
1.850
1.800
1.700
1.800
1.850
1.500
1.500
15.000

UPPER PLAN



LOWER PLAN

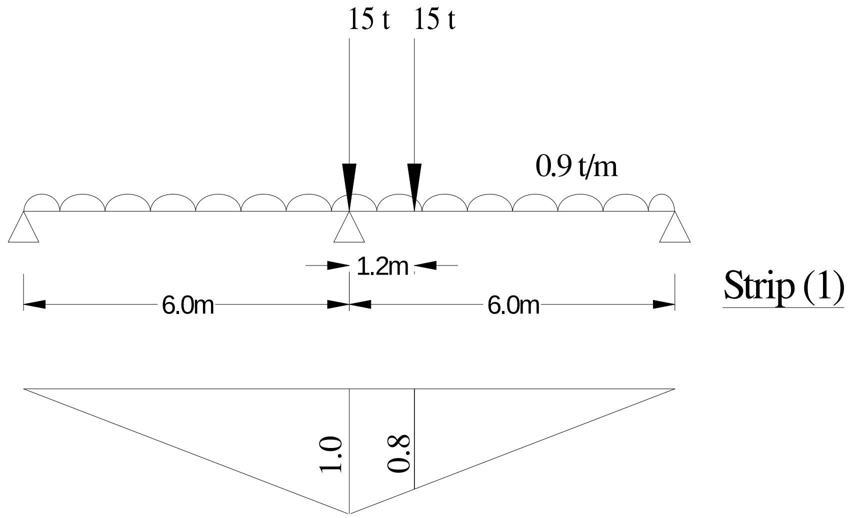
Question (2):

1) Max. Bending moment & Shear on Intermediate X.G.:

- Roadway Part:

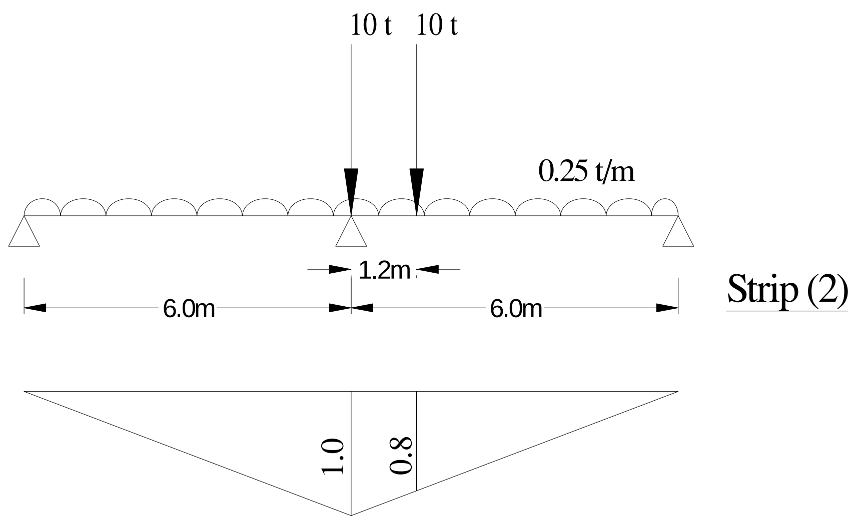
P_1=15(1+0.8) = **27 t**

W_1=0.9x6 = **5.4 t/m'**



P_2=10(1+0.8) = **18 t**

W_2=0.25x6 = **1.5 t/m'**

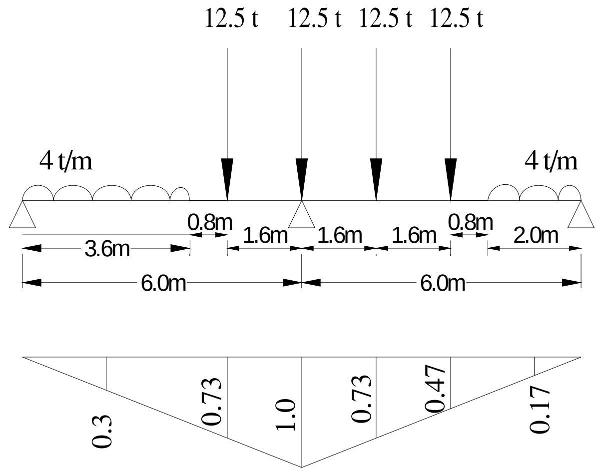


- Railway part:

P = 12.5(1+0.73+0.73+0.47) +4(3.6x0.3+2x0.17) = **42.3 t**

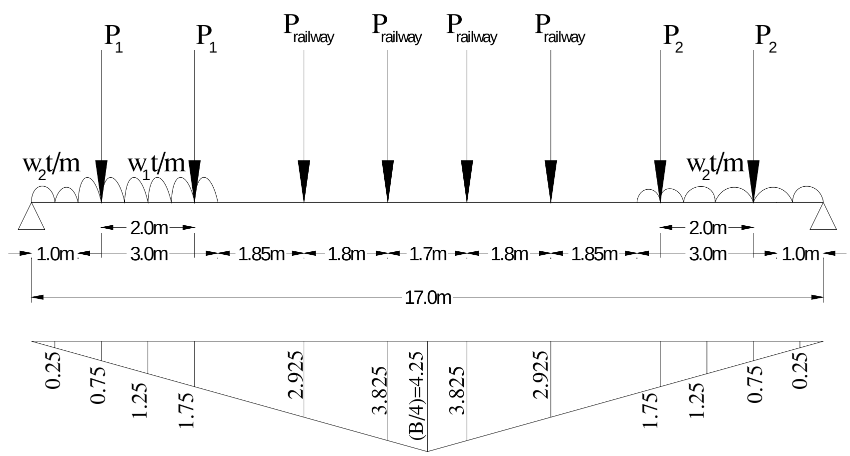
$$(1 + \mathrm{I}) = 0.73 + \frac{2.16}{\sqrt{2x17} - 0.2} = 1.114$$

∴ P (1+I) = 42.3x1.114 = **47.12 ton**



Railway strip

➔<u>Case of Max moment:</u>



$M_{L.L.+I}$=47.12x2x(3.825+2.925) +27(1.75+0.75) +18(1.75+0.75) +5.4(3x1.25) +1.5(3x1.25+2x1x0.25)

= **775.25 m.t**

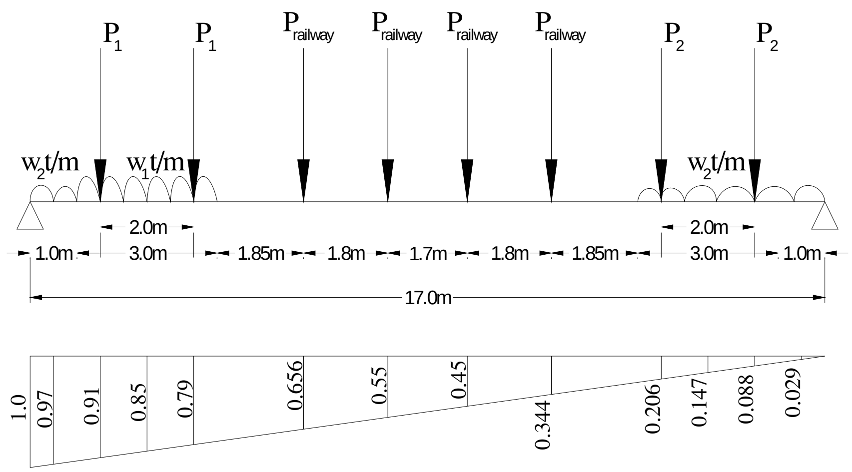
$M_{Fatigue}$=47.12x2x(3.825+2.925) +0.7x27(1.75+0.75) +0.7x18(1.75+0.75) +0.3x5.4(3x1.25) +0.3x1.5(3x1.25+2x1x0.25)

= **722.86 m.t**

➔Case of Max. Shear:

$Q_{L.L.+I}$ =47.12(4x0.5) +27(2x0.85) +18(2x0.147) +5.4(3x0.85) +1. 5(3x0.147+1x0.97+1x0.029)

= **175.13 t**



2) Design of Intermediate X.G:

➔Design values:

$M_{max.} = M_D + M_{L.+I}$ = 110+775.25= 885.25 m.t

$Q_{max.} = Q_D + Q_{L.+I}$ = 32+175.13= 207.13 t

$M_{Fatigue}$ = 722.86 m.t

➔Design of built up section:

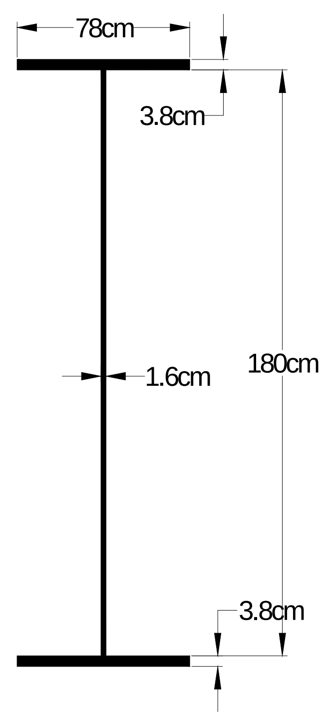
∗Web Dim's:

H_w = **180 cm** (given)

$t_w = \frac{d_w}{t_w} < \frac{830}{F_y}$ ∴ t_w = 0.78 cm

$= \frac{Q_{max}}{d_w t_w} = 0.35\ F_y$ ∴ t_w = 0.91 cm

$= \frac{d_w}{t_w} < \frac{190}{\sqrt{F_y}}$ ∴ t_w = 1.8 cm use t_w = **1.6 cm**



∗Flange Dim's:

$0.58F_y$ = ([T or C]/A) $T=C=\frac{M_{max}}{0.98d} = \frac{885.25x100}{0.98x180}$ =501.84 t

$A=\frac{501.84}{0.58x3.6}$ = 240.35 cm^2

$A = b_f\ t_f + (1/6)\ h_w\ t_w = b_f\ t_f + (1/6)$ x180x1.6

∴ $b_f\ t_f$ =192.35 $b_f = 20\ t_f$ ∴ t_f = 3.10 = **3.2 cm** ∴ b_f = **62 cm**

∗Properties of Area:

$$I_x = \frac{t_w x d_w{}^3}{12} + 2 b_f t_f (\frac{d_w}{2} + \frac{t_f}{2})^2$$

$$= \frac{1.6x180^3}{12} + 2x62x3.2(\frac{180}{2} + \frac{3.2}{2})^2 = 4106974.21 \text{ cm}^4$$

∗Checks:

1) Max Stresses:

$$\frac{M_{d+l+I}}{I_x} x(d/_2 + t_f) = \frac{885.25x100}{4106974.21} x(\frac{180}{2} + 3.2) = 2.0 \text{ t/cm}^2 < 0.58\ F_y = 2.1 \text{ t/cm}^2$$ **Safe**

2) Stress Range:

$$\frac{M_{Fatigue}}{I_x} x(d/_2 + t_f) = \frac{722.86x100}{4106974.21} x(\frac{180}{2} + 3.2) = 1.64 \text{t/cm}^2 < F_{sr} = 1.26 \text{ t/cm}^2$$ **Unsafe**

Increase Flange Dimension

$$\frac{M_{Fatigue}}{I_x} x(d/_2 + t_f) = \frac{722.86x100}{I_x} x(\frac{180}{2} + 3.2) = F_{sr} = 1.26 \text{ t/cm}^2$$

$$I_{x(Req.)} = 5716710.5 \text{ cm}^4 = \frac{t_w x d_w{}^3}{12} + 2 b_f t_f (\frac{d_w}{2} + \frac{t_f}{2})^2$$

$\therefore b_f\ t_f = 293.04$ $b_f = 20\ t_f$ $\therefore t_f =$ **3.8 cm** $\therefore\ b_f =$ **78 cm**

$$I_x = \frac{t_w x d_w{}^3}{12} + 2 b_f t_f (\frac{d_w}{2} + \frac{t_f}{2})^2$$

$$= \frac{1.6x180^3}{12} + 2x78x3.8(\frac{180}{2} + \frac{3.8}{2})^2 = 5784157.61 \text{ cm}^4$$

2) Recheck Stress Range:

$$\frac{M_{Fatigue}}{I_x} x(d/_2 + t_f) = \frac{722.86x100}{5784157.61} x(\frac{180}{2} + 3.8) = 1.15 \text{ t/cm}^2 < F_{sr} = 1.26 \text{ t/cm}^2$$ **Safe**

3) Shear Stress:

$$\frac{Q_{d+l+I}}{d_w t_w} = \frac{207.13}{180x1.6} = 0.72 \text{ t/cm}^2 < 0.35\ F_y = 1.26 \text{ t/cm}^2$$ **Safe**

4) Size of weld:

$$\frac{Q_{max} x [b_f t_f (\frac{d_w}{2} + \frac{t_f}{2})}{I_x} = 2\ S\ x0.2\ F_u$$

$$\frac{207.13x(78x3.8(90+1.9)}{5784157.61} = 2\ S\ x0.2x\ 5.2$$ $\therefore$ S=0.47 cm use S_{min} = **0.6 cm**

3) <u>Check Web Buckling of X.G:</u>

$$\alpha = \frac{d_1}{d} = \frac{1}{1.8} = 0.56$$

$$K_q = 4 + (\frac{5.34}{\alpha^2}) = 21.3$$

$$\lambda_q = \frac{d/t_w}{57}\sqrt{\frac{F_y}{K_q}} = \frac{180/1.6}{57}\sqrt{\frac{3.6}{21.3}} = 0.81$$

For $0.8 < \lambda_q < 1.2$

$$q_b = (1.5 - 0.625\lambda_q)0.35Fy$$

$= (1.5-0.625x0.81)x0.35x3.6=$ **1.25 t/cm^2**

∗Check Pure Shear:

$Q=0.94Q_{D+l+I} =0.94x207.13=194.7$ t

$$\frac{Q}{d_w t_w} = \frac{194.7}{180x1.6} = 0.676 \text{ t/cm}^2 < q_b = 1.25 \text{ t/cm}^2$$ **Safe**

4) Design of Intermediate Stiffener:

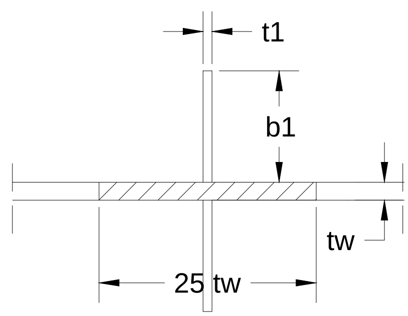
∗<u>Force:</u>

$Q_{stiff} =0.9\ Q_{D+L+I}$

$= 0.9x207.13=186.42$ t

$$C_s=0.65(\frac{0.35F_y}{q_b} -1)\ Q_{stiff}$$

$$=0.65(\frac{0.35x3.6}{1.25} -1) \text{ x } 141.71= 0.74 \text{ t}$$



∗<u>Choice of Section:</u>

$$F_c=\frac{Force}{Area} = \frac{0.74}{A} \quad \therefore A= 0.53 \text{ cm}^2$$

$$b_1=\frac{h_w}{30} + 5 = \frac{180}{30} + 5 = 11 \text{ cm}$$ ….. **Take b_1= 10 cm**

$A=b_1t_1 +25\ t_w^2$

$0.53 =2 \text{ x } 10 \text{ x } t_1 +25 \text{ x } 1.6^2$ $\therefore t_1 = -ve$ use t_{min} = **8 mm**

∗<u>Properties of Area:</u>

$$I_x = 2\frac{t_1 x {b_1}^3}{12} + 2t_1 b_1(\frac{b_1}{2} + \frac{t_w}{2})^2$$

$$=2x\frac{0.8x10^3}{12} + 2x0.8x10(\frac{10}{2} + \frac{1.6}{2})^2 = 671.57 \text{ cm}^4$$

$A=2x10x0.8+25x1.6^2 = 80$ cm^2 $\quad r_x = \sqrt{\frac{I_x}{A}} = \sqrt{\frac{671.57}{80}} = 2.89$ cm

∗<u>Checks:</u>

1)<u>Compactness:</u>

$$\frac{b_1}{t_1} = \frac{10}{0.8} = 12.5 < \frac{30}{\sqrt{F_y}} = 15.8$$

2)<u>Buckling:</u>

$$\lambda = \frac{0.8x180}{2.89} = 49.83 < 90$$

3) Stresses:

$F_c = 2.1 - 13.5 \times 10^{-5} \lambda^2$

$= 2.1 - 13.5 \times 10^{-5}(49.83)^2 = 1.76 \text{ t/cm}^2$

$f_{act} = \frac{F}{A} = \frac{0.74}{80} = 0.01 \text{ t/cm}^2 < 1.76 \text{ t/cm}^2$ **Safe**

4) Size of weld:

$F = f \times A = 0.2 F_u ([L/3] \times 4S)$

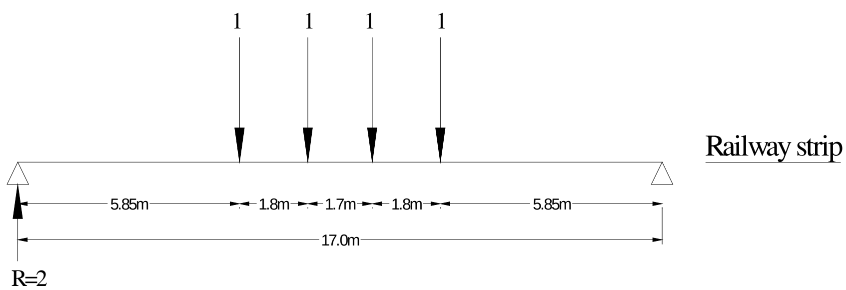
$0.74 = 0.2 \times 5.2 [(180/3) \times 4 \times S]$

$\therefore S = 0.003$ cm use S_{min} = **0.6 cm**

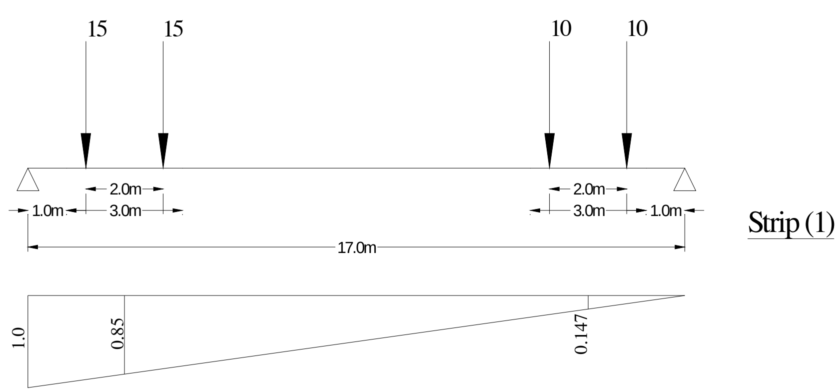
5) Maximum axial Force in Truss members:

∗Railway Strip:

$$(1 + \text{I}) = 0.73 + \frac{2.16}{\sqrt{60} - 0.2} = 1.02 < 1.1 \quad use \quad (1 + \text{I}) = 1.1$$

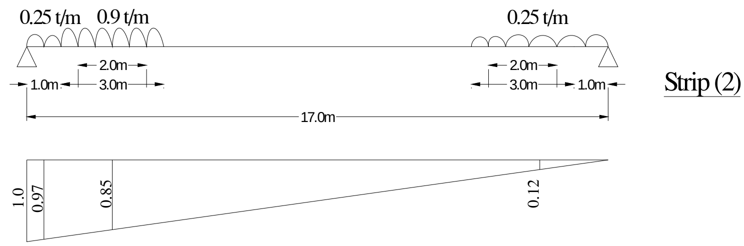


∗Roadway Strips:



P=15x2(0.85)+10x2(0.147)

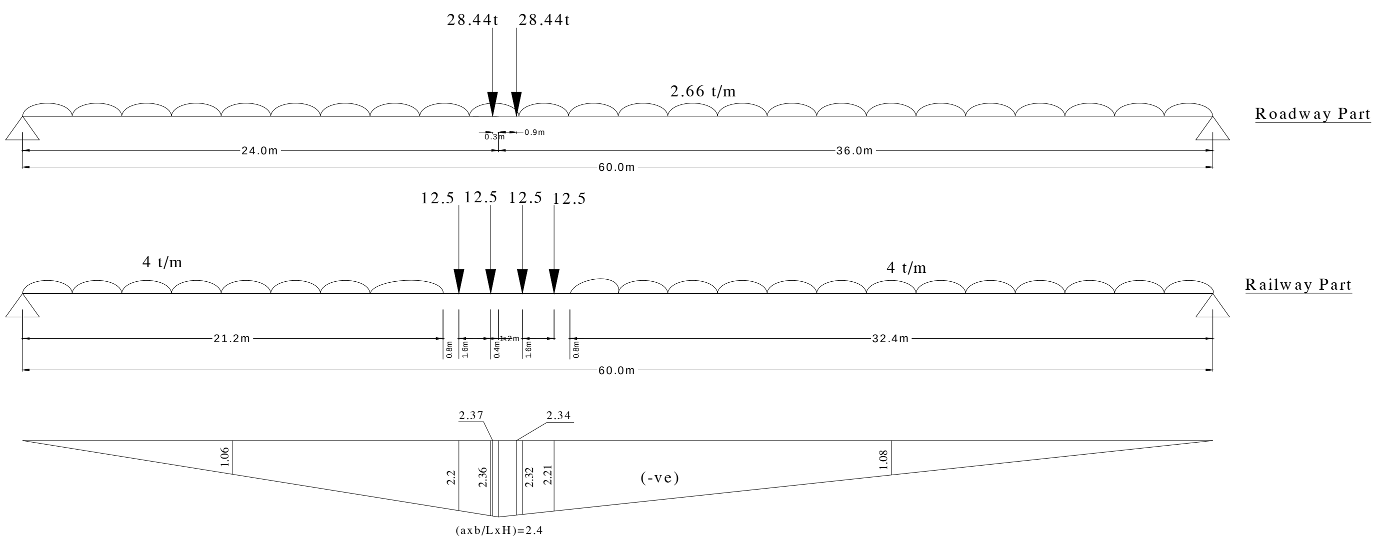
= **28.44 ton**



w= 0.25 x 4 x0.12 +0.9 x3 x0.85 + 0.25 x 1 x 0.97

= **2.66 t/m’**

➔<u>Member U_3 :</u>



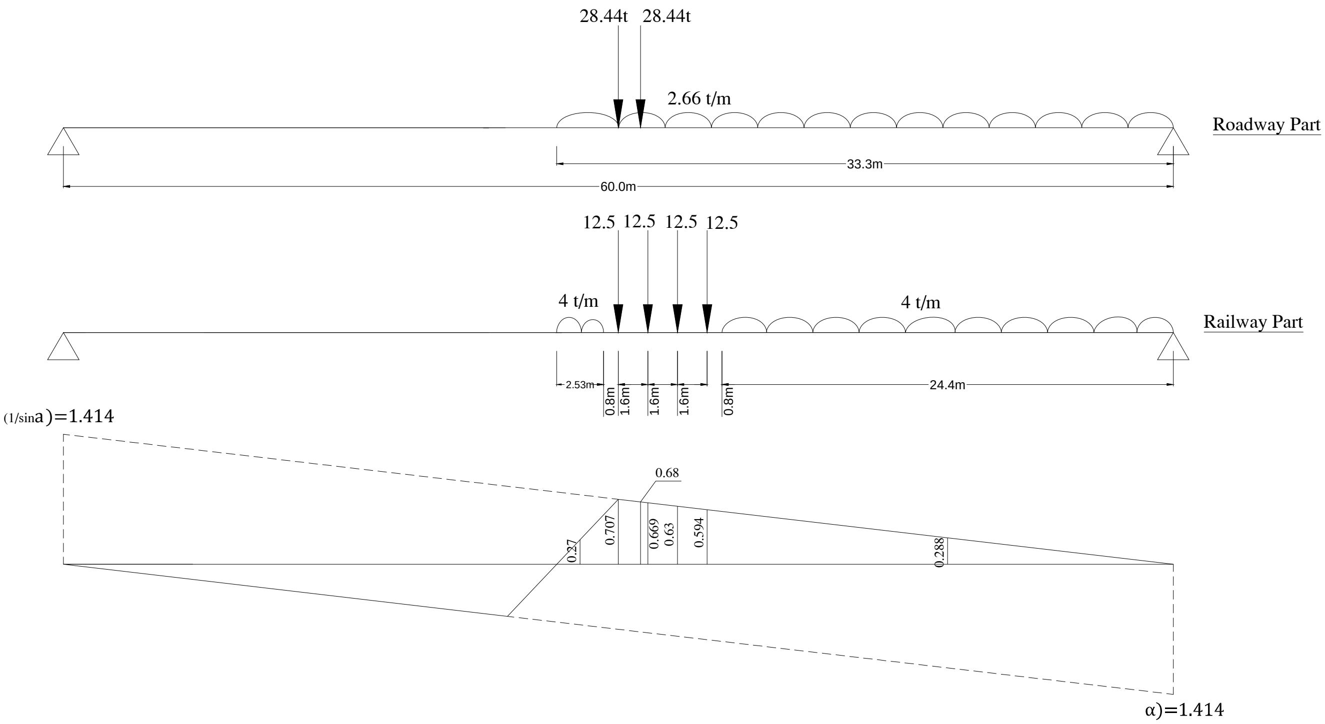
$F_{U_{3_{Roadway}}}$ = 28.44(2.37+2.34) + 2.66(36x1.08+24x1.06) = -305.04 t

$F_{U_{3_{Railway}}}$ = 12.5 (2.2+2.36+2.32+2.21) +4(21.2x1.06+32.4x1.08) = 343.48 x **1.1** x **2** = -755.66 t

F_{U_1} = 755.66 +305.04 = **-1060.7 t (Comp.)**

➔Member D_4:

Case of Comp.:

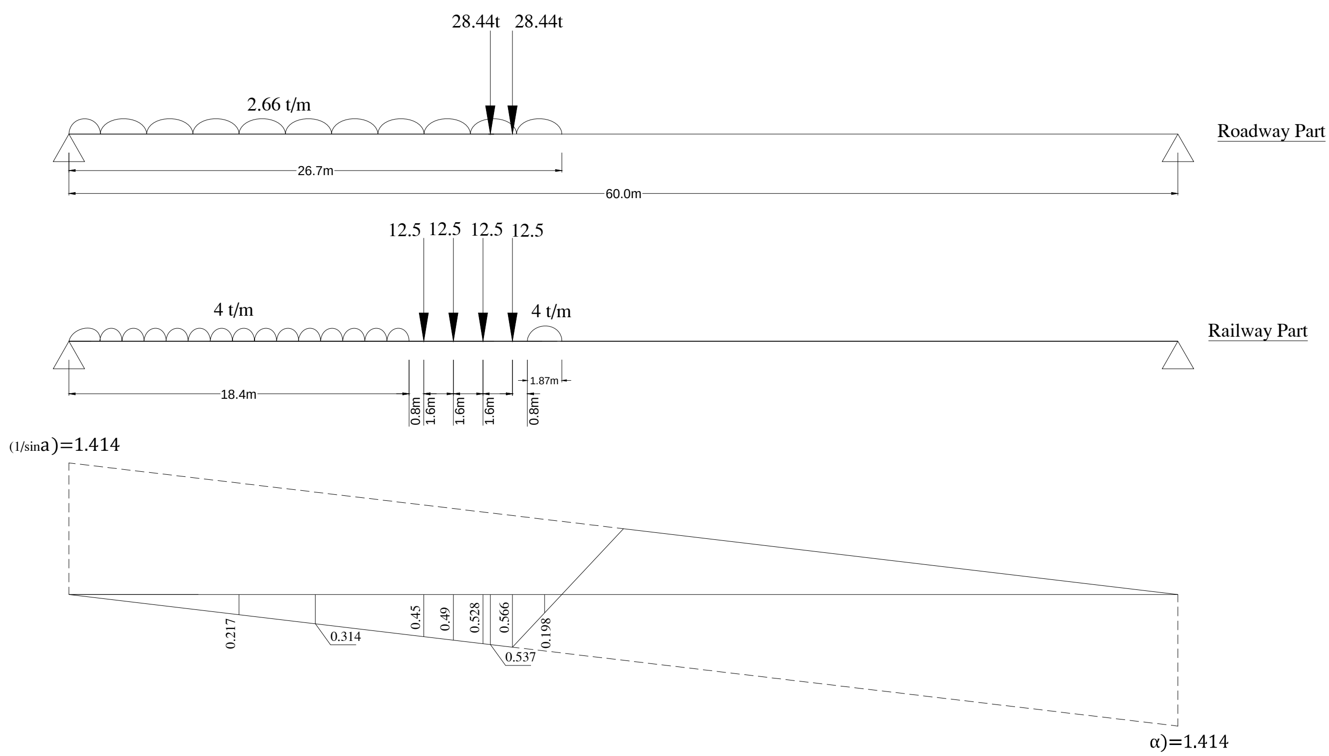


$F_{D_{4_{Roadway}}}$ = 28.44 (0.707+0.68) + 2.66(0.5x33.3x0.707) = **-** 70.76 t

$F_{D_{4_{Railway}}}$ = 12.5 (0.707+0.669+0.63+0.594) +4(24.4x0.288+2.53x0.27) = 63.34 x **1.1** x **2** = -139.35 t

F_{D_4} = 70.76 +139.35 = **-210.11 t (Comp.)**

Case of Tension.:



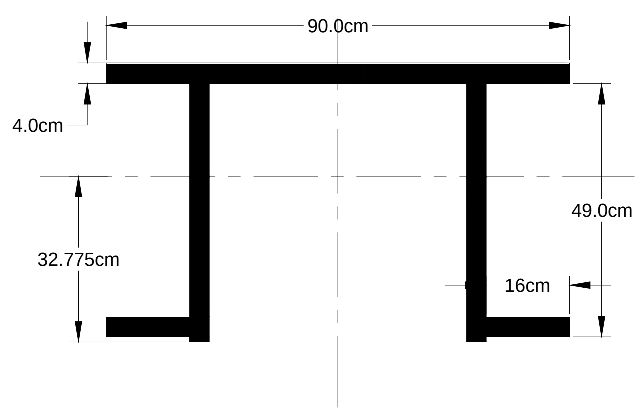
$F_{D_{4_{Roadway}}}$ = 28.44 (0.566+0.537) + 2.66(0.5x26.7x0.566) = + 51.47 t

$F_{D_{4_{Railway}}}$ = 12.5 (0.566+0.528+0.49+0.45) +4(18.4x0.217+1.87x0.198) = 42.88 x **1.1** x **2** = +94.33 t

F_{D_4} = 51.47 +94.33 = **+145.8 t (Tension)**

➔Member V_4:

Zero Member ….. $F_{V_{4_{Railway}}}$ = Zero



6) Design of Truss Members:

➔Design of Chord (U_3) (Comp. -1588 t):

h=50 cm, b=50 cm (given)

B= 50+2(10➔20) = 70➔90 cm = 90 cm

assume f=1.8 t/cm^2 < 0.58F_y =2.1

$\therefore$ f=1.8=$\frac{F=1588}{A}$ $\quad\therefore$ A=882 cm^2 = (2x50+90+2x20) t

$\therefore$ t=3.836 = **4.0 cm**

1) Check local buckling:

$\frac{b}{t} = \frac{50}{4}$ = 12.50 < $\frac{64}{\sqrt{F_y}}$ = 33.73

$\frac{a}{t} = \frac{16}{4}$ = 4 < $\frac{21}{\sqrt{F_y}}$ = 11.06

$\frac{h}{t} = \frac{50}{4}$ = 12.5 < $\frac{64}{\sqrt{F_y}}$ = 33.73

2) <u>Check global buckling :</u>

$\bar{Y} = \frac{50x4x25x2+90x4x52+16x4x3x2}{2x50x4+90x4+16x4x2=888}$ = 32.775 cm

$I_x = 2x\frac{4x50^3}{12} + 2x4x50(25-32.775)^2 + 90x4(52-32.775)^2 + 2x16x4(3-32.775)^2$
=354048.3 cm^4

$I_y = \frac{4x90^3}{12} + 2x4x50(27)^2 + 2x\frac{4x16^3}{12} + 2x4x16(37)^2$ =712562.7 cm^4

$r_x = \sqrt{\frac{I_x}{A}}$ =19.97 cm , $r_y = \sqrt{\frac{I_y}{A}}$ =28.33 cm

$\lambda_{in} = \frac{0.85x600}{19.97}$ = 25.54 < 90 $\lambda_{out} = \frac{2.5\sqrt[4]{2100x712562.7x600x0.08}}{28.33}$ = 45.68 <90

3) <u>Check Stress:</u>

F_c=2.1-13.5x10^{-5}(45.68)^2=1.82 t/cm^2

$f_{ca}=\frac{1588}{888}$ =1.79 t/cm^2 < F_c **Safe**

➔<u>Design of Diagonal (D_4) (Comp. -241.11 t,Tension+ 114.8 t):</u>

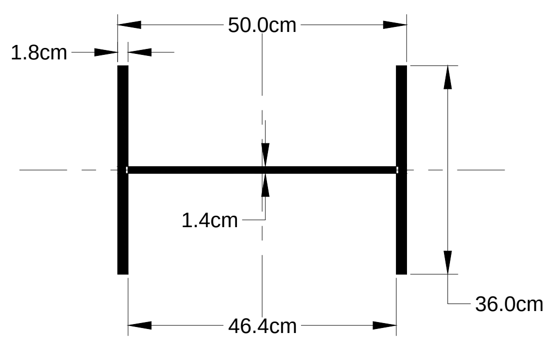
$\therefore$ f=1.2=$\frac{F=241.11}{A}$ $\therefore$ A=200.8 cm^2 = $2b_f t_f + 50x1.6$ $\therefore b_f t_f$=60.42 $\because b_f = 20t_f$

$\therefore t_f$=**1.8 cm** b_f=**36 cm**

1) <u>Check local buckling:</u>

$\frac{d_w}{t_w} = \frac{46.4}{1.4}$ = 33.14 < $\frac{64}{\sqrt{F_y}}$ = 33.73

$\frac{b_f/2}{t} = \frac{17.3}{1.8}$ = 9.61 < $\frac{21}{\sqrt{F_y}}$ = 11.06



2) <u>Check global buckling :</u>

$A = 46.4x1.4 + 2x36x1.8$ = 194.56 cm^2

$I_y = \frac{1.4x46.4^3}{12} + 2x1.8x36(25-0.9)^2$=86927.67 cm^4

$I_x = \frac{1.8x36^3}{12}x2$ =13996.8 cm^4

$r_x = \sqrt{\frac{I_x}{A}}$ =8.48 cm , $r_y = \sqrt{\frac{I_y}{A}}$ =21.14 cm

$\lambda_{in} = \frac{0.7x848.5}{8.48}$ = 70.03 <90 $\lambda_{out} = \frac{1.2x848.5}{21.14}$ = 48.17 <90

3) <u>Check Stress:</u>

F_c=2.1-13.5x10^{-5}(70.03)^2=1.438 t/cm^2

$f_{ca}=\frac{241.11}{194.56}$ =1.24 t/cm^2 < F_c **Safe**

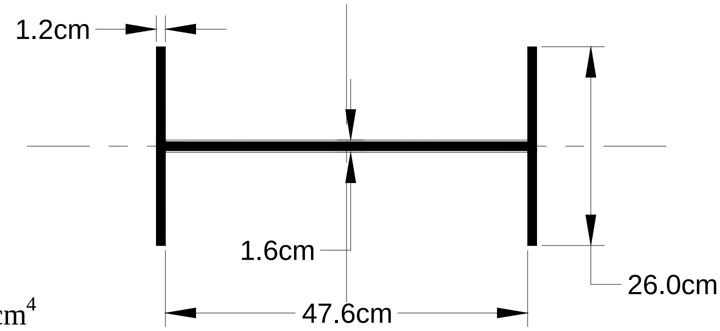
$f_{range}=\frac{114.8+241.11}{194.56}$ =1.83 t/cm^2 < F_{sr} =2.0 t/cm^2 **Safe**

➔ Design of Vertical (V_4) (Zero Member):

Take t_w=**1.6 cm**

$\therefore t_f$=**1.2 cm** b_f=**26 cm**

Check local buckling:



$\frac{d_w}{t_w} = \frac{47.6}{1.6} = 29.75 < \frac{64}{\sqrt{F_y}} = 33.73$

$\frac{b_f/2}{t} = \frac{12.2}{1.2} = 10.17 < \frac{21}{\sqrt{F_y}} = 11.06$

Check global buckling :

$A = 47.6x1.6 + 2x26x1.2 = 138.56\ cm^2$

$I_y = \frac{1.6x47.6^3}{12} + 2x1.2x26(25-0.6)^2 = 51530.5\ cm^4$

$I_x = \frac{1.2x26^3}{12}x2 = 3515.2\ cm^4$

$r_x = \sqrt{\frac{I_x}{A}} = 5.04\ cm$, $r_y = \sqrt{\frac{I_y}{A}} = 19.285\ cm$

$\lambda_{in} = \frac{0.7x600}{5.04} = 83.4 < 90$ $\lambda_{out} = \frac{1.2x600}{19.285} = 37.33 < 90$