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PROBLEM:

Design a through type single lane truss bridge for broad gauge main line loading. The effective span length of the bridge is 50 m. Consider $\gamma_m = 1.15$.

(1)TRUSS ARRANGEMENT [See Fig. E1]:

Effective Span of truss girder = 50 m.

Assume 10 panels @ 5 m interval.

Height and truss girder:

For economical considerations, height = $\frac{1}{8}$ *to* $\frac{1}{10}$ *of span*

Assume, height = 6m. ($\frac{1}{8.33}$ *of span) Hence, O.K.*

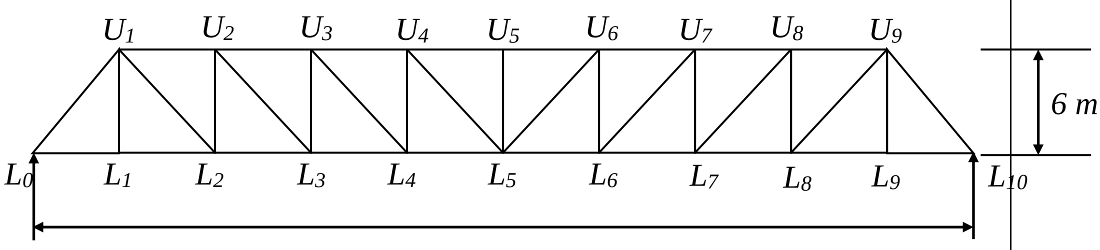

Fig. E1. Truss arrangement

(2) INFLUENCE LINE DIAGRAMS:

(i) ILD for L_0U_1 (Diagonal member):

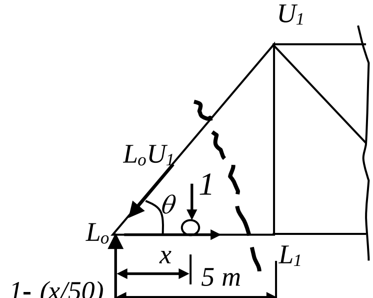

Fig. E2. Free body diagram

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(a) If, unit load is in between L_1 and L_{10} (i.e. $5 \le x \le 50$)

$$\Sigma V = 0.$$

$$L_0U_1 \sin\theta = 1 - (x/50) \Rightarrow L_0U_1 = \frac{1}{\sin\theta}\left(1 - \frac{x}{50}\right)$$

(b) If, unit load is in between L_0 and L_1 (i.e. $0 \le x \le 5$)

$$L_0U_1 = -\frac{1}{\sin\theta}\frac{9x}{50}$$

Then, we can get ILD as shown in Fig. E3.

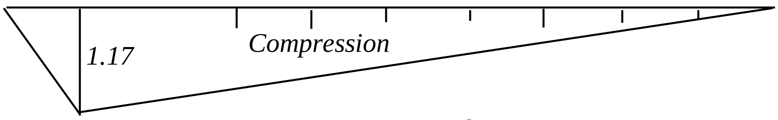

Fig. E3. ILD for L_0U_1

(ii) ILD for L_1U_1 (Vertical member): [See free body diagram Fig. E4]

(a) If, unit load is in between L_0 and L_1 (i.e. $0 \le x \le 5$)

$$\Sigma M_{L0} = 0.$$

$$5L_1U_1 = x$$

$$L_1U_1 = \frac{x}{5}$$

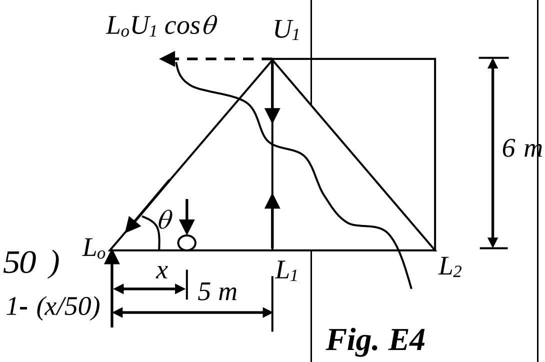

Fig. E4

(b) If, unit load is in between L_2 and L_{10} (i.e. $10 \le x \le 50$)

$$L_1U_1 = 0$$

Fig. E5 ILD for L_1U_1

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(iii) ILD for U_4U_5 and L_4L_5 : (Top and Bottom chord members respectively)

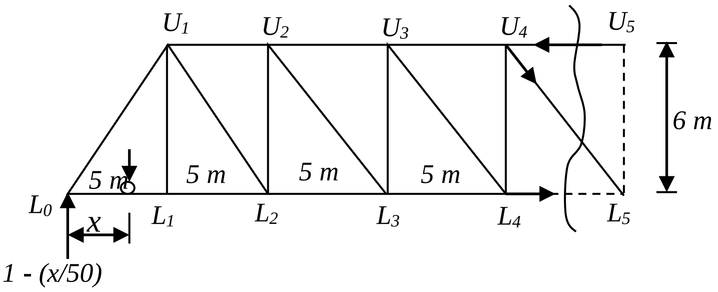

Fig. E6 Free body diagram

(a) If, the unit load is in between L_0 and L_4 (i.e. $0 \le x \le 20$)

$$\sum M_{L5} = 0$$

$$6U_4U_5 + (25 - x)*1 = 25*[1 - (x/50)]$$

$$U_4U_5 = \frac{1}{6} \left[25 \left(1 - \frac{x}{50} \right) - (25 - x) \right]$$

$$\sum M_{U4} = 0$$

$$6L_4L_5 + (20 - x)*1 = 20*[1 - (x/50)]$$

$$L_4L_5 = \frac{1}{6} \left[20 \left(1 - \frac{x}{50} \right) - (20 - x) \right]$$

(b) If, unit load is in between L_5 and L_{10} (i.e. $25 \le x \le 50$)

Then, $$U_4U_5 = \frac{1}{6} \left[25 \left(1 - \frac{x}{50} \right) \right]$$

$$L_4L_5 = \frac{1}{6} \left[20 \left(1 - \frac{x}{50} \right) \right]$$

ILDs for U_4U_5 and L_4L_5 are shown in Fig. E7 and Fig. E8 respectively.

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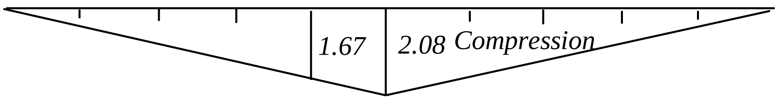

Fig. E7 ILD for U_4U_5

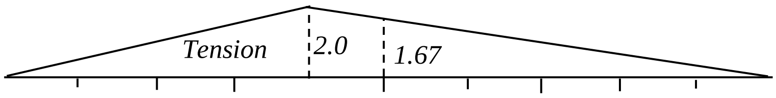

Fig. E8 ILD for L_4L_5

(3) LOADS:

(i) Dead load - *Dead loads acting on truss girder are as follows:*

RDSO Specifications

Weight of rails = $2 \times 0.6 = 1.2$ kN/m.

**Weight of sleepers* = $0.25 \times 0.25 \times \frac{7.5}{0.4} = 2.34$ kN/m.

Weight of fastenings (assumed) = 0.25 kN/m.

Weight of stringers (assumed) = 3.0 kN/m

Weight of cross girders (assumed) = 5.0 kN/m.

***Self-weight of truss by Fuller's Formula* = 13.0 kN/m

Total dead load per track = 24.8 kN/m

Therefore, Total dead load per girder $= \frac{24.8}{2} = 12.4$ kN/m

**[Assume 250 mm × 250 mm × 2m wooden sleepers @ 400 mm apart and weight of 7.5 kN/m³]*

***[Fuller's Formula* $= \frac{15\ell + 550}{100} = \frac{15 \times 50 + 550}{100} = 13.0$ kN/m]

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(ii) Live load

(a) Areas of Influence line diagrams for truss members discussed:

Area of influence line for $L_0U_1 = \frac{1}{2} \times 50 \times 1.17 = -29.3$ *(Compression)*

Area of influence line for $L_1U_1 = \frac{1}{2} \times 10 \times 1.0 = +5.0$ *(Tensile)*

Area of influence line for $U_4U_5 = \frac{1}{2} \times 50 \times 2.08 = -52$ *(Compression)*

Area of influence line for $L_4L_5 = \frac{1}{2} \times 50 \times 2 = +50$ *(Tensile)*

(b) Live loads and impact loads from IRS Bridge Rules - 1982:

*Live loads and impact factors for each loaded length are found from **IRS Bridge Rules - 1982**. For maximum forces in chord members, the whole of the span should be loaded and Live load is determined corresponding to maximum B.M. For other diagonal and vertical members, part of the span as indicated by influence line diagrams, should be loaded and the live load is determined corresponding to S.F. The impact factor is found corresponding to loaded length.*

For maximum force in members L_4L_5 *and* U_4U_5*:*

Load length = *50 m*

Live load for B.M. = *3895.2 kN*

$$\text{Impact factor} = 0.15 + \frac{8}{6+\ell} = 0.15 + \frac{8}{6+50} = 0.293$$

$$(LL + IL) \text{ per m per girder} = \frac{3895.2 \times (1 + 0.293)}{2 \times 50} = 50.36 \text{ kN/m}$$

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For maximum force in members L_0U_1 and L_1U_1:

L_0U_1:

Load length = 50 m
Live load for B.M. = 4184.6 kN

$$\text{Impact factor} = 0.15 + \frac{8}{6+\ell} = 0.15 + \frac{8}{6+50} = 0.293$$

$$(LL+IL)\text{ per m per girder} = \frac{4184.6 \times (1+0.293)}{2\times 50} = 54.1\text{ kN/m}$$

L_1U_1:

Load length = 10 m
Live load for S.F. = 1227.8 kN

$$\text{Impact factor} = 0.15 + \frac{8}{6+\ell} = 0.15 + \frac{8}{6+10} = 0.65$$

$$(LL+IL)\text{ per m per girder} = \frac{1227.8 \times (1+0.65)}{2\times 10} = 101.3\text{ kN/m}$$

(c) Longitudinal Loads from IRS Bridge Rules - 1982

Assume, there exist rail expansion joints in the bridge and prevent the transfer of longitudinal loads to approaches. It may be noted that for broad gauge bridges upto a loaded length of 44 m, the tractive effort is more than the braking force and for loaded lengths more than 44 m the braking force is more than the tractive effort.

Assume truss under consideration is simply supported by a hinge at L_0 and a roller at L_{10}. The longitudinal force in a member can be tensile or compressive depending on the direction of movement of train.

Panel L_4L_5:

Loaded length = 30 m

Tractive effort = 637.4 kN

Force per chord = 637.4/2 = ± 318.7 kN

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Unfactored loads:

Member	*Area of ILD*	*Load in kN/m*		*Forces in members (kN)*		
		DL	*LL+IL*	*DL*	*LL+IL*	*Long.L*
L_0U_1	*- 29.3*	*12.4*	*54.1*	*-363.3*	*-1585.1*	-
L_1U_1	*+5.0*	*12.4*	*101.3*	*+ 62*	*+ 506.5*	-
U_4U_5	*- 52.0*	*12.4*	*50.36*	*-644.8*	*-2618.7*	-
L_4L_5	*+ 50.0*	*12.4*	*50.36*	*+620*	*+2518*	*±318.7*

Use following Partial safety factors for the loads:

$\gamma_{DL} = 1.35; \gamma_{LL} = 1.50; \gamma_{LongL} = 1.50$

Factored loads:

Member	*Factored Forces in members (kN)*			*Total load (kN)*	
	DL	*LL+IL*	*Long.L*		
L_0U_1	*-490.4*	*- 2377.6*	-	*- 2868.0*	
L_1U_1	*+83.7*	*+ 759.8*	-	*+ 843.4*	
U_4U_5	*-870.5*	*-3928*	-	*- 4798.5*	
L_4L_5	*+ 837*	*+3777*	*±478*	*+ 5092*	*- 478*

Note: Negative sign represents compression and positive sign represents tension.

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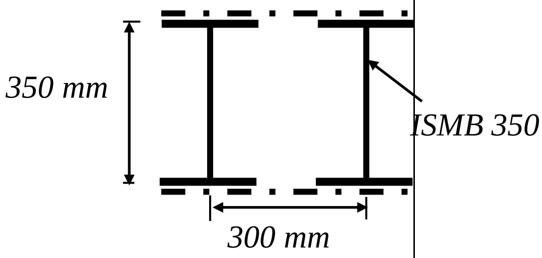
(4) DESIGN FOR TRUSS MEMBERS:

(i) ***Design of diagonal member (L_0U_1):*** *Note that in this illustration of this Member, the portal effect and fatigue are not considered.*

Length of the chord, L_0U_1 = ℓ = 7810 mm

Assume, effective length, $\ell_e = 0.7*\ell = 5467$mm

Try a built up member with two ISHB350 spaced @ 300 mm



$A = 18442\ mm^2$

r_x = 146.5 mm

r_y = 158.8 mm

λ_x = 5467/146.5 = 37.3

Then, σ_c = 221.8 N/mm^2

[See chapter on axially compressed columns using curve c]

*Axial capacity = (221.8/1.15)*18442/1000 = 3556.5 kN > 2868 kN*

Hence, section is safe against axial compression

(ii) Design of vertical member (L_1U_1):

Maximum tensile force = 843.4 kN

Try ISMB 350 @ 0.524 kN/m shown.

$A = 6671\ mm^2$

Axial tension capacity of the selected section = 6671 250/1.15*
= 1450 kN > 843.4 kN

Hence, section is safe in tension.

[Note: Welded connection assumed]

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(iii) Design of top chord member (U_4U_5):

Member length, ℓ = 5000 mm

Assume, effective length = 0.85ℓ = 4250 mm

Try the section shown.

$A = 25786\ mm^2$

$r_x = 165.4\ mm$

$r_y = 210\ mm$

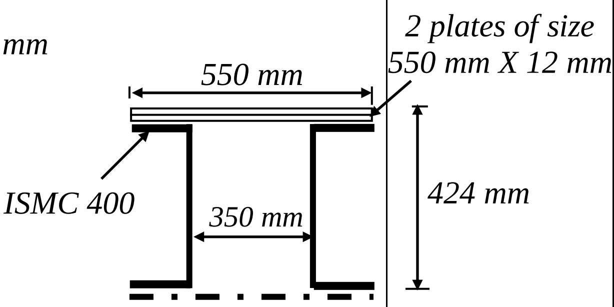
$\lambda_x = 4250/165.4 = 25.7$

Then, $\sigma_c = 239\ N/mm^2$

[See chapter on axially compressed columns using column curve c]

*Axial capacity = (239/1.15)*25786/1000 = 5359 kN > 4798.5 kN*

Hence, section is safe against axial compression



(ii) Bottom chord design(L_4L_5):

Maximum compressive force = 478 kN

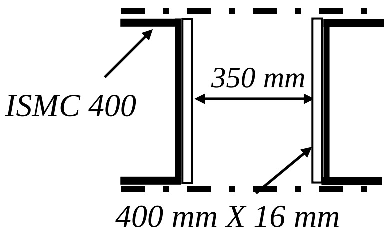
Maximum tensile force = 5092 kN

Try the box section shown.

$A = 25386\ mm^2$

$r_x = 144\ mm$

$r_y = 210\ mm$



Axial tension capacity of the selected section = 25386 250/1.15*
= 5518 kN > 5092 kN

Hence, section is safe in tension.

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Maximum unrestrained length = ℓ = *5000 mm*

λ_x = 5000/144 = 34.7

Then, σ_c = 225 N/mm^2

Axial capacity = (225/1.15) 25386/1000 = 4967 kN > 478 kN*

Hence, section is safe against axial compression also.

The example is only an illustration. The following have to be taken into consideration:

- *Design of lacings/batten*
- *Design of connections and effect of bolt holes on member strength*
- *Secondary bending effects*
- *Design for fatigue*