Connection gusset

7.8.1 Examples:

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.

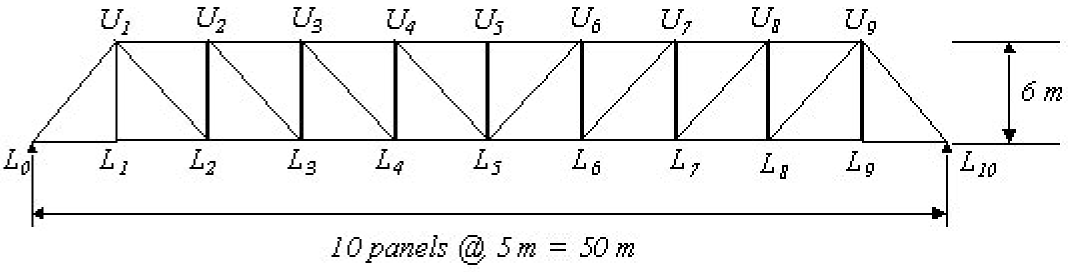


Fig. E1. Truss arrangement

(2) Influence line diagrams:

(i) ILD for L_0U_1 (Diagonal member):

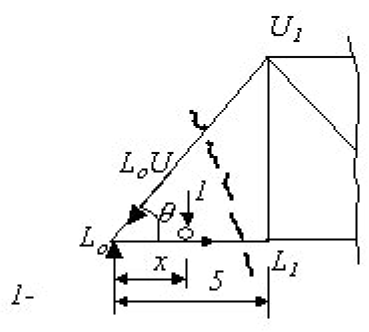


Fig. E2. Free body diagram

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

$$\sum V = 0$$

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

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

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

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. $5 \leq x \leq 50$)

$$\sum ML_0 = 0.$$

$$5L_1U_1 = x$$

$$L_1U_1 = x / 5$$

(b) If, unit load is in between L_2 and L_{10}

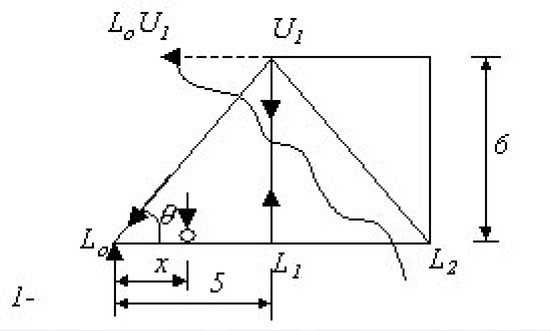


Fig. E4

$L_1U_1 = 0$

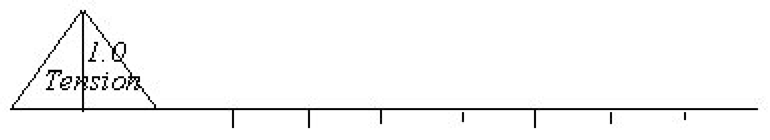


Fig. E5 ILD for L_1U_1

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

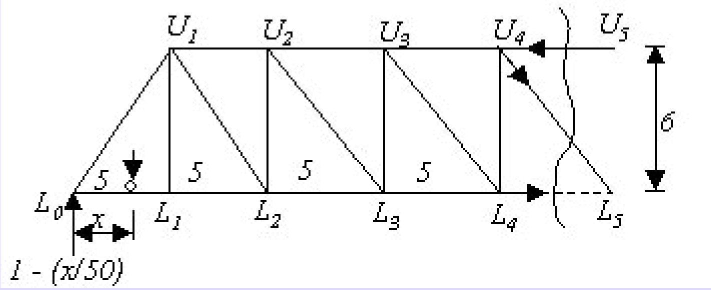


Fig. E6 Free body diagram

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

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

$$6U_4 U_5 + (25 - x)*1 = 25*\left[1 - (x/50)\right]$$

$$U_4 U_5 = \frac{1}{6}\left[\left(25\left(1 - \frac{x}{50}\right) - (25 - x)\right)\right]$$

$$\sum M_{u4} = 0$$

$$6L_4 L_5 + (20 - x)*1 = 20*\left[1 - (x/50)\right]$$

$$L_4 L_5 = \frac{1}{6}\left[\left(20\left(1 - \frac{x}{50}\right) - (20 - x)\right)\right]$$

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

Then,

$$U_4 U_5 = \frac{1}{6}\left[25\left(1 - \frac{x}{50}\right)\right]$$

$$L_4 L_5 = \frac{1}{6}\left[20\left(1 - \frac{x}{50}\right)\right]$$

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

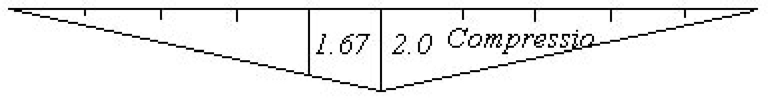


Fig. E7 ILD for U_4U_5

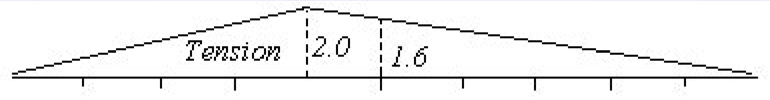


Fig. E8 ILD for *L_4L_5*

(3) Loads:

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

Weight of rails = 2 x 0.6 = 1.2 kN/m.

* Weight of sleepers = 0.25 x 0.25 x 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 = 24.8 / 2 = 12.4 kN/m

*[Assume 250 mm 250 mm 2m wooden sleepers @ 400 mm apart and weight of 7.5 kN/m^3]

$$**\left[\text{Fuller's Formula} = \frac{15l+550}{100} = \frac{15\ \text{x}\ 50+550}{100} = 13.0\,\text{kN/m}\right]$$

(ii) Live load

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

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

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

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

Area of influence line for $L_4L_5 = \frac{1}{2}\,\text{x}\,50\,\text{x}\,2 = +50$ (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

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

(LL+ IL) per m per girder = $\frac{3895.2\,\mathrm{x}\left(1+0.293\right)}{2\,\mathrm{x}\,50}=50.36\,\mathrm{kN/m}$

For maximum force in members L_0 U_1 and L_1 U_1:

L_0 U_1

Load length = 50 m

Live load for B.M. = 4184.6 kN

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

(LL+ IL) per m per girder = $\frac{4184.6\,\mathrm{x}\left(1+0.293\right)}{2\,\mathrm{x}\,50}=54.1\,\mathrm{kN/m}$

L_1 U_1:

Load length = 10 m

Live load for S.F. = 1227.8 kN

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

(LL+ IL) per m per girder = $\frac{1227.8\,x\left(1+0.65\right)}{2\,x\,10}=101.3\,kN/m$

(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 = $\pm 318.7\,kN$

Unfactored loads:

Member	Area of ILD	Load in kN/m		Forces in members (kN)		
		DL	LL+IL	DL	LL+IL	Long.L
L_0 U_1	- 29.3	12.4	54.1	-363.3	-1585.1	-
L_1 U_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		
$L_0 U_1$	-490.4	- 2377.6	-	- 2868.0	
$L_1 U_1$	+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.

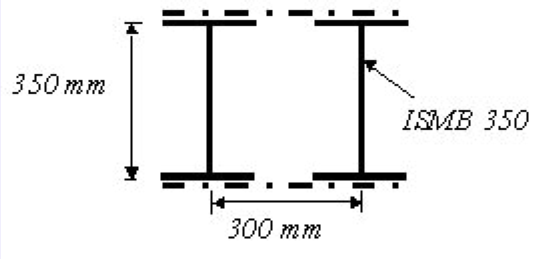
(4) Design for truss members:

(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, $l_e = 0.7*l = 5467$mm

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



$A = 18442\ mm^2$

$r_x = 146.5\ mm$

$r_y = 158.8\ mm$

$\lambda_x = 5467/146.5 = 37.3$

Then, $\sigma_c = 221.8\ N/mm^2$

[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]

(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.

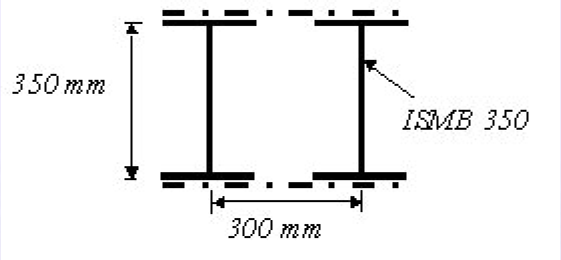
$A = 25786\ mm^2$

r_x= 165.4 mm

r_y = 210 mm

λ_x = 4250/165.4 = 25.7

Then, σ_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

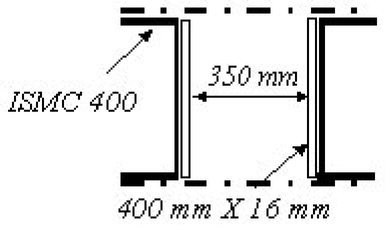
Hence, section is safe against axial compression

(iv) 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.

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