CHAPTER 6

COMPARISON OF THROUGH AND DECK TYPE TRUSS BRIDGES AND USE OF HIGH TENSILE STEEL

6.1 GENERAL

Depending on configuration, truss bridges are classified as deck type, through type and under slung truss. As presented earlier in Chapter 4, deck type truss bridge can be constructed as composite truss bridge to take advantage of composite action of RCC deck with steel truss. In case of simply supported deck type truss bridge, it is advantageous to make deck slab composite with top chord compression members. Buckling of the top chord compression members is effectively prevented by deck slab and shear studs. But in case of through type truss bridge, deck is constructed at the level of bottom chord members, which are always in tension. Due to this composite action of RCC deck with bottom chord members is not advantageous.

In this chapter truss bridges of span 30.0m and 90.0m having four different configurations viz. through type, deck type, semi deck type and under slung truss are analyzed and designed as per design guidelines discussed in Chapter 4. Comparison of analysis and design results in service load condition for (DL+LL) case, and at limit state of strength for overload condition of 2.25x(DL+LL) case is carried out. Also an attempt has been made to compare design results of a 90m span deck type truss bridge using structural steel of grade E250 and high tensile steel (HTS) of grade E410. It is observed deck type composite truss bridges using HTS are lightweight and found advantageous in earthquake prone areas.

6.2 GEOMETRIC DETAILS OF THE BRIDGE

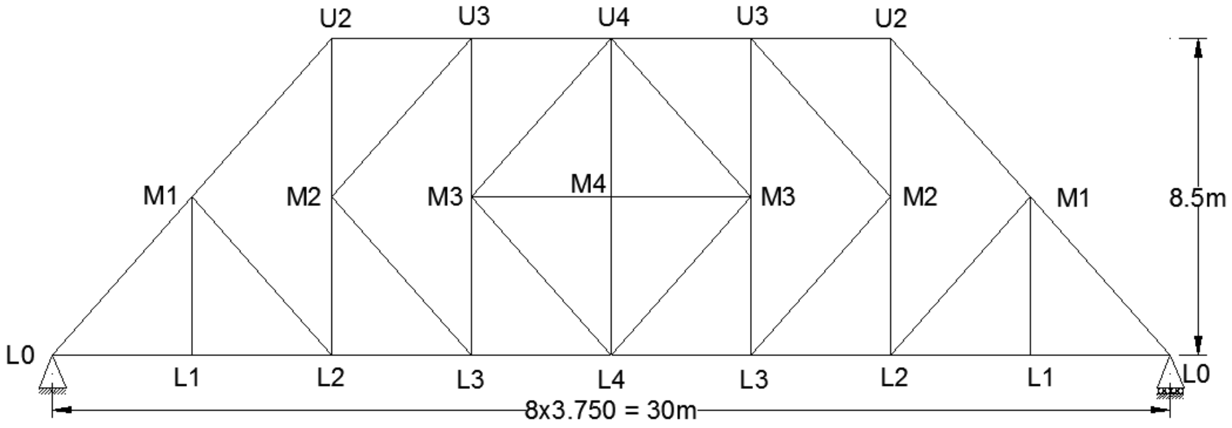
Four geometrically different truss configurations of 30.0m and 90.0m span have been analyzed for same loading and compared for maximum lateral and vertical deflections, and steel off take. Types of four truss configurations are as given below.

a. Through type truss bridge
b. Deck type truss bridge
c. Semi deck type truss bridge
d. Under slung truss bridge

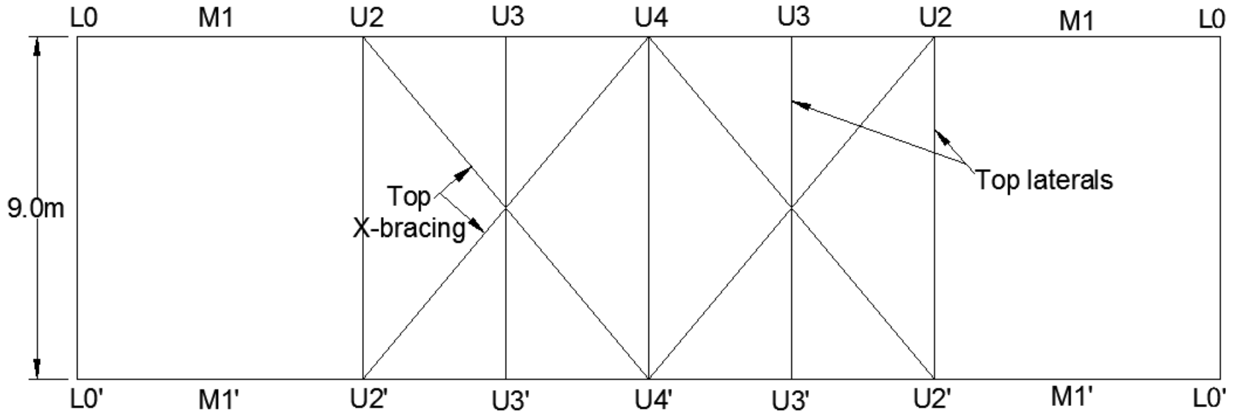
6.2.1 Geometric details for the 30.0m span bridges

Through type truss bridge:

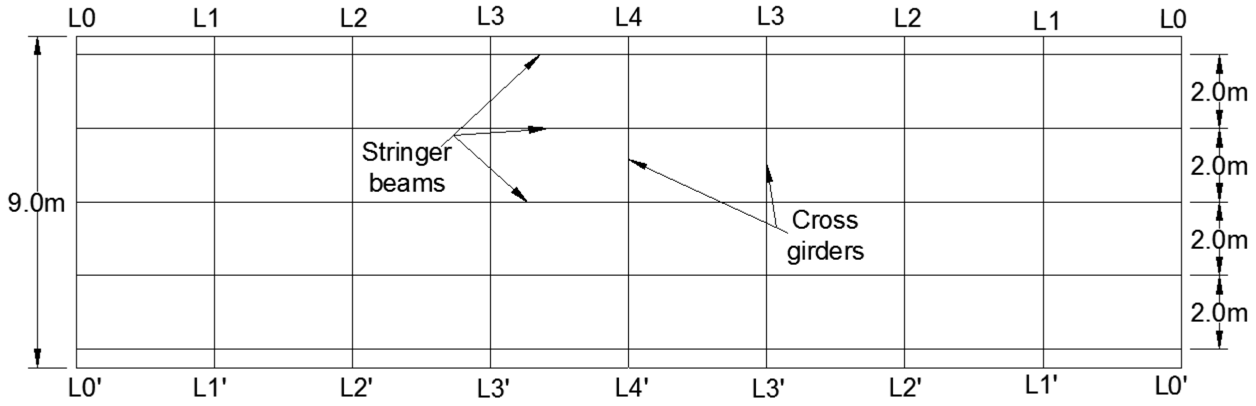
Figure 6.1 shows the 30.0m span K-type through truss bridge. Centre to centre distance between the trusses is 9.0m and height of truss is 8.5m. Cross girders are spaced at 3.75m and the five stringers are spaced at 2.0m c/c.



b. Elevation



c. Top plan

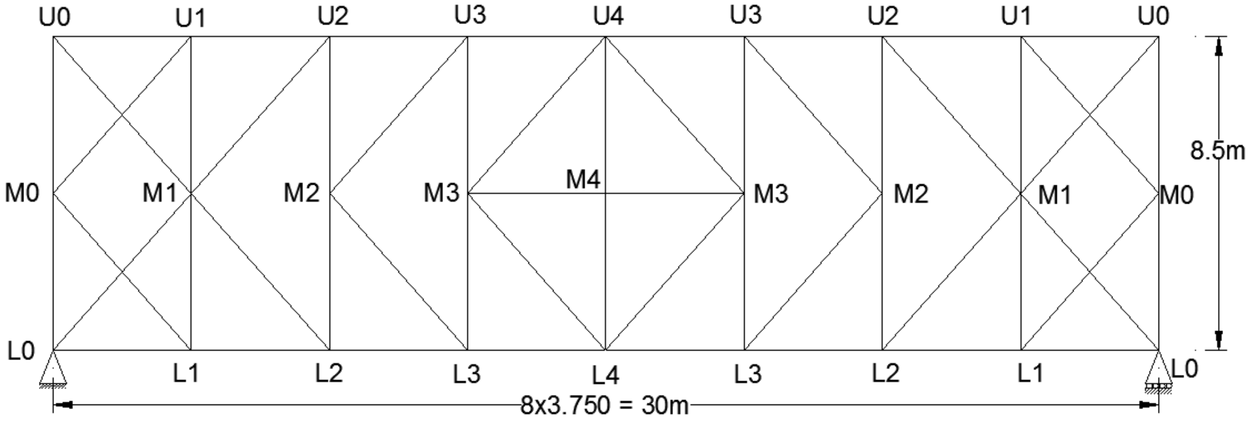


d. Bottom plan

Figure 6.1. 30.0m span Through type truss bridge

Deck type truss bridge:

Figure 6.2 shows the 30.0m span K-type deck truss bridge. Centre to centre distance between two trusses is 7.9m and height of truss is 8.5m. Cross girders are spaced at 3.75m and two stringers are spaced at 2.5m c/c. In the through type truss bridge, deck is supported only on cross girders and stringers due to obstruction of vertical and diagonal members. Therefore, five stringers are used to avoid cantilever projection of deck slab. In case of deck type truss bridge there is no such obstruction and it is possible to construct deck over top chord members, stringers and cross girders. As in deck type truss bridge top chord members also carry direct load from deck, only two stringer beams are required.



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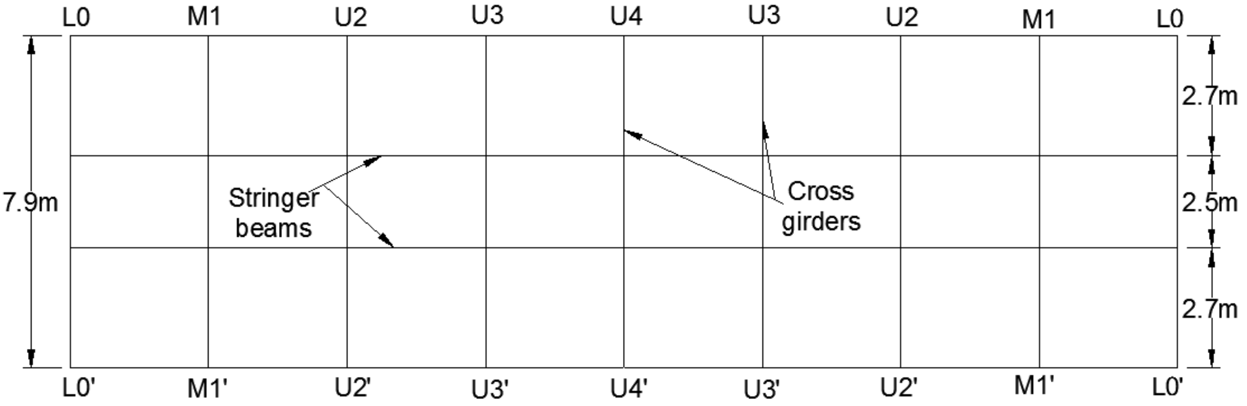
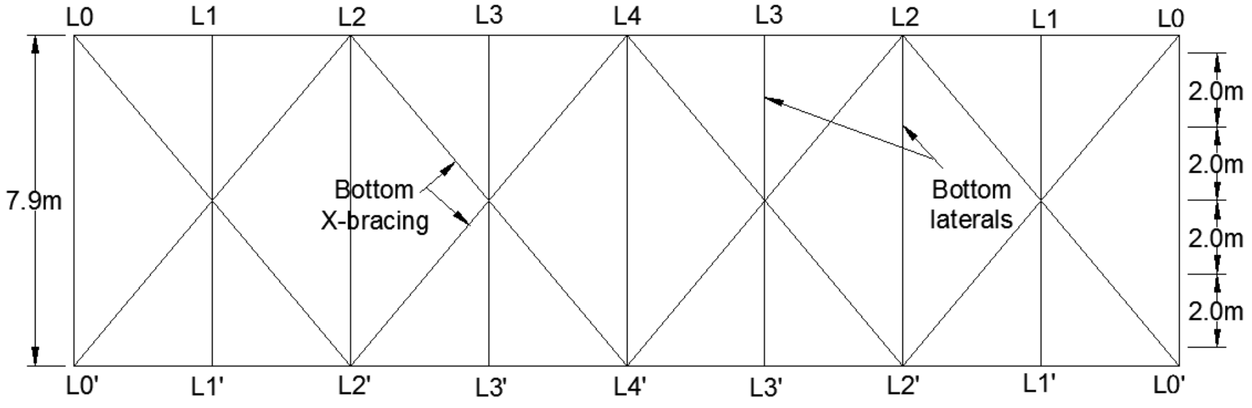


c. Top plan

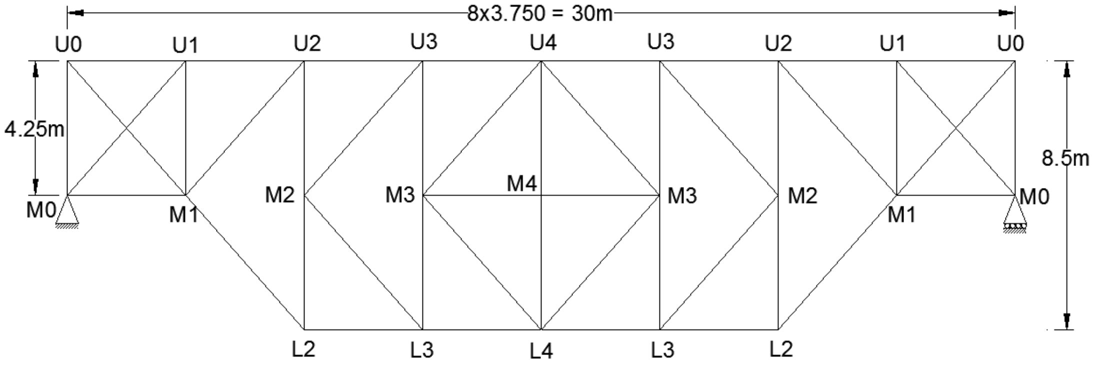


d. Bottom plan

Figure 6.2 30.0m span Deck type truss bridge

Semi deck type truss bridge:

Figure 6.3 shows the 30.0m span K-type semi-deck truss bridge. Centre to centre distance between two trusses is 7.9m and height of truss is 8.5m. Cross girders are spaced at 3.75m and two stringers are spaced at 2.5m c/c. Arrangement of cross girders and stringer beams is same as in case of the deck type truss bridge.



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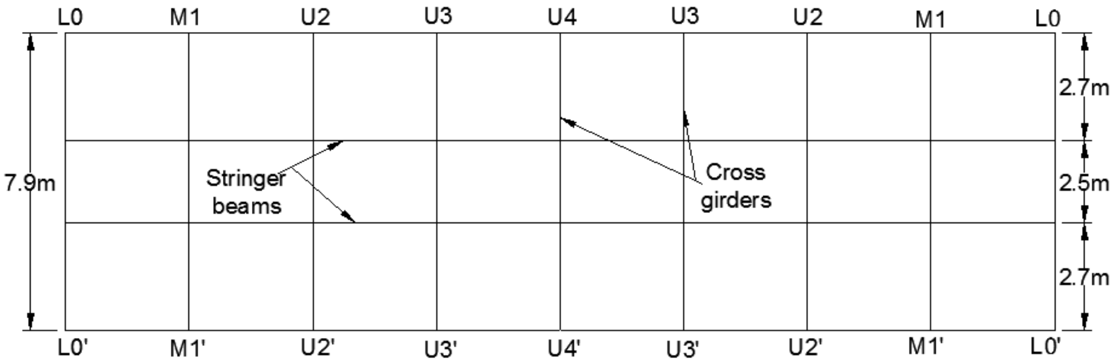
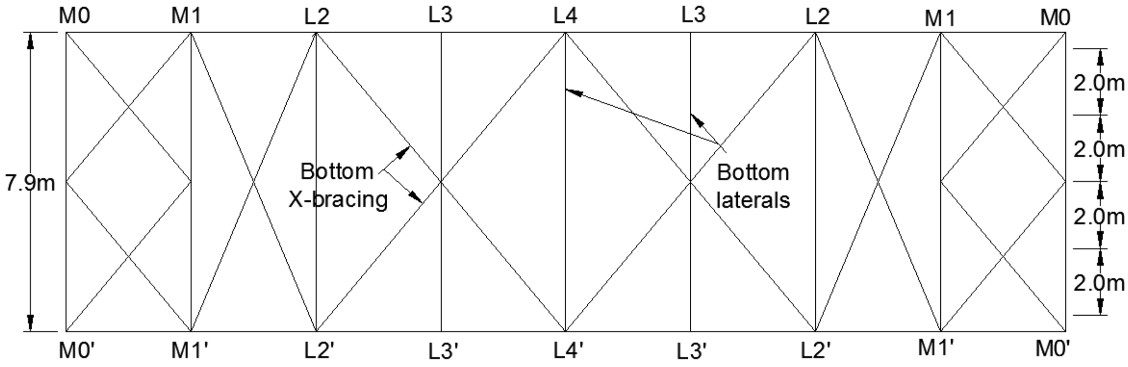


c. Top plan

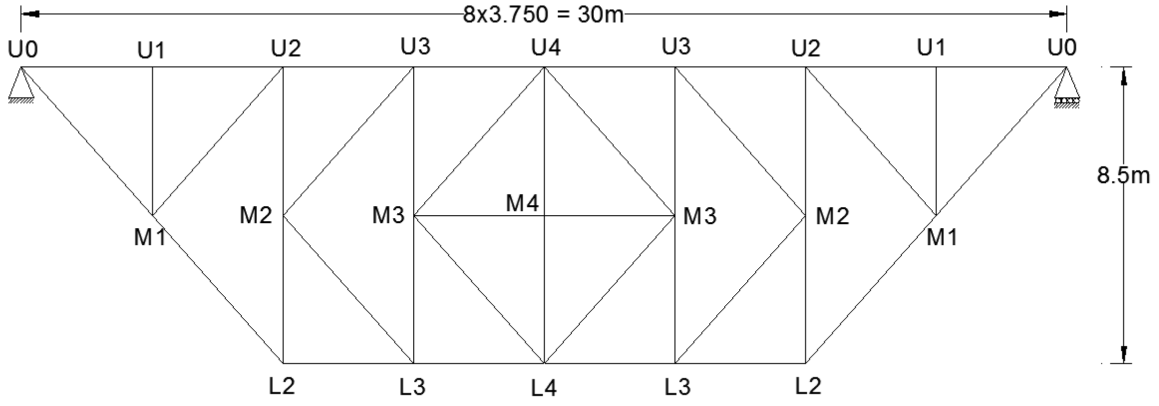


d. Bottom plan

Figure 6.3 30.0m span Semi type truss bridge

Under slung truss bridge:

Figure 6.4 shows the 30.0m span K-type under slung truss bridge. Centre to centre distance between the trusses is 7.9m and height of the truss is 8.5m. Cross girders are spaced at 3.75m and two stringers are spaced at 2.5m c/c. Arrangement of cross girders and stringer beams is same as in case of the deck type truss bridge.



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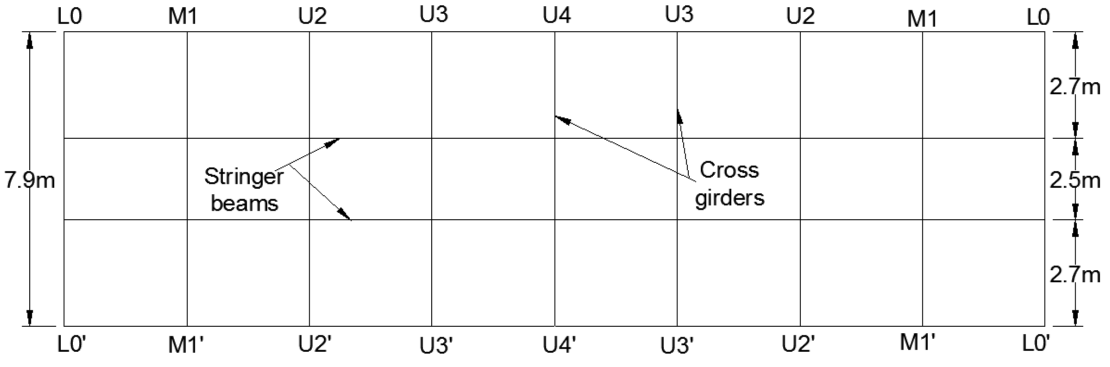
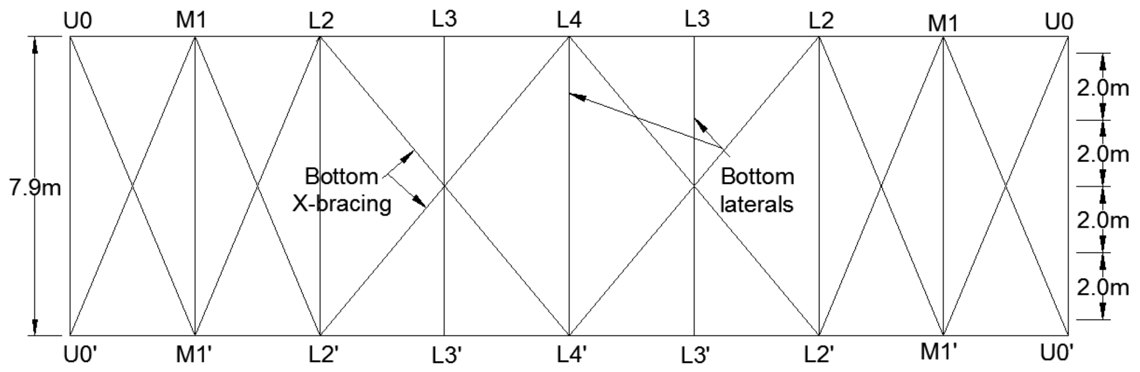


c. Top plan



d. Bottom plan

Figure 6.4 30.0m span Under slung truss bridge

6.2.2 Geometric details for the 90.0m span bridges

Four geometrically different trusses of through type and deck type of 90m span each and 5.5m carriageway have been taken for the comparison. These four trusses have been analyzed for same loading and compared for maximum lateral and vertical deflections, and steel off take. Details of four trusses taken for comparison are given below.

a. Through type truss bridge
b. Deck type truss bridge
c. Semi deck type truss bridge
d. Under slung truss bridge

Through type truss bridge:

Figure 6.5 shows the 90.0m span K-type through truss bridge. Centre to centre distance between the trusses is 7.2m and height of truss is 10.0m. Cross girders are spaced at 5.0m c/c and the three stringers are spaced at 2.0m c/c.

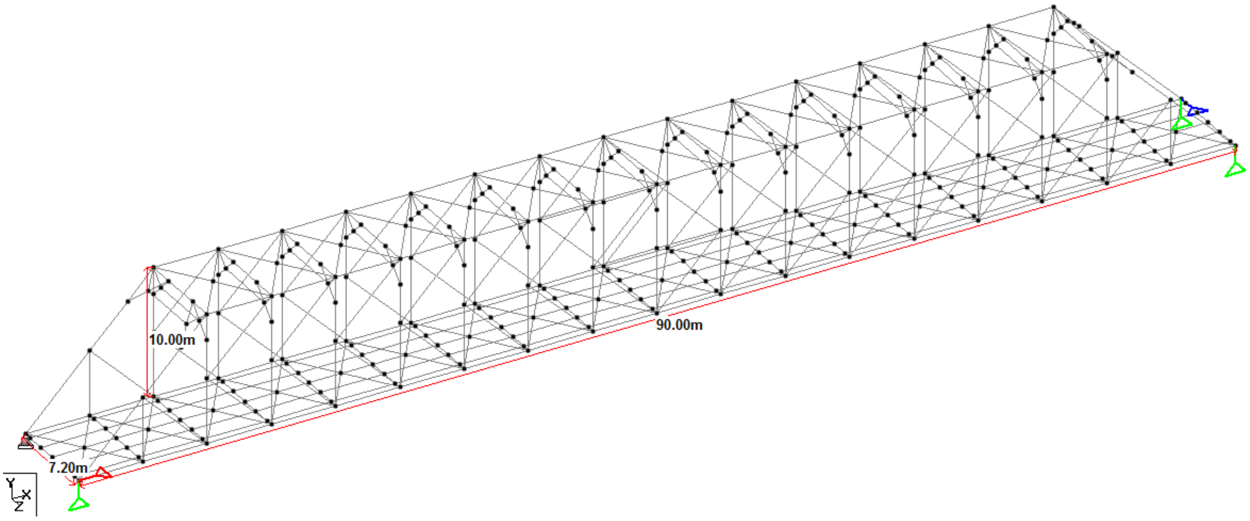


Figure 6.5 90.0m span Through type truss bridge

Deck type truss bridge:

Figure 6.6 shows the 90.0m span K-type deck truss bridge. Centre to centre distance between the trusses is 6.0m and height of truss is 10.0m. Cross girders are spaced at 5.0m c/c and the three stringers are spaced at 1.5m c/c.

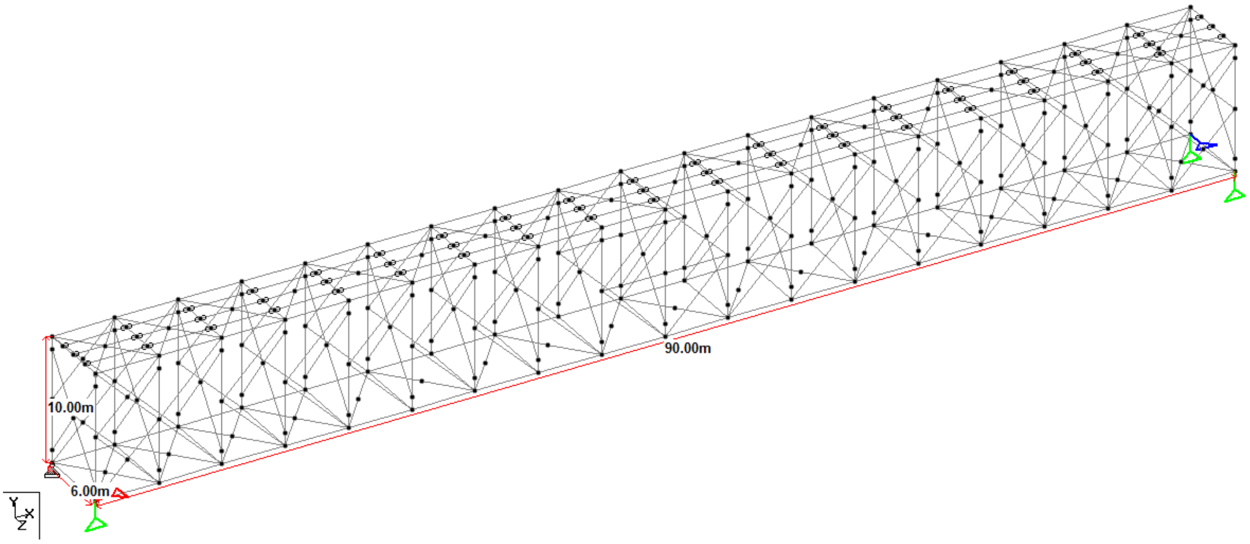


Figure 6.6 90.0m span Deck type truss bridge

Semi deck type truss bridge:

Figure 6.7 shows the 90.0m span K-type semi deck truss bridge. Centre to centre distance between the trusses is 6.0m and height of truss is 10.0m. Cross girders are spaced at 5.0m c/c and the three stringers are spaced at 1.5m c/c.

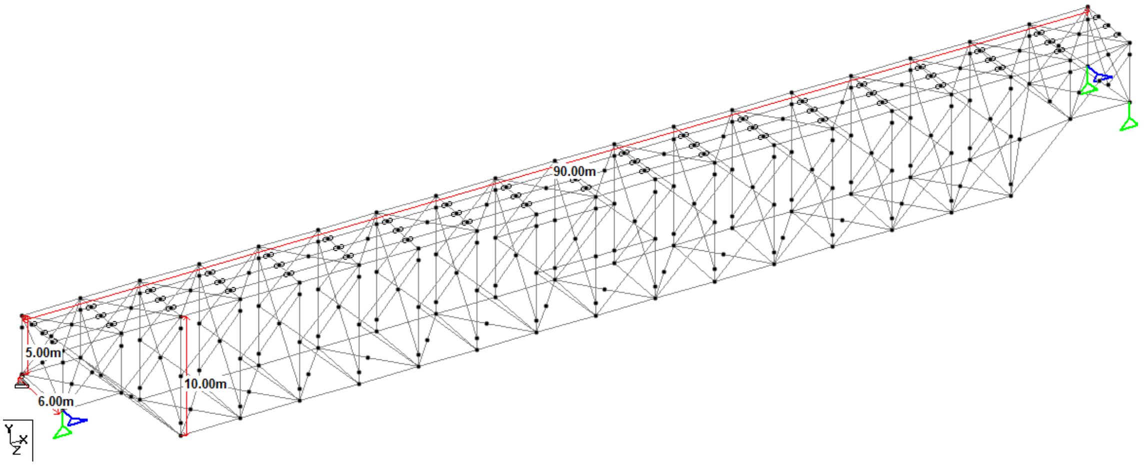


Figure 6.7 90.0m span Semi deck type truss bridge

Under slung truss bridge:

Figure 6.8 shows the 90.0m span K-type under slung truss bridge. Centre to centre distance between the trusses is 6.0m and height of truss is 10.0m. Cross girders are spaced at 5.0m c/c and the three stringers are spaced at 1.5m c/c.

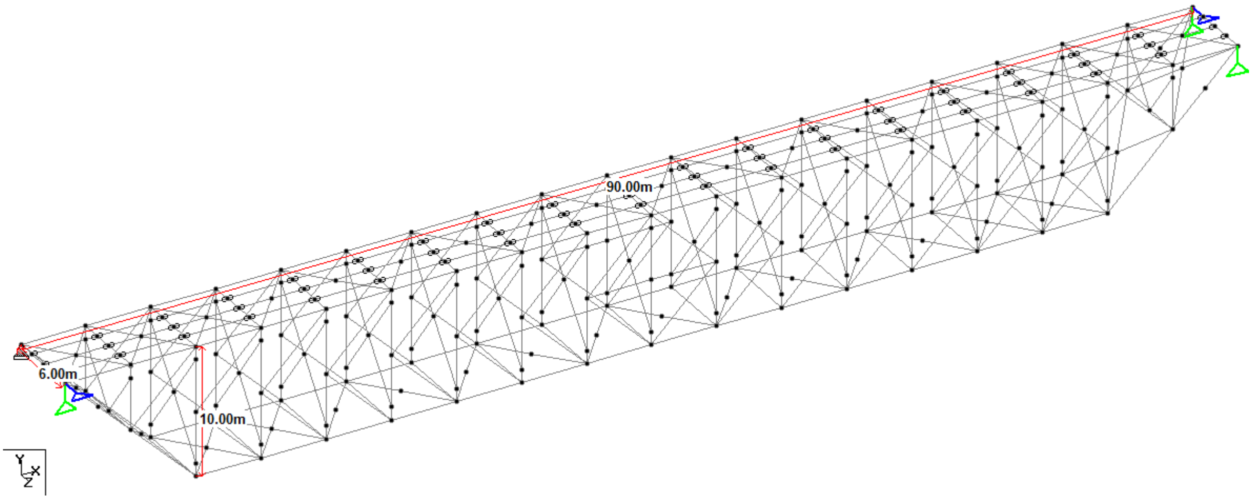


Figure 6.8 90.0m span Under slung truss bridge

6.3 ANALYSIS AND DESIGN

Analysis and design of the models are carried out using STAAD Pro. v8i software as per detailed procedure given in Chapter 4 in the following sequence.

6.3.1 Modeling

3D models are prepared in STAAD as per geometric details given in figures 6.1 to 6.8. As members used in these models are built up sections, section builder facility in STAAD is used to assign cross section of the truss members.

6.3.2 Loading

The two lane 30.0m span bridge and single lane 90.0m span bridge models have been designed for IRC Class-A, IRC Class-70R and IRC Class-AA loading. Wind pressure on the exposed area of the bridge is taken as 2.0 kN/m^2 and the design has been carried out for seismic Zone-V as per IRC:6-2010. Load combinations are taken as discussed in Chapter 4.

6.3.3 Design

The designs have been optimized using interactive steel design facility in STAAD Pro. v8i. The optimized design given by the software checks the section for slenderness ratio, shear along local X and Z axis of member, deflection along local X and Z axes of member and interaction ratio for combined axial force and bi-axial bending moments. The optimized cross section of members and interaction ratios for the truss members are given in Annexure A in tables A.1 to A.8, for the four types of bridges for the 30.0m and 90.0m span bridges.

The design of the bridge under service condition for (DL+LL) case is carried out without accounting for any composite action between the steel truss and the RCC deck slab, considering that entire load is carried by the trusses without any support from the deck slab.

The design at overload has been carried out assuming that the composite deck slab provides lateral support to the top chord compression members and permissible stress higher than the buckling stress up to yield stress is permitted in these members. All other compression members of the truss, where lateral support is not provided by the deck slab, have been designed according to the permissible buckling stress. Permissible stress in the tension members of the truss is taken as yield stress. Under this condition deflection limit criteria has not been imposed. Thus, interaction ratio of the composite top chord compression members is limited to 1.0, tension members to 1.0 and all other compression members to 0.667.

Interaction ratios given in tables A3.1 through A3.8 due to practical limitations are not exactly 1.0 as would have been ideally desired. However, the optimized sections have been arrived at as the minimum practically possible safe sections in each case.

6.4 COMPARISON BETWEEN THE BRIDGES OF DIFFERENT GEOMETRY

Comparison of the four types of bridges for 30.0m span and 90.0m span giving maximum lateral deflection under wind or seismic loads, vertical deflection for envelope of self weight, imposed load and live load cases, and steel off take are given in tables 9 through 13. The steel off take includes 20% extra steel for gusset plate, lacings and battens over the steel off take give by the software.

6.4.1 Comparison for the 30.0m span bridges

Comparisons for 30.0m span through type, deck type, semi deck type and under slung truss bridges for service condition and overload condition are given below.

6.4.1.1 Comparison for service load under (DL+LL) case

Maximum lateral and vertical deflections and steel off take in superstructure under service condition for (DL+LL) case are given in Table 6.1.

Table 6.1 Lateral and vertical deflections and steel off take for service condition for 30.0m span bridge

Bridge type	Max. lateral deflection (wind load) (mm)	Max. lateral deflection (seismic load) (mm)	Max. vertical deflection (DL+LL) (mm)	Total steel off take including 20% extra (t)
Through type	41.1	7.3	18.6	73.8
Deck type	16.4	4.5	17.9	70.6
Semi deck type	12.4	3.4	21.5	63.8
Under slung truss	13.1	3.5	21.0	59.4

It is seen that maximum lateral deflection of 12.4mm under wind load is minimum for the semi deck type bridge and for the seismic load it is again minimum at 3.4mm. Therefore, from the maximum lateral deflection consideration semi deck type bridge configuration is ideal most.

Maximum vertical deflection is minimum at 17.9mm for the deck type bridge model. For the semi deck type bridge model it is 21.5mm, which is 20.0% higher in comparison to the deck type bridge. However, the permissible deflection in the bridge is 50mm (L/600) as per cl 507.4 of IRC:24-2001, which is much higher than the deflection for the semi deck type bridge. Therefore, from the vertical deflection consideration semi deck type bridge may be acceptable.

From the total steel off take consideration under slung truss type of bridge is most economical. Second best option from the steel off take criteria is the semi deck type bridge, where the steel off take is more by 9.9% in comparison to the under slung truss bridge. Total steel off take in the semi deck type bridge is lower by 13.1% in comparison to the through type bridge, and 8.1% in comparison to the deck type bridge. Under slung truss bridges need support at the sharp edge of the truss, which may be often difficult to provide. Therefore, from steel off take consideration also semi deck type bridge option is acceptable.

6.4.1.2 Comparison for design at limit state of strength for overload condition of 2.25x(DL+LL) case

Maximum lateral and vertical deflections and steel off take of the superstructure for design at overload condition under 2.25x(DL+LL) case are given in Table 6.2.

Table 6.2 Lateral and vertical deflections and steel off take for overload condition

Bridge type	Max. lateral deflection (wind load) (mm)	Max. lateral deflection (seismic load) (mm)	Max. vertical deflection 2.25x(DL+LL) (mm)	Total steel off take including 20% extra (t)
Through type	40.0	7.0	18.6	97.2
Deck type	17.2	4.6	22.3	79.6
Semi deck type	12.9	3.6	28.2	74.7
Under slung truss	14.3	3.9	30.7	67.0

It is seen that lateral deflection of 12.9mm under wind load is minimum for the semi deck type bridge, and for the seismic load it is again minimum at 3.6mm. Therefore, from the maximum lateral deflection consideration semi deck type bridge configuration is ideal most.

Maximum vertical deflection is minimum at 18.6mm for the through type bridge model. For the semi deck type bridge model it is 28.2mm, which is 51.6% higher in comparison to the through type bridge model. However, vertical deflection is not a governing criterion at overload condition. Therefore, from the vertical deflection consideration semi deck type bridge may be acceptable.

From the total steel off take consideration under slung truss type bridge is most economical where steel off take is minimum at 67.0t. Second best option from the steel off take criterion is the semi deck type bridge, where the steel off take of 74.7t is more by 11.4% in comparison to the under slung truss bridge. Total steel off take in the semi deck type bridge is lower by 30.1% in comparison to the through type bridge, and 10.4% in comparison to the deck type bridge. Therefore, from steel off take consideration also semi deck type composite bridge option is acceptable.

6.4.2 Comparison for the 90.0m span bridges

Comparisons for 90.0m span through type, deck type, semi deck type and under slung truss bridges for service condition and overload condition are given below.

6.4.2.1 Comparison for service load under (DL+LL) case

Maximum lateral and vertical deflections and steel off take in superstructure under service condition for (DL+LL) case are given in Table 6.3.

Table 6.3 Lateral and vertical deflections and steel off take for service condition for 90.0m span bridge

Bridge type	Max. lateral deflection (wind load) (mm)	Max. lateral deflection (seismic load) (mm)	Max. vertical deflection (DL+LL) (mm)	Total steel off take including 20% extra (t)
Through type	52.4	3.2	144.3	306.7
Deck type	32.2	4.1	146.9	305.6
Semi deck type	31.8	3.4	150.7	295.2
Under slung truss	31.4	4.9	150.0	285.0

It is seen that for through type bridge maximum lateral deflection under wind condition is 52.4mm, and for deck, semi deck and under slung truss type bridges it ranges from 31.4mm to 32.2mm without much variation. Therefore, deck type, semi deck type and under slung truss bridges are preferable from lateral deflection consideration.

Vertical deflection in the four types of bridges varies between 144.3mm to 150.7mm without significant variation. Therefore, from vertical deflection consideration all types of bridges have similar performance.

Steel off take in the under slung truss bridge is minimum at 285.0t and it is maximum for the through type bridge at 306.7t. However, there is not much variation in steel off take in all four types of bridges for service load under (DL+LL) case.

Therefore, unlike short spans, in long span bridges steel off take of the bridge does not significantly vary with the type of truss arrangement.

6.4.2.2 Comparison of design at limit state of strength for overload condition of 2.25x(DL+LL) case

Maximum lateral and vertical deflections and steel off take in superstructure at overload condition for 2.25x(DL+LL) case are given in Table 6.4.

Table 6.4 Lateral and vertical deflections and steel off take for overload condition

Bridge type	Max. lateral deflection (wind load) (mm)	Max. lateral deflection (seismic load) (mm)	Max. vertical deflection 2.25x(DL+LL) (mm)	Total steel off take including 20% extra (t)
Through type	50.6	3.4	175.5	386.3
Deck type	30.9	4.0	209.9	346.8
Semi deck type	30.5	3.2	217.4	331.3
Under slung truss	30.6	4.4	220.4	313.9

It is seen that for through type bridge maximum lateral deflection under wind condition is 50.6mm, and for deck, semi deck and under slung truss type bridges it ranges from 30.5mm to 30.9mm without much variation. Therefore, deck type, semi deck type and under slung truss bridges are preferable from lateral deflection consideration.

Maximum vertical deflection is minimum at 175.5mm for the through type bridge model. For the semi deck type bridge model it is 217.4mm, which is 23.8% higher in comparison to the through type bridge model. However, vertical deflection is not a governing criterion at the overload condition. Therefore, from the vertical deflection consideration semi deck type bridge may be acceptable.

From the total steel off take consideration under slung truss type bridge is most economical where steel off take is minimum at 313.9t. Second best option from the steel off take criterion is the semi deck type bridge, where the steel off take of 331.3t is more by 5.5% in comparison to the under slung truss bridge. Total steel off take in the semi deck type bridge is lower by 16.6% in comparison to the through type bridge, and 4.6% in comparison to the deck type bridge. Therefore, from steel off take consideration also semi deck type composite bridge option is acceptable.

6.5 EFFECT OF BRIDGE SPAN ON BRIDGE CONFIGURATION SELECTION

In order to investigate effect of bridge span on selection of bridge configuration, through type, deck type, semi deck type and under slung truss type 30.0m span and 90.0m span bridges have been compared in Art. 6.3 above.

From lateral deflection consideration it is found that 30.0m span semi deck type bridge is most preferable among the four arrangements, as its lateral displacement in service condition under (DL+LL) case is 30.2% of the maximum deflection in case of through type bridge. However, for the 90.0m span bridge case there is 26.6mm variation in the lateral deflection in service condition from the maximum of 54.4mm in case of through type bridge to 31.8mm average deflection for the remaining three types of bridges, which comes out to be 60.9% of the maximum lateral deflection. Therefore, from lateral deflection consideration through type bridges are not preferable. Also, for long spans arrangements of the end panels of the truss do not significantly affect the lateral deflection. However, for short span bridges semi deck type bridge is most preferable from lateral deflection consideration.

In short span bridges (30.0m), steel off take of the bridge in service condition for (DL+LL) case significantly vary with the truss configuration. At the overload condition condition for 2.25(DL+LL) case, steel off take and cost of the bridge vary significantly with the truss configuration and cost of through type bridge is higher by 38.6% from the under slung truss type bridge. There is only 9.9% variation in cost of the semi deck type bridge from the under slung truss bridge. Thus, from steel off take consideration for lower span bridges, under slung truss bridge and semi deck type bridge configurations are preferable.

In longer span bridges (90.0m), steel off take and cost of the bridge in service condition for (DL+LL) case do not significantly vary with the truss configuration, and cost of through type bridge is higher by 7.1% from the under slung truss bridge cost. In the overload condition for 2.25(DL+LL) case, steel off take and cost of the bridge vary significantly with the truss configuration, and the cost of through type bridge is 21.4% higher from the average cost of the remaining three types of bridges.

Therefore, from the above comparison it can be inferred that for short spans composite semi deck type arrangement may be most desirable. For longer spans the difference between various types of truss arrangements decreases, but through type bridges are not preferable in comparison to the composite deck type, semi deck type and under slung truss bridges. Thus, for longer span bridges, from steel off take or cost consideration and lateral deflection consideration, under slung truss bridge and semi deck type bridge configurations, as for shorter span bridges, are preferable.

6.6 ABUTMENT AND EMBANKMENT REQUIREMENTS

In the through type bridges there is no requirement for the dirt walls at the two ends of the bridge (Figure 6.10). In the case of deck type bridges high abutment or dirt walls are needed at the two ends of the bridge (Figure 6.9), which also have to support the bridge in the lateral direction acting as seismic stoppers. Therefore, significant additional cost is required for this.

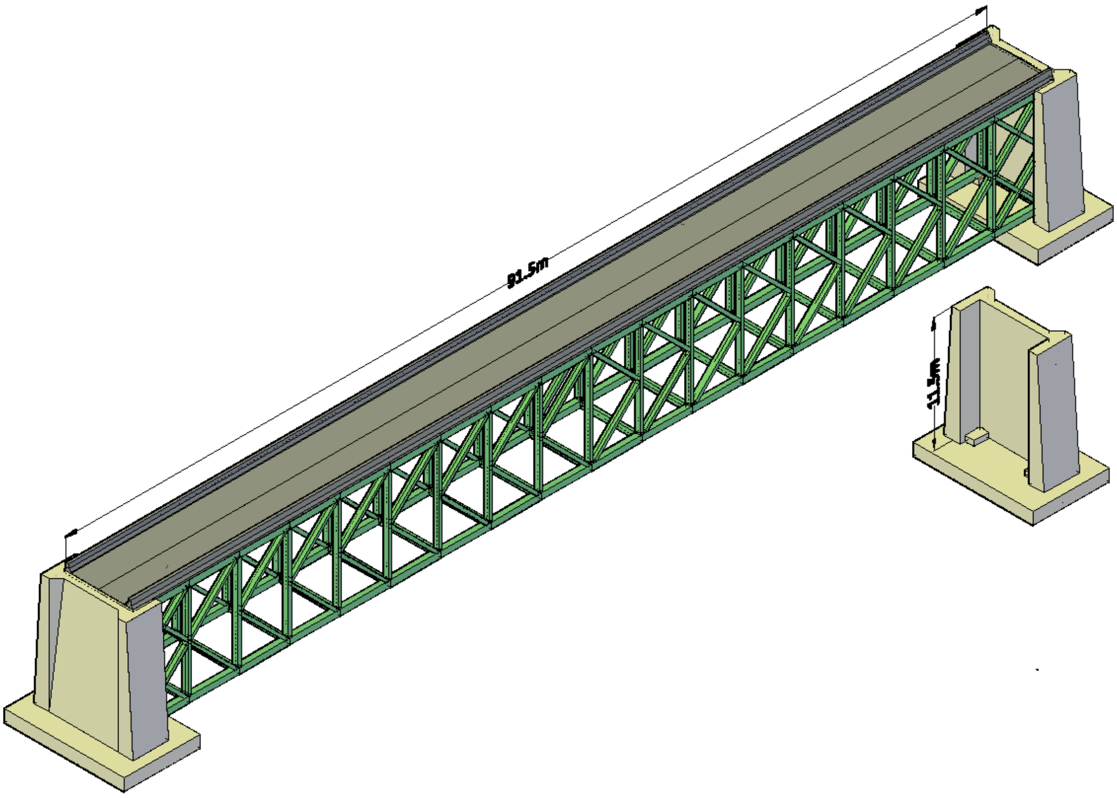


Figure 6.9 Abutment details for 90.0m deck type bridge.

In the case of semi deck type bridges (Figure 6.9) height of the abutment or dirt wall at the two ends of the bridge is reduced to half in comparison to the deck type bridge. Therefore, semi deck type bridge is preferable in this respect. In the case of composite under slung truss bridges (Figure 6.4) there is no need for the additional abutment or dirt wall, and therefore, it is most economical from this consideration.

Embankment height and height of the approach road also directly depend on the height of the abutment or the dirt wall, and therefore, from cost of the abutment and approach road consideration also under slung truss bridges are most economical and semi deck type bridges are the second best.

6.7 VALLEY PROFILE

Valley profile, particularly for short span bridges, many times dictates selection of the type of bridge. An example of 30.0m span bridge at Kotlibhel, Karnaprayag, Uttarakhand is quoted for this. Figure 6.10 shows layout of the 30.0m span through type bridge, where it has sufficient free board from the HFL. In this arrangement the deck slab rests over the bottom chord members of the truss which are in tension, and therefore, advantage of the deck slab in composite action with the truss is lost.

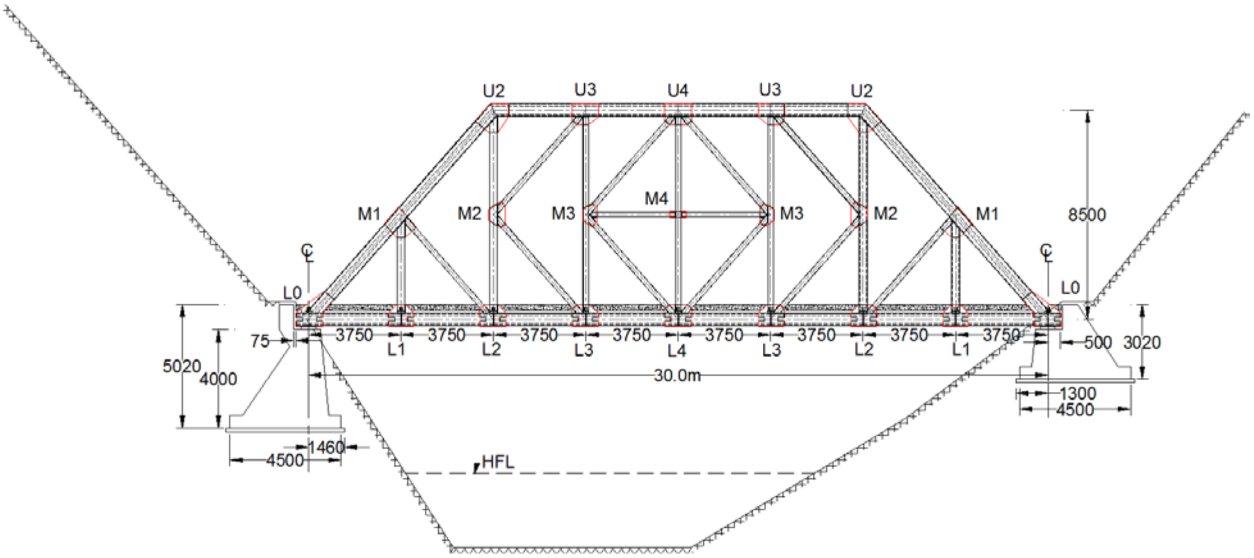


Figure 6.10 Valley profile and 30.0m span through type bridge

An alternate to the through type bridge as given above is shown in Figure 6.11 in the form of semi deck type bridge. This arrangement does not have sufficient free board from the HFL, and therefore, it becomes unacceptable even though composite deck with the top chord compression members may be provided.

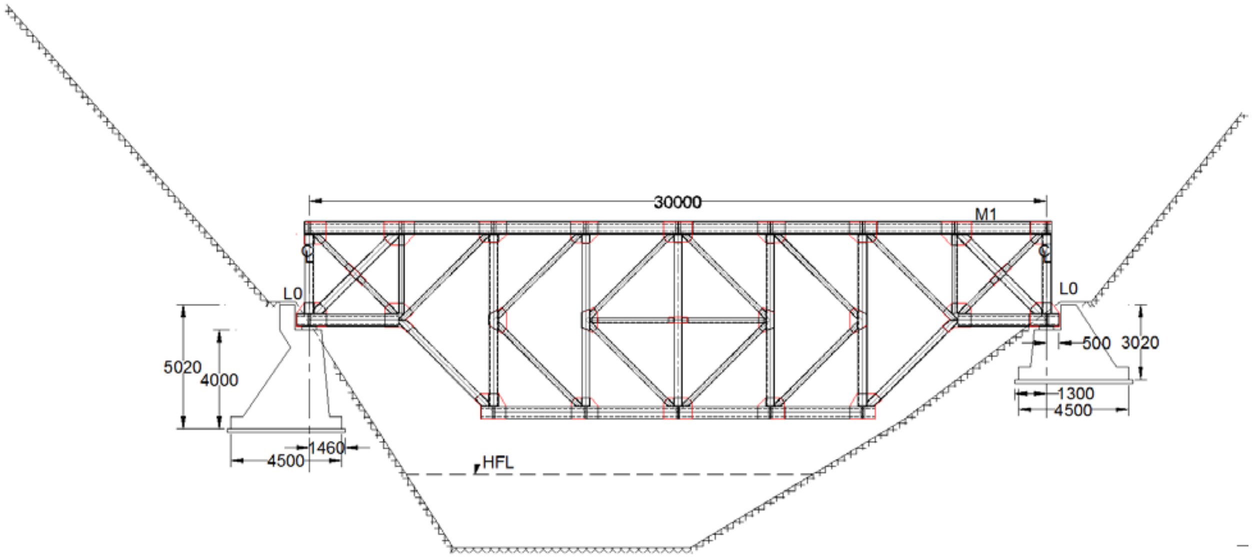


Figure 6.11 Valley profile and 30.0m span semi deck type bridge

The under slung truss bridge arrangement for the given valley profile may not at all be found feasible. Therefore, even though composite action of the truss with the deck slab is possible, and cost of the bridge will be minimum for this configuration, under slung truss arrangement for the bridge is not acceptable.

Thus, it may be concluded that in case of smaller spans valley profile may many times dictate selection of the type of bridge and in spite of all the disadvantages, through type bridge may be the only option.

6.8 USE OF HTS STEEL IN COMPOSITE STEEL TRUSS BRIDGES

The Bureau of Indian Standards (BIS) Committee has revised the specifications given in IS:2062-2006, ‘Steel for general structural steel purposes - specification’ to bring it in line with the international standards (EN & ASTM) on Carbon-Manganese and High Strength Low Alloy (HSLA) structural steels and also to align it as per the present practices being followed by the Indian steel industry, both in the integrated as well as secondary sectors. The specification has been made in such a way that it is now well comparable with other international standards like Euro and ASTM norms on similar grades of steel.

Specifications for High Tensile Structural (HTS) steel are given in IS:2062-2011, ‘Hot rolled medium and high tensile structural steel – specification’. Mechanical and chemical properties of E 250 to E 650, nine grades of steel are specified in the code. Out of these grades, E 410 grade of HTS steel is generally available in the Indian open market. National level steel manufacturing companies like Steel Authority of India (SAIL), and Tata Iron and Steel Company (TISCO) generally manufacture and supply E 410 grade steel sections as per IS:2062-2011 on demand and on prior notice. Therefore, due to supply constraints HTS steel is used only in a limited manner in India.

6.8.1 Properties of structural steel

IS:2062-2011 deals with different grades of steels for manufacture in India, which are reproduced in Table 6.5

Table 6.5 Properties of structural steel

Grade designation	Tensile Strength MPa	Yield Stress MPa			Percentage Elongation
		<20	20-40	>40	
E250	410	250	240	230	23
E275	430	275	265	255	22
E300	440	300	290	280	22
E350	490	350	330	320	22
E410	540	410	390	380	20
E450	570	450	430	420	20
E550	650	550	530	520	12
E600	730	600	580	570	12
E650	780	650	630	620	12

E 250 grade of structural steel is commonly manufactured and marketed in India, and it is extensively used in steel girder bridges. Rolled sections as given in IS:808-1989, ‘Dimensions for hot rolled steel beam, column, channel and angle sections’, are generally freely available in the Indian market for use in steel structures. Manufacture and availability of the rolled sections for all other grades of steel is limited and only on specific order basis. Availability of E 410 grade plates, among the HTS steel sections, is better but rolled sections even for this grade of steel are not readily available in the market, but these can be procured from manufacturers on order basis. Therefore, study of composite HTS steel 90.0m span truss bridge is carried out only for E 410 grade steel.

6.8.2 Design example of 90.0m span truss bridge using mild steel and HTS

Mild steel (E 250) and HTS (E 410) are used for design of 90.0m span composite semi deck type bridge (Figure 6.12). The bridges are designed as per Indian standards and their behaviour and cost are compared for evaluating their advantages and disadvantages.

The following modelling, analysis and design criteria are adopted for design of the semi deck type truss girder bridge superstructures.

6.8.2.1 Geometric arrangement for the 90.0m span bridge

Height of Truss (C/C distance between top chord and bottom chord members) = 8m

C/C distance between two trusses

= 6.0 m

Width of roadway = 5.5 m

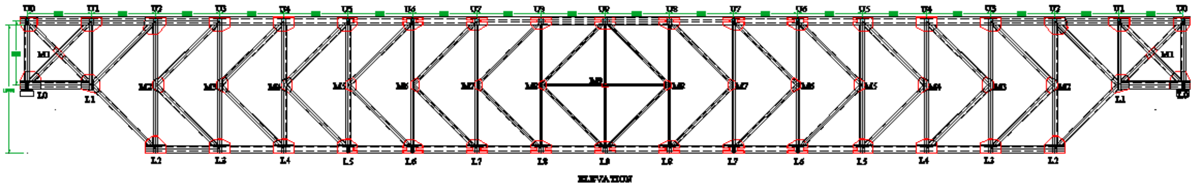
Panel length = 5m

Number of 5m top panels = 18

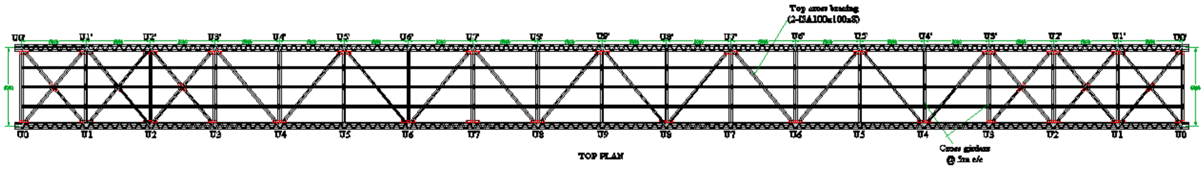
Number of 5m bottom panels = 18

C/C distance between cross girders = 5m

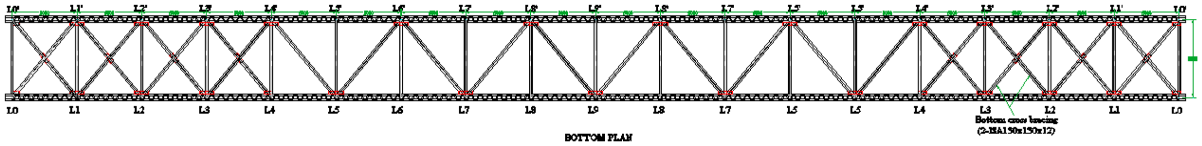
The elevation , top plan and bottom plan of the bridge is shown in Figure 6.12.



a. Elevation



b. Top plan



c. Bottom plan

Figure 6.12 90.0m span semi deck composite truss bridge

6.8.2.2 Modeling

The bridge is modelled as a space frame in STAAD Pro. Section builder is used for sections not covered in IS steel table.

As discussed in Chapter-4, due to shrinkage of deck slab, it will not be proper to consider the deck slab composite with the steel truss in the model. Stringer beams are assumed primarily to carry loads from the deck slab. Loads due to self weight of deck slab and live load through deck slab are considered to act on the stringer beams. The stringer beams are released in the longitudinal direction, so as to prevent bending of the cross girders in the horizontal plane. The ends of the stringer beams are connected with the cross girders with the help of loosely tightened bolts over longitudinal slots in the stringer beams. In addition to four vertical supports by POT-PTFE bearings at the two ends of the bridge, the bridge is modelled with horizontal supports at the top also. The deck slab of the bridge is restrained against horizontal deflection at the two ends by the abutments.

6.8.2.3 Loading

The bridge is analyzed in STAAD Pro. for DL, SIDL, LL, FPLL, Wind load, Seismic forces and their combinations as per IRC: 6-2010. Primary loads and load combinations as given in Chapter 4 are used for the analysis.

6.8.2.4 Design

E 250 and E 410 grades of steel (IS:2062-2011) are used in the design for the two 90.0m span bridge superstructures, for which minimum yield strengths are 250 N/mm^2 and 410 N/mm^2, and minimum ultimate tensile strengths are 410 N/mm^2 and 540 N/mm^2, respectively.

Interaction Ratio:

The Deck Slab is made monolithic with the steel truss by providing shear connectors along the top chord members, cross girders and stringer beams. Thus, buckling of the top chord members is prevented and permissible stress in top chord members can be safely taken as at least 250 N/mm^2 for E 250 grade steel and 410 N/mm^2 for E 410 grade steel. Therefore, in the overload condition the area of top chord members need not be increased from the service condition requirement.

Permissible stress in the tension members of the truss is taken as at least 250 N/mm^2 for E 250 grade steel and 410 N/mm^2 for E 410 grade steel. Therefore, area of the tension members of the truss also need not be increased for the overload condition.

Gusset plates are designed for service load condition to transmit maximum axial forces for the members meeting at the joint. Since there is no possibility of buckling of the gusset plates, permissible stress in gusset plates in overload condition is also taken as 250 N/mm^2 for E 250 grade steel and 410 N/mm^2 for E 410 grade steel, respectively, and their cross sectional areas are not increased from the service condition requirement for the overload condition. The design is carried out for axial force as well as biaxial bending in the members.

For design at service condition under (DL+LL) case, interaction ratio is limited to 1.0 in all members. For design at overload condition under 2.25x(DL+LL) case, interaction ratio is limited to 1.0 in all tension members and laterally supported top chord compression members. For other laterally unsupported compression members the interaction ratio is limited to 0.66. Design for 90.0m span composite truss bridge E250 E410 grade steel is given in Table A.9 and Table A.10 in Annexure A.

6.8.3 Cost comparison of structural steel in superstructure

As enquired from SAIL present cost of E 250 grade steel is Rs. 45,000.0 per tonne and E 410 grade steel is Rs. 55,000.0 per tonne.

Therefore, ratio of strength per unit cost for E410 and E250 steel is;

$$= \frac{\frac{410}{55000}}{\frac{250}{45000}} = \mathbf{1.34}$$

There is about 34% cost advantage and weight advantage in using E410 grade steel. For comparing cost of the superstructure in the two cases the costs are calculated using the above unit rates for structural steel.

Maximum vertical deflection, steel off take and cost of structural steel in superstructure under service condition for (DL+LL) case are given in Table 6.6.

Table 6.6 Deflection comparison of 90.0m span bridge designed using E250 and E410 steel

Bridge type	Max. vertical deflection for (DL+LL) case (mm)	Max. vertical deflection for LL case (mm)	Total steel off take including 20% extra (t)	Steel cost in superstructure (Million Rs.)
E 250	150.7	33.6	295.2	318.0
E 410	221.3	62.6	218.7	235.2

From the total steel off take consideration semi deck type bridge in E 410 grade steel is 35.0% economical in comparison to the E 250 grade bridge. Maximum vertical deflection of E 250 grade bridge is lower by 32.0% in comparison to the E 410 grade steel bridge.

Permissible deflection of the bridge in service condition (cl. 507.5.1, IRC: 24-2001) is 150.0mm (L/600). Therefore, where as the bridge in E 250 grade steel marginally passes from the maximum deflection criterion under the service load condition, E410 grade steel bridge deflection exceeds by 47.5%.

Permissible deflection of the bridge under live load with impact (cl. 507.5.1, IRC: 24-2001) is 112.5mm (L/800). Therefore, both E 250 and E 410 grade steel bridges pass this criterion safely and remain at 70.1% and 44.3%, respectively of the permissible deflection limit.

Since, E 410 grade steel bridge passes the deflection criterion under live load with impact condition, suitable camber may be provided in the bridge and dead load plus live load criterion may be violated. Violation of the deflection criterion under the dead load plus live load condition by providing suitable camber seems to be justified, as fatigue in the bridge is caused only by the live load.

Maximum vertical deflection, steel off take and cost of structural steel in superstructure at overload condition for 2.25x(DL+LL) case are given in Table 6.8.

Table 6.8 Maximum vertical deflection, steel off take and cost of structural steel for overload condition of 2.25(DL+LL).

Bridge type	Max. vertical deflection 2.25x(DL+LL) (mm)	Total steel off take including 20% extra (t)	Steel cost in superstructure (Million Rs.)
E 250	217.4	331.3	356.9
E 410	321.7	232.3	250.2

From the total steel off take consideration, semi deck type bridge in E 410 grade steel is 42.6% economical in comparison to the E 250 grade steel bridge. In the overload condition vertical deflection is not a governing criterion.

6.9 CONCLUDING REMARKS

Comparative study of four types of truss bridge configurations for 30.0m span and 90.0m span is presented. Through type, deck type, semi deck type and under slung truss bridges for the two spans are considered for 30.0m and 90.0m span respectively. Configuration of semi deck type truss bridges is proposed logically with design philosophy. This type of bridge configuration is not found in the literature in spite of their superior performance and it is introduced for the first time in this research.

Short span semi deck type bridge is most preferable under service load (DL+LL) case as well as at the overload condition for 2.25x(DL+LL) case in respect to lateral deflection and vertical deflection criterion. Although, from the total steel off take consideration, under slung truss type bridge is most economical, but under slung truss bridges need support at the sharp edge of the truss, which may be often difficult to provide. Considering overall feasibility in construction and performance, semi deck type bridge option is most preferable as compared to other bridge configurations.

In case of long span bridges, from vertical deflection consideration all types of bridges have similar performance under service load condition. There is not much variation in steel off take in all four types of bridges for service load under (DL+LL) case. Therefore, unlike short spans, in long span bridges cost of the bridge does not significantly vary with the type of truss arrangement.

Vertical deflection at overload condition in longer span bridges is more than permissible deflection in service condition. However, vertical deflection is not a governing criterion at the overload condition. From the vertical deflection consideration semi deck type bridge may be acceptable.

Choice for the semi deck type composite bridge arrangement may be restricted due to lower free board, particularly in short span bridges, when shallow valley profile is there. Due to moderate abutment height and matching height of the embankment, cost of abutment and the approach road is also reasonable in the case of composite semi deck type bridge arrangement.

Semi deck type truss bridge of 90.0m span is designed using E250 and E410 grade steel and comparative study is carried out. From the study, it is found that total steel off take and cost of the semi deck type bridge using E410 grade steel is 35.0% lower in comparison to the bridge using E250 grade steel.

Maximum vertical deflection under service load condition of E250 grade steel bridge is lower by 32.0% in comparison to the E410 grade steel bridge. Permissible deflection of the bridge in service condition is 150.0mm (L/600). Therefore, where as the bridge in E 250 grade steel marginally passes from the maximum deflection criterion under the service load condition, E410 grade steel bridge deflection exceeds by 47.5% from the limiting deflection.

Permissible deflection of the bridge under live load with impact is 112.5mm (L/800). Therefore, both E250 and E410 grade steel bridges pass this criterion safely and remain at 70.1% and 44.3%, respectively, of the permissible deflection limit.

Since, E410 grade steel bridge passes the deflection criterion under live load with impact condition, suitable camber may be provided in the bridge and dead load plus live load criterion may be violated. Violation of the deflection criterion under the dead load plus live load condition by providing suitable camber may be justified, as fatigue in the bridge is caused only by the live load.

Under overload condition, total steel off take of semi deck type bridge using E 410 grade steel is 42.6% lower as compared to the bridge using E250 grade steel. In the overload condition vertical deflection is not a governing criterion, and therefore, in this condition E410 grade steel bridge is superior from cost consideration. Thus use of high tensile steel in semi deck type composite truss bridge is preferable.