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Parametric Study for Economic Steel K -Truss Bridge

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Abstract
The economy of truss bridge is affected by several parameters such as weight of deck slab, stringer, cross girder, height of truss, panel spacing etc. Steel truss bridge is found economic for mid to long span ranges. K-truss has been widely used in long span, as presence of short members makes it capable to resist buckling from compression. The procedure here presented consists of minimization of weight of simple span, through type, double lane, RCC deck, steel K-truss bridge of 100m. The analysis has been done in accordance with the specifications of the Indian Codes by using working stress method. Manual calculations were performed to determine least weight of steel K-truss bridge with different combination of panel length and height of truss girder. The parameters affecting the economy has been analysed. Finally, economic height-to-span ratio and panel spacing of K-truss steel bridge of 100m span is obtained.

Keywords
K-truss bridge, economy, panel spacing, height-to-span ratio

1. Introduction

Steel bridge can be classified into truss bridge and plate girder bridge. Construction of simple span bridge for longer span can be achieved using trusses which is more economic. Various studies have been conducted to study the economical configuration of truss bridges. Whipple[1] performed investigation to provide best plan and proportions of parallel chord truss bridges. Emery[2] performed a trial-and-error procedure for determining least-weight proportions of iron parallel-chord trusses. Waddell[3] performed mathematical investigation on the economy of parallel-chord truss. Waling[4] used the theory of maxima and minima for the determination of least-weight proportions of parallel and polygonal warren bridge trusses. Dubois[5] provided rational formula for weight of floor system, stringer, trusses and for economic depth of parallel chord trusses. This formula is useful for approximation of weight of bridge, but it is complicated to use in practical life. Huang[6] performed optimal design and buckling analysis of a long- span steel trusses. Maraveas[7] performed optimal design of through-truss steel bridges, influence of both the height-to-span ratio and the deck type on the weight of the truss, on the total weight and the cost were discussed. Jamadar and Jadhav[8] optimized truss bridges with a span of 50 m and 60 m long at different heights while they are subjected to wind and railway loading from outcome such as deflection in order to identify the optimum bridge height. Most of these studies were limited to short ranges of medium span Warren and Pratt type, parallel chord truss bridges. For long span truss bridges, it is economical to keep variable height of truss. The effect of different parameters such as number of cross girder, number of stringer, height-to-span ratio on long span K-truss bridge has not been incorporated. Therefore, this paper aims to the study effect of various parameters on the economy of K-truss bridge and develop the relationship between weight, depth and panel length using the same design code provisions and steel sections available as used by engineers within Nepal so that the truss bridges can be made lighter in weight and more economic than they are at present

2. Development of Theory

A truss bridge consists of two vertical truss girders spaced at some distance apart. The lower panel points of the two truss girders are joined cross-girders. Cross girder receives the load from stringers which run parallel to the length of the two trusses. Stringer receives the load from deck slab. Among various factors, reduction in weight of the components of truss can bring economy in bridge

The process involves economisation principle for attaining minimum weight of deck slab, stringer, cross girder and truss weight. According to IRC 21:2000 [9] minimum thickness of deck slab is 200mm. Random selection of thickness increases unnecessary load and cost of the structure. Spacing of stringer controls the depth of slab. As the span of slab decreases, thickness also decreases. Trial and error method is done for the economic depth of slab for given stringer spacing.

Number of cross girders used or spacing between cross girder controls the weight of stringer. When the spacing between the cross girder decreases the span of stringer also decreases which causes decrease in the weight of the stringer. On the other hand, increase in the number of cross girders causes increase in weight of the steel. The proper combination of the number of stringer and number of cross girder gives economy in bridges.The standard section available has its certain capacity. The steel section available can be used for certain limit of combination of spacing of cross beam and number of stringers. The range in which the certain section can be used for certain span will enable to use the section to its fullest capacity and the overestimation of material will be reduced. Number of nodes where weight of cross and stringer becomes minimum can give the minimum weight of truss and eventually minimum total weight of truss bridge or for the truss configuration for which minimum weight of truss is obtained can give the total weight of the truss bridge minimum.

Economy of steel truss is governed by parameters like panel length, sections used, height of truss girder. As the height of truss increases the load on chord member decreases while in the web member it remains same. Decrease in load in chord member results decrease in weight of the truss. While in the web member due to increase in length of member it becomes slender.So, the web member should be made stronger which adds weight to the truss. Increase in the height of truss decreases weight of truss due to reduced weight of chord member but after increasing the height of truss girder up to certain limit the total weight of truss increases due to heavy web member. The economic height of the truss bridge is obtained at minimum weight. According to IRC24:2001 [10] depth of truss girder should not be less than 1/10 the effective span. The study of economic depth to span ratio for make overall design economy.

3. Economization Method

For the study of minimization of weight of truss bridge two methods have been followed. First method consists of sequentially minimisation of weight of deck slab for given stringer spacing. After minimum depth of slab is fixed for certain number of stringers, minimization of weight of stringer and cross girder for different panel spacing is carried out.After that minimum weight of truss girder for different height-to-span ratio of truss is found and finally total weight of the bridge is calculated. Second method involves backward calculation for minimizing the truss weight for different panel spacing and height-to-span ratio of truss, after that the weight of the stringer cross girder and deck slab for the panel length and height-to-span ratio where minimum weight of truss is found and finally calculation of total weight of bridge is done. Minimum weight of truss bridge among two method is compared and obtained .Hence, height-to-span ratio of truss and panel spacing for minimum weight can be achieved.

4. Analysis

The design and analysis of K-truss bridge has been conducted considering various parameters using working stress method. The process involves economization principle for attaining minimum weight of the deck slab, stringer, cross girder and truss.

4.1 Deck Slab:

For the analysis of two lane 100m span deck slab, standard carriage width of 7.5m and kerb width of 0.3m was taken. The slab is analysed for stringer spacing of 3.6m (3-stringers)and 2.4m (4-stringers). 70R track ,70R wheel loading and class A loading is applied in deck. Design bending moment was obtained from maximum bending moment of 70R track ,70R wheel loading and class A. Thickness of deck the slab is calculated for 3-stringer cases and 4-stringer cases. The thickness was checked against shear force. Volume of deck slab obtained in 3-stringer and 4-stringer cases can been seen from figure 3.

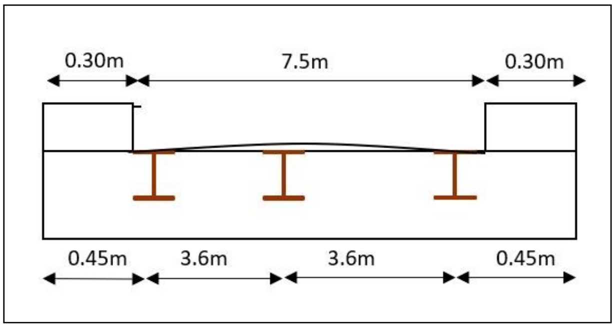

Figure 1: Cross-Section of Deck Slab with 3-stringer.

4.2 Stringer and Cross girder

Two cases of number of stringers are taken, viz. 3-stringer and 4-stringer and six cases of cross girder spacing are taken, viz. 5, 5.55, 6.25,7.14, 8.33 and 10m.

The design of the stringer and cross-girder was performed as per IRC: 24-2001[10] and IS 800:1984[11].Courbon's method was adopted for design of stringer.. Live load bending moment was obtained from IRC class A and 70R along with dead load bending moment and maximum bending moment obtained out of these was adopted as design bending moment. IS hot-rolled sections and plates are used from available steel sections (ISMB 600, 500, 400, 350, 300, 250, 200, 250). The length of stringer beam varies as spacing of cross girder varies .The weight stringer for every length of stringer or cross girder spacing is calculated. The ranges of steel section that can used for ranges of span of stringer is found and variation of weight of the stringer with span is observed.

The figure-4 illustrates the variation of weight of stringer as number of panel point varies or length of stringer varies of stringer for 3 stringers and 4 stringers cases. Design of cross girder was done using class 70R live load. Standard section (ISMB 600, 500, 400, 350, 300, 250, 200) was varied to obtain minimum weight. Variation of weight and ranges of standard section for different panel spacing is obtained.

4.3 Steel K-truss

K- Truss with four cases of panel length or node spacing are taken , viz. 5, 5.55, 6.25, and 7.14m and six depth of truss girder viz. 10, 11.11, 12.25, 14.29, 16.67, and 20m at the mid are considered for the study.

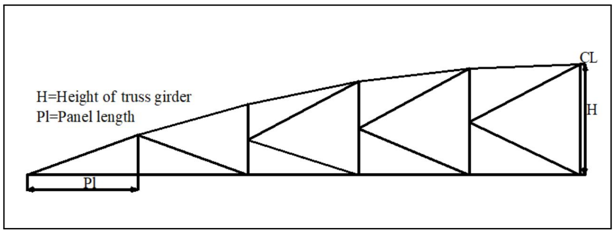

Figure 2: Geometry of K-Truss Bridge

The dead load from stringer, cross girder, deck was considered. The dead load for truss girder was calculated from the Fuller's formula (0.5*L (0.5*L+5.55), where L denotes span) Live load due to class 70R load was calculated. Lateral forces due wind and wind effects (overturning effect, lateral effect on top chord, lateral effect on bottom chord, portal effect and sway effects) are calculated. Using influence line diagram, the force on the member were calculated and then section of chord member and web member were designed according to nature of forces (tension or compression member) using built-up section from standard steel table. Variation of weight of steel truss with truss girder height is shown in figure 7.

5. Result

After analysis,following results can be observed:

5.1 Variation in volume of deck with change in number of stringer

Thickness of 100m span deck slab obtained for 3-stringer case is 220mm and four stringer cases is 200mm as number of load bearing stringer is decreased, thicker slab is required. Hence as shown in Figure-3 the volume required for 4 – stringer case is lesser than that of 3-stringer case.

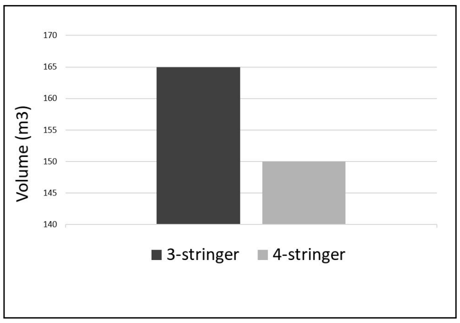

Figure 3: Volume of deck vs No of stringers

5.2 Variation in weight of stringer with number of panel point

When weight for 4-stringers and 3-stringers is compared from figure-4, total weight of 3 stringers is lesser than 4-stringers for same panel point. Even the section obtained is higher for 3-stringers, as number of stringers increase causes weight increases.

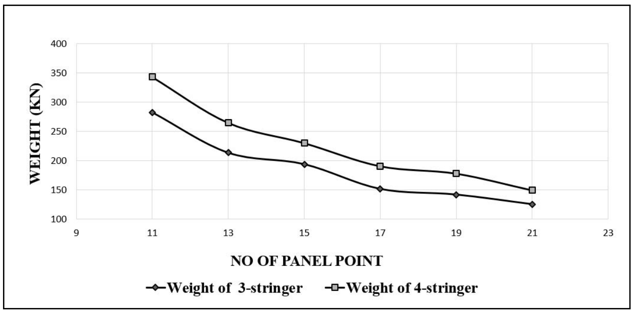

Figure 4: Weight of stringer vs number of panel point

5.3 Variation in weight of stringer and cross girder with number of panel point

From Figure-5,when number of panel point is increasing from panel number 11 to 21, weight of the cross girder is increasing. Whereas weight of the stringer is decreasing with increase in panel number. Hence total weight of stringer and cross girder is found to be minimum when the number of panel point range from 17 to 21 (i.e. spacing of cross girder at 6.25m, 5.55m and 5m). Thus, the economical spacing of cross girder is in range of 17-21 for 100 m span bridge.

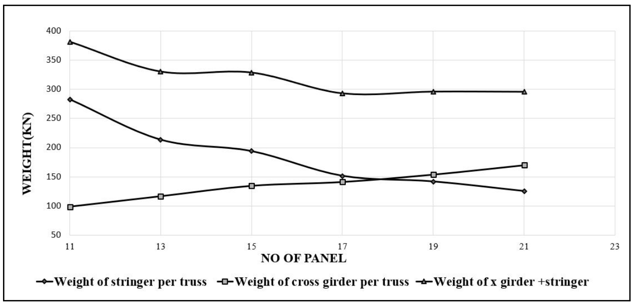

Figure 5: Weight of stringer,cross girder and total weight of stringer and cross girder vs number of panel point

5.4 Variation in weight of components of truss with height of truss.

From the analysis it is observed that when the height of the truss is increased the weight of bracing is slightly increased.The weight of cross girder and stringer remains constant. But the weight of top chord member and bottom chord member goes on decreasing and the weight web member goes increasing. As increase in height of the bridge causes reduction in load on top and bottom chord so that small sections can be used which makes the bridge lighter. But in other hand by increasing the height of bridge slender member is achieved in web member which is susceptible for buckling. So, the section of the web member increases which inherently adds weight on member.Hence, After reduction in weight upto certain height, weight of truss increases .Figure-6 shows the variation of weight of components of truss weight with height for 6.25m panel spacing.Similar type of variation is observed in other panel spacing (i.e. 7.25m, 5.55m, 5m)

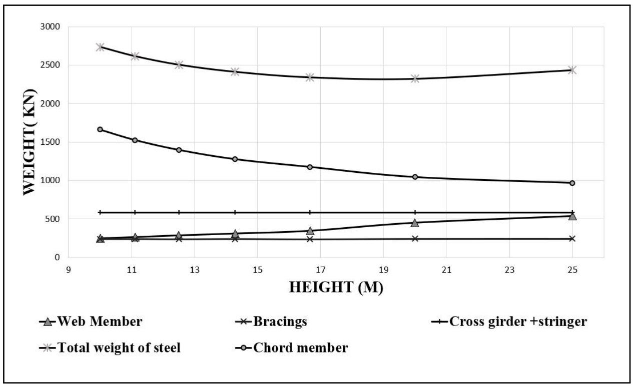

Figure 6: Variation in weight of components of truss with height for 6.25m panel spacing

5.5 Variation in weight of truss and total weight of steel with height of truss

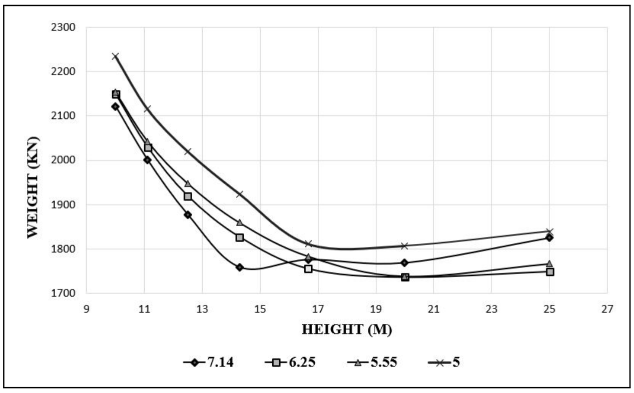

Figure 7: Weight of truss vs height of truss for different panel spacing

From figure-7 and figure-8, For every panel with increase in height (10m, 11.11m, 12.5m, 14.29m, 16.67m and 20m) of truss girder the weight of steel goes on decreasing but after certain height the weight goes on increasing. For panel spacing 6.25m, 5.55m, and 5m the minimum weight is obtained at 20m height (1/5th span) of truss girder. But for the 7.25m panel spacing minimum weight is obtained at 14.29m (1/7th span) of truss girder.

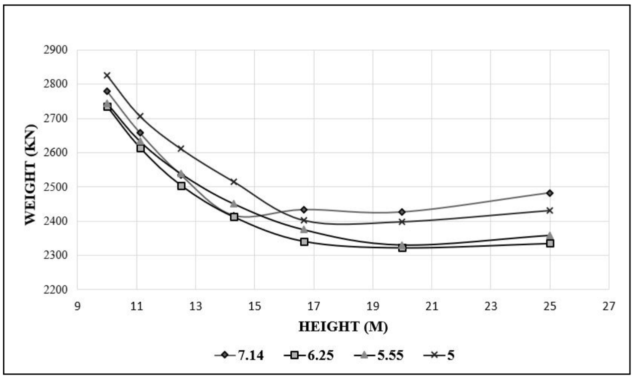

Figure 8: Total weight of steel vs height of truss for different panel spacing

Figure-9 shows the minimum weight of steel for different height of truss girder. The weight of total steel has decreased up to height to span ratio 1/5th and then increased. As prescribed by IRC code, this height of truss girder is not less than 1/10 the effective span and nearly equal to the ranges gained by other writers (1/6th to 1/8th). There is not much variation in weight for height-to-span ratio between the ranges of the 1/7th to 1/5th. Longer height of truss girder can cause increase in construction cost. So, as to keep the balance between cost of construction and cost of steel, height-to-span ratio can be taken in range of 1/7th to 1/5th.

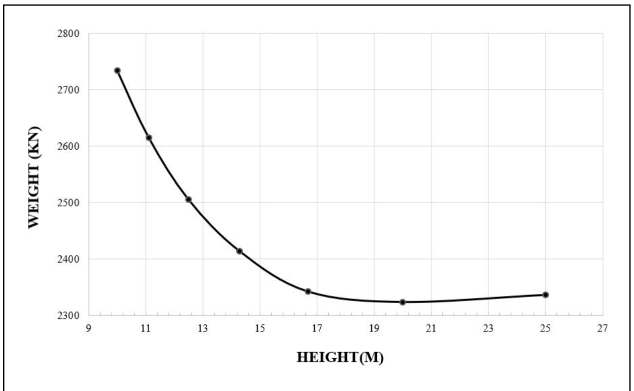

Figure 9: Minimum weight vs height of truss

Table 1: Comparison between total weight stringer and cross girder, minimum weight of truss and total weight of steel

Panel Spacing (m)	Minimum weight of truss (kN)	Weight of stringer+cross grinder (kN)	Total weight of steel (kN)
7.14	1759.32	657.00	2416.32
6.25	**1737.31**	**585.41**	**2322.72**
5.55	1739.09	591.42	2330.51
5	1807.43	607.32	2398.27

5.6 Comparison between total weight stringer and cross girder, minimum weight of truss and total weight of steel.

From table-1, shows the minimum weight of truss for the given panel length and total weight of stringer and cross girder for the given panel length. The minimum weight of cross girder and stringer is found to be at panel spacing 6.25m. Also, the minimum weight of the truss only and the total minimum weight of steel is found at 6.25m panel spacing. Hence,following first method, minimum weight of steel is obtained when weight of each component (deck, stringer,cross girder and truss) is sequentially minimised.

6. Conclusion

Parametric study for through-type steel truss bridges was performed for a span of 100m. The analysis and design were performed according to the current IRC codes using standard steel section. Based on the conducted study, following conclusions is drawn.

- Total weight of stringer and cross girder is found minimum at 6.25m spacing of cross girder for 100m span bridge.
- The weight of truss and total weight of steel is found to be minimum at range of height-to-span ratio of 1/7th to 1/5th.

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