IMPACT: International Journal of Research in
Engineering & Technology (IMPACT: IJRET)
ISSN(P): 2347-4599; ISSN(E): 2321-8843
Vol. 4, Issue 9, Sep 2016, 45-52

COMPARATIVE STUDY OF STEEL I - GIRDER AND PRESTRESSED STEEL I – GIRDER AS PER IRC24:2010

DHARA SHAH[1], DEVANG PATEL[2] & HETAL JANI[3]

[1]Faculty of Technology, CEPT University, Ahmedabad, India

[2]Partner, SID consultants, Ahmedabad, India

[3]M.Tech student, Faculty of Technology, CEPT University, Ahmedabad, India

ABSTRACT

Prestressing of structural elements especially steel girders improve their load bearing capacity and rigidity along with reduction in material consumption and overall cost for the same loading. The present study aims at preparing expedient interface for design of Steel I-Girder and Prestressed Steel I-Girder as per IRC24: 2010, encompassed through parametric study of two lane road bridges for varying span to depth ratios, considering 15m, 20m, 25m and 30m of spans. The analysis is done considering dead load, superimposed load and moving load as per class A-2 lane / class 70R loading. Design of prestressed steel I-girder is done by varying the diameter and number of strands. 9.5 mm, 11.1 mm, 12.7 mm and 15.2 mm diameter class B 7-ply strands are considered in 4, 8, 12, 16 and 20 numbers of groups. The cost comparison is done as per prevailing market rates. A definite increase in the bending capacity of steel I-girder is found when prestressed with strands, without any enhancement in shear capacity. Prestressed steel I-girder provides shallower depth of the girder for same L/D ratio. With increase in the strand area and number of strands, bending capacity increases for same L/D ratio. Prestressed steel I- girder shows cost saving up to 50% for 15m span, 37% for 20m span, 28% for 25m span and 20% for 30m span. Cost of girder per meter length decreases when applying the prestressing force with increase in L/D ratio.

KEYWORDS: Prestressed Steel I-Girder, Cost Comparison, IRC24:2010, L/D Ratio

INTRODUCTION

Prestressing is the introduction and distribution of exactly defined stresses in the cross section of member to increase the strength of the structure. Well-designed prestressed steel structures ensure economy and technological competence. Prestressed steel is a construction technique where in steel member is subjected to predetermined concentric/ eccentric force so as to introduce opposite stresses, which counteract those produced by external loading. In concrete, the prestressing force is mainly used to overcome the lack of tensile strength in concrete whereas in steel it is mainly for increasing the load carrying capacity of the member so as to achieve economical member sizes and reduction in weight. The main concern in normal steel girders is deflection, when subjected to unpredicted higher loadings. In such situations, prestressed steel girders prove to be a better choice.

PROBLEM FORMULATION

In the present study, two lane bridges are considered as shown in figure 1. Width of carriageway is assumed as 7.5m. Assumed sizes of non-structural components such as footpath, crash barrier and parapet are 1.5m, 0.3m x 0.5m and

0.5m x 1m. Thickness of deck slab assumed is 0.24m and wearing coat as 0.08m. Two types of loading i.e. class 70R and class A; are considered for analysis and design as per IRC6 [1]. The material properties considered for loading are given in Table 1.

Table 1: Material Properties

Material	Density
Reinforced concrete	25 kN/m^3
Structural steel	78.5 kN/m^3
Wearing coat	22 kN/m^3

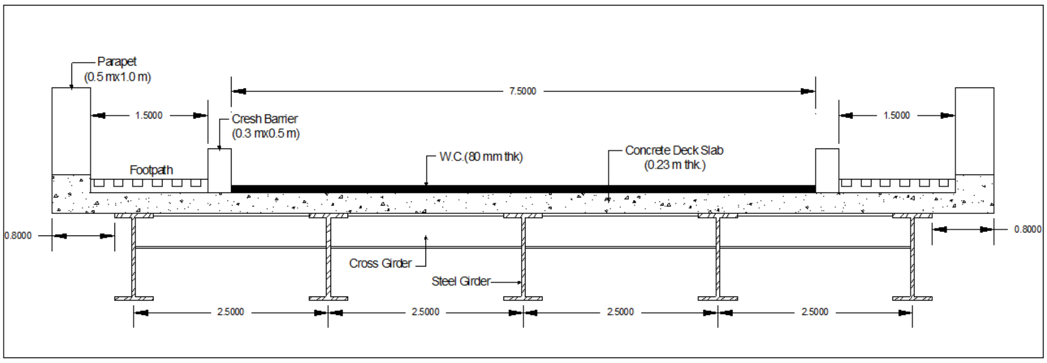

Figure 1: Cross Section for Two Lane Bridge

Span to depth ratio plays a vital role in achieving economy. As per the referred literature, span to depth ratio of a steel girder for a highway bridge generally varies from 12 to 18. Considering above, various span to depth ratios for different spans have been worked out as shown in Table 2. Welded plate girder is assumed. Depth of web has been calculated considering transverse stiffeners with panel ratio C/D as 1.5 where c is the spacing of stiffeners and d is depth of web. Wed resistance to shear buckling is verified as per IRC24 [2]. Width of the flange is assumed approximately as 0.3d. Thickness of the flange is assumed in such a way that the member falls under plastic / compact section category.

Table 2: Various Spans to Depth Ratios Considered

Span (m)	Span to Depth Ratios (L/D)
15	10.7, 11.13, 11.56, 12.02, 12.56, 13.11, 13.76, 14.48, 15.21, 16.03, 16.93, 18.03
20	11.7, 12.05, 12.42, 12.85, 13.28, 13.77, 14.27, 14.84, 15.41, 16.03, 16.75, 17.48, 19.31
25	11.76, 12.07, 12.36, 12.68, 13.01, 13.38, 13.78, 14.17, 14.62, 15.06, 15.53, 16.07, 16.6, 17.22, 17.83, 18.55
30	11.8, 12.06, 12.31, 12.58, 12.85, 13.13, 13.45, 13.76, 14.11, 14.48, 14.84, 15.21, 15.61, 16.06, 16.54, 17.01, 17.54, 18.07, 18.63

GRILLAGE ANALYSIS

Deck of bridge is idealized as series of grillage elements connected and restrained at joints. Deck is idealized into equivalent grillage by introducing grillage lines in transverse and longitudinal direction such that the ratio of centre to centre distance of transverse grillage line to that of longitudinal line is in between 1 to 2. Idealization is carried out for all spans. Typical grillage line diagram for 15m span is shown in figure 2.

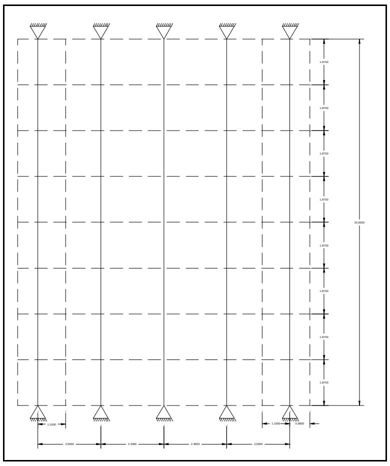

Figure 2: Grillage Line Diagram for 15m Span

Elastic properties of various grillage lines are worked out including flexural and torsional stiffness, calculated about neutral axis of the section. During consideration of live load and superimposed live load, composite action of deck and girder into equivalent steel section is done as shown in figure 3.

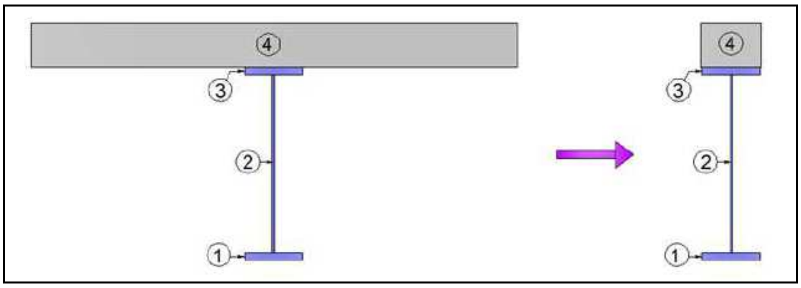

Figure 3: Equivalent Steel Section

Dead live and imposed live loads acting on the bridge superstructure are evaluated and approximately distributed to the nodes of grillage. Loads calculated are given in Table 3. Force responses and design envelopes are determined accordingly.

Table 3: Load Evaluation

Dead Load	Intensity
Weight on slab	
• On middle three longitudinal girders = 0.24x2.5x25	15 kN/m
• On edged two longitudinal girders = 0.24x1.9x25	11.4 kN/m
• Cross girder self-weight	1 kN/m (assumed)
Superimposed load	**Intensity**
Wearing coat	
• On middle three longitudinal girders = 2.5x2	5 kN/m
• Crash barrier =0.3x0.5x25	3.75 kN/m
• Footpath	
• Dead load = 1.5*0.15*25= 5.625 kN/m2	
• Live load = 5 kN/m2 or 500 - $\frac{(40L - 300)}{9}$	Whichever is greater
• Parapet = 0.5x1.0x25	2.5 kN/m

RESULTS AND INTERPRETATIONS

Design bending capacities of steel I -girder and prestressed steel I-girder have been obtained in graph forms along with deflection. Typical charts for 15m span showing bending capacities and deflection for of steel I-girder and prestressed steel I-girder are shown in figures 4 to 11. The permissible deflection as per IRC24 is L/600 where L is the span of the girder. From the charts shown, depth of the steel I-girder and prestressed I-girder section can be estimated based on the strength as well as serviceability criteria. The L/D ratio which satisfies both criteria can be adopted for the design of girder.

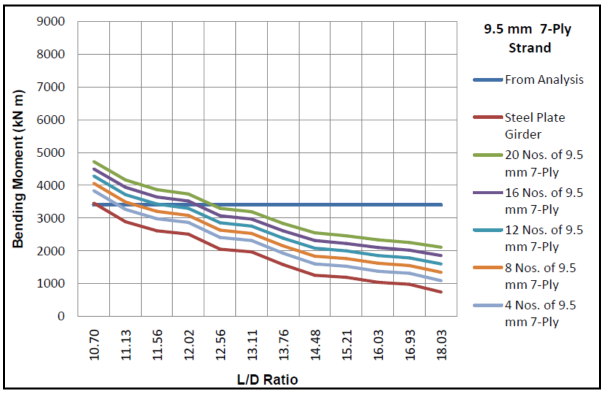

Figure 4: Bending Capacities of Steel I-Girder and Prestressed Steel I-Girder for 15m Span (Prestressing with 9.5mm -7ply)

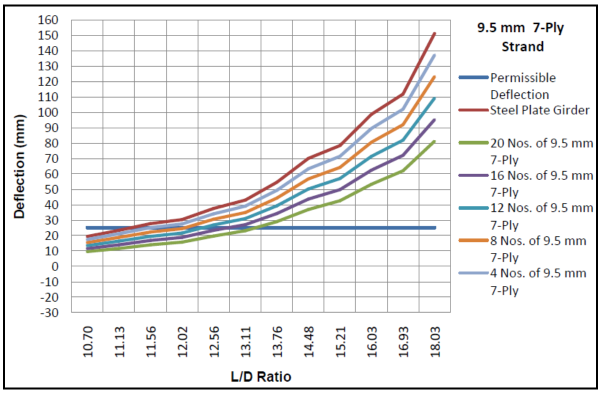

Figure 5; Deflection of Steel I-Girder and Prestressed Steel I-Girder for 15m Span(Prestressing with 9.5mm -7ply)

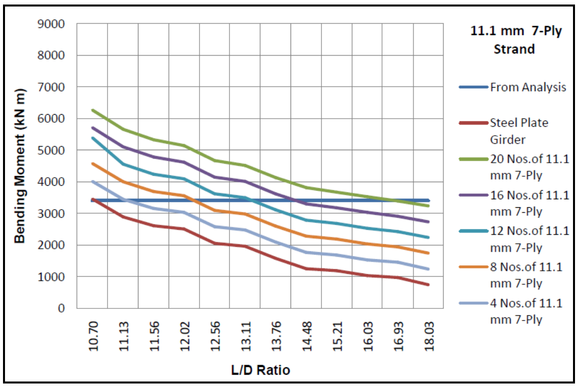

Figure 6: Bending Capacities of Steel I-Girder and Prestressed Steel I-Girder for 15mSpan (Prestressing with 11.1mm -7ply)

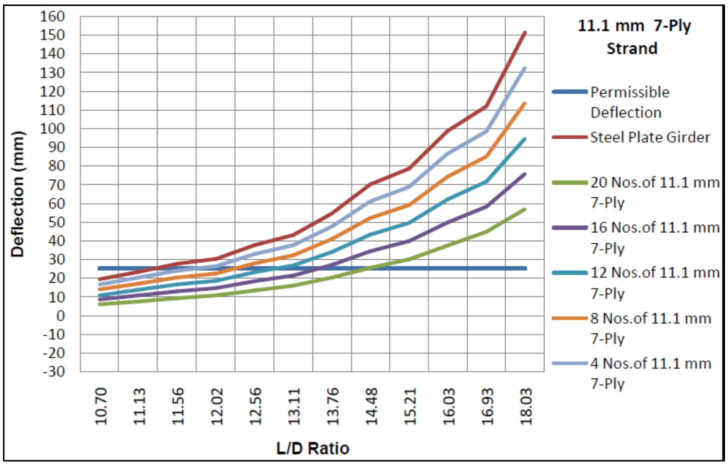

Figure 7: Deflection of Steel I-Girder and Prestressed Steel I-Girder for 15m Span (Prestressing with 11.1mm -7ply)

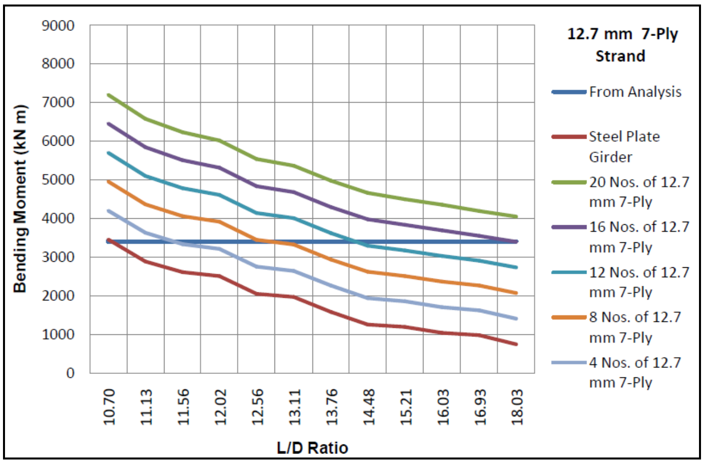

Figure 8: Bending Capacities of Steel I-Girder and Prestressed Steel I-Girder for 15m Span (Prestressing with 12.7mm -7ply)

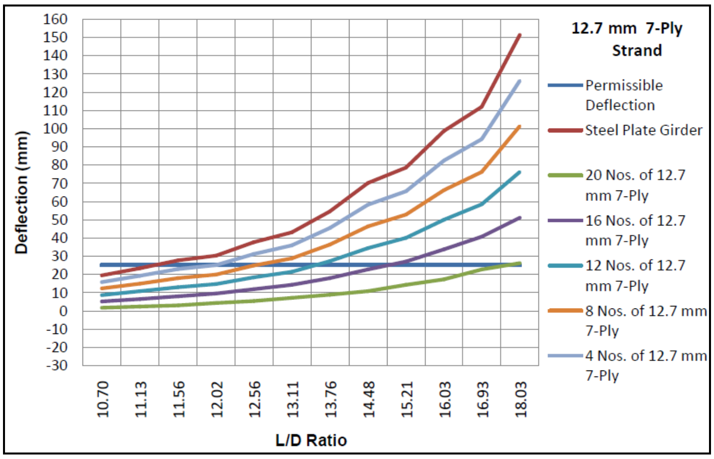

Figure 9: Deflection of Steel I-Girder and Prestressed Steel I-Girder for 15m Span (Prestressing with 12.7mm -7ply)

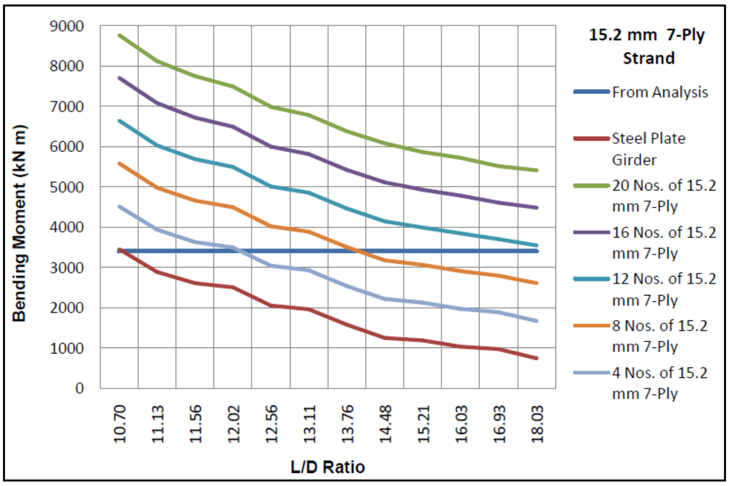

Figure 10: Bending Capacities of Steel I-Girder and Prestressed Steel I-Girder for 15m Span (Prestressing with 15.2mm -7ply)

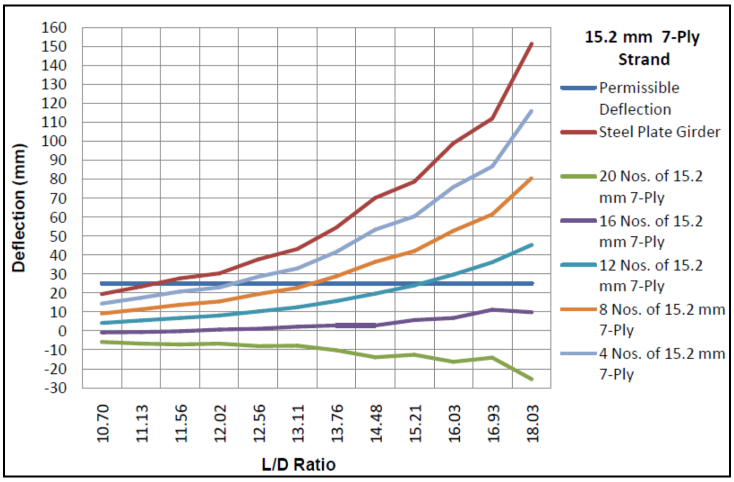

Figure 11: Deflection of Steel I-Girder and Prestressed Steel I-Girder for 15m Span (Prestressing With 12.7mm -7ply)

The cost comparison is done so as to achieve economy by introducing prestressing strands in steel girder. Cost is compared for 12.7 mm strand for all spans, considering L/D ratios which give optimum depth and permissible deflection of steel girder and prestressed steel girder, with strands in groups of 4, 8, 12, 16 and 20. Area of single strand of 12.7mm is 98.7 mm^2. Cost of steel section is assumed as Rs. 60000 per MT. Cost of prestressing steel stands is assumed as Rs. 100000 per MT. A typical cost comparison for 15m span is shown in Table 4.

Table 4: Cost Comparison for 15m Span Steel I-Girder

L/D	Area of Section	Volume of Section	Weight of Section	Cost of Steel Section	No. of Strands	Area of Strand	Volume of Strands	Weight of Strands	Cost of Strands	Cost of Fixtures	Total Cost	Total Cost Per M Length	% Savings W.R.T Steel Girder
	mm²	mm³	MT	Rs.		mm²	mm³	MT	Rs.	Rs.	Rs.	Rs.	
11	43700	0.656	5.146	308760	0	0	0.000	0.000	0	0	308760	20584	No prestressing
11	40000	0.600	4.710	282600	4	395	0.006	0.047	4650	233	287483	19166	6.9
13	31500	0.473	3.709	222540	8	790	0.012	0.093	9300	465	232305	15487	24.8
13	28600	0.429	3.368	202080	12	1184	0.018	0.140	13950	698	216728	14449	29.8
14	22800	0.342	2.685	161100	16	1579	0.024	0.186	18600	930	180630	12042	41.5
17	18400	0.276	2.167	130020	20	1974	0.030	0.232	23240	1162	154422	10295	50.0

CONCLUSIONS

- Present study provides a neat and compact method of designing steel I-girder and Prestressed steel I-girder using limit state method.
- Definite increase in bending capacity of steel I-girder is found when prestressed.
- No enhancement of shear capacity is found in the I-girder by prestressing as straight profile is considered in the study.
- Prestressed steel I-girder provides shallower depth as compared to normal steel I- girder for same span and loading.
- Prestressed steel I- girder shows cost saving up to 50% for 15m span, 37% for 20m span, 28% for 25m span and 20% for 30m span.
- Cost of girder per meter length decreases when applying the prestressing force with increase in L/D ratio.

REFERENCES

1. IRC6, "Standard specifications and code of practice for road bridges. Section II – Loads and stresses," Indian Roads Congress, New Delhi, 2010.
2. IRC18, " Design Criteria For Prestressed Concrete Road Bridges. (POST-TENSIONED CONCRETE).," Indian Road Congress, New Delhi, 2000.
3. IRC24, "Standard Specifications and tandard Specifications and Code of Practice for Road Bridges, Steel Road Bridges (Limit State Method - Third Revision)," Indian Road Congress, New Delhi, 2010.
4. IS6006, "Specification For Uncoated Stress Relieved Strand For Prestressed," Bureau Of Indian Standards, New Delhi, 1983.
5. IS800, "General construction in steel- code of practice," Bureau of Indian Standard, New Delhi, 2007.

6. IS1343, "Prestressed Concrete — Code Of Practice," Bureau of Indian Standard, New Delhi, 2012.
7. Hari Narayan Murthy A.V. and Gupta L.M., "Analysis and design of prestressed simply supported/ continuous steel beams," *Journal of structural engineering*, vol. 29, no. 2, 2002, pp. 129-134,
8. N. Subramanian, Design of steel structures, Oxford university, 2008.
9. Troitsky M.S, Prestressed steel bridges - theory and design, New York, N.Y.: Van Nostrand Reinhold, 1990.