Midhun B Sankar, Priya A Jacob / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 3, Issue 2, March -April 2013, pp.1131-1138

Comparison of Design Standards for Steel Railway Bridges

Midhun B Sankar, Priya A Jacob
(Department of Civil Engineering, Karunya University, Coimbatore)
(Department of Civil Engineering, Karunya University, Coimbatore)

ABSTRACT

The popularity of steel bridges is increasing in the modern era because of its unmatchable advantages. Engineers are using various national codes to achieve an optimum design. Some of the Asian countries are using their own codes and also American and other country code provisions to achieve better economy and better standards. In this regard the comparison of design codes is relevant. Comparison of code provisions for design of steel bridges enables us to know which country spends more money to meet their design standards also which country imposes maximum safety standards. In this paper design of steel bridge based on Indian and European standards are done and the results are compared. This study is concentrated on the total deflection and weight of the steel girder by varying the grade of steel, panel aspect ratio, web slenderness ratio. Based on the design results, conclusions are arrived at to know the behavior of plate girder bridges when designed using Indian and European standards.

Keywords - Steel bridges, design comparison, deflection, weight.

I. INTRODUCTION

Structural steels have high strength, ductility and strength to weight ratio. Thus it has become the obvious choice for long span bridges as steel is more efficient and economic. Among the various types of bridges plate girder bridges, truss bridges and box girder bridges are more commonly used. As the cost of steel is rising we have to reduce the amount of steel used without affecting the strength of sections. Various optimization methods are available to achieve better economic sections. All countries have developed their design codes based on the research works. There for the study of evolution of design procedure is essential in future developments.

In this paper a steel railway bridge is designed as per the Limit state method using the IS 800:2007 and Euro code 3.basically the Indian standards are derived from the British Standards. The basic concept are the same. Only the values of various parameters vary according to the design and fabrication/ erection practices existing in India. To eliminate the technical problems to trade between countries and also to unite technical specifications the Euro codes was introduced.

The objective of the work presented in this paper is to investigate total deflection, total weight of steel railway bridge under varying parameters such as grade of steel, panel aspect ratio, web slenderness .

II. REVIEW OF LITERATURE

An overview of the journals studied is briefly discussed below.

***(*1) Yoshiaki Okui, (2011) "Recent Topics of Japanese Design Codes for Steel and Composite Bridges".**

This paper gives an overview of Japanese design codes for steel and composite bridges are given. Also some important topics discussed in Standard Specifications for Steel and Composite Structures published by JSCE are introduced. The positive bending moment capacity of composite steel girders is examined through parametric study employing elasto-plastic finite displacement analyses. The effects of initial bending moment in un shored construction on the bending moment capacity and on the web slenderness limit for section classification are investigated. Observations made during the numerical study indicate that the non compact web slenderness limits in conventional design standards, which are based on tests of steel I-sections, are conservative for composite sections. Many sections, which are classified as slender by current specifications, demonstrate sufficient flexural capacity as non compact. The conventional web slenderness limits for non compact sections, which are independent of initial bending moment, seem to be inappropriate for composite girders. The initial bending moment, which is firstly applied to steel section only in un shored construction, has considerable effect on the non compact web slenderness limits. The web slenderness limits for compact and non compact sections are proposed on the basis of the parametric study.

(2) Swapnil B Kharmale,(2007).Comparative study of IS 800(Draft) and Eurocode3 ENV 1993-1-1

In this comparative study IS :800 (Draft) & Eurocode3 are compared. The limit state design of steel structures and comparison of design methodology for basic structural element by both codes are done. The comparison between two code over the basis of design ,section classification, maximum slenderness ratios, design of tension members, design compression members, design of members subjected to bending, design of members subjected to combined forces are made.

(3) Akira Takaue,(2010)"Applied design codes on international long-span bridge projects in Asia".

In this report, several bridge types and application of the design codes relevant to steel or composite structures utilized in international long-span bridge construction projects executed in Asian region in cooperation with Japanese consultant firms are introduced. Additionally, noteworthy considerations for the applicability are also described. In immediate future, the design concepts of steel or composite structures specified in the Japanese design codes will be revised in order to apply load factor design method; consequently, the actual results of the Project applying new revised the Japanese design codes will be increased although AASHTO LRFD or Euro Code based upon such the design methodology have been applied until now to several the Projects even executed by Japanese financial aids. Consequently, the development of the unified design code such as the Asia Code, which should be compiled to be incorporated with various studies and engineered technical experiences accumulated in various the major design codes, is extremely informative for the bridge engineers being involved with such the Projects.

(4) Subramanian. N, (2008) "Code Of Practice On Steel Structures -A Review Of IS 800: 2007".

This paper reviews the important features' of IS 800:2007. It discusses the topics which were not included in the previous editions. These include advanced analysis methods, fatigue provisions, durability, fire resistance, design for floor vibrations etc. One drawback is that it does not provide any commentary such as those available in ACI or AISC codes, which will enable the users to understand the rationale of different clauses.

***(*5) Arijit Guha and Ghosh M M,(2008) "IS: 800 - Indian Code of Practice for Construction in Steel and its Comparison with International Codes".**

The authors in this paper discusses that IS 800-2007 (LSM) is mostly based on international standards with load factors and partial safety factors suiting Indian conditions. The code has been mainly modelled in line with the Euro codes, with some additional references taken from the existing British Codes also. Another important aspect of this IS code is that this code does not totally do away with the existing Allowable Stress Design (ASD) method of analysis. As a matter of fact, one chapter in this code has been totally dedicated to design concepts based on the ASD method, with certain modification from the existing Indian Standard (IS) Code. Though in American code, both ASD and LRFD method of design is equally prescribed, in the case of the IS 800 (LSM), the ASD method with minor modification has been included to help in making a smooth and proper transition of design practice in India from ASD philosophy to LSM philosophy.

(6) Krishnamoorthy. M and D.Tensing, (2008). "Design of Compression members based on IS 800-2007 and IS 800-1984 - Comparison".

This paper discusses the design methodologies for the steel structures namely, working stress design method and limit state design methods are briefly explained. The importance of limit state design method is highlighted as an improved design philosophy to make allowances for the shortcomings in the "allowable stress design" was developed in the late 1970's and has been extensively incorporated in design standards and codes formulated in all the developed countries. Although there are many variations between practices adopted in different countries the basic concept is broadly similar, the probability of operating conditions not reaching failure.

(7) Hermin Jonsson, Johan Ljungberg,(2005). Comparison of design calculations for the railway bridge over Kvillebecken.

The aim of this thesis wok is the comparison of design calculations between Swedish and European standards. The railway bridge over kvillebecken is taken for the comparison. Comparison for different loads coming over the bridge, load models, dynamic factors, ultimate and limit states are made. Also the comparison between design calculations is made.

(8) Ajeesh ss and sreekumar s,(2011). Shear behavior of hybrid plate girders.

The objective of this paper is to investigate shear behavior of hybrid plate girder under varying parameters such as aspect ratio, slenderness ratio and yield strength of web panel using finite element method. The nonlinear finite element results were compared with the predictions of three theoretical models; viz Basler model, Cardiff model and Lee & Yoo model.

***(*9)Marta sulyok, Theodore V Galambos,(1995). Evaluation of web buckling test results on welded plate beams and plate girders subjected to shear.**

The purpose of this paper is to report values of reliability indices of welded beams and plate girders subjected to shear and combines bending and shear which are designed as per the load resistance and factor criteria according to the American institute of steel construction(AISC) and Cardiff model accepted by the Euro code 3.

III. GRADES OF STEEL USED

For the same steel material, the characteristic yield strength is different according to the codes, IS 800 and in EN 1991-2.

Table 1. Comparison between grades of steel used.

Indian	European
E 250 (Fe 410)	S235
E 410 (Fe 540)	S420
E 450 (Fe 570)	S460

Table 2. Yield strength and ultimate strength for different grades of steel

Code	Grade of steel	Yield strength[N/mm²]	Ultimate strength[N/mm²]
Indian	E 250 E 410 E450	250 410 450	410 540 570
European	S 235 S420 S460	235 420 460	360-510 410-560 470-630

IV. COMPARISON OF DESIGN PROCEDURE

A comparison is made between the design procedures used as per Indian standards and European standards in designing the deck plate of a steel bridge. The calculations for dimensions, design checks, design of stiffeners both end and intermediate stiffeners are compared and tabulated below.

Table 3. Comparison of dimensions

IS 800:2007	BS EN 1993
1.Depth of web Depth/span,(D/L) =1/10 to 1/15 Depth=$\sqrt[3]{(Mk/fy)}$ M-maximum moment k- d/tw , tw- thickness of web	**Depth of web** D/L =1/15 tmin- 10 to 20
2.Flange Area of flange, Af ≥ M*1.1/(fy*d) M-maximum moment For semi plastic section Breadth of flange,bt ≤ 13.6 tf	**Flange** Area of flange, Af =Mmax/d*py Py-Material yield strength Breadth of flange,bf=.3*tf tf- depth of flange

Table 4. Design checks

IS 800:2007	BS EN 1993
3.Check for moment capacity Design moment, Md =Ze*fy/γmo Ze- Section modulus Fy-Yield strength γmo- Material factor	**Check for moment capacity** Mc =Pyf*Af*hs Pyf-Yield strength Af-Area of flange hs- Centre to centre distance between flanges
4.Check for shear buckling Simple post critical method Clause 8-4.2.2a c/d ≥1 c- Stiffener spacing Shear buckling coefficient, Kv =5.35+4/(c/d)² Elastic critical shear stress, τcr = K∏²E/(12*(1-µ²)*(d/tw)²) Non dimensionless slenderness, λ w=√(fyw/√3*τcr) λ w > 1.2 shear stress τb =fyw/(√3*1.83²) Shear forceVn=Vcr=Av*τb > V	**Check for shear buckling** d/t > 66.2e <u>Check for serviceability</u> d/t < t <u>Check for flange buckling in to the web</u> Thickness, t ≥ (d/294)*√(Pyf/250) <u>critical shear strength qcr</u> Elastic critical stress,qe(a/d >1) - [1.0=0.75/(a/d)²][1000/(d/t)]² Slenderness parameter, λ w -√[0.6*(fyw/γm)/qe] > (a/d) If greater,qcr =qe fv =FVA/d*t fv should be greater than qcr
5.Local capacity of the web Clause 8.7.4 Local capacity, fw =(b1+n2)*tw*fyw/γmo If fw<Fv end stiffeners should be provided	**Local capacity of web** <u>basic shear strength, qb</u> φt=1.5qcr/√(1+(a/d)² yb=√(Pyw²-3qcr²+φ²) – φt qb=qcr+(yb/2[a/d + √(1+(a/d)²)] if qb >fv end panel is safe <u>Checks for the end panel</u> <u>Checks for shear capacity</u> Resisting shear force,Rtf=Hq/2 Av=t*a Pv=0.6*Pyw*Av If Rtf<Pv the end panel is safe <u>Checks for moment capacity</u> Resisting moment, Mtf= Hq*d/10 I=(1/12)*t*a³ Mq= I*Py/y If Mtf > Mq end panel is safe

Table 5.Design of stiffeners

IS 800:2007	BS EN 1993
6.Design of end stiffener Effective length on one side – 14tf <u>Buckling check</u> Area of buckling resistance A Moment of resistance Ix r =√(I/A) ,slenderness ratio λ =KL/r fcd – from IS 800 Table 9c Bearing resistance – fcd * A > Fv <u>Check for bearing capacity</u> Clause 8.7.5.2 Bearing strength of stiffener fpsd – Aq*fy*q/0.8 λ mo should be greater than shear load	**Design of stiffeners** <u>Load bearing stiffener at end</u> Design force due to bearing,fb Force fm due to moment Mtf Fm=Mtf/a, Total compression, Fc= Fb+Fm Area of stiffener – (0.8*Fc/Pys) Outstand should not be greater than 20tsε <u>Check for buckling</u> Buckling resistance, Pc=(σc*Ae/ λ m) >Fc <u>Check for bearing capacity</u> Buckling resistance of web Pcrip =(b1+n2)*t *pyw , Reqired resistance, FA=Fc- Pcrip Buckling resistance of stiffener, PA=Pys*A PA> FA
7.Design of intermediate stiffener c/d<√2 Hence minimum moment of inertia, Is =(1.5 d³t³/c²) <u>Check for buckling</u> Shear strength of stiffener alone required V-Vcr/ϒm0 Buckling resistance –A* fcd	**Design of intermediate stiffner** Minimum stiffeness Is≥0.75dt³ for a≥d√2 Is≥0.75dt³/a³ for a<d√2 <u>Check for buckling</u> Shear strength of stiffner alone required Fq=V-Vs Buckling resistance-σc*A/1.15 <u>Check for outstand</u> Outstand ≤ 13.7tsε

V. RESULTS AND DISCUSSION

A. Effect of grade of steel on deflection and weight

The steel railway bridge girder was loaded as per the Indian and European loading standards. The design was done for three different spans 40m, 50m and 60m. The total deflection and total weight were obtained by varying the grade of steel for each span. The results are taken keeping the deflection within the permissible limits.

a. Indian standards design results

Table 7.Effect of grade of steel as per Indian standards

steel	Span (L), m	Web depth (D), mm	Permissible limit L/600, mm	Deflection (δ) , mm	Weight (Tons)
250	40	2500	66.67	33.214	26.87
410	40	2500	66.67	49.52	20.77
450	40	2500	66.67	53.12	19.93
250	50	2500	83.33	67.19	44.21
410	50	2500	83.33	71.41	42.17
450	50	2500	83.33	76.59	40.01
250	60	2500	100	88.65	86.24
410	60	2500	100	94.94	81.25
450	60	2500	100	99.31	78.18

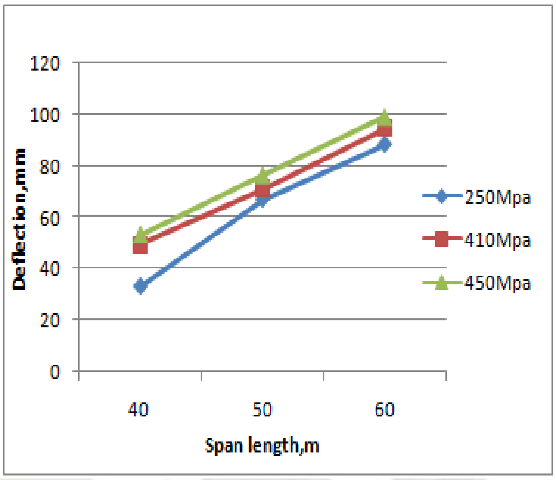

Fig 1.Variation of deflection with different grades of steel

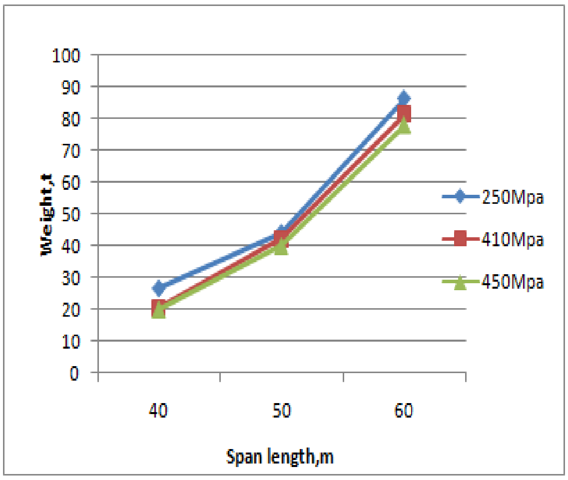

Fig 2. Requirement of steel with different grades of steel

b. European standard design results.

Table 8.Effect of grade of steel as per Euro standards

steel	Span (L), m	Web depth (D), mm	Permissible limit L/600, mm	Deflection (δ), mm	Weight (Tons)
S235	40	2500	66.67	32.27	19.33
S420	40	2500	66.67	45.94	17.81
S460	40	2500	66.67	48.91	17.21
S235	50	2500	83.33	66.4	42.73
S420	50	2500	83.33	74.92	40.62
S460	50	2500	83.33	79.74	38.84
S235	60	2500	100	77.23	59.44
S420	60	2500	100	91.85	55.35
S460	60	2500	100	97.97	54.53

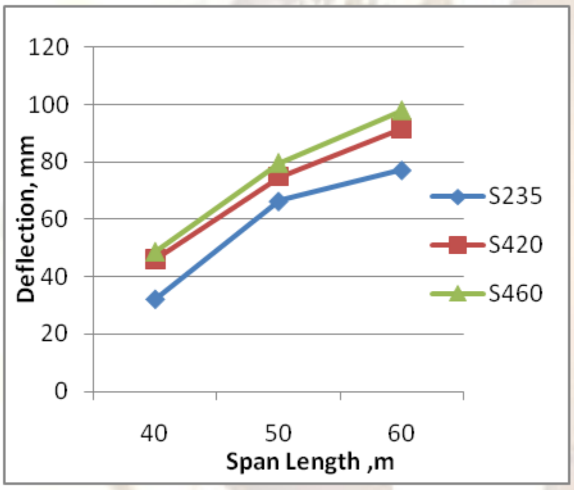

Fig 3.Variation of deflection with different grades of steel

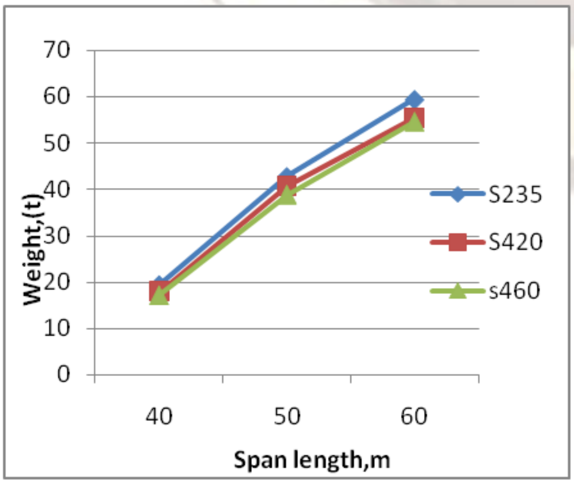

Fig 4. Requirement of steel with different grades of steel

B. Effect of panel aspect ratio on deflection and weight

Here the railway bridge plate girders were modeled by varying the aspect ratio (c/d) of web panel from 0.8 to 1.6. The aspect ratio was determined by varying the width (c) of the web panel keeping depth as constant. The effect of aspect ratio on deflection and weight of the panel was also compared by varying the grade of steel. The comparison of the effect of aspect ratio on deflection and weight for various grades of steel is shown in table below.

a. Indian standards design results.

Table 9.Effect of variation of aspect ratio on total deflection and weight

steel	Span (L), m	Web depth (D), mm	Panel aspect ratio	Permissible limit L/600, mm	Deflection (δ), mm	Weight (Tons)
250	40	2500	0.8	66.67	33.21	26.87
250	40	2500	1	66.67	37.93	26.49
250	40	2500	1.2	66.67	42.67	25.96
250	40	2500	1.4	66.67	48.93	25.35
250	40	2500	1.6	66.67	55.68	25.07
250	50	2500	0.8	83.33	67.19	44.21
250	50	2500	1	83.33	72.21	43.67
250	50	2500	1.2	83.33	78.59	42.81
250	50	2500	1.4	83.33	84.43	42.32
250	50	2500	1.6	83.33	89.58	41.98
250	60	2500	0.8	100	88.65	66.24
250	60	2500	1	100	94.94	65.82
250	60	2500	1.2	100	99.31	65.48
250	60	2500	1.4	100	**107.5**	65.12
250	60	2500	1.6	100	**115.1**	64.89

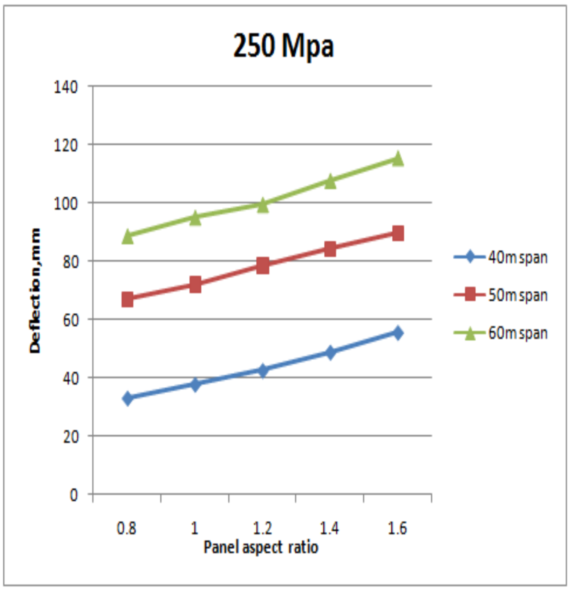

Fig 5. Maximum deflection with aspect ratio for 250Mpa

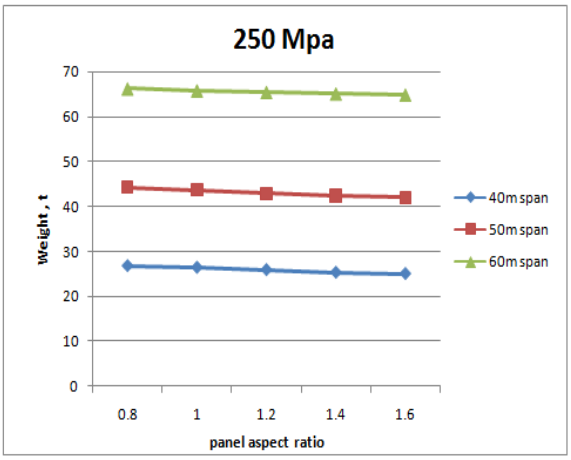

Fig 6. Requirement of steel with aspect ratio for 250Mpa

b. European standards design results.

Table 10.Effect of variation of aspect ratio on total deflection and weight

steel	Span (L), m	Web depth (D), mm	Panel aspect ratio	Permissible limit L/600, mm	Deflection (δ) , mm	Weight (Tons)
235	40	2500	0.8	66.67	32.27	19.33
235	40	2500	1	66.67	36.87	19.49
235	40	2500	1.2	66.67	41.43	18.96
235	40	2500	1.4	66.67	47.58	18.35
235	40	2500	1.6	66.67	54.39	18.07
235	50	2500	0.8	83.33	66.91	42.73
235	50	2500	1	83.33	71.51	41.67
235	50	2500	1.2	83.33	77.83	40.81
235	50	2500	1.4	83.33	83.59	40.32
235	50	2500	1.6	83.33	88.58	39.98
235	60	2500	0.8	100	77.23	59.24
235	60	2500	1	100	83.94	58.82
235	60	2500	1.2	100	91.31	58.48
235	60	2500	1.4	100	**99.45**	58.12
235	60	2500	1.6	100	**107.1**	57.89

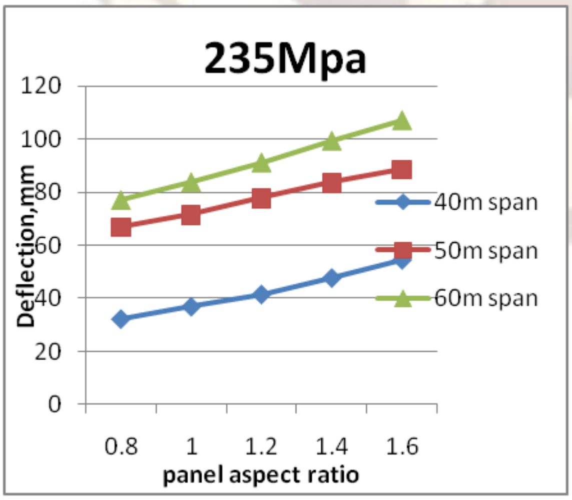

Fig 7. Maximum deflection with aspect ratio for S235

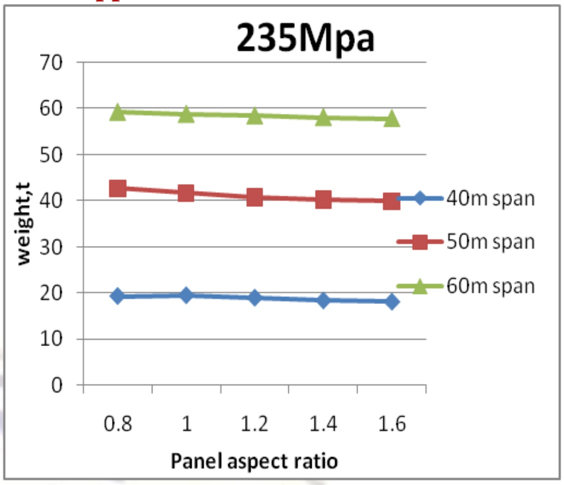

Fig 8. Requirement of steel with aspect ratio for S235

C. Effect of web slenderness ratio on deflection and weight.

Variation of web slenderness ratio (d/tw) in the railway girder was achieved by varying the thickness of web from 14mm to 20mm, keeping depth as constant. The variation in total deflection and total weight are monitored corresponding to varying slenderness ratio. The calculations are also done for different grades of steel for web. A comparison of the results is shown in tables.

a. Indian standards design results.

Table 11.Effect of slenderness ratio on total deflection and weight

steel	Span (L), m	Web depth (D), mm	Slenderness ratio,(d/t_w)	Permissible limit L/600, mm	Deflection (δ) , mm	Weight (Tons)
250	40	2000	125	66.67	29.97	26.93
250	40	2000	138	66.67	30.75	26.93
250	40	2000	156	66.67	31.53	26.93
250	40	2000	178	66.67	32.33	26.93
410	40	2000	125	66.67	42.64	20.48
410	40	2000	138	66.67	44.3	20.48
410	40	2000	156	66.67	45.13	20.48
410	40	2000	178	66.67	47.06	20.48
450	40	2000	125	66.67	45.28	19.99
450	40	2000	138	66.67	47.42	19.99
450	40	2000	156	66.67	48.54	19.99
450	40	2000	178	66.67	50.8	19.99

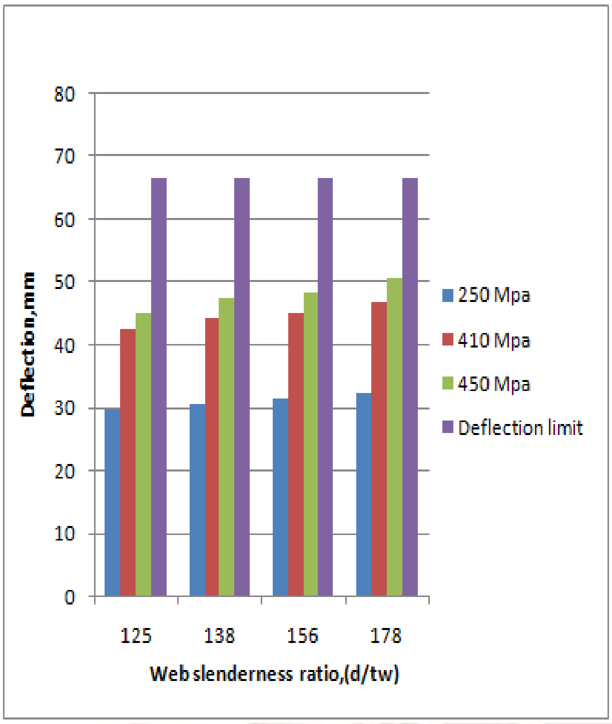

Fig 9. Variation of deflection with slenderness ratio

b. European standards design results.

Table 12.Effect of slenderness ratio on total deflection and weight

steel	Span (L), m	Web depth (D), mm	Slenderness ratio,(d/tw)	Permissible limit L/600, mm	Deflection (δ), mm	Weight (Tons)
235	60	2500	125	100	84.07	60.51
235	60	2500	138	100	86.9	57.7
235	60	2500	156	100	88.77	54.88
235	60	2500	178	100	90.69	51.09
420	60	2500	125	100	88.86	58.06
420	60	2500	138	100	90.63	55.24
420	60	2500	156	100	92.55	52.48
420	60	2500	178	100	94.06	50.48
460	60	2500	125	100	94.28	55.99
460	60	2500	138	100	**96.42**	52.99
460	60	2500	156	100	**99.02**	50.26
460	60	2500	178	100	**99.88**	48.06

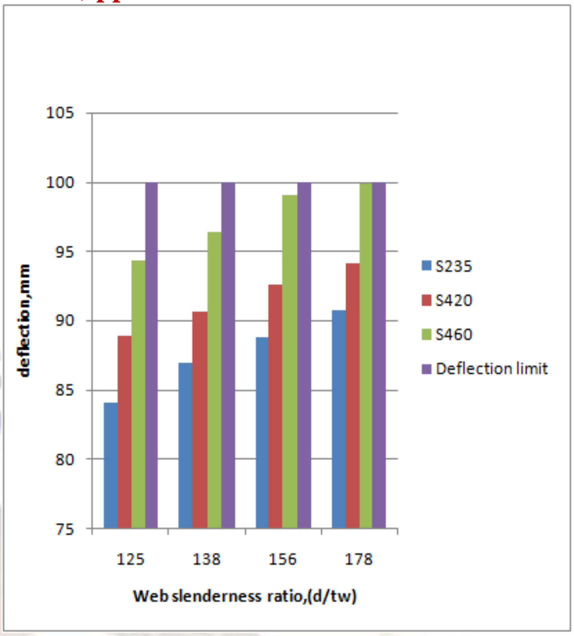

Fig 10. Variation of deflection with slenderness ratio

VI. Conclusion

The code provisions for design of steel railway bridge were studied and compared as per Indian and European standards. Parametric studies were performed for various grades of steel used in India and Europe, panel aspect ratio and web slenderness ratio. The following conclusions were arrived at from the design results.

1. For a railway bridge of constant span and depth, the total deflection of the girder increases as the grade of steel increases but the total weight decreases according to the Indian standards design.
2. A similar behaviour is found for European standards i.e., as grade of steel increases, deflection increases and weight reduces.
3. For a 40m span with varying aspect ratio (c/d) .8-1.6 the maximum deflection as per Indian standard design is more (55.68mm)when compared with European standard design (54.39mm). Similar results are found for 50m 60m spans.
4. From the results obtained as per Indian and European standards it is observed that stiffener spacing have much impact on the deflection of a plate girder bridge.
5. As web slenderness ratio (d/tw) increases (125-178) the deflection increases. From the results it is clear that the deflection is inversely proportional to the thickness of the web.
6. As per the design results obtained for plate girder bridge it is found that Indian standards spend more money to meet the design requirements when compared with Euro standards

REFERENCES

[1] Dr. N. Subramanian, (2008). "Code Of Practice On Steel Structures" -A Review Of IS 800: 2007, Civil Engineering and Construction Journal.

[2] Mr. Arijit Guha, Mr. M M Ghosh , (2008). "IS: 800 - Indian Code of Practice for Construction in Steel and its Comparison with International Codes", Institute for Steel Development & Growth (INSDAG).

[3] M. Krishnamoorthy, D.Tensing , (2008). "Design of Compression members based on IS 800-2007 and IS 800-1984-Comparison", Journal of Information Knowledge and Research in civil engineering.

[4] F. Faluyi , and C. Arum, (2012). "Design Optimization of Plate Girder Using Generalized Reduced Gradient and Constrained Artificial Bee Colony Algorithms", International Journal of Emerging Technology and Advanced Engineering.

[5] R. Abspoel, (2009). "Optimizing plate girder design", Nordic steel construction conference.

[6] Arijit Guha and Dr.T.K. Bandyopandhya (2004), "Structural Member Design Based on Draft IS: 800 (Limit State Method), Insdag's steel journal", Institute for steel development & Growth, Jan 2004, Volume5.

[7] Akira Takaue, (2010)."Applied design codes on long-span bridge projects in Asia", IABSE-JSCE Joint Conference on Advances in Bridge Engineering-II, August 8-10, Dhaka, Bangladesh.

[8] Subramanian, N (2008). Design of Steel Structures, Oxford University Press, New Delhi.

[9] IS 800:2007 (2007). "Indian standard code of practice for General Construction in Steel", Bureau of Indian Standards, New Delhi.

[10] ENV-1993-1-1, (1992). Eurocode 3: Design of Steel Structures. Part1.1, General Rules and Rules for Buildings, European Committee for Standardization, Brussels.

[11] Henrik Jonsson, Johan L jungberg. (2005) Comparison of design calculations of railway bridge over Kvillebacken, Master thesis, Sweden

[12] IS 800:2007 (2007). "Indian standard code of practice for General Construction in Steel", Bureau of Indian Standards, New Delhi.

[13] IS 800:1984 (1984). "Indian standard code of practice for General Construction in Steel", Bureau of Indian Standards, New Delhi.

[14] ENV-1993-1-1, (1992). Eurocode 3: Design of Steel Structures. Part1.1, General Rules and

Rules for Buildings, European Committee for Standardization, Brussels.

[15] ENV-1993-1-5, (1992). Eurocode 3: Design of Steel Structures. Part1.5, Plated structural elements, European Committee for Standardization, Brussels.

[16] ENV-1991-1-1, (2003). Eurocode 3: Actions on structures. Part2, Traffic loads on bridges, European Committee for Standardization, Brussels.