Comparative Study of Design of Steel Structural Elements by using IS 800:2007, AISC 13th Edition and BS: 5950, 1:2000

Amruta G. Whatte, S.S. Jamkar

Abstract- ***The task of the structural engineer is to design a structure which satisfies the needs of the client and the user. Specifically the structure should be safe, economical to build and maintain, and aesthetically pleasing. By considering the above needs of user this study gives the comparative design of structural element by using three different International Design Codes.Structural Elements such as tension member, compression member, flexural member, beam column, gusseted base, and beam column connection are designed for this comparative study. Same data is considered for the design of particular element and that element is designed by using Indian Standard (IS 800:2007), American Standard (AISC 13th Edition) and British Standard (BS 5950, 1:2000). The design methodology used in this study is same for all the codes but there are some differences in the constants or parameters depending on the code used. Finally the results are evaluated and compared in the tabular format.***

Keywords–IS 800:2007, AISC 13th edition, BS 5950 1:2000, LRFD, and ASD.

I. INTRODUCTION

In the present work, the detailed study of Design of structural element by using American Institute of Steel Construction and British Standard has been carried out with the comparison to the results by IS 800:2007 and submitted the comparative study of the same in the form of tables, which highlights the actual economy achieved by different codes of design for different structural sections. The observations made based on this study are very much necessary to the practicing structural engineers.The introduction of the paper should explain the nature of the problem, purpose, and the contribution of the paper.

The design of steel elements can be done by two methods:

1.1 Allowable Stress Design (Working Stress Method)

Working stress method of design based on the elastic theory in which material is assumed to be stressed well below its elastic limit under the design loads.The method, since relates safety to stress, defines factor of safety as the ratio of ultimate stress or yield stress to allowable or safe stress.This method is a well established method and that the method is simple in application and reliable

1.2 Load and Resistance Factor Design (Limit state Design)

The limit state method uses concept of fitness of the structure to perform its function satisfactorily during its service life span.

Manuscript Received on August, 2013.

Miss. Amruta G. Whatte, (Department of Applied Mechanics, Babasaheb Ambedkar Marathwada University, Aurangabad, M.S. India.

Prof. S.S. Jamkar, (Department of Applied Mechanics, Babasaheb Ambedkar Marathwada University, Aurangabad, M.S. India

The condition or the state at which structure becomes unsafe is called the limit state and the philosophy based on this concept is called limit state philosophy of design.This method is more general in comparison to the working stress method. Several independent factors are used in the limit state design, each of which plays a particular role to ensure the reliability of the structure and the guarantee against the occurrence of a limit state

1.3 Design Codes

Structural design is a major activity of the profession of structural engineering. The designers can call on their creative spirit to design an infinite scope of outcomes but there are some severe restrictions on this freedom, namely economics and the demands posted by the requirements of the structural design standards, sometimes called codes or design specifications.

A standard code serves as a reference document with important guidance. The contents of the standard code generally cover details of design. These details include the basis and concept of design, specifications to be followed, design methods, safety factors, loading values and etc. In present days, many countries have published their own standard codes. These codes were a product of constant research and development, and past experiences of experts at respective fields. Meanwhile, countries or nations that do not publish their own standard codes will adopt a set of readily available code as the national reference. Some of them are Indian standard, American standard, British standard, Euro standard, Japan code, Canadian standard etc.

1.4 Objective

This study aimed to design all structural Steel elements as per IS 800:2007, AISC 13th manual and BS 5950-1:2000 guidelines and their comparison.

II. SYSTEM DEVELOPMENT

There are various international codes available for the design of steel structures. Developments are still going on to achieve the great economy by using different methods as well as by using different codes of practice. In this chapter various designs are presented using three codes that is IS code, AISC code and BS code with step by step procedure.

This study gives the method of design of structural elements by different codes and comparison of results. Here design example of tension member will describes the methodology by IS method, BS method and AISC method.

2.1 Design Example

Design a tension member for unequal angle section of length 3 m, load on the member is

225 kN; diameter of bolt is 20mm.

2.1.1 Solution by IS Method

Yield strength of member = $\frac{Ag.fy}{\Upsilon mo}$

Where,

Yield Stress = F_y= 250 Mpa. [Assumed]

Partial Safety Factor = Υ_{mo}=1.1 [table no-5, IS: 800]

Therefore,225 × 10^3 =Ag × 250 / 1.1

Gross area A_g = 225 X 10^3 × 1.1 /250 = 990 mm^2

By using calculated gross area choose section from steel table having area slightly greater than the calculated.

Section chosen from steel table is

ISA: 100 X 75 X 8 mm.

Sectional Properties of the same section from the steel table are as follows:

A_g = 13.36 cm^2 = 1336 mm^2

To calculate the strength of one bolt, thickness of gusset plate should be known hence, assume the thickness of gusset plate is 10 mm.

Strength of one bolt[IS : 800, Pg. No.- 75]

Strength of one bolt as per Standards is the minimum strength by shear strength or bearing strength of the bolt.

Shear strength [IS : 800, Pg. No.- 75]

Shear strength of bolt is

$$V_{dsb}=\frac{fu\,(nn\times Anb+ns\times Asb)}{\sqrt{3}\times\Upsilon mb}$$

Where,Ultimate yield strength = f_u = 410 Mpa

Number of shear planes with threads intercepting the shear plane = n_n = 0

Number of shear planes without threads intercepting the shear planes = n_s = 0.78

Nominal plain shank area of bolt = A_{sb} = π / 4 ×$(20)^2$ = 314.15 mm^2

Partial Safety Factor for bearing type Υ_{mb} = 1.25

[IS 800, table no- 5, page no -30]

Therefore, shear strength is,

$$V_{dsb}=\frac{410\times(0\times Anb+0.78\times 314.15)}{\sqrt{3}\times 1.25}=46.40kN$$

Bearing Strength [IS : 800, Pg. No.- 75]

Bearing strength of bolt is

$$V_{dpb}=\frac{2.5\times Kb\times d\times t\times fu}{\Upsilon mb}$$

Constant = K_b = min of $(\frac{e}{3d0},\frac{P}{3d0}-0.25,\frac{fu}{fy},1)$

Here to calculate the constant K_b the values of end distance and pitch should be known therefore Assume, End distance (e) = 40 mm and Pitch (P) = 60 mm

Therefore, K_b = 0.66

$$V_{dpb}=\frac{2.5\times 0.66\times 20\times 8\times 410}{1.25}=86.592\ kN$$

As per IS 800 the strength of bolt is the least value from bearing strength or shear strength, here minimum value is of shear strength, therefore

Strength of one bolt = min. from $V_{dsb}$and V_{dpb}

Strength of one bolt = 46.40 kN

No of bolts can be calculated by knowing the total load applied on the member and the strength of one bolt and here both values are known therefore,

No. of bolts = $\frac{\text{Total load}}{\text{strength of one bolt}}=\frac{225}{46.40}$ = 4.84 ~ 5 No.

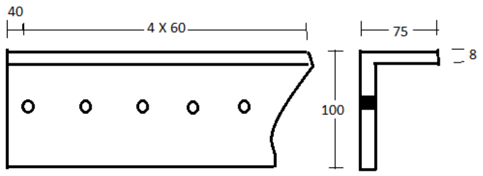


Fig.2.1 Design of Tension Member

Check for Design

Check for the design of tension member is taken as, the tensile strength of designed member should be greater than the load applied on the member, and the tensile strength nothing but the least value from strength due to yielding, strength due to rupture and strength due to block shear.

Strength against yielding

T_{dg}= $\frac{Ag.fy}{\Upsilon mb}$ = (1336 × 250)/1.1= 303.63 kN> 225 kN …………...OK

Strength against rupture

$$T_{dn}=\frac{\alpha.An.fu}{\Upsilon m1}$$

Where, α = 0.8 because number of bolts are 5

[IS 800 : 2007, page no - 33]

Net area = total gross area – area of hole

A_n = 1336-(22× 8) = 1160 mm^2

T_{dn}= $\frac{0.8\times 1160\times 410}{1.25}$= 304.38 kN > 225kN ...OK

Strength against block shearing [IS 800:2007, page no -33]

As per IS 800 :2007 strength of member due to block shear is calculated by two formulae and smaller one is supposed to be the final strength of member due to block shear.

A_{vg} = (40+60×4)8 = 2240mm^2

Where,

A_{vg} ,A_{vn} = minimum gross and net area in shear along bolt line parallel to external force, respectively

A_{tg}, A_{tn} = minimum gross and net area in tension from the bolt hole to the toe of the angle, end bolt line, perpendicular to the line of force, respectively

A_{vn} = A_{vg}– (4.5×22×8) = 1448 mm^2

A_{tg} = (100-40)8 = 480 mm^2

A_{tn} = A_{tg} – (0.5×22×8) = 392 mm^2

$T_{db1} = \frac{Avg.fy}{\sqrt{3}.\Upsilon mo} + \frac{0.9\,Atn.fy}{\Upsilon m1}$

$T_{db1} = \frac{2240\times250}{\sqrt{3}\times1.1} + \frac{0.9\times392\times410}{1.25} = 409.642$ kN

$T_{db2} = \frac{0.9\times Avn\times fu}{\sqrt{3}.\Upsilon m1} + \frac{Atg.fy}{\Upsilon mo}$

$= \frac{0.9\times1448\times410}{\sqrt{3}\times1.25} + \frac{480\times250}{1.1} = 355.879$kN

Therefore, Strength against block shear = min. from T_{db1} & T_{db2}

= 355.879kN > 225kN…………OK

Use Angle section of size - 100×75×8 mm with 5nos. of bolts having 20mm dia. bolts.

All checks are satisfied hence the designed member is safe.

2.2.2 Solution by AISC Method

Here, assume the grade of steel is A36 therefore yield strength fy= 36 ksi and ultimate strength fu = 58 ksi.

As per AISC manual, strength = fy ×Ag × φ

[AISC; page no-1503; eq no- D2-1]

Where, strength is nothing but the total load applied on the member = 50.56

Yield strength = fy = 36 and Constant = φ = 0.9

Therefore, 50.56= 36×Ag ×0.9

Ag = 50.56/(36×0.9) = 1.56 in^2

Hence, calculated gross area is 1.56 in^2, now choose an unequal angle section from AISC manual which has the same or slightly more are than calculated gross area.

$L\ 4 \times 3 \times \frac{5}{16}$ [AISC; Table-5-2; page no-5-16]

From the manual the gross area of the section chosen from table is 20.9 in^2

By assuming thickness of gusset plate = 0.39inch, the strength of bolt can be calculated, strength of one bolt is the least value from bearing strength or shear strength.

Bearing strength

$\varphi R_n = \varphi \times 1.2 \times Lc \times ta \times fu$[AISC; eqn- J3-2a]

Where, constant = φ = 0.75

Clear distance between edge of one hole to other hole

Lc= P – do = 2.36-0.79= 1.57 inch

$\varphi R_n = 0.75 \times 1.2 \times 1.57 \times 5/16 \times 58 = 25.61$ kip

Shear strength$\varphi R_n = \varphi \times F_v \times A_b \times N_s$

where, constant = φ = 0.75

Bolts ultimate shear stress = Fv = 58 ksi

Nominal cross-sectional area of bolt= Ab = $\pi/4\ d^2 = 0.49\ in^2$
No of shear planes = Ns = 0.78

$\varphi R_n = 0.75 \times 58\times 0.49 \times 0.78 = 16.63$ kip.

As per AISC, Strength of bolt is smaller of shear strength or bearing strength = 16.63 kip

No of bolts can be calculated by knowing the total load applied on the member and the strength of one bolt and here both values are known therefore,

No. of bolts $= \frac{\text{Total load}}{\text{strength of one bolt}}$ = 50.56/16.63

= 3.04 ~ 3Nos.

Check for strength

Check for the design of tension member is taken as, the tensile strength of designed member should be greater than the load applied on the member, and the tensile strength nothing but the least value from strength due to yielding, strength due to rupture and strength due to block shear.

Strength against yielding

$\varphi R_n = \varphi \times 0.6\times A_v \times f_y$ [AISC; eqn J5-3]

Where, constant = φ = 0.9

Gross area = Av = ha ×ta = 118.11 × 5/16 = 36.91 in^2

Yield strength = Fy = 36 ksi

$\varphi R_n = 0.9 \times 0.6 \times 36.91 \times 36 = 71.753$ kip > 50.56 kip ….OK

Strength against rupture

$\varphi R_n = \varphi \times 0.6\times A_{vn} \times f_u$ [AISC; J4-1]

Where, constant = φ = 0.75

Net area = $A_{nv} = [ha\text{-}n\,(dh+\frac{1}{16})]ta$

$= [118.11\text{-}3(0.87+\frac{1}{16})]\frac{5}{16} = 36.04\ in^2$

Ultimate strength = Fu = 58 ksi

$\varphi R_n = 0.75 \times 0.6\times 36.04\times 58 = 940.64$ kip >50.56 kip ….OK

Strength against block shear [AISC; J4-5]

$\varphi R_n = \varphi\ [\ 0.6 \times f_u\times A_{gt}] \le \varphi\ [\ 0.6\ .\ fu.\ A_{vn} + fu.A_{nt}]$

Where, Agv, Anv = minimum gross and net area in shear along bolt line parallel to external force, respectively

$A_{gv} = 7.08 \times \frac{5}{16} = 2.21\ in^2$

$A_{nv} = A_{gv}–(2.5\times0.87\times\frac{5}{16}) = 1.53\ in^2$

A_{gt}, A_{nt} = minimum gross and net area in tension from the bolt hole to the toe of the
angle, end bolt line, perpendicular to the line of force, respectively

$A_{gt} = 2.43 \times \frac{5}{16} = 0.76\ in^2$

$A_{nt} = A_{gt} – (0.5 \times 0.87 \times\frac{5}{16}) = 0.62\ in^2$

$\varphi R_n = 0.75\ [\ (0.6 \times 58\times1.53)+(36\times0.76)] \le 0.75\ [\ (0.6\times 58 \times1.53) + (58\times0.62)]$

$= 60.45 \le 66.90 = 60.45$ kip > 50.56 kip …....OK

Use angle section of size $L\ 4 \times3 \times \frac{5}{16}$ with 3 nos. of bolts having dia. 0.79 inch

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

All checks are satisfied hence the designed member is safe.

2.2.3 BS Method

Yield strength of member = $\frac{Ag.fy}{\Upsilon mo}$, $225 \times 10^3 = \frac{Ag \times 250}{1}$

Therefore gross area of the section is Ag = 900 mm^2

By using calculated gross area choose section from BS manual having area slightly greater than the calculated.

Section chosen from BS 5950 manual is

100 × 75 × 8 mm [BS EN; B-41;]

Sectional Properties of the same section from the steel table are as follows: A_g = 1350 mm^2

To calculate the strength of one bolt, thickness of gusset plate should be known hence, assume the thickness of gusset plate is 10 mm.

Strength of one bolt

Strength of one bolt as per Standards is the minimum strength by shear strength or bearing strength of the bolt.

Shear strength Ps = ps. As[BS: 5950; 135; table-30]

Where,ps = 160 and As = shear area = $\frac{\pi d2}{4}$

= $(\pi\ 20^2)/4$ = 314.16 mm^2

Ps = 160 × 314.16 = 50.26 kN

Bearing Strength

P^{bb}= d× tp × p^{bb} [BS : 5950; 136; table-31]

Where, d = dia. Of bolt = 20mm

ThickNess of section = tp = 8mm

Bearing strength = p^{bb}= 460

P^{bb}= 20× 8 × 460 = 73.6 kN

Strength of one bolt as per Standards is the minimum strength by shear strength or bearing strength of the bolt.

Therefore, Strength of bolt = 50.26 kN

No of bolts can be calculated by knowing the total load applied on the member and the strength of one bolt and here both values are known therefore,

No. of bolts = $\frac{\text{Total load}}{\text{strength of one bolt}}$ = 225/50.26 = 4.45 ~ 5nos.

Check for strength

Check for the design of tension member is taken as, the tensile strength of designed member should be greater than the load applied on the member, and the tensile strength nothing but the least value from strength due to yielding, strength due to rupture and strength due to block shear.

Strength against yielding

$P_n = \frac{Ag \times fy}{\Upsilon mo} = \frac{1350 \times 250}{1}$= 337.5 kN> 225 kN. ….OK

Strength against rupture

As per BS 5950-1:2000 the strength due to or strength against rupture is given by,

$T_{dn}= \frac{\alpha.An.fu}{\Upsilon m1}$

Where, α = 0.8 because number of bolts are 5

Net area = total gross area – area of hole

A_n = 1350-(22× 8) = 1174 mm^2

$T_{dn}= \frac{0.8 \times 1174 \times 410}{1.25}$ = 308.05 kN > 225kN

Strength against block shear

p_r= 0.6. P_y × t [L_v + k_e (L_t – k. D_t)]

Where, Design Strength = P_y= 275 N/mm^2

Thickness of section = t = 8mm

Length of member = L_v= 280mm and L_t = 49.5 mm

Eff.Area coeff. = K_e = 1.2

Constant = K = 0.5 and Dia. Of hole =D_t= 22mm

Therefore, p_r= 0.6 ×275 × 8 [280 + 1.2 (49.5 – 0.5×22)]= 430.05 > 225 kN.

All checks are satisfied hence the designed member is safe.

III. PERFORMANCE ANALYSES

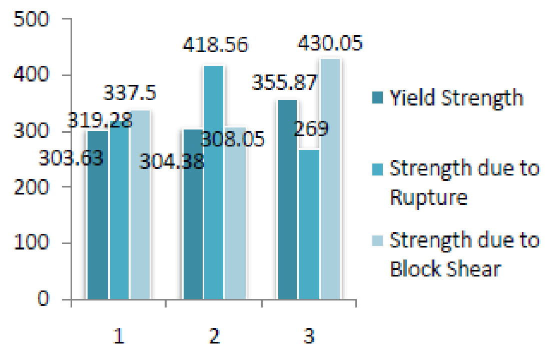
The parameters considered for the comparative study of tension member are yield strength, rupture strength and strength due to block shear. The results came from above system development, for these parameters by the design of tension member with IS 800: 2007, AISC 13th manual and BS 5950-1:2000 are presented in the table format as below:

Table 3.1: Parameters for Tension Member

Std. Code	Section Size	Yielding St.	Rupture St.	Shear St.
IS	100×75×8 mm	303.63 kN	304.38 kN	355.87 kN
AISC	L 4 ×3 × $\frac{5}{16}$	71.75 kip	94.06 kip	60.45 kip
		319.28 kN	418.56 kN	269.00 kN
BS : 5950	100×75×8 mm	337.50 kN	308.05 kN	430.05 kN

IV. RESULT DISSCUSOIN

The values of strengths are different for the same section by the three codes are as given in table no 3.1. for this study, the section sizes may be same or may not be same because of unavailability of same size section in all the three codes, still, tried to keep the sizes of section are near about same. The yield strength of given section by BS code is greater than remaining two codes because of the value of constant used in the formula is greater than other two. Similarly the strength due to rupture by AISC is greater than the IS and BS code. And strength due to block shear is more by BS method as compare to the IS and AISC code.The graphical representation is also express here as follows by using excel.



Graph 4.1

Graph 4.1

V. CONCLUSION

As per the result discussion it has been observed that, there is variation in the values of the strengths obtained by three different codes because of the variation in the values of the constants considered by the particular code are different and the main thing is that there is unavailability of same size section in all three codes.

REFERENCES

1. Danny J. Yong, AitziberLópez and Miguel A. Serna , "A comparative Study of AISC-LRFD and EC3 approaches to beam-column buckling resistance", Tecnun – University of Navarra, Spain ,‖6 September 2006.
2. Prof. Ravindra Bhimarao Kulkarni, Rohan Shrikant Jirage, "Comparative Study of Steel Angles as Tension Members Designed by Working Stress Method and Limit State Method", International Journal of Scientific & Engineering Research Volume 2, Issue 11, November-2011.
3. Prof. RavindraBhimaraokulkarni, VikasArjunPatil, "Design Aids of Flexural Members and Beam-Columns Based on Limit State Method", International Journal of Scientific & Engineering Research Volume 2, Issue 10, ‖Oct-2011.
4. Abbas Aminmansour, "A New Approach for Design of Steel Beam-Columns", Engineering Journal/Second Quarter ‖2000.
5. M E Brettle BEng (Hons), "Steel Building Design: Worked Examples - Open Sections In accordance with Eurocodes and the UK National Annexes", The Steel Construction Institute Silwood Park, Ascot, Berkshire SL5 7QN, ‖18 September 2012
6. Richard M. Drake and Sharon J. Elkin, "Beam-Column Base Plate Design-LRFD Method", Engineering Journal‖ First Quarter ‖1999.
7. M Krishnamoorthy, "Design of Compression Member based on IS 800: 2007 and IS 800:1984 comparisons", Journal of Information, Knowledge and Research in Civil Engineering, ISSN: 0975 – 6744‖NOV 11 TO OCT 12 ‖Volume 2, Issue 1
8. Bureau Indian Standard, General Construction in steel – Code of Practice, IS 800:2007 ‖3rd Revision‖ New Delhi ‖December 2007.
9. American Institute of steel Construction, 13th edition ‖United State of America ‖ December 2005 .
10. Part 1: Code of practice for design - Rolled and welded sections‖ BS 5950-1:2000‖ British Standard ‖ BSI 05-2001.
11. Design Examples , Version 13.1‖AISC , USA, May 2010.
12. T. Bat Quimby, "A Beginner's guide to the Steel Construction Manual",‖University of Alaska Anchorage ‖August 2008.
13. Chan Chee Han, " Comparison between BS 5950: Part 1:2000 and Eurocode 3 for the design of multi-story braced steel frame" ‖UniversitiTeknologi Malaysia ‖November 2006.
14. Perry Green, Thomas Sputo, "Design of all bolted extended angle, single angle, and tee shear connection",‖ University of Florida,‖AISC‖ January 2005.
15. "Steel Building Design: Design Data, ‖The Steel Construction Institute, Tata Steel, The British Construction Steelwork Association Ltd.
16. " Eurocode 3: Design of Steel Structure" – Part 1-1 : General rules and rules for building,‖ BS EN 1993-1-1:2005 ‖February 2006 and April 2009.
17. "Steelwork Design Guide to BS 5950-1:2000(Blue Book),Volume ,7th Edition,‖The steel Construction Institute and The British Constructional Steelwork Association Limited.
18. Prof. S.R. Satish Kumar and Prof. A.R. Santha Kumar, "Design of Steel Structure".IIT Madras
19. Prof. Dr. A. Verma, "Design of Steel Structure", CE 405.
20. S.K. Duggal, " Design of Steel Structure as per IS 800: 2007".
21. Design Examples , Version 14.1‖AISC , USA, October 2011.
22. Prof. ChanakyaArya, "Design of Structural Elements", 3rd Edition, designs to British Standards and Eurocodes.
23. Redbook, Handbook of Structural of Steelwork, 4th Eidition,The Steel Construction Institute silwood Park, Ascot, berkshrie, SL5 7QN.-
24. Steel Sectional Table.