DESIGN OPTIMIZATION OF STRUCTURAL STEEL SECTIONS AS PER INDIAN STANDARD CODES

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ABSTRACT. The paper is concerned with review of illustrated designs of standard Structural Steel Sections given in Indian Standard Special Publications, SP 6(1):1964; ISI Handbook for structural engineers (Part-1) - Structural Steel Sections. The paper presents analysis of different standard steel sections, as per the provisions of IS 800: 2007 using Euler's theory, to evaluate load carrying capacity subjected to compression considering different parameters such as effective length, slenderness ratio, radius of gyration, material yielding and inelastic buckling etc. The paper progresses with comparative analysis of results so obtained and load carrying capacity as per SP 6(1):1964, to obtain optimum sections to fulfill the aspect of economic designs with safety of the structure. It demonstrates the variations in the load carrying capacity of sections and suggests that there is likely to be need of improvisation in illustrated designs of SP 6(1) updating it to incorporate the design provisions of IS 800: 2007.This can be useful for structural designers of country for taking updated designs as reference.

Keywords: Radius of gyration, Yielding, Buckling, Euler's theory.

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LITERATURE STUDY

Guha et al. [1] compared IS 800:2007 (LSM) with several International codes. The code has been mainly modelled in line with the Euro codes, with some additional references taken from the existing British Codes also. 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.

Subramanian [2] reviewed the important features of the code IS 800:2007, based on limit states method of design and compared with the national codes of other countries. He studied new features included in recent code like methods of analysis, fire resistance and design against floor vibration

Kulkarni et al. [3] compared steel angles as tension members designed by working stress method and limit states method. The observations were made and concluded that the limit state method (LSM) gives higher values for tension member than working stress method (WSM) and the design of tension members using angles by is economical in case of limit state method compared to working stress method.

INTRODUCTION

An Overview SP: 6-1964 [12]

In order to reduce the work involved in design computations, and to facilitate the use of the Indian Standard Code of Practice for Use of Structural Steel in General Building Construction [IS: 800-1962 (Revised)], it was proposed to make available a number of design handbooks showing typical designs of different types of structures. This revised Handbook, which gives the properties of structural steel sections, was first issued in 1959.The first edition of this Handbook, which had been processed by Structural Sectional Committee, SMDC 6, was approved for publication by the Structural and Metals Division Council of ISI.
The matter contained in the Handbook is arranged from the point of view of maximum convenience in using the Handbook in the design office.

Broadly speaking, the contents have been grouped as follows:
Section (A) - Structural Shapes and Other Steel Products, Section (B) - Beams, Channels and Compound Sections Used as Girders, Section (C)- Angles, Single and Double, Used as Struts and Ties, Section (D)- Beams, Channels and Other Compound Sections Used as Columns.

An Overview of IS 800:2007 [10]

The steel economy programme was initiated by Indian Standards Institution in the year 1950 with the objective of achieving economy in the use of structural steel by establishing rational, efficient and optimum standards for structural steel products and their use. IS 800:1956 was the first in the series of Indian Standards brought out under this programme. The standard was revised in 1962 and subsequently in 1984, incorporating certain very important changes.
IS 800 is the basic Code for general construction in steel structures and is the prime document for any structural design and has influence on many other codes governing the design of other

special steel structures, such as towers, bridges, silos, chimneys, etc. The code was revised in the year 2007 and was made available since February 2008.

In this revision the following major modifications have been effected:

a) In view of the development and production of new varieties of medium and high tensile structural steels in the country, the scope of the standard has been modified permitting the use of any variety of structural steel provided the relevant provisions of the standard are satisfied.

b) The standard has made reference to the Indian Standards now available for rivets; bolts and other fasteners.

c) The standard is based on limit state method, reflecting the latest developments and the state of the art.

The revision of the standard was based on a review carried out and the proposals framed by Indian Institute of Technology Madras (IIT Madras). The project was supported by Institute of Steel Development and Growth (INSDAG) Kolkata with a number of academic, research, design and contracting institutes/organizations.

Limit State Design

The fundamental requirement of a structural design is that the elements of the structure should have adequate and reliable safety against failure, the structure should remain serviceable during its intended use, and the design is economical.

The limit states considered in the code may be grouped into the following two types:
a) Ultimate (safety) limit states, which deal with strength, sway or overturning, sliding, buckling, fatigue fracture and brittle fracture.

b) Serviceability limit states, which deal with discomfort to occupancy and/ or malfunction, caused by excessive deflection, vibration, corrosion (and subsequent loss of durability), fire resistance, etc.

ANALYSIS

Design Parameters

Design considerations as per IS 800: 2007 have been employed in the calculation of safe loads. Both ends are considered as hinge. Therefore, the value of effective length factor is (1.0). Different I- sections and channel sections have been considered for calculation of safe loads with the following preliminary data-

Yield Stress of Material (f_y) = 250 N/mm^2, Modulus of Elasticity (E) = 2 x 10^5 N/mm^2, Effective Length Factor (K) = 1.0, y-y axis has been considered as minor buckling axis and x-x axis as major buckling axis.

Table 1 Percentage variation in safe loads for ISHB 250 (y-y Axis)

DESIGNATION		ISHB 250					
size(mm), hxb		250x250			250x250		
sectional area, cm^2		64.96			69.71		
weight, kg/m		51.0			54.7		
radius of gyration, cm	r_{xx}	10.91			10.7		
	r_{yy}	5.49			5.37		
Effective Length in metre (y-y Axis)	L_y	SP 6 :1964	IS 800 :2007	Variation (%) w.r.t. IS 800 :2007	SP 6 :1964	IS 800 :2007	Variation (%) w.r.t. IS 800 :2007
	2.0	767.5	878.0	12.6	822.7	937.0	12.2
	2.5	755.7	822.8	8.2	809.4	876.1	7.6
	3.0	738.8	764.2	3.3	789.8	811.4	2.7
	3.5	716.4	702.6	-2.0	764.8	743.4	-2.9
	4.0	688.9	639.4	-7.7	732.8	674.0	-8.7
	4.5	653.1	576.9	-13.2	691.8	605.9	-14.2
	5.0	610.6	517.3	-18.0	643.6	541.5	-18.9
	5.5	562.3	462.4	-21.6	589.8	482.7	-22.2
	6.0	510.6	413.1	-23.6	533.5	430.2	-24.0
	6.5	460.6	369.5	-24.7	479.2	384.0	-24.8
	7.0	414.0	331.3	-25.0	429.1	343.8	-24.8
	7.5	371.6	297.9	-24.7	383.9	308.8	-24.3
	8.0	334.4	268.9	-24.4	345.4	278.4	-24.1
	8.5	299.3	243.6	-22.9	306.7	252.0	-21.7
	9.0	266.3	221.5	-20.2	273.1	229.0	-19.3
	9.5	237.5	202.1	-17.5	242.4	208.8	-16.1
	10.0	212.0	185.1	-14.5	218.1	191.1	-14.1
	11.0	173.9	156.7	-11.0	177.5	161.7	-9.8
	12.0	142.4	134.2	-6.1	145.7	138.4	-5.3
	13.0	119.2	116.2	-2.6	121.5	119.8	-1.4

Observations (Table 1)

For calculations as per IS 800: 2007, percentage variation of safe load in comparison to SP 6, varies from (+) 12.6(max.) to (-) 25.0(max.) for ISHB 250.It can be observed that most of the load values are found to be economical in case of IS 800:2007 compared to SP 6.

Table 2 Percentage variation in safe loads for ISHB 200 (y-y Axis)

DESIGNATION		ISHB 200						
size(mm), hxb			200			200		
sectional area, cm^2			47.54			50.94		
weight, kg/m			37.3			40		
radius of gyration, cm	r_{xx}		8.71			8.55		
	r_{yy}		4.51			4.42		
Effective Length in metre (y-y Axis)	L_y	SP 6 :1964	IS 800 :2007	Variation (%) w.r.t. IS 800 :2007	SP 6 :1964	IS 800 :2007	Variation (%) w.r.t. IS 800 :2007	
	2.0	554.2	607.6	8.8	592.9	646.6	8.3	
	2.5	539.3	555.5	2.9	575.9	589.3	2.3	
	3.0	518.9	500.2	-3.7	553.1	528.6	-4.6	
	3.5	491.1	443.9	-10.6	521.6	467.2	-11.6	
	4.0	455.4	389.7	-16.9	481.2	408.5	-17.8	
	4.5	413.1	340.1	-21.5	433.7	355.4	-22.0	
	5.0	367.3	296.5	-23.9	383.8	309	-24.2	
	5.5	323.5	259	-24.9	336.8	269.4	-25.0	
	6.0	283.7	227.2	-24.9	294.4	236	-24.7	
	6.5	249.2	200.3	-24.4	258.2	207.8	-24.3	
	7.0	224.8	177.5	-26.6	223.8	184	-21.6	
	7.5	189.3	158.2	-19.7	194.2	163.9	-18.5	
	8.0	164.3	141.8	-15.9	168.2	146.7	-14.7	
	8.5	145.1	127.6	-13.7	149.2	132	-13.0	
	9.0	128.4	115.5	-11.2	131.5	119.4	-10.1	
	9.5	113.1	104.9	-7.8	116	108.5	-6.9	
	10.0	101.0	95.7	-5.5	103.7	98.9	-4.9	
	11.0	81.5	80.6	-1.1	83.4	83.2	-0.2	

Observations (Table 2)

For calculations as per IS 800: 2007, percentage variation of safe load in comparison to SP 6, varies from (+) 8.8(max.) to (-) 26.6(max.) for ISHB 200.It can be observed that most of the load values are found to be economical in case of IS 800:2007 compared to SP 6.

Observations (Table 3)

For calculations as per IS 800: 2007, percentage variation of safe load in comparison to SP 6, varies from (+) 2.3 to (-) 25 for ISHB 150.It can be observed that most of the load values are found to be economical in case of IS 800:2007 compared to SP 6

Table 3 Percentage variation in safe loads for ISHB 150 (y-y Axis)

DESIGNATION		ISHB 150					
size(mm), hxb		150			150		
sectional area, cm^2		34.48			38.98		
weight, kg/m		27.10			30.60		
radius of gyration, cm	r_{xx}	6.50			6.29		
	r_{yy}	3.54			3.44		
	L_y	SP 6 :1964	IS 800 :2007	Variation (%) w.r.t. IS 800 :2007	SP 6 :1964	IS 800 :2007	Variation (%) w.r.t. IS 800 :2007
Effective Length in metre (y-y Axis)	2.0	389.9	399.1	2.3	438.5	444.6	1.4
	2.5	370.1	347.6	-6.5	413.8	6384.4	-7.6
	3.0	339.9	296.3	-14.7	377.5	325.3	-16.0
	3.5	302.2	249.5	-21.1	332.1	272.2	-22.0
	4.0	260.2	209.5	-24.2	283.4	227.5	-24.6
	4.5	220.8	176.6	-25.0	238.7	191.2	-24.8
	5.0	186.5	150.0	-24.3	201.5	162.0	-24.4
	5.5	157.7	128.6	-22.6	167.8	138.6	-21.1
	6.0	131.8	111.1	-18.6	140.0	119.6	-17.1
	6.5	110.8	96.9	-14.3	118.4	104.2	-13.6
	7.0	95.1	85.1	-11.8	100.8	91.5	-10.2
	7.5	81.0	75.3	-7.6	85.9	80.9	-6.2
	8.0	70.4	67.1	-4.9	74.6	72.0	-3.6
	8.5	61.2	60.1	-1.8	64.9	64.5	-0.6

CONCLUDING REMARKS

In the paper, the design procedures for columns under concentric loads as per IS 800:2007 are reviewed and applied for different of steel sections to obtain safe loads for the sections in both major buckling axis and minor buckling axis.

It can be observed that there are large variations in load carrying capacity of standard sections as per IS 800: 2007 compared to SP: 6(1)-1964.In some of the cases, safe loads given in SP: 6(1)-1964 seems to be uneconomical, on the other hand, in some of the cases, safe loads given in SP: 6(1)-1964 are likely to be unsafe compared to IS 800:2007.

Hence from the above observation, it can be concluded that load carrying capacity of sections given in SP: 6(1)-1964 are needed to be reviewed and load carrying capacity calculated as per IS 800:2007 are required to be incorporated.

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