Fourth Edition

DESIGN OF Steel Structures

By Limit State Method as Per IS: 800-2007

S.S. Bhavikatti

DESIGN OF STEEL STRUCTURES

By Limit State Method as Per IS 800-2007

FOURTH EDITION

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I.K. International Publishing House Pvt. Ltd.

NEW DELHI

Published by

I.K. International Publishing House Pvt. Ltd.
S-25, Green Park Extension
Uphaar Cinema Market
New Delhi–110 016 (India)
E-mail:info@ikinternational.com
Website: www.ikbooks.com

ISBN 978-93-82332-94-7

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Reprint 2015

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Published by Krishan Makhijani for I.K. International Publishing House Pvt. Ltd., S-25, Green Park Extension, Uphaar Cinema Market, New Delhi–110 016 and Printed by Rekha Printers Pvt. Ltd., Okhla Industrial Area, Phase II, New Delhi–110 020.

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PREFACE TO THE FOURTH EDITION

The author thanks the readers, specially Prof. K.V. Pramod of SDMCET, Dharwad and Dr. Ravindra R of R.V. College, Bangalore for their suggestions. Numerical mistakes and print mistakes have been corrected and Fig. 12.5 has been improved.

The author welcomes suggestions for further improvement.

S.S. Bhavikatti

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PREFACE TO THE FIRST EDITION

Design of steel structure is an important subject for all civil engineering students. So far working stress method was used for the design. Now-a-days whole world is changing over to limit state method since it is more rational. Hence the Indian code for steel design IS:800 has been revised in the year 2007. With an intention of providing a good textbook for civil engineering students, I have brought out this book. Hope that all universities in India will switch over to limit state method and the students will find this as a good textbook.

A sincere effort has been made in this book to present design procedure using simple language, neat sketches and systematically solved problems. Suggestions for improvements are most welcome.

I thank Bureau of Indian Standard for permitting to use some of the tables and India map showing wind load zones.

I also acknowledge AICTE for giving me an opportunity to associate with BVB College of Engineering and Technology, Hubli.

I am also thankful to the encouragement received from teachers and students from all over India for my earlier books. The keen interest and neat work of the publisher deserves special thanks.

S.S. Bhavikatti

ACKNOWLEDGEMENTS

"**Tables**, 2.1, 2.2, 2.3, 3.1, 5.1, 6.1, 6.2, 6.4(a), 6.4(b), 6.4(c), 6.4(d), 7.1, 7.2, 7.3, 7.4(a), 7.4(b), 7.5, 7.6, 12.1, 12.2, 12.3 on **Pages**: 30, 31, 32, 83, 135, 150, 153, 156, 157, 158, 159, 203, 211, 227, 228, 229, 230, 231, 369, 370, 374, and **Figures**, 12.5, 12.6, 12.7, 12.8 on **Pages**: 368, 371, 372 of this publication have been reproduced, with permission of BIS from IS 800:2007 and IS 875 (Part-3) 1987, to which reference is invited for further details. It is desirable that for more complete details reference be made only to the latest version of this standard which is available from Bureau of Indian Standard, Manak Bhawan, New Delhi."

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1

INTRODUCTION

Design of a building consists of two parts viz. (i) functional design and (ii) structural design. The first part consists in planning the building to serve its requirements taking into account ventilation, lighting, aesthetic view etc. The structural design consists in proportioning various elements of the building such that loads acting on it are transferred safely to the ground and at the same time unnecessarily excess material is not used.

For transferring the loads to the ground various materials, like asbestos sheets, tiles, bricks, cement concrete, reinforced concrete, steel, aluminium are used. However, main body of the present-day structures consists of R.C.C or steel. In tall structures composite construction of steel and concrete is also commonly used.

1.1 COMMON STEEL STRUCTURES

Steel has high strength per unit mass. Hence it is used in constructing large column-free structures. The following are the common steel structures in use:

1. Roof trusses for factories, cinema halls, auditoriums etc.
2. Trussed bents, crane girders, columns etc., in industrial structures.
3. Roof trusses and columns to cover platforms in railway stations and bus stands.
4. Single layer or double layer domes for auditoriums, exhibition halls, indoor stadiums etc.
5. Plate girder and truss bridges for railways and roads.
6. Transmission towers for microwave and electric power.
7. Water tanks.
8. Chimneys etc.

1.2 ADVANTAGES AND DISADVANTAGES OF STEEL STRUCTURES

The advantages of steel over other materials for construction are:

1. It has high strength per unit mass. Hence even for large structures, the size of steel structural element is small, saving space in construction and improving aesthetic view.

2. It has assured quality and high durability.
3. Speed of construction is another important advantage of steel structure. Since standard sections of steel are available which can be prefabricated in the workshop/site, they may be kept ready by the time the site is ready and the structure erected as soon as the site is ready. Hence there is lot of saving in construction time.
4. Steel structures can be strengthened at any later time, if necessary. It needs just welding additional sections.
5. By using bolted connections, steel structures can be easily dismantled and transported to other sites quickly.
6. If joints are taken care, it is the best water and gas resistant structure. Hence can be used for making water tanks also.
7. Material is reusable.

The disadvantages of steel structures are:

1. It is susceptible to corrosion.
2. Maintenance cost is high, since it needs painting to prevent corrosion.
3. Steel members are costly.

1.3 TYPES OF STEEL

Steel is an alloy of iron and carbon. Apart from carbon by adding small percentage of manganese, sulphur, phosphorus, chrome nickel and copper special properties can be imparted to iron and a variety of steels can be produced. The effect of different chemical constituents on steel are generally as follows:

(i) Increased quantity of carbon and manganese imparts higher tensile strength and yields properties but lower ductility, which is more difficult to weld.
(ii) Increased sulphur and phosphorus beyond 0.06 percent imparts brittleness, affects weldability and fatigue strength.
(iii) Chrome and nickel impart corrosion resistance property to steel. It improves resistance to high temperature also.
(iv) Addition of a small quantity of copper also increases the resistance to corrosion.

By slightly varying chemical composition various types of steels are manufactured to be used as structural member, tubes, pipes, sheets, strips, reinforcements for R.C.C, rivets, bolts, nuts and for welding.

In this chapter mainly structural steels are discussed and their properties presented. The structural steel is the steel used for the manufacture of rolled steel sections. These rolled steel sections are used to form steel frameworks required in the structures.

Structural steel may be mainly classified as mild steel and high tensile steel.

Structural steel is also known as standard quality steel. Its requirements have been specified in IS 226-1975. This steel is also available in copper bearing quality in which case it is designated as Fe 410-Cu-S, where 410 refers to ultimate tensile strength of 410 Mpa (= 410 N/mm^2).

This is also known as grade E250 steel in which 250 refers to 250 Mpa yield strength. E300 (Fe-440) and E-350 (Fe 490) steels are also manufactured.

In high tensile steel mechanical properties and resistance to corrosion are enhanced by alloying with small proportions of some other alloys or increasing the carbon content. Standards of high tensile steel are covered in IS 961-1975. Weldable quality steels which are recommended by IS 2007 are designated as E410 (Fe 540), E450 (Fe 570)D and E450 (Fe 590)E. As per IS 800-2007, the structural steel used in general construction, coming under the purview shall conform to IS 2062 i.e., to weldable quality steel.

Structural steel other than those specified under mild steel and high tensile steel conforming to weldable quality may also be used provided that the permissible stresses and other design provisions are suitably modified and the steel is also suitable for the type of fabrication adopted.

Steel (ordinary quality) that is not supported by mill test result may be permitted to be used for unimportant members, where their properties such as ductility and weldability do not affect the performance requirements of the structure as a whole.

In this book mild steel (structural steel-standard quality) and high tensile steel of weldable quality (conforming to IS 2062) are considered for the design.

1.4 PROPERTIES OF STRUCTURAL STEEL

The properties of steel required for engineering design may be classified as

(i) Physical Properties
(ii) Mechanical Properties.

(i) *Physical Properties*: Irrespective of its grade physical properties of steel may be taken as given below (clause 2.2.4 of IS 800-2007):

(a) Unit mass of steel, $\rho = 7850$ kg/m^3.
(b) Modulus of elasticity, $E = 2.0 \times 10^5$ N/mm^2.
(c) Poisson's ratio, $\mu = 0.3$.
(d) Modulus of rigidity, $G = 0.769 \times 10^5$ N/mm^2.
(e) Coefficient of thermal expansion, $\alpha_t = 12 \times 10^{-6}$/°C.

(ii) *Mechanical Properties:* The following are the important mechanical properties in the design:

(a) Yield stress f_y.
(b) The tensile or ultimate stress f_u.

(c) The maximum percentage elongation on a standard gauge length and
(d) Notch toughness.

Except for notch toughness, the other properties are determined by conducting tensile tests on samples cut from the plates, sections etc. IS 800-2007 gives mechanical properties of different types of structural steel products in its Table 1.1. Table 1.1 gives mechanical properties of structural steel conforming to IS 2062, which are used for the design in this book.

Table 1.1 Mechanical properties of structural steel conforming to IS Code 2062

Sl. No.	Grade/ Classification	Yield Stress in N/mm^2			Ultimate Tensile Stress in N/mm^2	Percentage Elongation
		$t < 20$ mm	$t = 20–40$ mm	$t > 40$ mm		
1	E250 (Fe 410W)A	250	240	230	410	23
2	E250 (Fe 410W)B	250	240	230	410	23
3	E250 (Fe 410W)C	250	240	230	410	23
4	E300 (Fe 440)	300	290	280	440	22
5	E350 (Fe 490)	350	330	320	490	22
6	E410 (Fe 540)	410	390	380	540	20
7	E450 (Fe 570)D	450	430	420	570	20
8	E450 (Fe 590)E	450	430	420	590	20

Notes:
1. Percentage elongation shall be taken over the gauge length $5.65\sqrt{S_a}$ where, S_a is original cross-sectional area of the specimen.
2. If elongation is non-proportional, 0.2 percent proof stress is taken as yield stress.

1.5 ROLLED STEEL SECTIONS

Like concrete, steel section of any shape and size cannot be cast on site, since steel needs very high temperature to melt it and roll into required shape. Steel sections of standard shapes, sizes and length are rolled in steel mills and marketed. User has to cut them to the required length and use required sections for the steel framework. Many steel sections are readily available in the market and are in frequent demand such steel sections are known as *Regular Steel Sections*. Some steel sections are not in use commonly, but the steel mills can roll them if orders are placed. Such steel sections are known as *Special Sections.*

Various types of rolled steel sections manufactured are listed below:

(i) Rolled steel I-sections (Beam sections)
(ii) Rolled steel Channel sections
(iii) Rolled steel Angle sections
(iv) Rolled steel Tee sections
(v) Rolled steel Bars
(vi) Rolled steel Tubes

(vii) Rolled steel Plates
(viii) Rolled steel Flats
(ix) Rolled steel Sheets and Strips.

Steel tables give nominal dimensions, weight per metre length and geometric properties of various rolled steel sections.

1.5.1 Rolled Steel I-section

The following five series of rolled steel I-sections are manufactured in India:

(a) Indian Standard Junior beams – ISJB
(b) Indian Standard Light Beams – ISLB
(c) Indian Standard Medium Beams – ISMB
(d) Indian Standard Wide-flange Beams – ISWB
(e) Indian Standard Heavy Beams – ISHB.

Figure 1.1 shows a typical I-section beam.

These sections are designated by the series to which they belong, followed by depth (in mm) and weight per metre run e.g. ISMB 500 @ 0.852 kN/m. It may not matter much if weight per metre length is not written in case of ISJB, ISLB and ISMB sections, since there is only one standard section for a specified depth. But in case of ISWB and ISHB sections weight per unit length should always be specified since for the same depth in these series more than one sections are available with different weight and properties e.g.

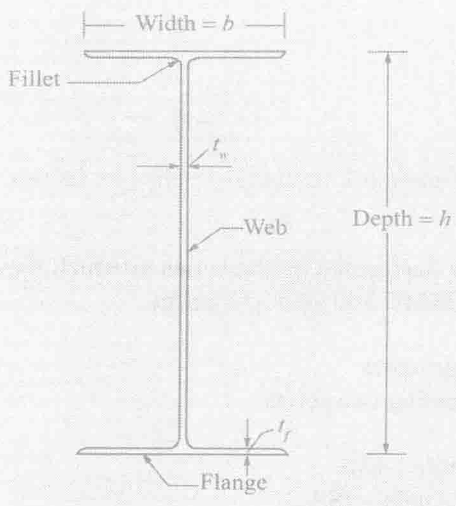

Figure 1.1 Rolled steel I-section.

ISWB 600 @ 1.423 kN/m
ISWB 600 @ 1.312 kN/m
ISHB 450 @ 0.855 kN/m
ISHB 450 @ 0.907 kN/m.

1.5.2 Rolled Steel Channel Sections

These sections are classified into the following four series:

(a) Indian Standard Junior Channel – ISJC
(b) Indian Standard Light Channel – ISLC
(c) Indian Standard Medium weight Channel – ISMC
(d) Indian Standard Special Channel – ISSC.

Figure 1.2 shows a typical channel section.

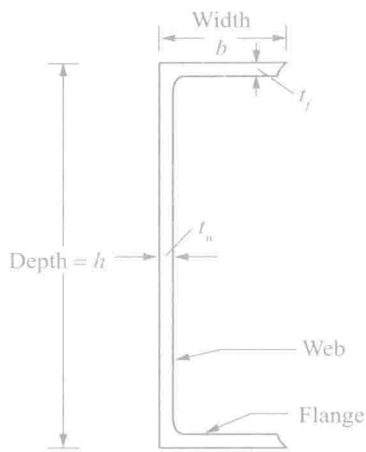

Figure 1.2 Rolled steel channel section.

Rolled steel channel sections are designated by the series to which they belong, followed by depth (in mm) and weight (in kN/m). e.g. ISMC 300 @ 0.351 kN/m.

1.5.3 Rolled Steel Angle Sections

These are classified into the following two series:

(a) Indian Standard Equal Angle – ISA
(b) Indian Standard Unequal Angle – ISA.

Figure 1.3 shows typical sections.

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