

# **Development of Design Tool for Design of Steel Columns**

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# **Development of Design Tool for Design of Steel Columns**

*A thesis submitted in partial fulfillment of requirements*

*For the degree of **BACHELOR OF***

**TECHNOLOGY IN  
CIVIL ENGINEERING**

**By**

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**2014**

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# NATIONAL INSTITUTE OF TECHNOLOGY

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## CERTIFICATE

*This is to certify that project entitled “Development of Design Tool for Design of Steel Columns” submitted by Sasanka Sekhar Sukla in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Civil Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my personal supervision and guidance. To the best of my knowledge the matter embodied in this project review report has not been submitted in any college/institute for awarding degree or diploma.*

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# Acknowledgement

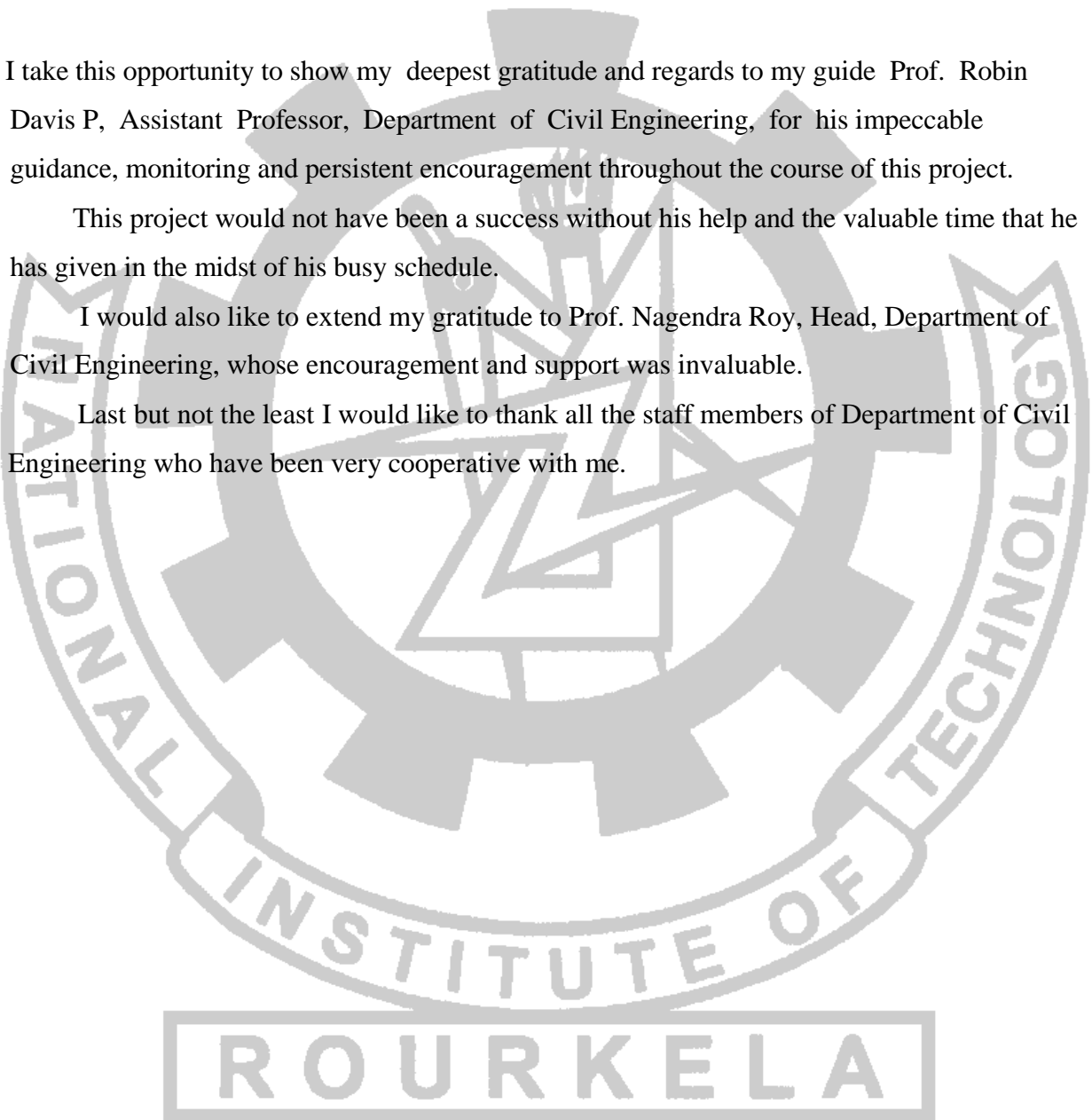
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I take this opportunity to show my deepest gratitude and regards to my guide Prof. Robin Davis P, Assistant Professor, Department of Civil Engineering, for his impeccable guidance, monitoring and persistent encouragement throughout the course of this project.

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# Abstract

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The design methodology based on Limit State Method involves numerous equations and parameters, which makes the design process a complex and tedious task. Also design being a trial and error process is very repetitive in nature. Hence use of spreadsheets can reduce the time and effort of a designer/engineer considerably. Because of the compactness and flexibility, spreadsheets have become one of the best choices for an engineer, despite the availability of number of mainstream design software packages.

Even though development of spreadsheets are very common now-a-days, not many of them includes a detailed design procedure for multiple international codes. So the main aim of this project is to prepare a Microsoft Excel Spreadsheet which will entail a detailed design of Steel Columns for three different steel codes. The three steel codes being the Indian Steel Code (IS 800-2007), the British Steel Code (BS 5950-2000) and the American Steel Code (AISC 360-2010).

The result of this project will be a design tool, which can be conveniently used by an engineer to check the design status of an column section and to strike a balance between safety and economy.

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# C H A P T E R - 1

## Introduction

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Steel due to its various advantages has been credited as a structural design material. High strength/weight ratio makes steel a very attractive structural material for high-rise buildings, long-span bridges, structures located on soft ground, and structures located in high seismic areas where forces acting on the structure due to an earthquake are in general proportional to the weight of the structure. Properly designed steel structures can have high ductility, which is an important characteristic for resisting shock loading such as blasts or earthquakes.

Because of the above reasons, design of steel structures and its elements has become an important aspect of structural engineering. Each and every element of a structure has its own property and own design constraints. Each component plays its own role in withstanding the applied load(s) and aids to the overall performance of the structure. Out of these various structural elements, columns play a major role in the transfer of load(s).

This chapter focuses on the characteristics and behavior of steel columns, the importance of spreadsheet as a design tool, the objective and scope of the present work and finally a review of available literature.

### 1.1 Columns

Columns are vertical posts that hold the entire structure and protect it from lateral disintegration. Their main function is to transmit compression pressure from all other structural members to the footing. In the context of strength and stability, they should be the second strongest structural component next to the underlying foundation. Designing a column requires accurate calculation of the total loads of the structure in order to create a counterbalancing strength. If the net end moments are zero, the compression member is required to resist load acting concentric to the

original longitudinal axis of the member and is termed *axially loaded column*, or simply *column*. If the net end moments are not zero, the member will be subjected to an axial load and bending moment(s) along its length. Such members are called *beam-columns*.

### 1.1.1 Behavior of Beam-Columns

- ✓ Under uniform compression the column has to be checked for its design compressive strength, as governed by the *flexural buckling*.
- ✓ Members subjected to uniform flexure are checked for *yielding* and *lateral torsional buckling*.
- ✓ Under combined axial force and bending moment, the column has to be designed for two types of failure condition.
  - Material Failure
  - Buckling Failure
- ✓ For a possible *material failure*, the *section strength* of the column has to be checked, whereas for the *buckling failure* the column has to be checked for *member strength* as stated by standard of codes.
- ✓ Behavior of columns largely depends on the end restraint conditions. The effective length of a column and hence its overall member buckling characteristic is dependent on the end condition.

## 1.2 Importance of Spreadsheet as a Design Tool

Steel design codes are constantly evolving over the years to meet the required performance of the structural elements. The latest version of Indian Code of Practice for general steel construction, IS 800-2007 is based on the Limit State Method. The design procedure has

undergone a drastic change in comparison to the earlier design code IS 800-1984, which was based on the Elastic Method of design. The same goes for the American Code of Specification for Structural Steel Buildings and the British Standards as well. The latest version of the former is AISC 360-2010 and that of the latter being BS 5950-2000. The design based on Limit State Method involves numerous complex equations and parameters. Hence flipping the pages of the design manual to look up a design strength parameter or a section size for a given load is not only time consuming but also cumbersome for the engineer.

Despite the availability of many powerful structural design software packages that seamlessly integrate analysis and design, *spreadsheet* applications are among the most widely used computational tools in the world of engineering and science. Traditionally, engineers have used spreadsheets to solve special and complex analysis and design problems that are not addressed in commercial packages or to perform simple and repetitive tasks that would not have been as efficiently accomplished if they were tackled otherwise. Spreadsheets are relatively easy to learn and use, allow adequate flexibility for integrating text, graphics, and charts into the solution document that they produce, and provide a powerful and user friendly platform for the development of simple to fairly complex analysis and design applications.

### 1.3 Problem Definition

This project is an attempt to prepare a Microsoft Excel Spreadsheet for the design of steel columns for Indian, British and American Steel codes. Which can be used for the following purposes.

- To check the design status of a desired section.
- To strike the balance between a safe section and an economic section.

### 1.4 Detailed operation of the Spreadsheet

The following are the detailed operations of the spreadsheet, which depicts the interaction of a user with the design procedure.

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- Selection of the appropriate Steel Code for the design
- Selection of a trial section
- Entry of load(s), end condition, span length and other design parameters
- Display of final interaction ratio and the design status

## **1.5 Scope of the Present Work**

The scope of this project is limited to preparation of Microsoft Excel Spreadsheet for the design of steel columns as per various major International codes. The design will be done for columns subjected to combined axial load and bending moment(s) and a trial section will be checked against the loading condition and the final design status will be displayed.

## **1.6 Flow of Work**

The steps adopted to accomplish the present work are by:

- Development of Main Sheet which will hold the design code and section data in Microsoft Excel 2010.
- Preparation of respective design sheets for different steel codes.
- Implementation of respective design methodologies in the design sheets.
- Comparison of the Excel Sheet results with the STADD-Pro V8i design results.

## **1.7 Review of Literature**

In the field of spreadsheet development, designers have depicted the usefulness of spreadsheet applications to produce useful design aids.( Elhouar, S. [2005] ).

In the field of study of design procedure for Indian steel code, many have explained the detailed design steps involved. ( Subramanian, N. [2008] ).

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In the field of design aids of flexural members and beam-columns based on Limit State Method, designers have, many have depicted the use of design charts. ( Kulkarni, R.B. [2011] ).

In the field of study of design procedure for British code, many have explained the detailed design steps involved. ( Chanakya, A. [2009] ).

## **1.8 Layout of the Thesis**

A brief overview of the work carried out in the thesis and organization of the same are summarized below.

Chapter 1 presents the characteristics and behavior of steel columns, the importance of spreadsheet as a design tool, the objective and scope of the present work, flow of work and finally a review of available literature.

Chapter 2 presents the detailed design methodologies for the design of steel columns as per the Indian steel code (IS 800-2007), the British steel code (BS 5950-2000), and the American steel code (AISC 360-2010).

Chapter 3 deals with the implementation of the design methodologies in Microsoft Excel spreadsheet.

Chapter 4 presents the comparison of Excel sheet results with the STAAD-Pro V8i results.

Chapter 5 summarizes the results of the work and conclusion.

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## C H A P T E R - 2

# Design Methodologies of Various Codes

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## 2.1 Introduction

Before implementing the design steps in the Excel spreadsheet, the design philosophies and methodologies were rigorously studied. The governing design equations, interaction ratio formulae, and numerous design parameters were analyzed and listed.

This chapter includes the detailed design procedure for design of steel columns as per the Indian steel code (IS 800-2007), the British code (BS 5950-2000) and the American code (AISC 360-2010).

## 2.2 Design Methodology of IS 800-2007

For designing a beam-column subjected to combined axial force and bending moment, the following design procedure is followed.

### 2.2.1 Design Compressive Strength, $P_d$

7.1.2 The design compressive strength  $P_d$ , of a member is given by:

$$P < P_d$$

Where,

$$P_d = A_c \cdot f_{cd}$$

Where,

$A_c$  = effective sectional area as defined in 7.3.2, and

$f_{cd}$  = design compressive stress, obtained as per 7.1.2.1.

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**7.1.2.1** The design compressive stress,  $f_{cd}$ , of axially loaded compression members shall be calculated using the following equation:

$$f_{cd} = \frac{f_y / \gamma_{m0}}{\phi + [\phi^2 - \lambda^2]^{0.5}} = \chi f_y / \gamma_{m0} \leq f_y / \gamma_{m0}$$

where

$$\phi = 0.5 [1 + \alpha (\lambda - 0.2) + \lambda^2]$$

$\lambda$  = non-dimensional effective slenderness ratio

$$= \sqrt{f_y / f_{cc}} = \sqrt{f_y \left( \frac{KL}{r} \right)^2 / \pi^2 E}$$

$$f_{cc} = \text{Euler buckling stress} = \frac{\pi^2 E}{\left( \frac{KL}{r} \right)^2}$$

where

$KL/r$  = effective slenderness ratio or ratio of effective length,  $KL$  to appropriate radius of gyration,  $r$ ;

$\alpha$  = imperfection factor given in Table 7;

$\chi$  = stress reduction factor (see Table 8) for different buckling class, slenderness ratio and yield stress

$$= \frac{1}{\left[ \phi + (\phi^2 - \lambda^2)^{0.5} \right]}$$

$\lambda_{m0}$  = partial safety factor for material strength.

### 2.1.2 Design Strength in bending (flexure)

The factored design moment,  $M$  at any section, in a beam due to external actions, shall satisfy

$$M \leq M_d$$

Where,

$M_d$  = Design bending strength of the section calculated as given in 8.2

#### a) 8.2.1 Laterally Supported Beam

$$M_d = \beta_b Z_p f_y / \gamma_{m0}$$

To avoid irreversible deformation under serviceability loads,  $M_d$  shall be less than  $1.2 Z_e f_y / \gamma_{m0}$  in case of simply supported and  $1.5 Z_e f_y / \gamma_{m0}$  in cantilever beams;

where

$\beta_b = 1.0$  for plastic and compact sections;

$\beta_b = Z_e / Z_p$  for semi-compact sections;

$Z_p, Z_e$  = plastic and elastic section moduli of the cross-section, respectively;

$f_y$  = yield stress of the material; and

$\gamma_{m0}$  = partial safety factor (*see 5.4.1*).

#### b) 8.2.2 Laterally Un-supported Beam

$$M_d = \beta_b Z_p f_{bd}$$

where

$\beta_b = 1.0$  for plastic and compact sections.

$\beta_b = Z_e / Z_p$  for semi-compact sections.

$Z_p, Z_e$  = plastic section modulus and elastic section modulus with respect to extreme compression fibre.

$f_{bd}$  = design bending compressive stress, obtained as given below [*see Tables 13(a) and 13(b)*]



$$f_{bd} = \chi_{LT} f_y / \gamma_{m0}$$

$\chi_{LT}$  = bending stress reduction factor to account for lateral torsional buckling, given by:

$$\chi_{LT} = \frac{1}{\left\{ \phi_{LT} + \left[ \phi_{LT}^2 - \lambda_{LT}^2 \right]^{0.5} \right\}} \leq 1.0$$

$$\phi_{LT} = 0.5 \left[ 1 + \alpha_{LT} (\lambda_{LT} - 0.2) + \lambda_{LT}^2 \right]$$

$\alpha_{LT}$ , the imperfection parameter is given by:

$$\alpha_{LT} = 0.21 \text{ for rolled steel section}$$

$$\alpha_{LT} = 0.49 \text{ for welded steel section}$$

The non-dimensional slenderness ratio,  $\lambda_{LT}$ , is given by

$$\begin{aligned} \lambda_{LT} &= \sqrt{\beta_b Z_p f_y / M_{cr}} \leq \sqrt{1.2 Z_e f_y / M_{cr}} \\ &= \sqrt{f_y / f_{cr, b}} \end{aligned}$$

where

$M_{cr}$  = elastic critical moment calculated in accordance with 8.2.2.1, and

$f_{cr, b}$  = extreme fibre bending compressive stress corresponding to elastic lateral buckling moment (see 8.2.2.1 and Table 14).

$$f_{cr, b} = \frac{1.1 \pi^2 E}{(L_{LT} / r_y)^2} \left[ 1 + \frac{1}{20} \left( \frac{L_{LT} / r_y}{h_f / t_f} \right)^2 \right]^{0.5}$$

### 2.1.3 Design Under Combined Axial force and Moment

Under combined axial force and bending moment, section strength as governed by material failure and member strength as governed by buckling failure shall be checked in accordance with 9.3.1 and 9.3.2 respectively.

#### 9.3.1 Section Strength

##### 9.3.1.1 Plastic and compact sections

In the design of members subjected to combined axial force (tension or compression) and bending moment, the following should be satisfied:

$$\left( \frac{M_y}{M_{ndy}} \right)^{\alpha_1} + \left( \frac{M_z}{M_{ndz}} \right)^{\alpha_2} \leq 1.0$$

where

$M_y, M_z$  = factored applied moments about the minor and major axis of the cross-section, respectively;

$M_{ndy}, M_{ndz}$  = design reduced flexural strength under combined axial force and the respective uniaxial moment acting alone (*see 9.3.1.2*);

$N$  = factored applied axial force (Tension,  $T$  or Compression,  $P$ );

$N_d$  = design strength in tension,  $T_d$  as obtained from 6 or in compression due to yielding given by  $N_d = A_g f_y / \gamma_{m0}$ ;

$M_{dy}, M_{dz}$  = design strength under corresponding moment acting alone (*see 8.2*);

$A_g$  = gross area of the cross-section;

$\alpha_1, \alpha_2$  = constants as given in Table 17; and

$\gamma_{m0}$  = partial factor of safety in yielding.

*For standard I or H sections*

$$\text{for } n \leq 0.2 \quad M_{ndy} = M_{dy}$$

$$\text{for } n > 0.2 \quad M_{ndy} = 1.56 M_{dy} (1 - n) (n + 0.6)$$

$$M_{ndz} = 1.11 M_{dz} (1 - n) \leq M_{dz}$$

### 9.3.2 Overall Member Strength

Members subjected to combined axial force and bending moment shall be checked for overall buckling failure as given in this section.

Members subjected to combined axial compression and biaxial bending shall satisfy the following interaction relationships:

$$\frac{P}{P_{dy}} + K_y \frac{C_{my} M_y}{M_{dy}} + K_{LT} \frac{M_z}{M_{dz}} \leq 1.0$$

$$\frac{P}{P_{dz}} + 0.6 K_y \frac{C_{my} M_y}{M_{dy}} + K_z \frac{C_{mz} M_z}{M_{dz}} \leq 1.0$$

where

$C_{my}, C_{mz}$  = equivalent uniform moment factor as per Table 18;

$P$  = applied axial compression under factored load;

$M_y, M_z$  = maximum factored applied bending moments about y and z-axis of the member, respectively;

$P_{dy}, P_{dz}$  = design strength under axial compression as governed by buckling about minor (y) and major (z) axis respectively;

$M_{dy}, M_{dz}$  = design bending strength about y (minor) or z (major) axis considering laterally unsupported length of the cross-section (see Section 8);

$$K_y = 1 + (\lambda_y - 0.2)n_y \leq 1 + 0.8 n_y;$$

$$K_z = 1 + (\lambda_z - 0.2)n_z \leq 1 + 0.8 n_z; \text{ and}$$

$$K_{LT} = 1 - \frac{0.1\lambda_{LT} n_y}{(C_{mLT} - 0.25)} \geq 1 - \frac{0.1n_y}{(C_{mLT} - 0.25)}.$$

where

$n_y, n_z$  = ratio of actual applied axial force to the design axial strength for buckling about the y and z axis, respectively, and

$C_{mLT}$  = equivalent uniform moment factor for lateral torsional buckling as per Table 18 corresponding to the actual moment gradient between lateral supports against torsional deformation in the critical region under consideration.

## 2.3 Design Methodology of BS 5950-2000

For designing a beam-column subjected to combined axial force and bending moment, the following design procedure is followed.

### 2.3.1 Design for Compressive Strength (In-Plane Buckling)

The compression resistance  $P_c$  of a member should be obtained from the following:

a) for class 1 plastic, class 2 compact or class 3 semi-compact cross-sections:

$$P_c = A_g p_c$$

b) for class 4 slender cross-sections:

$$P_c = A_{eff} p_{cs}$$

where

- $A_{\text{eff}}$  is the effective cross-sectional area from 3.6;
- $A_g$  is the gross cross-sectional area, see 3.4.1;
- $p_c$  is the compressive strength, see 4.7.5;

The compressive strength  $p_c$  should be taken as the smaller root of:

$$(p_E - p_c)(p_y - p_c) = \eta p_E p_c$$

from which the value of  $p_c$  may be obtained using:

$$p_c = \frac{p_E p_y}{\phi + (\phi^2 - p_E p_y)^{0.5}}$$

in which:

$$\phi = \frac{p_y + (\eta + 1)p_E}{2}$$

$$p_E = (\pi^2 E / \lambda^2)$$

where

- $p_y$  is the design strength;
- $\lambda$  is the slenderness, see 4.7.2.

### C.2 Perry factor and Robertson constant

The Perry factor  $\eta$  for flexural buckling under axial force should be taken as:

$$\eta = a(\lambda - \lambda_0)/1\,000 \text{ but } \eta \geq 0$$

in which the limiting slenderness  $\lambda_0$  should be taken as  $0.2(\pi^2 E / p_y)^{0.5}$ .

The Robertson constant  $a$  should be taken as follows:

- for strut curve (a):  $a = 2.0$ ;
- for strut curve (b):  $a = 3.5$ ;
- for strut curve (c):  $a = 5.5$ ;
- for strut curve (d):  $a = 8.0$ .

### 2.3.2 Design for Flexural Strength (Lateral Torsional Buckling)

For lateral-torsional buckling, the buckling resistance moment  $M_b$  should be obtained as follows:

- a) for rolled I-, H- or channel sections with equal flanges, either using the general method given in c), or alternatively using the simple method given in 4.3.7;
- b) for single angles, as given in 4.3.8;
- c) generally, except as given in a) or b),  $M_b$  should be determined from the following:
  - for class 1 plastic or class 2 compact cross-sections:
 
$$M_b = p_b S_x$$
  - for class 3 semi-compact cross-sections:
 
$$M_b = p_b Z_x; \text{ or alternatively}$$

$$M_b = p_b S_{x,eff}$$
  - for class 4 slender cross-sections:
 
$$M_b = p_b Z_{x,eff}$$

where

- $p_b$  is the bending strength from 4.3.6.5;
- $S_x$  is the plastic modulus about the major axis;
- $S_{x,eff}$  is the effective plastic modulus about the major axis, see 3.5.6;
- $Z_x$  is the section modulus about the major axis;
- $Z_{x,eff}$  is the effective section modulus about the major axis, see 3.6.2.

The bending strength  $p_b$  for resistance to lateral-torsional buckling should be taken as the smaller root of:

$$(p_E - p_b)(p_y - p_b) = \eta_{LT} p_E p_b$$

from which the value of  $p_b$  may be obtained using:

$$p_b = \frac{p_E p_y}{\phi_{LT} + (\phi_{LT}^2 - p_E p_y)^{0.5}}$$

in which:

$$p_E = (\pi^2 E / \lambda_{LT}^2)$$

$$\phi_{LT} = \frac{p_y + (\eta_{LT} + 1)p_E}{2}$$

where

- $p_y$  is the design strength;
- $\lambda_{LT}$  is the equivalent slenderness.

#### B.2.2 Perry factor and Robertson constant

The Perry factor  $\eta_{LT}$  should be taken as follows:

- a) for rolled sections:

$$\eta_{LT} = a_{LT}(\lambda_{LT} - \lambda_{L0})/1000 \quad \text{but} \quad \eta_{LT} \geq 0$$



For segments of uniform cross-section the equivalent slenderness  $\lambda_{LT}$  should be taken as:

$$\lambda_{LT} = uv\lambda\sqrt{\beta_W}$$

in which:

$$v = \frac{1}{[1 + 0.05(\lambda/x)^2]^{0.25}}$$

The buckling parameter  $u$  and  $x$  the torsional index are given by:

— for I or H-sections:

$$u = \left( \frac{4S_x^2 Y}{A^2 h_s^2} \right)^{0.25}$$

$$x = 0.566h_s(A/J)^{0.5}$$

### 2.3.3 Design for Combined Axial force and Moment

#### 4.8.3.2 Cross-section capacity

The cross-section capacity may be checked as follows.

a) Generally, except for class 4 slender cross-sections:

$$\frac{F_c}{A_g p_y} + \frac{M_x}{M_{cx}} + \frac{M_y}{M_{cy}} \leq 1$$

In the case of cross-sections that are not doubly-symmetric, reference may optionally be made to I.3.

b) Alternatively, for class 1 plastic or class 2 compact cross-sections, 4.8.2.3 may be applied.

c) For class 4 slender cross-sections:

$$\frac{F_c}{A_{\text{eff}} p_y} + \frac{M_x}{M_{cx}} + \frac{M_y}{M_{cy}} \leq 1$$

where

$A_{\text{eff}}$  is the effective cross-sectional area from 3.6;

$A_g$  is the gross cross-sectional area;

$F_c$  is the axial compression at the critical location;

and the other symbols are as detailed in 4.8.2.2.

**4.8.3.3 Member buckling resistance****4.8.3.3.1 Simplified method**

The buckling resistance of a member may be verified by checking that the following relationships are both satisfied:

$$\frac{F_c}{P_c} + \frac{m_x M_x}{p_y Z_x} + \frac{m_y M_y}{p_y Z_y} \leq 1$$

$$\frac{F_c}{P_{cy}} + \frac{m_{LT} M_{LT}}{M_b} + \frac{m_y M_y}{p_y Z_y} \leq 1$$

where

- $F_c$  is the axial compression;
- $M_b$  is the buckling resistance moment, generally from 4.3, but from I.4 for single angle members;
- $M_{LT}$  is the maximum major axis moment in the segment length  $L$  governing  $M_b$ ;
- $M_x$  is the maximum major axis moment in the segment length  $L_x$  governing  $P_{cx}$ ;
- $M_y$  is the maximum minor axis moment in the segment length  $L_y$  governing  $P_{cy}$ ;
- $P_c$  is the smaller of  $P_{cx}$  and  $P_{cy}$ ;
- $P_{cx}$  is the compression resistance from 4.7.4, considering buckling about the major axis only;

## 2.4 Design Methodology of AISC 360-2010

Unlike Indian and British Steel codes, AISC 360:2010 recommends two set of section classification systems. For compression, sections are classified as non-slender element or slender-element sections. For a non-slender element section, the width-to-thickness ratios of its compression elements shall not exceed  $\lambda_r$  from Table B4.1a. If the width-to-thickness ratio of any compression element exceeds  $\lambda_r$ , the section is a slender-element section. For flexure, sections are classified as compact, non-compact or slender-element sections. For a section to qualify as compact, its flanges must be continuously connected to the web or webs and the width-to-thickness ratios of its compression elements shall not exceed the limiting width-to-thickness ratios,  $\lambda_p$ , from Table B4.1b. If the width-to-thickness ratio of one or more compression elements exceeds  $\lambda_p$ , but does not exceed  $\lambda_r$  from Table B4.1b, the section is non-compact. If the width-to-thickness ratio of any compression element exceeds  $\lambda_r$ , the section is a slender-element section.



## 2.4.1 Design of Members for Compression

The design compressive strength,  $\phi_c P_n$ , and the allowable compressive strength,  $P_n / \Omega_c$ , are determined as follows. The nominal compressive strength,  $P_n$ , shall be the lowest value obtained based on the applicable limit states of flexural buckling, torsional buckling, and flexural torsional buckling.

$$\phi_c = 0.90 \text{ (LRFD)} \quad \Omega_c = 1.67 \text{ (ASD)}$$

### 2.4.1.1 Flexural Buckling Of Members without Slender Elements

The *nominal compressive strength*,  $P_n$ , shall be determined based on the *limit state of flexural buckling*.

$$P_n = F_{cr} A_g \quad (\text{E3-1})$$

The *critical stress*,  $F_{cr}$ , is determined as follows:

$$(a) \text{ When } \frac{KL}{r} \leq 4.71 \sqrt{\frac{E}{F_y}} \quad \left( \text{or } \frac{F_y}{F_e} \leq 2.25 \right)$$

$$F_{cr} = \left[ 0.658 \frac{F_y}{F_e} \right] F_y \quad (\text{E3-2})$$

$$(b) \text{ When } \frac{KL}{r} > 4.71 \sqrt{\frac{E}{F_y}} \quad \left( \text{or } \frac{F_y}{F_e} > 2.25 \right)$$

$$F_{cr} = 0.877 F_e \quad (\text{E3-3})$$

where

$F_e$  = elastic *buckling* stress determined according to Equation E3-4, as specified in Appendix 7, Section 7.2.3(b), or through an elastic buckling analysis, as applicable, ksi (MPa)

$$F_e = \frac{\pi^2 E}{\left( \frac{KL}{r} \right)^2} \quad (\text{E3-4})$$

### 2.4.1.2 Flexural Buckling Of Members with Slender Elements

- This section applies to slender-element compression members, as defined in Section B4.1 for elements in uniform compression.
- The nominal compressive strength,  $P_n$ , is found out based on a net correction factor,  $Q$ .
- For cross sections composed of only unstiffened slender elements,  $Q = Q_s$  ( $Q_a = 1.0$ ). For cross sections composed of only stiffened slender elements,  $Q = Q_a$  ( $Q_s = 1.0$ ). For cross sections composed of both stiffened and unstiffened slender elements,  $Q = Q_s Q_a$ . For cross sections composed of multiple unstiffened slender elements, it is conservative to use the smaller  $Q_s$  from the more slender element in determining the member strength for pure compression.

The nominal compressive strength,  $P_n$ , shall be the lowest value based on the applicable limit states of flexural buckling, torsional buckling, and flexural-torsional buckling.

$$P_n = F_{cr} A_g \quad (E7-1)$$

The critical stress,  $F_{cr}$ , shall be determined as follows:

$$(a) \text{ When } \frac{KL}{r} \leq 4.71 \sqrt{\frac{E}{QF_y}} \quad \left( \text{or } \frac{QF_y}{F_e} \leq 2.25 \right)$$

$$F_{cr} = Q \left[ 0.658 \frac{QF_y}{F_e} \right] F_y \quad (E7-2)$$

$$(b) \text{ When } \frac{KL}{r} > 4.71 \sqrt{\frac{E}{QF_y}} \quad \left( \text{or } \frac{QF_y}{F_e} > 2.25 \right)$$

$$F_{cr} = 0.877 F_e \quad (E7-3)$$

where

$F_e$  = elastic buckling stress, calculated using Equations E3-4 and E4-4 for doubly symmetric members, Equations E3-4 and E4-5 for singly symmetric members, and Equation E4-6 for unsymmetric members, except for single angles with  $b/t \leq 20$ , where  $F_e$  is calculated using Equation E3-4, ksi (MPa)

$Q$  = net reduction factor accounting for all slender compression elements;

= 1.0 for members without slender elements, as defined in Section B4.1, for elements in uniform compression

=  $Q_s Q_a$  for members with slender-element sections, as defined in Section B4.1, for elements in uniform compression.

## 2.4.2 Design of Members for Flexure

This applies to doubly symmetric I-shaped members and channels bent about their major axis, having compact webs and compact flanges as defined in Section B4.1 for flexure.

### 2.4.2.1 Yielding

#### Yielding

$$M_n = M_p = F_y Z_x \quad (\text{F2-1})$$

where

$F_y$  = specified minimum yield stress of the type of steel being used, ksi (MPa)

$Z_x$  = plastic section modulus about the  $x$ -axis, in.<sup>3</sup> (mm<sup>3</sup>)

## 2.4.2 Design of Members for Combined Axial force and Moment

(a) When  $\frac{P_r}{P_c} \geq 0.2$

$$\frac{P_r}{P_c} + \frac{8}{9} \left( \frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}} \right) \leq 1.0 \quad (\text{H1-1a})$$

(b) When  $\frac{P_r}{P_c} < 0.2$

$$\frac{P_r}{2P_c} + \left( \frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}} \right) \leq 1.0 \quad (\text{H1-1b})$$

where

$P_r$  = required axial strength using LRFD or ASD load combinations, kips (N)

$P_c$  = available axial strength, kips (N)

$M_r$  = required flexural strength using LRFD or ASD load combinations, kip-in. (N-mm)

$M_c$  = available flexural strength, kip-in. (N-mm)

$x$  = subscript relating symbol to *strong axis* bending

$y$  = subscript relating symbol to *weak axis* bending

**For design according to Section B3.3 (LRFD):**

$P_r$  = required axial strength using LRFD load combinations, kips (N)

$P_c = \phi_c P_n$  = design axial strength, determined in accordance with Chapter E, kips (N)

$M_r$  = required flexural strength using LRFD load combinations, kip-in. (N-mm)

$M_c = \phi_b M_n$  = design flexural strength determined in accordance with Chapter F, kip-in. (N-mm)

$\phi_c$  = resistance factor for compression = 0.90

$\phi_b$  = resistance factor for flexure = 0.90

## C H A P T E R - 3

# Implementation of Design Methodology in Microsoft Excel Sheet

## 3.1 Introduction

The spreadsheet is divided into three main components. Main Sheet, Design Sheet and the Section Data Sheet. The main sheet provides the available choices of design codes and a list of corresponding steel sections. The design sheet holds the detail design parameter and equations which finally shows the design status of the chosen section. Whereas the section data sheet contains all the section properties and data which are linked to the design sheet via macros.

### 3.1.1 Main Sheet

This sheet is linked to the ‘Design Sheet’ via Macros, which facilitates dynamic calculation and design for multiple sections. The main sheet provides the user options :

- To choose the required code,
- Required steel section as per the code,
- And the required design button, which will lead the user to the corresponding “Design Sheet”

The screenshot shows the 'Main Sheet' interface. At the top, there are two buttons: 'DESIGN' and 'GO TO'. Below these, there are two columns of options. The left column is titled 'Choose The Design Code' and contains three radio buttons: 'INDIAN CODE' (selected), 'BRITISH CODE', and 'AMERICAN CODE'. The right column is titled 'Sections' and contains a dropdown menu with 'ISMB 350' selected. Below these options, there are three buttons: 'Design As Per Indian Code', 'Design As Per British Code', and 'Design As Per American Code'. On the far right, there are three buttons: 'Indian Design', 'British Design', and 'American Design'. At the bottom right, there are three buttons: 'Indian Steel Sections', 'British Steel Sections', and 'American Steel Sections'.

Fig 3.1: The Main Sheet

### 3.1.2 Design Sheet

This 'design sheet' being linked with the 'main sheet' as well as the 'Indian steel' section sheet includes the data/information from these two sheets and performs broadly the following operations:

- Entry of the Span of the column, factored axial load and bending moments.
- Provides an option to select the required end restraint condition.
- Calculation of the design strength of the specified column using the defined formulae.
- Comparison of the strength with the applied load and moments.
- And finally determination of the Interaction ratio.

In case the design fails for the chosen section, the user can go to the main sheet and choose another appropriate section and redesign the column. The interaction ratio calculated at the end of the design can be used to strike the right balance between safety and economy.

### 3.2 Use of Macros for dynamic linking for the Main Sheet

One of the best features of Microsoft Excel is the macros. Macros facilitate dynamic/run time linking of data from cell to cell. When the user chooses the desired code, the active button invokes an assigned macro, which creates a dynamic drop down list of steel sections corresponding to the chosen code

```
Sub Indian()  
'  
' Indian Macro  
'  
'  
'  
Sheets("Main Sheet").Select  
Range("I5").Select  
With Selection.Validation  
    .Delete  
    .Add Type:=xlValidateList, AlertStyle:=xlValidAlertStop, Operator:= _  
xlBetween, Formula1:="=IC!$B$6:$B$97"  
    .IgnoreBlank = True  
    .InCellDropdown = True  
    .InputTitle = ""  
    .ErrorTitle = ""  
    .InputMessage = ""  
    .ErrorMessage = ""  
    .ShowInput = True  
    .ShowError = True  
End With  
End Sub
```

Fig-3.2: Macro for developing drop down list

### 3.3 Use of Vb-editor to write codes for User-defined Functions

Another excellent feature of Microsoft Excel is the vb-editor (Visual Basic Editor). Number of user-defined functions were created in order to link the section property (available in the section data sheet) with the design sheet. The function checks each and every section available in the section data sheet, against the section that has been entered by the user and by doing so assigns the corresponding section parameter/property in the design sheet.

```
Function Zxvalue(Zx As String)
Select Case Zx
Case "W44X335"
  Zxvalue = Range("AC!K6").Value
Case "W44X290"
  Zxvalue = Range("AC!K7").Value
Case "W44X262"
  Zxvalue = Range("AC!K8").Value
Case "W44X230"
  Zxvalue = Range("AC!K9").Value
Case "W40X593"
  Zxvalue = Range("AC!K10").Value
Case "W40X503"
  Zxvalue = Range("AC!K11").Value
Case "W40X431"
  Zxvalue = Range("AC!K12").Value
Case "W40X397"
  Zxvalue = Range("AC!K13").Value
```

Fig-3.3: User-defined function in vb-editor

### 3.4 Section Data Sheet

As the name suggests this sheet contains the detailed description on various steel sections available. This sheet is linked to the design sheet and depending on the steel section chosen in the 'main sheet', the 'design sheet' includes the corresponding data from this sheet.

This sheet includes the following data :

- Mass per meter (kg/m)
- Depth of the section
- Width of flange
- Thickness of web and flange
- Gross sectional area of the sections
- Radii of curvature for both the axes
- Elastic section moduli and Plastic section moduli



Indian Rolled Steel Sections													
Designations	mass per meter	Depth of section	Sectional Area	Thickness		Width of flange	Moment of inertia		Radius of Gyration		Section Modulus	Plastic Modulus	Radius at Root
				Web	Flange		Axis x-x	Axis y-y	Axis x-x	Axis y-y			
	kg/m	h	A	tw	tf	b	Ixx	Iyy	rxx	ryy	Zxx	Zyy	r
ISWB 450	79.4	450	1011.5	9.2	15.4	200	35057.6	1706.7	186.17	41.08	1558.10	1760.59	14.0
ISWB 500	95.2	500	1212.2	9.9	14.7	250	52290.9	2987.8	207.69	49.65	2091.60	2351.35	15.0
ISWB 550	122.5	550	1433.0	10.5	17.6	250	74906.1	3740.6	228.63	51.09	2723.90	3066.29	16.0
ISWB 600 1	133.7	600	170.38	11.2	21.3	250	106199	4702.5	249.70	52.50	3540.00	3986.66	17.0
ISWB 600 2	145.1	600	184.86	11.8	23.6	250	115627	5298.3	250.10	53.50	3854.20	4341.63	18.0
ISHB 150 1	27.1	150	34.48	5.4	9.0	150	1455.6	431.7	65.00	35.40	194.10	215.64	8.0
ISHB 150 2	30.6	150	38.98	8.4	9.0	150	1540	460.3	62.90	34.40	205.30	232.52	8.0
ISHB 150 3	34.6	150	44.08	11.8	9.0	150	1635.6	494.9	60.90	33.50	218.10	251.64	8.0
ISHB 200 1	37.3	200	47.54	6.1	9.0	200	3608.4	967.1	87.10	45.10	360.80	397.23	9.0
ISHB 200 2	40	200	50.94	7.8	9.0	200	3721.8	994.6	85.50	44.20	372.20	414.23	9.0
ISHB 225 1	43.1	225	54.94	6.5	9.1	225	5279.5	1353.8	98.00	49.60	469.30	515.82	10.0
ISHB 225 2	46.8	225	59.66	8.6	9.1	225	5478.8	1396.6	95.80	48.40	487.00	542.22	10.0
ISHB 250 1	51	250	64.96	6.9	9.7	250	7736.5	1961.3	109.10	54.90	618.90	678.73	10.0
ISHB 250 2	54.7	250	69.71	8.8	9.7	250	7983.9	2011.7	107.00	53.70	638.70	708.43	10.0
ISHB 300 1	58.8	300	74.85	7.6	10.6	250	12545.2	2193.6	129.50	54.10	836.30	921.68	11.0
ISHB 300 2	63	300	80.25	9.4	10.6	250	12950.2	2246.7	127.00	52.90	863.30	962.18	11.0
ISHB 350 1	67.4	350	85.91	8.3	11.6	250	19159.7	2451.4	149.30	53.40	1094.80	1213.53	12.0
ISHB 350 2	72.4	350	92.21	10.1	11.6	250	19802.8	2510.5	146.50	52.20	1131.60	1268.69	12.0
ISHB 400 1	77.4	400	98.66	9.1	12.7	250	28083.5	2728.3	168.70	52.60	1404.20	1556.33	14.0
ISHB 400 2	82.2	400	104.66	10.6	12.7	250	28823.5	2783	166.10	51.60	1444.20	1626.36	14.0
ISHB 450 1	87.2	450	111.14	9.8	13.7	250	3920.8	2985.2	187.80	51.80	1742.70	1955.03	15.0
ISHB 450 2	92.5	450	117.89	11.3	13.7	250	40349.9	3045	185.00	50.80	1793.30	2030.95	15.0

Fig-3.4: Section data sheet for Indian code

### 3.5 Development of Design sheet for IS 800-2007

Please Enter The Required Parameters			Section properties					
Span Length	4.0	m	Designation	ISHB 250 1	-	Ix	7736.5	cm <sup>4</sup>
Support Condition	<input type="radio"/> Both ends fixed <input checked="" type="radio"/> One end fixed one end pinned <input type="radio"/> One end fixed one end free <input type="radio"/> Both ends pinned		Mass per meter	51	Kg/m	Iy	1961.3	cm <sup>4</sup>
Factored Load	500	kN	Depth of section	250	mm	rx	109.1	mm
Mx (max. at top/bot)	45	kN-m	Width of section	250	mm	ry	54.9	mm
My (max. at top/bot)	0	kN-m	Thickness of web	6.9	mm	Zxx	618.9	cm <sup>3</sup>
			Thickness of flange	9.7	mm	Zyy	678.73	cm <sup>3</sup>
			Area of section	64.96	cm <sup>2</sup>	Radius of root	10	mm
Enter the following Parameters								
$\psi_x, (M^*M^*)$ with sign (-1< $\psi$ <1)			$\psi_y, (M^*M^*)$ with sign (-1< $\psi$ <1)					
-			0.6					

Fig-3.5: Indian Design sheet (parameters)

1	Design Compressive Strength of the member, Pd (As Per Clause 7.1.2)		Non dimensional effective slenderness ratio, $\lambda$		$\phi$	Effective Sectional Area As Per Cl-7.3.2		
			Major axis	0.33009	0.576593856	64.96		
			Minor axis	0.65597	0.826857942	cm <sup>2</sup>		
	Section Classification		h/b		Design Compressive Stress, fcd (N/mm2)			
	Web	Plastic	1		Major axis		1406.93	
	Flange	Semi-compact			Minor axis		1109.84	
	Overall	Semi-compact			Design Compressive Strength, Pd (kN)			
	Buckling Class		Imperfection factor					
	Major Axis	b	0.34					
	Minor Axis	c	0.49					
Effective Slenderness Ratio								
Major Axis	29.33088909							
Minor Axis	58.28779599							

Fig-3.6: Compressive Strength Calculation

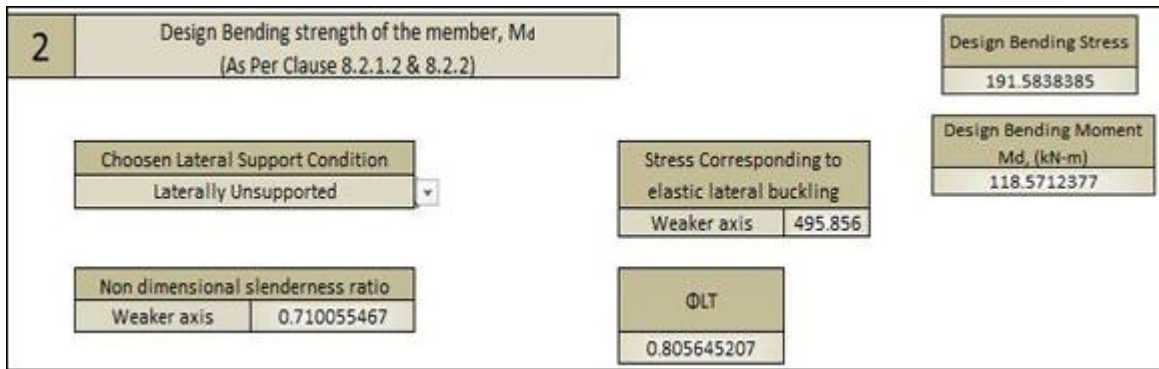


Fig-3.7: Design for Flexure

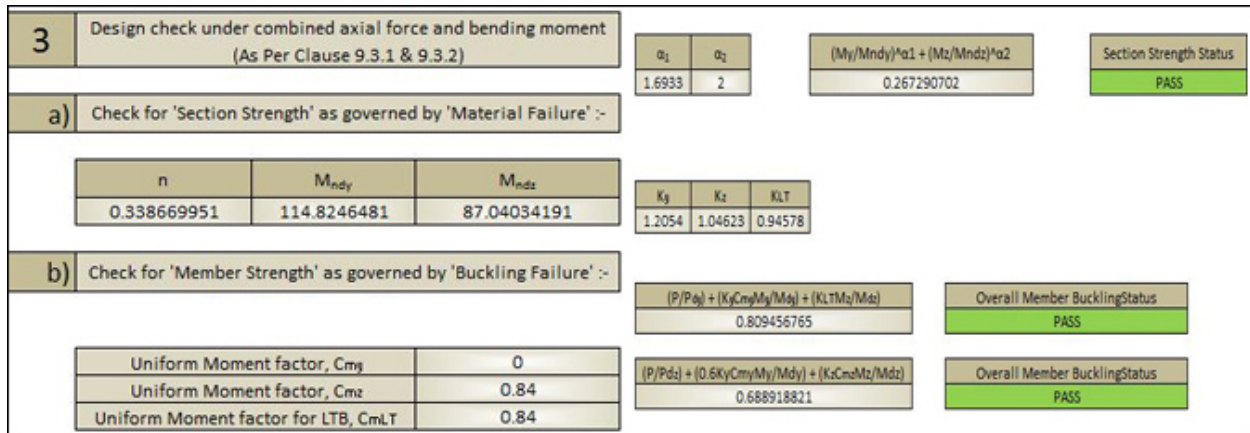


Fig-3.8: Design Check for combined Axial load and Moment

### 3.5.1 Results Obtained

A column carrying an axial load of 500 kN and moment in z-direction of magnitude 45 kNm, was checked for its overall buckling capacity and section strength using IS 800:2007 in the Excel sheet.

- Span of the column taken: 4.0 m.
- End condition: Both ends Fixed
- Lateral Support Condition: “Laterally Unsupported”
- Column section chosen: ISHB 200 (trial section)
- Axial compressive load: 500 kN
- $M_x = 45 \text{ kNm}$ ,  $M_y = 0$



**And following results were obtained:**

- The design compressive strength was found to be 1406.93 kN and 1109.84 kN about major and minor axis respectively. Both of these values are greater than the applied compressive load.
- The design bending stress and the design bending moment were found to be 191.58N/mm<sup>2</sup> and 118.57 kNm respectively.
- Finally the interaction ration was found out for the section. Which came out to be less than unity, showing that the chosen section is safe.

**3.6 Development of Design sheet for BS 5950-2000**

This sheet was prepared by incorporating the design methodology of BS 5950-2000. The design was carried out in 3 steps. First the In plane buckling capacity was checked, followed by the lateral torsional buckling capacity and finally the capacity of the member under combined action of axial force and moment.

# BUCKLING RESISTANCE CHECK #		
A. In Plane Buckling:		
Section Classification		$\lambda$
Web	Plastic	90.09009009
Flange	Plastic	
Overall	Plastic	
Buckling Class		Robertson Constant
X-X	Class b	3.5
Y-Y	Class c	5.5
$\lambda_0$	17.47565632	
$\eta_x$	0.254150518	
$\eta_y$	0.399379386	
PE (N/mm <sup>2</sup> )	249.2865403	
$\Phi_{x-x}$ (N/mm <sup>2</sup> )	288.8214219	
$\Phi_{y-y}$	306.9232228	

Fig-3.9: Design for In Plane Buckling

Compressive Strength $P_c$ (N/mm <sup>2</sup> )		$P_{cx} = A_g * p_{cx}$	$P_{cy} = A_g * p_{cy}$	Pc, smaller of $P_{cx}$ and $P_{cy}$
$p_{cx}$	157.075908	2356.138613	2087.55949	2087.559489
$p_{cy}$	139.170633			
$F_c/P_c + m_x M_x/p_y Z_x + m_y M_y/p_y Z_y$		Squash Load	Axial Force/Squash Load	
1.300600074		3975	0.503144654	
STATUS		FAIL		

Fig-3.10: Design for In Plane Buckling (cont....)

<b>B. Lateral Torsional Buckling:</b>				
Enter The effective length ratio	0.7			Pb, bending strength
Effective Length, LE	7	Robertson Constant		205.9015158
$\nu$	0.79163059	7.0		
$\lambda$	90.09009009			
$\beta_w$	1			Mb
$\lambda_{LT}$	60.62036049			403.155168
$\lambda_{LO}$	34.95131263			
$\eta_{LT}$	0.179683335			
PE (N/mm <sup>2</sup> )	550.5741835			$F_c/P_{cy} + m_{LT} M_{LT}/M_b + m_y M_y/p_y Z_y$ [Clause B-4.8.3.3.1]
$\Phi_{LT}$	457.2515945			1.334235294
				STATUS
				FAIL
<b>C. Cross Section Capacity Checks:</b>				
CROSS-SECTION CAPACITY CHECK [Clause B-4.8.3.2]				
$F_c/A_g p_y + M_x/M_{cx} + M_y/M_{cy}$	0.334897			
STATUS	PASS			
	$M_{cx}$ (kNm)	$M_{cy}$ (kNm)		
	518.87	187.302		

Fig-3.11: Design for Lateral Torsional Buckling and Cross section Capacity check

### 3.7 Development of Design sheet for AISC 360-2010

Just like the british code, various design equations and formulae were incorporated while preparing this sheet. First the compressive strength of the member is checked followed by the strength of member in flexure and finally strength of member under the combined action of axial force and moment.

Please Enter The Required Parameters		
Length of Column	14	ft.
Factored Load	400	kips
Mx	250	kip-ft
My	80	kip-ft

Grade of STEEL	A529 grade50
Fy (ksi)	50
Fu (ksi)	70
E (ksi)	29000

Section properties					
Designation	W14X99	-	$I_x$	1110	$\text{in.}^4$
Mass per meter W	99	lb/ft	$I_y$	402	$\text{in.}^4$
Depth of section h	14.2	in.	$r_x$	6.17	in.
Width of section $b_f$	14.6	in.	$r_y$	3.71	in.
Thickness of web $t_w$	0.485	in.	$Z_x$	173	$\text{in.}^3$
Thickness of flange $t_f$	0.78	in.	$Z_y$	83.6	$\text{in.}^3$
Area of section a	29.1	$\text{in.}^2$	$S_x$	157	$\text{in.}^3$
Torsional constant J	5.37	$\text{in.}^4$	$S_y$	55.2	$\text{in.}^3$
Warping constant $C_w$	18000	$\text{in.}^6$	$r_{ts}$	4.14	in.
$b_f/2t_f$	9.359	-	$h_o$	13.4	in.
$h/t_w$	23.5	-			

Fig-3.12 & Fig-3.13: Design for American Code (Parameters)

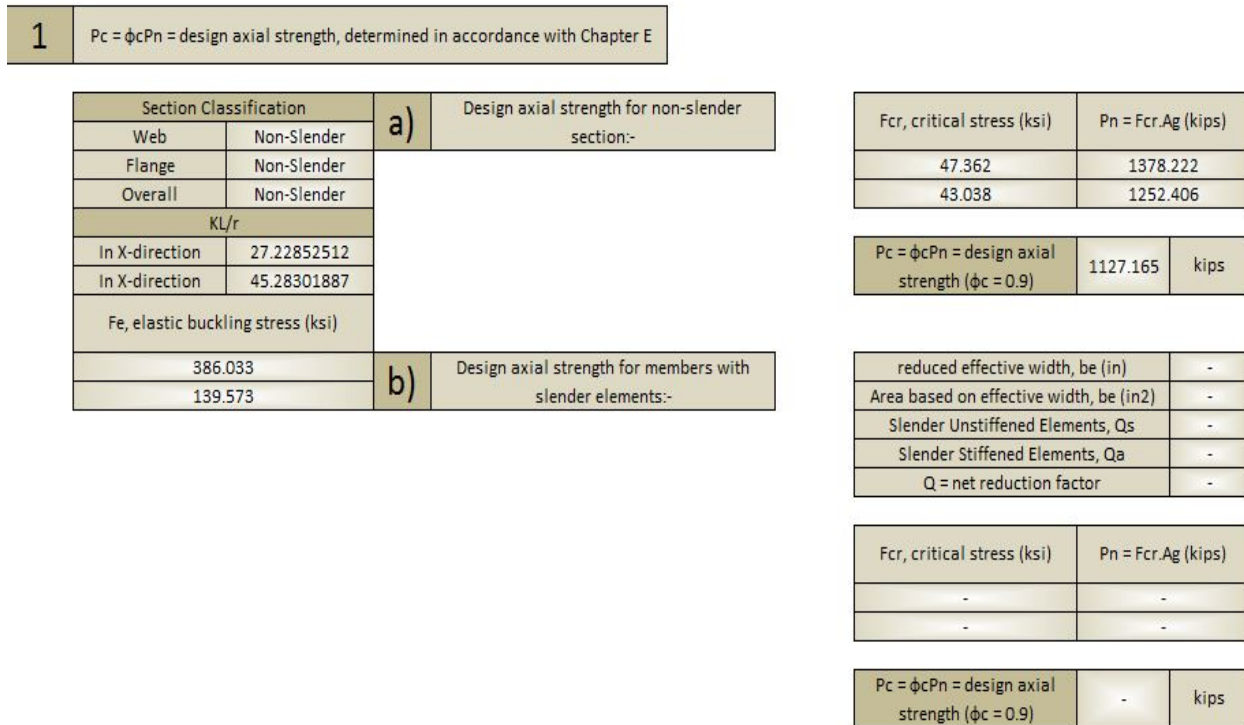


Fig-3.14: Design for Compressive Strength (without and with slender elements)

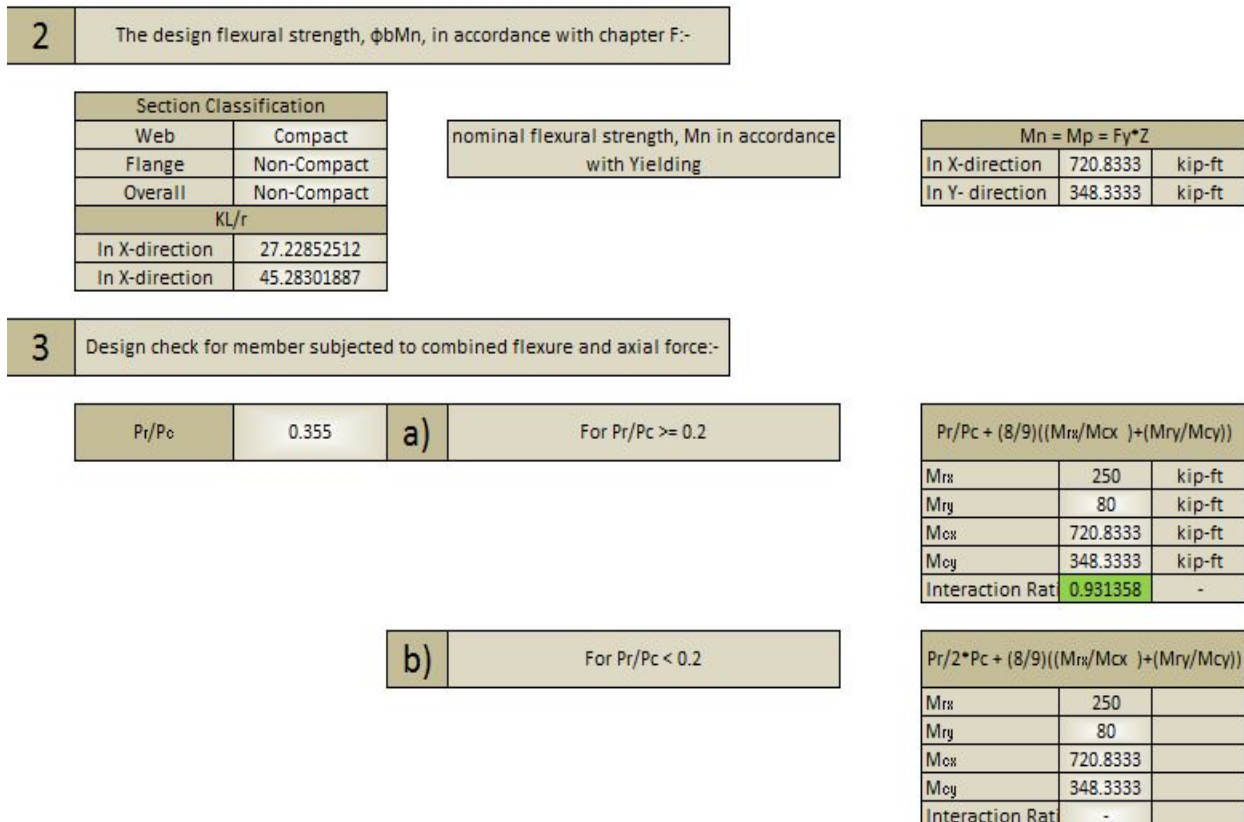


Fig-3.15: Design for Flexure and Combined action of Axial force and Moment

### 3.7.1 Results Obtained:

Verify if an ASTM A992 W14×99 has sufficient available strength to support the axial forces and moments listed below. The unbraced length is 14 ft. and the member has pinned ends.  $KL_x = KLy = Lb = 14.0$  ft.

LRFD
$P_u = 400$ kips
$M_{ux} = 250$ kip-ft
$M_{uy} = 80.0$ kip-ft

Fig-3.16: Design Problem Data

#### And following results were obtained

- Section chosen W14×99 .
- The overall section classification for “compression” was found to be ‘Non-Slender’ and for “Flexure” to be ‘Non-Compact’ .
- The  $KL/r$  ratio was found to be 27.23 and 45.28 along X and Y axis respectively.
- $P_c = \phi_c P_n$  = design axial strength, determined in accordance with Chapter E was found to be 1127.165 kips.
- The Nominal flexural strength,  $M_n$  in accordance with Yield was found to be 720.83 kip-ft. and 320.33 kip-ft. X and Y axis respectively.
- The  $P_r/P_c$  ratio was found to be 0.355 ( $\geq 0.2$ ) .
- Finally the interaction ratio was found to be 0.931 (Safe) .



## C H A P T E R - 4

# Comparison of the Excel Sheet results with the STADD-Pro V8i results (For BS 5950-2000)

## 4.1 Staad Output:

ALL UNITS ARE - KN METE (UNLESS OTHERWISE NOTED)					
MEMBER	TABLE	RESULT/ FX	CRITICAL COND/ MY	RATIO/ MZ	LOADING/ LOCATION
*	1	ST UC305X305X118	FAIL	BS-4.8.3.3.1	2
		2000.00	C	20.00	100.00

DESIGN DATA (units - kN,m)		BS5950-1/2000	
Section Class	:	PLASTIC	
Squash Load	:	3975.00	
Axial force/Squash load	:	0.503	
		z-z axis	y-y axis
Compression Capacity	:	3390.3	2066.4
Moment Capacity	:	518.9	187.4
Reduced Moment Capacity	:	298.6	187.4
Shear Capacity	:	1645.2	600.1
BUCKLING CALCULATIONS (units - kN,m)			
(axis nomenclature as per design code)			
		x-x axis	y-y axis
Slenderness	:	51.539	90.075
Radius of gyration (cm)	:	13.582	7.771
Effective Length	:	7.000	7.000
LTB Moment Capacity (kNm) and LTB Length (m):		400.61,	7.000
LTB Coefficients & Associated Moments (kNm):			
mLT = 1.00	:	mx = 1.00	: my = 1.00
Mlt = 100.00	:	Mx = 100.00	: My = 20.00
		myx = 1.00	
		My = 20.00	

Fig-4.1 &amp; Fig-4.2: Staad-pro Column Design data for BS 5950-2000

## 4.2 Excel Output/data

The Required Parameters		
Span Length	10	meter
End Support Condition (Non Sway Case)	Effectively restrained in both ends ▼	
End Support Condition (Sway Case)	Effectively restrained in both ends ▼	
Factored Load	2000	kN-m
Mx	100	kN-m
My	20	kN-m
Grade of Steel	S275 ▼	ε
Design strength, py (N/mm <sup>2</sup> )	265	1.014982108

Squash Load	Axial Force/Squash Load
3975	0.503144654

Section Classification		λ
Web	Plastic	90.09009009
Flange	Plastic	
Overall	Plastic	

Fig-4.3 , Fig-4.4 & Fig-4.5: Excel sheet Column design data as per BS 5950-2000

## 4.3 Comparison Of Results

### 4.3.1 Staad

CRITICAL LOADS FOR EACH CLAUSE CHECK (units- kN,m) :							
CLAUSE	RATIO	LOAD	FX	VY	VZ	MZ	MY
BS-4.2.3-(Y)	0.017	1	-	10.0	-	-	-
BS-4.2.3-(Z)	0.001	1	-	-	2.0	-	-
BS-4.3.6	0.250	1	-	10.0	-	100.0	-
BS-4.7 (C)	0.968	2	2000.0	-	-	-	-
BS-4.8.3.2	0.335	2	2000.0	10.0	2.0	100.0	20.0
BS-4.8.3.3.1	1.346	2	2000.0	-	-	100.0	20.0

Fig-4.6: Staad-pro output of Critical clauses and the corresponding Interaction ratios

### 4.3.2 Excel

Excel Sheet Result	
Clause	Ratio
BS-4.3.6	0.248043453
BS-4.7	0.95805653
BS-4.8.3.2	0.334897
BS-4.8.3.3.1	1.334235294

Fig-4.7: Excel Sheet output of critical clauses and corresponding Interaction ratios



## C H A P T E R - 5

# Result of the Project and Conclusion

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### 5.1 Result & Conclusion

- In this project multiple International Steel design methodologies were implemented in spread sheet for the design of steel columns.
  - The results of the spread sheet were successfully checked by comparing the results with the Staad-pro V8i results.
  - The comparison between these two results was found to be satisfactorily matching.
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