

IMPROVEMENT AND ENHANCEMENT OF DESIGN TOOLS FOR THE DESIGN OF STEEL BEAMS AS PER INDIAN AND INTERNATIONAL STANDARDS

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ABSTRACT: Steel design codes are in the process of evolution over the years. The design approach has been changing over the years. The Indian codes now follow limit state design approach in line with other inter-national codes. The latest version of the Code of Practice for general construction in steel, IS 800-2007 is based on Limit State Method of design and it supersedes the previous dated version of this code IS 800-1984 which is based on elastic method, [6]. The design based on limit state method involves many equations and parameters. Therefore the design of steel structural members and connections involves tedious equations. In this study, design tools using microsoft excel spreadsheets and charts have been prepared for the design of flexure members which will save the time of engineer"s considerably. Similar tools have also been developed for British Standards BS 5950-2000 and American Standards AISC 360-2010.

I. INTRODUCTION

Iron, in its various forms, has been in usage since several thousand years BC. The two great ancient Indian epics, Ramayana and Mahabharatha, had shown the importance of iron long back and being mostly used as weapons. The Hittites Empire was the first user of iron dated 3 to 4 millenniums ago. There are many evidences of iron usage in our country from the time of Indus Valley civilization. The most important ones are the "Iron pillar, Delhi" and "Howrah Bridge, Kolkata". Recent construction is of the Second Hooghly cable stayed bridge in Kolkata which runs a total length of 823 meters and uses 13200 tonnes of steel, [12].

II. SIGNIFICANCE & OBJECTIVE

Steel design codes are in the process of evolution over the years. The design approach has been changing over the years. The Indian codes now follow limit state design approach in line with other inter-national codes. Different tools are used in the steel and offshore steel industry for the design of steel elements. The need of such design tools is required in situations of primary, secondary and tertiary steel elements in the steel industry. The three kinds of steel elements are the elements that support major, moderate and minor equipment or loading and the final objective of the work is To develop design tools for designing steel beams for prominent code groups:

- Indian Standards
- British Standards

- American codes

Work methodology

The first section of this chapter incorporates the point by point approach received for the outline of steel beams as per different guidelines from the previous chapter and utilizing it for making of design tools using spreadsheets. The results have also been verified from staad checks and comparison is made. The second part involves the use of charts for the design of flexure members and demonstrated with an example.

SPREADSHEET FOR DESIGN OF BEAMS AS PER AISC 360:2010

The design sheet made encourages the work of selecting a fitting section for steel beam. To use this spreadsheet, the steps are:

Step1: If the user has to go for American Standards for beam design, choose the „AMERICAN

CODE" option. A macro named „american" come into operation. In the drop down box a set of American wide flange W sections will be displayed. Select any section.

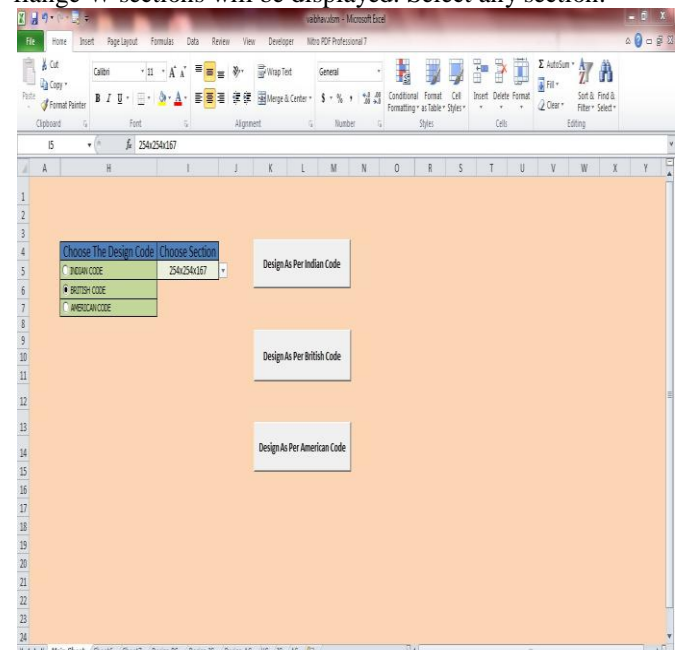


Figure22. Selection of American Code and American Steel Selection from the Main Sheet

```

Sub american ()
    american Macro
    Sheets("Main Sheets").Select
    Range("15").Select
    With Selection.Validation
        .Delete
        .Add Type="xlValidateList, AlertStyle=xlValidAlertStop, Operator=" _
            xlBetween, Formula1:=""$B:$B6:$B627$"
        .IgnoreBlank = True
        .InCellDropdown = True
        .InputTitle = ""
        .ErrorTitle = ""
        .InputMessage = ""
        .ErrorMessage = ""
        .ShowInput = True
        .ShowError = True
    End With
    Sheets("Main Sheets").Select
    Range("15").Select
    
```

Figure23. Visual Basic code for American macro
Step2: Click on the command „Design As Per British Code“. Now the macro „American_design“

runs and user is taken to a new sheet „Design AC“. In this sheet the section is matched from sheet

„AS“ and properties are displayed.

```

Sub American_design ()
    American_design Macro
    Sheets("Design AC").Select
    Range("C5").Select
    End Sub
    
```

Figure24. Visual Basic code for American_design macro

Designation	Depth of section d	Flange width b	Flange thickness t _f	Web thickness t _w	Area A	Mass per length W	Depth of section d	Flange width b	Flange thickness t _f	Web thickness t _w	Area A	Mass per length W
W8X67	8.00	21.00	0.57	0.43	19.7	67	8.00	21.00	0.57	0.43	19.7	67

Figure25. Properties of American Steel Sections

Step3: The user is required to fill the parameters along with the grade of steel.

Design As Per American Code AISI 360:2010

Please Enter The Required Parameters		Section properties	
Span Length	5 metre	Designation	W8X67
load Factors	Dead 1.2, Imposed 1.6	Mass per length W	67 lb/ft
Loading UDL	Dead (kN/m) 25, Imposed (kN/m) 18.75	Depth of section d	9 in.
Grade of STEEL	A36	Width of section b _f	8.28 in.
F _y (ksi)	36	Thickness of web t _w	0.57 in.
F _u (ksi)	58	Thickness of flange t _f	0.935 in.
E (ksi)	29000	Area of section A	19.7 in. ²
		Torsional constant J	5.05 in. ⁴
		Warping constant C _w	1440 in. ⁶
		b _f /2t _f	4.43
		h _o /t _w	11.1

Figure26. Input parameters to be filled by the user

Step4: After finishing the above work, a detailed result is displayed indicating the status of the section. If the section is unsafe revise the section.

Design As Per American Code AISI 360:2010

Grade of STEEL	A36
F _y (ksi)	36
F _u (ksi)	58
E (ksi)	29000

Section Classification	
Web	Compact
Flange	Compact
Class of section	Compact

Detailed Results: SHEAR CAPACITY "kip"		"kN"
Actual Shear V _u	33.72	150.00
section shear capacity V _u	99.73	443.59
Usage Factor	0.34 SAFE	

AISC Eq. F2
AISC Eq. F2

Please Enter The Required Parameters

Span Length	5	metre
load Factors	Dead 1.2, Imposed 1.6	
Loading UDL	Dead (kN/m) 25, Imposed (kN/m) 18.75	

Section properties

Designation	W8X67	-	I _x	272	in. ⁴
Mass per length W	67	lb/ft	I _y	88.6	in. ⁴
Depth of section d	9	in.	r _x	3.72	in.
Width of section b _f	8.28	in.	r _y	2.12	in.
Thickness of web t _w	0.57	in.	Z _x	70.1	in. ³
Thickness of flange t _f	0.935	in.	Z _y	32.7	in. ³
Area of section A	19.7	in. ²	S _x	60.4	in. ³
Torsional constant J	5.05	in. ⁴	S _y	21.4	in. ³
Warping constant C _w	1440	in. ⁶	r _{ts}	2.43	in.
b _f /2t _f	4.43	-	h _o	8.07	in.
h _o /t _w	11.1	-			

summary of results

Shear	0.34	PASS
Moment	0.73	PASS
LL defl.	0.78	PASS
DL+LL defl.	1.04	FAIL

Detailed Results: MOMENT CAPACITY "kip-in" "kN-m"

Actual Moment M _u	1659.60	187.53
Allowable Moment M _n	2271.24	256.65
(a) yielding	2271.24	
(b) LTB	2378.67	
(c) Flange Local Buckling	-	
(d) Web Local Buckling	-	
Usage Factor	0.73 SAFE	

Detailed Results: DEFLECTION

Actual Deflection LL (mm)	10.79
Allowable Deflection LL (mm)	13.89
Usage Factor	0.78 SAFE

Detailed Results: DEFLECTION

Actual Defl DL+LL (mm)	21.57
Allowable Defl DL+LL (mm)	20.83
Usage Factor	1.04 NOTSAFE

parameters:	
Lp (in.)	105.90
Lr (in.)	8.14E+02
Fcr	43.69
Mcr	2638.86

Figure27. Excelsheet showing the adequacy of the beam

VERIFICATION OF DESIGN TOOL WITH STAAD OUTPUT

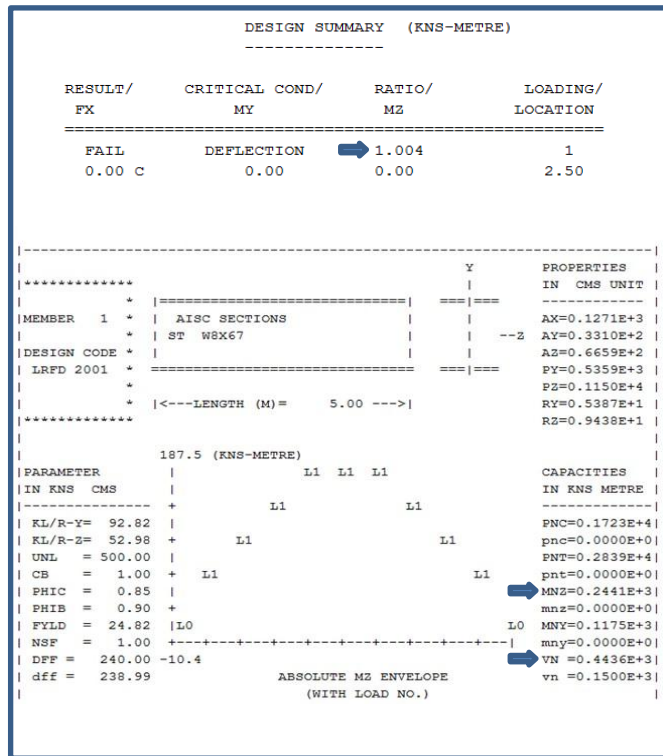
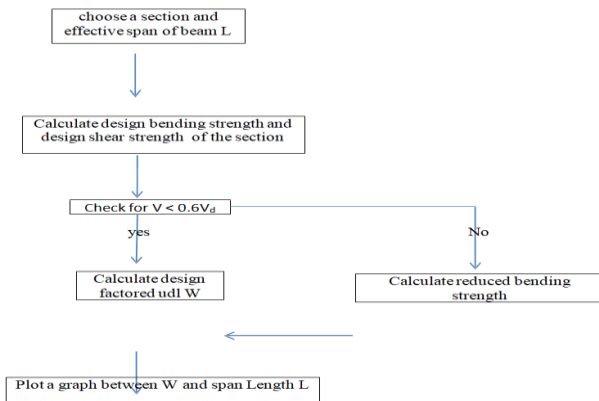


Figure28. Staad result for beam design using American Code

DESIGN CHART PREPARATION FOR FLEXURE MEMBERS

The design charts have been prepared using the Indian Standard Code of Practice for laterally supported and laterally unsupported beams. The procedure embraced is represented diagrammatically and then showed with the design examples given underneath.

Design Procedure for laterally supported beam



Design example

Beam Details

Beam span length = 1m Simply supported beam
 Section used = ISLC 150

The section is assumed to be plastic. Solution:
Properties of ISLC150:

D=150mm

tw=4.8mm

$$Z_e = 93 \times 10^3 \text{ mm}^3 \quad Z_p = 106.17 \times 10^3 \text{ mm}^3$$

Step1: Design capacity of section

$$d/tw = 24.67 < 67\epsilon$$

$$M_d = \beta_b * Z_p * f_y / Y_{mo} = 24.13 \text{ kNm} < 1.2Z_e * f_y / Y_{mo}$$

$$= 25.36 \text{ kNm} \quad V_d = (f_y * h * tw) / (\sqrt{3} * Y_{mo}) = 94.48 \text{ kN}$$

Step2: Check for $V \leq 0.6V_d$

$$V = (4 * M_d) / L = 96.52 \text{ kN}$$

Since $V > 0.6 V_d$ the section fails in shear . And also $V > V_d$

Hence to calculate the maximum load the section can take for the given length, V is taken equal to V_d .

Step3: Reduced Design capacity of section

$$\beta = 1.0$$

$$M_{fd} = (Z_p - A_v * y) * f_y / Y_{mo}$$

$$= 18 \text{ kNm} \quad M_{dv} = 18 \text{ kNm}$$

Step4: Calculation of factored uniformly distributed load W

$$W = (8 * M_{dv}) / L^2$$

$$W = 144 \text{ kN/m.}$$

The entire design chart has been prepared in light of the above example demonstrated

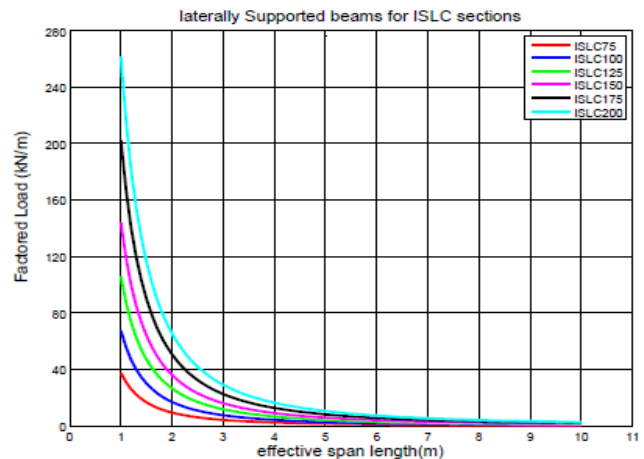


Figure29. Factored load vs effective span length graph for ISLC sections

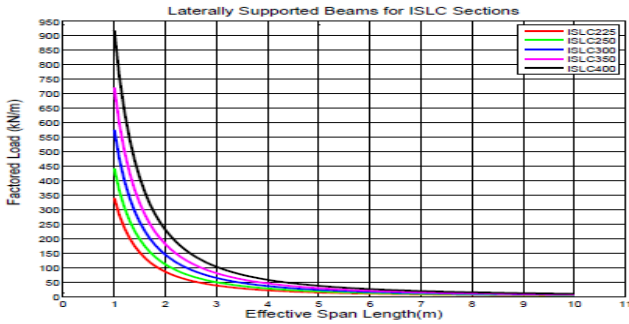


Figure30. factored load vs effective span length graph for ISLC sections

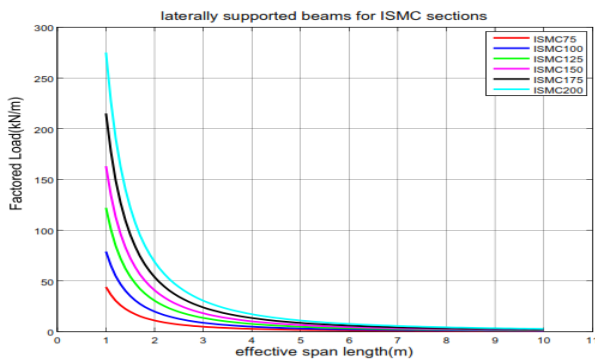


Figure31. factored load vs effective span length graph for ISMC sections

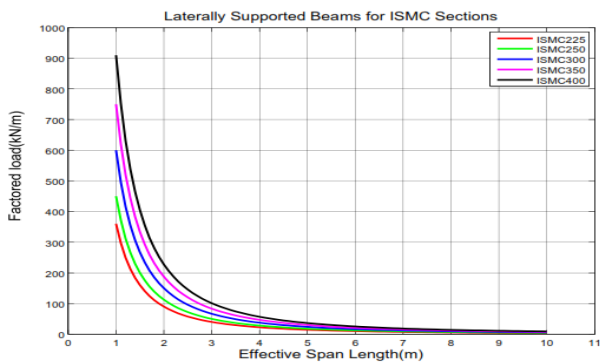


Figure32. factored load vs effective span length graph for ISMC sections

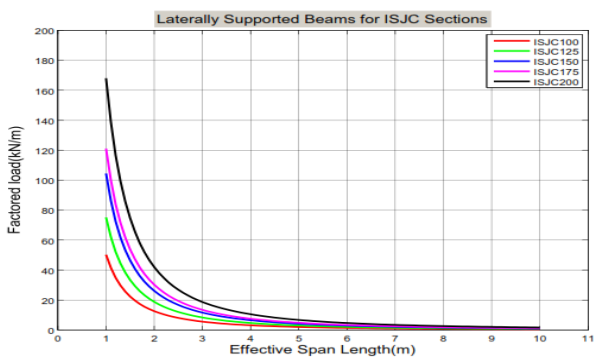


Figure33. factored load vs effective span length graph for ISJC sections

Design example
 Beam Details

Beam span length = 1m
 Section used = ISLC 150
 Ends are fully restrained against torsion and warping is not restrained in both flanges. The section is assumed to be plastic.

Solution:

Properties of ISLC150:

D=150mm

tf = 7.8mm tw=4.8mm

ry = 23.7 mm Zp=106.17 X 10³ mm³

Step1: calculation of bending compressive stress

$$f_{cr,b} = 1.1 * \pi^2 * E * [1 + 1 * (LLT / r_y)^2]^{0.5} (LLT / r_y)^2 * 20 * (h_f / t_f)^2$$

$$f_{cr,b} = 1373.25 \text{ N/mm}^2$$

Step2: Calculation of parameters

$$\lambda_{LT} = \sqrt{(f_y / f_{cr,b})} = 0.43$$

$$\phi_{LT} = 0.5 [1 + \alpha_{LT} (\lambda_{LT} - 0.2) + \lambda_{LT}^2] = 0.62 \quad X_{LT} = 1 / [\phi_{LT} + (\phi_{LT}^2 - \lambda_{LT}^2)^{0.5}] = 0.94$$

Step3: Calculation of design bending compressive stress

$$f_{bd} = X_{LT} f_y / \gamma_{mo}$$

$$f_{bd} = 213.64 \text{ N/mm}^2$$

Step4: Calculation of design bending strength

$$M_d = \beta_b Z_p f_{bd} = 22.68 \text{ kNm}$$

Step5: Calculation of factored uniformly distributed load W

$$W = (8 * M_d) / L^2$$

$$W = 181.44 \text{ kN/m}$$

The entire design chart has been prepared in light of the above example demonstrated.

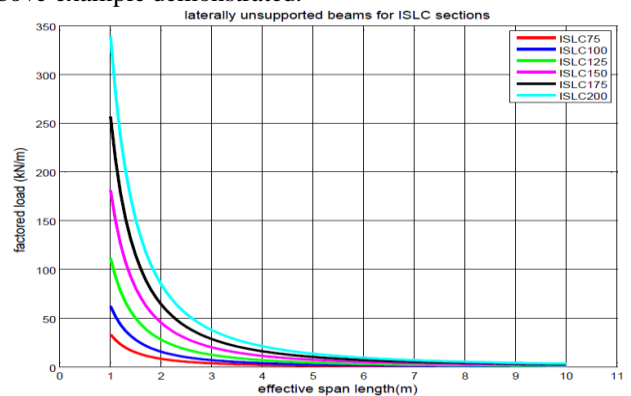


Figure34. factored load vs effective span length graph for ISLC sections

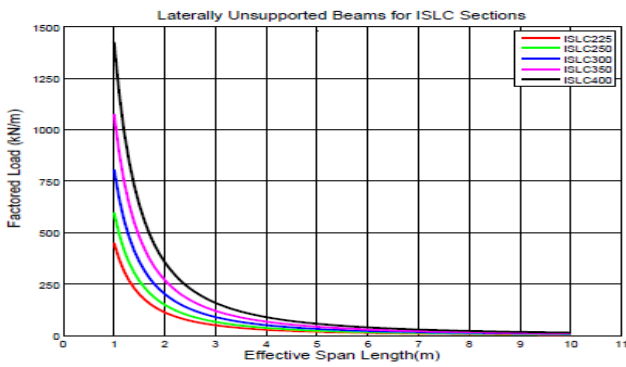


Figure35. factored load vs effective span length graph for ISLC sections

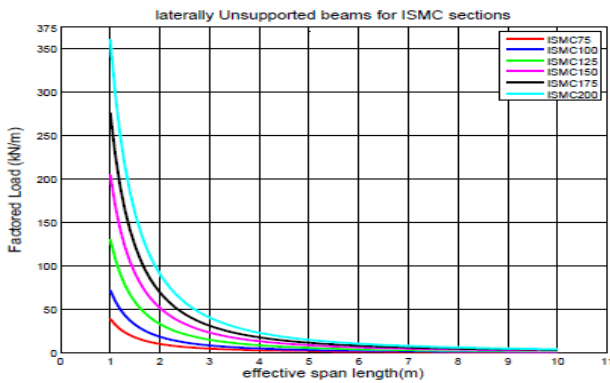


Figure36. factored load vs effective span length graph for ISMC sections

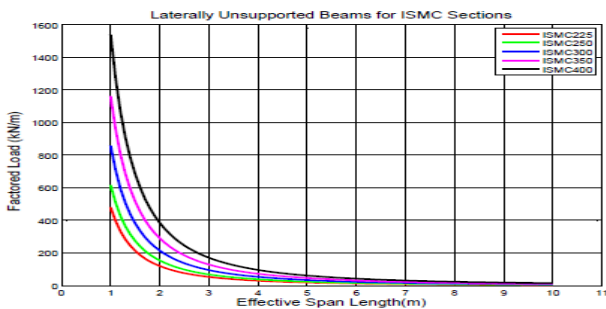


Figure37. factored load vs effective span length graph for ISMC sections

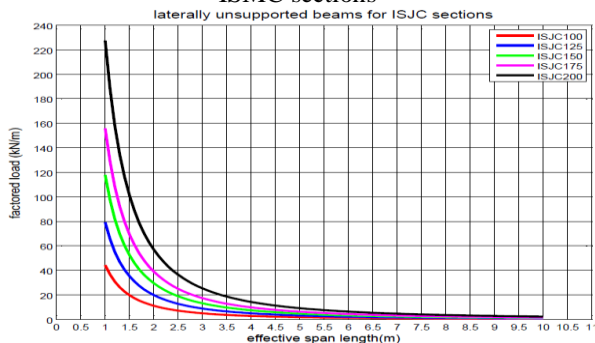


Figure38. factored load vs effective span length graph for ISJC sections

SUMMARY

From the design methods delineated in the second chapter, the design tools have been developed. The outputs obtained as per various tools are verified also with the help of other

software packages or hand calculation using the standards.

III. CONCLUSION

The objective of this study demands the development of design tools for three prominent standard code groups, Indian Standard, British Standard, and American Standard. Applying the guidelines discussed in second chapter design aids using spreadsheets and charts are developed. Soundly working of these tools are demonstrated by carrying out an example which is being verified with the help of staad output. Charts have been prepared for the purpose of selecting steel sections straightforwardly. The design tools are proven to be much significant and valuable.

SCOPE OF FUTURE WORK

Spreadsheet development packages offer numerous computational, diagraming, and charting devices that could be used to handle numerous sorts of design aids with sensible exertion. Using them to their fullest improves the nature of design experience. These graphs have been demonstrated profitable. Consequently effort should be made to produce design aids utilizing spreadsheet requisition as a part of all fields of civil engineering.

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