Summer Fellowship Report

On

Validation of Design and Detailing modules of OSDAG

Submitted by

Shahadad PP

Under the guidance of

Prof.Siddhartha Ghosh
Civil Engineering Department
IIT Bombay

Under the Mentorship of

Sourabh Das
Project Research Associate

July 3, 2020

Acknowledgment

I would like to thank FOSSEE for providing me a platform to work on something I am very interested in. I am thankful to everyone who thought of having and involved in selection process based on screening tasks. I am grateful to be a part of team which promotes open source software.

I thank all the Osdag members, who are wonderful mentors and great team. I thank Sourabh Das (Project Research Associate), Danish Ansari (Assistant Project Manager),Deepthi Reddy (Project Research Associate), Yash Lokhande (Project Research Assistant), Darshan Viswakarma (Project Research Associate), Anand Swaroop (Project Research Associate), Kumari Anjali Jatav (Project Research Assistant) and whole team, who made us feel welcome and planned all the tasks meticulously during this period.

I am grateful that I got a chance to work under Prof. Siddhartha Ghosh, who took time to mentor us and monitored individual contributions as well.

Contents

1 Introduction **3**
1.1 Osdag Internship 3
1.2 What is Osdag? 3
1.3 Who can use ? 4

2 Validation of Design modules of OSDAG **5**
2.1 Validation for End Plate Design Modules 5
2.2 Validation for Seated Angle Design Modules 15

Chapter 1

Introduction

1.1 Osdag Internship

Osdag internship is provided under the FOSSEE project. FOSSEE project promotes the use of FOSS (Free/Libre and Open Source Software) tools to improve quality of education in our country. FOSSEE encourages the use of FOSS tools through various activities to ensure availability of competent free software equivalent to commercial (paid) softwares.
The FOSSEE project is a part of the National Mission on Education through Infrastructure and Communication Technology(ICT), Ministry of Human Resources and Development, Government of India.
Osdag is one such open source software which comes under the FOSSEE project. Osdag internship is provided through FOSSEE project. Any UG/PG/PhD holder can apply for this internship. And the selection will be based on a screening task.

1.2 What is Osdag?

Osdag is Free/Libre and Open Source Software being developed for design of steel structures. Its source code is written in Python, 3D CAD images are developed using PythonOCC. Github is used to ensure smooth workflow between different modules and team members. It is in a path where people from around the world would be able to contribute to its development. FOSSEE's "Share alike" policy would improve the standard of the software when the source code is further modified based on the industrial and educational needs across the country.

Design and Detailing Checklist (DDCL) for different connections, members and structure designs is one of the important bi-products of this project. It would create a repository and design guide book for steel construction based on Indian Standard codes and best industry practices.

1.3 Who can use ?

Osdag is created both for educational purpose and industry professionals. As Osdag is currently funded by MHRD, Osdag team is developing software in such a way that it can be used by the students during their academics and to give them a better insight look in the subject.
Osdag can be used by anyone starting from novice to professionals. It's simple user interface makes it flexible and attractive than other software. Video tutorials are available to help get started.

Chapter 2

Validation of Design modules of OSDAG

I have validated design modules for two of the shear connections. For preparation of these validations I have followed Indian Standard codes, various text books, AISC codes,Euro codes and INSDAG manuals. Shear connections, though have a capacity to transfer small moments and to even take axial loads in few cases (fin plates), they are used to transfer shear force predominantly. I have validated Seated Angle and End Plate connections. It covers all modules of these connections i.e., Column flange - Beam web, Column web - Beam Web, Beam web - Beam web.

2.1 Validation for End Plate Design Modules

End plate is welded to the beam and is bolted to the supporting section at site. It can transfer shear force and axial force.

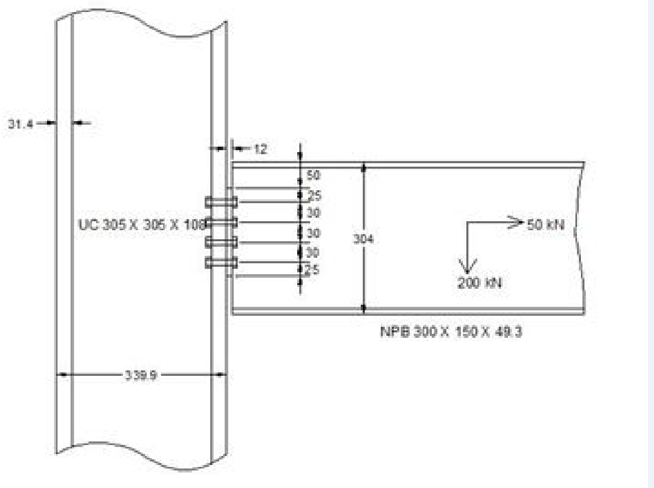

Figure 2.1: End plate connection

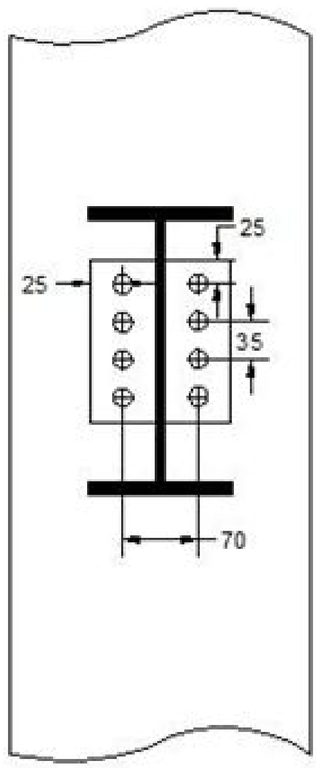

Figure 2.2: End plate connection

User Inputs

Listed below are the inputs which would be collected from the user through the Osdag design window GUI.

Note: The fields marked with * are mandatory user inputs

- **Connecting members**

  Connectivity*
  - Column flange to Beam web
  - Column web to Beam web
  - Beam to Beam

  Primary Beam Section/ Column Section*
  Secondary Beam Section/ Beam Section*
  Material

- **Factored loads**

  Vert. Shear (kN)
  Axial load (kN)

- **Bolt**

  Diameter (mm)
  Type
  Property class

- **Plate**

  Thickness (mm)

- This document is for validation of End plate connection in OSDAG shear connection design module.
- The design checks for validation are documented algorithmically and chapter wise in the document.
- Each check has an associated OSDAG Result column for giving feedback wether the hand calculation result matches with OSDAG result or not.

Supported beam shear checks

Check	Required	Provided	OSDAG Result
Supported beam- web shear capacity(kN)	$V \leq V_d$	$V_d =$ design shear strength $= V_n/\gamma_{mo}$ $V_n = V_P = \frac{A_v f_{yw}}{\sqrt{3}}$ $V_d = V_n/\gamma_{mo}$	MATCH or MIS MATCH

Bolt Design Checks

Check	Required	Provided	OSDAG
Shear Capacity (kN)		$V_{dsb} = \frac{f_u b\ n_n\ A_{nb}}{\sqrt{3}\ \gamma_{mb}}$	MATCH or MIS MATCH
No of Bolts	$R_u = V$ $n_{trial} = R_u/V_{bolt}$		MATCH or MIS MATCH
Min. Pitch (mm)	$P_{min} = 2.5\ d$		
Max. Pitch (mm)	$P_{max} = \min(16\ t,\ 200\ mm)$	Ensure minimum plate height	MATCH or MIS MATCH
Min. End Distance (mm)	$e_{min} = [1.7] * d_0$		
Max. End Distance (mm)	$e_{max} = 12\ t\ \varepsilon$ $\varepsilon = \sqrt{\frac{250}{f_y}}$	e_{min} rounded to nearest multiple of 5	MATCH or MIS MATCH
Min. Edge Distance (mm)	$e`_{min} = [1.7] * d_0$		
Max. Edge Distance (mm)	$e`_{max} = 12\ t\ \varepsilon$ $\varepsilon = \sqrt{\frac{250}{f_y}}$	e_{min} rounded to nearest multiple of 5	MATCH or

Check	Required	Provided	OSDAG
			MIS MATCH
Min. Plate Height (mm)	$0.6 * d_b$		MATCH or MIS MATCH
Bearing Capacity (kN)		$V_{dpb} = \frac{2.5\ k_b\ d\ t\ f_u}{\gamma_{mb}}$	MATCH or MIS MATCH
		$k_b = minimum\ of$ $i)\frac{e}{3d_0}$ $ii)\frac{P}{3d_0} - 0.25$ $iii)\frac{f_{ub}}{f_u}$ $iv)1$	
Capacity (KN)		$V_{db} = min\ (V_{dsb}, V_{dpb})$	MATCH or MIS MATCH

Weld Checks

Check	Required	Provided	OSDAG
Min Weld Size (mm)	$t_{w_{min}}$given by$IS800 : 2007\ cl.10.5.2.3\ Table21,$		
Max Weld Size (mm)	$Thickness\ of\ Thinner\ part$	s	MATCH or MIS MATCH

Check	Required	Provided	OSDAG
Weld Strength (kN/mm)	$Effective\ weld\ length = l_w$ $Vertical\ shear V_{wv} = \frac{V}{l_w}$ $Horizontal shear = \frac{A}{l_w}$ $R_w = \sqrt{(H)^2 + (V)^2}$ $f_w = \frac{t_t * f_u}{\sqrt{3} * \gamma_{mw}}$ $t_t = thraoat\ thickness = 0.7 * weldsize(s)$ $minimum\ weld\ size\ required =$ $s = \frac{f_w * \sqrt{3} * \gamma_{mw}}{0.7 * f_u}$	$f_w = \frac{t_t * f_u}{\sqrt{3} * \gamma_{mw}}$	MATCH or MIS MATCH

Bolt Design Checks Continues

Gauge (mm)	$G = 2\ e +\ t_w + 2\ w$	G	MATCH or MIS MATCH
Tension Capacity (kN)	$T_d \leq T_{db}$ $T_{db} = T_{nb}/\gamma_{mb}$ $T_{nb} = 0.9 f_{ub} A_n/\gamma_{mb} < f_{yb} A_{sb}/\gamma_{mo}$ $Tension\ force\ in\ each\ bolt$ $= F/n$		MATCH or MIS MATCH
Prying force (kN)	$Q = \frac{l_v}{2 l_c}[T_e - \frac{\beta \eta f_o b_e t^4}{27 l_c l_v^2}]$ $l_c =$ $1.1t\sqrt{\frac{\beta f_o}{f_y}}$ Or edge distance, which is smaller. Total tension force in each bolt $= T + Q$		MATCH or MIS MATCH

Bolt Subjected to Combined Shear- and Tension	$=(\frac{V_{sb}}{V_{db}})^2 + (\frac{T_b}{T_{db}})^2$ ≤ 1.0		

Plate Design Checks

Check	Required	Provided	OSDAG
Min. Plate Height (mm)	$0.6 * d_b$		
Max. Plate Height (mm)	$d_b - 2(t_{bf} + r_{b1} + gap)$		
Min. Plate Length (mm)	$2 * e_{min} + (n\ c - 1) * G_{min})$		
Min.Plate Thickness (mm)	t_w		
Shear yielding Capacity (V_dy) (kN)		$V_{dg} = \frac{A_v * f_y}{\sqrt{3} * \gamma_{mo}}$	MATCH or MIS MATCH
Block Shear Capacity in Shear (V_db) (kN)		$smaller\ of\ T_{db} =$ $(A_{vg} f_y)/((\sqrt{3}\gamma_{m0}) + (0.9 A_{tn} f_u)/\gamma_{m1})$ OR $(0.9 A_{vn} f_u)/((\sqrt{3}\gamma_{m1}) + (A_{tg} f_y)/\gamma_{m0})$	MATCH or MIS MATCH
Shear Capacity (V_d) (kN)	V	$V_d = Min(V_{dy}, V_{dn}, V_{db})$	
Moment Capacity (kNmm)	$= \frac{F}{n} \times (e + w)$	Lowest of $= \frac{2 \times (e + w) t^2}{4} \times f_y/\gamma_{mo}$ OR $= \frac{p t^2}{4} \times f_y/\gamma_{mo}$	MATCH or MIS MATCH

Block shear diagram

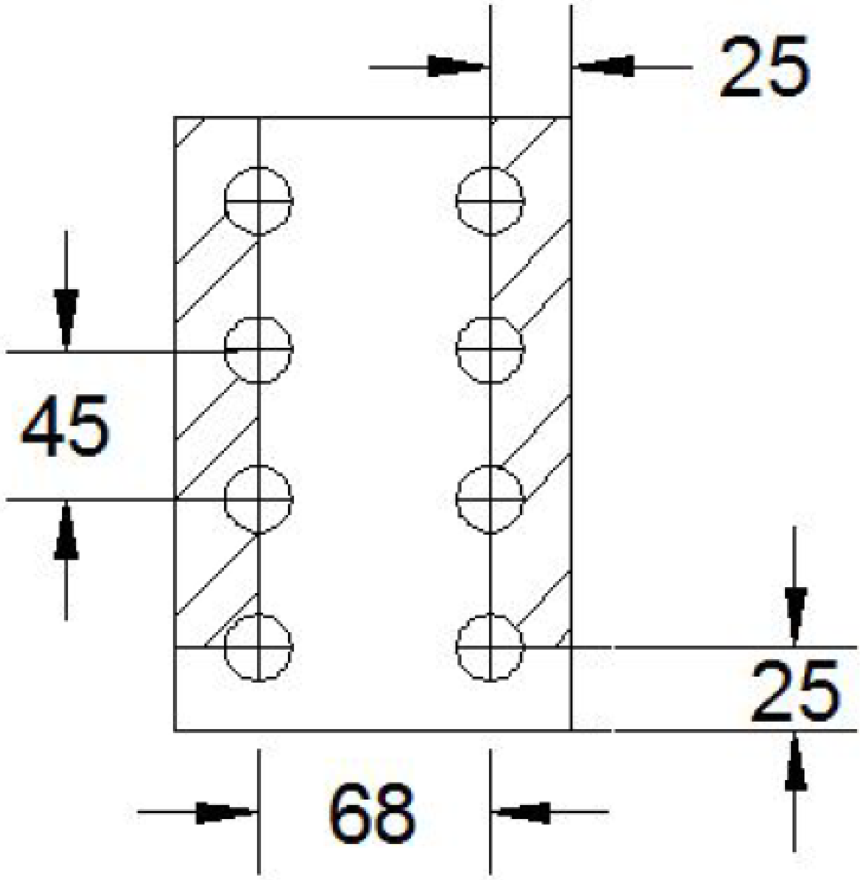

Figure 1: Block shear diagram

2.2 Validation for Seated Angle Design Modules

Seated angle can transfer only shear force. It is bolted to both primary and secondary sections.

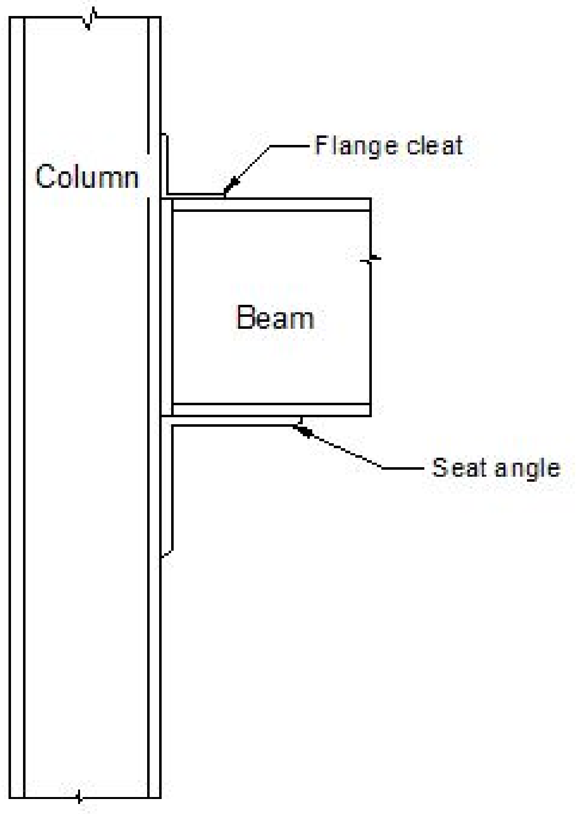

Figure 2.3: 3D drawing of typical seat angle connection

User Inputs

Listed below are the inputs which would be collected from the user through the Osdag design window GUI.

Note: The fields marked with * are mandatory user inputs

- **Connecting members**

  Connectivity*
  - Column flange to Beam web
  - Column web to Beam web

  Primary Beam Section/ Column Section*
  Secondary Beam Section/ Beam Section*
  Material

- **Factored loads**

  Vert. Shear (kN)

- **Bolt**

  Diameter (mm)
  Type
  Property class

- **Angle section**

  Seated angle*
  Top angle *

- This document is for validation of seated angle connection of OSDAG shear connection design module.
- The design checks for validaation are documented algorithmically and chapter wise in the document.
- Each check has an associated OSDAG Result column for giving feedback wether the hand calculation result matches with OSDAG result or not.

Design Checks

Check	Required	Provided	OSDAG Result
Length of angle (mm)	width of beam	width of beam $+ 10 + 10$	MATCH or MIS MATCH
Length of bearing required at root line of beam (b) (mm)	$= \dfrac{R}{t_w f_{yw}/\gamma_{mo}}$		
Required length of outstanding leg (mm)	$b + R1$	Length of angle leg	MATCH or MIS MATCH
Length of bearing on cleat (mm) [b1]	$b - (T + r)$		
Distance from end of bearing on cleat to root angle (mm) [b2]	$b_1 + Gap - (t_a + r_a)$		
Moment demand (kNmm)	$R \times \dfrac{b_2}{b_1} \times \dfrac{b_2}{2}$		MATCH or MIS MATCH
Moment Capacity (kNmm)		$1.5 Z f_y / \gamma_{mo}$	MATCH or MIS MATCH
Shear Capacity of out standing leg of cleat (kN)	R	$wt f_y / (\sqrt{3} \times \gamma_{mo})$	MATCH or MIS MATCH

Supported beam shear checks

Check	Required	Provided	OSDAG Result
Supported beam-web shear capacity(kN)	$V \leq V_d$ $V = R$	$V_d =$ design shear strength $= V_n/\gamma_{mo}$ $V_n = V_P = \dfrac{A_v f_{yw}}{\sqrt{3}}$ $V_d = V_n/\gamma_{mo}$	MATCH or MIS MATCH

Bolt Design Checks

Check	Required	Provided	OSDAG
Shear Capacity (kN)		$V_{dsb} = \dfrac{f_ub\ n_n\ A_{nb}}{\sqrt{3}\ \gamma_{mb}}$	MATCH or MIS MATCH
No of Bolts	$n_{trial} = R_u/V_{bolt}$		MATCH or MIS MATCH
No of Columns			
No of Rows			
Min. Pitch (mm),SA	$P_{min} = 2.5\ d$		
Max. Pitch (mm),SA	$P_{max} = \min(16\ t,\ 200\ mm)$ $= \min(16 *\ 12,\ 200\ mm)$		
Min. End Distance (mm),SA	$e_{min} = [1.5] * d_0$		

Check	Required	Provided	OSDAG
Max. End Distance on column(mm)SA	$e_{max} = 12\ t\ \varepsilon$ $\varepsilon = \sqrt{\frac{250}{f_y}}$	length of angle leg-t-Pmin	MATCH or MIS MATCH
Max. End Distance on beam(mm),SA	$e_{max} = 12\ t\ \varepsilon$ $\varepsilon = \sqrt{\frac{250}{f_y}}$	Half the available length	MATCH or MIS MATCH
Min. Edge Distance (mm)SA	$e`_{min} = [1.5] * d_0$		
Max. Edge Distance on column (mm),SA	$e`_{max} = 12\ t\ \varepsilon$ $\varepsilon = \sqrt{\frac{250}{f_y}}$	$e`_{min}$	MATCH orMIS MATCH
Max. Edge Distance on beam (mm),SA	$e`_{max} = 12\ t\ \varepsilon$   $\varepsilon = \sqrt{\frac{250}{f_y}}$   $e`_{max} = 12\ * 12 * \sqrt{\frac{250}{250}}$ $= 144$	The bolt on the beam is kept as the centre of the available space while maintaining min edge distances. $=(L - Gap - R_1)/4$	MATCH or MIS MATCH
Min. Gauge (mm),SA	$G_{min} = 2.5\ d$		
Max. Gauge on column (mm),SA	$G_{max} = \min(16\ t,\ 200\ mm)$	$(L - (2 * E_{min}))/2$	MATCH or MIS MATCH

Check	Required	Provided	OSDAG
Max. Gauge on beam (mm),SA	$G_{max} = \min(16\ t,\ 200\ mm)$	$L - (2 * e`_{provided})$	MATCH or MIS MATCH
Min. Pitch (mm),TA	$P_{min} = 2.5\ d$		
Max. Pitch (mm),TA	$P_{max} = \min(16\ t,\ 200\ mm)$		MATCH or MIS MATCH
Min. End Distance (mm),TA	$e_{min} = [1.5] * d_0$		
Max. End Distance on column(mm)TA	$e_{max} = 12\ t\ \varepsilon$ $\varepsilon = \sqrt{\frac{250}{f_y}}$	$L_t - t_a - E_{min}$	MATCH or MIS MATCH
Max. End Distance on beam(mm),TA	$e_{max} = 12\ t\ \varepsilon$ $\varepsilon = \sqrt{\frac{250}{f_y}}$	$L_t - t_a - E_{min}$	MATCH or MIS MATCH
Min. Edge Distance (mm),TA	$e`_{min} = [1.5] * d_0$		
Max. Edge Distance on column (mm),TA	$e`_{max} = 12\ t\ \varepsilon$ $\varepsilon = \sqrt{\frac{250}{f_y}}$	$=(L - Gap - R_1)/4$	MATCH or MIS MATCH
Max. Edge Distance on beam (mm),TA	$e`_{max} = 12\ t\ \varepsilon$ $\varepsilon = \sqrt{\frac{250}{f_y}}$	The bolt on the beam is kept as the centre of the available space while maintaining min edge distances. $=(L - Gap - R_1)/4$	MATCH or

FOSEE		Module -Seated angle connection	
OSDAG		Validation of OSDAG with sample problems	

Check	Required	Provided	OSDAG
			MIS MATCH
Min. Gauge (mm),TA	$G_{min} = 2.5\ d$ $=$		
Max. Gauge on column (mm),TA	G_{max} min$(16\ t,\ 200\ mm)$	$(L-(2*E_{min}))/2$	MATCH or MIS MATCH
Max. Gauge on beam (mm),TA	$G_{max} = \min(16\ t,\ 200\ mm)$	$L-(2*e`_{provided})$	MATCH or MIS MATCH

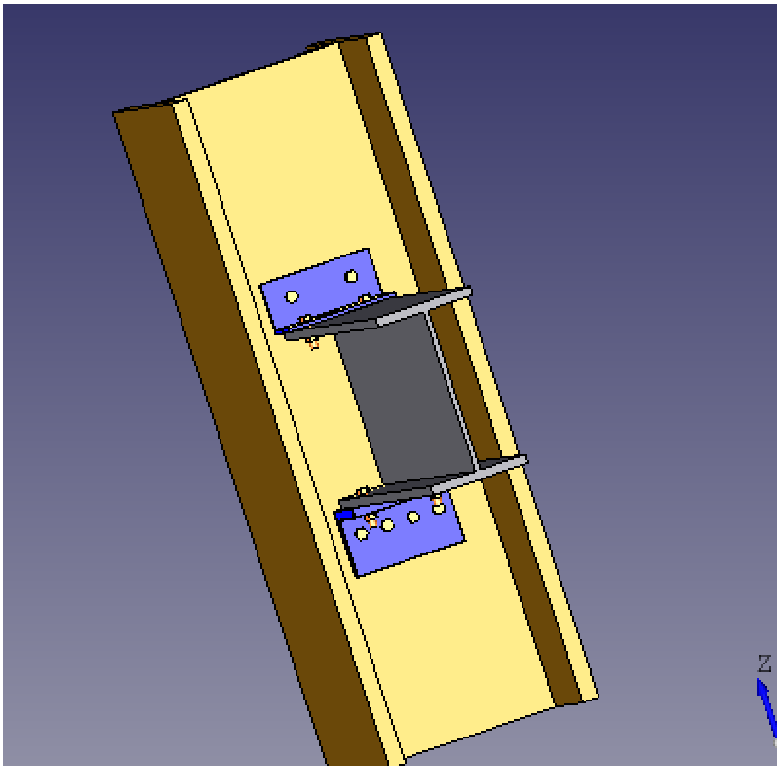

Figure 1: 3D View

References

IS 800:2007. *Indian Standard Code of Practice for General Construction in Steel,*2007.

IS 808:1989. *Indian Standard Code of Practice for Dimensions or Hot Rolled Steel Beam, Column, Channel and Angle Sections,*1989.

SP 6(1):1964.*Indian Standard Code of Practice for Structural Steel Sections,*1964.

American Institute of Steel Construction.*Steel Construction Manual,*15 edition,2017.

American Institute of Steel Construction.*Design guide 4 - Extended End plate moment connections/Seismic and wind applications,*2016.

Institute of Steel Development and Growth.*Hand Book on Structural Steel Detailing,*2008.

N. Subramanian.*Design of Steel Structures.*Oxford University Press,12 edition,2008.

M.L.Gambhir.*Fundamentals of structural steel design.*McGraw Hill Education,,2013.