Summer Fellowship Report

On

Preparation of DDCL (Design and Detailing Check List) and Design Calculations using Python

Submitted by

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Under the guidance of

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July 12, 2019

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), Ajmal Babu MS (Project Research Associate), Danish Ansari (Project Research Assistant), Yash Lokhande (Project Research Assistant), Darshan Viswakarma (Project Research Associate), Anand Swaroop (Project Research Associate), 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. Sidharth Ghosh, who took time to mentor us and monitored individual contributions as well.

Contents

Chapter 1

Introduction

1.1 FOSSEE Summer Fellowship

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.
Under FOSSEE summer fellowship I have worked on one of the FOSSEE projects, Osdag. Osdag is Open Source Software for Design(and detailing) of Steel Structures. Any UG/PG/PhD holder can apply for this fellowship and the selection was based on a screening tasks. There were three screening tasks out of which two needs to be completed. For the first task, which was mandatory task, few set of questions were provided which needs to be designed using Osdag. Upon submitting this successfully we can access second and third tasks and choose one. I have chosen second task which was hand calculations for the same set of questions provided in task 1. These calculations should be documented in Latex. A sample file was provided to guide the applicants.
I found these tasks both useful and of level which can be done in a month or less. The solutions I have submitted for the second task was used for preparation of DDCLs (Design and detailing check list) during my internship period.

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.

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. The video tutorials of Osdag can be accessed here.

Chapter 2

Preparation of DDCL

Design and Detailing Checklist (DDCL) is a document which contains all the checks one should make for designing any component. DDCLs 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.

DDCL for shear connections were already available on webforms with comments from experts. I have compiled all the changes, comments into the structure provided by the team for three of the shear connections using LaTex. 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 created DDCLs for Fin Plate, Cleat 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. For preparation of these DDCLs, in addition to web forms provided, I have followed Indian Standard codes, various text books, International Standards and INSDAG manuals.

2.1 DDCL for Fin Plate

Fin Plate is one of the shear connections, which is used when both shear and axial load needs to be transferred between two members. Fin plate connection comprises of single plate which is ususally shop welded to the supporting section and has predrilled holes so that it can be bolted to supported section at site. The DDCL of Fin Plate is attached vide Appendix - A

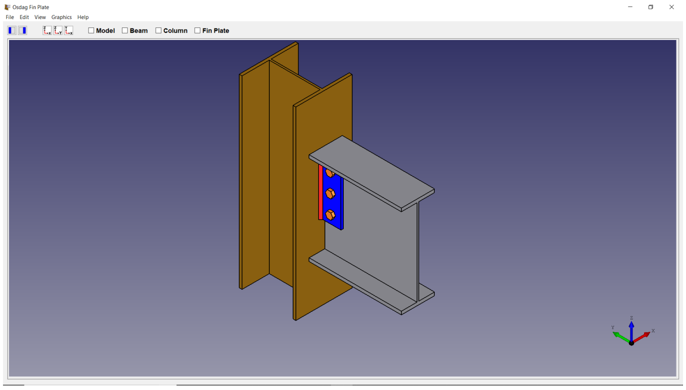


Figure 2.1: 3D drawing output of typical Fin plate connection

2.2 DDCL for Cleat Angle

Cleat angle can transfer only shear force. It is bolted to both primary and secondary sections. Though this connection eliminates welding, it takes larger number of bolts than any other shear connection driving up the cost. The DDCL of Cleat Angle is attached vide Appendix - B

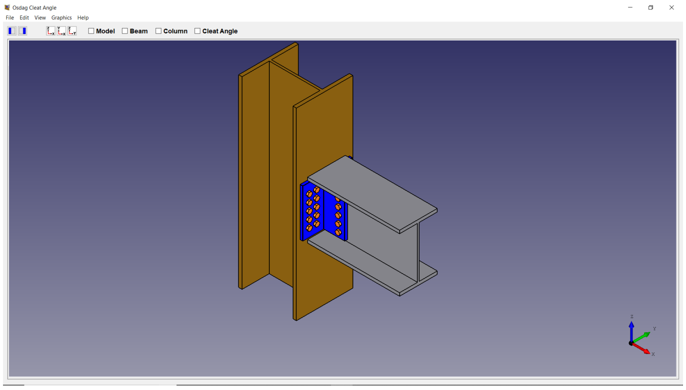


Figure 2.2: 3D drawing output of typical Cleat angle connection

2.3 DDCL for End Plate

End plate is welded to the beam at shop and is bolted to the supporting section at site. It can transfer only shear force. Though this connection is relatively inexpensive it has a disadvantage of having no room for site adjustment. The DDCL of End Plate is attached vide Appendix - C

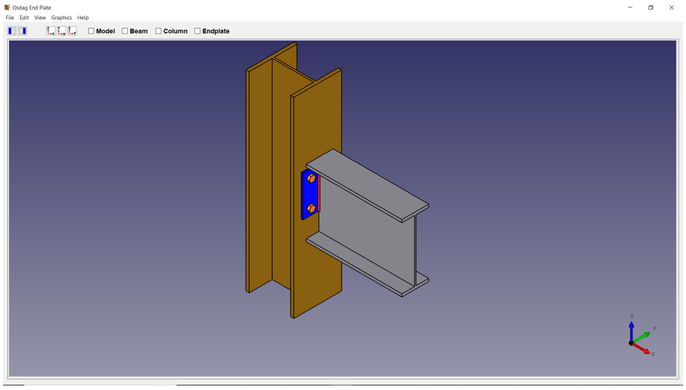


Figure 2.3: 3D drawing output of typical End plate connection

Chapter 3

Design calculations using python

After writing DDCLs for different shear connections I have written python code for calculating values of stresses and capacities of members and connections for Fin plate module. For this I have used existing formulae library and provided structure. I have worked on stiffener design and continuity plate weld design in Beam - Column end plate connection.

3.1 Fin Plate design caluclations using python

Existing code for fin plate needed few additions and I have added few checks and introduced iterative code for optimum design, which is attached vide Appendix -D, Appendix-E, Appendix-F.

3.2 Stiffener design in Beam Column End Plate using Python

For Beam Column End plate design I have added python code for weld design between beam and end plate. Concerned code is attached vide Appendix-G.

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.

American Institute of Steel Construction. *Design guide - 13 - Wide flange column stiffening at moment connections*, 2018a.

American Institute of Steel Construction. *Design guide 16 - Flush and Extended Multiple-Row Moment End-Plate Connections*, 2018b.

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

N. Subramanian. *Design of Steel Structures.* Oxford University Press, 12 edition, 2013.

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

Appendices

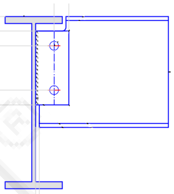
Appendix A

DDCL for Fin plate

Osdag®
Open steel design and graphics

Design and Detailing Checklist (DDCL)
and
Design and Detailing Query (DDQ)

Fin Plate Connection



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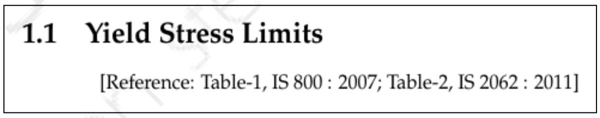
June 2019

Contents

Reviewer Details & Guideline(s) for filling DDCL/DDQ

1. Name of the reviewer:
2. Institute/Company/Organization:
3. Designation:

- This document is for Design and Detailing Check List (DDCL) and Design and Detailing Query (DDQ) created by Osdag team, IIT Bombay.
- The checks are documented algorithmically and chapter wise in the document where the checks and sub-checks are given in the section and subsection respectively.
- Reference of the check is given just below the check title



1.1 Yield Stress Limits

[Reference: Table-1, IS 800 : 2007; Table-2, IS 2062 : 2011]

- Each check has an associated checkbox and a comment box for giving feedback. The checkbox can be checked and unchecked multiple times. The comments can be of multiply lines/paragraph and is not restricted by the size of the comment box.
- You can open the the pdf using any standard pdf viewer. The pdf has been tested on Adobe Acrobat Reader DC (Windows) and Okular, Foxit reader, Document viewer (Ubuntu). Please save the pdf (current or as a copy) after filling the feedback.
- If you check on the 'Not Ok' checkbox during the review, please specify your reason in the comment box with reference(s) (if any). It is mandatory!
- Send the document after review to sghosh@civil.iitb.ac.in.

  For any queries or help on filling the feedback document, contact Danish Ansari at [danishdyp@gmail.com / +91 9765147757]

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*
  Ultimate strength of beam material - f_u (MPa)*
  Yield strength of beam material - f_y (MPa)*

- **Factored loads**

  Vert. Shear (kN)*
  Axial Force (kN)

- **Bolt**

  Diameter (mm)*
  Type *
  Property class *

- **Plate**

  Thickness (mm)*
  Height (mm)
  Width (mm)
  note: f_u and f_y of plate is taken same as beam material

- **Weld**

  Size (mm)*

Check 1

Material Strength

The ultimate strength (f_u) and the yield strength (f_y) of the beam material and plate material are assumed to be same.

The values of material strength will be subjected to the following limits depending on the grade of the material, in **MPa**;

1.1 Yield Stress Limits

[Reference: Table-1, IS 800 : 2007; Table-2, IS 2062 : 2011]

$$250 \leq f_y \leq 650 \tag{1.1}$$

1.2 Ultimate Stress Limits

[Reference: Table-1, IS 800 : 2007; Table-2, IS 2062 : 2011]

$$410 \leq f_u \leq 780 \tag{1.2}$$

Where,
f_y = yield stress of the beam/plate material; and
f_u = ultimate stress of the beam/plate material.

Is this check: **Ok** / **Not Ok**

Comment(s):

Check 2

Factored Loads

2.1 Design shear force

[ref: cl.10.7 IS 800:2007]

Design shear force (V_u) for connection is minimum of (0.15*V_d, 40kN) but greater than given shear load.
design shear capacity
[ref: cl.8.4 IS 800:2007]

$$V_d = V_p/\gamma_{mo} \tag{2.1}$$

where,
V_p = plastic shear capacity of beam
γ_{mo} = 1.1 [ref:cl.5.4.1, IS 800:2007]

$$V_p = \frac{A_v f_{yw}}{\sqrt{3}} \tag{2.2}$$

where,
A_v = shear area [ref:cl.8.4.1.1 of IS 800:2007 to calculate shear area]
f_{yw} = yield strength of web

Is this check: **Ok** **/ Not Ok**

Comment(s):

Check 3

Bolt Design

Bolts of diameter 12, 16, 20, 24, 30 and 36 mm conforming to IS 1363 (part 1) 2002 are available for carrying out the design.

The default bolt hole type is 'Standard'
The default parameters of the bolt, however, can be changed by using the 'Design Preference' menu from the Osdag design window GUI.
V_{bolt} is used where bolt capacity is considered. V_{bolt} is taken as V_{dsf} if friction grip bolting is done and is taken as V_{db} for bearing type bolts

3.1 Bearing Bolt

(Already reviewed)

3.1.1 Design strength of bolt (V_{db})

[Reference: Cl. 10.3.2, IS 800:2007]

The design strength of bolt is taken as the smaller of the value as governed by shear, $\boldsymbol{V_{dsb}}$ (Sec. 3.1.1.1) and bearing $\boldsymbol{V_{dpb}}$ (Sec. 3.1.1.2).

$$V_{db} = min\ (V_{dsb}, V_{dpb}) \tag{3.1}$$

3.1.1.1 Shear capacity of bolt (V_{dsb})

[Reference: Cl. 10.3.3, IS 800:2007]

Assumption: The shear plane(s) will always pass through the threads of the bolt.

$$V_{dsb} = \frac{f_u\ n_n\ A_{nb}}{\sqrt{3}\ \gamma_{mb}} \tag{3.2}$$

Where,
f_u = ultimate tensile strength of a bolt;
n_n = number of shear planes with threads intercepting the shear plane;
A_{nb} = net shear area of the bolt at threads;
γ_{mb} = partial safety factor = 1.25;
[Ref: Table 5, IS 800:2007]

3.1.1.2 Bearing capacity of bolt (V_{dpb})

[Reference: Cl. 10.3.4, IS 800:2007]

$$V_{dpb} = \frac{2.5\ k_b\ d\ t\ f_u}{\gamma_{mb}} \tag{3.3}$$

Where,
k_b is smaller of $\frac{e}{3\ d_0}, \frac{p}{3\ d_0} - 0.25, \frac{f_{ub}}{f_u}, 1.0;$
e, p = end and pitch distances of the bolt along bearing direction;
d, d_0 = diameter of bolt and bolt hole;
t = summation of the thicknesses of the connected plates experiencing bearing stress in the same direction;
γ_{mb} = partial safety factor = 1.25.
[Ref: Table 5, IS 800:2007]

3.2 Friction Grip Bolt

(Already reviewed)

3.2.1 Slip resistance of bolt (V_{dsf})

[Reference: Cl. 10.4.3, IS 800:2007]

$$V_{dsf} = \frac{\mu_f\ n_e\ K_h\ F_o}{\gamma_{mf}} \tag{3.4}$$

Where,
μ_f = coefficient of friction (slip factor);
[Ref: Table 20, IS 800:2007 for typical values]
n_e = number of effective interfaces offering frictional resistance to slip;
K_h = 1.0 for bolts in clearance holes and 0.85 for bolts in oversized holes;
F_o = proof load = $A_{nb} * f_o$;
γ_{mf} = partial safety factor;
f_o = proof stress = $0.7 f_{ub}$

3.3 Check for long joints and large grip lengths

[Reference: Cl. 10.3.3, IS 800:2007]

Assumption: The shear plane(s) will always pass through the threads of the bolt.

$$V_{bolt_{reduced}} = V_{bolt}\ \beta_{lj}\beta_{lg} \tag{3.5}$$

Where,
β_{lj}, β_{lg} = factors, given by;

$$\beta_{lj} = 1.075 - 0.005(l_j/d) \tag{3.6}$$

$$\beta_{lg} = 8/(3 + l_g/d) \leq \beta_{lj} \tag{3.7}$$

Where,
l_J = length of joint (measured in the direction of load transfer);

l_g = total thickness of the connected plates (grip length)($l_g \leq 8d$);
d = nominal diameter of the bolt.

Is this check: **Ok** / **Not Ok**

Comment(s):

Check 4

Number of Bolts and Bolt checks

Note: The **trial** number of bolts is calculated based on resultant of axial and shear forces. Actual force acting on the bolt (direct shear + axial + Force due to eccentricity of shear force) is calculated later in the design and the number of bolts required is then updated accordingly in an iterative way.

The procedure to calculate number of bolts is as follows;

Step 1: Resultant of shear and axial forces (R_u)

$$R_u = \sqrt{V_u^2 + A_u^2} \tag{4.1}$$

where,
V_u = Shear Load
A_u = Axial Load

Step 2: Trial number of bolts

$$n = R_u/V_{bolt} \tag{4.2}$$

DDQ: minimum number of bolts for fin plate is considered as 3 in Osdag. Is this correct?

Is this check: **Ok** / **Not Ok**

Comment(s):

Step 3: Check for stress developed in Bolt from Moment due to eccentricity

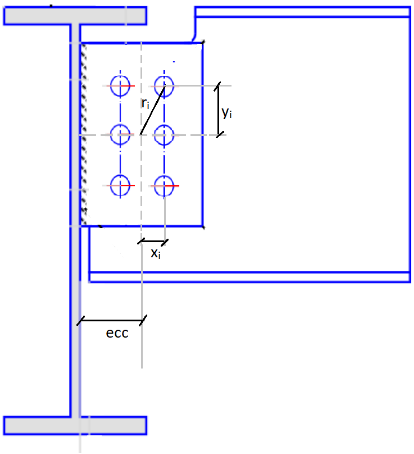


Figure 4.1: Shear due to eccentricity of load

Horizontal shear force acting on each bolt due to moment developed by eccentricity is given by,

$$V_{mh} = \frac{V_u * ecc * y_{max}}{\Sigma r_i^2} \tag{4.3}$$

Vertical shear force acting on each bolt due to moment developed by eccentricity is given by,

$$V_{mv} = \frac{V_u * ecc * x_{max}}{\Sigma r_i^2} \tag{4.4}$$

where,
ecc = distance between bolt center line to face of connected supporting section
y_{max} = vertical distance of farthest bolt from center of rotation of bolt group
x_{max} = Horizontal distance of farthest bolt from center of rotation of bolt group
r_i = distance of each bolt from center of rotation of bolt group

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Is this check: **Ok** / **Not Ok**

Comment(s):

Step 4: Resultant load on bolt
Vertical force acting on each bolt (assuming uniform shear distribution) is given by,

$$V_{bv} = V_u/n \tag{4.5}$$

Horizontal force acting on each bolt (assuming uniform shear distribution) is given by,

$$A_{bh} = A_u/n \tag{4.6}$$

Resultant force on each bolt is given by,

$$V_{res} = \sqrt{(V_{bv} + V_{mv})^2 + (V_{mh} + A_{bh})^2} \tag{4.7}$$

If the calculated V_{res} is greater than bolt capacity, then spacing is adjusted to decrease V_{res} by increasing increase Σr_i^2. if V_{res} is still greater than bolt capacity, number of bolts are increased and the process is repeated till V_{res} is less than bolt capacity. Please note that bolt group capacity shall also be checked for long joint condition.

Is this check: **Ok** / **Not Ok**

Comment(s):

Check 5

Detailing

5.1 Pitch (p) and Gauge (g)

[Reference: Cl. 10.2.2 and 10.2.3, IS 800 : 2007]

(Already reviewed)

$$2.5\,d \;\leq\; p \; or \; g \;\leq\; \min(32\,t,\; 300\,\text{mm}) \tag{5.1}$$

Where,
d = diameter of bolt;
t = thickness of the thinner plate.

5.2 End (e) and Edge (e')

[Reference: Clause 10.2.4, IS 800 : 2007]

(Already reviewed)

$$[1.5 \text{ or } 1.7] \times d_0 \;\leq\; e \; or \; e' \;\leq\; 12\,t\,\varepsilon \tag{5.2}$$

$$\varepsilon = \sqrt{\frac{250}{f_y}} \tag{5.3}$$

Where,
1.5 for machine-flame cut edges and 1.7 for hand-flame cut edges;
d_0 = diameter of the hole;
t = thickness of the thinner plate;
f_y = yield stress of the plate.

Check 6

Plate Dimensions

6.1 Plate height (h_p)

Based on detailing,

$$h_p = (n_r - 1) * p + 2 * e' \tag{6.1}$$

6.2 Minimum plate height (h_{min})

[Ref: Handbook on Structural Steel Detailing, INSDAG - Chapter 5, Section 5.2.3, Page 5.7]

$$h_{min} = 0.6 * d_b \tag{6.2}$$

6.2.1 Check for maximum plate height

For Beam-column connectivity,

$$h_p \leq d_b - 2(t_{bf} + r_{b1} + gap) \tag{6.3}$$

For Beam-Beam connectivity with single notch

$$h_p \leq d_b - t_{bf} + r_{b1} - notch_h \tag{6.4}$$

For Beam-Beam connectivity with double notch

$$h_p \leq d_b - (2 * notch_h) \tag{6.5}$$

Where,
d_b = Depth of supported beam
t_{bf} = Thickness of supported beam flange
r_{b1} = Root radius of supported beam flange
gap = Clearance between fin plate and supported beam flange
$notch_h$ = max(T_{bf}, t_{bf}) + max(R_{b1}, r_{b1}) + max($T_{bf}/2$, $t_{bf}/2$, 10)
D_b = Depth of supporting beam
T_{bf} = Thickness of supporting beam flange
R_{b1} = Root radius of supporting beam flange

6.3 Plate width (w_p)

Based on detailing,

$$w_p = (n_c - 1) * g + 2 * e' + gap \tag{6.6}$$

Where,
w_p = width of plate;
n_c = number of columns;
g = gauge;
e' = edge distance;
gap = gap between connecting members

6.4 Plate thickness (t_p)

6.4.1 Minimum plate thickness

$$t_p \geq t_w \tag{6.7}$$

Where,
t_p = Thickness of fin plate
t_w = Thickness of beam web

Note: Plate thickness is taken greater than beam web thickness to ensure the shear strength of plate, assuming beam is designed to be safe against shear.

6.4.2 Maximum plate thickness

[Reference: Handbook on Structural Steel Detailing, INSDAG - Chapter 5, Section 5.2.3, Page 5.7]

$$t_p \leq 0.5 * bolt\ diameter \tag{6.8}$$

Note: It is advised to limit plate thickness to 0.5 times bolt diameter to ensure ductility in connection.

Is this check: **Ok** / **Not Ok**

Comment(s):

Check 7

Fin Plate Checks

7.1 Block shear capacity

[Reference: Cl. 6.4.1, IS 800 : 2007]

$$T_{db1fin} = \frac{A_{vg} f_y}{\sqrt{3}\gamma_{m0}} + \frac{0.9 A_{tn} f_u}{\gamma_{m1}} \tag{7.1}$$

$$T_{db2fin} = \frac{0.9 A_{vn} f_u}{\sqrt{3}\gamma_{m1}} + \frac{A_{tg} f_y}{\gamma_{m0}} \tag{7.2}$$

7.1.1 Block shear capacity of fin plate under shear load

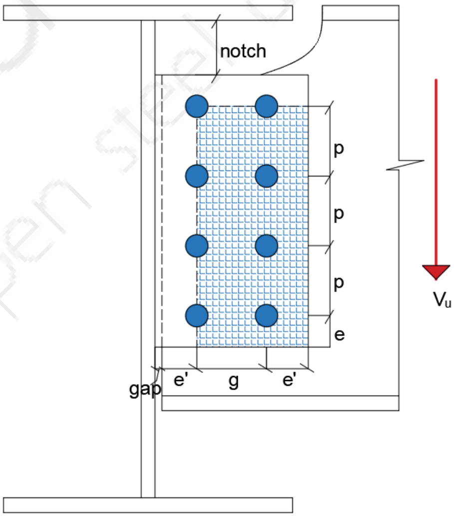


Figure 7.1: Block Shear failure path for fin plate under shear load

A_{vg} = Minimum gross area in shear along bolt line parallel to shear force = $(h_p - e) \ * \ t_p$

A_{vn} = Minimum net area in shear along bolt line parallel to shear force = $(h_p - e - (n_r - 0.5) * d_o) \ * \ t_p$

A_{tg} = Minimum gross area in tension along bolt line perpendicular to shear force =$(w_p - e' - gap) * t_p$

A_{tn} = Minimum gross area in tension along bolt line perpendicular to shear force =$(w_p - e' - gap - (n_c - 0.5 * d_o) * t_p$

7.1.2 Block shear capacity of fin plate under Axial load

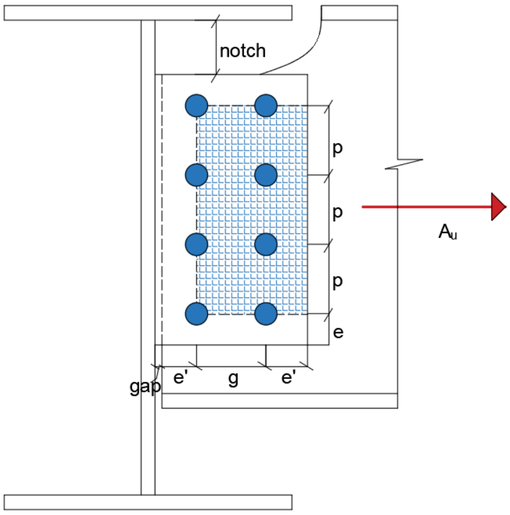


Figure 7.2: Block Shear failure path for fin plate

A_{vg} = Minimum gross area in shear along bolt line parallel to axial force=$(w_p - e' - gap) * t_p$

A_{vn} = Minimum net area in shear along bolt line parallel to axial force= $(w_p - e' - gap - (n_c - 0.5 * d_o) * t_p$

A_{tg} = Minimum gross area in tension along bolt line perpendicular to axial force = $(h_p - e) * t_p$

A_{tn} = Minimum net area in tension along bolt line perpendicular to axial force = $(h_p - e - (n_r - 0.5) * d_o) \ * \ t_p$

n_r = number of bolt rows
n_c = number of bolt columns
f_u = Ultimate stress of the plate material
f_y = Yield stress of the plate material
e = end distance
e' = edge distance
gap = gap between connecting members
γ_{m0} = 1.10
γ_{m1} = 1.25

7.2 Shear yielding check of fin plate

[cl.8.4.1.1 of IS 800:2007]

$$V_{dg} = \frac{0.6 * A_v * f_y}{\sqrt{3}\gamma_{mo}} \tag{7.3}$$

where,
A_v = gross shear area of fin plate $(h_p * t_p)$
f_y = yield strength of fin plate
γ_{m0} = 1.1 [Ref: Table 5, IS 800:2007]

DDQ: Shear capacity of the member/plate is taken as 0.6 times its actual capacity, so that the section does not fall under high shear category and moment capacity can be calculated according to cl.8.2.1.2 IS 800:2007 and need not consider cl.9.2.2 IS 800:2007. But, will this make the section uneconomical? Please Comment.

Is this check: **Ok** / **Not Ok**

Comment(s):

7.3 Shear rupture check of fin plate

[J4.2(b) Specification for Structural Steel Buildings, June 22, 2010, AISC]

$$V_{dn} = 0.75 * A_{vn} * f_u \tag{7.4}$$

where,
A_{vn} = net shear area of fin plate $((h_p * t_p) - (n_r * d_o))$
f_u = ultimate strength of fin plate

7.4 Tension yielding check of fin plate

[cl.6.2 of IS 800:2007]

$$N_{dg} = \frac{A_g * f_y}{\gamma_{m0}} \tag{7.5}$$

where,
A_g = gross tensile area of fin plate $((w_p * t_p))$
f_y = yield strength of fin plate
γ_{m0} = 1.1 [Ref: Table 5, IS 800:2007]

7.5 Tension rupture check of fin plate

[cl.6.3.1 of IS 800:2007]

$$N_{dn} = \frac{0.9 * A_n * f_u}{\gamma_{m1}} \tag{7.6}$$

Where,
A_n = net tensile area of fin plate $((w_p * t_p) - (n_c * d_o))$

f_y = yield strength of fin plate
γ_{m1} = 1.25 [Ref: Table 5, IS 800:2007]

7.6 Moment capacity of plate

[Reference: Cl. 8.2.1.2, IS 800 : 2007]

$$M_d = \frac{1.2 f_y Z}{\gamma_{m0}} \tag{7.7}$$

Where,
Z = Section modulus = $w_p * h_p^2/6$
γ_{m0} = 1.1 [Ref: Table 5, IS 800:2007]

7.7 Combined capacity of plate

[Reference: Cl. 9.3.1.1, IS 800 : 2007]

$$\frac{M_u}{M_d} + \frac{A_u}{N_{dg}} \leq 1 \tag{7.8}$$

Where, A_u = Factored applied axial force
N_{dg} = Gross tension capacity
M_u = moment developed due to eccentricity of shear force = $V_u * ecc$
M_d = Moment capacity of plate as calculated in section 8.6

DDQ: Do we need to check fin plate for any other criteria?

Is this check: **Ok** / **Not Ok**

Comment(s):

Check 8

Member Checks

8.1 Block shear capacity of supported beam web

$$T_{db1beam} = \frac{A_{vg} f_y}{\sqrt{3}\gamma_{m0}} + \frac{0.9 A_{tn} f_u}{\gamma_{m1}} \tag{8.1}$$

$$T_{db2beam} = \frac{0.9 A_{vn} f_u}{\sqrt{3}\gamma_{m1}} + \frac{A_{tg} f_y}{\gamma_{m0}} \tag{8.2}$$

8.1.1 Block shear capacity of supported beam web under shear load

This check is necessary only under Beam-Beam connection when the flange of supported member is cut as a notch

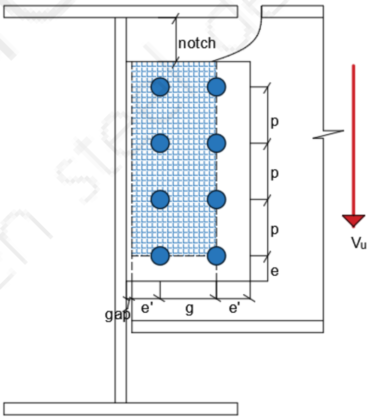


Figure 8.1: Block Shear failure path for supported beam web plate

Where,
A_{vg} = Minimum gross area in shear along bolt line parallel to shear load = $(h_p - e) \ * \ t_w$

A_{vn} = Minimum net area in shear along bolt line parallel to shear load = $(h_p - e - (n_r - 0.5) * d_o) \ * \ t_w$

A_{tg} = Minimum gross area in tension along bolt line perpendicular to shear load=$(w_p - e') * t_w$

A_{tn} = Minimum net area in tension along bolt line perpendicular to shear load =$(w_p - e' - ((n_c - 0.5) * d_o)) * t_w$

8.1.2 Block shear capacity of supported beam web under axial load

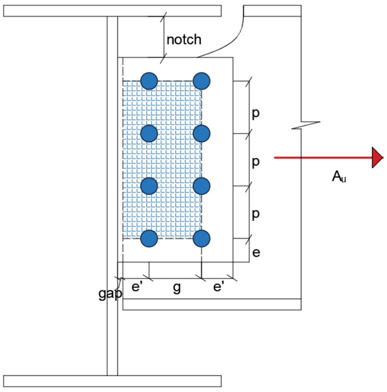


Figure 8.2: Block Shear failure path for supported beam web plate

Where,
A_{vg} = Minimum gross area in shear along bolt line parallel to axial load = $(w_p - e') * t_w$

A_{vn} = Minimum net area in shear along bolt line parallel to axial load = $(w_p - e' - ((n_c - 0.5) * d_o)) * t_w$

A_{tg} = Minimum gross area in tension along bolt line perpendicular to shear load = $(h_p - e) * t_w$

A_{tn} = Minimum gross area in tension along bolt line perpendicular to shear load= $(h_p - e - (n_r - 0.5) * d_o) * t_w$

n_r= number of bolts in one line
n_c= number of bolt lines
p = pitch
g = gauge
f_u = Ultimate stress of the beam material
f_y = Yield stress of the beam material
γ_{m0} = 1.10 [Ref: Table 5, IS 800:2007]
γ_{m1} = 1.25 [Ref: Table 5, IS 800:2007]

For safe design

$$T_{db} \geq V_u \tag{8.3}$$

$$T_{dba} \geq A_u \tag{8.4}$$

Where,
$T_{db} = min(T_{db1fin}, T_{db2fin}, T_{db1beam}, T_{db2beam})$
$T_{dba} = min(T_{dba1fin}, T_{dba2fin}, T_{dba1beam}, T_{dba2beam})$

Is this check: **Ok** **/ Not Ok**

Comment(s):

8.2 Shear yielding check of Beam web

[cl.8.4.1.1 of IS 800:2007]

$$V_{dg} = \frac{0.6 * A_v * f_y}{\sqrt{3}\gamma_{mo}} \tag{8.5}$$

Where,
A_v = gross shear area of supported section ($h_w * t_w$)
h_w = height of beam web - $n_{notch} * notch_h$
n_{notch} = number of notches (1 or 2)
$notch_h$ = height of notch
t_w = thickness of beam web
f_y = Yield strength of beam web
γ_{mo} = 1.10 [Ref: Table 5, IS 800:2007]

8.3 Shear rupture check of Beam web

[J4.2(b) Specification for Structural Steel Buildings, June 22, 2010, AISC]

$$V_{dn} = 0.75 * A_{vn} * f_u \tag{8.6}$$

Where,
A_{vn} = net shear area of beam web ($(h_w * t_w) - (n_r * d_o)$) h_w = height of beam web - $n_{notch} * notch_h$
n_{notch} = number of notches (1 or 2)
$notch_h$ = height of notch
t_w = thickness of beam web
f_u = Ultimate strength of beam web

DDQ: Is this check necessary?

Is this check: **Ok** / **Not Ok**

Comment(s):

8.4 Tension yielding check of Beam web

[cl.6.2 of IS 800:2007]

$$N_{dg} = \frac{A_g * f_y}{\gamma_{m0}} \tag{8.7}$$

Where,
A_g = gross tensile area of beam web $((w_p * t_w))$ f_y = yield strength of beam
γ_{m0} = 1.1 [Ref: Table 5, IS 800:2007]

8.5 Tension rupture check of Beam web

[cl.6.3.1 of IS 800:2007]

$$N_{dn} = \frac{0.9 * A_n * f_u}{\gamma_{m1}} \tag{8.8}$$

Where,
A_n = net tensile area of beam web $((w_p * t_w) - (n_c * d_o))$ f_y = yield strength of beam
γ_{m1} = 1.25 [Ref: Table 5, IS 800:2007]

8.6 Moment capacity of Beam web

[Reference: Cl. 8.2.1.2, IS 800 : 2007]

$$M_d = \frac{1.2 f_y Z}{\gamma_{m0}} \tag{8.9}$$

Where,
Z = Section modulus
f_y = yield strength of beam
γ_{m0} = 1.1 [Ref: Table 5, IS 800:2007]

Note: Section modulus of beam web shall be calculated at notched section.

8.7 Combined capacity of Beam web

[Reference: Cl. 9.3.1.1, IS 800 : 2007]

$$\frac{M_u}{M_d} + \frac{A_u}{N_{dg}} \leq 1 \tag{8.10}$$

Where,
A_u = Factored applied axial force

N_{dg} = Gross tension capacity of beam web
M_u = moment developed due to eccentricity of shear force = $V_u * ecc$
M_d = Moment capacity of beam web as calculated in section 9.6

DDQ: Should we check moment capacity of beam and combined capacity of beam only under double notched condition?

Is this check: **Ok** / **Not Ok**

Comment(s):

DDQ: Do we need to check beam for any other criteria?

Is this check: **Ok** / **Not Ok**

Comment(s):

Check 9

Weld Design

9.1 Minimum Weld Size ($t_{w_{\text{minimum}}}$)

[Reference: Table 21, IS 800:2007]

Step 1: Thickness of thicker element (Already reviewed)
Thickness of thicker element is given by,

for Beam-Beam Connection,

$$t_{thicker} = maximum\ (t_p,\ t_{pbw}) \tag{9.1}$$

for Column Flange - Beam Web Connection,

$$t_{thicker} = maximum\ (t_p,\ t_{cf}) \tag{9.2}$$

for Column web - Beam web Connection,

$$t_{thicker} = maximum\ (t_p,\ t_{cw}) \tag{9.3}$$

Where,
t_p = thickness of fin plate;
t_{pbw} = thickness of supporting beam web;
t_{bw} = thickness of supported beam web;
t_{cf} = thickness of column flange;
t_{cw} = thickness of column web.

Step 2: Minimum weld size
(Already reviewed)

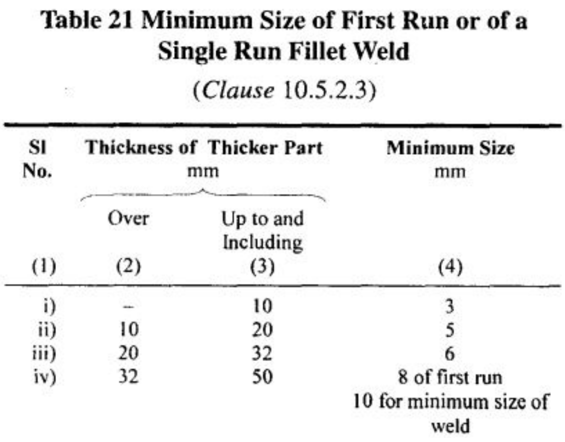


Table 21 Minimum Size of First Run or of a Single Run Fillet Weld

(*Clause* 10.5.2.3)

Sl No.	Thickness of Thicker Part mm		Minimum Size mm
	Over	Up to and Including	
(1)	(2)	(3)	(4)
i)	–	10	3
ii)	10	20	5
iii)	20	32	6
iv)	32	50	8 of first run 10 for minimum size of weld

Figure 9.1: minimum weld size

9.2 Maximum Size of Weld

for Beam-Beam Connection,

$$t_{ww} \leq maximum\ (t_p,\ t_{pbw}) \tag{9.4}$$

for Column Flange - Beam Web Connection,

$$t_{ww} \leq maximum\ (t_p,\ t_{cf}) \tag{9.5}$$

for Column web - Beam web Connection,

$$t_{ww} \leq maximum\ (t_p,\ t_{cw}) \tag{9.6}$$

Where,
t_p = thickness of fin plate;
t_{pbw} = thickness of supporting beam web;
t_{bw} = thickness of supported beam web;
t_{cf} = thickness of column flange;
t_{cw} = thickness of column web.

9.3 Effective Weld Length

(Already reviewed)
[Reference: based on reasoning]

9.3.1 Effective weld length (L_{eff})

$$L_{eff} = h_p - 2\ w_t \geq 4\ w_t \tag{9.7}$$

Where,
h_p = height of fin plate;
w_t = thickness of weld;
r_1 = root radius;

9.3.2 Check for long joint of weld

[cl.10.5.4.4 and 10.5.7.3 of IS 800:2007]
If the maximum length l_j of the side welds transferring shear along its length exceeds 150 times the throat size of the weld, t_t, the reduction in weld strength is given by,
if $l_j \geq$ 150 * t_t
then,
f_{wd} = β_{lw} * f_{wd}
where,

$$\beta_{lw} \;=\; 1.2 \;-\; \frac{0.2\, l_j}{150\, t_t} \;\leq\; 1.0 \tag{9.8}$$

For flange to web connection, where the welds are loaded for the full length, the above limitation would not apply.

9.4 Size of Weld

9.4.1 Size of weld (w_t)

[Reference: Cl. 10.5.7, IS 800:2007 and Example 6.26, DOSS by N. Subramanian (14th edition, 2014)]

Step 1: Capacity of unit weld (f_{unit})

$$f_{\text{unit}} = K\, \frac{f_u}{\sqrt{3}\, \gamma_{mw}} N/mm^2 \tag{9.9}$$

Where,
K = constant (Cl. 10.5.3.2, Table 22, IS 800:2007);
f_u = smaller of the ultimate stress of the weld or of the parent metal, and
γ_{mw} = partial safety factor.

Step 2: Stresses acting on weld

Assumption: Weld is subjected to direct shear force and bending stress developed due to eccentricity of shear force. Line of action of Shear force is assumed at bolt group center and distance from weld to bolt group center is taken as eccentricity.
Stress developed at weld due to moment per unit length of weld,

$$V_{wh} = \frac{M_u * y_{max}}{2 * I_p} N/mm^2 \tag{9.10}$$

where,
V_{wh} = Horizontal stress on weld
M_u = moment developed at weld due to shear force = $V_u * ecc$
I_p = Polar moment of inertia = $2 * L_{eff}^3/12$

[Ref: section 6.7, page 494, DOSS by N. Subramanian (14th edition, 2014)].
y_{max} = $h_p/2$

d_{bw} = distance between weld and bolt center of gravity
L_{eff} = effective length of weld
Stress developed at weld due to shear load per unit length of weld,

$$V_w = \frac{V_d}{2*1.0*L_{eff}} N/mm^2 \tag{9.11}$$

Stress developed at weld due to axial load per unit length of weld,

$$A_w = \frac{A_d}{2*1.0*L_{eff}} N/mm^2 \tag{9.12}$$

Resultant shear load on weld due to combined effect of shear and bending stress is given by,

$$R = \sqrt{(V_{wh} + A_w)^2 + {V_w}^2} N/mm^2 \tag{9.13}$$

Step 3: Size of weld (w_t)

$$w_t = \frac{R}{f_{\text{unit}}} mm \tag{9.14}$$

Is this check: **Ok** / **Not Ok**

Comment(s):

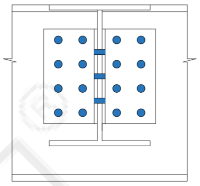
Appendix B

DDCL for Cleat angle

Osdag®
Open steel design and graphics

Design and Detailing Checklist (DDCL)
and
Design and Detailing Query (DDQ)

Cleat Angle Connection



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Under the guidance of:
Prof. Siddhartha Ghosh

Indian Institute of Technology, Bombay
June 2019

Contents

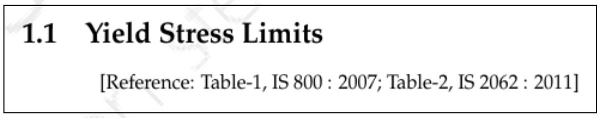
Reviewer Details & Guideline(s) for filling DDCL/DDQ

1. Name of the reviewer:

2. Institute/Company/Organization:

3. Designation:

- This document is for Design and Detailing Check List (DDCL) and Design and Detailing Query (DDQ) created by Osdag team, IIT Bombay.
- The checks are documented algorithmically and chapter wise in the document where the checks and sub-checks are given in the section and subsection respectively.
- Reference of the check is given just below the check title



1.1 Yield Stress Limits

[Reference: Table-1, IS 800 : 2007; Table-2, IS 2062 : 2011]

- Each check has an associated checkbox and a comment box for giving feedback. The checkbox can be checked and unchecked multiple times. The comments can be of multiply lines/paragraph and is not restricted by the size of the comment box.
- You can open the the pdf using any standard pdf viewer. The pdf has been tested on Adobe Acrobat Reader DC (Windows) and Okular, Foxit reader, Document viewer (Ubuntu). Please save the pdf (current or as a copy) after filling the feedback.
- If you check on the ’Not Ok’ checkbox during the review, please specify your reason in the comment box with reference(s) (if any). It is mandatory!
- Send the document after review to sghosh@civil.iitb.ac.in.

  For any queries or help on filling the feedback document, contact Danish Ansari at [danishdyp@gmail.com / +91 9765147757]

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*
  Ultimate strength of beam material - f_u (MPa)*
  Yield strength of beam material - f_y (MPa)*

- **Factored loads**

  Vert. Shear (kN)*

- **Bolt**

  Diameter (mm)*
  Type *
  Property class *

- **Plate**

  Thickness (mm)*
  Height (mm)
  Width (mm)
  note: f_u and f_y of plate is taken same as beam material

- **Weld size**

  Fillet weld thickness (mm)*

Check 1

Material Strength

The ultimate strength (f_u) and the yield strength (f_y) of the beam material and plate material are assumed to be same.

The values of material strength will be subjected to the following limits depending on the grade of the material, in **MPa**;

1.1 Yield Stress Limits

[Reference: Table-1, IS 800 : 2007; Table-2, IS 2062 : 2011]

$$250 \leq f_y \leq 650 \tag{1.1}$$

1.2 Ultimate Stress Limits

[Reference: Table-1, IS 800 : 2007; Table-2, IS 2062 : 2011]

$$410 \leq f_u \leq 780 \tag{1.2}$$

Where,
f_y = yield stress of the beam/plate material; and
f_u = ultimate stress of the beam/plate material.

Is this check: **Ok** / **Not Ok**

Comment(s):

Check 2

Factored Loads

2.1 Design shear force

[ref: cl.10.7 IS 800:2007]

Design shear force (V_u) for connection is minimum of (0.15*V_d, 40kN) but greater than given shear load.
design shear capacity
[ref: cl.8.4 IS 800:2007]

$$V_d = V_p/\gamma_{mo} \tag{2.1}$$

Where,
V_p = plastic shear capacity of beam
γ_{mo} = 1.1 [ref:cl.5.4.1, IS 800:2007]

$$V_p = \frac{A_v f_{yw}}{\sqrt{3}} \tag{2.2}$$

Where,
A_v = shear area [ref:cl.8.4.1.1 of IS 800:2007 to calculate shear area]
f_{yw} = yield strength of web

Is this check: **Ok** / **Not Ok**

Comment(s):

Check 3

Bolt Design

Bolts of diameter 12, 16, 20, 24, 30 and 36 mm conforming to IS 1363 (part 1) 2002 are available for carrying out the design.

The default bolt hole type is 'Standard'
The default parameters of the bolt, however, can be changed by using the 'Design Preference' menu from the Osdag design window GUI.
V_{bolt} is used where bolt capacity is considered. V_{bolt} is taken as V_{dsf} if friction grip bolting is done and is taken as V_{db} for bearing type bolts

3.1 Bearing Bolt

(Already reviewed)

3.1.1 Design strength of bolt (V_{db})

[Reference: Cl. 10.3.2, IS 800:2007]

The design strength of bolt is taken as the smaller of the value as governed by shear, $\boldsymbol{V_{dsb}}$ (Sec. 3.1.1.1) and bearing $\boldsymbol{V_{dpb}}$ (Sec. 3.1.1.2).

$$V_{db} = min\ (V_{dsb}, V_{dpb}) \tag{3.1}$$

3.1.1.1 Shear capacity of bolt (V_{dsb})

[Reference: Cl. 10.3.3, IS 800:2007]

Assumption: The shear plane(s) will always pass through the threads of the bolt.

$$V_{dsb} = \frac{f_u\ n_n\ A_{nb}}{\sqrt{3}\ \gamma_{mb}} \tag{3.2}$$

Where,
f_u = ultimate tensile strength of a bolt;
n_n = number of shear planes with threads intercepting the shear plane;
A_{nb} = net shear area of the bolt at threads;
γ_{mb} = partial safety factor = 1.25;
[Ref: Table 5, cl.5.4.1, IS 800:2007]

3.1.1.2 Bearing capacity of bolt (V_{dpb})

[Reference: Cl. 10.3.4, IS 800:2007]

$$V_{dpb} = \frac{2.5\,k_b\,d\,t\,f_u}{\gamma_{mb}} \tag{3.3}$$

Where,
k_b is smaller of $\frac{e}{3\,d_0}, \frac{p}{3\,d_0} - 0.25, \frac{f_{ub}}{f_u}, 1.0$;
e, p = end and pitch distances of the bolt along bearing direction;
d, d_0 = diameter of bolt and bolt hole;
t = summation of the thickness of the connected plates experiencing bearing stress in the same direction;
γ_{mb} = partial safety factor = 1.25;
[Ref: Table 5, cl.5.4.1, IS 800:2007].

3.2 Friction Grip Bolt

(Already reviewed)

3.2.1 Slip resistance of bolt (V_{dsf})

[Reference: Cl. 10.4.3, IS 800:2007]

$$V_{dsf} = \frac{\mu_f\,n_e\,K_h\,F_o}{\gamma_{mf}} \tag{3.4}$$

Where,
μ_f = coefficient of friction (slip factor);
[Ref: Table 20, IS 800:2007 for typical values]
n_e = number of effective interfaces offering frictional resistance to slip;
K_h = 1.0 for bolts in clearance holes and 0.85 for bolts in oversized holes;
F_o = proof load = $A_{nb} * f_o$;
γ_{mf} = partial safety factor.
A_{nb} = net area of bolt.
f_o = proof stress = 0.7 f_{ub}.

3.3 Check for long joints and large grip lengths

[Reference: Cl. 10.3.3, IS 800:2007]

Assumption: The shear plane(s) will always pass through the threads of the bolt.

$$V_{bolt_{reduced}} = V_{bolt}\,\beta_{lj}\beta_{lg} \tag{3.5}$$

Where,
β_{lj}, β_{lg} = factors, given by;

$$\beta_{lj} = 1.075 - 0.005(l_j/d) \tag{3.6}$$

$$\beta_{lg} = 8/(3 + l_g/d) \leq \beta_{lj} \tag{3.7}$$

Where,
l_J = length of joint (measured in the direction of load transfer);
l_g = total thickness of the connected plates (grip length)($l_g \leq 8d$);
d = nominal diameter of the bolt.

Is this check: **Ok** / **Not Ok**

Comment(s):

Check 4

Number of Bolts and Bolt checks

Note: The **trial** number of bolts is calculated based on shear force. Actual force acting on the bolt (direct shear + Force due to eccentricity of shear force) is calculated later in the design and the number of bolts required is then updated accordingly in an iterative way.

The procedure to calculate number of bolts is as follows;

Step 1: Trial number of bolts

$$n = V_u/V_{bolt} \tag{4.1}$$

DDQ: minimum number of bolts for cleat angle is considered as 3 in Osdag. Is this correct?

Is this check: **Ok** **/ Not Ok**

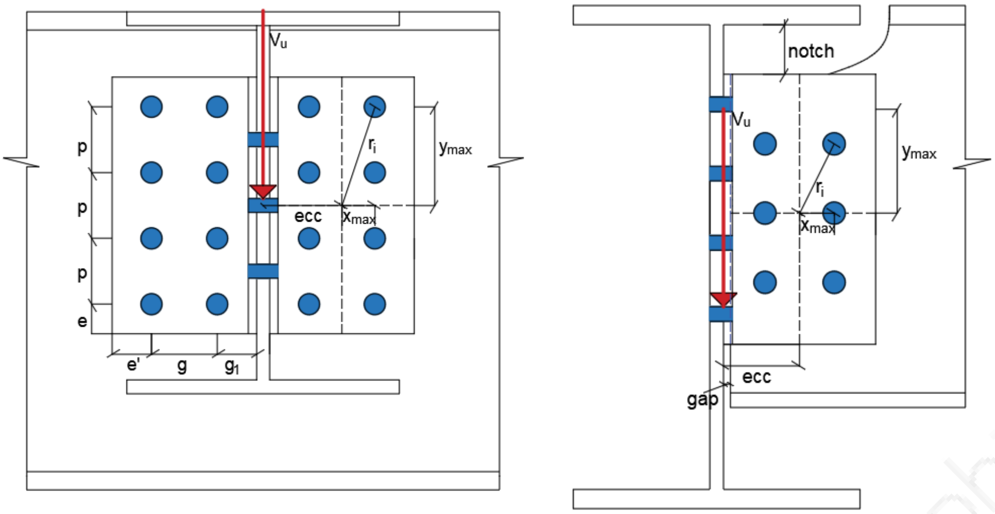
Comment(s):

Step 2: Check for stress developed in Bolt from Moment due to eccentricity
Horizontal shear force acting on each bolt due to moment developed by eccentricity is given by,

$$V_{mh} = (V_{eq}) * ecc * y_{max}/\Sigma r_i^2 \tag{4.2}$$

Vertical shear force acting on each bolt due to moment developed by eccentricity is given by,

$$V_{mv} = (V_{eq}) * ecc * x_{max}/\Sigma r_i^2 \tag{4.3}$$



(a) shear force on bolts on primary beam (b) shear force on bolts on secondary beam

Figure 4.1: Shear due to eccentricity of load

Where,
V_{eq} = Equivalent shear load acting on the connection.
  V_{eq} = $V_u/2$ for supporting section [Ref: Fig 5.1(a)]
  V_{eq} = V_u for supported section [Ref: Fig 5.1(b)]
ecc = distance between bolt center line to face of connected supporting section
y_{max} = vertical distance of farthest bolt from center of rotation of bolt group
x_{max} = Horizontal distance of farthest bolt from center of rotation of bolt group
r_i = distance of each bolt from center of rotation of bolt group

---

Is this check: **Ok** **/ Not Ok**

Comment(s):

Step 4: Resultant load on bolt
Vertical force acting on each bolt (assuming uniform shear distribution) is given by,

$$V_{bv} = V_u/n \tag{4.4}$$

Resultant force on each bolt is given by,

$$V_{res} = \sqrt{(V_{bv} + V_{mv})^2 + V_{mh}^2} \tag{4.5}$$

If the calculated V_{res} is greater than bolt capacity, then spacing is adjusted to decrease V_{res} by increasing increase Σr_i^2. if V_{res} is still greater than bolt capacity, number of bolts are increased and the process is repeated till V_{res} is less than bolt capacity. Please note that bolt capacity shall also be checked for long joint condition.

Is this check: **Ok** / **Not Ok**

Comment(s):

Check 5

Detailing

5.1 Pitch (p)

[Reference: Cl. 10.2.2 and 10.2.3, IS 800 : 2007]

(Already reviewed)

$$2.5\,d \;\leq\; p \;\leq\; \min(32\,t,\; 300\ \mathrm{mm}) \tag{5.1}$$

Where,
p = pitch;
d = diameter of bolt;
t = thickness of the thinner plate.

5.2 gauge

[Reference: Table XXXI, SP 6(1):1964]

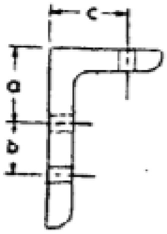


Figure 5.1: gauge distances in angle section

The permitted gauge distances a,b,c in the figure are given in Table XXXI, SP 6(1):1964 for different leg lengths.

5.3 End (e) and Edge (e')

[Reference: Clause 10.2.4, IS 800 : 2007]

(Already reviewed)

$$[1.5 \text{ or } 1.7] \times d_0 \ \leq \ e \; or \; e' \ \leq \ 12 \, t \, \varepsilon \tag{5.2}$$

$$\varepsilon = \sqrt{\frac{250}{f_y}} \tag{5.3}$$

Where,
1.5 for machine-flame cut edges and 1.7 for hand-flame cut edges;
d_0 = diameter of the hole;
t = thickness of the thinner plate;
f_y = yield stress of the plate;
e = end distance;
e' = edge distance.

Check 6

Cleat Dimensions

6.1 Cleat height (h_p)

Based on detailing,

$$h_p = (n_r - 1) * p + 2 * e \tag{6.1}$$

Where,
h_p = length of cleat plate
n_r = number of bolt rows
e = end distance
p = pitch

6.1.1 Check for maximum plate height

Based on detailing,
For Beam-column connectivity,

$$h_p \leq d_b - 2(t_{bf} + r_{b1} + gap) \tag{6.2}$$

For Beam-Beam connectivity with single notch

$$h_p \leq d_b - t_{bf} + r_{b1} - notch \tag{6.3}$$

For Beam-Beam connectivity with double notch

$$h_p \leq d_b - (2 * notch) \tag{6.4}$$

Where,
d_b = Depth of supported beam
t_{bf} = Thickness of supported beam flange
r_{b1} = Root radius of supported beam flange
gap = Clearance between cleat angle and supported beam flange
$notch_h$ = max(T_{bf}, t_{bf}) + max(R_{b1}, r_{b1}) + max($T_{bf}/2$, $t_{bf}/2$, 10)
D_b = Depth of supporting beam
T_{bf} = Thickness of supporting beam flange
R_{b1} = Root radius of supporting beam flange

6.2 Plate leg length (w_p)

Based on detailing,

$$w_p = (n_c - 1) * g + e' + g_1 \tag{6.5}$$

Where,
n_c = number of bolt lines;
g_1 = gauge between leg and first line on bolts
g = gauge between two bolt lines
[Ref: Table XXXI, SP 6(1):1964 for gauge distances for different leg lengths]

Is this check: **Ok** / **Not Ok**

Comment(s):

Check 7

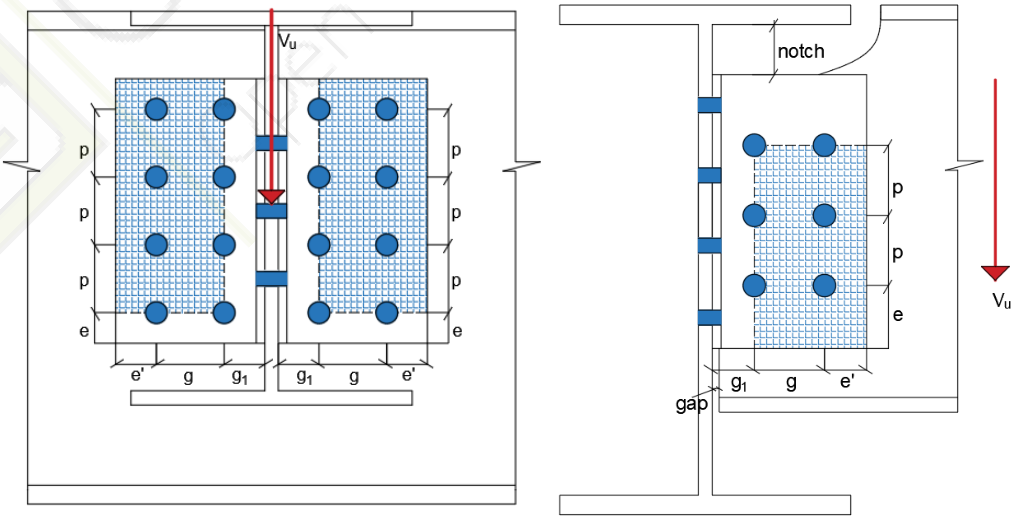
Cleat angle Checks

7.1 Block shear capacity

[Reference: Cl. 6.4.1, IS 800 : 2007]
Block shear capacity of the cleat angle shall be calculated at primary and secondary connections

$$T_{db1} = \frac{A_{vg} f_y}{\sqrt{3}\gamma_{m0}} + \frac{0.9 A_{tn} f_u}{\gamma_{m1}}$$

$$T_{db2} = \frac{0.9 A_{vn} f_u}{\sqrt{3}\gamma_{m1}} + \frac{A_{tg} f_y}{\gamma_{m0}}$$



(a) Block shear path in primary connection (b) Block shear path in secondary connection

Figure 7.1: Block shear path in cleat angle

where,
A_{vg} = Minimum gross area in shear along bolt line parallel to external force = $(h_p - e) * t_p$

A_{vn} = Minimum net area in shear along bolt line parallel to external force = $(h_p - (n_r - 0.5) * d_o) * t_p$

A_{tg} = Minimum gross area in tension from the bolt hole to the toe of the angle, end bolt line, perpendicular to the line of force=$(w_p - g_1) * t_p$

A_{tn} = Minimum net area in tension from the bolt hole to the toe of the angle, end bolt line, perpendicular to the line of force=$(w_p - g_1 - (n_c - 0.5) * d_o) * t_p$
n_r = number of bolts in one line
n_c = number of bolt lines
d_o = diameter of bolt hole
t_p = thicckness of cleat angle leg
f_u = Ultimate stress of the cleat angle material
f_y = Yield stress of the cleat angle material
γ_{m0} = 1.10 [Ref: Table 5, IS 800:2007]
γ_{m1} = 1.25 [Ref: Table 5, IS 800:2007]

Note: block shear capacity is twice the calculated value because of two cleat angle back to back connection

$$T_{db} = min(2 * T_{db1-pri}, 2 * T_{db2-pri}, 2 * T_{db1-sec}, 2 * T_{db2-sec})\ kN \tag{7.1}$$

For safe design,

$$T_{db} \geq V_u \tag{7.2}$$

7.2 Shear yielding check of cleat angle

[cl.8.4.1.1 of IS 800:2007]

$$V_{sy} = \frac{0.6 * A_v * f_y}{\sqrt{3}\gamma_{mo}} \tag{7.3}$$

Where,
A_v = gross shear area of cleat angle $(h_p * t_p)$
f_y = yield strength of cleat angle

DDQ: Shear capacity of the member/plate is taken as 0.6 times its actual capacity, so that the section does not fall under high shear category and moment capacity can be calculated according to cl.8.2.1.2 IS 800:2007 and need not consider cl.9.2.2 IS 800:2007. But, will this make the section uneconomical? Please Comment.

7.3 Shear rupture check of cleat angle

[J4.2(b) Specification for Structural Steel Buildings, June 22, 2010, AISC]

$$V_{dn} = 0.75 * A_{vn} * f_u \tag{7.4}$$

Where,
A_{vn} = net shear area of $((h_p * t_p) - (n_r * d_o))$

f_u = ultimate strength of cleat angle

7.4 Moment capacity of cleat angle

[Reference: Cl. 8.2.1.2, IS 800 : 2007]

$$M_d = \frac{1.2 f_y Z}{\gamma_{m0}} \tag{7.5}$$

for safe design,

$$M_u \leq M_d \tag{7.6}$$

Where,
M_u = moment due to eccentricity of shear force = $V_u * ecc$
V_u = Design shear force
ecc = distance between centre of gravity of bolt group center of supported beam web, as shown in figure 4.1
Z = Section modulus of cleat angle
γ_{m0} = 1.1 [Ref: Table 5, IS 800:2007]

DDQ: Do we need to check cleat angle for any other criteria?

Is this check: **Ok** / **Not Ok**

Comment(s):

Check 8

Member Checks

8.1 Block shear capacity of supported beam web

$$T_{db1beam} = \frac{A_{vg} f_y}{\sqrt{3}\gamma_{m0}} + \frac{0.9 A_{tn} f_u}{\gamma_{m1}} \tag{8.1}$$

$$T_{db2beam} = \frac{0.9 A_{vn} f_u}{\sqrt{3}\gamma_{m1}} + \frac{A_{tg} f_y}{\gamma_{m0}} \tag{8.2}$$

This check is necessary only under Beam-Beam connection when the flange supported member is cut as a notch

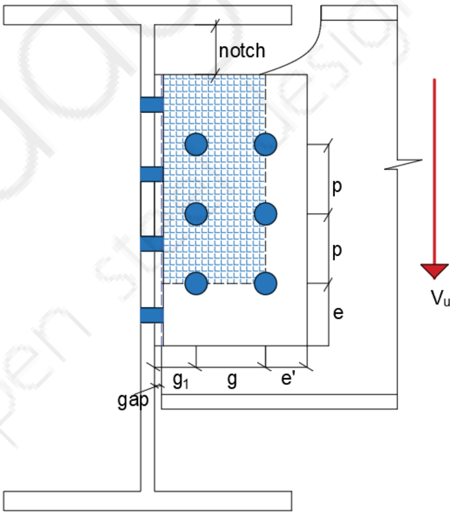


Figure 8.1: Block shear path in secondary Beam

where,

A_{vg} = Minimum gross area in shear along bolt line parallel to shear load = $(h_p - e)\ *\ t_w$

A_{vn} = Minimum net area in shear along bolt line parallel to shear load = $(h_p - e - (n_r - 0.5) * d_o)\ *\ t_w$

A_{tg} = Minimum gross area in tension along bolt line perpendicular to shear load=$(w_p - e') * t_w$

A_{tn} = Minimum net area in tension along bolt line perpendicular to shear load =$(w_p - e' - ((n_c - 0.5) * d_o) * t_w$

n_r = number of bolts in one line
n_c = number of bolt lines
d_o = diameter of bolt hole
t_w = thickness of beam web
f_u = Ultimate stress of the beam
f_y = Yield stress of the beam
γ_{m0} = 1.10 [Ref: Table 5, IS 800:2007]
γ_{m1} = 1.25 [Ref: Table 5, IS 800:2007]

$$T_{dbbeam} = min(T_{db1beam}, T_{db2beam}) \tag{8.3}$$

For safe design,

$$T_{dbbeam} \geq V_u \tag{8.4}$$

8.2 Shear yielding check of Beam web

[cl.8.4.1.1 of IS 800:2007]

$$V_{sy} = \frac{0.6 * A_v * f_y}{\sqrt{3}\gamma_{mo}} \tag{8.5}$$

Where,
A_v = gross shear area of supported section ($h_w * t_w$)
h_w = height of beam web - $n_{notch} * notch_h$
n_{notch} = number of notches (1 or 2)
$notch_h$ = height of notch
t_w = thickness of beam web
f_y = yield strength of web
γ_{mo} = 1.1 [Ref: Table 5, IS 800:2007]

8.3 Shear rupture check of Beam web

[J4.2(b) Specification for Structural Steel Buildings, June 22, 2010, AISC]

$$V_{dn} = 0.75 * A_{vn} * f_u \tag{8.6}$$

Where,
A_{vn} = net shear area of beam web ($(h_w * t_w) - (n_r * d_o)$) h_w = height of beam web - $n_{notch} * notch_h$
n_{notch} = number of notches (1 or 2)
$notch_h$ = height of notch
t_w = thickness of beam web
f_u = ultimate strength of web

Is this check: **Ok** / **Not Ok**

Comment(s):

8.4 Moment capacity of Beam web

[Reference: Cl. 8.2.1.2, IS 800 : 2007]

$$M_d = \frac{1.2 f_y Z}{\gamma_{m0}} \tag{8.7}$$

Z = Section modulus
γ_{m0} = 1.1 [Ref: Table 5, IS 800:2007]
f_y = yield strength of web

Note: Section modulus of beam web shall be calculated at notched section.
DDQ: Should we check moment capacity of beam only under double notched condition?

Is this check: **Ok** **/ Not Ok**

Comment(s):

Do we need to check members for any other criteria?

Is this check: **Ok** **/ Not Ok**

Comment(s):

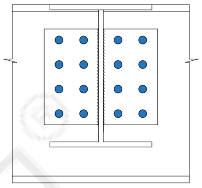
Appendix C

DDCL for End plate

Osdag®
Open steel design and graphics

Design and Detailing Checklist (DDCL)
and
Design and Detailing Query (DDQ)

End Plate Connection



Prepared by:
Deepthi Reddy

Under the guidance of:
Prof. Siddhartha Ghosh

Indian Institute of Technology, Bombay
June 2019

Contents

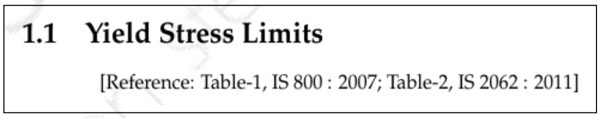
Reviewer Details & Guideline(s) for filling DDCL/DDQ

1. Name of the reviewer:

2. Institute/Company/Organization:

3. Designation:

- This document is for Design and Detailing Check List (DDCL) and Design and Detailing Query (DDQ) created by Osdag team, IIT Bombay.
- The checks are documented algorithmically and chapter wise in the document where the checks and sub-checks are given in the section and subsection respectively.
- Reference of the check is given just below the check title



1.1 Yield Stress Limits

[Reference: Table-1, IS 800 : 2007; Table-2, IS 2062 : 2011]

- Each check has an associated checkbox and a comment box for giving feedback. The checkbox can be checked and unchecked multiple times. The comments can be of multiply lines/paragraph and is not restricted by the size of the comment box.
- You can open the the pdf using any standard pdf viewer. The pdf has been tested on Adobe Acrobat Reader DC (Windows) and Okular, Foxit reader, Document viewer (Ubuntu). Please save the pdf (current or as a copy) after filling the feedback.
- If you check on the 'Not Ok' checkbox during the review, please specify your reason in the comment box with reference(s) (if any). It is mandatory!
- Send the document after review to sghosh@civil.iitb.ac.in.

For any queries or help on filling the feedback document, contact Danish Ansari at [danishdyp@gmail.com / +91 9765147757]

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*
  Ultimate strength of beam material - f_u (MPa)*
  Yield strength of beam material - f_y (MPa)*

- **Factored loads**

  Vert. Shear (kN)*

- **Bolt**

  Diameter (mm)*
  Type *
  Property class *

- **Plate**

  Thickness (mm)*
  Height (mm)
  Width (mm)
  note: f_u and f_y of plate is taken same as beam material

- **Weld**

  size (mm)*

Check 1

Material Strength

The ultimate strength (f_u) and the yield strength (f_y) of the beam material and plate material are assumed to be same.

The values of material strength will be subjected to the following limits depending on the grade of the material, in **MPa**;

1.1 Yield Stress Limits

[Reference: Table-1, IS 800 : 2007; Table-2, IS 2062 : 2011]

$$250 \leq f_y \leq 650 \tag{1.1}$$

1.2 Ultimate Stress Limits

[Reference: Table-1, IS 800 : 2007; Table-2, IS 2062 : 2011]

$$410 \leq f_u \leq 780 \tag{1.2}$$

Where,
f_y = yield stress of the beam/plate material; and
f_u = ultimate stress of the beam/plate material.

Is this check: **Ok** / **Not Ok**

Comment(s):

Check 2

Factored Loads

2.1 Design shear force

[ref: cl.10.7 IS 800:2007]

Design shear force (V_u) for connection is minimum of (0.15*V_d, 40kN) but greater than given shear load.
design shear capacity
[ref: cl.8.4 IS 800:2007]

$$V_d = V_p/\gamma_{mo} \tag{2.1}$$

Where,
V_p = plastic shear capacity of beam
γ_{mo} = 1.1 [ref:cl.5.4.1, IS 800:2007]

$$V_p = \frac{A_v f_{yw}}{\sqrt{3}} \tag{2.2}$$

Where,
A_v = shear area [ref:cl.8.4.1.1 of IS 800:2007 to calculate shear area]
f_{yw} = yield strength of web

Is this check: **Ok** **/ Not Ok**

Comment(s):

Check 3

Bolt Design

Bolts of diameter 12, 16, 20, 24, 30 and 36 mm conforming to IS 1363 (part 1) 2002 are available for carrying out the design.

The default bolt hole type is ’Standard’.
The default parameters of the bolt, however, can be changed by using the 'Design Preference’ menu from the Osdag design window GUI.
V_{bolt} is used where bolt capacity is considered. V_{bolt} is taken as V_{dsf} if friction grip bolting is done and is taken as V_{db} for bearing type bolts

3.1 Bearing Bolt

(Already reviewed)

3.1.1 Design strength of bolt (V_{db})

[Reference: Cl. 10.3.2, IS 800:2007]

The design strength of bolt is taken as the smaller of the value as governed by shear, **V_{dsb}** (Sec. 3.1.1.1) and bearing **V_{dpb}** (Sec. 3.1.1.2).

$$V_{db} = min\ (V_{dsb}, V_{dpb}) \tag{3.1}$$

3.1.1.1 Shear capacity of bolt (V_{dsb})

[Reference: Cl. 10.3.3, IS 800:2007]

Assumption: The shear plane(s) will always pass through the threads of the bolt.

$$V_{dsb} = \frac{f_u\ n_n\ A_{nb}}{\sqrt{3}\ \gamma_{mb}} \tag{3.2}$$

Where,
f_u = ultimate tensile strength of a bolt;
n_n = number of shear planes with threads intercepting the shear plane;
A_{nb} = net shear area of the bolt at threads;
γ_{mb} = partial safety factor = 1.25;
[Ref: Table 5, cl.5.4.1, IS 800:2007]

3.1.1.2 Bearing capacity of bolt (V_{dpb})

[Reference: Cl. 10.3.4, IS 800:2007]

$$V_{dpb} = \frac{2.5\, k_b\, d\, t\, f_u}{\gamma_{mb}} \tag{3.3}$$

Where,
k_b is smaller of $\frac{e}{3\, d_0}, \frac{p}{3\, d_0} - 0.25, \frac{f_{ub}}{f_u}, 1.0$;
e, p = end and pitch distances of the bolt along bearing direction;
d, d_0 = diameter of bolt and bolt hole;
t = summation of the thickness of the connected plates experiencing bearing stress in the same direction;
γ_{mb} = partial safety factor = 1.25;
[Ref: Table 5, cl.5.4.1, IS 800:2007].

3.2 Friction Grip Bolt

(Already reviewed)

3.2.1 Slip resistance of bolt (V_{dsf})

[Reference: Cl. 10.4.3, IS 800:2007]

$$V_{dsf} = \frac{\mu_f\, n_e\, K_h\, F_o}{\gamma_{mf}} \tag{3.4}$$

Where,
μ_f = coefficient of friction (slip factor);
[Ref: Table 20, IS 800:2007 for typical values]
n_e = number of effective interfaces offering frictional resistance to slip;
K_h = 1.0 for bolts in clearance holes and 0.85 for bolts in oversized holes;
F_o = proof load = $A_{nb} * f_o$;
γ_{mf} = partial safety factor.
A_{nb} = net area of bolt.
f_o = proof stress = 0.7 f_{ub}.

3.3 Check for long joints and large grip lengths

[Reference: Cl. 10.3.3, IS 800:2007]

Assumption: The shear plane(s) will always pass through the threads of the bolt.

$$V_{bolt_{reduced}} = V_{bolt}\, \beta_{lj} \beta_{lg} \tag{3.5}$$

Where,
β_{lj}, β_{lg} = factors, given by;

$$\beta_{lj} = 1.075 - 0.005(l_j/d) \tag{3.6}$$

$$\beta_{lg} = 8/(3 + l_g/d) \leq \beta_{lj} \tag{3.7}$$

Where,
l_J = length of joint (measured in the direction of load transfer);
l_g = total thickness of the connected plates (grip length)($l_g \leq 8d$);
d = nominal diameter of the bolt.

Is this check: **Ok** / **Not Ok**

Comment(s):

Check 4

Number of Bolts and Bolt checks

Note: The **trial** number of bolts is calculated based on shear force. Actual force acting on the bolt (direct shear + Force due to eccentricity of shear force) is calculated later in the design and the number of bolts required is then updated accordingly in an iterative way.

The procedure to calculate number of bolts is as follows;

Step 1: Trial number of bolts

$$n = V_u/V_{bolt} \tag{4.1}$$

Where,
V_u = Design Shear load;
V_bolt = Bolt capacity.

DDQ: minimum number of bolts for end plate is considered as 4 (2 on each side of secondary beam) in Osdag. Is this correct?

Is this check: **Ok** / **Not Ok**

Comment(s):

Step 2: Check for stress developed in Bolt from Moment due to eccentricity

Horizontal shear force acting on each bolt due to moment developed by eccentricity is given by,

$$V_{mh} = (V_{eq}) * ecc * y_{max}/\Sigma r_i^2 \tag{4.2}$$

Vertical shear force acting on each bolt due to moment developed by eccentricity is given by,

$$V_{mv} = (V_{eq}) * ecc * x_{max}/\Sigma r_i^2 \tag{4.3}$$

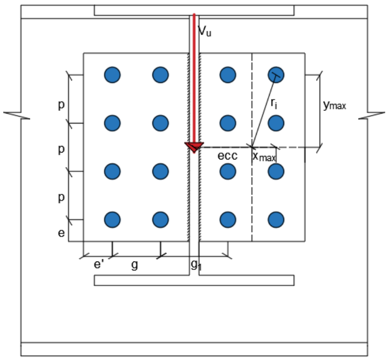


Figure 4.1: Shear due to eccentricity of load

Where,
V_{eq} = Equivalent shear load acting on the connection.
V_{eq} = $V_u/2$ for supporting connection [Ref: Fig 5.1(a)]
V_{eq} = V_u for supporting connection [Ref: Fig 5.1(b)]
ecc = distance between bolt center line to face of connected supporting section
y_{max} = vertical distance of farthest bolt from center of rotation of bolt group
x_{max} = Horizontal distance of farthest bolt from center of rotation of bolt group
r_i = distance of each bolt from center of rotation of bolt group

Step 3: Resultant load on bolt

Vertical force acting on each bolt (assuming uniform shear distribution) is given by,

$$V_{bv} = V_u/n \tag{4.4}$$

Resultant force on each bolt is given by,

$$V_{res} = \sqrt{(V_{bv} + V_{mv})^2 + V_{mh}^2} \tag{4.5}$$

If the calculated V_{res} is greater than bolt capacity, then spacing is adjusted to decrease V_{res} by increasing Σr_i^2. if V_{res} is still greater than bolt capacity, number of bolts are increased and the process is repeated till V_{res} is less than bolt capacity. Please note that bolt capacity shall also be checked for long joint condition.

Is this check: **Ok** **/ Not Ok**

Comment(s):

Check 5

Detailing

5.1 Pitch (p) and Gauge (g)

[Reference: Cl. 10.2.2 and 10.2.3, IS 800 : 2007]

(Already reviewed)

$$2.5\,d \;\leq\; p \; or \; g \;\leq\; \min(32\,t,\; 300\text{ mm}) \tag{5.1}$$

Where,
p = pitch;
g = gauge;
d = diameter of bolt;
t = thickness of the thinner plate.

5.2 Gauge (g_1)

[Ref: section 27.2.6, Steel Designer's Manual (6th Ed) Page: 837]

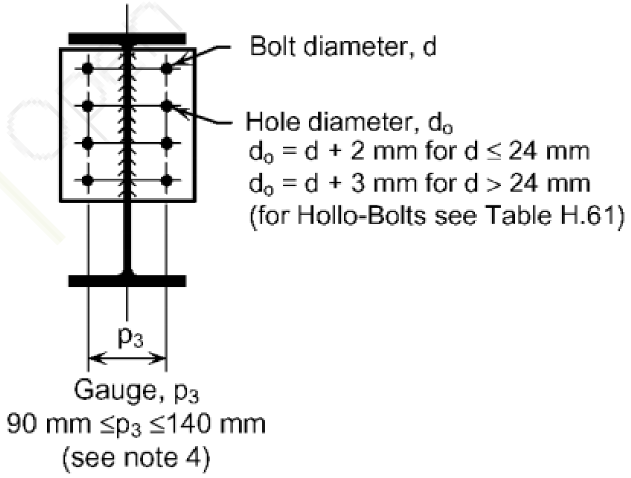


Figure 5.1: limitation on g_1

$$90mm \;\leq\; g_1 \;\leq\; 140mm \tag{5.2}$$

Where,
g_1 = gauge distance between first bolt lines on either side of supported beam;

5.3 End (e) and Edge (e')

[Reference: Clause 10.2.4, IS 800 : 2007]

(Already reviewed)

$$[1.5 \text{ or } 1.7] \times d_0 \;\leq\; e\; or\; e' \;\leq\; 12\, t\, \varepsilon \tag{5.3}$$

$$\varepsilon = \sqrt{\frac{250}{f_y}} \tag{5.4}$$

Where,
1.5 for machine flame cut edge and 1.7 for hand flame cut edge;
d_0 = diameter of the hole;
t = thickness of the thinner plate;
f_y = yield stress of the plate;
e = end distance;
e' = edge distance.

Is this check: **Ok** / **Not Ok**

Comment(s):

Check 6

End Plate Dimensions

6.1 End Plate height (h_p)

Based on detailing,

$$h_p = (n_r - 1) * p + 2 * e \tag{6.1}$$

Where,
h_p = length of end plate
n_r = number of bolt rows
e = end distance
p = pitch

6.1.1 Minimum plate height

[Ref: section 27.2.6, Steel Designer's Manual (6th Ed) Page: 837]

$$h_p \geq 0.6 d_b \tag{6.2}$$

6.1.2 Check for maximum plate height

Based on detailing,
For Beam-column connectivity,

$$h_p \leq d_b - 2(t_{bf} + r_{b1} + gap) \tag{6.3}$$

For Beam-Beam connectivity with single notch

$$h_p \leq d_b - t_{bf} + r_{b1} - notch \tag{6.4}$$

For Beam-Beam connectivity with double notch

$$h_p \leq d_b - (2 * notch) \tag{6.5}$$

Where,
d_b = Depth of supported beam
t_{bf} = Thickness of supported beam flange
r_{b1} = Root radius of supported beam flange
gap = Clearance between end plate and supported beam flange
$notch_h$ = max(T_{bf}, t_{bf}) + max(R_{b1}, r_{b1}) + max($T_{bf}/2$, $t_{bf}/2$, 10)
D_b = Depth of supporting beam
T_{bf} = Thickness of supporting beam flange
R_{b1} = Root radius of supporting beam flange

6.2 Plate width (w_p)

Based on detailing,

$$w_p = 2 * ((n_c - 1) * g + e' + g_1/2) \tag{6.6}$$

Where,
n_c = number of bolt lines on one side of supported beam;
g_1 = gauge between leg and first line on bolts
g = gauge between two bolt lines
[Ref: Table XXXI, SP 6(1):1964 for gauge distances for different leg lengths]

Is this check: **Ok** / **Not Ok**

Comment(s):

Check 7

End Plate Checks

7.1 Block shear capacity

[Reference: Cl. 6.4.1, IS 800 : 2007]

$$T_{db1} = \frac{A_{vg} f_y}{\sqrt{3}\gamma_{m0}} + \frac{0.9 A_{tn} f_u}{\gamma_{m1}}$$

$$T_{db2} = \frac{0.9 A_{vn} f_u}{\sqrt{3}\gamma_{m1}} + \frac{A_{tg} f_y}{\gamma_{m0}}$$

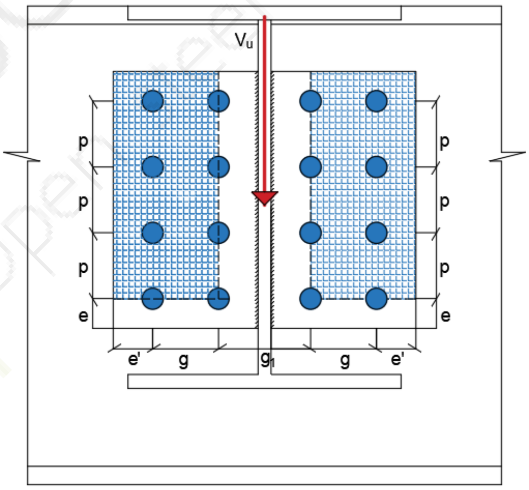


Figure 7.1: Block shear path in End Plate

Where,
A_{vg} = Minimum gross area in shear along bolt line parallel to external force = $(h_p - e) * t_p$

A_{vn} = Minimum net area in shear along bolt line parallel to external force = $(h_p - (n_r - 0.5) * d_o) * t_p$

A_{tg} = Minimum gross area in tension from the bolt hole to the toe of the angle, end bolt line, perpendicular to the line of force = $\frac{w_p - g_1}{2} * t_p$

A_{tn} = Minimum net area in tension from the bolt hole to the toe of the angle, end bolt line, perpendicular to the line of force=$(\frac{w_p - g_1}{2} - (n_c - 0.5) * d_o) * t_p$
n_r = number of bolt rows
n_c = number of bolt columns
f_u = Ultimate stress of the plate material
f_y = Yield stress of the plate material
γ_{m0} = 1.10
γ_{m1} = 1.25

Note: block shear capacity is twice the calculated value because plate is extended on both sides of supported beam.

$$T_{db} = min(2 * T_{db1}, 2 * T_{db2})\ kN$$

For safe design,
$T_{db} \geq V_u$

7.2 Shear yielding check of End Plate

[cl.8.4.1 of IS 800:2007] Shear capacity of the member/plate is taken as 0.6 times its full capacity, so that the section does not fall under high shear category. Full capacity of the section is given by cl. 8.4.1 of IS 800:2007

$$V_{dg} = \frac{0.6 * A_v * f_y}{\sqrt{3}\gamma_{mo}} \tag{7.1}$$

Where,
A_v = gross shear area of end plate ($h_p * t_p$)
f_y = yield strength of end plate
γ_{m0} = 1.1 [Ref: Table 5, IS 800:2007]

DDQ: Shear capacity of the member/plate is taken as 0.6 times its actual capacity, so that the section does not fall under high shear category and moment capacity can be calculated according to cl.8.2.1.2 IS 800:2007 and need not consider cl.9.2.2 IS 800:2007. But, will this make the section uneconomical? Please Comment.

Is this check: **Ok** **/ Not Ok**

Comment(s):

7.3 Shear rupture check of End plate

[J4.2(b) Specification for Structural Steel Buildings, June 22, 2010, AMERICAN INSTITUTE OF STEEL CONSTRUCTION

$$V_{dn} = 0.75 * A_{vn} * f_u \tag{7.2}$$

where,

A_{vn} = net shear area of end plate $((h_p * t_p) - (n_r * d_o))$

f_u = ultimate strength of end plate

DDQ: Do we need to check End Plate for any other criteria?

Is this check: **Ok** / **Not Ok**

Comment(s):

Check 8

Member Checks

8.1 Shear yielding check of Beam web

[cl.8.4.1 of IS 800:2007] Shear capacity of the member is taken as 0.6 times its full capacity, so that the section does not fall under high shear category. Full capacity of the section is given by cl. 8.4.1 of IS 800:2007

$$V_{dg} = \frac{0.6 * A_v * f_y}{\sqrt{3}\gamma_{mo}} \tag{8.1}$$

where,
A_v = gross shear area of supported section ($h_w * t_w$)
h_w = height of beam web - $n_{notch} * notch_h$
n_{notch} = number of notches (1 or 2)
$notch_h$ = height of notch
t_w = thickness of beam web
f_y = yield strength of beam material
γmo = 1.1 [Ref: Table 5, IS 800:2007]

8.2 Shear rupture check of Beam web

[J4.2(b) Specification for Structural Steel Buildings, June 22, 2010, AISC

$$V_{dn} = 0.75 * A_{vn} * f_u \tag{8.2}$$

where,
A_{vn} = net shear area of End plate $((h_w * t_w) - (n_r * d_o))$ h_w = height of beam web - $n_{notch} * notch_h$
n_{notch} = number of notches (1 or 2)
$notch_h$ = height of notch
t_w = thickness of beam web
f_u = ultimate strength of beam material

Do we need to check members for any other criteria?

Is this check: **Ok** / **Not Ok**

Comment(s):

Check 9

Weld Design

9.1 Minimum Weld Size ($t_{w_{\text{minimum}}}$)

[Reference: Table 21, IS 800:2007]

Step 1: Thickness of thicker element (Already reviewed)
Thickness of thicker element is given by,

for Beam-Beam Connection,

$$t_{thicker} = maximum\ (t_p,\ t_{pbw}) \tag{9.1}$$

for Column Flange - Beam Web Connection,

$$t_{thicker} = maximum\ (t_p,\ t_{cf}) \tag{9.2}$$

for Column web - Beam web Connection,

$$t_{thicker} = maximum\ (t_p,\ t_{cw}) \tag{9.3}$$

Where,
t_p = thickness of end plate;
t_{pbw} = thickness of supporting beam web;
t_{bw} = thickness of supported beam web;
t_{cf} = thickness of column flange;
t_{cw} = thickness of column web.

Step 2: Minimum weld size
(Already reviewed)

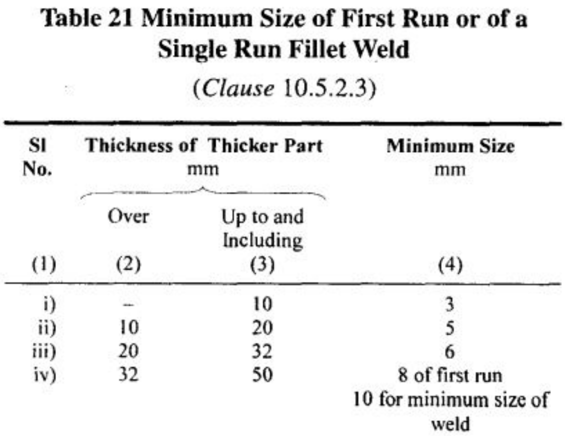


Table 21 Minimum Size of First Run or of a Single Run Fillet Weld

(*Clause* 10.5.2.3)

Sl No.	Thickness of Thicker Part mm		Minimum Size mm
	Over	Up to and Including	
(1)	(2)	(3)	(4)
i)	–	10	3
ii)	10	20	5
iii)	20	32	6
iv)	32	50	8 of first run 10 for minimum size of weld

Figure 9.1: minimum weld size

9.2 Maximum Size of Weld

for Beam-Beam Connection,

$$t_{ww} \leq \ maximum \ (t_p, \ t_{pbw}) \tag{9.4}$$

for Column Flange - Beam Web Connection,

$$t_{ww} \leq \ maximum \ (t_p, \ t_{cf}) \tag{9.5}$$

for Column web - Beam web Connection,

$$t_{ww} \leq \ maximum \ (t_p, \ t_{cw}) \tag{9.6}$$

Where,
t_p = thickness of end plate;
t_{pbw} = thickness of supporting beam web;
t_{bw} = thickness of supported beam web;
t_{cf} = thickness of column flange;
t_{cw} = thickness of column web.

9.3 Effective Weld Length

(Already reviewed)

9.3.1 Effective weld length (L_{eff})

$$L_{eff} = h_p - 2 \ w_t \geq 4 \ w_t \tag{9.7}$$

Where,
h_p = height of end plate;
w_t = thickness of weld;

9.3.2 Check for long joint of weld

[cl.10.5.4.4 and 10.5.7.3 of IS 800:2007]

If the maximum length l_j of the side welds transferring shear along its length exceeds 150 times the throat size of the weld, t_t, the reduction in weld strength is given by,
if $l_j \geq 150 * t_t$
then,
$f_{wd} = \beta_{lw} * f_{wd}$
where,

$$\beta_{lw} \;=\; 1.2 \;-\; \frac{0.2\, l_j}{150\, t_t} \;\leq\; 1.0 \tag{9.8}$$

Note: For flange to web connection, where the welds are loaded for the full length, the above limitation would not apply.

9.4 Size of Weld

9.4.1 Size of weld (w_t)

[Reference: Cl. 10.5.7, IS 800:2007 and Example 6.26, DOSS by N. Subramanian (14th edition, 2014)]

Step 1: Capacity of unit size of weld ($f_{\text{unit}}(N/mm^2)$)

$$f_{\text{unit}} = K\,\frac{f_u}{\sqrt{3}\,\gamma_{mw}} N/mm^2 \tag{9.9}$$

Where,
K = constant (Cl. 10.5.3.2, Table 22, IS 800:2007);
f_u = smaller of the ultimate stress of the weld or of the parent metal (N/mm^2), and
γ_{mw} = partial safety factor.

Step 2: Stresses acting on weld

Assumption: Weld is subjected to only direct shear force. Line of action of Shear force is assumed at center of end plate (at supported beam section).
Shear stress developed at weld due to shear load per unit length of unit size weld,

$$V_w = \frac{V_d}{2 * 1.0 * L_{eff}} N/mm^2 \tag{9.10}$$

Step 3: Size of weld (w_t)

$$w_t = \frac{V_w}{f_{\text{unit}}} mm \tag{9.11}$$

Is this check: **Ok** / **Not Ok**

Comment(s):

Appendix D

Fin Plate design caluclations using python

```
#########################################################################
# Fin plate thickness
# Calculation for maximum plate thickness
max_plate_thk = fin_max_thk(bolt_dia)
max_plate_thk = round(max_plate_thk, 3)

if web_plate_t > max_plate_thk:
        logger.warning(": Maximum plate thickness preferred for ductility
        ↪   is half the diameter of bolt,"
                       " [Ref. INSDAG detailing manual, 2002]")
        logger.info(": Increase the bolt diameter or decrease the plate
        ↪   thickness")

#########################################################################
# Bolt design
shear_ecc = True
connecting_plates_tk_web = [web_plate_t, beam_w_t]
n_planes_web = 1

[bolt_shear_capacity, bolt_bearing_capacity], bolt_fu, bolt_fy = \
    GetBoltValues.get_bolt_value(bolt_type, bolt_grade, beam_fu,
    ↪   web_plate_fu, dp_bolt_hole_type,
                                 bolt_dia, n_planes_web, edge_type,
                                 ↪   connecting_plates_tk_web, mu_f,
                                 ↪   beam_fy,
                                 web_plate_fy, corrosive_influences)
bolt_shear_capacity = round(bolt_shear_capacity * 10**-3,3)
if bolt_bearing_capacity != 'N/A':
    bolt_bearing_capacity = round(bolt_bearing_capacity * 10**-3, 3)
web_bolt_capacity = min(bolt_bearing_capacity, bolt_shear_capacity)

web_plate_l, \
bolt_line, \
bolts_one_line, \
bolts_required, \
bolt_capacity, \
vres, \
moment_demand, \
```

```
    pitch, \
    gauge, \
    edge_dist, \
    end_dist, \
    min_end_dist, \
    min_pitch,\
    max_spacing,\
    max_edge_dist = \
        GetWebPlateDim.get_web_plate_details(bolt_dia, dp_bolt_hole_type,
        ↪  edge_type, connecting_plates_tk_web,
                                             beam_fy, web_plate_fy,
                                             ↪  corrosive_influences,
                                             ↪  web_plate_l_input,
                                             min_plate_height,
                                             ↪  max_plate_height,
                                             ↪  web_bolt_capacity*1000, 2,
                                             shear_load*1000, gap, shear_ecc)
    web_plate_w_req = gap + edge_dist * 2 + gauge * (bolt_line - 1)

    if web_plate_w_input != 0:
        web_plate_w = web_plate_w_input
        edge_dist_rem = web_plate_w - edge_dist - gap - gauge * (bolt_line - 1)
        if web_plate_w < web_plate_w_req:
            design_status = False
            logger.error(':increase plate width')
            logger.info('Required plate width is %2.2f' % web_plate_w_req)
        if edge_dist_rem > max_edge_dist or edge_dist < min_end_dist:
            web_plate_w_allowed = gap + edge_dist + (bolt_line-1)*gauge +
            ↪  max_edge_dist
            design_status = False
            logger.error(':decrease plate width')
            logger.info('Allowed plate width is %2.2f' % web_plate_w_allowed)
    else:
        web_plate_w = web_plate_w_req
        edge_dist_rem = edge_dist

    moment_demand = round(moment_demand * 10**-6, 3)

    if vres > bolt_capacity:
        design_status = False
        logger.error(':increase bolt dia/grade')
        vres_kn = vres * 10**-3
        logger.info('Required bolt capacity is %2.2f' % vres_kn)

    # # Weld design
    t_weld_req = 0
    weld_stress = 0
    weld_strength = 0
    l_weld_eff = 0

    if design_status is True:
        ############## Check for maximum weld thickness: cl: 10.5.3.1 ; IS 800
        ↪  ###########
        '''
        Here t_thinner_beam_plate indicates thickness of thinner part of
↪   members
```

```
                connected by the fillet weld.
        '''
        if connectivity == "Column flange-Beam web":
                t_thinner_col_plate = min(column_f_t.real, web_plate_t.real)

        if connectivity == "Column web-Beam web":
                t_thinner_col_plate = min(column_w_t.real, web_plate_t.real)

        if connectivity == "Beam-Beam":
                t_thinner_col_plate = min(PBeam_w_t.real, web_plate_t.real)

        max_weld_t = t_thinner_col_plate

        if t_weld > max_weld_t:
                design_status= False
                logger.error(": Weld thickness is more than maximum allowed
                ↪  weld thickness [cl. 10.5.3.1]")
                logger.warning(": Maximum weld thickness allowed is %2.2f mm "
                ↪  % (max_weld_t))
                logger.info(": Decrease the weld thickness")

        w = GetWeldValues
        weld_strength = w.get_weld_strength(connecting_fu=[beam_fu, weld_fu],
        ↪  weld_fabrication=weld_fabrication,
                                            t_weld=t_weld, weld_angle=90)
        new_web_plate_l = web_plate_l
        while True:
            l_weld = 2 * new_web_plate_l
            l_weld_eff =
            ↪  IS800_2007.cl_10_5_4_1_fillet_weld_effective_length(t_weld,
            ↪  l_weld)
            d = new_web_plate_l
            Ip_weld = 2 * d**3/12
            y_max = d / 2
            x_max = 0
            force_l = shear_load*1000
            force_w = 0.00
            force_t = moment_demand
            weld_stress = GetWeldValues.get_weld_stress(force_l, force_w,
            ↪  force_t, Ip_weld, y_max,
                                                        x_max, l_weld_eff)
            t_weld_req =
            ↪  weld_stress/w.get_weld_strength(connecting_fu=[beam_fu,
            ↪  weld_fu], weld_fabrication=weld_fabrication,
                                            t_weld=1.0, weld_angle=90)
            if weld_strength > weld_stress:
                break
            elif new_web_plate_l+10 < max_plate_height and web_plate_l_input ==
            ↪  0:
                new_web_plate_l += 10
                logger.warning('weld stress is guiding plate height, trying
                ↪  with length %2.2f mm' % new_web_plate_l)
            else:
                design_status = False
                logger.error(": Weld thickness is not sufficient [cl. 10.5.7,
                ↪  IS 800:2007]")
```

```
                logger.warning(": Minimum weld thickness required is %2.2f mm "
                 ↪  % t_weld_req)
                logger.info(": Increase the weld thickness or length of
                 ↪  weld/fin plate")
                break

        #  Recalculating edge distance for new plate height
        end_dist = end_dist + ((new_web_plate_l - web_plate_l)/2)
        web_plate_l = new_web_plate_l
        if end_dist > max_edge_dist:
            design_status = False
            logger.error(": Weld thickness is not sufficient [cl. 10.5.7, IS
             ↪  800:2007]")
            logger.warning(": Minimum weld thickness required is %2.2f mm " %
             ↪  t_weld_req)
            logger.info(": Increase the weld thickness or length of weld/fin
             ↪  plate")

    ############################################################
    # Plate Checks
    block_shear_capacity = 0
    moment_capacity = 0
    if design_status is True:
        block_shear_capacity = DoShearChecks.blockshear(bolts_one_line,
         ↪  bolt_line, pitch, gauge, web_plate_t, end_dist,
                                                        edge_dist_rem,
                                                         ↪  dia_hole, beam_fy,
                                                         ↪  beam_fu)
        shear_yielding_capacity = DoShearChecks.shear_yielding_b(web_plate_l,
         ↪  web_plate_t, web_plate_fy)
        shear_rupture_capacity = DoShearChecks.shear_rupture_b(web_plate_l,
         ↪  web_plate_t,
                                    bolts_one_line, dia_hole, web_plate_fu)

        plate_shear_capacity = min(block_shear_capacity,
         ↪  shear_rupture_capacity, shear_yielding_capacity)

        if shear_load > plate_shear_capacity:
            design_status = False
            logger.error(":shear capacity of the plate is less than the applied
             ↪  shear force, %2.2f kN [cl. 6.4.1]"
                         % shear_load)
            logger.warning(":Shear capacity of plate is %2.2f kN" %
             ↪  plate_shear_capacity)
            logger.info(": Increase the plate thickness")

        moment_capacity = 1.2 * (web_plate_fy / 1.1) * (web_plate_t *
         ↪  web_plate_l * web_plate_l) / 6 * 10 ** -6
        if moment_capacity < moment_demand:
            design_status = False
            logger.error(": Plate moment capacity is less than the moment
             ↪  demand [cl. 8.2.1.2]")
            logger.warning(": Re-design with increased plate dimensions")
    # End of calculation
```

Appendix E

Imported file get_bolt_values

```
from utilities.is800_2007 import IS800_2007
from utilities.other_standards import *
from utilities.common_calculation import *
import numpy


class CommonBoltCalc:
    def __init__(self, bolt_dia, bolt_hole_type, edge_type,
    ↪   connecting_plates_tk, member_fy, plate_fy, corrosive_influences):
        [self.bolt_shank_area, self.bolt_net_area] =
        ↪   IS1367_Part3_2002.bolt_area(bolt_dia)
        self.min_pitch = IS800_2007.cl_10_2_2_min_spacing(bolt_dia)
        self.min_gauge = IS800_2007.cl_10_2_2_min_spacing(bolt_dia)
        self.min_edge_dist =
        ↪   IS800_2007.cl_10_2_4_2_min_edge_end_dist(bolt_dia,
        ↪   bolt_hole_type, edge_type)
        self.min_end_dist = self.min_edge_dist
        self.max_spacing =
        ↪   IS800_2007.cl_10_2_3_1_max_spacing(connecting_plates_tk)
        self.max_edge_dist =
        ↪   IS800_2007.cl_10_2_4_3_max_edge_dist(connecting_plates_tk,
        ↪   plate_fy, corrosive_influences)
        self.max_end_dist = self.max_edge_dist
        self.dia_hole = IS800_2007.cl_10_2_1_bolt_hole_size(bolt_dia,
        ↪   bolt_hole_type)


class GetBoltValues(CommonBoltCalc):
    @staticmethod
    def get_bolt_value(bolt_type, bolt_grade, member_fu, plate_fu,
    ↪   bolt_hole_type, bolt_dia, n_planes, edge_type,
                       connecting_plates_tk, mu_f, member_fy, plate_fy,
                       ↪   corrosive_influences):
        """

        :param bolt_type: bearing or friction grip bolt
        :param bolt_grade: grade of bolt
        :param member_fu: ultimate strength of member
        :param plate_fu: ultimate strength of plate (This is taken same as
↪   member strength)
```

```
        :param bolt_hole_type: standard or over-sized
        :param bolt_dia: diameter of bolt
        :param n_planes: number of shear planes
        :param edge_type: shear or hand flame cut
        :param connecting_plates_tk: thickness of connecting plates
        :param mu_f: slip factor for friction grip bolts
        :param member_fy: yield strength of member
        :param plate_fy: yield strength of plate
        :param corrosive_influences: yes or no
        :return: capacity of bolt (shear and bearing), ultimate strength of
↪   bolt and yield strength of bolt
        """

        a = CommonBoltCalc(bolt_dia, bolt_hole_type, edge_type,
        ↪   connecting_plates_tk,
                           member_fy, plate_fy, corrosive_influences)
        [bolt_fu, bolt_fy] = IS1367_Part3_2002.get_bolt_fu_fy(bolt_grade)
        if bolt_type == "Bearing Bolt":
            bolt_shear_capacity = IS800_2007.cl_10_3_3_bolt_shear_capacity(
                f_u=bolt_fu, A_nb=a.bolt_net_area, A_sb=a.bolt_shank_area,
                ↪   n_n=n_planes, n_s=0)
            bolt_bearing_capacity =
            ↪   IS800_2007.cl_10_3_4_bolt_bearing_capacity(
                f_u=min(member_fu, plate_fu), f_ub=bolt_fu,
                ↪   t=min(connecting_plates_tk), d=bolt_dia,
                e=a.min_edge_dist, p=a.min_pitch,
                ↪   bolt_hole_type=bolt_hole_type)
            bolt_capacity = [bolt_shear_capacity, bolt_bearing_capacity]

        elif bolt_type == "Friction Grip Bolt":
            bolt_shear_capacity = IS800_2007.cl_10_4_3_bolt_slip_resistance(
                f_ub=bolt_fu, A_nb=a.bolt_net_area, n_e=n_planes, mu_f=mu_f,
                ↪   bolt_hole_type=bolt_hole_type)
            bolt_bearing_capacity = 'N/A'
            bolt_capacity = [bolt_shear_capacity, bolt_bearing_capacity]

        return bolt_capacity, bolt_fu, bolt_fy

class GetWebPlateDim(CommonBoltCalc):

    @staticmethod
    def get_web_plate_l_req(bolts_one_line, pitch, end_dist):
        web_plate_l_req = float((bolts_one_line - 1) * pitch + 2 * end_dist)
        return web_plate_l_req

    @staticmethod
    def get_spacing_adjusted(gauge_pitch, edge_end, max_gauge_pitch):
        while gauge_pitch > max_gauge_pitch:
            edge_end += 5
            gauge_pitch -= 5
        return gauge_pitch, edge_end

    @staticmethod
    def get_web_plate_l_bolts_one_line(web_plate_l_input, web_plate_l_max,
    ↪   web_plate_l_min, bolts_required, min_pitch, min_end_dist):
        if web_plate_l_input != 0:
```

```
            web_plate_l = web_plate_l_input
            max_bolts_one_line = int(((web_plate_l - (2 * min_end_dist)) /
            ↪   min_pitch) + 1)
            bolt_line = int(math.ceil((float(bolts_required) /
            ↪   float(max_bolts_one_line))))
            bolts_one_line = max(int(math.ceil(float(bolts_required) /
            ↪   float(bolt_line))), 2)
        else:
            max_bolts_one_line = int(((web_plate_l_max - (2 * min_end_dist))
            ↪   / min_pitch) + 1)
            bolt_line = int(math.ceil((float(bolts_required) /
            ↪   float(max_bolts_one_line))))
            bolts_one_line = max(int(math.ceil(float(bolts_required) /
            ↪   float(bolt_line))), 2)
            web_plate_l = max(web_plate_l_min,
                              GetWebPlateDim.get_web_plate_l_req
                              (bolts_one_line, min_pitch, min_end_dist))

        return bolt_line, bolts_one_line, web_plate_l

    @staticmethod
    def get_pitch_end_dist(web_plate_l, min_end_dist,
    ↪   bolts_one_line,max_spacing,max_end_dist):
        """

        :param web_plate_l: length of plate
        :param min_end_dist: minimum end distance
        :param bolts_one_line: bolts in one line
        :param max_spacing: maximum pitch
        :param max_end_dist: maximum end distance
        :return: pitch, end distance, length of plate (false if applicable)
        """
        pitch = round_up((web_plate_l - (2 * min_end_dist)) / (bolts_one_line
        ↪   - 1), multiplier=1)
        end_dist = (web_plate_l - pitch*(bolts_one_line-1))/2
        if pitch > max_spacing:
            pitch, end_dist = GetWebPlateDim.get_spacing_adjusted(pitch,
            ↪   end_dist, max_spacing)
            if end_dist >= max_end_dist:
                web_plate_l = False
        return pitch, end_dist,web_plate_l

    @staticmethod
    def get_vres(bolts_one_line, pitch, gauge, bolt_line, shear_load, ecc):
        """

        :param bolts_one_line: number of bolts in one line
        :param pitch: pitch
        :param gauge: gauge
        :param bolt_line: number of bolt lines
        :param shear_load: shear load
        :param ecc: eccentricity
        :return: resultant load on bolt due to eccentricity of shear force
        """
        length_avail = (bolts_one_line - 1) * pitch
        ymax = length_avail / 2
```

```
        xmax = gauge * (bolt_line - 1) / 2
        r_sq = 0
        n = float(bolts_one_line) / 2.0 - 0.5
        b = float((bolt_line - 1)) / 2
        for x in numpy.arange(b, -b - 1, -1):
            for y in numpy.arange(-n, n + 1, 1):
                r_sq = r_sq + ((gauge * x) ** 2 + (abs(y) * pitch) ** 2)
        sigma_r_sq = r_sq
        vbv = shear_load / (bolts_one_line * bolt_line)
        moment_demand = round(shear_load * ecc, 3)
        tmh = moment_demand * ymax / sigma_r_sq
        tmv = moment_demand * xmax / sigma_r_sq
        vres = math.sqrt((vbv + tmv) ** 2 + tmh ** 2)
        return vres

    @staticmethod
    def get_bolt_red(bolts_one_line, pitch, bolt_capacity, bolt_dia):
        """

        :param bolts_one_line: bolts in one line
        :param pitch: pitch
        :param bolt_capacity: capacity of bolt
        :param bolt_dia: diameter of bolt
        :return: reduced bolt capacity if long joint condition is met
        """
        length_avail = (bolts_one_line - 1) * pitch
        if length_avail > 15 * bolt_dia:
            beta_lj = 1.075 - length_avail / (200 * bolt_dia)
            bolt_capacity_red = beta_lj * bolt_capacity
        else:
            bolt_capacity_red = bolt_capacity
        return bolt_capacity_red

    @staticmethod
    def get_web_plate_details(bolt_dia, bolt_hole_type, edge_type,
    ↪   connecting_plates_tk,
                           member_fy, plate_fy, corrosive_influences,
                           ↪   web_plate_l_input,
                              web_plate_l_min, web_plate_l_max,
                              ↪   bolt_capacity, bolt_line_limit, shear_load,
                              ↪   gap, shear_ecc):
        """

        :param bolt_dia: diameter of bolt
        :param bolt_hole_type: holt type (standard or oversize)
        :param edge_type: shear flame or hand flame cut
        :param connecting_plates_tk: thickness of all connecting plates
        :param member_fy: yield strength of member
        :param plate_fy: yield strength of plate
        :param corrosive_influences
        :param web_plate_l_input: input value of plate length
        :param web_plate_l_min: minimum plate length
        :param web_plate_l_max: maximum plate length
        :param bolt_capacity: capacity of bolt
        :param bolt_line_limit: maximum number of bolt lines allowed
        :param shear_load: load along the length
```

```
        :param gap: gap between members which adds up to eccentricity
        :param shear_ecc: if eccentricity effect needs to be considered this
↪   value should be passed as "True"
        :return: web_plate_l, bolt_line, bolts_one_line, bolts_required,
↪   bolt_capacity_red, vres, moment_demand, \
               pitch, gauge, edge_dist, end_dist, a.min_edge_dist,
↪   a.min_pitch, a.max_spacing, a.max_edge_dist
        """
        a = CommonBoltCalc(bolt_dia, bolt_hole_type, edge_type,
        ↪   connecting_plates_tk,
                           member_fy, plate_fy, corrosive_influences)
        b = GetWebPlateDim
        min_edge_dist = round_up(a.min_edge_dist, multiplier=5)
        min_end_dist = round_up(a.min_edge_dist, multiplier=5)
        min_pitch = round_up(a.min_pitch, multiplier=5)
        min_gauge = round_up(a.min_gauge, multiplier=5)

        # initialising values to start the loop
        bolts_required = max(int(math.ceil(shear_load/bolt_capacity)),3)
        # calculation of  bolts in one line and check for given web plate
        ↪   height = 0 or user input value
        [bolt_line, bolts_one_line, web_plate_l] =
        ↪   b.get_web_plate_l_bolts_one_line(web_plate_l_input,
                                web_plate_l_max, web_plate_l_min,
                                ↪   bolts_required, min_pitch, min_end_dist)
        bolts_required = bolt_line * bolts_one_line
        vres = bolt_capacity+1
        bolt_capacity_red = bolt_capacity
        moment_demand = 0
        web_plate_l_input_original = web_plate_l_input

        while bolt_line <= bolt_line_limit and vres > bolt_capacity:
            # for calculated length and bolts in one line, pitch,end dist and
            ↪   updated value of plate is calculated
            [pitch, end_dist, web_plate_l] =
            ↪   b.get_pitch_end_dist(web_plate_l, min_end_dist,
            ↪   bolts_one_line,
                                        a.max_spacing, a.max_end_dist)
            # If updated value of length is false, loop is terminated
            if web_plate_l is False:
                break
            # Horizontal Shear due to eccentricity of load
            gauge = min_gauge
            edge_dist = min_edge_dist
            # If length is not false and check for shear eccentricity is true
            ↪   resultant force in bolt is calculated
            if web_plate_l is not False and shear_ecc is True:
                ecc = gauge * (bolt_line - 1.5) + edge_dist + gap
                moment_demand = shear_load * ecc
                while True:
                    vres = b.get_vres(bolts_one_line,pitch,
                                      gauge,bolt_line,shear_load,ecc)
                    bolt_capacity_red = b.get_bolt_red(bolts_one_line,
                                                       pitch,bolt_capacity,
                                                       bolt_dia)
```

```
                    print vres, bolt_capacity_red, bolts_required,
                    ↪   bolts_one_line, pitch, end_dist
                    # if input is 0, length of plate is increased for
                    ↪   calculated bolts in one line.
                    # This increases spacing which decreases resultant force
                    if vres > bolt_capacity_red:
                        if web_plate_l+10 <= web_plate_l_max and
                        ↪   web_plate_l_input_original == 0:
                            web_plate_l += 10
                            [pitch, end_dist, web_plate_l] =
                            ↪   b.get_pitch_end_dist(web_plate_l,
                            ↪   min_end_dist,
                                                            bolts_one_line,
                                                            ↪   a.max_spacing,
                                                            ↪   a.max_end_dist)
                        # If length cannot be increased number of bolts is
                        ↪   increased by 1 and loop is repeated
                        else:
                            bolts_required += 1
                            # calculation of  bolts in one line and check for
                            ↪   given web plate height = 0
                            # or user input value
                            [bolt_line, bolts_one_line, web_plate_l] =
                            ↪   b.get_web_plate_l_bolts_one_line(
                                web_plate_l_input,
                                web_plate_l_max, web_plate_l_min,
                                ↪   bolts_required, min_pitch, min_end_dist)
                            break
                    else:
                        break
            else:
                break
        bolts_required = bolt_line * bolts_one_line
        return web_plate_l, bolt_line, bolts_one_line, bolts_required,
        ↪   bolt_capacity_red, vres, moment_demand, \
               pitch, gauge, edge_dist, end_dist, a.min_edge_dist,
               ↪   a.min_pitch, a.max_spacing, a.max_edge_dist


class DoShearChecks():
    # Function for block shear capacity calculation
    @staticmethod
    def blockshear(numrow, numcol, pitch, gauge, thk, end_dist, edge_dist,
    ↪   dia_hole, fy, fu):
        '''

        Args:
            numrow (str) Number of row(s) of bolts
            dia_hole (int) diameter of hole (Ref. Table 5.6 Subramanian's
↪   book, page: 340)
            fy (float) Yeild stress of material
            fu (float) Ultimate stress of material
            edge_dist (float) edge distance based on diameter of hole
            end_dist (float) end distance based on diameter of hole
            pitch (float) pitch distance based on diameter of bolt
            thk (float) thickness of plate or beam web
```

```

        Returns:
            Capacity of fin plate under block shear

        '''
        Avg = thk * ((numrow - 1) * pitch + end_dist)
        Avn = thk * ((numrow - 1) * pitch + end_dist - (numrow - 0.5) * dia_hole)
        Atg = thk * (gauge * (numcol - 1) + edge_dist)
        Atn = thk * (gauge * (numcol - 1) + edge_dist - (numcol - 0.5) * dia_hole)
        Tdb1 = (Avg * fy / (math.sqrt(3) * 1.1) + 0.9 * Atn * fu / 1.25)
        Tdb2 = (0.9 * Avn * fu / (math.sqrt(3) * 1.25) + Atg * fy / 1.1)
        Tdb = min(Tdb1, Tdb2)
        Tdb = round(Tdb / 1000, 3)
        return Tdb

    # Check for shear yielding ###
    @staticmethod
    def shear_yielding_b(length, thickness, fy):
        '''
        Args:
            A_v (float) Area under shear
            beam_fy (float) Yeild stress of beam material
        Returns:
            Capacity of beam web in shear yeiding
        '''
        A_v = length * thickness
        V_p = (0.6 * A_v * fy) / (math.sqrt(3) * 1.10 * 1000)  # kN
        return V_p

    # Check for shear rupture ###
    @staticmethod
    # TODO: This formula based on AISC guidelines, check if this should be included
    def shear_rupture_b(length, thickness, bolts_one_line, dia_hole, fu):
        '''
        Args:
            A_vn (float) Net area under shear
            beam_fu (float) Ultimate stress of beam material
        Returns:
            Capacity of beam web in shear rupture
        '''
        A_vn = (length - bolts_one_line*dia_hole) * thickness
        R_n = (0.75 * fu * A_vn) / 1000  # kN
        return R_n
```

Appendix F

Imported file get_weld_values

```python
from utilities.is800_2007 import IS800_2007
from utilities.other_standards import *
from utilities.common_calculation import *


class GetWeldValues(object):
    @staticmethod
    def get_weld_strength(connecting_fu, weld_fabrication, t_weld,
    ↪   weld_angle):
        f_wd =
        ↪   IS800_2007.cl_10_5_7_1_1_fillet_weld_design_stress(connecting_fu,
        ↪   weld_fabrication)
        throat_tk = \
            IS800_2007.cl_10_5_3_2_fillet_weld_effective_throat_thickness\
                (t_weld, weld_angle)
        weld_strength = f_wd * throat_tk
        return weld_strength

    @staticmethod
    def get_weld_stress(weld_shear, weld_axial, weld_twist, Ip_weld, y_max,
    ↪   x_max, l_weld):
        T_wh = weld_twist * y_max/Ip_weld
        T_wv = weld_twist * x_max/Ip_weld
        V_wv = weld_shear/l_weld
        A_wh = weld_axial/l_weld
        print(T_wh, T_wv, V_wv, A_wh)
        weld_stress = math.sqrt((T_wh+A_wh)**2 + (T_wv+V_wv)**2)
        return weld_stress
```

Appendix G

Stiffener design in Beam Column End Plate using Python

```python
    #Note: for more number of iteration more numbers of  available size
    ↪  should be provided

    # Beam stiffeners
    st_status = False
    if endplate_type == 'flush':
        st_number = 0
    elif endplate_type == 'one_way':
        st_number = 1
        if number_of_bolts >= 12:
            st_status = True
    else:
        st_number = 2
        if number_of_bolts >= 20:
            st_status = True

    st_fu = beam_fu
    st_fy = beam_fy
    st_height = l_v + pitch_dist + end_dist
    for plate_tk in available_plates:
        if plate_tk >= beam_tw:
            st_thickness = plate_tk
            break
    # Length of stiffener (st_length) (as per AISC, DG 16 recommendations)
    cf = math.pi / 180  # conversion factor to convert degree into radian
    st_length = math.ceil(((st_height - 25) / math.tan(30 * cf)) + 25)
    if weld_method == 'fillet':
        st_notch_bottom = round_up(value=weld_thickness_flange, multiplier=5,
        ↪  minimum_value=5)
        st_notch_top = st_notch_bottom
    else:
        st_notch_bottom = 5
        st_notch_top = st_notch_bottom
    st_beam_weld_min = IS800_2007.cl_10_5_2_3_min_weld_size(st_thickness,
    ↪  beam_tf)
    st_beam_weld_max = max(beam_tf, st_thickness)

    if st_status is True:
```

```
        st_force = 4 * tension_in_bolt
        st_moment = st_force * (l_v + pitch_dist / 2)

        while st_length <= 1000:
            st_eff_length = st_length - st_notch_bottom
            st_shear_capacity = st_eff_length * st_thickness * st_fy /
            ↪   (math.sqrt(3) * gamma_m0)
            st_moment_capacity = st_eff_length ** 2 * st_thickness * st_fy /
            ↪   (4 * gamma_m0)
            available_welds = list(filter(lambda x: (st_beam_weld_min <= x <=
            ↪   st_beam_weld_max), welds_sizes))
            for st_beam_weld in available_welds:
                st_beam_weld_throat = IS800_2007.\
                    cl_10_5_3_2_fillet_weld_effective_throat_thickness(
                    fillet_size=st_beam_weld, fusion_face_angle=90)
                st_beam_weld_eff_length =
                ↪   IS800_2007.cl_10_5_4_1_fillet_weld_effective_length(
                    fillet_size=st_beam_weld, available_length=st_eff_length)
                st_weld_shear_stress = st_force / (2 *
                ↪   st_beam_weld_eff_length * st_beam_weld_throat)
                st_weld_moment_stress = st_moment / (2 * st_beam_weld_throat
                ↪   * st_beam_weld_eff_length ** 2 / 4)
                st_eq_weld_stress = math.sqrt(st_weld_shear_stress ** 2 +
                ↪   st_weld_moment_stress ** 2)
                if st_eq_weld_stress <=
                ↪   IS800_2007.cl_10_5_7_1_1_fillet_weld_design_stress(
                        ultimate_stresses=(weld_fu, beam_fu, st_fu)):
                    break
            if st_moment <= st_moment_capacity and st_force <=
            ↪   st_shear_capacity and \
                    st_eq_weld_stress <=
                    ↪   IS800_2007.cl_10_5_7_1_1_fillet_weld_design_stress(
                    ultimate_stresses=(weld_fu, beam_fu, st_fu)):
                break
            else:
                st_length += 20

        # stiffener warnings

        if st_moment >= st_moment_capacity:
            logger.warning("stiffener cannot take moment, current stiffener
            ↪   length %2.2f" % st_length)
        if st_force >= st_shear_capacity:
            logger.warning("stiffener cannot take shear force, current
            ↪   stiffener length %2.2f" % st_length)
        if st_eq_weld_stress >=
        ↪   IS800_2007.cl_10_5_7_1_1_fillet_weld_design_stress(
                ultimate_stresses=(weld_fu, beam_fu, st_fu)):
            logger.warning("stiffener weld cannot take stiffener loads,
            ↪   current weld thickness is %2.2f" % st_beam_weld)
```