Summer Fellowship Report

On

Osdag

Submitted by

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Under the guidance of

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and
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July 11, 2019

Acknowledgement

First of all, I am grateful to the FOSSEE at IIT for successfully arranging the internship program for us. And I would also thankful to the IIT for the FOSSEE project for giving me an opportunity to do internship with Osdag. It helped me to enhance my knowledge in structural steel design and testing of software. I feel grateful to have met so many different people and professionals who guided me through this internship period.

I would like to specially acknowledge Prof. Siddhartha Ghosh with my deepest gratitude who in spite of being busy with his duties, took time out to hear, guide and keep me on the correct path and allowing me to carry out my project at their esteemed research lab (SSRR lab).

I would also like to acknowledge the members of the Osdag team; Danish Ansari (Project Research Assistant), Ajmal Babu MS (Project Research Engineer), Sourabh Das (Project Research Assistant) for their careful and precious guidance which was extremely valuable for my both Hard and Software Skills.

I consider this Internship as a big opportunity in my career development. I shall strive to use the acquired skills and knowledge in the best possible way, and I will continue to work on its improvement, in order to attain desired career objectives.

Contents

Chapter 1

Introduction to Osdag Internship

Osdag internship is provided under the FOSSEE project. FOSSEE project promotes the use of FOSS(Free and Open Source Software) tools to improve quality of education in our country.

The development of Osdag is currently funded by the Ministry of Human Resource Development (MHRD), Govt. of India, through the FOSSEE project under the National Mission of Education (NME) through ICT.

Osdag is a cross-platform free/libre and open-source software for the design (and detailing) of steel structures, following the Indian Standard IS 800:2007. It allows the user to design steel connections, members and systems using a graphical user interface. The interactive GUI provides a 3D visualisation of the designed component and creates images for construction/fabrication drawings. The design is typically optimised following industry best practices.

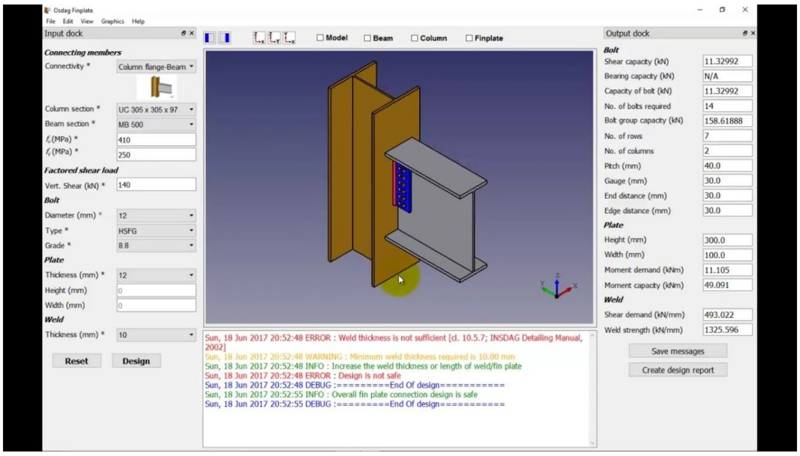
Osdag is primarily built upon Python and other Python-based FLOSS tools, such as, PyQt, OpenCascade, PythonOCC, and svgwrite. It uses SQLite for managing steel section databases. Osdag is currently under development. A beta version of Osdag containing some shear connection design modules was released in June, 2017.

1.1 What is Osdag ?

Osdag is a cross-platform free and open-source software for the design of steel structures, following the Indian standard IS 800:2007.

Osdag is a GUI-based cross-platform free and open-source software for the design (and detailing) of steel structures, following the Indian Standard IS 800:2007. Osdag is currently under development. An alpha verion of Osdag containing a few connection design modules is expected to be released in September 2016.

It is used for solving steel structures problems and to see how the connection will look after practical implementation. There are different modules available in Osdag with various connectivities.



1.2 Who can use ?

Osdag is generally created for industry professionals but it also keep students in mind. As Osdag is funded by MHRD, Osdag team tries to manipulate 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.

Basically Osdag can be used by anyone starting from novice to professionals. It's simple and sober user interface makes it flexible and attractive than the other softwares. Also there are video tutorials to get started.

Chapter 2

Preparation of DDCL

2.1 What is DDCL

DDCL is Design and Detailing checklist.
The checklist is intended to serve as a convenient guide in design development as well as final checking of procedures and specifications in the design. Its main usefulness for this purpose is that it points out errors and discrepancies that frequently occurs.
Brief specification is workout in the DDCL.I have created the DDCL for seated angle connection using La-tex. For DDCL I have followed Indian Standard codes, various text books.

2.2 DDCL for Seated Angle connection

Seated angle is one of the shear connections, which is used when both shear and axial load needs to be transferred between beam-column.
And transfers the reaction from the beam to column through the angle seat. The beam reaction is transferred by bearing, shear, and bending of the horizontal leg of the bottom angle, by vertical shear through the fasteners, and by horizontal force in the fasteners between the vertical leg and the column.

The angle seat may be bolted or fillet welded to the column and the angles are assumed to be rigid compared to the bolts.

The DDCL file for Seated angle connection is attached vide Appendix-A.

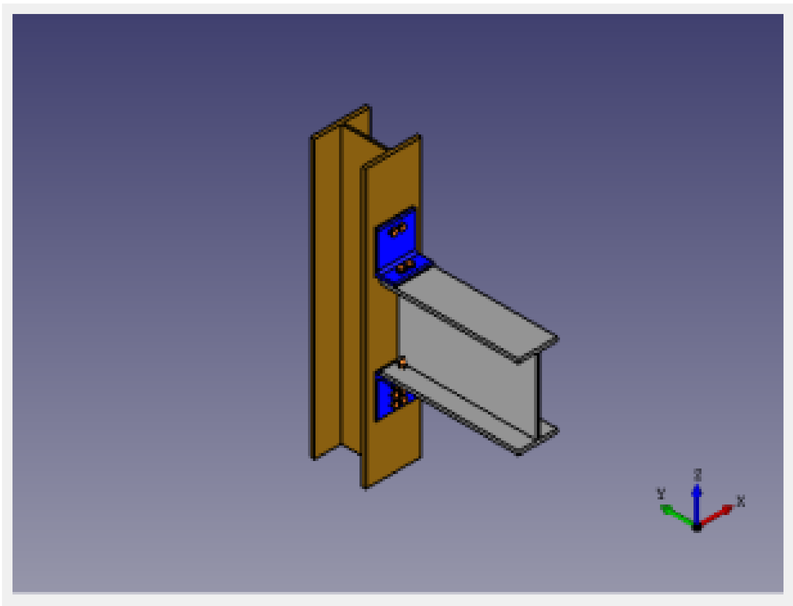


Figure 2.1: Figure : 3D drawing output of typical Seated angle connection

Chapter 3

Conclusion

Overall, I would describe my internship as a positive and instructive experience. I have been able to meet and network with so many people that I am sure will be able to help me with opportunities in the future.

Critical and Analytical Thinking To organize our tasks and assignment, we need to analyze our problems and assignment, and to formulate a good solution to the problem. We would have to set contingency plan for the solution, so that we are well prepared for the unforeseeable situations.

Time Management As overall technician and programmer are always racing against tight timeline and packed schedule, a proper time management will minimize facing overdue deadlines. An effective time management allows us to do our assignment efficiently and meet our schedules. Scheduling avoids time wastage and allows us to plan ahead, and gaining more as a result.

Reference

- IS 800:2007 Indian Standard Code of Practice for General Construction in Steel, 2007.
- N. Subramanian. Design of Steel Structure,Oxford University Press, 12 Edition, 2013.
- S.k.Duggal. Design of Steel Structure. .

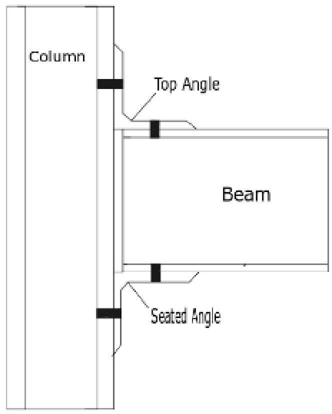
Appendices

Appendix A

DDCL for Seated Angle Connection

Design and detailing checklist (DDCL)

Seated angle plate



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July 11, 2019

Contents

User Input

- Connecting members

  Connecting members= Beam web to beam web (or) beam web to column web (or) beam web to column flange

  Column Section

  Primary Beam Section

  Secondary Beam Section

  Gap between two sections

  Ultimate strength of section, f_u

  Yield strength of section, f_y

- Factored loads

  Vertical shear force

  Axial force

- Fastener Details

  Bolt diameter, d

  Hole Type

  Bolt type = Bearing bolt type or friction grip bolt

  Property class

  Ultimate strength of bolt, $f_u b$

  Yield stress of bolt, $f_y b$

  Slip factor, μ_f

- Seated angle details

  Top angle

  Bottom angle

Check 1

Bolt Design

1.1 Bolt Value

1.1.1 Friction grip type bolt

1.1.1.1 Slip resistance V_{dsf}

[Reference : Cl. 10.4.3 IS 800 : 2007]

$$V_{dsf} = \mu_f n_e K_h F_o / \gamma_{mf} \tag{1.1}$$

where,
μ_f = coefficient of friction (slip factor) as specified in Table 20 of IS 800:2007 for typical average values for Coefficient of friction;
n_e = number of effective interfaces offering frictional resistance to slip;
K_h = 1.0 for fasteners in clearance holes;
= 0.85 for fasteners in oversized and short slotted holes and for fasteners in long slotted holes loaded perpendicular to the slot;
= 0.7 for fasteners in long slotted holes loaded parallel to the slot;
F_o = minimum bolt tension (proof load) at installation and may be taken as $A_{nb} * f_o$
f_o = proof load = $0.7 * f_{ub}$
A_{nb} = net area of bolt at threads ;
f_{ub} = ultimate bolt capacity;
γ_{mf} = partial safety factor = 1.25 [Table 5 of IS 800 : 2007]

1.1.2 Bearing type bolts

1.1.2.1 Shear capacity of the bolt V_{dsb}

[Reference : Cl. 10.3.3 IS 800 : 2007]

$$V_{dsb} = (n_n A_{nb} + n_s A_{sb}) f_{ub} / \sqrt{3} \gamma_{mb} \tag{1.2}$$

where,
f_{ub} = Ultimate tensile strength of a bolt
n_n = number of shear planes with threads intercepting the shear plane;

n_s = number of shear planes without threads intercepting the shear plane;
A_s = Nominal plain shank area of the bolt;
A_n = Net shear area of the bolt at threads, may be taken as area corresponding to root diameter at the thread (Table 4.3 S.K.Duggal);
γ_{mb} = partial safety factor = 1.25 [Table 5 IS 800 : 2007]

1.1.2.2 Bearing capacity of the bolt (V_{dpb})

[Reference : Cl. 10.3.4 IS 800 : 2007]

$$V_{dpb} = 2.5 * k_b * d * t * f_u/\gamma_{mb} \tag{1.3}$$

where,
k_b = is smaller of e/3d_o, (p/3d_o)-0.25 , f_{ub}/f_u, 1;
e,p = end and pitch distances of the fastener along bearing direction;
d_o = diameter of the hole;
[for d_o refer Table 19, IS 800 : 2007]
f_{ub},f_u = Ultimate tensile stress of the bolt and the ultimate tensile stress of the plate respectively;
d = Nominal diameter of the bolt;
t = Summation of the thicknesses of the connected plates experiencing bearing stress in the same direction, or if the bolts are counter sunk, the thickness of the plate minus one half of the depth of countersinking;

Note:
The bearing resistance (in the direction normal to the slots in slotted holes) of bolts in holes other than standard clearance holes may be reduced by multiplying the bearing resistance obtained resistance as above, V_{dpb}, by the factors given below:
a) Over size and short slotted holes - 0.7, and
b) Long slotted holes - 0.5

1.1.3 Design strength for bolt (V_{bolt})

From here on 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

1.2 Reduction factors for bolt capacity

1.2.1 Long joint

[Reference : clause 10.3.3.1 IS 800 : 2007]
If $l_j \geq$ 15d
then,reduction factor β_{ij} is given by,

$$\beta_{ij} = 1.075 - l_j/(200d)\ but\ 0.75 \ \leq\ \beta_{ij}\ \leq\ 1.0 \tag{1.4}$$

where,
l_j = the distance between the first and last rows of bolts in the joint, measured in the direction of the load transfer;
d = nominal diameter of bolt;
This applies for both bearing and friction grip type connections. It is not applicable if shear distribution is uniform, ex: flange to web connection in built-up sections

1.2.2 Large grip lengths

[Reference : clause 10.3.3.2 IS 800 : 2007]
When the grip length, lg(equal to the total thickness of the connected plates) exceeds 5 times the diameter, d of the bolts, the design shear capacity shall be reduced by a factor β_{lg},given by:

$$\beta_{lg} = 8d/(3d + l_g) < \beta_{lj} < 8d \tag{1.5}$$

l_g shall in no case be greater than 8d.

1.2.3 Packing plates

[Reference : clause 10.3.3.3 IS 800 : 2007]
The design shear capacity of bolts carrying shear through a packing plate in excess of 6 mm shall be decreased by a factor, β_{pk} given by:

$$\beta_{pk} = (1 - 0.0125t_{pk}) \tag{1.6}$$

where,
t_{pk} = thickness of the thicker packing, in mm;

1.2.4 Reduced bolt capacity

Final shear load acting on bolt is given by,

$$V_{bolt\ reduced} = \beta_{lj} * \beta_{lg} * \beta_{pk} * V_{bolt} \tag{1.7}$$

Check 2

Design shear load on bolt

Design shear force (V_d) must be greater than 0.15 times Shear capacity of supported section or 40kN which ever is lesser. [Reference : cl.10.7 IS 800 : 2007]

$$V_d = min(0.15 * V_{dbeam},\ 40kN) \tag{2.1}$$

Shear capacity of supported beam section is minimum of its plastic shear capacity and its buckling shear capacity [Reference : cl.8.4 IS 800 : 2007]

1) Plastic shear capacity
[Reference : clause 8.4.1 IS 800 : 2007]

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

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

2) Buckling shear capacity
[Reference : clause 8.4.2.1 IS 800 : 2007]

Resistance to buckling shear shall be verified when, $\frac{d}{t_w} > 67\varepsilon$

[Reference : clause 8.4.2.2 IS 800 : 2007]

$$V_{cr} = A_v \tau_b \tag{2.3}$$

where,
τ_b = shear stress corresponding to web buckling, determined as follows:
1] when, $\lambda_w \leq 0.8$ $\tau_b = \frac{f_{yw}}{\sqrt{3}}$
2] when, $0.8 < \lambda_w < 1.2$ $\tau_b = \frac{[1-0.8(\lambda_w-0.8)]f_{yw}}{\sqrt{3}}$
3] when, $\lambda_w \geq 1.2$ $\tau_b = f_{fw}/\sqrt{3}\gamma_w^2$

where,
λ_w = non-dimensional web slenderness ratio for shear buckling stress, given by:

$\lambda_w = \sqrt{\frac{f_{yw}}{\sqrt{3}\tau_{cr,e}}}$
$\tau_{cr,e}$ = the elastic critical shear stress of the web
$\tau_{cr,e} = \frac{k_v \pi^2 E}{12(1-\mu^2)[d/t_w]^2}$

where,
μ = poisson's ratio, and
k_v = 5.35 when transverse stiffeners are provided only at supports
= 4.0+5.35/$(c/d)^2$ for c/d < 1.0
= 5.35+4.0/$(c/d)^2$ for c/d ≥ 1.0
where c, d are the spacing of transverse stiffeners and depth of the web, respectively.

Design shear capacity of supported section

$$V_{dbeam} = \frac{V_n}{\gamma_{mo}} \tag{2.4}$$

where,
V_n = lesser of V_p and V_{cr}
γ_{mo} = 1.1

2.1 Minimum Number of bolts

The minimum number of bolts required,

$$n = \frac{V_d}{V_{bolt}} \tag{2.5}$$

Check 3

Detailing Checks

3.1 Pitch (p) and gauge (g) distances

3.1.1 Minimum pitch (p) and gauge distances

[Reference : Cl. 10.2.2 IS 800 : 2007]

$$p \; or \; g \geq 2.5 * d_0 \tag{3.1}$$

3.1.2 Maximum pitch (p) and gauge distances

[Reference : Cl. 10.2.3.1 IS 800 : 2007]

$$p \; or \; g \leq min(32 * t, 300 \; mm) \tag{3.2}$$

[Reference: Cl. 10.2.3.2, 10.2.3.3, IS 800 : 2007]

For bolts on column section

$$p \; or \; g \leq min(16 * t, 100 + 4 * t, 200 \; mm) \tag{3.3}$$

where,

t = thickness of thinner plate being connected

3.2 End (e) and edge (e′) distances

3.2.1 Minimum end (e) and edge (e′) distances

[Reference : Cl. 10.2.4.2 IS 800 : 2007]

For sheared or hand-flame cut edges;

$$e \; or \; e' \; \geq \; 1.7 * d_0 \tag{3.4}$$

For rolled, machine-flame cut, sawn and planed edges;

$$e \; or \; e' \; \geq \; 1.5 * d_0 \tag{3.5}$$

where,

d_o = diameter of hole (Refer Table 19, IS 800 : 2007)

3.2.2 Maximum end (e) and edge (e′) distances

[Reference : Cl. 10.2.4.3 IS 800 : 2007]

$$e \; or \; e' \;\leq\; 12 * t * \varepsilon \tag{3.6}$$

where,

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

t = thickness of the thinner plate;

f_y = yield stress of the plate

Check 4

Seated Angle Design and Checks

4.1 Design of seated angle

4.1.1 Length of seated angle

[Reference : N. Subramanian]

Length = Width of beam

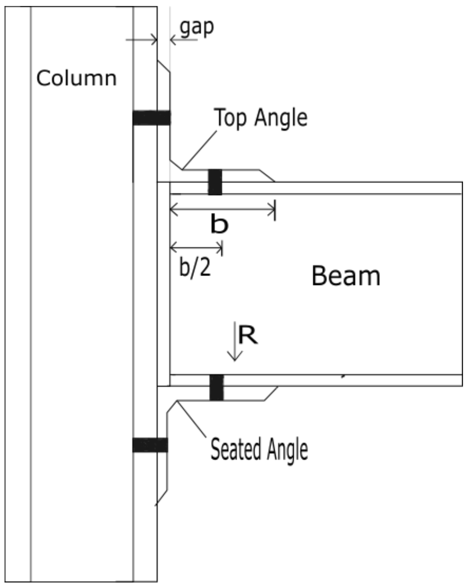

Figure 4.1: seated angle connection

4.1.2 Outstanding leg of the seat angle

[Reference : N. Subramanian]

$$b = [R/t_w(f_{yw}/\gamma_{m0})]$$

where,
R= reaction from the beam;
t_w = thickness of the web of the beam;
f_{yw} = yield strength of the web of the beam;

γ_{m0} = partial safety factor for material = 1.10 ;

4.1.3 Shear capacity for outstanding leg

[Reference : clause 8.4 IS 800 : 2007]
The factored design shear force, V, in a beam due to external actions shall satisfy

$$V \leq V_{dp}$$

where,
V_{dp} = design strength;

$$V_{dp} = W * t * f_y/(\sqrt{3} * \gamma_{m0})$$

where,
W = width of the seated angle;
t = thickness of the angle leg;
f_y = characteristic yield stress;
γ_{m0} = partial safety factor for material = 1.10;

4.2 Moment capacity of outstanding leg

1] Case 1 :

[Reference : clause 8.2.1.2 IS 800 : 2007]

$$If, V \leq 0.6 * V_d$$

The design bending strength, M_d shall be taken as;

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

To avoid irreversible deformation under serviceability loads,
shall be less than,

$$M_d = 1.2 * Z_e * f_y/\gamma_{m0} \text{......for simply supported beams.}$$

$$M_d = 1.5 * Z_e * f_y/\gamma_{m0} \text{...........for cantilever beams.}$$

where,
β_b = 1.0 for plastic and compact section;
$\beta_b = Ze/Zp$ for semi-compact sections;
Z_e,Z_p = plastic and elastic section module of the cross-section, respectively;
f_y = yield stress of the material;
γ_{m0} = partial safety factor;

2] Case 2 :

[Reference : clause 8.2.1.3 IS 800 : 2007]

$$If, V \geq 0.6 * V_d$$

The design bending strength, M_d shall be taken as;

$$M_d = M_{dv}$$

where,
M_{dv} = Design bending strength under high shear;

[Reference : clause 9.2.2 IS 800 : 2007]

Plastic or Compact Section :

$$M_{dv} = M_d - \beta(M_d - M_{fd}) \leq 1.2 * Z_e * f_y/\gamma_{mO}$$

where,
β = $(2V/V_d - 1)^2$
M_d = plastic design moment of the whole section disregarding high shear force effect considering web buckling effects;
V = factored applied shear force;
V_d = design shear strength as governed by web yielding or web buckling ;
M_{fd} = plastic design strength of the area of the cross-section excluding the shear area, considering partial safety factor γ_{mO};
Z_e = elastic section modulus of the whole section;