Semester-Long Internship Report

On

Development of Compression Member design module in Osdag

Submitted by

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CHAPTER 1

INTRODUCTION

1.1 COMPRESSION MEMBERS

A compression member is a very commonly encountered structural member. They are subjected to loads such that it tends to decrease their length. It is also known by other terms like column, stanchion and strut. It depends on which type of structure we are using as a compression element, for example if we are using it in a building to support the incoming gravity load we call it a column and if used in a truss it is called a strut as it is generally in an inclined position. Unlike the member subjected to tension, it is assumed that the gross cross sectional area will be effective in resisting the applied load in case of compression member. Generally bolt holes are often ignored in the design of columns on the assumption that the action of bolts will replace the material removed for holes.

There can be various sections that can be used as a compression member like Angles, Channels, I-sections, Box sections etc. Even combinations of units can also be used like double angle, double channel, double I-sections and four angle units. However, it depends on the loading and its nature (axial or eccentric). In general columns carrying axial or eccentric loads, I-sections are usually preferred. It should be noted that the flanges or web portion of I-section can be easily connected to the beams they support and also cover plates can be used to strengthen it further.

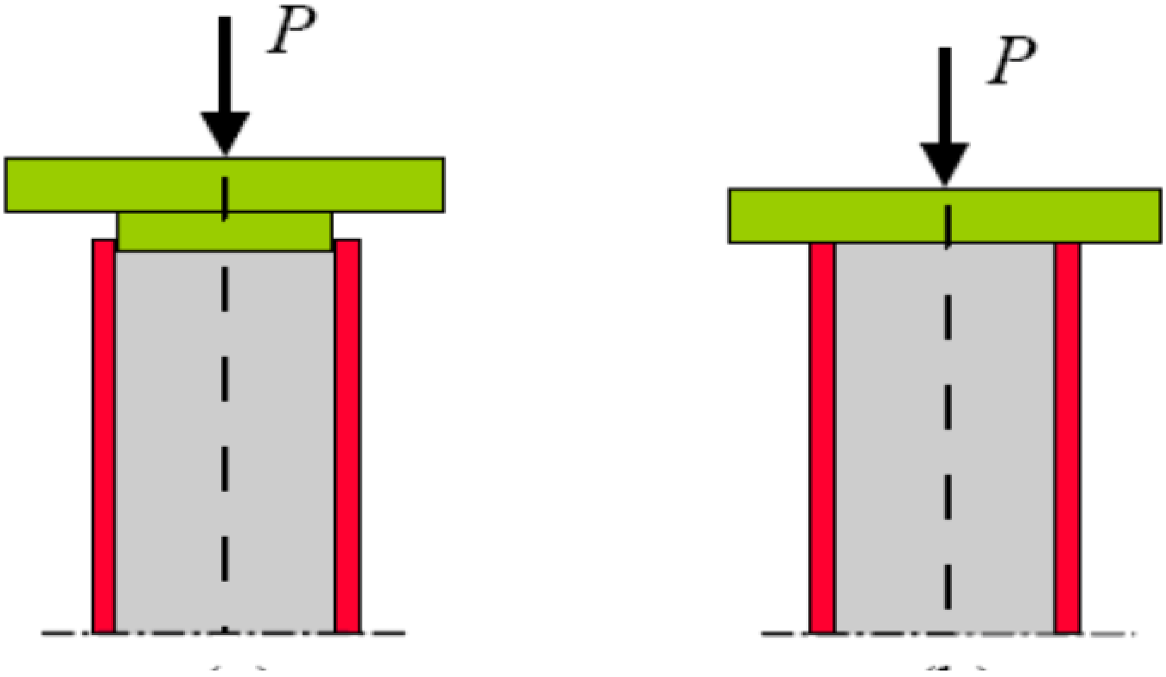


Fig. 1.1 Action of Compression force

1.2 ABOUT OSDAG

Open Steel Design And Graphics (OSDAG) is Free/Libre and Open-Source Software (FLOSS) being developed for the design and detailing of steel structures following IS 800:2007 and other relevant design codes. OSDAG helps users in designing steel connections, members and systems using interactive Graphical User Interface (GUI).

OSDAG is being developed both for use in academia as well as industry educational purposes and also industry professionals. OSDAG is an umbrella project under FOSSEE and FOSSEE is a project under the National Mission on Education through ICT (NMEICT) and funded by the Ministry of Education (MoE).

The source code of OSDAG is written in Python. 3D CAD models are developed using PythonOCC. The development is modular and test driven. GitHub is used as a version control and collaboration tool to ensure smooth workflow in the development process of different modules. SQLite is used for the management of the database. A standard design report is prepared based on LaTeX and echoes all the information pertaining to a particular design.

Fig. 1.2 Home page of OSDAG

Major advantages of using OSDAG include:

- Integration with modern ICT tools, bringing standardization in design and detailing of steel structures, and replacing existing costly software.
- Use of Open Source tools across the overall development of software, making it developer friendly.
- 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 count.

1.3 WHO CAN USE OSDAG

The OSDAG team is developing the software in such a way that it can be used by the students during their academics in order to bolster the understanding of steel design which otherwise is complex and challenging. It can also be used by teachers in the steel design course as a teaching aid to give assignments/tutorials, etc. This will help in creating a well trained pool of students who can develop into professionals in the structural steel industry. This will promote the use of steel in the country. OSDAG can be used by anyone starting from neophytes to professionals. Various self learning materials like Video Tutorials, Design Examples, Discussion Forum, etc. are available to help get started. OSDAG supports both Windows as well as Ubuntu. Given below are some of the resources where one can learn OSDAG in an easy and professional way:

- The video tutorials of OSDAG can be easily accessed from https://osdag.fossee.in/resources/videos or YouTube.
- The sample design problems for different modules can be viewed from https://osdag.fossee.in/resources/sample-design.
- One can view the user tools used for the development of OSDAG from https://osdag.fossee.in/resources/user-tools.
- Developer tools used in the development of OSDAG can be viewed from https://osdag.fossee.in/resources/developer-tools.
- OSDAG can be downloaded from https://osdag.fossee.in/resources/downloads

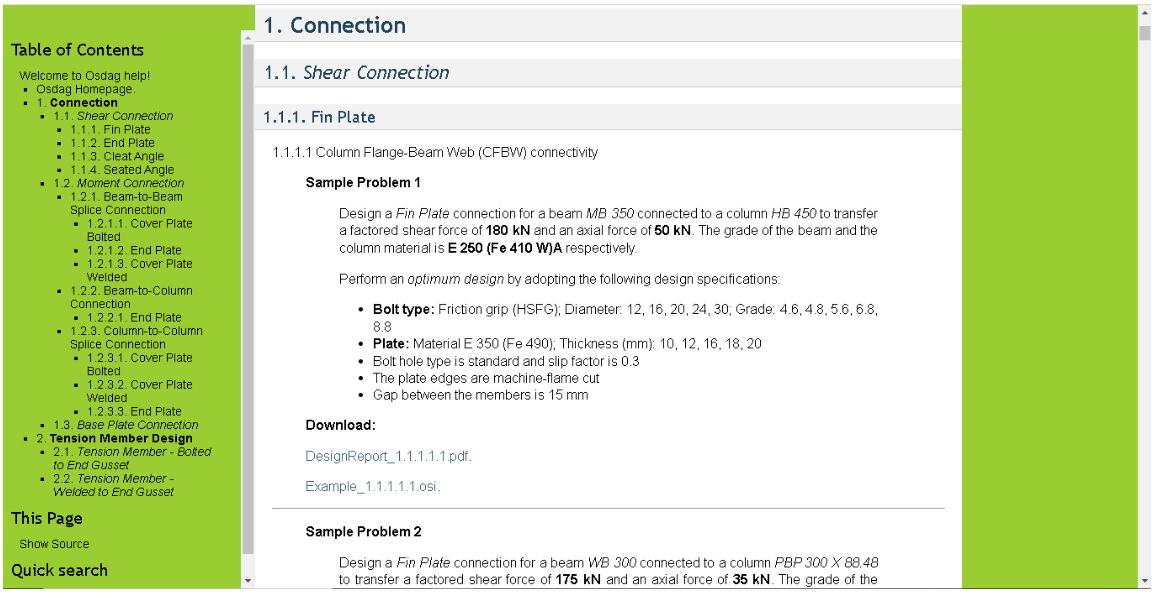


Fig. 1.3 Sample design problems in OSDAG

1.4 AXIALLY LOADED COLUMN

Axial loading on columns is due to loads from floors, walls and roofs which are transmitted to the column through beams and also because of its self weight. Such types of columns only take axial load i.e. no eccentricity is present and the net end moments are zero. But, the occurrence of this phenomenon is relatively rare. If the beam arrangement or the loading is asymmetrical it will result in generation of moments. The response of a column to an axially applied load depends on length of the member, material characteristics, its cross section geometry, support conditions, residual stresses and imperfections. There can be different modes of possible failures in axially loaded compression members like squashing, overall flexural buckling, torsional buckling, local buckling and local failure.

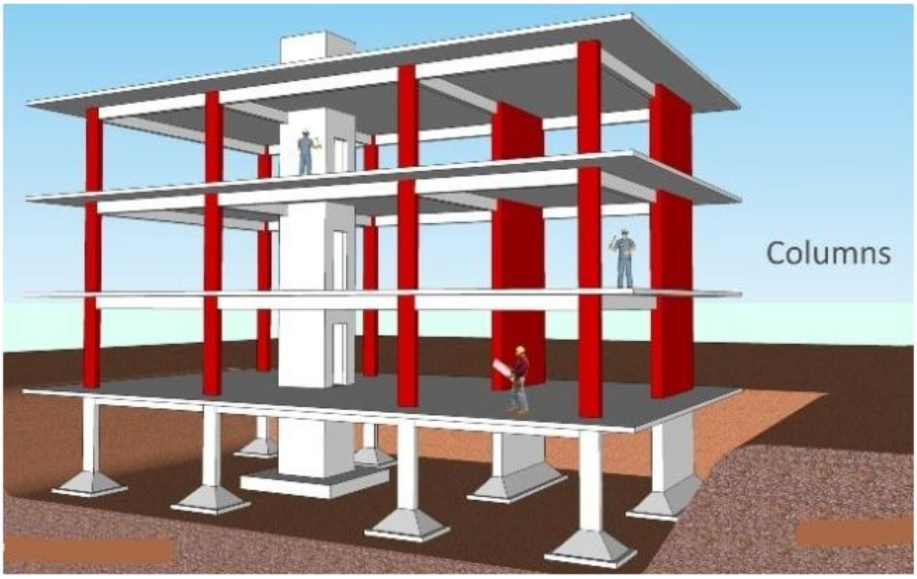


Fig. 1.4 Column in a framed building (In Red)

Squashing occurs in columns having relatively smaller length. It occurs by yielding of cross-section of the column.

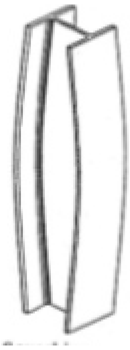


Fig. 1.5 Squashing

The cross-sections are deflected without any torsional rotation in the case of **Overall flexural buckling**. If no lateral restraints are provided across the member length, the weaker axis of the cross-section starts deflecting. The schematic representation of Overall flexural buckling is shown below.

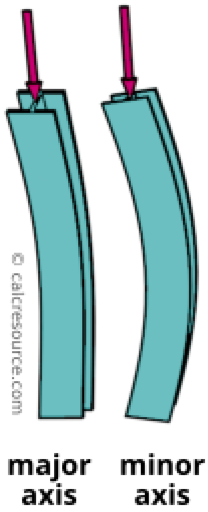


Fig. 1.6 Overall flexural buckling

Torsional buckling is a less common type of failure, and looks like the member is subjected to torsional moments. In this type of failure the cross-sections are rotated around the longitudinal member axis without accounting to any deflection. Torsional buckling is a common mode of failure in the case of point symmetric sections. The schematic representation of torsional failure is shown below.

Fig. 1.7 Torsional buckling.

A combination of both flexure and twisting failure is possibly known as **Flexural-Torsional buckling** and occurs in open cross-section having single symmetry or no symmetry at all. The schematic representation of flexural-torsional failure is shown below.

Fig. 1.8 Flexural-Torsional buckling

Local buckling is a major concern in the design of steel structures, it occurs in hot rolled steel sections usually having outstanding flange elements with unsupported edges and which are thin and slender. Local buckling greatly reduces the axial load carrying capacity of column sections. A schematic representation is shown below.

Fig. 1.9 Local buckling

1.5 BEAM - COLUMN

Typically, columns encounter moment about one or both the axes in addition to the axial load, because of following reasons:

- The incoming compressive force may be transferred eccentrically to the column which creates an eccentric force because of which an equivalent axial force and bending moment acts on the column.
- In braced rigid portal frames, the beams are subjected to gravity loads due to which the rotation takes place at the junction of the beam column joint that causes transfer of bending moments to the column in combination with axial load.
- In multi-storey multi bay unraced frames due to the action of gravity and wind loads, the columns are subjected to deflection and bending. In such cases the column may experience both axial compression and bending moment.

Columns that are subjected to both axial load and bending moment are referred to as beam-columns. In steel structures, beam-columns are often subjected. to a biaxial moment which acts in two different planes. In the case of I-sections the minor axis bending is also very important because the minor axis bending resistance is small when compared to the major axis resistance.

Under combined axial load and bending moment, the column may fail by either material failure or buckling failure. So, it becomes important to check the section strength to prevent the material failure and member strength to prevent the buckling failure.

CHAPTER 2

GENERAL DESIGN PROCEDURES AS PER IS 800:2007

2.1 AXIAL LOAD ON COLUMNS

There are two cases when it comes to axial load on columns i.e. checking the load carrying capacity of a section and design of columns. In the former case a particular section is selected and the load carrying capacity is determined, when it comes to the design of the column, a section is found out with the given axial load and other parameters.

2.1.1 CHECKING LOAD CARRYING CAPACITY

The design procedure is as follows:

1. A section is to be selected for which load carrying capacity is to be found out.
2. Based on the selected section, the sectional properties should be noted down.
3. For the selected section buckling class will be defined as per Table 10 of IS 800:2007 as shown in below figure.

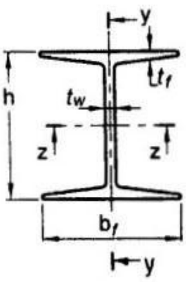
Cross-Section (1)	Limits (2)	Buckling About Axis (3)	Buckling Class (4)
Rolled I-Sections 	$h/b_f > 1.2$: $t_f \le 40$ mm	z-z y-y	a b
	$40 \le$ mm $< t_f \le 100$ mm	z-z y-y	b c
	$h/b_f \le 1.2$: $t_f \le 100$ mm	z-z y-y	b c
	$t_f > 100$ mm	z-z y-y	d d

Fig. 2.1 Table 10 of IS 800:2007

Where,

h is the depth of section, b_f is breadth of flange and t_f is the thickness of flange.

4. The selected section is classified into plastic, compact and semi-compact according to Table 2 of IS 800:2007 as shown in the below figure.
   Where,

   $b = b_f / 2$ and $d = h - 2(r_1 + t_f)$

   r_1 = Root radius

d = Clear depth of web

Compression Element (1)			Ratio (2)	Class of Section: Class 1 Plastic (3)	Class 2 Compact (4)	Class 3 Semi-compact (5)
Outstanding element of compression flange	Rolled section		b/t_f	9.4ε	10.5ε	15.7ε
	Welded section		b/t_f	8.4ε	9.4ε	13.6ε
Internal element of compression flange	Compression due to bending		b/t_f	29.3ε	$33.5\,\varepsilon$	42ε
	Axial compression		b/t_f	Not applicable		
Web of an I, H or box section	Neutral axis at mid-depth		d/t_w	84ε	105ε	126ε
	Generally	If r_1 is negative:	d/t_w	$\frac{84\varepsilon}{1+r_1}$ but $\leq 42\varepsilon$	$\frac{105.0\,\varepsilon}{1+r_1}$	$\frac{126.0\,\varepsilon}{1+2r_1}$ but $\leq 42\varepsilon$
		If r_1 is positive:	d/t_w		$\frac{105.0\,\varepsilon}{1+1.5r_1}$ but $\leq 42\varepsilon$	
	Axial compression		d/t_w	Not applicable		42ε

Fig. 2.2 Table 2 of IS 800:2007

5. If all conditions are satisfied as given in Table 2, then the effective area (A_{eff}) is taken as gross area as long as the section is semi-compact or better. Otherwise reduction should be made considering the holes not fitted with rivets or bolts from gross area to calculate effective sectional area respectively.
6. Find slenderness ratio () as given in the below equation and check for the limits from Table 3 of IS 800:2007.

   $$\lambda = KL / r_{min} \qquad (2.1)$$

   Where is the slenderness ratio, KL = effective length from Table 11 of IS 800:2007 and r_{min} is the minimum radius of gyration.

7. Calculate the design compressive stress (f_{cd}) as per clause 7.1.2.1 of IS 800:2007, which is given by,

   $$f_{cd} = (f_y / \gamma_{mo}) / (\phi + [\,\phi^2 - \lambda^2\,]^{0.5} <= (f_y / \gamma_{mo}) \qquad (2.2)$$

   Where, f_y = Yield stress in MPa

   γ_{mo} = Partial safety factor as per Table 5 of IS 800:2007 and is taken as 1.10.

   $$\phi = 0.5\,[\,1 + \alpha(\lambda - 0.2) + \lambda^2\,] \qquad (2.3)$$

   α = imperfection factor as given in Table 7 of IS 800:2007

   = Non dimensional effective slenderness ratio = $\sqrt{f_y / f_{cc}} f_{cc}$

   = Euler buckling stress which is given by

$f_{cc} = {}^{2}E / (KL / r_{min})^2$ (2.4)

E = Modulus of elasticity and is equal to 2 x 10^5 MPa

Table 3 Maximum Values of Effective Slenderness Ratios

Sl No.	Member	Maximum Effective Slenderness Ratio (*KL/r*)
(1)	(2)	(3)
i)	A member carrying compressive loads resulting from dead loads and imposed loads	180
ii)	A tension member in which a reversal of direct stress occurs due to loads other than wind or seismic forces	180
iii)	A member subjected to compression forces resulting only from combination with wind/earthquake actions, provided the deformation of such member does not adversely affect the stress in any part of the structure	250
iv)	Compression flange of a beam against lateral torsional buckling	300
v)	A member normally acting as a tie in a roof truss or a bracing system not considered effective when subject to possible reversal of stress into compression resulting from the action of wind or earthquake forces[1)]	350
vi)	Members always under tension[1)] (other than pre-tensioned members)	400

[1)] Tension members, such as bracing's, pre-tensioned to avoid sag, need not satisfy the maximum slenderness ratio limits.

Fig. 2.3 Table 3 of IS 800:2007

8. Calculate the design compressive strength (P_d) as per clause 7.1.2 of IS 800:2007 which is given by,

$P_d = A_{eff} \times f_{cd}$ (2.5)

Table 7 Imperfection Factor, α

(*Clauses* 7.1.1 *and* 7.1.2.1)

Buckling Class	a	b	c	d
α	0.21	0.34	0.49	0.76

Fig. 2.4 Table 7 of IS 800:2007

2.1.2 DESIGN OF COLUMN FOR AXIAL LOAD

The design procedure is as follows:

1. For the given axial load (P), a suitable trial section is taken based on the following formula,

   $A_{req} = P / f_{cd}$ (2.6)

   Where,

   f_{cd} = Design compressive stress which is assumed to be 0.4 to 0.6 times of f_y. If length of member is large then $0.4f_y$, if length of member is small then $0.6f_y$ and $0.5f_y$ if medium.

2. Based on the Required area (A_{req}), the section is selected from the list of available I-sections as given in IS 808:1989.

   The order of preference in selecting the section should be:

   A. ISHB (Indian Standard Heavy Beam)
   B. ISMB (Indian Standard Medium Beam)

3. For the selected section buckling class will be defined as per Table 10 of IS 800:2007.

   Where,

   h is the depth of section, b_f is breadth of flange and t_f is the thickness of flange

4. The selected section is classified into plastic, compact and semi-compact according to Table 2 of IS 800:2007.

   Where,

   $b = b_f / 2$ and $d = h - 2(r_1 + t_f)$

   r_1 = Root radius

d = Clear depth of web

5. If all conditions are satisfied as given in Table 2, then the effective area (A_{eff}) is taken as gross area as long as the section is semi-compact or better. Otherwise reduction should be made considering the holes not fitted with rivets or bolts from gross area to calculate effective sectional area respectively.
6. Find slenderness ratio () as given in the below equation and check for the limits from Table 3 of IS 800:2007.

   $\lambda = KL / r_{min}$ (2.7)

   Where   is the slenderness ratio, KL = effective length from Table 11 of IS 800:2007 and r_{min} is the minimum radius of gyration.

7. Calculate the design compressive stress (f_{cd}) as per clause 7.1.2.1 of IS 800:2007, which is given by,

   $f_{cd} = (f_y / \gamma_{mo}) / (\phi + [\phi^2 - \lambda^2]^{0.5} <= (f_y / \gamma_{mo})$ (2.8)

   Where, f_y = Yield stress in MPa

   γ_{mo} = Partial safety factor as per Table 5 of IS 800:2007 and is taken as 1.10.

   $\phi = 0.5 [1 + \alpha(\lambda - 0.2) + \lambda^2]$ (2.9)

   α = imperfection factor as given in Table 7 of IS 800:2007

   = Non dimensional effective slenderness ratio = $\sqrt{f_y / f_{cc} f_{cc}}$

   = Euler buckling stress which is given by

   $f_{cc} = {}^2E / (KL / r_{min})^2$ (2.10)

   E = Modulus of elasticity and is equal to 2×10^5 MPa

8. Calculate the design compressive strength (P_d) as per clause 7.1.2 of IS 800:2007 which is given by,

   $P_d = A_{eff} \times f_{cd}$ (2.11)

   If P_d is greater than P, design is safe otherwise we need to repeat from step 2 by selecting a section having more area than previously selected section.

2.2 BEAM - COLUMN DESIGN

The design procedure of beam - column for axial load and bending moment is given below as per IS 800:2007 but it should be noted that it involves a lot of trial and error, iteration process and is given as follows:

For the design of beam-column the below given parameters are necessary to be mentioned before starting the design:

A. Axial load (P)
B. Moment about z-z axis (M_z)
C. Moment about y-y axis (M_y)
D. Length of the member (L)
E. End conditions

1. The given axial load and moment is converted into equivalent axial load (P_{eff}) as suggested by Yura (1988), is given by:
   $P_{eff} = P + 2M_z / d + 7.5M_y / b$ (2.12)
   Where,
   d = depth of the beam
   b = width of the beam
2. A trial section should be selected and P_{eff} should be found out, for the same trial section find the load carrying capacity (P_d) as mentioned in the sub topic 2.1.1.
3. If $P_d < P_{eff}$ again repeat the same steps as mentioned in 2.1.1 by selecting a section having higher area. Continue the process until it satisfies the criteria $P_d > P_{eff}$
4. The section which satisfies the criteria will be taken as a trial section for the design of beam-column.
5. The selected trial section is classified into plastic, compact and semi-compact according to Table 2 of IS 800:2007
   Where,
   $b = b_f / 2$ and $d = h - 2(r_1 + t_f)$

   r_1 = Root radius

   d = Clear depth of web

6. Check for resistance to combined effects as per clause 9.3.1.1 of IS 800:2007:
   For plastic and compact sections:
   $(M_y / M_{ndy})^{\alpha 1} + (M_z / M_{ndz})^{\alpha 2} <= 1.0$ (2.13)
   Where,
   M_{ndy}, M_{ndz} = Design reduced flexural strength under combined axial force and respective uniaxial moment acting alone as per clause 9.3.1.2 and is given in below figure.
   For semi-compact sections: as per clause 9.3.1.3
   $(N / N_d) + (M_y / M_{dy}) + (M_z / M_{dz}) <= 1.0$ (2.14)
   Where,
   N = Factored applied axial load in compression
   N_d = Design strength in compression due to yielding and is given by,
   $N_d = (A_g x f_y) / \gamma_{mo}$ (2.15)
   A_g = Gross area of the trial section
   M_y, M_z = Factored moments about minor and major axis of the cross section respectively

M_{dy}, M_{dz} = Design strength under corresponding moment acting alone and is given by,

$M_{dy} = (Z_{py} \times f_y) / \gamma_{mo}$ (2.16)
$M_{dz} = (Z_{pz} \times f_y) / \gamma_{mo}$ (2.17)
$M_{dy} = (Z_{ey} \times f_y) / \gamma_{mo}$ (2.18)
$M_{dz} = (Z_{ez} \times f_y) / \gamma_{mo}$ (2.19)

Table 17 Constants α_1 and α_2
(*Clause* 9.3.1.1)

Sl No. (1)	Section (2)	α_1 (3)	α_2 (4)
i)	I and channel	$5n \geq 1$	2
ii)	Circular tubes	2	2
iii)	Rectangular tubes	$1.66/(1-1.13n^2) \leq 6$	$1.66/(1-1.13n^2) \leq 6$
iv)	Solid rectangles	$1.73+1.8n^3$	$1.73+1.8\,n^3$

NOTE — $n = N/N_d$.

Fig. 2.5 Table 17 of IS 800:2007

7. Calculation of design compressive strength (P_{dy} and P_{dz}) as per clause 7.1.2 of IS 800:2007 w.r.t both the axis.
   $P_{dy} = A_{eff} \times f_{cdy}$ (2.20)
   $P_{dz} = A_{eff} \times f_{cdz}$ (2.21)
8. If P_{dy} and P_{dz} is less than P then again repeat from step 2 onwards until it satisfies.
9. Check for buckling resistance in bending as per clause 8.2.2 of IS 800:2007:
   $M_{cr} = [(\pi^2 E I_y h_f) / (2L_{LT}^2)] [1+(1/20)((L_{LT}/r_y)/(h_f t_f))^2]^{0.5}$ (2.22)
   Where,
   M_{cr} = Elastic critical moment
   h_f = C/C distance between flanges
   L_{LT} = Effective length for torsional buckling from clause 8.3 of IS 800:2007
   I_y = Moment of Inertia about the weaker axis
   r_y = Radius of gyration about weaker axis
   $\lambda_{LT} = \sqrt{(\beta_P Z_P f_y)/M_{cr}} <= \sqrt{(1.2 Z_P f_y)/M_{cr}}$ (2.23)
   $\phi_{LT} = 0.5[1 + \alpha_{LT}(\lambda_{LT} - 0.2) + \lambda_{LT}^2]$ (2.24)
   $\chi_{LT} = 1 / (\phi_{LT} + [\phi_{LT}^2 - \lambda_{LT}^2]^{0.5} <= 1.0$ (2.25)
   Where,
   β_P = 1.0 for plastic and compact sections, Z_e/Z_p for semi-compact sections

Z_p, Z_e = Plastic and elastic modulus w.r.t extreme compression fibre

α_{LT} = Imperfection factor given as 0.21 for rolled section and 0.49 for welded steel section.

χ_{LT} = Bending stress reduction factor to account for lateral torsional buckling.

$f_{bd} = (\chi_{LT} f_y) / \gamma_{mo}$ (2.26)

Where,

f_{bd} = Design bending compressive stress

Design bending strength (M_d) of laterally unsupported beam as governed by lateral torsional buckling is given by:

$M_d = \beta_P Z_P f_{bd}$ (2.27)

If $M_{dz} > M_z$ and $M_{dy} > M_y$ then the section is safe.

10. Check for buckling resistance in combined bending and axial compression as per clause 9.3.2.2 of IS 800:2007,

$(P/P_{dy}) + (K_y C_{my} M_y) / Mdy + (K_{LT} M_z) / M_{dz} <= 1.0$ (2.28)

$(P/P_{dz}) + (0.6 K_y C_{my} M_y) / Mdy + (K_z C_{mz} M_z) / M_{dz} <= 1.0$ (2.29)

Where,

P = Applied axial load under compression

P_{dy}, P_{dz} = Design compressive strength under minor axis and major axis

M_y, M_z = Factored moments about minor and major axis of the cross section respectively

C_{mz}, C_{my} and C_{mLT} = Equivalent uniform moment factor given by table 18 of IS:2007, is given by

C_{mz}, C_{my} and $C_{mLT} = 0.6 + 0.4 > 0.4$ (2.30)

$= M_2 / M_1$

M_1 = Moment at bottom of column

M_2 = Moment at top of column

$K_y = 1 + (\lambda_y - 0.2) n_y <= 1 + 0.8 n_y$ (2.31)

$K_y = 1 + (\lambda_z - 0.2) n_z <= 1 + 0.8 n_z$ (2.32)

Where,

λ_y = Non dimensional effective slenderness ratio about y-y axis

λ_z = Non dimensional effective slenderness ratio about z-z axis

n_y = Ratio of applied axial force to the design axial strength about the y-y axis

n_z = Ratio of applied axial force to the design axial strength about the z-z axis

$K_{LT} = 1 -[(0.1 \lambda_{LT} n_y) / (C_{mLT} - 0.25)] >= 1 -[(0.1 n_y) / (C_{mLT} - 0.25)$ (2.33)

CHAPTER 3

DESIGN PROCEDURE IN OSDAG

3.1 FLOWCHART OF DESIGN PROCESS

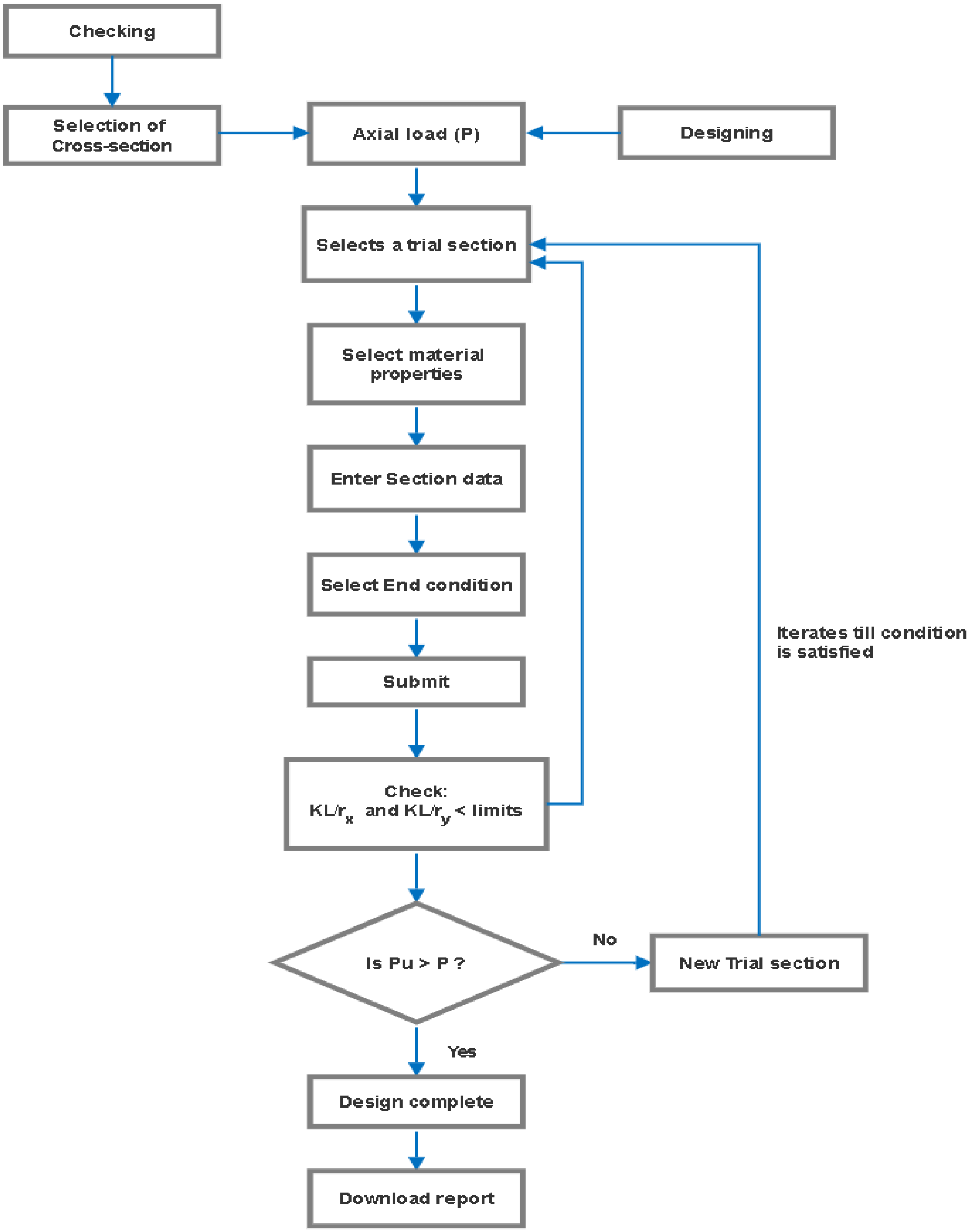


Fig. 3.1 Flowchart of design process

3.2 DESIGN STEPS IN OSDAG

The design flow in OSDAG is explained with the help of an example as shown below in brief. The design steps are very user friendly.

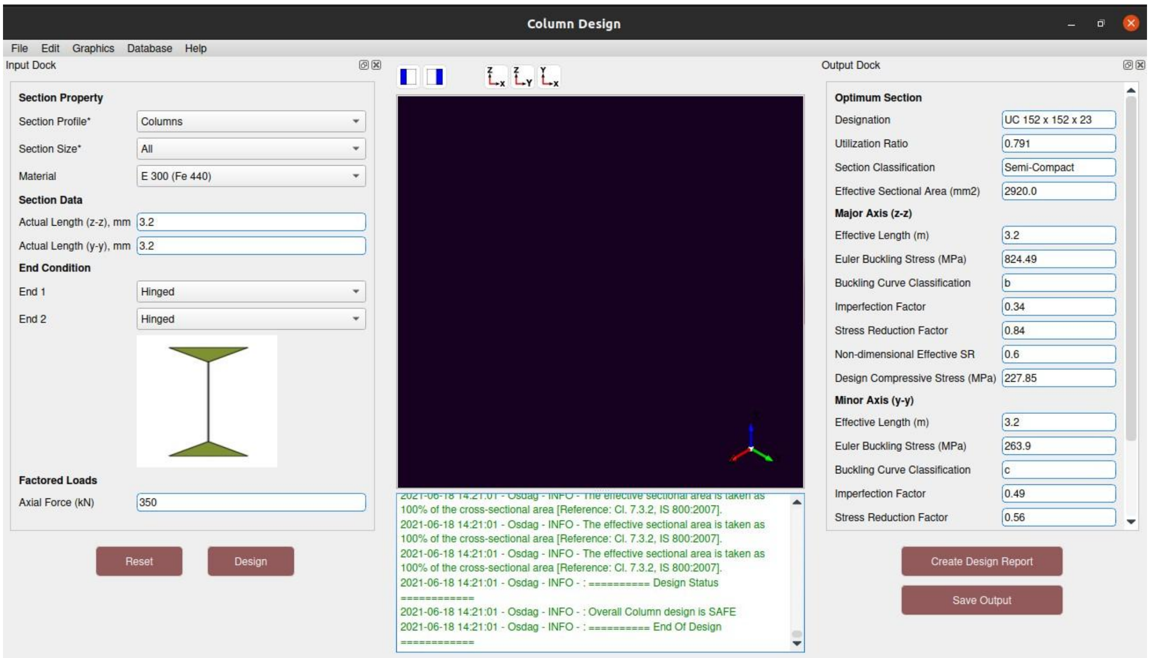


Fig. 3.2 Design Example In Osdag

3.2.1 INPUT DOCK

In the input dock the solver is required to enter or select the values as given in the problem or on his own for experimental purpose. It is placed on the left side of the design console as shown above:

1. User is required to select any one section profile from columns, beams or hollow sections based on his preference.
2. Based on the selected section profile, the different section sizes available in the database will be shown up in the dropdown menu of section size. The user can select all or any preferred size alone to carry out the design checks.
3. The user has a wide range of material preferences to select from and can be selected from the dropdown menu provided against the material tab.
4. Then the user needs to enter the length of the member w.r.t to both the axis manually. Generally it is the same except when there are any bracings provided.
5. Then the user is required to enter the factored axial load acting on the column. If this field is left empty then it is considered as case 1 in axial load design (where the user is required to select a particular section to find the load carrying capacity) or else case 2 (design of columns).
6. Once the input dock parameters are filled, the user needs to click on design and if he wants to change the selected data he can click on reset button.

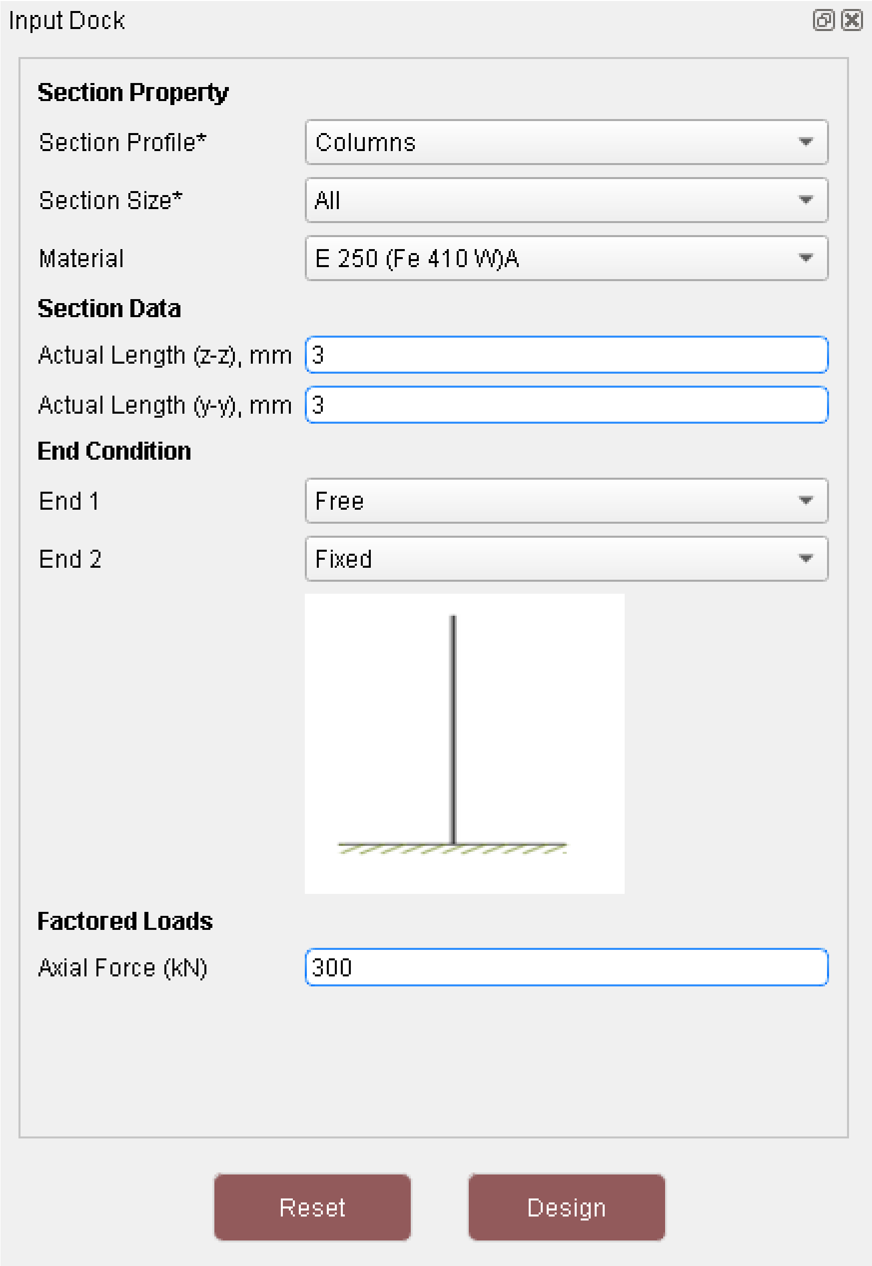


Fig. 3.3 Input dock

3.2.2 OUTPUT DOCK

Once clicking on the submit button, the code starts calculating the required design parameters and returns the values in the output dock which is shown on the right side of the design console.

1. The user can view the required outputs in this dock like details regarding optimum section.
2. Various design parameters related to both the major and minor axis can be viewed.
3. The technical design report can be downloaded only in the case when the design is successful from the Create Design Report button at the bottom of the output dock.

4. The output can be saved for any future or study use.

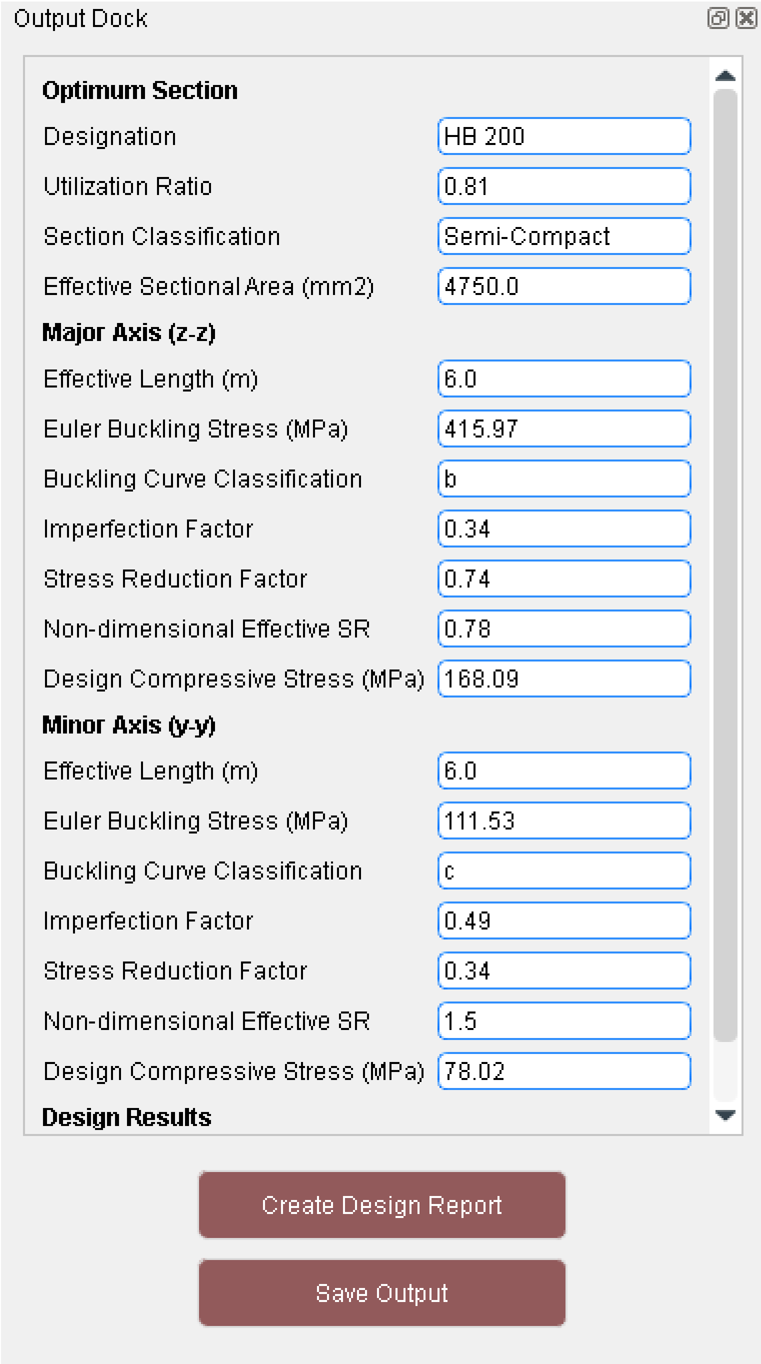


Fig. 3.4 Output dock

3.2.3 LOG MESSAGES CONSOLE

The log messages console is located in between the input dock and output dock. This is one of the highly useful features provided in Osdag to alert the user. It displays messages related to important notes, limitations and clauses for some important functions of IS 800:2007 codebook.

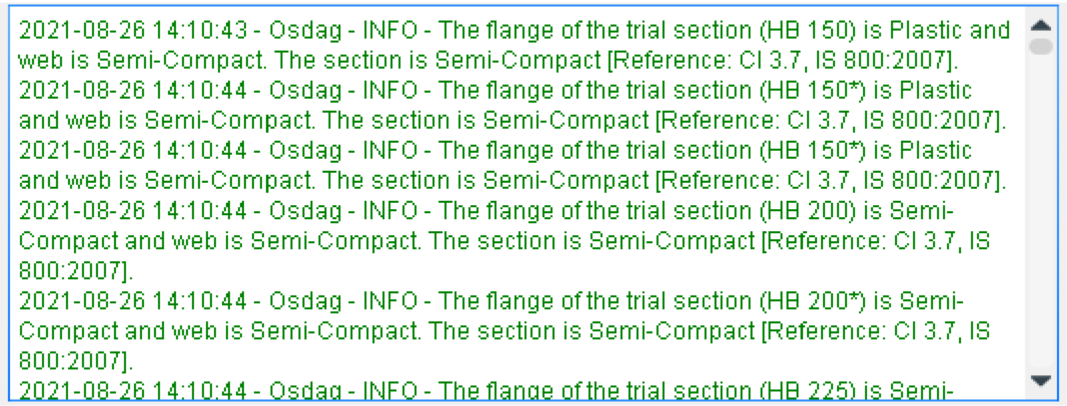


Fig. 3.5 Log messages console

3.3 ADVANTAGES

1. Provides a clear and concise interface which is easy to understand.
2. Minimal error in calculations as it is calculated through well developed algorithms.
3. Faster calculation as compared to manual calculation.
4. Optimization of sections based on Utilization Ratio (UR) and Cost.
5. Iterations are done internally as soon as the section fails.
6. Provides the user to select sections on his own from wide ranges.
7. Generation of design report for understanding purpose.
8. Generates log messages with critical end limits and clauses for the convenience of the user.
9. Design preferences can be utilized to customize the required data.
10. Provides a platform to further implement any new additions.

CHAPTER 4

DEVELOPMENT OF COMPRESSION MEMBER MODULE

4.1 CODE DEVELOPMENT

The algorithms for the design procedure for axial load on columns has been developed by using Python 3 as the main language and necessary FLOSS tools have been used wherever required. Below a sample of functions written has been presented and explained in brief.

```
epsilon = math.sqrt(250 / f_y)

ratio = width / thickness

if section_type == 'Rolled':
    if ratio <= (9.4 * epsilon):
        section_class = 'Plastic'
    elif ratio <= (10.5 * epsilon):
        section_class = 'Compact'
    elif ratio <= (15.7 * epsilon):
        section_class = 'Semi-Compact'
    else:
        section_class = 'Slender'
else:
    if ratio <= (8.4 * epsilon):
        section_class = 'Plastic'
    elif ratio <= (9.4 * epsilon):
        section_class = 'Compact'
    elif ratio <= (13.6 * epsilon):
        section_class = 'Semi-Compact'
    else:
        section_class = 'Slender'

return [section_class, ratio]
```

Fig 4.1 Function of section classification

A simple function is shown in Fig. 6.1 to demonstrate the classification of sections into plastic, compact or semi-compact as per Table 2 of IS 800:2007. For hot rolled section type it takes the conditions given under if clause and for any other condition it goes into else clause. This function returns the type of section class and the ratio in the output dock.

```
@staticmethod
def Table2_i(width, thickness, f_y, section_type='Rolled'):
    """ Calculate the limiting width to thickness ratio as per Table 2 for;
            sr. no i) Outstanding element of compression flange

    Args:
        width: width of the element in mm (float or int)
        thickness: thickness of the element in mm (float or int)
        f_y: yield stress of the section material in MPa (float or int)
        section_type: Type of section ('Rolled' or 'Welded') (string)

    Returns:
        A list of values with;
        1- The class of the section as Plastic, Compact, Semi-compact or Slender on account of the flange
        2- Ratio

        ['Section Class', 'Ratio']

    Reference: Table 2 and Cl.3.7.2, IS 800:2007

    """
```

Fig. 4.2 Arguments and Returns of the above given function

4.2 GRAPHICAL USER INTERFACE

GUI plays an important role in any software development as it enriches the aesthetic looks and provides an easier interface to the user in order to carry out his works. GUI in OSDAG has been developed in such a way that it can be easily understood while performing design. All the input and output parameters have been presented in simple words so that there won"t be any confusion to anyone who is using OSDAG.

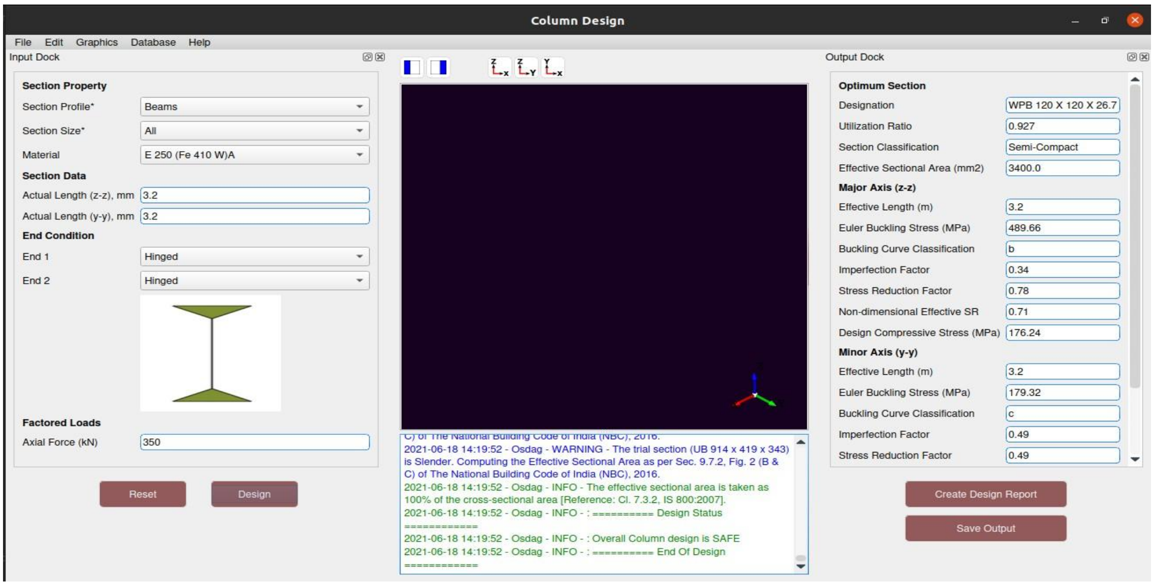


Fig. 4.3 GUI of design with Beams

4.3 DESIGN PREFERENCES TAB

Design preferences tab provides an advantage to the end user to select his desired properties and options instead of conventional ones. The user can experiment by using the preferences in order to fulfill his needs by utilising the various options given in the design preferences tab. OSDAG interface provides a separate tab for design preferences where the user can select by clicking onto it. While testing the design if any one of the parameters is not working well or the end result is not as expected, the user can always come back and change the particular parameter from the drop down menu provided to achieve the desired output.

In the below figure the optimization of design preferences has been shown. The main purpose of **optimization** is to achieve the most stable design relative to a set of prioritized conditions or constraints in the given design scope. They include maximizing factors such as strength, reliability, efficiency, and utilization. In OSDAG, optimization plays a very important role as design of steel structures provides many limits which have to be followed definitely and can‟t be ignored at any cost. There are four such parameters in OSDAG which helps in optimising the design efficiently. They are:

1. **Allowable Utilization Ratio (UR) :** It is a value which tells about the efficiency of a section based on its load carrying capacity. In general, it is defined as the ratio of demand to the load carrying capacity of the section. Its maximum value is 1 when both demand and capacity are equal but, it should be noted that whenever UR is 1 it might become difficult in conditions where external loads increase suddenly which inturn gives UR of more than 1, which is critical as capacity becomes less than demand. Its minimum value is set at 0.1 and default value is set at 1.0. The user can change the section profile depending upon the required UR.

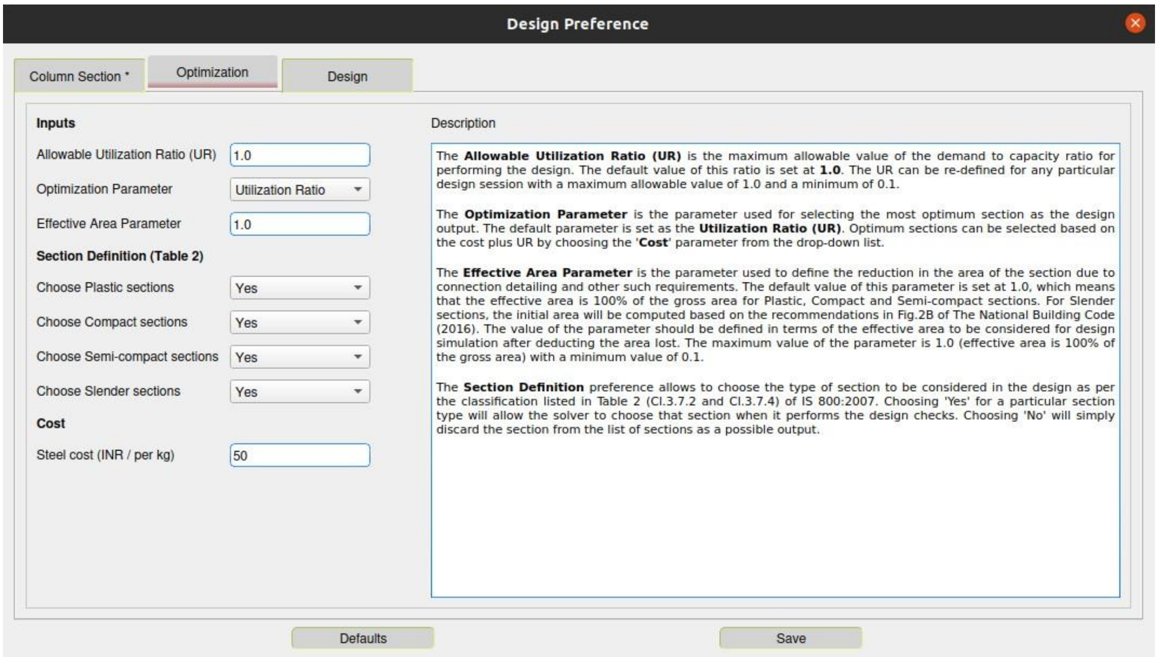


Fig. 4.4 Optimization of Design Preferences

2. **Optimization Parameter :** This is a parameter which provides the user to select the mode of optimization in order to select the most optimum section whether based on UR or Cost + UR. Cost is also a critical parameter when it comes to the designing phase as there are many financial constraints involved in the whole design process and the designer should entertain the constraints involved by not compromising on the design safety parameters. The user can select his preference from the dropdown menu given against it. The user can enter the Cost of steel per kg metre run in order to calculate the cost required for overall design connection which will be linked with the optimization process. This parameter is givenspecial weightage in OSDAG.
3. **Effective Area Parameter :** This parameter is used to indicate the reduction in gross area of the selected cross section based on the connection detailing and bolt or rivet hole criteria's. The default value is set at 1 which means that 100 % of the gross area is effective in carrying the load for plastic, compact and semi-compact sections. When it comes to slender sections, The National Building code (2016) provides a set of recommendations to compute the initial area. While the maximum value is set at 1, the minimum value is set at 0.1. This parameter provides the user information on how much area is being utilized for connection detailing purposes and subsequently the user can select a section having effective area nearly close to the gross area.
4. **Section Definition :** This parameter provides the user an extra advantage in selecting the type of section to be considered for design checks. Selecting Yes will allow you to solve from the sections choosed and selecting No simply discards the section from the list of sections provided.

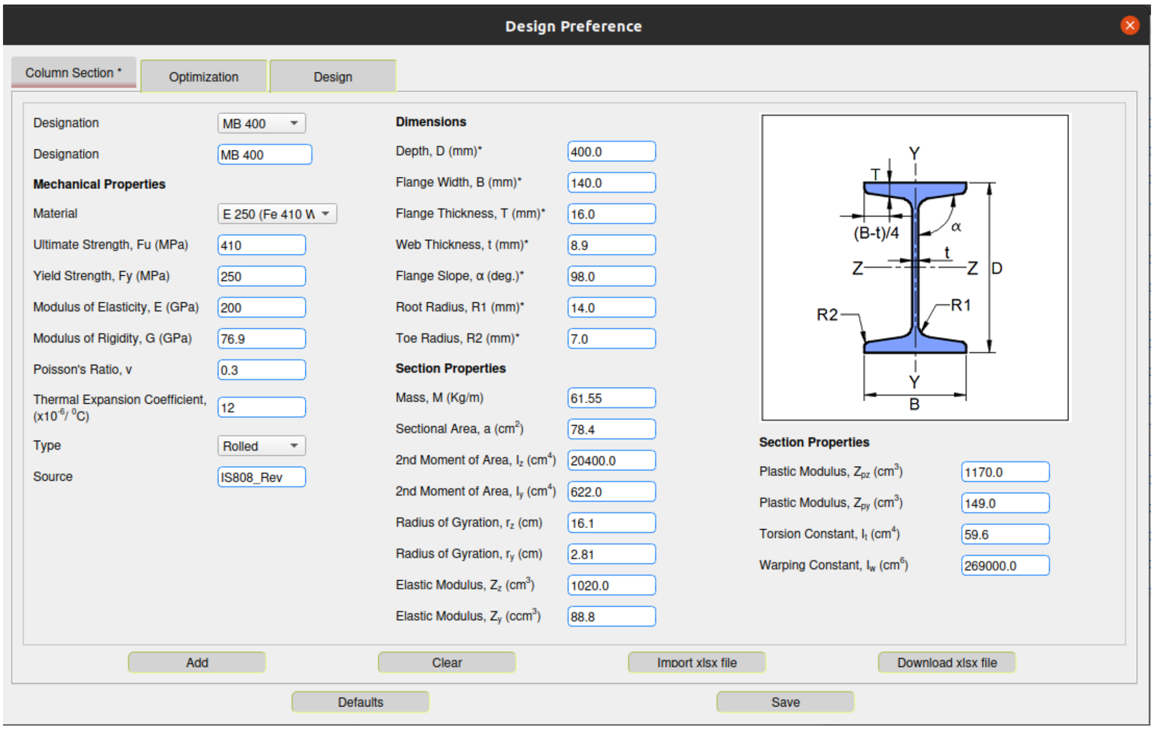


Fig. 4.5 Design Preferences for I-sections

The above given figure shows the properties of hot rolled I-sections which can be changed as per the solver's preferences. In order to add any new section to the list of sections which will be used for design checks, the user can easily add in by clicking on the Add button provided in the left bottom corner. Also it provides an opportunity to the user to import any xlsx file and simultaneously download the xlsx file. OSDAG supports the customization for different hollow sections as well which are shown in the below figures.

APPENDICES

Appendix A

Testing of Compression member module

	A	B	C	D	E
4		**Solving for which type of sec**	Hollow		
5					
6		**Input Data:**			
7					
8		**Section:**	CHS 114.3 x 3.6		
9					
10		**Material:**	E 250 (Fe 410 W		
11					
12		**Factored load:**	300	kN	
13					
14		**Column length along z-z**	3	m	
15		**Along y-y**	3	m	
16					
17		**End condition:**			
18					
19		**At one end :** Translation	Restrained		
20		Rotation	Restrained		
21		**At other end :** Translation	Restrained		
22		Rotation	Restrained		
23					
24		**Effective length along z-z**	1950	mm	
25		**Along y-y**	1950	mm	
26					
27		**Yield stress:**	250	Mpa	
28					
29		**Assumed fcd**	125	Mpa	
30					
31		**Section properties:**			
32					
33		Area(mm^2)	1252		
34		Depth(mm)	114.3		
35		Breadth(mm)			
36		Thickness of web(mm)			
37		Thickness of flange(mm)	3.6		
38		Root radius 1(mm)			
39		Root radius 2(mm)			
40		Iz(mm^4)	1919800		
41		Iy(mm^4)	1919800		
42		Rz(mm)	39.2		
43		Ry(mm)	39.2		
44		Zez(mm^3)	33590		
45		Zey(mm^3)	33590		
46		Zpz(mm^3)	33590		
47		Zpy(mm^3)	33590		
48					
49					
50					
51					

Input values

Output Data:

Area Required	2400	mm^2

Buckling Class about z-z :	a
Buckling Class about y-y :	a

Section classification		
For Hollow	-2.00	#N/A
For Hollow	31.75	Semi-Compact

Major Axis z-z	
Effective length (m)	1.95
Euler Buckling Stress (Mpa)	797.69
Buckling Curve Classification	a
Imperfection Factor	0.21
phi	0.69
Stress Reduction Factor	0.90
Non-dimensional Effective SR	0.56
Design Compressive Stress(Mpa)	205.59
Design Compressive Strength(kN)	257.40

Slenderness ratio	49.74	Pass

Minor Axis y-y	
Effective length (m)	1.95
Euler Buckling Stress (Mpa)	797.69
Buckling Curve Classification	a
Imperfection Factor	0.21
phi	0.69
Stress Reduction Factor	0.90
Non-dimensional Effective SR	0.56
Design Compressive Stress(Mpa)	205.59
Design Compressive Strength(kN)	257.40

UR	1.166

Output values

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