Semester-Long Internship Report

On

Development of Algorithms for Welded Plate Girder and Gusseted Truss Connections

Submitted by

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I am also thankful to everyone at FOSSEE who was involved in the selection process based on the screening tasks, for providing me a platform to work on and an opportunity to be a part of the team which promotes open-source softwares.

Table of Contents

Chapter 1: Introduction

1.1 Osdag Internship

Osdag internship is provided under the FOSSEE project. FOSSEE project promotes the use of FOSS (Free/Libre and Open-Source Software) tools to improve the quality of education in our country. FOSSEE encourages the use of FOSS tools through various activities to ensure the availability of competent free software equivalent to commercial (paid) software.

The FOSSEE project is a part of the National Mission on Education through Information and Communication Technology (ICT), Ministry of Education, Government of India.

Osdag is one such open-source software that comes under the FOSSEE project. Osdag internship is provided through the FOSSEE project. Any UG/PG/Ph.D. holder can apply for this internship. And the selection will be based on a screening task.

1.2 What is Osdag?

Osdag is Free/Libre and Open-Source Software being developed for the design 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).

The source code is written in Python, 3D CAD images are developed using PythonOCC. GitHub is used to ensure smooth workflow between different modules and team members. It is in a path where people from around the world would be able to contribute to its development. FOSSEE's "Share alike" policy would improve the standard of the software when the source code is further modified based on the industrial and educational needs across the country.

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

Figure: Home page of OSDAG

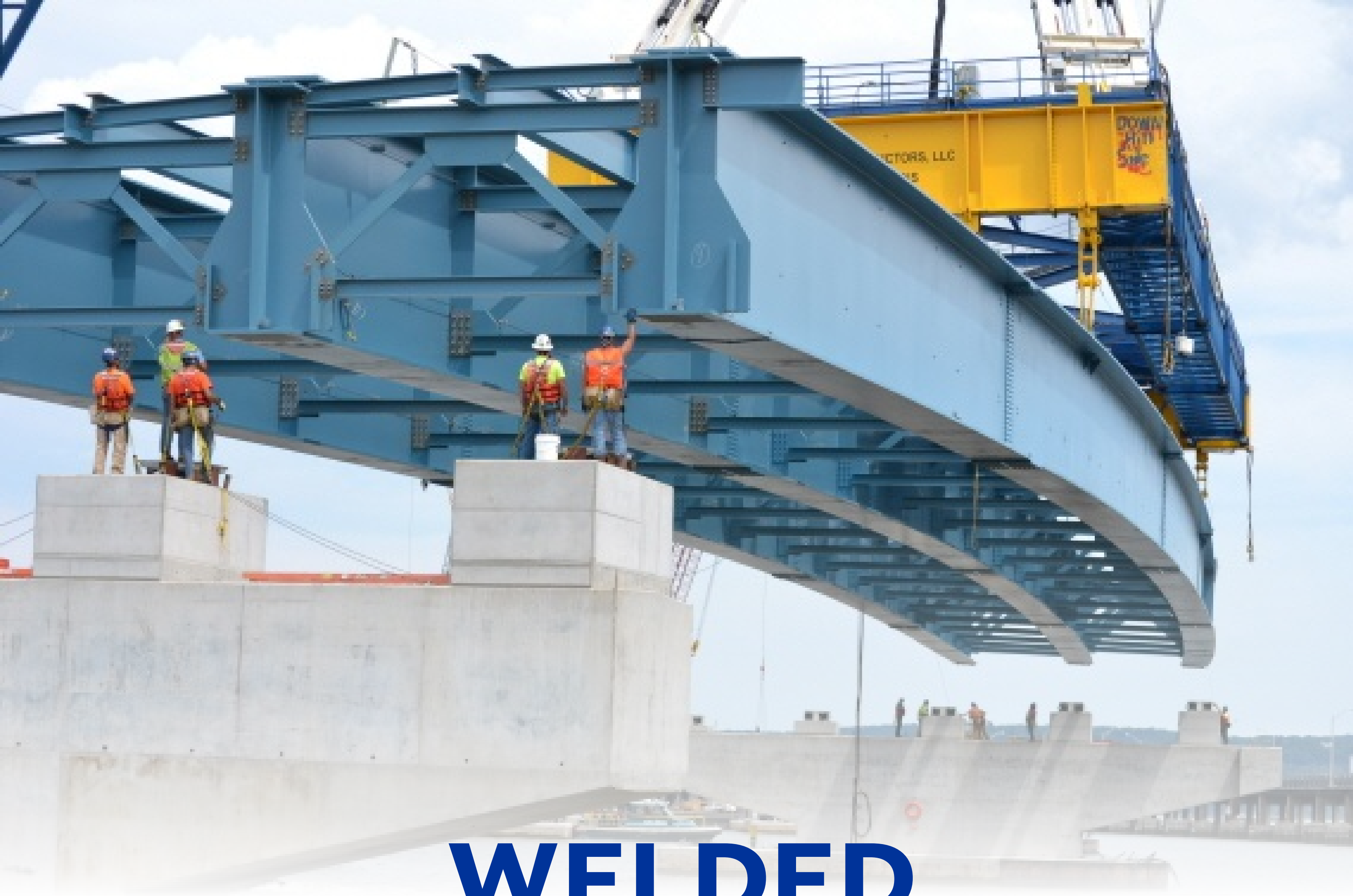
1.3 Who can use Osdag?

Osdag is primarily created for use in academia for students and teachers but industry professionals also find it useful. As Osdag is currently funded by MHRD, the 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. Its 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.

- 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

OSDAG can be downloaded from https://osdag.fossee.in/resources/downloads



WELDED PLATE GIRDER

Chapter 2: Plate Girders

2.1 Introduction

Plate girders are deep built-up flexural members used to resist high bending moments and shear forces over long spans where the standard rolled or compound beams cannot satisfy the design requirements. Generally, plate girders consist of two flange plates welded to web plate to form an I-section. The major function of the flange plates is to resist the stresses arising from the applied bending moments. The major aim of the web plate is to resist the applied shear forces. For making the plate girders light and economical, the web depth must be increased as possible to decrease the required flanges area while keeping the web thickness thin as possible. So, in addition to economy, they also provide maximum flexibility. The designer has the freedom to choose components of convenient size. It is possible to provide the exact amount of steel required at each section along the length of the girder by changing the flange areas and keeping the depth of the girder constant. In other words, it can be shaped to match the bending moment curve itself. Thus, a plate girder offers limitless possibilities to the creativity of the engineer.

Since the web is usually a slender plate, hence to prevent the girder from failing due to web bucking under shear force more than its capacity, vertical and horizontal stiffeners are used to avoid web buckling.

Figure: An example of a typical plate girder bridge

2.2 Elements of a Plate Girder

The most common components of welded stiffened and unstiffened plate girders are:

1. Web plate
2. Flange plate
3. End Bearing stiffeners
4. Load Bearing stiffeners
5. Intermediate transverse stiffeners
6. Longitudinal stiffeners
7. Connection between stiffeners, flange and the web

2.3 Assumptions made in the design algorithm of Plate Girder

1. The algorithm has been split in two separate modules namely:
    - Unstiffened Girder with thick web (without intermediate transverse stiffeners)
    - Stiffened Girder with thin web (with intermediate transverse stiffeners)
2. The bending moments are assumed to be carried by the flanges and the shear by the web.
3. The plate girder is assumed as simply supported and laterally restrained throughout.
4. The Self-weight of the Plate Girder (kN/m) is assumed as equal to (Factored UDL x Span Length / 400) where Factored UDL is in kN/m and Span Length in metres.
5. A total of four concentrated loads can be added by the user along with the uniformly distributed load.
6. The algorithm assumes a minimum thickness of 8 mm for any element.
7. A chamfer of 15mm has been assumed for the provision of fillet welds.

Osdag
Open steel design and graphics

Algorithm by: Aamir Durrany
(Intern, Osdag)

ALGORITHM: WELDED PLATE GIRDER (UNSTIFFENED THICK WEB)

INPUT DOCK:

Girder Details

Span Length (m)*	*min: 1, max: 50*	L
Imposed Factored UDL* (KN/m) Excluding Self Weight	*min: 1, max: 1000*	fact_udl
Concentrated Loads *	*No / Yes*	

If "Yes" then ask "Number of loads" and the following details according to the number of loads specified. (max 4)

Factored Load 1 (kN)*	*min: 1, max: 2000*	P1
Load 1 distance from left support (m) *	*min: 0.1, max: L-0.1*	a1
Factored Load 2 (kN)*	*min: 1, max: 2000*	P2
Load 2 distance from left support (m) *	*min: 0.1, max: L-0.1*	a2
Factored Load 3 (kN)*	*min: 1, max: 2000*	P3
Load 3 distance from left support (m) *	*min: 0.1, max: L-0.1*	a3
Factored Load 4 (kN)*	*min: 1, max: 2000*	P4
Load 4 distance from left support (m) *	*min: 0.1, max: L-0.1*	a4
Web Type	*Unstiffened Thick Web*	
Material Yield Stress (MPa) *	*250 MPa*	fy

The plate girder shall be assumed as simply supported and laterally restrained throughout.

STEP 1: LOAD CALCULATION

- $$\underset{kN/m}{self\_wt} = \frac{fact\_udl \times L}{400}$$

- $$\underset{kN/m}{w} = fact\_udl + self\_wt$$

- $b1 = L - a1$
- $b2 = L - a2$
- $b3 = L - a3$
- $b4 = L - a4$

- Calculate Shear Force at x=0, at x=L and under each concentrated load (at x=a1, at x=a2, at x=a3, at x=a4) using the below formula:

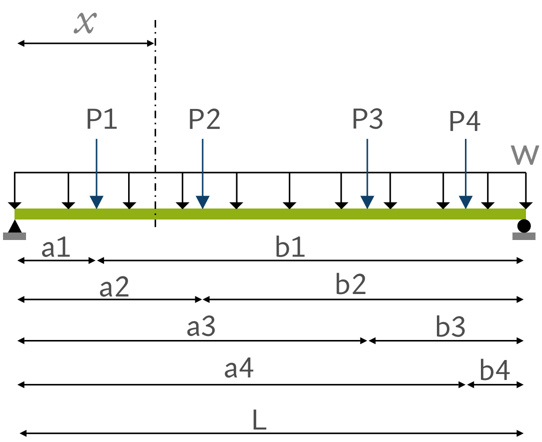
SF at any section 'x' metres from left support is given by:

$$SFx = \left(\frac{wL}{2} - wx\right) + \begin{Bmatrix} P1\ b1 / L & \textit{...if } x < a1 \\ -P1\ a1 / L & \textit{...if } x > a1 \\ \underbrace{\frac{P1\ b1}{L} \ \textbf{or}\ \frac{-P1\ a1}{L}}_{\text{whichever is greater in magnitude}} & \textit{...if } x = a1 \end{Bmatrix} + \begin{Bmatrix} P2\ b2 / L & \textit{...if } x < a2 \\ -P2\ a2 / L & \textit{...if } x > a2 \\ \underbrace{\frac{P2\ b2}{L} \ \textbf{or}\ \frac{-P2\ a2}{L}}_{\text{whichever is greater in magnitude}} & \textit{...if } x = a2 \end{Bmatrix}$$

$$+ \begin{Bmatrix} P3\ b3 / L & \textit{...if } x < a3 \\ -P3\ a3 / L & \textit{...if } x > a3 \\ \underbrace{\frac{P3\ b3}{L} \ \textbf{or}\ \frac{-P3\ a3}{L}}_{\text{whichever is greater in magnitude}} & \textit{...if } x = a3 \end{Bmatrix} + \begin{Bmatrix} P4\ b4 / L & \textit{...if } x < a4 \\ -P4\ a4 / L & \textit{...if } x > a4 \\ \underbrace{\frac{P4\ b4}{L} \ \textbf{or}\ \frac{-P4\ a4}{L}}_{\text{whichever is greater in magnitude}} & \textit{...if } x = a4 \end{Bmatrix}$$

- Calculate Maximum Shear Force (**SF_max**) using the above formula. It will be at either x=0 or at x=L.

References / Remarks



- Bending Moment at any section 'x' metres from left support is given by:

$$BMx = \frac{wx(L-x)}{2} + \begin{Bmatrix} \dfrac{P1\ b1\ x}{L} & ...if\ x \le a1 \\ \dfrac{P1\ b1\ x}{L} - P1\,(x-a1) & ...if\ x > a1 \end{Bmatrix}$$

$$+ \begin{Bmatrix} \dfrac{P2\ b2\ x}{L} & ...if\ x \le a2 \\ \dfrac{P2\ b2\ x}{L} - P2\,(x-a2) & ...if\ x > a2 \end{Bmatrix} + \begin{Bmatrix} \dfrac{P3\ b3\ x}{L} & ...if\ x \le a3 \\ \dfrac{P3\ b3\ x}{L} - P3\,(x-a3) & ...if\ x > a3 \end{Bmatrix}$$

$$+ \begin{Bmatrix} \dfrac{P4\ b4\ x}{L} & ...if\ x \le a4 \\ \dfrac{P4\ b4\ x}{L} - P4\,(x-a4) & ...if\ x > a4 \end{Bmatrix}$$

- Calculate Maximum Bending Moment (**BM_max**) using the above formula.

STEP 2: PROPORTIONING OF WEB

- epsilon = $\sqrt{250 / fy}$ *...Clause 8.4.2.1*

- Optimum depth of web (web_depth):

  web_depth *(mm)* = $(BM\_max \times 10^6 \times 200 \times epsilon / fy)^{0.33}$

  Ignore the post-decimal part & round it off to the nearest lower multiple of 10.

- Optimum thickness of web (web_thickness):

  web_thickness *(mm)* = $\left[\dfrac{BM\_max \times 10^6}{[200 \times epsilon]^2 \times fy}\right]^{0.33}$ *...Clause 8.6.1.1*

  Ignore the post-decimal part & round it off to the nearest higher multiple of 2.
  Minimum value of web_thickness = 8mm

STEP 3: PROPORTIONING OF FLANGE

- flange_area (mm²) $= \dfrac{\text{BM\_max} \times 10^6 \times 1.1}{\text{fy} \times \text{web\_depth}}$

- flange_breadth (mm) = 0.3 x web_depth

Ignore the post-decimal part & round it off to the nearest higher multiple of 10.

- flange_thickness (mm) = flange_area / flange_breadth

Ignore the post-decimal part & round it off to the nearest higher multiple of 5.
Minimum value of flange_thickness = 8mm.

STEP 4: CLASSIFICATION OF FLANGE

- flange_outstand (mm) = (flange_breadth - web_thickness) / 2

- Calculate: flange_outstand / flange_thickness

if $\dfrac{\text{flange\_outstand}}{\text{flange\_thickness}} \le 8.4 \times \text{epsilon}$ *then* **flange_type** = plastic

if $8.4 \times \text{epsilon} < \dfrac{\text{flange\_outstand}}{\text{flange\_thickness}} \le 9.4 \times \text{epsilon}$ *then* **flange_type** = compact

if $9.4 \times \text{epsilon} < \dfrac{\text{flange\_outstand}}{\text{flange\_thickness}} \le 13.6 \times \text{epsilon}$ *then* **flange_type** = semi_compact

if $\dfrac{\text{flange\_outstand}}{\text{flange\_thickness}} > 13.6 \times \text{epsilon}$ *then* **flange_type** = slender

STEP 5: CLASSIFICATION OF WEB

...Table 2 of the code

if $\dfrac{\text{web\_depth}}{\text{web\_thickness}} \le 84 \times \text{epsilon}$ *then* **web_type** = plastic

if $84 \times \text{epsilon} < \dfrac{\text{web\_depth}}{\text{web\_thickness}} \le 105 \times \text{epsilon}$ *then* **web_type** = compact

if $\dfrac{\text{web\_depth}}{\text{web\_thickness}} > 105 \times \text{epsilon}$ *then* **web_type** = slender

STEP 6: CALCULATE Zp AND Ze

- $Zp = 2\left[\text{flange\_breadth} \times \text{flange\_thickness} \times \left\{\frac{\text{web\_depth}}{2} + \frac{\text{flange\_thickness}}{2}\right\}\right]$
  (mm³)

- $\text{section\_depth} = \text{web\_depth} + 2(\text{flange\_thickness})$
  (mm)

- $Ze = \frac{2}{\text{section\_depth}} \times \left\{\frac{\text{flange\_breadth} \times (\text{section\_depth})^3}{12} - \frac{(\text{flange\_breadth} - \text{web\_thickness})(\text{web\_depth})^3}{12}\right\}$
  (mm³)

STEP 7: CHECK FOR BENDING STRENGTH OF FLANGE

...Clause 8.2.1.2

- $Bb = 1$ *...if flange_type = "plastic" or "compact"*
  $Bb = Ze / Zp$ *...if flange_type = "semi_compact" or "slender"*

- $\text{moment\_capacity} = Bb \times fy \times Zp \times 10^{-6} / 1.1$
  (KN m)

  if: moment_capacity > BM_max
  print "section is safe in bending" and proceed to the next step.

  else: increase **flange_thickness** by increments of 2 mm and repeat from Step-4 till here until **moment capacity > BM_max.**

STEP 8: CHECK FOR SHEAR STRENGTH OF WEB

...Clause 8.4.2.2
...Clause 8.6.1

- $\text{tau\_cr\_e} = \frac{5.35 \times \pi^2 \times 2 \times 10^5}{12(1 - 0.3^2)(\text{web\_depth} / \text{web\_thickness})^2}$
  (N / mm²)

- $\text{lamda\_1} = \sqrt{\frac{fy}{\sqrt{3} \times \text{tau\_cr\_e}}}$

- *if:* $\text{lamda\_1} \le 0.8$ *then:* $\textbf{tau\_b\_1} = fy / \sqrt{3}$

  if: $0.8 < \text{lamda\_1} < 1.2$ *then:* $\textbf{tau\_b\_1} = [1 - (\text{lamda\_1} - 0.8)](fy / \sqrt{3})$

  if: $\text{lamda\_1} \ge 1.2$ *then:* $\textbf{tau\_b\_1} = \frac{fy}{\sqrt{3}\,[\text{lamda\_1}]^2}$

- vcr = tau_b x web_depth x web_thickness x 10^{-3}
(kN)

absolute value of max Shear Force

- *if*: vcr > | SF_max | *print*: *"section is safe in shear" & proceed to next step.*
else: increase **web_thickness** by increments of 2 mm and repeat from Step-5 till here until **vcr > |SF_max|**

STEP 9: CHECK FOR LOCAL CAPACITY OF WEB

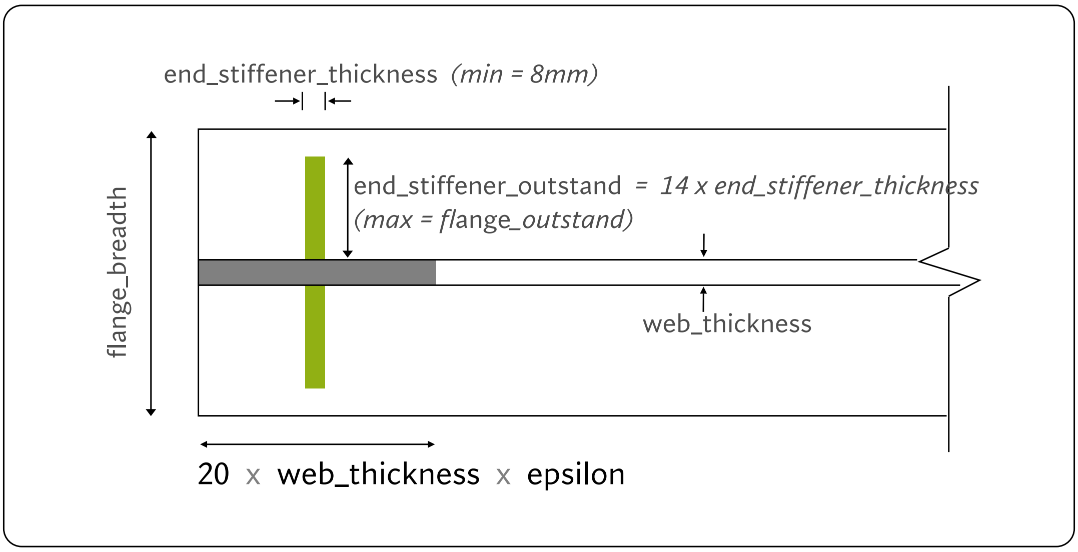
...Clause 8.7.4

- local_capacity_web = 2.5 x flange_thickness x web_thickness x fy x 10^{-3} / 1.1
(kN)

if: local_capacity_web > | SF_max |
print: *"End bearing stiffeners are not required since the local capacity of the web at its connection to the flange is greater than the reaction."* & directly go to **step-11.**

else if: local_capacity_web < | SF_max |
print: *"End bearing stiffeners are required since the local capacity of the web at its connection to the flange is less than the reaction."* & proceed to **next step.**

STEP 10: DESIGN OF END BEARING STIFFENER



Note: *If the loading is symmetrical, provide the same stiffener design on both the ends of the plate girder since the shear force will be same at both the ends and it will be the maximum (SF_max).*
In case of an unsymmetrical loading, only one of the end-support will have the max shear, the other being comparatively less. So in such a case, to achieve economy in design, this step needs to be performed at both the ends of the plate girder taking into account their respective shear forces.

DIMENSIONING:

...Clause 8.7.1.2

- *Initially assume:* end_stiffener_thickness = **8** mm
- end_stiffener_outstand = 14 x end_stiffener_thickness x epsilon

  *(Max permissible value = **flange_outstand**. Limit it at flange_outstand if it exceeds)*

Buckling Check:

- Calculate Effective area as: *...Clause 8.7.1.5*

  eff_area = (20 x web_thickness x epsilon x web_thickness) + 2(end_stiffener_outstand x end_stiffener_thickness)

- $$\text{moi} = \frac{20 \times \text{web\_thickness} \times \text{epsilon} \times (\text{web\_thickness})^3}{12} + \frac{\text{end\_stiffener\_thickness} \times (2 \times \text{end\_stiffener\_outstand})^3}{12}$$

- $r = \sqrt{\text{moi / eff\_area}}$
- lamda_2 = 0.7 x web_depth / r *...Clause 8.7.1.5*
- Calculate **fcd** from pg 42 - table 9c of IS 800:2007 through interpolation.
- buckling_resistance = eff_area x fcd x 10^{-3} *...(Total buckling resistance of the pair of stiffeners)*

  if: buckling_resistance < | SFx |

  then: increase **end_stiffener_thickness** by an increment of **2** mm and **repeat this step.**

  if: buckling_resistance > | SFx | *then:* proceed ahead.

Bearing Check:

- bearing_capacity =

$$\frac{2\,(\text{end\_stiffener\_outstand} - 15) \times \text{end\_stiffener\_thickness} \times \text{fy} \times 10^{-3}}{0.8 \times 1.1}$$

if: bearing_capacity < | SFx |

then: increase **end_stiffener_thickness** by an increment of **2** mm and **repeat this step.**

... | SFx | *is the absolute value of Shear Force at the location of the end-bearing stiffener.*

Note: Both the end-stiffeners of the pair shall have same dimensions.

STEP 11: DESIGN OF LOAD CARRYING STIFFENERS

...Clause 8.7.3

Perform this step only if user specifies Concentrated Loads in the input dock.

if: local_capacity_web > largest of {P1, P2, P3, P4}

then: print *"No load carrying stiffeners are required since the local capacity of the web at the position of concentrated loads is greater than the loads."*

and directly go to the **next step (step-12).**

if: local_capacity_web < **P1**

then:

print *"Load carrying stiffener is required below concentrated load 1"*

step 11.1 :

DIMENSIONING:

- *Initially assume:* load1_stiffener_thickness = **8** mm
- load1_stiffener_outstand = 14 x load1_stiffener_thickness x epsilon

  *(Max permissible value = **flange_outstand**. Limit it at flange_outstand if it exceeds)*

Buckling Check:

- Calculate Effective area as: *...Total effective area for the pair of stiffeners*

  eff_area_2 = (40 x web_thickness x epsilon x web_thickness) + 2(load1_stiffener_outstand x load1_stiffener_thickness)

- $$\text{moi\_2} = \frac{40 \times \text{web\_thickness} \times \text{epsilon} \times (\text{web\_thickness})^3}{12} + \frac{\text{load1\_stiffener\_thickness} \times (2 \times \text{load1\_stiffener\_outstand})^3}{12}$$
- $$\text{r\_2} = \sqrt{\text{moi\_2} / \text{eff\_area\_2}}$$
- lamda_3 = 0.7 x web_depth / r_2
- Calculate **fcd_2** from pg 42 - table 9c of IS 800:2007 through interpolation.
- buckling_resistance_2 = eff_area_2 x fcd_2 x 10^{-3}

if: buckling_resistance_2 < P1 *...Clause 8.7.5.1*

then: increase **load1_stiffener_thickness** by increment of **2** mm and repeat step 11.1

if: buckling_resistance_2 > P1 *then:* proceed ahead.

Bearing Check:

- bearing_capacity_2 =

$$\frac{2\,(\text{load1\_stiffener\_outstand} - 15) \times \text{load1\_stiffener\_thickness} \times f_y \times 10^{-3}}{0.8 \times 1.1}$$

if: bearing_capacity_2 < P1 *...Clause 8.7.5.2*

then: increase **load1_stiffener_thickness** by increment of 2 mm and repeat step 11.1

Note: Provide the stiffener on both the sides of the web.

if: local_capacity_web < **P2**

then:

print *"Load carrying stiffener is required below concentrated load 2"*

step 11.2 :

DIMENSIONING:

- *Initially assume:* load2_stiffener_thickness = **8** mm
- load2_stiffener_outstand = 14 x load2_stiffener_thickness x epsilon

  *(Max permissible value = **flange_outstand**. Limit it at flange_outstand if it exceeds)*

Buckling Check:

- Calculate Effective area as: *...Total effective area for the pair of stiffeners*

  eff_area_3 = (40 x web_thickness x epsilon x web_thickness) + 2(load2_stiffener_outstand x load2_stiffener_thickness)

- $$\text{moi\_3} = \frac{40 \times \text{web\_thickness} \times \text{epsilon} \times (\text{web\_thickness})^3}{12} + \frac{\text{load2\_stiffener\_thickness} \times (2 \times \text{load2\_stiffener\_outstand})^3}{12}$$

- $\text{r\_3} = \sqrt{\text{moi\_3} / \text{eff\_area\_3}}$

- lamda_4 = 0.7 x web_depth / r_3

- Calculate **fcd_3** from pg 42 - table 9c of IS 800:2007 through interpolation.

- buckling_resistance_3 = eff_area_3 x fcd_3 x 10^{-3}

  if: buckling_resistance_3 < P2 *...Clause 8.7.5.1*

  then: increase **load2_stiffener_thickness** by increment of **2** mm and repeat step 11.2

  if: buckling_resistance_3 > P2 *then:* proceed ahead.

Bearing Check:

- bearing_capacity_3 =

$$\frac{2\,(\text{load2\_stiffener\_outstand} - 15) \times \text{load2\_stiffener\_thickness} \times fy \times 10^{-3}}{0.8 \times 1.1}$$

if: bearing_capacity_3 < P2 *...Clause 8.7.5.2*

then: increase **load2_stiffener_thickness** by increment of 2 mm and repeat step 11.2

Note: Provide the stiffener on both the sides of the web.

if: local_capacity_web < **P3**

then:

print *"Load carrying stiffener is required below concentrated load 3"*

step 11.3 :

DIMENSIONING:

- *Initially assume:* load3_stiffener_thickness = **8** mm
- load3_stiffener_outstand = 14 x load3_stiffener_thickness x epsilon

  *(Max permissible value = **flange_outstand**. Limit it at flange_outstand if it exceeds)*

Buckling Check:

- Calculate Effective area as: *...Total effective area for the pair of stiffeners*

  eff_area_4 = (40 x web_thickness x epsilon x web_thickness) + 2(load3_stiffener_outstand x load3_stiffener_thickness)

- $$\text{moi\_4} = \frac{40 \times \text{web\_thickness} \times \text{epsilon} \times (\text{web\_thickness})^3}{12} + \frac{\text{load3\_stiffener\_thickness} \times (2 \times \text{load3\_stiffener\_outstand})^3}{12}$$

- $$\text{r\_4} = \sqrt{\text{moi\_4} / \text{eff\_area\_4}}$$

- lamda_5 = 0.7 x web_depth / r_4
- Calculate **fcd_4** from pg 42 - table 9c of IS 800:2007 through interpolation.
- buckling_resistance_4 = eff_area_4 x fcd_4 x 10^{-3}

if: buckling_resistance_4 < P3 *...Clause 8.7.5.1*

then: increase **load3_stiffener_thickness** by increment of **2** mm and repeat step 11.3

if: buckling_resistance_4 > P3 *then:* proceed ahead.

Bearing Check:

- bearing_capacity_4 =

$$\frac{2\,(\text{load3\_stiffener\_outstand} - 15) \times \text{load3\_stiffener\_thickness} \times \text{fy} \times 10^{-3}}{0.8 \times 1.1}$$

if: bearing_capacity_4 < P3 *...Clause 8.7.5.2*

then: increase **load3_stiffener_thickness** by increment of 2 mm and repeat step 11.3

Note: Provide the stiffener on both the sides of the web.

if: local_capacity_web < **P4**

then:

print *"Load carrying stiffener is required below concentrated load 4"*

step 11.4 :

DIMENSIONING:

- *Initially assume:* load4_stiffener_thickness = **8** mm
- load4_stiffener_outstand = 14 x load4_stiffener_thickness x epsilon

  *(Max permissible value = **flange_outstand**. Limit it at flange_outstand if it exceeds)*

Buckling Check:

- Calculate Effective area as: *...Total effective area for the pair of stiffeners*

  eff_area_5 = (40 x web_thickness x epsilon x web_thickness)
  + 2(load4_stiffener_outstand x load4_stiffener_thickness)

- $$\text{moi\_5} = \frac{40 \times \text{web\_thickness} \times \text{epsilon} \times (\text{web\_thickness})^3}{12} + \frac{\text{load4\_stiffener\_thickness} \times (2 \times \text{load4\_stiffener\_outstand})^3}{12}$$

- $$\text{r\_5} = \sqrt{\text{moi\_5} / \text{eff\_area\_5}}$$

- lamda_6 = 0.7 x web_depth / r_5
- Calculate **fcd_5** from pg 42 - table 9c of IS 800:2007 through interpolation.
- buckling_resistance_5 = eff_area_5 x fcd_5 x 10^{-3}

if: buckling_resistance_5 < P4 *...Clause 8.7.5.1*

then: increase **load4_stiffener_thickness** by increment of **2** mm and repeat step 11.4

if: buckling_resistance_5 > P4 *then:* proceed ahead.

Bearing Check:

- bearing_capacity_5 =

$$\frac{2\,(\text{load4\_stiffener\_outstand} - 15) \times \text{load4\_stiffener\_thickness} \times \text{fy} \times 10^{-3}}{0.8 \times 1.1}$$

if: bearing_capacity_5 < P4 *...Clause 8.7.5.2*

then: increase **load4_stiffener_thickness** by increment of 2 mm and repeat step 11.4

Note: Provide the stiffener on both the sides of the web.

STEP 12: DESIGN OF WELD AT WEB-FLANGE JUNCTION

- section_depth = web_depth + 2(flange_thickness)
- $$moi\_z = \frac{flange\_breadth \times (section\_depth)^3}{12} - \frac{(flange\_breadth - web\_thickness)\,(web\_depth)^3}{12}$$
- Calculate minimum weld strength required (qw): *(kN/mm)*

$$qw = \frac{|SF\_max| \times flange\_breadth \times flange\_thickness \times section\_depth}{2 \times 2 \times moi\_z}$$

*From the below table provide a suitable weld size (**s1**) whose design capacity just exceeds **qw**.*

Table-1: Design Capacity of fillet welds

Leg Length s (**mm**)	Design Capacity per unit run (**kN/mm**) for fy = 250 Mpa ; site welded
4	0.442
5	0.553
6	0.663
8	0.884
10	1.106
12	1.327
15	1.659
18	1.990
20	2.212
22	2.433
25	2.765

(Reference Book: N. Subramanian; Table: 6.5)

STEP 13: DESIGN OF WELD FOR END-BEARING STIFFENER

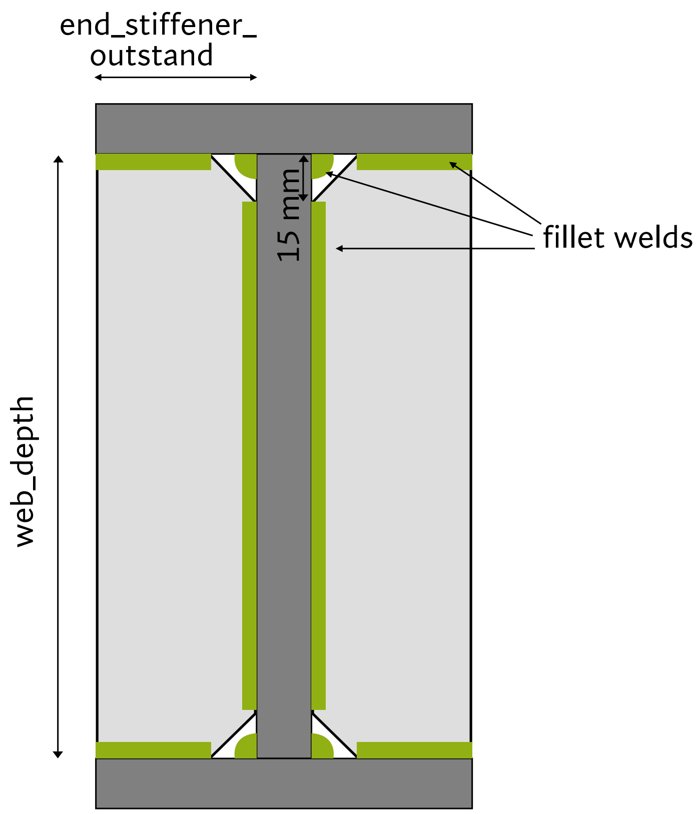
...Clause 8.7.2.6

This step is applicable when end stiffener is provided.

- Calculate minimum weld strength required q: *(kN/mm)*
- $q1 = \dfrac{\text{web\_thickness}^2}{5 \times \text{end\_stiffener\_outstand}}$
- $q2 = \dfrac{(|SFx| - \text{local\_capacity\_web}) / 2}{\text{web\_depth} - 30}$
- q = q1 + q2

*From table-1, provide a suitable weld size (**s2**) whose design capacity just exceeds **q**. provide same weld size to the stiffener on the opposite side of the web.*

Note: End-bearing stiffener is welded to web and also to compression & tension flanges. The weld is provided on both sides of the stiffener.



End Bearing Stiffener

STEP 14: DESIGN OF WELD FOR LOAD CARRYING STIFFENERS

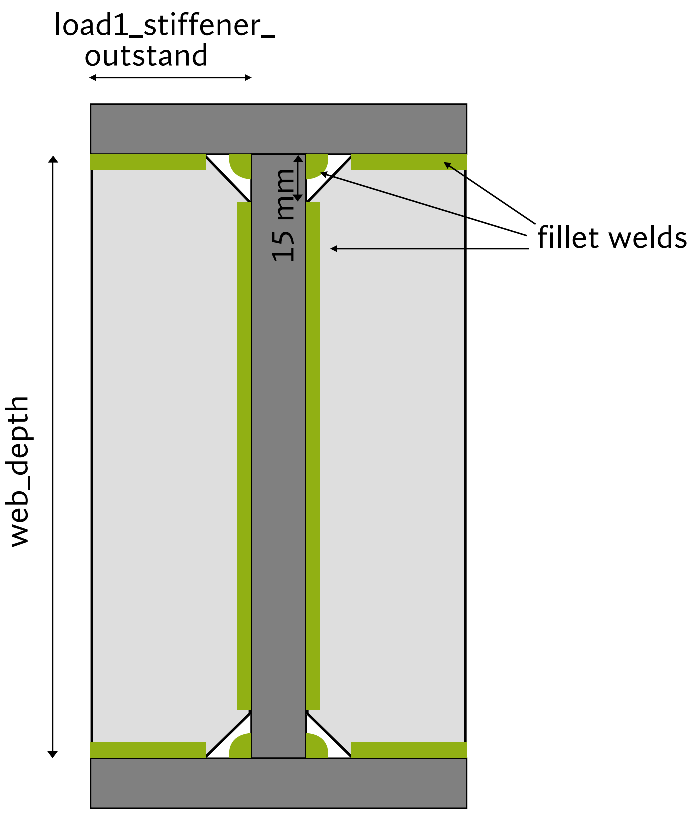
This step is applicable when load-carrying stiffener is provided.

- Calculate minimum weld strength required q: *(kN/mm)*
- $q3 = \dfrac{\text{web\_thickness}^2}{5 \times \text{load1\_stiffener\_outstand}}$
- $q4 = \dfrac{(|SFx| - \text{local\_capacity\_web}) / 2}{\text{web\_depth} - 30}$ ... | SFx | *is the absolute value of Shear Force at the location of this stiffener.*
- q_load1 = q3 + q4

*From table-1 provide a weld size **(s3)** whose design capacity just exceeds **q_load1.** provide same weld size to the stiffener on the opposite side of the web.*

Note: Load Carrying Stiffener is welded to web & also to compression & tension flanges. The weld is provided on both sides of the stiffener.

Note: Follow this same procedure for the design of all other Load Carrying Stiffeners. For brevity, those steps have not been shown.



Load-1 Carrying Stiffener

OUTPUT DOCK:

Load Calculation

Maximum Shear Force (kN)	*SF_max*
Maximum Bending Moment (kNm)	*BM_max*

Web Details

Web Thickness (mm)	*web_thickness*
Web Depth (mm)	*web_depth*
Local Capacity of Web (kN)	*local_capacity_web*
Shear Strength of Web (kN)	*vcr*
Classification of Web	*web_type*

Flange Details

Flange Breadth (mm)	*flange_breadth*
Flange Thickness (mm)	*flange_thickness*
Bending Strength (Moment Capacity) of Flange (kNm)	*moment_capacity*
Classification of Flange	*flange_type*

End Bearing Stiffener Details

Thickness (mm)	*end_stiffener_thickness*
Depth (mm)	*web_depth*
Outstand (mm)	*end_stiffener_outstand*
Buckling Resistance (kN)	*buckling_resistance*
Bearing Resistance (kN)	*bearing_capacity*

Load Bearing Stiffener Details

Stiffener Under Concentrated Load-1

Thickness (mm)	*load1_stiffener_thickness*
Depth (mm)	*web_depth*
Outstand (mm)	*load1_stiffener_outstand*
Buckling Resistance (kN)	*buckling_resistance_2*
Bearing Resistance (kN)	*bearing_capacity_2*

Do the same for stiffeners under other loads too.

Fillet Weld Details

At Web-Flange Junction

Size of Fillet Weld between Web-Flange Junction (mm)	*s1*
Strength of Fillet Weld between Web-Flange Junction (kN/mm)	*corresponding capacity*

For End Stiffeners

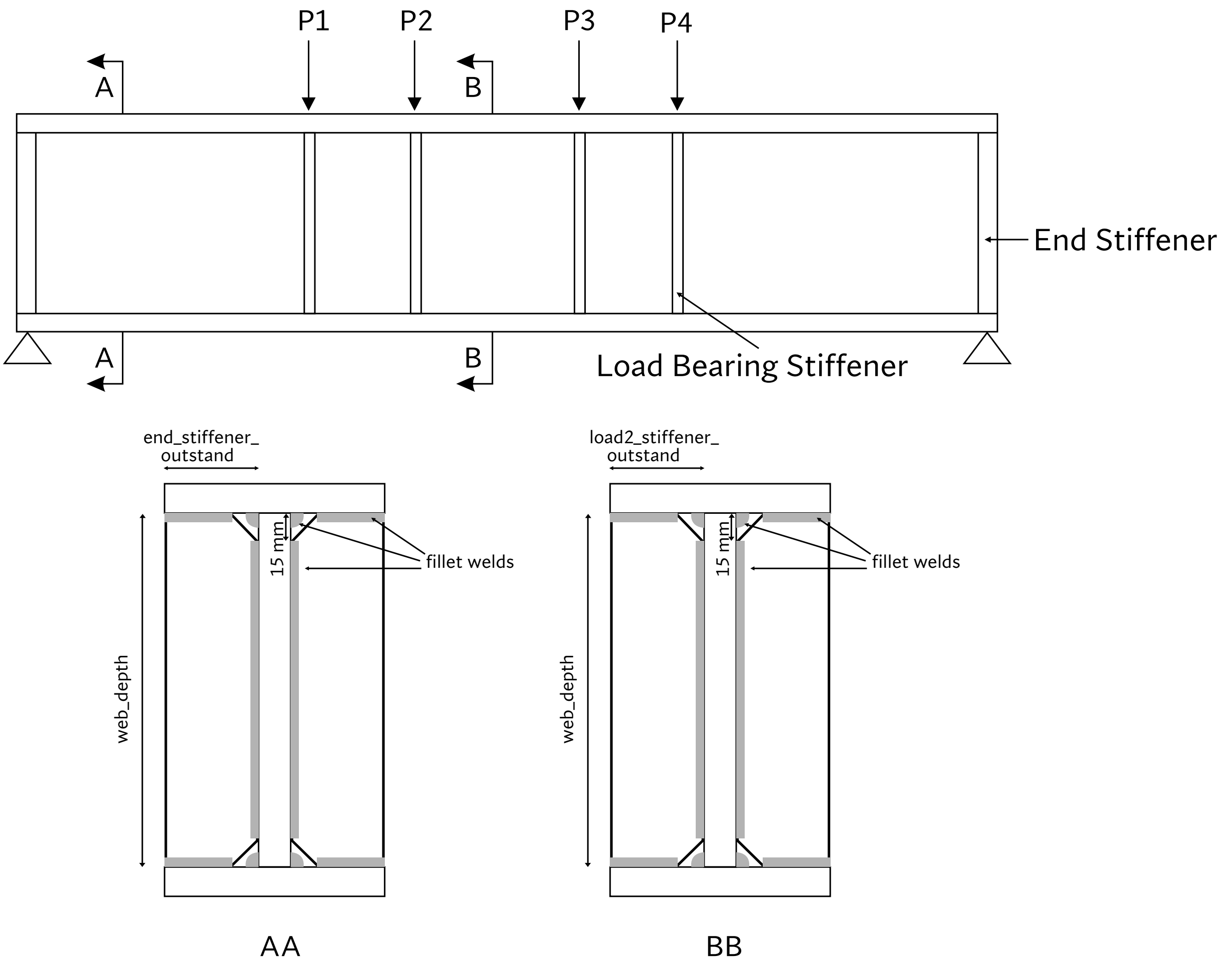
Size of Fillet Weld for End Stiffeners (mm)	*s2*
Strength of Fillet Weld of End Stiffeners (kN/mm)	*corresponding capacity*

For Load Carrying Stiffeners

Stiffener Under Concentrated Load-1:

Size of Fillet Weld (mm)	*s3*
Strength of Fillet Weld (kN/mm)	*corresponding capacity*

Do the same for stiffeners under other loads too.



End of Algorithm

Example-1

- span length (m) = 24
- Imposed factored UDL (KN/m) = 100
- Web type : unstiffened thick web
- Material yield stress = 250 MPa

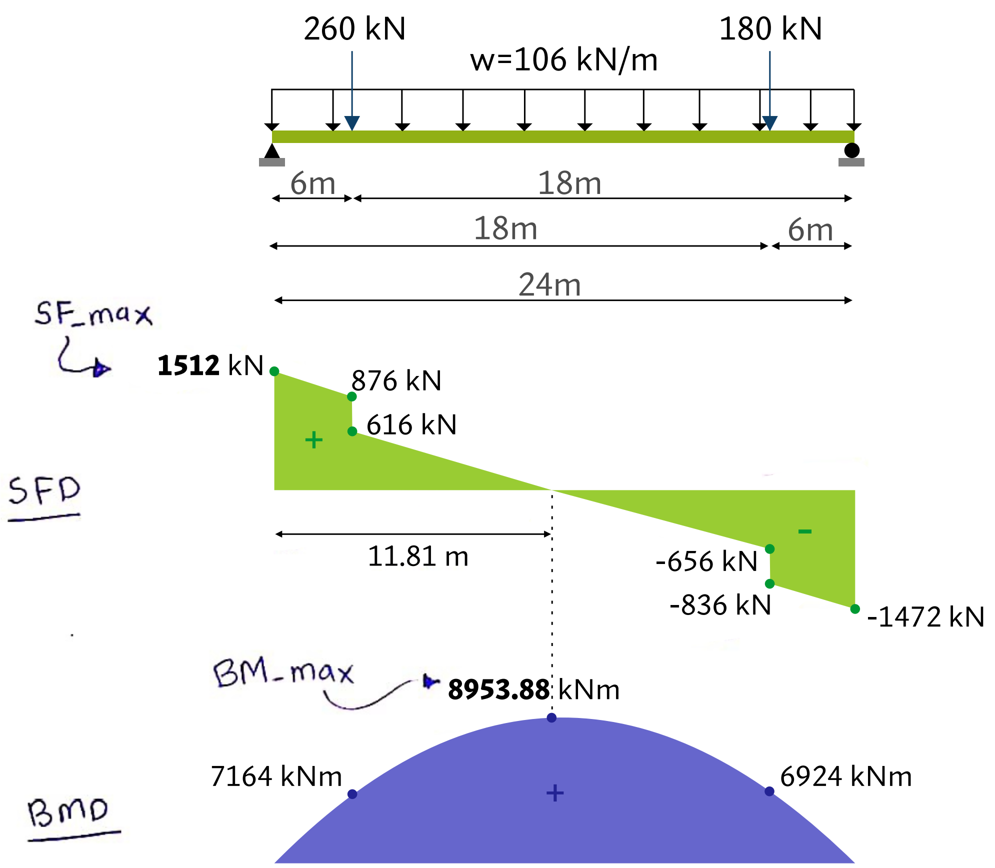
CONCENTRATED LOADS:

- Factored load 1 (KN) = 260
- Distance from left (m) = 6

- Factored load 2 (KN) = 180
- Distance from left (m) = 18

STEP 1 : LOAD CALCULATION

- self weight = 100 × 24/400 = 6 KN/m
- Total UDL (w) = 100 + 6 = 106 KN/m



- $SF(\text{at } x=0) = \left(\frac{106\times24}{2} - 0\right) + \left\{\frac{260\times18}{24}\right\} + \left\{\frac{180\times6}{24}\right\} = 1512$

- $SF(\text{at } x=18) = \left[\frac{106\times24}{2} - 106(18)\right] + \left\{\frac{-260\times6}{24}\right\} + \left\{\begin{matrix}45\\ \boxed{\text{OR}}\\ -135\end{matrix}\right\} = -836$

Point of max BM will lie at point of zero shear. Point of zero shear would lie between the two point loads, ie, between $x = 6$ and $x = 18$. The shear force equation for this section (b/w $x = 6$ & 18) is :

$$SF_{(6<x<18)} = 1512 - 106x - 260$$

$$0 = 1512 - 106x - 260 \Rightarrow \boxed{x = 11.81\ m}$$

So, BM @ $x = 11.81$ is calculated as:

$$BM(x = 11.81) = \frac{106 \times 11.81(24 - 11.81)}{2} + \left\{\frac{260 \times 18 \times 11.81}{24}\right\} - 260(11.81 - 6)$$

$$+ \frac{180 \times 6 \times 11.81}{24}$$

$$BM_{max} = 8953.88\ kN \cdot m$$

STEP 2 : PROPORTIONING OF WEB

- $\varepsilon = \sqrt{250/250} = 1$
- Optimum depth of web $= \left[\frac{8953.88 \times 10^6 \times 200}{250}\right]^{0.33} = 1787.24 \approx 1780\ mm$

  $\therefore \boxed{d = 1780\ mm}$
- optimum thickness of web $= \left[\frac{8953.88 \times 10^6}{(200)^2 \times 250}\right]^{0.33} = 9.42 \approx 10\ mm$

  $\therefore \boxed{t_w = 10\ mm}$

STEP 3 : PROPORTIONING OF FLANGE

- Flange area $= \frac{BM_{max} \times \gamma_{mo}}{f_y \times d} = \frac{8953.88 \times 10^6 \times 1.1}{250 \times 1780} = 22133.1$
- Flange breadth $= 0.3 \times 1780 = 534 \approx \boxed{540\ mm}$
- Flange thickness $= \frac{22133.1}{540} = 40.9 \approx$ $\boxed{45\ mm}$

STEP 4 : CLASSIFICATION OF FLANGE

- Flange outstand $= (540-10)/2 = 265$ mm
- $\frac{b}{t_f} \to \frac{\text{outstand}}{\text{thickness}} = \frac{265}{45} = 5.8$ — since its less than 8.4ε $\therefore$ flange type = plastic

STEP 5 : CLASSIFICATION OF WEB

- $\frac{\text{web depth}}{\text{web thickness}} = \frac{1780}{10} = 178$ — since its greater than 105ε $\therefore$ web type = slender

STEP 6 : CALCULATE Z_p and Z_e

- $$Z_p = 2\Big[\underbrace{b_f \cdot t_f}_{\text{area}} \underbrace{\left\{\frac{d}{2} + \frac{t_f}{2}\right\}}_{\bar{y}}\Big] = 2\left[540 \times 45 \left\{\frac{1780}{2} + \frac{45}{2}\right\}\right]$$
  $$= 44347500 \text{ mm}^3$$

- section depth $(D) = 1780 + 2(45) = 1870$
- $$Z_e = \frac{I}{\bar{y}} \quad I \to \frac{b_f D^3}{12} - \frac{2(\text{outstand})d^3}{12}, \quad \bar{y} \to D/2$$
  $$= \frac{2}{1870} \times \left\{\frac{540 \times (1870)^3}{12} - \frac{(540-10)(1780)^3}{12}\right\} = 48315602.5 \text{ mm}^3$$

STEP 7 : CHECK FOR BENDING STRENGTH OF FLANGE

- $\beta_b = 1$ $\because$ flange type = plastic
- moment capacity $= \frac{\beta_b \cdot f_y \cdot Z_p}{\gamma_{mo}} = \frac{250 \times 44347500 \times 10^{-6}}{1.1}$

$$= 10078.97 \text{ KN.m}$$

since moment capacity (10078.97 KNm) is greater than the maximum bending moment (8953.88 KN.m), hence the section is safe in bending.

STEP 8 : CHECK FOR SHEAR STRENGTH OF WEB

- Elastic critical shear stress $\tau_{cr,e} = \dfrac{k_v \cdot \pi^2 \cdot E}{12(1-\mu^2)(d/t_w)^2}$

$$\therefore \tau_{cr,e} = \frac{5.35 \times \pi^2 \times 2\times10^5}{12(1-0.3^2)(178)^2} = 30.52$$

- $\lambda = \sqrt{250/\sqrt{3} \times 30.52} = 2.17$

$$\because \lambda = 2.17 > 1.2 \quad \therefore \underbrace{\tau_{b1}}_{\text{shear stress corresponding to buckling}} = \frac{f_y}{\sqrt{3}\,\lambda^2} = 250/\sqrt{3}\,(2.17)^2 = 30.65$$

- $\underbrace{V_{cr}}_{\text{shear force corresponding to web buckling}} = \tau_b \cdot d \cdot t_w = 30.65 \times 1780 \times 10 \times 10^{-3} = 545.6\ \text{KN}$

$$\boxed{V_{cr} = 545.6\ \text{KN}}$$

since V_{cr} (545.6 KN) < Max shear force (1512 KN) ; we shall increase web thickness by increments of 2mm & repeat from step-5 till here until $V_{cr} > SF_{max}$. ⚠

Web thickness of 16 mm satisfies the criteria. All the iterations and calculations have not been shown for brevity. Below is the summary of the result:

- web type = slender (unchanged) ... step-5
- Z_p = unchanged
- section depth = unchanged
- I_e = 51331512.66 (changed) 6.24% ↑

$\Big\}$ step-6

- β_b = unchanged
- moment capacity = unchanged

$\Big\}$ step-7

- $\tau_{cr,e}$ = 78.137
- λ = 1.359
- τ_b = 78.15
- V_{cr} = $\boxed{2225.71}$ (307.9% ↑) Safe in shear
- new web thickness → 16 (60% ↑)

$\Big\}$ Step-8

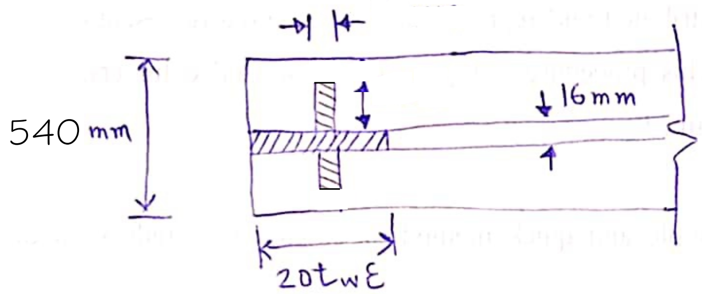
STEP-9: CHECK FOR LOCAL CAPACITY OF WEB

- local capacity of web $= 2.5 \times t_f \times t_w \times f_y / \gamma_{m0} = \dfrac{2.5 \times 45 \times 16 \times 250 \times 10^{-3}}{1.1}$

$= \boxed{409\ kN} < 1512\ kN$ ⚠

End bearing stiffeners are required since the local capacity of the web at its connection to the flange is less than the reaction.

STEP-10: DESIGN OF END BEARING STIFFENER



- Effective area = area of shaded region $= (20 \times 16 \times 16) + 2(112 \times 8)$
$= 6912\ mm^2$
- $moi = \dfrac{20 \times 16 \times (16)^3}{12} + \dfrac{8 \times (2 \times 112)^3}{12} = 7602176\ mm^4$
- $r = \sqrt{moi / 6912} = 33.16$
- $\lambda = 0.7 \times 1780 / 33.16 = 37.57$
- $f_{cd} = 201.15$
- Buckling resistance = eff. area $\times f_{cd} \times 10^{-3} = 1390.41$ kN
< 1512 kN (SF_max) ⚠

Hence increase the thickness by 2mm (new thickness = 10mm)

- Revised eff area = 7920
- Revised moi = 18402560
- Revised r = 48.2
- Revised lamda = 25.84
- Revised fcd = 216.4
- Buckling Resistance = 1713.95 kN

✔ Since Buckling Resistance (1713.95 kN) > 1512 kN (SF_max), the stiffener is safe in bucking.

- bearing capacity $= \dfrac{2(b_s - 15)\, t_q \times f_y}{0.8 \times 1.1} = \dfrac{2 \times (140-15) \times 10 \times 250}{0.8 \times 1.1} \times 10^{-3}$

$= 710.22$ kN < 1512 kN (SF_max) ⚠

So increase thickness by increments of 2mm & repeat this step until the check is satisfied.

Thicknesses of 12 and 14 mm were found to be insufficient. Thickness of 16 mm satisfies the Bearing check. So all the revised values are:

- Revised eff area = 12288
- Revised moi = 119996416
- Revised r = 98.82
- Revised lamda = 12.6
- Revised fcd = 224.97
- Buckling Resistance = $\boxed{2764.45 \text{ kN}}$

- Revised Bearing Resistance = 1900 kN > 1512 kN (SF_max)
  Hence the stiffener is now safe in Bearing.

STEP-11: DESIGN OF LOAD CARRYING STIFFENERS

since local capacity of web (409 KN) is greater than the largest concentrated load (260 KN), hence no load carrying stiffeners are required.

STEP-12: DESIGN OF WELD AT WEB-FLANGE JUNCTION

- section depth = 1870 mm
- $I_z = \frac{540 \times 1870^3}{12} - \frac{(540-10)(1780)^3}{12} = 4.5175 \times 10^{10}$
- minimum weld strength required:

$$q_w = \frac{1512 \times 540 \times 45 \times 1870}{2 \times 2 \times 4.5175 \times 10^{10}} = 0.380 \text{ KN/mm}$$

Provide a pair of 4mm fillet welds. (Table 1 of algorithm)
Design capacity = 0.442 KN/mm > 0.380 KN/mm ∴ SAFE

STEP-13: DESIGN OF WELD FOR END-BEARING STIFFENER

- $q_1 = \frac{t_w^2}{5 \times b_s} = \frac{16^2}{5 \times 262} = 0.195$

- $q_2 = \frac{(SF_{max} - \text{local capacity of web})/2}{\text{depth of web} - 30} = \frac{(1512 - 409)/2}{1780 - 30} = 0.315$

- $q = q_1 + q_2 = 0.195 + 0.315 = 0.51$ KN/mm.

Provide a pair of 5 mm fillet welds.
Design capacity = 0.553 KN/mm > 0.51 KN/mm ∴ SAFE

OUTPUT DOCK:

Load Calculation

Maximum Shear Force (kN)	1512
Maximum Bending Moment (kNm)	8953.88

Web Details

Web Thickness (mm)	10
Web Depth (mm)	1780
Local Capacity of Web (kN)	255.68
Shear Strength of Web (kN)	767.17
Classification of Web	slender

Flange Details

Flange Breadth (mm)	540
Flange Thickness (mm)	45
Bending Strength (Moment Capacity) of Flange (kNm)	10078.97
Classification of Flange	plastic

End Bearing Stiffener Details

Thickness (mm)	16
Depth (mm)	1780
Outstand (mm)	224
Buckling Resistance (kN)	2764.45
Bearing Resistance (kN)	1900

Fillet Weld Details

At Web-Flange Junction

Size of Fillet Weld between Web-Flange Junction (mm)	4
Strength of Fillet Weld between Web-Flange Junction (kN/mm)	0.442

For End Stiffeners

Size of Fillet Weld for End Stiffeners (mm)	5
Strength of Fillet Weld of End Stiffeners (kN/mm)	0.553

End of Example

Algorithm by: Aamir Durrany
(Intern, Osdag)

ALGORITHM: WELDED PLATE GIRDER (STIFFENED THIN WEB)

INPUT DOCK:

Girder Details

Span Length (m)*	*min: 1, max: 50*	L
Imposed Factored UDL* (KN/m) Excluding Self Weight	*min: 1, max: 1000*	fact_udl
Concentrated Loads *	*No / Yes*	

If "Yes" then ask "Number of loads" and the following details according to the number of loads specified. (max 4)

Factored Load 1 (kN)*	*min: 1, max: 2000*	P1
Load 1 distance from left support (m) *	*min: 0.1, max: L-0.1*	a1
Factored Load 2 (kN)*	*min: 1, max: 2000*	P2
Load 2 distance from left support (m) *	*min: 0.1, max: L-0.1*	a2
Factored Load 3 (kN)*	*min: 1, max: 2000*	P3
Load 3 distance from left support (m) *	*min: 0.1, max: L-0.1*	a3
Factored Load 4 (kN)*	*min: 1, max: 2000*	P4
Load 4 distance from left support (m) *	*min: 0.1, max: L-0.1*	a4
Web Type	*Stiffened Thin Web*	
Stiffener spacing-to-web-depth (c/d) ratio*	*min: 0.1, max: 3*	c_by_d
Material Yield Stress (MPa) *	*250 MPa*	fy

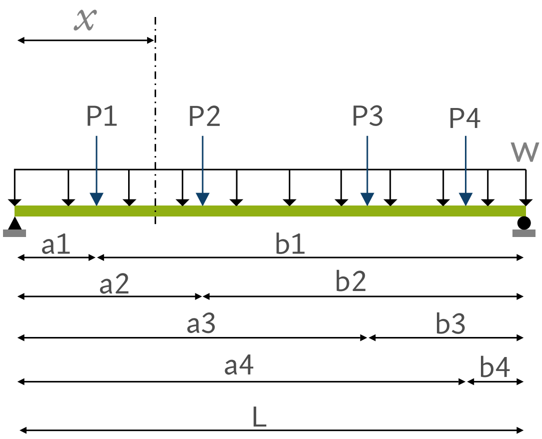
(The final c/d ratio may be slightly lower than this in order to provide equally spaced intermediate transverse stiffeners)

The plate girder shall be assumed as simply supported and laterally restrained throughout.

STEP 1: LOAD CALCULATION

References / Remarks

- $$\underset{\text{kN/m}}{\text{self\_wt}} = \frac{\text{fact\_udl} \times L}{400}$$
- $$\underset{\text{kN/m}}{w} = \text{fact\_udl} + \text{self\_wt}$$
- $b1 = L - a1$
- $b2 = L - a2$
- $b3 = L - a3$
- $b4 = L - a4$



- Calculate Shear Force at x=0, at x=L and under each concentrated load (at x=a1, at x=a2, at x=a3, at x=a4) using the below formula:

SF at any section 'x' metres from left support is given by:

$$SFx = \left(\frac{wL}{2} - wx\right) + \begin{cases} P1\ b1 / L & \text{...if } x < a1 \\ -P1\ a1 / L & \text{...if } x > a1 \\ \dfrac{P1\ b1}{L} \ \textbf{or} \ \dfrac{-P1\ a1}{L} & \text{...if } x = a1 \end{cases} + \begin{cases} P2\ b2 / L & \text{...if } x < a2 \\ -P2\ a2 / L & \text{...if } x > a2 \\ \dfrac{P2\ b2}{L} \ \textbf{or} \ \dfrac{-P2\ a2}{L} & \text{...if } x = a2 \end{cases}$$

whichever is greater in magnitude *whichever is greater in magnitude*

$$+ \begin{cases} P3\ b3 / L & \text{...if } x < a3 \\ -P3\ a3 / L & \text{...if } x > a3 \\ \dfrac{P3\ b3}{L} \ \textbf{or} \ \dfrac{-P3\ a3}{L} & \text{...if } x = a3 \end{cases} + \begin{cases} P4\ b4 / L & \text{...if } x < a4 \\ -P4\ a4 / L & \text{...if } x > a4 \\ \dfrac{P4\ b4}{L} \ \textbf{or} \ \dfrac{-P4\ a4}{L} & \text{...if } x = a4 \end{cases}$$

whichever is greater in magnitude *whichever is greater in magnitude*

- Calculate Maximum Shear Force (**SF_max**) using the above formula. It will be at either x=0 or at x=L.

- Bending Moment at any section 'x' metres from left support is given by:

$$BMx = \frac{wx(L-x)}{2} + \left\{ \begin{array}{ll} \dfrac{P1\ b1\ x}{L} & \textit{...if } x \le a1 \\ \dfrac{P1\ b1\ x}{L} - P1\,(x-a1) & \textit{...if } x > a1 \end{array} \right\}$$

$$+ \left\{ \begin{array}{ll} \dfrac{P2\ b2\ x}{L} & \textit{...if } x \le a2 \\ \dfrac{P2\ b2\ x}{L} - P2\,(x-a2) & \textit{...if } x > a2 \end{array} \right\} + \left\{ \begin{array}{ll} \dfrac{P3\ b3\ x}{L} & \textit{...if } x \le a3 \\ \dfrac{P3\ b3\ x}{L} - P3\,(x-a3) & \textit{...if } x > a3 \end{array} \right\}$$

$$+ \left\{ \begin{array}{ll} \dfrac{P4\ b4\ x}{L} & \textit{...if } x \le a4 \\ \dfrac{P4\ b4\ x}{L} - P4\,(x-a4) & \textit{...if } x > a4 \end{array} \right\}$$

- Calculate Maximum Bending Moment (**BM_max**) using the above formula.

STEP 2: PROPORTIONING OF WEB

- epsilon = $\sqrt{250 / fy}$ *...Clause 8.4.2.1*

- Optimum depth of web (web_depth):

  $$\underset{(mm)}{\text{web\_depth}} = (\text{BM\_max} \times 10^6 \times 200 \times \text{epsilon} / fy)^{0.33}$$

  Ignore the post-decimal part & round it off to the nearest lower multiple of 10.

- Optimum thickness of web (web_thickness):

  $$\underset{(mm)}{\text{web\_thickness}} = \left[\frac{\text{BM\_max} \times 10^6}{[200 \times \text{epsilon}]^2 \times fy} \right]^{0.33}$$ *...Clause 8.6.1.1*

  Ignore the post-decimal part & round it off to the nearest higher multiple of 2.
  Minimum value of web_thickness = 8mm

STEP 3: PROPORTIONING OF FLANGE

- flange_area (mm²) $= \dfrac{\text{BM\_max} \times 10^6 \times 1.1}{\text{fy} \times \text{web\_depth}}$

- flange_breadth (mm) $=$ 0.3 x web_depth

Ignore the post-decimal part & round it off to the nearest higher multiple of 10.

- flange_thickness (mm) $=$ flange_area / flange_breadth

Ignore the post-decimal part & round it off to the nearest higher multiple of 5.
Minimum value of flange_thickness = 8mm.

STEP 4: CLASSIFICATION OF FLANGE

- flange_outstand (mm) = (flange_breadth - web_thickness) / 2

- Calculate: flange_outstand / flange_thickness

if $\dfrac{\text{flange\_outstand}}{\text{flange\_thickness}} \leq 8.4 \times \text{epsilon}$ *then* **flange_type** = plastic

if $8.4 \times \text{epsilon} < \dfrac{\text{flange\_outstand}}{\text{flange\_thickness}} \leq 9.4 \times \text{epsilon}$ *then* **flange_type** = compact

if $9.4 \times \text{epsilon} < \dfrac{\text{flange\_outstand}}{\text{flange\_thickness}} \leq 13.6 \times \text{epsilon}$ *then* **flange_type** = semi_compact

if $\dfrac{\text{flange\_outstand}}{\text{flange\_thickness}} > 13.6 \times \text{epsilon}$ *then* **flange_type** = slender

STEP 5: CLASSIFICATION OF WEB

...Table 2 of the code

if $\dfrac{\text{web\_depth}}{\text{web\_thickness}} \leq 84 \times \text{epsilon}$ *then* **web_type** = plastic

if $84 \times \text{epsilon} < \dfrac{\text{web\_depth}}{\text{web\_thickness}} \leq 105 \times \text{epsilon}$ *then* **web_type** = compact

if $\dfrac{\text{web\_depth}}{\text{web\_thickness}} > 105 \times \text{epsilon}$ *then* **web_type** = slender

STEP 6: CALCULATE Zp AND Ze

- Zp (mm³) = $2\left[\text{flange\_breadth} \times \text{flange\_thickness} \times \left\{\frac{\text{web\_depth}}{2} + \frac{\text{flange\_thickness}}{2}\right\}\right]$
- section_depth (mm) = web_depth + 2(flange_thickness)
- Ze (mm³) = $\frac{2}{\text{section\_depth}} \times \left\{\frac{\text{flange\_breadth} \times (\text{section\_depth})^3}{12} - \frac{(\text{flange\_breadth} - \text{web\_thickness})(\text{web\_depth})^3}{12}\right\}$

STEP 7: CHECK FOR BENDING STRENGTH OF FLANGE

...Clause 8.2.1.2

- Bb = 1 *...if flange_type = "plastic" or "compact"*

  Bb = Ze / Zp *...if flange_type = "semi_compact" or "slender"*

- moment_capacity (KN m) = Bb x fy x Zp x 10^{-6} / 1.1

  if: moment_capacity > BM_max

  print "section is safe in bending" and proceed to the next step.

  else: increase **flange_thickness** by increments of 2 mm and repeat from Step-4 till here until **moment capacity > BM_max.**

STEP 8: CHECK FOR SHEAR STRENGTH OF WEB

...Clause 8.4.2.2
...Clause 8.6.1

- Calculate: **spacing** (mm) = c_by_d x web_depth
- Calculate: **no_of_panels** = L x 1000 / spacing

  Round it off to the nearest higher integer

- Re-Calculate: **spacing** = L x 1000 / no_of_panels
- Re-Calculate: **c_by_d** = spacing / web_depth
- *If* **c_by_d ⩾ 1**: *then* **kv** = $5.35 + \frac{4}{(\text{c\_by\_d})^2}$
- *else if* **c_by_d < 1**: *then* **kv** = $4 + \frac{5.35}{(\text{c\_by\_d})^2}$
- tau_cr_e (N / mm²) = $\frac{kv \times \pi^2 \times 2 \times 10^5}{12(1 - 0.3^2)(\text{web\_depth} / \text{web\_thickness})^2}$

- lamda_1 $= \sqrt{\dfrac{fy}{\sqrt{3} \times tau\_cr\_e}}$

- *if:* lamda_1 $\leq$ 0.8 *then:* **tau_b_1** = fy /$\sqrt{3}$

  if: 0.8 < lamda_1 < 1.2 *then:* **tau_b_1** = [1 - (lamda_1 - 0.8)] (fy /$\sqrt{3}$)

  if: lamda_1 $\geq$ 1.2 *then:* **tau_b_1** $= \dfrac{fy}{\sqrt{3}\ [lamda\_1]^2}$

- **vcr** = tau_b x web_depth x web_thickness x 10^{-3}
  (kN)

  absolute value of max Shear Force

- *if:* vcr > | SF_max |
  then: change the **web_thickness** to **8** mm and repeat from **Step-5** till here.

- *if:* vcr > | SF_max |
  then print: *"The web is stocky enough to need any intermediate transverse stiffeners even at the least permissible value of web thickness (8mm). So based on the input loads, we recommend you to design this Plate Girder as an Unstiffened Girder. We have a separate module for it."* ***and terminate the algorithm here.***

STEP 8-B: CHECK FOR ADEQUACY OF END-PANEL

...Shear & Moment Capacity Checks (Vn > Rtf ; Mq > Mtf)

Check for Shear Capacity:

- **vdp** = web_depth x web_thickness x fy x 10^{-3} / $\sqrt{3}$
  (kN)

- **hq** $= 1.25 \times vdp \left[1 - \dfrac{vcr}{vdp} \right]^{0.5}$ *... hq is the Longitudinal Shear*
  (kN)

- **rtf** = hq / 2
  (kN)

- **vn** $= \dfrac{web\_depth \times web\_thickness \times fy \times 10^{-3}}{\sqrt{3} \times 1.1}$ *... vn is the Nominal Shear Capacity*
  (kN)

if: vn < rtf *then:* increase web_thickness by 2mm and repeat from **Step-5** till here.
if: vn > rtf *then:* print *"End Panel is safe in shear" and proceed ahead.*

Check for Moment Capacity:

- **mtf** = hq x web_depth x 10^{-3} / 10
  (kNm)

- **moi_panel** = web_thickness x $(\text{spacing})^3$ / 12
  (mm⁴)

- **mq** = $\dfrac{\text{moi\_panel} \times \text{fy} \times 10^{-6}}{(\text{spacing} / 2) \times 1.1}$
  (kNm)

if: mq < mtf *then:* increase web_thickness by 2mm and repeat from **Step-5** till here.
if: mq > mtf *then:* print *"End Panel is safe in bending" and proceed ahead.*

STEP 9: CHECK FOR LOCAL CAPACITY OF WEB

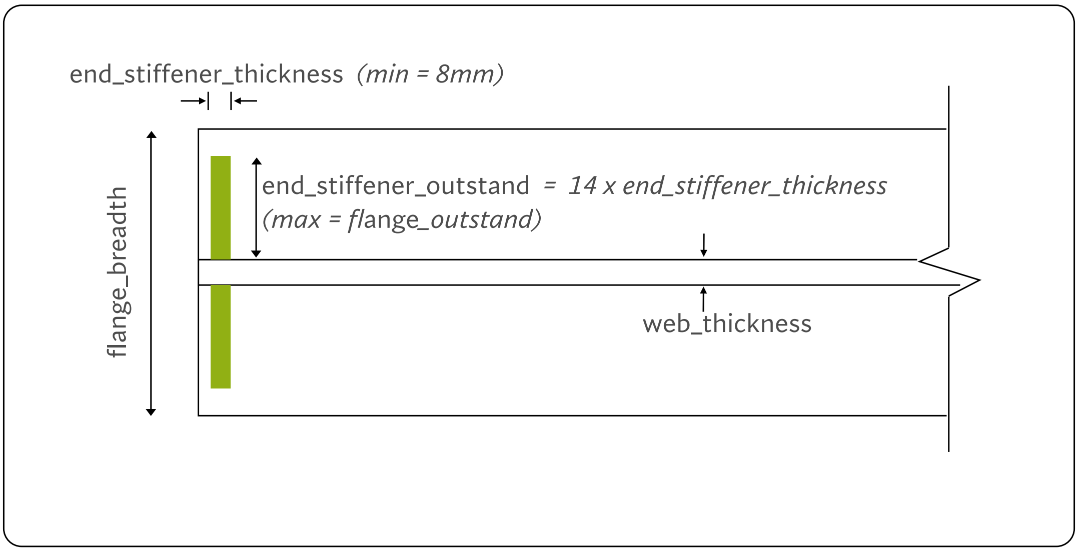
...Clause 8.7.4

- local_capacity_web = 2.5 x flange_thickness x web_thickness x fy x 10^{-3} / 1.1
  (kN)

if: local_capacity_web > | SF_max |
print: *"End bearing stiffeners are not required since the local capacity of the web at its connection to the flange is greater than the reaction."* & directly go to **step-11.**

else if: local_capacity_web < | SF_max |
print: *"End bearing stiffeners are required since the local capacity of the web at its connection to the flange is less than the reaction."* & proceed to **next step.**

STEP 10: DESIGN OF END BEARING STIFFENER



Note: *If the loading is symmetrical, provide the same stiffener design on both the ends of the plate girder since the shear force will be same at both the ends and it will be the maximum (SF_max).*
In case of an unsymmetrical loading, only one of the end-support will have the max shear, the other being comparatively less. So in such a case, to achieve economy in design, this step needs to be performed at both the ends of the plate girder taking into account their respective shear forces.

TOTAL AND NET COMPRESSIVE LOAD CALCULATION:

Total compressive load on the end-stiffener (fc):

- $$\mathbf{fc} = SF\_max + \frac{mtf}{spacing \times 10^{-3}}$$
  (kN)

Net compressive load on the end-stiffener (fc_net):

- **fc_net** = fc - local_capacity_web
  (kN)

MINIMUM AREA REQUIREMENT:

...Clause 8.7.5.2

- **area_min** = $0.8 \times fc \times 1.1 \times 10^3 / fy$ *...Total minimum area for the pair of stiffeners*
  (mm^2)

DIMENSIONING:

- *Initially assume:* end_stiffener_thickness = **8** mm
- end_stiffener_outstand = 14 x end_stiffener_thickness x epsilon
  *(Max permissible value = **flange_outstand**. Limit it at flange_outstand if it exceeds)*
- area_end_stiffener = 2 x end_stiffener_outstand x end_stiffener_thickness
  (Total provided area for the pair of stiffeners)

if: area_end_stiffener < area_min
then: increase end_stiffener_thickness by an increment of **2** mm and redo the dimensioning.

if: area_end_stiffener > area_min *then:* proceed ahead.

Buckling Check: *...(Buckling Resistance should be greater than |SFx|)*

Note: Here while performing buckling check, we shall consider only the core area of the end-stiffener, and not the effective area.

- $$moi = \frac{end\_stiffener\_thickness \times (2 \times end\_stiffener\_outstand)^3}{12}$$
  (Total moment of inertia of the pair of stiffeners)

- $r = \sqrt{moi / area\_end\_stiffener}$

- lamda_2 = 0.7 x web_depth / r ...*Clause 8.7.1.5*

- Calculate **fcd** from pg 42 - table 9c of IS 800:2007 through interpolation.

- buckling_resistance = area_end_stiffener x fcd x 10^{-3}

  (Total buckling resistance of the pair of stiffeners)

if: buckling_resistance < | SFx |
then: increase **end_stiffener_thickness** by increment of 2 mm and repeat this step.

...| SFx | *is the absolute value of Shear Force at the location of the end-bearing stiffener.*

Bearing Check: ...*(Bearing Resistance should be greater Net compressive load)*

- bearing_capacity =

$$\frac{2\,(\text{end\_stiffener\_outstand} - 15) \times \text{end\_stiffener\_thickness} \times fy \times 10^{-3}}{0.8 \times 1.1}$$

if: bearing_capacity < fc_net
then: increase **end_stiffener_thickness** by increment of **2** mm and repeat this step.

if: bearing_capacity > fc_net
then: print "*end stiffener is safe in bearing*" and proceed ahead.

Note: Both the end-stiffeners of the pair shall have same dimensions.

STEP 11: DESIGN OF LOAD CARRYING STIFFENERS

...*Clause 8.7.3*

Perform this step only if user specifies Concentrated Loads in the input dock.

if: local_capacity_web > largest of {P1, P2, P3, P4}
then: print "*No load carrying stiffeners are required since the local capacity of the web at the position of concentrated loads is greater than the loads.*"
and directly go to the **next step (step-12).**

if: local_capacity_web < **P1**

then:

print *"Load carrying stiffener is required below concentrated load 1"*

step 11.1 :

DIMENSIONING:

- *Initially assume:* load1_stiffener_thickness = **8** mm
- load1_stiffener_outstand = 14 x load1_stiffener_thickness x epsilon

  *(Max permissible value = **flange_outstand**. Limit it at flange_outstand if it exceeds)*

Buckling Check:

- Calculate Effective area as: *...Total effective area for the pair of stiffeners*

  eff_area_2 = (40 x web_thickness x epsilon x web_thickness) + 2(load1_stiffener_outstand x load1_stiffener_thickness)

- $$\text{moi\_2} = \frac{40 \times \text{web\_thickness} \times \text{epsilon} \times (\text{web\_thickness})^3}{12} + \frac{\text{load1\_stiffener\_thickness} \times (2 \times \text{load1\_stiffener\_outstand})^3}{12}$$

- $\text{r\_2} = \sqrt{\text{moi\_2} / \text{eff\_area\_2}}$
- lamda_3 = 0.7 x web_depth / r_2
- Calculate **fcd_2** from pg 42 - table 9c of IS 800:2007 through interpolation.
- buckling_resistance_2 = eff_area_2 x fcd_2 x 10^{-3}

if: buckling_resistance_2 < P1 *...Clause 8.7.5.1*

then: increase **load1_stiffener_thickness** by increment of **2** mm and repeat step 11.1

if: buckling_resistance_2 > P1 *then:* proceed ahead.

Bearing Check:

- bearing_capacity_2 =

$$\frac{2\,(\text{load1\_stiffener\_outstand} - 15) \times \text{load1\_stiffener\_thickness} \times \text{fy} \times 10^{-3}}{0.8 \times 1.1}$$

if: bearing_capacity_2 < P1 *...Clause 8.7.5.2*

then: increase **load1_stiffener_thickness** by increment of 2 mm and repeat step 11.1

Note: Provide the stiffener on both the sides of the web.

if: local_capacity_web < **P2**

then:

print *"Load carrying stiffener is required below concentrated load 2"*

step 11.2 :

DIMENSIONING:

- *Initially assume:* load2_stiffener_thickness = **8** mm
- load2_stiffener_outstand = 14 x load2_stiffener_thickness x epsilon

  *(Max permissible value = **flange_outstand**. Limit it at flange_outstand if it exceeds)*

Buckling Check:

- Calculate Effective area as: *...Total effective area for the pair of stiffeners*

  eff_area_3 = (40 x web_thickness x epsilon x web_thickness)
  + 2(load2_stiffener_outstand x load2_stiffener_thickness)

- $$\text{moi\_3} = \frac{40 \times \text{web\_thickness} \times \text{epsilon} \times (\text{web\_thickness})^3}{12} + \frac{\text{load2\_stiffener\_thickness} \times (2 \times \text{load2\_stiffener\_outstand})^3}{12}$$

- $\text{r\_3} = \sqrt{\text{moi\_3} / \text{eff\_area\_3}}$

- lamda_4 = 0.7 x web_depth / r_3

- Calculate **fcd_3** from pg 42 - table 9c of IS 800:2007 through interpolation.

- buckling_resistance_3 = eff_area_3 x fcd_3 x 10^{-3}

  if: buckling_resistance_3 < P2 *...Clause 8.7.5.1*

  then: increase **load2_stiffener_thickness** by increment of **2** mm and repeat step 11.2

  if: buckling_resistance_3 > P2 *then:* proceed ahead.

Bearing Check:

- bearing_capacity_3 =

  $$\frac{2\,(\text{load2\_stiffener\_outstand} - 15) \times \text{load2\_stiffener\_thickness} \times \text{fy} \times 10^{-3}}{0.8 \times 1.1}$$

  if: bearing_capacity_3 < P2 *...Clause 8.7.5.2*

  then: increase **load2_stiffener_thickness** by increment of 2 mm and repeat step 11.2

Note: Provide the stiffener on both the sides of the web.

if: local_capacity_web < **P3**

then:

print *"Load carrying stiffener is required below concentrated load 3"*

step 11.3 :

DIMENSIONING:

- *Initially assume:* load3_stiffener_thickness = **8** mm
- load3_stiffener_outstand = 14 x load3_stiffener_thickness x epsilon

  *(Max permissible value = **flange_outstand**. Limit it at flange_outstand if it exceeds)*

Buckling Check:

- Calculate Effective area as: *...Total effective area for the pair of stiffeners*

  eff_area_4 = (40 x web_thickness x epsilon x web_thickness) + 2(load3_stiffener_outstand x load3_stiffener_thickness)

- $$\text{moi\_4} = \frac{40 \times \text{web\_thickness} \times \text{epsilon} \times (\text{web\_thickness})^3}{12} + \frac{\text{load3\_stiffener\_thickness} \times (2 \times \text{load3\_stiffener\_outstand})^3}{12}$$

- $$\text{r\_4} = \sqrt{\text{moi\_4} / \text{eff\_area\_4}}$$

- lamda_5 = 0.7 x web_depth / r_4
- Calculate **fcd_4** from pg 42 - table 9c of IS 800:2007 through interpolation.
- buckling_resistance_4 = eff_area_4 x fcd_4 x 10^{-3}

if: buckling_resistance_4 < P3 *...Clause 8.7.5.1*

then: increase **load3_stiffener_thickness** by increment of **2** mm and repeat step 11.3

if: buckling_resistance_4 > P3 *then:* proceed ahead.

Bearing Check:

- bearing_capacity_4 =

$$\frac{2\,(\text{load3\_stiffener\_outstand} - 15) \times \text{load3\_stiffener\_thickness} \times \text{fy} \times 10^{-3}}{0.8 \times 1.1}$$

if: bearing_capacity_4 < P3 *...Clause 8.7.5.2*

then: increase **load3_stiffener_thickness** by increment of 2 mm and repeat step 11.3

Note: Provide the stiffener on both the sides of the web.

if: local_capacity_web < **P4**

then:

print *"Load carrying stiffener is required below concentrated load 4"*

step 11.4 :

DIMENSIONING:

- *Initially assume:* load4_stiffener_thickness = **8** mm
- load4_stiffener_outstand = 14 x load4_stiffener_thickness x epsilon

  *(Max permissible value = **flange_outstand**. Limit it at flange_outstand if it exceeds)*

Buckling Check:

- Calculate Effective area as: *...Total effective area for the pair of stiffeners*

  eff_area_5 = (40 x web_thickness x epsilon x web_thickness)
  + 2(load4_stiffener_outstand x load4_stiffener_thickness)

- $$\text{moi\_5} = \frac{40 \times \text{web\_thickness} \times \text{epsilon} \times (\text{web\_thickness})^3}{12} + \frac{\text{load4\_stiffener\_thickness} \times (2 \times \text{load4\_stiffener\_outstand})^3}{12}$$

- $\text{r\_5} = \sqrt{\text{moi\_5} / \text{eff\_area\_5}}$
- lamda_6 = 0.7 x web_depth / r_5
- Calculate **fcd_5** from pg 42 - table 9c of IS 800:2007 through interpolation.
- buckling_resistance_5 = eff_area_5 x fcd_5 x 10^{-3}

if: buckling_resistance_5 < P4 *...Clause 8.7.5.1*

then: increase **load4_stiffener_thickness** by increment of **2** mm and repeat step 11.4

if: buckling_resistance_5 > P4 *then:* proceed ahead.

Bearing Check:

- bearing_capacity_5 =

$$\frac{2\,(\text{load4\_stiffener\_outstand} - 15) \times \text{load4\_stiffener\_thickness} \times \text{fy} \times 10^{-3}}{0.8 \times 1.1}$$

if: bearing_capacity_5 < P4 *...Clause 8.7.5.2*

then: increase **load4_stiffener_thickness** by increment of 2 mm and repeat step 11.4

Note: Provide the stiffener on both the sides of the web.

Note: Follow this same procedure for the design of all the Intermediate Transverse Stiffeners. For brevity, those steps have not been shown.

MINIMUM MOMENT OF INERTIA REQUIREMENT FOR THE PAIR:

...Clause 8.7.2.4

- *if:* c_by_d ≥ $\sqrt{2}$ *then:* **moi_min** = 0.75 x web_depth x $(\text{web\_thickness})^3$

else if: c_by_d < $\sqrt{2}$ *then:* **moi_min** = 1.5 x $(\text{web\_depth})^3$ x $(\text{web\_thickness})^3$ / $(\text{spacing})^2$

DIMENSIONING:

- *Initially assume:* int_stiffener_thickness = **8** mm
- int_stiffener_outstand = 14 x int_stiffener_thickness x epsilon

  *(Max permissible value = **flange_outstand**. Limit it at flange_outstand if it exceeds)*
- moi_int_stiffener = int_stiffener_thickness x $(2 \times \text{int\_stiffener\_outstand})^3$ / 12

  (moi of the pair considering the stiffener area only)

if: moi_end_stiffener < moi_min

then: increase int_stiffener_thickness by increment of 2 mm and redo the dimensioning.

if: moi_end_stiffener > moi_min *then:* proceed ahead.

Buckling Check:

... Considering the effective area

- Calculate Effective area as:

  eff_area_6 = (40 x web_thickness x epsilon x web_thickness) + (2 x int_stiffener_outstand x int_stiffener_thickness)

- moi_int_eff =

$$\frac{40 \times \text{web\_thickness} \times \text{epsilon} \times (\text{web\_thickness})^3}{12} + \frac{\text{int\_stiffener\_thickness} \times (2 \times \text{int\_stiffener\_outstand})^3}{12}$$

  (moi considering the effective area)

- r_6 = $\sqrt{\text{moi\_int\_eff / eff\_area\_6}}$
- lamda7 = 0.7 x web_depth / r_6
- Calculate **fcd_6** from pg 42 - table 9c of IS 800:2007 through interpolation.
- buckling_resistance_6 = eff_area_6 x fcd_6 x 10^{-3}
- buckling_force = [| SFx | - vcr] / 1.1

  ... |SFx | is the absolute value of shear force at that location.

  ...vcr has been calculated in step-8.

if: buckling_resistance_6 < buckling_force

then: increase **int_stiffener_thickness** by increment of 2 mm and repeat the buckling check.

- section_depth = web_depth + 2(flange_thickness)

- $$\text{moi\_z} = \frac{\text{flange\_breadth} \times (\text{section\_depth})^3}{12} - \frac{(\text{flange\_breadth} - \text{web\_thickness})\,(\text{web\_depth})^3}{12}$$

- Calculate minimum weld strength required (qw): *(kN/mm)*

$$\text{qw} = \frac{|\text{SF\_max}| \times \text{flange\_breadth} \times \text{flange\_thickness} \times \text{section\_depth}}{2 \times 2 \times \text{moi\_z}}$$

*From the below table provide a suitable weld size (**s1**) whose design capacity just exceeds **qw**.*

Table-1: Design Capacity of fillet welds

Leg Length s (**mm**)	Design Capacity per unit run (**kN/mm**) for fy = 250 Mpa ; site welded
4	0.442
5	0.553
6	0.663
8	0.884
10	1.106
12	1.327
15	1.659
18	1.990
20	2.212
22	2.433
25	2.765

(Reference Book: N. Subramanian; Table: 6.5)

STEP 14: DESIGN OF WELD FOR END-BEARING STIFFENER

...Clause 8.7.2.6

This step is applicable when end-bearing stiffener is provided.

- Calculate minimum weld strength required q: *(kN/mm)*

- $$q1 = \frac{\text{web\_thickness}^2}{5 \times \text{end\_stiffener\_outstand}}$$

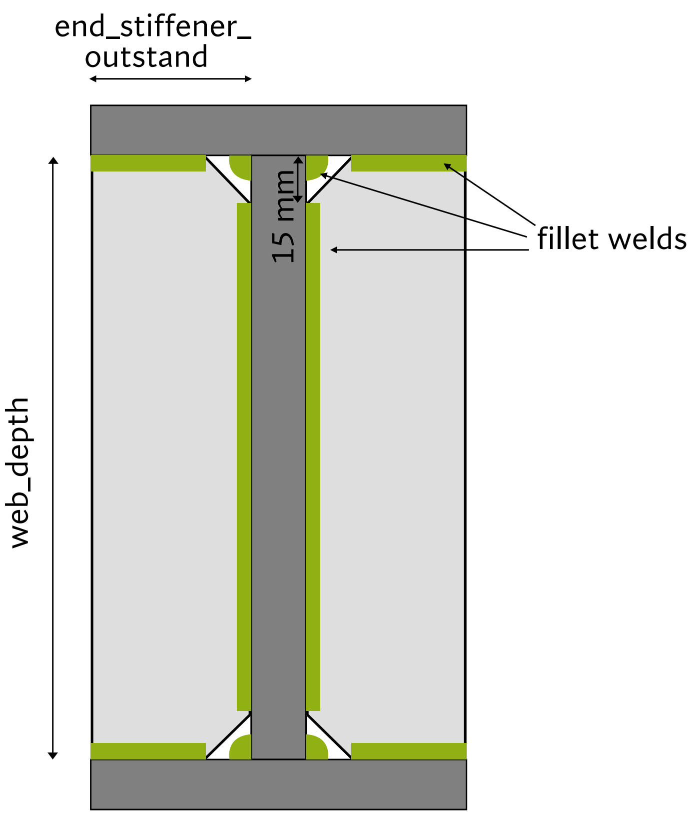
- $$q2 = \frac{(\,|SFx| - \text{local\_capacity\_web})\,/\,2}{\text{web\_depth} - 30}$$

...| SFx | is the absolute value of Shear Force at the location of the end-bearing stiffener.

- q = q1 + q2

*From table-1, provide a suitable weld size (**s2**) whose design capacity just exceeds **q**. provide same weld size to the stiffener on the opposite side of the web.*

Note: End-bearing stiffener is welded to web and also to compression & tension flanges. The weld is provided on both sides of the stiffener.



End Bearing Stiffener

STEP 15: DESIGN OF WELD FOR LOAD CARRYING STIFFENERS

This step is applicable when load-carrying stiffener is provided.

- Calculate minimum weld strength required q: *(kN/mm)*

- $$q3 = \frac{web\_thickness^2}{5 \times load1\_stiffener\_outstand}$$

- $$q4 = \frac{(|SFx| - local\_capacity\_web) / 2}{web\_depth - 30}$$

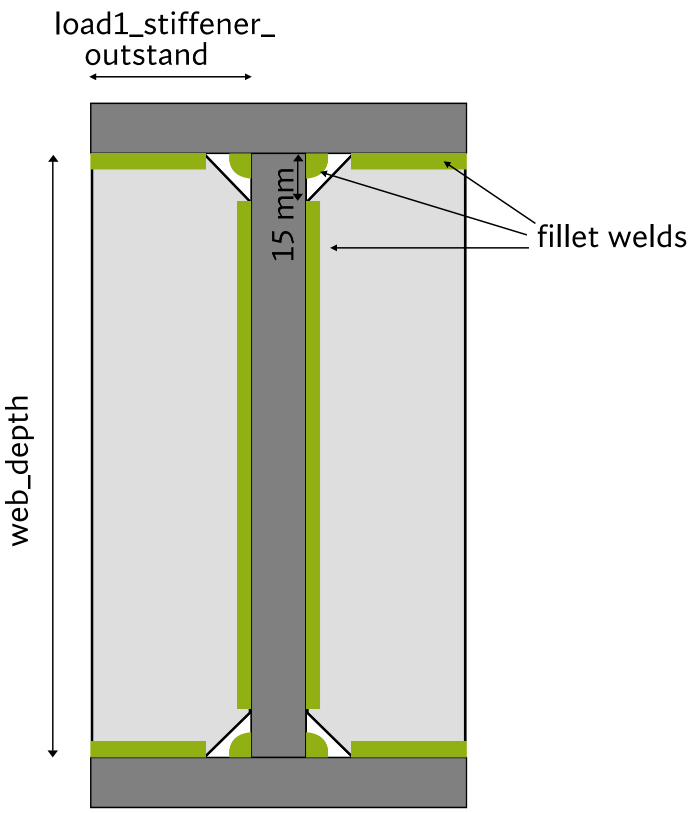
...|SF*x*| *is the absolute value of Shear Force at the location of the load-carrying stiffener.*

- q_load1 = q3 + q4

*From table-1 provide a weld size (**s3**) whose design capacity just exceeds **q_load1.** provide same weld size to the stiffener on the opposite side of the web.*

Note: Load Carrying Stiffener is welded to web & also to compression & tension flanges. The weld is provided on both sides of the stiffener.

Note: Follow this same procedure for the design of all other Load Carrying Stiffeners. For brevity, those steps have not been shown.



Load-1 Carrying Stiffener

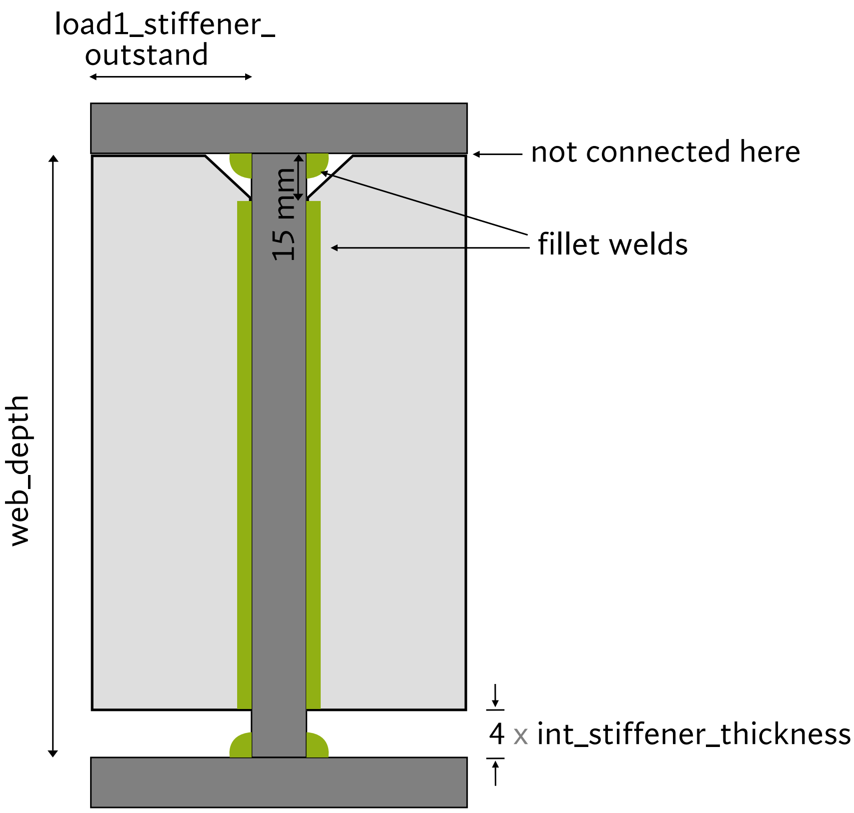
- Calculate minimum weld strength required q: *(kN/mm)*
- $$q5 = \frac{\text{web\_thickness}^2}{5 \times \text{int\_stiffener\_outstand}}$$
- $$q6 = \frac{(\,|SFx| - \text{local\_capacity\_web}) / 2}{\text{web\_depth} - 15 - (4 \times \text{int\_stiffener\_thickness})}$$

...| SFx | *is the absolute value of Shear Force at the location of the Intermediate Transverse Stiffener.*

- q_load2 = q5 + q6

*From table-1 provide a weld size (**s4**) whose design capacity just exceeds **q_load2.** provide same weld size to the stiffener on the opposite side of the web.*

Note: Intermediate Transverse Stiffener is welded to web & extended just upto the top compression flange but not welded to it. And it is terminated at a distance of {4 x int_stiffener_thickness} *away from the bottom tension flange.*



Intermediate Transverse Stiffener

OUTPUT DOCK:

Load Calculation

Maximum Shear Force (kN)	*SF_max*
Maximum Bending Moment (kNm)	*BM_max*

Web Details

Web Thickness (mm)	*web_thickness*
Web Depth (mm)	*web_depth*
Local Capacity of Web (kN)	*local_capacity_web*
Shear Strength of Web (kN)	*vcr*
Classification of Web	*web_type*

Flange Details

Flange Breadth (mm)	*flange_breadth*
Flange Thickness (mm)	*flange_thickness*
Bending Strength (Moment Capacity) of Flange (kNm)	*moment_capacity*
Classification of Flange	*flange_type*

End Bearing Stiffener Details

Thickness (mm)	*end_stiffener_thickness*
Depth (mm)	*web_depth*
Outstand (mm)	*end_stiffener_outstand*
Buckling Resistance (kN)	*buckling_resistance*
Bearing Resistance (kN)	*bearing_capacity*

Load Bearing Stiffener Details

Stiffener Under Concentrated Load-1

Thickness (mm)	*load1_stiffener_thickness*
Depth (mm)	*web_depth*
Outstand (mm)	*load1_stiffener_outstand*
Buckling Resistance (kN)	*buckling_resistance_2*
Bearing Resistance (kN)	*bearing_capacity_2*

Do the same for stiffeners under other loads too.

Intermediate Transverse Stiffener Details

Stiffener 1 ▾

Thickness (mm)	*int_stiffener_thickness*
Depth (mm)	*web_depth-(4 x)*
Outstand (mm)	*int_stiffener_outstand*
Buckling Resistance (kN)	*buckling_resistance_6*
Spacing (mm)	*spacing*

Do the same for other stiffeners too.

Fillet Weld Details

At Web-Flange Junction

Size of Fillet Weld between Web-Flange Junction (mm)	*s1*
Strength of Fillet Weld between Web-Flange Junction (kN/mm)	*corresponding capacity*

For End Stiffeners

Size of Fillet Weld for End Stiffeners (mm)	*s2*
Strength of Fillet Weld of End Stiffeners (kN/mm)	*corresponding capacity*

For Load Carrying Stiffeners

Stiffener Under Concentrated Load-1:

Size of Fillet Weld (mm)	*s3*
Strength of Fillet Weld (kN/mm)	*corresponding capacity*

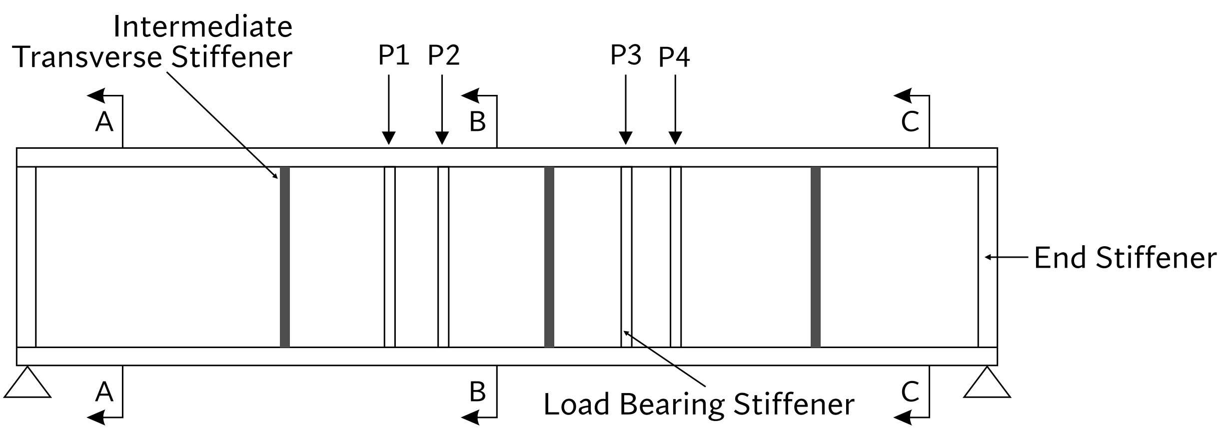
Do the same for stiffeners under other loads too.

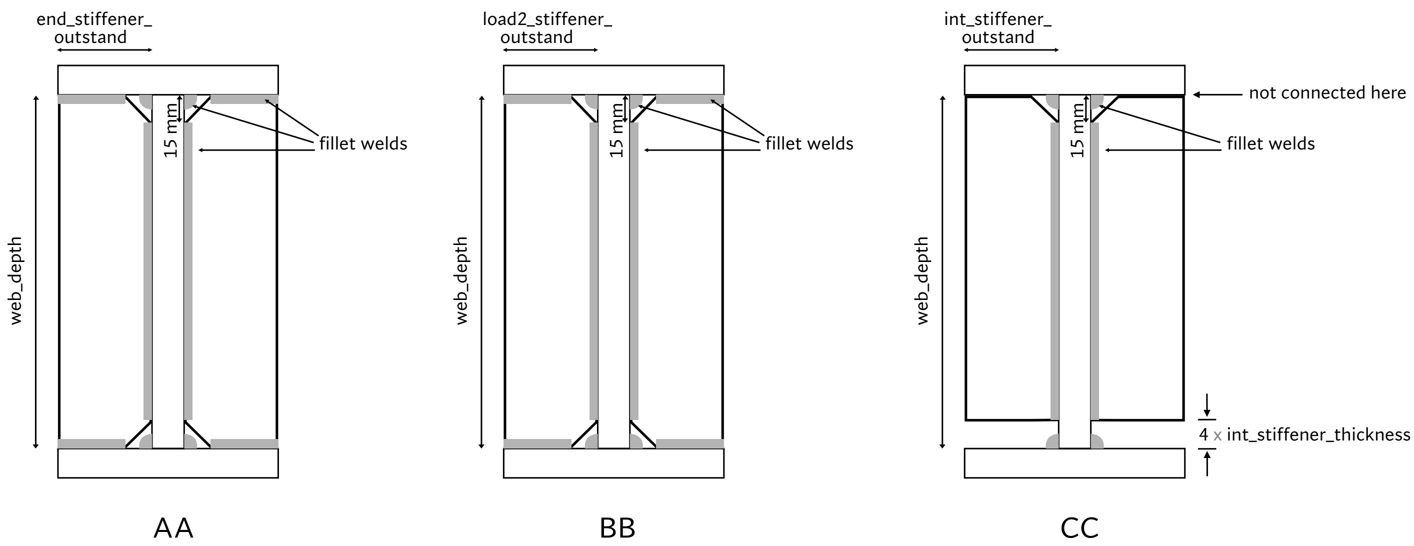
For Intermediate Transverse Stiffeners

Stiffener-1:

Size of Fillet Weld (mm)	*s4*
Strength of Fillet Weld (kN/mm)	*corresponding capacity*

Do the same for other stiffeners too.





End of Algorithm

Example - 2

WELDED PLATE GIRDER (STIFFENED THIN WEB)

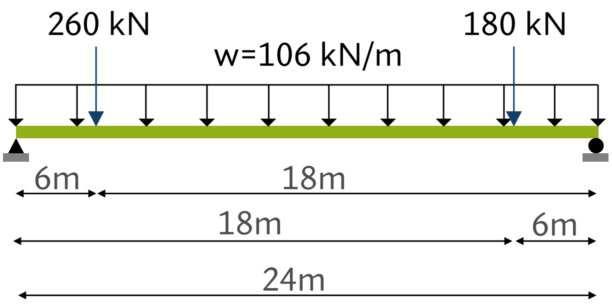
- span length (m) = 24
- Imposed factored UDL (kN/m) = 100
- Web type : stiffened thin web
- Material yield stress = 250 MPa
- c/d = 1.4

CONCENTRATED LOADS:

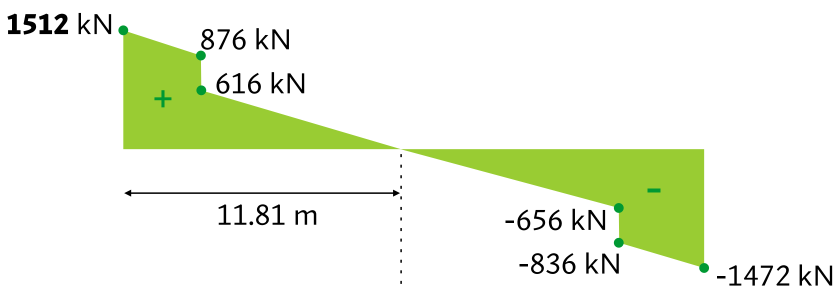
- Factored load 1 (kN) = 260
- Distance from left (m) = 6
- Factored load 2 (kN) = 180
- Distance from left (m) = 18

STEP 1 : LOAD CALCULATION

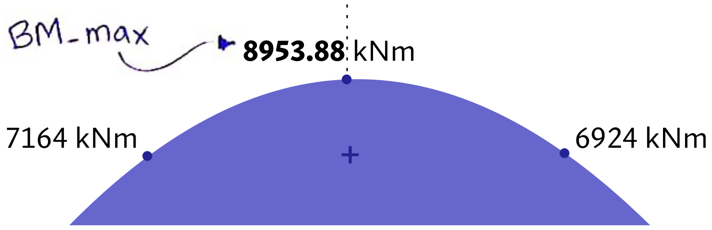
- self weight = $100 \times 24 / 400 = 6$ kN/m
- Total UDL (w) = $100 + 6 = 106$ kN/m



SFD



BMD



- $SF(\text{at } x=0) = \left(\frac{106 \times 24}{2} - 0\right) + \left\{\frac{260 \times 18}{24}\right\} + \left\{\frac{180 \times 6}{24}\right\} = 1512$
- $SF(\text{at } x=18) = \left[\frac{106 \times 24}{2} - 106(18)\right] + \left\{\frac{-260 \times 6}{24}\right\} + \left\{\begin{matrix} 45 \\ \text{OR} \\ -135 \end{matrix}\right\} = -836$

Point of max BM will lie at point of zero shear. Point of zero shear would lie between the two point loads, ie, between $x = 6$ and $x = 18$. The shear force equation for this section (b/w $x=6$ & 18) is:

$$SF_{(6<x<18)} = 1512 - 106x - 260$$

$$0 = 1512 - 106x - 260 \Rightarrow \boxed{x = 11.81\ m}$$

So, BM @ $x = 11.81$ is calculated as:

$$BM(x=11.81) = \frac{106 \times 11.81(24-11.81)}{2} + \left\{\frac{260 \times 18 \times 11.81}{24}\right\} - 260(11.81-6)$$

$$+ \frac{180 \times 6 \times 11.81}{24}$$

$$BM_{max} = 8953.88\ kN \cdot m$$

STEP 2 : PROPORTIONING OF WEB

- $\varepsilon = \sqrt{250/250} = 1$
- Optimum depth of web $= \left[\frac{8953.88 \times 10^6 \times 200}{250}\right]^{0.33} = 1787.24 \approx 1780\ mm$

  $\therefore \boxed{d = 1780\ mm}$
- optimum thickness of web $= \left[\frac{8953.88 \times 10^6}{(200)^2 \times 250}\right]^{0.33} = 9.42 \approx 10\ mm$

  $\therefore \boxed{t_w = 10\ mm}$

STEP 3 : PROPORTIONING OF FLANGE

- Flange area $= \frac{BM_{max} \times \gamma_{mo}}{f_y \times d} = \frac{8953.88 \times 10^6 \times 1.1}{250 \times 1780} = 22133.1$
- Flange breadth $= 0.3 \times 1780 = 534 \approx \boxed{540\ mm}$
- Flange thickness $= \frac{22133.1}{540} = 40.9 \approx \boxed{45\ mm}$

STEP4 : CLASSIFICATION OF FLANGE

- Flange outstand = $(540-10)/2 = 265$ mm
- $\frac{b}{t_f} \rightarrow \frac{\text{outstand}}{\text{thickness}} = \frac{265}{45} = 5.8$ since its less than 8.4ε
  ∴ flange type = plastic

STEP5 : CLASSIFICATION OF WEB

- $\frac{\text{web depth}}{\text{web thickness}} = \frac{1780}{10} = 178$ since its greater than 105ε
  ∴ web type = slender

STEP 6 : CALCULATE Z_p and Z_e

- $$Z_p = 2\left[\underbrace{b_f \cdot t_f}_{\text{area}} \underbrace{\left\{\frac{d}{2} + \frac{t_f}{2}\right\}}_{\bar{y}}\right] = 2\left[540 \times 45 \left\{\frac{1780}{2} + \frac{45}{2}\right\}\right]$$
  $$= 44347500 \text{ mm}^3$$

- section (D) depth = $1780 + 2(45) = 1870$
- $$Z_e = \frac{I}{\bar{y}} \quad I \rightarrow \frac{b_f D^3}{12} - \frac{2(\text{outstand})d^3}{12}, \quad \bar{y} \rightarrow D/2$$
  $$= \frac{2}{1870} \times \left\{\frac{540 \times (1870)^3}{12} - \frac{(540-10)(1780)^3}{12}\right\} = 48315602.5 \text{ mm}^3$$

STEP7: CHECK FOR BENDING STRENGTH OF FLANGE

- $\beta_b = 1$ ∵ flange type = plastic
- moment capacity $= \frac{\beta_b \cdot f_y \cdot Z_p}{\gamma_{mo}} = \frac{250 \times 44347500 \times 10^{-6}}{1.1}$

$$= 10078.97 \text{ KN.m}$$

since moment capacity (10078.97 kNm) is greater than the maximum bending moment (8953.88 KN.m), hence the section is safe in bending.

STEP-8 : CHECK FOR SHEAR CAPACITY OF WEB

- spacing (mm) $= \left(\frac{c}{d}\right) \times d = 1.4 \times 1780 = 2492$ mm
- no. of panels $= 24 \times 10^3 / 2492 = 9.63 \approx 10$ panels
- Recalculate spacing $= 24 \times 10^3 / 10 = \boxed{2400 \text{ mm}}$
- Recalculate c/d $= 2400/1780 = \boxed{1.34}$
- $\because c/d \geq 1 \quad \therefore K_v = 5.35 + \frac{4}{(c/d)^2} = 5.35 + \frac{4}{(1.34)^2} = 7.55$
- $\tau_{cr,e} = \frac{7.55 \times \pi^2 \times 2 \times 10^5}{12(1-0.3^2)(178)^2} = 43.07 \text{ N/mm}^2$
- $\lambda = \sqrt{250/\sqrt{3} \times 43.07} = 1.83$
- $\because \lambda \geq 1.2 \quad \therefore \tau_{b1} = 250/\sqrt{3} \cdot (1.83)^2 = 43.09$
- $V_{cr} = 43.09 \times 1780 \times 10 \times 10^{-3} = 767.17$ KN

$\boxed{V_{cr} = 767.17 \text{ KN}}$

STEP 8-B : CHECK FOR ADEQUACY OF END PANEL

Check for Shear capacity :

- $V_{dp} = 1780 \times 10 \times 250 \times 10^{-3}/\sqrt{3} = 2569.2$ KN
- $H_q = 1.25 \times 2569.2 \left[1 - \frac{767.17}{2569.2}\right]^{0.5} = 2689.62$ KN
- $R_{tf} = \frac{2689.62}{2} = 1344.81$ KN
- $V_n = \frac{1780 \times 10 \times 250 \times 10^{-3}}{\sqrt{3} \times 1.1} = 2335.6$ KN

$\because V_n > R_{tf}$ End Panel is safe in shear. ✓

Check for Moment Capacity : $M_{tf} = 2689.62 \times 1780 \times 10^{-3}/10 =$ 478.75 KNm

- $I = 10 \times (2400)^3/12 = 1.152 \times 10^{10}$ mm^4
- $M_q = \frac{1.152 \times 10^{10} \times 250 \times 10^{-6}}{\left(\frac{2400}{2}\right) \times 1.1} = 2181.81$ KNm

$\because M_q > M_{tf} \therefore$ End Panel is safe in bending. ✓

STEP-9 : CHECK FOR LOCAL CAPACITY OF WEB

- local capacity of web $= 2.5 \times 45 \times 10 \times 250 \times 10^{-3} / 1.1 = 255.68$ KN

$\because$ local capacity of the web is less than the maximum shear force (1512 KN), hence end-bearing stiffeners are required.

STEP-10 : DESIGN OF END BEARING STIFFENER

- Total compressive load on the end-stiffener (fc):

$$f_c = 1512 + \frac{478.75}{2400 \times 10^{-3}} = 1711.47 \text{ KN}$$

- Net compressive load on the end-stiffener (fc-net):

$$f_{c\text{-}net} = 1711.47 - 255.68 = 1455.79 \text{ KN}$$

MINIMUM AREA REQUIREMENT :

- area_min $= 0.8 \times 1711.47 \times 1.1 \times 10^3 / 250 = 6024.36$ mm²
- Assume thickness = 8 mm
- End stiffener outstand $= 14 \times 8\varepsilon = 112$ mm [$\therefore$ Area $= 2 \times 112 \times 8 = 1792$]
- Revised End stiffener thickness = 16
- Area of end stiffener = $\underbrace{2 \times 224}_{\text{outstand}} \times 16 = 7168$ mm2

$\because$ 7168 > 6024.36 $\therefore$ $\boxed{\text{OK}}$

Hence provide a pair of $\underbrace{224}_{}$ × 16 mm

less than flange outstand (265) $\therefore$ OK

Buckling Check :

- $I = \dfrac{16 \times (2 \times 224)^3}{12}$ = 119887189.3
- $r = \sqrt{I / 7168} = 129.36$
- $\lambda = 0.7 \times 1780 / 129.36 = 9.63$
- $f_{cd} = 227.11$
- buckling resistance = $\overset{7168}{\text{area}} \times f_{cd} \times 10^{-3}$ = 1627.92 KN > SFmax (1512 KN) $\therefore$ $\boxed{\text{OK}}$

Bearing check:

- bearing capacity $= \dfrac{2(224-15)\times 16 \times 250 \times 10^{-3}}{0.8\times 1.1} = 1900$ KN

$\because$ 1900 KN > fc-net (1455.79 KN) $\therefore$ End stiffenener is safe in bearing.

STEP - II : DESIGN OF LOAD CARRYING STIFFENERS

It is required only below concentrated load-1 since local capacity of web (255.68) is less than the load (260).

DIMENSIONING :

- Assume thickness = 8 mm
- Outstand = $14\times 8\varepsilon$ = 112 mm.

Buckling check :

- Effective area = $(40\times 10\times 10) + 2(224\times 16) = 11168 \text{ mm}^2$
- $I = \dfrac{40\times 10\times 10^3}{12} + \dfrac{16(2\times 224)^3}{12} = 119920522.7$
- $r = \sqrt{I/A} = 103.62$
- $\lambda = 0.7\times 1780/103.62 = 12.02$
- $f_{cd} = 226.394$
- buckling resistance $= 11168\times 226.394\times 10^{-3} = 2528.36$ KN

Buckling resistance of the stiffener (2528.36) > load (260)

Hence provide a pair of 112 mm × 8 mm stiffeners below 260 KN load.

Bearing check :

- bearing capacity $= \dfrac{2(112-15)\times 8\times 250\times 10^{-3}}{0.8\times 1.1} = 440.9$ KN

$\because$ 440.9 KN > load (260 KN) Hence stiffener is safe in bearing.

STEP-12 : DESIGN OF INTERMEDIATE TRANSVERSE STIFFENERS

I_{min} for the pair of stiffeners $= 1.5 \times d^3 \times t_w^3 / (\text{spacing})^2$

$\therefore$ $I_{min} = 1.5 \times (1780)^3 \times 10^3 / (2400)^2$ ..... $\because$ $c/d = 1.34 < \sqrt{2}$

$\Rightarrow 14.68 \times 10^5 \text{ mm}^4$

DIMENSIONING :

- Assume stiffener thickness as 8 mm.
- The corresponding maximum outstand $= 14 \times 8 \times \varepsilon = 112$ mm
- $I_{(provided)} = 8 \times (2 \times 112)^3 / 12 = 7492949.3 \text{ mm}^4$
  $\approx 74 \times 10^5 \text{ mm}^4$
  $> I_{min}$.

$\because$ $I_{(provided)} > I_{min}$, $\therefore$ $\boxed{\text{OK}}$ ✓

Buckling check :

- Effective area $= (40 \times 10 \times 10) + 2(112 \times 8) = 5792 \text{ mm}^2$
- $I = \dfrac{40 \times 10 \times (10)^3}{12} + \dfrac{8 \times (2 \times 112)^3}{12} = 74.96 \times 10^5 \text{ mm}^4$
  [7496282.6]
- $r = \sqrt{I/A} = 35.97$
- $\lambda = 0.7 \times 1780 / 35.97 = 34.63$
- $f_{cd} = 204.981$
- Buckling Resistance $= 5792 \times 204.981 \times 10^{-3} = \boxed{1187.24 \text{ KN}}$
- Buckling force $= [SF_{(@2400 \text{ mm})} - V_{cr}] \div 1.1$
  $\rightarrow 2.4$ m

$\rightarrow SF_{(@2.4m)} = \left(\dfrac{106 \times 24}{2} - 106(2.4)\right) + \left(\dfrac{260 \times 18}{24}\right) + \left(\dfrac{180 \times 6}{24}\right)$

$= 1257.6$ KN

$\therefore$ buckling force $= 1257.6 - 767.17 = \boxed{490.43 \text{ KN}}$

$\because$ Buckling Resistance (1187.24) > Buckling force (490.43)

$\therefore$ Intermediate stiffener is safe in buckling. ✓

Similarly the other eight intermediate transverse stiffeners can be designed based on the shear force at their respective locations.

STEP-13 : DESIGN OF WELD AT WEB-FLANGE JUNCTION

- section depth = 1780 + 2(45) = 1870
- $I_z = \frac{540 \times (1870)^3}{12} - \frac{(540-10)(1780)^3}{12} = 4.517 \times 10^{10}$
- Minimum weld strength required (q_w)

$$q_w = \frac{1512 \times 540 \times 45 \times 1870}{2 \times 2 \times 4.51 \times 10^{10}} = 0.38 \text{ KN/mm}$$

Provide a pair of 4mm fillet welds. (Table 1 of algorithm).
Design capacity = 0.442 KN/mm > 0.38 KN/mm ∴ SAFE ✓

STEP-14 : DESIGN OF WELD FOR END-BEARING STIFFENER

- $q_1 = \frac{(10)^2}{5 \times 224} = 0.0892$
- $q_2 = \frac{(1512 - 409)/2}{1780 - 30} = 0.3151$

$q = q_1 + q_2 = 0.404$ KN/mm

Provide a pair of 4mm fillet welds. ✓

similarly the end-stiffener at the right end of the girder can be designed considering the SF at that location (1472 KN).

STEP-15 : DESIGN OF WELD FOR LOAD CARRYING STIFFENER

(stiffener below concentrated load-1)

- $q_1 = \frac{(10)^2}{5 \times 112} = 0.178$
- $q_2 = \frac{[SF_{(x=6m)} - \text{local capacity of web}]/2}{\text{web depth} - 30}$

→ $SF(x=6m): \left(\frac{24 \times 106}{2} - 106 \times 6\right) + \left\{\frac{260 \times 18}{24}\right\} + \left\{\frac{180 \times 6}{24}\right\} = 876 \text{ KN}$

- $\therefore q_2 = \dfrac{[876 - 409]/2}{1780 - 30} = 0.1334$

$q = q_1 + q_2 = 0.311$ KN/mm

$\therefore$ provide a pair of 4mm fillet welds.

STEP- 16 : DESIGN OF WELD FOR INTERMEDIATE TRANSVERSE STIFFENERS

- $q_1 = \dfrac{10^2}{5 \times 112} = 0.178$
- $q_2 = \dfrac{[1257.6 - 409]/2}{1780 - 15 - [4 \times 8]} = 0.244$

$q = q_1 + q_2 = 0.422$ KN/mm

$\therefore$ Provide a pair of 4mm fillet welds.

OUTPUT DOCK:

Load Calculation

Maximum Shear Force (kN)	1512
Maximum Bending Moment (kNm)	8953.88

Web Details

Web Thickness (mm)	10
Web Depth (mm)	1780
Local Capacity of Web (kN)	255.68
Shear Strength of Web (kN)	767.17
Classification of Web	slender

Flange Details

Flange Breadth (mm)	540
Flange Thickness (mm)	45
Bending Strength (Moment Capacity) of Flange (kNm)	10078.97
Classification of Flange	plastic

End Bearing Stiffener Details

Thickness (mm)	8
Depth (mm)	1780
Outstand (mm)	112
Buckling Resistance (kN)	1627.92
Bearing Resistance (kN)	1900

Load Bearing Stiffener Details

Stiffener Under Concentrated Load-1

Thickness (mm)	8
Depth (mm)	1780
Outstand (mm)	112
Buckling Resistance (kN)	2528.36
Bearing Resistance (kN)	440.9

Do the same for stiffeners under other loads too.

Intermediate Transverse Stiffener Details

Stiffener 1

Thickness (mm)	8
Depth (mm)	1748
Outstand (mm)	112
Buckling Resistance (kN)	1187.24
Spacing (mm)	2400

Do the same for other stiffeners too.

Fillet Weld Details

At Web-Flange Junction

Size of Fillet Weld between Web-Flange Junction (mm)	4
Strength of Fillet Weld between Web-Flange Junction (kN/mm)	0.442

For End Stiffeners

Size of Fillet Weld for End Stiffeners (mm)	4
Strength of Fillet Weld of End Stiffeners (kN/mm)	0.442

For Load Carrying Stiffeners

Stiffener Under Concentrated Load-1:

Size of Fillet Weld (mm)	4
Strength of Fillet Weld (kN/mm)	0.442

Do the same for stiffeners under other loads too.

For Intermediate Transverse Stiffeners

Stiffener-1:

Size of Fillet Weld (mm)	4
Strength of Fillet Weld (kN/mm)	0.442

Do the same for other stiffeners too.

End of Example

GUSSETED TRUSS CONNECTION

Chapter 3: Gusseted Truss Connection

3.1 Introduction

Gusset plate connections are commonly used to join members in steel truss bridges. The gussets are the crucial parts of the structure through which all the internal forces from the connected members are transmitted. They are with us for centuries and if you're not a structural engineer, you will never notice them. And it's OK, they should be made like this – inconspicuous, modest but unshakably safe. The designer has to do a number of checks on gusset plates - such as, in tension members, check for gross section yield strength, net section rupture resistance, block shear failure, etc.

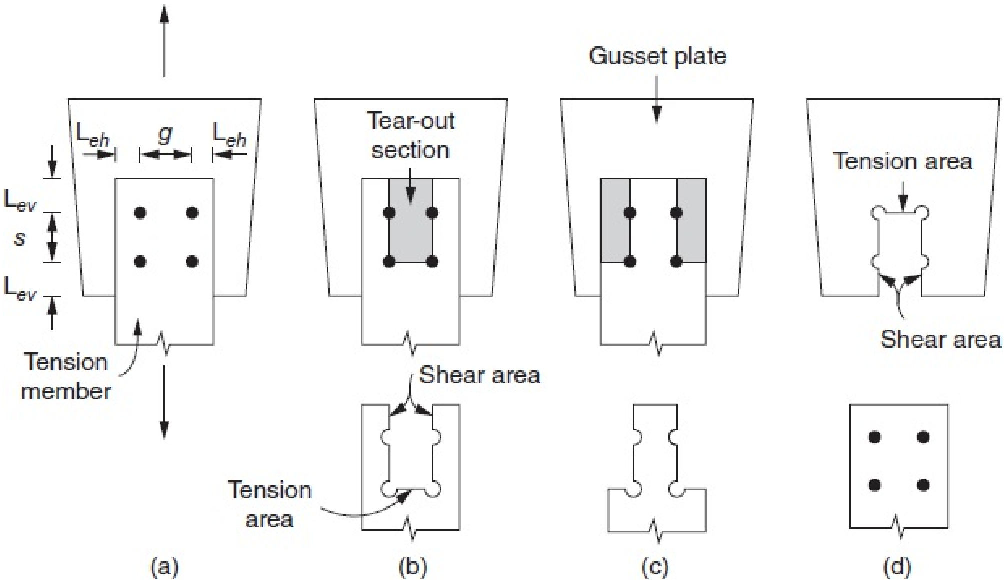
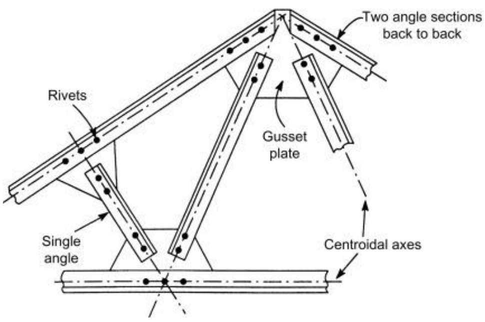
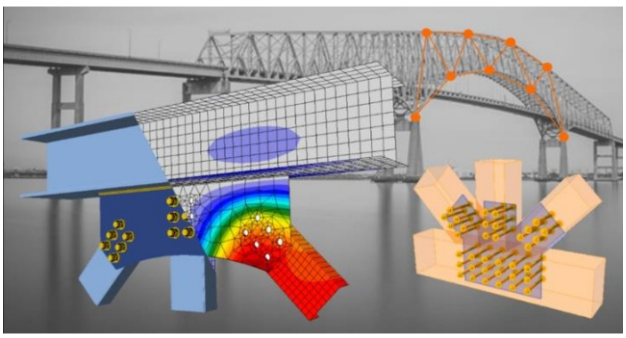


Figure: Possible shear failure paths

The gusset connection design can become completely different when it comes to compression members. We still have to check all the shear failures, but the buckling problem starts to play a much more important role. A crucial parameter in the compression member connection design is the fact of whether the member can or cannot sway out of the gusset's plane. This will influence the behaviour of the failure mechanism and the creation of the plastic hinges in the plates. Therefore, the algorithm at this stage supports the definition of only tension forces.

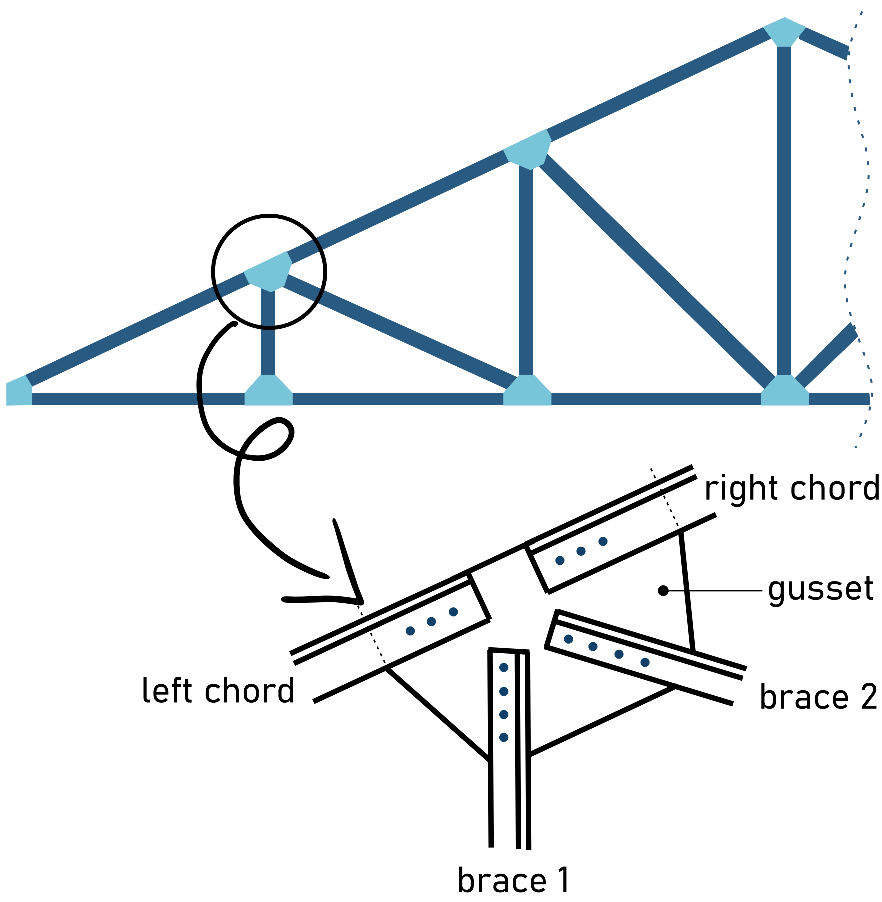




Osdag
Open steel design and graphics

Algorithm by: Aamir Durrany
(Intern, Osdag)

ALGORITHM: GUSSETED TRUSS CONNECTION (BOLTED)



INPUT DOCK:

Connecting Members

Number of Members:*

min: 2, max: 10

(Out of the total number of members, one member would be referred "Left Chord" and one member would be referred "Right Chord" and the remaining members shall be referred as member 1, member 2, etc...)

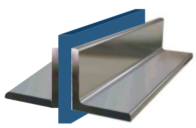
Section Profile:* *Angles, Channel, etc...*

(To be specified for chords & braces separately. Both the chords shall have a common section profile and so will all the braces)

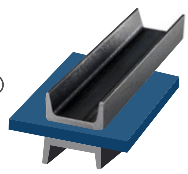
angle

channel

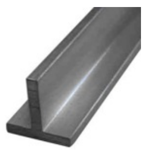
Isection



D_angle
(Double Angle back to back)



D_channel
(Double Channel back to back)



tee

Conn_Location*

Long Leg / Short Leg

Section Size (Left & Right Chord)*

All / User Defined

(refer steel table database for the list of sections corresponding to each Section Profile)

Section Size (All Other Braces)*

All / User Defined

(refer steel table database for the list of sections corresponding to each Section Profile)

Angle Between Right and Left Chord:
(anticlockwise, degrees) *

min: 10, max: 350

Angle Between Right Chord and Member 1:
(anticlockwise, degrees) *

min: 10, max: 350

Angle Between Right Chord and Member 2:
(anticlockwise, degrees) *

min: 10, max: 350

and so on...for {No of members - 2}

Material grade *

options are:
E 165 (Fe 290)
E 250 (Fe 410 W) A
E 250 (Fe 410 W) B
E 250 (Fe 410 W) C
E 300 (Fe 440)
E 350 (Fe 490)
E 410 (Fe 540)
E 450 (Fe 570) D
E 450 (Fe 590) E

Factored Tensile Loads

Right Chord (kN)*

min: 30% of design yield strength (Refer Clause 10.7)

Left Chord (kN)*

min: 30% of design yield strength

Member # (kN)* *(required for each member)*

min: 30% of design yield strength

(if the user had specified a section profile and a section size, & further if he specifies an axial force less than 30% of design yield strength, then assume axial force less equal to 30%. mention it in the warning)

Bolt

Diameter (mm)* — *All / User Defined*

options for "User defined" : 8, 10, 12, 14, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 42, 45, 48, 52, 56, 60, 64

Type — *Bearing Bolt (default) / Friction Grip Bolt*

Grade* — *All / User Defined*

options for "User defined" : 3.6 , 4.6 , 4.8 , 5.6 , 5.8 , 6.8 , 8.8 , 9.8 , 10.9

Plate

Thickness (mm)* — *All / User Defined*

options for "User defined" : 8, 10, 12, 14, 16, 18, 20, 22, 25, 28, 32, 36, 40, 45, 50, 56, 63, 75, 80, 90, 100, 110, 120

STEP 1

defining some variables:

- Section profile for chord left: chord_L
  Section profile for chord right: chord_R
  Section profile for all braces: SP_brace

- Section size for chord left: size_chord_L
  Section size for chord right: size_chord_R
  Section size for brace 1: size_brace1
  Section size for brace 2: size_brace2 ...

- User defined factored tensile load (unit kN)
  In brace 1: F1 ; in brace 2: F2 ...
  In chord left: F_l ; in chord right: F_r
  datatype: int
  unit: kN

- bolt diameter: d → datatype: int

- bolt grade: bolt_grade → datatype: float

  each of these bolt_grade have a corresponding fub value as follows: → datatype: int

bolt_ grade	3.6	4.6	4.8	5.6	5.8	6.8	8.8	9.8	10.9
fub	330	400	420	500	520	600	800	900	1040

Tensile properties of bolts in steel constructions

Specification IS 1367 (Part 3) (ISO 898)	Grade/classification	Properties		
		Yield stress f_y MPa (min)	Ultimate tensile stress f_{ub} MPa (min)	Elongation percentage (min)
Specifications of fasteners threaded steel for technical supply conditions	3.6	180	330	25
	4.6	240	400	22
	4.8	320	420	14
	5.6	300	500	20
	5.8	400	520	10
	6.8	480	600	8
	8.8 : (d < 16 mm)	640	800	12
	(d > 16 mm)	660	830	12
	9.8	720	900	10
	10.9	940	1040	9

- Material Grade: material_grade

  each of these material_grade have a corresponding fy & fu value as follows:
  → datatype: int

- Material Grade: material_grade

  each of these material_grade have a corresponding fy & fu value as follows:
  → datatype: int

Table 1 (*Concluded*)

Sl No.	Indian Standard	Grade/Classification	Properties			
			Yield Stress MPa, *Min*			Ultimate Tensile Stress MPa, *Min*
(1)	(2)	(3)	fy (4)			fu (5)
			d or *t*			
			< 20	20-40	> 40	
viii)	IS 2062	E 165 (Fe 290)	165	165	165	290
		E 250 (Fe 410 W) A	250	240	230	410
		E 250 (Fe 410 W) B	250	240	230	410
		E 250 (Fe 410 W) C	250	240	230	410
		E 300 (Fe 440)	300	290	280	440
		E 350 (Fe 490)	350	330	320	490
		E 410 (Fe 540)	410	390	380	540
		E 450 (Fe 570) D	450	430	420	570
		E 450 (Fe 590) E	450	430	420	590

Note: These Mpa (N/mm^2) values needs to be converted into KN/mm^2 during calculations.

defining some variables:

- Let the no. of shear planes for each brace be: nsp_brace → datatype: int

  This variable shall have the following values:

  nsp_brace = 1
  ... if SP_brace = angle or channel or tee

  nsp_brace = 2
  ... if SP_brace = D_angle or D_channel

- Let the pitch be: p → datatype: float

  Let the initial value of p be: 2.5d

  max value: 16t or 200mm (whichever is least)

  10.2.3.2 The distance between the centres of two adjacent fasteners (pitch) in a line lying in the direction of stress, shall not exceed 16*t* or 200 mm, whichever is less, in tension members and 12*t* or 200 mm, whichever is less, in compression members; where *t* is the thickness of the thinner plate. In the case of

- d_hole → datatype: float

  d_hole = d + 1 ... if d = 12 or 14

  d_hole = d + 2 ... if d = (16, 18, 20 ,22 ,24)

  d_hole = d + 3 ... if d is greater than 24

- end_dist → datatype: float *(parallel to line of force)*

  Let its initial value be: **1.5 d_hole**

- edge_dist → datatype: float *(perpendicular to line of force)*

  Let its initial value be: **1.5 d_hole**

  10.2.4.2 The minimum edge and end distances from the centre of any hole to the nearest edge of a plate shall not be less than 1.7 times the hole diameter in case of sheared or hand-flame cut edges; and 1.5 times the hole diameter in case of rolled, machine-flame cut, sawn and planed edges.

  & end

  10.2.4.3 The maximum edge distance to the nearest line of fasteners from an edge of any un-stiffened part should not exceed 12 $t\varepsilon$, where $\varepsilon = (250/fy)^{1/2}$ and *t* is the thickness of the thinner outer plate. This would not apply to fasteners interconnecting the components of back to back tension members. Where the members

  Here fy = Yield Stress of the material

- Let the thickness of gusset be: t_gusset

  → datatype: float

  if t_gusset is not specified by the user

  {

  Let the initial value of t_gusset be: 12

  }

- Thickness of size_brace1 shall be: t_brace_1

  available in steel table ← → datatype: float

  t_brace_1 = thickness of connected leg
  ... if SP_brace = angle or channel or tee

  t_brace_1 = twice the thickness of connected leg
  ... if SP_brace = D_angle or D_channel

- t → datatype: float

  where, t = (minimum of t_gusset and t_brace_1)

if section profile & section size is user defined

{

in case the value of $\frac{\text{Force applied}}{\text{area of section (mm}^2\text{)}}$ is greater than:

fy in MPa ←

$$\frac{\text{Area of section (in mm}^2\text{) x Material grade x }10^{-3}}{1.1}$$

then print the following error:

"The factored tensile force ( ) exceeds the tension yield capacity ( ) of the section. Please choose a larger section or decrease the load."

}

if section profile is user defined (& not the section size)

{

in case the value of $\frac{\text{Force applied}}{A_{Lsup}\ \left\{\text{area of largest section under that profile (mm}^2\text{)}\right.}$

is greater than:

fy in MPa ←

$$\frac{A_{Lsup}\text{ (in mm}^2\text{) x Material grade x }10^{-3}}{1.1}$$

then print the following error:

"The factored tensile force ( ) exceeds the tension yield capacity ( ) of the largest section available under the designated section profile. Please decrease the load."

STEP 2

shear capacity of bolt

if bolt type = bearing bolt, then:

{

10.3.3 ***Shear Capacity of Bolt***

The design strength of the bolt, V_{dsb} as governed shear strength is given by:

$$V_{dsb} = V_{nsb} / \gamma_{mb}$$

where

V_{nsb} = nominal shear capacity of a bolt, calculated as follows:

$$V_{nsb} = \frac{f_u}{\sqrt{3}}\left(n_n\, A_{nb} + n_s\, A_{sb}\right)$$

f_u = 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_{sb} = nominal plain shank area of the bolt; and

A_{nb} = net shear area of the bolt at threads, may be taken as the area corresponding to root diameter at the thread.

if bolt diameter, bolt_grade, section profile and section size is user defined

{

- Vdsb → datatype: float

  → in MPa

$$\text{Vdsb} = \frac{\text{fub x nsp1 x 0.78 x } \pi \text{ x } (d^2) \text{ x } (10^{-3})}{\sqrt{3} \text{ x 1.25 x 4}}$$

- Kb → datatype: float

Kb = minimum of

- $\frac{\text{end\_dist}}{3 \times (\text{d\_hole})}$
- $\frac{\text{p}}{3 \times (\text{d\_hole})}$
- $\frac{\text{fub}}{\text{fu}}$
- 1

10.3.4 ***Bearing Capacity of the Bolt***

The design bearing strength of a bolt on any plate, V_{dpb} as governed by bearing is given by:

$$V_{dpb} = V_{npb} / \gamma_{mb}$$

where

V_{npb} = nominal bearing strength of a bolt

$= 2.5\, k_b\, d\, t\, f_u$

where

k_b is smaller of $\frac{e}{3d_0}$, $\frac{p}{3d_0} - 0.25$, $\frac{f_{ub}}{f_u}$, 1.0;

e, p = end and pitch distances of the fastener along bearing direction;

d_0 = diameter of the hole;

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; and

t = summation of the thicknesses of the connected plates experiencing bearing stress in the same direction, or if the bolts are countersunk, the thickness of the plate minus one half of the depth of countersinking.

- Vdpb → datatype: float

  in MPa

  $$\text{Vdpb} = \frac{2.5 \times \text{Kb} \times \text{d} \times \text{t} \times \text{fub} \times (10^{-3})}{1.25}$$

- bolt_value → datatype: float

  bolt_value = minimum of (Vdsb and Vdpb)

}

if bolt type = friction grip bolt, then:

{ *Cl. 10.4.3* $V_{dsf} = V_{nsf} / \gamma_{mf}$

V_{nsf} = nominal shear capacity of a bolt as governed by slip for friction type connection, calculated as follows:

$$V_{nsf} = \mu_f\, n_e\, K_h\, F_o$$

where

μ_f = coefficient of friction (slip factor) as specified in Table 20 ($\mu_f = 0.55$),

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,

γ_{mf} = 1.10 (if slip resistance is designed at service load),

= 1.25 (if slip resistance is designed at ultimate load),

F_o = minimum bolt tension (proof load) at installation and may be taken as $A_{nb} f_0$,

A_{nb} = net area of the bolt at threads, and

f_o = proof stress (= $0.70 f_{ub}$).

NOTE — V_{ns} may be evaluated at a service load or ultimate load using appropriate partial safety factors, depending upon whether slip resistance is required at service load or ultimate load.

- $V_{nsf} = \mu_f \times nsp\_brace \times K_h \times F_o$

where, μ_f = Slip Factor = 0.55 *(Default Value)*

(User may input other values too. Range should be between 0.1 and 0.55. User can Refer Table 20)

K_h = 1 *(Standard Clearance Holes)*

= 0.85 *(Oversized & Short-Slotted Holes)*

= 0.7 *(Long-Slotted Holes)*

...the type of hole needs to be specified by the user at the INPUT dock

F_o = Proof Load = 0.7 fub

- $V_{dsf} = \dfrac{V_{dsf}}{1.1}$ ... (if slip resistance is designed at service load),

$= \dfrac{V_{dsf}}{1.25}$ ... (if slip resistance is designed at ultimate load),

...User needs to specify at the INPUT dock that where has the slip resistance been designated at.

- bolt_req → datatype: float

  $$\text{bolt\_req} = \frac{F1}{V_{dsf}}$$

  Round off bolt_req to the nearest higher integer

  }

  }

else if any or all of the 4 parameters (bolt diameter, bolt_grade, section profile and section size) is not user defined, then:

{

assume the least value for the non-user defined parameter(s), perform all the calculations of this step, and store the number of bolts required under each case/combination in a variable.

}

STEP 3

Determining the highest number of parallel rows possible for arranging the bolts:

This step is common for both the cases - whether values are user defined or not. In case when the values are not user defined, this step has to be performed on all the case/combinations created in the previous step.

- If bolt_req = 1 or 2 or 3 then provide 1 row.
- if bolt_req = 4 or more then:

  if width of connected leg is more than (2e + 5p); provide 6 rows

  else if width of connected leg is more than (2e + 4p); provide 5 rows

  else if width of connected leg is more than (2e + 3p); provide 4 rows

  else if width of connected leg is more than (2e + 2p); provide 3 rows

  else if width of connected leg is more than (2e + p); provide 2 rows

for brevity, the above formulas are written only upto 6 rows. The formulas can be expanded for accompanying more number of rows.

STEP 4

This step is common for both the cases - whether values are user defined or not:

Arrange the bolts in those many rows with the assumed values of p and e

STEP 5

Long-connection-length Reduction Factor (rf_lc) & large-grip Reduction Factor (rf_lg):

This step is common for both the cases - weather values are user defined or not:

10.3.3.1 ***Long joints***

When the length of the joint, l_j of a splice or end connection in a compression or tension element containing more than two bolts (that is the distance between the first and last rows of bolts in the joint, measured in the direction of the load transfer) exceeds $15d$ in the direction of load, the nominal shear capacity (*see* **10.3.2**), V_{db} shall be reduced by the factor β_{lj}, given by:

$$\beta_{lj} = 1.075 - l_j / (200\ d) \text{ but } 0.75 \le \beta_{lj} \le 1.0$$

$$= 1.075 - 0.005(l_j / d)$$

d = Nominal diameter of the fastener.

If length of joint is greater than 15d, then

$$\text{rf\_lc} = 1.075 - \frac{\text{length of joint}}{200 \times d}$$

datatype: float

If length of joint is less than 15d, then rf_lc = 1

10.3.3.2 ***Large grip lengths***

rf_lg

datatype: float

When the grip length, l_g (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:

$$\beta_{lg} = 8\ d / (3\ d + l_g) = 8 / (3 + l_g / d)$$

β_{lg} shall not be more than β_{lj} given in **10.3.3.1**. The grip length, l_g shall in no case be greater than $8d$.

else if grip length is less than 5d ; then: rf_lg = 1

multiply rf_lc & rf_lg with the Vdsb value and repeat from step 2 to step 5 (including step2 & step5). The previous calculated values shall be overwritten.

Applying 3 Design checks:

if bolt diameter, bolt_grade, section profile & section size is user defined

{

- **gsy** → datatype: float

Gross section yield strength (for brace 1): *fy in MPa*

$$gsy = \frac{(\text{gross area}) \times fy \times 10^{-3}}{1.1} \times 2$$

multiply by 2 only if SP_brace = D_angle or D_channel

- **nsr** → datatype: float

Net section rupture strength (for brace 1): *fu in MPa*

$$nsr = \frac{0.9 \times (\text{Net Area}) \times fu \times 10^{-3}}{1.25} \times 2$$

multiply by 2 only when SP_brace = D_angle or D_channel

- **btr** → datatype: float *Block tearing resistance (for brace 1):*

6.4.1 ***Bolted Connections***

The block shear strength, T_{db} of connection shall be taken as the smaller of,

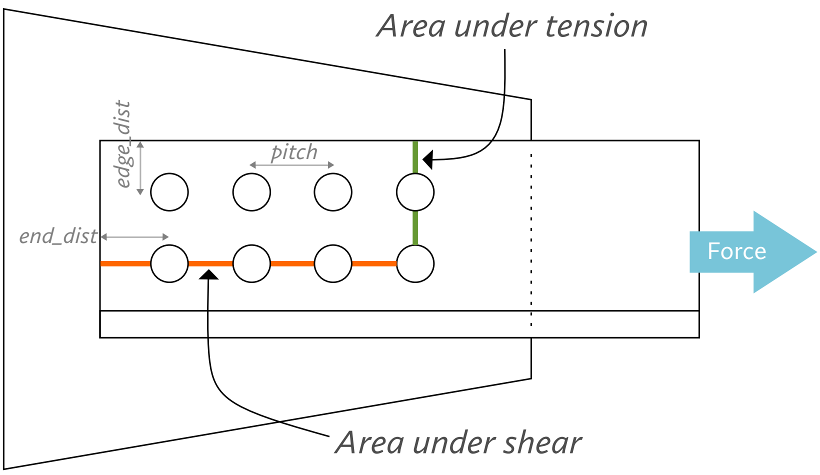
$$T_{db} = [A_{vg} f_y / (\sqrt{3}\,\gamma_{m0}) + 0.9 A_{tn} f_u / \gamma_{m1}]$$

or 1.1 1.25

$$T_{db} = (0.9 A_{vn} f_u / (\sqrt{3}\,\gamma_{m1}) + A_{tg} f_y / \gamma_{m0})$$

...Avg = Gross area in shear
...Atn = Net area in tension
...Avn = Net area in shear
...Atg = Gross area in tension

multiply by 2 only when SP_brace = D_angle or D_channel



*...**Avg** = **Gross area in shear** = [end distance + { { pitch x (no of bolts in a row - 1) } - bolt_dia x (0.5) }] x thickness of connected leg*

*...**Atn** = **Net area in tension** = [edge_dist + { { pitch x (no of rows - 1) } - bolt_dia x (no of rows - 0.5) }] x thickness of connected leg*

*...**Avn** = **Net area in shear** = [end distance + { { pitch x (no of bolts in a row - 1) } - bolt_dia x (no of bolts in a row - 0.5) }] x thickness of connected leg*

*...**Atg** = **Gross area in tension** = [edge_dist + { { pitch x (no of rows - 1) } - bolt_dia x (0.5) }] x thickness of connected leg*

If the lesser of the above 3 checks is greater than F1 value, then proceed ahead.

else: increase the end distance & the pitch by increments of 2mm, until it finally satisfies the 3 design checks. (upto max end dist and max pitch & within available section size)

else: give the following error: *“Choose a larger section”*

}

if bolt diameter, bolt_grade, section profile & section size is not user defined

{

Calculate the connection length (connLen1) for all the cases/combinations created in the previous step.

arrange the list of cases/combinations created in the previous step in the increasing order of the volume of material used.
(volume = connLen1 x total thickness)

Now apply the 3 design checks, mentioned in this step, on the list of cases.

The first case/combination to satify the 3 design checks mentioned in this step shall be selected.

}

STEP 7

if bolt diameter, bolt_grade, section profile and section size is user defined

{

Calculate the connection length (connLen1)

}

STEP 8

if bolt diameter, bolt_grade, section profile and section size is user defined

{

Compare all the connection lengths. The one giving the least connection length shall be selected as the final configuration. Label this connection length as connLenBrace1

Incase there are multiple configurations that give the least length, the one among those giving highest strength utilization ratio shall be selected:

Strength UtilizationRatio = bolt_value x bolt_req / F1

}

STEP 9

The algorithm for brace#1 ends here. Repeat all the steps for all the other braces connected at the joint.

STEP 10

Every brace shall have a final configuration. Identify the critical net section on the gusset plate considering the final configurations of all the braces.

STEP 11

Now check the gusset plate for net section rupture at that section, and also for gross section yield and for block tearing.

(Use the formulas of step 6)

If these 3 checks are satisfied, design is complete. End the program here.

STEP 12

If these 3 checks are not satisfied, increase the gusset thickness by 2mm and repeat step 11.

OUTPUT DOCK:

Section Details:

Brace 1 *(similar for all other braces)*

Designation	*section size*
Tension Yield Capacity (kN)	*gsy*
Tension Rupture Capacity (kN)	*nsr*
Block Shear Capacity (kN)	*btr*
Pattern	*shear pattern*
Tension Capacity (kN)	*lesser of gsy, nsr, btr*
Utilization Ratio	*F1/Tension Capacity*

Bolt Details

Diameter (mm)	
Property Class	*bolt grade*
Shear Capacity (kN)	*Vdsb*
Bearing Capacity (kN)	*Vdpb*
Long Joint Red.Factor	*rf_lc*
Large Grip Red.Factor	*rf_lg*
Capacity (kN)	*Bolt Value*
Bolt Force (kN)	*F1 / No of bolts*
Spacing	*spacing details*

Left Chord *(similar for right chord)*

Designation	*section size*
Tension Yield Capacity (kN)	*gsy*
Tension Rupture Capacity (kN)	*nsr*
Block Shear Capacity (kN)	*btr*
Pattern	*shear pattern*
Tension Capacity (kN)	*lesser of gsy, nsr, btr*
Utilization Ratio	*F_l/Tension Capacity*

Bolt Details

Diameter (mm)	
Property Class	*bolt grade*
Shear Capacity (kN)	*Vdsb*
Bearing Capacity (kN)	*Vdpb*
Long Joint Red.Factor	*rf_lc*
Large Grip Red.Factor	*rf_lg*
Capacity (kN)	*Bolt Value*
Bolt Force (kN)	*F_l / No of bolts*
Spacing	*spacing details*

Gusset Plate Details

Thickness (mm)	*t_gusset*
Plate Length along brace 1 (mm)	*connection length*
Plate Length along brace 2 (mm)	*connection length*
(similar for all other braces)	
Plate Length Along Left Chord (mm)	*connection length*
Plate Length Along Right Chord (mm)	*connection length*
Tension Yield Capacity (kN)	*gsy*
Tension Rupture Capacity (kN)	*nsr*
Block Shear Capacity (kN)	*btr*
Pattern	*shear pattern*
Tension Capacity (kN)	*lesser of gsy, nsr, btr*

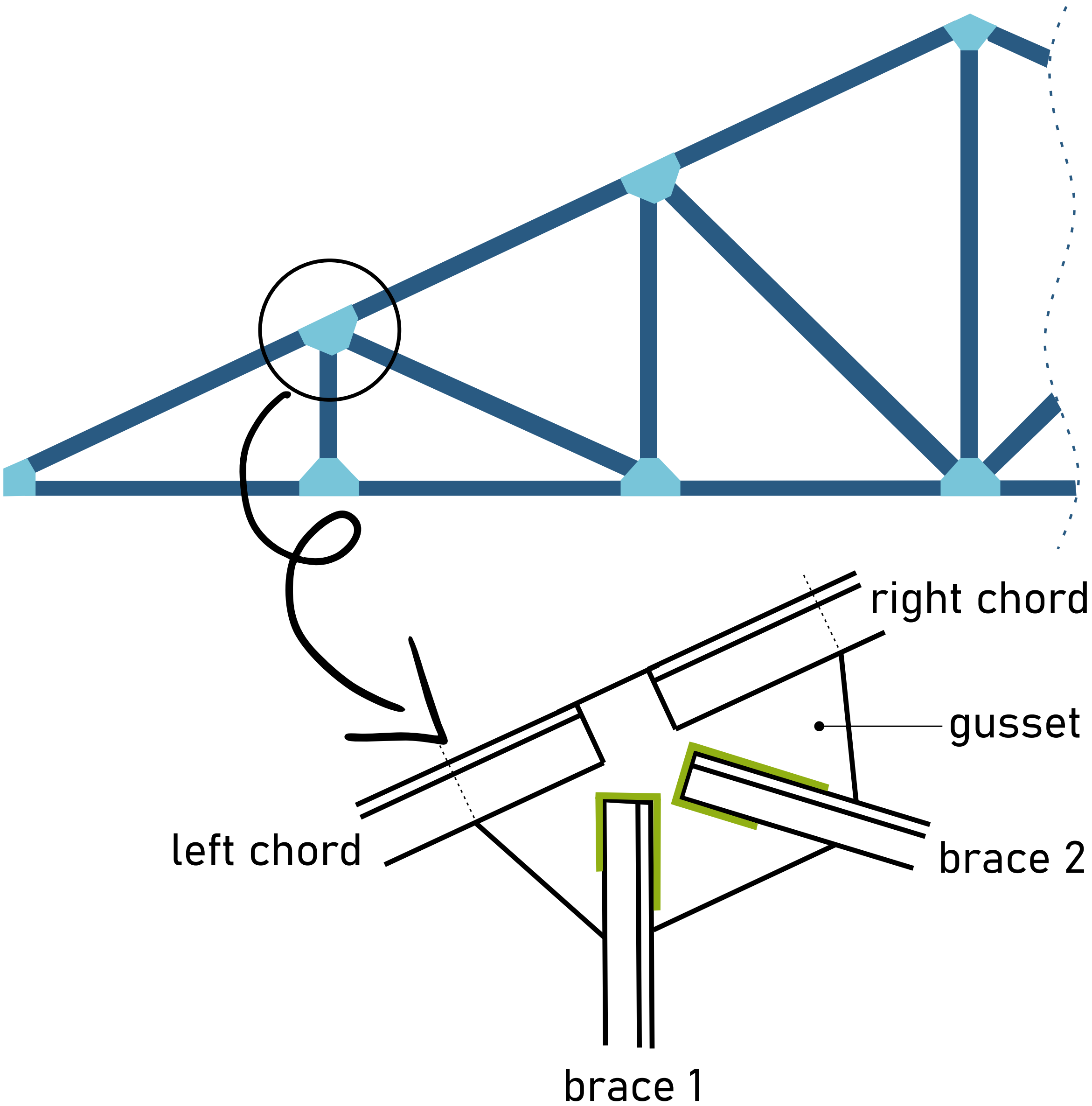
Create Design Report

Save Output

End of Algorithm

Algorithm by: Aamir Durrany
(Intern, Osdag)

ALGORITHM: GUSSETED TRUSS CONNECTION (WELDED)



INPUT DOCK:

Connecting Members

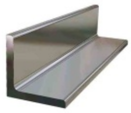
Number of Members:*

min: 2, max: 10

(Out of the total number of members, one member would be referred "Left Chord" and one member would be referred "Right Chord" and the remaining members shall be referred as member 1, member 2, etc...)

Section Profile:* *Angles, Channel, etc...*

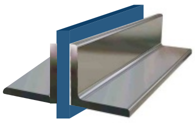
(To be specified for chords & braces separately. Both the chords shall have a common section profile and so will all the braces)



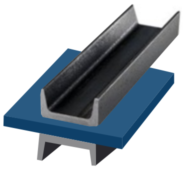
angle

channel

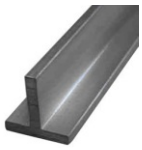
Isection



D_angle
(Double Angle back to back)



D_channel
(Double Channel back to back)



tee

Conn_Location*

Long Leg / Short Leg

Section Size (Left & Right Chord) *

All / User Defined

(refer steel table database for the list of sections corresponding to each Section Profile)

Section Size (All Other Braces) *

All / User Defined

(refer steel table database for the list of sections corresponding to each Section Profile)

Angle Between Right and Left Chord: (anticlockwise, degrees) *

min: 10, max: 350

Angle Between Right Chord and Member 1: (anticlockwise, degrees) *

min: 10, max: 350

Angle Between Right Chord and Member 2: (anticlockwise, degrees) *

min: 10, max: 350

and so on...for {No of members - 2}

Material grade * *(use same grade for weld too)*

options are:
E 165 (Fe 290)
E 250 (Fe 410 W) A
E 250 (Fe 410 W) B
E 250 (Fe 410 W) C
E 300 (Fe 440)
E 350 (Fe 490)
E 410 (Fe 540)
E 450 (Fe 570) D
E 450 (Fe 590) E

Factored Tensile Loads

Right Chord (kN)*

min: 30% of design yield strength (Refer Clause 10.7)

Left Chord (kN)*

min: 30% of design yield strength

Member # (kN)* *(required for each member)*

min: 30% of design yield strength

(if the user had specified a section profile and a section size, & further if he specifies an axial force less than 30% of design yield strength, then assume axial force less equal to 30%. mention it in the warning)

Plate

Thickness (mm)* *All / User Defined*

options for "User defined" : 8, 10, 12, 14, 16, 18, 20, 22, 25, 28, 32, 36, 40, 45, 50, 56, 63, 75, 80, 90, 100, 110, 120

STEP 1

defining some variables:

- Section profile for chord left: chord_L
  Section profile for chord right: chord_R
  Section profile for all braces: SP_brace

- Section size for chord left: size_chord_L
  Section size for chord right: size_chord_R
  Section size for brace 1: size_brace1
  Section size for brace 2: size_brace2 ...

- User defined factored tensile load (unit kN)
  In brace 1: F1 ; in brace 2: F2 ...
  In chord left: F_l ; in chord right: F_r
  unit: kN
  datatype: int

- Material Grade: material_grade

  each of these material_grade have a corresponding fy & fu value as follows:
  datatype: int

Table 1 (*Concluded*)

Sl No.	Indian Standard	Grade/Classification	Properties: Yield Stress MPa, *Min* fy			Properties: Ultimate Tensile Stress MPa, *Min* fu
(1)	(2)	(3)	(4)			(5)
			d or *t* < 20	*d* or *t* 20-40	*d* or *t* > 40	
viii)	IS 2062	E 165 (Fe 290)	165	165	165	290
		E 250 (Fe 410 W) A	250	240	230	410
		E 250 (Fe 410 W) B	250	240	230	410
		E 250 (Fe 410 W) C	250	240	230	410
		E 300 (Fe 440)	300	290	280	440
		E 350 (Fe 490)	350	330	320	490
		E 410 (Fe 540)	410	390	380	540
		E 450 (Fe 570) D	450	430	420	570
		E 450 (Fe 590) E	450	430	420	590

Note: These Mpa (N/mm^2) values needs to be converted into KN/mm^2 during calculations.

defining some variables:

- Let the no. of shear planes for each brace be: nsp_brace → datatype: int

  This variable shall have the following values:

  nsp_brace = 1 ... if SP_brace = angle or channel or tee

  nsp_brace = 2 ... if SP_brace = D_angle or D_channel

- Let the thickness of gusset be: t_gusset

  → datatype: float

  if t_gusset is not specified by the user

  { Let the initial value of t_gusset be: 12 }

- Thickness of size_brace1 shall be: t_brace_1

  → datatype: float

  available in steel table

  t_brace_1 = thickness of connected leg ... if SP_brace = angle or channel or tee

  t_brace_1 = twice the thickness of connected leg ... if SP_brace = D_angle or D_channel

- t → datatype: float

  where, t = (minimum of t_gusset and t_brace_1)

if section profile & section size is user defined

{

in case the value of $\dfrac{\text{Force applied}}{\text{area of section (mm}^2\text{)}}$ is greater than:

fy in MPa

Area of section (in mm^2) x Material grade x 10^{-3} / 1.1

then print the following error:

"The factored tensile force ( ) exceeds the tension yield capacity ( ) of the section. Please choose a larger section or decrease the load."

}

if section profile is user defined (& not the section size)

{

in case the value of $\dfrac{\text{Force applied}}{\text{area of largest section under that profile (mm}^2\text{)}}$

A_{Lsup}

is greater than:

fy in MPa

A_{Lsup} (in mm^2) x Material grade x 10^{-3} / 1.1

then print the following error:

"The factored tensile force ( ) exceeds the tension yield capacity ( ) of the largest section available under the designated section profile. Please decrease the load."

STEP 2

Size of Weld:

Note: If the section_profile is back to back, the calculations shall be made by considering single side (by dividing the F1 by 2. The output (design weld parameters) would be applicable for the other side too.

Choose the minimum permissible weld size (3mm) as the size of the weld; and store it in a variable: weld_size

10.5.2.3 The size of fillet welds shall not be less than 3 mm. The minimum size of the first run or of a single run fillet weld shall be as given in Table 21, to avoid the risk of cracking in the absence of preheating.

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

Note: weld_size should be preferably less than its max limit, as specified:

- For square edge :
  weld_size should be less than {thickness of thinner member - 1.5mm}
- For round edge :
  weld_size should be less than {3/4th of the thickness of thinner member}

10.5.8.1 Where a fillet weld is applied to the square edge of a part, the specified size of the weld should generally be at least 1.5 mm less than the edge thickness in order to avoid washing down of the exposed arris (*see* Fig. 17A).

10.5.8.2 Where the fillet weld is applied to the rounded toe of a rolled section, the specified size of the weld should generally not exceed 3/4 of the thickness of the section at the toe (*see* Fig. 17B).

Note: In no case shall the weld_size be less than 3mm

STEP 3

Effective Throat Thickness:

throat_thickness = 0.7 x weld_size

Note: throat_thickness shall not be less than 3mm as specified in Cl 10.5.3.1

10.5.3 ***Effective Throat Thickness***

10.5.3.1 The effective throat thickness of a fillet weld shall not be less than 3 mm and shall generally not exceed $0.7t$, or $1.0t$ under special circumstances, where t is the thickness of the thinner plate of elements being welded.

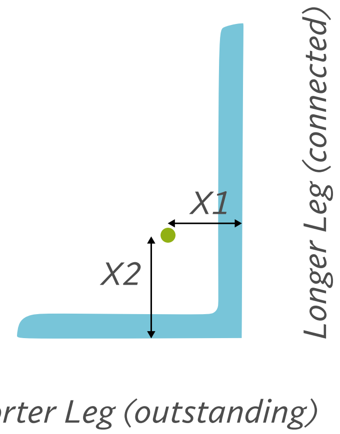
STEP 4

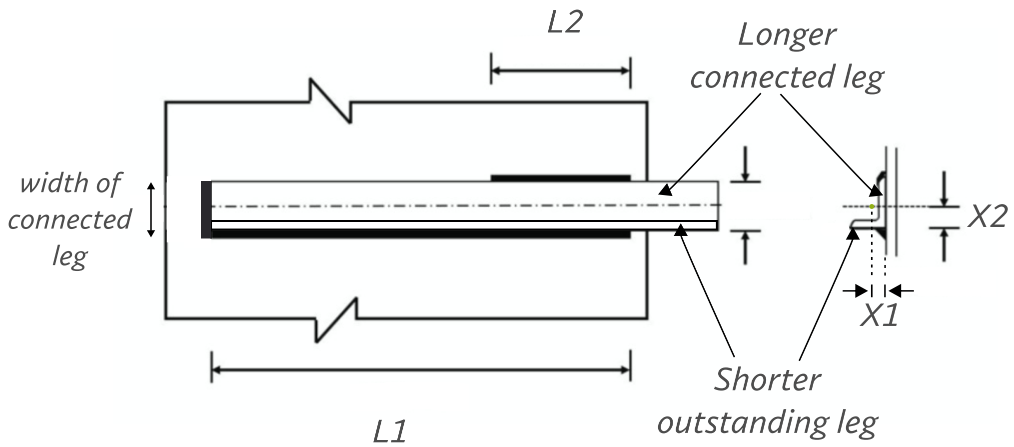
To determine the effective length of weld:

$$\text{eff\_weld\_length} = \frac{F1 \times \sqrt{3} \times 1.25}{f_u \times \text{throat\_thickness}}$$

STEP 5

Proportioning the weld length according to the C.G. of section:





An unequal angle section

- $$\frac{L1}{X1} = \frac{L2}{X2}$$

- L1 + L2 = {eff_weld_length - width of connected leg}

Using the above 2 equations, determine the weld length proportioning.

Note: if section_size is not defined by user, choose section sizes one by one and perform all the steps till here on every section_size.

STEP 6

Calculate overlap length

Overlap length = greater of L1 and L2

STEP 7

Long-connection-length Reduction Factor (rf_lc):

If length of joint is greater than {150 x throat_thickness} then:

$$rf\_lc = 1.2 - \frac{0.2 \times \{\text{weld or overlap length}\}}{150 \times \text{throat\_thickness}}$$

If length of joint is less than {150 x throat_thickness} then: rf_lc = 1

If rf_lc is less than 1, then increase the F1 value in step 4 by the same % as the % decrease if rf_lc with respect to 1 and then repeat from step 4 to step 6. Now we shall have a greater connection length after considering the loss of strength due to rf_lc.

- $$weld\_strength = \frac{eff\_weld\_length \times f_u \times throat\_thickness}{\sqrt{3} \times 1.25}$$

STEP 8

Applying Design check on brace:

if section profile & section size is not user defined

{

- gsy → datatype: float *Gross section yield strength (for brace 1):*

fy in MPa

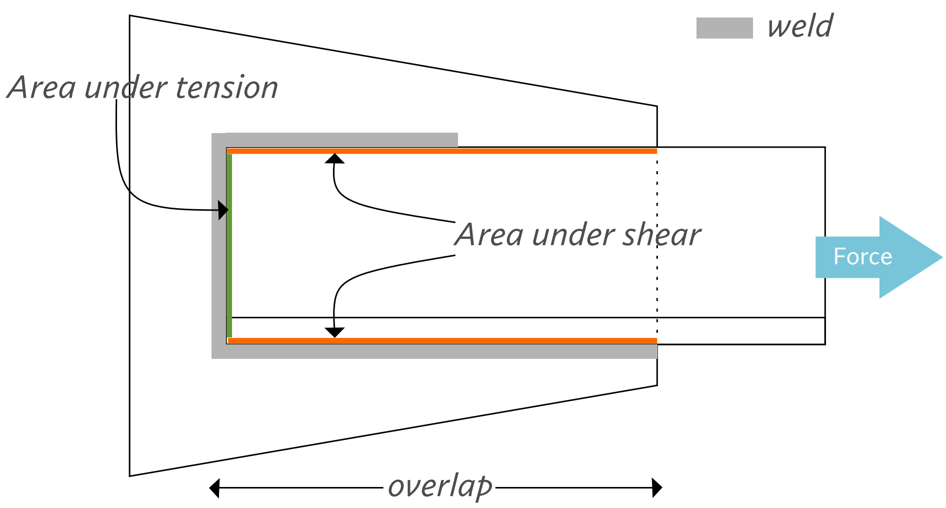
$$gsy = \frac{(\text{gross area}) \times fy \times 10^{-3}}{1.1} \times 2$$

multiply by 2 only if SP_brace = D_angle or D_channel

- btr → datatype: float

6.4.2 ***Welded Connection***

The block shear strength, T_{db} shall be checked for welded end connections by taking an appropriate section in the member around the end weld, which can shear off as a block.



6.4.1 *Bolted Connections* *(same for welded too)*

The block shear strength, T_{db} of connection shall be taken as the smaller of,

1.1 1.25

$$T_{db} = [\,A_{vg}\, f_y /(\sqrt{3}\,\gamma_{m0}) + 0.9 A_{tn} f_u /\gamma_{m1}\,]$$

or

$$T_{db} = (0.9 A_{vn}\, f_u /(\sqrt{3}\,\gamma_{m1}) + A_{tg}\, f_y /\gamma_{m0}\,)$$

*...**Avg** = **Gross area in shear** = 2 x [length of overlap] x thickness of connected leg*

*...**Atn** = **Net area in tension** = [width of connected leg] x thickness of connected leg*

*...**Avn** = **Net area in shear** = 2 x [length of overlap] x thickness of connected leg*

*...**Atg** = **Gross area in tension** = [width of connected leg] x thickness of connected leg*

Avg, Atn, Avn, Atg will multiply by 2 when SP_brace = D_angle or D_channel

If the least among gsy and btr is greater than F1 value, then proceed to the next step.
else: reject this section and choose the next larger section size within the user defined section profile.
}

STEP 9

Repeat step 1 - step 8 for all the section size

STEP 10

Optimization based on overlap length

Arrange all the designed sections in the increasing order of overlap length. The section size giving the least overlap length shall be selected as the most optimum section.

STEP 11

The algorithm for brace#1 ends here. Repeat all the steps for all the other braces connected at the joint.

STEP 12

Design check for Gusset Plate

- gsy_gusset = $\dfrac{\text{width of brace x t\_gusset x fy x } 10^{-3}}{1.1}$

- btr_gusset

Use same formula of btr mentioned in step 8, the only difference shall be that instead of "thickness of connected leg"; "thickness of gusset plate" (t_gusset) shall be used.

If the least of gsy_gusset & btr_gusset is greater than F1 value, then proceed to the next step.
else: increase the gusset thickness by increments of 2mm, repeat step 12 until the least of gsy_gusset & btr_gusset becomes more than F1.

STEP 13

Repeat step 12 for every brace. Each brace would give a unique t_gusset. The greatest among all the t_gusset shall be chosen as the final t_gusset.

OUTPUT DOCK:

Section Details:

Brace 1 *(similar for all other braces)*

Designation	*section size*
Tension Yield Capacity (kN)	*gsy*
Utilization Ratio	*F1/Tension Capacity*

Weld Details

Type	*Fillet Weld*
Size (mm)	*weld_size*
Strength (kN)	*weld_strength (from Step 7)*
Long Joint Red.Factor	*rf_lc*
Reduced Strength (kN)	*weld_strength (from Step 7)*
Stress (N/mm2)	*F1 / {weld_length x throat_thickness}*
Eff. Length (mm)	*eff_weld_length (at step 7)*

Gusset Plate Details

Thickness (mm)	*t_gusset*
Plate Length along brace 1 (mm)	*greater of L1 and L2*
Plate Length along brace 2 (mm)	*greater of L1 and L2*
(similar for all other braces)	
Plate Length Along Left Chord (mm)	*greater of L1 and L2*
Plate Length Along Right Chord (mm)	*greater of L1 and L2*
Tension Yield Capacity (kN)	*gsy_gusset*
Block Shear Capacity (kN)	*btr_gusset*
Pattern	*shear pattern*
Tension Capacity (kN)	*lesser of gsy_gusset, btr_gusset*

Create Design Report

Save Output

End of Algorithm

Chapter 4: References

- IS 800:2007, General Construction in Steel-Code of Practice, Third Revision, Bureau of Indian Standards (BIS), New Delhi
- Design of Steel Structures (2013), N. Subramanian, 12th Impression, Oxford University Press