Techno India NJR Institute of Technology

Design of Steel Structures Lab

(6CE4-22)

Rakesh Yadav
(Associate Professor)
Department of CE

Course Overview:

Student will learn basics of DSS from these 40 hours course. The subject has the significance to understand the types of structural steel members. Students will be able to analyse the structural behaviour and design under the different loading like Gravity forces, lateral forces (wind & seismic loads), temperature effects, vibrations etc. Students will learn about the types of structural steel elements as connections, tension and compression members, members subjected to bending or beams, roof truss, steel bridges, steel tanks etc. with corelating to Indian standards. DSS is the main requirement for the job role in the companies like Tata Steel, Jindal steel & Power Ltd, L&T construction etc. Most of the questions asked during the placement drive for these Company are created from this subject. Student should learn and develop problem solving abilities using DSS in order to get a good job in top civil engineering company**.**

Course Outcomes:

CO.NO.	Cognitive Level	Course Outcome
1	**Analysis**	Learner will be able to solve the designing of tension and compression members.
2	**Evaluation**	Learner will be able to solve the designing of beams and beam columns.
3	**Synthesis**	Learner will be able to solve the designing of bolt and weld connections.
4	**Synthesis**	Learner will be able to solve the designing of the gantry girder.
5	**Application**	Classify and design the structural steel components of industrial building.

Prerequisites:

1. Analyze characteristics of water and wastewater

2. Students will develop an appreciation for the importance of environmental engineering as a major factor in preserving and protecting human health and the environment

For Techno India NJR Institute of Technology
पंकज पोरवाल
Dr. Pankaj Kumar Porwal
(Principal)

Course Outcome Mapping with Program Outcome:

Course Outcome	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO364.1	3	3	3	3	2	2	2	1	1	1	2	3	2	1	1
CO364.2	3	2	2	3	2	1	2	1	1	1	1	1	2	1	1
CO364.3	2	2	2	1	2	2	2	2	1	1	2	1	2	1	1
CO364.4	3	2	2	2	2	2	1	1	2	1	2	2	2	1	1
CO364.5	3	3	3	32	1	2	1	1	1	1	2	2	2	1	1
CO364 (AVG)	2.8	2.4	2.4	8.2	1.8	1.8	1.6	1.2	1.2	1	1.8	1.8	2	1	1

Course Coverage Module Wise:

Lab No.	Exp. No.	Name of Experiment
1	1	Case study of foot over bridges/truss- girder bridge in vicinity home town of the students, preferably in groups of 8-10 students. A report including photographs marked with names and section details of different members in it
2	1	Case study of foot over bridges/truss- girder bridge in vicinity /home town of the students, preferably in groups of 8-10 students. A report including photographs marked with names and section details of different members in it
3	1	Case study of foot over bridges/truss- girder bridge in vicinity home town of the students, preferably in groups of 8-10 students. A report including photographs marked with names and section details of different members in it
4	2	Case study of a structure using tubular sections or light gauge sections in vicinity /hometown of the students, preferably in groups of 8-10 students. A report including photographs marked with names, size and section details of different members in it

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Faculty Lab Manual Link

1. https://r.search.yahoo.com/_ylt=AwrxzALl4qxhC3UAPWu7HAx.;_ylu=Y29sbwNzZzMEcG9zAzEEdnRpZAMEc2VjA3Ny/RV=2/RE=1638749029/RO=10/RU=https%3a%2f%2fwww.iare.ac.in%2fsites%2fdefault%2ffiles%2flab1%2fEnvironmental_Engineering%2520_Laboratory_Lab_MANUAL.pdf/RK=2/RS=wegI0PvdQ_xKJ3fWJJE2IP5K808-

Assessment Methodology:

1. Practical exam Of Environmental lab Experiment
2. Internal exams and Viva Conduct.
3. Final Exam (practical paper) at the end of the semester.

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Techno India NJR Institute of Technology

Academic Administration of Techno NJR Institute

Syllabus Deployment

Name of Faculty	: Mr. Rakesh Yadav	Subject Code: 6CE4-22
Subject	: Steel Structures Design	
Department	: Civil Engineering	Sem: VI
Total No. of Labs Planned: 6		

COURSE OUTCOMES HERE (3 OUTCOMES)

At the end of this course students will be able to:

CO1. Able to get the knowledge about design of joints and design of structural steel members subjected to tensile and compressive force.

CO2. Able to design the beams and columns under various loading and supporting conditions..

CO3. Able to know the design of structural systems such as roof trusses.

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Techno India NJR Institute of Technology
Department of Civil Engineering
3rd Year - VI Semester: B.Tech. (Civil Engineering)

6CE4-22: Steel Structures Design

1. Find the shape factor of a rectangular section.

Solution:

(i) Shape factor for rectangular section of size $b \times d$. (Refer Fig. 10.13)

Yield moment $(M_y) = f_y \cdot z$ where f_y = yield stress and z = section modulus

$$= f_y \cdot \frac{I_{zz}}{y_{max}} \quad \text{Here, } I_{zz} = I_{xx}$$

$$= f_y \cdot \frac{bd^3/12}{d/2}$$

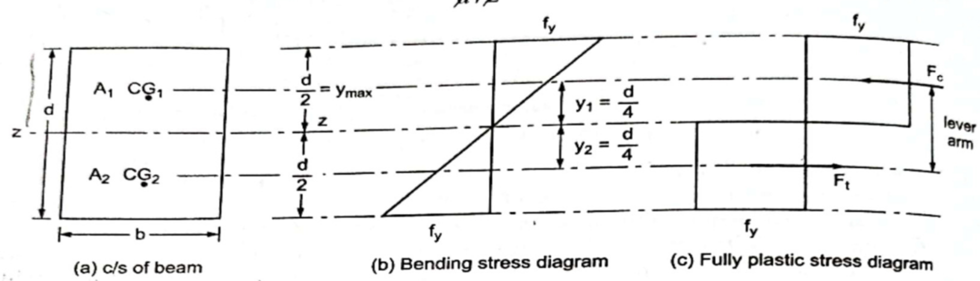


Fig. 10.13 Stress diagram for rectangular section

$$\therefore \quad M_y = f_y \cdot \frac{bd^2}{6}$$

Let, A_1 be the area under compression and A_2 be the area under tension respectively.

$\therefore \quad F_c = F_t$ F_c = compressive force, F_t = tensile force

$\therefore \quad f_y \cdot A_1 = f_y \cdot A_2$ as $A_1 = A_2 = \frac{A}{2}$

Now,

Plastic moment capacity is the moment of resistance when yield stress is 'f_y' at all fibres.

$$\therefore \quad M_p = F_c \cdot y_1 + F_t \times y_2$$

$$= f_y A_1 \cdot y_1 + f_y A_2 \cdot y_2$$

$$= f_y \cdot \frac{A}{2}\left[\frac{d}{4} + \frac{d}{4}\right]$$

$$= f_y \cdot \frac{A}{2} \cdot \frac{d}{2} \qquad \text{but} \Rightarrow A = bd$$

$$= f_y \cdot \frac{A \cdot d}{4}$$

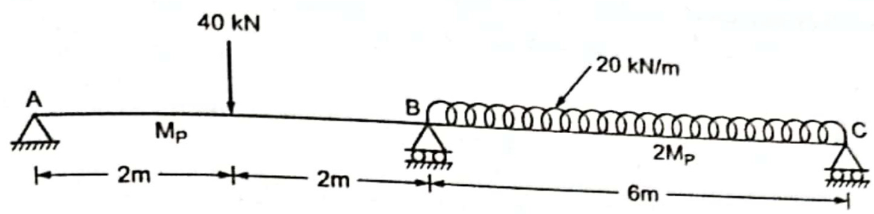
$$M_p = f_y \cdot \frac{bd^2}{4}$$

Hence, shape factor $(S) = \dfrac{M_p}{M_y}$

$$= \frac{f_y \cdot b\, d^2/4}{f_y \cdot b\, d^2/6} = \frac{6}{4}$$

$S = 1.5$ For rectangular section.

2. Calculate Plastic Moment Capacity required for Continuous beam with working load as shown in Fig.



Solution:

Load factor = 1.5

∴ Collapse load on $AB = 40 \times 1.5 = 60$ kN and

Collapse load on $BC = 20 \times 1.5 = 30$ kN/m

The loading is shown in Fig. 10.34.

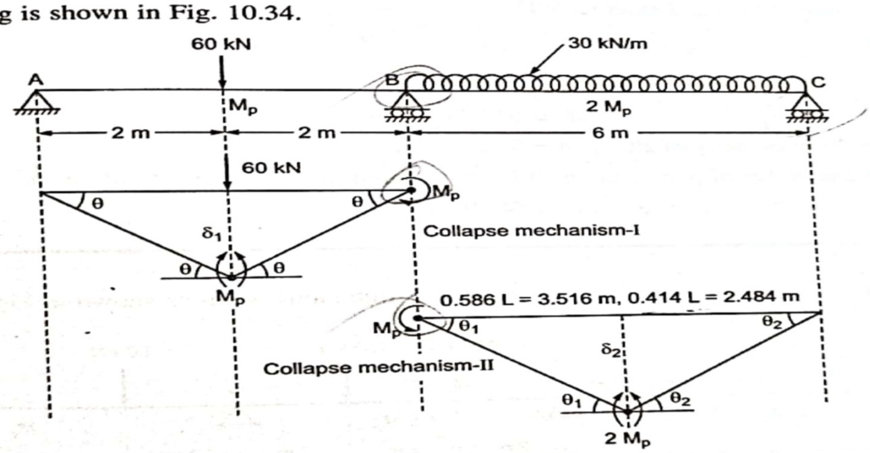


Fig. 10.34 Beam mechanism

(I) From Collapse Mechanism-I (Refer Fig. 10.34)

$$2\theta = \delta_1 = 2\theta$$

$$\text{Internal WD} = M_p\,(\theta + \theta) + M_p \cdot \theta = 3M_p \cdot \theta$$

$$\text{External WD} = 60 \times \delta_1 = 60 \times 2\theta = 120\,\theta$$

From the principle of virtual work

$$\text{Internal WD} = \text{External WD}$$

$$3M_p \cdot \theta = 120\,\theta$$

$$\therefore \qquad M_p = \frac{120}{3} = 40 \text{ kNm}$$

Plastic moment capacity of AB span = 40 kNm.

(II) From Beam Mechanism-II (Refer Fig. 10.34)

$$3.516\ \theta_1 = \delta_2 = 2.484\ \theta_2$$

$$\theta_1 = \frac{2.484\ \theta_2}{3.516} \qquad \therefore \quad \theta_1 = 0.706\ \theta_2$$

$$\text{Internal WD} = M_p \cdot \theta_1 + 2M_p\,(\theta_1 + \theta_2)$$

$$= 0.706\ M_p \cdot \theta_2 + 2M_p\,(0.706\ \theta_2 + \theta_2)$$

$$= 4.118\ M_p \cdot \theta_2$$

$$\text{External WD} = (30 \times 6) \times \frac{\delta_2}{2} = 90 \times 2.484\ \theta_2 = 223.56\ \theta_2$$

Equating, internal WD and external WD

We have,

$$4.118\ M_p \cdot \cancel{\theta_2} = 223.56\ \cancel{\theta_2}$$

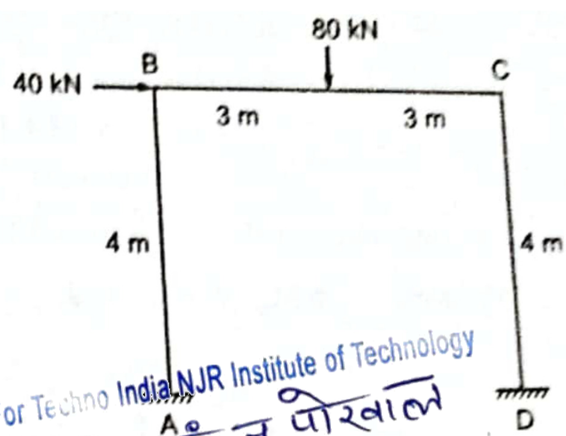
$$M_p = 54.288 \text{ kNm}$$

Plastic moment capacity of BC span = 54.288 kNm

$\therefore$ The higher value of plastic moment is the required moment capacity of beam

$$\therefore \qquad M_p = 54.288 \text{ kNm}$$

4 Determine plastic moment capacity of the section required for frame shown in given Fig. Load are working load factor = 1.75. Asume same M_p for all members



(i) Beam mechanism (Refer Fig. 10.38)

Fig. 10.37

$$\text{Internal WD} = M_p\,\theta + M_p\,\theta + M_p\,(\theta + \theta) = 4M_p\,\theta$$

$$\text{External WD} = 140 \times \delta \qquad \text{as, } \delta = 3\theta$$

$$= 420\,\theta$$

Eauation, Internal work done and external workdone

We have, $4\,M_p\theta = 420\,\theta$

$$M_p = \frac{420}{4} = 105 \text{ kNm}$$

$\therefore$ Plastic moment capacity of beam $BC = 105$ kNm

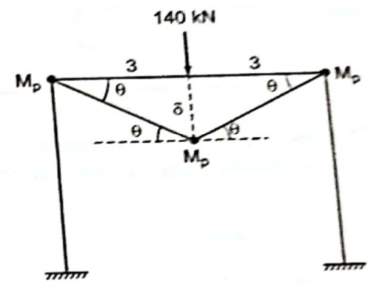


Fig. 10.38

(ii) Sway Mechanism (Refer Fig. 10.39)

$$\text{Internal WD} = M_p\theta + M_p\theta + M_p\theta + M_p\theta$$

$$= 4M_p\theta$$

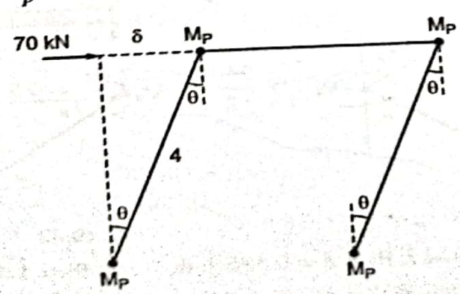
$$\text{External WD} = 70 \times \delta$$

$$= 70 \times 4\theta \qquad \text{as, } \delta = 4\theta$$

$$= 280\,\theta$$

Equating, $4\,M_p\theta = 280\,\theta$

$\therefore$ $M_p = 70$ kNm



(iii) Combined Mechanism (Refer Fig. 10.40)

$$\text{Internal WD} = M_p\theta + M_p(\theta + \theta) + M_p\theta + M_p\theta + M_p\theta = 6\,M_p\cdot\theta$$

$$\text{External WD} = 70 \times \delta_1 + 140 \times \delta_2;\ \delta_1 = 4\theta$$

$$= 70 \times 4\theta + 140 \times 3\theta;\ \delta_2 = 3\theta$$

$$= 700\,\theta$$

Equating, internal *WD* and external *WD*.

We have, $6\,M_p \cdot \theta = 700 \cdot \theta$

$$M_p = \frac{700}{6}$$

$\therefore$ $M_p = 116.67$ kNm

$\therefore$ Plastic moment capacity of frame is the highest of above

$\therefore$ $M_p = 116.67$ kNm

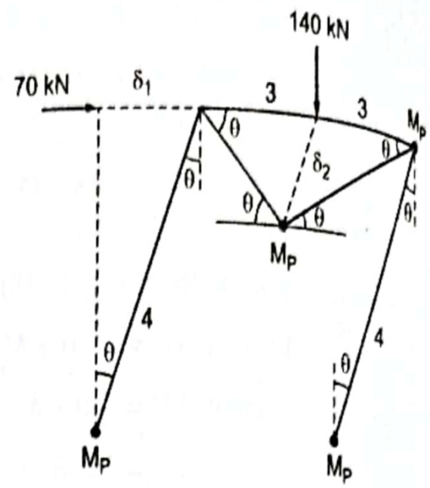


Fig. 10.40

5 **Explain the Types of Bolted connection and write the failure modes of bolted connections.**

Bolted Connections

Connections are always needed to connect two members. It is necessary to ensure functionality and compactness of structures. Prime role of connections is to transmit force from one component to another. Steel connections can be made by bolts or welds. Connections accounts for more than half cost of steel structure. Connections are designed more conservative than members because they are more complex.

1. **Types of Bolts**
    1) Unfinished Bolt – ordinary, common, rough or black bolts
    2) High strength Bolt – friction type bolts
2. **Classifications of Bolted connections:**
    1) Based on Joint:
    2) Lap Joint
    3) Butt Joint
    4) Based on Load transfer Mechanism**:**
    5) Shear and bearing,
    6) Friction
3. **Grade classification of Bolts:**
    - The grade classification of a bolt is indicative of the strength of the material of the bolt. The two grades of bolts commonly used are grade 4.6 and 8.8.
    - For 4.6 grade 4 indicates that ultimate tensile strength of bolt = 4 × 100 = 400 N/mm2 and 0.6 indicates that the yield strength of the bolt is 0.6 × ultimate strength = 0.6 × 400 = 240 N/mm2

Most Imp Failure of Bolted Joints.

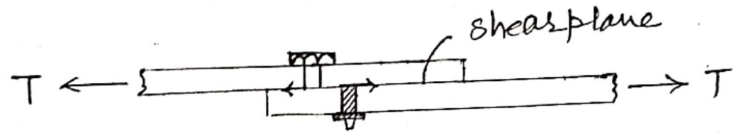
There are two categories of failure

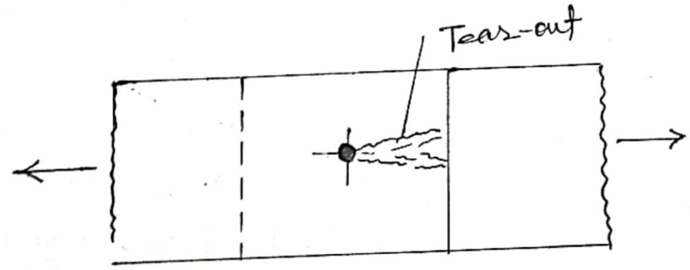
(a) Failure of Bolts. (b) Failure of plates.

(i) Shear failure :-

(a) Shear stresses are generated when plates slip due to applied force, Maxm shear stress in bolt may exceed to the nominal shear capacity

(b) When plate material is weaker than bolt than shear tear-out at end of the connected member take place.

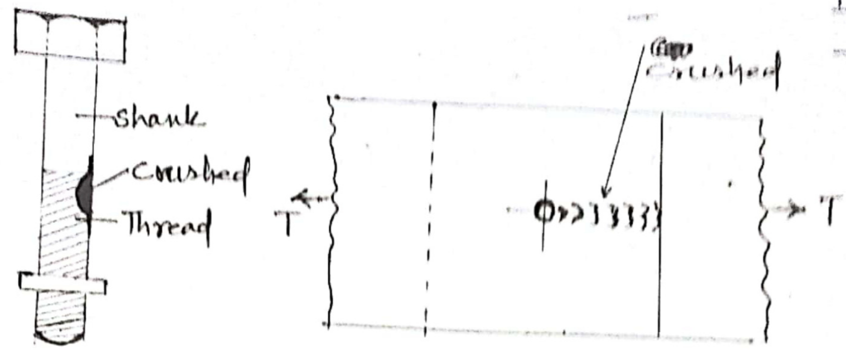




(ii) Bearing Failure

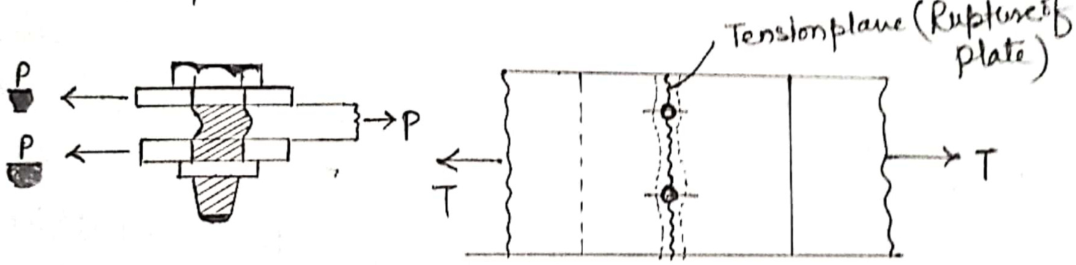
(a) Bolts are Crushed around the half Circumference. The plate having good strength in bearing which may press the bolt shank. So bolt deforms due to high local bearing stress.

(b) If plate material is weaker, It gets crushed



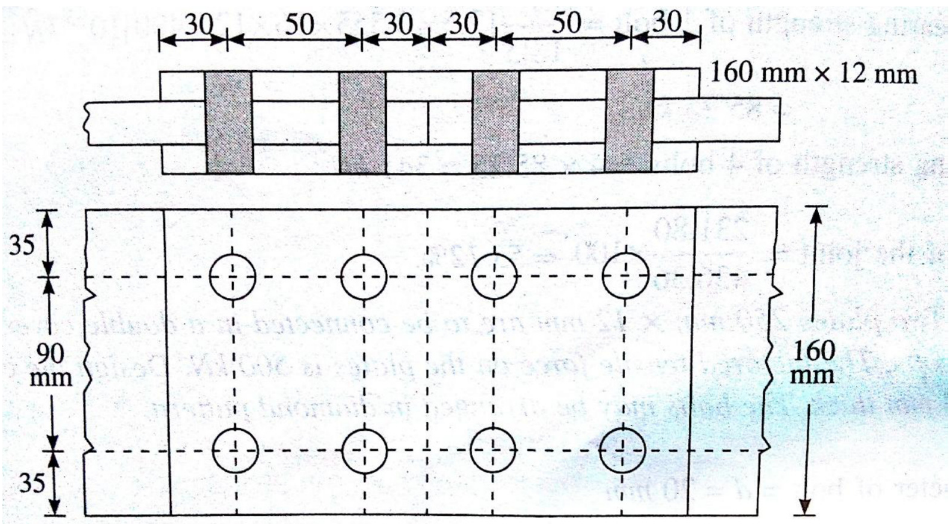
(iii) <u>Tensile Failure</u> :(a) Bolts are subjected to tension at tension plane (Stressed Area), also weaker than plate material.

(b) It occurs when plate is not sufficient flexible and weaker than Bolt material.



iv) <u>Block-shear Failure</u> :- In this failure, The failure of member occurs along a path involving tension on one plane and shear on perpendicular plane along the fasteners. When a block of material within bolted area breaks away from the remainder area. Such failure may appear.

6. Find the efficiency of the butt join shown in figure. Bolts are 16mm diameter of grade 4.6. Cover plates are 8mm thick.



Shear Strength (*IS 800:2007, Clause 10.3.3, page no. 75)*

$$Vdsb = Vnsb\gamma mb$$

$Vnsb = fu\sqrt{}3\times [nnAnb + nsAsb]\ Vdsb$

$= 400\sqrt{}3\times 1.25\times [(2 \times 0.78 \times \pi 4\times 162) + (0 \times \pi 4\times 162)]$

= 57.95 kN

Bearing Strength:*(IS 800:2007, Clause 10.3.4, page no. 75)*

$$Vdpb = Vnpb\gamma mb$$

$$Vnpb = 2.5kb\ dtfu$$

$Vdpb = 2.5 \times 0.56 \times 16 \times 12 \times 4101.25 = 88.16\ kN$

e = 30mm

p = 50 mm

e/3do = 30/ (3 × 18) = 0.56;

p/3do – 0.25 = [50/ (3 ×18)] – 0.25 = 0.67;

fub/fu = 400/410 = 0.976;

$Efficiency\ of\ the\ joint$ = [$Strength\ of\ the\ Joint\ per\ pitch\ length$ / $Strength\ of\ solid\ plate\ per\ pitch\ Length$] ×100

Strength the joint per pitch length = 57.95 kN

$Strength\ of\ solid\ plate\ per\ pitch\ length$ = $0.9A_nf_u\gamma_{m1}$ (clause no. 6.3.1, page no. 32, IS 800:2007)

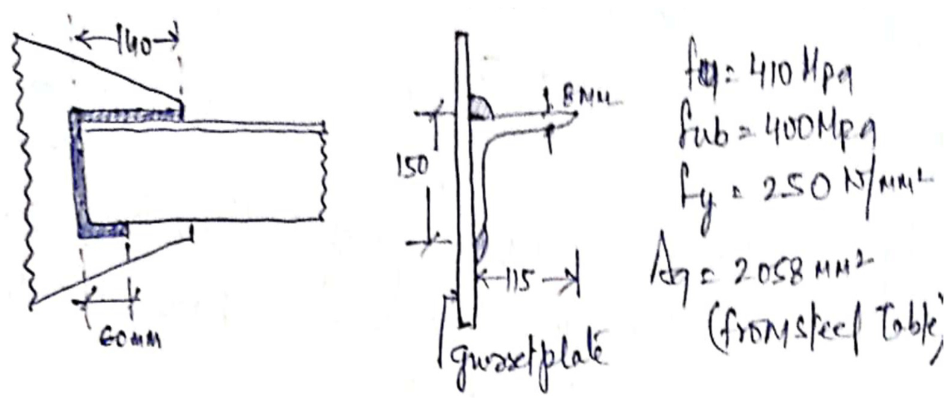
= 0.9× (50−16) ×12×4101.25

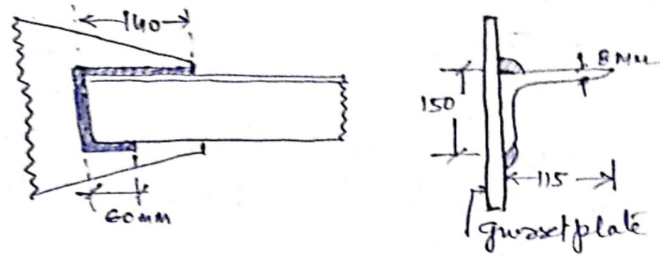
= *120.44 kN*

$Efficiency\ of\ the\ joint$ = [57.95120.44] ×100

= *48.11 %*

7. **Compute tensile strength of an angle ISA 150X115X8 mm of Fe 410 grade connected with gusset plate for a) Gross section yielding b) Net Section rupture.**





$f_u = 410$ Mpa
$f_{ub} = 400$ Mpa
$f_y = 250$ N/mm²
$A_g = 2058$ mm²
(from steel Table)

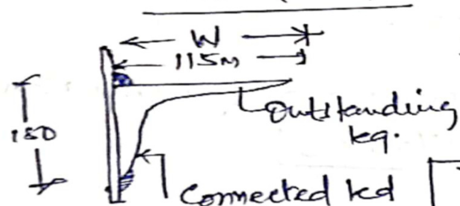
ANS

(1) Strength in Yielding of Gross Area :-

$$T_{dg} = \frac{A_g \cdot f_y}{\gamma_{m0}} = \frac{2058 \times 250}{1.10}$$

$$T_{dg} = 467.73 \text{ kN}$$

(2) Strength in fracture/Rupture ~~at Net Section~~ of Critical section :-



Shear width $(b_s) = 115$ mm
As per IS 800:2007
$b_s = W$

$$T_{dn} = \frac{0.9 A_{nc} \cdot f_u}{\gamma_{m1}} + \frac{\beta A_{go} \cdot f_y}{\gamma_{m0}} \quad \text{— (A)}$$

Weld Length $(L_c) = 140 + 150 + 60 = 350$ mm

$$\beta = \left\{1.4 - 0.076\left(\frac{115}{8}\right)\left(\frac{250}{410}\right)\left(\frac{115}{350}\right)\right\} \le \left\{\frac{410}{250} \times \frac{1.10}{1.25}\right\} \ge 0.7$$

$$\beta = 1.1811 \le 1.443 \ge 0.7 \quad \therefore \beta = 1.18$$

Now Net Area of Connected Leg $(A_{nc}) = \left\{150 - \left(\frac{8}{2}\right)\right\} \times 8 = 1168$ mm²

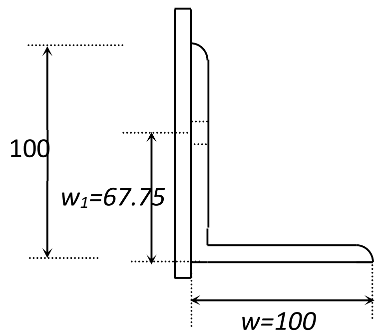
Net Area of Outstand leg $(A_{go}) = \left\{115 - \left(\frac{8}{2}\right)\right\} 8 = 888$ mm²

$$T_{dn} = \frac{0.9 \times 1168 \times 410}{1.25} + \frac{1.18 \times 888 \times 250}{1.10}$$

$$T_{dn} = 516.54 \text{ kN}$$

STRENGTH OF THE ANGLE (Min. Value) = 467.73 kN

8. **Design a single Equal angle 100 x 100 x 8 mm, connected to a gusset plate at the ends with 20mm diameter bolts with the connection length of 250mm to transfer tension.**



Net area of connected leg *(A_{nc})* = $(100-8/2-21.5)\times 8$ = 596 mm²

Gross area of outstanding leg *(A_{go})* = $(100-8/2)\times 8$ = 768 mm²

Area of gross section *(A_g)* = $(100+100-8)\times 8$ = 1536 mm²

Yield stress of steel *(f_y)* = 250 MPa

Ultimate stress of steel *(f_u)* = 410 MPa

Minimum End distance of fastener = 32.25 mm

Minimum Edge distance of fastener = 32.25 mm

Strength as governed by Rupture of Critical section:

Table 10.1

Shear Lag Distance *(b_s)* = 160 mm

Connection length (*L_c*) = 250 mm

Hence β $= 1.4-0.076\times(w/t)\times(f_y/f_u)\times(b_s/L_c)$

= 1.4-0.076x((100/8)x(250/410)x(152/250) = 1.03

Clause 6.3.2

Tensile strength, T_{dn} = $0.9\times A_{nc}\times(f_u/\gamma_{m1})+\beta\times A_{g0}\times(f_y/\gamma_{m0})$

$$= 0.9\times 596\times\left(\frac{410}{1.25}\right)+1.03\times 768\times\left(\frac{250}{1.1}\right)$$ = 356 kN

Strength as governed by Yielding of Gross section:

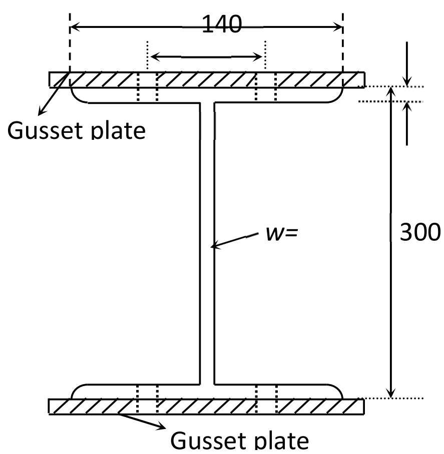
Tensile strength, T_{dg} = $A_g \times (f_y/\gamma_{m0})$ = $1536 \times (250/1.1)$

= 349 kN

Hence yielding of gross area governs the member strength.

Therefore Design Tensile Strength of the member , T_d = 349 kN **Clause 6.2**

9. Design the tensile strength of section ISMB300 with gusset plate connected to the flange. The section is connected to end gusset plate by using four rows of 18 mm bolts at a section and a connection length of 100mm.



Section properties:

Gross area A = 5626 mm^2

Depth of section D = 300 mm

Breadth of flange b = 140 mm

Thickness of flange t_f = 12.40 mm

Thickness of web t_w = 7.5 mm

Net area of connected leg (A_{nc})

= 5626-(300-2*12.4)*7.5-4*19.5*12.4

= 2594.80 mm^2

Area of outstanding leg (A_{go}) = $(300 - 2\times 12.4)\times 7.5$ = 2064 mm^2

Tensile strength by yielding of gross section:

T_{dg} = $A_g \times f_y/\gamma_{m0}$ = $5626 \times 250/(1.1\times 1000)$ = 1279 kN

Tensile strength by rupture of critical section:

w_1 = (g)/2 = 40 mm; *w = 300/2 = 150 mm* **Clause 6.2**

b_s = 150 + 40 – (12.4+7.5)/2 = 180.05mm ; L_c = 100 mm

$\beta = 1.4 - 0.076 \times (w/t) \times (f_y / f_u) \times (b_s / L_c)$

$= 1.4 - 0.076 \times (150/7.5) \times (250/410) \times (180.05/100)$ = *-0.268* < 0.7

Hence β = 0.7

$T_{dn} = 0.9 \times A_{nc} \times (f_u / \gamma_{m1}) + \beta \times A_{g0} \times (f_y / \gamma_{m0})$ **Clause 6.3.3**

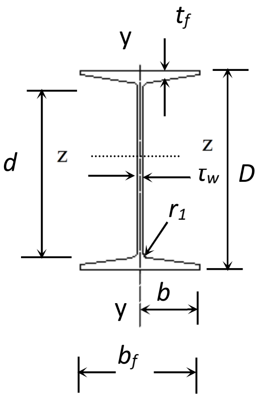
$= ((0.9 \times 2594.8 \times 410/1.25) + (0.7 \times 2064 \times 250/1.1))/1000$

= 1094.35 kN

The tensile strength of the section is 1094 kN.

10. Design the compressive strength of the column section ISLB 500 @0.75 kN/m with the effective length of the column as 5 m. Assume the buckling axis as y-y axis and basic yield strength (f_y) as 250 mPa.

Section Properties:



Gross area of the section (A_g)= *95.50x10 ^{2}mm^2*

Depth of section (*D*) = *500 mm*

Full Width of flange (b_f) = *180 mm*

Thickness of flange (t_f) = *14.1 mm*

Thickness of web (t_w) = *9.2 mm*

Radius of gyration(r_y) = *33.4 mm*

Radius at root (r_1) = *17 mm*

Yield stress (f_y) = 250 mPa

Section classification:

$$\varepsilon = \sqrt{\frac{250}{f_y}} = 1$$

Flange:

$b = b_f / 2 = 180 / 2 = 90$ mm

$b / t_f = 90 / 14.1 = 6.38 < 9.4\, \varepsilon$ **(Plastic)**

∴ Flange is fully effective

Web: **Table 3.1**

$d = D - 2 \times t_f - 2 \times r_1$

$= 500 - 2 \times 14.1 - 2 \times 17 = 437.8\ mm$

$d / t_w = 437.8 / 9.2 = 47.6 > 42\, \varepsilon$ **(Slender)**

∴ Web is not fully effective

Section is classified as **Slender**

Net area of the section $= A_g - (((d / t_w) - 42) \times t_w \times t_w)$

$= (95.50 \times 10^2) - ((47.6 - (42 \times 1)) \times 9.2 \times 9.2) = 90.77 \times 10^2\ mm^2$