Sub - Structural Design - II
Sem - 5th
Branch - Civil

Bishnu Bharati Swain
Lecture in civil

1) Introduction
2) General Design consideration
3) Connection
4) Tension Member
5) Comp. Member
6) Beam
7) Gantry Girder
8) plate girder
9) Industrial building.

INTRODUCTION

IS codes

IS 800 : 2007 → General construction in steel
(with abendment no.1, ~~Generally~~ Janury 2012)

IS 808 : 1989 → Dimensions for steelsections
(Steel Tables)

Steel :- It is an alloy of Iron having carbon content b/w 0.1 - 1.1 %

- Based on carbon content 3 types of steel.
  1. low carbon steel → (0.1 – 0.25 %) carbon.
  2. Medium carbon steel → (0.25 – 0.60 %)
  3. High carbon steel → (0.6 – 1.1 %)

Deoxiders such as silicon or Aluminium are used to control dissolved oxygen during the Manufacturing process

- lower % of oxygen content is good for durability (air in voids will be less) of steel and on the Basis of oxygen content we classify steel as
  - (i) Killed Steel → (< 30 ppm oxygen)
  - (ii) Semi-killed → (30 – 150 ppm)
  - (iii) Rimmed steel → (>150 ppm oxygen)

Structural steel are generally killed or semi-killed.
carbon % in structural steel is generally < 0.25 %.
(Low carbon steel) → Ductility ↑

Mild steel has a carbon content of nearly 0.1%

IS 800:2007 can be used for structural Mild steel or High Tension structural steel.

Various Grades of steel :-

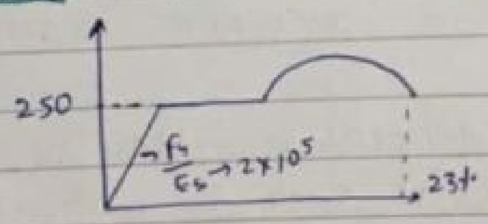
Grade	Ultimate stress (MPa)	Yield stress (MPa)
✓ E 250 (Fe 410) A	410	250
B	410	250
C	410	250
E 300 (Fe 440)	440	300
E 350 (Fe 490)	490	350
E410 (Fe 540)	540	410

E 250 (Fe 410) A → Grade of steel
(E 250 → char. yield stress; Fe 410 → char. ultimate stress)

Fe 410 W → Weldability Higher
(410 → char. ultimate stress)

NOTE ① Structural steel is specified according to charecteristic ultimate Tensile stress i.e (f_u)
It is the ultimate stress below which not more than 5% of the materials are expected to fall.

② R/F Bars in RCC are specified according to yield stress



③ Thinner the sec^n, Higher is the strength due to Higher amount of rolling, cold working, uniform rate of cooling etc.

Ex.

	$t < 20$ mm	$20 < t < 40$ mm	$t > 40$ mm
E 250 (fe410)	$f_y = 250$ MPa	240 MPa	230 MPa

t → कम, Rolling ज्यादा, strength → ज्यादा

④ Brittle fracture occurs due to higher Tensile stress, lower temp., thicker material, Rapid change of stresses etc.

⑤ Stainless steel is low carbon steel with around 10.5% cromium by weight. strain → कम, Ductility ↑, corrosion ↓

Grade A is used for Non-critical applications i.e. when members are not prown to brittle fracture. Normal structure

Grade B is used for critical applications when Temp. doesn't fall below 0°C and when parts are prown to Brittle fracture or Fluctuations of stresses as in case of Bridges

Grade C has a gurenteed low temp. upto −40°C and it shall be used for impact loading and higher chances of Brittle Fracture Ex. Ship, sea, Marine

Physical properties of steel (For all Grades)

① Density of steel → $\rho = 7850$ kg/m³

② Modulus of Elasticity → 2×10^5 MPa

③ Poisson's Ratio → $\mu = 0.3$ → Elastic zone; $\mu = 0.5$ → plastic zone

④ Shear Modulus → $G = \dfrac{E}{2(1+\mu)} = 0.769 \times 10^5$ MPa (Elastic zone)

⑤ Specific Gravity → 7.85

⑥ Cofficient of thermal expansion → $\alpha = 12 \times 10^{-6}$ /°C

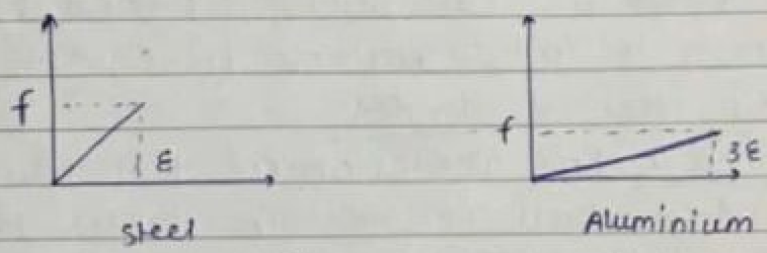
* Advantage of Steel as a Structural Material

1. High strength per unit weight
2. High Ductility. High toughness
3. uniformity ie very less quality control issues
4. Environment friendly. can be 100% recycled
5. Easy connections and faster constructions
6. Easy repair and Modifications
7. longer life is properly Maintained.

* Disadvantages

1. Higher Maintainence due to corossion
2. Fire proofing cost
3. prown to buckling due to longer and slender member → (can't used more than 50% strength)
4. fatigue

Aluminium



- Higher strength to unit Wt. Ratio compare to steel
- However due to lower Modulus ($1/3^{rd}$ of steel) Bigger sec^n are required to avoid buckling
- Greater Resistance to corossion and Hence less maintainence
- Density ≈ $1/3^{rd}$ of steel. (2700-2800 kg/m^3)
- Cofficient of thermal expansion ≅ 2 x steel = $23 \times 10^{-6} /°c$
- less Ductile than Mild steel
- Doesn't have a well defined yield point and hence yield is assumed @ 0.2% proof strain → (stress) corresponding
- As it's Modulus is $1/3^{rd}$ of steel, it can absorb 3 times the energy @ same stress level compare to steel Member of same dimension provided the stress doesn't exceed the proportionality Limit. Hence also used for impact loading provided Higher Deflection is allowed.

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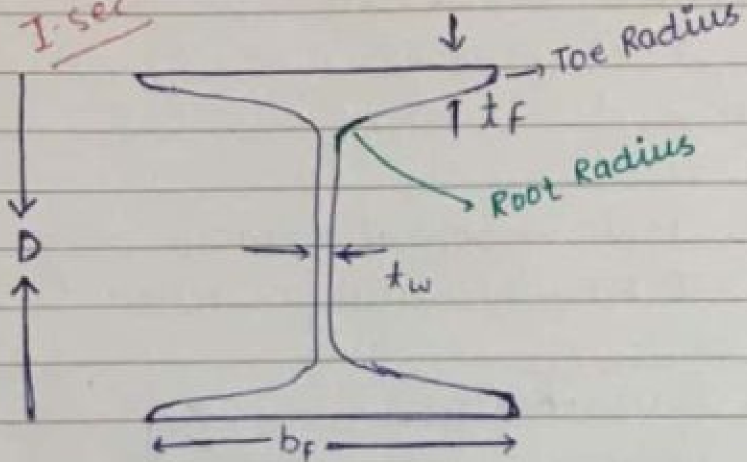
• Design concept same as steel structure.

Standared structural steel sections :-

I-sec^n



ISJB → Indian standared junior Beam

ISLB → IS Light Beam

ISMB → IS Medium Beam

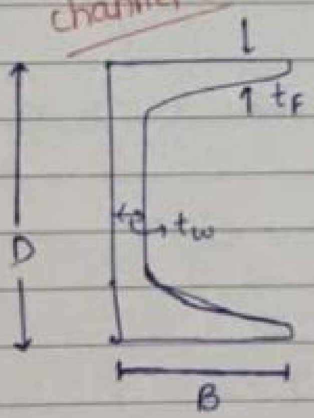
ISHB → IS Heavy Beam

ISSC → IS column section (Type of I section)

Ex: ISMB 300 → D = 300 mm , B | b_f = 140 mm

t_f = 13.1 mm , t_w = 7.7 mm

channel sec^n



ISJC → Junior channel

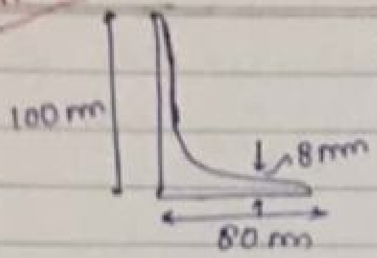
ISLC → Light channel

ISMC → Medium channel

Ex: ISMC 100 → D = 100 mm B = 50 mm

t_f = 7.7 mm , t_w = 5 mm.

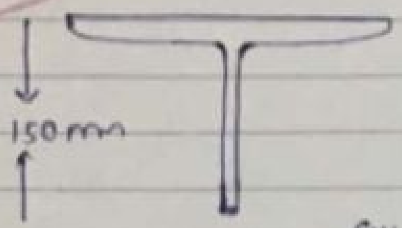
Angle secⁿ



ISA → IS equal / unequal Angle

ISA → 100 x 80 x 8

T-secⁿ



ISNT → Normal T- section
ISMT → Medium T- section

Ex: ISNT 150 @ 223.7 N/m

ISRO → Round Bars
Ex: ISRO10 (dia = 10 mm)

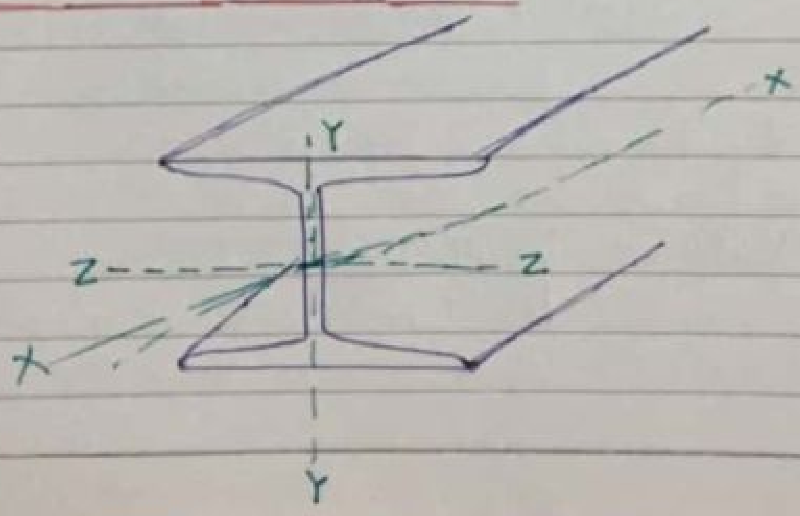
ISSQ → square Bars
Ex: ISSQ 10 (10 mm = side)

ISPl → plate
Ex: ISPl2000x1000x8 (lxbxt)

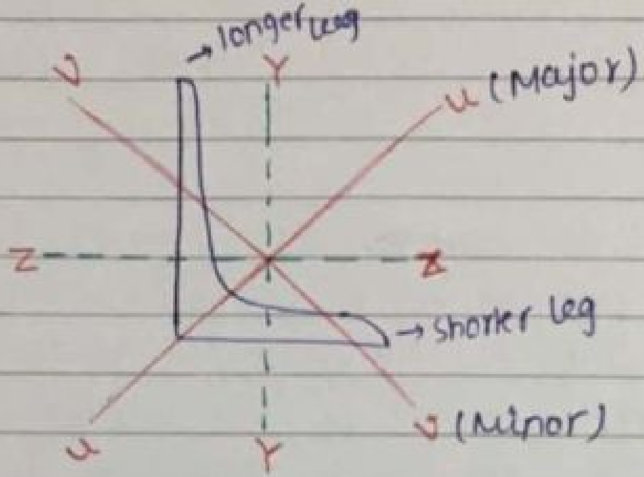
ISFl → Flat secⁿ
Ex 30 ISF10 → (30 mm → width, 10 m → thickness)

These secⁿ can be used either alone (Rolled secⁿ) or in combinations (built up secⁿ)

Convention for Member Axes :-



along length → x-x
parallel to Flange → Z-Z (Major)
⊥ to Flange → Y-Y (Minor Axis)



parallel to smaller leg → Z-Z (higher Inertia)
⊥ to smaller leg → Y-Y (lesser Inertia)
in Earlier version of the IS code i.e IS 800 1984
Major Axis was denoted as x-x

GENERAL DESIGN consideration

structure shall fulfill safety, serviceability, Economy, Aesthetic and environmental criteria.

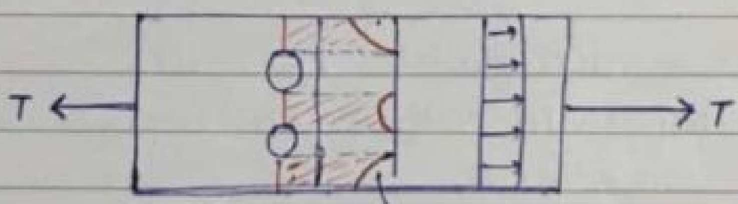
3. Design Methods :-

(i) Elastic / WSM
(ii) plastic / ULM
(iii) LSM

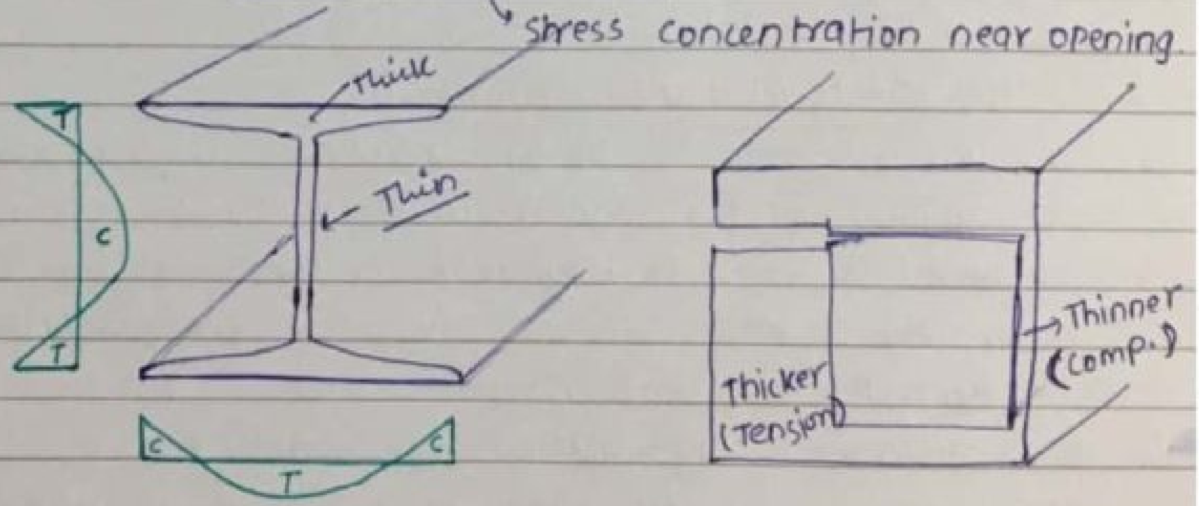
(i) WSM

It assumes linear elastic Response and safety is ensured by ensuring working stress to be less than permissible stress.
(strength of Material / FOS) = f_y/FOS

However assumptions of stress being less than permissible stress is not realistic because of stress concentration. and long term effect of creep & shrinkage, Residual stress and other secondary stresses.



NOTE



Flange की length ज्यादा रहती, web की कम due to comp in web

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- Unequal Rate of cooling due to diff^{n} thickness and exposed area and uneven comp. by roller will lead to generation of residual stress. The part of sec^{n} which cools first will have comp. because it will resist the shortening of slower cooling part. Also the slower cooling part will have Tension

- Does not utilise the reserve strength derived from ductility and redistribution of stress and hence FOS doesnot give a realistic figure or exact Margin of safety

- FOS does not have a scientific Basis and is based on experience.

- It fails to discriminate b/w diff^{n} types of load that are simultaneously acting but have varying degree of uncertainity.

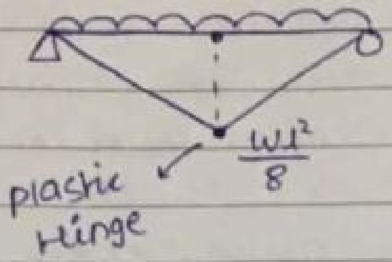
② ULM or load Factor Method

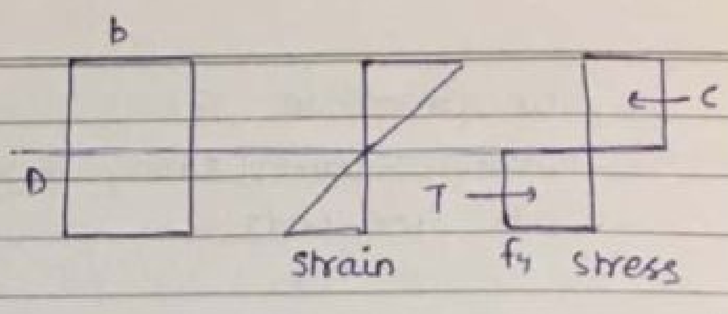
Design is done as in the case of plastic analysis in which working load multiplied by load factor is ensured to be less than the collapse load or ultimate load. However this Method does not consider serviceability cond^{n} like deflection. vibration etc

Also structure subjected to impact and Fatigue loading shall not be design with plastic theory. As it uses full Material strength beyond elastic limit

- Also safety for material is not considered Hence this gives smaller c/s than WSM.

③ ~~LSM~~:-



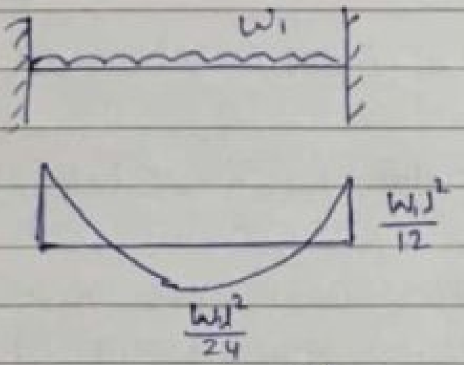


$$C = T = f_y \cdot \frac{bD}{2}$$

$$MOR = f_y \cdot \frac{bD^2}{4} = f_y \cdot Z_p$$

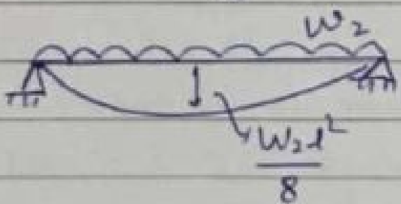
$$M_e = f_y \cdot Z_e = f_y \cdot \frac{bd^2}{6}$$

$Z_e \rightarrow$ elastic Modulus
$Z_p \rightarrow$ Plastic Modulus



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

$$\frac{W_1 l^2}{12} = M_p \text{ (Hinge @ ends)}$$



$$\frac{W_2 l^2}{8} = \frac{M_p}{2}$$

$$\Rightarrow \boxed{W_1 + W_2 = \frac{16 M_p}{l^2}}$$

③ LSM:- To avoid all deficiencies of WSM & plastic Method, LSM was proposed. partial safety factors are used for load and Material strength both based on acceptable probability of failure derived using realiability analysis (level 1)

- partial safety factor takes into account possible overloads and understrength.

Design action (considering partial safety factor for loads) $\leq$ Design strength (considering partial safety factor for Materials)

- Factored load / Design load (f_d) = charecteristic load x γ_f

  $\gamma_f \rightarrow$ partial safety factors for loads depending on loads combination and limit state being considered.

- Design strength (f_d) = $\frac{\text{charecteristic strength}}{\gamma_m}$

  $\gamma_m \rightarrow$ partial safety factor for material strength

* charecteristic load is the load which has 95% probability of not being exceeded during the life of the structure

* charecteric strength is the strength below which not more than 5% of test samples are expected to fall.

γ_f accounts for ($\gamma_f \rightarrow$ partial safety for loads)

(i) possibility of load exceeding charecteristic load
(ii) possibility of inaccurate assessment of load
(iii) Uncertainity in assessment of effect of load.
(iv) Uncertainity in the assessment of limit state being considered

γ_m accounts for ($\gamma_m \rightarrow$ partial safety factor for Material)

(i) possibility of strength falling below charecteristic strength
(ii) Reduction in Member size due to faulty construction
(iii) Reduction in strength due to febrication & Tolerences.

(joint match उसे पर)

(iv) uncertainity in theoritical assumptions.
(v) uncertainity in the calculation of strength of Member

Limit states are the states beyond which the structure becomes unfit for use.
The limit states are classified as —
1) Limit state of strength / ultimate limit state
2) Limit state of serviceability

Limit state considered by IS code.

① Limit state of strength

1) strength including yielding, buckling and transformation into a Mechanism (plastic Hinge formation)
2) stability against overturning and sway
3) failure due to excessive deformation or Rupture
4) Fracture due to fatigue
5) Brittle fracture.

② Limit state of serviceability

(i) deformation & deflection (can cause damage to non-structural component and finishes but not to structural component)
2) vibration (causing discomfort)
3) repairable damage or crack due to Fatigue
4) corossion, durability
5) Fire resistance

Limit state Method consider safety @ Ultimate load and serviceability @ Working Load.

NOTE In practice structures are designed for critical state and check for other State However in most of cases ultimate limit state governs the design

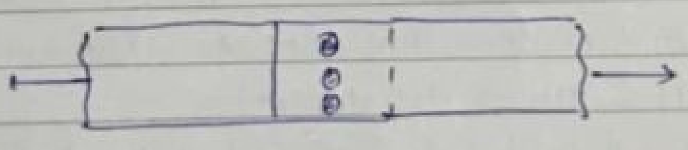
Partial safety factor for material (γ_m)

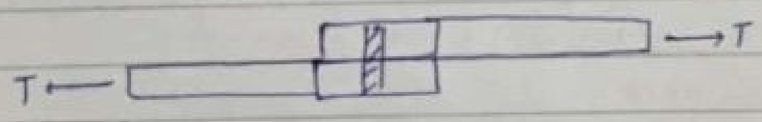
Defination	γ_m
(i) Resistance Governed by yielding (γ_{m0})	1.10
(ii) Resistance Governed by buckling (γ_{m0})	1.10
(iii) Resistance Governed by ultimate stress (γ_{m1})	1.25

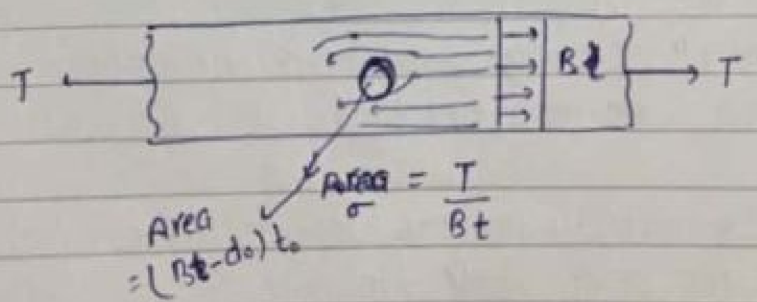
For connections	Shop Fabrication	Field Fabrication
Bolt - Bearing type (γ_{mb})	1.25	1.25
Bolts - Friction type (γ_{mf})	1.25	1.25
Rivets (γ_{mr})	1.25	1.25
Welds (γ_{mw})	1.25	1.5

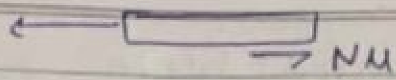
We generally consider Rupture in Net Area and yielding in Gross secn

Yielding is not considered @ Net secn i.e @ joint location as some yielding @ joint is allowed & Basically we need to check excessive deformation and Rupture

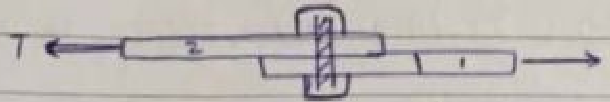


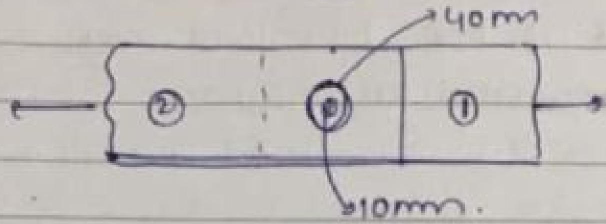


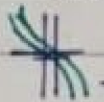




अगर bolt. hole से छोटा हो.

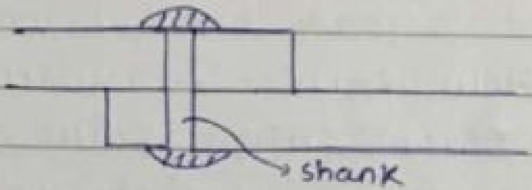






अगर Hole, bolt से छोटा हो
— Shear से force transfer

Rivet



Partial safety factor for Load (γ_f)

Combination	Limit state of strength					Limit state of serviceability			
	D.L	L.L		EQ/W.L	A.L	D.L	L.L		EQ/W.L
		Leading	Accom.				Leading	Accom.	
DL+LL+CL	1.5	1.5	1.05	—	—	1	1	1	—
D.L+L.L+C.L	1.2	1.2	0.53	1.2	—	1	0.8	0.8	0.8
same + EQ/W.L	1.2	1.2	1.05	0.6	—	1.0	0.8	0.8	0.8
DL+EQ/WL	1.5 or 0.9	–	–	1.5	—	1	–	–	1
DL+ER	1.2 or 0.9	1.2	–	–	–	No serviceability check required			
DL+LL+AL	1.0	0.35	0.35	–	–				

C.L → crane load

A.L → Accidental load

ER → Errection load

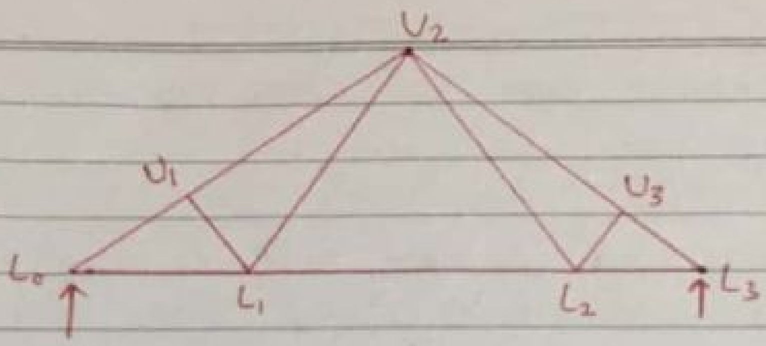
NOTE 0.9 value shall be considered when stability against overturning, sliding or stress reversal is critical

- leading live load is the live load causing the higher load effects and acommpaning L.L is the L.L except leading L.L i.e load causing lower effects.
- Impact, collissions, fire etc can be called as Accidental load.
- Wind load and EQ load are not considered simultaneously
- Although fatigue failure is usually considered as Ultimate limit state, fatigue failure design is carried out @ working load because in case of fatigue load applied is normal load or charecteristic load with higher no. of repeatations.

The charecteristic load require statistical Data in the absence of which the load can be considered from different IS code.

IS 875 (part-1) → D.L
(part-2) → L.L
(part-3) → W.L
(part-4) → snow load
(part-5) → Erection load.
IS 1893 (part-1) → EQ load

Que.



Find the design comp. and tensile force for the principle Rafter.

Member	DL(KN)	LL(KN)	WL(KN)
L_0U_1	-9.5	-9.5	32.5
U_1U_2	-8.0	-8.0	32.5
U_2U_3	-8.0	-8.0	32.5
U_3L_3	-9.5	-9.5	32.5

Member	1.5(DL+LL)	0.9 DL+1.5WL	1.2 (DL+LL+WL)
L_0U_1	-28.5	40.2	16.2
U_1U_2	-24	41.5	19.8
U_2U_3	-24	41.5	19.8
U_3L_3	-28.5	40.2	16.2

Design comp. force = -28.5 KN

Design Tensile force = 41.5

WSM

Permissible stress

- Axial Tension/comp. = $0.6 f_y$
- Bending Tension/comp. = $0.66 f_y$
- in shear = $0.4 f_y$
- in Bearing = $0.75 f_y$

} Structure

LSM

→ $\frac{f_y}{1.1}$ → All

$\frac{f_y}{\sqrt{3} \times 1.1}$ → shearing.

$\frac{f_y}{\sqrt{3} \times 1.25}$ → Bolt or Weld

BOlted CONNECTIONS

Depending upon Rigidity of joint connections are classified as:-

① Rigid connection / Moment connection :-

Develop the full or significant Moment capacity of connecting Members and retain the original angle b/w the members

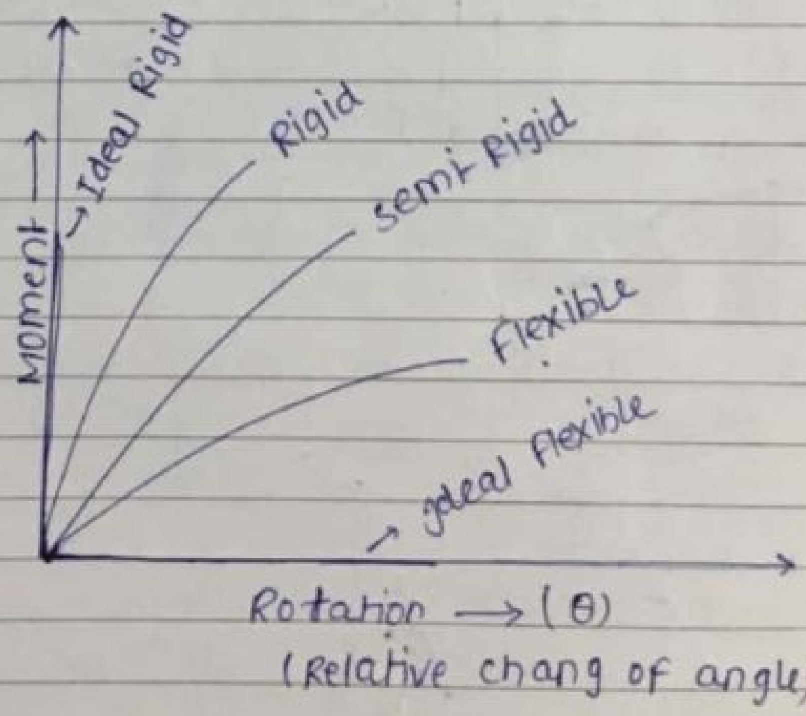
② Simple / Flexible connection

No moment transfer is considered b/w the connected parts and hence joints are assumed to be pin or Hinge connection

③ Semi- Rigid connection

Does not have sufficient Rigidity to hold the original Angle b/w the members and develop less than full Moment capacity of the connected Members.

NOTE In Reality all the connections are semi- Rigid. However for convinience We assume either Rigid or simple conne.

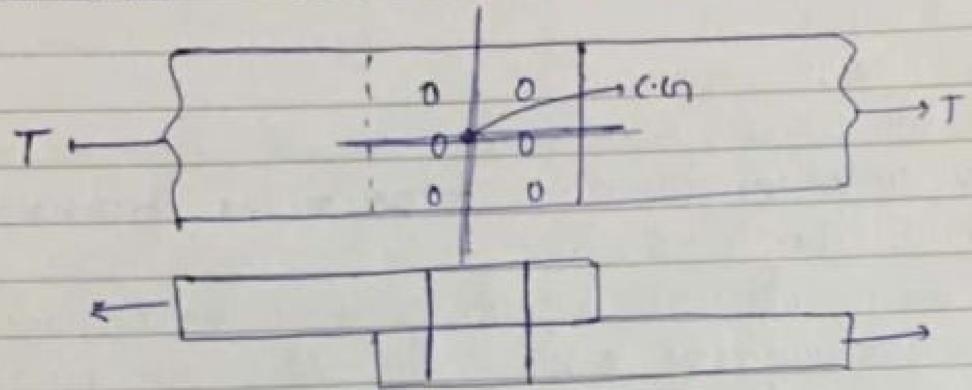


Also connections can be classified as -

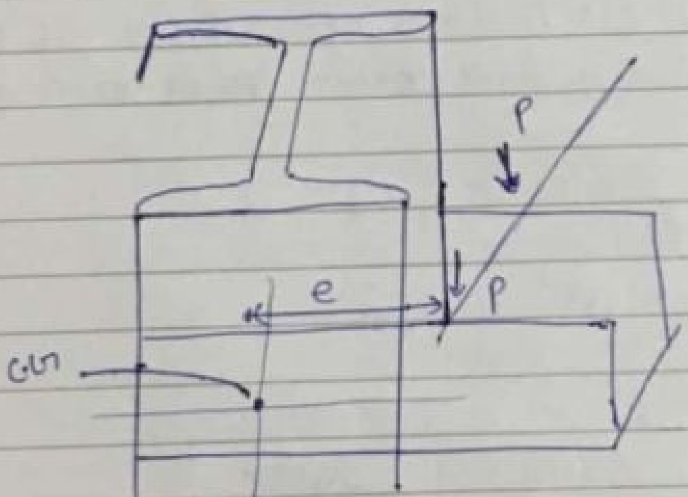
A) Direct connection B) Eccentric connection.

if the resultant load passes through the C.G of connection ⟶ Direct connection

If the resultant load does not pass through the C.G of Connection ⟶ Eccentric connection.

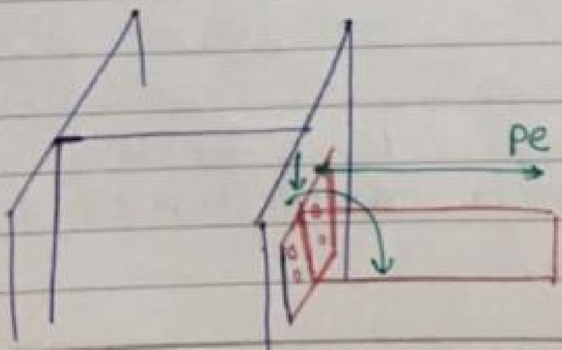


Direct connection.



Direct shear + Twisting Moment

Eccentric connection



Direct shear + BM

Eccentric

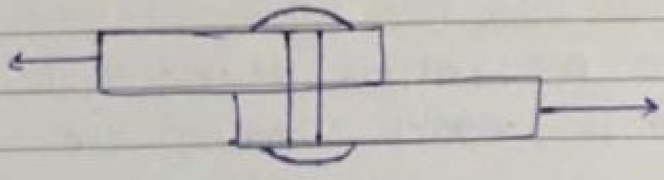
Various type of connections —

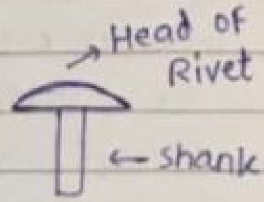
① Rivet

② Bolted

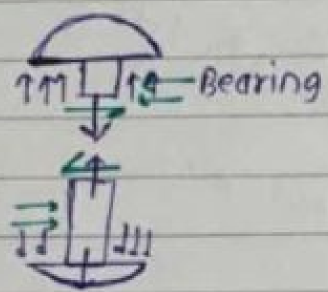
③ Welded

Rivet





Rivets are inserted in the hole made to join the member Hammering is done to make head on the other side



Rivetting
- Hot rivetting (around 980°c)
- cold rivetting

&

Rivetting
- Field Rivetting
- Shop Rivetting

The Nominal dia of Rivet is the shank dia under cold temp. and the Gross Dia of Rivet is taken as the Dia of Hole.

It is assumed that during Hammering action the Rivet hole is completely filled with the material so from strength calculation point of view Diameter of Rivet is taken as Diameter of Hole. and it is called Gross Dia of Rivet

for ease in construction. Rivet holes are generally made larger than the shank dia.

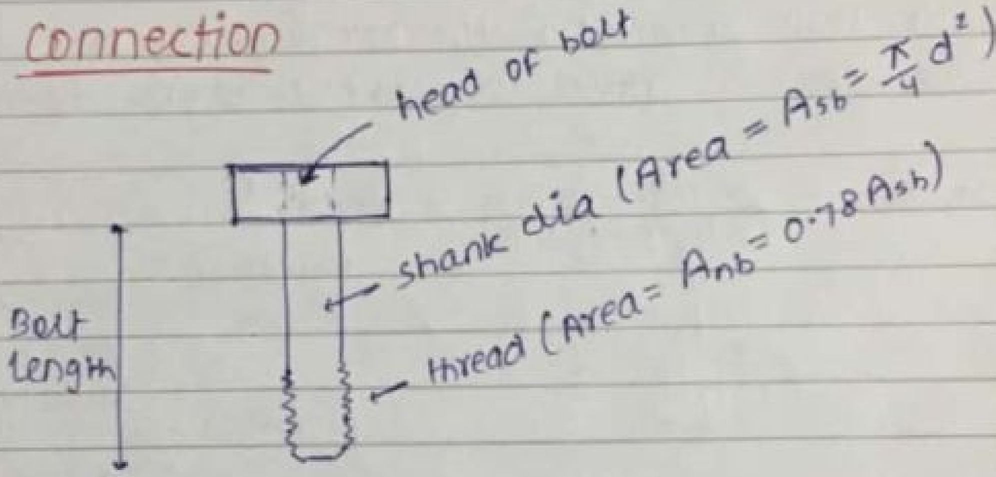
Gross Diameter = Dia of hole (d_0) = d + 1.5 mm. (d ≤ 25 mm)
= d + 2 mm (d ≥ 25 mm)

d → nominal dia of Rivet

All formulas of Bearing type bolt are applicable for Rivets.

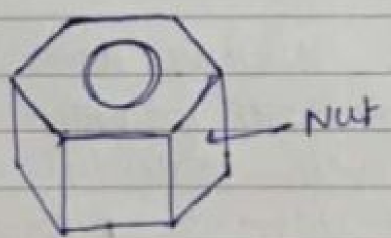
Rivets are good for fatigue loading, alternate stress, Dynamic loading, impact loading etc.

Bolted connection



A_{sb} → shank dia of bolt

A_{nb} → Net area of bolt



Type of Bolt

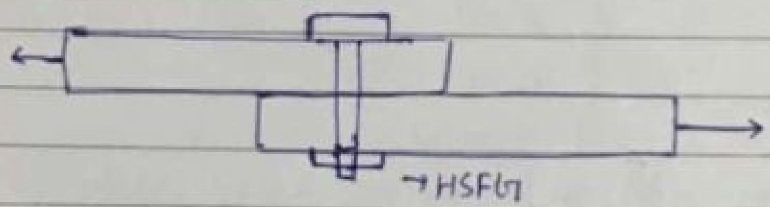
1. Black bolt / unfinished / ordinary / Rough / common Bolt
2. Turned bolt / close Tolerance Bolt
3. High strength Bolt (can be HSFG Type or Bearing Type)

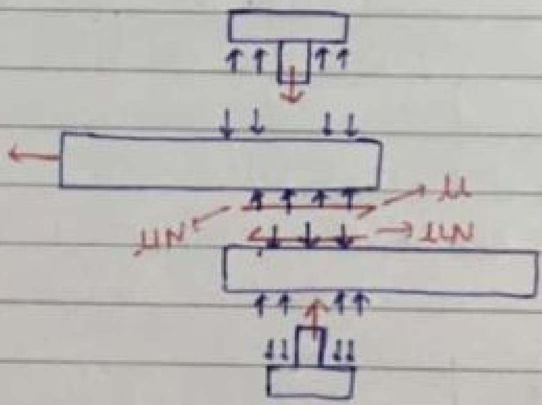
① Black Bolts :- These are primarily used in light str under static load such as small Trusse purlins etc. Also used as Temperory Fastners during eriction.

- Least expansive bolts with high tolerance, However
- it may not produce the least expansive connection.
- Not recommended for connections subjected to impact, Fatigue or dynamic load.

② Turned- Bolts :- Has less tolerance allowed than Black. These Bolts are used when accurate Alignment of components in there.

③ High strength Bolts :-





High strength bolts are less Ductile than ordinary. Bolts may be tighten until High Tensile stress is developed so that the connected parts are clamped together tightly.

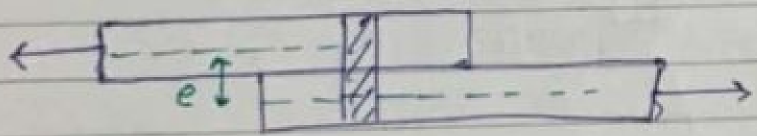
permits the load to be primarily transfer by Friction

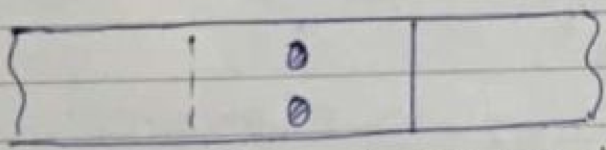
- Due to the friction the slip in the joint is eliminated and Hence the joints with HSFG Bolts are called non-slip Connection. The cofficient of friction is called slip factor and the induced initial Tension is called proof load.

  - Better for Bridges, siesmic loading, Fatigue etc.
  - These Bolts can replace riveted connection.

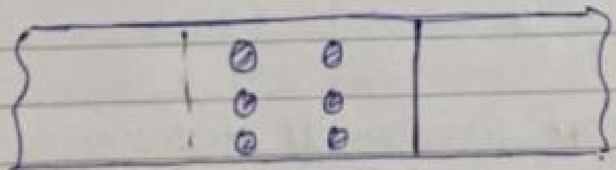
Bearing Type connection (Direct / simple connection)

Two Types of joint
① Lap joint
② Butt joint

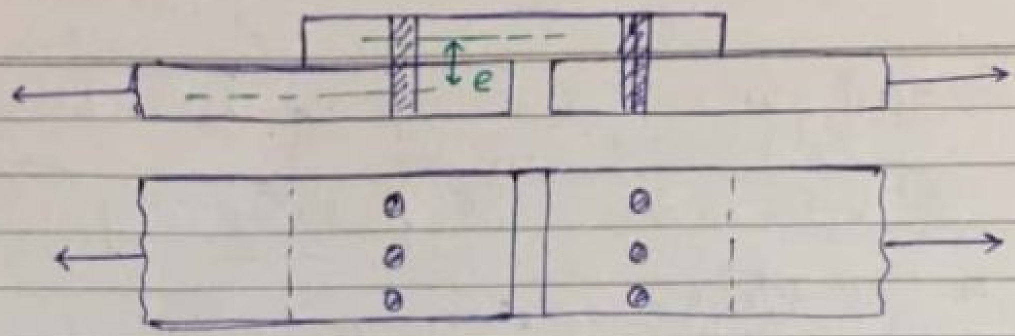




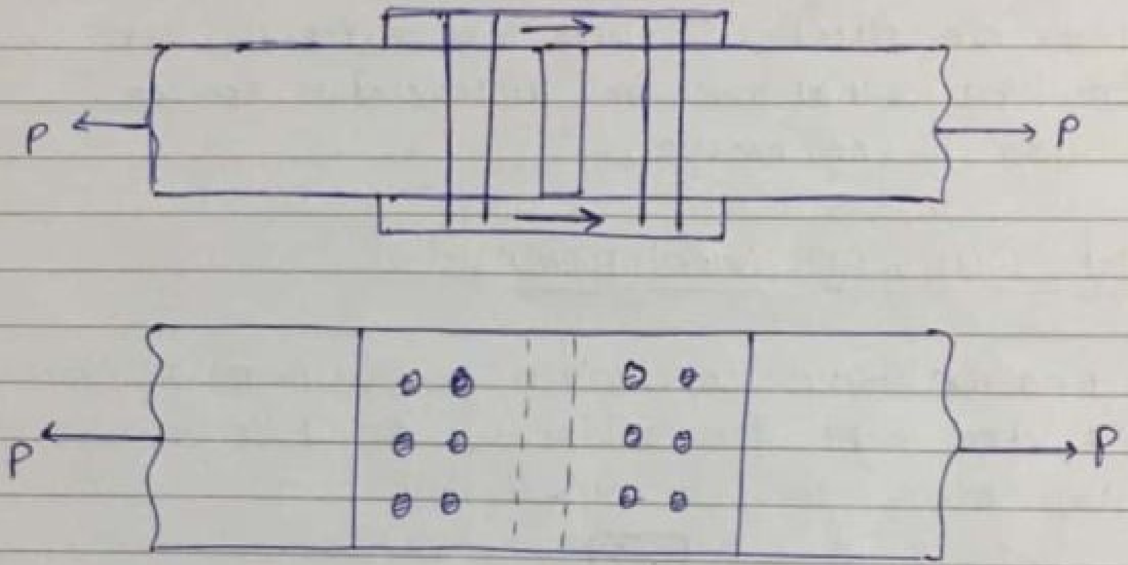
single bolted lap joint



Double bolted Lap joint



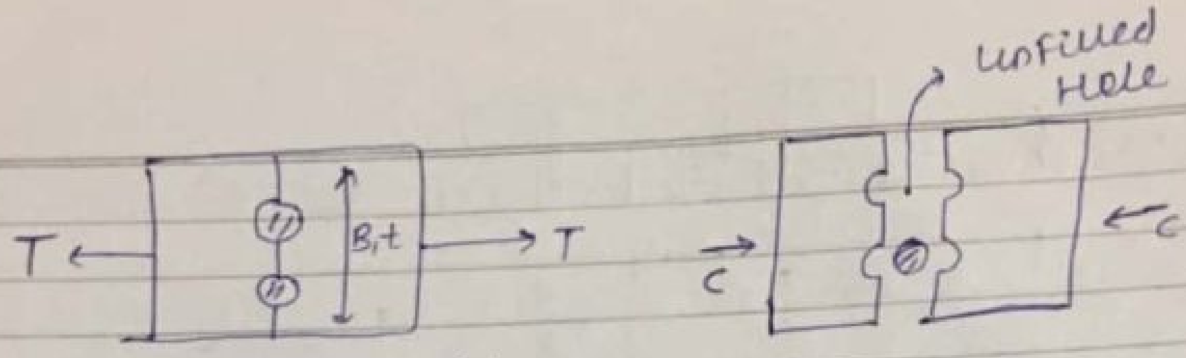
Single cover Single bolted butt joint



Double bolted Double cover Butt joint

Due to eccentricity in load in lap joint and single cover and butt joint bending will be generated and Hence Bolts may fails in Tension, To Minimise this effect at least two Bolts in a line shall be provided in a lap joint.

- Eccentricity of load is eliminated in Double cover Butt joint and hence this type of joints are prefered.



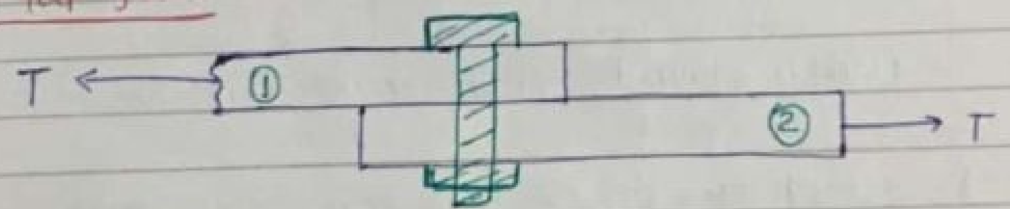
$A_n = (B - 2d_0)t$ $\quad$ $A = (B - d_0)t$

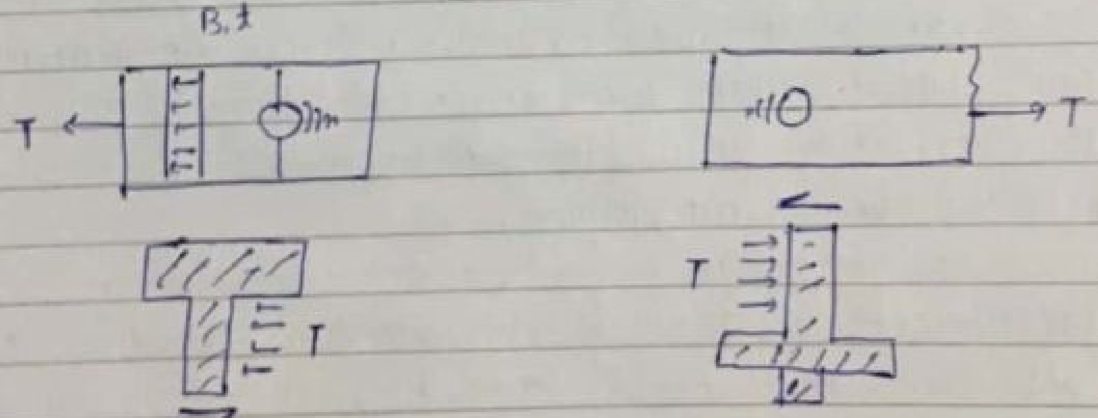
In case of Tension, Net Area is effective
In case of compression, Gross Area is effective provided all holes are filled, if Holes are unfilled, Area corresponding to that must be subtracted to get the eff. Area in compression.

Load Transfer Mechanism :-

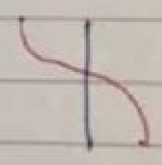
① In Bearing type connection → By shearing & Bearing
② In Friction type connection → By Friction.

In lap joint

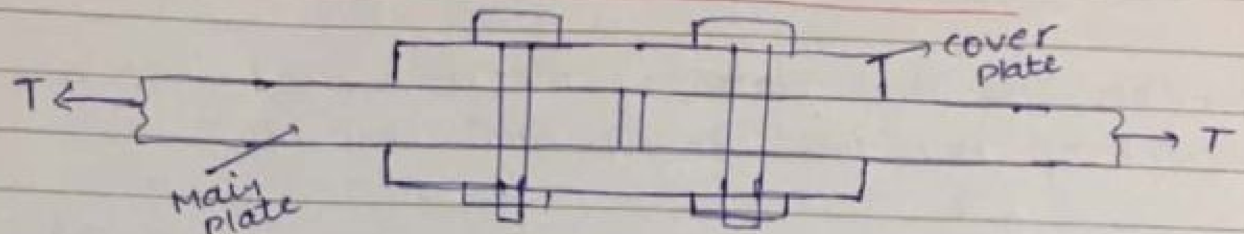


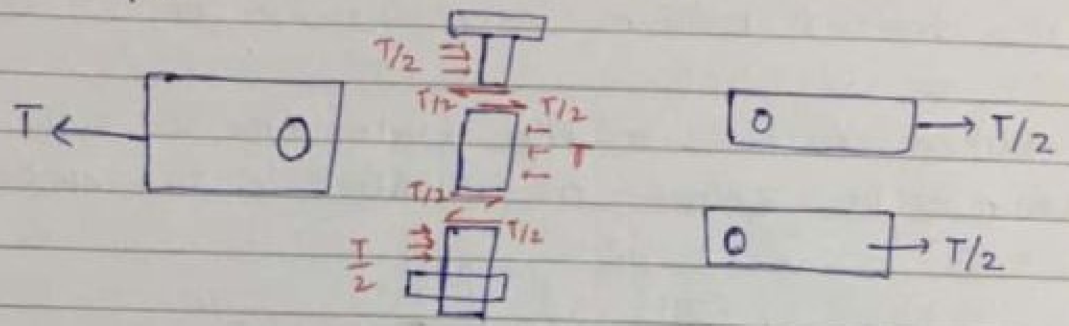


single shear plane



In double cover single bolted Butt joint





(Double shear plane)

- single shear plane in case of lap joint and single cover Butt joint
- Double shear plane in case of Double cover butt joint.
- shear capacity of a bolt in double cover bolt joint is higher than that of a bolt in lap joint

NOTE . Bolts are designated as M16, M20, M18 (5–36 mm)
. Bolts of property class (3.6 — 12.4) are available

M20 bolt of property class 4.6

$d = 20$ mm

$f_{ub} = 400$ MPa , $f_{yb} = 400 \times 0.6 = 240$ MPa

Normally we use 4.6 and 8.8

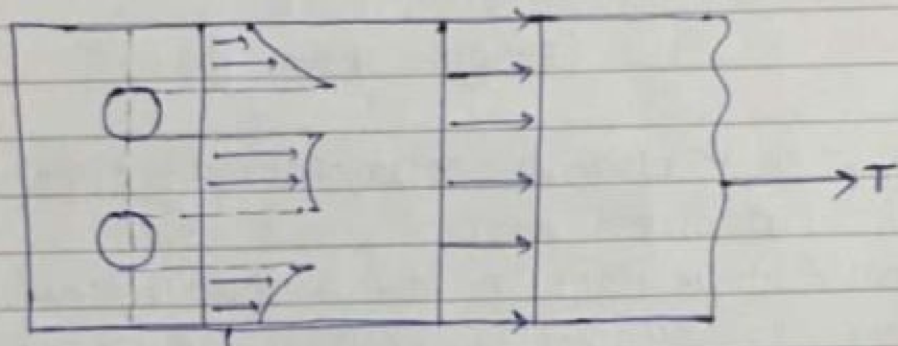
Scanned with CamScanner

Assumptions in Bolted connection (Bearing Type):-

① Friction b/w the plates is Neglected and load is resisted by bolts in shearing and Bearing.

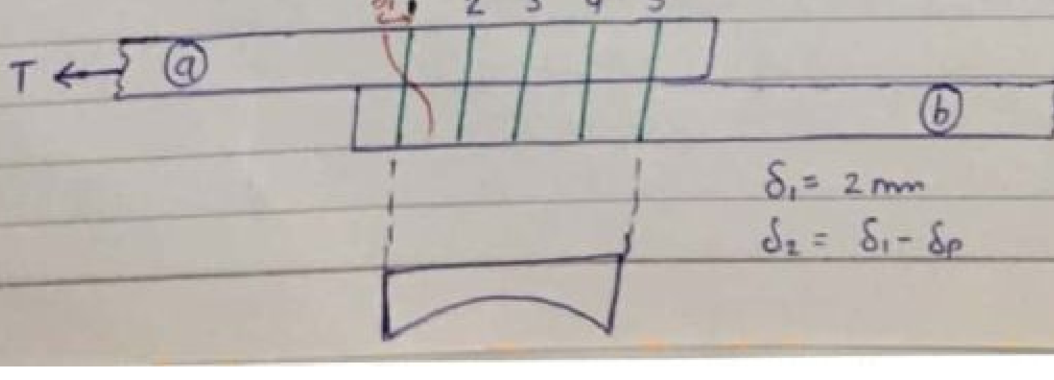
② shear stress is uniform over the c/s of the Bolt

③ Distribution of stress in the plate b/w the bolt hole is uniform i.e stress concentration is Neglected



The above assumption is not valid @ working load condition. However @ ultimate load due to High Ductility of steel, redistribution of stress will be there and uniform stress distribution may be assumed.

④ Bolts in a Group subjected to direct load share the load equally i.e Bolts are equally stressed. (Assuming same Dia bolts)

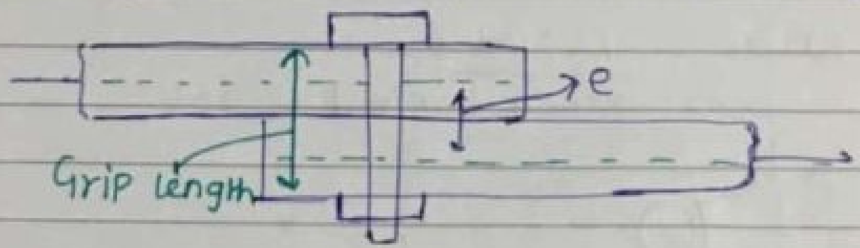


NOTE for short length of joint, the forces in bolt will be redistributed by plastic Action and hence the bolt will share the shear force equally.

However in a long joint, the shear force is not evenly distributed among the bolts and the bolts at the ends of a joint resist the highest amount of SF. This may lead to progressive joint failure called UnButtoning effect. To account for this IS code recommends reducing in the shearing capacity of bolts for long joints.

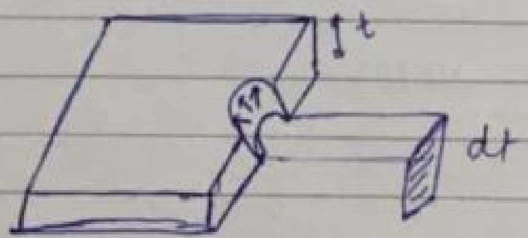
However in ∞ Rigid plate the stress in all bolts will be same even in the elastic condition.

⑤ Bending stress developed in Hole is Neglected.



if the Grip length is more correction factor is introduced to reduce the permissible shear stress

⑥ Bearing stress is assumed to be uniform over the Nominal contact Area b/w the plate and the Bolt.

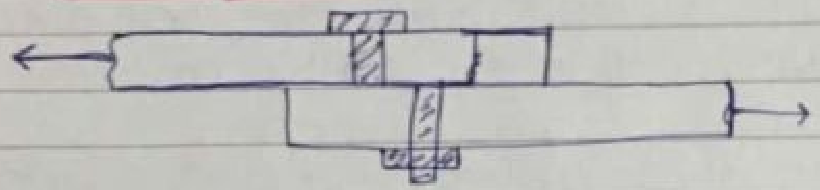


d → Nominal dia of bolt

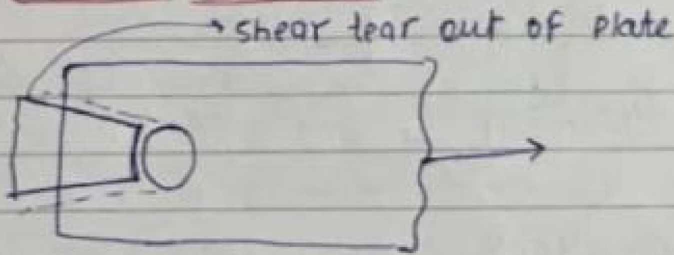
(7) if Nothing is specified then the area for resisting single shear shall normally be taken as the area of root of thread (A_{nb})
for Double shear, take one shear plane at shank area and other @ root of thread.

Failure of bolted connections

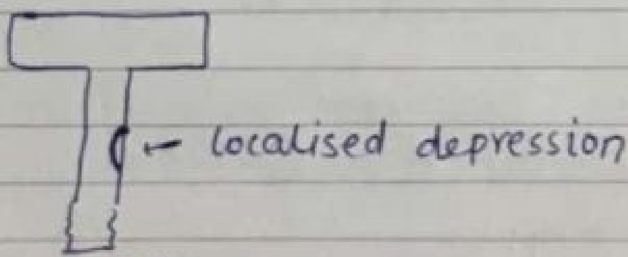
(I) Shear failure of bolt :-



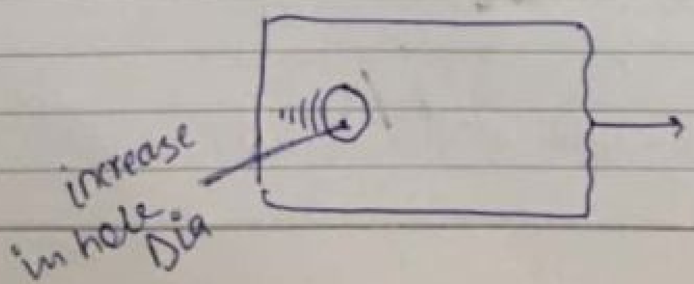
(II) shear failure of plates.



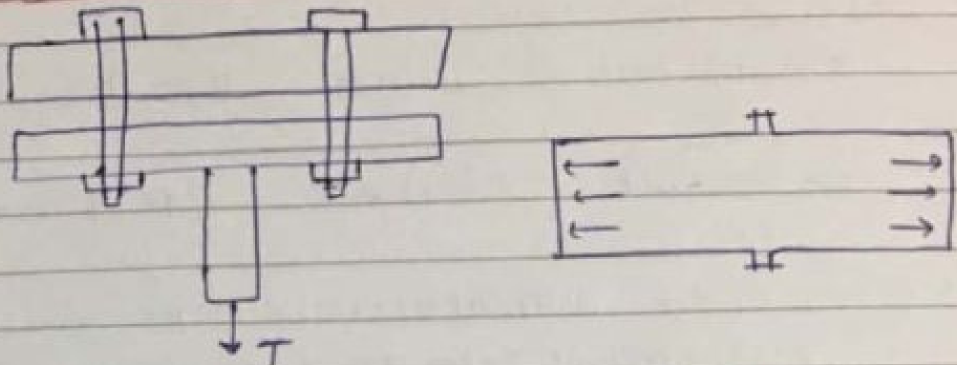
(iii) Bearing failure of bolts



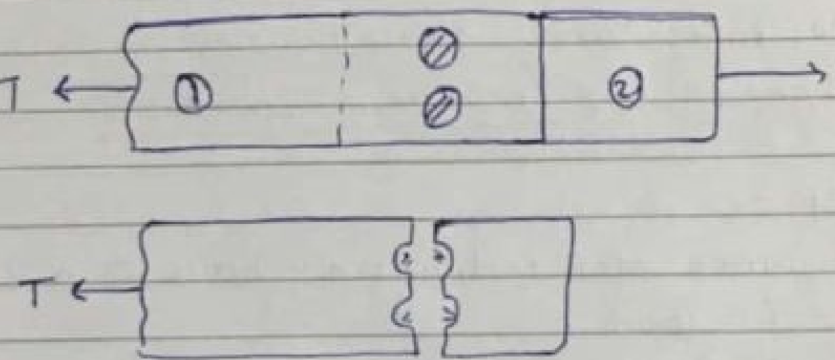
(iv) Bearing failure of plates.



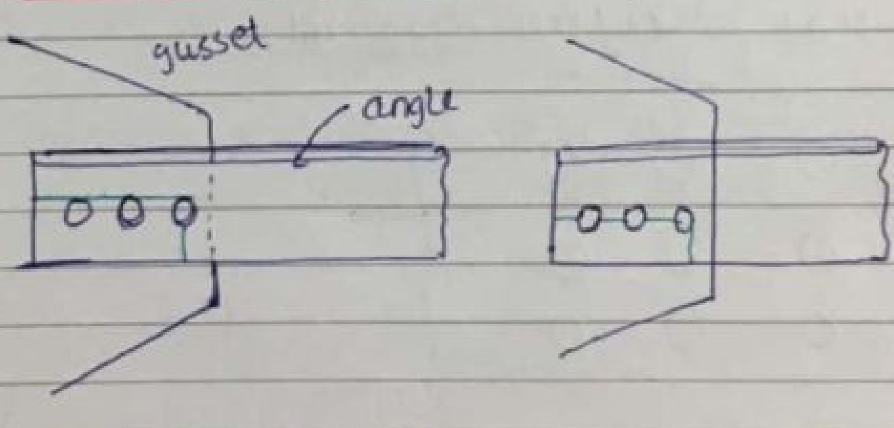
(V) Tension Failure of bolts :-

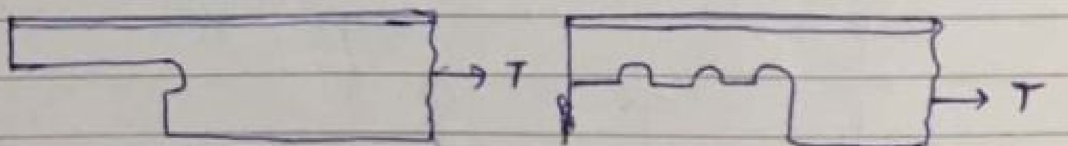


(Vi) Tension failure of plate / Tearing of plate / Rupture of plate



(Vii) Block shear failure :-





shear yielding + Tensile rupture

shear Rupture + Tensile yielding

(i) In General, Max. pitch = Min $\begin{cases} 32t \\ 300\ mm \end{cases}$

When connection is not exposed to weather

$= Min \begin{cases} 16t \\ 200\ mm \end{cases}$

When connection is exposed to weather

(ii) For two members placed back to back
Max. pitch of tacking bolt should not exceed
1000 mm for Tension Member and 600 mm → (comp. member)

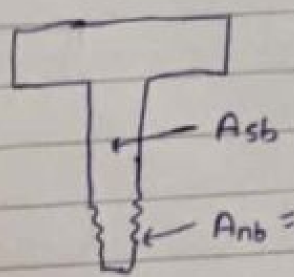
Bearing type connection

Strength of bolt / Bolt Value (V_{db}) = Min. $\begin{cases} \text{Shearing strength of bolt } (V_{dsb}) \\ \text{Bearing strength of bolt } (V_{dpb}) \end{cases}$

① **Shearing strength of Bolt**

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

V_{nsb} – nominal shearing strength of bolt
γ_{mb} → partial safety factor for material; bearing type bolt (1.25)



$$V_{dsb} = \frac{f_{ub}}{\sqrt{3}\,\gamma_{mb}} \left[n_n A_{nb} + n_s A_{sb} \right] \times \beta_{lj} \times \beta_{lg} \times \beta_{pk}$$

$f_{ub} \rightarrow$ ultimate Tensile strength of bolt
$A_{nb} \rightarrow$ net shear area of bolt @ thread
$A_{sb} \rightarrow$ nominal shank Area of bolt $\left(\frac{\pi}{4} d^2\right)$
$n_n \rightarrow$ no. of shear plane through thread
$n_s \rightarrow$ no. of shear plane throug shank

for single shear plane $n_n = 1$, $n_s = 0$
for Double shear plane $n_n = 1$, $n_s = 1$

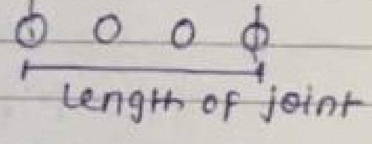
β_{lj}, β_{lg}, β_{pk} are reduction factors taking into account the effect of long joint, large Grip length and packing plate respectively.

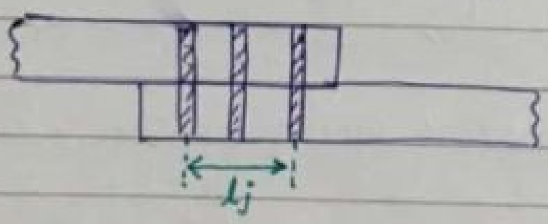
For long joints (β_{lj}) • apply when $l_j > 15d$

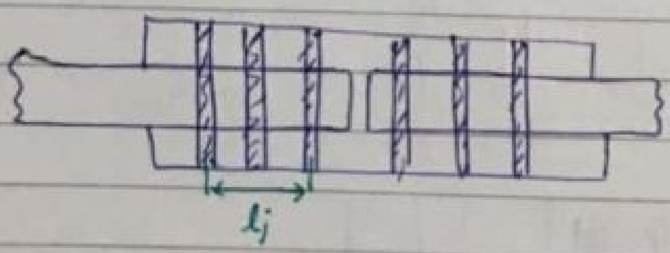
$$\beta_{lj} = 1.075 - \frac{l_j}{200d}$$

$d \rightarrow$ dia of bolt

Also $0.75 \leq \beta_{lj} \leq 1$





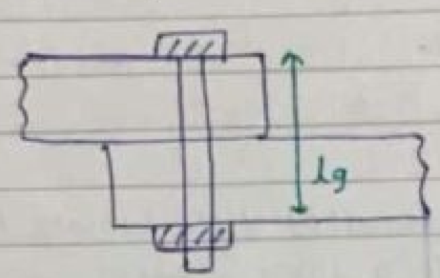


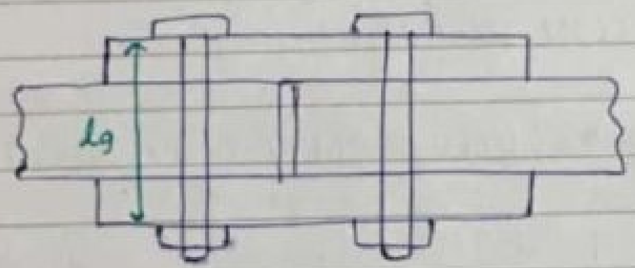
$l_j \rightarrow$ c/c distance b/w the extreme bolts in the dir^n of load transfer

For large grip length (β_{lg}) • apply when $l_g > 5d$

$$\beta_{lg} = \frac{8d}{l_g + 3d}$$

$\beta_{lg} \not> \beta_{lj}$ & $l_g \not> 8d$

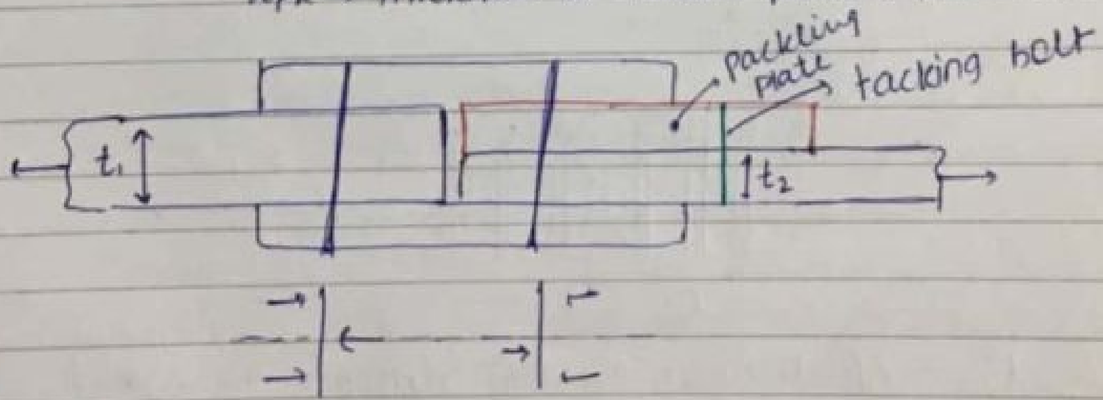




For packing plate (β_{pk}) • apply when $t_{pk} > 6mm$

$$\beta_{pk} = 1 - 0.0125\, t_{pk}$$

t_{pk} → thickness of thicker packing plate in mm.



② Bearing strength of Bolt :-

$$V_{dpb} = \frac{V_{npb}}{\gamma_{mb}} = \frac{2.5\, K_b\, d\, t\, f_u}{\gamma_{mb}}$$

f_u → plate

$$K_b = \text{Min}\left\{ \frac{e}{3d_0},\ \frac{p}{3d_0} - 0.25,\ \frac{f_{ub}}{f_u},\ 1 \right\}$$

d → nominal dia of bolt

t → sum of thicknesses of plate experiencing bearing in the same dir^n

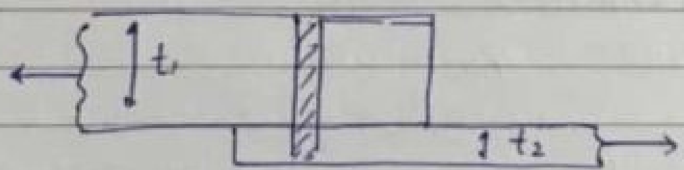
e → end distance in the bearing dir^n

p → pitch distance in the bearing dir^n

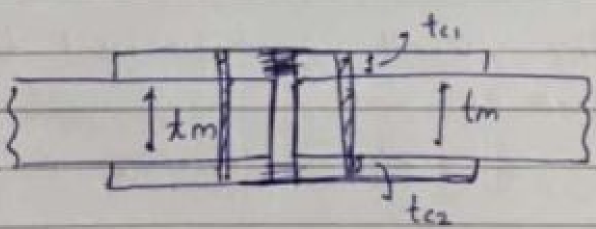
d_0 → Dia of bolt hole

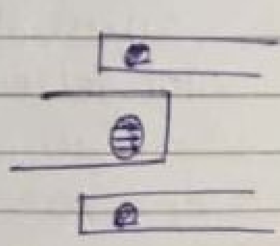
f_{ub} → ultimate Tensile strength of bolt

f_u → ultimate Tensile strength of plate

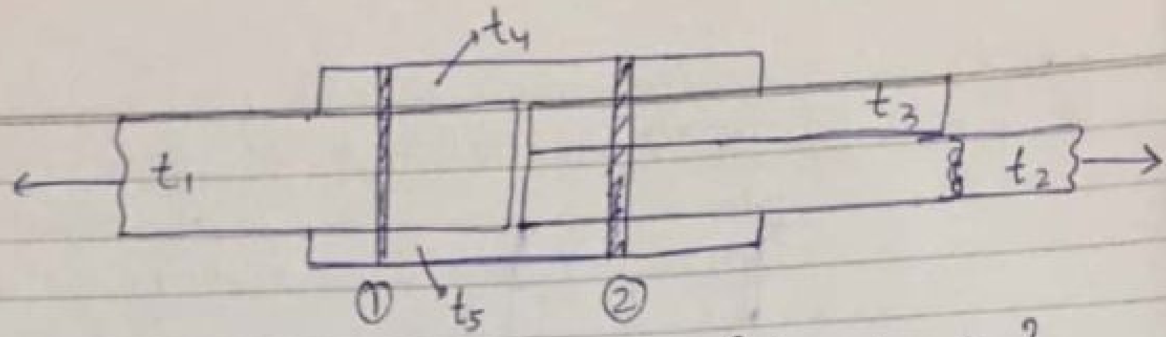


$$t = \text{Min}(t_1, t_2)$$





$$t = \text{Min}\{ t_{c1} + t_{c2},\ t_m \}$$



for Bolt ①, $t = \text{Min}\{t_1, t_4 + t_5\}$

for Bolt ②, $t = \text{Min}\{t_2, t_4 + t_5\}$

③ **Tensile strength of bolt :-**

Net section rupture $T_{dn} = \frac{0.9 f_{ub}}{\gamma_{mb}} A_{nb}$

Gross section yielding $T_{dg} = \frac{f_{yb}}{\gamma_{mo}} A_{sb}$

$A_{nb} \rightarrow$ net Area $= 0.78 A_{sb}$

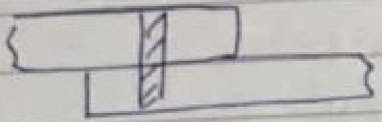
$\gamma_{mb} \rightarrow 1.25$, $\gamma_{mo} \rightarrow 1.1$

The yielding criteria is checked so that excessive yielding doesnot result in non-functional joint before Rupture

Que. Calculate the strength of M20 bolt Grade 4.6 for following cases
The Main plates to be joined are 12 mm thick and Fe 410
i) lap joint
ii) single cover butt joint with cover plate 10 mm thick
iii) double cover butt joint with thickness of each cover plate 8 mm.

$f_u = 410$ mpa $f_y = 250$ mpa
$f_{ub} = 400$ mpa $f_{yb} = 240$ mpa {400×0.6)
$d = 20$ mm $d_0 = 20+2 = 22$ mm
Main plate $t = 12$mm

(i) lap joint



single shear case

a) $V_{dsb} = \frac{f_{ub}}{\sqrt{3}\,\gamma_{mb}} [n_n A_{nb} + n_s A_{sb}]\, \beta_{lj}\, \beta_{lg}\, \beta_{pk}$ (assume 1, 1 $l_g < 5d$, 1)

$V_{dsb} = \frac{400}{\sqrt{3} \times 1.25} [1 \times 0.78 \times \frac{3.14}{4} \times 20^2 + 0 \times \frac{3.14}{4}, 20^2] \, 1 \times 1 \times 1$

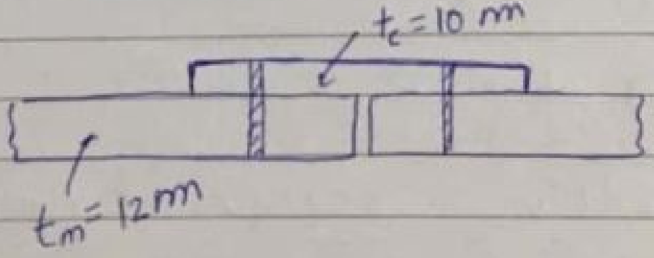
$V_{dsb} = 45.27$ KNm

b) $V_{dpb} = \frac{2.5\, K_b\, d\, t\, f_u}{\gamma_{mb}}$ $K_b = \min\left\{ \frac{e}{3d_0} \cdot \frac{P}{3d_0} - 0.25 \cdot \frac{f_{ub}}{f_u}, 1 \right.$ (e: 1.5d_0, P: 2.5d)

$V_{dpb} = \frac{2.5 \times 0.5 \times 20 \times 12 \times 410}{1.25}$ $K_b = \{ 0.5$

$V_{dpb} = 98.4$ KN

(ii)



M 20

$d = 20mm$

$d_o = 22\ mm$

Fe 410 , class 4.6

$V_{db} = Min[V_{dsb}, V_{dpb}]$

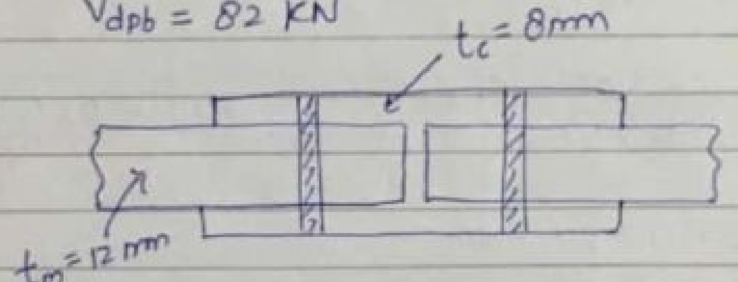
single shear case

$V_{dsb} = 45.27\ KN$

$$V_{dpb} = \frac{2.5\ k_b d t f_u}{\gamma_{mb}} = \frac{2.5 \times 0.5 \times 20 \times 10 \times 410}{1.25}$$

$V_{dpb} = 82\ KN$

(c)



M20

$d = 20\ mm$ Fe 410 , class → 4.6

$d_o = 22\ mm$

$$V_{dsb} = \frac{f_{ub}}{\sqrt{3}\gamma_{mb}}[n_n A_{nb} + n_s A_{sb}]$$

$$= \frac{400}{\sqrt{3} \times 1.25}\left[1 \times \frac{\pi}{4} \times 20^2 \times 0.78 + 1 \times \frac{3.14}{4} \times 20^2\right]$$

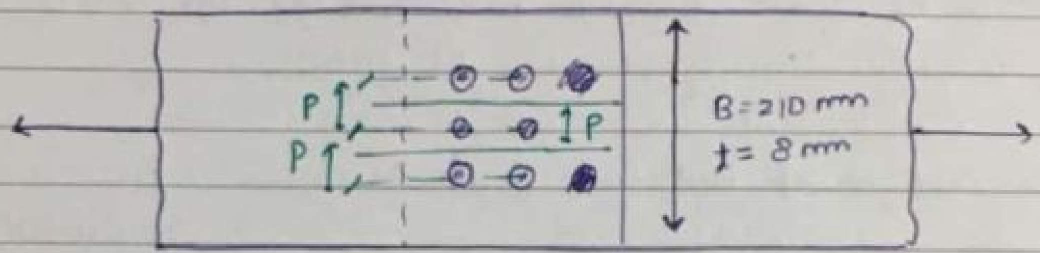
$= 103.27\ KN$

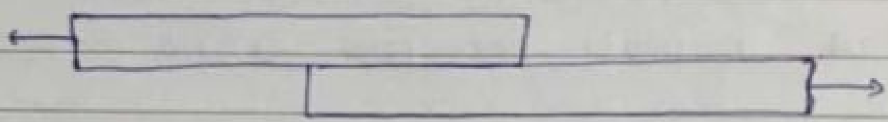
$$V_{dpb} = \frac{2.5\ k_b d t f_u}{\gamma_{mb}} = \frac{2.5 \times 0.5 \times 20 \times 12 \times 410}{1.25} = 98.40\ kN$$

$\Rightarrow V_{db} = $ (bolt value) $= Min(103.27, 98.40)$

$= 98.40\ kN$

Que. Two plates of Fe410 Grade steel each (210×8) mm are to be joined using 20 mm dia, 4.6 Grade to form a lap joint, the joint is supposed to transfer a factored load of 250 kN. Design the joint and determine suitable pitch for the bolt.





Fe 410, M20, Bolt class = 4.6

$F_u = 410$ MPa, $F_{ub} = 400$ MPa, $d = 20$ mm

$f_y = 250$ MPa, $f_{yb} = 240$ MPa, $d_o = 22$ mm

$P_u = 250$ kN

single shear case

$V_{dsb} = 45.27$ kN

$$V_{dpb} = \frac{2.5 K_b d t f_u}{\gamma_{mb}}$$

$$K_b = Min\left[\frac{e}{3d_o}, \frac{p}{3d_o} - 0.25, \frac{f_{ub}}{f_u}, 1\right] = 0.50$$

($e \rightarrow 1.5d_o$, $p \rightarrow 2.5d$)

$$V_{dpb} = \frac{2.5 \times 0.5 \times 20 \times 8 \times 410}{1.25} = 65.60 \text{ kN}$$

$V_{db} = Min[45.27, 65.60] = 45.27$ kN

$\Rightarrow$ No of bolts $= \frac{250}{45.27} = 5.52$

provide 6 bolts

consider the distance b/w the bolts as p, and calculate strength of joint per pitch length of the plate
Here, p is in transverse dir^n of load.

The strength of bolts per pitch length = 2×45.27
= 90.54 kN

let us calculate the p value by equating strength of plate per pitch length = Bolt strength per pitch length.

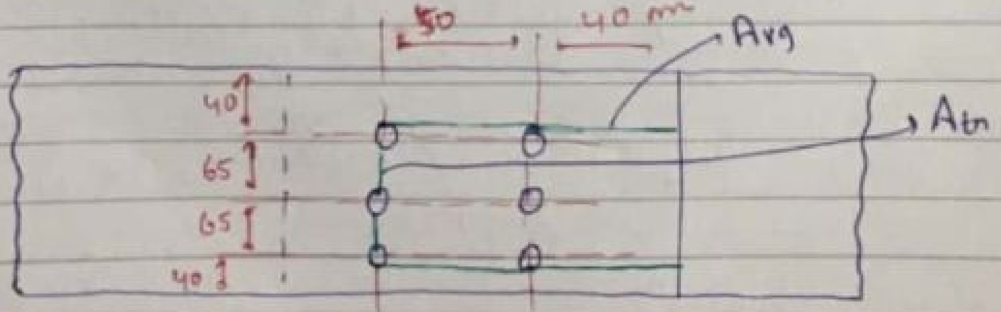
$$(P - d_o) t \left(\frac{0.9 f_u}{\gamma_{m1}} \right) = 90.54$$

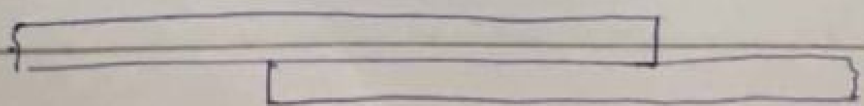
$$(P - 22) \times 8 \times \left(\frac{0.9 \times 410}{1.25} \right) = 90.54 \times 10^3 \text{ N}$$

$$P \geq 60.33 \text{ mm}$$

Min Gauge provided shall be $2.5d = 50$ mm
adopt $p = 65$ mm and $e = \frac{210 - 2 \times 65}{2} = 40 \text{ mm} > 1.5 d_o$

Block Shear Failure



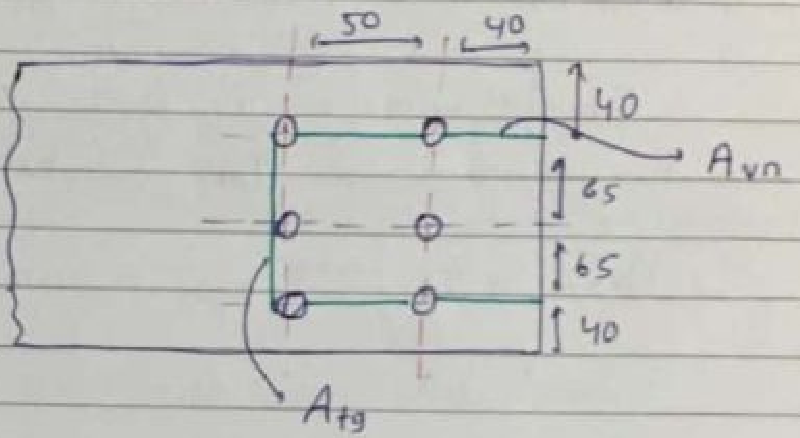


$$A_{vg} = (40+50)\times 8\times 2 = 1440\ mm^2$$

$$A_{tn} = (2\times 65 - 2\times \underset{d_0}{22})\times 8 = 688\ mm^2$$

$$T_{db_1} = \frac{f_y}{\sqrt{3}\,\gamma_{m0}}\cdot A_{vg} + \frac{0.9 f_u}{\gamma_{m1}} A_{tn}$$

$$T_{db_1} = \frac{250}{\sqrt{3}\times 1.1}\times 1440 + \frac{0.9\times 410}{1.25}\times 688 = 392.05\ KN$$



$$A_{vn} = (40+50-1.5d_0)\times t\times 2$$

$$A_{vn} = 912\ mm^2$$

$$A_{tg} = (65+65)\times 8 = 1040\ mm^2$$

$$T_{db_2} = \frac{0.9 f_u}{\sqrt{3}\,\gamma_{m1}} A_{vn} + \frac{f_y}{\gamma_{m0}} A_{tg}$$

$$= \frac{0.9\times 410\times 912}{\sqrt{3}\times 1.25} + \frac{250\times 1040}{1.1} = 391.79 > 250\ KN.$$

Que. calculate efficiency of joint of the previous question.

Strength of joint = Min $\begin{cases} n\times V_{db} \\ \text{Tearing strength of plate} \\ \text{Block shear failure} \end{cases}$