SKDAV GOVT.POLYTECHNIC, ROURKELA

DEPARTMENT OF CIVILENGINEERING

LECTURE NOTE

ON

STRUCTURAL DESIGN II

SEMESTER-5TH

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Structural Steel Fasteners & Connections: Bolted Connection.

→ Different elements or members of steel structures are required to be joined to one another either at their ends or at some intermediate length in order to facilitate the transmission of member forces which is known as connection.

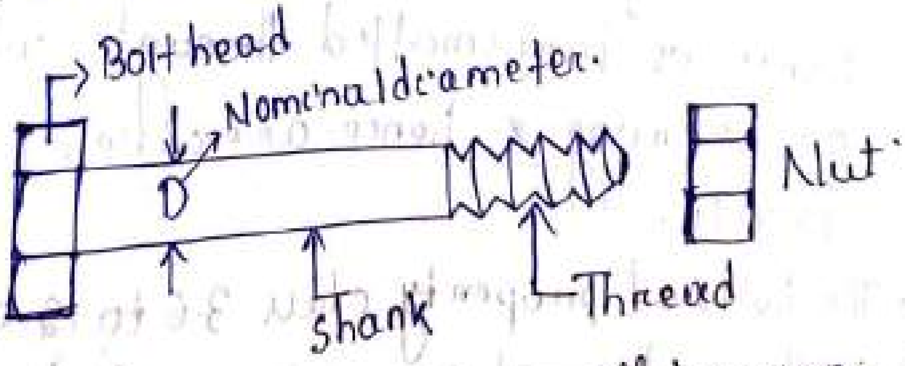
→ The devices required for preparing a connection are called connectors or fasteners. There are mainly four types of fasteners commonly used.

(a) Bolts (b) welds (c) Rivets (d) pins.

→ As a connection or a joint is the weakest part of a structure, which are to be properly designed.

Bolted Connections:-

A bolt is a metal pin with a head at one end & a shank threaded at other end to receive a nut.



Bolts are used for the purpose of joining together pieces of metals having holes through which there are inserted & the nuts are tightened at the threaded ends.

Types of bolts.

(i) unfinished bolts or black bolts.

(ii) finished bolts or turned bolt.

(iii) High strength friction grip bolt (HSFG).

(i) unfinished or black bolts:

→ They are also known as ordinary or common bolts.

→ These bolts are made from low carbon mild steel round rods with square or hexagonal head & the shank is left unfinished or rough.

→ These are used for light structures subjected to static loads as well as for secondary members such as purlins, roof trusses etc, but not recommended for structures subjected to vibration & fatigue.

→ As the bolt is unfinished, it may not establish perfect contact with structural member resulting in loose joints.

→ In the joints made with such bolts, the force is transmitted through interlocking or bearing & hence are called bearing type joints.

* The bolts of property class 3.6 to 12.9 are available, out of which most commonly used black bolt is property class 4.6.

leaning of property class 4.6. :-

$\frac{1}{100}$ x nomonal ultimate strength = 4
of bolt (f_u).

$$\frac{\text{yield stress of bolt } (f_{yb})}{\text{ultimate strength of bolt } (f_{ub})} = 0.6.$$

(ii) finished & turned bolts :-

-> These bolts are formed from mild steel hexagonal rods & are made by turning to circular shape.

-> As the connection is more tight, in this case it ensures better bearing contact between the bolts & holes. These are used where accurate alignment of components are necessery such as machine parts, structures subjected to dynamic loading etc.

(iii) High strength friction grip bolts :-

-> These bolts are made from high strength steel rods like black bolts, but the surface of the shank of these bolts is kept unfinished & these bolts are tightened until very high tensile stresses are developed using calibrated wrenches so that the connected parts are clamped tightly together between bolts & nut heads.

-> This permits the loads to be transferred primarily by friction & not by shear.

→ Thus results into no slippage in the joints the joints made with such bolts are known as slipcritical joint.

→ These are suitable for members subjected to dynamic load also.

Bolt holes:- table 19 (page 73).

Nominal size of fastener (d)	bolt hole (mm)
12-14	+1
16-22	+2
24	+2
>24	+3.

Advantages of bolted connection:-

(i) use of simple tools & less skilled labour & working area.

(ii) speedy & noiseless errection.

(iii) Economical due to reduced labour & equipment cost.

(iv) Minimum strength reduction at joint due to less number of holes or bolts.

(v) Easy alternation or dismantling of connection.

Disadvantages of bolted Connection:-

(i) high cost of material.

(ii) Reduced tensile strength due to area reduction

(iii) Susceptibility to loosening of bolts under vibration & dynamic loads.

Classification of bolts based on load transfer Mechanism

-> divided into two groups.

(i) bearing type or slip type connection.

(ii) friction grip type or slip critical connection.

(i) bearing type of bolt :-

-> load transfer takes place by shearing & bearing of member.

ex finished bolts, unfinished bolt.

(ii) friction grip type bolt :-

-> load transfer takes place by friction between the members.

ex High strength friction grip (HSFG) bolt.

Advantages of HSFG bolts over bearing type bolt :-

(i) Rigidity of joint due to no slip condition.

(ii) No shearing or bearing stresses in member as the load transfer mechanism is mainly by friction.

(iii) Large clamping forces provide high static strength of joints.

Disadvantages of HSFG bolts over bearing type bolts.

(i) Material cost of HSFG bolts is greater than that of ordinary bolts.

(ii) special workmanship is required in installing & tightening of these bolts.

-> Additional labour cost is required for surface preparation of members to be joined.

Types of bolted connections / Joints :-

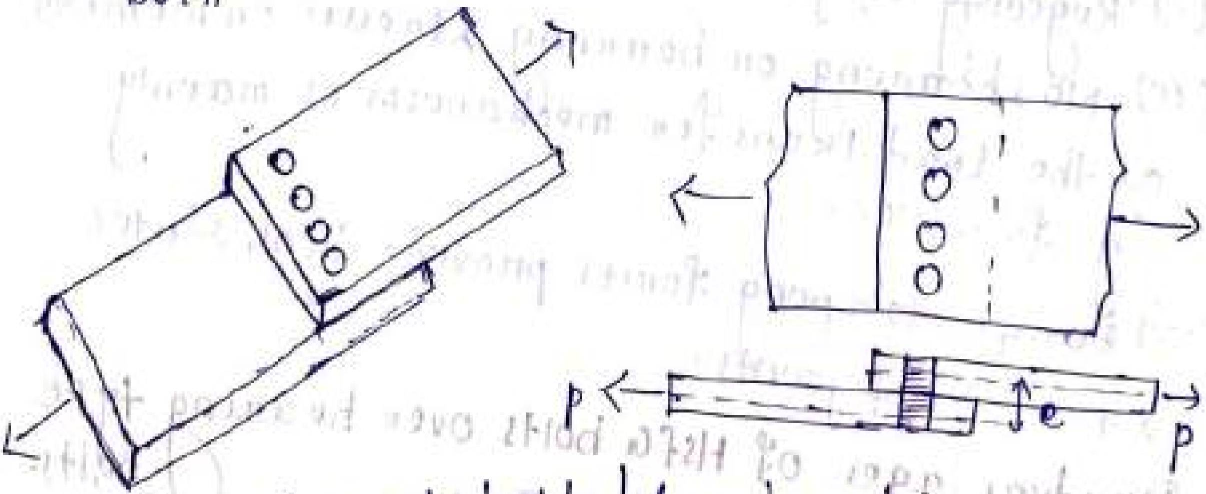
(a) Lap joint (b) butt joint.

(a) Lap joint

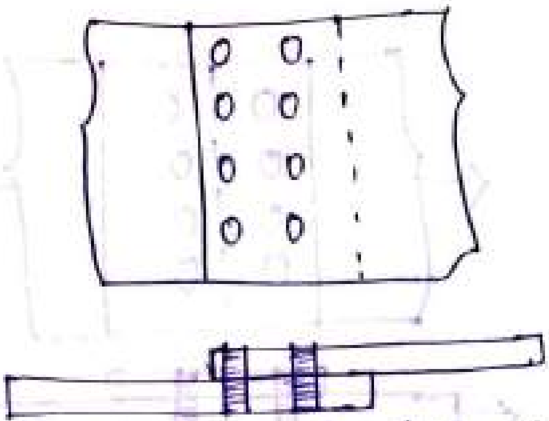
-> The two members to be connected overlap one another.

-> This constitutes the simplest type of joint requiring no extra cover plates.

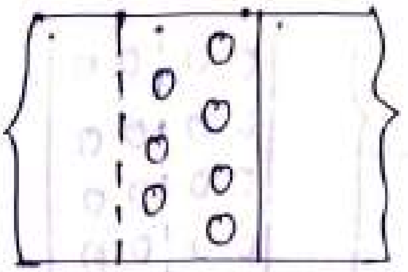
-> Since the centre of gravity of members joined in a lap joint are not collinear, the load in the lap joint has eccentricity, which may cause undesirable bending action. In order to minimize the effect of bending in lap joint, we have to increase no of bolts.



(single bolted Lap joint)



(double bolted lap joint)
(chain bolting)

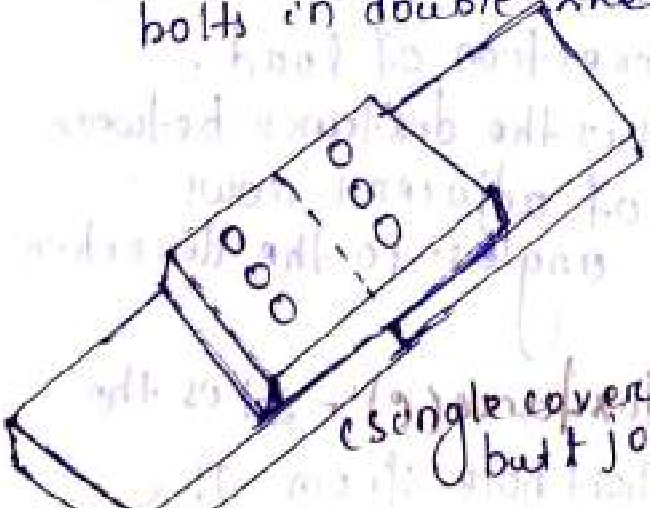


(Zigzag bolting)

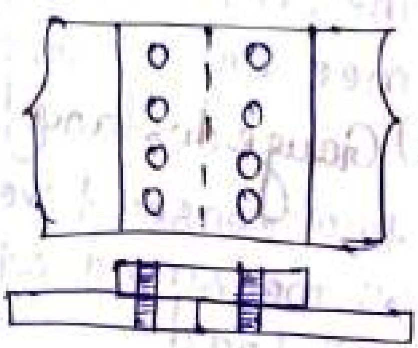
(b) Butt joint:-

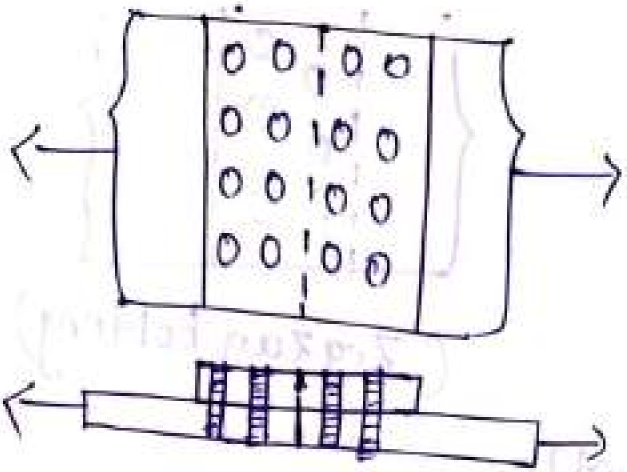
→ In this type of joint, the two members to be connected are placed end to end i.e. butt against each other & the connection is made by providing additional plates either on one side or on both sides. These additional plates are called cover plates where the members to be joined are called main plate.

→ bending is eliminated as there is no eccentricity of forces & the bolts are subjected to shear in two planes known as bolts in double shear.

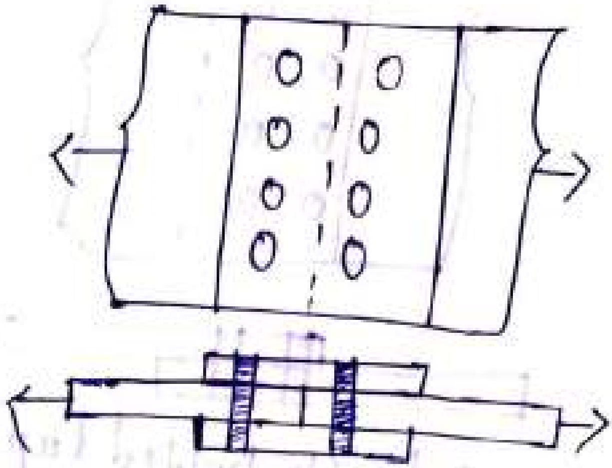


(single cover butt joint)

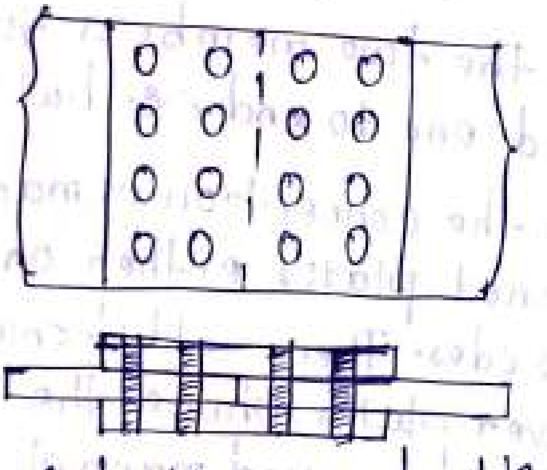




(single cover double bolted butt joint).



(double cover single bolted butt joint)



(double cover double bolted butt joint)

Terms used in bolted Connections:-

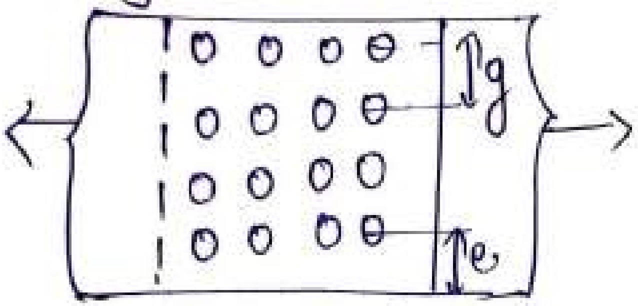
(1) pitch of bolt (p):- It is the distance between the centres of two consecutive bolts in a row measured along the direction of load.

(2) Gauge distance (g):- It is the distance between two consecutive bolts of adjacent rows & is measured at right angles to the direction of load.

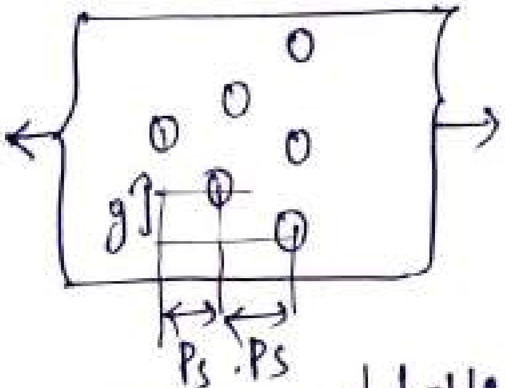
(3) Edge distance / end distance (e):- It is the distance of centre of bolt hole from the

adjacent edge or end of plate.

4. Staggered pitch :- (Ps) It is the centre to centre distance of staggered bolts measured along the direction of load.



(chain bolting).



(staggered bolted connection)

ssumptions in the analysis of bearing bolts:

following assumptions are made in the design of bearing type of bolted connection:-

1) The stress distribution on the plates between the bolt holes is uniform.

(2) The friction between the plates is negligible.

(3) The shearing stress is uniformly distributed over the cross section of bolt.

(4) The bolts in a group share the direct load equality.

(5) Bending stresses developed in bolts is neglected.

Coadal provisions for bolted joints:-

(i) Minimum pitch:- 2.5d, where d = nominal diameter of bolt. (cl:10.2.2)

(ii) Maximum pitch:(cl:10.2.3)

(a) 16t or 200mm whichever is less (for tensile member)

(b) 12t or 200mm, whichever is less, (for compression member)

t = thickness of thinner member.

(iii) Maximum gauge distance:- 100+4t or 200 mm } whichever is less. (cl:10.2.3.3)

(iv) Minimum edge distance:-(cl:10.2.4).

(a) 1.7do (for sheared or hand flame cut edges)

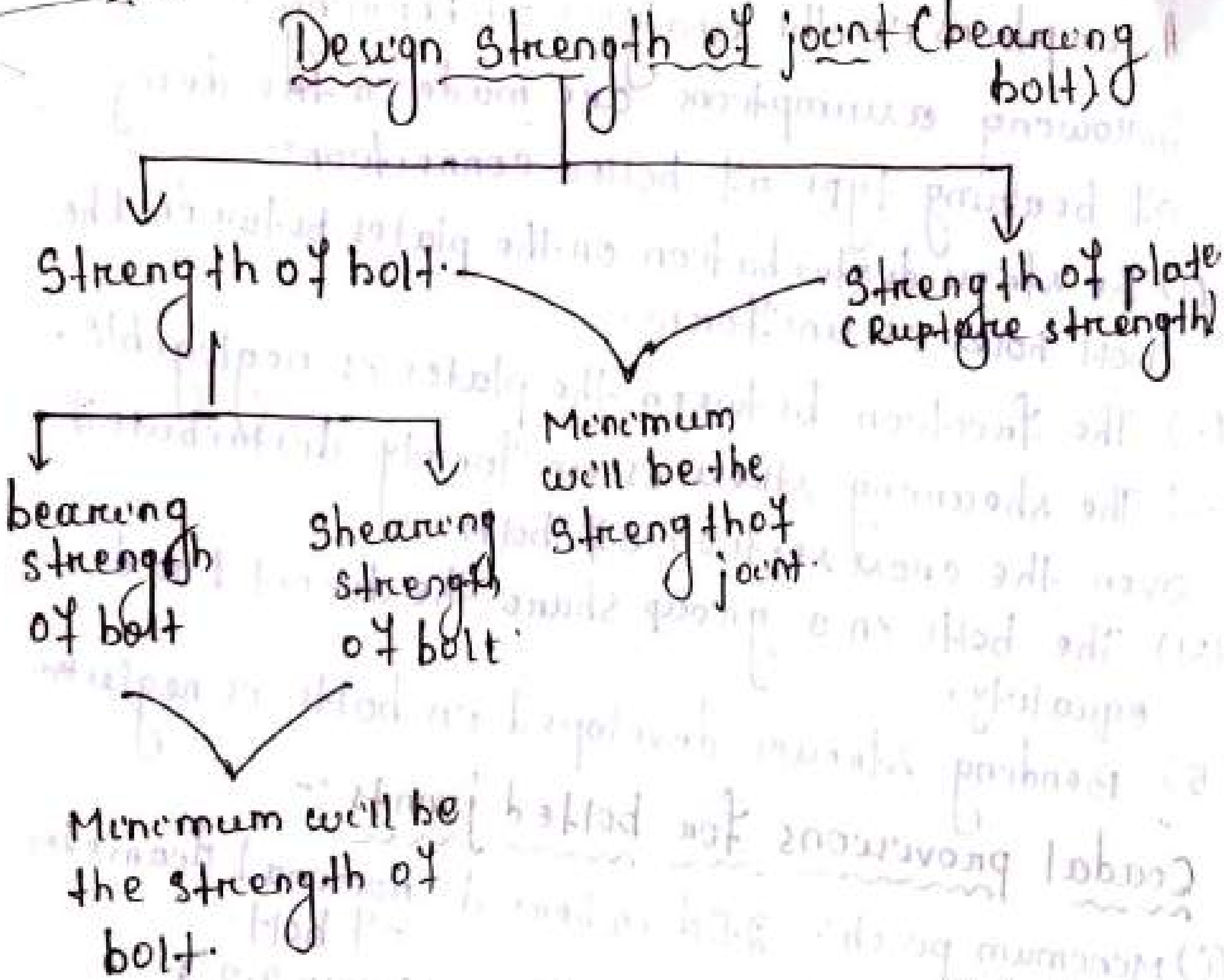
(b) 1.5do (rolled, machine flame cut, planed edge)

(v) Maximum edge distance:- (cl:10.2.4.3)

(a) $12t\varepsilon$ } ~~whichever is less.~~

(b) $40+4t$

where $\varepsilon = \sqrt{\frac{250}{fy}}$



Design strength of bearing type of bolts in a joint:-

(A) shear strength of bolt
(B) Bearing strength of bolt. } Minimum will be taken

(A) shear strength of bolt :- (cl: 10.3.3)

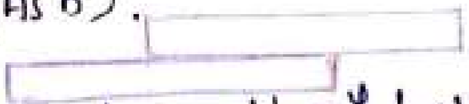
The design shear strength of the bolt (V_{dsb}):

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

γ_{mb} = partial safety factor of material of bolt (table No-05)

V_{nsb} = nominal shear capacity of bolt:

$$V_{nsb} = \frac{f_{ub}}{\sqrt{3}} (n_n A_{nb} + n_s A_{sb}).$$



f_{ub} = ultimate tensile strength of bolt

A_{sb} = nominal shank area of bolt $= \frac{\pi}{4} d^2$

A_{nb} = net area of bolt at threads $= 0.78 \times \frac{\pi}{4} d^2$

n_n = number of shear planes with threads intercepting the shear plane.

($n_n = 1$ (for single shear)

$n_n = 2$ (for double shear).

n_s = number of shear planes without threads intercepting the shear plane

($n_s = 0$ (for single shear)

($n_s = 1$ (for double shear))

Reduction factors for shear capacity of bolts:- (cl: 10.3.3.1)

(i) Reduction factor for long joint:-

$$\beta_{lj} = 1.075 - \frac{l_j}{200d} \quad (0.75 \le \beta_{lj} \le 1.0). \quad (\text{when } l_j > 15d)$$

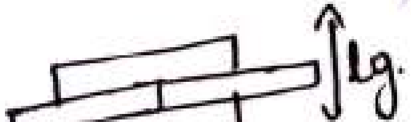
(ii) Reduction factor for large grip length:- (β_{lg})

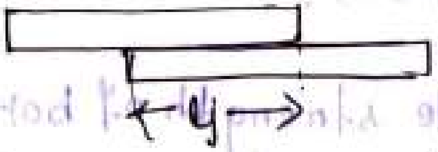
$$\beta_{lg} = \frac{8d}{3d + l_g} \quad (l_g > 5d) \qquad (cl: 10.3.3.2)$$

(iii) Reduction factor for packing plate (β_{pk}) (cl. 10.3.3.3)

$$\beta_{pk} = 1 - 0.0125 t_{pk} \quad (t_{pk} > 6mm)$$

t_{pk} = thickness of thicker packing in mm.





If $l_j > 15d$, $l_g > 5d$ & $t_{pk} > 6$:
then the modified nominal shear capacity of bolt is:

$$V_{nsb} = \frac{f_{ub}}{\sqrt{3}} (n_n A_{nb} + n_s A_{sb}) \beta_{lj} \beta_{lg} \beta_{pk}.$$

(B) Bearing strength of bolt:- (cl. 10.3.4).

The design strength of bolt, V_{dpb}:-

$$V_{dpb} = \frac{V_{npb}}{\gamma_{mb}}.$$

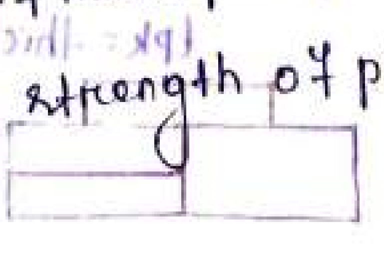
V_{npb} = nominal bearing strength of bolt
$= 2.5 k_b d t f_u$.

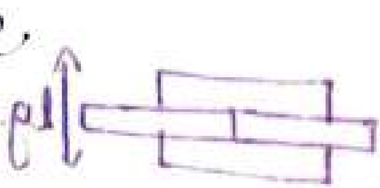
$$k_b = \left.\begin{array}{l} \frac{e}{3d_0} \\ \frac{p}{3d_0} - 0.25 \\ \frac{f_{ub}}{f_u} \\ 1 \end{array}\right\}$$ whichever is less.

e = end distance
p = pitch distance
f_{ub} = ultimate strength of bolt
d_0 = diameter of bolt hole.

d = nominal diameter of bolt.
t = summation of thickness of coverplate } less.
thickness of main plate

f_u = ultimate strength of plate.





Rupture strength of plate :- (Cl: 6.3)

The design tensile strength of a plate in the joint is the strength of thinner member against rupture which is given by:-

$$T_{dn} = \frac{0.9 A_n f_u}{\gamma_{m1}}$$

γ_{m1} = partial safety factor for failure at ultimate stress = 1.25

f_u = ultimate stress of material

A_n = net effective area of plate at critical section

$= \left(b - n d_0 + \sum \frac{p_{si}^2}{4 g_i}\right) t$ (for staggered bolted connection)

$= (b - n d_0) t$ (for chain bolted connection).

Efficiency of a joint:-

$$\eta \text{ (efficiency)} = \frac{\text{Strength of joint}}{\text{Strength of solid plate}} \times 100$$

Strength of solid plate:-

$$T_{dg} = \frac{A_g f_y}{\gamma_{m0}}$$

f_y = yield stress of material

A_g = gross area of cross section

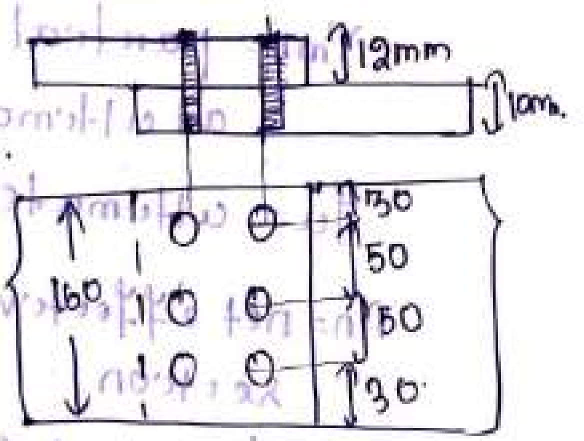
γ_{m0} = partial safety factor for failure by yielding = 1.1 (from table 5)

Q- find the maximum force that can be transmitted through a double bolted chain lap joint consisting of 6 bolts in 2 ~~rows~~ column. Given that M16 bolts of grade 4.6 & plates of fe410 are used. Also find the efficiency of joint. (Given e=30, p=50).

Given data:- Double bolted lap joint

Thickness of plate $t_1 = 10mm$, $t_2 = 12mm$.

Total no. of bolts = 6



Dia of bolt $d = 16mm$.

hole dia $d_0 = 16+2 = 18mm$.

end distance (e) = 30mm.

pitch (p) = 50mm.

Grade of bolt 4.6

$f_{ub} = 400$ Mpa, $f_{yb} = 240$ MPa

$f_y = 250$ Mpa

ultimate strength of plate $f_u = 410$ Mpa.

Required: efficiency of joint $\eta = ??$

Solution:-

(A) Strength of bolt:-

(a) shear strength of a bolt:-

nominal shear strength $V_{nsb} = \frac{f_{ub}}{\sqrt{3}}(n_n A_{nb} + n_s A_{sb})$

$f_{ub} = 400$, $A_{nb} = 0.78 \times \frac{\pi}{4} \times (16)^2$

$A_{sb} = \frac{\pi}{4} \times (16)^2$

for single shear (Lap joint):-

$n_n = 1$, $n_s = 0$.

$$V_{nsb} = \frac{400}{\sqrt{3}} \left(1 \times 0.78 \times \frac{\pi}{4} \times 16^2 + 0 \times n\,sb\right).$$

$$= 36.217 \text{ kN}$$

$$V_{dsb} = \frac{V_{nsb}}{\gamma_{mb}} = \frac{36.216}{1.25} = 28.974 \text{ kN}.$$

Design shear strength of a bolt:- 28.974 kN

Design shear strength of 6 no. of bolt:-

$$28.974 \times 6 = \boxed{173.846 \text{ kN.}}$$

(b) Bearing strength of bolt:-

The bearing strength of bolt against the thinner plate will be critical

Nominal strength/bolt @ (V_{npb}):-

$$V_{npb} = 2.5\, k_b d t f_u.$$

$d = 16\text{mm}$

$f_u = 410$

$t =$ thickness of thinner plate $= 10\text{mm}.$

$$k_b = \begin{cases} \dfrac{e}{3d_0} = \dfrac{30}{3\times18} = 0.56 \\ \dfrac{p}{3d_0} - 0.25 = \dfrac{50}{3\times18} - 0.25 = 0.676 \\ \dfrac{f_{ub}}{f_u} = \dfrac{400}{410} = 0.9756 \\ 1 \end{cases} \text{ whichever is less}$$

$k_b = 0.56.$

$V_{npb} = 2.5 \times 0.56 \times 16 \times 10 \times 410$

$= 91.840$ kN per bolt.

Design bearing strength per bolt

$V_{dpb} = \frac{V_{npb}}{\gamma_{mb}} = \frac{91.840}{1.25}$

$= 73.47$ kN.

Design bearing strength of 6 no. of bolt,

$73.47 \times 6 = \boxed{440.832 \text{ kN.}}$

Design strength of joint bolt in joint:-

minimum of $\begin{cases} V_{dsb} = 173.846 \\ V_{dpb} = 440.832 \end{cases}$

$= \boxed{173.846}$

(B) Rupture strength of plate (T_{dn}):-

$T_{dn} = \frac{0.9 f_u A_n}{\gamma_{ml}}$ $f_u = 410$, $\gamma_{ml} = 1.25$

$A_n = (b - n d_0) t$

$= (160 - 3 \times 18) \times 10$

$= 1060 \text{ mm}^2$

$T_{dn} = \frac{0.9 \times 410 \times 1060}{1.25} = \boxed{312.912 \text{ kN}}$

Strength of joint:- minimum of $\begin{cases} \text{strength of bolt} = 173.846 \text{ kN} \\ \text{rupture strength of plate} = 312.912 \text{ kN} \end{cases}$

$= \boxed{173.846 \text{ kN.}}$

Strength of solid plate (Tdg):- $\frac{A_g f_y}{\gamma_{m0}}$

$f_y = 250$ Mpa, $\gamma_{m0} = 1.1$

$A_g = b \times t = 160 \times 10$
$= 1600\ mm^2$

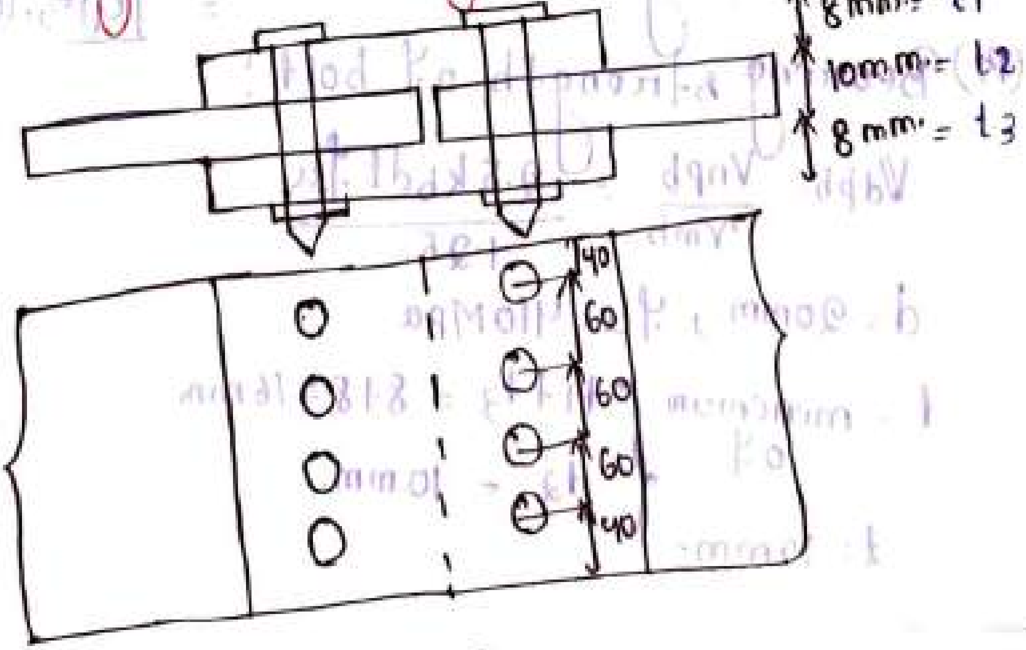
$T_{dg} = \frac{1600 \times 250}{1.1} = \boxed{363.636\ kN}$

∴ efficiency of joint $\eta = \frac{\text{strength of joint}}{\text{strength of solid plate}} \times 100$

$= \frac{173.846}{363.636} \times 100$

$\boxed{\eta = 47.8\%}$

Q-02 A single bolted double cover butt joint is used to connect two plates each 10mm thick. The bolts used were 20mm dia of grade 4.6 & cover plates were of 8mm thick. If 4 bolts were provided in a bolt line a pitch of 60mm with edge end distance 40mm, Calculate the strength & efficiency of the joint



Given data:

$f_u = 410 Mpa$, $f_{ub} = 400 Mpa$ (for bolt grade 4.6)

$f_y = 250 Mpa$. $f_{yb} = 240 Mpa$

$d = 20mm$, $d_o = 22mm$.

$P = 60mm$, $e = 40mm$.

Solution:

(A) Strength of a bolt in joint :-

(a) Shear strength of bolt :

$A_{sb} = \frac{\pi}{4} \times d^2 = \frac{\pi}{4} \times (20)^2 = 314 mm^2$

$A_{nb} = 0.78 \times \frac{\pi}{4} d^2 = 0.78 \times \frac{\pi}{4} \times (20)^2 = 245 mm^2$

for butt joint $n_n = 1$, $n_s = 1$.

$$V_{dsb} = \frac{V_{nsb}}{\gamma_{mb}} = \frac{f_{ub}}{\sqrt{3}\,\gamma_{mb}}(n_n A_{nb} + n_s A_{sb})$$

$$= \frac{400}{\sqrt{3} \times 1.25}(1 \times 245 + 1 \times 314)$$

$$= 103.276 kN.$$

Shear strength of one bolt = 103.276 kN.

Shear strength of 4 no's bolt = 103.276 × 4

= $\boxed{413.105 kN.}$

(B) Bearing strength of bolt:

$$V_{dpb} = \frac{V_{npb}}{\gamma_{mb}} = \frac{2.5 k_b d t f_u}{1.25}$$

$d = 20mm$, $f_u = 410 MPa$

$t = $ minimum of $\begin{cases} t_1 + t_3 = 8 + 8 = 16 mm \\ t_2 = 10 mm. \end{cases}$

$t = 10mm$.

$$k_b = \left\{ \begin{array}{l} \frac{e}{3d_0} = \frac{40}{3\times22} = 0.606 \\ \frac{p}{3d_0} - 0.25 = \frac{60}{3\times22} - 0.25 = 0.659 \\ \frac{f_{ub}}{f_u} = \frac{400}{410} = 0.976 \\ 1 \end{array} \right\}$$ whichever is minimum

$k_b = 0.606$

$$V_{dpb} = \frac{2.5\times0.606\times20\times10\times410}{1.25}$$

$= 99.384\ kN$

bearing strength of one bolt = 99.384 kN.

bearing strength of 4no's bolt = 99.384×4

$= \boxed{397.54\ kN}$

(A) Design strength of bolt in joint :-

minimum of $\left\{ \begin{array}{l} V_{dsb} = 413.105 \\ V_{dpb} = 397.54 \end{array} \right.$

$= \boxed{397.54\ kN}$

(B) Rupture strength of plate :-

$f_u = 410$, $\gamma_{m1} = 1.25$

$$T_{dn} = \frac{0.9 A_n f_u}{\gamma_{m1}}$$

$A_n = (b - n d_0)\, t$

$= (260 - 4\times22)\times10 = 1720\ mm^2$

$$T_{dn} = \frac{0.9\times1720\times410}{1.25} = \boxed{507.74\ kN.}$$

Design strength of joint:-

$$\text{minimum of} \begin{cases} \text{Design strength of bolt } (397.54\,kN) \\ \text{Rupture strength of plate } \cancel{(174.036\,kN)}\ (507.74\,kN) \end{cases}$$

$= 397.54\,kN.$

Strength of solid plate:-

$$T_{dg} = \frac{A_g f_y}{\gamma_{m0}}$$

$A_g = b \times t = 260 \times 10 = 2600\,mm^2$

$f_y = 250\,MPa$

$\gamma_{m0} = 1.1$

$$T_{dg} = \frac{2600 \times 250}{1.1} = 590.91\,kN.$$

$$\text{efficiency of joint } \eta = \frac{\text{strength of joint}}{\text{strength of solid plate}} \times 100$$

$$= \frac{397.54}{590.91} \times 100$$

$$\boxed{\eta = 67.28\%}$$

Design procedure for bearing bolted joint:-

For the design of a lap or butt joint, when the thickness of plates & force to be transmitted is known, the following are steps for design:-

(1) The size of bolt is determined from Unwin's formula as $d = 6\sqrt{t}$

t = thickness of plate in mm.

The diameter of bolts so computed is rounded off to available size of bolts.

(2) The strength of bolts in shear & bearing are computed assuming suitable value of pitch, edge distance. The minimum of the above is taken as bolt value & the number of bolts required is obtained by deviding the applied force by bolt value.

(3) The bolts are suitably arranged to produce a convenient & efficient joint.

(4) The joint is checked for rupture strength of plate with the assumed arrangement of bolts which should be more than the applied load.

Q-03 Two steel plates of 10mm & 12mm thick are to be joined by a lap joint so as to transmit a load of 120kN using 20mm dia bearing bolts of property class 4.6 & plates of grade Fe410. Find the number & arrangement of bolts, if each of (i) plates are (i) 100mm wide (ii) 200mm wide.

Given data:- dia of bolt (d) = 20mm.

$d_o = 22mm$

$P_u = 120kN$.

$f_{ub} = 400$ Mpa

$f_u = 410$ Mpa.

(i) for 100 mm wide plate

$A_{nb} = 0.78 \times \frac{\pi}{4} d^2 = 0.78 \times \frac{\pi}{4} \times (20)^2$

$= 245 mm^2$

$A_{sb} = \frac{\pi}{4} \times d^2 = \frac{\pi}{4} \times (20)^2$

$= 314 mm^2$

$\gamma_{mb} = 1.25$

$$V_{dsb} = \frac{1}{\gamma_{mb}} \frac{f_{ub}}{\sqrt{3}} (n_n A_{nb} + n_s A_{sb})$$

$$= \frac{1}{1.25} \times \frac{400}{\sqrt{3}} (1 \times 245 + 0 \times 314)$$

$$= 45.26 \text{ kN}.$$

Design strength of a bolt in bearing:-

$$V_{dpb} = \frac{V_{npb}}{\gamma_{mb}} = 2.5 k_b d t \frac{f_u}{\gamma_{mb}}.$$

$f_u = 410$ Mpa, $\gamma_{mb} = 1.25$

$d = 20$ mm.

$t = 10$ mm.

$$k_b = \left\{ \begin{array}{l} \frac{e}{3d_0} = \frac{40}{3 \times 22} = 0.606 \\ \frac{p}{3d_0} - 0.25 = \frac{60}{3 \times 22} - 0.25 = 0.66 \\ \frac{f_{ub}}{f_u} = \frac{400}{410} = 0.976 \\ 1 \end{array} \right\} \text{whichever is less}$$

$k_b = 0.606$

$$V_{dpb} = 2.5 \times 0.606 \times 20 \times 10 \times \frac{410}{1.25}$$

$$= 99.38 \text{ kN}.$$

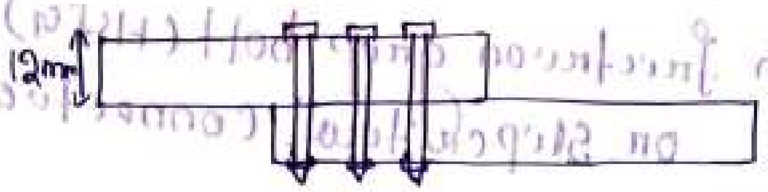
Design strength of a bolt = minimum of $\left\{ \begin{array}{l} V_{dsb} = 45.26 \\ V_{dpb} = 99.38 \end{array} \right.$

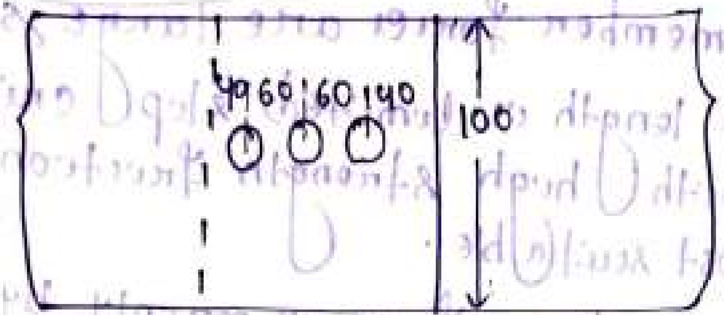
$= 45.26.$

Number of bolts required to transmit a load of 120 kN:-

$$n = \frac{120}{45.26} = 2.65 \simeq 3 \text{ nos}.$$

(i) The bolts are to be arranged along the length in a row because width is not sufficient to accomodate them in a row along the width.





Check for rupture strength of plate :-

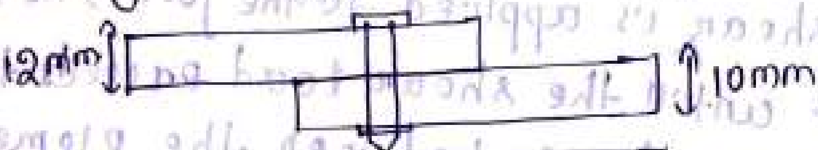
$$A_n = (b - n d_0)t$$

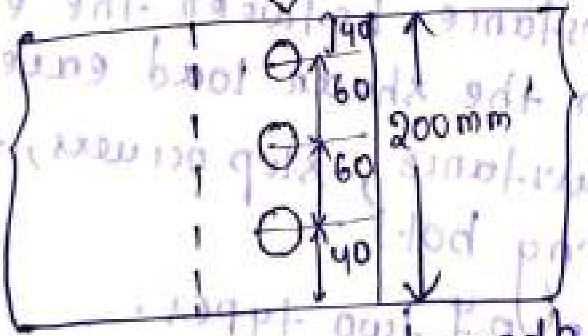
$$= (160 - 1\times22)10 = 780\,mm^2$$

$$T_{dn} = \frac{0.9 A_n f_u}{\gamma_{ml}} = \frac{0.9\times780\times410}{1.25} = 230.26\,kN > 120\,kN$$ (ok)

(ii) When each plate is 200mm wide :-

To reduce the length of joint, bolts may be arranged along the width in a row :





Check for rupture strength of plate :-

$$A_n = (b - n d_0)t$$

$$= (200 - 3\times22)\times10 = 1340\,mm^2$$

$$T_{dn} = \frac{0.9 A_n f_u}{\gamma_{ml}} = \frac{0.9\times1340\times410}{1.25}$$

$$= 395.57\,kN > 120\,kN$$ (ok).

High Strength friction grip bolt (HSFG) or slip critical connection.

-> When the member forces are large & where the connection length is limited, slip critical connection with high strength friction grip bolts are most suitable.

-> Resistance to shear force is mainly by friction & shear or bearing are not the criteria for load transmission as in case of bearing type bolts.

-> The nut is tightened to develop a clamping force on the plates which is indicated as the tensile force in the bolt. This tension is about 90% of proof load.

-> When a shear load is applied to the joint, no slip will occur until the shear load exceeds the frictional resistance between the elements jointed. When the shear load exceeds the frictional resistance, slip occurs, then it acts as bearing bolt.

-> HSFG bolts are of two types.

(i) parallel shank type.

(ii) Waisted shank type.

(i) parallel shank type :-

(a) -> parallel shank type HSFG bolts are designed for no slip at serviceability loads. Hence they slip at higher loads & slip into bearing at ultimate load. therefore such bolts should be checked for their bearing strength at ultimate load.

(ii) Waisted shank type :-

-> Waisted shank HSFG bolts are designed for no slip even at ultimate load & hence there is no need to check for their bearing strength.

Shear Capacity of HSFG bolts :- (cl: 10.4.) IS 800

The design slip resistance = $\frac{\text{nominal shear capacity of bolt}}{\gamma_{mf}}$

$$\boxed{V_{dsf} = \frac{\mu_f n_e K_h F_o}{\gamma_{mf}}}$$

μ_f = coefficient of friction (slip factor) (table 20).

n_e = number of effective interfaces offering frictional resistance to slip.

for Lap joint, $n_e = 1$

for butt joint, $n_e = 2$.

K_n = 1 for fasteners in clearance holes

= 0.85 for fasteners in oversized & short slotted holes & for long slotted holes loaded perpendicular to the slot.

= 0.70 for fasteners in long slotted holes loaded parallel to the slot.

F_0 = minimum bolt tension (proof load) at installation = $A_{nb} f_0$

A_{nb} = Net area of bolt at heads = $0.78 \times \frac{\pi}{4} d^2$.

f_0 = proof stress = $0.70 f_{ub}$.

γ_{mf} = 1.1 (if slip resistance is designed at service load)

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

Reduction factor for shear capacity of HSFG bolt

The provision for long joints in 10.3.3.1 shall apply to friction grip connections also.

Q Two plates of 12mm thick are joined by double cover butt joint with 20mm HSFG bolts of property class 8.8 & cover plates of 8mm thick. Assuming that the fasteners are in clearance holes & slip factor as 0.30, determine the shear capacity of a bolt if (i) slip resistance is designed at service load (ii) slip resistance is designed at ultimate load.

For HSFG bolt of grade 8.8 :-

$f_{ub} = 800 \text{ N/mm}^2$.

For fasteners in clearance holes $K_h = 1$

slip factor (μ_f) = 3 (given)

Nominal shear capacity of bolt (V_{nsf}) =>

$$V_{nsf} = \mu_f n_e K_h F_0$$

For butt joint $n_e = 2$

$F_0 = 0.7 f_{ub} A_{nb}$

$= 0.7 \times 800 \times 245.04$ $\left(A_{nb} = 0.78 \times \frac{\pi}{4} \times d^2\right)$

$= 137.22$ kN $\quad = \left(0.78 \times \frac{\pi}{4} \times 20^2\right)$

$V_{nsf} = \mu_f n_e k_h F_0$ $\quad = 245.04$

$= 0.3 \times 2 \times 1 \times 137.22$

$= \cancel{823.32}\ 82.332$ kN

(i) If slip resistance is designated at service load:

Design shear capacity of bolt (V_{dsf}) = $\frac{V_{nsf}}{\gamma_{mf}}$

$$V_{dsf} = \frac{\cancel{823.32}\ (82.332}{1.1} = \cancel{748.50 \text{ kN}}\ 74.85 \text{ kN}.$$

(ii) If slip resistance is designated at ultimate load $\gamma_{mf} = 1.25$

$$V_{dsf} = \frac{V_{nsf}}{\gamma_{mf}} = \frac{\cancel{823.32}}{\cancel{1.25}} = \frac{82.332}{1.25}$$

$= 65.86$ kN

Q An ISA 110×110×8 mm carries a factored tensile force of 60kN. It is connected to a 12mm thick gusset plate. Design a high strength bolted joint when (a) no slip is permitted (b) slip is permitted. Steel is of grade Fe410. Assume bolts in clearance holes & slip factor as 0.3.

Solution:- Dia of bolt, $d = 6\sqrt{t}$

$= 6\sqrt{8}$

$= 16.97$ mm

$\simeq 16$ mm

For HSFG bolt of property class 8.8:-

$f_{ub} = 800$ Mpa; $A_{nb} = 0.78 \times \frac{\pi}{4} \times d^2$

$= 0.78 \times \frac{\pi}{4} \times (16)^2$

$= 156.83 \text{ mm}^2$

For fe410 grade of steel; $f_u = 410$ Mpa

(a) When slip is not permitted (slip critical connection):-

proof load $F_o = A_{nb} \times 0.7 f_{ub}$

$= 156.83 \times 0.7 \times 800$

$= 87.824$ kN

design shear capacity of bolt,

$$V_{sf} = \frac{\mu_f n_e k_h F_o}{\gamma_{mf}}$$

For lap joint $n_e = 1$

For bolts in clearance hole $k_h = 1$

$$V_{sf} = \frac{0.3 \times 1 \times 1 \times 87.824}{1.25} = 21.10 \text{kN}$$

($\gamma_{mf} = 1.25$ for slip resistance at ultimate load)

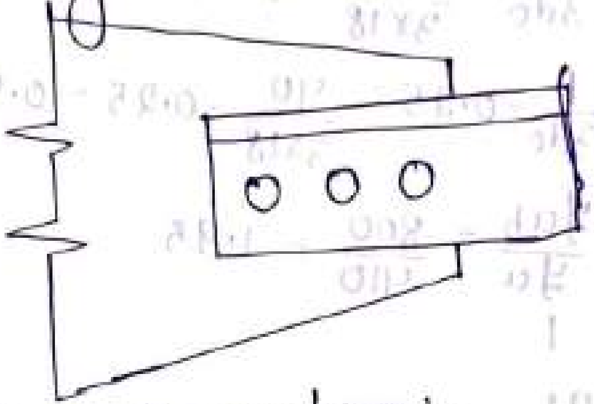
No. of bolts required =

$$\frac{\text{external load}}{\text{shear capacity of a bolt}} = \frac{60}{21.10}$$

$= 2.84 \approx 3\text{nos}.$

Hence provide 3 nos of 16mm dia 8.8 grade HSFG bolts for making the connection.

(b)



(b) Bearing type Connection :-

for bearing type connection we will design for bearing strength & shearing strength.

for Lap joint $n_n = 1$, $n_s = 0$,

(i) Strength of the bolt in single shear :-

$$V_{dsb} = \frac{V_{nsb}}{\gamma_{mb}} = \frac{1}{\gamma_{mb}}\left\{\frac{f_{ub}}{\sqrt{3}}(n_n A_{nb} + n_s A_{sb})\right\}$$

$$= \frac{1}{1.25}\left\{\frac{800}{\sqrt{3}}(1 \times 157 + 0)\right\}$$

$$\boxed{V_{dsb} = 58.01\,\text{kN}}$$

(ii) strength of bolt in bearing :-

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

$\gamma_{mb} = 1{\cdot}25, \quad d_0 = 16+2 = 18\,mm$

Assume $e = 1{\cdot}5 d_0 = 1{\cdot}5 \times 18 = 27\,mm \approx 30\,mm.$

$P = 2{\cdot}5 d = 2{\cdot}5 \times 16 = 40\,mm.$

$$K_b = \text{least of} \begin{cases} \dfrac{e}{3d_0} = \dfrac{30}{3\times18} = 0{\cdot}55 \\ \dfrac{P}{3d_0} - 0{\cdot}25 = \dfrac{40}{3\times18} - 0{\cdot}25 = 0{\cdot}491 \\ \dfrac{f_{ub}}{f_u} = \dfrac{800}{410} = 1{\cdot}95 \\ 1 \end{cases}$$

$K_b = 0{\cdot}491$

$$V_{dpb} = 2{\cdot}5\, k_b\, d\, t \frac{f_u}{\gamma_{mb}}$$

$$= 2{\cdot}5 \times 0{\cdot}491 \times 16 \times 8 \times \frac{410}{1{\cdot}25}$$

$$\boxed{V_{dpb} = 51{\cdot}54\,kN.}$$

$$\text{Strength of bolt} = \text{minimum of} \begin{cases} V_{dsb} = 58{\cdot}01\,kN \\ V_{dpb} = 51{\cdot}54\,kN \end{cases}$$

$= 51{\cdot}54\,kN.$

No. of bolts required $= \dfrac{60}{51{\cdot}54} = 1{\cdot}16 \approx 2$ NOS.

Hence provide 2 nos of 16mm dia HSFG bolts.