Design of Steel connection

Unit 2 part 1

Date
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2. Design of steel connection

Types of Bolts :

There are two types of bolts

1) black bolt
2) High strength bolt.

1) Black bolt : The black bolt are made from mild steel rod with square or hexagonal head.

- Black bolt are ordinary, rough, unfinished and commonly used bolt.

- They are least expensive.

- They are mainly used for light structure not recommended for connection subjected to impact or dynamic load.

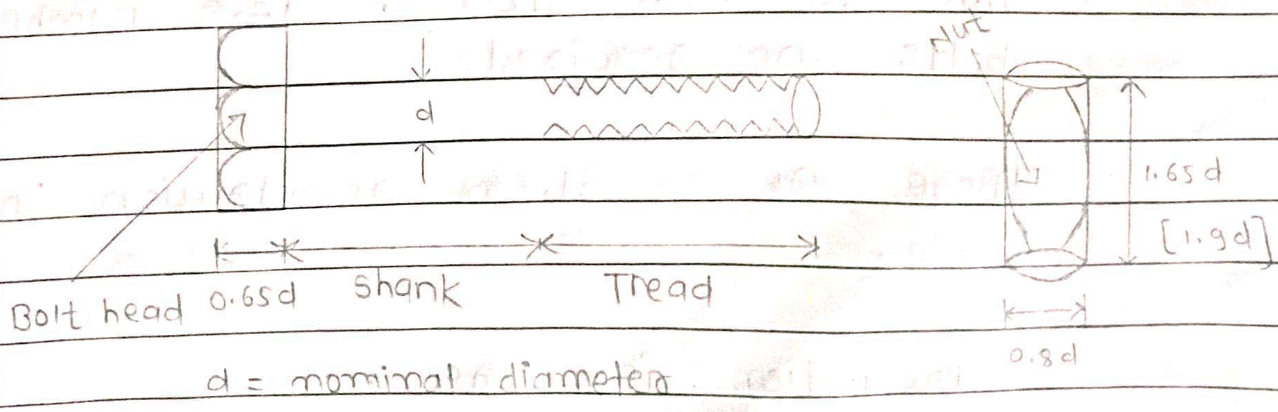


fig: hexagonal black bolt & nut.

2) High strength bolt :→ This bolt is also called as friction grip bolt.

- high strength bolt are made from medium carbon steel.
- The bolt of property class 8.8 and 10.9 are commonly used steel.
- They are identified by class identification 8.8 S and 10.9 S and S denotes by high strength.
- This bolt are used for impact or dynamic loading structure.

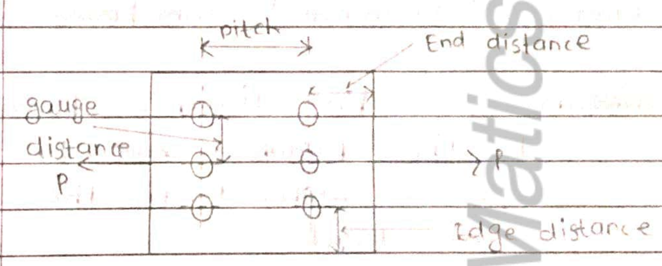
* Advantages of HSFG bolt :→

- It does not allows slip between the connected members.
- load are transfered by friction only
- Due to high strength less number of bolts are required.
- There are no stress concentration in the hole.
- Deformation is more.

W-23, S-23, S-22

* Advantages of Bolted connection over welding connection

1) It requires simple tools and unskilled labour
2) No specialized equipment is required
3) It is noiseless.
4) As soon as the bolts are tightened the connection starts supporting load.
5) Progress of work is fast.
6) It is easily dismental and reuse the material.



X Pitch (P) → It is the distance between centre of any two adjacent hole in the direction of load parallel to the load.

Minimum pitch = $2.5 \times d$

where d = diameter of bolt.

- maximum pitch for compression member - $12t$ or 200mm whichever is less

for tension member - $16t$ or 200mm whichever is less.

where t = thickness of thinner plate.

* Gauge (G) :→ It is the distance between two holes perpendicular to the direction of load.

- There is no criteria for minimum gauge.

- maximum gauge distance shall not exceed [4t + 100] or [200 mm] whichever is less.

End distance :→ The distance from centre of the fastener hole to the edge of element in the direction of load.

Edge distance :→ It is the distance from centre of fastener hole to the edge of the element perpendicular to the direction of load.

- The minimum edge and end distance from the centre of any hole to the nearest edge of plate shall not be less than 1.7 times the hole diameter for hand-flame cut and 1.5 times the hole diameter in case of road machine fu flame cut

* Gross cross sectional area :→

It is the area of unthreaded portion of the bolt. or shank

$$A_g = \frac{\pi}{4} \times d^2$$

* Net effective cross sectional area :→

It the cross sectional area at the root of thread.

$$A_n = 0.78 \times A_g$$

$$A_n = 0.78 \times \frac{\pi}{4} \times d^2$$

* Specification for bolt hole :

* Bolt hole : bolt holes are made larger than bolt diameter to

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facilitate erection

0 – 14 → do = d+1 , 16 – 24 → do = d+2

more than 24 → do = d+3.

Nominal bolt diameter (d) mm	12	14	16	18	20	22	24	27	30
Diameter of hole do	13	15	18	20	22	24	26	30	33

* ultimate tensile strength of bolt (fub) :→

V.V.Imp

ultimate tensile stength of bolt (fub) and yeild Stress of bolt for bolt class 4.65.

ultimate tensile strength of bolt (fub) =

$$f_{ub} = 4 \times 400$$
$$f_{ub} = 400 \ N/mm^2$$

yield stress of the bolt (f_{yb}) = $0.6 \times f_{ub}$

$$f_{yb} = 0.6 \times 400$$
$$f_{yb} = 240 \ N/mm^2$$

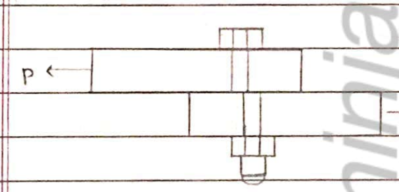
* failure of Bolted Joint

1) shear failure of Bolt :

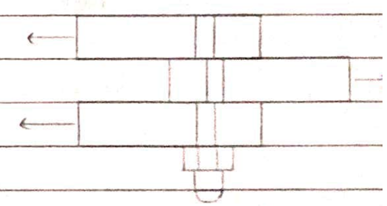
Shear stresses are generated when the plate slip due to applied force.

The maximum she· factored shear force in the bolt may exceed the nominal shear capicity of the bolt.

The shear failure of bolt take place at the bottom shear plane. the bolt may fail in single or double Shear.



Single Shear

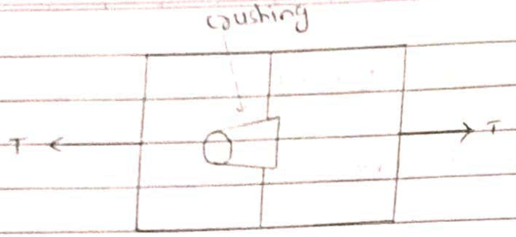


Double Shear

2) shear failure of plate

When the strength of plate is less than the shearing strength of bolt the tearing failure of plate may occure

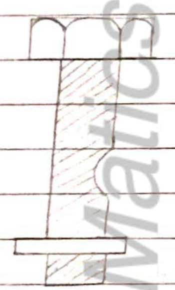
To avoid this type of failure the minimum edge distance shall be provided.



Shear tear out of plate

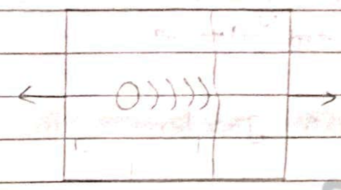
3) Bearing failure of bolt :

Normally the bolt material is off much higher strength then that of steel plate through which bolt passes. as a result bearing failure take place in the plate material. the bolt may deform due to high local bearing stress between the bolt & plate.



4) Bearing failure of plate :

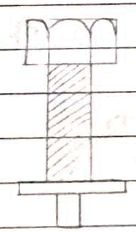
when an ordinary bolt subjected to shear force the slip takes place. and bolt comes in contact with the plate. the plate may get crushed if the plate material is weeker than bolt material the bearing problem can be complecated by the presence of a near by bolt.



5) Tension failure of bolts :

The bolt subjected to tensile force fails if factor tensile force is greater than tensile capacity of the bolt.

The tensile capacity depend upon tensile strength of bolt. and minimum cross sectional area of the threaded length



Design of Steel connection

Type - 1

* find Bolt value :->

for fe 410 grade of steel
$f_u = 410\ N/mm^2$

for bolt, 4.6 grade.

$f_{ub} = 4 \times 100 = 400\ N/mm^2$
$f_{yb} = 0.6 \times f_{ub} = 0.6 \times 400 = 240\ N/mm^2$.

1) Bolt in shear

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

$$V_{nsb} = \left[\frac{f_{ub}}{\sqrt{3}}\right] \times (n_n A_{nb} + n_s A_{sb})$$

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

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

$\gamma_{mb} = 1.25$ (constant value)

for single shear : $n_n = 1$ and $n_s = 0$

for double shear : $n_n = 1$ and $n_s = 1$

2) Bolt in bearing :->

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

$V_{npb} = 2.5 \times k_b \times d \times t_p \times f_u$

k_b — ① $\frac{e}{3d_0}$ ② $\frac{p}{3d_0} - 0.25$

③ $\frac{f_{ub}}{f_u}$ ④ 1

take k_b as smaller value

$e = 1.7 \times d_0$ and $1.5 \times d_0$
$p = 2.5 \times d$

where,
V_{dsb} = design shear strength of bolt

V_{nsb} = nominal shear strength of bolt

n_n = number of shear planes passes through threaded section

n_s = number of shear planes passes through shank.

d = nominal diameter of bolt

d_0 = diameter of bolt hole.

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γ_{mb} = partial safety factor of bolt.
e = edge distance
p = pitch distance

V_{npb} = nominal bearing strength of bolt.

Q. Determine the bolt value of 20 mm diameter bolt connecting 10 mm plate in single shear. bolt used are 4.6 grade. Plate of 410 grade take area of bolt 245 mm^2.

Given data :

$d = 20$ mm
$d_0 = d + 2 = 20 + 2 = 22$ mm
$t_p = 10$ mm
4.6 grade of bolt
grade of plate $(f_u) = 410\ N/mm^2$

$f_{ub} = 4 \times 100 = 400\ N/mm^2$
$f_{yb} = 0.6 \times f_{ub} = 0.6 \times 400 = 240\ N/mm^2$

① Design shear strength of bolt :

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

$$V_{nsb} = \left[\frac{f_{ub}}{\sqrt{3}}\right] \times (n_n A_{nb} + n_s A_{sb})$$

for single shear : $n_n = 1$ & $n_s = 0$

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

$[A_{nb} = 245\ mm^2]$

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

$[A_{sb} = 314.15\ mm^2]$

$$V_{nsb} = \left(\frac{400}{\sqrt{3}}\right) \times (1 \times 245 + 0 \times 314.15)$$

$V_{nsb} = 56.58 \times 10^3$ N

$[V_{nsb} = 56.58 \times 10^3 N]$

$$V_{dsb} = \frac{V_{nsb}}{\gamma_{mb}} = \frac{56.58 \times 10^3}{1.25}$$

$V_{dsb} = 45.26 \times 10^3$ N

$[V_{dsb} = 45.26$ kN$]$

② design bearing strength of bolt :

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

$V_{npb} = 2.5 \times k_b \times d \times t_p \times f_u$

k_b – ① $\frac{e}{3d_0}$. $e = 1.7 \times d_0 = 1.7 \times 22$

$e = 37.4$ mm

$p = 2.5 \times d = 2.5 \times 20 =$

① $\frac{e}{3d_0} = \frac{37.4}{3 \times 22} = 0.56$

② $\frac{p}{3d_0} - 0.25 = \frac{2.5 \times 20}{3 \times 22} - 0.25 = 0.50$

③ $\frac{f_{ub}}{f_u} = \frac{400}{410} = 0.97$

④ 1

take [$k_b = 0.50$]

$V_{npb} = 2.5 \times 0.50 \times 20 \times 10 \times 410$

$V_{npb} = 102.5 \times 10^3$ N

$V_{dpb} = \frac{102.5 \times 10^3}{1.25}$

$V_{dpb} = 82 \times 10^3$ N

[$V_{dpb} = 82$ kN]

bolt value : minimum of V_{dsb} and V_{dpb}

[bolt value = 46.4 kN]

W-22

2) determine the bolt value of 16 mm diam. bolt of 4.6 grade use to connect two angle 80×50×6 Place back to back on both side of 8 mm thick gasset plate also determine nomber of bolt required for joint when it carries a dired factor load of 106.5 kN draw neat sketch of design connection

Given data :

$d = 16$ mm , $d_0 = d+2 = 16+2 = 18$ mm

grade of bolt = 4.6

2 angles 80×50×6 back to back.

gusset plate thickness = 8 mm

no of bolt = ?

$P_u = 106.5$ kN

$f_u = 410$ N/mm^2

$f_{ub} = 4 \times 100 = 400$ N/mm^2

$f_{yb} = 0.6 \times f_{ub} = 0.6 \times 400 = 240$ N/mm^2

1) design of Shear Strength of bolt

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

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

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

$[A_{nb} = 156.82 \ mm^2]$

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

$[A_{sb} = 201.06 \ mm^2]$

$n_n = 1$ & $n_s = 0$

due to double angle.

$V_{nsb} = 2 \times \left(\frac{f_{ub}}{\sqrt{3}}\right) \times (n_n A_{nb} + n_s A_{sb})$

$V_{nsb} = 2 \times \frac{400}{\sqrt{3}} \times (1 \times 156.82 + 0 \times 201.06)$

$[V_{nsb} = 72.43 \times 10^3 \ N]$

$V_{dsb} = \frac{V_{nsb}}{\gamma_{mb}} = \frac{72.43 \times 10^3}{1.25}$

$V_{dsb} = 57.94 \times 10^3 \ N$

$[V_{dsb} = 57.94 \ kN]$

2) design of bearing strength of bolt

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

$V_{npb} = 2.5 \times k_b \times d \times t_p \times f_u$.

$t_p = 8mm$ (because 2 angles back to back $(6+6) = 12$)

k_b - 1) $\frac{e}{3d_0}$, $e = 1.7 \times d_0 = 1.7 \times 18$

$e = 30.6 \ mm$

$p = 2.5 \times d = 2.5 \times 16 = 40 \ mm$

1) $\frac{e}{3d_0} = \frac{30.6}{3 \times 18} = 0.56$

2) $\frac{p}{3d_0} - 0.25 = \frac{40}{3 \times 18} - 0.25 = 0.74 - 0.25 = 0.49$

3) $\frac{f_{ub}}{f_u} = \frac{400}{410} = 0.97$

4) 1

take $k_b = 0.49$

$V_{npb} = 2.5 \times 0.49 \times 16 \times 8 \times 410$

$[V_{npb} = 64288 \ N]$

$V_{dpb} = \frac{V_{npb}}{\gamma_{mb}} = \frac{64288}{1.25}$

$V_{dpb} = 51430 \times 10^3$ N

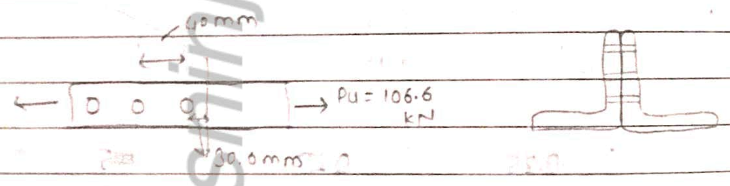
[$V_{dpb} = 51.43$ kN]

Bolt value = minimum of V_{dsb} and V_{dpb}

[Bolt value = 51.43 kN]

no. of bolt = $\frac{P_u}{BV} = \frac{106.5}{51.42}$

no. of bolt = 2.07 (≃ 3)



Q. 3) An inclined truss member consist of 2 angle 100×75×10 mm. connected back to back with longer leg to either side of gusset plate 12mm thick. design the bolted joint to transfer a design force of 750 kN. use 16 mm diameter bolt. of 4.6 grade. and steel f_u 410.

Given data :

d = 16 mm , $d_0 = d+2 = 16+2 = 18$ mm
2 angles 100×75×10 mm connected back to b
thickness of gusset plate = 12 mm
P_u = 750 kN
f_u = 410 N/mm²
grade of bolt = 4.6.

$f_{ub} = 4.6 \times 100 = 400$ N/mm²
$f_{yb} = 0.6 \times f_{ub} = 0.6 \times 400 = 240$ N/mm².

i) design of shear strength of bolt :

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

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

$n_n = 1$ & $n_s = 0$

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

[$A_{nb} = 156.82$ mm²]

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

[$A_{sb} = 201.06$ mm²]

due to 2 angles

$V_{nsb} = 2 \times \frac{f_{ub}}{\sqrt{3}} \times (n_n A_{nb} + n_s A_{sb})$

$V_{nsb} = 2 \times \frac{400}{\sqrt{3}} \times (1 \times 156.82 + 0 \times 201.06)$

$[V_{nsb} = 72.43 \times 10^3 \ N]$

$V_{dsb} = \frac{V_{nsb}}{\gamma_{mb}} = \frac{72.43 \times 10^3}{1.25}$

$V_{dsb} = 57.94 \times 10^3 \ N$

$[V_{dsb} = 57.94 \ kN]$

2) design of bearing strength of bolt :

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

$V_{npb} = 2.5 \times k_b \times d \times t_p \times f_u$

$t_p = 12 \ mm$ (because 2 angles connected back to back $(10+10) = 20 \ mm$)

k_b –

$e = 1.7 \times d_0 = 1.7 \times 18$

$e = 30.6 \ mm$

$p = 2.5 \times d = 2.5 \times 16 = 40 \ mm$

1) $\frac{e}{3d_0} = \frac{30.6}{3 \times 18} = 0.56$

2) $\frac{p}{3d_0} - 0.25 = \frac{40}{3 \times 18} - 0.25 = 0.49$

3) $\frac{f_{ub}}{f_u} = \frac{400}{410} = 0.97$

4) 1 take $k_b = 0.49$

$V_{npb} = 2.5 \times 0.49 \times 12 \times 16 \times 410$

$[V_{npb} = 96.432 \times 10^3 \ N]$

$V_{dpb} = \frac{V_{npb}}{\gamma_{mb}} = \frac{96.432 \times 10^3}{1.25}$

$V_{dpb} = 77.14 \times 10^3 \ N$

$[V_{dpb} = 77.14 \ kN]$

value of bolt : minimum value of V_{dsb} and V_{dpb}

$[\text{value of bolt} = 57.94 \ kN]$

no of bolt $= \frac{P_u}{f_u} = \frac{750}{57.94} = 12.94$

$\approxeq 13$ no.

Q) Determine bolt value of 16 mm diameter bolt of 4.6 grade to connect two angles 90 x 60 x 6 mm back to back on opposite side of gusset plate of 8 mm thickness. also determine number of bolts required it it carries a direct factored load of 110 kN. take pitch = 50 mm and edge distance = 40 mm Draw neat sketch of design connection.

Given data :

$d = 16mm$

$d_0 = d+2 = 16+2 = 18\,mm$

grade of bolt = 4.6

2 angles of 90x60x6 mm back to back.

thickness of plate = 8 mm

$P_u = 110\ kN$, $f_u = 410\ N/mm^2$

$p = 50\ mm$

$e = 40\ mm$

$f_{ub} = 4 \times 100 = 400\ N/mm^2$

$f_{yb} = 0.6 \times f_{ub} = 0.6 \times 400 = 240\ N/mm^2$.

1) design of shear strength of bolt :→

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

$$V_{nsb} = \left[\frac{f_{ub}}{\sqrt{3}}\right] \times (n_n A_{nb} + n_s A_{sb})$$

$n_n = 1$ & $n_s = 0$

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

$[A_{nb} = 156.82\ mm^2]$

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

$[A_{sb} = 201.06\ mm^2]$

due 2 angles connected back to back.

$$V_{nsb} = 2 \times \left[\frac{f_{ub}}{\sqrt{3}}\right] \times (n_n A_{nb} + n_s A_{sb})$$

$$V_{nsb} = 2 \times \left[\frac{400}{\sqrt{3}}\right] \times (1 \times 156.82 + 0 \times 201.06)$$

$$V_{nsb} = 72.43 \times 10^3\ N$$

$$V_{dsb} = \frac{V_{nsb}}{\gamma_{mb}} = \frac{72.43 \times 10^3}{1.25}$$

$$V_{dsb} = 57.94 \times 10^3\ N$$

$[V_{dsb} = 57.94\ kN]$

2) design of bearing strength of bolt

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

$V_{npb} = 2.5 \times k_b \times t_p \times d \times f_u$.

$t_p = 8mm$ (2 angles connected back to back (6+6) = 12)

k_b - $e = 50mm$, $p = 40mm$

1) $\frac{e}{3d_0} = \frac{50}{3\times18} = 0.92$

2) $\frac{p}{3d_0} - 0.25 = \frac{40}{3\times18} - 0.25 = 0.49$

3) $\frac{f_{ub}}{f_u} = \frac{400}{410} = 0.97$

4) 1

take $k_b = 0.49$

$V_{npb} = 2.5 \times 0.49 \times 8 \times 16 \times 410$

$V_{npb} = 64.28 \times 10^3$ N

$V_{dpb} = \frac{V_{npb}}{\gamma_{mb}} = \frac{64.28 \times 10^3}{1.25}$

$V_{dpb} = 51.43 \times 10^3$ N

[$V_{dpb} = 51.43$ kN]

bolt value : minimum of V_{dpb} and V_{dsb}

bolt value = 51.43 kN

no. of bolt = $\frac{P_u}{\text{bolt value}} = \frac{110}{51.43}$

no of bolt = 2.13 $\simeq$ 3.

Type 2 :

Step (1) and step (2) are same as type (1)

Step (3) strength of bolt = $\frac{0.9 f_u}{\gamma_{mb}} \times$ area of plate

area of plate = $(b - nd_0) \times t$

Strength of bolt = $\frac{0.9 f_u}{\gamma_{mb}} \times (b - nd_0) t$

no. of bolt = $\frac{\text{Strength of bolt}}{\text{bolt value}}$

1) determine bolt value of 16 mm diameter bolt of 4.6 grade. to connect 2 angle

20-5-23 5-23

6 marks.

1) A plate of 100 × 10 is connected by plate 200 × 12 by lap joint. by means of 18 mm diameter bolt in single line. calculate number of bolt required to utilise full strength of connection. assume grade of bolt & plate are 4.6 & 410.

Given data :

$d = 18\ mm$, $d_0 = d + 2 = 18 + 2 = 20\ mm$

grade of bolt = 4.6

grade of plate = 410

plate of 100×10 connected by plate 200×12.

bolt in single line.

no. of bolt = ?

$f_{ub} = 4 \times 100 = 400\ N/mm^2$

$f_{yb} = 0.6 \times f_{ub} = 0.6 \times 400 = 240\ N/mm^2$.

i) design of shear strength of bolt :

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

$$V_{nsb} = \left[\frac{f_{ub}}{\sqrt{3}}\right] \times (n_n A_{nb} + n_s A_{sb})$$

$$A_{nb} = 0.78 \times \frac{\pi}{4} \times d^2 = 0.78 \times \frac{\pi}{4} \times (18)^2$$

$$A_{nb} = 198.48\ mm^2$$

$$A_{sb} = \frac{\pi}{4} \times d^2 = \frac{\pi}{4} \times (18)^2$$

$$A_{sb} = 254.46\ mm^2$$

take $n_n = 1$ & $n_s = 0$

$$V_{nsb} = \frac{400}{\sqrt{3}} \times (1 \times 198.48 + 0 \times 254.46)$$

$$V_{nsb} = 45.83 \times 10^3\ N$$

$$V_{dsb} = \frac{V_{nsb}}{\gamma_{mb}} = \frac{45.83 \times 10^3}{1.25}$$

$$V_{dsb} = 36.66 \times 10^3\ N$$

$$\left[V_{dsb} = 36.66\ kN\right]$$

2) design of bearing strength of bolt :

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

$$V_{npb} = 2.5 \times k_b \times t_p \times d \times f_u .$$

$t_p = 10$ mm

k_b — $e = 1.7 \times d_0 = 1.7 \times 20 = 34$ mm

$p = 2.5 \times d = 2.5 \times 18 = 45$ mm

1) $\frac{e}{3d_0} = \frac{34}{3 \times 20} = 0.56$

2) $\frac{p}{3d_0} - 0.25 = \frac{45}{3 \times 20} - 0.25 = 0.5$

3) $\frac{f_{ub}}{f_y} = \frac{400}{410} = 0.97$

4) 1

take $k_b = 0.5$

$V_{npb} = 2.5 \times k_b \times t_p \times d \times f_u$

$V_{npb} = 2.5 \times 0.5 \times 10 \times 18 \times 410$

$V_{npb} = 92.25 \times 10^3$ N

$V_{dpb} = \frac{V_{npb}}{\gamma_{mb}} = \frac{92.25 \times 10^3}{1.25}$

$V_{dpb} = 73.8 \times 10^3$ N

[$V_{dpb} = 73.8$ KN]

bolt value → take minimum of V_{dsb} & V_{dpb}

bolt value (bv) = 37.5 KN

3) Strength of bolt :→

$P_u = \frac{0.9 f_u}{\gamma_{mb}} \times (b - n d_0) \times t$

$P_u = \frac{0.9 \times 410}{1.25} \times (100 - 1 \times 20) \times 10$

$P_u = 236.16 \times 10^3$ N

[$P_u = 236.16$ KN]

no of bolt = $\frac{\text{Strength of bolt}}{\text{bolt value}}$

$= \frac{236.16}{36.66}$

[no of bolt = 6.44 no.] ≃ 5

12) A lap joint consist of two plate 100×10mm connected by 20 mm diameter bolt of grad 4.6 all bolts are in one line. Calculate Strength of single bolt & number of bolt to be provided in the joint.

Given data:

$d = 20$ mm

$d_o = d+2 = 20+2 = 22$ mm

Plate size = 100×10 mm

grade of bolt = 4.6

grade of plate = 410.

$n = 1$

$f_{ub} = 4 \times 100 = 400$ N/mm^2

$f_{yb} = 0.6 \times 400 = 240$ N/mm^2.

① design of shear strength of bolt :→

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

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

$n_n = 1$ & $n_s = 0$

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

$A_{nb} = 245.04$ mm^2

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

$A_{sb} = 314.15$ mm^2.

$$V_{nsb} = \frac{400}{\sqrt{3}} \times (1 \times 245.04 + 0 \times 314.15)$$

$V_{nsb} = 56.58 \times 10^3$ N

$$V_{dsb} = \frac{V_{nsb}}{\gamma_{mb}} = \frac{56.58 \times 10^3}{1.25}$$

$V_{dsb} = 45.27 \times 10^3$ N

[$V_{dsb} = 45.27$ kN]

2) design of bearing strength of bolt:

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

$V_{npb} = 2.5 \times k_b \times t_p \times d \times f_u$.

$t_p = 10$ mm

k_b — $e = 1.7 \times d_o = 1.7 \times 22 = 37.4$ mm

$p = 2.5 \times d = 2.5 \times 20 = 50$ mm

1) $\frac{e}{3d_o} = \frac{37.4}{3 \times 22} = 0.56$

2) $\frac{p}{3d_o} - 0.25 = \frac{50}{3 \times 22} - 0.25 = 0.50$

3) $\frac{f_{ub}}{f_u} = \frac{400}{410} = 0.97$

4) 1

take $k_b = 0.50$

$V_{npb} = 2.5 \times 0.50 \times 10 \times 20 \times 410$

$V_{npb} = 102.5 \times 10^3$ N

$V_{dpb} = \frac{102.5 \times 10^3}{1.25}$

$V_{dpb} = 82 \times 10^3$ N

[$V_{dpb} = 82$ kN]

bolt value = minimum of V_{dsb} & V_{dpb}

= 46.40 kN

3) Strength of bolt

$P_u = \frac{0.9 \times f_u \times (b - nd_o) \times t}{\gamma_{mb}}$

$P_u = \frac{0.9 \times 410 \times (100 - 1 \times 22) \times 10}{1.25}$

$P_u = 230.25 \times 10^3$ N

$P_u = 230.25$ kN

no. of bolts $= \frac{P_u}{BV} = \frac{230.25}{45.27}$

= 5.08 no

no. of bolts ≃ 5

Type 3 : calculate efficiency of bolt

Step 1 : design of shear strength of bolt.

Step 2 : design of bearing strength of bolt.

Step 3 : find bolt value

Step 4 : Strength of Plate in tearing

$T_{dn} = \frac{0.9 \times f_u (P - nd_o) \times t}{\gamma_{mb}}$

Step 5 : Strength of Joint

minimum of bolt value & T_{dn}

Step 6 : strength of solid plate $= \frac{0.9 \times f_u \times P \times t}{\gamma_{mb}}$

Step 7 : efficiency (η) $= \frac{\text{strength of joint}}{\text{strength of solid plate}} \times 100$

W-22

Q1) determine the efficiency of lap joint use to connect 2 plate of 10 mm thick. use fe 410 grade of plate material and 4.6 grade of bolt take end distance is 30 mm. & bolt diameter 20 mm. with 50 mm pitch

Given data:

$d = 20mm$

$d_0 = d+2 = 20+2 = 22mm$

$t_p = 10 mm$

$f_u = 410$

grade of bolt = 4.6

$e = 30 mm$

$p = 50 mm$

$f_{ub} = 4 \times 100 = 400 N/mm^2$

$f_{yb} = 0.6 \times 400 = 240 N/mm^2$.

1) design of shear strength of bolt:

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

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

$n_n = 1$ & $n_s = 0$

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

$A_{nb} = 245.04 mm^2$

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

$A_{sb} = 314.15 mm^2$

$V_{nsb} = \frac{400}{\sqrt{3}} \times (1 \times 245.04 + 0 \times 314.15)$

$V_{nsb} = 56.58 \times 10^3 N$

$V_{dsb} = \frac{V_{nsb}}{\gamma_{mb}} = \frac{56.58 \times 10^3}{1.25}$

$V_{dsb} = 45.27 \times 10^3 N$

[$V_{dsb} = 45.27 kN$]

2) design of bearing strength of bolt:

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

$V_{npb} = 2.5 \times k_b \times t_p \times d \times f_u$.

$t_p = 10mm$, $e = 30 mm$, $P = 50 m$

k_b - 1) $\frac{e}{3d_0} = \frac{30}{3 \times 22} = 0.45$

2) $\frac{p}{3d_0} - 0.25 = \frac{50}{3\times22} - 0.25 = 0.50$

3) $\frac{f_{ub}}{f_u} = \frac{400}{410} = 0.97$

4) 1

$k_b = 0.45$

$V_{npb} = 2.5\times0.45\times10\times20\times410$

$V_{npb} = 92.25\times10^3$ N

$V_{dpb} = \frac{V_{npb}}{\gamma_{mb}} = \frac{92.25\times10^3}{1.25}$

$V_{dpb} = 73.8\times10^3$ N

$V_{dpb} = 73.8$ kN

3) bolt value = minimum of V_{dsb} & V_{dpb}

[bolt value = 45.27 kN]

4) strength of plate in tearing

$T_{dn} = \frac{0.9\times f_u\times(p-nd_0)\times t}{\gamma_{mb}}$

$T_{dn} = \frac{0.9\times410\times(50-1\times22)\times10}{1.25}$

$T_{dn} = 82.65\times10^3$ N

[T_{dn} = 82.65 kN]

5) strength of joint : minimum of bolt value & T_{dn}.

Strength of joint = 45.27 kN

6) Strength of solid plate = $\frac{0.9\times f_u\times p\times t}{\gamma_{mb}}$

$= \frac{0.9\times410\times50\times10}{1.25}$

$= 147.6\times10^3$ N

[Strength of S.P = 147.6 kN]

7) Efficiency of bolt (η) = $\frac{\text{Strength of joint}}{\text{Strength of S.P}}\times100$

$= \frac{45.27}{147.6}\times100$

[η = 30.67]

2) 12 mm thick plate are connected using double bolt lap joint. using 16 mm diameter bolt of 4.6 grade at pitch of 80 mm. calculate strength & efficiency of joint.

given data :

$t_p = 12 mm$
$d = 16 mm$
$d_0 = d+2 = 16+2 = 18 mm$
$p = 80 mm$

grade of bolt = 4.6
$f_u = 410$

$f_{ub} = 4 \times 100 = 400 N/mm^2$
$f_{yb} = 0.6 \times 400 = 240 N/mm^2$

1) design of shear strength of bolt :

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

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

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

$$A_{nb} = 156.82 mm$$

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

[$A_{sb} = 201.06 mm$]

$n_n = 1$, $n_s = 0$

$$V_{nsb} = \frac{400}{\sqrt{3}} \times (1 \times 156.82 + 0 \times 201.06)$$

$$V_{nsb} = 36.21 \times 10^3 N$$

$$V_{dsb} = \frac{V_{nsb}}{\gamma_{mb}} = \frac{36.21 \times 10^3}{1.25}$$

$$V_{dsb} = 28.97 \times 10^3 N$$

[$V_{dsb} = 28.97 kN$]

2) design of bearing strength of bolt.

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

$$V_{npb} = 2.5 \times k_b \times t_p \times d \times f_u$$

$e = 1.7 \times d_0 = 1.7 \times 18 = 30.6 mm$

$p = 80 mm$, $t_p = 12 mm$

1) $\frac{e}{3d_0} = \frac{30.6}{3\times18} = 0.566$

2) $\frac{P}{3d_0} - 0.25 = \frac{80}{3\times18} - 0.25 = 1.231$

3) $\frac{f_{ub}}{f_u} = \frac{400}{410} = 0.97$

4) 1

$k_b = 0.566$

$V_{npb} = 2.5\times0.566\times12\times16\times410$

$V_{npb} = 111.38\times10^3$ N

$V_{dpb} = \frac{V_{npb}}{\gamma_{mb}} = \frac{111.38\times10^3}{1.25}$

$V_{dpb} = 89.11\times10^3$ N

[$V_{dpb} = 89.11$ kN]

3) bolt value = minimum of V_{dsb} & V_{dpb}

[Bolt value = 28.97 kN]

4) Strength of ~~[illegible]~~ plate in tearing $(T_{dn}) = \frac{0.9\times f_u\times(P-nd_0)\times t}{\gamma_{mb}}$

$T_{dn} = \frac{0.9\times410\times(80-1\times18)\times12}{1.25}$

$T_{dn} = 219.62\times10^3$

[$T_{dn} = 219.62$ kN]

5) strength of joint = minimum of bolt value & T_{dn}

$= 28.97$ kN

$= 2\times28.97$

[Strength of Joint = 57.94 kN]

6) Strength of Solid plate $= \frac{0.9\times f_u\times P\times t}{\gamma_{mb}}$

$= \frac{0.9\times410\times80\times12}{1.25}$

Strength of S.P $= 283.392\times10^3$

$= 283.39$ kN

7) efficiency $(\eta) = \frac{\text{strength of Joint}}{\text{Strength of S.P}}\times100$

$= \frac{57.94}{283.39}\times100$

[$\eta = 20.44$]

Type - 4 :-

3) Design a lap joint to carry a service load of 350 kN. the bolt are 20 mm diameter 4.6 grade. and placed in double row plate are made up of 2 flats 10 mm thick fe 410 grade steel.

Given data :

Service load = 350 kN

factor load = 1.5 × 350

= 525 kN = 525×10^3 N

d = 20 mm

do = d+2 = 20+2 = 22 mm

t = 10 mm

Placed in double row.

4.6 grade of bolt.

$f_{ub} = 4 \times 100 = 400\ N/mm^2$

$f_{yb} = 0.6 \times 400 = 240\ N/mm^2$.

① design of shear strength of bolt :

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

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

$n_n = 1$ & $n_s = 0$

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

$A_{nb} = 245.04\ mm^2$

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

$A_{sb} = 314.15\ mm^2$

$$V_{nsb} = \frac{400}{\sqrt{3}} \times (1 \times 245.04 + 0 \times 314.15)$$

$V_{nsb} = 56.58 \times 10^3$ N

$$V_{dsb} = \frac{V_{nsb}}{\gamma_{mb}} = \frac{56.58 \times 10^3}{1.25}$$

$V_{dsb} = 45.26 \times 10^3$ N

[V_{dsb} = 45.26 kN]

2) bolt value = $\frac{\text{factored load}}{V_{dsb}} = \frac{525}{45.26}$

BV = 11.59 ≃ 12.

Arrange the bolt in double line. strength of bolt joint per pitch length on the basi of shear = 2 × 45.26

= 90.52 kN

$T_{dn} = 90.52 \times 10^3 \, N$

3) Strength of plate $(T_{dn}) = \frac{0.9 \times f_u \times (p - n d_0) \times t}{\gamma_{mb}}$

$90.52 \times 10^3 = \frac{0.9 \times 410 \times (p - n d_0) \times 10}{1.25}$

$\frac{90.52 \times 10^3 \times 1.25}{0.9 \times 410 \times 10} = p - 1 \times 22$

$30.66 = p - 22$

$p = 30.66 + 22$

$[p = 52.66 \text{ mm}] \cong 60$

minimum pitch as per IS :

$p = 2.5 \times d_0 = 2.5 \times 20 = 50 \text{ mm}$

4) design strength of bolt :

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

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

$e = 1.7 \times d_0 = 1.7 \times 22 = 37.4 \cong 40 \text{ mm}$

1) $\frac{e}{3d_0} = \frac{40}{3 \times 22} = 0.60$

2) $\frac{p}{3d_0} - 0.25 = \frac{60}{3 \times 22} - 0.25 = 0.65$

3) $\frac{f_{ub}}{f_u} = \frac{400}{410} = 0.97$

4) 1 = 1

$k_b = 0.60$

$V_{npb} = 2.5 \times 0.60 \times 10 \times 20 \times 410$

$V_{npb} = 123 \times 10^3 \, N$

$V_{dpb} = \frac{123 \times 10^3}{1.25}$

$V_{dpb} = 98.40 \text{ kN}$

$V_{dpb} = 98.40 \text{ kN} > V_{dsb} = 45.26 \text{ kN}$.

2) design the lap joint between the plate of size 100 x 16 mm thick & 100 x 10 thick so as to transmit factor load of 110 kN using single row of 16 mm ~~dia~~ bolt of grade 4.6 and grade 410.

Given data :→

factor load = 110 kN
plate 1 = 100×16 mm
plate 2 = 100×10 mm
in single row
$d = 16\ mm$
$d_0 = d+2 = 16+2 = 18\ mm$
grade of bolt = 410

$f_{ub} = 4\times100 = 400\ N/mm^2$
$f_{yb} = 0.6\times400 = 240\ N/mm^2$

1) design of shear strength of bolt :

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

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

$n_n = 1$ & $n_s = 0$

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

$A_{nb} = 156.82\ mm^2$

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

$A_{sb} = 201.06\ mm^2$

$$V_{nsb} = \frac{400}{\sqrt{3}} \times (1\times156.82 + 0\times201.06)$$

$V_{nsb} = 36.21\times10^3\ N$

$$V_{dsb} = \frac{V_{nsb}}{\gamma_{mb}} = \frac{36.21\times10^3}{1.25}$$

$V_{dsb} = 28.97\times10^3\ N$

[$V_{dsb} = 28.97\ kN$]

2) no. of bolt required = $\frac{\text{factor load}}{V_{dsb}}$

$$= \frac{110}{28.97} = 3.79$$

[no of bolt ≃ 4. no.]

3) bolt in single row

$T_{dn} = 28.97\times10^3\ N$

$$T_{dn} = \frac{0.9 \times f_u \times (P - n d_0) \times t}{\gamma_{mb}}$$

$$28.97\times10^3 = \frac{0.9\times410\times(P - 1\times18)\times10}{1.25}$$

$$\frac{28.97\times10^3\times1.25}{0.9\times410\times10} = P - 18$$

$9.81 = P - 18$

$P = 9.81 + 18$

$P = 27.81 \cong 30\text{ mm}$

As per IS standard $P = 2.5 \times d = 40\text{ mm}$

3) design of bearing strength of bolt :

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

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

k_b - $e = 1.7 \times d_0 = 1.7 \times 18 = 30.6 \cong 40$

1) $\frac{e}{3d_0} = \frac{40}{3 \times 18} = 0.740$

2) $\frac{P}{3d_0} - 0.25 = \frac{40}{3 \times 18} - 0.25 = 0.49$

3) $\frac{f_{ub}}{f_u} = \frac{400}{410} = 0.97$

4) 1

take $k_b = \sout{0.356}$ 0.49

$V_{npb} = 2.5 \times 0.49 \times 10 \times 16 \times 410$

$V_{npb} = 80.36 \times 10^3\ N$

$V_{dpb} = \frac{V_{npb}}{\gamma_{mb}} = \frac{80.36 \times 10^3}{1.25}$

$V_{dpb} = 64.28 \times 10^3\ N$

$V_{dpb} = 64.28\ kN$

$V_{dpb} = 64.28\ kN > V_{dsb} = 28.97\ kN$