PROBLEMS ON MOMENT RESISTANT BOLTED CONNECTION

Type I - Beam to column connections

Problem 1) : Two framing (Framed connections) angles ISA 150 × 150 × 10 mm are use to make Beam to column connections. One angle is placed on either side of the web of beam. Bolts of 16 mm $\emptyset - 03$ No. $grade$ 4.6 are used to connect the angle legs to the beam web. Determine the reaction that can be transferred to the joint ?

Given; column section ISHB 300 @ 618.03 N/m

Beam section ISMB 350 @ 514.04 N/m

Answer :

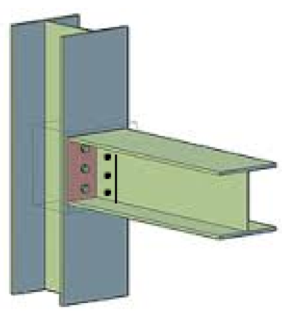


Fig : Isometric Veiw

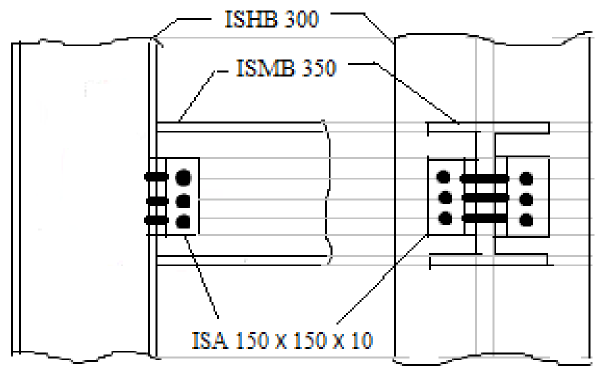


Fig : Front View

Fig : Side View

Given :

a) Properties of Beam section ISMB 350……………………………...*See Steel Table*

t_f = thick. of flange = 10.6 mm;

b) Properties of Column section ISHB 400………………………………*See Steel Table*

Thick. Of web t_w = 8.1 mm

diameter of Bolt (d) = 16 mm

∴ Bolt hole Diameter (d_0) = 16 +2 = 18 mm

∴ Edge Distance (e) = 1.5 × d_0 = 27 mm say 30 mm

∴ Pitch (p) = 2.5 × d = 40 mm

Take F_e 250 Grade of steel ; $f_{y=}$ 250 $N/_{mm^2}$

For bolts 4.6 grade, as per IS 1367 , $F_u = F_{ub}$ = 400 $N/_{mm^2}$

Step 1) Design Strength of one Bolts connecting angle legs to the beam web ;

i) Design Strength of bolt in Shear (V_{ds}) …(*Double shear*)

V_{ds} = { 1/ ɣ [$\frac{F_u}{\sqrt{3}}$ $(n_n A_{nb})$] }………………………………………………cl 10.3.3, pg 75

Where $F_u = F_{ub}$ = 400 $N/_{mm^2}$

n_n = No. of shear planes with threads intercepting shear planes. = 2

ɣ = Partial safety factor for Bolt Material = 1.25 ……………. IS 800-2007 ;Table 5 ; pg. 30

$A_{nb} = 0.78\ to\ 0.80 \times \frac{\pi}{4} \times d^2 = 160.84\ mm^2$

∴ V_{ds} = 59.43 KN

ii) Design Strength of Bolt in Bearing (V_{bs})

V_{bs} = 1/ ɣ (2.5 $K_b\ d\ t\ F_u$) …………………………………IS 800-2007; cl. 10.3.4 ; pg. 75

Where, $F_u = F_{ub}$ = 400 $N/_{mm^2}$

d = 16 mm ;

t = t_w = 8.1 mm

ɣ = Partial safety factor for Bolt Material = 1.25 …………………………… IS 800-2007 ;Table 5 ; pg. 3

K_b= Least of the following

iii) $\frac{e}{3\times d_0} = \frac{30}{3\times 18} = 0.555$

iv) $\frac{p}{3\times d_0}$ - 0.25 = $\frac{40}{3\times 18}$ - 0.25 = 0.490

v) $\frac{F_{ub}}{F_{uP}} = \frac{400}{410}$ = 0.975

vi) 1.00

∴ $K_b = 0.490$

V_{bs} = { 1/ 1.25 (2.5 × 0.490 × 16 × 8.1 × 400)}

= 50.88 KN

∴ Bolt value = Least value from above = 50.88 KN

Maximum end reaction that can be transferred = 3 × 50.88 = 152.64 KN

Problem 2) : An I- Beam ISMB 400 @ 735.75 N/m Carrying A Factored Load Of 220 KN Is To Be Supported On column section ISHB 300 @ 618.03 N/m. Bolts of 20 mm $\emptyset\ of\ grade$ 4.6 are used to connect the angle legs to the beam web. Design the connection ?

Answer :

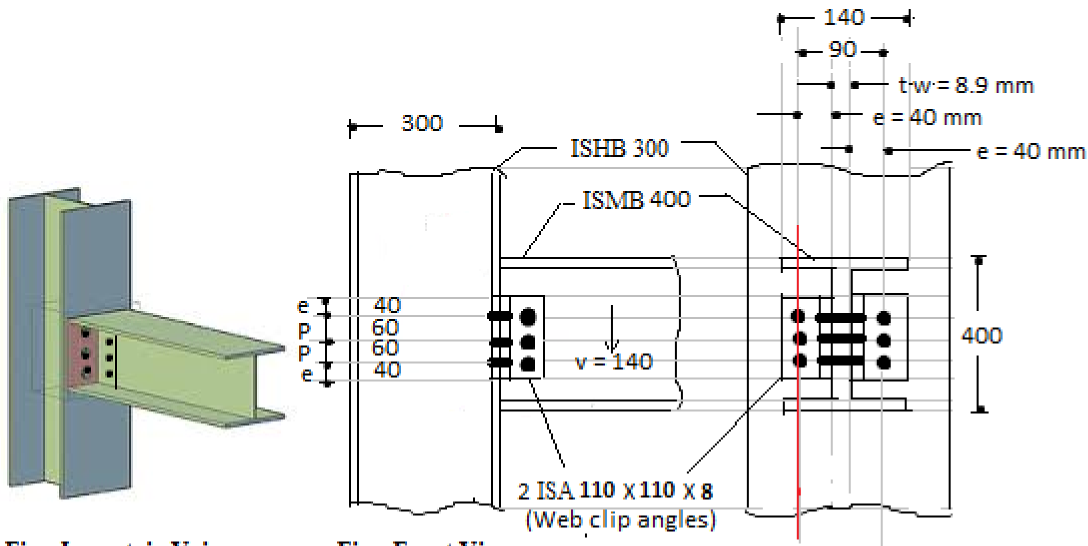


Fig : Isometric Veiw **Fig : Front View**

Fig : Side Veiw

Given :

a) Properties of Beam section ISMB 400………………………………...*See Steel Table*

$b_f = 140$ mm ; t_f = thick. of flange = 16 mm; t_w = 8.9 mm

b) Properties of Column section ISHB 300………………………………*See Steel Table*

$b_f = 250$ mm ; t_f = thick. of flange = 10.6 mm; t_w = 9.4 mm

diameter of Bolt (d) = 20 mm

∴ Bolt hole Diameter (d_0) = 20 +2 = 22 mm

∴ Edge Distance (e) = $1.5 \times d_0$ = 40 mm

∴ Pitch (p) = 2.5 × d = 50 mm say 60 mm

Take F_e 250 Grade of steel ; $f_y = 250\ {}^{N}/_{mm^2}$

For bolts 4.6 grade, as per IS 1367 , $F_u = F_{ub} = 400\ {}^{N}/_{mm^2}$

Step 1) Check for size of web clip angles ;

i) Factored load = **v = 220 KN**

ii) Shearing strength of Two legs of angles = $\frac{f_y A_v}{\sqrt{3}\,\gamma}$ ....cl. 8.4.1 & 8.4.1.1, pg 59

$$where, \quad A_v = h\,(2t)$$

h = depth of connecting angle = 2(60) + 2(40) = 200 mm

t = thickness of connecting angle = ?

equating , $\frac{250 \times 200\,(2t)}{\sqrt{3} \times 1.10} = 220 \times 10^3$

$$\therefore \quad t = 4.19 \; say \; 8 \; mm$$

Providing 2ISA 110 × 110 × 8 Web clip *(Stiffener)* angles. (Two equal angle back to back)

Step 2) Design of connection of web clip angles to the web of Beam;

i) Design Strength of bolt in Shear (V_{ds}) ...(*Double shear*)

V_{ds} = { 1/ ɣ [$\frac{F_u}{\sqrt{3}}$ ($n_n A_{nb}$)] }..cl 10.3.3, pg 75

Where $F_u = F_{ub}$ = 400 N/mm^2

n_n = No. of shear planes with threads intercepting shear planes. = 2

ɣ = Partial safety factor for Bolt Material = 1.25 .... IS 800-2007 ;Table 5 ; pg. 30

$$A_{nb} = 0.78 \; to \; 0.80 \times \frac{\pi}{4} \times d^2 = 251.327 \; mm^2$$

$\therefore$ V_{ds} = 92.866 KN

ii) Design Strength of Bolt in Bearing (V_{bs})

V_{bs} = 1/ ɣ (2.5 $K_b\, d\, t\, F_u$) ....IS 800-2007; cl. 10.3.4 ; pg. 75

Where, $F_u = F_{ub}$ = 400 N/mm^2

d = 20 mm ;

t = t_w = 8.9 mm

ɣ = Partial safety factor for Bolt Material = 1.25 .... IS 800-2007 ;Table 5 ; pg. 3

K_b= Least of the following

iii) $\frac{e}{3 \times d_0} = \frac{40}{3 \times 22} = 0.606$

iv) $\frac{p}{3 \times d_0}$ - 0.25 = $\frac{60}{3 \times 22}$ - 0.25 = 0.659

v) $\frac{F_{ub}}{F_{uP}} = \frac{400}{410}$ = 0.975

vi) 1.00

$\therefore K_b = 0.606$

V_{bs} = { 1/ 1.25 (2.5 $\times$ 0.606 $\times$ 20 $\times$ 8.9 $\times$ 400)}

= 86.294 KN

$\therefore$ Bolt value = Least value from above = 86.294 KN

$\therefore$ No. of Bolts Required = $\frac{140}{86.294}$ = 1.62 Say 03 no

Step 3) Design of connection of web clip angles to the Flange of Column ;

i) Design Strength of bolt in Shear (V_{ds}) …(*single shear*)

$$V_{ds} = \frac{92.866}{2} = 46.43 \text{ KN}$$

ii) Design Strength of Bolt in Bearing (V_{bs})

V_{bs} = 1/ ɣ (2.5 $K_b\, d\, t\, F_u$) ……………………………….IS 800-2007; cl. 10.3.4 ; pg. 75

Where, $F_u = F_{ub}$ = 400 $^N/_{mm^2}$

d = 20 mm ;

t = t_f = 10.6 mm

ɣ = Partial safety factor for Bolt Material = 1.25 …………………………… IS 800-2007 ;Table 5 ; pg. 3

K_b= Least of the following

iii) $\frac{e}{3\times d_0} = \frac{40}{3\times 22} = 0.606$

iv) $\frac{p}{3\times d_0}$ - 0.25 = $\frac{60}{3\times 22}$ - 0.25 = 0.659

v) $\frac{F_{ub}}{F_{uP}} = \frac{400}{410}$ = 0.975

vi) 1.00

$\therefore K_b = 0.606$

V_{bs} = { 1/ 1.25 (2.5 $\times$ 0.606 $\times$ 20 $\times$ 10.6 $\times$ 400)}

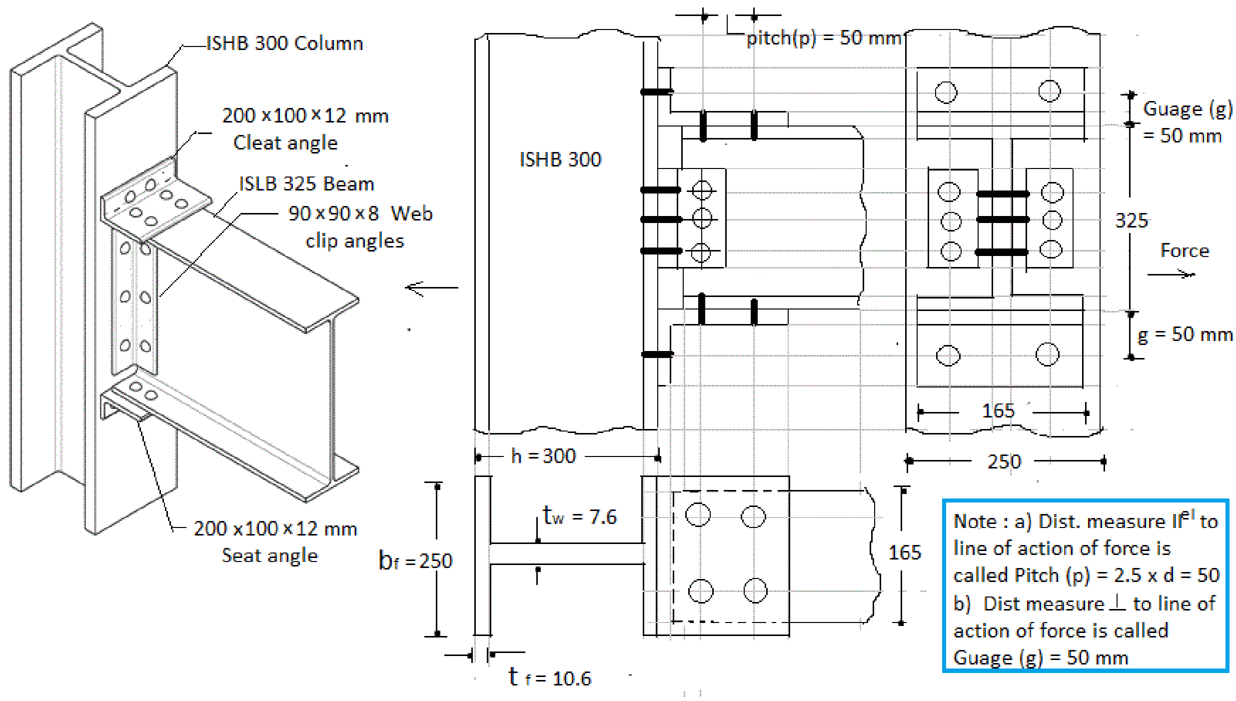
= 102.77 KN

$\therefore$ Bolt value = Least value from above = 46.43 KN

$\therefore$ No. of Bolts Required = $\frac{140}{46.43}$ = 03 no.

Problem 3) : A Factored load of 175 KN along with factored moment of 15 KNm are transmitted by an ISLB 325 @ 422.8 N/m beam to a ISHB 300 @ 576.8 N/m column in framed construction. Design connection ?

Answer :



Given :

a) Properties of Beam section ISLB 325………………………………….*See Steel Table*

Depth (h) = 325 mm , b_f = width of flange = 165 mm ;

t_f = thick. of flange = 9.8 mm; Thick. Of web t_w = 7 mm

b) Properties of Column section ISHB 300……………………………….*See Steel Table*

Depth (h) = 300 mm , b_f = width of flange = 250 mm ;

t_f = thick. of flange = 10.6 mm; Thick. Of web t_w = 7.6 mm

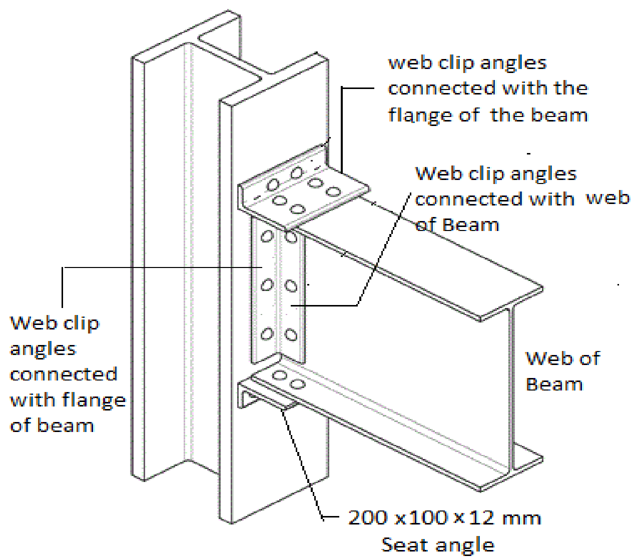
Let, diameter of Bolt (d) = 20 mm

∴ Bolt hole Diameter $(d_0) = 20 + 2 = 22$ mm

∴ Edge Distance (e) $= 1.5 \times d_0 = 33$ say 40 mm

∴ Pitch (p) $= 2.5 \times d = 50$ mm

Let us assume guage distance (g) = 50 mm



Step 1)

i) Design Strength in single Shear (V_{ds})

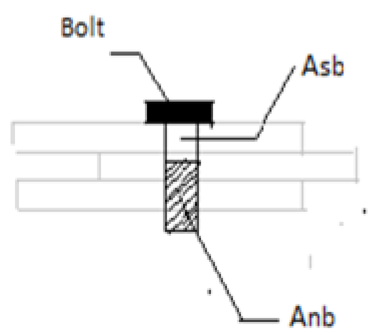
V_{ds} = { 1/ ɣ [$\frac{F_u}{\sqrt{3}}$ $(n_n A_{nb})$] }………………………………………………cl 10.3.3, pg 75

Where $F_u = F_{ub} = 400 \ {}^{N}/_{mm^2}$

n_n = No. of shear planes with threads intercepting shear planes. = 1

ɣ = Partial safety factor for Bolt Material = 1.25 ……………. IS 800-2007 ;Table 5 ; pg. 30

Anb = 0.78 to 0.80 (π d²/4)
= **251.327 mm²**



$\boldsymbol{V_{ds}}$ **= 464.33 KN**

ii) Design Strength in Double Shear (V_{ds}) = 2 × 464.33 = 928.66 KN

i) Design Strength of Bolts in web clip angles to web of beam (t = 7 mm)

= V_{bs} = 1/ ɣ (2.5 $K_b\, d\, t\, F_u$) ……………………………IS 800-2007; cl. 10.3.4 ; pg. 75

K_b= Least of the following

i) $\frac{e}{3\times d_0} = \frac{40}{3\times 22} = 0.606$

ii) $\frac{p}{3\times d_0}$ - 0.25 = $\frac{50}{3\times 22}$ - 0.25 = 0.5075

iii) $\frac{F_{ub}}{F_{uP}} = \frac{400}{410} = 0.975$

iv) 1.00

$$\therefore\ K_b = 0.606$$

$$\boldsymbol{V_{bs} = 1/1.25\ (2.5\ \times 0.606 \times\ 20\ \times 7 \times 400) = 67.872\ \ KN}$$

ii) Design Strength of Bolts in web clip angles to column Flange (t = 10.6 mm)

$$V_{bs} = 1/1.25\ (2.5\ \times 0.606 \times\ 20\ \times 10.6 \times 400) = 102.778\ \ KN$$

iii) Design tensile Strength of the bolt

T_{dn} = 1/ ɣ (0.9 A_n F_u)………………………………………… IS 800-2007; cl. 6.3.1 ; pg. 32

ɣ = Partial Safety Factor for failure by Rupture = 1.25

……………………………………………………………………… IS 800-2007 ; Table 5 ; pg. 30

A_n = Net effective area of the member = 251.327 mm^2

Where, $F_u = F_{ub}$ = 400 $^{N}/_{mm^2}$

$$\therefore\ \boldsymbol{T_d = 70.573\ \ KN}$$

Let us provide angle of 120 mm × 100 mm × 12 mm cleat and seat angles provided with guage distance of 50 mm

The bolt of one of the cleat angle and seat angle will be subjected to a tension T and force of P

The restoring couple P (50 + 325 + 50) will resist the moment so that

Moment (M) = P (50 + 325 + 50)

Lever arm = (Distance from center of top bolts to Bottom Bolts)

= 50 + 325 + 50 = 425 mm

$$\therefore\ Horizontal\ pull = \ P\ = {}^{Moment}/_{425}$$

$$P = \frac{15 \times 10^6}{425} = 35294.11\ \ \text{N}$$

$For\ design\ purpose\ , the\ \ Tension\ for\ the\ angle\ taken\ as$

$$\text{Tension in the Bolt} = T = P\left\{1 + 0.75\left[\frac{g - \frac{t}{2}}{e}\right]\right\}$$

$$\text{where}, \quad t = 12 \text{ mm}$$

$$\therefore \ T = 61517 \text{ N}$$

$$\text{No. of bolts require in cleat angle and seat angle};$$

$$= \frac{61517}{70573} = 0.87 \text{ say } 02 \text{ no.}$$

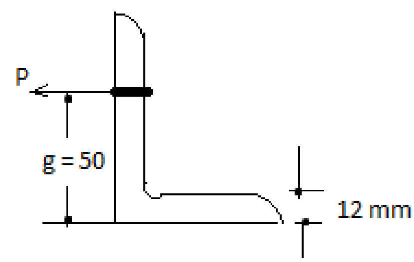
Provide 02 bolts for cleat and seat angles which are connected to column Flange.

For design purpose, the maximum Bending moment for the angle taken as

$$M = 0.5\,P\left\{\frac{g - \frac{t}{2}}{e}\right\};$$

where, $t = 12$ mm

$\therefore$ **M = 776470.42 Nmm**



iv) Design bending strength of the angle leg s/c

$$= \frac{1.2\ f_y\ Z}{\gamma} = \frac{1.2 \times 250 \times \frac{(b \times h^2)}{6}}{\gamma} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{cl. 8.2.1.2, pg 53}$$

$$Z = \text{plastic section modulus} = \frac{(b \times h^2)}{6}$$

$$\text{Equating}, \ \frac{0.2 \times 250 \times 165 \times t^2}{1.10} = 776470.42$$

ɣ = Partial safety factor for Bolt Material = 1.10 .... IS 800-2007 ;Table 5 ; pg. 30

$$\therefore \ \boldsymbol{Thickness\ of\ angle\ provided\ t = 11\ mm\ say\ 12\ mm}$$

v) Connection of the web clip angles with the flange of the beam ;

$$\text{Horizontal shear} = V_h = \frac{Moment}{\text{height of beam}} = \frac{15 \times 10^6}{325} = 46154$$

$$\text{Minimum No. of bolts require}; = \frac{46154}{46433} = 1$$

$$\text{Providing } 04 \text{ no. of bolts}$$

vi) Connection of the web clip angles with the Web of the beam ;

$$\text{Minimum No. of bolts require}$$

$$= \frac{Vertical\ shear}{strengt\ of\ Bolt} = \frac{175 \times 10^3}{67872} = 2.578 \text{ say } 03 \text{ no.}$$

Problem 4) : A Factored load of 180 KN along with factored moment of 75 KNm are transmitted by a ISMB 600 @ 1202.7 N/m Beam to an ISHB 400 @ 806.4 N/m column. Design split connection ?

Answer :

Given :

a) Properties of Beam section ISMB 600……………………………….*See Steel Table*

Depth (h) = 600 mm , b_f = width of flange = 210 mm ;

t_f = thick. of flange = 20.8 mm; Thick. Of web t_w = 12 mm

b) Properties of Column section ISHB 400……………………………….*See Steel Table*

Depth (h) = 400 mm , b_f = width of flange = 250 mm ;

t_f = thick. of flange = 12.7 mm; Thick. Of web t_w = 10.6 mm

Let, diameter of Bolt (d) = 22 mm

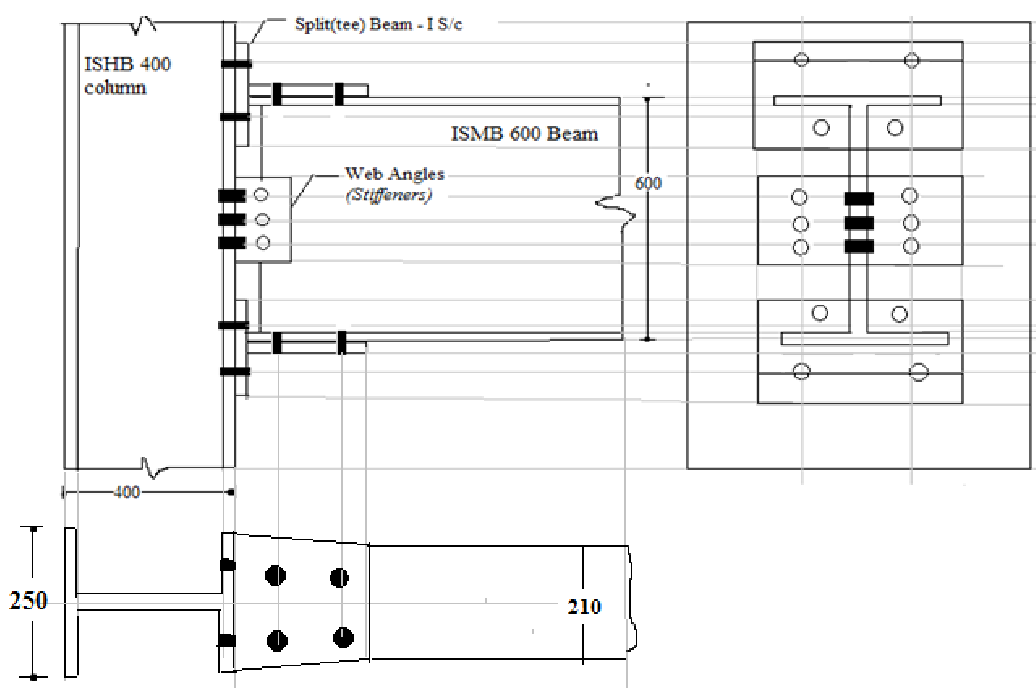
∴ Bolt hole Diameter (d_0) = 22 +2 = 24 mm

∴ Edge Distance (e) = 1.5 × d_0 = 35 mm

∴ Pitch (p) = 2.5 × d = 55 say 60 mm

Take F_e 250 Grade of steel ; $f_y = 250\ {}^{N}/{}_{mm^2}$

Moment (75 KNm) on connection will resisted by split beams and load(180 KN) will resisted by web angles and bolts.



Step 1) Design Strength of Bolts connecting split beams(tee) to flange of beam ;

i) Design Strength of bolt in single Shear (V_{ds})

V_{ds} = { 1/ ɣ [$\frac{F_u}{\sqrt{3}}$ $(n_n A_{nb})$] }……………………………………………cl 10.3.3, pg 75

Where $F_u = F_{ub} = 400 \ {}^{N}/_{mm^2}$

n_n = No. of shear planes with threads intercepting shear planes. = 1

ɣ = Partial safety factor for Bolt Material = 1.25 ……………. IS 800-2007 ;Table 5 ; pg. 30

$$A_{nb} = 0.78 \ to \ 0.80 \times \frac{\pi}{4} \times d^2$$

$$= 0.78 \ to \ 0.80 \times \frac{\pi}{4} \times 20^2$$

V_{ds} = 54781 N

ii) Design Strength of Bolt in Bearing (V_{bs})

V_{bs} = 1/ ɣ $(2.5 \ K_b \ d \ t \ F_u)$ …………………………………IS 800-2007; cl. 10.3.4 ; pg. 75

Where, $F_u = F_{ub} = 400 \ {}^{N}/_{mm^2}$

d = 22 mm ;

t = t_w = 12 mm

ɣ = Partial safety factor for Bolt Material = 1.25 …………………………… IS 800-2007 ;Table 5 ; pg. 3

K_b= Least of the following

i) $\frac{e}{3 \times d_0} = \frac{40}{3 \times 24} = 0.555$

ii) $\frac{p}{3 \times d_0} - 0.25 = \frac{80}{3 \times 24} - 0.25 = 0.583$

iii) $\frac{F_{ub}}{F_{uP}} = \frac{400}{410} = 0.975$

iv) 1.00

$\therefore \ K_b = 0.555$

V_{bs} = { 1/ 1.25 (2.5 × 0.555 × 22 × 12 × 400)}

= 54.781 KN

∴ Bolt value = Least value from above = 54.781 KN

$$\text{Pull in split beams (tee)} = \frac{Moment\ in\ the\ connection}{depth\ of\ Beam}$$

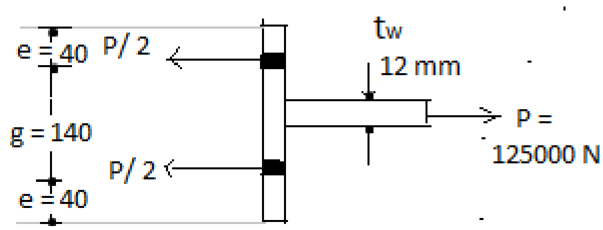
$$P = \frac{75 \times 10^6}{600} = 125 \quad KN$$

$$\therefore \quad \text{No. of Bolts Required} = \frac{125}{54.781} = 03 \text{ Say } 04 \text{ no.}$$

iii) Design of the tee (Split Beam) ;

$$Calculation\ of\ thickness\ of\ flange\ for\ split\ beam(t_{f)}\ Required\ ;$$

Let us assume the guage distance (g) = 140 mm and t_w = 12 mm



Max. Bending moment for flange of tee = $M_t = \frac{P}{4} \times (140 - 12)$

$$= \frac{125000}{4} \times (140 - 12)$$

$$M_t = 3.75 \times \ 10^6 \ \frac{N}{mm}$$

Design Bending strength = $\dfrac{1.2\ f_y\ Z}{\gamma} = \dfrac{1.2 \times 250 \times \frac{(b \times h^2)}{6}}{\gamma}$ ………………….cl. 8.2.1.2, pg 53

$$= \frac{0.2\ f_y\ l\ t^2}{\gamma} = \frac{0.2 \times 250 \times\ 250 \times t^2}{1.10}$$

Where , l = flange width of column = 250 mm

ɣ = Partial safety factor for Bolt Material = 1.10 ……………. IS 800-2007 ;Table 5 ; pg. 30

$$\therefore \frac{0.2 \times 250 \times 250 \times t^2}{1.10} = 3.75 \times 10^6$$

(thickness of flange for split beam)t_f = 18.16 mm

Referring steel table, let us consider ISWB 600 @ 1311.6 N/m I – section having

(t_{f}) = 21.3 mm and t_w = 11.2 mm

iv) Design of web Angles ;

The connecting bolts are in double shear

a) The design strength of bolts in double shear = 2 × 54.781 = 109.56 KN

b) Design Strength of Bolt in Bearing (V_{bs})

V_{bs} = 1/ ɣ (2.5 K_b d t F_u) ....IS 800-2007; cl. 10.3.4 ; pg. 75

Where, $F_u = F_{ub} = 400\ ^{N}/_{mm^2}$

d = 22 mm ;

t = t_w = 12 mm

ɣ = Partial safety factor for Bolt Material = 1.25 .... IS 800-2007 ;Table 5 ; pg. 3

K_b= Least of the following

v) $\frac{e}{3 \times d_0} = \frac{40}{3 \times 24} = 0.555$

vi) $\frac{p}{3 \times d_0}$ - 0.25 = $\frac{80}{3 \times 24}$ - 0.25 = 0.583

vii) $\frac{F_{ub}}{F_{uP}} = \frac{400}{410} = 0.975$

viii) 1.00

$$\therefore K_b = 0.555$$

V_{bs} = { 1/ 1.25 (2.5 × 0.555 × 22 × 12 × 400)}

= 54.781 KN

∴ Bolt value = Least value from above = 109.56 KN

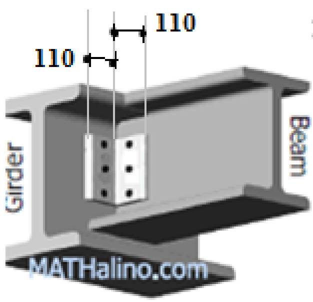
∴ No. of Bolts Required = $\frac{125}{109.56}$ = 02 say 03 no.

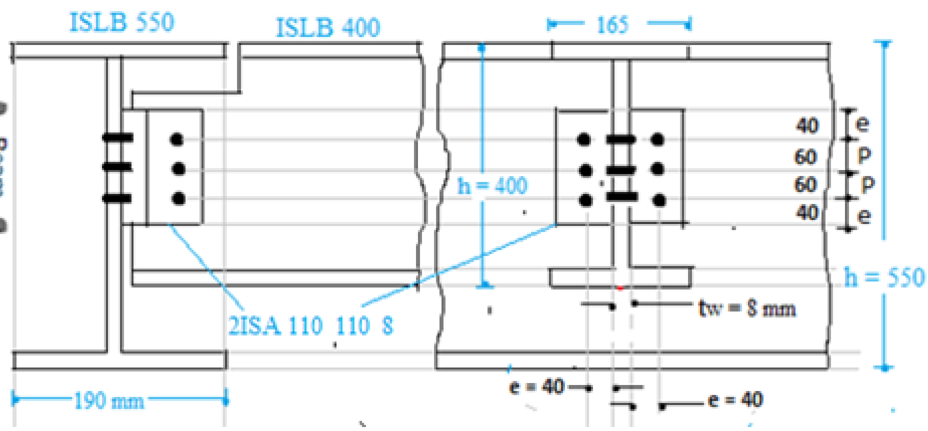
The outspread legs of these angles are connected to the flange of column with 03 no. of bolts on each leg.

Type II - Beam to Beam connections

Problem 1) : A secondary beam ISLB 400@558.2 N/m is to be connected to the web of main beam ISLB 550@846.6 N/m. The factored end reaction is 220 KN. Design the connection. Use 20 mm diameter bolt of grade 4.6.?

Answer :





Given :

a) Properties of Beam section ISLB 400…………………………………*See Steel Table*

b_f = 165 mm ; t_f = thick. of flange = 12.5 mm; t_w = 8 mm

b) Properties of Column section ISLB 550………………………………*See Steel Table*

b_f = 190 mm ; t_f = thick. of flange = 15 mm; t_w = 9.9 mm

diameter of Bolt (d) = 20 mm

∴ Bolt hole Diameter (d_0) = 20 +2 = 22 mm

∴ Edge Distance (e) = 1.5 × d_0 = 40 mm

∴ Pitch (p) = 2.5 × d = 50 mm say 60 mm

Take F_e 250 Grade of steel ; $f_y = 250 \ ^{N}/_{mm^2}$

For bolts 4.6 grade, as per IS 1367 , $F_u = F_{ub} = 400 \ ^{N}/_{mm^2}$

Step 1) Check for size of web clip angles ;

i) Factored load = **v = 220 KN**

ii) Shearing strength of Two legs of angles $= \dfrac{f_y A_v}{\sqrt{3}\,\gamma}$ ……..cl. 8.4.1 & 8.4.1.1, pg 59

$$where, \quad A_v = h\,(2t)$$

h = depth of connecting angle = 2(60) + 2(40) = 200 mm

t = thickness of connecting angle = ?

equating , $\frac{250 \times 200\ (2t)}{\sqrt{3} \times 1.10} = 220 \times 10^3$

$\therefore\ t = 4.19\ say\ 8\ mm$

Providing 2ISA 110 × 110 × 8 Web clip *(Stiffener)* angles. (Two equal angle back to back)

Step 2) connection between the angles and the web of secondary beam ;

i) Design Strength of bolt in Shear (V_{ds})……(*Double shear)*

V_{ds} = { 1/ɣ [$\frac{F_u}{\sqrt{3}}$ ($n_n\, A_{nb}$)] }...cl 10.3.3, pg 75

Where $F_u = F_{ub}$ = 400 $N/_{mm^2}$

n_n = No. of shear planes with threads intercepting shear planes. = 2

ɣ = Partial safety factor for Bolt Material = 1.25 ……………. IS 800-2007 ;Table 5 ; pg. 30

$A_{nb} = 0.78\ to\ 0.80 \times \frac{\pi}{4} \times d^2$

$= 0.78\ to\ 0.80 \times \frac{\pi}{4} \times 20^2 = 251.32\ mm^2$

V_{ds} = 90548 N

ii) Design Strength of Bolt in Bearing (V_{bs})

V_{bs} = 1/ɣ (2.5 $K_b\, d\, t\, F_u$) ....IS 800-2007; cl. 10.3.4 ; pg. 75

Where, $F_u = F_{ub}$ = 400 $N/_{mm^2}$

d = 20 mm ;

(ISLB 400) t = t_w = 8 mm

ɣ = Partial safety factor for Bolt Material = 1.25 ……………………………. IS 800-2007 ;Table 5 ; pg. 3

K_b= Least of the following

ix) $\frac{e}{3 \times d_0} = \frac{40}{3 \times 22} = 0.606$

x) $\frac{p}{3 \times d_0} - 0.25 = \frac{80}{3 \times 22} - 0.25 = 0.659$

xi) $\frac{F_{ub}}{F_{uP}} = \frac{400}{410} = 0.975$

xii) 1.00

$$\therefore\ K_b = 0.606$$

V_{bs} = { 1/ 1.25 (2.5 × 0.606 × 22 × 8 × 400)}

= 77567 KN

∴ Bolt value = Least value from above = 77.567 KN

∴ No. of Bolts Required = $\frac{220}{77.567}$ 2.83 Say 03 no.

Step 3) Connection between the angles and the web of main beam ;

i) Design Strength of bolt in Shear (V_{ds})……*(single shear)*

$$V_{ds} = \frac{90548}{2} = 45274 \text{ N}$$

iii) Design Strength of Bolt in Bearing (V_{bs})

V_{bs} = 1/ ɣ (2.5 $K_b\, d\, t\, F_u$) ………………………………IS 800-2007; cl. 10.3.4 ; pg. 75

Where, $F_u = F_{ub}$ = 400 $N/_{mm^2}$

d = 20 mm ;

(ISLB 550) t = t_w = 9.9 mm

ɣ = Partial safety factor for Bolt Material = 1.25 …………………………… IS 800-2007 ;Table 5 ; pg. 3

K_b= Least of the following

ii) $\frac{e}{3\times d_0} = \frac{40}{3\times 22} = 0.606$

iii) $\frac{p}{3\times d_0} - 0.25 = \frac{80}{3\times 22} - 0.25 = 0.659$

iv) $\frac{F_{ub}}{F_{uP}} = \frac{400}{410} = 0.975$

v) 1.00

$$\therefore\ K_b = 0.606$$

V_{bs} = { 1/ 1.25 (2.5 × 0.606 × 22 × 9.9 × 400)}

= 105589.44 KN

∴ Bolt value = Least value from above = 45274 N

∴ No. of Bolts Required = $\frac{220}{45274}$ = 4.85 Say 06 no. ; Provide 06 Bolts with 03 no. bolts in each angle.