UNIT II CONNECTIONS IN STEEL STRUCTURES

Axially loaded bolted connections for Plates and Angle Members using bearing type bolts

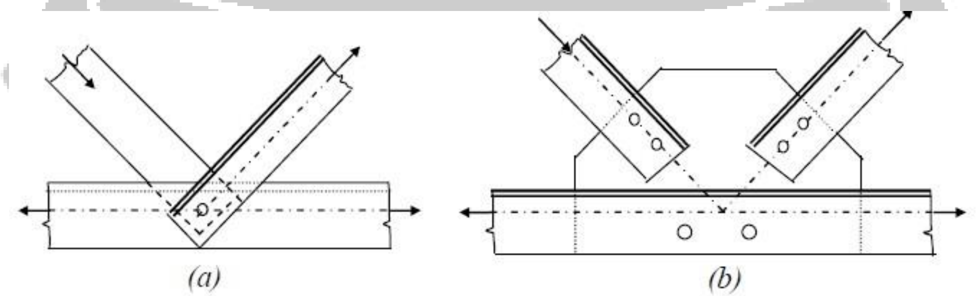
1.0 INTRODUCTION

Connections form an important part of any structure and are designed more conservatively than members. This is because, connections are more complex than members to analyse, and the discrepancy between analysis and actual behaviour is large. Further, in case of overloading, we prefer the failure confined to an individual member rather than in connections, which could affect many members.

Connections can also be classified in the following ways:

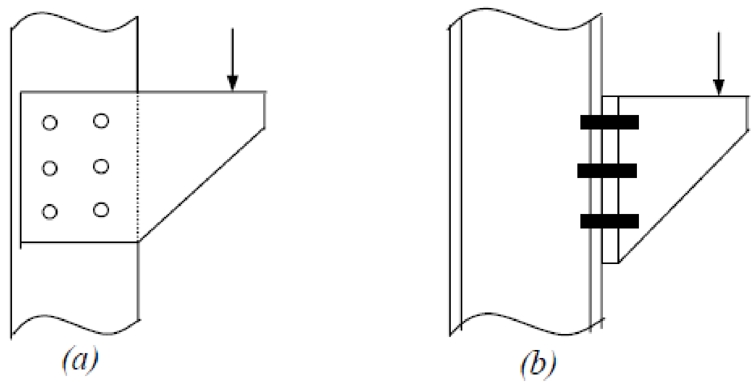
(a) Classification based on the type of resultant force transferred:

The bolted connections are referred to as concentric connections (force transfer in tension and compression member), eccentric connections (in reaction transferring brackets) or moment resisting connections (in beam to column connections in frames). Ideal concentric connections should have only one bolt passing through all the members meeting at a joint [Fig.*a*]. However, in practice, this is not usually possible and so it is only ensured that the centroidal axes of the members meet at one point [Fig. *b*].



Concentric Connections

The Moment connections are more complex to analyse compared to the above two types and are shown in Fig. *a* and Fig. *b*. The connection in Fig. *a* is also known as bracket connection and the resistance is only through shear in the bolts. The connection shown in Fig. *b* is often found in moment resisting frames where the beam moment is transferred to the column. The connection is also used at the base of the column where a base plate is connected to the foundation by means of anchor bolts. In this connection, the bolts are subjected to a combination of shear and axial tension.

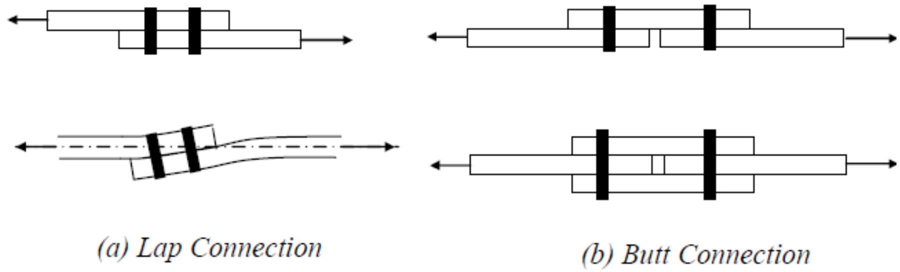


Moment Connections

(b) Classification based on the type of force experienced by the bolts:

The bolted connections can also be classified based on geometry and loading conditions into three types namely, shear connections, tension connections and combined shear and tension connections.

Typical shear connections occur as a *lap* or a *butt* joint used in the tension members. While the lap joint has a tendency to bend so that the forces tend to become collinear, the butt joint requires *cover plates*. Since the load acts in the plane of the plates, the load transmission at the joint will ultimately be through shearing forces in the bolts. In the case of lap joint or a single cover plate butt joint, there is only one shearing plane, and so the bolts are said to be in *single shear*. In the case of double cover butt joint, there are two shearing planes and so the bolts will be in *double shear*. It should be noted that the single cover type butt joint is nothing but lap joints in series and also bends so that the centre of the cover plate becomes collinear with the forces.

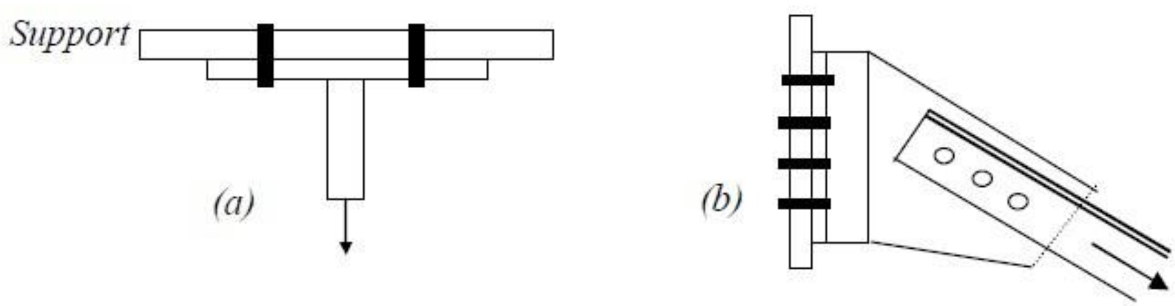


Shear Connections

A hanger connection is shown in Fig. *a*. In this connection, load transmission is by pure tension in the bolts. In the connection shown in Fig. *b* the bolts are subjected to both tension and shear.

(c) Classification based on force transfer mechanism by bolts: The bolted connections are

classified as bearing type (bolts bear against the holes to transfer the force) or friction type (force transfer between the plates due to the clamping force generated by the pre– tensioning of the bolts).



(a) Tension Connection (b) Tension plus Shear Connection

The design strength in tension of a plate, *Tdn,*as governed by rupture of net cross-sectional area, *An,* at the holes is given by

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

where γ_{ml} = partial safety factor at ultimate stress = 1.25

f_u = ultimate stress of the material of plate

A_n = net effective area at critical section

$$= \left[b - nd_o + \Sigma \frac{p_{si}^2}{4g_i} \right] t$$

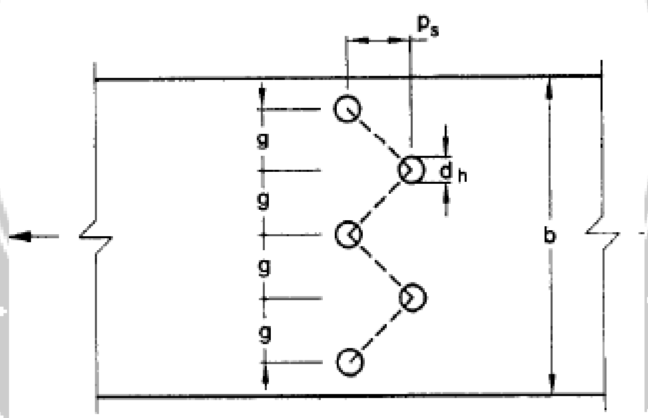
where b = width of plate

t = thickness of thinner plate

d_o = diameter of the bolt hole

n = number of bolt holes

Note: If there is no staggering of the bolts, $p_{si} = 0$ and hence, $A_n = [b - nd_o]\ t$



where

b, t = width and thickness of the plate, respectively,

d_h = diameter of the bolt hole (2 mm in addition to the diameter of the hole, in case the directly punched holes),

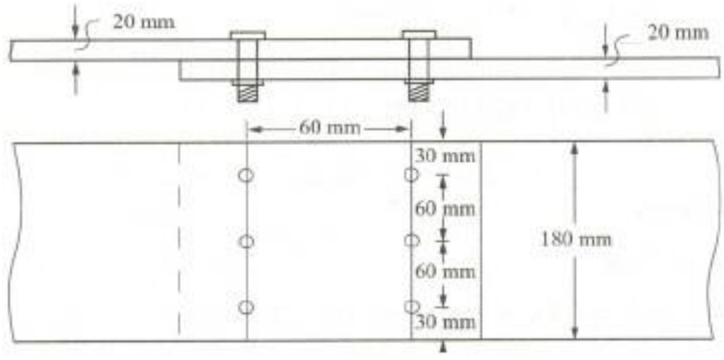
g = gauge length between the bolt holes, as shown in Fig. 5,

p_s = staggered pitch length between line of bolt holes, as shown in Fig. 5,

n = number of bolt holes in the critical section, and

i = subscript for summation of all the inclined legs.

Find the efficiency of the lap joint shown in fig. given M20 bolt of grade 4.6 and plate of grade Fe410 [E250] are used.



Given Data:-

t = 20mm

Bolt:- M20

Grade 4.6 => fu = 400N/mm^2

fy = 250N/mm^2

Plate:-

Fe 410 [E250]

Fu = 410 N/mm^2

Fy = 250 N/mm^2 [Table 1 – I.S 800 – 2007]

Efficiency of the joint $= \frac{\text{strength of joint}}{\text{strength of solid plate}} \times 100$

Strength of connection is least of strength of plate at critical section and strength of bolt in shear & bearing.

Strength of plate @ the joint:-

Tensile force $T_{dn} = \frac{0.9 A_n f_u}{\gamma_{ml}}$

$A_n = (b - n d_o) t$

ps = 0 [∵ Bolts are on a straight line]

= (180 – 3x22) 20 [∵ d_o = 20+2=22]

An = 2280mm^2

γ_{ml} = 1.25 [from table 5- I.S 800-2007]

[d_o = Dia of bolt hole = 20+2=22mm]

$T_{dn} = \frac{0.9 \times 2280 \times 410}{1.25}$

T_{dn} = 673.056 KN

(i) Strength of bolt in shear $V_{dsb} = \frac{V_{nsb}}{\gamma_{mb}}$

$$V_{nsb} = \frac{fu}{\sqrt{3}}[N_n A_{nb} + N_s A_{sb}]$$

N_n = No.of shear planes @ the thread = 1

N_s = No.of shear planes @ shank $N_s = 0$ for lap jt $N_s = 1$

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

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

$A_{nb} = 245mm^2$

$$V_{nsb} = \frac{400}{\sqrt{3}}[1 \times 245 \times 6]$$

$V_{nsb} = 339.481\ KN$ $\quad \because V_{dsb} = \frac{339.48}{1.25}$

V_{dsb} = 271.58 KN

(ii) <u>Strength of bolt in bearing:</u> [cls 10.3.4 IS]

Take

$$\beta_{ij} = \beta_{ig} = \beta_{pk} = 1$$

$$V_{dbp} = \frac{V_{nbp}}{\gamma_{mb}}$$

V_{dbp} = 2.5 kb dt fu

Kb = least of $e/3d_o$, $p/3d_o - 0.25$, $\frac{fub}{Fu}$, 1.0

$$k_b \Rightarrow \frac{30}{3 \times 22}, \frac{60}{3 \times 22} - 0.25$$

$$k_b \Rightarrow 0.45, 0.659, 0.976, 1$$

Take K_b value of whichever less [$\therefore K_b = 0.45$]

$$V_{nbp} = 2.5 \times 0.45 \times 20 \times 20 \times 410$$

V_{nbp} = 186.3 KN

$$V_{dbp} = \frac{186.3}{1.25}$$

V_{dbp} = 149.04 KN

∴ Design strength of bolt = 6 x 149.04

V_{dbp} bolt = 894.24 KN

Design strength of the joint = 271.58 KN

Design strength of jt is the least of strength of joint 673.06 KN, 271.58 KN & 894.24 KN

Strength of Solid Plate:-

Strength of Solid Plate = $\frac{fy \times Ag}{\gamma_{ml}}$

[yielding sides the strength of solid plate]

$$= \frac{250}{1.1} \times 180 \times 20$$

Strength of solid plate = 818.18 KN

$\therefore$ Efficiency of joint $\eta = \frac{271.58}{818.18} \times 100$

$$\eta = 33.19$$

2. Find the efficiency of the joint for the above problem if instead of lap joint, a double cover butt joint is provided. Two cover plates each of size 12mm and 6 nos. of bolts are provided on each side.

Given Data:-

[Table 1, I.S 800-2007] [Pg.No.13]

Plate:-

Fe410 [250]

Fu = 410 N/mm^2

Fy = 250 N/mm^2

Bolt:-

M20, Grade 4.6

φ of bolt = 20 mm

fu_b = 400 N/mm^2

fy_b = 240 N/mm^2

The strength of plate at the joints and the strength of bolts in bearing are same as that of the previous problem.

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(1) Strength of plate @ the joint:-

$$T_{dn}=\frac{0.9\,Anfu}{\gamma_{ml}}$$

$$A_n=[b-nd_o]t$$

$$= [180 - 3 \times 22]\ 20$$

$$A_n = 2280mm^2$$

$$\gamma_{ml}=1.25$$ [from tables-5 IS 800-2007 Pg.No:30]

$$d_o = 20+2 = 22$$

$$= \frac{2280\times0.9\times410}{1.25}$$

$$T_{dn}=673.056\,KN$$

(2) Strength of bolts:-

(i) Strength of bolt in bearing : (cls 10.3.4 IS 800-2007)

$$V_{dbp}=\frac{V_{nbp}}{\gamma_{mb}}$$

$$V_{nbp}=2.5\,kb.\,dt.\,fu$$

$$K_b=\frac{o}{3d_o},\frac{p}{3d_o}-0.25,\frac{fub}{fu},1.0$$

$$= \frac{30}{3\times22},\frac{60}{3\times22}-0.25,\frac{400}{410},1.0$$

$$K_b=0.45,0.659,0.976,1$$

Take kb value of whichever is less

$$\because K_b=0.45$$

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

$$V_{nbp}=186.3\,KN$$

$$V_{dbp}=\frac{186.3}{1.25}$$

$$V_{dbp}=149.04\,KN$$

$\therefore$ Strength of bolt in bearing = 6 x 149.04

$$V_{dbp}=894.24\,KN$$

(ii) Strength of bolt in shear:- [cls:10.3.3 IS 800-2007]

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

$$V_{nsb}=\frac{fu}{\sqrt{3}}[N_n A_{nb}+N_{sA_{sb}}]$$

$\because$ Double cover butt jt provided each bolts resists shear along two planes, the section at the root & another section at the shank.

$\because n_n = n_s = 1$ for each bolts

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

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

$$A_{nb} = 245mm^2$$

$$A_{sb} = \frac{\pi d^2}{4}$$

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

$$A_{sb} = 314.16mm^2$$

$$\therefore V_{nsb} = \frac{400}{\sqrt{3}}[6 \times 245 + 6 \times 314.16]$$

$$V_{nsb} = 774.8KN$$

$$\boxed{V_{dsp} = 619.84KN}$$

Reduction factors $\beta_{lj} = \beta_{lg} = \beta_{pk} = 1$

$\therefore$ Design Strength of the joint = 619.84 KN [least of 673 KN, 894.4 KN, 619.84 KN]

<u>Strength of the solid plate:-</u>

Strength of the solid plate = $\frac{f_y A_g}{\gamma_{ml}}$

$= \frac{250}{1.1} \times 180 \times 20$ [Tks of thinner plate is the least of sum of cover plate 20(or) 24mm]

Strength of the solid plate = 818.18KN

$$\eta = \frac{619.84}{818.18} \times 100$$

$$\eta = 75.76\%$$