

1.0 INTRODUCTION

Connections become complex when they have to transmit axial and shear forces in addition to bending moments, between structural members oriented in different directions. A variety of components such as angle cleats, stiffeners and end plates are used to transfer and also disperse the loads from one member to another. In particular, bolted connections pose additional problems because they employ discrete rather than continuous load paths to effect the transfer. This is in addition to the complex behaviour of the bolts themselves. Attempts to develop complex design procedures which can produce more economical and yet safe connections are rendered futile by the variety of connection configurations possible and more importantly, the variability of behaviour due to practical limitations in fabrication and erection. Therefore the most rational philosophy for design would be to base it on simple analysis and use higher load factors for increased safety. However, it is easier said than done and is fraught with pitfalls unless one develops a certain insight into the behaviour.

In structural design, it is a common tendency to follow a tradition, which has produced satisfactory designs in the past so that one need not worry about having overlooked some important aspect of behaviour. This tendency has crystallised into some standard connection types for which simplified analysis procedures can be used with great advantage. The flange and web angle connection shown in Fig. 1(a) is an example of a typical beam-to-column moment connection. It is important for the novice to become familiar with such connection types and their advantages/disadvantages, which are described in the subsequent sections of this chapter.

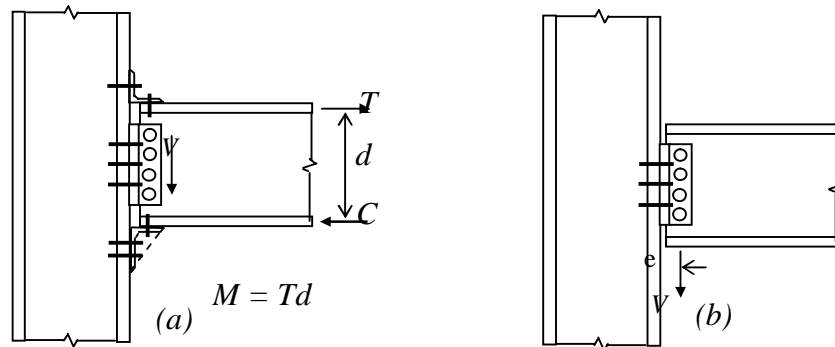


Fig. 1 Standard Connections (a) moment connection (b) simple connection

It is also equally important to remember the assumptions made in traditional analysis so that the elements of the connection are proportioned appropriately. For example, with reference to the connection shown in Fig. 1(a), the angles are assumed to be rigid compared to the bolts. However the top angle will have a tendency to open out while the bottom will have a tendency to close unless sufficiently thick angles are used. Similarly,

the connector behaviour is assumed to be linearly elastic, whereas in reality, if bearing bolts are used, due to the hole size being larger than the bolt shank some slip is likely to take place. This slip may be adequate to release the end moment and make the beam behave as a simply supported one. Therefore it may be advantageous to go for HSFG bolts, which will behave linearly at least at working loads thereby ensuring serviceability of the connection.

Another simplification commonly used is that the distribution of forces is arrived at, by assuming idealised load paths. In the simple connection effected through a pair of short web cleats [Fig. 1(b)], it is assumed that the bolts connecting the beam web and the angles resist only the shear that is transferred. However, if the length of the web cleats is comparable to the depth of the beam, additional shear forces are likely to arise in these bolts due to the eccentricity between the bolt line and the column face and should be considered in design. Further, if the web cleats are unduly stiff, they will satisfy equilibrium but the required rotation for the beam end to act as simply supported may not be possible. Therefore it is important to build ductility into the system by keeping the angles as thin as possible. The aim of the present chapter is to point out these aspects, which will lead to good connection designs.

2.0 ANALYSIS OF BOLT GROUPS

In general, any group of bolts resisting a moment can be classified into either of two cases depending on whether the moment is acting in the shear plane or in a plane perpendicular to it. Both cases are described in this section.

2.1 Combined Shear and Moment in Plane

Consider an eccentric connection carrying a load of P as shown in Fig. 2. The basic assumptions in the analysis are (1) deformations of plate elements are negligible, (2) the total shear is assumed to be shared equally by all bolts and (3) the equivalent moment at the geometric centre (point O in Fig. 2) of the bolt group, causes shear in any bolt proportional to the distance of the bolt from the point O acting perpendicular to the line joining the bolt centre to point O (radius vector).

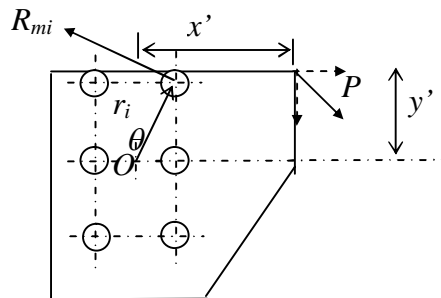


Fig. 2 Bolt group eccentrically loaded in shear

Resolving the applied force P into its components P_x and P_y in x and y -directions respectively and denoting the corresponding force on any bolt i to these shear components by R_{xi} and R_{yi} and applying the equilibrium conditions we get the following:

$$R_{xi} = P_x/n \text{ and } R_{yi} = P_y/n \quad (1)$$

where n is the total number of bolts in the bolt group and R_{xi} and R_{yi} act in directions opposite to P_x and P_y respectively.

The moment of force P about the centre of the bolt group (point O) is given by

$$M = P_x y' + P_y x' \quad (2)$$

where x' and y' denote the coordinates of the point of application of the force P with respect to the point O . The force in bolt i , denoted by R_{mi} , due to the moment M is proportional to its distance from point O , r_i , and perpendicular to it.

$$R_{mi} = k r_i \quad (3)$$

where, k is the constant of proportionality. The moment of R_{mi} about point O is

$$M_i = k r_i^2 \quad (4)$$

Therefore the total moment of resistance of the bolt group is given by

$$MR = \sum k r_i^2 = k \sum r_i^2 \quad (5)$$

For moment equilibrium, the moment of resistance should equal the applied moment and so k can be obtained as $k = M/\sum r_i^2$, which gives R_{mi} as

$$R_{mi} = M r_i / \sum r_i^2 \quad (6)$$

Total shear force in the bolt R_i is the vector sum of R_{xi} , R_{yi} and R_{mi}

$$R_i = \sqrt{\left[(R_{xi} + R_{mi} \cos \theta_i)^2 + (R_{yi} + R_{mi} \sin \theta_i)^2 \right]} \quad (7)$$

After substituting for R_{xi} , R_{yi} and R_{mi} from equations (1) and (6) in (7), using $\cos \theta_i = x_i/r_i$ and $\sin \theta_i = y_i/r_i$ and simplifying we get

$$R_i = \sqrt{\left\{ \left[\frac{P_x}{n} + \frac{M y_i}{\sum (x_i^2 + y_i^2)} \right]^2 + \left[\frac{P_y}{n} + \frac{M x_i}{\sum (x_i^2 + y_i^2)} \right]^2 \right\}} \quad (8)$$

The x_i and y_i co-ordinates should reflect the positive and negative values of the bolt location as appropriate.