CHAPTER

Joints and Connections

22

Most metal structures consist of members connected at joints, which, generally, are either bolted, riveted, or welded. The design of such joints is complex in that discontinuities occur, for example, in the region of bolt holes so that stresses are difficult to determine. However, simplifying assumptions may be made and these, allied to experience, are capable of producing safe designs.

In this chapter, we shall examine methods of analysis of bolted, riveted, and welded joints, although bolted and riveted joints may be analysed by the same procedure.

22.1 Bolted and riveted joints

Different forms of steel structures require joints of different geometries and arrangements of bolts or rivets. In the following, we examine the most common types of connection and their modes of failure.

Simple lap joint

Figure 22.1 shows two plates of thickness t connected by a single line of rivets; this type of joint is called a *lap joint* and is one of the simplest used in construction.

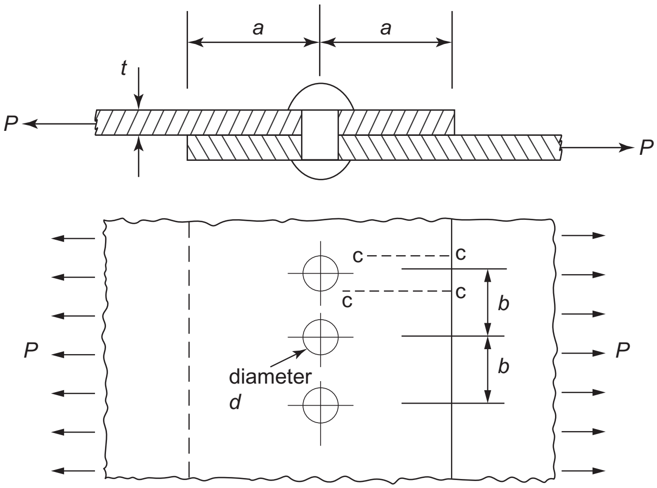

FIGURE 22.1

Simple riveted lap joint.

Structural and Stress Analysis. https://doi.org/10.1016/B978-0-08-102586-4.00022-6

Suppose that the plates carry edge loads of P/unit width, that the rivets are of diameter d, are spaced a distance b apart, and that the distance from the line of rivets to the edge of each plate is a. Four possible modes of failure must be considered as follows.

Rivet shear

The rivets may fail by shear across their diameter at the interface of the plates. Then, if the maximum shear stress the rivets will withstand is τ_1 failure will occur when

$$Pb = \frac{\tau_1(\pi d^2)}{4}$$

which gives

$$P = \frac{\pi d^2 \tau_1}{4b} \tag{22.1}$$

Bearing pressure

Either rivet or plate may fail due to bearing pressure. Suppose p_b is this pressure, then failure will occur when

$$\frac{Pb}{td} = p_b$$

so that

$$P = \frac{p_b td}{b} \tag{22.2}$$

Plate failure in tension

The area of plate in tension along the line of rivets is reduced due to the presence of rivet holes. Therefore, if the ultimate tensile stress in the plate is σ_{ult} failure occurs when

$$\frac{Pb}{t(b-d)} = \sigma_{ult}$$

from which

$$P = \frac{\sigma_{ult} t(b-d)}{b} \tag{22.3}$$

Shear failure in a plate

Shearing of the plates may occur on the planes cc resulting in the rivets being dragged out of the plate. If the maximum shear stress at failure of the material of the plates is τ_2, failure of this type will occur when

$$Pb = 2at\tau_2$$

which gives

$$P = \frac{2at\tau_2}{b} \tag{22.4}$$

EXAMPLE 22.1

Two steel plates are connected by two steel straps each 10 mm thick as shown in Fig. 22.2; the rivets have a diameter of 15 mm. If the tensile stress in the steel plates must not exceed 200 N/mm^2 and the shear strength of the rivets is 300 N/mm^2, determine the maximum allowable rivet spacing such that the joint is equally strong in shear and in tension.

A tensile failure in the plate occurs on the reduced plate cross section along the rivet lines. This area is given by

$A_p = (b - 15) \times 20^2$ (see Fig. 22.1)

The failure load/unit width, P_f, is then, from Eq. (22.3)

$$P_f = \frac{(b-15) \times 20 \times 200}{b} \tag{i}$$

The area of cross section of each rivet is

$$A_r = \frac{\pi \times 15^2}{4} = 176.7 \text{ mm}^2$$

Since each rivet is in double shear, the area of cross section in shear is $2 \times 176.7 = 353.4$ mm^2. Then, the failure load/unit width in shear is

$$P_f = \frac{353.4 \times 300}{b} \tag{ii}$$

For failure to occur simultaneously in shear and in tension, i.e. equating Eqs (i) and (ii),

$$353.4 \times 300 = (b - 15) \times 20 \times 230$$

which gives $b = 38.05$ mm.

Say, a rivet spacing of 40 mm.

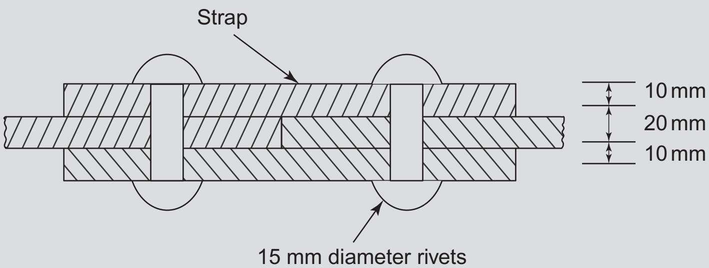

FIGURE 22.2

Joint of Ex. 22.1.

Joint efficiency

The efficiency of a joint or connection is measured by comparing the actual failure load with that which would apply if there were no rivet holes in the plate. Then, for the joint shown in Fig. 22.1, the joint efficiency is given by

$$\eta = \frac{\sigma_{ult} t (b-d)/b}{\sigma_{ult} t} = \frac{b-d}{b} \tag{22.5}$$

Group riveted joints

Rivets may be grouped on each side of a joint such that the joint efficiency is a maximum. Suppose that two plates are connected as shown in Fig. 22.3 and that six rivets are required on each side. If it is assumed that each rivet is equally loaded, then the single rivet on the line aa takes one-sixth of the load. The two rivets on the line bb then share two-sixths of the load, while the three rivets on the line cc take three-sixths of the load. On the line bb, the area of cross section of the plate is reduced by two rivet holes and that on the line cc by three rivet holes so that, relatively, the joint is as strong at these sections as at aa. Therefore, a more efficient joint is obtained than if the rivets were arranged in, say, two parallel rows of three.

Eccentrically loaded riveted joints

The bracketed connection shown in Fig. 22.4 carries a load P offset from the centroid of the rivet group. The rivet group is therefore subjected to a shear load P through its centroid together with a moment or torque Pe about its centroid.

It is assumed that the shear load P is distributed equally among the rivets causing a shear force in each rivet parallel to the line of action of P. The moment Pe is assumed to produce a shear force S in each rivet, which acts in a direction perpendicular to the line joining a particular rivet to the centroid of the rivet group.

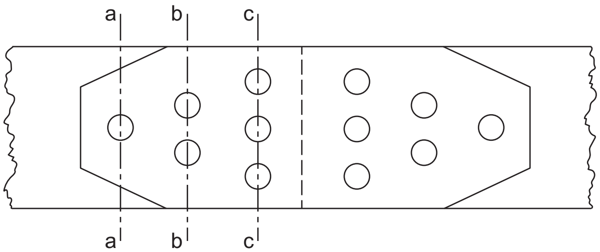

FIGURE 22.3

A group-riveted joint.

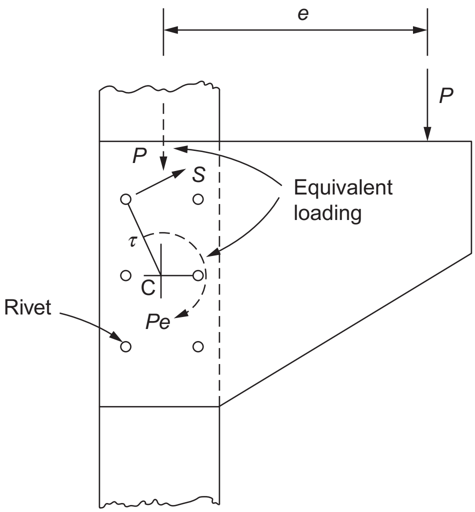

FIGURE 22.4

Eccentrically loaded joint.

Furthermore, the value of S is assumed to be proportional to the distance of the rivet from the centroid of the rivet group. Then

$$Pe = \sum Sr$$

If $S = kr$ where k is a constant, then

$$Pe = k \sum r^2$$

from which $k = Pe / \sum r^2$ and

$$S = \frac{Pe}{\sum r^2} r \tag{22.6}$$

The resultant force on a rivet is then the vector sum of the forces due to P and Pe.

EXAMPLE 22.2

The bracket shown in Fig. 22.5 carries an offset load of 5 kN. Determine the resultant shear force in the rivets at A and B.

The vertical shear force on each rivet is $5/6 = 0.83$ kN. The moment Pe on the rivet group is $5 \times 75 = 375$ kNmm. The distance of rivet A (and B, G, and H) from the centroid C of the rivet group is given by

$$r = \sqrt{(20^2 + 25^2)} = 32.02 \text{ mm}$$

The distance of D and F from C is 20 mm so that

$$\sum (r^2) = 4 \times 32.02^2 + 2 \times 20^2 = 4900$$

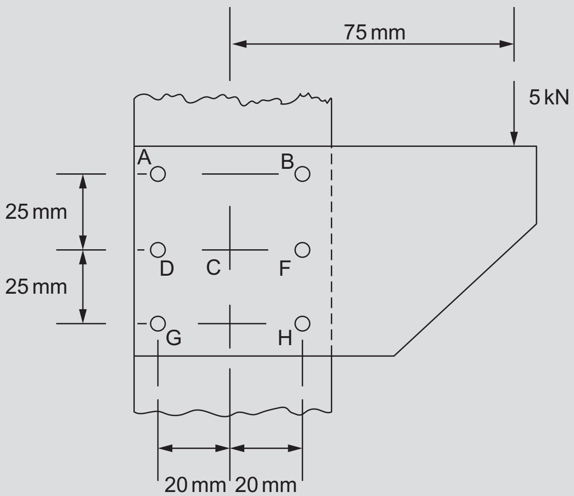

FIGURE 22.5

Joint of Ex. 22.2.

From Eq. (22.6), the shear force on rivets A and B due to the moment is

$$S = \frac{375}{4900} \times 32.02 = 2.45 \text{ kN}$$

The force system on rivet A due to P and Pe is shown in Fig. 22.6(a) while that on rivet B is shown in Fig. 22.6(b). The resultant force on each rivet may then be found either by calculation or graphically as described in Chapter 2.

Here, the moment is applied in the plane of the connection. A different situation arises when the moment is applied in a plane perpendicular to the plane of the connection as shown in Fig. 22.7.

In this case, it is assumed that rotation takes place about the bottom rivet (or bolt) so that the moment resisted by each rivet is proportional to its distance from the bottom rivet. Suppose F_o is the force on a rivet at unit distance from the bottom rivet, then the force on a rivet a distance y from the bottom rivet is $F_o y$. It follows that the moment resisted by this rivet is $F_o y^2$. Summation of all the moments resisted by the rivet group is then equal to the applied moment. Thus

$$\sum F_o y^2 = Pe$$

from which $F_o = \frac{Pe}{\sum y^2}$

The force on any rivet is therefore

$$F = \frac{Pe}{\sum y^2} y \tag{22.7}$$

This force will clearly be a maximum on the rivet furthest from the bottom rivet.

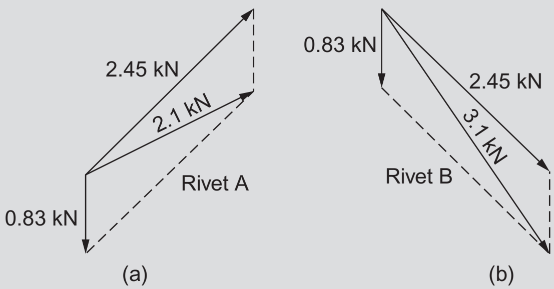

FIGURE 22.6

Force diagrams for rivets of Ex. 22.2.

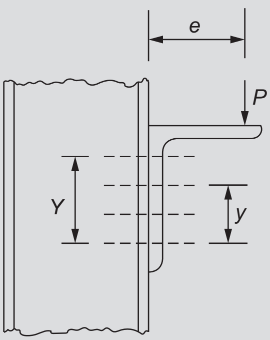

FIGURE 22.7

Moment applied perpendicular to the plane of the connection.

EXAMPLE 22.3

A Universal Beam is supported at each end by an angle section, which is bolted to the vertical flange of a column as shown in Fig. 22.8. Each bolt has a diameter of 10 mm.

If the beam, at each of its supports, produces a downward load of 50 kN on the angle, calculate the maximum principal stress in a bolt.

The moment of the force on the angle = 50 × 100 = 5000 kNm

Also, in Eq. (22.7)

$$\sum y^2 = 40^2 + 80^2 + 120^2 + 160^2 = 48000 \text{ mm}^2$$

Therefore, from Eq. (22.7), the maximum tensile force (on the top bolt) is

$$\text{Max.tensile force} = \frac{5000 \times 160}{48000} = 16.7 \text{ kN}$$

The corresponding tensile stress is then

$$\text{Tens.stress} = \frac{16.7 \times 10^3}{(\pi/4) \times 10^2} = 212.6 \text{ N/mm}^2$$

$$\text{The shear force/bolt} = 50/5 = 10 \text{ kN.}$$

From Ex. 10.5, the maximum shear stress is given by

$$\tau_{\max} = \frac{16 \times 10 \times 10^3}{3 \times \pi \times 10^2} = 169.8/\text{mm}^2$$

The maximum principal stress is then, from Eq. (14.8)

$$\sigma_{\max} = \frac{212.6}{2} + \frac{1}{2}\sqrt{\left(212.6^2 + 4 \times 169.8^2\right)}$$

i.e. $\sigma_{\max} = 306.6$ N/mm^2

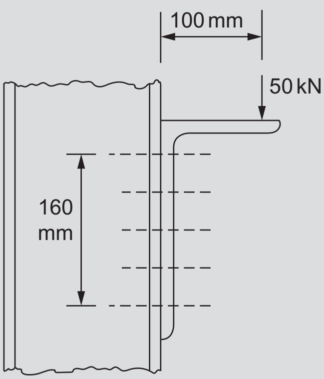

FIGURE 22.8

Bracket of Ex. 22.3.

22.2 Welded connections

Welded joints are widely used in steel construction and are probably becoming more prevalent than bolted or riveted connections. In this section, we shall examine the different types of weld and how they may be analysed under different loading conditions.

Types of weld

Figures 22.9(a)–22.9(d) show different forms of *butt weld* in which the weld lies substantially within the extension of the planes of the surfaces of the parts or within the extension of the planes of the surfaces of the smaller of two parts of different size, for example that shown in Fig. 22.9(d).

The different parts of a butt weld are given different terms and are shown in detail in Fig. 22.10.

The different types of *fillet weld* are shown in Figs 22.11(a)–22.11(d) and are generally triangular in cross section. The terms describing the different parts of a fillet weld are illustrated in Figs 22.12(a)–22.12(c).

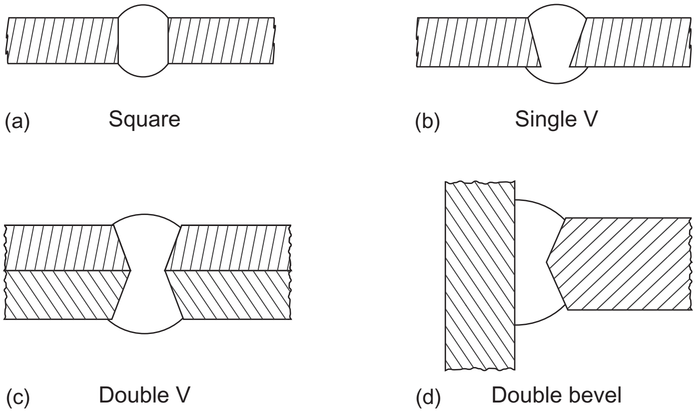

FIGURE 22.9

Types of butt weld.

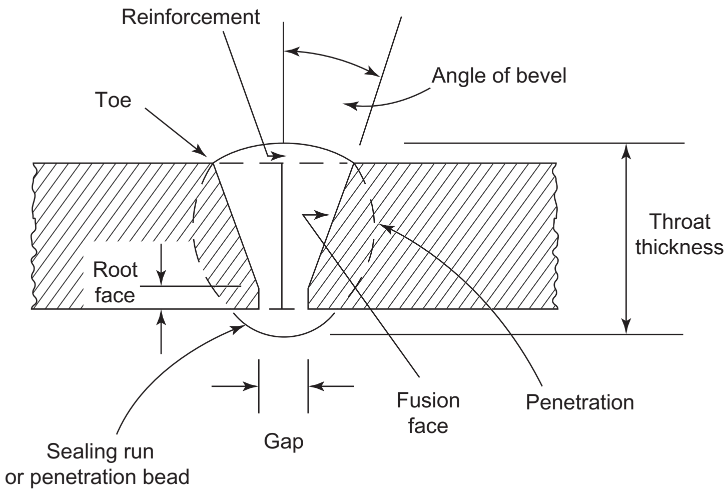

FIGURE 22.10

Terms in butt welds.

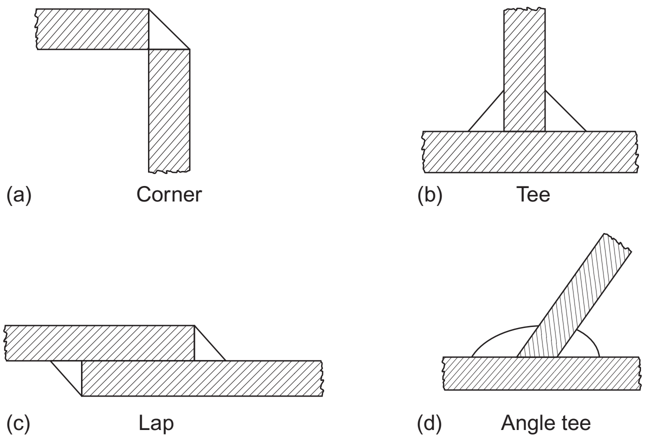

FIGURE 22.11

Types of fillet weld.

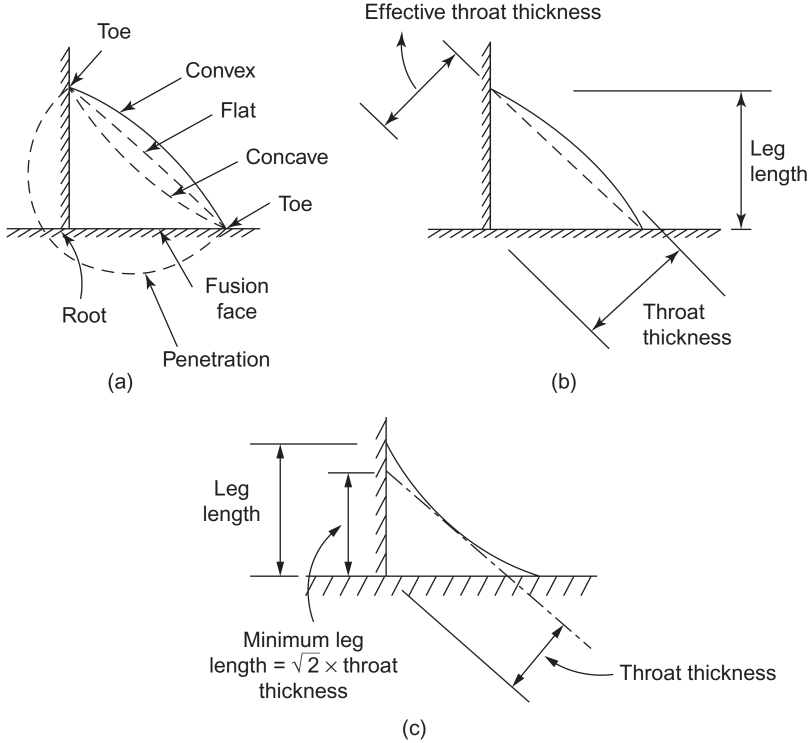

FIGURE 22.12

Terms in fillet welds.

Design of welds

Butt welds under static loads are stressed equally with the parent plates and the design of the plates automatically controls the size of the butt weld required.

Fillet welds may be subjected to longitudinal tension or compression and a longitudinal shear on the throat area. They may be also subjected to transverse tension or compression on the throat area. It is usual to neglect the longitudinal tension or compression when combined with longitudinal shear, for example welds connecting web to flanges of built up beams, so that fillet welds are designed solely to withstand longitudinal shear and transverse tension or compression.

When direct tensile or compressive forces act across the throat area, the resultant force/mm may be obtained and the stress calculated by dividing the force/mm by the throat thickness.

When direct tensile or compressive forces across the throat are combined with longitudinal shear, the two stresses may be combined to obtain the maximum principal stress. From Eq. (14.8) in which $\sigma_y = 0$

$$\sigma_{\max} = \sigma_{\mathrm{I}} = \frac{\sigma_x}{2} + \sqrt{\left(\frac{\sigma_x{}^2}{4} + \tau_{xy}{}^2\right)} \tag{22.8}$$

Also, from Eq. (14.11)

$$\tau_{\max} = \sqrt{\left(\frac{\sigma_x{}^2}{4} + \tau_{xy}{}^2\right)} \tag{22.9}$$

and these maximum stresses may be equated to the maximum allowable values of stress to determine limiting forces or size of weld.

Strength of welds

The strength of a weld may be conveniently expressed in terms of the strength/linear mm of the weld, F. Then

$$F = \sigma t \tag{22.10}$$

where σ is the stress in the weld and t the effective throat thickness.

For welds subjected to a load P, which may be tensile or compressive across the throat area or a shear load along the throat area, the strength or load/linear mm may be determined by dividing the load P by the effective length l.

i.e.

$$F = \frac{P}{l} \tag{22.11}$$

EXAMPLE 22.4

A tension connection is made between a 50 × 12 mm flat and an angle with a 40-mm overlap welded all round as shown in Fig. 22.13. Determine the size of fillet weld required for a load of 90 kN if the working stress is 100 N/mm^2.

The total length of weld is 180 mm so that the force/linear mm = 90 × 10^3/180.

Then the stress is given by Eq. (22.10)

i.e.

$$100 = \frac{90 \times 10^3}{180t}$$

which gives $t = 5$ mm.

From Fig. 22.12(c) the size of the weld, i.e. the leg length, is $(\sqrt{2})t = (\sqrt{2}) \times 5 = 7.07$ mm.

Say, a weld size of 8 mm.

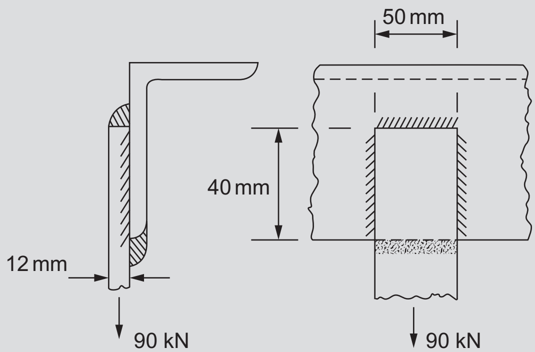

FIGURE 22.13

Connection of Ex. 22.4.

For welds subjected to bending, the stress is given by Eq. (9.9), that is

$$\sigma = \frac{My}{I}$$

Substituting in Eq. (22.10) gives the strength/linear mm. Then

$$F = \frac{Myt}{I}$$

or

$$F = \frac{My}{I^1} \tag{22.12}$$

where $I^1 = I/t$ the second moment of area of weld/linear mm of throat thickness and y is the distance from the centroidal axis to the inside of the furthest weld.

EXAMPLE 22.5

A bending moment of 12.5 kNm is resisted by fillet welds joining a 50 × 100 mm rectangular section to a fabrication as shown in Fig. 22.14. If the working stress in the welds is limited to 100 N/mm^2, determine the size of weld required.

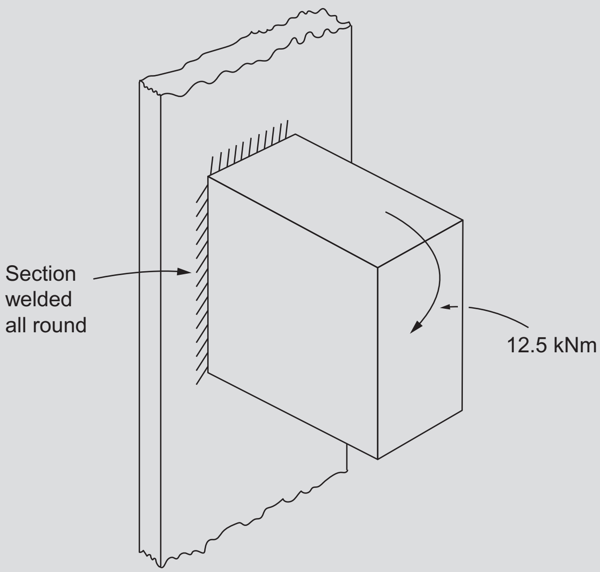

FIGURE 22.14

Joint of Ex.22.5.

In Eq. (22.12) $I^1 = 2(50 \times 50^2) + \dfrac{2 \times 100^2}{12} = 41.7 \times 10^4\ \text{mm}^3$

From Eq. (22.12) $F = \dfrac{12.5 \times 10^6 \times 50}{41.7 \times 10^4} = 1498.8\ \text{N/mm}$

Then, from Eq. (22.10)

$$t = \frac{1498.8}{100} = 14.99\ \text{mm}$$

The required weld size is then $(\sqrt{2}) \times 14.99 = 21.2$ mm.
Say, a weld size of 22 mm.

Welds may be subjected to torsion in which case the torsion formula for circular sections (Eq. (11.4)) may be used with reasonable accuracy. That is

$$\frac{T}{J} = \frac{\tau}{R}$$

where T is the applied torque, J the polar second moment of area of the weld arrangement, and R the distance from the centre of torsion to the inside of the furthest weld. The strength, or load/linear mm, is given by $F = \tau t$. Then, substituting for τ from the earlier equation

$$F = \frac{TRt}{J}$$

or

$$F = \frac{TR}{J^1} \tag{22.13}$$

where $J^1 = J/t$ the polar second moment of area/mm of the throat thickness of the weld about the centre of torsion.

EXAMPLE 22.6

A pressed steel channel 150 × 100 × 9.5 mm is subject to a torque of 12.5 kNm.

Calculate the size of weld required if the section is welded all round as shown in Fig. 22.15. The allowable stress is 100 N/mm^2.

Initially we find the vertical position of the centroid of the weld by taking moments about a line through the toes of the weld. Then

$$(2 \times 100 + 2 \times 83 + 115 + 150)\bar{y} = 2(100 \times 50) + 2(83 \times 41.5) + 115 \times 90.5 + 150 \times 100$$

which gives $\bar{y} = 67.0$ mm

Now $J^1 = I_x{}^1 + I_y{}^1$

i.e. $$J^1 = 150 \times 33^2 + 115 \times 23.5^2 + 2 \times \frac{23.5^3}{3} + 4 \times \frac{67.0^3}{3} + 2 \times \frac{33^3}{3} + \frac{150^3}{12} + \frac{115^3}{12} + 2 \times 75^2 + 2 \times 83 \times 65.5^2$$

from which $J^1 = 2.91 \times 10^6\ \text{mm}^3$

Also $R_{max} = \sqrt{(75^2 + 67^2)} = 100.6$ mm

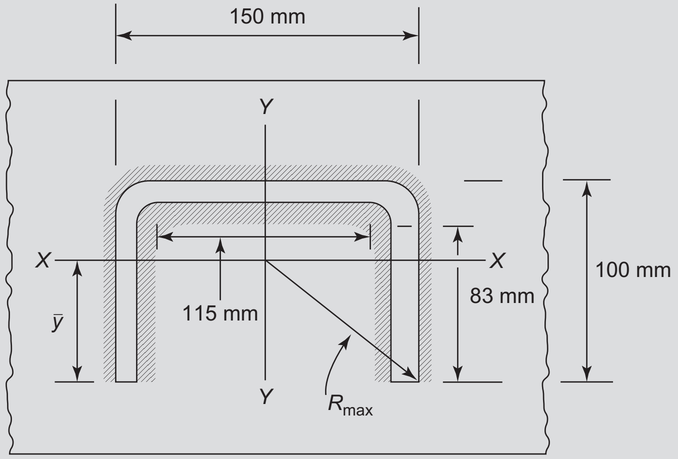

FIGURE 22.15

Joint of Ex. 22.6.

Then, from Eq. (22.13) $F = \dfrac{12.5 \times 10^6 \times 100.6}{2.91 \times 10^6} = 432.1 \text{ N/mm}$

The required thickness is then $t = \dfrac{432.1}{100} = 4.32 \text{ mm}$

i.e. weld size $= (\sqrt{2}) \times 4.32 = 6.1 \text{ mm}$

Say, a 6.5 mm weld.

In some situations, welds may be subjected to a combination of loads, for example combined bending and direct loads or combined bending and torsion. In these cases, the stresses are obtained separately and then added vectorially.

EXAMPLE 22.7

A bracket is built up from 150 × 25 mm flange plates and a 500 × 15 mm web as shown in Fig. 22.16. The bracket carries a load of 800 kN at a distance of 300 mm from the face of the column to which it is welded. Determine the size of fillet weld required assuming an allowable weld stress of 100 N/mm^2.

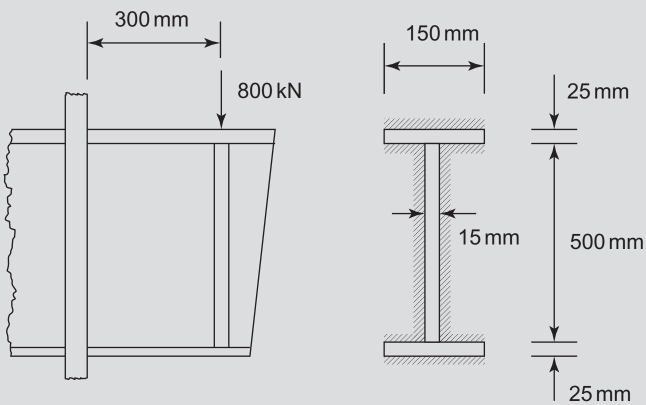

FIGURE 22.16

Joint of Ex. 22.7.

For the welds

$$I^1 = 2 \times 150 \times 275^2 + 2 \times 135 \times 250^2 + 2 \times \frac{500^3}{12} = 60.4 \times 10^3 \text{ mm}^4$$

The applied bending moment is given by

$$M = 800 \times 0.3 = 240 \text{ kNm}$$

Then, from Eq. (22.12), the load/mm due to bending is

$$F_b = \frac{240 \times 10^6 \times 275}{60.4 \times 10^6} = 1092.7 \text{N/mm}$$

The total length of fillet weld is 2 × 150 + 2 × 500 + 2 × 135 = 1570 mm.

The load/mm (which will be a shear load) is then

$$F_s = \frac{800 \times 10^3}{1570} = 509.6 \text{ N/mm}$$

$$\text{The resultant load/mm is then} = \sqrt{\left(1092.7^2 + 509.6^2\right)} = 1205.7 \text{ N/mm}$$

Then, from Eq. (22.10)

$$t = \frac{1205.7}{100} = 12.1 \text{ mm}$$

so that the size of weld required = $(\sqrt{2}) \times 12.1 = 17.1$ mm, say, a weld size of 18 mm.

Clearly an 18-mm size of fillet weld would be too large for the web, which is 15 mm thick. In this situation, it is assumed that the welds on the flange and web have throat thicknesses, which are proportional to the thickness of the respective plate:

i.e. $\frac{t_{f1}}{t_{web}} = \frac{25}{15} = 1.7$

Then $t_{fl} = 1.7 t_{web}$

In the determination of I^1 if t_{web} = unit throat thickness the value of I^1 for the flanges must be multiplied by 1.7. Also, in the determination of the load/mm due to direct stress, the length of the flange welds must be multiplied by 1.7 to determine an effective length of weld. Then

$$I^1 = 2 \times 150 \times 275^2 \times 1.7 + 2 \times 135 \times 250^2 \times 1.7 + 2 \times \frac{500^3}{12} = 88.1 \times 10^6 \text{ mm}^3$$

Therefore, $F_b = \frac{240 \times 10^6 \times 275}{88.1 \times 10^6} = 749.1 \text{ N/mm}$

and $F_s = \frac{800 \times 10^3}{570 \times 1.7 + 1000} = 406.3 \text{ N/mm}$

$$\text{Resultant} = \sqrt{\left(749.1^2 + 406.3^2\right)} = 852.2 \text{N/mm}$$

Therefore, the size of web weld required is given by

$$\text{Size} = \frac{(\sqrt{2}) \times 852.2}{100} = 12.1 \text{ mm}$$

Say, a weld size for the web of 12.5 mm and for the flanges 1.7 × 12.5 = 21.3 mm, say, 21.5 mm.

EXAMPLE 22.8

A bracket supports a load of 100 kN at a distance of 150 mm from the edge of a stanchion and is constructed by welding a 300-mm-wide plate to the face of the stanchion with an overlap of 200 mm as shown in Fig. 22.17. If the plate can be welded on three sides only, find the size of weld required for an allowable stress of 80 N/mm^2.

To find the position of the centre of torsion (the centroid of the weld) take moments about BC

$$(200+300+200)\bar{x}=2\times 200\times 100$$

which gives $\bar{x}=57.1$ mm

$$\text{Then the torque applied} = 100\times 10^3\,(150+142.9)=29.3\times 10^6\ \text{Nmm}$$

$$J^1=I_x{}^1+I_y{}^1=2\times 200\times 150^2+\frac{300^3}{12}+300\times 57.1^2+2\times\frac{57.1^3}{3}+2\times\frac{142.9^3}{3}$$

from which $J^1=14.3\times 10^6\ \text{mm}^3$

The maximum radius to a part of the weld $=\sqrt{(150^2+142.9^2)}=207.2$ mm

The load/mm due to the torque is, from Eq. (22.13)

$$F_t=29.3\times 10^6\times 207.2=424.5\,\text{N/mm}$$

and the direct load/mm (actually a shear load) is

$$F_s=\frac{100\times 10^3}{700}=142.9\,\text{N/mm}$$

The resultant load/mm is then found by calculation or graphically (see Chapter 2) and is equal to 533.2 N/mm. Therefore, the size of weld required is

$$\text{Size}=\frac{(\sqrt{2})\times 533.2}{80}=9.4\ \text{mm}$$

Say, a weld size of 10 mm.

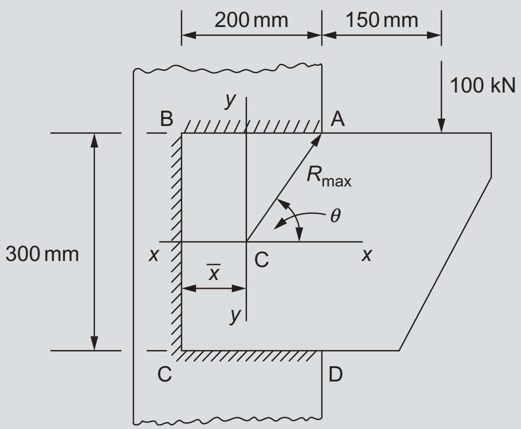

FIGURE 22.17

Bracket of Ex. 22.8.

In some cases, joints are fabricated using combinations of butt and fillet welds.

The size of the butt weld is determined by plate thickness and so its share of the load may be calculated. The fillet welds can then be designed to take the remainder of the load.

EXAMPLE 22.9

The joint of a rigid frame composed of plate sections is required to carry a bending moment of 650 kNm. The allowable stress for the butt welds is 150 N/mm^2 while that for the fillet welds is 100 N/mm^2. For the arrangement shown in Fig. 22.18, calculate the size of fillet weld required.

$I^1{}_B$ for the butt welds is given by

$$I^1{}_B = 2 \times 230 \times 287.5^2 = 38.02 \times 10^6 \text{ mm}^3$$

Therefore, the moment taken by the butt welds is

$$M_B = \frac{150 \times 38.02 \times 10^6 \times 25 \times 10^{-6}}{300} = 475.3 \text{ kNm}$$

It follows that the moment taken by the fillet weld is $650 - 475.3 = 174.7$ kNm.

$I^1{}_F$ for the fillet welds is given by

$$I^1{}_F = 2 \times 210 \times 275^2 + 2 \times 550^3 = 59.5 \times 10^6 \text{ mm}^3$$

Then, from Eq. (22.12)

$$F_F = \frac{174.7 \times 10^6 \times 275}{59.5 \times 10^6} = 807.4 \text{ N}$$

so that $t = \dfrac{807.4}{100} = 8.07$ mm

The required size of weld is then $(\sqrt{2}) \times 8.07 = 11.4$, say, a 12-mm weld.

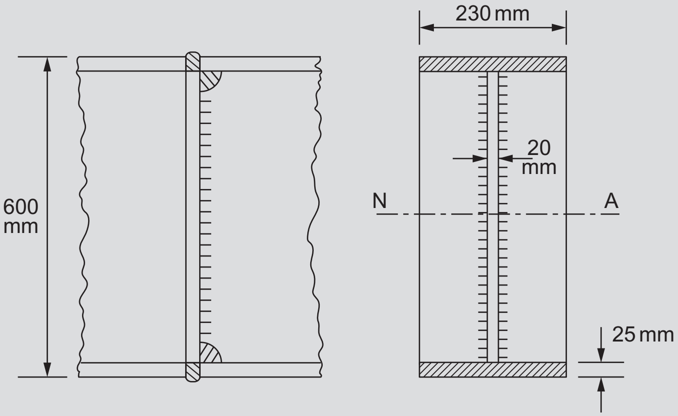

FIGURE 22.18

Joint of Ex. 22.9.

PROBLEMS

P.22.1 The double riveted butt joint shown in Fig. P.22.1 connects two plates, which are each 2.5 mm thick, the rivets have a diameter of 3 mm. If the failure strength of the rivets in shear is 370 N/mm^2 and the ultimate tensile strength of the plates is 465 N/mm^2, determine the necessary rivet pitch if the joint is to be designed such that failure due to shear in the rivets and failure due to tension in the plates occur simultaneously. Calculate also the joint efficiency.

Ans. Rivet pitch is 12 mm. Joint efficiency is 75%.

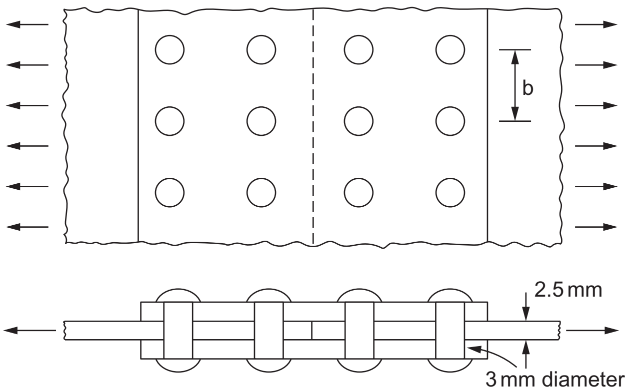

FIGURE P.22.1

P.22.2 The rivet group shown in Fig. P.22.2 connects two narrow lengths of plate one of which carries a 15-kN load positioned as shown. If the ultimate shear strength of a rivet is 350 N/mm^2 and its failure strength in compression is 600 N/mm^2, determine the minimum allowable values of rivet diameter and plate thickness.

Ans. Rivet diameter is 4.2 mm, plate thickness is 1.93 mm.

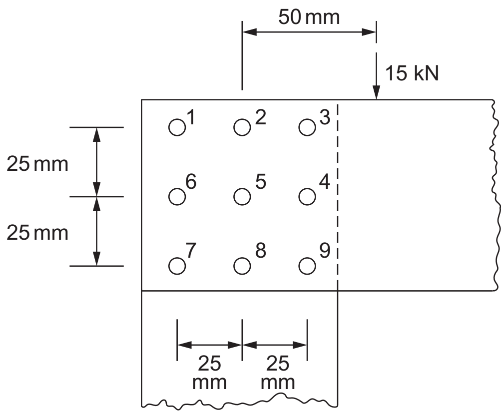

FIGURE P.22.2

P.22.3 Calculate the safe load *P* on the lap joint shown in Fig. P.22.3 if the shear strength of a rivet is 140 N/mm^2 and its bearing strength is 400 N/mm^2.

Ans. Shear is the critical condition and the safe load is 176.0 kN.

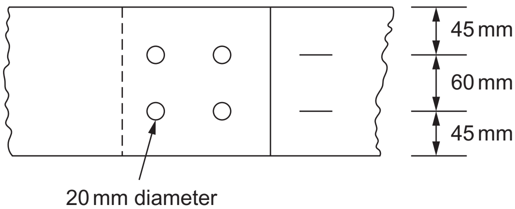

FIGURE P.22.3

P.22.4 Calculate the safe load W on the tie in the joint shown in Fig. P.22.4 if the shear strength of a rivet is 140 N/mm^2, its bearing strength is 400 N/mm^2, and the tensile strength of steel is 275 N/mm^2.

Ans. Shear is the critical condition and the safe load is 176.0 kN.

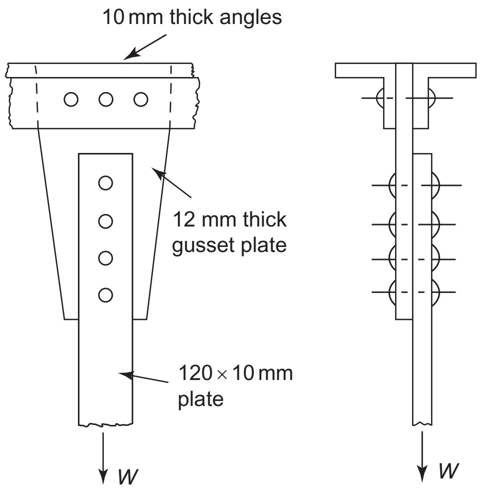

FIGURE P.22.4

P.22.5 A tension member is welded to the leg of an angle section to form a joint in a rigid frame as shown in Fig. P.22.5. If the load in the tension member is 100 kN, determine the required size of weld if the working stress is 100 N/mm^2.

Ans. 10 mm.

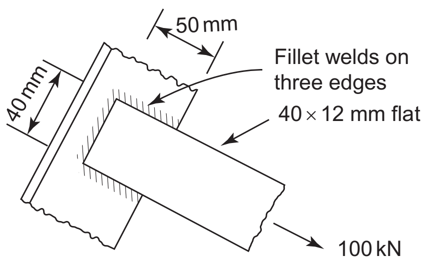

FIGURE P.22.5

P.22.6 A steel box section cantilever having walls 20 mm thick is welded on all four sides to the vertical face of a stanchion as shown in Fig. P.22.6. If the cantilever carries a vertically downward load of 75 kN applied at a distance of 500 mm from the face of the stanchion, determine the size of fillet weld required assuming a working stress of 100 N/mm^2.

Ans. 16 mm.

P.22.7 The bracket shown in Fig. P.22.7 is welded on three of its edges to the vertical face of a column as shown in Fig. P.22.7. The bracket carries a load of 50 kN offset a distance of 200 mm from the edge of the column. Determine the size of weld required assuming an allowable stress of 120 N/mm^2.

Ans. 7 mm.

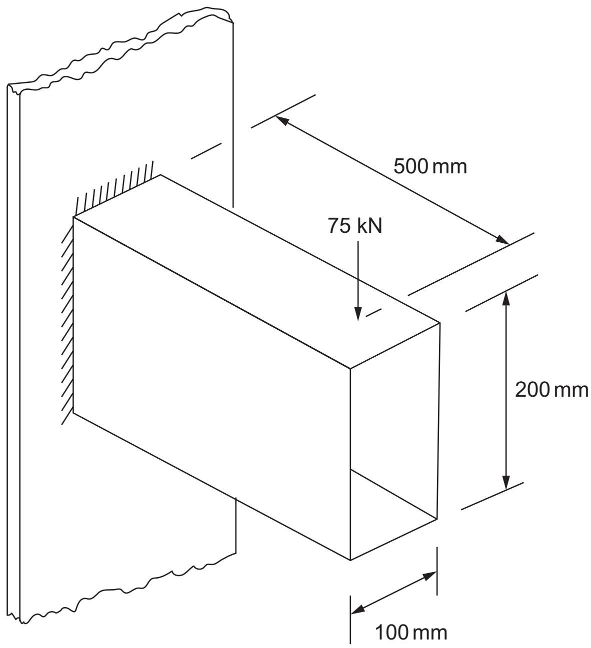

FIGURE P.22.6

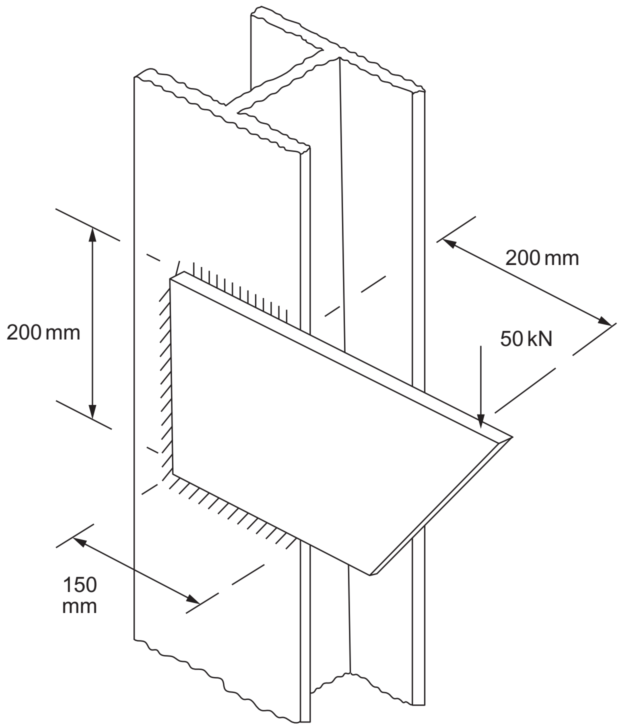

FIGURE P.22.7

P.22.8 Two identical I-section beams are to be connected in line by a combination of butt and fillet welds as shown in Fig. P.22.8. The joint, part of a rigid frame, is required to withstand a bending moment of 200 kNm. If the butt welds have an allowable stress of 120 N/mm^2 and the fillet welds an allowable stress of 110 N/mm^2, calculate the size of fillet weld required.

Ans. 10 mm.

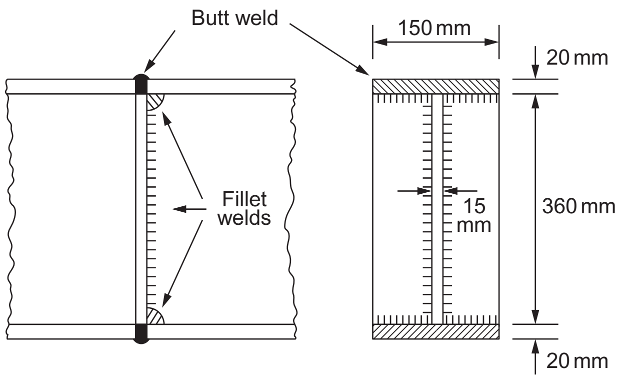

FIGURE P.22.8