

FATIGUE OF BOLTED STEEL LAP JOINTS AND DOUBLERS

1. NOTATION

Both SI and lbf in units are quoted.

f_t	tensile strength of material	N/m ²	lbf/in ²
N	number of load cycles		
R	stress ratio, S_{min}/S_{max}		
S_a	alternating stress, $(S_{max} - S_{min})/2$	N/m ²	lbf/in ²
S_{max}	maximum stress based on gross cross-sectional area of centre plate of joint	N/m ²	lbf/in ²
S_{min}	minimum stress based on gross cross-sectional area of centre plate of joint	N/m ²	lbf/in ²

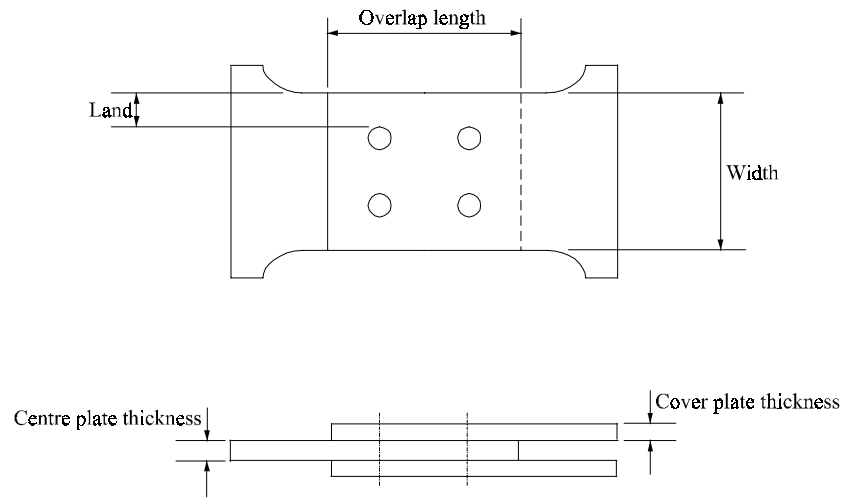
2. INTRODUCTION

This Data Item presents fatigue data for bolted steel lap joints. The data relate to joints fabricated from seven different structural steels with tensile strengths ranging from 400 to 867 MN/m² (58×10^3 to 126×10^3 lbf/in²), secured, with the exception of one group of joints, with either ASTM A325 or ASTM A490 bolts. With one exception the joints are all double lap joints with 2, 3, 4, 6 or 10 bolts. The exception is a double cover plate butt joint with two bolts for which the load on the centre plate is nominally similar to the load on the centre plate of a two bolt double lap joint. The two types of joint are shown in Sketches 2.1 and 2.2 where some of the terminology used in this Item is also illustrated.

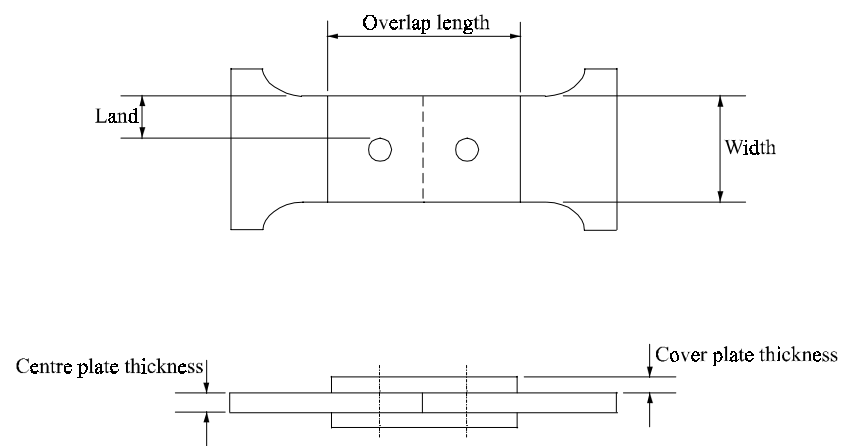
Also presented in this Item are some data for 'doubblers'. A doubler is the same as a double cover plate butt joint except that the centre plate is continuous, as shown in Sketch 2.3. It should be noted that in a doubler, despite the continuous centre plate, some of the load will be transmitted by the cover plates via friction between the surfaces of the assembly. In all cases the thickness of the centre plate is less than or equal to half the total thickness of the joint or doubler.

In the majority of the tests the applied load is transmitted by friction between the plates of the joint with little or no gross slip between the plates. Where a significant amount of slip did occur in the joint it has been indicated in the tables of Section 9.

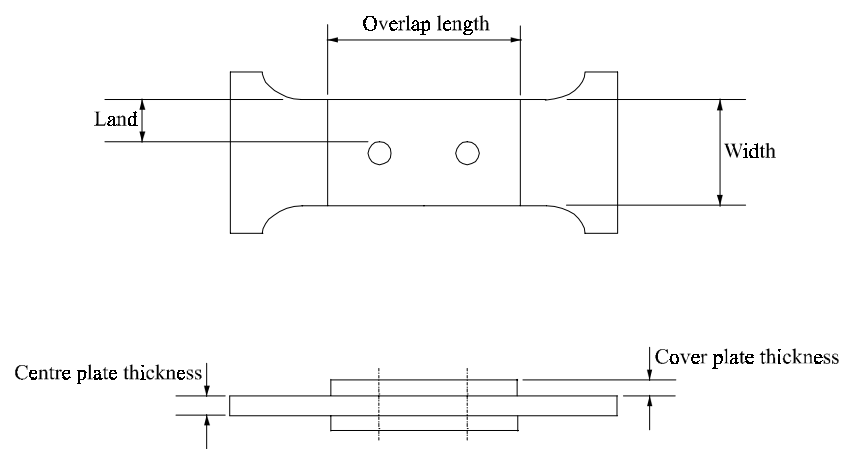
All material and bolt specifications referred to in this Item are American Society for Testing and Materials (ASTM) specifications.



Sketch 2.1 Typical double lap joint



Sketch 2.2 Typical double cover plate butt joint



Sketch 2.3 Typical doubler

3. FRETTING FATIGUE

Although the specific mechanisms of failure for each joint were not stated categorically by the authors of the derivations, in the majority of cases the crack which led to failure of the joint had been initiated at or near the critical section of the joint in a region where noticeable fretting had occurred. Fretting arises in the following manner. When a lap joint is subjected to a cyclic stress, the members of the joint experience different strains. As a result of the different strains, relative slip occurs between the contacting surfaces of the joint. When this situation leads to the initiation of a crack at an interface, which subsequently grows by fatigue and leads to the failure of the joint, it is termed fretting fatigue. The relative slip is very small, less than about $75\mu\text{m}$ (3×10^{-3} in) in amplitude, and tends not to occur uniformly over the whole area of the contacting surfaces. Fretting in a bolted joint will tend to occur over a relatively narrow annular band concentric with the bolt and typically of a mean diameter of approximately one and a half times the diameter of the bolt. Inside the inner edge of this band the amount of slip is too small for significant fretting to occur, while beyond the outer edge of the band the surface shear stress caused by the pressure between the plates tends to be insufficient for cracks to be initiated by fretting. Owing to the combination of the normal and shear forces that are present when fretting occurs, a crack that is initiated by fretting tends to grow initially at an angle to the surface from which it starts. For a fuller description of fretting fatigue see Data Item No. 90031*.

The process by which components fail under fatigue loading can be divided into two stages. The first stage is the crack initiation or crack nucleation stage during which a small crack is formed. The second stage is the crack growth or crack propagation stage when the crack grows steadily up to the point when the component fails. In the absence of fretting the crack initiation stage accounts for almost all of the fatigue life of the component. However, the presence of fretting greatly accelerates the crack initiation process and can therefore markedly reduce the life of a component.

4. PRESENTATION OF DATA

The data are presented in Section 9 as semi-logarithmic fatigue plots. The data are presented in a normalised form in terms of the ratio of the alternating stress on the gross section of the joint or doubler to the tensile strength of the material, S_a/f_t . This ratio is plotted on the ordinate. In all of the joints and doublers the thickness of the centre plate is less than or equal to half the total thickness of the joint or doubler[†] and the gross stresses on the joint or doubler are therefore calculated using the thickness of the centre plate. The number of load cycles to failure, N , is plotted on the abscissa which has a logarithmic scale. The exact definition of failure varies depending upon the derivation from which the data were taken. For Derivations 1 and 2 failure was defined as the literal failure of the joint. For the tests reported in Derivations 3 to 5, a device was fitted to the testing machine which caused it to shut down when a crack developed in the test specimen. Any attempt to continue to apply the maximum cyclic load repeatedly usually resulted in complete rupture of the specimen after a relatively small number of additional cycles. The development of a crack that caused the machine to shut down was therefore used as the criterion for failure. A table containing information about the joint or doubler, such as details of the material, thicknesses of plates, overlap length, width, number of bolts, clamping pressure *et cetera*, accompanies each plot. Clamping pressure is defined in this Data Item as the number of bolts multiplied by the bolt tension divided by the net overlap area of the joint. Sketches of the joints and doublers, dimensioned in millimetres, also accompany the plots of data.

In some cases, data for the same materials for either plain plates or plates with a hole were given by the authors and these data are plotted for comparison with the joint data. Details, such as dimensions, of the

* Data Item No. 90031, "Fretting fatigue".

[†] In Tables 9.15 and 9.16 this statement appears to be incorrect. This is only due, however, to rounding errors when expressing the dimensions to a common base.

plain plates or plates with holes were not always given but they have been included where they were available. The absence of a specimen type in the tables accompanying the plots indicates that the tests were performed on a bolted joint. All joint data are represented on the plots by hollow symbols or crosses while data for plain plates, plates with holes and doublers are represented by filled symbols and are identified in the tables by the specimen codes of Section 7.

The initial bolt tensions given in the tables were obtained using several different methods depending on the derivation from which they were taken. The different methods are set out below.

- | | |
|---------------------|--|
| Derivation 1 | The bolt tension was obtained using calibrated torque wrenches and elongation gauges. |
| Derivation 2 | Method was not stated. |
| Derivation 3 | The bolt tension was obtained using three electrical strain gauges on a short steel sleeve placed under the bolt head, the sleeve having been calibrated by direct tensile loading of a bolt and sleeve assembly. |
| Derivations 4 and 5 | The load versus elongation relationship for the bolts was ascertained and the bolts were then tightened using the snug plus half a turn method. Snug corresponded to the load given by a torque of 102 N m (75 ft lbf). It should be noted that this method of tightening the bolts takes the materials of which they are made well into the plastic region of their stress-strain curves. |

5. FACTORS AFFECTING THE FATIGUE STRENGTH OF BOLTED JOINTS

There are a number of factors that affect the fatigue strength of bolted lap joints. These factors include clamping pressure, the surface finish of the contacting surfaces of the joint and the relative dimensions of the joint, such as the centre and cover plate thicknesses. The following notes discuss these factors, and others, and where possible assess their effect in the light of the available data.

5.1 Number of Bolts and Clamping Pressure

Figures 9.1 and 9.2 show data for two and four bolt joints. With the exception of the data for the four bolt joint shown in Figure 9.2 which shows a slightly higher fatigue strength, the data for the different joints are virtually indistinguishable. This is not unexpected since the joints are geometrically similar, the two bolt joint being equivalent to half a four bolt joint, and as far as can be ascertained the clamping pressures for all the joints are also similar. Figure 9.3 shows data for two three bolt joints and a four bolt joint. Once again the data are virtually indistinguishable. Again this is not unexpected since the joints are all dimensionally similar and the clamping pressure varies only slightly. The effect of the different bolt arrangements as shown in Sketches 9.3a and 9.3b is discussed in Section 5.3.

Data for three, six and ten bolt joints are presented in Figure 9.4. The six bolt joint has a higher fatigue strength than the ten bolt joint which in turn has a slightly higher fatigue strength than the three bolt joint. The joints all have the same centre and cover plate thicknesses and land, the only factor varying markedly being the clamping pressure which is high for the six and ten bolt joints and much lower for the three bolt joint. That suggests that the high clamping pressure is responsible for the better fatigue strength.

In Figure 9.5 data for four and six bolt joints are plotted. At lower numbers of cycles the six bolt joint with A490 bolts appears to have considerably lower fatigue strength than the four bolt joint with the same bolts and the six bolt joint with A325 bolts. This conclusion is founded, however, on the evidence of only one data point, that is the left most data point for the six bolt joint with A490 bolts, and is inconsistent with the

remainder of the data particularly those for the other six bolt joint shown in Figure 9.5. The contradiction with much of the other data where higher clamping pressure gives higher fatigue strength cannot be explained easily other than by suggesting that the left most data point for the six bolt joint with A490 bolts is at the extreme lower limit of the scatter. The difference in strength of the three joints disappears as the load decreases. Figure 9.7 shows data for two pairs of four and six bolt joints with contacting surfaces having different finishes. Both of the six bolt joints exhibit marginally larger fatigue strengths than their four bolt counterparts, particularly at lower loads, and the joints are all dimensionally identical which suggests that the higher clamping pressure of the six bolt joint may be responsible for its slightly higher fatigue strength. The effect of the different contacting surfaces of the two pairs of joints is discussed in Section 5.5. Figures 9.8 and 9.9 also give data for four and six bolt joints. In Figure 9.8 the joint with the higher clamping pressure, that is the six bolt joint, exhibits a marginally higher fatigue strength at lower applied loads. In Figure 9.9 there are comparatively few data points and there is no discernible difference between those for the four bolt joint and those for the six bolt joint.

Data for four bolt joints tested at similar applied stresses but with different clamping pressures are plotted in Figure 9.10. The number of specimens that failed is not large but a steady increase in endurance with increasing clamping pressure is apparent.

Data for two and four bolt joints fabricated from three different materials are plotted on Figures 9.12 to 9.14. In each of the three figures there are very small differences between the data for the different joints. All the joints are dimensionally similar, the two bolt joint being equivalent to half a four bolt joint and so large variations in the fatigue strengths of the joints would not be expected. The small variations that are present may have been due to slightly different clamping pressures, only minimum values for which are available.

Figure 9.17 presents data for joints of three different widths. Although the overlap lengths of the joints are not known, comparable, if not absolute, values of clamping pressure can be calculated by assuming an overlap length. The fatigue strengths of the joints and doublers are all similar. The two joints with the higher clamping pressures do, however, exhibit higher fatigue strength at higher numbers of cycles. At lower number of cycles the beneficial effect of higher clamping pressure may have been offset by the smaller lands of the two narrower joints, the lands in both cases being less than the diameter of the bolt.

In conclusion, the number of bolts in a joint does not appear to be an important factor in itself. The overriding factor seems to be clamping pressure: greater clamping pressure gives higher fatigue strength. The importance, therefore, of the number of bolts relates only to the fact that a larger number of bolts is a means of obtaining a higher clamping pressure for a given bolt tension and joint geometry. An exception to this is seen in Table 9.4 where a ten bolt joint exhibits a lower clamping pressure than a six bolt joint for virtually the same bolt tension because of the lower net area of the six bolt joint.

5.2 Tensile strength

Figures 9.1, 9.2, 9.3, 9.5 and 9.12 to 9.14 present data for two and four bolt double lap joints made out of six different material specifications having seven different tensile strengths (specimens fabricated from two different heats of A242-50T high strength low alloy steel with different tensile strengths were tested). When these are compared on the basis of absolute alternating stress, as they are in Figures 9.18 and 9.19, a tendency for fatigue strength to increase with increasing tensile strength is discernible. The increase is not, however, as great as the increase in tensile strength and this is largely due to the increased sensitivity of the stronger steels to fretting and also to stress concentration at the holes.

5.3 Bolt Arrangement

Figure 9.3 shows data for two three bolt joints with different bolt arrangements. There appears to be little

or no difference between the fatigue strength of the arrangement shown Sketch 9.3a and the fatigue strength of the arrangement shown in Sketch 9.3b. It is suggested, however, that it is better engineering practice to 'feed' the load gradually into, and out of, the joint via several bolts rather than only one. That is to say that the arrangement of bolts shown in Sketch 9.3a is preferable to that shown in Sketch 9.3b.

5.4 Bolt Tightening Procedure

Data for joints that have undergone different bolt tightening procedures are shown in Figure 9.6. The first procedure involved assembling the joints in the usual manner. The second procedure involved assembling the joints in the usual manner, leaving them for approximately one month and then tightening the nuts a further 30° before commencing the fatigue test. In the third procedure the joints were again assembled in the normal way and the joint was then subjected to two thousand cycles of repeated loading after which the bolts were tightened a further 30° before the test was continued. The final procedure involved loosely assembling the joint, slipping the joint to bring the bolts into bearing and then tightening the nuts.

Inspection of Figure 9.6 shows that there is no apparent difference between the fatigue strengths of the joints assembled using the four methods outlined above.

5.5 Condition of Contacting Surfaces

In Figure 9.7 the results of tests on four and six bolt joints with grit blasted surfaces are compared with those with dry mill scale surfaces. The amount of data is limited, but for both the four and six bolt joints it can be seen that grit blasting of the contacting surfaces gives an improvement in fatigue strength over a range of applied stress.

The only other surface tested besides dry mill scale was a surface which had been abraded to a roughness of approximately 1.5 μm (60×10^{-6} in) centre line average. The joints with this surface were the two bolt double cover plate butt joints, the data for which are plotted in Figures 9.15 to 9.17. It is difficult to assess the effect of this surface finish due to the fact that no other data for this type of joint are available. The joints relating to the data in Figure 9.1 do, however, have some similarities with those represented by the data in Figure 9.15; the tensile strengths of the joint materials are similar as are the curves for the plates with holes. Comparing these sets of data suggests that an abraded surface is marginally better than a dry mill scale surface at lower numbers of cycles. Another indication of the effect of this surface is the coefficient of friction which, at 0.19 - 0.23, is roughly in the middle of the range of coefficients of friction obtained for dry mill scale surfaces. It should be noted, however, that in some cases the coefficient of friction of the abraded surface increased to as much as 0.3.

A clean dry mill scale surface represents a roughness of approximately 25 μm (1×10^{-3} in) centre line average.

5.6 Stress Ratio

Figures 9.7 to 9.9 present results of tests on four and six bolt joints conducted at stress ratios of zero, -1 and 0.5 respectively. The joints tested at a ratio of -1, that is fully reversed loading, exhibit the highest fatigue strength, while those tested at a ratio of 0.5 exhibit the lowest fatigue strength. This is as expected.

5.7 Cover and Centre Plate Thicknesses

Figures 9.15 and 9.16 present the results of tests on double cover plate butt joints with different centre and cover plate thicknesses. In Figures 9.15 and 9.16 fatigue strength decreases with increasing centre plate thickness. In Figure 9.16, however, the cover plate thickness is also decreasing and these results would have been affected by this. Combining the effects of the thicknesses of the two plates by considering the

ratio of cover plate thickness to centre plate thickness suggests that this ratio should ideally be greater than unity for maximum fatigue strength.

The data for the doublers are almost indistinguishable from the corresponding joint data. Fretting was the cause of failure for the majority of both the joints and the doublers and since the stress distribution in the centre plate and the relative displacements of the plates are similar for joints and doublers the close likeness of the pairs of joint and doubler data is not unexpected. It should be noted that the doublers were tested with no transverse or normal loads applied to the cover plate. The application of any such loads would be likely to have a considerable effect on the fatigue strength of the doubler.

5.8 Joint Width

Figure 9.17 presents data for two bolt double cover plate butt joints of different widths. The data are largely indistinguishable though the widest joint does seem to exhibit slightly lower fatigue strength than the two narrower joints, particularly at lower stresses. Although the narrower joints have smaller lands, they have larger clamping pressures which may be responsible for the higher fatigue strengths.

5.9 General Conclusions

Within the range of the data presented and with the exception of material tensile strength, clamping pressure seems to be the most important factor affecting the fatigue of bolted joints, the higher the clamping pressure the better is the fatigue strength of the joint. This is demonstrated to greater or lesser degrees in Figures 9.1, 9.2, 9.4, 9.7, 9.8, 9.10 and 9.17. The number of bolts in the joint is not important in itself, being only a means of increasing the clamping pressure.

The tensile strength of the material used to fabricate a joint does affect its fatigue strength, higher tensile strength generally giving higher fatigue strength. This effect, which can be seen in Figures 9.18 and 9.19, is not as pronounced as might be expected due to the increased sensitivity of the stronger steels to fretting and also to stress concentration at the holes.

The procedure used to tighten the bolts, whether it be additional tightening of the bolts sometime prior to service, during service or with the bolts in bearing, has little or no effect on joint fatigue strength as shown in Figure 9.6.

On the evidence of Figure 9.7, an improvement in fatigue strength can be obtained by grit blasting the contacting surfaces of the joint rather than leaving mill scale on.

Regarding the relative thicknesses of the centre and cover plates, Figures 9.15 and 9.16 indicate that, for the double cover plate butt joints, a ratio of cover to centre plate thickness of at least unity seems to give the best fatigue strength.

A useful conclusion that can be drawn from many of the figures in Section 9 is that, for a particular material, the fatigue strength of a bolted joint generally falls below that of plain plate and above that of a plate with a hole in it. The reason that the joints tend to be stronger than the plain plates with a hole in them, despite the presence of fretting in the joints which is absent from the plain plate, is that the transmission of the load via friction between the plates of the joint markedly reduces the load in the centre plate at the section through the holes.

6. DERIVATION

This section lists selected sources that have assisted in the preparation of this Item.

1. MUNSE, W. H.
WRIGHT, D. T.
NEWMARK, N. M. Laboratory tests of bolted joints. *Transactions of the American Society of Civil Engineers*, Vol. 120, pp. 1299-1321, 1953.
2. HANSEN, N.G. Fatigue tests of joints of high strength steels. *Proceedings of the American Society of Civil Engineers, Journal of the Structural Division*, Vol. 85, No. ST3, pp. 51-69, 1959.
3. SPIERS, R.
CULLIMORE, M. S. G. Geometrical factors influencing the fatigue of friction grip bolted joints. *Hungarian Academy of Sciences, Third Conference on Dimensioning and Strength Calculation, Budapest*, pp. 253-263, 1968.
4. BIRKEMOE, P. C.
MEINHEIT, D. F.
MUNSE, W. H. Fatigue of A514 steel in bolted connections. *Proceedings of the American Society of Civil Engineers, Journal of the Structural Division*, Vol. 95, No. ST10, pp. 2011-2030, October 1969.
5. BIRKEMOE, P. C.
SRINIVASAN, R. Fatigue of bolted high strength structural steel. *Proceedings of the American Society of Civil Engineers, Journal of the Structural Division*, Vol. 97, No. 3, pp. 935-950, March 1971.

7. ABBREVIATIONS

AB	Abraded to CLA of $1.5\mu\text{m}$ ($60 \times 10^{-6}\text{in}$)	SS	Structural steel
CLA	Centre line average	NA	Not available
DB	Doubler	PP	Plain plate
DMS	Dry mill scale	PWH	Plate with a hole
GB	Grit blasted		

8. INDEX TO FATIGUE DATA

<i>Material</i>	<i>Material tensile strength MN/m² (10³ lbf/in²)</i>	<i>Stress ratio, R</i>	<i>No. of bolts</i>	<i>Surface finish</i>	<i>Figure and Table number</i>
A242-50T	517-538 (75-78)	0	2, 4	DMS	9.1, 9.2, 9.18, 9.19
A440	566 (82)	0	3, 4	DMS	9.3, 9.19
A514B	867 (126)	0	3, 6, 10	DMS	9.4
A514B	867 (126)	0	4, 6	DMS	9.5, 9.7, 9.19
A514B	867 (126)	0	6	DMS	9.6
A514B	867 (126)	0	4, 6	GB	9.7
A514B	867 (126)	-1	4, 6	DMS	9.8
A514B	867 (126)	0.5	4, 6	DMS	9.9
A7	NA	-1	4	NA	9.10, 9.11
A7	400 (58)	0	2, 4	DMS	9.12, 9.18, 9.19
A94	641 (93)	0	2, 4	DMS	9.13, 9.18, 9.19
SS	614 (89)	0	2, 4	DMS	9.14, 9.18, 9.19
Mild bar	556-680 (81-99)	-1	2	AB	9.15, 9.16, 9.17

9. FATIGUE DATA

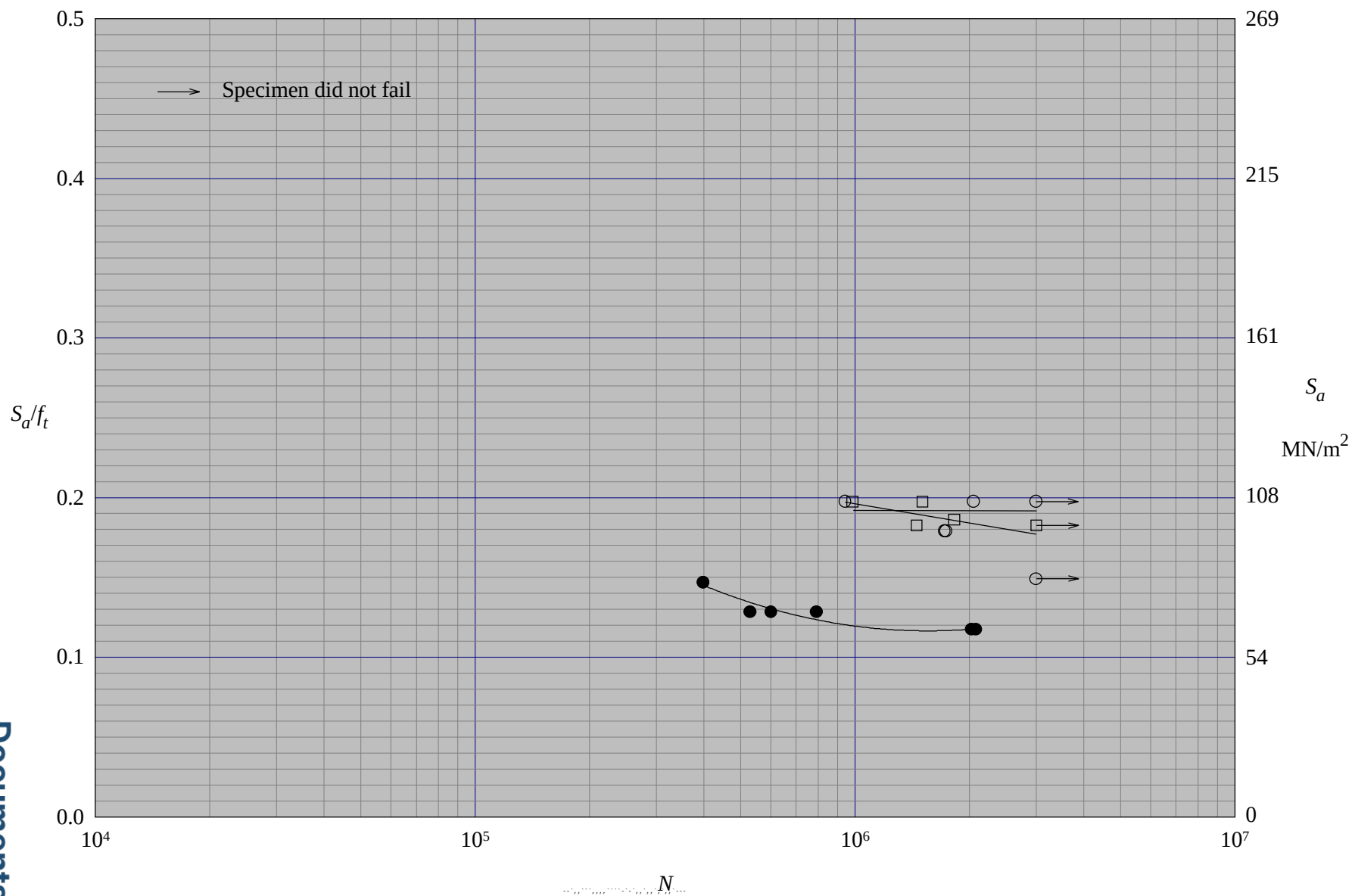


FIGURE 9.1 TWO AND FOUR BOLT DOUBLE LAP JOINTS OF A242-50T HIGH STRENGTH LOW ALLOY STEEL WITH $R = 0$. SEE TABLE 9.1.

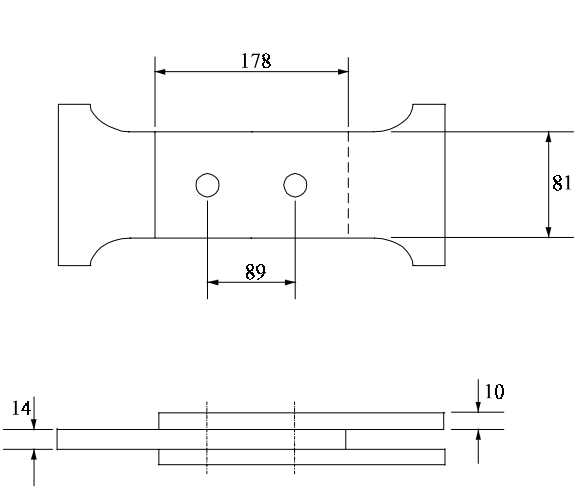


TABLE 9.1 Details of Joints for Figure 9.1

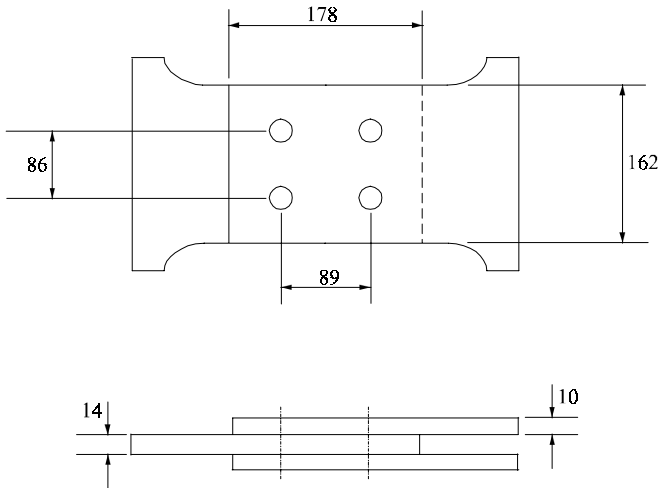
Symbol and specimen type (see Section 7 for key)	Material specification	Condition of contacting surfaces (see Section 7 for key)	Material tensile strength MN/m ² (10 ³ lbf/in ²)	Bolt type	No. of bolts	Average initial bolt tension kN (10 ³ lbf)	Bolt diameter mm (in)	Dimensions of joint, doubler or plate					Coefficient of friction	Clamping pressure MN/m ² (10 ³ lbf/in ²)	Derivation Number
								Overlap length mm (in)	Width mm (in)	Land mm (in)	Centre plate thickness mm (in)	Cover plate thickness mm (in)			
○	A242-50T	DMS	538 (78)	A325	2	>114 (26)	19 (0.8)	178 (7)	81 (3.2)	30 (1.2)	14 (0.6)	10 (0.4)	NA	>17 (2.4)	2
□	"	"	"	"	4	"	"	"	162 (6.4)	28 (1.1)	"	"	"	"	
● PWH	"	"	"	—	—	—	27 (1.1)*	—	102 (4)	37 (1.5)	16 (0.6)	—	"	—	

* Diameter of hole in plate.

All dimensions in millimetres



Sketch 9.1a Two bolt double lap joint



Sketch 9.1b Four bolt double lap joint

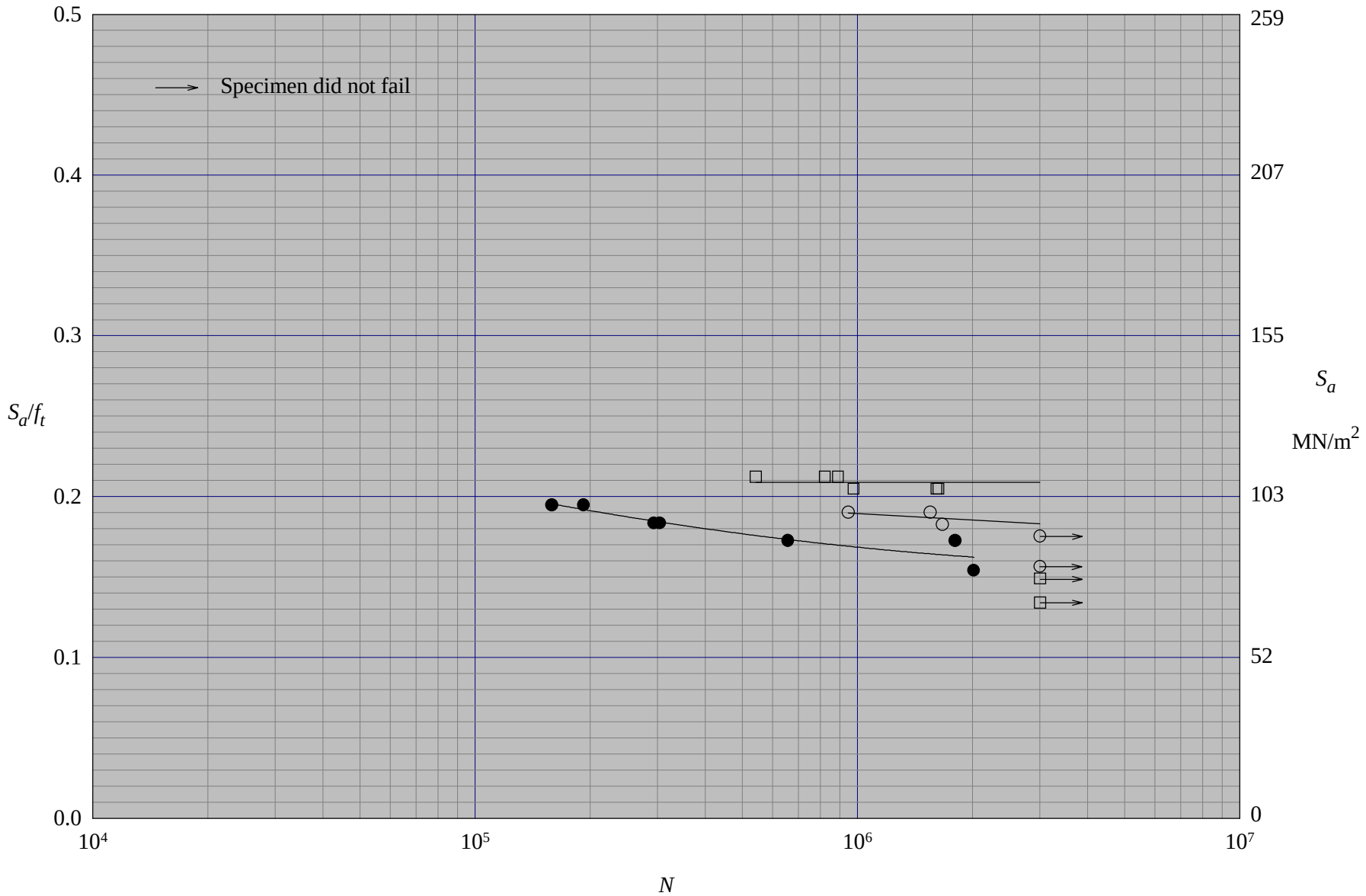


FIGURE 9.2 TWO AND FOUR BOLT DOUBLE LAP JOINTS OF A242-50T HIGH STRENGTH LOW ALLOY STEEL WITH $R = 0$. SEE TABLE 9.2.

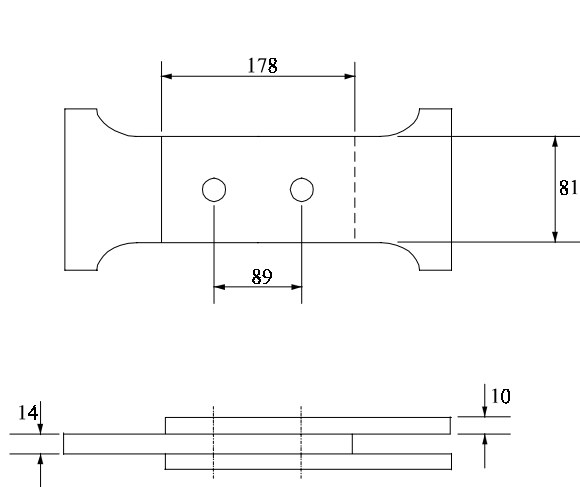


TABLE 9.2 Details of Joints for Figure 9.2

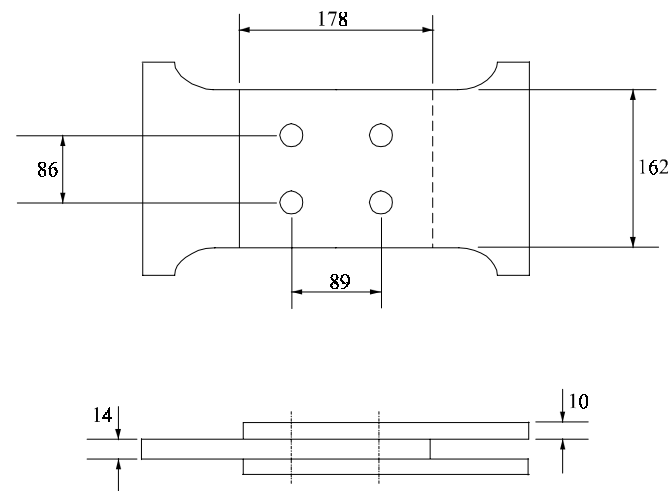
Symbol and specimen type (see Section 7 for key)	Material specification	Condition of contacting surfaces (see Section 7 for key)	Material tensile strength MN/m ² (10 ³ lbf/in ²)	Bolt type	No. of bolts	Average initial bolt tension kN (10 ³ lbf)	Bolt diameter mm (in)	Dimensions of joint, doubler or plate					Coefficient of friction	Clamping pressure MN/m ² (10 ³ lbf/in ²)	Derivation Number
								Overlap length mm (in)	Width mm (in)	Land mm (in)	Centre plate thickness mm (in)	Cover plate thickness mm (in)			
○	A242-50T	DMS	517 (75)	A325	2	>114 (26)	19 (0.8)	178 (7)	81 (3.2)	30 (1.2)	14 (0.6)	10(0.4)	NA	>17 (2.4)	2
□	"	"	"	"	4	"	"	"	162 (6.4)	28 (1.1)	"	"	"	"	
● PWH	"	—	—	—	—	—	27 (1.1)*	—	102 (4)	37 (1.5)	16 (0.6)	—	"	—	

* Diameter of hole in plate.

All dimensions in millimetres



Sketch 9.2a Two bolt double lap joint



Sketch 9.2b Four bolt double lap joint

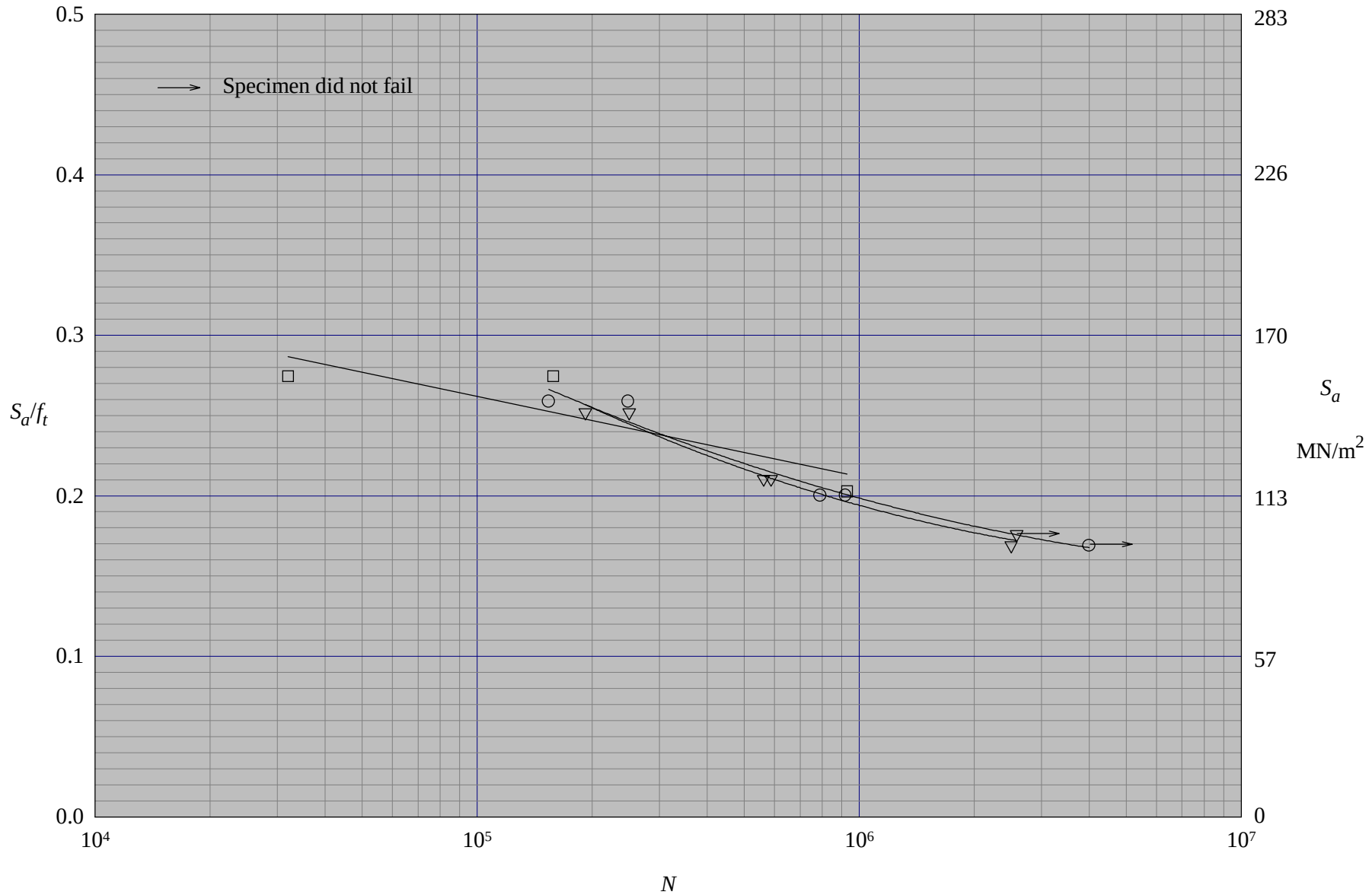


FIGURE 9.3 THREE AND FOUR BOLT DOUBLE LAP JOINTS OF A440 STEEL WITH $R = 0$. SEE TABLE 9.3.



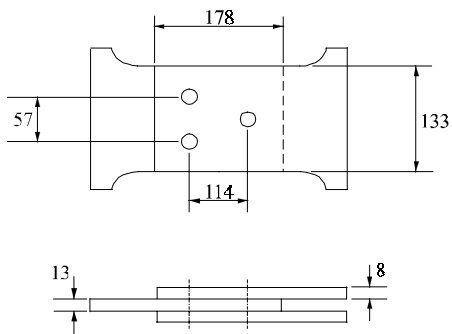
TABLE 9.3 Details of Joints for Figure 9.3

Symbol and specimen type (see Section 7 for key)	Material specification	Condition of contacting surfaces (see Section 7 for key)	Material tensile strength MN/m ² (10 ³ lbf/in ²)	Bolt type	No. of bolts	Average initial bolt tension kN (10 ³ lbf)	Bolt diameter mm (in)	Dimensions of joint, doubler or plate					Coefficient of friction	Clamping pressure MN/m ² (10 ³ lbf/in ²)	Derivation Number
								Overlap length mm (in)	Width mm (in)	Land mm (in)	Centre plate thickness mm (in)	Cover plate thickness mm (in)			
○	A440	DMS	566 (82)	A490	3*	239 (54)	19 (0.8)	178 (7)	133 (5.3)	28 (1.1)	13 (0.5)	8 (0.3)	0.18-0.22	32 (4.6)	5
□	"	"	"	"	3 [†]	240 (54)	"	"	"	"	"	"	0.16-0.19	"	
▽	"	"	"	"	4	195 (44)	"	"	"	"	"	"	0.16	35 (5)	

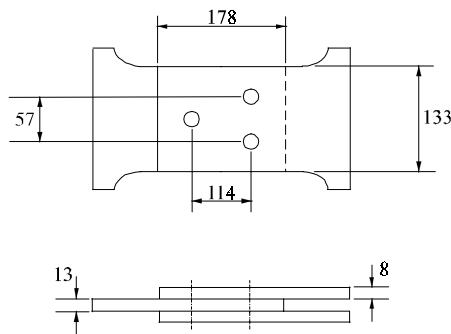
* See Sketch 9.3a below for arrangement of bolts.

† See Sketch 9.3b below for arrangement of bolts.

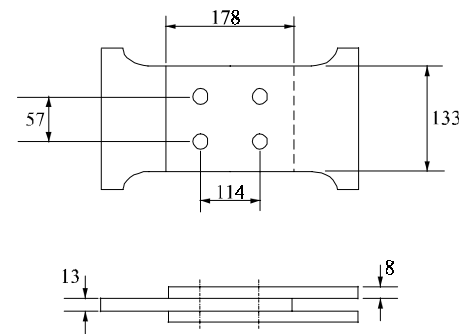
All dimensions in millimetres



Sketch 9.3a Three bolt double lap joint



Sketch 9.3b Three bolt double lap joint



Sketch 9.3c Four bolt double lap joint