

FATIGUE STRENGTH OF LONGITUDINAL FLANGE-TO-WEB WELDS IN STEEL I-BEAMS AND T-SECTIONS

1. NOTATION

I	second moment of area of beam cross-section	m^4	in^4
M	moment applied to beam section	N m	lbf in
N	endurance		
S_a	longitudinal alternating stress (half range) at weld	N/m^2	lbf/in^2
y_w	distance of weld from neutral axis (see Sketch 2.2)	m	in

Both SI and British units are quoted.

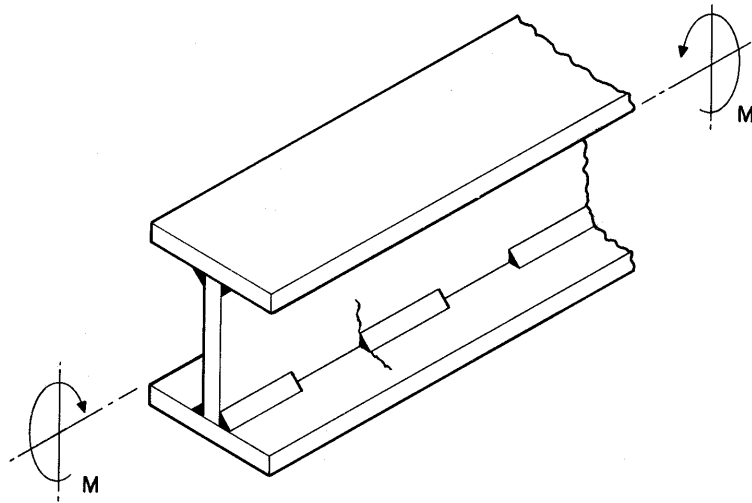
2. NOTES

This Item presents data on the as-welded fatigue strength of symmetrical section I-beams and T-sections built up from flat steel plate using longitudinal flange-to-web welds, see Sketches 2.1 to 2.3. Data are presented for continuous automatic and manual welds, both with and without full penetration, and for discontinuous fillet welds. The I-beams were tested in simple bending under three- and four-point loading. The T-sections were loaded axially and uniformly across their complete cross-section.

Since in all cases the depth of the I-beam was large and the dimensions of the weld relatively small in relation to the cross-sectional dimensions of the beam, the data for I-beams are presented in terms of the longitudinal stress range acting on the weld. The stress was calculated by using simple bending theory, $S_a = My_w/I$, where y_w was the distance from the neutral axis to the inside of the flange. Where three-point bending was employed the principal stresses were calculated but they did not differ significantly in either magnitude or direction from the stresses obtained from simple bending theory. Therefore the data for all beams are plotted using simple bending theory, there being no discernible difference between three- and four-point loading cases.

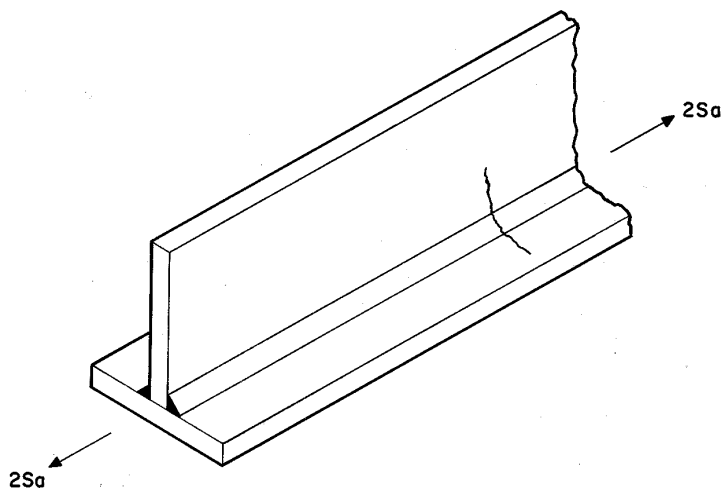
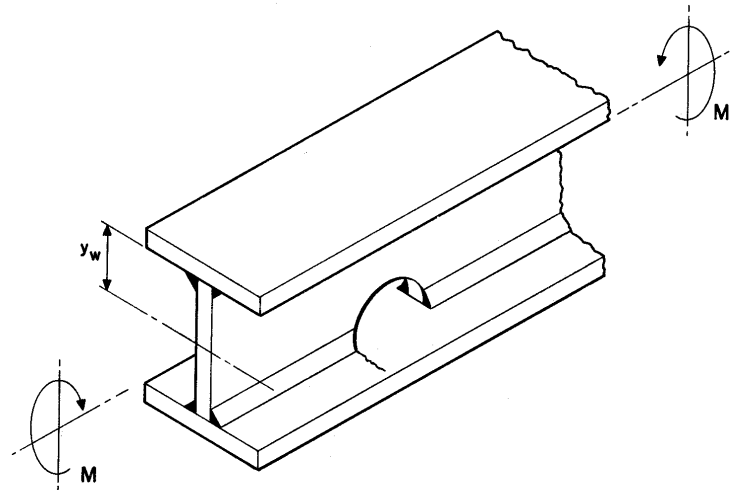
T-section specimens were tested under uniform axial loading at four mean stress levels with a cyclic stress range of $2S_a$. They all exhibited a fatigue strength which was indistinguishable from that of I-beams in bending, described in the previous paragraph, because the flange-to-web detail was identical. The data may therefore be taken to apply to I-beams that are subjected to uniform axial loading.

Figure 1 gives data for all continuously welded I-beams in bending and axially loaded T-sections. The mean line through the data is provided together with scatter bands which contain 95 per cent of all the data. Figures 2 and 3 give data for continuous automatic and continuous manual welds respectively showing the effects of depth of penetration and comparing the data with the 95 per cent scatter bands from Figure 1. Figure 4 shows the data for intermittent fillet welded beams and beams with cope holes and similarly compares these with the 95 per cent scatter bands from Figure 1.



Sketch 2.1 I-beam with
intermittent fillet welded
web-to-flange joint

Sketch 2.2 I-beam with cope
hole in the web



Sketch 2.3 T-section under
uniform axial loading

Provided that the welds are sound and free from major defects, the endurance of welded beams is independent of the properties of the plate and weld materials (except in the low cycle fatigue region). For longitudinally loaded welds in beams the endurance of welds is independent of the applied mean stress. This is because as-welded longitudinal joints contain a highly localised system of residual stresses in the direction of loading which results from the internal constraints applied during cooling of the weld and which are of the order of the yield strength. Hence, any applied loading will cause local yielding during the first few load cycles. The actual stress experienced in the critical region, whether in the tensile or compressive side of the beam, will thereafter cycle between the yield strength and the yield strength less the applied stress range irrespective of applied mean stress and stress ratio. Thus, fatigue cracks can initiate in the weld on either the tensile or the compressive side of the beam. In the vast majority of cases the crack in the tension flange leads to failure first but in a very few cases failures in the compression side have been recorded. Therefore welds on the compression side should not be assumed to be immune to fatigue failure. Very large joints may, due to fuller development of residual stress, be expected to produce an endurance at the lower edge of the scatter band.

Failures in beams initiate at either internal defects such as porosity or slag inclusions, or from surface defects such as weld ripples, blowholes or variations in weld bead geometry. Fatigue endurance is lower if surface defects cause initiation of fatigue cracks before internal defects. Fatigue cracks, once formed, run through the thickness of the flange then transversely across the flange and web to cause failure, as shown in Sketches 2.1 to 2.3.

3. CONTINUOUS AUTOMATIC WELDS

The data for joints manufactured by automatic welding are given in Figure 2. The symbols show the results for joints with complete web penetration and those for joints with partial web penetration. Joints with full penetration exhibit a slightly higher fatigue strength on average than those with partial penetration as the figure shows. The root defect produced by incomplete web penetration lies parallel to the loading direction and therefore would not be expected to affect seriously the fatigue strength. Where a nominally continuous weld has un-repaired start-stop positions the fatigue strength can be expected to fall to the lower end of the scatter-band for continuous welds and in more severe cases the fatigue strength may be compared to that of a discontinuous weld.

4. CONTINUOUS MANUAL WELDS

Data for manually welded beams, given in Figure 3, indicate that full penetration joints again show a slightly higher fatigue strength on average than those joints having partial web penetration. The data show that a good manual weld is not necessarily worse than a weld produced by the automatic process but, in production circumstances, a fatigue strength at the lower end of the 95 per cent scatter band for continuous welds is to be expected. Manual welding does not display the uniformity shown by automatic welding and will vary in quality with the expertise of the individual welder. Surface defects such as weld ripples and variations in weld geometry occur and are the major source of crack initiation and the fatigue strength is, in general, lower than that for automatic welding. Failure occurs in a similar manner in both automatically and manually welded beams.

5. INTERMITTENT WELDS AND BEAMS WITH COPE HOLES

Beams and T-sections with these features, shown in Sketches 2.1 and 2.2 respectively, have a stress concentration at weld ends where the weld run is stopped. The fatigue strength of these joint types is shown in Figure 4 and falls in the main distinctly below the 95 per cent scatter band for continuous welded beams