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### III a 5

## The Fatigue Strengths of Welded Connections in St. 37 and St. 52.

## Dauerfestigkeit von geschweißten Verbindungen von St. 37 und St. 52.

## La résistance à la fatigue des assemblages soudés en acier St. 37 et St. 52.

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It has been shown in previous experiments that the fatigue strengths obtained in laboratory experiments with round and flat bars of St. 37 which have been worked smooth, are the same as those of the unwelded material as rolled, but in the case of St. 52 they are lower than the latter. Hence in St. 37 the fractures occur outside and in St. 52 within the weld, but in spite of this the fatigue strength of the welded connection of St. 52 is at least 30 % higher than that in St. 37. Since, moreover, the permissible stresses in St. 52 are 30 % higher than those in St. 37, the same should be true of the welded connections, provided that heavy coated, high quality electrodes have been used.

The values determined are shown in Table 1.

Table 1.

Bending fatigue strengths for welded and unwelded St. 37 and St. 52.

Material	Fatigue strength kg/mm <sup>2</sup>	Breakage
(a) Bending fatigue tests on round specimens.		
St. 37 — unwelded	$\sigma_{wb} = 20.1$	—
— welded	$= 20.1$	Outside
St. 52 — unwelded	$\sigma_{wb} = 30.8$	—
— welded	$= 26.4$	Inside
Deposited weld metal	$\sigma_{wb} = 24.3$	—
(b) Bending fatigue tests on flat specimens.		
St. 37 — unwelded	$\sigma_{wb} = 17.8$	—
— welded	$= 17.8$	Partly in weld
St. 52 — unwelded	$\sigma_{wb} = 30.5$	—
— welded	$= 22.5$	In weld
(c) Torsion fatigue test on round specimens.		
St. 37 — unwelded	$\sigma_w = 11.5$	—
— welded	$= 11.5$	Outside
St. 52 — unwelded	$\sigma_w = 17.2$	—
— welded	$= 15.5$	Inside
Deposited weld metal	$\sigma_w = 15.3$	—

These results, while interesting for purposes of comparison, are of little practical importance, for the conditions in practice are quite different, the majority of connections in welded bridges and building structures not being worked over, with the result that non-uniform distribution of stress occurs and these effects are further increased by notch action at the edges of the weld or at the base of fillet seams. There are, therefore, two factors which play a decisive part, namely 1) the execution and workmanship of the weld. 2) The design of the connection.

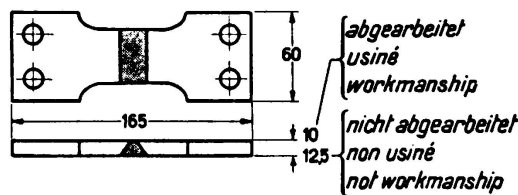


Fig. 1.

Shape and dimensions of flat bending specimen for fatigue tests.

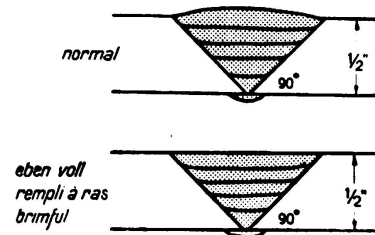


Fig. 2.

Execution of welds.

The effect attributable, to the execution and workmanship of the weld was examined by the authors with the aid of flat bending test bars as indicated in Fig. 1, the weld itself being carried out either in the usual way or smoothed (see Fig. 2), while in a third experiment the upper surface of the bead was filed off. The results of these experiments are shown in Table 2 together with values for unwelded material of three different types of St. 52 — a chrome-copper steel (I), a manganese-silicon steel (II), and a manganese steel (III).

Table 2.

Fatigue strengths of welded connections in St. 52.

Steel	Not welded. Upper surface filed	Welded		
		Weld filed	Not worked	
			Welded in ordinary way	Filled smooth
I	31.0 kg/mm <sup>2</sup>	23.0 kg/mm <sup>2</sup>	11.0 kg/mm <sup>2</sup>	15.0 kg/mm <sup>2</sup>
II	29.0 „	21.5 „	9.5 „	16.5 „
III	31.5 „	22.5 „	8.0 „	14.0 „

In the case of all the bars which have not been smoothed fracture occurs at the junction of the weld metal and the plate material, either on the upper side of the V seam (Fig. 3) or on the root side at the edge of the backing bead (Fig. 4); a circumstance which may be explained by changes in the micro-structure caused by the more or less remarkable hardening effect at these places (Fig. 5). The efforts of the steel maker will, therefore, be directed towards limiting this increase in hardness as much as possible, but as the phenomenon is

connected with the increased strength of these steels it cannot be entirely avoided. The most favourable results were found in the chrome-copper, chrome-molybdenum and manganese-silicon steels when the amount of alloy element present

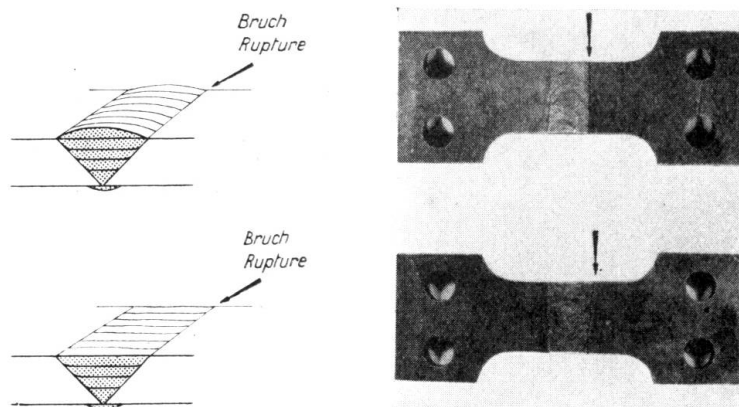


Fig. 3.

Fatigue failures at transition from weld to plate.

was as low as possible, and especially when the carbon content did not exceed 0.15 to 0.20 %.<sup>1</sup>

The effect of shape was examined in a T-connection carried out in several different ways and tested under dynamic loading simultaneously with static pre-

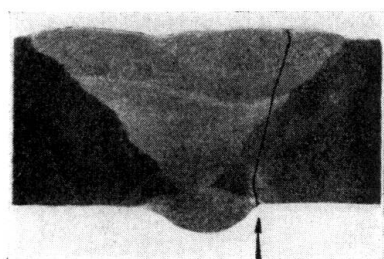
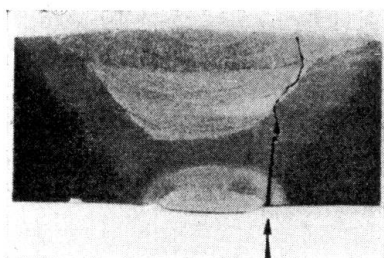


Fig. 4.

Beginning of fatigue failure at edge of reverse bead.

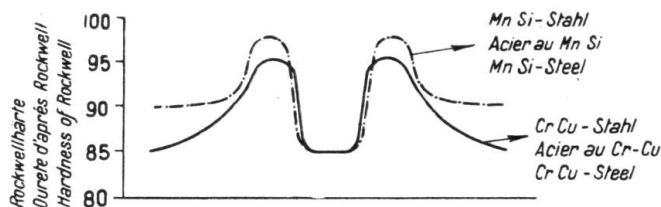
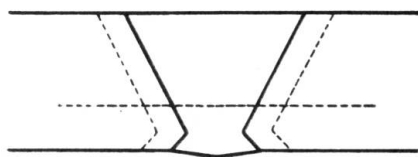


Fig. 5.

Distribution of hardness in a welded connection in St. 52.

stressing. In accordance with the method of calculation adopted by the bridge construction bureau of the Netherlands Railways the dynamic stress was taken as

<sup>1</sup> See Smit-Laschtydschrift, Vol. 1, N° 2 (1937).

30 % of the static pre-stress, and it was sought to obtain in each connection the maximum value of this pre-stress which did not result in fracture after two million changes of load (see Fig. 6).

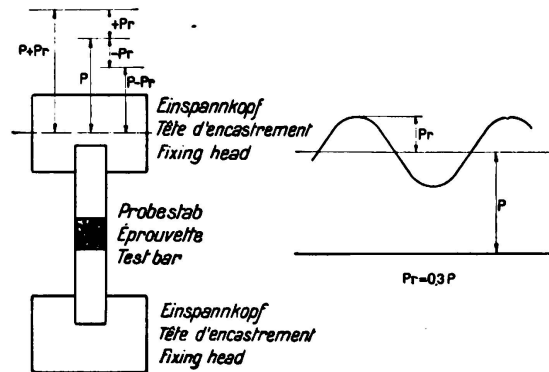


Fig. 6.

Variations of stress in experiments on stress alternating between tension and compression.

The experiments were carried out in a Losenhausen pulsating machine. The T-connection was made in the form of a double-sided fillet weld and as an X-weld (Fig. 7 and 8). The results of the experiments are given in Table 3.

Table 3.  
Results of fatigue tests on welded connections  
in St. 37 and St. 52.

Material	Connection	Maximum statical pre-stress kg/cm <sup>2</sup>	Dynamic stress	Stress changes without fractures
St. 37	X-weld (Fig. 7 a)	1900	$\pm 30\%$	$2 \cdot 10^6$
	Fillet weld (Fig. 7 b)	1250	$\pm 30\%$	$2 \cdot 10^6$
St. 52	X-weld (Fig. 7 a)	2000	$\pm 30\%$	$2 \cdot 10^6$
	Fillet weld (Fig. 7 b)	1000	$\pm 30\%$	$2 \cdot 10^6$

These results indicate that the fillet seams of the connections in St. 37 possess a higher dynamic strength than those in St. 52, but in the case of the X-seams the values are approximately equal. This clearly shows that the fatigue strength of welded connections in St. 52 is not greater than in St. 37, a fact which may be explained by the greater notch sensitiveness of St. 52. Moreover in both cases the strength of X welds is much greater than that of the fillet seams, and the general rule holds good, therefore, to adopt butt welded connections wherever possible.

When fillet welds cannot be avoided they are best made as shown in Fig. 9, the weld having the maximum possible depth, and being made smooth at the edges with a gradual transition into the parent metal without any notches.

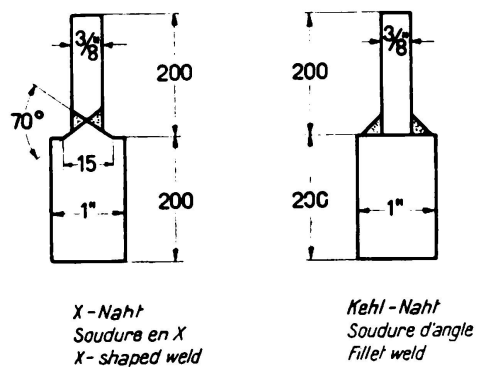


Fig. 7.

Shape and dimensions of specimens for tensile-compressive alternating stress experiments.

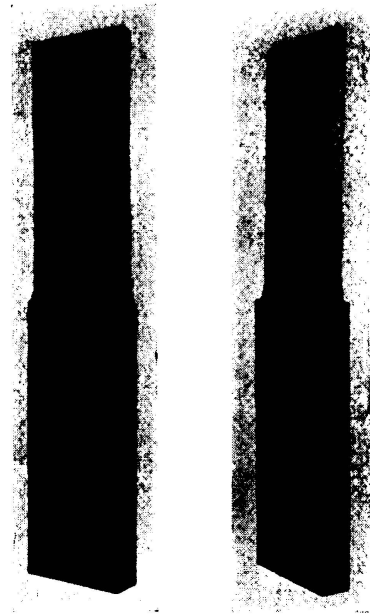


Fig. 8.

Welded specimens for experiments as in Fig. 7.

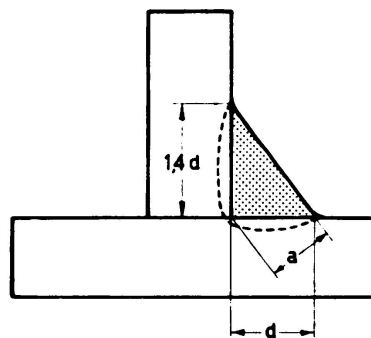


Fig. 9.

Ideal form of fillet seam offering maximum resistance to static and dynamic loading.

The author's experiments were further extended to fatigue tensile tests with shear stresses, but as these have not yet been completed the results will be reported later.