Zeitschrift: IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht

Band: 2 (1936)

Artikel: Strengthening of the Austerlitz viaduct in Paris by electric arc welding

Autor: Fauconnier, M.

DOI: https://doi.org/10.5169/seals-3329

V 14

Strengthening of the Austerlitz Viaduct in Paris by Electric Arc Welding.

Verstärkung der Austerlitzbrücke der Pariser Stadtbahn durch elektrische Licht=Bogenschweißung.

Renforcement du Viaduc d'Austerlitz par soudure à l'arc électrique.

M. Fauconnier,
Directeur des Travaux Neufs de la Compagnie du Métropolitain de Paris.

Line No. 5 of the Metropolitan Railway of Paris crosses the Seine close to the Gare d'Austerlitz by a steel bridge covering a single span of 140 m between the banks, which is a greater span than that of any other bridge in Paris.

The structure consists of a three-hinged arch, with the side hinges carried not on the abutments but on cantilevers which project 14 m. The result is an

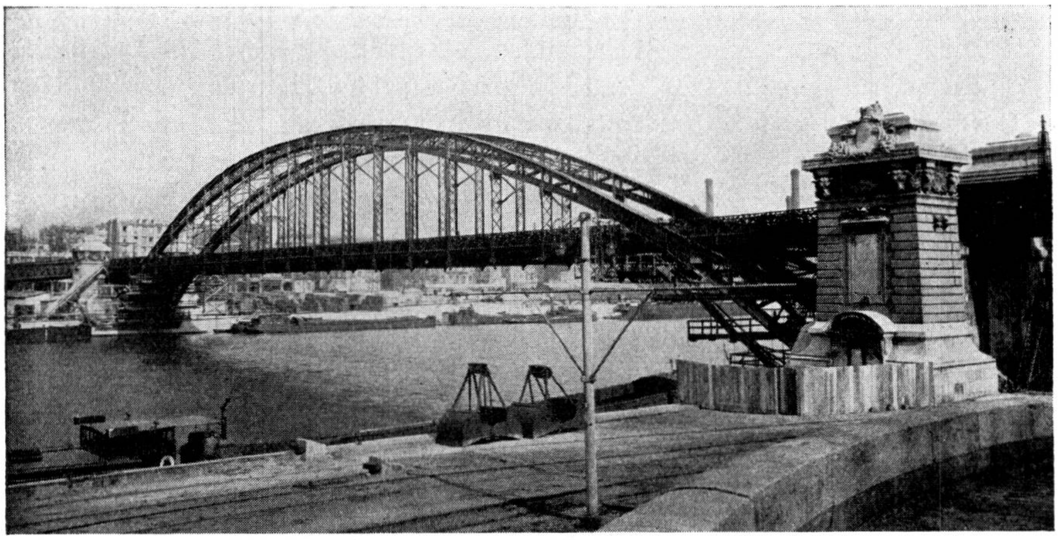


Fig. 1.
Austerlitz bridge.

appearance of lightness which has deservedly won the admiration of engineers (Fig. 1). The weight is 820 tonnes. Unfortunately the design was carried out on the assumption of a light train load of 121 tonnes with a length of 50 m, whereas to-day, thirty years after the construction of the bridge, the typical train for the Metropolitan Railway measures 105 m in length and weighs 420 tonnes. The live load is consequently more than trebled.

The bridge is now being strengthened by the Company and the conditions governing this work are, to the author's knowledge, without precedent anywhere in the world. The effective cross sections of the arch are being increased by as much as 60 %, and the weight of the structure is being increased from 800 to 1000 tonnes. The arch is of the three hinged type and its span is considerable. The equilibrium of the cantilevers must be re-established in such a way that the line of pressure continues to pass through the middle third, and all this work must be done under a traffic of 700 trains a day across the bridge.

The reinforcing members, which are 70 × 140 mm flats and various rolled sections, are being placed between the lines of rivets, and the strength elements of the original structure are being maintained complete.

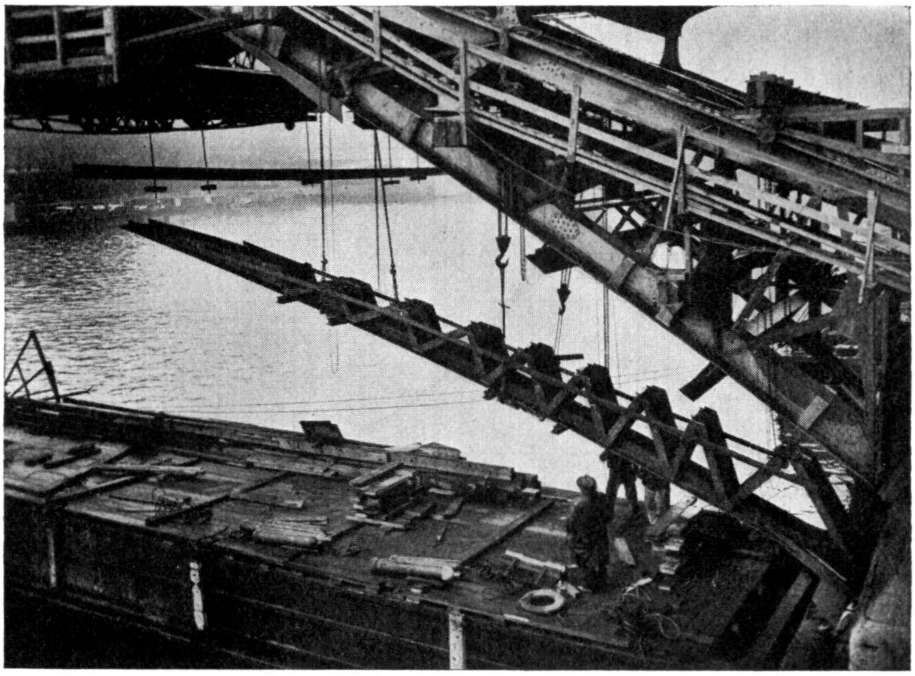


Fig. 2.
Strengthening of springings.

The condition of stability for the cantilevers (namely that the line of pressure should remain within the middle third) is being satisfied by adopting the expedient of welding into place under the lower flange a supplementary construction which is fabricated beforehand and is erected in a single operation.

The calculation has been based on the following simple assumption: namely that the added steel receives no stress except from live load, while the old steel carries the whole of the dead load and at the same time participates in resisting live load. The validity of this assumption has been proved by direct experiment.

It might be thought that it would be essential to take account of internal stresses due to welding, but actually this is a mistake, for such stresses are local in their incidence, and in proportion as they tend to become dangerous they also tend to be compensated by the high ductility which is characteristic of Steel 37.

The original metal is an extra mild Martin steel containing less than 0.10 % of carbon and is, therefore, perfectly suited for welding. Its breaking stress is 40 kg/mm² and the elongation 32 %. The steel used for the reinforcement has purposely been chosen milder still so as to ensure perfect welding qualities, its breaking stress being 37 kg/mm² and elongation 34 %, and the chemical composition being required to comply strictly with the following analysis:

$$C \leqq 0.10\ \%$$
$$Mn \leqq 0.40\ \%$$
$$Si \leqq 0.20\ \%$$
$$P \leqq 0.04\ \%$$
$$S \leqq 0.04\ \%$$

The resilience is required to be not less than 10 kgm/cm² as measured on a *Mesnager* specimen.

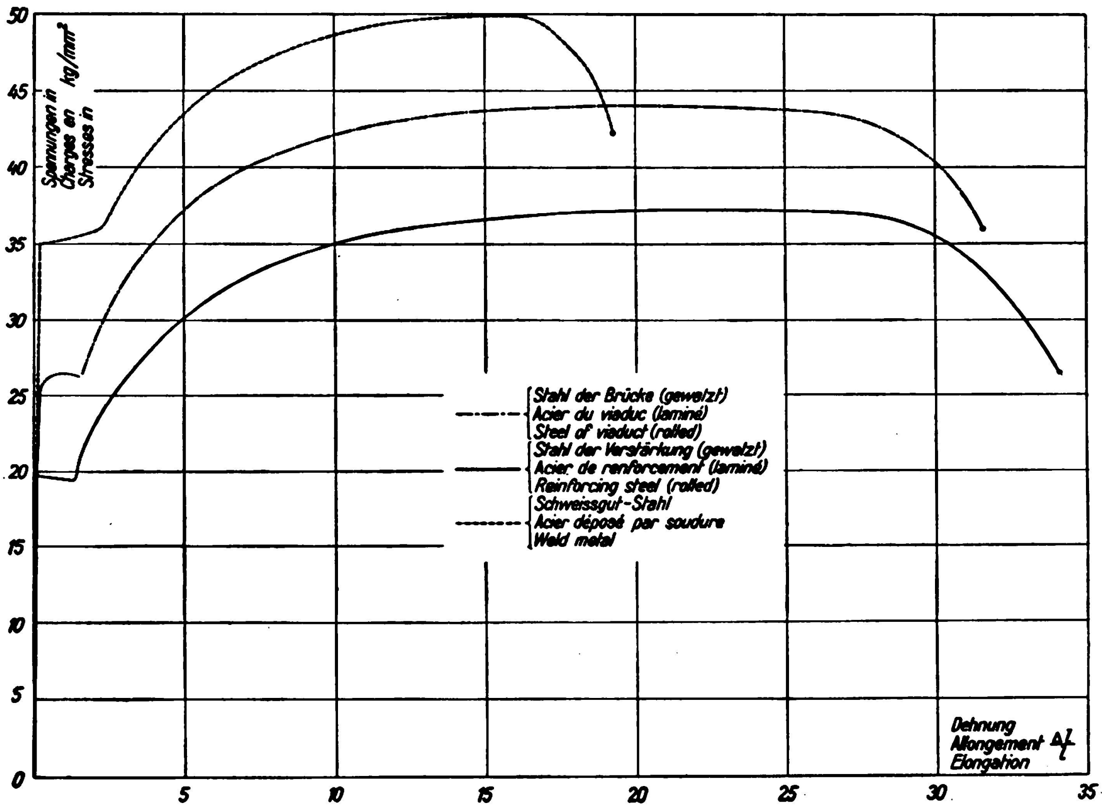


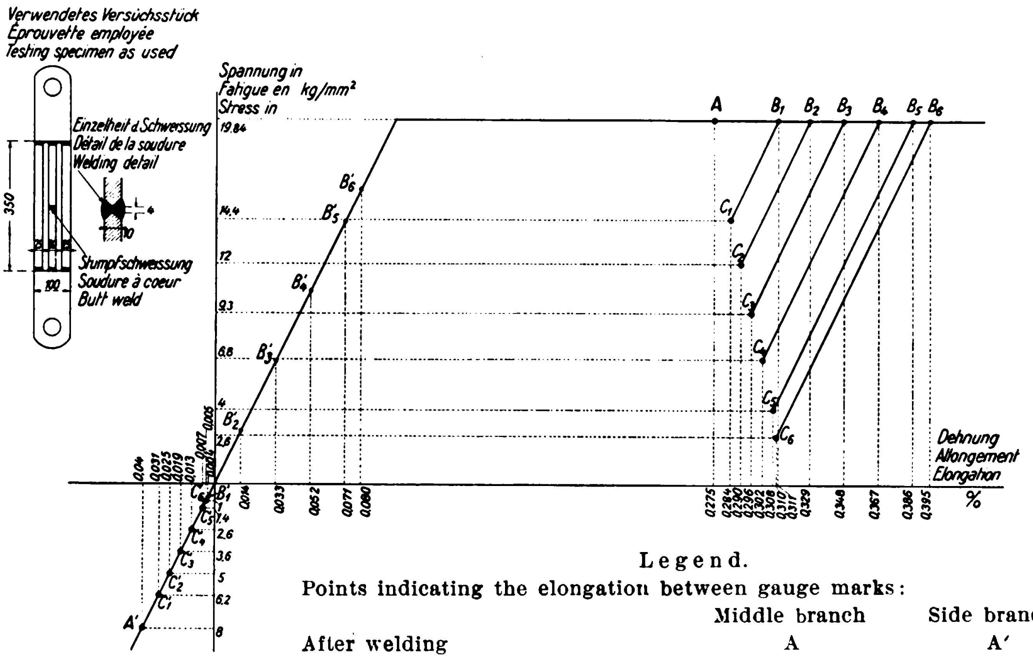
Fig. 3.

Stress-deformation diagrams of steel.

The upper curve in Fig. 3 represents the cast metal deposited from the electrodes, giving 48 kg/mm² ultimate strength and 20 % elongation, with a minimum resilience of 8 kgm/cm² on the *Mesnager* bar. All three curves in Fig. 3 are of similar shape.

An essential condition to be satisfied is that any elongation of the metal between the limits of 1 and 15 per 1000 should be unaccompanied by increase in stress. Now, in arc welding, it is the case that the molten metal contracts by 10—15 per thousand in the process of changing from a semi-plastic state, wherein it offers practically no strength, to its final condition with the normal ultimate strength of 45—50 kg/mm²; hence it is important, when working on tightened members, that the parent material close to the weld seam should be capable of following the deformation imposed, by itself extending.

By virtue of this property, which the diagrams indicate to be a characteristic of really mild steel, the final equilibrium is obtained without the internal stresses exceeding the elastic limit at any point or at any time.



Legend.

Points indicating the elongation between gauge marks:

	Middle branch	Side branches
After welding	A	A′
After imposition of external loads	B1 B2 B3 B4 B5 B6	B′1 B′2 B′3 B′4 B′5 B′6
After removal of external loads	C1 C2 C3 C4 C5 C6	C′1 C′2 C′3 C′4 C′5 C′6

Fig. 4.

Diagram of internal stresses under the influence of external forces. Deformation diagram.

A large number of measurements of internal stresses were carried out systematically, and the results so obtained — usually of the order of 14 kg/cm² — were below the elastic limit. This still leaves open the question whether, under the effects of external loads (dead and live) added to the internal stresses, the total stress might not rise to an excessive value, but it has been shown, notably by *Dr. Kommerell* and Mr. *G. Fish* by reference to the stress strain diagram, that such apprehension is unjustified, and the author has confirmed experimentally as regards simple compressive and tensile strains that the internal stresses are relieved under the action of the external loads. The following essential fact was established: if any external load is applied momentarily to a welded system in such a way as to cause *permanent* elongation of any kind in any element of that sytem, then, when the force is removed, an internal effect occurs which reduces the residual internal tension within the element concerned.

The specimen used had three branches, as shown in Fig. 4, the central piece being jointed. At the centre the shrinkage due to welding causes simple deformations which can easily be measured with a *Huggenberger* deformeter; these are limited to an elongation of the central portion which is thus placed under tensile stress, and to a shortening of the side bars which are placed in compression. The application of external load to this specimen is effected in a tensile testing machine, fitted with arrangements to avoid the introduction of bending stresses. The different stages of the test are represented in the diagram, Fig. 4, and its accuracy is remarkable; it will be seen that in the central piece the action of the external load has enabled the tensile stress to be reduced from 19.8 to 2.6 kg/mm^2

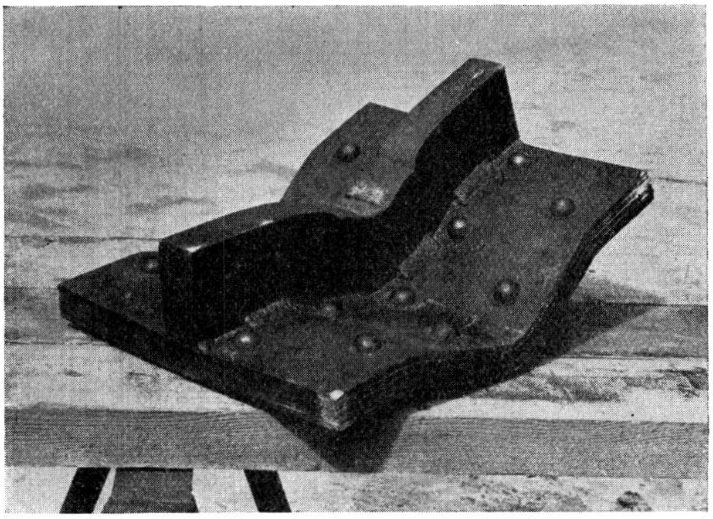


Fig. 5.

1st Homogeneity test.

(Deformation without rupture, under a pressure of 700 tons.)

and the permanent elongation is increased from 0.275 % to 0.310 %. By carrying the test further it would be possible entirely to eliminate the internal stresses. No sign of cracking was observed.

In order that this relief of internal stresses may be ensured in practice it is necessary that the ductility of the parent metal, the weld metal and the cast metal should be as high as possible, and should be of the same order of magnitude for all three. Homogeneity is the quality required.

The existence of this homogeneity has been shown by a curious kind of test. To a member composed of five riveted plates there was affixed a bar measuring 60×130 mm by means of weld seams 16×16 mm in cross section, carried out in several runs. These large seams were made discontinuous, and immediately close to the rivets there was nothing but a small seam of 5×5 mm.

This connection withstood, without fracture, a load of 700 tonnes. Fig. 5 shows the unbelievable amount of deformation sustained by the piece in question, and affords an answer to all possible criticism; homogeneity has in fact been obtained.

For the purpose of comparison the same test was carried out with a continuous seam of 8 × 8 mm (reduced to 5 × 5 mm close to the rivets). Instead of 700 tonnes being applied without breakage as in the preceding test, the failure of the seam then took place under a load of 170 tonnes (Fig. 6).

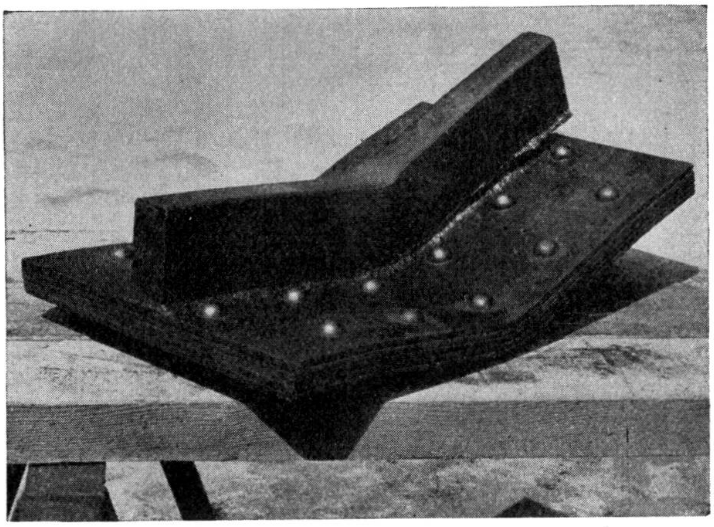


Fig. 6.

2nd Homogeneity test.

(Ruptured under a load of 170 tons.)

To sum up, the work now being carried out on the Métropolitain in Paris is the most difficult kind of welding job that can arise, because applying to structure parts not only tightened but under traffic the whole time. The operation is already well advanced; its success is directly dependent on the remarkably high quality of the electrode used (type L 40 as supplied by the Soudure Autogène Française) and, above all, on the choice of a very ductile reinforcing metal, namely Steel 37 of *prescribed chemical composition.*