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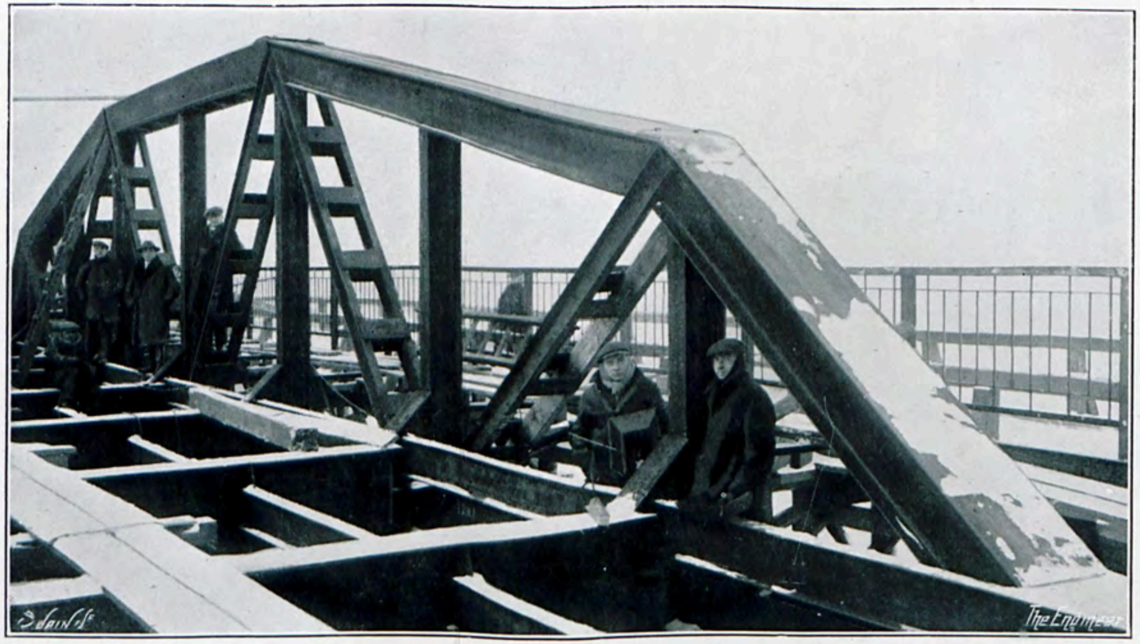

Fig. 4—Bridge during Construction

THE FIRST ARC-WELDED BRIDGE IN EUROPE.

THE first welded road bridge in the world and the first arc welded steel bridge in Europe was erected for the Polish Government near Lowicz, over the river Sludwia. It is situated on the principal State highway, Warsaw-Poznan-Berlin, and has a total width of 10 m. and a clear span of 26 m. The arrangement is rather exceptional, as the footpaths are carried on brackets on the outsides of the two main girders.

The calculations for moving loads were made in compliance with the specifications of the Polish Ministry of Public Works, issued in 1925. These specifications provide that the roadway is to be divided into longitudinal zones, each 2.50 m. broad, and each zone is to be loaded with a 20 ton (12 + 8) steam roller, 6 m. long—1, Fig. 1—with before and behind it a permanent load of 500 kilos. per square metre = 1.25 ton per metre length of a zone. To find the permissible live load on the total width of the roadway, the load of one zone is to be multiplied by the coefficient $a = 0.4\ b$ for the width of the roadway $b < 5.00$ m. and $a = 1 + 0.2\ b$ for $b > 5.00$ m. This means that the total live load of the roadway may grow proportionally to the width of the roadway until $b = 5.00$ m. is reached; it then increases more slowly, for b greater than 5 m.

The cross beams were calculated as semi-rigid fixed beams, and the internal stresses were calculated with loads in the worst positions, and the compression members were calculated for buckling by the formula Tetmajer-Jasinski.

The material of the bridge is mild steel with an ultimate tensile strength of 3,700—4,200 kilos. per square centimetre, and a minimum elongation of 20 per cent.

SPECIFICATION FOR THE ARC WELDED CONSTRUCTION.

Specification for the arc welded construction was accepted by the Polish Ministry of Public Works in April, 1928, on the base of the proposition settled on the conference of the Directory of Soudure Electrique Autogène and the author. It is the first official specification for welded steel structures in the world. The following provisions are made in it:—The electrodes are to be prepared from mild steel with an ultimate strength of 3,700—4,200 kilos. per square centimetre; it shall contain a minimum of 0.1 per cent. carbon and 0.25 per cent. manganese. They will be submitted to the following tests:—

TENSION TESTS.—The specimens of mild steel are to be welded as shown in 2, Fig. 1, and the section is then to be reduced according to 3, Fig. 1. The ultimate tensile stress must equal at least 80 per cent. of the ultimate stress of the mild steel, *i.e.*, 0.8 × 3,700 =2.960 kilos. per square centimetre—three tests.

For the elongation test the specimens are to be prepared from a steel plate in which a groove 9 mm. deep has been cut. In this groove welded metal is to be placed in successive layers—4, Fig 1. Afterwards, the specimen is to be reversed, reduced by 9 mm.—5, Fig. 1—on the other side, and filled with the electrode again. The plate constituted in this manner is then to be divided into three pieces, from which three round test pieces, 10 mm. in diameter, are to be formed—6, Fig. 1—and on them the elongation is to be measured. The elongation shall be 18 per cent. at least—three tests.

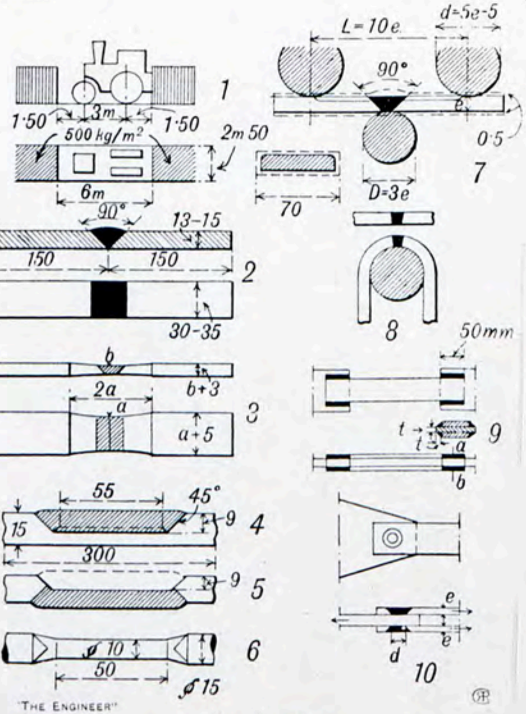

Fig. 1—Tests

Bending tests are to be carried out on flat plates, 120 × 70 × 15 mm., and are to be vee-welded in the middle—7, Fig. 1—and then be bent round a bar of a diameter equal to three times the thickness of the specimen—8, Fig. 1. No cracks shall appear when bending the specimen through 180 deg.—three tests.

For shearing tests the test pieces are to be made from two steel plates joined to gussets with welds 5 × 5 mm., 10 × 10 mm., 15 × 15 mm., and 5 cm. long—9, Fig. 1. The sections of the plates must be sufficient to resist the force S.

Width of the Weld.

mm.	kg.	kg./cm.
t = 5	S = 12,000	R = 1,000
t = 10	S = 20,000	R = 1,800
t = 15	S = 28,000	R = 2,400

The minimum resistances of the welds are R—3 × 3 = 9 tests.

For shear tests in holes—10, Fig. 1—the test pieces must resist the force S depending on the thickness of the plate and on the diameter of the hole.

Thickness of steel plating. mm.	Diameter of hole at the bottom. mm.	S. kg.	S s. kg.
e = 8 ...	d = 8 ...	1,000 ...	750
e = 10 ...	d = 10 ...	1,400 ...	1,100
e = 12 ...	d = 12 ...	2,000 ...	1,600
e = 15 ...	d = 14 ...	3,000 ...	2,500

S s is the minimum resistance of the welds in holes —2 × 4 = 8 tests.

The welds were calculated according to the author's formula:—

$$K_s = (K_n - \mu\, t)\, t \text{ kilos. per square centimetre}$$
$$= (640 - 80\, t)\, t \text{ kilos. per sq. centimetre,}$$

where t is the width of the weld.

Flux-covered electrodes Arcos-Tensilend, manufactured by Soudure Electrique Autongène, Brussels, were used.

Construction of the Bridge.

The main members of the bridge are parabolic girder trusses—Fig. 2. Their theoretical span l is 27.0 m., and the height in the middle h is 4.30 m., thus—

$$\frac{h}{l} = \frac{1}{6.28}$$

All members of the trusses consist of plates, U beams, and angles—Figs. 3 and 4. The chords are double T-shaped, and consist exclusively of plates, the distance apart of the vertical plates being 300 mm., their height 370 mm., and their thickness 12 mm. The upper chord has one longitudinal plate, the lower one is composed of two plates of the dimensions shown in the drawings. Originally, the chords were designed with two and three plates, but they were replaced with chords of one and two plates to diminish the quantity of welding. The drawings show the principal features of the design.

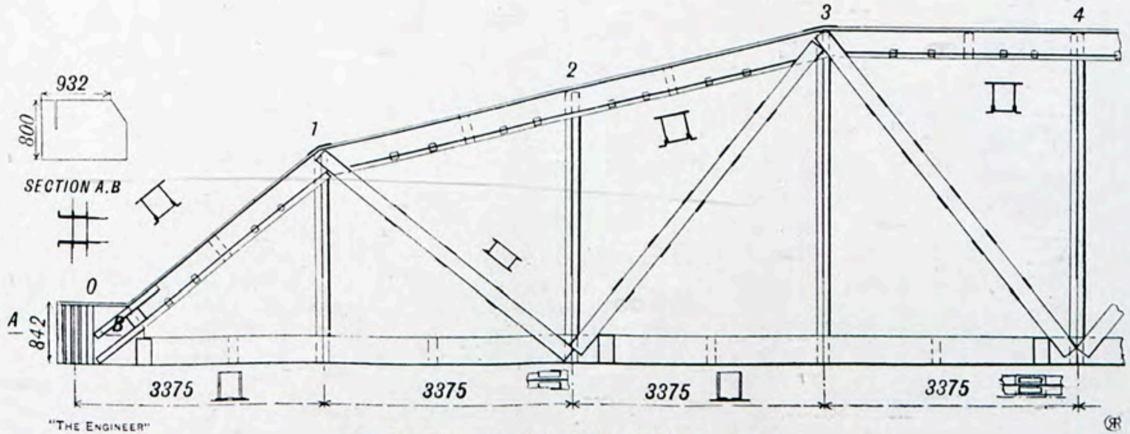

Fig. 2—Main Girder of Arc-Welded Bridge

I beams were used as longitudinal stringers, and were welded to the cross girders with the help of trapezoidal plates, not only for the purpose of fixing the stringers, but also to stiffen the web of the cross girder. This construction permitted the stringers to be calculated as continuous

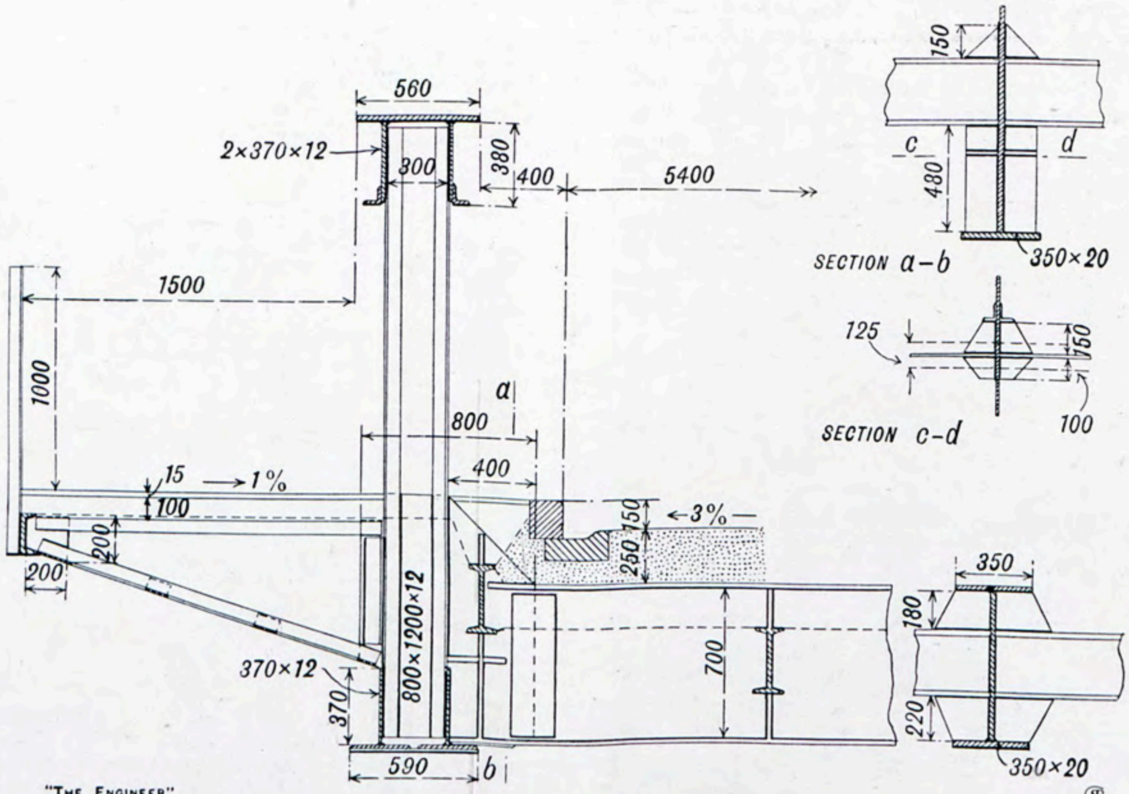

Fig. 3—Part Cross Section

beams on elastic supports. The elasticity of supports diminishes to a great degree the advantage of continuity of beams, but it draws the cross beams into co-operation, and renders it possible to obtain a saving of 12 per cent. of the material of the cross beams.

All the plates are butt welded, but as in the calculation it was admitted that the butt weld has only 75 per cent. of the resistance of the constructional material, supplementary cover plates were added.

The wind bracing consists of angles, 70 × 70 × 7, welded to horizontal gussets joined to the lower chords of the main trusses, and of the cross beams.

The Erection of the Bridge.

Pieces up to 7 m. long were welded in the shop. To prevent the separate parts from moving, special forms—15, Fig. 5—were arranged at intervals of about 1 m. The forms consisted of 20 mm. round bars bent to suit the cross sections of the welded piece. Gussets were welded to the interior of these bars and between them a gap of 5 cm. to 6 cm. was left. The opening was adjusted by means of two angles, so as to secure a width corresponding to the thickness of the vertical plates, *i.e.*, 12 mm. As horizontal locks, 50 mm. channel irons were employed. For the upper chord, which has a double T section, the channel stiffeners were placed between the vertical plates of the chord—16, Fig. 5. Between the gussets and the flange plates, a space of 25 mm. was left to permit the free access of the electrode.

The verticals are formed from a plate and four angles. All these parts were fixed by aid of two screws on both ends, and some short welds along each vertical. The two channel irons of the diagonals were fixed by means of two short channel irons, provisionally screwed to them. The exact distance of the channel irons was also assured by aid of plates with two suitable notches cut in them—17, Fig. 5. The cross girders were constructed by aid of forms similar to those employed for the chords—18, Fig. 5.

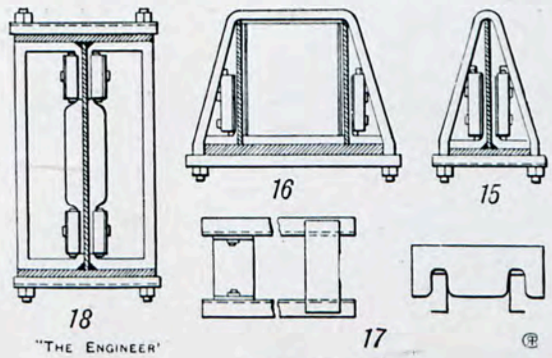

Fig. 5—Forms

The available electric current at the field was about 180 ampères and 30 volts. Hand welding was used everywhere. The shop work was done in the bridge works of K. Rudzki, in Minsk Mazowiecki, near Warsaw, with the aid of the welders sent by Soudure Electrique Autogène, of Brussels. The assembling on the site was executed on a temporary wooden trestle bridge. All the steel parts were brought to their proper place by aid of a wooden crane. The work began by building up the floor of the bridge, and afterwards the main trusses were erected. Three welders were employed for the construction of the bridge. The work occupied 1,100 hours-men in the shop and 900 in the field.

The floor of the bridge is of reinforced concrete.

The total weight of the bridge is 55 tons, as against 70 tons had it been riveted. The saving of construction material was thus about 21 per cent. Unfortunately, an equal saving was not effected in the cost of the bridge, as a great part of the amortisation of the cost of necessary arc welding machines had to be included. Hence, the arc welded bridge cost almost as much as a riveted bridge would have cost. Nevertheless, the author is firmly convinced that with the time the proportion of costs of the two types of bridges will be in favour of arc welded bridges. The courageous initiative of the Ministry of Public Works, and especially of Minister Moraczewski and Director of the Highways Department, Mr. Nestorowicz, who are the first Government Ministers to sanction arc welded structures, ought to be greatly appreciated.

The design of the bridge was made by the author, who also supervised the construction and erection. Messrs. Dolinski and Jasinski were also the supervisors in the shop, Mr. Swiercsynski at the field.