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Experience obtained with Structures Executed in Yugoslavia.

Erfahrungen bei ausgeführten Bauten in Jugoslavien

Observations sur les ouvrages exécutés en Yougoslavie.

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The new method of construction could at first be introduced into Yugoslavia only with difficulty, since the most important client, the State, obtained the greater part of its requirements in steel structures from Germany in the form of compensations. Consequently the State had few orders left for the home industry, which possessed excellent equipment for riveting work, but could utilize it only to a small extent; welding technique was therefore of interest only for subsidiary work and from a theoretical point of view. Since 1928 Prof. *Bryla*, the pioneer of welded constructions in Poland, has certainly — in a series of articles in the "Tenički list" — been calling the attention of architects and engineers to the theoretical principles of the new method, to its advantages and to the constructions already carried out in Poland; but the new method of construction was first only adopted to any considerable extent in 1931.

The development of welding abroad also compelled the home works to occupy themselves with it more closely and to introduce it into their own service. In addition to roofing structures with spans up to 25 m, boilers, tank, pylons, pipe lines, etc., were constructed by welding (Fig. 1).

The approaching termination of compensation deliveries and the annually increasing stringency in financial means, induced first of all the Ministry of Public Works to investigate the possibility of introducing the new method for public constructions, particularly because of its economy and the possibility of executing the work in the country. The first trial was made at the beginning of 1932 with a small bridge on the state highway between Paraćin and Zaječar, for which the grading was already in existence. Fig. 2 shows the dimensions and details of this bridge, which was executed as a plate girder bridge of 24.72 m span. The structural design is based on the designs usual at that time. The decking is formed by reinforced concrete arching held between the transverse girders, the thrust of the arching being transmitted to the abutments by means of tie rods. Because of its stiffness, it takes the place of the lower wind bracing. The bridge was calculated for the loading for 1st class bridges according to DIN 1072; the dimensions and design were based on DIN 1073 and 4100. The bridge is made of St 37; for the arc welding Böhler B-Elite

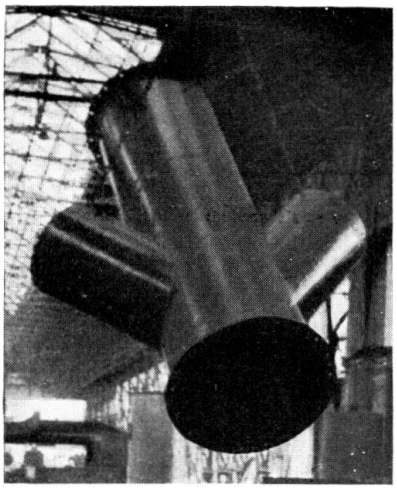

Fig. 1.
Branching of tubes, electrically welded.

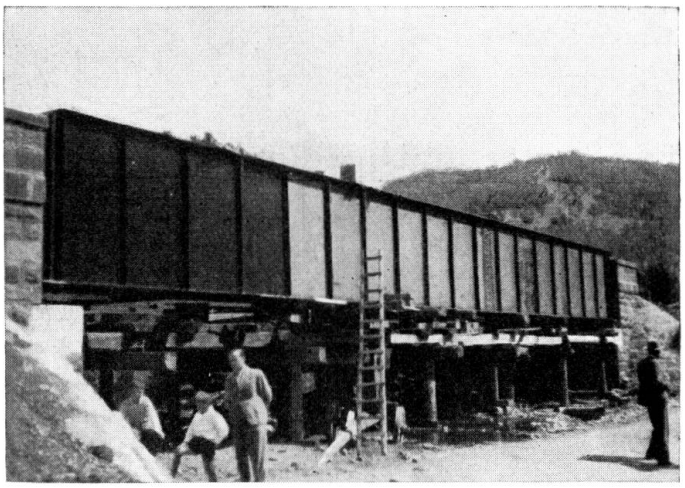

Fig. 2.
Grza Bridge.

core-electrodes were used. The weight of the bridge amounts to 32.16 tons. The stresses measured on the occasion of the trial loading agreed very well with the calculated stresses; the elastic deflection amounted to 13.05 mm.

Based on the experience gained, the same firm, Sartid-Smederevo, undertook in the following year the construction of the bridge over the Brnjica on the Banal highway between Golubac and Dobra: the main dimensions of this bridge were fixed by the already existing substructure for a steel bridge (compensation delivery) of 30 m span. Although alternative projects in reinforced concrete were also permitted, the firm decided to make the bridge of high-tensile steel. Fig. 3 shows the dimensions and details of this bridge, which has been designed as a parabolic girder of 31.20 m span, with a height of 3.90 m. The chords

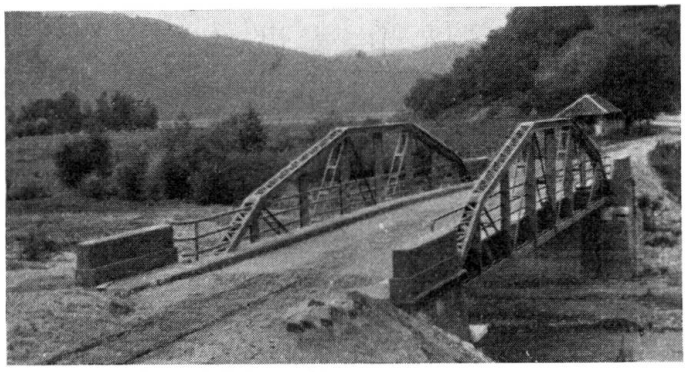

Fig. 3.
Bridge over River Brujica.

and diagonals are formed of channel sections, the cross girders are of the plate type, and the decking is similar to that of the Grza bridge. The design closely resembles that of riveted structures. The calculations and the dimensioning were based on the German standards DIN 1073 and 4100 for a loading with 18-ton steam roller, 12-ton lorry and a human crowd of 460 kg/m^2. The bridge is executed in St 52 with the exception of the verticals, for which St 37 had

to be used in order to obtain the requisite moment of inertia. The electrodes used were Böhler B-Elite core-electrodes 18 for St 52 and Böhler B-Elite core-electrodes for St 37 and the caulking joints. The weight of the steel structure with bearings amounts to 29.485 tons. The tensions in the members as measured at the tests agreed well with the calculated values; the deflection was only 6 mm, as compared with the calculated amount of 22 mm, and it disappeared completely when the load was removed.

Also in the western part of Yugoslavia, welded bridges were constructed in 1933.

To the order of the municipality of Maribor, the Splošna stavbena družba erected a steel bridge over the left arm of the River Drava to connect with the island on which the municipal bathing establishment is situated. The bridge is a continuous hinged lattice girder bridge of 21.42 + 61.20 + 21.42 m span. The hinges are situated in the first panel points of the side openings next to the river piers. The middle opening is spanned by a riveted lattice girder stiffened with a bar-arch; the two approach girders are allwelded lattice girders.

In 1934 the bridge-building firm Sartid was entrusted with the supplying and erecting of the bridge over the Stara Reka on the Banal highway Gostivar-Kičevo-Bitoli in southern Serbia. This is a small bridge of 18.90 m span, with 5.40 m between the main girders, which are designed as trapezoid Warren

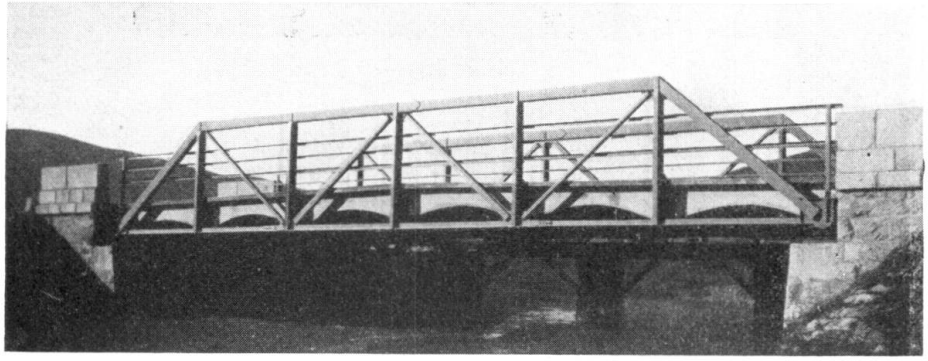

Fig. 4.
Bridge over the Stora reka.

girders with a maximum depth of 2.50 m (Fig. 4). The upper boom and the diagonals are of box-shaped cross-section, formed from two channel irons with the adjacent flanges connected together by welding. The flanges of the plated cross girders are of channel irons with the flanges turned downwards. This design allows the cross girders to take the horizontal thrust of the decking the design of which is the same as in the bridges over the Grza and the Brnjica. The calculations and design were according to DIN 1073 and 4100 for the loading of 2nd class highway bridges — 18-ton steam roller. The main and cross girders are made of St 52, the verticals of St 37. The welding rods were Böhler B-Elite core electrodes 18 and KV. The total weight of the steel superstructure amounts to 10.408 tons. The test loading showed an elastic deflection of 9.5 mm, as compared with the calculated 13 mm.

The favourable experience with the welded method in bridge building induced

the firm Sartid to construct a Danube towed lighter at their shipyard at Smederevo entirely by welding. Fig. 5 shows the details of this lighter, which has a draft unloaded of 0.3 m, with 60 wagon loads 1.9 m, and with 67.8 wagon loads 2.1 m; it has 3 holds with a total capacity of 733 m^3. All the sections of the frame ribs were designed in accordance with the requirements of welding technique. The jointing of the separate plates (hull 5 mm thick, deck 4.5 mm thick) was, because of the small plate thickness, executed according to the rules of Bureau Veritas with an overlap of about 20 mm.

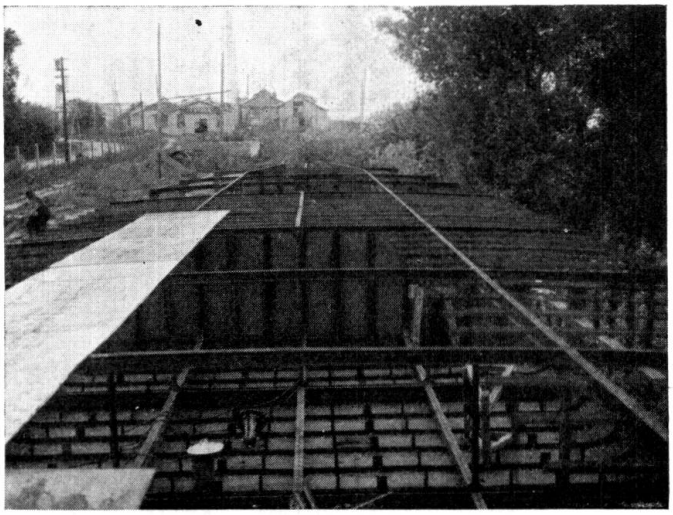

Fig. 5.
Danube lighter.

Based on thorough experiments, the type of welding rod used was the bare electrode "EV-37-Braun" of the Westphälische Union Hamm. The following table gives a comparison between the deadweight of this welded lighter and that of a riveted lighter of the same draft:

	welded	riveted	saving
Hull	71 tons	107 tons	33,5 %
Fittings and equipment . .	7 „	7 „	. . .
Woodwork	15 „	15 „	. . .
Sundries	1 „	1 „	. . .
Total	94 tons	130 tons	27 %

i. e. when carring the same cargo, the draft of the welded lighter is less, which is of great importance from the economical point of view. This first all-welded Danube lighter has been in continuous service since 1st May 1935. During this period it was damaged in a storm, one side being bulged in at a vertical weld, but the welded joint itself did not suffer any damage at all.

The experience gained with the structures described above, and the studies made of foreign rules and the test results hitherto published, induced the Ministry of Public Works to issue in 1934 its own rules for welded structures; these take home conditions into consideration and are intended to encourage the new method of construction. They are almost identical with the Polish

rules, and were prepared with the collaboration of Prof. Bryla. They contain nothing more than what must absolutely be contained in such rules, and avoid mentioning anything which really belongs to handbooks or instructions.

The favourable experience gained by the Ministry of Public Works with the welded methods — which at the same time showed the ability of home works to handle them — induced also the Ministry of Traffic to abandon its policy of reserve and to introduce the new method for railway bridges. The first experiment was made with a single-line bridge over Tratinska Street in Zagreb, the order for which was passed to the Splošna stavbena družba, Maribor, in autumn 1934. Exactly as in the case of other bridges over streets in Zagreb, this was also designed as a framed bridge with three spans, with hinges in the side spans. The general arrangement is shown in Fig. 6. The number of joints depended on the size of plates which the home rolling mills were capable of supplying. The brace of the frame was welded together over the whole length in the workshops; the erecting joint was located at the bottom of the frame, the web plates coming up against a plate set at right angles to the plane of the

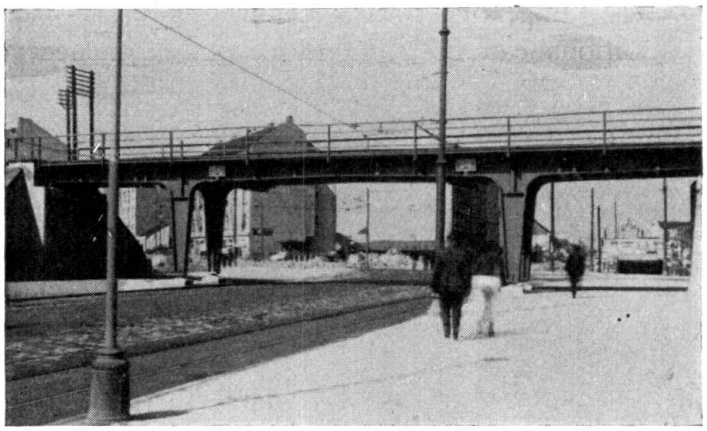

Fig. 6.

web and being connected to it by fillet welds. The erecting joints were desgned in such a way that the amount of overhead welding was reduced to what was absolutely necessary. The continuity of the rolled longitudinal girders is ensured by "continuity plates" welded to the decking plates. The decking is formed of plates 12 mm thick and has the form of a wide smooth trough, the water running off in the direction of the abutments. Footways covered with checker plates are arranged on brackets on both sides, outside the main girders. The bridge was erected at the side and then pushed into its definite position. The calculations were made in accordance with the rules of the Ministry of Traffic, and the dimensioning and execution were in accordance with the rules of the Ministry of Public Works. The bridge is made of St 37 with bearings of cast steel, and the total weight amounts to 49 tons. The trial loading showed a perfectly elastic deflection of 5.25 mm as compared with the calculated 6.80 mm.

Almost at the same time the Ministry of Traffic undertook the strengthening of the bridge over the Neretva at Gabela on the narrow-gauge railway between Mostar and Dubrovnik, which was no longer sufficiently strong for present-day loads. The bridge has two openings of $100.0 + 31.2$ m span and static

calculations showed the necessity of strengthening the diagonals D 1—4 and D 7—10 in the longer span and D 11, 12 and 14 in the shorter span. The project of strengthening by means of welding was prepared by the works departement of the Yugoslavian State Railways.

From what has been said, it can be seen that welded methodes have been successfully introduced in Yugoslavia in all branches of steel structural work. The experience gained in these first constructions may be summarised as follows: —

1) Fusion welding did not prove successful and had to abandon the field to the more economical arc welding.

2) The work hitherto carried out has proved the ability and reliability of home engineering firms to supply and erect welded steel structures.

3) Welding technique makes it possible to utilize the products of home rolling mills to a very great extent and reduces the importation of foreign rolled sections to a minimum, a point of great economical importance under present conditions.

4) By means of welding, old steel structures which no longer conform to modern traffic conditions can be economically strengthened, and without any interference to traffic.

5) From the point of view of design, mistakes were avoided by a study of work already executed and also of up-to-date foreign literature, as well as by the careful and gradual adoption of welding methods; this facilitated the introduction of designs suited to welding technique. Thanks to our rules, the butt joint suitable for dynamic stressing was rapidly introduced and its advantages were soon recognised, as also the importance of bevelling the ends of cover plates and flange plates in order to increase the fatique strength. There is also an evident tendency to avoid cover plates for butt joints, since they act unfavourably under dynamic stressing. In addition to the usual rolled sections, also half I sections have been adopted for the chords of lattice girders and as web plate stiffeners in plate girders.

6) When carrying out welded work, care must be taken that only well-trained and reliable men are employed. The tests for welders are severe and are carried out in accordance with certain rules; only those men who can absolutely fulfil the conditions stipulated are allowed to do welding work. By the introduction of the welding log book in the workshops and on site, marking the welds with a special sign indicating the welder who has executed it, constantly inspecting for good penetration and porosity by making occasional borings adhering to prescribed dimensions of welded joints, and by entering all these data in the log books, the feeling of responsibility of the welders is increased and the quality of the welds is improved. An endeavour should be made to reduce to a minimum the amount of welding required to be done on site. With regard to distortion, the considerable transverse shrinkage has been counteracted by pre-stressing. Simultaneous welding of fillets from both sides causes only slight distortion horizontally. In long joints, the step back method of welding is adopted, starting either from the middle or from the ends. The danger of the root weld cracking when subsequent layers of weld metal are applied, can

be avoided, for example by heating the places where no welding has yet been done. In the butt welding of rolled sections the thick flanges must first be welded and then the thin web, in order to avoid the risk of the web joint cracking. Otherwise the designer must pay attention to distortion when designing the cross-sections, and take certain precautions in each case to prevent it. By arranging for movable poles, pole connection at the proper places, tacking at points where many edges come together, proper inclination of the electrodes, and also correct sequence of the welds with regard to the pole position, it will always be possible to obtain a good, steady arc.

7) The importance was soon recognised of the inspecting authorities having not only a theoretical but also a practical training, and all engineers and technicians of the Ministries of Public Works and Traffic who have to supervise welding work are given an opportunity of attending a course of welding.

8) The welding constructions hitherto carried out have proved the economy of the new method; according to the type of structure, savings in weight of 15% and upwards have been made.

9) With regard to electrodes, it has been found that to distinguish the different kinds by different colours is not sufficient to prevent them being mixed up at places where work is done with different kinds of electrodes, and that it is desirable to distinguish the different kinds by means of rolled-in marks.

These favourable results, obtained by the harmonious collaboration of owners and contractors, show how welding technique has been introduced into an almost entirely agricultural country and has there continued to develop. The orders, of quite respectable magnitude considering the conditions in our country, which have recently been placed by the Ministries of Traffic and Public Works, prove that the authorities have resolved to keep to this new method and to develop it to the economical advantage of the country, due attention being paid to pioneer work done abroad.

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