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Développement de la soudure lors de la reconstruction des ponts hongrois sur le Danube et la Tisza

Die Entwicklung der Schweissung bei der Herstellung der neuen Donau- und Theissbrücken in Ungarn

Welding experiences at the construction of the newest Danube and Tisza bridges in Hungary

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From the several all-welded deck constructions of various Danube and Tisza bridges (fig. 1) a special attention is to be called upon that of the Arpádbridge, a plate girder bridge over the Danube in Budapest (1) comprising four main girders and stiffened by sway-bracings of the Vierendeel-type. It is generally acknowledged that welding is specially advantageous for the construction of monolithes i.e. for frames.

Welded sway bracings of the Vierendeel type, cross-girders and side-walk cantilevers were offering a saving in material of 15 % as compared to riveted constructions. That is why the decision of the Highway-Bridge Department was made in the favour of the welded types. As field connections were riveted, just as the main girders themselves, the fabrication of these secondary girders necessitated shop-welding only. For the execution of this job the « Elin-Hafergut » automatic welding process (2) was adopted with very satisfactory results.

Prior to the adoption of this welding process a series of

(1) See : *L'Ossature Métallique*, 1947/Oct.

(2) See : *Elektroschweissung*, 1939/1 and 1941/12.
It must be understood that welding is executed by this process with carefully pressed. exceptionnally long (1.0 — 1.5 m = 3 — 5 ft) electrodes with an absolutely centric core of large diameter (5 — 7 mm). These electrodes are put into the fillet of the section to be welded in an inclined (at 45°) position and assuring a contact at their ends. A notched copper bar (40 × 40 mm — 60 × 60 mm square) is used for cover and the electric arc is drawn at the end of the extreme electrode. The electrodes are burning one after the other under the copper shelter producing a uniform quality, reliable weld all along the section without any interruption and with the production of minimum heat.

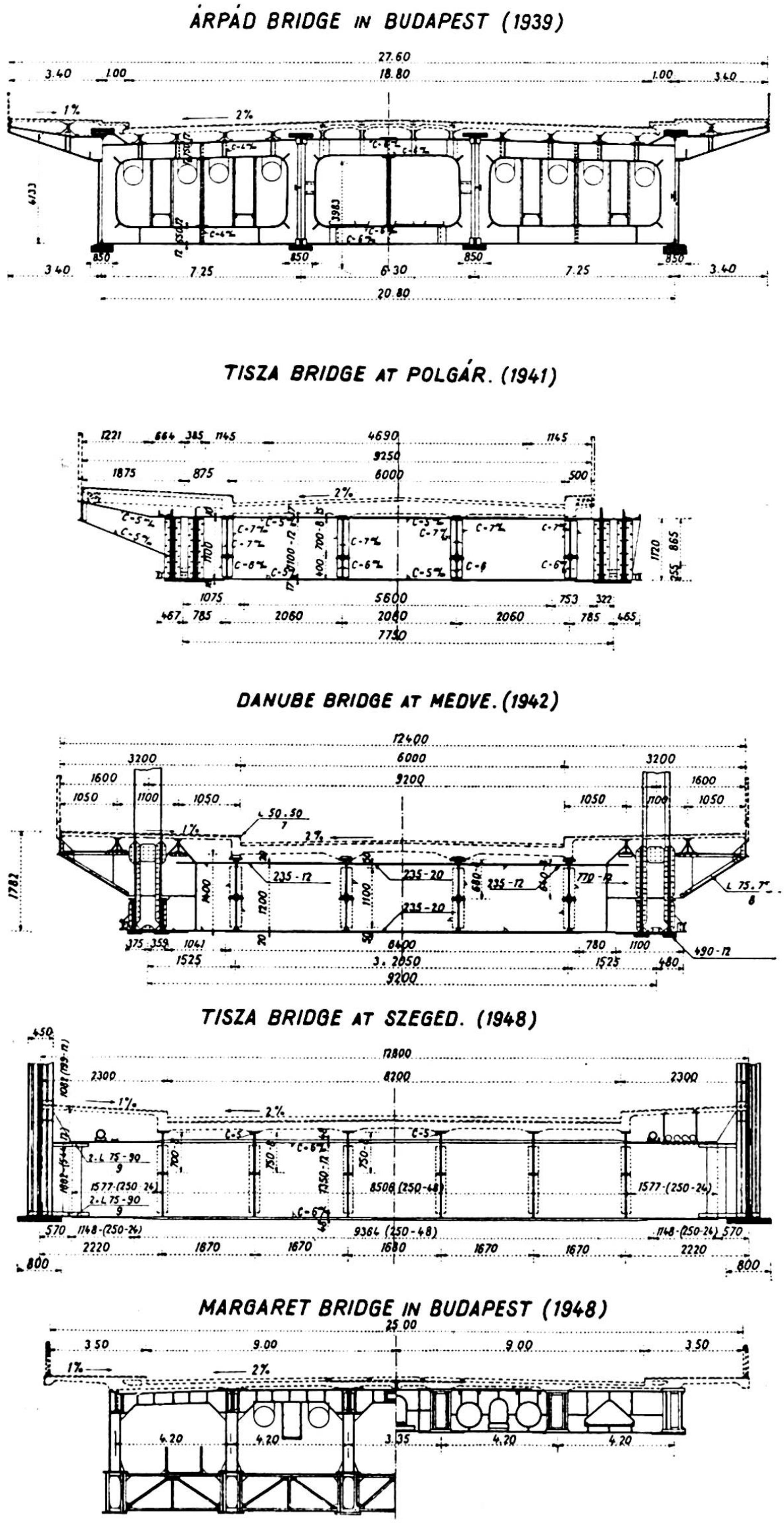

Fig. 1. Cross sections showing welded deck-girders of the most recent Hungarian Danube and Tisza bridges.

Fig. 2. View of the steel construction of the Arpád-bridge showing welded elements from underneath.

experiments was done giving some comparative information between the quality and economy obtained with this process and with ordinary welding (by hand).

These experiments comprised the fabrication of four cross girders (2 ft 5 in deep and 24 ft 2 in long) two of them hand- and two of them automatically welded. Test specimens were cut out from these girders in order to give all comparative information as to the tensile-strength, yield-point, elongation and shear resistance of the welds (³).

These tests have proved, that the Hafergut-process is at least equal to the best hand-welds and the figures obtained are well beyond the values stipulated in the official standard specifications.

Tensile strength of butt-welds	:	$\sigma_{Bw} = 36$ kg/mm² (= 51 500 lb/sq.in).
Elongation of butt-welds	:	$\delta_w = 12$ %.
Bending elongation of butt-welds	:	$\delta_b = 23.7$ %.
Shear resistance for the unit length of fillet-weld	:	$t = 1\,369$ kg/cm (= 7 670 lb/in).
Fatigue - strength (Endurance limit) (2 million pulsations from $0 - p$)	:	$p = 17$ kg/mm² (= 24 242 lb/sq.in).

The process has secured perfectly uniform and smooth weld-surfaces, reliable fusion at the root of the weld (³) and the welded structure altogether made a pleasing appearance, inspite of the skew lay out of the steel construction (fig. 2).

The process required specially pressed electrodes, securing absolute concentricity of the core, which were imported from Germany (Hamm) or from Switzerland (Oerlikon) but at present Hungarian Industry has also developped a similar type of electrode with promising qualities.

The mechanical properties of the « Hamm » electrode are the following :

(³) See : L. Péter, *Elektroschweissung*, 1942/9.

Tensile strength : $\sigma_{Bc} = 42$ kg/mm² (60 000 lb/sq. in);
Yield point : $\sigma_{se} = 37$ kg/mm² (53 000 lb/sq. in);
Elongation : $\delta_{e10} = 10$ %.

Chemical analysis :

C = 0.148 %	S = 0.046 %	Cr = 0.17 %
Mn = 0.48 %	P = 0.007 %	Cu = 0.192 %
Si = 0.061 %	Ni = 0.017 %	W = 0.08 %

The texture of the weld, made by the Hafergut-process was uniformly more coarse-grained as that of the hand-weld; the first layers of this latter one have naturally undergone subsequent heat treatment, resulting in some recristallisation and a fine-grained texture in the underlying layers (fig. 3).

Consequently some deterioration of the fatigue-strength might be feared of, but the tests however did not prove so.

No detrimental deformation or excessive shrinkage has been experienced during the execution, the due deformation of the flanges being counteracted by a previous counter bending of the flange plates in the opposite direction. The average shortening (longitudinal shrinkage) of these girders dit not exceed 0.3-0.4 ‰.

As to the economic side of the process — according to the observation of the welding shop — it made possible a saving of 2/3-3/4 in wages, whilst the cost of material, current and equipment surpassed only by 20 % that of the usual hand-welding.

Experiments at the reconstruction of the Chain-Bridge

Very interesting experiments have been done in connection with the reconstruction of the first and best known permanent bridge of Budapest and of the whole country, namely i.e. *T. W. Clark's Chain-Bridge* constructed from 1839 to 1849. The steel superstructure of this bridge was entirely renewed in 1913-1915 when the wrought iron chains, the wooden stiffening girder and the cast iron deck-girders were changed up with higher quality carbon-manganese steel construction. During the siege of

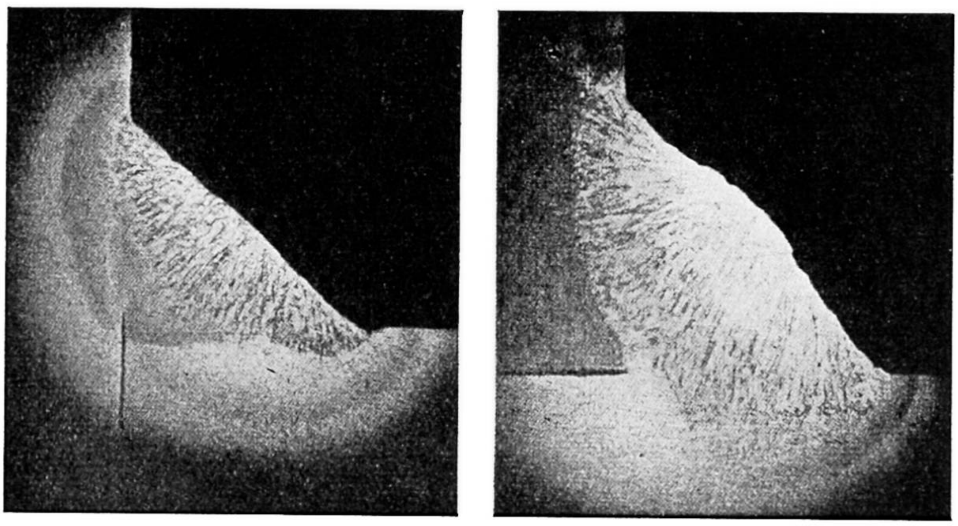

Fig. 3. Typical macro-structure of a fillet weld made :
a) By usual hand welding,
b) By the « Hafergut » process.

Fig. 4. View of the blown up « Chain-bridge » Budapest.

Budapest the German troops have blown up the left side anchoring chambers of the bridge, inducing so a mighty slip of the chains (16 meters = 53 ft 0 in over the left pylone and about 3 meters = 10 ft 0 in over the right pylone) which tremendous deformation led to the entire collapse of the bridge. Although many of the chains broke and many again suffered plastic torsion or buckling still it was evident, that a considerable part of them might be reutilized (fig. 4).

The least deformation set in around the pins, where the rigidity of the chain-bundle was the greatest. Considering that the greatest amount of work is required for the fabrication and accurate tooling of the eyes of the single chain elements it was obvious to save these parts at least for a possible reutilization. Two proper joints would be needed for this purpose to tie the two eye-parts to a shorter and narrower new chain element. This joint most suitably might be feased out by welding. Furthermore the usual way of chain-fabrication, namely the cutting out of the chain shape from a wider plate and a subsequent milling off of the edges might be also greatly simplified if this costly process might be restricted to the eye parts only, which might be joined by welding to the narrower middle plate. (See fig. 5.)

Bearing in mind that the chains — as constant tension members — are the least subject to a variation of stresses, a fairly high endurance limit might be attributed to them and consequently as a rule they are very suitable bridge construction members to be welded.

E. g. in our case the tension stress is ranging from 1 080 kg/cm^2 = 15 400 lb/sq. in (due to dead-weight only) to 1 721 kg/cm^2 = 24 500 lb/sq. in (from dead-weight + live load + temperature + wind load).

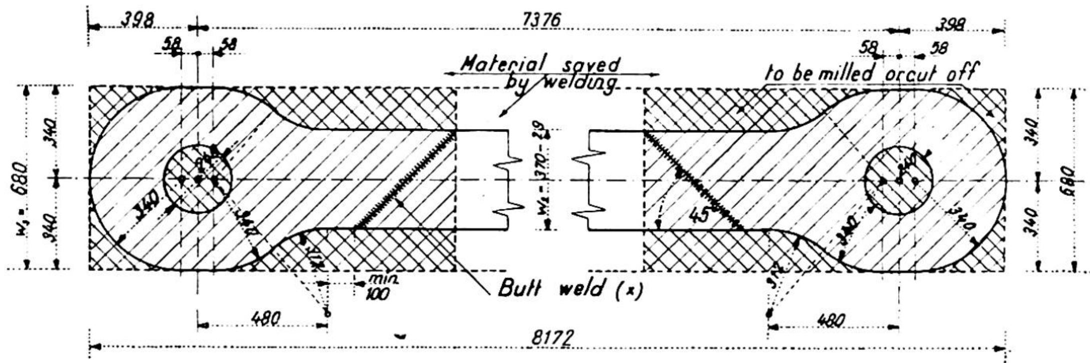

Fig. 5. Plan for the reutilization of the eye parts of the recuperated chain elements suggesting also a possible economic way of chain fabrication by welding.

To clear up the problem of chain welding some experiments were done under our direction by the Technological Institute of Budapest (Prof. Dr L. Gillemot and Ing. L. Péter). Six test pieces were welded with X-shape butt welds by Oerlikon-Univers electrodes. The location of the cut out test-specimens is shown on figure 6, which were destined to check the tensile and fatigue strength of the butt-weld both in longitudinal and in transversal direction. Further test specimens were cut out from the weld-deposit itself. All tests were done with normal and with annealed specimens. The temperature applied was 730° C and 930° C (1 250° F and 1 600° F).

The results obtained are summarised in Table I. From these data it is to be stated that the high-quality carbon-manganese steel from which the chains of the restored bridge were fabricated in 1913-1915, are neither in

Mechanical property	Parent metal			Weld deposit			Welded joint					
							Longitudinal			Transversal		
	As received	Annealed		As received	Annealed		As received	Annealed		As received	Annealed	
		730°	930°		730°	930°		730°	930°		730°	930°
Yield point σ_f kg/mm²	31.3	32.6	29.7	59.3	42.3	38.2						
Tensil strength σ_h kg/mm²	56.7	55.5	55.1	63.1	53.2	45.5	57.1	53.7	46.3	59.3	51,8	46.7
Elongation δ %	25	22.5	19.7	10.2*	29.4*	30*						
Reduction of area ψ %	53.3	53.8	51.4		72.2	64.5						
Endurance limit σ_u kg/mm²	24.2	—	—						18.5		18.0	
Charpy keyhole notch cleavage test mkg/cm² .	7.5	9.6	9.6									

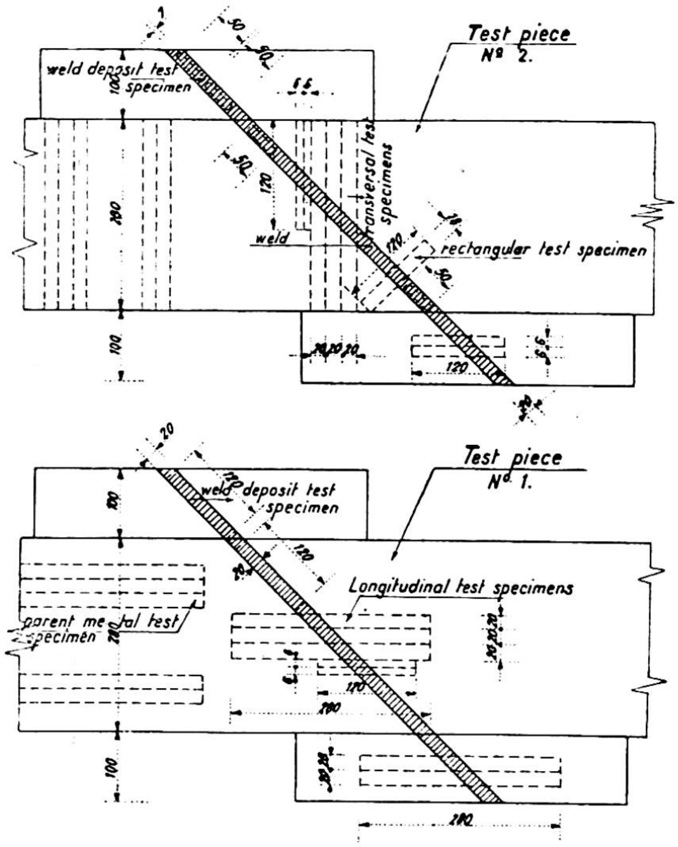

Fig. 6. Test-pieces showing the location of test specimens.

a state of fatigue nor aged nor subject to any trace of corrosion-fatigue. Inspite of their fairly high Carbon and Silicon content they are readily weldable and the applied Oerlikon-Universe electrode is capable of yielding butt welds equal at least to the parent metal as to its mechanicals properties, if carefully prepared.

Rectangular			Note
As recei-ved	Annealed		
	730°	930°	
59.7	50.7	41.8	*) for a distance of 5 d
	17.0		2 million cycles from 0 — p limit

TABLE I.

RESULTS OF VARIOUS TESTS MADE FOR CHAIN BRIDGE RECONSTRUCTION

(1947/48)

Chemical analysis of parent metal (1913) :
C = 0.28 %; Si = 0.13 %; Mn = 0.94 %;
P = 0.034 %; S = 0.052 %

Specification for parent metal :
σ_f = 29-31 kg/mm²;
σ_h = 50-55 kg/mm²; δ_{10} = 25-21 %

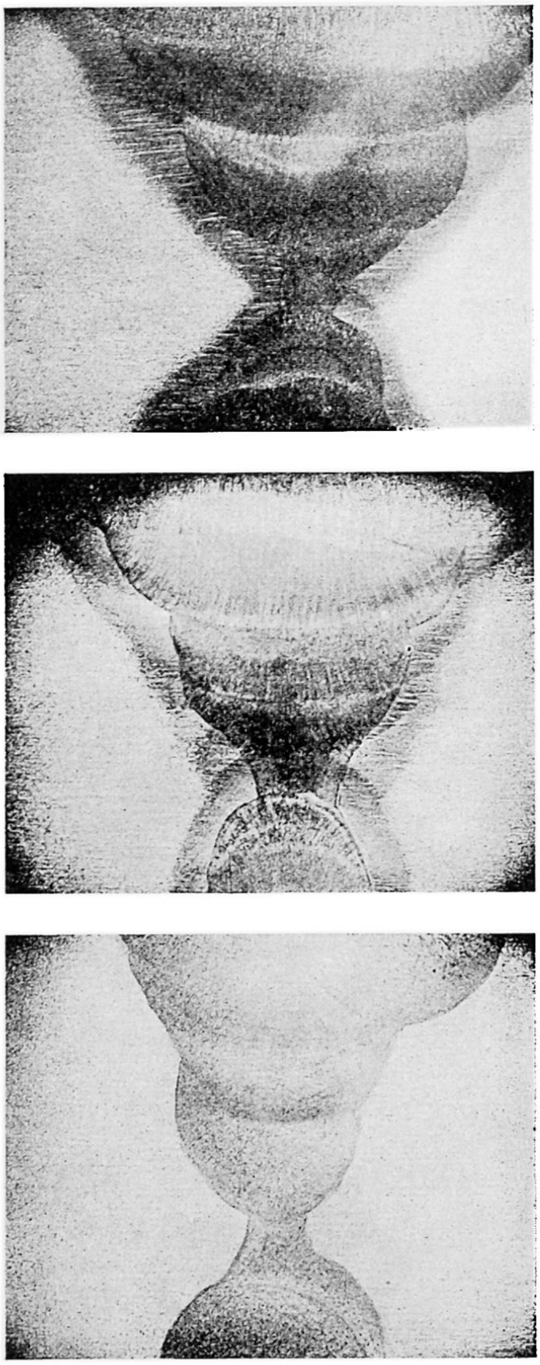

Fig. 7. Macrostructure of X-welds of the test specimens :

a) As rolled condition;
b) Stress relieving heat treatment (730° C);
c) Normalising heat treatment (930° C).

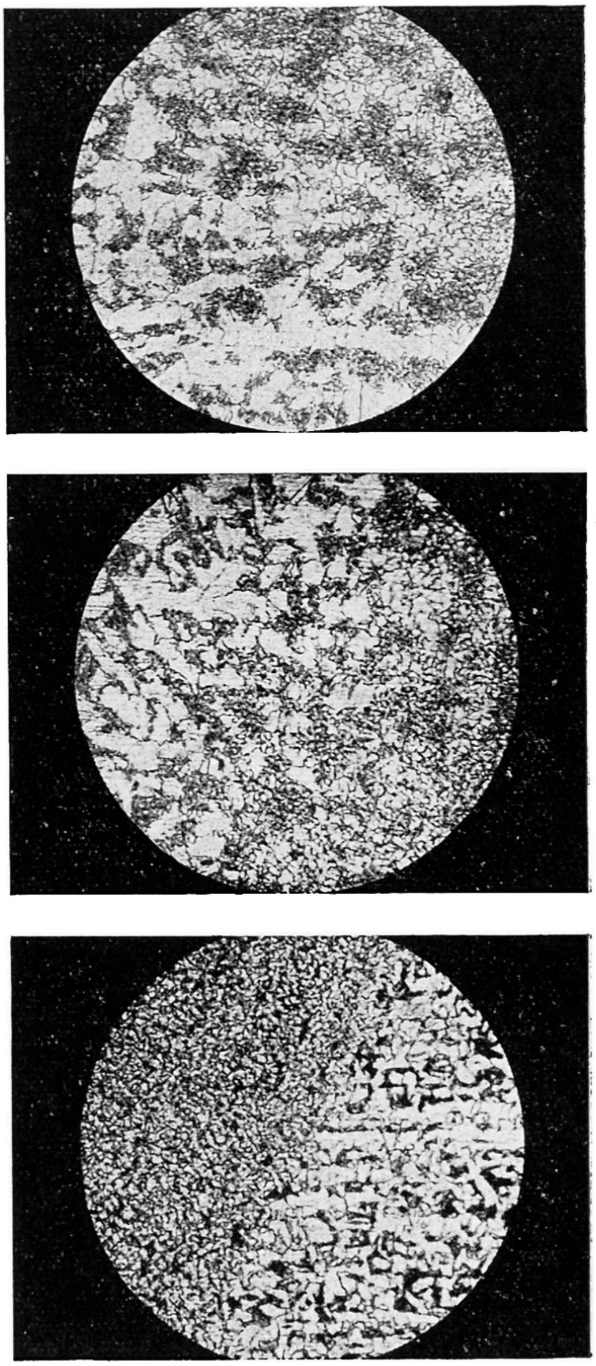

Fig. 8. Microstructures of the same welds (transition zone) :

a) As rolled;
b) Stress-relieved;
c) Normalised.

The X-ray photographs taken from the X shaped butt welds have manifested the first class quality of welds.

Annealing of the welds is raising considerably their ductility (by 200 %) and results in a considerable inner stress relief between the differently hard transition-zones. Annealing to 930° C (1 600° F) makes disappear entirely all difference in the microstructure of the transition-zone and yields a further raise of 20 % in the Charpy keyhole notch cleavage test results (Table I).

These results are to be seen from figure 7, *a*, *b*, *c*, showing the macrostructure and from figure 8, *a*, *b*, *c*, showing the microstructure of the welds.

This latter has got a purely ferritic structure differing from the transition-zone in the size of the crystals only. The microscopic checks have revealed however no internal crack or harmful internal structural change whatever.

Considering that any heat treatment over the lower critical-temperature (730° C = 1 250° F) may bring about some changes in the metal's internal microstructure (ferrite ⟶ austenite) practically a stress-relieving heat-treatment was advisable only, which would produce a very substantial raise of the weld's ductility. All other mechanical properties being entirely satisfactory in the as-rolled state already.

A delicate problem was still left to be studied; namely the accurate length-control of the welded chain elements without setting up any harmful residual stresses.

The measure of shrinkage can't be estimated as punctually in advance, that the distance between the pin holes (7 500-8 500 mm) could have been granted up to 1 mm accuracy. A reboring of the pin holes and consequently the application of new larger diameter pins was unavoidable.

Simultaneously experiments were made with the restraightening of the badly crooked chain-plates (fig. 9).

This operation was done by cold mongering of the single elements which suffered in most cases serious plastic deformation. This procedure proved also successful but resulted naturally in a different elongation for each member of the chain bundle varying according to the radius and to the angle of curvature

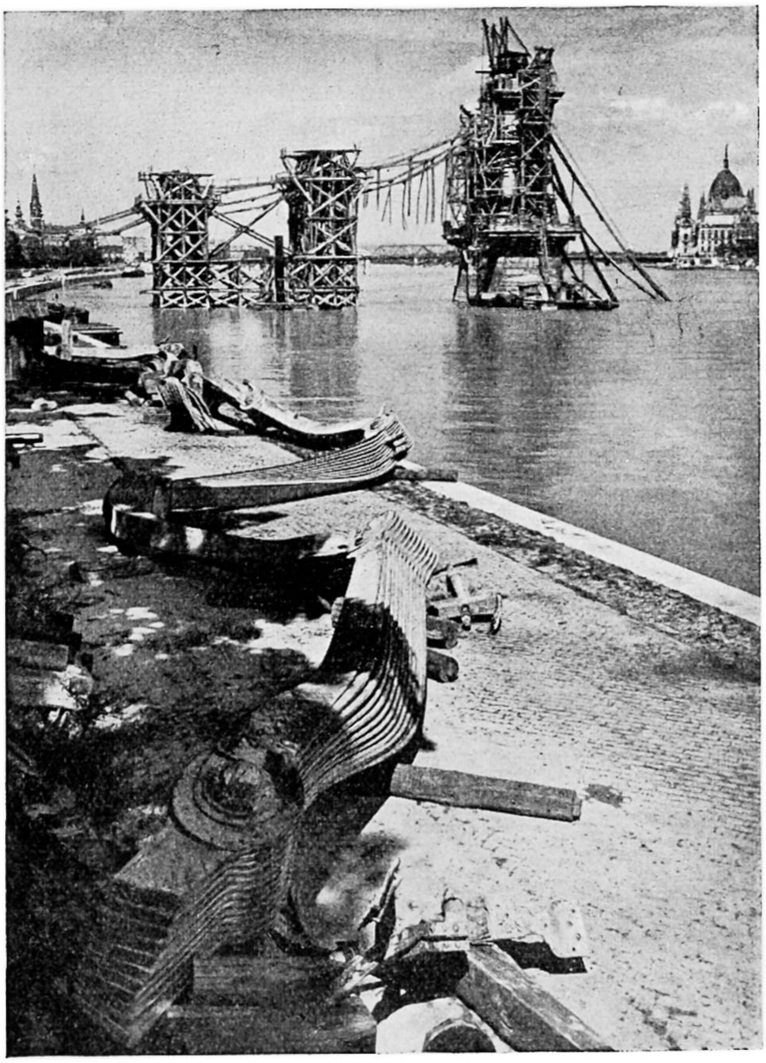

Fig. 9. Recuperated, crooked chain-bundles in foreground, supporting and staging, with the saved chain-line of the right span to be readjusted in the background.

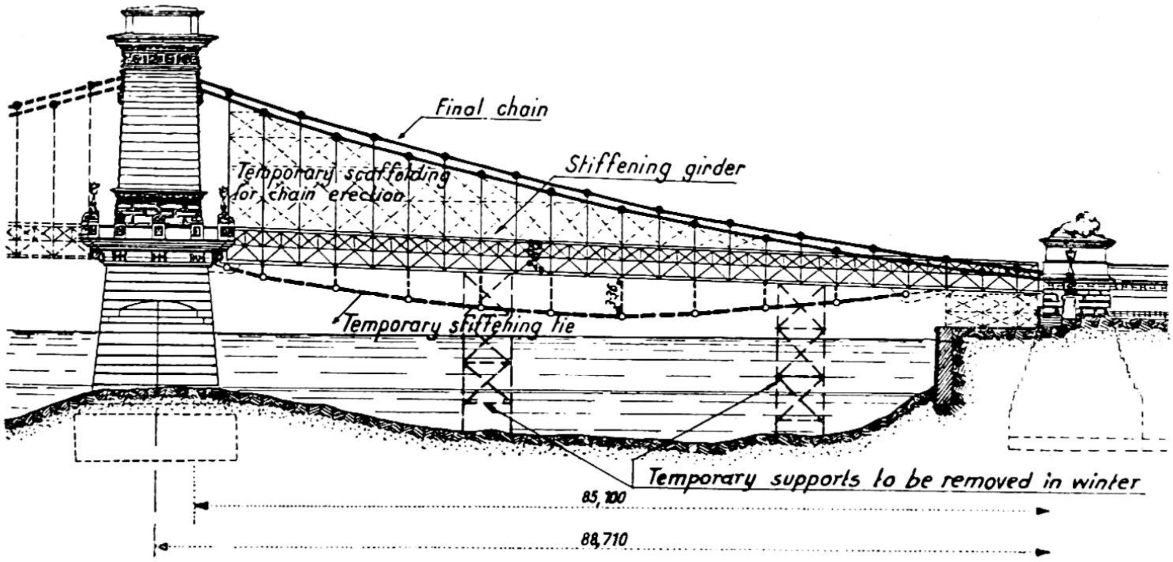

Fig. 10. Erection (readjustment) scheme of the chains in the right span of the bridge showing new stiffening trusses and temporary welded stiffening-tie underneath.

and a general embrittlement of the steel-material (fig. 9). In the total length of the chain elements in one bundle this difference amounted up to 2-5 mm. This involved also reboring of the chain bundles and required new pins. Test specimens were taken from the restraightened parts of the chain material to check any deterioration of the mechanical properties due to this cold machining of the steel material. But the tests have delivered no considerable change as compared to the original.

Tensile strength : $\sigma_B = 53$ kg/mm² (75 000 lb/sq. in).
Yield point : $\sigma_s = 34.2$ kg/mm² (50 000 lb/sq. in).
Elongation : $\delta_{10} = 22$ %.
Reduction of area : $\psi = 49$ %.

Brinnel hardness was raised from 155 to 185-195 at some badly crooked sections.

Considering the economic advantages of restraightening and with special regard to the absolute urgency of the work, which might have an unfavourable influence upon the required reliability of welding and upon the required carefulness of the subsequent heat treatment, the idea of welding was given up for this time and it was finally decided, that the crooked chains would be carefully restraightened and rebored, and the still missing chain elements would be fabricated in the usual way. Only a temporary stiffening tie will be composed of welded chain elements. These are welded out of the heavily injured chains which were cut in two, either by the rupture of the bridge or when removing a certain length of the chain line as debris from the river bed. This job comprises the welding of some 80 chains and will afford a good opportunity to make further observations and gain further information on the possibility of chain fabrication by welding. (Which might be needed for the reconstruction work of the other chain bridge : the Elisabeth bridge in Budapest.)

This stiffening-tie will temporarily raise the load carrying capacity of the right span stiffening girders which will have to carry, beside their own weight, the total dead load of the chains which suffered the least displacement and may be easily readjusted from a temporary scaffolding built on the stiffening girder, which is of course not dimensioned for this overloading. The stiffening girder is erected by floating crane on temporary supports which must be removed before the appearance of drifting-ice and will then be replaced by this tie (fig. 9 and 10).

Welding of the tube-trusses for the Kossuth-bridge

The construction of the Warren-trusses for the *Kossuth-bridge* in Budapest and for the new highway bridge at *Szolnok* is of quite a special interest.

As it is known from the literature ([4]), Budapest and the whole country was deprived from all its large span bridges and communication was restored by military small-span pontoon and wooden pile bridges which were not able to resist neither high floods in spring time, nor drifting ice in winter. The *Kossuth-bridge* was meant to be the first permanent link in Budapest over the Danube just as the highway bridge at Szolnok was the first one over the river Tisza. Both of them were to be built within an extremely short delay amidst the most unfavourable circumstances, just under post-war conditions in an entirely devastated country. The construction of the Kossuth-bridge was started in May 1945 and was to be completed in January 1946, i.e. before drifting ice would carry away all the temporary pontoon- and pile-bridges. In an absolute want and penury of material, only some tube sections might have been secured for the steel construction of the bridge which were left from the war. And as it was indispensable to build at least two 55 m (184 ft 0 in) and one 78 m (260 ft 0 in) large spans (fig. 1) the trusses of these spans had to be composed of these tubes available. All junctions and splicings of the tubes could not be economically solved but by welding. Thus we were compelled to establish the largest span all-welded bridge in the country within the shortest period, and amidst the most unfavourable circumstances.

Some important considerations which were all against the given welded construction :

1. Recent bridge construction practice prefers to apply plate-girders for spans of this size owing to some unfavourable experiences gained with trusses.

2. The construction of a welded bridge of such an exceptional size would require first-class workmanship, reliable workmen and a carefully specified succession for the laying of each bead of weld, as well for shop welds as for field welds. A very careful erection and assembly of the whole construction would be also required. None of these preconditions of a reliable work were fulfilled owing chiefly to the lack of time, to the lack of erection cranes and of other equipment and to the lack of qualified labour, workmen being chiefly prisoners of war and those who were left had to dispense with the most simple needs of their own and their family's alimentation and to defy the rage of a never precedented inflation of the Hungarian currency.

([4]) *Travaux*, 1947, août; *Structural Engineer*, 1948, Dec.; *Magyar Technika*, 1946, May; *Tér és Forma*, 1946, February.

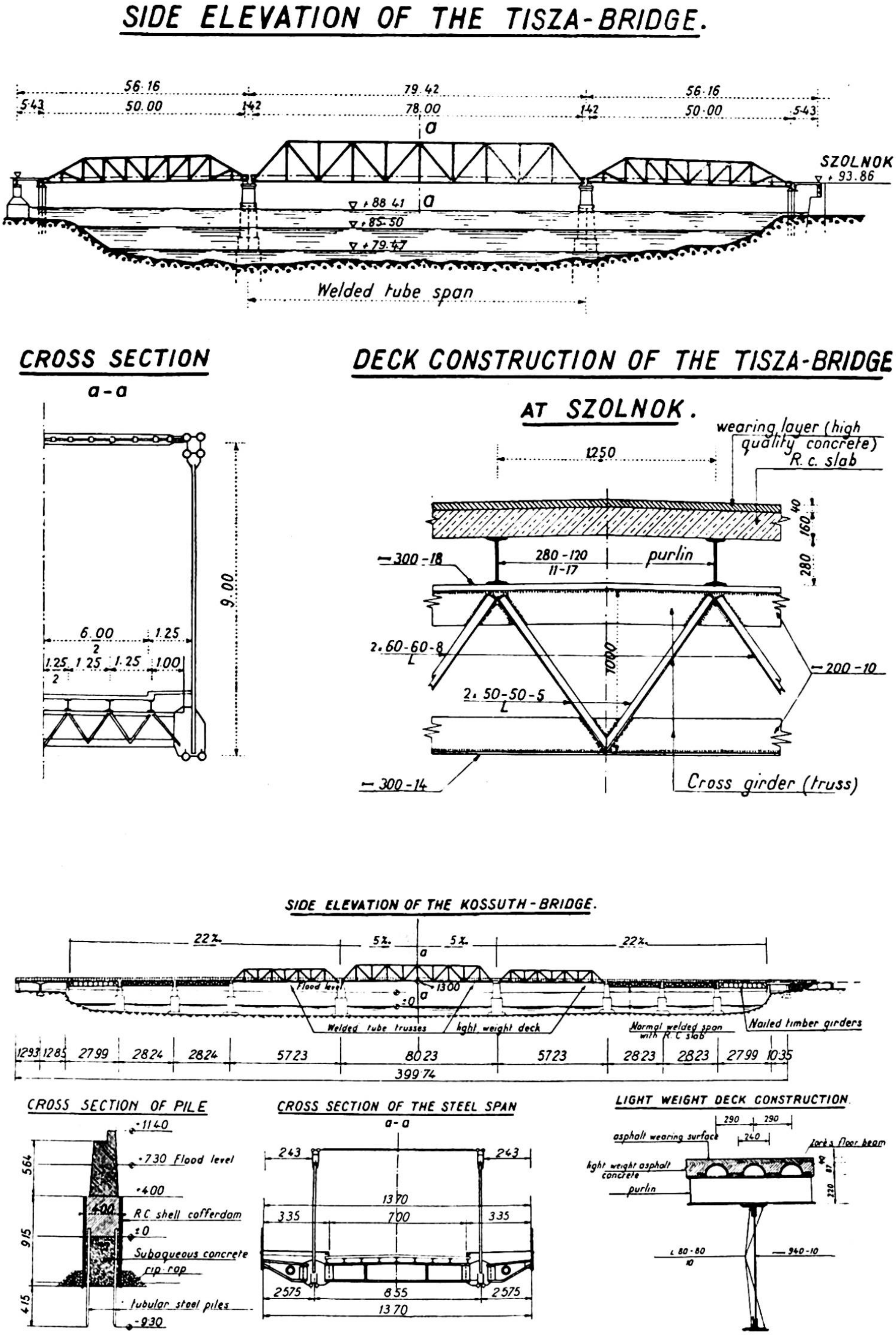

Fig. 11. General plan of the « Szolnok » and « Kossuth » bridges.

3. The chemical analysis of the available steel material (high quality steel) :

C	= 0.31 %	Tensile strength : σ_B	= 55 kg/mm² (80 000 lb/sq. in)
Mn	= 0.65 %	Yield point : σ_s	= 36 kg/mm² (50 000 lb/sq. in)
Si	= 0.28 %	Elongation : δ (2.5d)	= 27 %
P	= 0.037 %		
S	= 0.036 %		

was also not a favourable one, owing to the fairly high C and Si content.

At last the uniformity of the available electrodes could also not be secured, because the small quantities of different electrodes in stock that must have been made use of.

4. Owing to the required rapidity of construction and bearing in mind that the application of R. C. deck construction was excluded (we could not afford the required time for hardening nor run the risk of a hard frost in winter time) a very simple light-weight : $g = 250$ kg/m² = 50 lb/sq. ft steel deck construction was specified (see fig. 11, *b*). This comprised *Zores* floor beams, recuperated from the debris of the blown up bridges, filled with an asphaltic-concrete and covered with a hard asphalt-coating, which could be opened for traffic when laid immediately. It was also evident that this considerable reduction of dead weight will lead to an increased susceptibility for oscillation, which again leads to an earlier fatigue.

5. It was also foreseen that a considerable part of field welds would be prepared in winter at very low temperatures : an undesired factor which also increases the weld's brittleness.

6. Tubes are especially not suitable to have first class butt-welds considering that a rewelding of the root from underneath is out of question.

Welded trusses composed of tubular sections are otherwise considered generally economical and largely applied in air-plane construction. This statement refers of course primarily to structures consisting of *single tube* sections. In the case of the Kossuth-bridge the size of the tube sections was limited; in order to develop sections for 260 ft 0 in span trusses we had to put two tubes together and for the upper chord even four. This

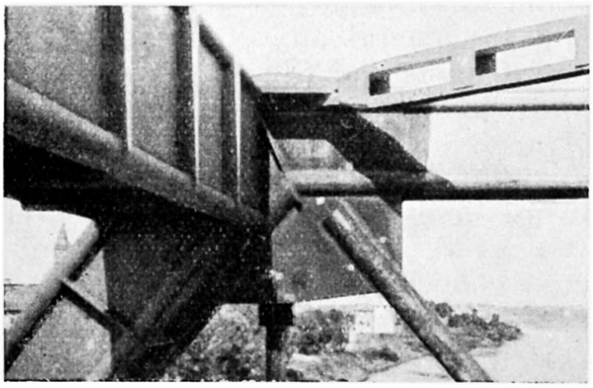

Fig. 12. Upper chord junction showing a double tube diagonal, joined to a double chord by a gusset plate welded by fillet weld.

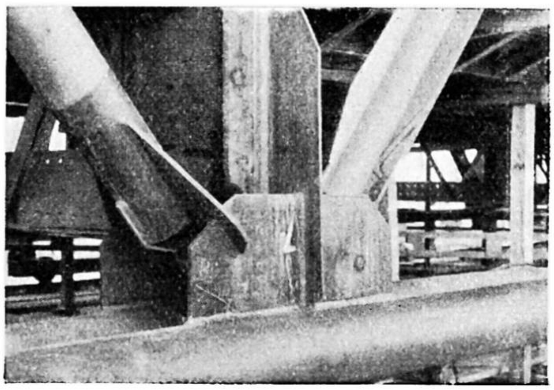

Fig. 13. Lower chord junction showing a single tube diagonal, joined to a double tube chord by a notched transversal plate welded to the gusset plates again by fillet weld.

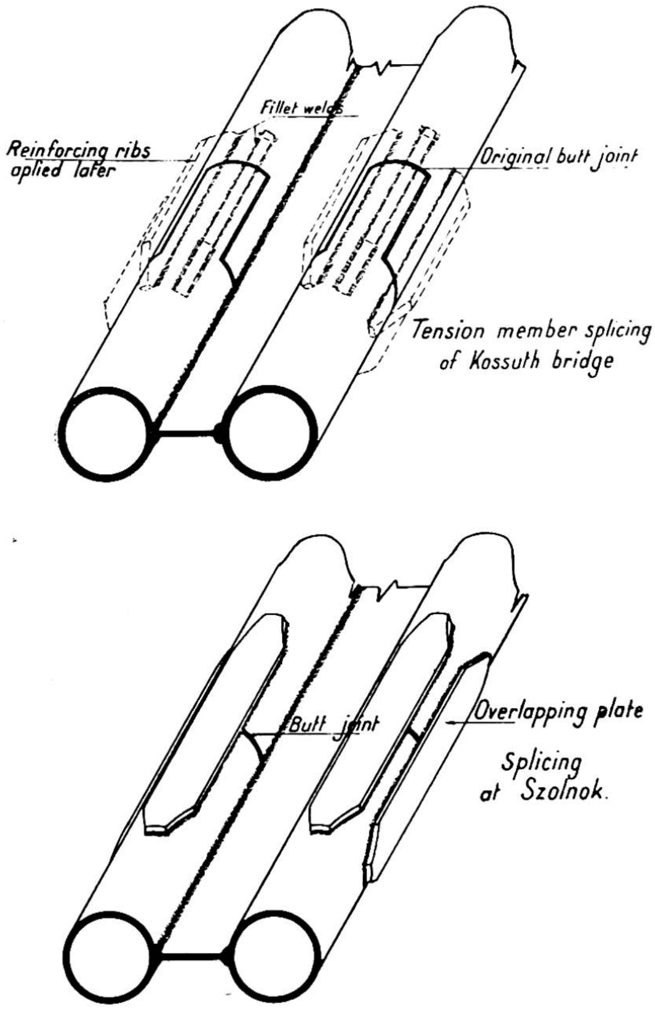

Fig. 14. Welded splicings :

a) At Kossuth bridges : the original tongue and grove butt weld showing reinforced ribs (dotted) applied subsequently.
b) At Szolnok a simple butt joint with welded cover plates.

circumstance rendered the solution of the junctions undeniably more difficult. The general idea adopted for them was the application of fairly large gusset plates on which all notched tubes were welded by filled-welds. Figure 12 illustrates how a double-tube diagonal was joined to the gusset, whereas figure 13 is showing how single bar diagonals were welded to the double gusset-plates.

We were quite aware that from the point of view of stress-transmission these solutions had some defects, but they made at the other hand a rather easy and quick fabrication and simple and reliable field welding possible and this latter ought to be the decisive factor. Any inaccuracy in fabrication could be easily repaired — when it became a trouble in the assembly — by simple widening or lengthening of the notches or by a slight increase of the strength of the filled welds.

Greater difficulties were encountered with the field joints of the tension members i.e. primarily at the splicings of the lower chords.

In order to assure a uniform joint and to avoid the application of any overlapping plates and fillet welds and in general any combined joint where the questionable cooperation of butt-welds and fillet-welds of different elastic qualities ought to be taken into account, a « tongue and groove » shaped butt joint was specified (fig. 14).

Regarding the fact that according to the welding specifications a butt weld may be computed for the transmission of 70-75 % of the total tensile forces only, the missing 30-25 % was to be overtaken by the longitudinal butt welds. Owing to the defective cooperation of longitudinal and transversal butt welds only 60 % of the actual weld area was taken into account and with regard to the expected faulty and irreparable fusion at the root section of the tubes, the actual thickness of the tubes was lessened by 0.2 cm. The admitted working stresses in the butt weld were taken to 1 000 kg/cm² (14 000 lb/sq. in) for tension and to 500 kg/cm² (7 000 lb/sq. in) for shear, thus giving the following formula for a welded joint in a tension member of the truss. The total tensile force :

$$P = D \cdot \pi \cdot (t - 0.2)\ 1\,000\ \text{kg/cm}^2 + 0.6\ L\ 4 \cdot (t - 0.2)\ 500\ \text{kg/cm}^2$$

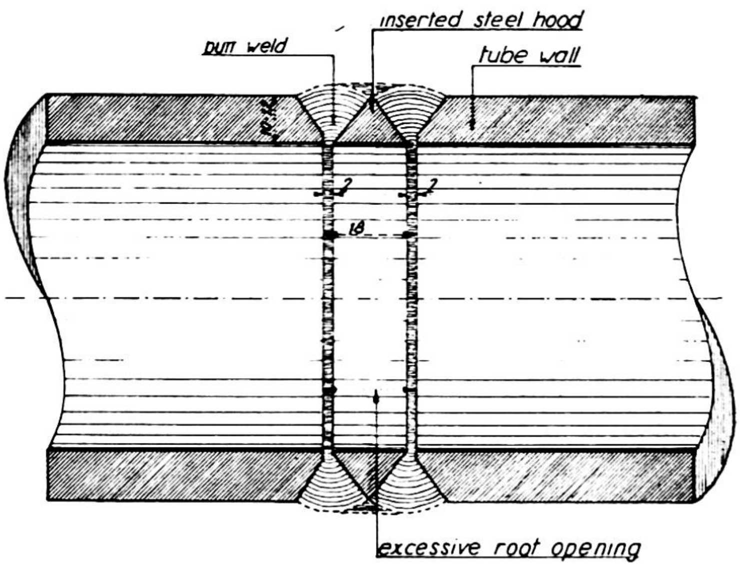

Fig. 15. Welding scheme at excessive root openings.

(where D = mean diameter, and t = thickness of tube section in cm and L cm denotes the length of longitudinal butt weld to be applied).

But even this great precaution did not prove adequate enough. The difference of ductility of longitudinal and transversal welds was still bigger and owing to their much greater rigidity these latter had to transmit the whole tension alone before any of the longitudinal welds could come into action at all.

In itself this would not have been of major importance, considering that nowadays the resistance of butt-welds is at least equal to that of the parent metal, but the bad quality of these welds did not allow to rely on the joints as they were.

It was but natural that being aware of the numerous unfavourable circumstances, a very strict control of welding work was introduced quite from the very beginning of the work; but unfortunately enough the fabrication shop was 130 km off from Budapest and the constant inspection of the work was greatly curbed by the lack of trained personnel and by the enormous difficulties of traveling (chiefly in the first three months restricted to occasional military cars only). The first X-ray equipment was available only when the assembly and erection work was started and then it was set at work at once to check field welds. The first radiographs revealed a very bad quality of welds. Pores, slag inclusions and first of all lack of fusion at the root section were the main defects, even hair cracks were found at some places. Nearly 50 % of the butt welds was found defective and had to be repaired. No improvement was experienced either with the field welds, where two reasons were chiefly responsible for this bad quality work :

a) *The winter season* with a cold sometimes of — 5°, — 15° C (23°, 5° F) which resulted in an increased brittleness of the welds. According to Ing. L. Péter's experiments elongation values were reduced in a cold of — 15° C (5° F) by 42 % and area-reduction (contraction) values by 12 %.

b) *The defective accuracy* in steel work fabrication which resulted sometimes in root openings of 12-18 mm in the field joints. In order to establish the necessary magnetic circumstances we were compelled to insert a small triangular steel hood into the root-opening thus creating two weld

	Width of bridge	Truss Weight		Deck construction Weight	
		Total	Per unit surface	Total	Per unit surface
Kossuth-bridge 78 m = 260 ft span . . .	2.25 + 7.0 + 2.25 = 11.50 m (38 ft 8 in)	180t	200 kg/m² 40 lb/sq. ft	50t	56 kg/m² 11.2 lb/sq. ft
Kossuth-bridge 55 m = 184 ft span . . .	2.25 + 7.0 + 2.25 = 11.50 m (38 ft 4 in)	100t	158 kg/m² 33 lb/sq. ft	30t	48 kg/m² 9.6 lb/sq. ft
Szolnok bridge 78 m = 260 ft span . . .	1.0 + 6.0 + 1.0 = 8 m (26 ft 8 in)	145t	232 kg/m² 46.4 lb/sq ft	35t	56 kg/m² 11.2 lb/sq. ft

roots and a very difficult weld to make, with fairly large and brittle transition zones (fig. 15).

Under such circumstances the decision was made, that all splicings of the tension members must be thoroughly repaired in the way that regardless to the reliability of the transversal butt-welds overlapping plates were specified to transmit all tension by their fillet welds. In order to reduce the extent of the hardened transition zone, narrow rib like plates were applied for overlapping, with gradual bevelled transition at both their endings (fig. 14, *a*, dotted line). All fillet-welds were much easier to make and in the given case, when a subsequent rewelding of the root from the back was impossible and the occurrence of excessive rootopenings was very great, they proved altogether more reliable.

In this way the trusses were completed and the bridge opened for traffic (18-1-1946) but every year there is an X-ray supervision for the control of the most critical joints and junction-points.

All observations and experiences were well utilized at the construction of the entirely similar 260 ft 0 in all-welded span of the highway-bridge at Szolnok (fig. 11), which followed immediately the fabrication and erection of the Kossuth-bridge.

1. The gradual improvement of the communication made it possible to introduce in shop work already a constant X-ray control of the welds resulting a beneficial classification of the welders. With a constant training and instruction of the welders it was obtained that only 10 % of the shop welds was to be repaired or renewed whereas at the Kossuth-bridge 11 % of the tension butt-welds was to be renewed at once and another 38 % was advised to be done subsequently.

The percentage of defective field-welds was reduced to 3 %. (It is to be noted that in Germany e.g. the percentage of defective welds was reduced by the introduction of X-ray control from 32 % to 2-3 %.)

2. The second improvement was the alteration of the tension member splicing. The tongue-groove type was abandoned for a simple butt joint covered with regular overlapping plates (fig. 14, *b*).

These latter and their fillet-welds were dimensioned to transmit all tension force, the first class quality of the butt welds not being granted in advance.

TABLE II.

Total steel Consumption		Note
Total	Per unit surface	
230^t	256 kg/m^2 51 lb/sq. ft	II. Class loading Light steel deck
130^t	206 kg/m^2 41 lb/sq. ft	II. Class loading Light steel deck
180^t	288 kg/m^2 57.6 lb/sq. ft	I. Class loading R. C. deck

This modification resulted not only in the production of more sound welds and the leave out of any cooperation problem but it rendered steelwork fabrication also much easier and more accurate.

3. Welding work was executed in springtime and not in winter, which resulted not only more ductile welds but also assured safer and more reliable work of the welders.

4. Welds were made in a carefully worked out succession to minimize any harmful distortion or internal stress. This could not be followed at the Kossuth-bridge where work was so exceedingly urgent that one practically had to start welding on each element when it arrived from the shop and was fitted to its proper place and one could not wait very often for the arrival of the next element which actually ought to have a preference at one or both endings in the proper succession of welding.

The succession of welding work was in general :

a) All junction points were adjusted and fixed in their final horizontal and vertical position.

b) All joints of the chords were welded, beginning from the supports towards the middle of the span.

c) Diagonals and verticals (web members) were welded to the junction points in turn afterwards from the middle of the span towards the supports.

5. A more accurate fabrication has put an end to excessive root-openings, which were primarily responsible for defective fusion at the root section.

6. A continuous R. C. slab deck was built instead of the lightweight steel deck construction of the Kossuth-bridge which granted a beneficial stiffening effect and, increasing the dead weight, reduced oscillation too (fig. 11, *a*).

This bridge was opened for traffic on the 19th of May 1946 and the previous test loading furnished very satisfactory results as to the behaviour of welds as well as to deflection.

The welded tube construction was altogether a very light-one as it is to be seen from table II. The total steel demand per unit surface (1m^2)

is well below 300 kg which is by 25-50 % less than the usual figures obtained with normal riveted steel constructions.

Résumé

L'auteur décrit en premier lieu l'exécution et les résultats des essais réalisés avant la soudure des éléments de tablier du pont Arpád à Budapest. Lors des travaux de reconstruction du pont suspendu de Budapest, on effectua des essais statiques et dynamiques pour contrôler la soudabilité des aciers au manganèse et à haute teneur en carbone.

Pour terminer il décrit les poutres en treillis en construction tubulaire soudée de 55 et 78 mètres de portée du pont de Kossuth sur le Danube et du pont près de Szolnok sur la Tisza. Il explique les causes de défauts dans les soudures, décelés par l'examen radiographique, et donne des détails constructifs des nœuds.

Zusammenfassung

Der Verfasser beschreibt zuerst die Art und die Ergebnisse der Versuche, die vor der Schweissung der Fahrbahnträgerelemente der Arpád-Brücke in Budapest durchgeführt wurden. Dann folgt ein Bericht über die Wiederherstellungsarbeiten der Kettenbrücke in Budapest. Auch hier wurden statische und dynamische Versuche angestellt, um die Schweissbarkeit der hochwertigen Carbon-Mangan-Stähle zu überprüfen.

Abschliessend werden die geschweissten Rohrfachwerkträger von 55 und 78 m Spannweite der Kossuth-Brücke über die Donau bei Budapest und der Theissbrücke bei Szolnok beschrieben. Die Ursachen der durch Röntgenuntersuchungen festgestellten Fehler in den Schweissnähten werden erklärt und konstruktive Einzelheiten der Knotenpunkte gegeben.

Summary

In the first instance the author describes the execution and results of tests made before welding the parts of the floor of the Arpád-bridge at Budapest. During reconstruction work on the Budapest suspension bridge, static and dynamic tests were made to check the weldability of manganese steel having a high carbon content.

In conclusion he describes the tubular construction lattice girders, welded and of a span of 55 and 78 metres, of the Kossuth bridge over the Danube and the bridge near Szolnok over the Tisza. He explains the causes of defects in the welding, discovered by an X-ray control and gives constructive details of the joints.