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IIId 10

Experience obtained with Structures Executed in Roumanie.

Erfahrungen bei ausgeführten Bauwerken in Rumänien.

Observations sur les ouvrages exécutés en Roumanie.

Dr. C. Miklósi,
Directeur de l'Usine Electrique et des Tramways de Timişoara.

1) During the past few years, welding has been fairly extensively adopted for large structural jobs in Roumania. Of the various processes, arc welding is probably the most widely adopted, although the other systems, especially electric resistance and oxy-acetylene welding, also have prospects, the latter being promoted to a certain extent by the calcium carbide and oxygen industries.

Welding is employed industrially in Roumania on quite a large scale in the manufacture of railway rolling stock, and particularly for the light rail autocars recently introduced. A large number of electrical machines, such as alternators and transformers, have also been manufactured by the welding process. The crude oil industry is also an important contributory factor to the use of welding, since it utilizes welded distillation towers of very large dimensions. The height of such towers reaches 26—30 m, the diameter of the rings being 4,5 m and their thickness 20 mm. In the "cracking" or distillation towers this latter dimension is as much as 50 mm.

After this brief survey, we shall now proceed to the actual subject of this report, particularly the problem of welded bridges and structures, but before describing a few examples of these we shall deal with the fundamental problems which designers in this country have had to face.

2) Until about ten years ago the discredit had to be combatted which was brought upon welding by the confusion of ideas prevailing as regards the fatigue strength of certain jobs, among which may be mentioned arc-welded rail joints. An attempt was made to strengthen up the elements of the joint by welding fillets applied between the fish-plates and head (or flange) of the rail. This of course proved a complete failure, the cause of which was attributed to the technical process adopted, i. e. the arc-welding.

3) This was wrong, as subsequent experiments[1] showed that, in a joint of the type described, very high peak stresses were encountered, especially at the base of the notches existing between the ends of the two rails. The transition from the section composed of the rail and the two fish-plates to the section composed of

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[1] Dr. C. Miklósi, Prof. C. E. Theodorescu: Contribution à l'étude de la soudure des rails Bull. Scient. de l'Ecole Polytechn. de Timişoare, 1926. Report for the Third International Congress of Tramways and Ligt Railways, Budapest, 1925.

the two fish-plates alone, was actually very abrupt, as it also was to a less marked extent at the ends of the fish-plates. These considerations showed that failure was due to the design arrangement adopted rather than to the process of welding.

4) As a result of the experimental data obtained, an endeavour was made to eliminate the notches, or else to neutralize them, especially the one on the flange side, where, in the particular case referred to, the stress was highest, the track being laid on sleepers. The solution adopted consisted in (1) inserting a steel plate between the previously milled heads of the rails; (2) subjecting the contact surfaces to a sufficient pressure; and (3) fitting a plate below the flanges, and welding up flange and plate. This gave a joint as in Fig. 1, in which the bottom notch was covered by the plate referred to. The effect of the sudden transition of section between the rail-heads was practically eliminated owing to the initial compression set up. The sudden transition of section between the fish-plates, or between the bottom plate and the rail, continued to exist.

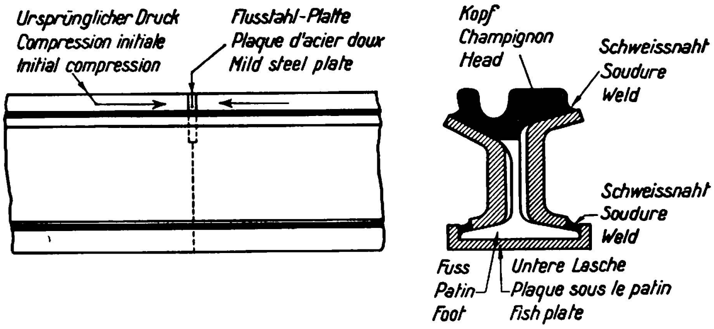

Fig. 1.

Rail joint with welded-on fish plates and cout-out notching between rail butts.

This constructive idea achieved a certain amount of success, since up to now the joints made by this method have stood up to the passage of more than 2 million axles, without giving. This shows the importance of the non-uniform distribution of the stresses, or, more precisely, the creation of a triaxial zone of localized stresses, from the standpoint of the strength of welded jobs subjected to repeated stresses.

5) A triaxial zone of this kind may be set up, not only when a sudden transition of cross-section is involved (the classic case of this being represented by a notch), but also as the result of interposing, by welding, a metal whose properties are different from those of the parts joined by welding. The author has idealized the case where the interposed metal has a strength lower than that of the base metal. For this purpose, a plate of mild steel of 37 kg/mm^2 ultimate strength was welded between two cylindrical bars of hard steel of 70 kg/mm^2 ultimate strength. The weld was made on perfectly flat surfaces which had been previously polished and cleaned with a solution of alcohol and ether. After the whole had been subjected to an initial pressure sufficient to ensure perfect contact, the joint was connected to the secondary of a welding transformer, which raised the temperature to 1000^0 C. This gave a perfect weld[2].

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[2] A. Rejtö: Les lois fondamentales de la mécanique des déformations passagères et permanentes et leurs applications. (The fundamental laws of the mechanics of deformations, temporary and permanent, and how to apply them). Bull. de l'Act Hongr., 32, 1913, Nr. 3.

6) A case of this kind gives rise to very interesting speculations. When the test-piece shown in Fig. 2 was subjected to a tensile test[3], its ultimate strength was found to be equal to 65 kg/mm², i. e. very little below that of hard steel; permanent deformation began at a stress of 43,5 kg/mm², which is the yield stress limit of hard steel. Breakage took place along a plane at right angles to the direction of pull, in the interposed metal. It follows that the latter yielded under the influence of a triaxial zone of stresses, one of these being due to the external force and the other two to the presence of the harder metal which, in trying to prevent the contraction of the mild steel plate, transmitted to it the transverse stresses in question.

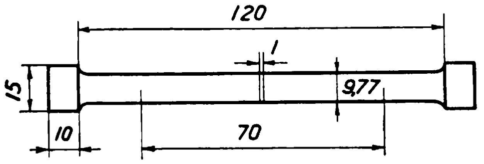

Fig. 2.

Test bar for tension with joint of weld metal.

Permanent deformations due to slip were set up in the hard steel only, to the extent determined by the cohesion of the interposed layer, thus causing an elongation of 5,1 % measured over a diameter between supports of 7 times the diameter of the test-piece. Finally, the presence of a softer metal interposed in the form of a thin layer between two parts of harder metal, may be regarded as a notch giving rise to peak stresses. The presence of the lower strength metal does not appreciably reduce the static strength, but, like a notch, it must have an unfavourable effect when the weld in question is subjected to repeated stresses, because, in this latter case, it is a question of standing up to a local disintegration, and this calls for certain plastic properties and sufficient cohesion at the part endangered.

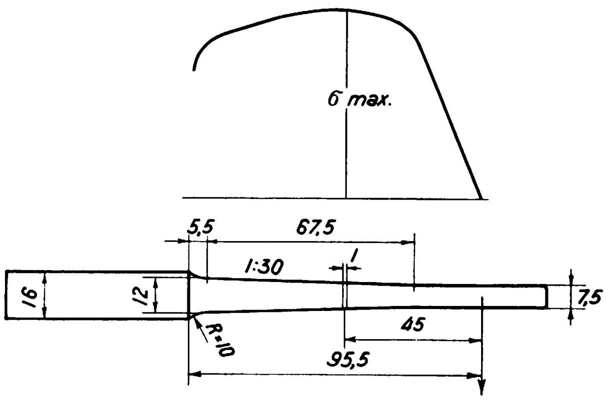

Fig. 3.

Fatigue bending test on rotating bar with intermediate joint of weld metal.

7) In order to prove this fact by experiment, the writer subjected test pieces as in Fig. 3 to rotary bending tests. The steel plate of 43 kg/mm² strength was interposed between two pieces of hard steel of 79 kg/mm² strength. The test-piece was conical in shape, the interposed plate being at the region of the very

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[3] Ir. St. Welding Symposium, 1935, II., p. 645.

pronounced maximum on the stress curve. Fracture took place in the plate after the following revolutions:

Stressing in, kg/mm^2	29.2	28	25.2	23.3	21.9
Revolutions	228,000	430.000	2,304,000	5,760,000	10,080,000

It follows that the oscillatory fatigue strength is 21,9 kg/mm^2, i. e. roughly equal to the value which characterizes the soft metal of the plate. This is the reverse of what happened in the case of static stressing.

If the filler metal is harder than the base metal, the plastic properties of the former are improved, due to the latter being subjected to transverse compression[4]. It is the base metal which more readily loses its plastic qualities, although to a relatively lesser extent, which shows that it is well to work with a filler which is slightly harder than the base metal.

After these considerations, we shall now proceed to discuss a few welded structures.

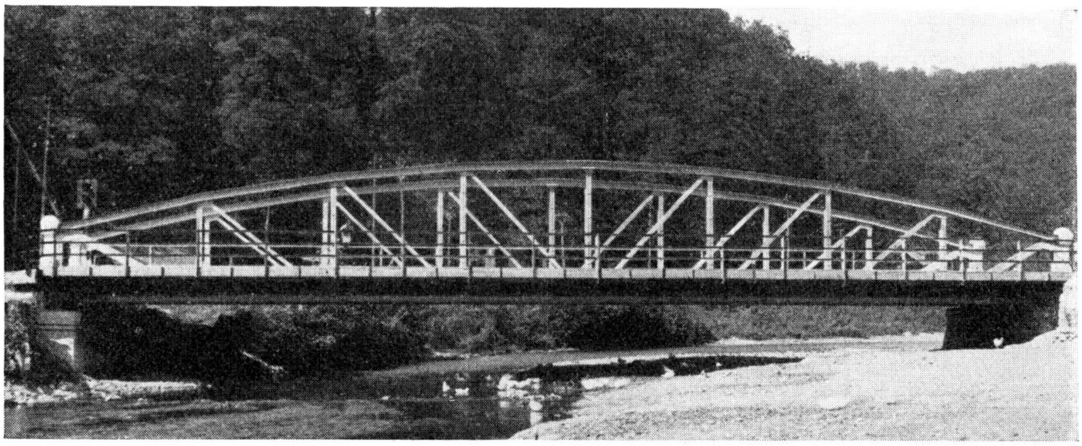

Fig. 4.

View of welded road bridge built by the Reşita Steel Works.

8) Fig. 4 is a general view of the road bridge built in 1931 by the Reşita Steel Works. The span is 30 m, and 36 tons of 42 kg/mm^2 strength steel were used in its construction.

9) At the Grozăveşti Electric Power Station of the city of Bucarest an open conduit has been constructed above ground to form part of the water circulating system, especially between the condensers and the cooling towers. The conduit was arranged 7,5 m above ground, and covers a length of 80 m. Of 2×2 m square section, it deals with 4,15 m^3 a second. The total weight of steel in the structure is 54 tons. Fig. 5 shows the conduit in course of construction.

10) Another example of welded structures is the new boiler house of the Timişoara Electric Power Station, which was put up during the present year

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[4] Kármán: Festigkeitsversuche unter allseitigem Druck. (Tests to determine strength under Compression from all sides). ZVDI., 55, 1911, p. 1749.

to house two boilers. In this case the welded type of construction was selected because of the advantages it presents as regards future extensions in both directions, and also to make it adaptable to possible future requirements not foreseen when the scheme was originally planned.

The framework of the building comprises three main frames each having two hinged foundation joints, and three half-frames each supported by two hinged joints, one being on the foundation and the other on a corner of the main frame. The frames are 15,90 — 17,40 m high, while the span is 14 m for the main frames and 4,40 m for the half-frames. The distance between two frames is 7.50 m. Fig. 7 shows the layout. In this illustration will also be seen the wind bracing, formed by several horizontal joists in the planes of the two outside walls, and by a single joint between the uprights on the inside, in front of which is the service gallery. The coal bunkers are in the top portion of this gallery.

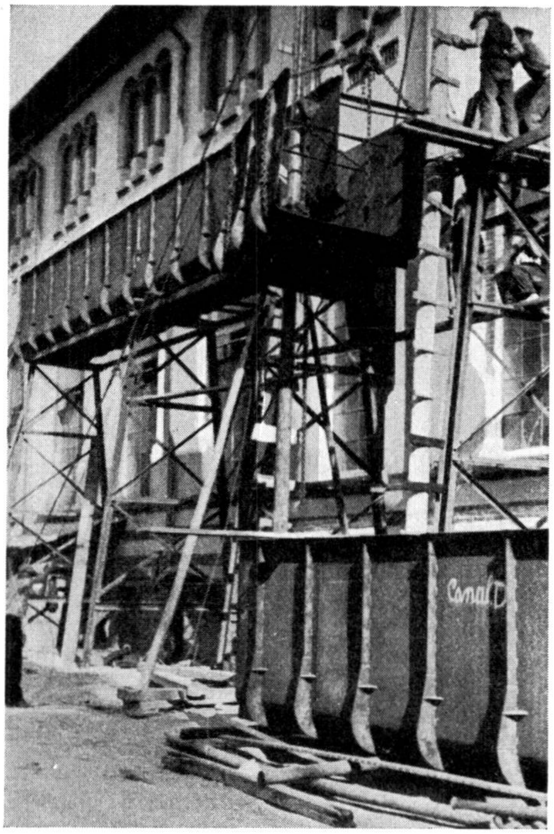


Fig. 5.

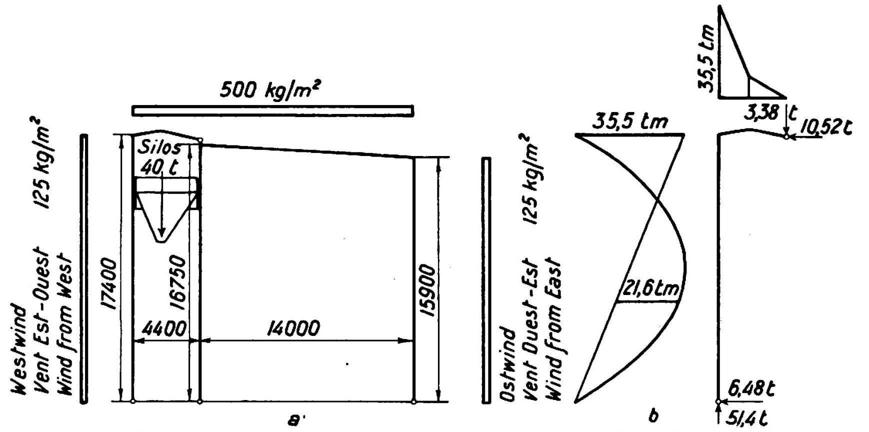
Aqueduct in the Grozăvesti Works during erection.

The outside walls, 20 cm thick including insulation, are secured in a steel skeleton the horizontal beams of which transmit the wind pressure to the frames. The dimensions were calculated on the following loads: Weight of roof, including snow and fortuitous loads, 500 kg/m^2; wind-pressure, 125 kg/m^2; two 40-ton bunkers.

The steel used, of the 37 kg/mm^2 strength type, was welded by coated electrodes, and the specification of the filler metal was: Yield stress limit, 40,8 kg/mm^2; ultimate strength, 50,1 kg/mm^2; elongation $(1/d = 5)$, 21 %; reduction of area, 47 %; notching action *(Mesnager)* 10,1 kgm/cm^2.

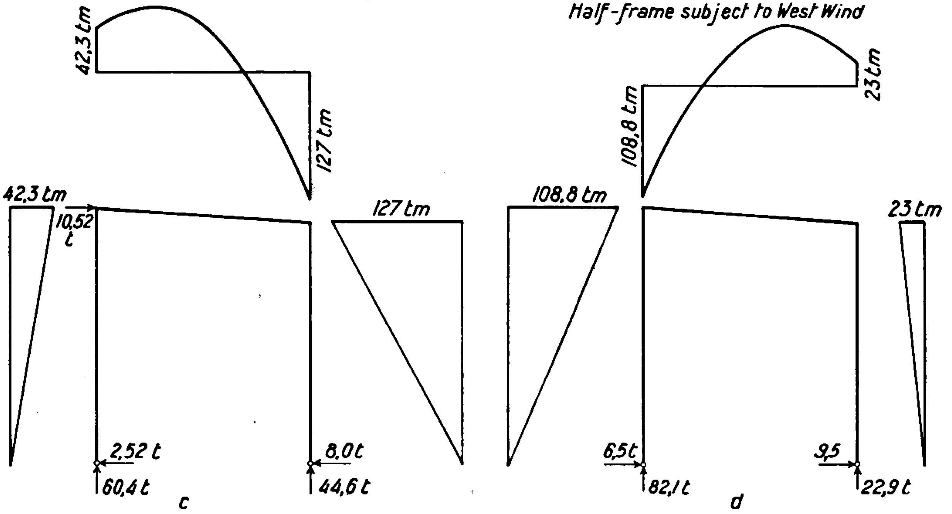
For these metals, the following tensile stress rates could be allowed:

For the base metal (steel)	1400 kg/mm²
For the butt-welded joints	1050 kg/mm²



a Äussere Kräfte Charges extérieures External loads

b Einhüftiger Rahmen, Westwind
Semicadre avec vent Est-Ouest
Half-frame subject to West Wind



c Hauptrahmen, Westwind
Cadre principal avec vent Est-Ouest
Main frame subject to West Wind

d Hauptrahmen, Ostwind
Cadre principal avec vent Ouest-Est
Main frame subject to East Wind

Fig. 6.

Boiler House of Timişoara Works. Reactions and bending moments.

Fig. 6 and 7 shows the reactions and the variation in bending moments which the building must stand up to, the corresponding stress rates being given in Tables I and II.

As this particular building is subject to stresses which are practically invariable, an immediate transition between the parts of the flanges of different thickness without tapering of the thicker flange was allowed for the butt-welds. Similarly, double V-butt-welded joints were permitted between different parts of the web. Finally, at the request of the contractors to whom the work was entrusted, two bolted joints were allowed on each of the main frames to

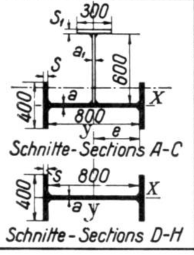
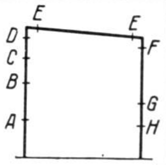
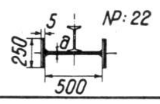
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
												Druck Compression Compression		Biegung Flexion Bending		Schema Schéma Type
Nº		Querschnitte Profils Cross sections	Zeichen Désignation Designation	Höhe über dem Fundament Hauteur au dessus de la fondation Height above foundation level	S cm^2	$J_{max.}$ cm^4	$J/e_{max.}$ cm^3	S cm	a cm	s' cm	a' cm	N t	$\sigma = \frac{N}{S}$ kg/cm²	M tm	$\sigma = \frac{M}{J/e}$ kg/cm	
1	Äusserer Hauptrahmen Cadres principaux extrèmes Main frame	 Schnitte-Sections A-C Schnitte-Sections D-H	A	4,55	250	174'000	4'300	1,0	1,0	1,0	1,0	82,1	328	28	650	
2			B	9,25	360	312'700	7'600	2,0	1,0	2,0	1,0	82,1	228	58	763	
3			C	12,75	540	478'000	11'500	3,0	1,5	4,0	1,0	82,1	152	81	705	
4			D	15,50	320	456'000	11'000	3,0	1,0			52,1	163	99	900	
5			E		240	312'700	7'600	2.0	1,0			8,05	335	67	882	
6			F	14,70	320	456'000	11'000	3.0	1,0			44,60	139	118	1073	
7			G	7,75	240	312'700	7'600	2.0	1,0			44,60	186	60	790	
8			H	4,15	240	174'000	4'300	1,0	1,0			44,60	186	31	720	
9	Einhüft. Rahmen Semicadre Half frame		b	6,35	202	60'000	2'260	1,5	1,0			51,38	254	21,6	955	
10			c	16,275	237	85'000	3'120	2,2	1,0			21,38	90	29,0	930	
11			d		237	85'000	3'120	2,2	1,0			10,524	44,5	30,5	976	

Fig. 7.

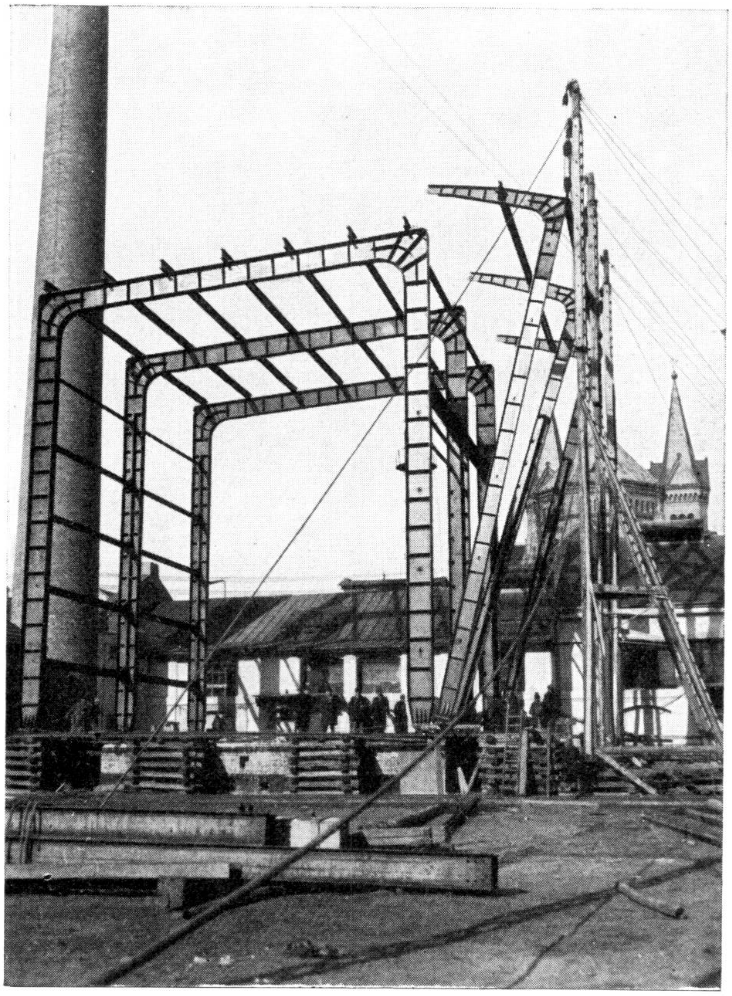


Fig. 8.

Boiler House of Timişoara Works. Erection of Half-Frames.

facilitate transport and erection. One welded joint was made on each half-frame at the site.

The finished structure weighs 144 tons, this weight being distributed as follows:

3 Main Frames	47,20	tons (metric)
3 Half-frames	12,00	,,
9 Supports for Spherical Domes . .	0,87	,,
Wind Bracing:		
a) Between inside uprights	2,77	,,
b) At the side walls	7,34	,,
Roof Purlins	11,81	,,
Wall Framework	48,07	,,
Coal Bunkers	14,26	,,

Fig. 8 shows the half-frames being erected with the aid of derricks anchored by wire ropes.