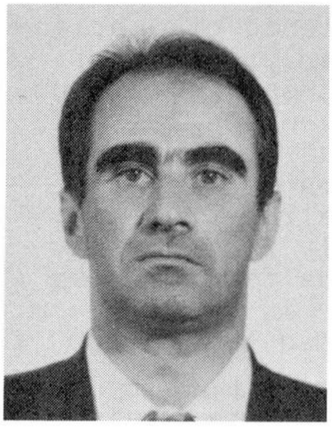
Mechanized Welding of Erection Joints in Road Bridges

Soudage mécanisé exécuté sur les assemblages de ponts-routes

Mechanisiertes Schweissen der Montageverbindungen in Strassenbrücken

Vladimir SOSNOVSKII
Civil Engineer
E.O. Paton Welding Inst.
Kiev, USSR

Boris LEBEDEV
Prof. Dr.
E.O. Paton Welding Inst.
Kiev, USSR



Vladimir Sosnovskii, born 1937, graduated from the Inst. of Transp. Eng., Moscow. Since 1962 he has been working at the E.O. Paton Electric Welding Institute in the field of development of mechanized welding methods.

Boris Lebedev, born 1923, received his civil engineering degree at the Kiev Constr. Inst. Since 1951 he has been working at the E.O. Paton Electric Welding Institute in the field of improvement and strength of welded structures and mechanization of welding operations.

SUMMARY

The paper contains some information on the development of welded road bridge construction in the USSR. Mechanized methods for welding of a butt of a unique design in the main girders under erection conditions are considered. The methods of flat and vertical welding of joints in bridges operating at temperatures down to −50° C are suggested and various types of welding devices are described.

RESUME

L'article fournit des renseignements sur la construction de ponts-routes soudés en URSS. Il tient compte des procédés de soudage mécanisé appliqués aux joints de conception originale des poutres principales, en fonction des conditions de montage. En outre, il expose les méthodes de soudage mises en œuvre à des températures inférieures à −50° C sur des assemblages horizontaux et verticaux de structures de pont. Il présente enfin divers types d'installations de soudage.

ZUSAMMENFASSUNG

Neue Montageverfahren für geschweisste Strassenbrücken in der UdSSR wurden entwickelt. Sie betreffen die mechanisierte Ausführung von Stumpfstössen in Hauptträgern, unter Montagebedingungen und Schweissverfahren für Stösse in flacher und senkrechter Lage, für Brückenbetriebstemperaturen bis −°50C. Verschiedene Typen von Schweissgeräten werden vorgestellt.

1928 may be considered the beginning of welded bridge construction in our country. Manual arc welding of a bridge structure 25 m long under shop conditions was realized then in Vladivostok under the guidance of professor Vologdin. Welding under erection conditions was first used in our country in 1935-1936 for construction of a 45 m long bridge. These works were guided by professor Nikolaev. The wide application of automatic submerged-arc welding under factory conditions became possibly in 1939-1940, when the E.O.Paton Electric Welding Institute headed by professor Evgeniy Paton created the equipment and developed the technology for automatic welding. However, the efforts on welding the span structures for a bridge across the Dnieper in Kiev were interrupted by the War.

Professor Paton, the founder of our Institute, on graduating in 1894 from the engineering-construction department of the Dresden Polytechnical Institute, devoted about 35 years of his scientific and engineering activity to creation of fundamentals of design and technology for construction of more than 35 bridges with riveted joints. As far back as in the 20-s the experience of a scientist and an engineer prompted him that the further progress of bridge building and other industries would be impossible without replacement of riveted joints by the welded ones. Since 1929 and up to the end of his life (1953), for about 25 years, professor Paton had been engaged in solution of the problems related to welding and investigation of strength of welded structures and, first of all, for bridge construction. It was only in 1953 that it became possible to complete construction of the first in our country all-welded beam bridge across the Dnieper in Kiev 1524 m long with 24 spans 58 and 87 m long, its total mass being 10000 t.

Under the shop conditions mostly all the joints were made by automatic and semiautomatic submerged-arc welding. In vertical and horizontal erection connections 81.7 % of welds were made with automatic devices, 8.6 % - with semiautomatic ones and 9.7 % - by manual welding.

A unique design of an erection butt was suggested to weld erection joints in I-beams or vertical members in box blocks by mechanized methods. That design allowed to weld all vertical and horizontal flat joints with automatic devices and, besides, to avoid the labour-consuming operations of check assembly of a span structure at a factory due to cutting-in of inserts in erection (Fig.1). The drawback of that erection butt design was the larger quantity of welds. However, as shown by the practice of the last 30 years, making of such a butt does not cause any difficulties and provides the high quality of joints.

At present, the home bridge building widely applies erection of span structures of prefabricated large-sized blocks, this providing the 2.5 times decrease in the amount of welding operations in site. Despite of all this, still 8-12 % of all welded joints in flat and vertical positions must be made under difficult erection conditions.

The largest amount of the erection operations falls on flat welding of butts in I-beam flanges or box members, orthotropic and ribbed plates, webs, etc. Such butt or lap joints are made by automatic submerged-arc welding and, in the case of butt joints, by providing the back bead formation.

The technology of welding butt joints in metal from 12 to 40 mm thick in one or several passes was developed by the Institute of

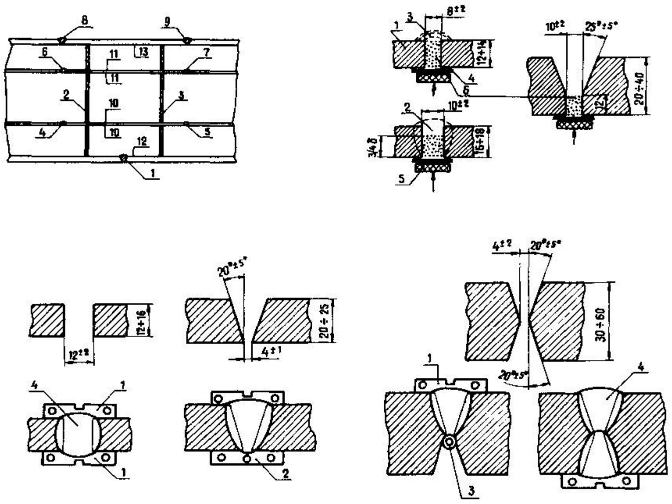


Fig.1 Design of erection butt in main girders and sequence of its mechanized welding.

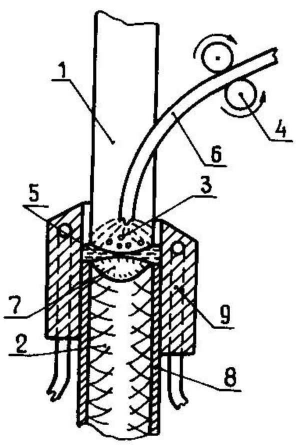


Fig.2 Edge preparation of plates and assembly of a butt joint for erection automatic welding:
1 - base metal;
2 - weld;
3 - flux;
4 - glass cloth backing;
5 - forming copper backing;
6 - metal-chemical filler.

Metal Grade	δ mm	V_{weld}, m/h	Weld metal σ_{τ} MPa	σ_{ε} MPa	El %	RA, %	KCU, J/cm^2 at T °C, weld metal -20°	-40°	-60°	HAZ -20°	-40°	-60°	KCV weld, at t=-20°C
Automatic welding in flat position with metal-chemical insert													
10XCHD	16	20	629	512	25	60	94-176/125	97-117/110	62-98/77	114-199/168	92-102/95	58-101/68	32-60/43
	25	20	641	507	27	63	112-135/126	95-122/119	72-101/76	82-183/140	74-142/103	60-98/71	35-72/45
	32	18	643	514	26	68	133-171/155	115-150/126	86-114/96	117-190/172	64-145/102	66-122/80	38-82/50
Flux-cored wire welding of vertical joints													
10XCHD	12	8.4	662	562	25	60	101-152/124	87-105/93	66-98/80	95-110/104	62-92/80	60-64/59	54-60/56
	16	7.8	650	533	28	67	94-120/114	85-103/94	67-81/71	94-117/108	82-103/95	48-79/68	35-58/56
10XCHD	20	6.8	619	521	24	60	100-135/115	94-112/102	71-88/80	115-160/138	70-115/99	44-72/60	50-77/57
	32	6.6	638	560	25	60	148-164/156	104-118/112	70-91/78	97-151/126	86-145/107	46-66/57	48-70/52
14G2AF	16	7.2	682	572	27	64	95-156/117	87-95/91	72-80/76	62-67/64	52-67/58	50-65/55	47-67/50
	20	6.6	633	540	28	68	129-144/137	65-107/96	62-79/68	74-89/68	60-88/74	55-60/57	47-66/54
	32	6.2 I pass	640	538	29	67	112-124/117	72-111/91	62-88/85	107-117/113	92-107/100	57-60/58	47-90/52
		6.8 II pass					110-124/115	90-105/99	82-90/86	137-150/142	80-115/97	62-72/68	55-77/62

Table 1 Mechanical properties of weld metal

Transport Engineering. This technology included the application of special metal-chemical filler developed by the Paton Institute. As shown in Fig.2, a gap is filled with a certain amount of the filler, depending on the metal thickness. A copper plate with a few layers of glass cloth is pressed to a butt from its lower back side. Joints 12...14 mm thick without a groove are made in one pass, while those with the 18 mm metal thickness - in two passes with smooth back weld formation and reinforcement up to 2 mm. For the larger metal thickness welding is performed with the V-groove and the 12 mm root face. The root bead is made by using the filler and the rest weld layers - following the conventional technology with an arrangement of beads on the groove sides. This technology of welding allows to avoid the edge preparation and back bead welding operations and, besides, to reduce the number of weld layers, to decrease the value of welding strains, as well as to exert the preliminary positive effect on chemical composition of deposited metal, thermal cycle of welding and mechanical properties of weld metal. As shown by the studies, mechanical properties of weld metal produced by using the metal-chemical filler meet the USSR standard requirements for different regions with the design temperature below -50°C (Table 1). Characteristics of some steels used in our country for bridge structures are briefly given in Table 2.

Depending on the steel grade, fatigue limit of such butt joints is 20...30 % higher than that of joints made with manual backing run welding in overhead position. In welding with the filler the productivity of welding operations increases 2-3 times. To raise the productivity of erection operations the orthotropic and ribbed plates were enlarged into blocks at special stands before building-in into a bridge structure (Fig.3).

Short vertical butts in open ribs of the ribbed plates are made by arc self-shielding flux-cored wire welding with forced weld formation by using a light-weight portable device.

Fillet welds with the 6...12 mm legs of lap and T-joints located in flat position are made in one or two layers by semiautomatic submerged-arc or self-shielding flux-cored wire welding. The small-section fillet welds in vertical or overhead position are made in one pass with free weld formation by pulsing-arc CO_2 welding using the 1.2 mm dia. welding wire with an automatic welding device.

The certain amount of erection welded joints operating both in tensile and compression zones of a bridge structure must be made in vertical position. Depending on the metal thickness, such butt joints are made either in one or two passes with forced weld formation. For some known reasons, electroslag welding is not used for such vertical joints in the home bridge building. These vertical joints can be made by arc welding with solid welding wire under fused or ceramic fluxes, as well as with self-shielding flux-cored and activated wires (Fig.4).

Depending on the metal thickness, butt joints are assembled by the Π-shaped clamp without edge bevelling or with V- and X-grooves with a gap shown in Fig.5.

The developed welding technology and consumables (fluxes and welding wires) provide the required mechanical properties of welded joints for bridges operating at temperatures down to -50 °C (Table 1).

Material	δ mm	Chemical composition (wt%)								Mechanical properties				
		C	Si	Mn	Cr	Ni	Cu	V	N	MPa σ_E	MPa σ_z	El. %	KCU J/cm² at T°C -40	-70
10XCHD	5÷40	0.12	0.8÷1.10	0.50÷0.80	0.60÷0.90	0.50÷0.80	0.40÷0.60			390	530÷670	19	39	29
15XCHD	5÷32	0.12÷0.18	0.40÷0.70	0.40÷0.70	0.60÷0.90	0.30÷0.60	0.20÷0.40			345	470÷670	21	29	29
14G2AFD	5÷50	0.12÷0.18	0.30÷0.60	1.20÷1.60	0.40	0.30	0.15÷0.30	0.07÷0.12	0.015÷0.025	390	540	20	39	29
15G2AFD	5÷32	0.12÷0.18	0.17	1.20÷1.60	0.30	0.30	0.20÷0.40	0.08÷0.15	0.015÷0.30	390	540	19	39	29

Table 2 Brief characteristics of base metal

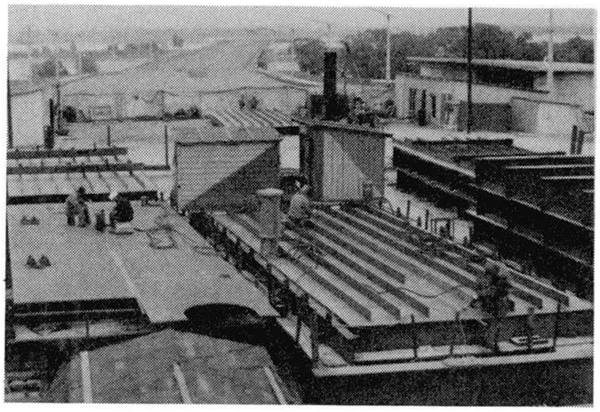


Fig.3 Enlargement of orthotropic and ribbed plates into erection blocks.

Fig.4 Flow diagram of welding vertical joints with forced weld formation: 1 - base metal; 2 - weld; 3 - gas shielding of arc; 4 - feed mechanism; 5 - slag pool; 6 - self-shielding wire; 7 - metal pool; 8 - slag crust; 9 - forming shoe.

Fig.5 Shape of grooves in plates and sequence of welding vertical erection joints: 1 - water-cooled copper shoe; 2 - water-cooled copper backing; 3 - copper pipe with water; 4 - weld.

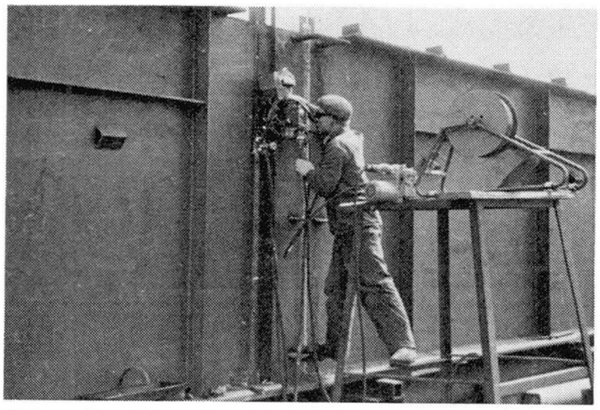


Fig.6 Device for submerged-arc welding of vertical joints.

Devices created at the Paton Institute are used for welding vertical joints. Submerged-arc welding of joints with and without a groove is carried out with a device which moves along a butt on a rail of a usual angle 50x50 (Fig.6). Self-shielding flux-cored and activated wire welding of joints without a groove is performed with the help of the single-arc railless device (Fig.7) or the double-arc one moving along the angle (Fig.8). The devices as shown in Fig.9 or in Fig.8 are used to weld joints with V- or X-grooves. Welding devices have controllable mechanisms for electrode oscillations along and across the groove, as well as the instruments which fix the slag pool level, this allowing to automate the travel speed of the device when it moves along a butt. Speed of welding the vertical one-pass joints is 5-8 m/h, this being about 5 times as high as in manual welding. Welding starts from the run-in tab and finishes at the run-out tab in any season of the year without any preheating, because the low travel speed of the device results in self-heating of the sufficient lengths of metal plates from the welding pool.

The quality of welded joints is controlled by ultrasonic and X-ray methods in the volumes specified by our standards. Mechanical properties of welded joints are checked by using the reference specimens welded under the same conditions as the main structure.

The above methods of mechanized welding under erection conditions were widely applied for construction of more than 35 railway bridges in our country and abroad under different climatic conditions.

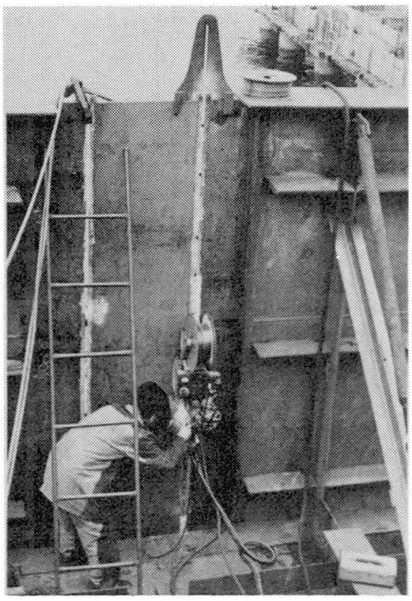


Fig.7 Single-arc railless device for welding vertical joints in metal 10...20 mm thick.

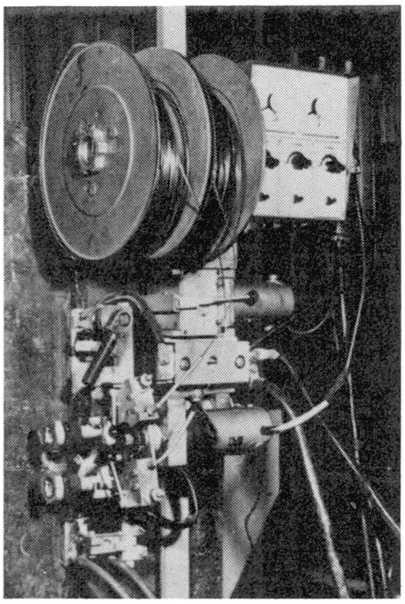


Fig.8 Double-arc device for welding vertical joints in metal 25...60 mm thick.

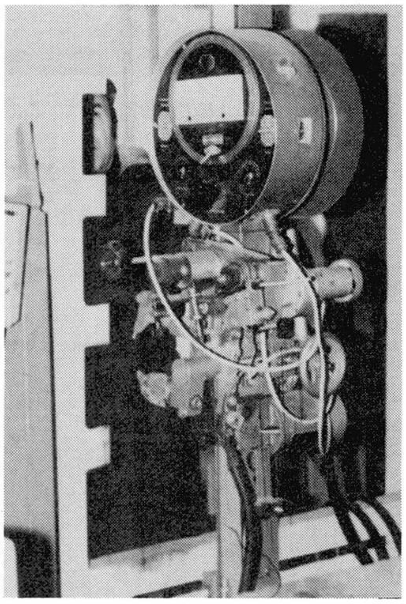


Fig.9 Single-arc device for welding joints in metal 16... 40 mm thick in any spatial position.