THE E.O. PATON ALL-WELDED BRIDGE IS SIXTY YEARS OLD

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The question of construction of motor-road bridge across the Dnieper river was raised before the Great Patriotic War. By that time the technical project of the bridge with driving atop and split through main truss girders, manufactured using riveting, was drawn up and approved. In that period at the Electric Welding Institute of the Academy of Sciences of the UkrSSR the method of automatic submerged arc welding was developed allowing producing high-quality welds and Evgeny O. Paton proposed to manufacture spans of the bridge using welding. In spite of the opinion of opponents, the initiative of Evgeny Paton was supported by the Government of the USSR, and the decision was taken to construct the Kiev bridge applying welding with riveted site joints. To fulfill the project, the supports were manufactured in 1940–1941, and at the plant of metal structures in Dnepropetrovsk the production of assembly elements of spans using automatic submerged arc welding began. However, the construction of bridge was interrupted because of the war, and it was restored after its termination. As far as equipment and technologies providing high quality of assembly welds were created by that time, Evgeny Paton proposed to construct all-welded bridge in Kiev across the Dnieper river applying automatic welding not only under shop conditions, but also in site. The all-welded Kiev bridge across the Dnieper river was constructed in close cooperation with the Kiev enterprise «Proektstalkonstruktsia», the plant of metal structures in Dnepropetrovsk, Bridge Construction Group of the Ministry of Rail Roads, the E.O. Paton Electric Welding Institute of the Academy of Sciences of the UkrSSR and the Ministry of Municipal Economy of the UkrSSR. 3 Ref., 16 Figures.

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At the beginning of the 1930s the welding began to be applied widely in ship building, industrial building, transport, handling machine building and other fields of industry instead of riveting. It allowed introducing many innovations and simplifications reducing the volume of consumed metal and labor intensity in manufacture of structures. However, the transition from riveting to welding was considerably difficult, especially during manufacture of large-size metal structures and, in the first turn, spans of bridges operated under the conditions of low climatic temperatures and complex alternating loading.

There was troubled news from the West Europe about the serious problems with welded bridges. One could not but remind the widely known cases of fractures of welded bridges in Germany and Belgium. That was quite enough to form the negative attitude towards application of welding in bridge construction.

In that period at the Laboratory of Electric Welding of the All-Ukrainian Academy of Sciences (Kiev), transformed in 1934 into the Electric Welding Institute of the Academy of Sciences of UkrSSR, the purposeful study of load-carrying capacity of welded joints and structures was started. In that laboratory, organized and headed by the academician Evgeny Paton, during the first period the experimental investigations were carried out by comparing the results of tests of similar welded and riveted joints of specimens, girders and integral structures at static, alternating and impact loadings. The carried out tests allowed obtaining the most visual and convincing proves of strength of welded joints and advantages of welding technology. In those and other comparative investigations the welded joints were fractured due to fatigue not in weld metal, but in base metal in the joint zone. It became obvious that the main cause of their fracture is the concentration of stresses created by the shape of joints and welds or technological defects of welding.

It was also assumed that insufficient strength and toughness of weld metal, its lower homogeneity than that of base metal will decrease the resistance of structures to fatigue fractures. In that period the works on search for rational design and technological solutions were carried out providing preset cyclic life of welded joints and assemblies. The investigations related mainly to bridges, railway cars and cranes. They persuasively showed that welded joints and assemblies can be reasonably applied in critical structures,

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undergone the effect of alternating stresses. The full strength of butt joints with removed «weld reinforcement» and base metal at alternating loads was proved.

The question of construction of motor-road bridge in Kiev across the Dnieper river was raised before the Great Patriotic War. By that time the technical project of the bridge with driving atop and split through main truss girders, covering the spans of 58 m length (in the floodplain part) and 87 m (in the navigable one) was drawn up and approved. As in that period at the Electric Welding Institute of the Academy of Sciences of the UkrSSR the method of automatic submerged arc welding was developed allowing the producing of high-quality welds, E.O. Paton proposed to manufacture spans of the bridge using welding. And then, the opponents of application of welding in bridge construction raised their swelled heads over. At the meeting they stood up for the technology of riveting of bridges widely used by that time, and in support of that they presented the pictures from the foreign journals with fractured spans, in building of which the welding was applied.

Evgeny Paton, basing on the results of the first profound research works of welding process, as well as on his intuition, was firmly convinced that the cause of the disasters abroad was not in the main principles of welding process, but in its wrong primitive application. The designers used to leave the design of bridges, accepted during riveting, unchanged, i.e. they did not consider the peculiarities of the process of joining the elements using welding. Besides, the steel applied for riveting turned to be quite unsuitable for welding, and quality of welds in use of manual welding at that time was disastrously low.

After Evgeny Paton had briefly stated the principles of construction of the welded bridge in Kiev across the Dnieper river, including the selection of steel suitable for welding, the application of automatic submerged arc welding and strict control of quality of welded joints, N.S. Khrushchev, the Secretary of the Central Committee, resumed: «We will weld the bridge. I mean weld! Failures of other countries shall not discourage us».

Only due to a high authority and engineering courage Evgeny Paton succeeded to win a favorable decision of the directive bodies. The initiative of Prof. Paton was supported by the Government of the USSR, which resulted in taking the decision on the construction of Kiev bridge with welded and riveted site joints, in accordance with which the necessary changes in the project were made.

To realize the project the supports were manufactured and right on the approach of the Great Patriotic War the plant of metal structures in Dnepropetrovsk started manufacturing of assembly elements of spans using automatic submerged arc welding. The war interrupted construction of the bridge.

In 1946, Evgeny Paton, being recognized as the leader in the field of welding and bridge construction and foreseeing the great challenges in manufacture of bridge spans using welding, appealed to the Government of the USSR with proposal to implement welding in construction of bridges, which supported his initiative and issued special resolution on this matter. To fulfill the resolution of the government Prof. Paton united and organized the mutual work of designers of bridges and colleagues of the Electric Welding Institute. They conducted a great complex of investigations and designing developments to work out the basic principles of designing the welded bridges, stated by E.O. Paton already in 1933 [1]. As a result of this great work the main problems were solved opening the wide possibilities of application of welding in construction of bridges. They are described in work [2] in details and related to modernization of design of the bridge, its assemblies and applied steel. The creation of proper equipment and technology, providing the high quality of both the shop and also site welds [3] was principally important.

The obtained results allowed E.O. Paton to raise the question about construction of all-welded bridge in Kiev across the Dnieper river, applying automatic welding not only under shop conditions but also in site. The proposal of Paton, supported by the Government of the USSR, was accepted, and the technical project, and later the working projects were amended correspondingly, considering the results of the recent investigations of the Electric Welding Institute and also modernized design changes in accordance with the Resolution of the Council of Ministers of the USSR of May 17, 1948 of the project assignment which related to the following points:

- truss girders of the bridge shall be welded with a solid wall of not higher than 3.6 m;
- existing type of supports shall be preserved along the whole length with girth rails on columns;
- in the navigable spans the truss girders shall be applied with the solid haunches.

All these and other developments of the E.O. Paton Electric Welding Institute served as the research background for designing, manufacture

Figure 1. All-welded E.O. Paton bridge across the Dnieper river in Kiev

and construction of the first largest all-welded bridge in Europe (Figure 1). The plant manufacture of metal structures of the bridge of total weight of 10,000 t was performed since December, 1951 till April 1953, and erection works — since April, 1952 to October, 1953. The total length of the bridge is 1543 m. It has 24 spans — 20 by 58 m and 4 navigable by 87 m. In the cross section the span structure has four double-T main girders with the solid wall, placed one against another at the distance of 7.6 m, which are united between one another by transverse braces. The longitudinal braces are present only along the lower girth between the middle main girders along the whole length of the bridge. Over the supports the longitudinal braces were mounted between all the four main girders. The upper girths are joined by transverse rolled beams with the ferroconcrete plate of a roadway included into their operation for bending. The width of the bridge is 27 m (roadway is 21 m, two footways of 3 m each).

The realization of construction of the bridge was entrusted to the Ministry of Municipal Economy of the USSR, which organized the Special management of bridge construction.

The construction of Kiev bridge across the Dnieper river was carried out by the staff colleagues of Kiev department of «Proektstalkonstruktsia», plant of metal structures (Dnepropetrovsk), Bridge Construction group of the Ministry of Rail Roads, the E.O. Paton Electric

Figure 2. General view of the rig cross-arm for assembly and welding of large-size assembly elements in the workshop of plant of metal structures in Dnepropetrovsk

Figure 3. Process of assembly of trusses in the rig

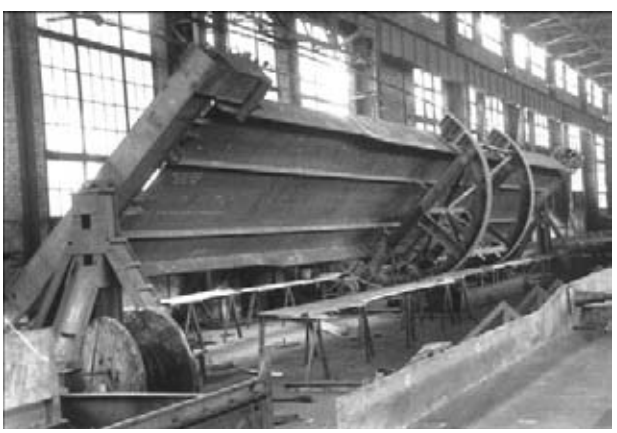

Figure 4. Long beam in the tilter

Figure 5. Welding of wall butt weld using tractor TS-17-M

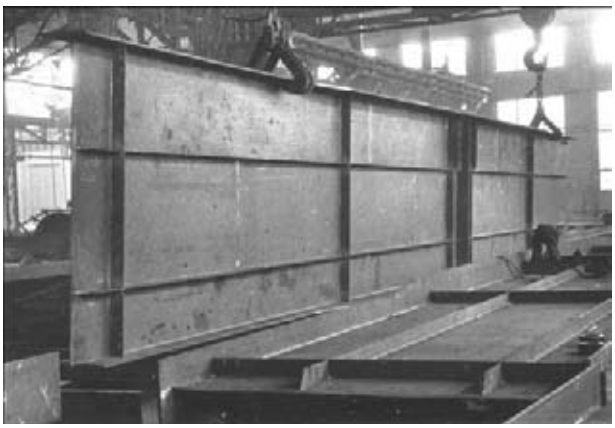

Figure 8. Welding-on of edges of stiffeners

Figure 6. Welding-on of stiffener using semi-automatic machine PSh-5 with holder DSh-27

Figure 9. Welding of girth welds of haunch in the rig

Welding Institute of the Academy of Sciences of the UkrSSR and the Ministry of Municipal Economy of the UkrSSR in close cooperation between each other.

The plant of metal structures in Dnepropetrovsk provided and equipped the special workshops for production of large blocks and put into service the mass production line for assembly elements (Figures 2–4). The workers of the Bridge Construction Group trained and instructed by the specialists of the Electric Welding Institute (Figures 5–9), carried out the welding works all the year round. The inspection, monitoring and acceptance of welding works were performed by the inspection bodies, organized and governed by the Electric Welding Institute (Figure 10).

The delivery of ready assembly elements of the bridge to Kiev was performed by railway transport (Figures 11 and 12). Welding of site

Figure 7. Process of welding of longitudinal butts using tractor TS-17M in the tilter

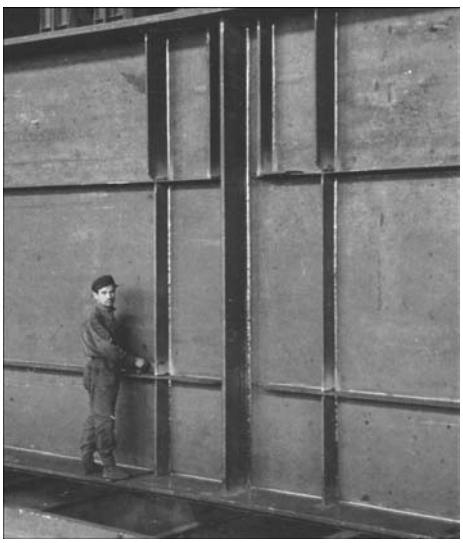

Figure 10. Inspection of welds

Figure 11. Echelon with main beams on the plant rails

Figure 12. Haunch loaded on the platform

joints, as well as shop welding was performed using automatic machines (Figures 13 and 14).

The E.O. Paton Kiev welded road bridge is unique by a number of its characteristic features not only in our country, but also in the whole world. His uniqueness consists in the following:

• all the joints in the bridge spans are manufactured at the plant and in site using welding, i.e. the bridge is all-welded. If to take into account its total length of 1543 m and about 10,000 t of steel used for spans and the total length of welds of 10,668 m, one can confirm that even today it remains the largest all-welded bridge in the world;

• manufacture of assembly elements at the plant and producing of site welds was performed mainly using automatic and semi-automatic welding. Manual welding was applied in producing less critical elements of the bridge (braces, transverse beams, etc.);

• during designing the bridge the principle of blocks enlargement was used, which allowed producing 97 % of all the shop welds of main trusses and 88 % of all the site welds of main trusses using automatic and semi-automatic welding. Moreover, the presence of large single-type blocks allowed mechanizing the assembly-welding operations and organizing line method of

Figure 13. Welding of vertical site butt using automatic machine A-314

Figure 14. General view of welded site butt in the span

manufacture at the plant and in site, which enhanced the quality of welding works and decreased their labor efficiency.

The exclusive role in the construction of this bridge belongs to Evgeny Paton, who persistently worked over the problem of welded construction of bridges during many years and was the initiator of construction of the all-welded bridge in Kiev. Till the last days of his life E.O. Paton steadfastly kept an eye on its construction.

Figure 15. Testing of the bridge

Figure 16. Solemn opening of the bridge in November 5, 1953

The bridge was inspected by the laboratory of the Moscow Road Transport Institute both during the process of construction as well as after its completion. In conclusion the bridge was tested on static and dynamic loading (Figure 15). The tests gave the positive results.

In November 4, 1953 the Governmental Commission carried out the full-scale inspection of the built road-transport bridge across the Dnieper river in Kiev, studied the technical documentation and resolved to accept the bridge into the permanent operation since November 5, 1953 applying all types of loads on it envisaged by the project without the speed limit. The main works on the construction of the bridge were evaluated by the Governmental Commission for «excellent».

In November 5, 1953 the Council of Ministers of the UkrSSR approved the Act of the Governmental Commission of the acceptance of the all-welded road-transport bridge across the Dnieper river in Kiev according to the Resolution № 2348 and appointed to open the traffic along the bridge for November 5, 1953 (Figure 16). That was the end of the responsible and the most difficult stage in formation of the welded construction of bridges.

In December 18, 1953 according to the Resolution of the Council of Ministers of the USSR the newly built bridge was named after Evgeny Paton.

In 1995 the American Welding Society included the all-welded bridge in Kiev across the Dnieper river into the list of outstanding engineering structures.

After 60 years of operation the E.O. Paton bridge is continuing its reliable operation at the design load of N-10 and considerably increased intensiveness of traffic (80,000 vehicles per day at the design value of 10,000).

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