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Evolution of Systems, Structural Forms and Construction Technology of Precast Reinforced Concrete Bridges in the USSR

Une évolution des systèmes, des formes constructives et de la technologie de construction des ponts en béton armé en URSS

Evolution von Systemen, Konstruktionsformen und Bautechnologie vorgefertigter Stahlbetonbrücken in der UdSSR

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The first instances of application of precast reinforced concrete bridges in the USSR for highway bridges date from the first quarter of the century and in the case of railway bridges from 1938 (not taking into account earlier application of reinforced concrete slabs for bridging small spans). However precast reinforced concrete construction start to be widely used in the post-war period which is explained by the introduction of prestressed concrete.

Precast beams for railway bridges with spans of more than 12m and for highway bridges with spans of more than 24m are already made (with hollow slabs being applied for 9m spans) using high-strength reinforcement in the form of strands of 24 or 48 5mm dia wires with a strength of 170 kg/mm^2 as well as in the form of strands and large-size rods. The maximum lengths of reinforced concrete beams achieved in this country are as follows:

standard beams for railway - up to 34m, standard beams for highways - up to 33m (single-piece beams) and up to 42m (beams laterally divided into several pieces).

For some bridges on highways 64m long T-beams and 71m long box beams have been used.

The main schemes of reirforcement and cross sections of non-continuous beams are rather permanent (Fig.1).

It is necessary to note a highly effective application of so-called beams without diaphragms for highway bridges. Clarification of the methods of thre-dimentional calculations of span-type structures using electronic digital computers has shown the possibility of employing various optimum arrangements of standard beams for different wiuths of bridges by using concreted inserts.

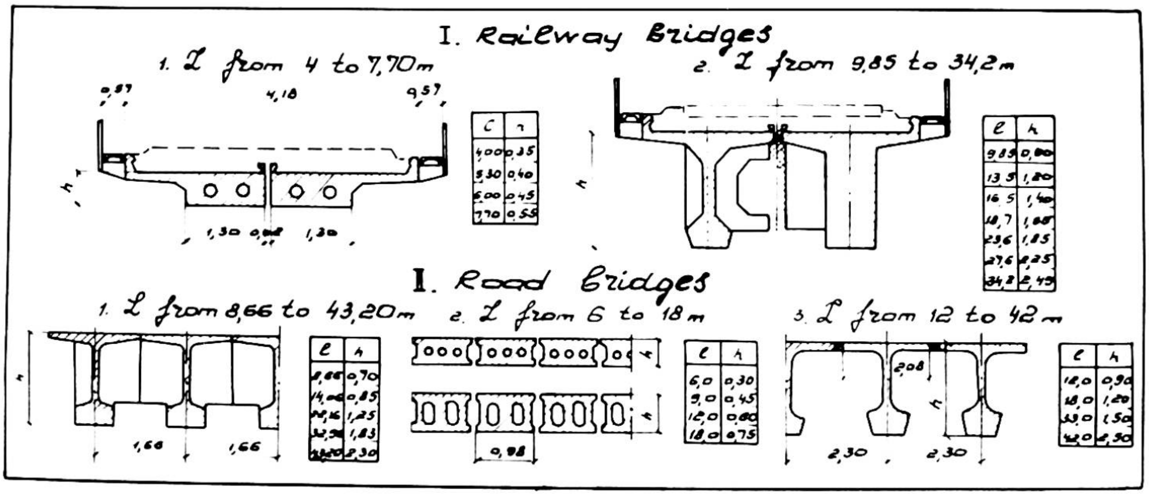

Fig. 1

For the railway oridge spans of more than 18m and for the highway bridge spans of more than 33m the ends of the reinforcement rods are often turned back.The use of prestressed vertical stirrups is more seldom.As a rule all beams which can be transported as a single pieces are fabricated by prestressed method.Highway bridge beams weighing up to 100 tons are installed by means of cantilever-lock or cantilever-leader-lock cranes permitting lateral movement.Railway bridge beams weighing upto 130 tons are installed with the help of cantilever swing cranes ensuring up to 5.5m deviation of the load from the railway track as well as locomotive cranes with a load-lifting capacity of 125 tons.71m large-span beams of 800 tons by weight were transported to the piers by special cranes and were installed by means of a floating unit. Complicated auxiliary arrangements used for the 2.8 km bridge across the river Volga were fully justified as they were used 64 times.

The first experience of application of precast thrust-arch constructions dates from 1938. Later on, since 1948, there have been built precast super-arch structures on railway bridges. An arched thrust railway bridge of a completely precast design with 150m spans was built in 1961, with the railway track being laid in the middle of the bridge.

In the last years there were constructed reinforced concrete arch-type bridges with tie beams with up to 66m spans (Fig.2) as well as continuous reinforced concrete trusses of tubular elements with 55 m spans (Fig.3).

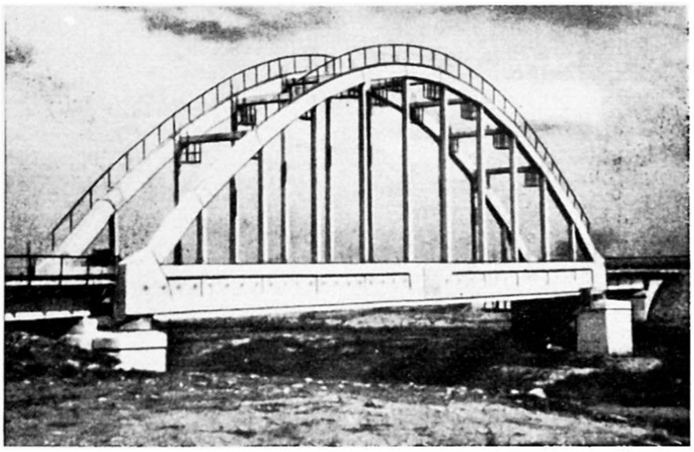

Fig.2

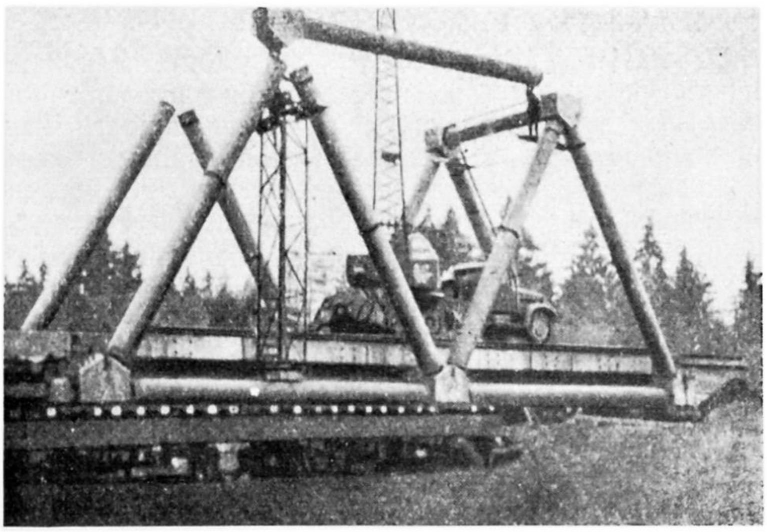

Fig.3

They have been exploited quite successfully.

The joints of precast reinforced concrete bridges carring railway loads such as hinge-type joints with welded reinforcement, joints with steel embeded parts and joints which are longitudinaly pressed both by means of stretched bundles passed through them and by means of continuous mechanical winding-on of reinforcement are worthy of attention.

Various type of joints were subjected to special static and dynamic tests at a changeable load cycle equal to 2×10^6.

In the USSR precast prestressed span-type structures with large spans have been mostly developed for highway bridges. The following clasification of the designs used in non-thrust bridges could be mentioned:

1. Non-continuous beam-type bridges of up to 71m described above;
2. Continuous beam-type bridges with upto 84m spans;
3. Trestle-type non-thrust bridges and beam-type bridges of various cantilever designs with hinges in the spans of up to 148m.

The above mentioned span-type structures have been built in the form of girders.

4. Arch-cantilever bridges with up to 124m spans.

5. Span structures with a through truss. There were not many of them used in the large-span bridges.

The largest of them is the bridge across the river Volga in Saratov which has through continuous prestressed reinforced concrete trusses arranged according to the scheme:

106 + 3 + 166 + 106m.

As there are detailed publications on the above subject, some in the paper of the Association, we shall not discuss the bridges of this type any further, though in addition to the described type, there are several other types of bridges with continuous trusses constructed in the Ukraine.

Several precast thrust arched bridges with up to 124m spans as well as the precast arch-type bridge for combined highway and underground-train traffic with an underground station at the Lenin Stadium in Moscow on it occupy a special place.

As for erection method it is necessary to point out that it is only the precast arched bridges that are constructed with the use of auxiliary supporting arrangements in the form of standard steel centering.In all other cases more progressive methods are used:

- Erection with the help of 1-2 supports;
- Longitudinal movement of continuous precast reinforced concrete structures;
- Transportation of assembled structures by water;
- Cantilever assembly method.

The first stage means the use of "classical" reinforced concrete units of span structures: thrust and non-thrust arch-type bridges.

Allproblems connected with the introduction of precast reinforced concrete were solved at this stage by means of dividing structures into more or less large elements of the systems which were widely used in bridging long span when using monolithic concrete. Joining was done by welding the reinforcement ends and by concreting the joints.

The next stage connected with the use of prestressing is a deviation from the "classical" (in regard to reinforced concrete) arched design. It is characterized by the creation of systems corresponding in a better way to the industrial essence of the precast construction. After their creation the methodological approach to the solution of the problem has changed: it is not from systems toward their embodiment in precast reinforced concrete but on the contrary, it is from precast reinforced concrete towards the creation of systems in which the main industrial properties of the former could be most fully and rationally used.

There appeared various modifications of the cantilever designs of span-type structures in which the increase of stresses at the root of the cantilever,due to its being built up,made it necessary to increase the quantity of stressed reinforcement for suspending the following units.

This gave the possibility of using the cantilever assembly methods.

Cantilever systems have also another technological advantage over the arch-type structures. The latter consists of a great number of elements fulfilling various static and constructive functions in the system: arches,posts, girders and traffic-way beams whereas cantilever systems of span-type structures with a continuous web and box-type cross section have a three-dimentional block as the main and the only type of the assembly element.

Installation of the unit with only one glued joint formed completes all the erection works to be done in the section of the span-type structure. Owing to these properties the cantilever systems have found wide application in the course of a short time.

Proposals of specialists from the Institute "Soyuzdornii" on the use of cantilever assembly precast prestressed reinforced concrete span-type structures were published as far back as 1955.

The cantilever assembly method was used in the construction of more than 20 largest bridges across such rivers of the country as Volga, Dnieper, Oka, Moscow, Don and others. In most bridges the cantilever beams or cantilever frames with a continuous web were used. Such bridges were designed using various static schemes (Fig. 4).

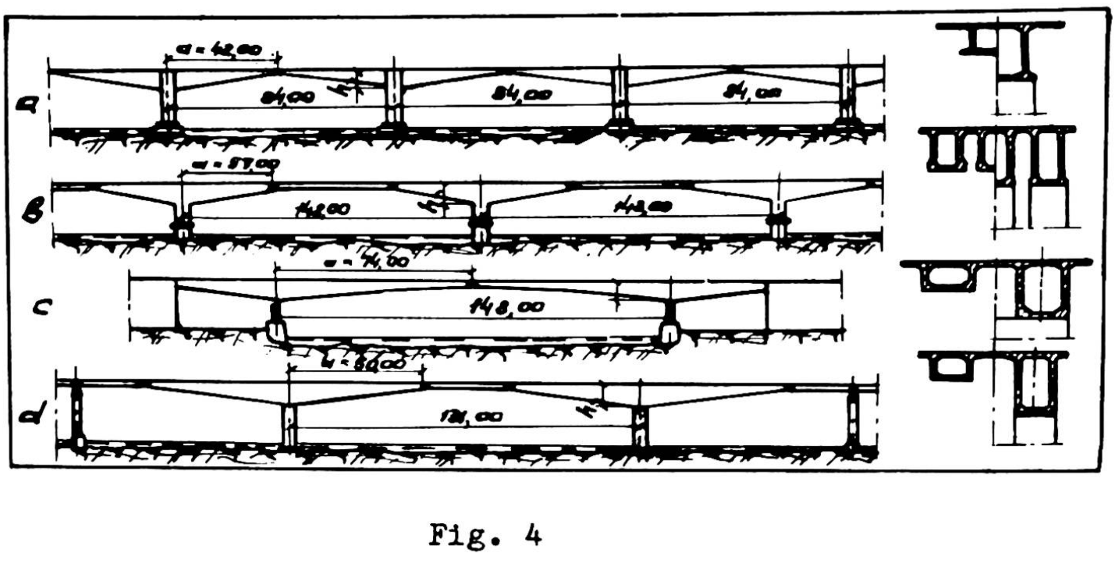

Fig. 4

T A B L E No.1

Some Information on Bridges with Girder Assembled by Cantilever Method

NN	Bridge scheme	Max. span achived in m	Max. number of large spans	Max. width of bridge	"a" canti- lever over- hang	"h" canti- lever height	Ratio h/a
1.	Frame-cantilever (Scheme "a", Fig.4)	84	3	25.5	42	6	1/7
2.	Frame-cantilever with suspended beam (Scheme "b", Fig.4)	148	3	24	57	9.50	1/6
3.	Beam-cantilever (Scheme "c", Fig.4)	148	1	42	74	7.5	1/9.9
4.	Beam-cantilever with a beam in the middle (Scheme "d",Fig.4)	131	3	17	50	6.5	1/7.7

The bridges with a longitudinaly movable hinge in the span have an increased deformability. In order to compensate next lasting deformations the following measures were taken:

- the rigidity of cantilevers was increased by developing their height;
- high-grade concrete $R_{28} = 500$ kg/cm^2 was used. As a rule, precast elements were loaded in this case at a later time.
- camber experienced during the erection of structures was taken into account by calculating possible deformations

due to shrinkage and creep.

Observations over individual bridges show that within 4 to 5 years long-term deformations to considerable extent stabilized. For example,in a 148m span bridge with the minimum height of the cantilever (No.3,Table 1) the calculated deformation compensated by the camber was 26.4 cm. The actual deformationwas close to the design one which was calculated taking into account the actual value of the age of concrete blocks by the time of loading. Further increase of rigidity is achieved by using continuous systems.

Some discussions were caused in this country by the question of selecting the cross section of blocks to be assembled and by their erection weight which ranges from 15 to 180 tons. In most cases the erection weight of units used in bridges already constructed was equal to 35 and 65 tons.

Most bridges were constructed using box-type blocks, (Fig.4) however for two bridges there were used T-blocks which have better transportability at a length of up to 6m. For some bridges box-type units were assembled of flat prefabricated elements at the construction site.

Strands of wire with a diameter of 5mm and a strength of 170 kg/mm^2 as well as skew-coiled wire ropes with a diameter of 45mm and a strength of 190 kg/mm^2,with the design modulus of elasticity being equal to $1.6 \times 10^6 kg/cm^2$ were used as a high-strength prestressed reinforcement for the bridges.

High-strength wire was used in the cantilever-type bridges at the upper part of girder in the open channels according to the diagram of stresses for cantilever-type bridges.Along with this,various methods of arranging,anchoring and straining of reinforcement were employed.

In the course of several years of application of cantilever assembly the joining method has gone through the following evolution:

- joint with welded reinforcement poured with concrete;
- joint on cement mortar;
- glued joint.

For glued joints adjoining surfaces of blocks were initially formed by means of alternate concreting of cantilever blocks.

In the last years blocks having constant height were manufactured in rigid steel formworks as individual interohangeable units.Glued joints were made by applying a thin layer of syntetic epoxy resin based glue onto the both ends of the blocks to be joined.After pressing the joint thickness was equal to 1mm.Works at the bridge were carried on the year around,with the outside air temperature being equal up to 30^{o} below zero.

Investigations made in the scientific research institute on dry and glued joints showed the following:

1. Dry preliminarily pressed joints reduce the shear strength up to 10% and require the adoption of special measures against atmospheric influence as well as improved waterproofing.
2. Glued joints proved to be,in regard to shear,stronger than the concreted section.
3. It is possible to allow a considerable tension in the glued joint,however,for the sake of caution,it was not permitted to exceed 5 kg/cm^2.

In the USSR all norm documentation on calculations and cantilever-type assemby of precast reinforced concrete bridges has been worked out and made standard.

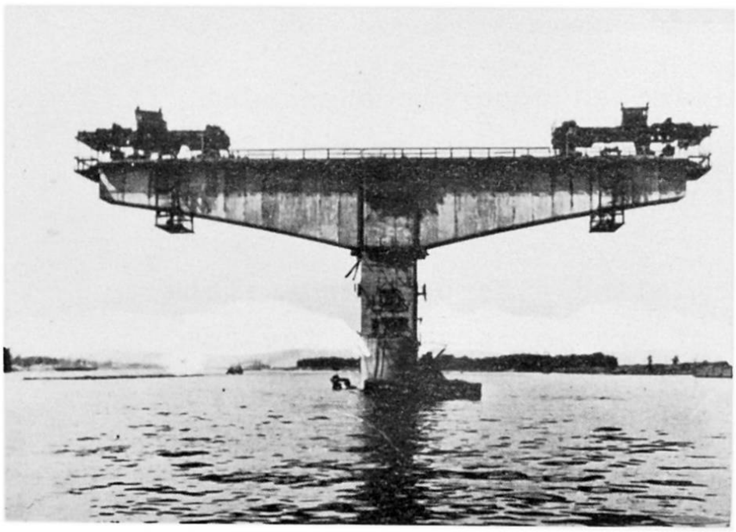

Fig. 5

Erection of cantilever and continuous bridges by a cantilever type assembly is carried out with the help of various cranes out of which most wide-spread are movable electrified cranes of two types: 65 tons cantilever-swing crane (Fig.5) and 35 ton cantilever bridge crane (Fig.6).

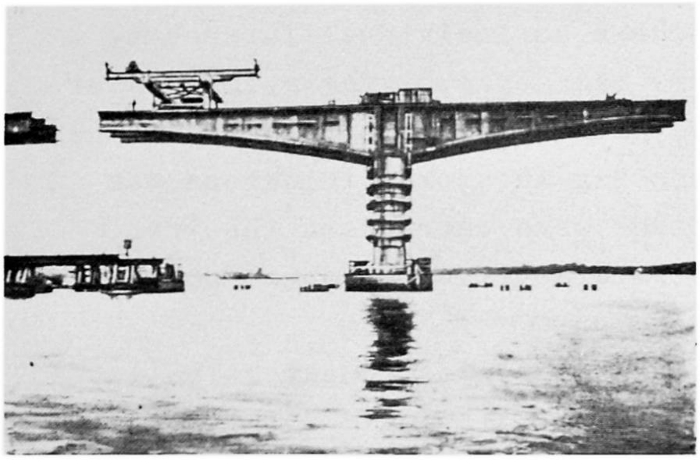

Fig. 6

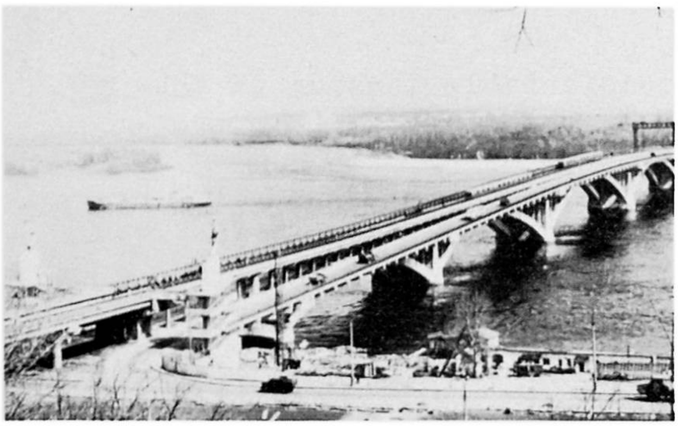

Fig. 7

Among bridges of other designs it is necessary to point out the bridge in Kiev,capital of the Ukraine,recently constructed across the Dnieper for a combined automobile and undergraund-train traffic.

This bridge has an arch-cantilever design which main idea is that precast arches of a permanent thickness made of standard elements are combined at the upper part in the locks of the adjacent spans by means of prestressed traffic-way joining slab (Fig. 7).

A peculiar precast reinforced concrete suspended bridge with the traffic-way being provided by a stiffening beam have been constructed in Kiev according to the scheme 66 + 144 + 66 metre.

In connection with the limited size of this article the question of application of precast concrete for the construction of supports is not considered here.In the USSR precast reinforced concrete construction as well as prestressing and epoxy resins found in the last years wide application in the bridge supports. Rigorous climatic and hard hydrological conditions in many regions of the country are hampering wide utilization of precast units for bridge supports,however, there are available at present well-tested and effective constructions.

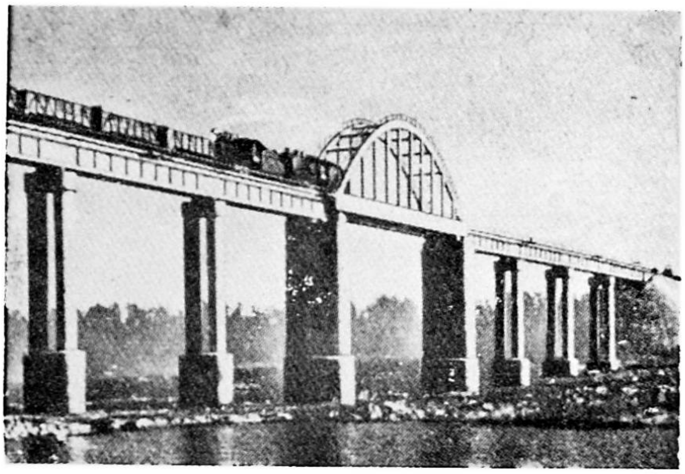

Fig. 8

Of interest are high precast bridges in which the supports are made of reinforced concrete cylinders manufactured by means of centrifuging (Fig. 8).

Further evolution of precast prestressed reinforced concrete bridges is progressing in the USSR in the direction of improvement of designes, constructive forms and technology of manufacture and erection.

SUMMARY

The report is considering systems, constructive forms and building technology used in the USSR in span-type structures of precast prestressed reinforced concrete bridges as well as their development.

It is considering also unique designs of precast railway bridges with continuous trusses and non-thrust arches.

Besides, it shows wide development of precast construction of highway bridges and the efficiency of the cantilever assembly method, proposed in the USSR in 1955 for the construction of bridges of frame and beam-cantilever systems of large blocks joined by gluing.

RÉSUMÉ

Le rapport fait part de l'état actuel des conceptions constructives et des méthodes technologiques d'aujourd'hui en URSS et leur progression dans le domaine de la construction des ponts assemblés des pièces préfabriquées en béton armé précontraint.

Des constructions originales des ponts sous-mentionnés sont envisagées avec la mise à profit des poutres à travers et des arcs non butés pendant le perçage d'un chemin de fer. On a mis en relief un large emploi des méthodes de construction des ponts-routes et l'efficacité du montage en suspension des ponts à partir des systèmes de poutres à console de grand encombrement assemblés sur col. Ce procédé est proposé en URSS en 1955.

ZUSAMMENFASSUNG

Im Vortrag werden Systeme, Konstruktionsformen, Technologie und Entwicklung im Bau von vorgespannten Stahlbetonbrücken aus Fertigteilen in der UdSSR erörtert.

Es werden Originalkonstruktionen von Eisenbahnbrücken mit Zugband und Fachwerkbrücken aus Fertigteilen in Betracht gezogen. Weiter werden die breite Entwicklung des Strassenbrückenbaus aus Fertigteilen und die Wirksamkeit der in der UdSSR 1955 vorgeschlagenen **Freivor**bauverfahren von Rahmen- und Kragarmbrücken aus grossen Blocks mit Klebestössen gezeigt.