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# Designing of the Draw Bridge

## Projet de ponts mobiles

## Projektierung von Drehbrücken

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**SUMMARY**

Construction of movable bridges is one of the ways to solve the problem of overpassing a waterway. The designing of the draw bridge involves the traffic passage structures and the turning machinery. The main drives used for bridge opening may be of electromechanical or electrohydraulic type. The construction technology ensures uninterrupted navigation. The construction of the bridge is carried out without interrupting road traffic.

**RESUME**

Le pont mobile est une des solutions au problème du transport sur un cours d'eau. Le projet d'un pont mobile est une étude complexe comprenant des constructions civiles et mécaniques. La commande principale d'ouverture et de fermeture est électromécanique ou électrohydraulique. La technique de construction d'un pont mobile assure généralement une navigation continue, et au cours d'une rénovation, un trafic automobile continu.

**ZUSAMMENFASSUNG**

Die Drehbrücke stellt eine mögliche Lösung zur Wegkreuzung mit einer Wasserstrasse dar. Ihr Entwurf ist komplex, gilt es doch, die Funktion der Verkehrsüberführung mit der des Drehmechanismus in Einklang zu bringen. Der Antrieb kann elektromechanisch oder elektrohydraulisch erfolgen. Das Bauverfahren muss unbehinderten Schiffsverkehr erlauben, während eine spätere Instandsetzung bei laufendem Strassenverkehr erfolgen soll.

When constructing bridges over navigable rivers or other water-ways, it is necessary that free navigation be ensured with due regard for its further development. It is known that these requirements are met by observing the bridge clearance which depends on the class of the river.

Construction of a high-level bridge is seen as the simplest solution of the above problem. However, such an approach is not always justified and sometimes is even technically unfeasable.

Construction of the bridge with a movable span is another possible solution of the task related to the problem of overpassing a water-way. The height of other spans of the bridge may only slightly exceed the calculated navigation horizon level.

When deciding on the method to be used for spanning a water-way, one compares the above variants as to their carrying capacity, construction cost, maintenance charges etc.

Designing of the movable bridge is a sophisticated task. As a construction, the bridge is seen not only as a structure intended for carrying traffic load but also as the turning machinery of the bridge which includes electric equipment, signalling and communication facilities. Once actuated, the turning mechanisms lift the span to allow a clear passageway for vessels.

The profile and size of the bridge clearance of the movable spans in drawn position depend on the class of the water-way and are specified by appropriate items of the request for proposal. The bridge clearance of the movable span in bridged position as well as the height of the adjoining navigation spans will be determined proceeding from the local navigation conditions.

Preference is given to the following kinds of movable bridges,i.e. bascules (single-leaf and double-leaf), swing spans and the vertical-lift type.

The railway and combined-traffic bridges use mostly a vertical-lift system (Fig.1). Other systems may be used when explicitly specified by appropriate items of the request for proposal.
A single-leaf bascule railway bridge over the Neva river should be mentioned here to illustrate the case. The lifting span of the bridge gives 42 m clearance what is explained by high architectural requirements this particular bridge was to meet. This is a deck bridge, with the axis of rotation being stationary and the counterweight rigidly fixed. In bridged position, the axis of rotation is unloaded and the counterweight is not wedged.

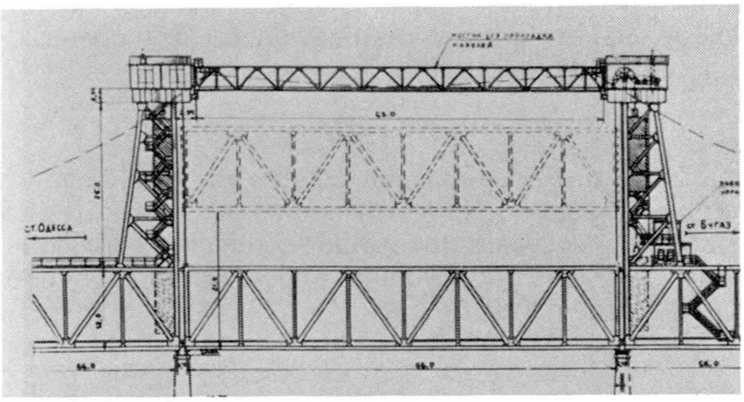

Fig.1 The vertical-lift bridge

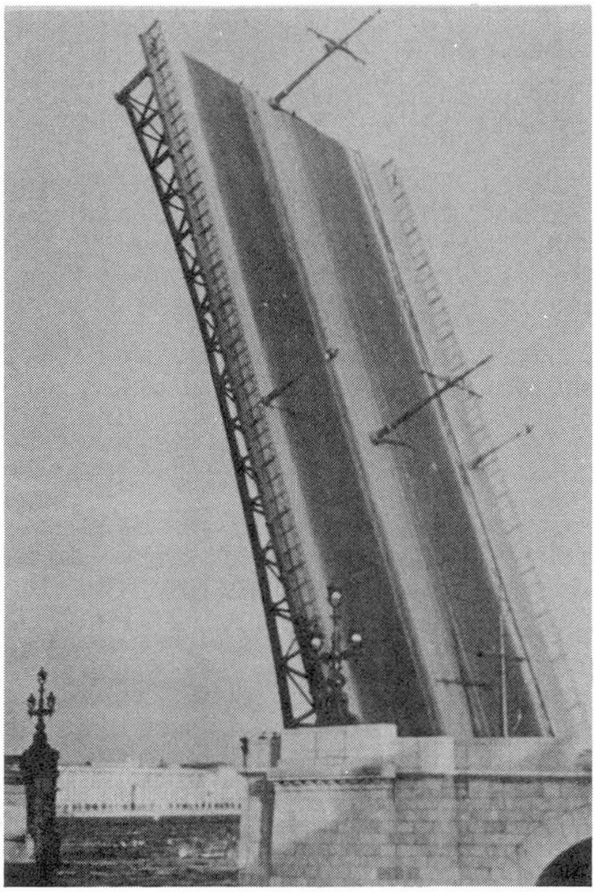

Fig.2 The single-leaf bascule bridge

The motor-road and town movable bridges are designed to employ a single-leaf bascule system for the clear span of up to 55 m (Fig.2) and a vertical-lift type for the larger span length. As examples of the long-span motor-road vertical-lift bridges we may mention here a bridge over the Severnaya Dvina river in the city of Arkhangelsk that was constructed in 1990, with a calculated length of the span of 84m, and a bridge that is now being constructed over the navigation pass of the dam, which is designed to protect Leningrad from floods, with a record-breaking span length of 120.45 m. These are deck-type bridges which have orthotropic roadway. The towers of the first bridge are of a box type and are mounted directly on the supports, with the counterweights arranged inside the towers. A movable span of the second bridge is of a unique structure: it has no towers - to lift the span to the height of 9 m (to get the bridge clearance of 25 m), the metal framework structures are used,which are located under the span structure in the piers of the movable span.

The prime mechanisms used to raise the bridge have, as a rule, three drives. These are the main drive, the reserve drive and the emergency drive.

The operation of the main drive is based on electromechanical or electrohydraulic principle. Operation of the reserve drive is similar to that of the main drive, or else it may work powered by an internal combustion engine. As a rule, the emergency drive is operated manually. As many-year experience shows, the latter may not necessarily be installed when the main drive is of electrohydraulic type.

The bridge drives may be operated either automatically or manually. These are equipped with interlock protective devices and signalling facilities to indicate the end positions of the span structure and drawing mechanisms.

Duration of bridge lifting depends on traffic intensity. When the road and waterway traffic is heavy and the bridge is to be opened many times a day, it takes 2 minutes to lift (lower) the bridge by means of the main drive (this procedure includes all operations on lifting and lowering the bridge). When the water-way traffic is low and the bridge is opened 1-2 times a day (usually at night) for a short period of time just to let the waiting ships pass, the duration of bridge lifting may be extended to 5 minutes.

In order to reduce the dead weight of the steel structures and to increase the resistance to corrosion, the rolled metal elements are usually made of low-alloy structural steel with the yield limit of 340 (35) or 390 (40) MPa (kgs/mm$^2$), which correspond to the standards used for the design of permanent bridges.

The movable span structures are designed to employ welded factory-made elements which are assembled with the help of welded, or combined bolt-and-welded, joints. The joints of elements working under stressed conditions should be designed to use high-strength bolts.

In order to facilitate the production and assembly processes, the parameters of movable bridges are so designed as to make them unified with the existing typical projects and factory standards.

The roadway of the movable spans of highway and town bridges are designed to employ steel orthotropic plates. The roadway is covered with asphalt, the layer of covering being no less than 45 mm thick. Steps must be taken to ensure adequate engagement between asphalt and metal surfaces as well as to protect the metal structures from corrosion.

It is recommended that thin-layer coating (15-20 mm thick) be used to cover the steel orthotropic plates of the single-leaf bascule bridges, with the clear span exceeding 40 m. It was revealed, however, that application of such coating was not a complete success. Therefore, its structure and technology need to be further improved.

Railway tracks on the movable spans are designed to be fixed directly to the steel orthotropic plate or to the metal ties, with the provision of electric insulation of the railway circuits. There should be railjoints at the ends of the movable span, and on a railway bridge there should also be rail locks.

In any position, the movable span must be balanced by counterweights.

During lifting operation, the vertical-lift and bascule spans become slightly unbalanced due to their own weight (overweight). The unbalance should be of such magnitude as to ensure that the movable span, when in bridged position, is snugged against the supports, thus eliminating a possibility of self-opening of the bridge during its exploitation.

In order to regulate the balance of the movable span, one may change the mass of the counterweight within the range of -3% to +5% of its calculated mass by removing or adding up demountable blocks.

Depending on the volume density required, the counterweights are filled with concrete, cast-iron concrete, or cast-iron castings of regular shape formed with the use of cement mortar.

As a rule, the counterweights for vertical-lift bridges are designed to be made of a monolithic concrete reinforced by a steel frame and supporting nets. The counterweights are equipped with devices which are used for hanging them up to the beams of the tower caps so that to remove the load from the carrying ropes (counterweight wedging).

The axes of rotation of the bascule bridges and the pivots of the swing bridges are usually unloaded and do not transfer the vertical load onto the supports. The unloading of the axes of rotation is achieved by the use of bearing members with swinging posts which are placed in one vertical plane. In the process of bridging they get engaged into mesh with the balance beams fastened to the main girders and raise the wing together with the axes of rotation to the height of 2-3 mm. The axes of pulleys on the vertical-lift bridges are unloaded by wedging the counterweights.

All bridges built after 1965 and the motor-road and town movable bridges which are being constructed at present employ a single-leaf bascule system with a rigidly fixed counterweight and a stationary axis of rotation which get unloaded in the normal position of the bridge. The maximum efficiency in this case is achieved when the electrohydraulic drive is used. This ensures a more rational arrangement of the movable span, a reduction in mechanisms mass by 25-30% as compared with an electromechanic drive, and a considerable reduction in the width of the supports along the frontal side of the bridge. Many-year experience shows that this system of the movable bridge has proved to be the simplest and most reliable one.

The hydraulic drive circuit incorporates the systems of interlock and tracking devices which provide reliable lifting of the bridge with the wind intensity of 6. Oil feed from pumping plants to the main pipe-line ensures synchronism in the operation of hydraulic cylinders, no matter how many pumps are used. Thus, one may regulate the speed of rotation of the wing ensuring a smooth start and stoppage.

The towers on the vertical-lift bridges are usually erected on adjoining stationary span structures. This system is less sensitive to deformations in supports of the movable span as compared with the case when the towers are mounted directly on the supports. Moreover, this system makes it possible to use a more simple method to eliminate aftereffects of deformations in supports. A schematic diagram and structural solutions of these bridges have many things in common: counterweight ropes play the role of the working ropes whereas synchronism in the movement of the ends of the span structure is achieved by a system of mechanisms equipped with an "electric shaft".

In addition to staircases, every tower of the vertical-lift bridge should have an elevator to take the personnel and necessary equipment to the control and machine rooms located at the top of the tower.

In order to facilitate the inspection and maintenance of the turning machinery of the vertical-lift bridges as well as to exclude the use of underwater-laid cables within the movable span, it is recommended that a special cable (flying) bridge be provided, especially on the railway bridges.

When constructing the movable bridges, a certain technological sequence in spanning the bridge must be observed in order to ensure uninterruped navigation: the navigation span is bridged upon the completion of the movable span, or else during an inter-navigation period.

Reconstruction of movable bridges is carried out without interruption in navigation. As a rule, urban bridges are also reconstructed without interrupting the intertown traffic. For this purpose, a temporary retractable bridge is constructed to run in parallel with the existing bridge. The experience of exploitation of two bridges over the Neva river in Leningrad shows that this system is the best one to satisfy the conditions of temporary exploitation, and therefore may be recommended for duplicating under similar conditions, for such a solution of the problem is found to be a most simple and reliable in use.

The principal technical solutions implemented by the Bridge Design Institute during the 60th were both progressive and original. Some of the projects were accomplished for the first time in the bridge construction practice. Therefore, difficulties and even failures were unavoidable. Sometimes these resulted in emergency situations during the construction and exploitation of the motor-road and town bridges, mostly of bascule type.

Here are some examples to illustrate the above: a complete fall of the asphalt covering from the wing during a trial lifting of the bridge; two failures in the system of hydraulic drive, one of these being so serious that a hydraulic cylinder was to be replaced a self-opening of the bridge during the storm wind.

A very serious failure occurred in 1982 on a double-leaf movable bridge over the Neva river in Leningrad, after 18 years of its exploitation: a counterweight (750 tons) collapsed from the left-shore wing due to formation of numerous defects in the welded joints of the counterweight structure following the lack of proper maintenance and failure in taking necessary measures to eliminate the defects. Some structural mistakes made at the design stage also contributed to the above accidents. As to the right-shore wing, once the structural and some minor defects were eliminated, the wing has been exploited without any restrictions.

The fact that the Institute has analyzed the causes of the above accidents is an important factor which shall help increase dependability of the movable bridges to be designed.

Lengiprotransmost is a leading institution in this country in the field of complex design of the movable bridges.

With a view of further development of the existing norms in the design of permanent bridges, Lengiprotransmost has worked out a "Guide for the designing of movable bridges" which replaced the earlier edition of 1972. This Guide describes the experience of the Institute in the field of designing the movable bridges as well as the native and foreign experience in the bridge construction and bridge exploitation.