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# Controlling Methods of Bridge Launching Process

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## Summary

Over the past two decades the erection of steel and composite bridges by method of incremental launching has become one of the most widely used. To assure the safety of erection process and reliability of the bridge structures during construction, a special attention is paid for controlling of launching process. This paper presents some typical practices related to techniques of erection control and provides some details on means of control implementation applied for bridge construction in Russia.

## 1. Introduction

Erection of bridges by method of incremental launching comprises site preassembly of steel superstructure from manufactured at specialized shops segments. These segments weigh up to 35 t and normally are 10.5 and 21 m long, they are transported to construction site by railways or highways. During the process of launching the superstructures bear over special sliding devices located on top of piers. The typical features of the Russian erection practice using the method of incremental launching were discussed in detail in ref. [1].

When the erection by method of incremental launching is implemented, the stressed-strained state of bridge structures is persistently changed. During this period the launched superstructure is very sensible to deviations from design assumptions. Typical superstructure cross sections commonly applied in practice are single and two box girders (three box structures are rarely used). Linear weight of such superstructures varies in a range of 7-12 t/m, this normally results in overpier reactions up to 1600-2000 t for spans of 130-160 m. The coefficient of friction between the polished stainless steel of sliding device and antifriction material (e.g. teflon) depends on various factors and is typically within a range of 4-8%. A possible exceedance of safe reaction values or coefficient of friction may cause a loss of load carrying capacity of superstructure or piers or both. Therefore the control of stressed-strained state of superstructures and piers during the launching process is an important aspect.

## 2. Methods of Control at Launching

### 2.1 Development of controlling techniques

Generally the methods of control comprise continuous visual inspection of different bridge components and measuring (monitoring) of load effects in the structures by means of various signaling and controlling systems and devices. The following factors are continuously checked: reactions at piers, superstructure pushing-out forces, stresses in superstructure web panels, deviation of pier tops, cantilever end deflection, wind velocity, deviation of superstructure in plan. The construction site is also equipped by telephone and radio communications.

The development of practice for implementation of control during erection included the elaboration of new and improvement of existing individual devices and systems to measure various parameters. The developed modern controlling technique links the individual control of pier and superstructure behaviour into a single system, showing on a computer display of the central command station a global picture of launching process. The work of controlling system has been tested in real conditions of steel superstructure launching for the bridge over the Volga river (v. Pristannoe) and proved its efficiency.

The controlling system comprises a central computer located at a command station, which manages the overall launching process. The information are obtained by means of a set of gauges, forming a network, and transferred to the central computer for data processing, storing and displaying results. A general scheme of controlling system is shown in Fig. 1. A detailed description of the controlling system is given below.

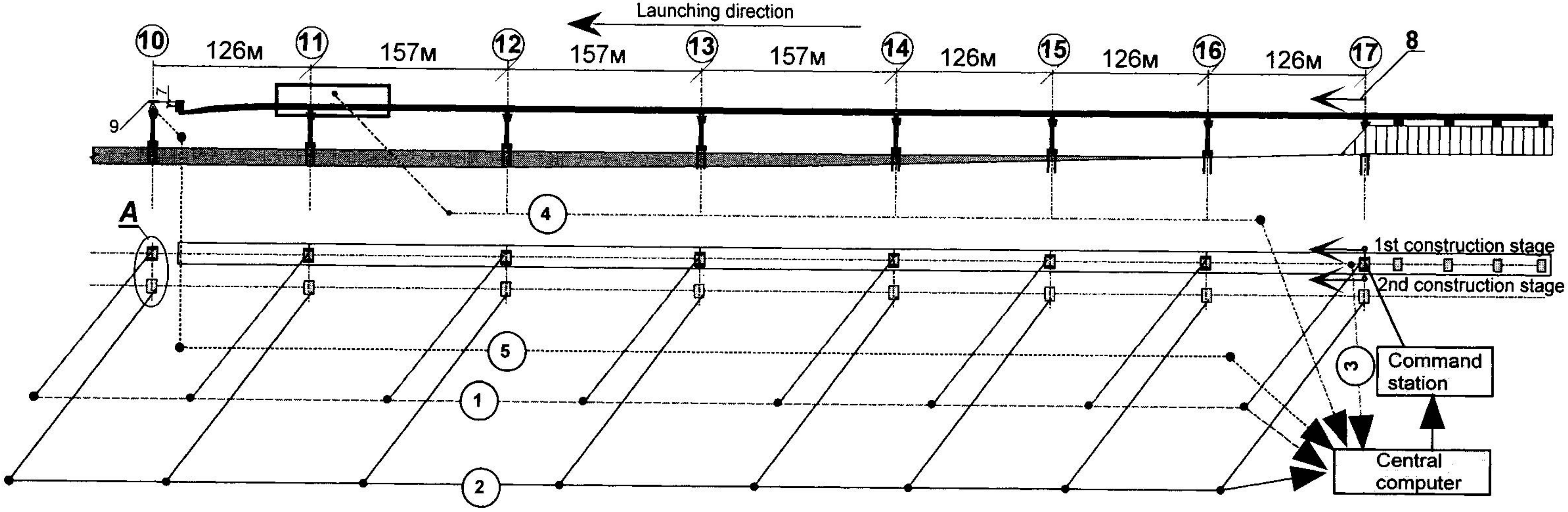
### 2.2 Background to choice of main parameters for control

During the superstructure launching the stresses and deformations exceeding allowable values may occur. This may turn the elements of bridge structures into a state of failure. Due to inaccuracy of sliding devices installation or superstructure assembly on jig supports, a dangerous overloading of one of the box webs may occur at launching. Even if works are completed within allowable tolerances regulated by standards, total accumulated vertical deviations may reach a significant value of up to 10-15 mm. Such deviations at levels of bearing of adjacent beams located over one pier lead to overloading of one of superstructure webs. Narrow boxes having a large torsion stiffness is the most critical in this case.

Theoretical values of pier reactions, bending moments and shear forces for any superstructure section are calculated using a computer program that models the launching process [1]. The results of computation include values of reactions, bending moments, shear forces, deflections at each stage of launching at superstructure sections chosen by the Designer. Moreover the values of ultimate reactions based on provision of stability for web panels of main beams are also determined. During the process of launching the data on measured values of reactions are transferred to the computer (Fig. 1, 1$^{st}$ group of gauges) and compared to the computed (design) and ultimate values.

In the most loaded superstructure sections (the root of the largest cantilever during launching and main girder joints having site splice kinks), the stresses at web panels adjacent to bottom flanges are measured (Fig. 1, 4$^{th}$ group of gauges).

At certain stages of launching the reactions at piers may reach values comparable to operation condition. The antifriction materials applied for sliding devices have a sufficient magnitude of friction coefficient depending on many factors - air temperature, specific pressure, time of launching interruption and some others. To control the state of piers, the deviations of pier tops are measured, representing a function of their load-carrying capacity (Fig. 1, 2$^{nd}$ group of gauges).



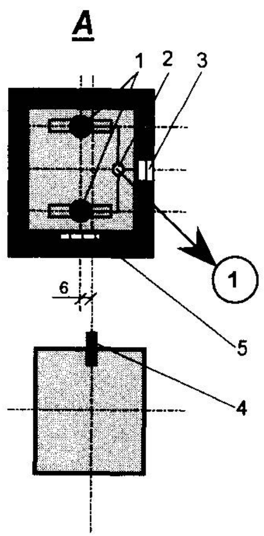




Fig. 1. General scheme of controlling system for bridge launching

(1) - group of gauges for collection of data on reactions,

(2) - group of gauges for collection of data on pier top deviations,

(3) - group of gauges for collection of data on pushing-out force and length of superstructure movement ,

(4) - group of gauges for collection of data on stress values at webs ,

(5) - group of gauges for collection of data on superstructure cantilever end horizontal and vertical deviations ,

1 -hydraulic jacks of 1000t capacity, 2 - manometer, 3 - pumping station, 4 - laser, 5 - screen scale, 6 - deviation of pier top, 7 - deviation of cantilever end in vertical (deflection) and horizontal directions, 8 - pushing device, 9 - videocamera

Also other parameters, which do not influence on workability of structural elements but provide the successful implementation of erection, are controlled. These are control of value of pushing-out force (Fig. 1, 3[rd] group of gauges) and control of cantilever end horizontal and vertical deviation (Fig. 1, 5[th] group of gauges).

### 2.3 Details about work of controlling system

To maintain the computer controlling system in working condition, and to outline and track the influence of temperature and some other temporary factors, during the intervals of launching, on variability of loaded pier and superstructure behaviour, 24 hours regime of work have been required.

The principles of relevant information interpretation about launching process are discussed below.
A typical monitor screen is shown in Fig. 2. The monitor screen contains a mosaic graphic display consisting of lighted, coloured tiles which interpret the status of all conditions being monitored by the computer system. The screen is divided by 5 windows. The purpose of each window is obvious from Fig. 2.

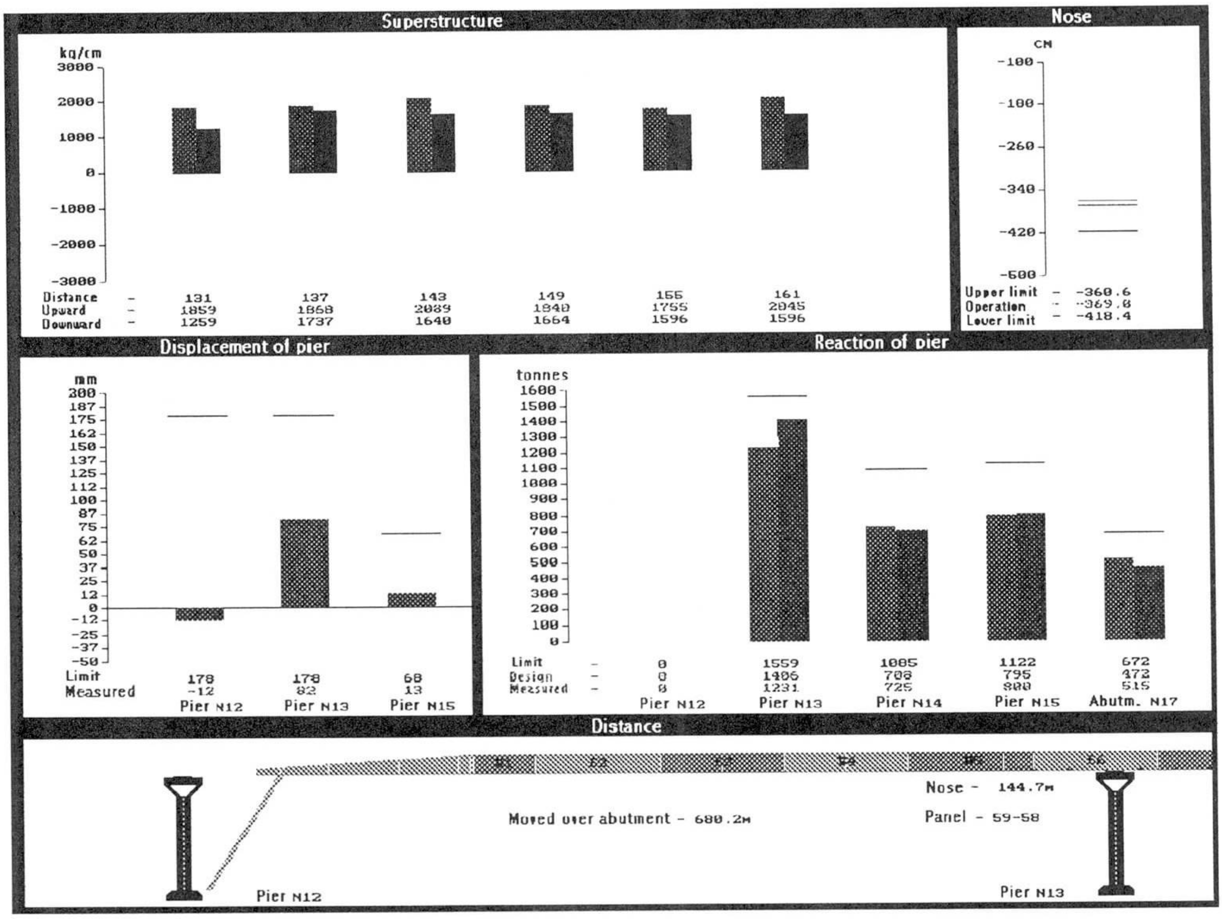



Fig. 2. Typical monitor screen with parameters controlled during launching process

The principle of reaction value control is based on continuous comparison of design (calculated) values to that of measured at each moment of time. This information is presented in window «Reaction of pier». In adjacent window «Displacement of pier» the information on pier top displacement during launching is shown. Next window «Superstructure» demonstrates data on stress values in the superstructure webs. In each window the information is grouped by a single type in a form of histograms and figures. In these three windows the values of ultimate (allowable) parameters are input by the Designer. The beginning of dangerous situation is reflected in the computer by turning the colour of histograms into red. If the value is exceeded, an electric signal is given to the command station and the process of launching is automatically stopped to investigate the reasons of fault state beginning.

Window «Nose» provides information on three dimensional position of nose end, characterizing superstructure deflection and deviation in plan. Bottom window «Distance» schematically shows superstructure passing over pier with synchronous reflection how launching proceeds (in real scale of time).

For a typical plot showing how reactions at pier change when launching proceeds see Fig. 3. The values of the design reactions have been obtained by the computer analysis of superstructure launching and measured values - from field measurements. As it is noted from the plot the results are in good agreement with the measured ones. The dispersion is very small.

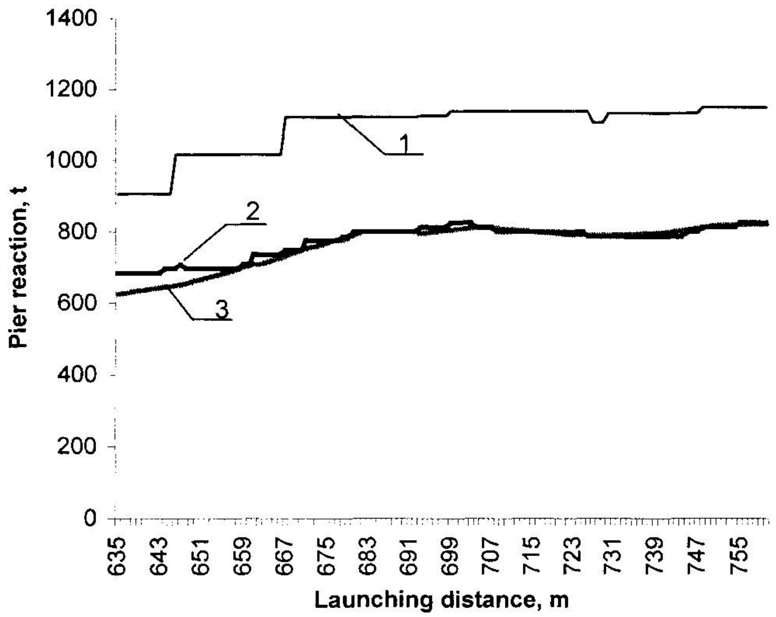



Fig. 3. Typical plot of pier reactions change related to consequent stages of launching. 1 - ultimate reaction values, 2 - design (calculated) reaction values, 3 - measured values of reactions

### 2.4 Means of parameters measurement

To level the reactions at superstructure webs, hydraulic converters (jacks) are installed under the sliding devices. These jacks are connected into a single hydraulic system over the pier and the information on reactions are taken by means of manometers and special gauges. The measurement accuracy is within a limit of 5 tons.

To control the deviations of piers, laser measurement units are installed on pier tops of the 2nd construction stage and photo receiver - on pier tops of the 1st construction stage. Because of possibility of fault situation quick development (within few seconds), a deviation measuring gauge is questioned by the central computer 10 times a second. The measurement accuracy is not greater than 2 mm.

Stresses at superstructure web are determined by measuring of web deformations using digital indicators with accuracy of 2 μm. By technical reasons the indicators are normally required to be in action for some launching stages only in the most stressed positions of the superstructure.

To determine a position of distant object, a special target is fixed to a nose and videocamera connected to the computer is installed over the pier. Theoretical calculations and experimental results have shown that using this method the position of object (in case of moving) at a distance of up to 100m could be measured with an accuracy of 1 cm.

## 3. Some notes on safety of bridge structures during erection

Over the duration of erection phase, the bridge structure threatened by certain hazards. During launching the bridge may be exposed to natural hazards such as wind, earthquake etc. Consideration of these aspects is essential for design with respect to safety.

The condition of launching is more critical for wind action than completed bridge, especially with the largest cantilever of superstructure under erection. The current Russian codes concerning bridge construction and erection design stipulate a design of pulling and restraint systems for launching for a wind loading corresponding to a wind speed of up to 13 m/s. This limit of wind speed is based on provision of safety for construction works. However this limit is not likely to be a reasonable approach. Because during launching the allowed wind speed may be exceeded for a certain short period of time and it would be very dangerous to stop overall technological cycle of erection and leave a large free superstructure cantilever. In such a case the launching should normally be continued to reach the pier and fix it in this position. The design specifications are required to establish a relevant procedure to treat the action of such an extreme event.

The analysis of superstructure under the launching conditions for wind interaction usually made for the same value of wind loading as specified for operation condition. Evidently it would be more appropriate to apply a reduced wind speed in erection calculations to allow for the short period at which the relevant structure is at risk. The use of methods based on risk analysis theory is an appropriate tool to establish the reasonable value of load and to elaborate a set of appropriate safety measures for erection of bridges exposed to extreme events.

## 4. Conclusion

The worked out methods have been tested at a large number of bridge projects. The recently worked out complex controlling system showed its efficiency, this was expressed in timely warning about the development of dangerous situations which might further cause a failure. Using this system of monitoring in the launching process assures reliability for the bridge structures during superstructure erection and therefore reach the goal of cost saving construction.

At the same time it should be noted that the elaboration of controlling system was based on non-contact methods of measuring and transferring the obtained data into figures. This system has some advantages. However it has been noted that the accuracy of measurements was slightly reduced in case of high air humidity. To improve the controlling system further research into means of providing protection to its components for operation independently of level of humidity has been conducted. Also a location of main cable over the superstructure requires continuous pulling during the process of launching which is an inconvenient operation and in addition may affect work of certain part of the system. The results of research will improve the technical parameters and reliability of computer system control for stress-strained state of launched superstructure and bridge piers.

## 5. References

1. Zhuravov L.N., Chemerinsky O.I., Seliverstov V.A., Launching Steel Bridges in Russia. Structural Engineering International, vol. 6, No. 3, p.p. 183-186. IABSE, Zurich, 1996.