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PRINCIPLES OF ASSESSING THE EFFECTIVENESS OF THE BRIDGE RECONSTRUCTION IN THE CONDITIONS OF MEGAPOLIS

***Fedorova Sofia**, the third-year student of the department "bridges and tunnels" of the Petersburg State University of Railway Transport, Saint-Petersburg.*
(Scientific adviser - Chizhov S., Candidate of Engineering sciences, Associate Profesor)

The reconstruction of the bridge structures is of particular interest and special complexity due to close connection with engineering tasks in the conditions of a megapolis and limitations for using in daily life of urban people.

The main problems in reconstruction are the need to take into account the architectural appearance, the volume-plaining appearance of space, associated with the construction, the junctions, the bridge clearance, and the additional functions that are taken into account, such as skip of pedestrians, bicycles, railway transport, ships and communications. It is also very important to forecast changes in these factors. The opportunity of reconstruction is determined by economic feasibility of applying the reconstruction technologies.

The reconstruction of the city's bridges is strongly connected with modernization of transport infrastructure, roads, and embankments. There are many ways of reconstruction, depending on initial conditions, types of bridges, cross obstacles, and type of load. Since the issue of reconstruction of such structures is not only an engineering problem but also an organizational, it is extremely important to define areas of responsibility, financing structure, time-limits and connect the production technology works with the possibilities of the city to use the reserve roads.

Assessment of the effectiveness of the reconstruction can be carried out considering the whole range of complex factors, influencing the functional properties of structures in the transport system, using the coefficient of functionality, determined with considering the operational stages for each of the individual functions of the structures in the transport system.

$$C_f = \frac{\sum R_t}{\sum CO_{\sup} + CO_m}$$

where

C_f – coefficient of functionality

$\sum R_t$ – total revenue by n – function

$\sum CO_{\sup}$ – the costs of supporting the n – function

CO_m – maintenance costs

A set of functional properties and number of dependent parameters will include the characteristics, defining the state of the facilities and transport system. Depending on the characteristics of the transport system and facilities the number of parameters will differ. So, for urban transport facilities effectiveness will depend on the ability of performing complex functional load in urban transport infrastructure. In General, the functional properties of bridges located in urban areas, are to provide capacity depending on the load type (X1), volume-spatial solution in the form of geometric parameters, defined by the dimensions of the constructive elements of the structure, for each type of load (x2), characteristics of the bridge clearance, determining the ability of the organization of traffic, pedestrians, passing ships, use for utilitarian purposes (X3), additional functional qualities (X4), associated with the implementation of additional functions, not directly connected with the implementation of the transport purpose.

Each of these parameters can be considered as a parameter of reliability, determining the safety exploitation of the facility after reconstruction

$$\left.\begin{array}{l} X_1 = f(\alpha_{12}, \alpha_{12} \ldots \alpha_{1m}) \\ X_2 = f(\alpha_{21}, \alpha_{22} \ldots \alpha_{2m}) \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ X_n = f(\alpha_{1n}, \alpha_{2n} \ldots\ldots \alpha_{3m}) \end{array}\right\},$$

where

X_n – coefficient of reliability.

$\alpha_{1n}, \alpha_{2n} \ldots\ldots \alpha_{3m}$ – random values.

Meanwhile, depending on the functional properties, the set of parameters determining the reliability and service life of structures will change.

$$\int_0^S \{R\} = \int_0^S \begin{Bmatrix} X_{11} & X_{12} & X_{1i} \ldots & X_{1m} \\ X_{21} & X_{22} & X_{2i} \ldots & X_{2m} \\ X_{i1} & X_{i2} & X_{i3} \ldots & X_{im} \\ X_{n1} & X_{n2} & X_{n3} \ldots & X_{nm} \end{Bmatrix},$$

where

R – reliability,

S – resource of structure.

The parameters, defining the reliability of structure in accordance with the functional purpose, may be regarded as a sign of failure for certain properties and be controlled in the monitoring process at the maintenance at the stage of exploitation.

As an example of realization of this approach to evaluate the effectiveness of the reconstruction can serve American bridges in St. Petersburg.

In Saint-Petersburg there are a number of examples that show an individual approach to reconstruction of the bridges. One of this is the reconstruction of “American bridges” across Obvodniy channel, which is located on the main railway line Saint Petersburg-Moscow, where there is the high-speed movement. (Image 1).

The determination of C_f before the reconstruction showed, that the contents of the cost of maintaining buildings has sharply increased, because of the need to ensure high-speed trains and crossing vehicles in bridge clearance.

Image 1 – American bridges before reconstruction

American bridges were named so because the spans that were used industrially were manufactured in the standard American metal trusses. The average service of the bridges was about a hundred years. They even may serve longer, because only heavy passenger's trains passed through them. But the rapid increase in the number of cars in the early 90s raised the question of the throughput of bridge clearance and demanded the reconstruction of the embankments of Obvodniy channel. The bridges are located in the heart of the city and crossing the Obvodniy channel, the embankments of which are used as transit highway. The area is filled with objects of industrial-civil purpose and considered as dense urban area.

Properly, the project for reconstruction of bridges and embankments were divided into two main parts. (Image 2).

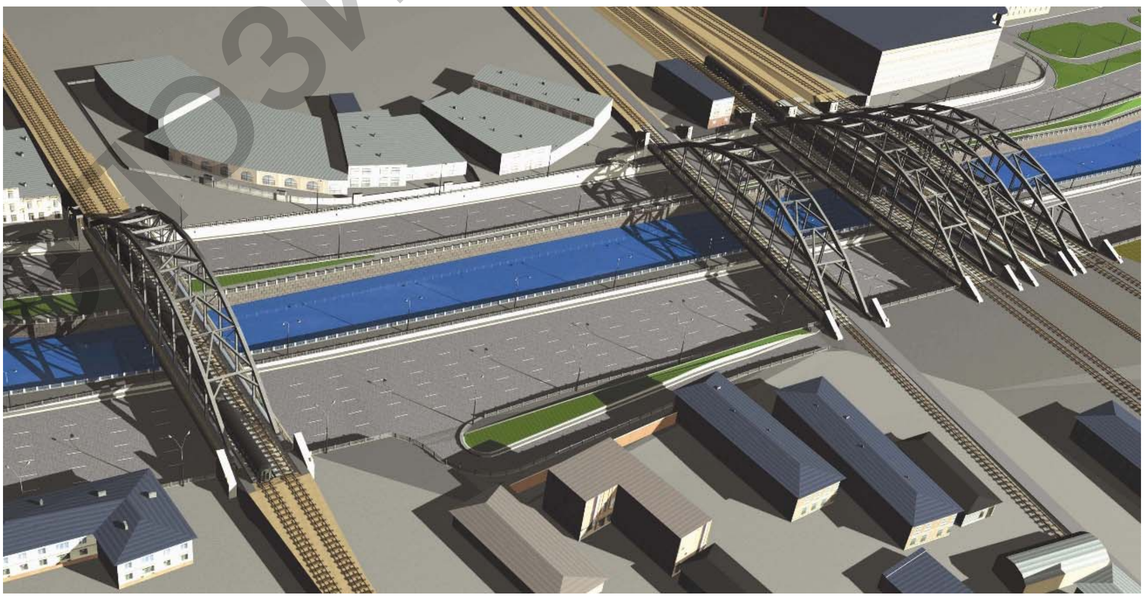

Image 2 – View of the site reconstruction

Initially, it was decided to reconstruct the bridge, and then proceed to the reconstruction of the embankments of the Obvodniy channel. In the first stage, the Institute Lengiprotrans developed a general concept of reconstruction of transport hub, considering the switching of the movement, the demolition of buildings and transport communications. Reconstruction of bridges was carried out in stages. Meanwhile, the production of works on construction of new facilities was going along with the dismantling of old structures.

The need of solution of functional properties complex required the development of unique, applied in combination with the decrease of the carriageway level, in according with modern requirements for road clearance.

The project aimed to cover the Obvodniy channel by single span *(L=110m)* without intermediate supports and to build on the site of existing bridges, four new structures, identical in construction and scheme of work. (Image 3).

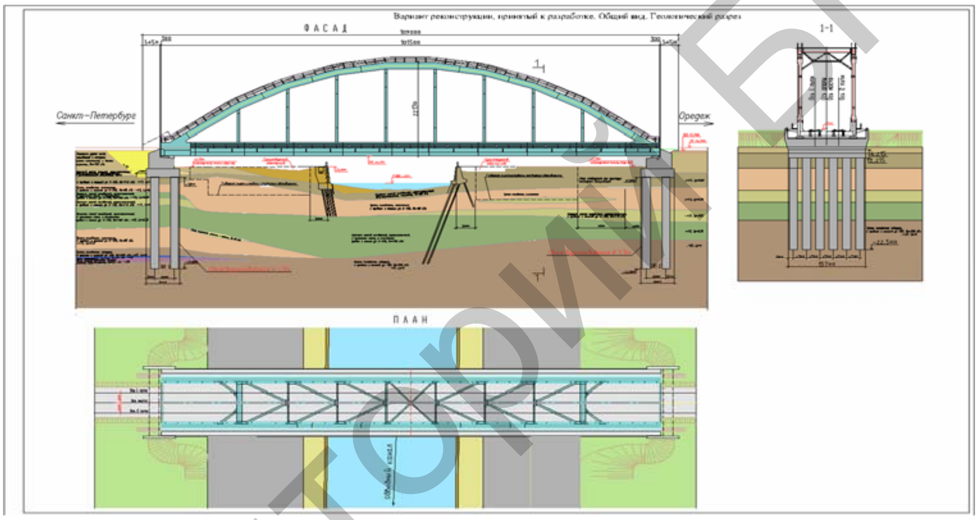

Image 3 – Principal design of bridges

Modeling of the superstructure in the software package Revit, showed compliance with the requirements for carrying capacity at various speeds of trains.

The highlight of the project was a metal arch with the ride from below, to be included in joint work with the ballastless roadway slab with anchor bolts of Nelson. Construction of the arch was developed by the Institute "Giprostroymost". Depending on the intended use of the project includes the construction of four railway bridges.

The changes were subjected to further validation by mathematical simulation of the designs for various working conditions in the design process and when performing input control of project documentation. After the construction of each structure, each of them was tested, which confirmed the results of the calculation. (Image 4).

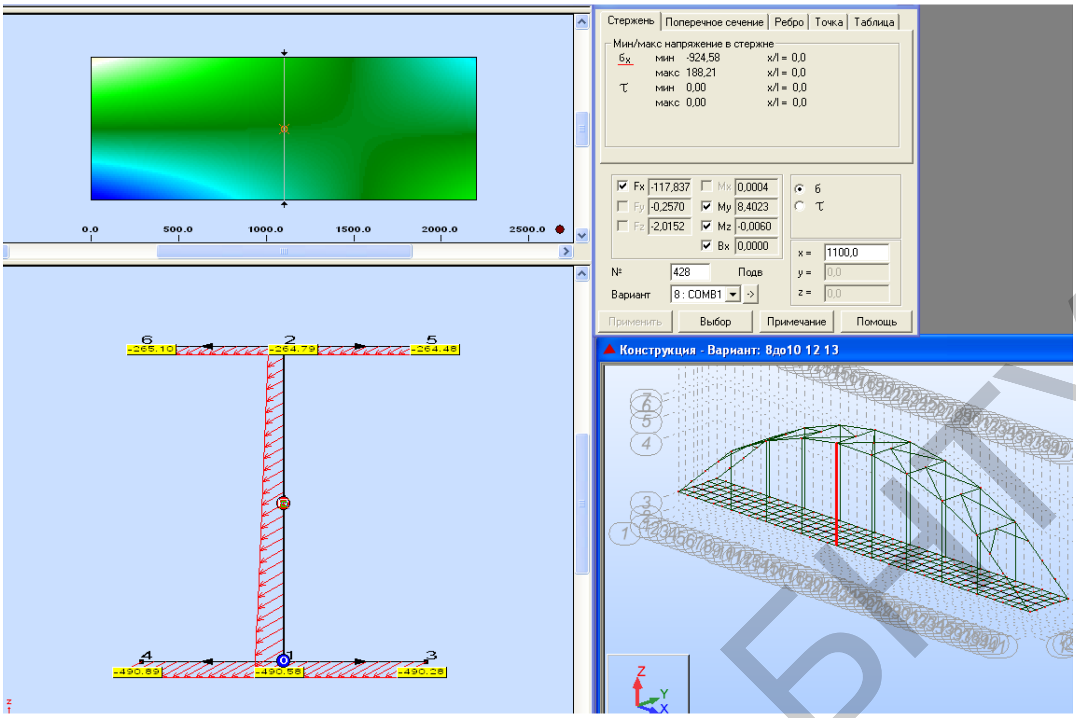

Image 4 – The results of the calculation in the graphical representation

The production of works included the following main stages:

- Construction of upper station system;
- Installation of elements of the arches;
- Construction of foundations of the bridge;
- Dismantlement of old and temporary structures;
- Installation practices (including cross shifting of the span)

During the process of construction, a permanent monitoring was organized for the nearby buildings. This resulted in high efficiency in preventing possible deformation of the bases of constant and dynamic loads from the arch and equipment. According to the monitoring results of deformation, the foundation soil has been eliminated or did not exceed the allowable rate.

It should be noted that since the work took place on the existing road in the vicinity of the contact network and of the zone of moving trains, security of works and occupational safety was significantly important. A significant amount of work occurred in the dismantling of obsolete structures, including spans and supports permanent and temporary bridges.

A significant amount of work occurred in the dismantling of obsolete structures, including spans and supportive permanent and temporary bridges. Dismantlement was organized with consideration to eliminate the possibility of ingress of debris at the Obvodniy channel and to comply with all necessary environmental requirements.

Reconstruction of embankments of Obvodniy channel provides four-lane traffic on both sides. Since the superstructure has a greater building height than the current design, the project provides for the lowering of the carriageway and the construction of a transport tunnel is shallow at the intersection of the embankment with bridges. As span has a high construction height, than the previous structure, the project covers lowering of the roadway level and constructing of a shallow transport tunnel at the intersection of the embankment with bridges. (Image 5).

Image 5 – View of the embankment after reconstruction

Conclusions:

Evaluation of the effectiveness of a transportation hub after the reconstruction showed:

1. Total operating costs for the provision of functional properties of buildings, in according with the technical specifications reduced by 48.7% compared to the original.
2. The use of unique constructive solutions of arched metal span L=110 m, with riding on the ballast, allowed to provide the required load capacity and operational safety for train loading on the bridge, for vehicles and pedestrians in the bridge clearance.
3. Reconstruction of the bridge provided the opportunity for the comprehensive improvement of the surrounding areas and infrastructure, which belong to the historical center of St. Petersburg.
4. The project implementation will allow to increase throughput of site of the highway, to produce a full landscaping of the adjacent territory, to ensure the safety of trains and users of transport infrastructure.
5. Last, but not least, if we talk about the effectiveness of the reconstruction, it is a way to improve the quality of life.

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