Information modeling technologies in bridge testing

Prokopova Marina Valentinovna
Candidate of Technical Sciences, Associate Professor
Rostov State Transport University
Zershchikov Valentin Andreevich
Student
Rostov State Transport University
Leonov Andrey Yurievich
Student
Rostov State Transport University
Rostov-on-Don, Russia

Abstract. *During the operation of bridges, it becomes necessary to check the operability of the structure. BIM technologies make it possible not only to design engineering structures, but also to perform verification calculations of the structure during operation. In this case, the calculations should agree with the results of instrumental tests of the bridge. The article presents a comparative analysis of the results of modeling the stress-strain state of a metal bridge and test data using the Tensor MS system.*

Keywords: *information modeling, model, BIM, metal bridge, calculation, stress-strain state, testing, sensors.*

Introduction

Information modeling technologies are actively implemented in the design of buildings through the development of an architectural model with subsequent calculations in design programs. In the process of modeling, an intelligent copy of a building or structure is developed. Decree of the Government of Russia № 331 obliges to use information modeling technologies in the design of objects of state orders for any purpose and regardless of their cost. In the design of engineering structures, including bridges, the implementation of BIM technologies is only gaining momentum. For the design of bridges, a bundle of Inventor-Revit programs is used, which provides high accuracy of dimensions and shapes. Civil 3D is also used in the design of bridges and infrastructure. Among the many BIM design programs for bridges, Midas Civil is the best.

There are enough examples of bridge projects using BIM technologies. One of them is the famous "Russian Bridge" with a length of more than 3 km, with the longest cable-stayed span in Russia - 1104 m. The height of the bridge is 334 m. The project was developed in 6 months. This highly complex project was carried out using the Midas software, in which the structural analysis and the general model of the bridge were performed. Modeling technologies made it possible to calculate cables, which consist of strands of ropes from 13 to 85 pieces [1].

The information model of the structure is also necessary during the operation of the facility. When conducting constant monitoring and periodic inspections of the technical condition of bridges, the implementation of structural calculations using the model allows in a short time to obtain information about the stress-strain state of structures and to develop solutions for strengthening or reconstruction.

When examining and testing a metal railway bridge in the Krasnodar Territory, the service life of which is more than 30 years, it was decided to determine the stresses in the bridge structures using the Tensor MS system. Also, computational models were developed in finite element analysis programs for performing verification calculations. To draw conclusions about the stress-strain state of the bridge, a comparison of calculations and tests is performed.

Materials and methods

Railway bridge 42.25 m long, single-span metal, span length 28.05 m, width of the bridge between the railing - 5.0 m. Abutments and cones are made of monolithic reinforced concrete, concrete stairs with platforms are arranged on the abutments. The adjoining approaches on both sides are crushed stone. The superstructure is metal, it consists of the main beams, operational facilities in the form of metal railings and a service sidewalk, which is a wooden flooring on metal structures.

When examining and testing the bridge, the tasks of determining the technical state of structures, their wear, detecting defects and deformations, checking the strength and bearing capacity were solved [2]. In the process of measuring work, the main geometric and stiffness characteristics of the structure, the height of the under-bridge dimensions, the gaps between the spans and abutments, and the correct location of the supporting parts were established. A general view of the bridge is shown in fig. 1.

The main beams (lower and upper) are of I-section 550x10 № 55a according to OST 10016-39. The beams are combined into a common spatial structure of the superstructure with uprights and braces, consisting of 5 panels, each 5.4 m in size. The connection of all metal elements is riveted.

To establish the load-carrying capacity of the bridge and the speed of movement, the bridge was run-in under a test load. Dynamic tests were carried out by repeated passage of a single locomotive without hindrance at speeds of 5, 10, 15, 18 km/h. In this case, the leveling of the main beams was carried out in order to determine the deflections of the superstructure from the load. At the maximum speed of the locomotive, the vertical displacements of the central point of the superstructure were 7-8 mm.

Fig. 1. General look of the bridge

To determine the stress-strain state of structural elements of the bridge, spatial finite element models of a metal bridge have been developed in the StructureCad and Midas Civil programs. The calculations were performed for the main combination of loads, taking into account the load from a moving locomotive.

To analyze the stress-strain state of structures, a mobile automated measuring system for vibration diagnostics Tensor-MS was used. With the help of strain gauges of the Tensor MS strain gauge control system, the vibrations of the spans from the passage of the test load (frequencies and decrements of vibrations, amplitudes and modes of vibrations of elements and structures) were recorded. The sensors were installed in the weakest places. Based on the results obtained, the stresses in the elements on which the sensors were installed were calculated. Fig. 2 shows a graph of stresses in the lower main girder of the superstructure in the process of running in with a test load (when the locomotive is passing). According to the technical characteristics, the measurement error is up to 10% [3].

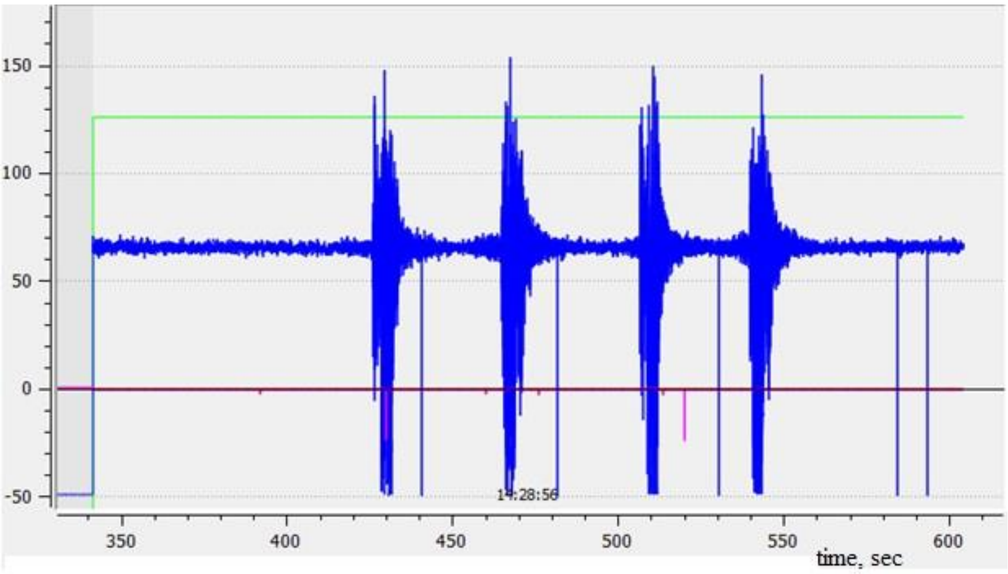

Fig. 2. Graph of stresses in structures during the passage of a locomotive

Results and discussion

As a result of modeling the bridge superstructure in the StructureCad program (fig. 3) and Midas Civil (fig. 4), the values of displacements, forces and stresses in the elements were obtained.

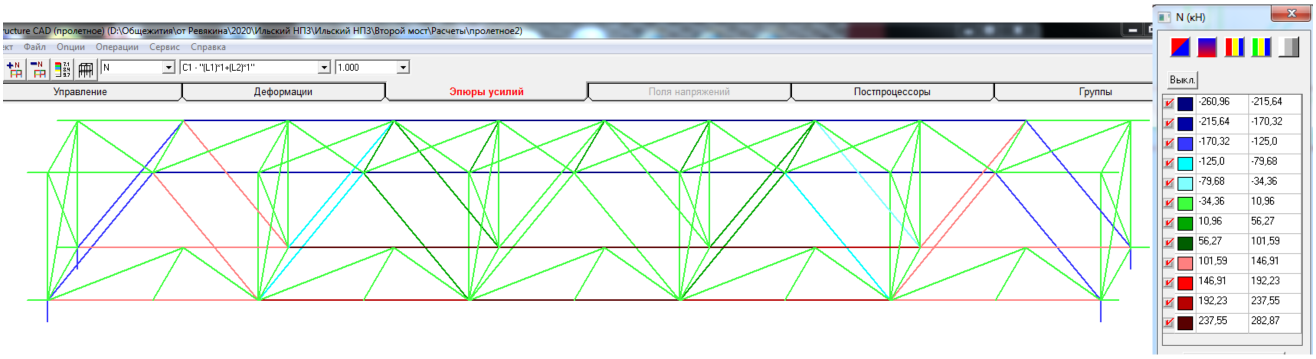

Fig. 3. N forces in elements obtained in StructureCad PC

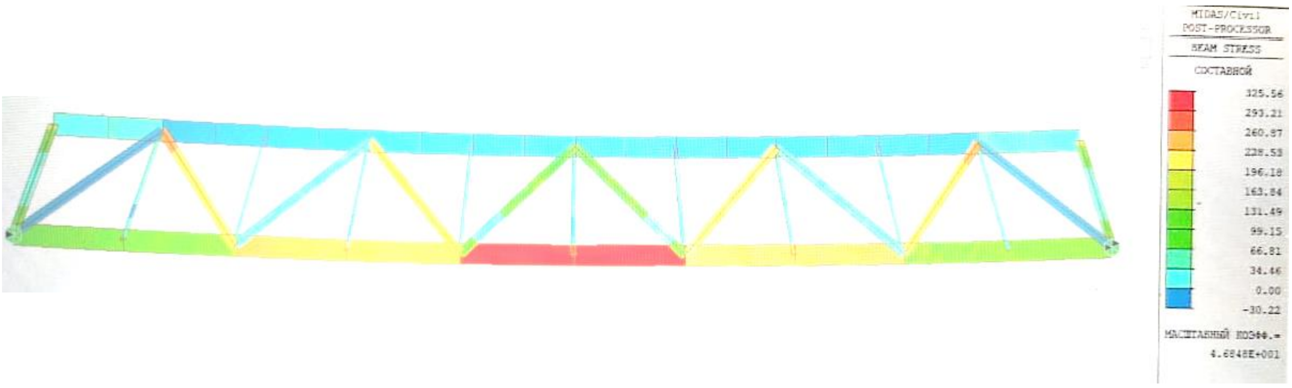

Fig. 3. N forces in elements obtained in the Midas Civil PC

The results obtained were compared with the data of tensometric observations and are shown in table 1.

Table 1 – Comparison of calculation results

Index	StructureCad PC	Midas Civil PC	Tensor MS
Deflection of the lower beam in the center of the span, mm	7.5	8.0	9.0
Maximum longitudinal forces, kN	282.87	293.28	155.0
Maximum transverse forces, kN	14.23	12.15	14.3

As a result of the analysis of the obtained values of the stress-strain state of the bearing structures of the bridge structure under the action of test loads, it can be seen that the calculation complexes have results that are close in convergence to each other (the discrepancy is no more than 5%). Strain gauge data have overlap. The most significant indicator of the superstructure performance is that the tensile forces in the calculations and test data have a significant discrepancy.

Conclusions

Testing of engineering structures is a responsible activity that requires an individual approach. In the process of testing, it is necessary to carry out a set of works. Information modeling technologies make it possible to get an idea of the stress-strain state of the structures of an operating structure [4, 5]. The performed calculations showed the possibility of using finite element modeling programs when checking the state of operated bridges and high convergence results in direct instrumental tests.

References

1. The longest cable-stayed bridge in the world. The official website of the information and analytical agency SeaNews. [Electronic resource] https://seanews.ru/2020/05/29/ru-samyj-dlinnyj-vantovyj-most-v-mire

2. SP 79.133330.2012 "SNiP 3.06.07-86. Bridges and pipes. Inspection and Testing Rules. Updated edition"

3. Yashnov A.N., Snejkov I.I. (2019). Experience of diagnostics of engineering structures by the method of small impacts. Russian journal of transport engineering, [online] 3(6). Available at: https://t-s.today/PDF/23SATS319.pdf (in Russian). DOI: 10.15862/23SATS319

4. A. Prokopov, M Prokopova, N Hamidullina Computer Modeling of Deformation Processes in the Event of Liquidation of a Dip Over a Rock Mine // IOP Conference Series: Earth and Environmental Science, 2019, Volume 272, 2. Section one. DOI: 10.1088/1755-1315/272/2/022118

5. Prokopov, A.Yu. Modeling of geomechanical processes preceding the accident during the construction of the ventilation shaft of the Moscow metro / A. Yu. Prokopov, M. V. Prokopova, Ya. S. Rubtsova, A. A. Medvedev // Bulletin of the Rostov State Transport University. – 2020. – № 3(79). – P. 145-153. – DOI 10.46973/0201-727X_2020_3_145.