ORGANIZATION OF BRIDGE LOAD TESTING: RECENT EXPERIENCES

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Summary: *Bridge Load Testing, in addition to the technical part, is closely related to the solution of organizational tasks, especially in the case of large and dilapidated structures during short time for test preparation and execution. In the paper, on examples of extensive and demanding tests of significant bridge structures, possible requirements and appropriate organizational solutions are presented.*

Keywords: *bridges, load testing, organization*

1. INTRODUCTION

During the past decade in the Republic of Serbia, as well as in the region, in order of improvement of existing road infrastructure, many projects have been implemented for construction of new and reconstruction of existing roads. Within these activities, according to the requirements of the road route, it is inevitable to build and reconstruct the appropriate structures, mainly bridges, as the most numerous and very important structures on the roads.

The obligatory activity before approval of carrying capacity of new, as well as significantly reconstructed bridges, is a confirmation of their response, which requires load testing of such important structures. In the Republic of Serbia the same is required by the technical regulations, the standard SRPS U.M1.046 [1], which is in fact identical to the standard JUS U.M1.046, and it is similar in our surrounding. Almost as a rule, in addition to the technical part of the implementation of the test, which implies the arrangement and the number of required measuring points, the level of the required test load, etc., the realization of the test is associated with significant organizational difficulties.

The same includes the satisfaction of a large number of requests and constraints: short execution time, shifting of execution deadlines, possibilities of traffic closing, possibilities of access to measuring points, weather conditions, contractor capabilities as participants in tests, compliance with designer's requirements, limited financial resources, etc. Accordingly, the organization task is an extremely important for the efficient and adequate execution of bridge testing. In the following are presented the

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main points of three, in an organizational sense very demanding, tests of significant bridge structures:

- Bridge *Gazela* on the highway E75 – after reconstruction,
- Bridges of the viaduct incorporated in North Approach Roads to the Ada bridge accross the Sava River in Belgrade – after competition of construction, and
- Bridge *Kostova greda* on the road M18 in Montenegro – for the purpose of reconstruction.

2. GAZELA BRIDGE LOAD TESTING

After more than 30 years of exploitation of the *Gazela bridge,* figure 1, on the part of the E75 highway through Belgrade, according to identified significant damages and requirements for strengthening of the structures within the bridge, during the period July 2011 - August 2012, extensive reconstruction works were carried out. The construction works were performed with the reduction of traffic, because that complete suspension of traffic which were not possible due to the importance of the part of the E-75 highway through Belgrade.

Figure 1. Gazela bridge before and after reconstruction

After the reconstruction, extensive load testing was carried out of all structures, figure 2, two approaching and main structure across the Sava river, with spans of L = 68.8 + 332.0 + 68.8m. Approaching structures, simply supported beams with cross sections consists of two box-shaped beams connected with cross beams, were tested by measuring global deflections and local strains in the critical cross-section at the mid-span of the both structures. The main structure was tested separately.

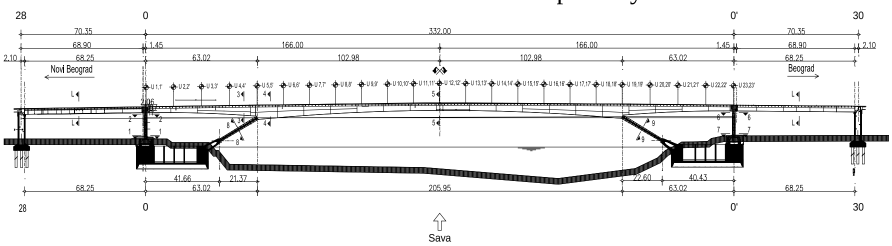

Figure 2. Test sections of all structures of Gazela bridge

Load testing of such a significant structure, in an organizational sense, was very complex for several reasons, with the most significant ones being distinguished:

- Extensive work on test preparation (a large number of test sections and test points on all three structures);
- Large number of participants in the preparation and execution of testing;
- Uncertain procurement of large quantities of repro-materials;
- Limited preparation time;
- Pre-determined and fixed execution dates due to planned suspension of traffic;
- Requirement for testing during the night time;
- Large volume of geodetic works in night conditions;
- Other: difficult working conditions in the period of high temperatures, difficult access to measuring points, etc.

Due to extremely extensive work, preparation and testing was carried out jointly by the participation of two laboratories, Laboratory for Structural Testing of the Institute IMS Belgrade and Laboratory for Structures of the Faculty of Civil Engineering, University of Belgrade, with the involvement of associates, so that the total number of direct perpetrators was 35.

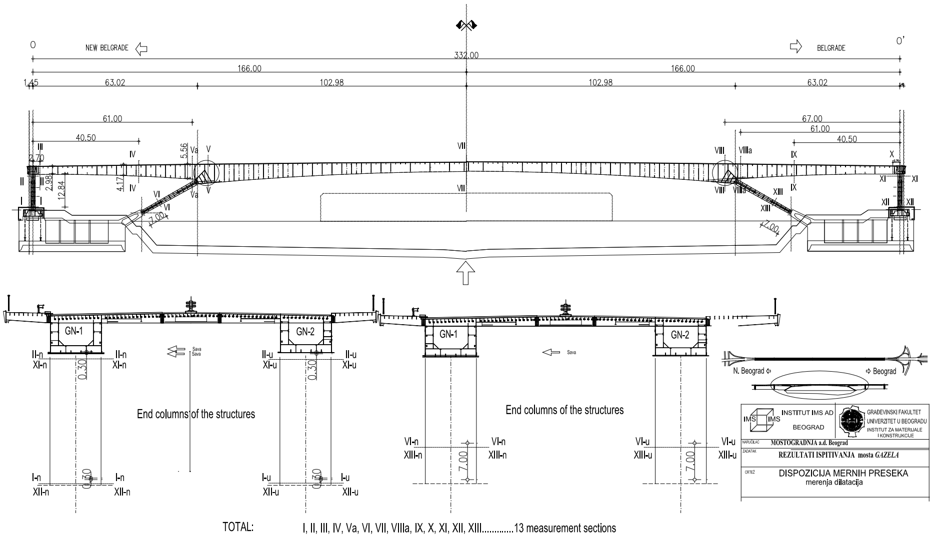

Figure 3. Layout of Gazela bridge main structure local deformation sections

To carry out the test was necessary to engage practically 100% of the available equipment of both laboratories for conducting simultaneous measurements, especially during the testing of the main span structure with a large number of test-cross-sections at mutually large distances, figure 3.

In a short time of about 30 days, parallel with the partially installation of instruments, it was necessary to procure a large amount of necessary repro-materials (strain gages, adhesives, cables, etc.) under conditions of uncertain delivery time of importing components and lack of manufacturer / supplier stock (e.g. appropriate cables).

Figure 4. Main structure of Gazela bridge – preparation for strain measurements

In particular, a very short time for test preparation activities was provided for the case of approaching structures, so it was completed just a few hours before the start of the test, which required a great effort and endurance of the technicians.

Due to the importance of the part of the highway E75 through Belgrade, the suspension of traffic was planned during night time, between 10.00 pm to 6.00 am. The tests were carried out according to the traffic closing schedule, while both approaching structures were tested during the night June 30 / July 01, 2012, while the main structure was tested during the night of August 11/ August 12, 2012.

Figure 4. Survey measurements during Gazela bridge main structure load test

A large volume of surveying works in night conditions and limited available time required four teams, each consisted of three-four perpetrators, with the schedule of each team measurement points according to figure 5.

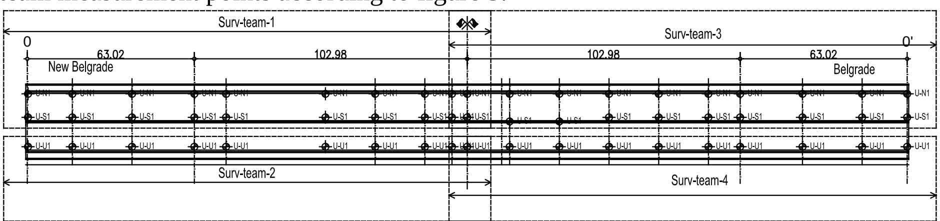

Figure 5. Allocation of surveying points of four surveying teams

Depending on the level of skill of the geodetic teams, a schedule of measuring points for each team has been made. The schedule included double measurement of deflection (level) at mid-span test points (benchmark), for the purpose of controlling and increasing the reliability of the results of geodetic measurements under difficult conditions, during night and limited time of 20 minutes for each test load phase.

Communication between the participants was carried out by radio stations. In the case when it was necessary to be present at various, remote, locations of very long structure during short execution time predicted for each test load phase, a motorcycle were used.

Figure 6. Survey measurement points and level measurements during of Gazela bridge main structure load test

The presented key requirements and organizational solutions during demanding and extensive testing of structures within the *Gazela bridge* ensured efficient execution of the tests of both approaching structures during the planned 10 hours (including required switching position of the measuring instruments and accessories from one structure to the another), as well as the testing the main structure with 15 phase of the static and three phases of the dynamic load of the main structure.

3. TESTING OF BRIDGE STRUCTURES OF THE LONG VIADUCT

Within the north accessing roads to the *Ada bridge* over the river Sava in Belgrade, the *Construcciones RUBAU* – Belgrade ltd. construction company, in a very short period between 2016 and 2017, completed the viaduct with a total of 10 structures of significant lengths and corresponding accessing roads, figure 7.

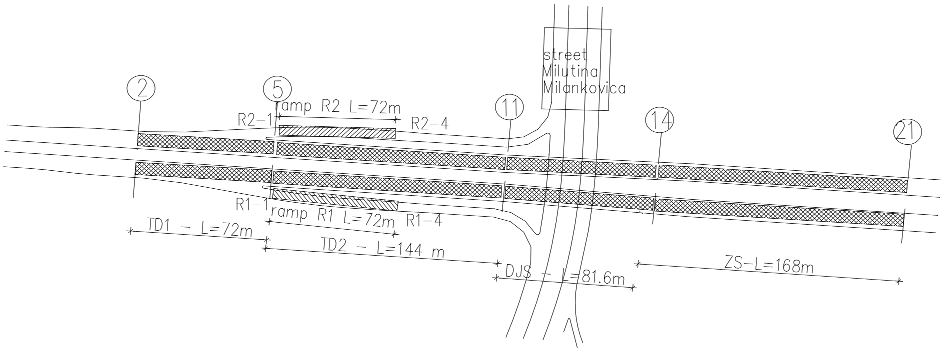

Figure 7. Layout of viaduct structure – part of Ada bridge north accessing roads in Belgrade

Practically, a significant part of the road is located on structures with a total length of more than one kilometer (taking into the account structures on the left and right traffic lane), with lengths from 72m to 168m. The bridges along the straight part as well as the ramps were erected as pretension concrete structures.

The testing of all viaduct structures was carried out after the completion of the asphalt cover, immediately after the installation of protective fences and barriers. The favorable circumstance was the fact that it was possible to pre-install a part test instruments, which includes installation of strain gages and partial cabling (installation of cables for connection with the acquisition system on some structures), figure 8. Also, it is possible to approach underneath the structures, because of the absence of obstacles (river, etc.), which significantly influenced to the conditions of execution load testing of bridges.

Figure 8. Preliminary installation of instruments on part-ZS_right_lane of the viaduct

It was necessary to overcome a number of circumstances that made enforcement difficult, by properly organizing the conduct tests, whereby the following should be stated:

- Extremely short deadline for testing all structures;
- Delaying date of start of testing and shortened for the commencement of the examination due to delays of paving works;
- Very long lengths of some structures with a numerous of measuring points at a large distance;
- Presence of electric tram lines in the zone of instrument installation;
- Parallel rolling of other finishing works (construction of the fence, drainage under the bridge, painting, etc.).

The available time for the completion tests of seven days, just before the start day of the testing, was shortened to 5 days due to the delay of other works, in the first place because delaying of the completion of paving due to atmospheric precipitation. In such conditions, the only solution was to test 2 structures per day, which required an increase the number of direct precipitators and the quick efficient shifting of test equipment from one to another structure which have being examined during the same day, in order to achieve the predicted schedule of all bridge testing.
Regard this fact, since there was the possibility of installing electronic displacement measuring instruments and acquisition systems under the bridge, the tests were significantly accelerated. The choice of the method of displacement measurement using electronic instruments proved to be very useful instead of the application of the geodetic method of deflection measurement as a significantly slower method, which in this case was not necessary.

Figure 9. Acquisition system underneath of multi-span bridge structure

The applied method of measurement is also advantageous for the reason that it allows check of the acquired results immediately, even in the case of very long structures with a large number of measuring points, figure 10. An additional advantage of the electronic measurements of displacement is the increasing in reliability of measurement with the elimination of possible reading errors due to the existence of a digital record of results for the eventual additional checks during analyzing procedure.

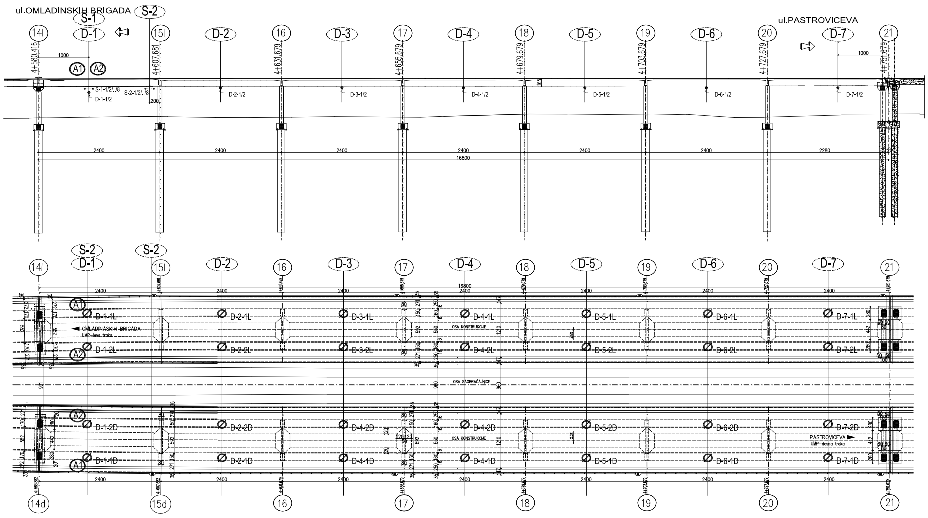

Figure 10. Layout of instrument positions on part-ZS_right_left L=7 x 24 =168 m

The applied organization of extensive testing of the multi-span structures, with occasionally bad weather conditions and parallel execution of some finishing construction works on secondary bridge elements, figure 11, provided possibilities to achieve predicted dynamics testing, and all tests carried out with the high reliability of the results. It should be noted that assumed layout of measuring sections for strain measurements avoided adverse effects of the use of long cables from strain gages, while the LVDTs are less sensitive to these effects, and all were simultaneously connected with the acquisition system. In the case of seven span bridges, at the same time were connected 14 LVDT instruments for simultaneous measurements.

Figure 11. Bad weather conditions during testing execution with other activities

4. TESTING OF THE OLD *KOSTOVA GREDA* BRIDGE STRUCTURE

For the purpose of reconstruction section Scepan Polje - Pluzine of the road M18 / E762 in Montenegro, *Kostova greda bridge*, with spans L = 15.00 + 122.00 + 15.00m, was tested, figure 12.

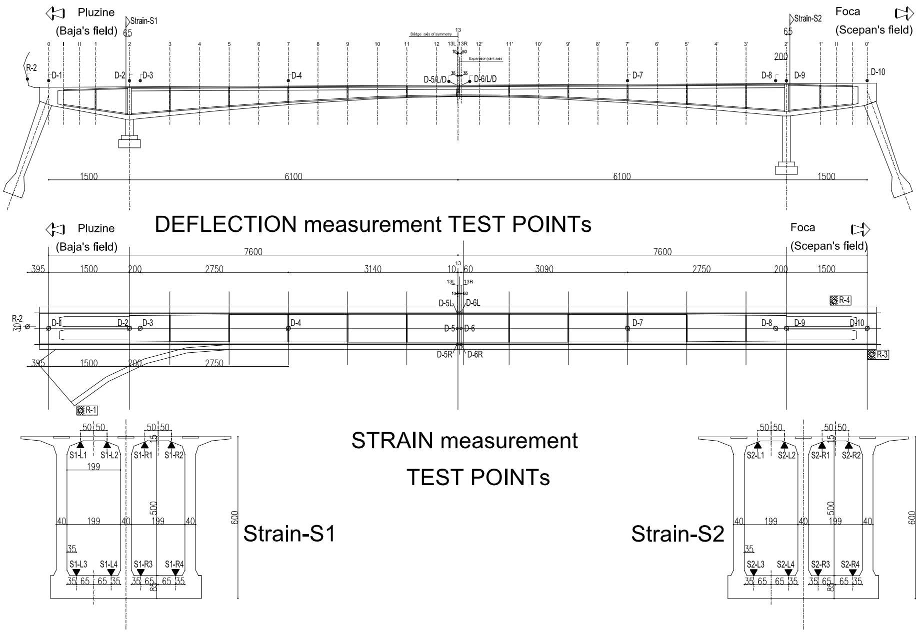

Figure 12. Test sections and test points of load tested Kostova greda bridge

Specificity of this structure, built during the 1967-1968., is its static system, consists of two console beams connected together by a "Gerber's joint" at mid-point of the main span. Such static system was chosen because it allowed a console construction method above the deep canyon of the Piva river, as well as the fact that on both sides of the structure are tunnels on the route.

According to the unusual static system, the importance of bearing capacity of anchors at the ends of the structure, as well as the detected deformations at the position of the "Gerber's joint" (with expansion joint at the same position) at the mid-section of main span, for the needs of the bridge reconstruction by designer was required to carry out load test. The aim of test was to find out real structural response after it has been in use for a long time.
The specificity of the conducted load test, which significantly complicated and made the execution difficult, as follows:

- Lack of subcontractor for supporting activities;
- Extremely unfavorable route on the road close to the bridge and short time of traffic suspension;
- Extremely unfavorable weather conditions for the preparation and execution of the test during the winter;
- Unknown condition of the structure after many years of use.

It is common practice to engage a subcontractor for supporting works, lifting for accessing test points, and other construction equipment during testing. In this case, since the bridge was in operation, it was not possible to provide the subcontractor for the execution of these activities, nor additional equipment. Figure 13 illustrates the difficult access to the entrance to the bridge box-type main beam, as well as the necessary resources that have to be independently provided.

Figure 13. Test section and test points of load tested Kostova greda bridge on section Šćepan polje – Plužine of the road M18 in Montenegro

In order to carry out the test, suspension of traffic was provided twice during a day with duration of 3 hours each. During this time, it was required to perform the necessary geodetic deflection measurements of the structure using geodetic method in extremely unfavorable weather conditions. Surveying measurements were carried out in the presence of improvised protection, Figure 14, which ensured that measurements were performed within the short time and with a very good quality of the obtained results.

Finally, in the case of testing this old bridge, exceptional attention is devoted to permanent monitoring of structural response for security reasons. For this purpose, the operators preliminarily processed the results after each test load phase, which were compared with the corresponding computations. In this way, the possible risks are avoided, and the established structural response indicates that in some test load phases response did not correspond to the design one due to the lack of connection between the two parts of structure at "Gerber's joint".

Figure 14. Geodetic measurement during load testing of Kostova greda bridge under improvised protection of snow and rain

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ОРГАНИЗАЦИЈА ИСПИТИВАЊА МОСТОВА: СКОРАШЊА ИСКУСТВА

Резиме: *Испитивање мостова пробним оптерећењем, поред техничког дела, тесно је повезано са решавањем организационих проблема, посебно када је реч о великим и разуђеним конструкцијама и кратком времену извршења испитивања. Рад, на примерима обимних и захтевних испитивања значајних мостовских конструкција, приказује могуће захтеве и одговарајућа организациона решења.*

Кључне речи: *мостови, испитивање пробним оптерећењем, организација*