LOADING TESTS OF HIGHWAY BRIDGES IN SLOVAKIA

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Abstract

The role of bridge testing is to verify technical stage (condition) and safety of bridge. Technical frame of loading test is given by standards. There are presented basic Slovak standards for loading tests and deformation measurement of bridges. Information about classification, preparing and realisation of tests are included in paper. Geodetic and non-geodetic method is used for determination of bridge deformations. Methodology and instrumentation of most used measuring methods are described.

The paper is complete by description of new measurement methods used for loading tests of Lafranconi Bridge in Bratislava. The tests were carried-out with co-operation of the TU Vienna. Department of Surveying of the SUT in Bratislava has participated at loading test of more then 20 bridges in Slovakia.

1. Introduction

The way construction in different geologic and morphologic conditions (surrounding), which is typical for mountains, can be realised only by construction of bridges, viaduct's and tunnels. To determinate the number and localization of these constructions in terrain, the multi criteria evolution of the region is used.

The assumption of putting the bridges and viaducts into operation is realization of tests, which aim is to proof and to confirm the quality of these structures. Parallel is the function of the structures controlled. Providing of tests is given by technical norms (standards), in Slovakia by STN 73 6209.

2. Technical frame of bridge test

The norm STN 73 6209 specifies the design, providing and processing of loading tests, which is necessary for putting bridges and viaducts into operation. During the test are observed and quantified the effect of the loading on the tested construction. There are measured deformations, displacements, rotations, relative deformations and force values (strain, axis force, bending moments, etc.) actuating at several parts of tested construction. Important part of the test is the localization of perturbations, leaks, quantification of their greatness, form and position at the construction.

Middle point of the loading test is the quantification (measurement) of position changes and deformations of selected parts of the structure. Most of these measurements are realized by geodetic methods and using geodetic technology. The advantage of geodetic methods is the ability to observe a big amount of points with high accuracy. Deformation and displacement of the structure can be determined in relation not only to the another parts of the tested structure, but also in relation to the control points located in safety distance of the structure. The suitable location of these points in surrounding guaranteed the stability (relative stability) of the structure reference system built by the

control points. This way determined deformations and displacements could be consider as absolute deformations in relation to STN 73 0405.

The loading tests are different in relation to the used loading. According to the STN 73 6209 static and dynamic tests are known. During the **static** test the loading retrieved on the tested structure static effects, only. The static tests are divided into:

- **basic tests,** which are provided at all bridges whit higher span as 18 m, eventually at the bridges defined by designer or builder,
- **tightened tests,** which are provided at bridges failed the design requirements or standards (in form, quality of material or installation) in volume, that evocate uncertainty of right and safety function of the structure,
- **special tests,** which are provided during the construction and can be accepted as basic or to tightened tests.

The government, designer or the builder can determine the realization of the tightened test. The special test is provided only in cases, the structure is loaded during their construction (e.g. by crane used for construction). This loading is consider as testing load and all the measurements are provided in the time of the first structure loading.

Dynamic loading tests are provided, if the loaded structure can not fulfill the requirements defined in standard STN 73 6209 (part No.61 and 62), or in case that this test is required by the designer or the builder. Dynamic test are provided on bridges of state and local railways with span higher then 50 m or bridges with continuous structure longer then 80 m.

3. Test preparation

The test supplier deliver all the documents and data, including attachments required for the static and dynamic calculations, which are necessary for the advisement of the loaded bridge structure. The theoretic values of deformations and forces must be calculated for condition, which was accepted for design of the structure. It is takes into account its efficiency of testing load.

Before starting the test there will be created the chart flow of tests including:

- loading phases, schemes of load location on the structure and the time of their application,
- calculated deformation and force values, there are measured, including the efficiency of testing load,
- measuring method, used instruments and their location on the tested structure or their surrounding,
- preparing works, supporting equipments and schemes of their location,
- progress and time table of loading test (bridge closing plane),
- organization of the test, date of results and reports preparation (partial or full),
- safety actions.

The test preparation is realized according to standard STN 73 2030.

The fulfilling of the design requirements - structure quality, parameters, quality of the productions and installation, must be indicated before the test. If there are indicated differences between the structure and parameters given by the design, the statement of designer is required. Before starting the test, detailed inspection of the structure must be realized with the participation of surveyor responsible for the geodetic measurements.

If new bridges or bridges after general reconstruction are tested, is the static test provided first, only after this can be the dynamic test realized. If there is provided the test of bridge, which is in operation, the order of tests is not defined.

Before the test it is necessary to define the highs of pillars, middle points of bridge fields and measuring points given by STN 73 6201. The test of railway bridges includes the measurement of relative position of rails and longitudinal axis of the bridge and their main structure. If there are tested

new railway bridges or bridges after reconstruction, it hast to be repeated the high measurements after the test.

During the test must be the influence of different warm of the structure accepted. Testing of big, complicate and statically undefined structures are measurements of without loading and under different conditions (temperature) realized. The temperature characteristic of the structure can be given in the best way by 24-hour test of unloaded structure. These measurements must be realized before the loading test.

Before the dynamic test is necessary to measure the flatness of the road in longitudinal and transverse direction, including the road part before and after the loaded bridge structure.

4. Test realization

The loading test is carried-out by prepared time schedule. The volume of the test load is determined by their required efficiency. Efficiency of the test load η must insure:

a) for the basic loading test $0{,}5 \leq \eta \leq 1{,}0$,
b) for the to tightened test $1{,}0 \leq \eta \leq 1.2$.

Biggest load is usable in abnormal case and by realization of spatial tests only. It must be proved, that this extra load cannot effect permanent deformations on any part of the tested construction.

The dynamic test is provided with load, which maximum efficiency is equal to norm value of vertical moved load, including dynamic effects and effects of centrifugal forces given by STN 73 6203.

During the static loading test are measured the deformations and force values, which are necessary for the objective examination of the facilities of tested construction. It must be measured:

- vertical deformation of bridge fields in the middle (extremely places where are expected the maximum deformations),
- vertical displacements of pillars (settlement, subsidence),
- relative deformation of extremely loaded construction parts.

Necessary part of measurement is the observation of breaches. After their detection, the longitude, width, form and orientation, all of breaches must be measured.

According to the construction type are measured the vertical and horizontal displacements of chosen point. If the construction consists of more beams it is necessary to measure the vertical deflection (sag) all of main beams. For the deck bearing structures are given by the STN 73 6209 the vertical deformation measurement under all lanes and tracks. In this case, will be the number of measuring points given by the test maker. The named standard recommend, include to the measurements, the measurement of relative deformations on extremely loaded construction parts, too.

During the dynamic test are measured the deformation and force flow according to the time:

- vertical deformation (deflection) in the middle of bridge fields or in points with maximum deformation values,
- car velocities.
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There are relative deformations measured in chosen points. Horizontal and vertical construction oscillations are observed in the middle of bridge fields. The horizontal displacements of bearings at pillars are measured, too. The quality of measuring instruments and their position and control are given by the STN 73 2030.

The STN 73 6209 gives the time schedule of the test, position of the load in all test phases, impact time during the static test and realization of the dynamic test

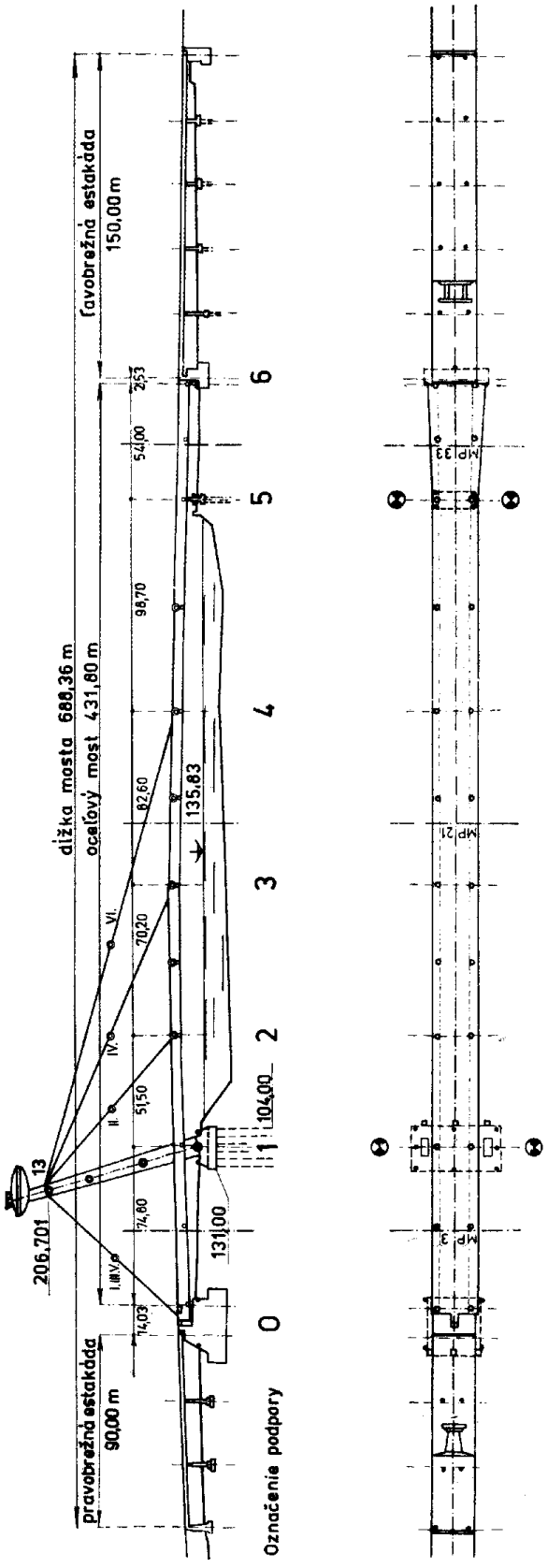

Fig.1 Measurement points and instrument positions at the New Bridge in Bratislava

5. Geodetic measurements

Vertical and horizontal displacements of points, deformation or inclination of the tested construction are determined by geodetic methods. The advancement of geodetic methods is the determination of absolute and not only relative values of deformation (displacement). The observation points are chosen out of the bridge or over the bridge pillars (Fig.1). Their stability must be controlled during the test, by measurements to the group of control points located out of the bridge structure in a sufficient range. The stability of control points will be determined by measurement and analyses of invariant parameters (lengths, angles and high differences), which are measured between the control points.

Geodetic measurement of **vertical deformations** of bridges is generally realized by leveling (precise leveling) or trigonometric high determination (trigonometric method). Using the leveling method, the measurement process is different from the generally application by:

- set-up of the measurement process (more instrument are used for measurement, the measurement is realized only in one direction),
- reading only the left scale at the invar staff,
- using the side sights of different length,
- leaving the correction of nominal staff length and different sight length.

These differences of measurement process have not effect to the accuracy of deformation determination, because there are given as the difference of two high differences measured in different epoch (test phase). Reading of one scale only is necessary for time shorting, which is given for the measurement in each epoch. More instruments and different length of sights can be used only if the instruments are controlled before the test is started, and the positions of instruments are during the test not changed.

The **trigonometric method** will be used only in cases where the deformations can be not determined by leveling method. This situation is not scattered and is typical for the big bridge constructions (Michalčák et al., 1985). Exploitation of trigonometric method can be determined by the position of control points at construction parts with closed access (points situated at cables, beams, etc.). In other side, before the test, the applicability of the

trigonometric method must be determined very sensitive, mainly from the accuracy and the timing specifications given by the measurement point of view.

For the measurement of **horizontal deformations** is generally used the alignment method, less the intersection or polar method. By application of alignment method will be the control sight chosen at the border of the bridge construction or in their neighbourhood. If the observation points are non-accessible or with special equipment only, will be these signed during the whole loading test (Fig.2).

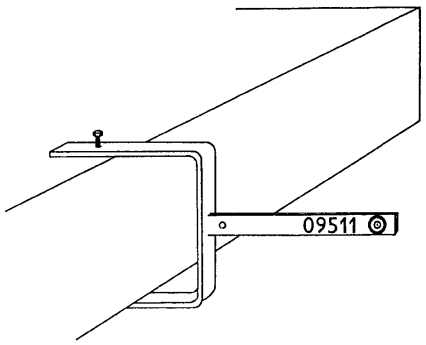

Fig.2 Sign for horizontal deformation measurement at Lafranconi Bridge in Bratislava

Horizontal deformations of small bridges can be determined by reading of scales positioned horizontally and parallel to the direction of deformations. Increasing the span of construction will be increasing the length of sights and the reading of scales must be changed whit the aiming to concentric circle signs. The value of deformation will be calculated from the angle, which is measured to the sign (paralactic angle measurement). The calculation must be realized at the station and real-time. For this case will be used the table prepared for the test or the software of the total station.

The inclinations of bridge construction or their parts (generally the pillars) are measured by geodetic and non-geodetic method too. The application of geodetic methods, need enough place in the surrounding of the pillars, mainly in direction perpendicular to the measured inclination or place for the vertical projection.

Important part of all measurement is the accuracy determination of measured values. This is the base of the method and instrument selection and their position during the measurement. The first step is the calculation of the a priori accuracy characteristics of deformations (displacements). There are going-out from the requirements of the test contractor or from the requirements of STN 73 0405 (after the understanding of the contractor). In the second step the contractor of geodetic measurements determines the methods, which will use for the determination of deformations. After the selection of methods will be calculated the a priori accuracy characteristics of measured values with the requirement to fulfill the accuracy requirements of determined values. The result of this process is the selection of instruments, methods and number of measurement replications, which ensure the fulfilling of all requirements.

6. Documentation of the loading test

The flow (process, behavior) of the loading test must be in details registered and documented. The documentation of the test included:

- registration of bridge data given by STN 73 6201,
- date of measurement,
- temperature flow (air and construction),
- used measurement instruments and their position (connection),
- measured values (displacements, absolute and relative deformations, etc.),
- sensitivity and working area of the used instruments,
- data (information) of the used loading, loading characteristics,
- marking of the load and their position in all test epochs,

- number and time of the measurement, measured values,
- differences between the actually and previous measurement, differences between the actually and zero measurement (zero reading),
- time of the load application in the actually epoch,
- instrument reading (sequences, series, time schedule, number of replications, etc.).

The loading test contractor makes the interpretation of results by STN 73 6201, stage 52-57. Outgoing from the measurement values are calculated the maximum, permanent and elastic deformation, and the force values or their relative coefficients. These are compared with maximum deviations (critical values) given by STN 73 6201, stage 58-69.

After the loading test the contractor makes first the **preliminary report**, which include mainly the maximum deformations or deformations in the middle of bridge fields. In preliminary report are included:

- registration of bridge data given by STN 73 6201,
- measurement values and instrument and measurement equipment positions,
- another data for static tests defined by STN 73 6209, st.70,
- another data for dynamic tests defined by STN 73 6209, st.70.

The geodetic measurement results are included to the preliminary report in form and structure required by the contractor. Usually are these included in graphs or tables.

In the preliminary report will be included the results of direct visualization of the object (structure) during the test (mainly data from breaches, disturbing stability of elements and structure parts, etc.). At the end of report the contractor express if the tested structure fulfill the requirements of STN 736209. Another side he must workout the design of process, which realization sure the safely operation of the bridge (speed or last limit, etc.). The report can include the design of structure corrections, which will effect the fulfilling of the test requirements, too.

Final document of the loading test is the **detailed report**, which include:

- data of bridge registration given by STN 73 6201,
- the main data of the tested bridge, including data of the structure dimension,
- data of the load,
- test description, vehicle positions and motion, loading phases, time, air and structure temperature flow, etc.,
- calculation of theoretical deformation values,
- used instruments and their positions,
- measured data and their comparison with criteria,
- efficiency of the load,
- results of the direct visualization of the structure before, during and after the test (description of breaches, vibrations, etc.),
- final valuation of the tested bridge based on the test results and the expression, if the tested structure can fulfill the requirements given by STN 73 6209.

The final report must include the separate geodetic documentation, which consists of the description of used methods, a priori calculation of accuracy of the measured and determined values, used instruments and their positioning at the bridge structure or surrounding, time schedule of measurements, theoretical values. The geodetic part of the report carries-out the contractor of geodetic measurements.

7. Application of modern geodetic technology for bridge testing

Modern geodetic instrumentation enables the exploitation of automatic measuring process. Tank the high accuracy and automatic measurement are the new methods registered and we can see the come back of many old methods. Typical in this field is the trigonometric method for high determination or the polar method. Both methods are formerly known as methods with rapid but not very accurate co-ordinate determination.

Our department has used in co-operation with the TU Vienna the trigonometric high determination method for measurement of vertical bridge deformations (Kopáčik et al., 1993). For this method was used the Leica TM3000V robot theodolite with CCD camera (Fig.3). The measurement was realized inside the bridge structure, where the 12 measured points are signed by spot lamps, of diameter 15 mm. The distances between the instrument and the measured points are from 14.5 m to 137.6 m. Deformations determined by Leica were compared with values determined by precise leveling method. The maximum difference between two methods was 1.7 mm.

Fig.3 Leica TM3000V from TU Vienna at Lafranconi Bridge in Bratislava

Today most preferred GPS technology can be used for deformation measurement too. From their higher accuracy in horizontal plane point of view in comparison with vertical, it is used more for the determination of the horizontal deformation of high pillars. We find information that write about the using of this technology for vertical deformation measurement on bridges (Kapovic et al., 1998). The number of these applications is not significant.

Interesting in the next time would be the exploitation of laser scanners for deformation measurement. The accuracy given by this technology is acceptable for bridge deformation measurement, only the time, which is necessary for the measurement and data processing is too long today.

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