LOADING TEST OF EXTRADOSED BRIDGE SEGMENT – EXTRADOSED BRIDGE IN POVAŽŠKÁ BYSTRICA

Doc.Ing.M.Chandoga,PhD., PROJSTAR PK, s.r.o., Bratislava, Slovakia
Ing.J.Sedlák, Ing.A.Prítula, Civil Engineering faculty of STU, Bratislava, Slovakia
Ing.Ján Kucharík,PhD., VÚIS- MOSTY,s.r.o., Bratislava, Slovakia

ABSTRACT:

This paper deals with the verification of technological processes, quality of construction and of the static function of a segment specimen. The verification of construction technology and the loading test preceded the actual construction of the segmental extradosed bridge. The dimensions of the segmet’s cross-section were similar to the real bridge cross-section. The cross sectional area is composed of prefabricated diaphragms and monolithic parts; the aim of the loading test proved the static function and capacity of selected parts of the cross-section. Some results of monitoring of the segment during the construction, as well as the loading tests, are introduced in this report.

Key words:
extradosed bridge, pre-stressed concrete, loading test, technological practice

INTRODUCTION

With regard to the fact that the extra-dosed bridge, carrying full highway width, is the first of its kind in the Slovak Republic, the investor (National Highway Administration, a.s.) required a few tests. Most of them were accomplished during the production of the testing segment (Fig.1). Two types of tests were executed on the testing segment:

1. The first test was focused on proving the reliability of fabrication of the testing segment with a similar technology as used during fabrication of the extra-dosed bridge. In this stage of casting and compaction, hydrating heat of concrete and rheological properties was monitored.
2. The second test was aimed at proving the static action during the pre-stressing and loading processes. Transverse pre-stressing of the segment's upper slab and external loading, see Fig.7, was used to observe strains and deflections of the testing segment.

The investor also required testing of the selected parts and components of the bridge during the construction process, as well as during the service life of the bridge. Strains in the concrete were monitored by means of strain gauges, forces in pre-stressing tendons and extra-dosed cables were tested by elastomagnetic sensors. These results are not the subject of this paper.

1. CONSTRUCTION OF THE TESTING SEGMENT

The shape of the cross-section of a real extra-dosed bridge and the shape of the experimental segment are depicted in the picture below. In the first stage, a hollow box with a hole for the steel parts of anchorage suspension and diaphragms was built. In the second stage, tensioned diaphragms were cast. It was necessary to build technological holes in the top slab for casting these diaphragms with a special concrete mixture. Construction of the segment represented a convenient training for placing reinforcement, casting and compaction of concrete with the desired quality of concrete mixture.

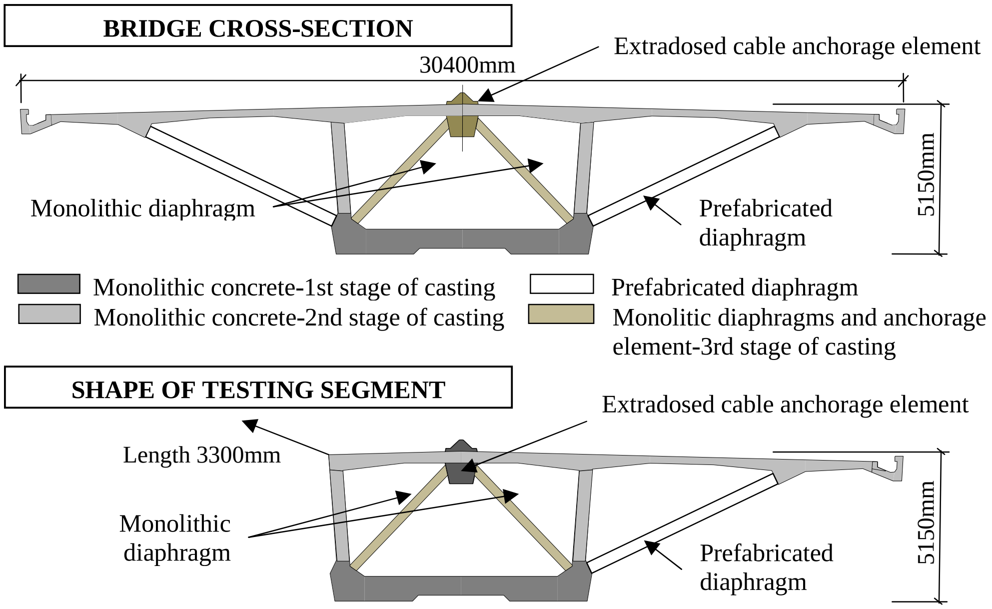


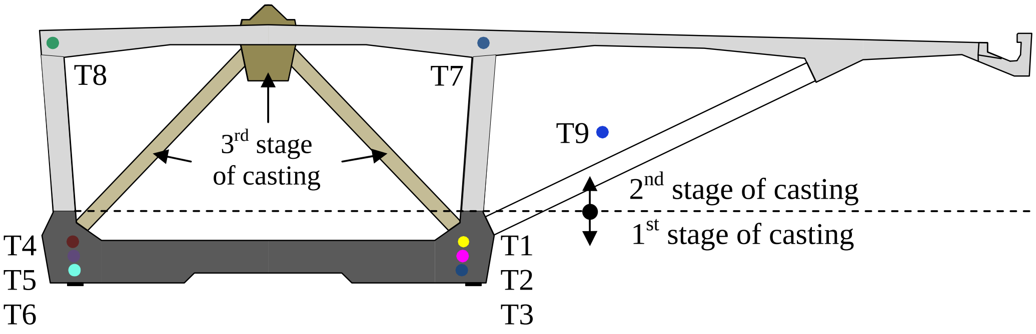
Fig.1. Shape of testing segment

2. MECHANICAL PROPERTIES OF CONCRETE

2.1 HYDRATION HEAT

In Fig.1 we can see several dimensions of the cross-section of the segment. The thickness of the bottom slab is 0,7 - 0,9m, and of the walls is 0,45 m, and the upper slab, 0,25 - 0,5m. The length of the segment is 3,3m; it means that 60m^3 of fresh concrete was cast into formwork in 4 hours. It was necessary to observe hydrating heat development before the fabrication of the extradosed bridge, and make changes in the concrete mixture, if necessary. The type of mixture used for casting the testing segment - concrete class C45/55 - was used for casting the segments of the extradosed bridge. The development of hydration heat is shown in Fig.2.

The maximum temperature in the concrete in the 24 hours after casting reached 70°C (26°C ambient temperature), then the temperature decreased slowly during the next 24 hours to 60°C (26°C ambient temperature). These temperatures are relatively high, but to be expected for this concrete mixture. No cracks or shrinkage were observed during the curing process, as a result of the high hydration temperature (temperature gradient). There was no influence of high temperature on the mechanical properties of the concrete.



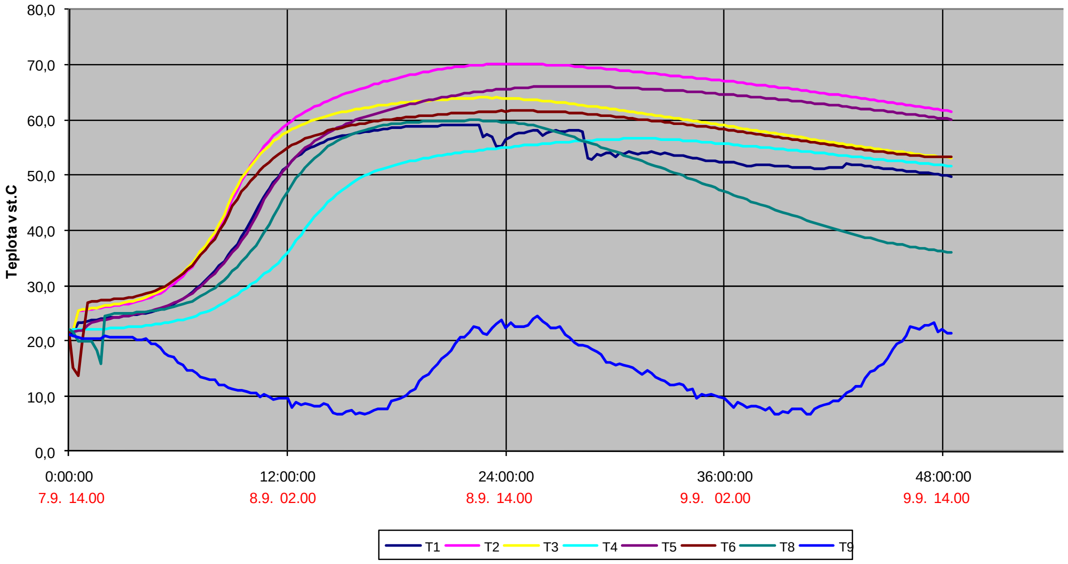


Fig.2 Development of temperature in concrete

2.2 COMPRESSIVE STRENGTH AND MODULUS OF ELASTICITY IN TIME

The development of the compressive strength of concrete in time has been monitored on testing specimens. Each time the compressive strength was tested on three cubes with dimensions 150x150x150mm.

The same procedure was applied with the static modulus of elasticity, which was monitored on testing specimens with dimensions 100x100x400mm. The dynamic modulus of elasticity was also monitored. The results of the test are summarized in Fig.3:

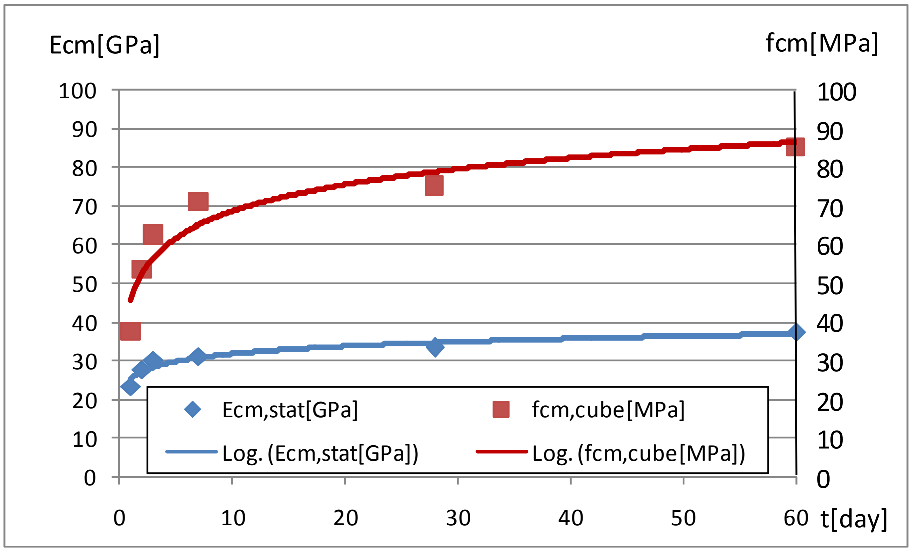


Fig.3. Development of compressive strength and modulus of elasticity in time

2.3 CREEP AND SHRINKAGE

Free shrinkage was monitored on site, with similar ambient conditions as the segment. Strains were monitored on testing specimens (100x100x400mm) by strain gauges. The behavior of free shrinkage is displayed in Fig.4:

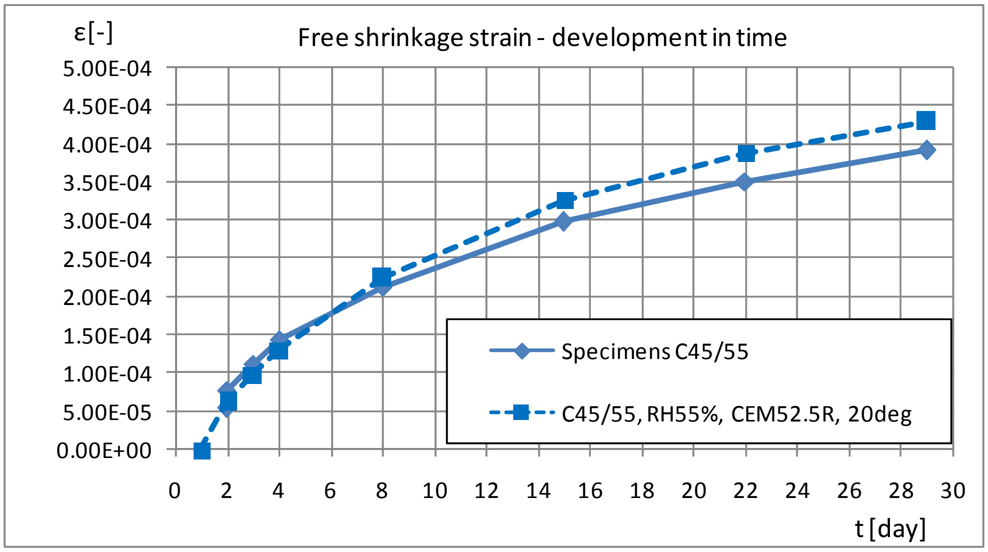


Fig.4. Development of free shrinkage in time

Volumetric changes due to creep of the concrete were measured on three specimens (100x100x400mm), the specimens were loaded with 70kN force (7MPa) and stored in laboratory conditions (at a temperature of 20 ± 3°C, RH 55±5%). Strains were measured with gauges (accuracy 1/1000mm, base 200mm).

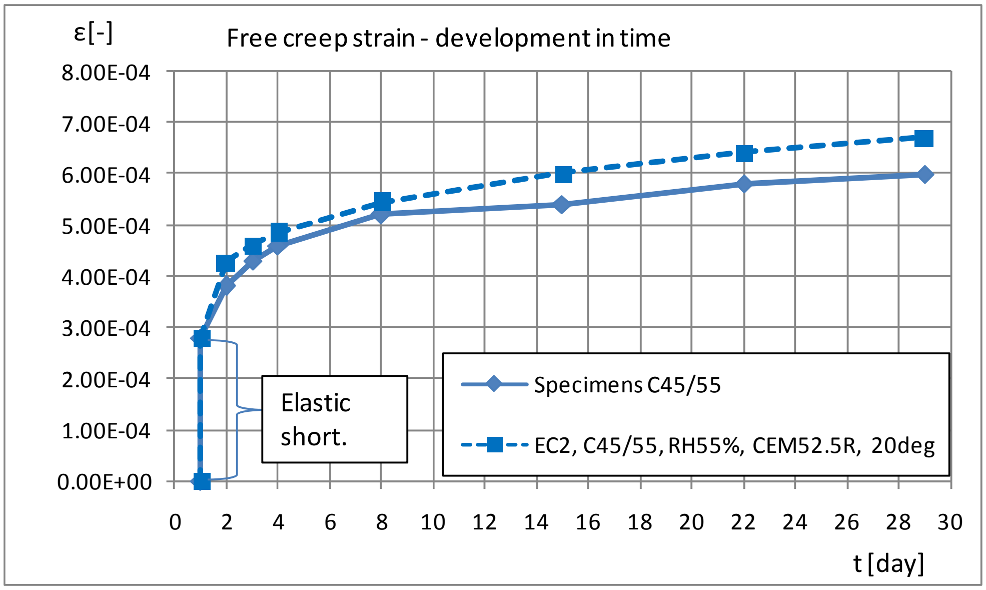


Fig.5. Development of free creep in time

Specimen loading lasted 1 day; and the formwork was removed from the casting after 18 hours. Immediate elastic strain due to loading was $2{,}8.10^{-4}$, which represents 25GPa modulus of elasticity (pressure 7MPa).

3. LOADING TEST

The main goal of the loading test was to assess the static behavior of the selected structural member of the tested segment. From the static aspect, the most interesting part of the segment is the pre-stressed upper slab, supported by a sloping diaphragm. There are two critical sections in this structural member, see Fig.6. - Section "1" and Section "2". Their resistance is highly influenced by transverse prestressing. Forces in prestressing units were monitored using elastomagnetic sensors PSS16, strains in concrete were monitored using strain gauges. The plan of loading and the selected results of the loading tests are summarized in chapters 3.2 and 3.3.

3.1 THEORETICAL MODEL

For comparison of measured results, a 2D non-linear model with measured properties of the materials of the segment was created. Also the real position and the amount of reinforcement and prestressing steel was taken into account.

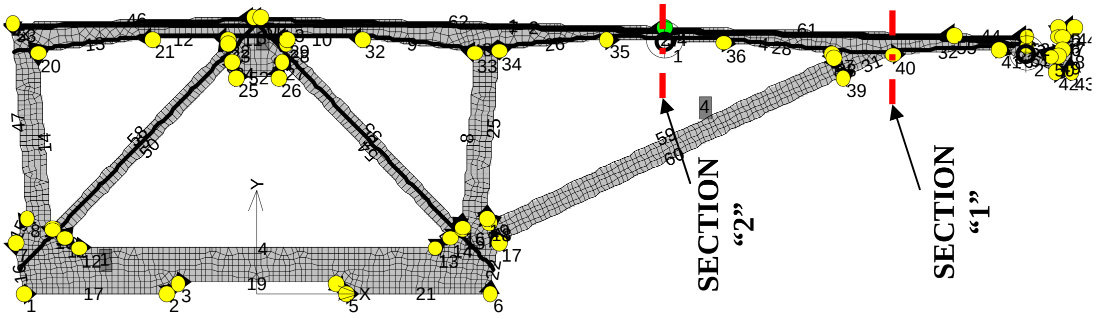


Fig.6. Theoretical FEM model

3.2 LOADING TEST – SECTION "1"

The amount of load in Section "1" was determined by the requirements of decompression in the upper fibers of the concrete. The expected level of load causing decompression in Section "1" was 375kN. Section "1" was loaded with concrete barriers (each 35kN) stored at the end of the cantilever, see Fig.7. This part of the loading test was divided into 6 stages (Load Case 1-6). The cantilever was gradually loaded with 3, 5, 8, 10 and 12 concrete barriers. 12 concrete barriers created a 420kN load, which was 12% higher than the expected level of load which would cause decompression.

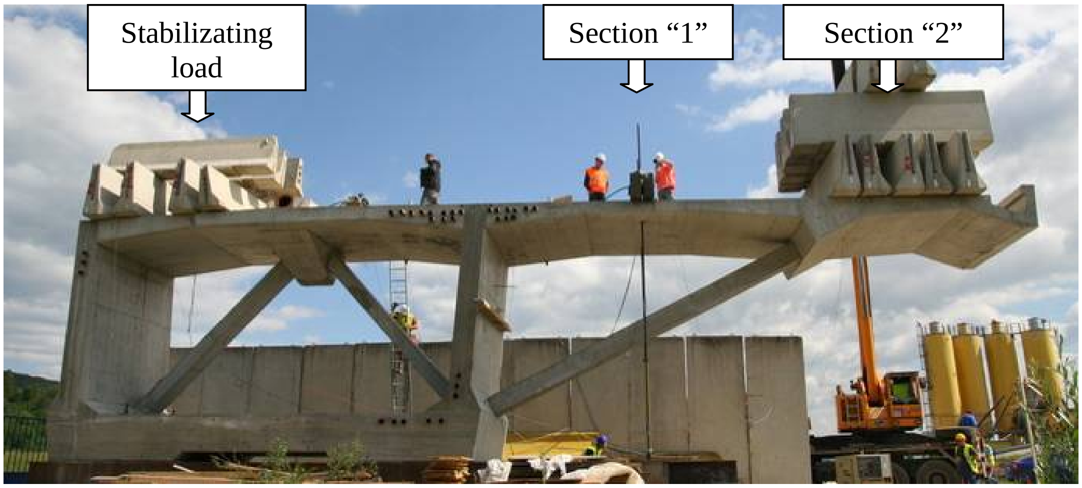


Fig.7. Bridge segment – Loading test of Section “1”

Selected results of loading test of Section “1” are introduced in following part of this paper.

Deflections of the upper slab were measured by surveying methods from two locations. Deformations were also measured electronically using gauges. Deflections of the upper slab during the loading test of Section “1” are shown in Fig.8. Deformations of the cantilever part of the upper slab were favorable with respect to the theoretical model.

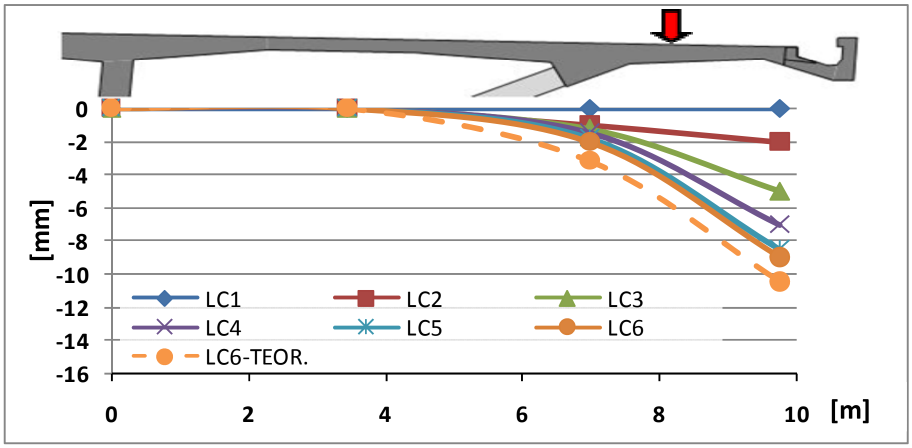


Fig.8. Deflections – Loading test of „Section 1“

Concrete strains were measured using strain gauges. The temperature effect was subtracted from the measured values of the concrete strains, then were measured the values converted to stresses using the measured modulus of elasticity of concrete. The selected results of measurement of stresses in concrete compared with theoretical model are summarized in the following figures:

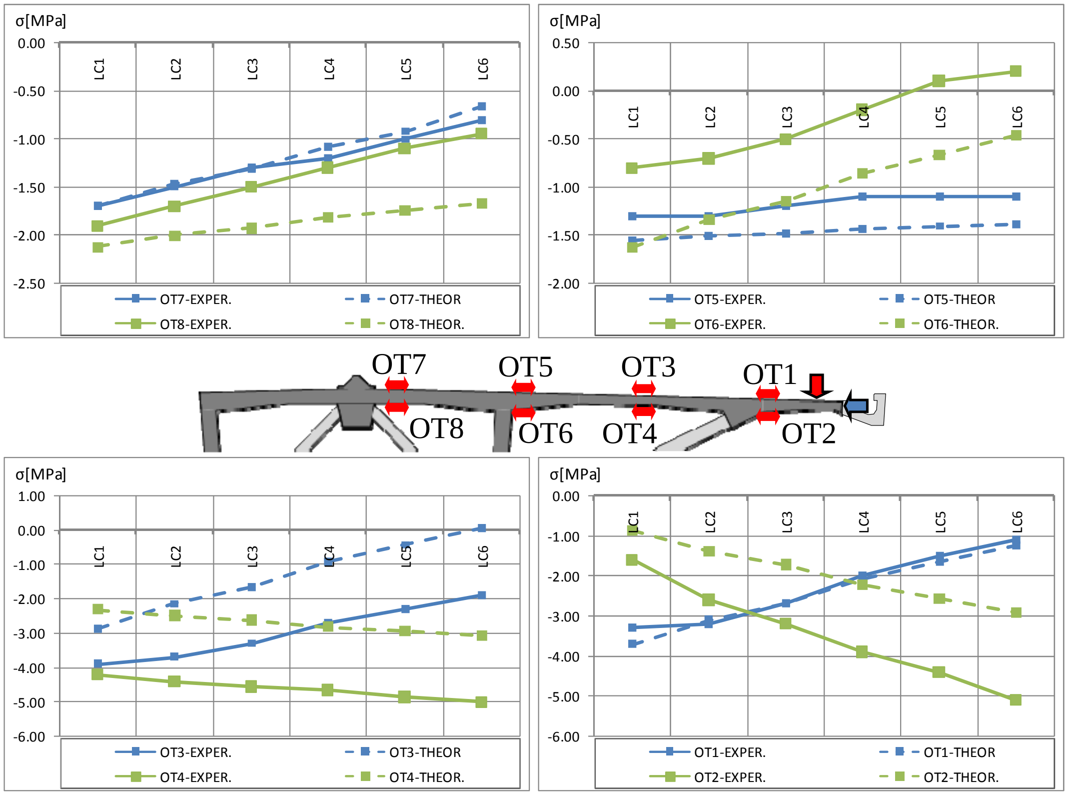


Fig.9. Concrete stresses – Loading test of „Section 1“

The compressive reserve caused by transverse prestressing in the upper fiber of Section “1” (OT1) was -3,2MPa. The value of stress in Section “1” (OT1) reached -1,0MPa with fully loaded cantilever (LC6 – 12 concrete barriers). The decompression of the upper fiber of the pre-stressed concrete slab was not reached.

Stresses in diaphragms during loading test of Section “1” were also measured using strain gauges, results of monitoring are in shown in Fig.10. Again we can see a good match between theoretical and measured values of stresses in concrete.

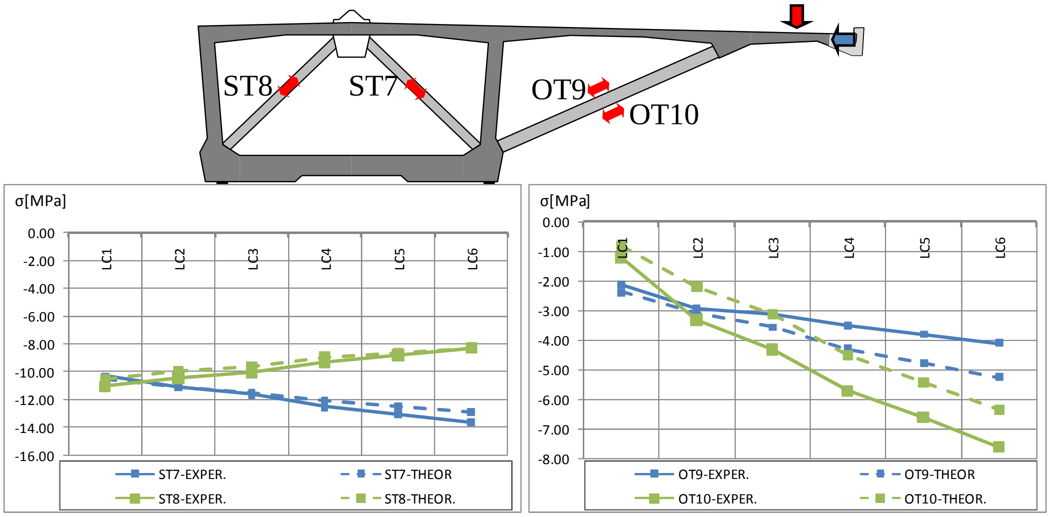


Fig. 10. Concrete stresses – Loading test of „Section 1“

3.3 LOADING TEST – SECTION “2”

The mid span of the upper slab was gradually loaded using hydraulic jack and prestressing rods anchored to steel beams stored under the segment. Maximum force was limited by capacity of hydraulic jacks – 1000kN. Expected load level causing first cracks was 300kN, expected load level causing ultimate limit state of Section “2” was 840kN according to theoretical model.

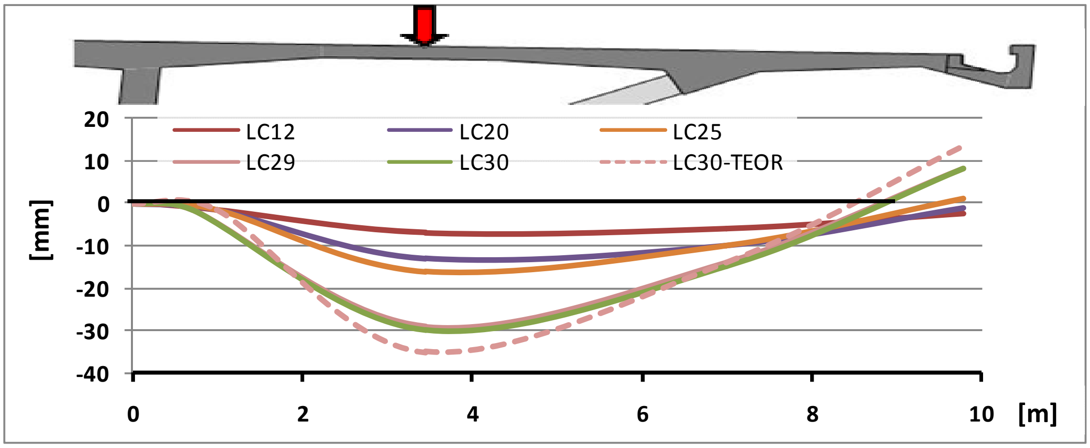


Fig.11. Deflections – Loading test of „Section 1“

Deflections of the upper slab during the selected load cases of the loading test of Section “2” are shown in the Fig.11. Deformations of cantilever part of the upper slab were favorable with respect to the theoretical model.

Selected results of measurement of stresses in concrete compared with theoretical model are summarized in the following figures:

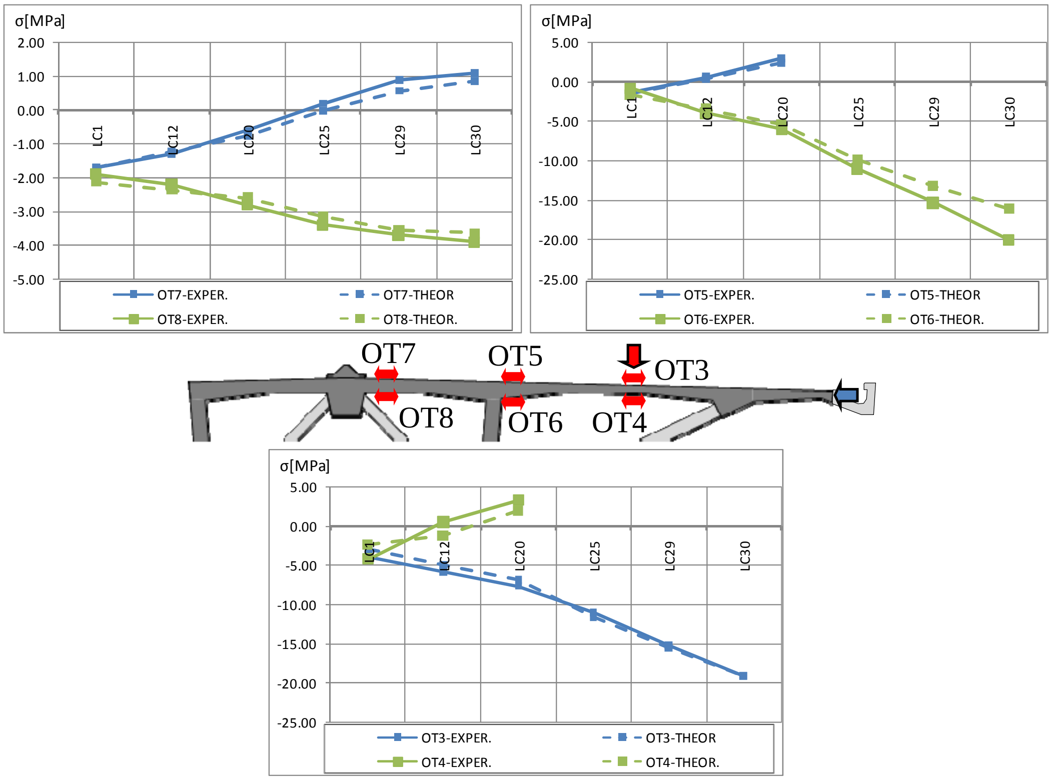


Fig.12. Concrete stresses – Loading test of „Section 2“

Decompression of bottom fiber in Section “2” was reached with load of 302,3kN; expected value according to theoretical model was 190kN. Decompression state was reached with 1,5-times higher load than expected.

The first crack in the bottom fiber of the concrete appears during load case LC25 (600kN), expected value of load causing first crack was 300kN. First crack state was reached with 2-times higher load than expected according to theoretical model.

In theoretical model, ultimate limit state of Section “2” was reached with load at level 840kN. In fact, this state was not reached with load 840kN, loading test continued up to 1000kN (capacity of hydraulic jacks). With the force of 1000kN, cracks were evidently recognized at the top surface (OT5), also at the bottom surface (OT6) of upper slab. Maximum width of cracks was 0,3mm, most of them closed after removing load. Crack pattern and measured crack width is on Fig.14.

Stresses in diaphragms during loading test of Section “2” were also measured using strain gauges; results of monitoring are in following Fig.13. Again we can see good match between theoretical and measured values of stresses in concrete.

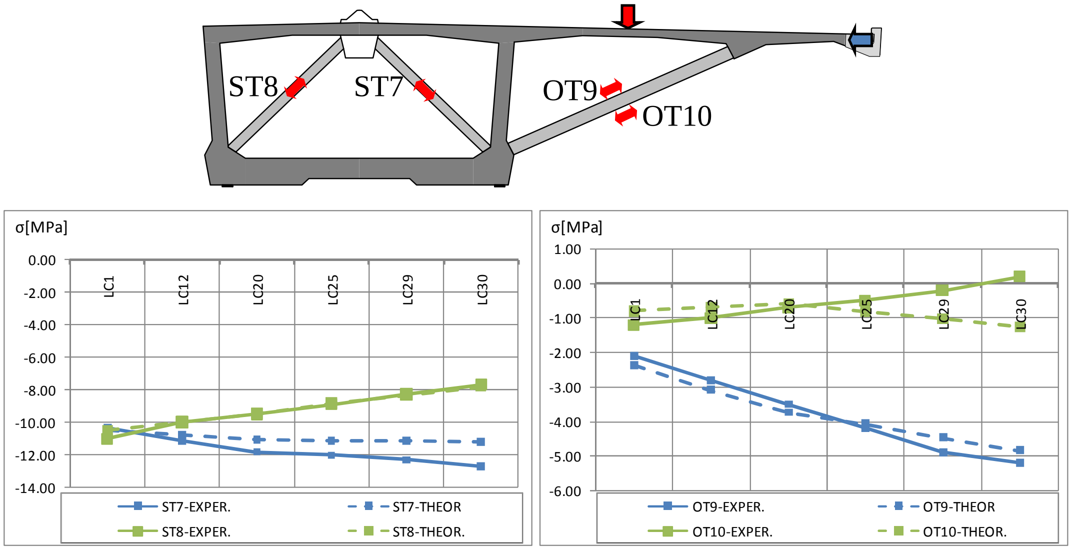


Fig. 13. Concrete stresses – Loading test of „Section 2“

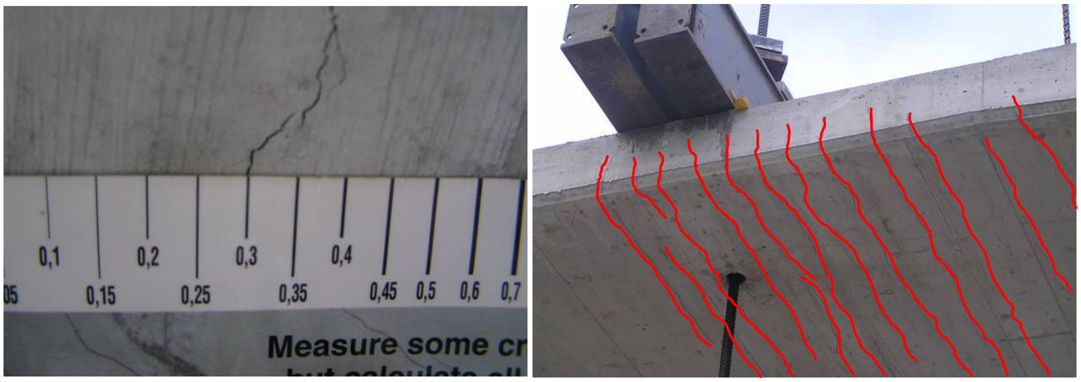


Fig. 14. Cracks at the bottom surface of the upper slab – Loading test of „Section 2“

4. CONCLUSIONS

The construction of the testing segment proved the reliability of fabrication and high quality of works. The monitored parameters of concrete during the construction reached the expected levels. The construction of the testing segment in the same scale as the extra-dosed bridge was a very good and valuable experience for placing reinforcement, casting and compaction of concrete with the designed mixture.

The loading test of both cross-sections has also proved a higher compatibility with the theoretical models, than predicted. Both monitored cross sections proved high bearing capacity under load. Most of the monitored parameters during loading tests were in a good match with the theoretical non-linear FEM model.

REFERENCES

1. Chandoga,M. and co. :“Loading test of Extradosed Bridge Segment”. Design and Final report. Projstar-PK, Ltd, Bratislava, May-Jun 2009
2. Kucharík,J. and co. :“Loading test of Extradosed Bridge Segment – stress/strain measurement in concrete”. Final report. VÚIS- Mosty, Ltd, Bratislava, Jun 2009