# SHORT AND LONG TIME DEFLECTION OF PRE AND POST-TENSIONED BRIDGE BEAMS

Milan Chandoga, Jaroslav Halvonik, and Andrej Pritula

Faculty of Civil Engineering at SUT, Radlinskeho 13, 813 68 Bratislava, Slovakia (professor, professor, PhD student)

## Abstract

Paper deals with monitoring of deformations of two different prestressed precast beams and with analysis of some aspects which influence short and long term deflections of the beams. The first type “T1” is 32,1 m long precast beam prestressed partially by pre-tensioned tendons and later by three post-tensioned tendons. The second type “T2” is pre-tensioned precast beam with length of 29,96m

**Keywords:** cambers, bridge girders, pre-tensioned, post-tensioned, strain, curvature

## 1 Introduction

Slab-on-girder bridges belong to the very frequent option for construction of long elevated highways in Slovakia. In order to reach required vertical elevation of highways short and long-term deformations of prestressed precast beams play important role in bridge designing. It sometimes happens that the theoretical values differ from actual ones and even actual deformations differ from beam to beam. The deflections of prestressed beams are influenced by many factors, some of them are structural but some of them can be governed e.g. by concrete technology or by ambient conditions during hardening of a concrete.

## 2 Precast beams type “T1”

Prestressed precast beams had a length of 32,1 m, depth 1,4 m and were used for construction slab-on-girder bridges where continuity over a intermediate support is ensured by RC diaphragm. Therefore prestressing consisted of 18 pre-tensioned low relaxation strands $\phi$LS15,5/1800 MPa and three post-tensioned polygonal tendons, see fig.1. Transfer of strand was scheduled 18 hours after casting and four strand tendons were prestressed one month later.

### 2.1 Deformations

Mid-span bending moments due to the first prestressing only slightly exceeded moments due to self-weight of the beams. Therefore predicted cambers were only 9 mm with expected growth up to 11 mm (one month later) and after tendon prestressing cambers should increase up to 35 mm. However actual cambers measured on storage yard were ranging from 1,6 mm to 13,7 mm and fully prestressed from 24 to 39 mm. Some beams which were produced later had instead of camber even sag. To find the reason of camber differences an extensive monitoring was carried out. The monitoring consisted of laboratory testing of materials and in-situ measurements which included measurements of cambers, concrete strains, monitoring of prestressing forces and measurements of curvatures on 1 m long segments with the same cross-section as the beam.

**Fig. 1** Beams DSP VP-I04

### *2.2 Monitoring*

Three beams were monitored for cambers at the time of prestressing transfer, after setting on the temporary supports at storage yard and after stressing of post-tensioned tendons. The measured cambers ranged from 7,7 to 10,5 mm just after prestress transfer. Beams started to loos cambers soon and after setting on the temporary supports, one beam had instead of camber small deflection. Development of cambers at mid-span section is in fig.2. All beams continued in loosing of their cambers and deformation had changed in deflection. Prestressing of post-tensioned tendons lifted beams again approximately by 24 mm. Obtained cambers due to post-tensioning very well coincided with predicted values.

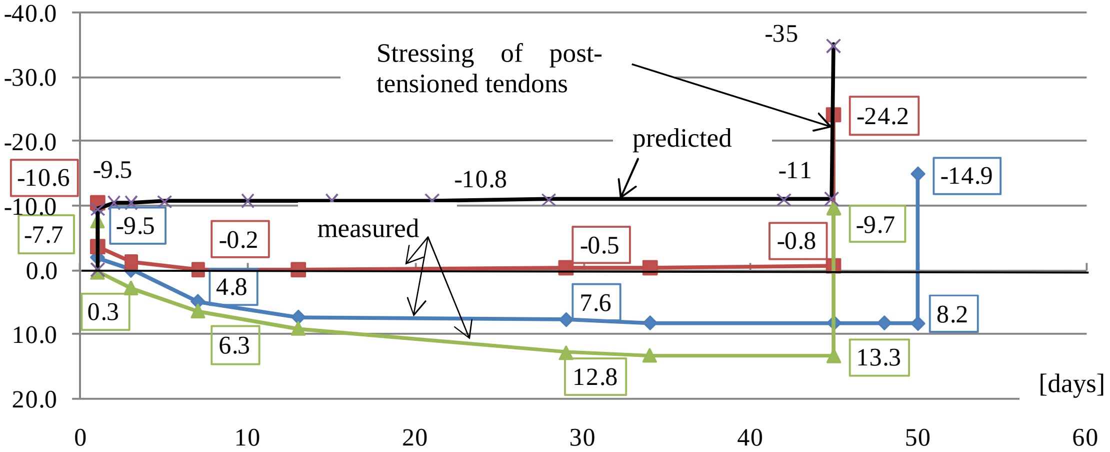


**Fig. 2** DSP VP-I04 Development of deformations of monitored beams at mid-span cross-section

Monitoring of prestressing forces was carried-out by elasto-magnetic sensors Projstar PSS20. Sensors were installed on top and bottom strands. Measurements have confirmed prestressing forces used for prediction of beam deformations. Measured values were higher only by 3 % and average prestress losses due to elastic shortening of concrete in the bottom flange were similar with predicted values 6,7 kN to 6,9 kN per strand. Different situation was with losses in the top flange where measured values were 47% higher than predicted ones.

Excessive elastic losses in the top strands were confirmed by measurements of concrete strains. Strains were measured by strain gages embedded in beams. Each beam was equipped by three gauges, one in the bottom, second 600 mm above bottom surface and the third one 50 mm below the top surface. Measured instant strains (shortly after prestress transfer) in the bottom well coincided with theoretical values, e.g. beam N1 255 vs. 256 microstrains, while top measured strains were much higher than assessed values 306 vs. 212 microstrains. Development of concrete strains in the top flange is in fig.3.

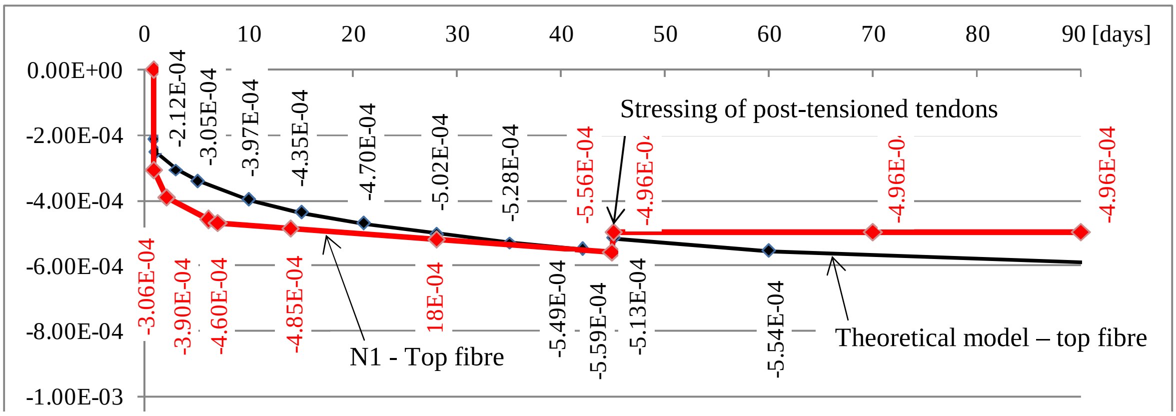


**Fig. 3** Development of concrete strains – top fibre, mid-span section

Developments of concrete strains were also tested on one meter long segments. Three segments were cast together with three beams. Segments had not been prestressed, so only deformation due to the shrinkage and temperature could develop. Each segment was equipped by three strain gauges (top, bottom, mid). Measured strains in the top flange $\varepsilon_{top}$ were higher than in the bottom $\varepsilon_{bottom}$ in each segment after removal of temperature effects. The largest differences had been developed within one day since casting, see fig.4. After one day further growing become very slow. Strain differences indicate development of curvature in segments. Differences were ranging from 100 to 150 microstrains and thus curvature from 7,7.10$^{-5}$ m$^{-1}$ to 11,5.10$^{-5}$ m$^{-1}$. Additional beam deflection obtained by numerical integration of curvature was between 9 and 14 mm. The main reason of the strain differences was uneven shrinkage along the beam depth.

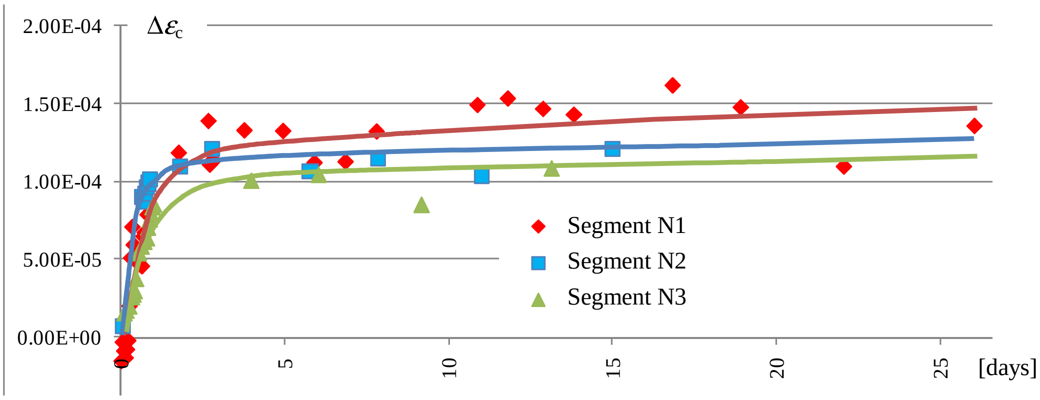


**Fig. 4** Development of strain differences $\Delta\varepsilon_c = \varepsilon_{top} - \varepsilon_{bottom}$

### *2.3 Testing of material properties*

All important properties of concrete were tested. Concrete strength, creep, shrinkage and modulus of elasticity were measured. Beams were casting from high-strength concrete C55/67. Concrete placing was divided into two stages. When formwork was half-full, vibrators attached to bottom part of the formwork started compaction. The same procedure was used when formwork was full. Compaction was very intensive and therefore it was expected some segregation of aggregates. It was observed that the fine aggregates concentrated in the top flange with thin layer of water on a surface and larger aggregates sank to the bottom. Therefore two sets of samples were prepared. The first one were concrete samples taken from the beam top flange shortly after intensive compaction of concrete and the second one samples made from reference concrete taken from the same batch. Obtained results confirmed different properties of concrete, see table 1 and fig.5. It was observed lower modulus of elasticity and density as well as higher shrinkage for concrete taken from the top flange.

**Table 1**
**Comparison of material properties**

| Three samples | Concrete from top flange | | | Reference concrete | | |
|---|---|---|---|---|---|---|
| | Density | $f_{c,cube}$ | $E_{cm}$ | Density | $f_{c,cube}$ | $E_{cm}$ |
| | [kg/m$^3$] | [MPa] | [GPa] | [kg/m$^3$] | [MPa] | [MPa] |
| Mean | 2271,3 | 62,49 | 25,70 | 2360,5 | 64,00 | 32,83 |

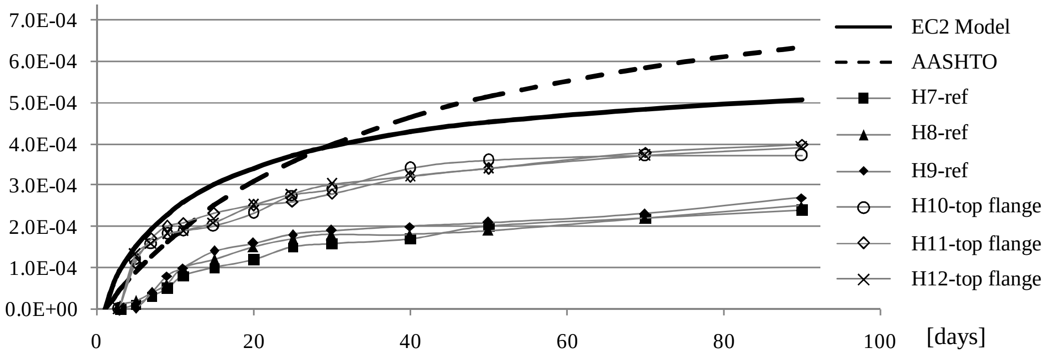
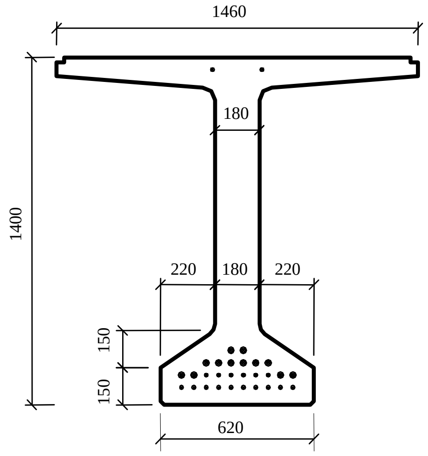


**Fig. 5** Shortening of samples due to free shrinkage

## 3 Precast beam type„T2“



Prestressed precast beams with a length of 29,96 m were used for construction of slab-on-girder bridge which consist of simply supported girders. Beams were prestressed only by pre-tensioned tendons, 28 strands ϕLS15,7/1860 MPa in the bottom flange and 2 strands in the top flange. Beams were cast from concrete C45/55.

As previous ones the “T2” beam was monitored for uneven shrinkage along the beam depth. Test was carried out in order to know how the different arrangement of vibrators for concrete compaction influences deformations due to uneven shrinkage. Vibrators were attached to the form in several levels so the intensity of the compaction was lower than in “T1” beams. One segment for was cast and obtained maximum strain differences between top and bottom flange were aprox. 70 microstrains, see fig.6. The differences were developed within one day and after five days they remained constant. Additional deflection calculated from developed curvature was 5 mm. Thanks to the high amount of prestressing resulting in sufficient cambers, more than 50 mm, uneven shrinkage did not influence much geometry of the beams.

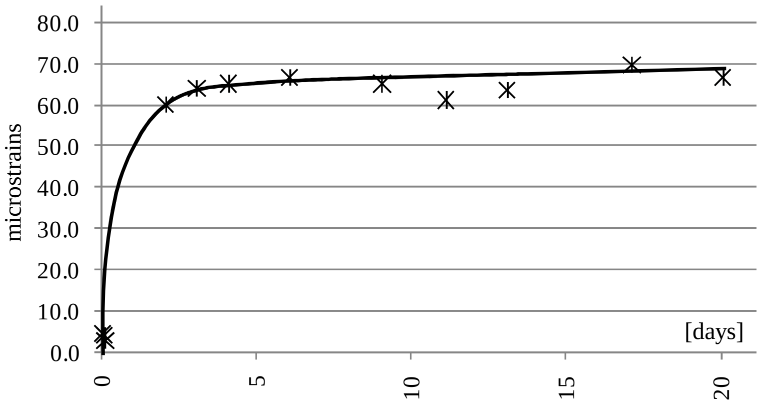


**Fig. 6** Development of strain differences $\Delta\varepsilon_c = \varepsilon_{top} - \varepsilon_{bottom}$ beam “T2”

## 4 Conclusions

More than 200 beams “T1” were checked for camber within the project. An average measured camber 22 mm was obtained using statistical evaluation while predicted value was 35 mm. We assume that main reason of lower cambers were uneven properties of concrete along the beam depth caused by segregation of aggregates during intensive concrete compaction. Differences were also eyes striking due to the low amount of pre-tensioned prestressing. Much better results were obtained for pre-tensioned beams “T2” where different way of concrete compaction brought more homogenous concrete in beams and additional deflection 5 mm was neglected compare to the final value of camber.

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