chapter 2

Abstract

Free cantilever method has become a very common method for the concrete bridges construction. Those structures have been very sensitive to prediction of deformation during their erection and service life, too. Structure monitoring system during construction is very important for getting real information about deformation development with time and other influences that can affect the complex structural behavior. The creep and shrinkage of concrete and temperature influence have been considered as main influences on deformation development with time. In many cases bridge designer does not have enough information about all influences during the structure erection. Underestimating of above mentioned effects often causes that predicted deformations did not corresponded to real recorded values. In ultimate cases, the excessive deformations may lead to serviceability problems, deterioration of aesthetics, and eventually early reconstruction of the bridge.

The structural behavior assessment is based on numerical analysis and long-term monitoring of the prestressed concrete bridge. The study results were compared to in-situ measurements that have been regularly carried out since the very early stages of construction.

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Keywords: Prestressed concrete bridge, Bridge monitoring, Long-term behavior, Differential shrinkage;

1. Introduction

Bridges built by the free cantilever method are mainly used for wide spans in places where stationary support can not be used. Concreting and prestressing of concrete are executed stage by stage by using the formwork traveler.

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Consequently, each individual segment has different age of concrete. The rheological effects like the shrinkage and creep have significant impact on stress redistribution and deformation of structures in the final construction stage in service life but also in various construction stages, respectively. Monitoring of bridges shows real behavior of structure during construction and also in service life. Currently, monitoring is in progress on the highway bridge, which is at present still under construction. Experimental results are compared to computational model realized in Midas Civil Software according to Eurocode 2.

2. Bridge 205 on Highway D1, Dubna Skala – Turany

Prestressed concrete bridge has five spans (74.99 m+119.97 m+74.98 m+52.99 m+36.99 m), with total length 362.08m. The main span (119.97 m) has been built by the free cantilever method and other spans on stationary support. Length of each cantilever is 49.25 m. Cantilever consists of 11 segments with length from 4.4 m to 5.0 m. Longitudinal section of this span is presented in Fig.3. The cross-section is a single box girder. Width of the top flange is 13.65 m and the bottom flange is 7.00 m. The cross-section height is variable, from 2.85 m to 6.50 m. Thickness of the webs varies from 450 mm (center of span) to 800 mm (above support). The top flange has a constant thickness of 300 mm, the bottom flange has variable thickness, from 240 mm (center of span) to 920 mm (above support).

Materials used for cast-in-situ structure are concrete C 40/50 and prestressed tendons with characteristic strength 1860 MPa. Cables consist of 15 or 18 tendons with diameter 15.7 mm.

Bridge has started to be built in autumn 2012 and is currently is under construction. Detailed monitoring has been carried out during the first construction stages. Obtained results are compared to the numerical model performed in the MIDAS CIVIL software.

2.1. Monitoring System

In this highway bridge, D1 Dubna Skala – Turany, the complex monitoring system was applied. It enables obtaining of a complex image of the bridge behavior during the building process. The main monitored variables are stresses in concrete. It is ensured by integrated vibrating wire gauges which are placed in representative cross-section before concreting, see Fig.1. Vibrating wire gauges are placed in all exposed cross-sections. Simultaneously, the temperature is measured in the monitored cross-section. By measuring the temperature, we can observe the development of hydration heat in concrete with rapid development of strength. Results obtained by measurement during the building process enable control of the quality of works, as well as the accuracy of the applied design model, which can be improved in this way. The built-in monitoring system will also be used during the operation life of the bridge. From the measurement results we will be able to identify the behavior of the structure over a certain time, its response to the traffic conditions, climatic changes of an aggressive environment, etc. The system will also allow detecting the failures and deciding about the adequate measures.

and shrinkage of concrete, modulus of elasticity (aging) and tendon relaxation. Temperature difference between the top and bottom fibers of the beam is represented by the temperature gradient.

Such a realistic modeling of structural behavior can be achieved using the software Midas Civil. The finite elements on eccentricity represent the concrete box girder, prestressed tendons, supports, temporary support system and the formwork traveler. All the operations in the construction are respected in the structural analysis according to the real construction schedule.

The structure was analyzed in typical section – "L1", the first segment of cantilever, where strain gauges were installed.

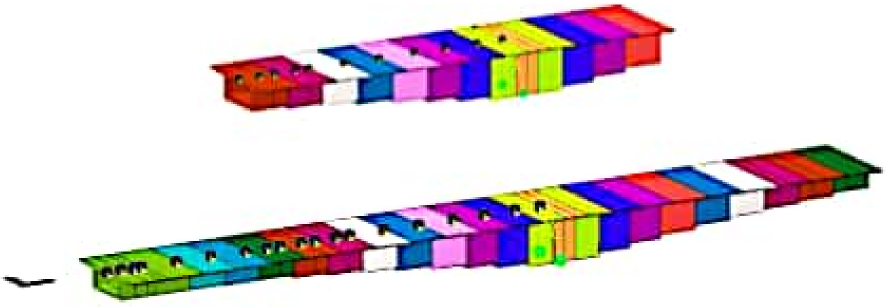

Fig. 4. Numerical phased model

Theoretical numerical model was performed in Midas Civil software according to construction schedule and according to Eurocode 2. From the cross-section the left-hand side was chosen to be analyzed – gauges S1D, S3S, S5D.

Two calculations were performed:

1. Calculation which takes into account differential shrinkage of cross-section.
2. Calculation which takes into account uniform shrinkage of cross-section

Shrinkage strain is underestimated in numerical model due to assumption of uniform cross-section of box girder. Model does not take into account different development of shrinkage in the thinner top flange and thicker bottom flange and the web. The cross-section is divided into three parts, see Fig. 5, and each part has different parameters. Temperature and relative humidity are taken into account also. In the first days after concreting temperature difference between the analyzed fibers was observed, see Fig. 7. The highest temperature is in the web, then in the top flange and the lowest is in the bottom flange - that is due to the fact that the bottom flange of cross-section L1 was concreted earlier than the rest of the section. After three days the temperature in both flanges was the same, but the temperature of the webs still remained significantly higher. For that reason, differential shrinkage strain was calculated in each construction stage separately according to EC2.

The values of the total shrinkage strain follow from:

$$\varepsilon_{cs} = \varepsilon_{cd} + \varepsilon_{ca} \tag{1}$$

where

ε_{cs} is the total shrinkage strain
ε_{cd} is the drying shrinkage strain
ε_{ca} is the autogenous shrinkage strain

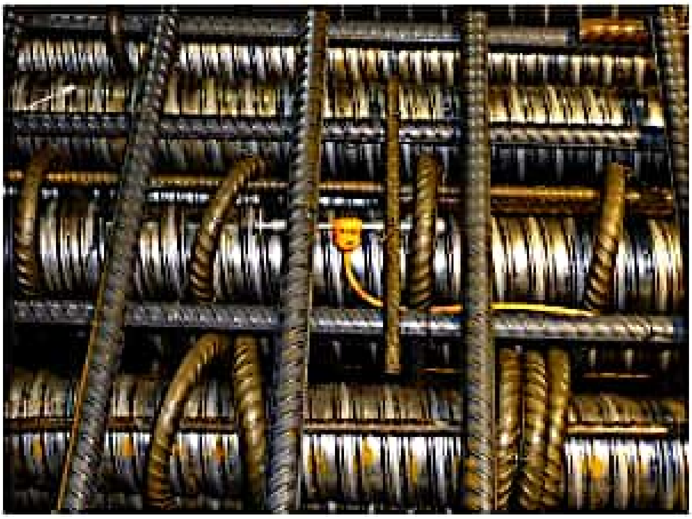

Fig. 1. Strain wire gauge

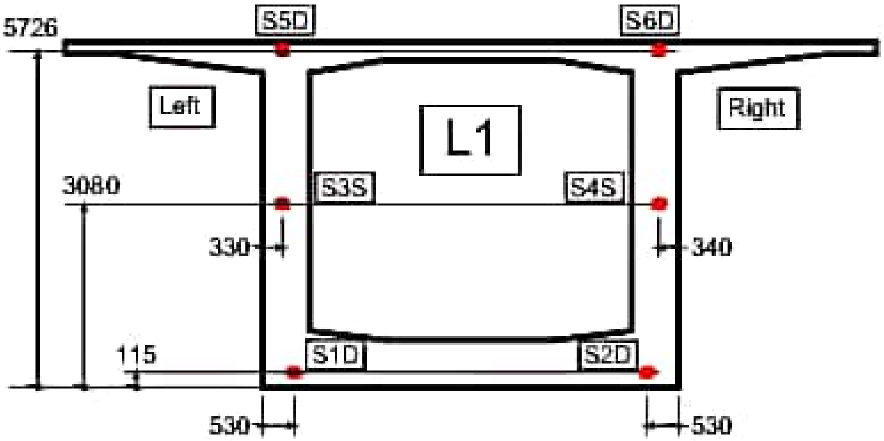

Fig. 2. Position of strain gauges in cross-section"L1".

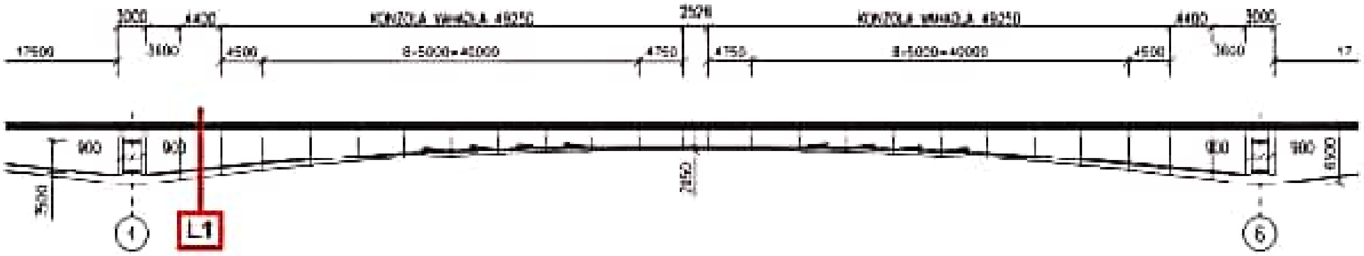

Fig. 3. Location of strain gauges placed in span built by the free cantilever method.

2.2. Structural Model

The detailed finite element model was developed for the analysis. Structural model of bridges, constructed by the cantilever method, must respect the changes of static system and boundary conditions. Concrete of various ages is combined. Therefore, during both construction and throughout the service life, account must be taken of the creep

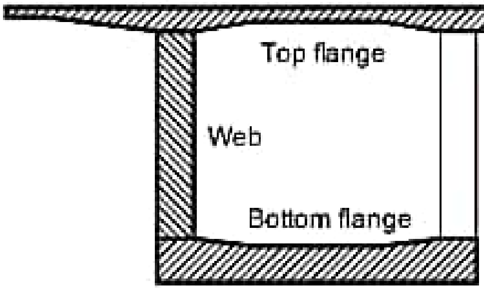

Fig. 5. Differential shrinkage – division of parts of cross-section.

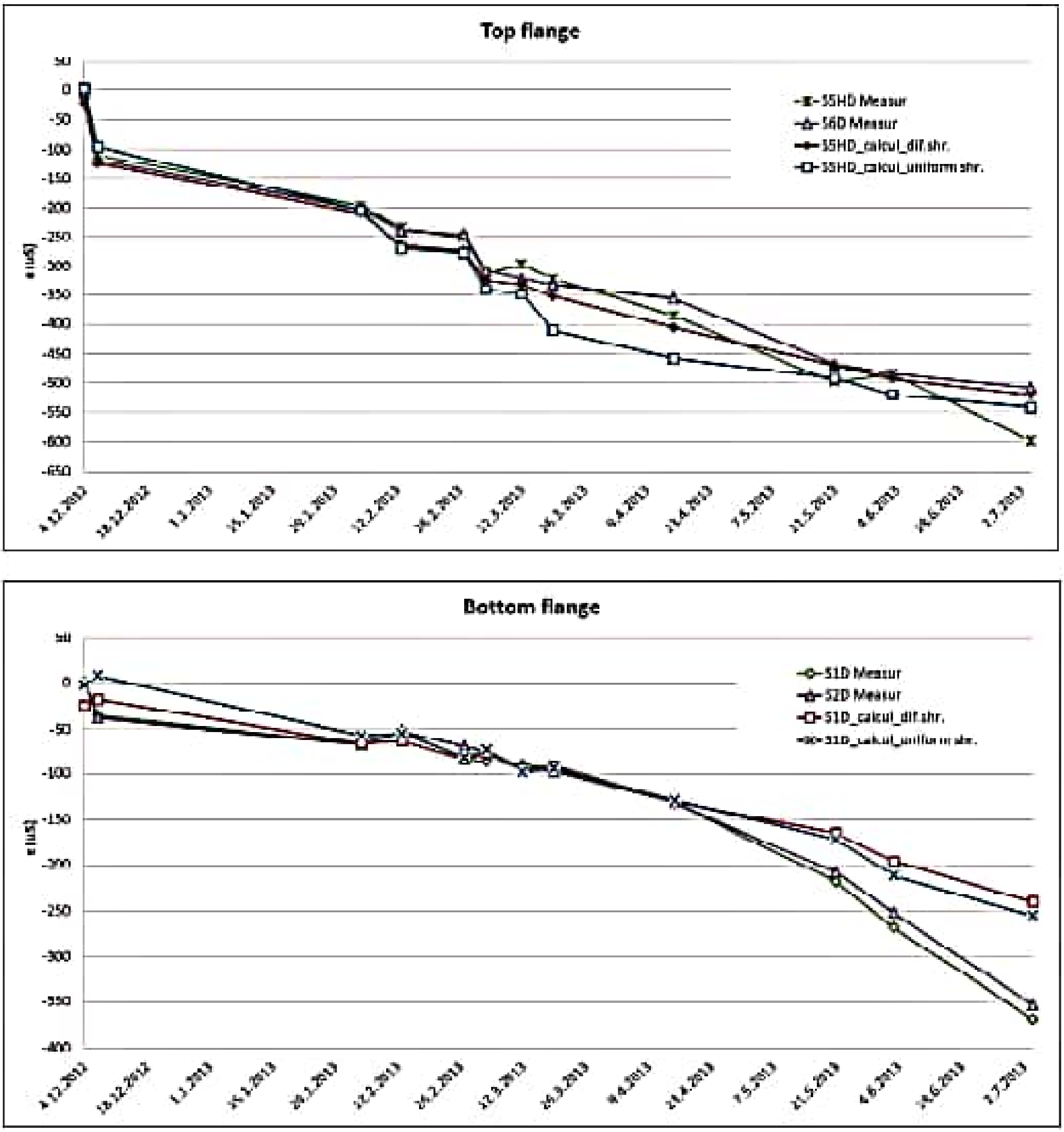

Fig. 6. Micro strains in top and bottom flange.

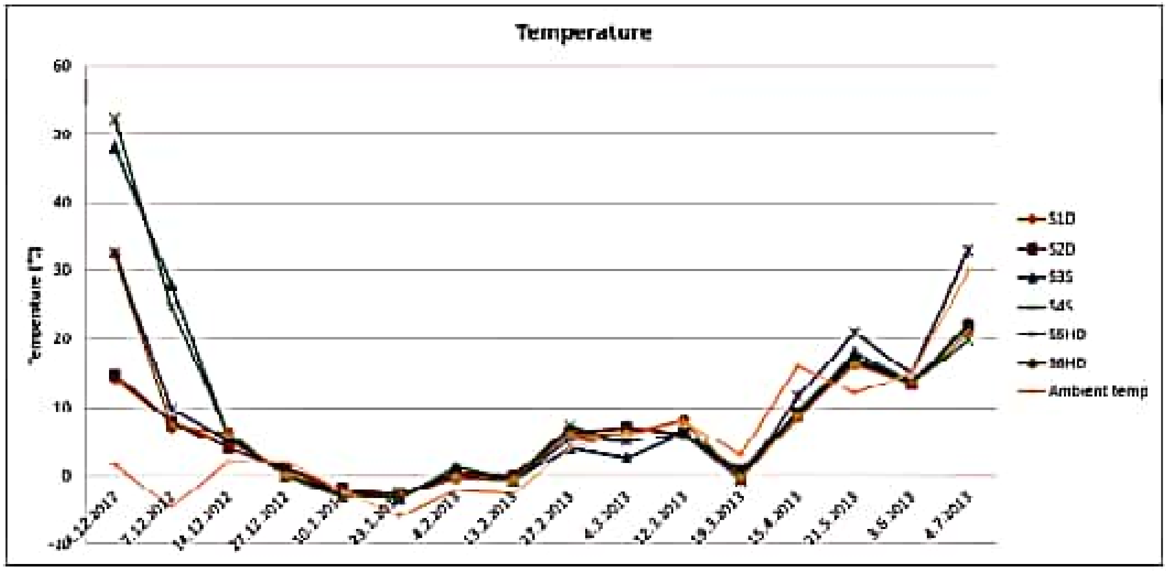

Fig. 7. Temperature of concrete in the bottom flange, webs and the top flange, ambient temperature.

3. Conclusion

In this study experimental and numerical results were compared. The good agreement between theoretical values and in-situ measurements in the top and bottom fibers of the cross-section was observed.

Differential shrinkage has considerable influence on development of stresses in the cross-section. In numerical model, the shrinkage effects on the prestressed concrete box girder bridges is usually analyzed with assumption that the shrinkage strain is uniform over the entire cross-section of the box girder. The underestimation of differential shrinkage can lead to wrong assumptions of development and redistribution of stresses in the structure.

The temperature and relative humidity are the major environmental factors which influence the shrinkage. Due to poor thermal conductivity of concrete, temperature changes from surface to interior points of cross-section, the daily nonlinear temperature distribution arises.

Experiences from monitoring of the prestressed concrete box girder bridges and comparing to theoretical models have enabled authors to understand the problem and formulate presented conclusions.

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