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Experimental Stress Analysis

Long-Time Monitoring of Thermal Actions on a Prestressed Concrete Bridge Structure

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Abstract: This paper describes the results of a long-term experiment, in which the temperature changes in cross-section plane of the prestressed concrete box-girder bridge (the 3rd type of a bridge supporting structure according to Eurocode 1 [2]) are systematically observed in years 2005 - 2009. The obtained results are compared with limit values prescribed in Eurocode 1 [2].

Keywords: Prestressed concrete bridge, Thermal actions, Uniform temperature component, Temperature component varying linearly, Temperature component varying non-linearly

1. Introduction

Absolute majority of important building structures are permanently exposed to the climatic changes of air temperature, changes of insolation of their surfaces during days and year periods. These changes cause time variable courses of temperature in individual components, cross-sections and points of these structures. Changes in temperature cause deformation of a structure. If we restrain these deformations, then additional strains – thermal actions arise in the structure. In some cases, thermal actions significantly affect ultimate and serviceability limit states of the structure.

This paper describes the results of a long-term experiment, in which the temperature changes in cross-section plane of the pre-stressed concrete box-girder bridge are systematically observed in years 2005 - 2009. The obtained results are compared with limit values prescribed in Eurocode 1 [2].

2. Brief description of the performed experiment

The 3rd type of a bridge (according to 6.1.1 from Eurocode 1 [2]) was chosen for the experiment - the prestressed concrete box-girder bridge at the 63rd km of the motorway D1 over Želivka reservoir. The motorway D1 crosses this valley in the form of two bridges of identical construction, one for each traffic direction. Both bridges consist of a pair of boxes (the boxes A to D from the left viewed from

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Prague). The experiment is performed only on the outside northeast box (on the box A) of the left bridge used for the traffic from Brno to Prague.

The supporting structure of this bridge consists of a 3-span frame (54 m, 75 m and 54 m). It was assembled of two rows of box type segments of a constant height 4.20 m and width of the upper slab 6.0 m (Fig. 1) which were mutually connected. The total width of the supporting structure is thus 13.0 m.

A measuring line, which is installed on the bridge, consists of the measuring device MS2+ from the firm Comet System and of the 16 temperature sensors of type N1ATG7/0. All the sensors are placed in a single cross-section of the box A in the middle of the central span (Fig. 1). The bridge temperature changes are monitored permanently, the temperature in the observed points of the box cross-section is scanned every 15 minutes by trouble free activity of the measuring device.

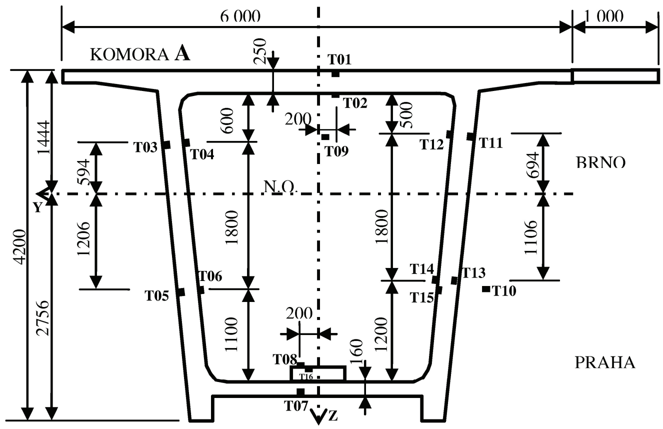

Fig. 1. Positions of the temperature sensors in the observed cross-section of the box A.

3. The main results of the performed experiment

In accordance with Eurocode 1 [2] the measured thermal field in the observed bridge cross-section was decomposed in four basic temperature components:

- a uniform temperature component ΔT_u,
- a temperature component varying linearly in vertical direction ΔT_{My},
- a temperature component varying linearly in horizontal direction ΔT_{Mz},
- a temperature component varying non-linearly ΔT_E.

The evaluation procedure with an approximation plane smoothing through measured temperature data, which is in detail described in [1], was used.

Evaluated year's extreme values of basic components of thermal action and their comparison with corresponding values prescribed in the Eurocode 1 [2] are listed in Tab. 1, were $\Delta T_{My,heat}$ corresponds to the stage of the bridge, when the upper surface is warmer than the bottom surface and by $\Delta T_{My,cool}$ the upper surface is colder than the bottom surface, $\Delta T_{Mz,min}$ corresponds to the stage of the bridge, when the surface of the inner sidewall is warmer than the external sidewall surface and by $\Delta T_{Mz,max}$ the surface of external sidewall is colder than the inner sidewall surface. The course of the evaluated uniform temperature component ΔT_u is presented in Fig. 2 (year 2007) and in Fig. 3 (year 2009).

Table 1. The evaluated extreme values of the basic components of temperature loads ΔT_u, ΔT_{My} and ΔT_{Mz} of years 2005 to 2009

	ΔT_u		ΔT_{My}		ΔT_{Mz}	
	$T_{e,min}$ [°C]	$T_{e,max}$ [°C]	$\Delta T_{M,\ heat}$ [°C]	$\Delta T_{M,\ cool}$ [°C]	Min. [°C]	Max. [°C]
Experiment 2005	-	29,1	-5,2	1,9	-	-
Experiment 2006	-10,3	29,2	-5,0	**3,3**	**-2,2**	2,2
Experiment 2007	-3,7	**29,2**	**-5,2**	2,9	-1,7	**2,6**
Experiment 2008	-3,5	26,7	-4,5	2,1	-1,8	2,3
Experiment 2009	**-10,6**	26,4	-4,5	2,9	-1,4	2,1
Code - Method 1	-24	39,5	-6	5	-5	5

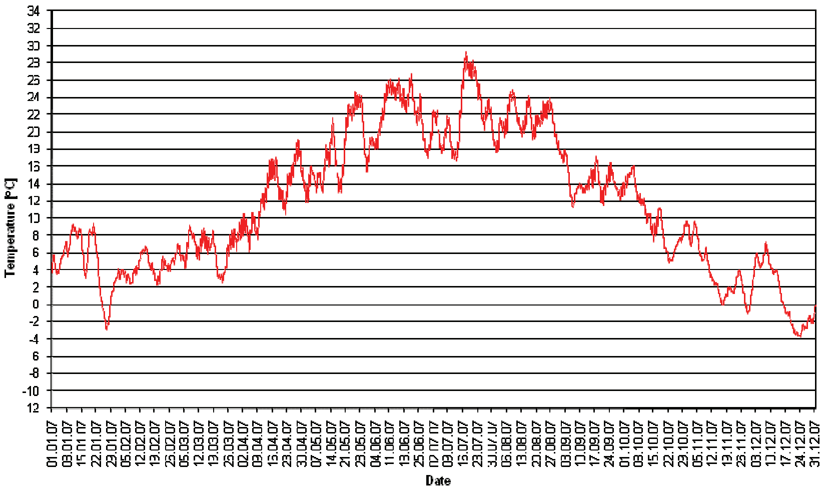

Fig. 2. Course of the evaluated uniform component of temperature ΔT_u on the bridge during the year 2007.

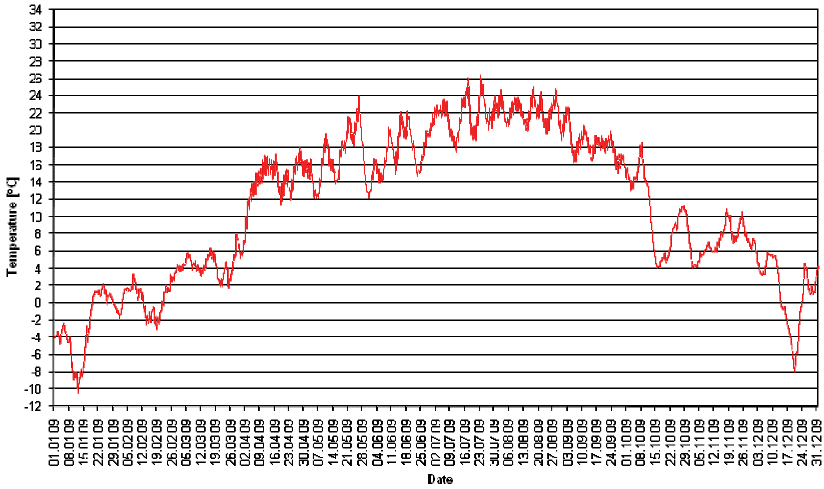

Fig. 3. Course of the evaluated uniform component of temperature ΔT_u on the bridge during the year 2009.

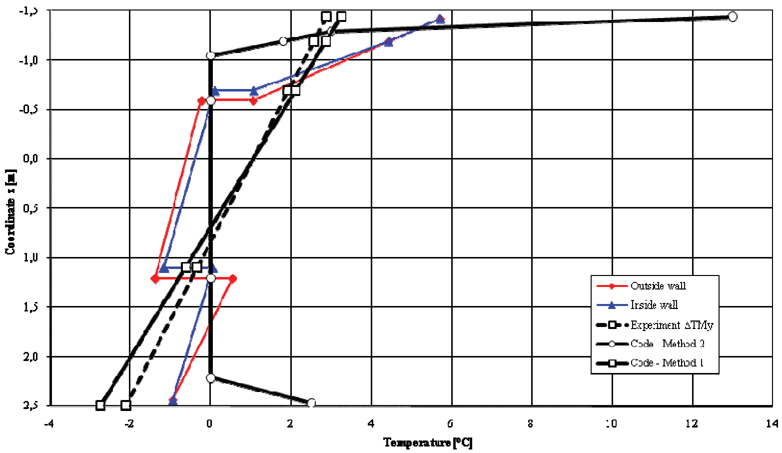

Fig. 4. The comparison of the measured values of temperature in the cross-section in the time instant of the evaluated extreme differential heating $\Delta T_{My,\ heat.}$ = -5,0 °C with the Method 1 a Method 2 prescribed in the Eurocode 1 – 19th July 2006 1:00.

Two methods for application of the differential temperature component in vertical direction for bridges are described in Eurocode 1 [2], Method 1 presumes the temperature component varying linearly ΔT_{My} , Method 2 prescribes the temperature component varying non-linearly. In the national application document from standard [2] in the article 2.8 there is prescribed that the method 2 should be applied in Czech Republic. The simplified method 1 can be applied for the bridges of the 1st and the 3rd types in specific cases of the concrete project.

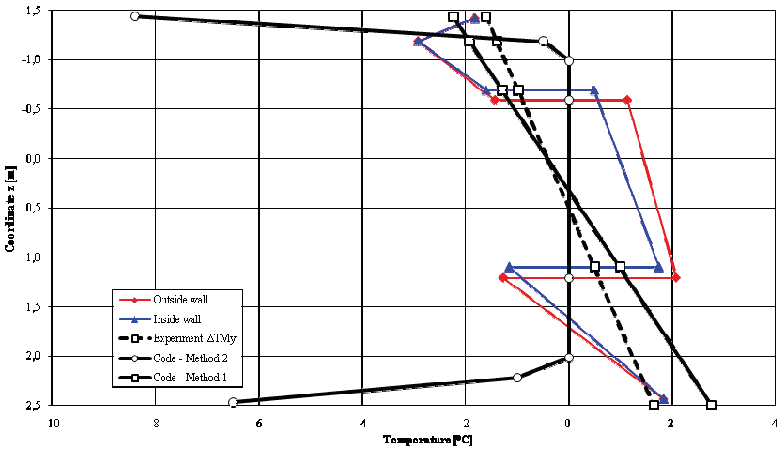

Fig. 5. The comparison of the measured values of temperature in the cross-section in the time instant of the evaluated extreme differential cooling $\Delta T_{My,\ cool.}$ = +3,3 °C with the Method 1 a Method 2 prescribed in the Eurocode 1 – 7th February 2006 15:30.

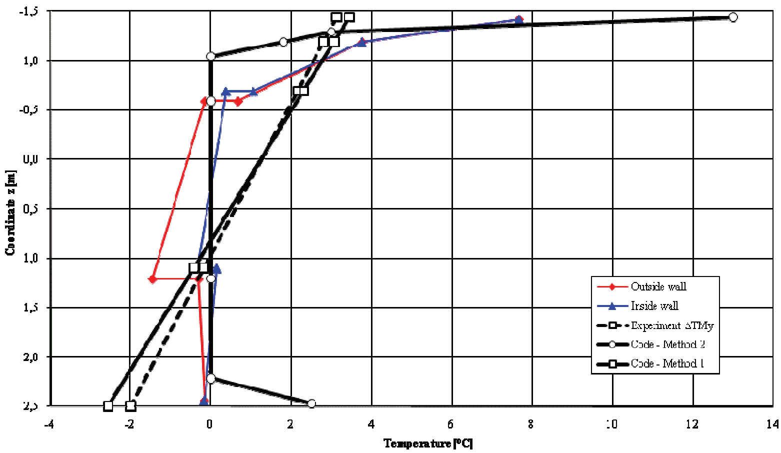

Fig. 6. The comparison of the measured values of temperature in the cross-section in the time instant of the evaluated extreme differential heating $\Delta T_{My,\ heat.}$ = -5,2 °C with the Method 1 a Method 2 prescribed in the Eurocode 1 – 1st May 2007 20:30.

In the Figs. 4 to 11, there is shown the comparison of the evaluated extreme values ΔT_{My} of each year with the vertical linear differential thermal action component (Method 1), with the vertical nonlinear differential thermal action component (Method 2), that are prescribed by Eurocode 1 [2] for the investigated bridge and with the measured values of temperature in the bridge cross-section in the time instant of the extreme differential heating and cooling.

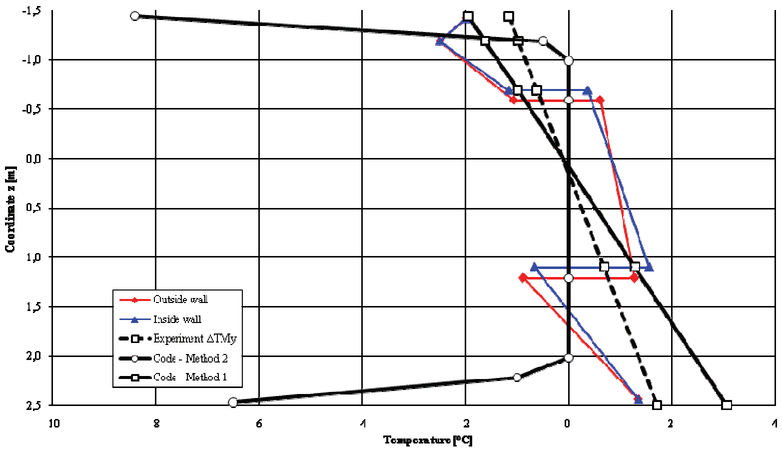

Fig. 7. The comparison of the measured values of temperature in the cross-section in the time instant of the evaluated extreme differential cooling $\Delta T_{My,\ cool.}$ = +2,9 °C with the Method 1 a Method 2 prescribed in the Eurocode 1 – 1st January 2007 12:45.

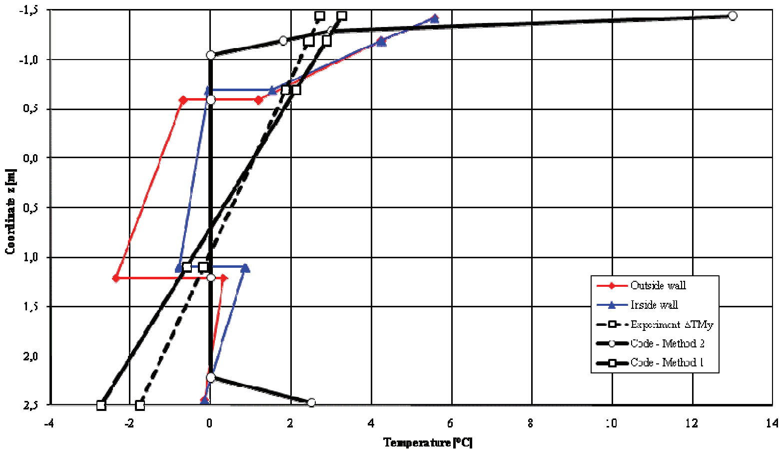

Fig. 8. The comparison of the measured values of temperature in the cross-section in the time instant of the evaluated extreme differential heating $\Delta T_{My,\ heat.}$ = -4,5 °C with the Method 1 a Method 2 prescribed in the Eurocode 1 – 13th September 2008 20:30.

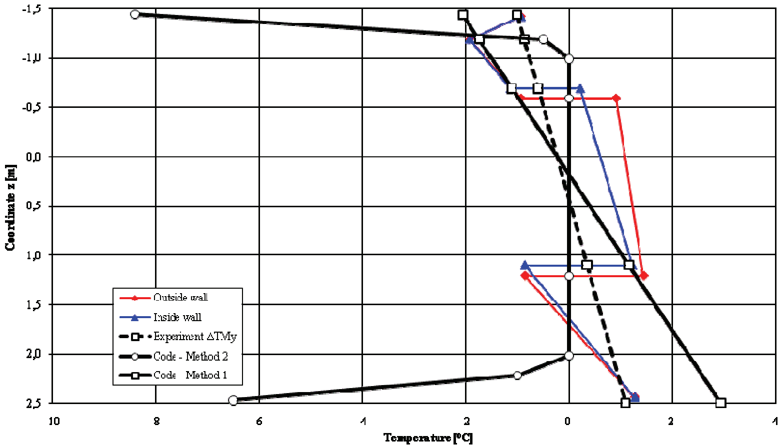

Fig. 9. The comparison of the measured values of temperature in the cross-section in the time instant of the evaluated extreme differential cooling $\Delta T_{My,\ cool.}$ = +2,1 °C with the Method 1 a Method 2 prescribed in the Eurocode 1 – 1st December 2008 15:00.

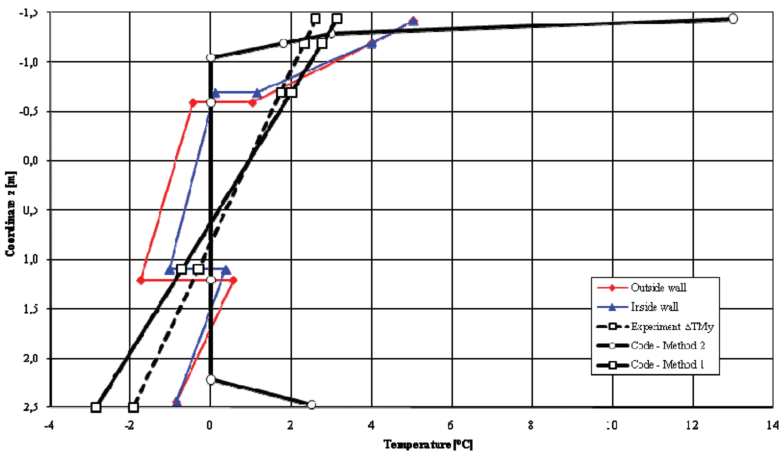

Fig. 10. The comparison of the measured values of temperature in the cross-section in the time instant of the evaluated extreme differential heating $\Delta T_{My,\ heat.}$ = -4,5 °C with the Method 1 a Method 2 prescribed in the Eurocode 1 – 24th May 2009 0:00.

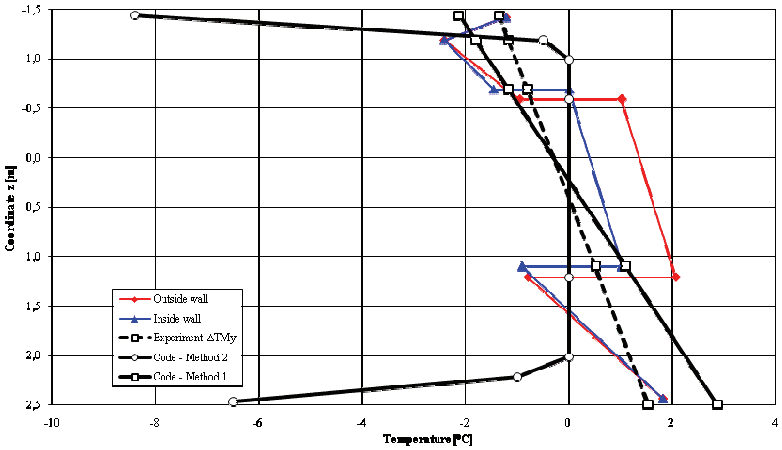

Fig. 11. The comparison of the measured values of temperature in the cross-section in the time instant of the evaluated extreme differential cooling $\Delta T_{My,\ cool.}$ = +2,9 °C with the Method 1 a Method 2 prescribed in the Eurocode 1 – 22nd December 2009 15:15.

4. Conclusions

The main results of a long-term experiment, in which the temperature changes in cross-section plane of the pre-stressed concrete box-girder bridge were systematically observed in years 2005 – 2009, were presented in the paper. From the results in Tab. 1, it is clear that the values prescribed in the Eurocode 1 [2] were not exceeded in the years 2005 - 2009. From the Figs. 4 to 11, it is obvious that the differences prescribed in the Eurocode 1 for the Method 2 do not correspond with the measured real values and that the curve for the Method 1 is more apposite to the measured course of the temperature on the observed bridge, in contrary to the regulation of the NAD, which prescribes usage of the Method 2.

Acknowledgements

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References

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