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THE SPATIAL COMPONENTS EVALUATION PROCEDURE OF THERMAL ACTION ON THE PRE-STRESSED CONCRETE BRIDGE

POSTUP VYHODNOCENÍ PROSTOROVÝCH SLOŽEK ZATÍŽENÍ TEPLOTOU NA MOSTU Z PŘEDPJATÉHO BETONU

Abstract

This paper describes the basic spatial components evaluation procedure of thermal actions from the results of a long-term experiment, in which the temperature changes in cross-section plane of the prestressed concrete box-girder bridge are systematically observed. The regression plane was smoothed through the measured temperature data in each observed point of the bridge cross-section using the regression analysis at every time instant of the performed measurement. The results of the evaluation are compared with limit values prescribed in standard [1].

Abstrakt

V tomto článku je popsán postup vyhodnocení základních prostorových složek zatížení teplotou z výsledků dlouhodobého experimentu, při kterém byly systematicky sledovány změny teploty v rovině průřezu komorového mostu z předpjatého betonu. Skrze naměřené hodnoty teploty v jednotlivých bodech průřezu byla pomocí regresní analýzy pro každý časový okamžik provedeného měření proložena rovina. Získané výsledky jsou porovnány s hodnotami předepsanými v normě [1].

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. Temperature change causes deformation of a structure. If we restrain these deformations, then an additional strain – temperature load arises in the structure. In accordance with Czech standard ČSN EN 1991-1-5 we can divide the temperature course in four basic components of temperature in a certain cross-section:

a) uniform component of temperature ΔT_u ,
b) linearly changing difference component of temperature in the vertical direction ΔT_{My} ,
c) linearly changing difference component of temperature in the horizontal direction ΔT_{Mz} ,
d) non linear difference component of temperature ΔT_E .

This article describes the procedure used for evaluation of basic components of temperature load from the data collected during a long-term experiment – observation of temperature changes - in the cross-section plane of the prestressed concrete box-girder bridge. The regression plane was smoothed through the measured temperature data in each observed point of the bridge cross-section

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using the regression analysis at every time instant of the performed measurement. The results of the evaluation are compared with limit values prescribed in standard [1].

2 BRIEF DESCRIPTION OF THE PERFORMED EXPERIMENT

For the experiment, the box-girder bridge at the 63th km of motorway D1 over Želivka reservoir was chosen. 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 Prague). The experiment is preformed only on the outside box (on the box A) of the left bridge used for the traffic from Brno to Prague.

The supporting structure consists of a 3-span frame (54 m, 75 m a 54 m) made from prestressed concrete. The supporting structure of this bridge 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 o supporting structure is thus 13.0 m.

A measuring line, which permanently monitors temperature changes, is installed on the bridge. The measuring line 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 (see Fig. 1).

For the purpose of calculating basic components of temperature, the sensors are placed in pairs in slabs and sidewalls. For the sensors No. 1, 3, 5, 7, 11 and 13 openings were drilled from the inside of the supporting structure to place the sensors approximately 2 – 3 cm from an external surface of the supporting structure. The sensors No. 2, 4, 6, 8, 12 and 14 are attached at the inner surface of the box. The air temperature is measured in the box and outside of the structure. The sensor No. 9 is suspended freely inside of the cell and the sensor No. 10 monitors the outside temperature of the air in the space between the boxes A and B. The temperature of the bridge in the observed points of the box cross-section is scanned every 15 minutes by trouble free activity of the measuring device.

3 THE EVALUATION OF BASIC COMPONENTS OF TEMPERATURE LOAD

By evaluation of basic components of temperature load (ΔT_u , ΔT_{My} , ΔT_{Mz}) of the monitored cross-section of the prestressed concrete bridge, the measured values were processed using the regression analysis. An approximation plane described by equation

$$T(y_i, z_i, t) = \Delta T_u(t) + K_y(t)\,y + K_z(t)\,z \qquad (1)$$

was interlaid through the measured values of temperature $T(y_i,z_i,t)$ in individual points of the cross-section at each time instant t of the measurement where y_i and z_i are the horizontal and vertical coordinates of the point in which the temperature was measured, $K_y(t)$ is the slope of a straight plane approximation in horizontal direction and $K_z(t)$ is the slope of a straight plane approximation in vertical direction corresponding to the time of measurement t. For the estimate of the parameters of the regression plane, the Least Square Method was used, which in this case leads to solving a system of three equations of three unknowns $\Delta T_u(t)$, $K_y(t)$ and $K_z(t)$

$$\begin{aligned}
N \quad \Delta T_u(t) + \sum_{i=1}^{N} y_i \quad K_y(t) + \sum_{i=1}^{N} z_i \quad K_z(t) &= \sum_{i=1}^{N} T_i \\
\sum_{i=1}^{N} y_i \quad \Delta T_u(t) + \sum_{i=1}^{N} y_i^2 \quad K_y(t) + \sum_{i=1}^{N} y_i\, z_i \quad K_z(t) &= \sum_{i=1}^{N} y_i\, T_i \\
\sum_{i=1}^{N} z_i \quad \Delta T_u(t) + \sum_{i=1}^{N} y_i\, z_i \quad K_y(t) + \sum_{i=1}^{N} z_i^2 \quad K_z(t) &= \sum_{i=1}^{N} z_i\, T_i
\end{aligned} \qquad (2)$$

where N is the number of points where the measurement was pursued and through which the regression plane leads and $T_i(t)$ are temperatures measured in these points in moments t. The using

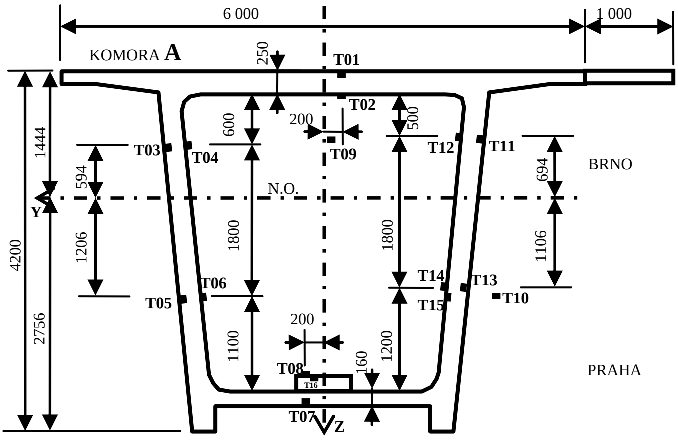

Fig. 1 Positions of the temperature sensors in the observed cross-section of the box A

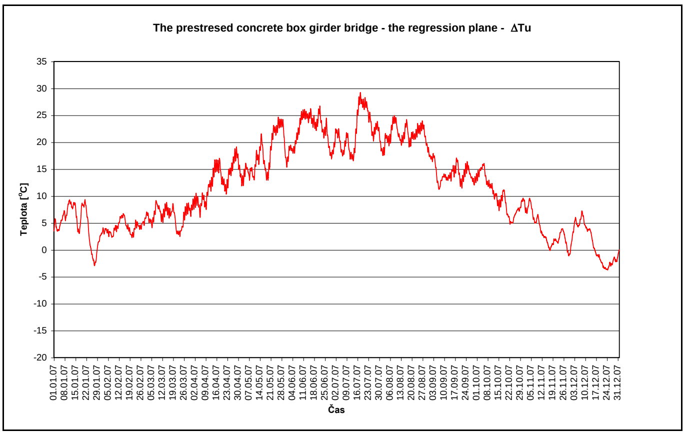

Fig. 2 Course of a uniform component of temperature ΔT_u on the bridge during the year 2007

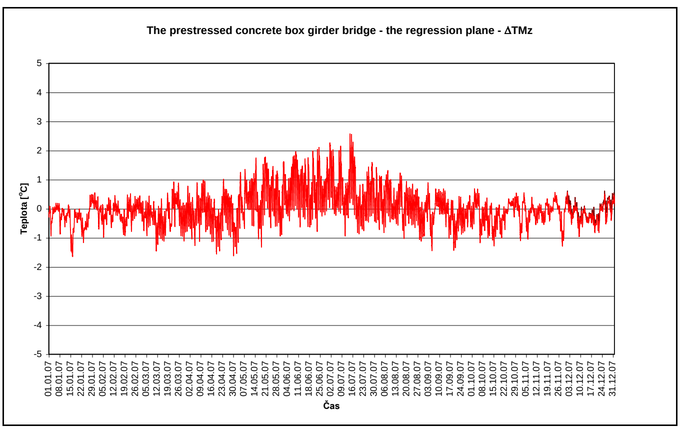

Fig. 3 Course of a linearly changing difference component of temperature in the horizontal direction ΔT_{Mz} on the bridge during the year 2007

Tab. 1 The evaluated extreme values of the basic components of temperature loads of years 2006 and 2007

	ΔT_u		ΔT_{My}		ΔT_{Mz}	
	$T_{e,min}$ [°C]	$T_{e,max}$ [°C]	$\Delta T_{My,\ heat}$ [°C]	$\Delta T_{My,\ cool}$ [°C]	$\Delta T_{Mz,\ min}$ [°C]	$\Delta T_{Mz,\ max}$ [°C]
Experiment 2006	-10.3	29.3	-5.1	3.3	-2.2	2.2
Experiment 2007	-3.7	29.2	-5.1	2.9	-1.7	2.6
Standard [1]	-24	40	-10	5	-5	5

of the Least square method means that approximation plane parameters were determined based on condition that sum of quadrates of nonlinear difference components of temperature for all observed points of the cross-section is minimal. The nonlinear difference component of temperature $\Delta T_E(y_i, z_i, t)$ was determined in the individual points of the box based on relation

$$\Delta T_E(y_i, z_i, t) = T(y_i, z_i, t) - (\Delta T_u(t) + K_y(t)\, y + K_z(t)\, z) \tag{3}$$

4 CONCLUSION

The courses of the uniform component of temperature ΔT_u and the linearly changing difference component of temperature in the horizontal direction ΔT_{Mz} of the prestressed concrete box-girder bridge evaluated by the method described in previous chapter during the year 2007 are presented in Fig. 2 and 3.

Evaluated extreme values of basic components of thermal action and their comparison with corresponding values prescribed in the standard [1] are listed in Tab. 1, were $T_{e,max}$, $T_{e,min}$ are the maximal and the minimal uniform components of temperature of the bridge, $\Delta T_{My,heat}$ 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 evaluation procedure with the vertical regression line smoothing through temperature data measured on the observed bridge is described in paper [2]. The ΔT_{Mz} is impossible to evaluate by this technique. But when the evaluated extreme values of ΔT_u and ΔT_{My} are compared with the values determined using the regression plane smoothing (see Tab. 1), the differences are small and not exceed the limit 0.1 °C.

From the listed results, it is clear that the values prescribed in the standard ČSN EN 1991-1-5 [1] were not exceeded in the years 2006 and 2007.

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