10.2478/tvsb-2013-0005

Transactions of the VŠB – Technical University of Ostrava

No. 2, 2013, Vol. XIII, Civil Engineering Series

paper #5

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EXPERIMENTAL MEASUREMENT IN THE FOUNDATION SLAB OF NATIONAL SUPERCOMPUTER CENTRE

Abstract

In the paper is described the method of experimental temperature and strain measurement of reinforced concrete foundation slab during building-up of National Supercomputing Centre in Ostrava. This is a continuous measurement during the construction of this special structure.

Keywords

Experimental measurement, temperature, stress, concrete foundation, sliding joints.

1 INTRODUCTION

At the beginning of 2013 the construction of the Centre of Excellence – National Supercomputing Centre in the campus of VSB - Technical University of Ostrava was initiated under the "OP R&DI project from IT4 Innovations". With regard to the complexity of construction, complex foundation conditions and concreting in winter conditions, it was decided to verify the temperature behaviour and stress state of the foundation slab during the construction.

2 STRUCTURAL DESIGN

The load-bearing part of the supercomputer is a spatial reinforced concrete structure consisting of a base plate with ribs, bearing walls, columns and slabs of individual floors see Fig.1. The length of the building is 63 m, the width is 33.5 m. The base structure consists of a foundation slab with a thickness of 400 mm, which is in the longitudinal and transverse direction reinforced by the stiffening ribs. Positioning of the ribs upwards enables to creation of the so-called sliding joint [6] at the bottom surface of the foundation slab in order to eliminate the stress due to volume changes in the concrete, see [3, 4] and [5]. For the quality control of the construction works both temperature and stress changes in the foundation slab are continually measured.

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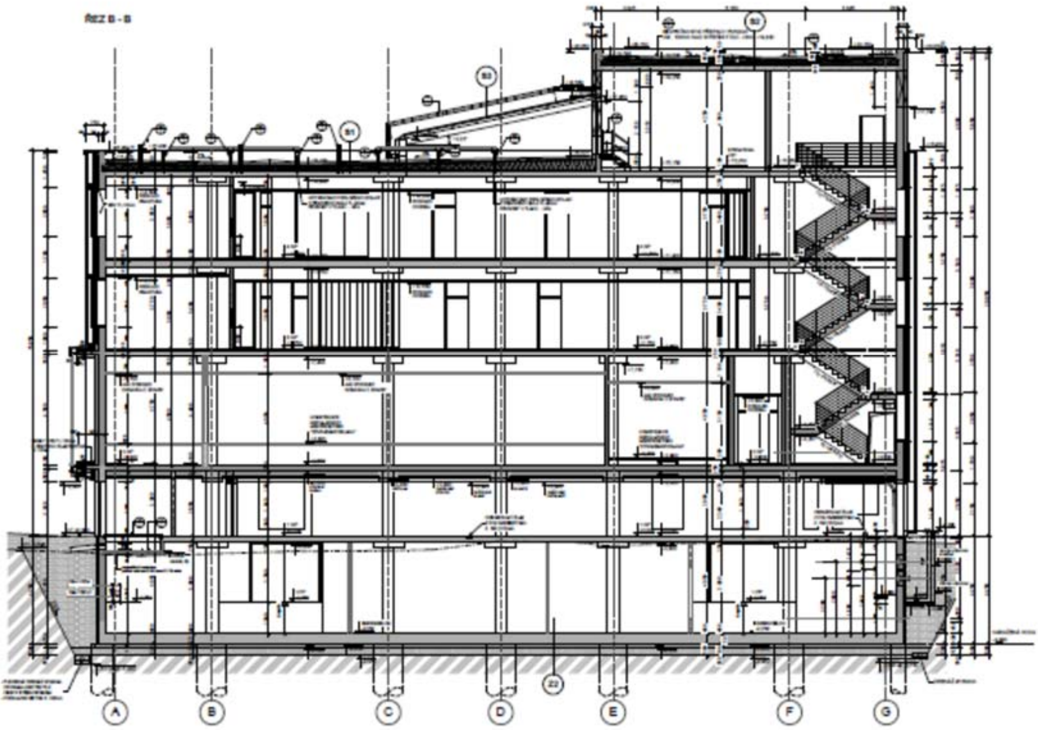


Fig. 1: Schematic cross-section of the object

3 MEASUREMENT OF TEMPERATURE AND STRESS CHANGES

The goal of the measurements was to record the change of the hydration heat during concreting of the foundation slab with a thickness of 400 mm, and a change of stress in the concrete and the reinforcement during hardening and construction of related structures. Measurement procedures and equipment were selected based on these requirements. To obtain the current temperature at different heights string strain gauges were selected and optical fibres were used for the control measurement. To monitor stress changes in the selected height levels of the concrete slab, the string gauges were used. To determine stress change in the reinforcement near the top and bottom rim, foil strain gauges were used [1, 9].

3.1 Foil strain gauges

Foil strain gauges are the passive electrical sensors used for indirect measurement of mechanical stress. This method uses the physical properties of the change of an electric resistance of a thin conductor during its stretching or shortening. The first strain gauge measurements were carried out in 1938 in order to explore the parts of a locomotive. Thin conductors were used for scanning. Currently, the most commonly used foil strain gauges, which should be used for the given experimental measurement. Each sensor includes a sealed conductor tilde, on which it is possible to determine the change in electric resistance [ΔR / R], which is linearly dependent on the deformation [μm/m] [7, 8].

Fig. 2: Mounting of the foil one half bridge on the reinforcement

Based on the parameters of the used strain gauges and wiring method it is possible to convert the resulting deformation to the stress change [N.mm^{-2}]. Strain gauge measurements may be affected primarily by changes in temperature, which results in expansion of the sensor conductor without impact on the stress change of the measured structure. This adverse effect can be compensated by connecting several sensors to the so-called "bridge", either as a quarter-bridge, half-bridge or full-bridge, see Fig. 2. Different types of connections bring both advantages and disadvantages. Another variable influencing the resulting value is creep, which is created by constant mechanical stress, and results in the sensors loosing their sensitivity over time. It is caused by the changes in strain gauge materials and adhesive. The last significant impact that may affect the measured results is an electromagnetic field. This is primarily a strong alternating magnetic field and its associated induction in the feeding cables.

3.2 String gauge sensors

String gauge sensors are used to measure strain, stress, temperature, angle, and other derived quantities. Basic types of strain gauge sensors are, depending on the location two: the internal and external sensors. The internal sensors allow measurement of the desired quantities inside concrete elements, see Fig. 3, while the external sensors are coupled along the perimeter of the measured body. The great advantage of these sensors is their resistance to moisture and mechanical damage, such that they are also suitable for in-situ measurements (in construction sites).

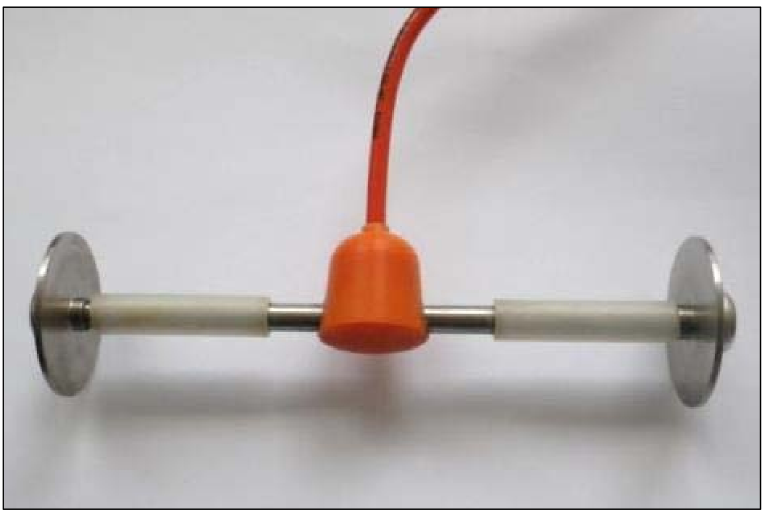


Fig. 3: String gauge sensors

3.3 The measurement procedure

Obtaining the appropriate data for further numerical analysis is determined by selection of an ideal location for mounting the sensors. With regard to the development of stress due to volume changes of the concrete and friction in the foundation joint space between the ribs, the approximate middle of reinforced concrete slab was selected, see Fig. 4, such that these processes were captured by the sensor during the shaping and shrinkage. Another criterion was the location of the sensors near the elevator shaft, so as to allow cable extension above the floor and thereby enable continuous measurements, not only throughout the construction period, but also during operation of the building.

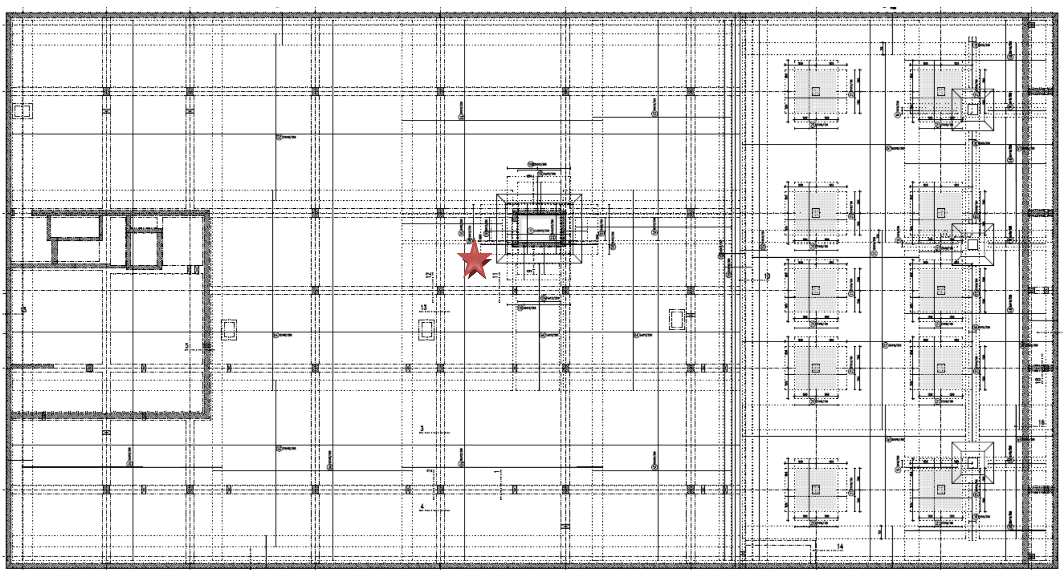
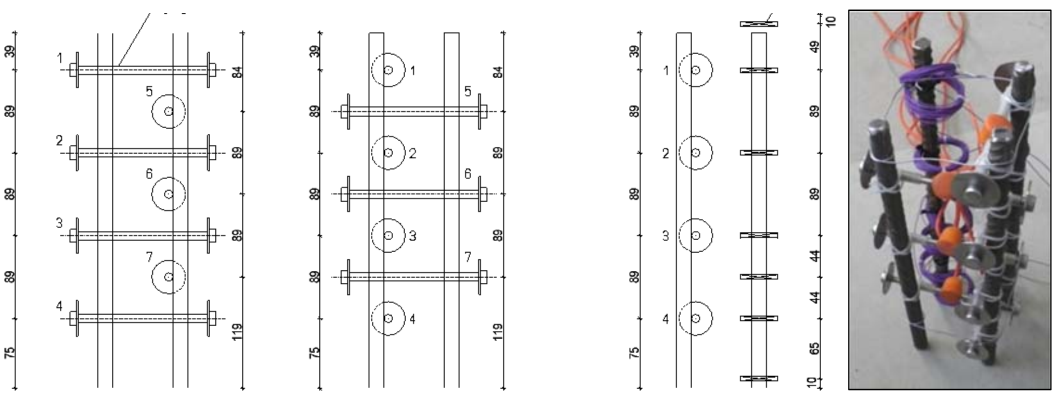


Fig. 4: Schematic chart of the foundation slab and location of the sensors

To mount the floating string gauge sensors the so-called measuring column, which provided mounting of the sensors to the correct height level and direction, and simultaneously the reliable fixation of the sensors during concreting, was used. The column was fitted with a total of seven string gauges and seven bundles of optical fibres, see Fig. 5.



(a) (b)

Fig. 5: (a) Schematic layout of the sensors on a measuring column; (b) Setting of measuring column mounted to a reinforced concrete slab

Besides the optic fibres and string strain gauges mounted on the measuring column, foil strain gauges were also installed. These sensors are placed on the concrete reinforcement so as to capture the changes in stress in the reinforcement at the top and bottom margin in two main directions. Foil strain gauges are on each rod doubled because of the high susceptibility to damage. These sensors are connected to a "halfbridge" so that heat compensation took place on the measured element.

3.4 The measured data

Monitoring of the temperatures with string strain gauges was initiated the day after concreting due to the inaccessibility of the measuring point. Temperature change in the concrete slab was supposed to be monitored, also with an optical fibre, from the initiation of the concreting, which has been taken out of the concreting area. However, during the concreting, due to the concrete mix processing, mechanical damage to the 60 m-long cable occurred.

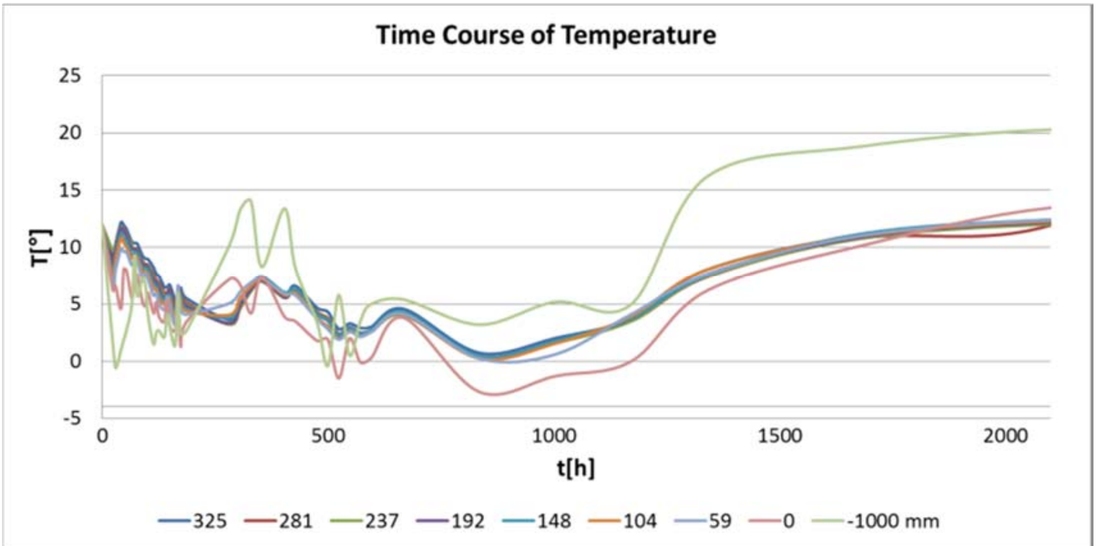


Fig. 6: Graph of temperature change over time

Temperature readings from string strain gauges were performed three times daily for 14 days. Simultaneously, surface temperature of the concrete slab and the external environment using a non-contact digital thermometer was also measured. In the next 12 days the reading was performed only once a day. The last intervals of temperature readings were conducted after seven days.

The listed Fig. 6 describes the recording of each sensor, whose height placement is shown in the legend, and sensors listed in descending order from 0 down. The green curve describes external environment temperature, and it is evident that especially in the first phase of hardening, the concrete, despite the low or negative temperatures, maintained its own temperature due to the development of hydration heat. Upon completing the hydration process the convergence and stabilization of external environment temperature and concrete also took place.

4 CONCLUSIONS

Experimental verification of theoretical assumptions of stress changes in the foundation structures due to fluctuations of external environment temperature, development of hydration heat and volume changes of concrete is necessary for verification of the proposed computational models.

The measurement results confirmed theoretical calculations [6] and the favourable impact of concrete mix hydration [1, 2, 3] on the temperature of sliding joints even in winter [4, 5]. Comparing the measured and calculated stresses in the concrete and the reinforcement helps to better understand the behaviour of the foundations immediately after concreting. The results of the experiment will enable to reduce the amount of technologically demanding shrink bands that slow down the progress of construction work. Currently, further evaluation and comparison of experimentally measured data with numerical models of the transient temperature field including development of hydration heat is being carried out, see [1] to [6]. The measurement throughout the entire construction period, and subsequently during operation of the completed building is also expected in a limited mode [10].

ACKNOWLEDGMENT

The paper was realized with financial support of the Ministry of Education, support of specific university research of Conceptual Development of FAST VSB-TU Ostrava in 2013, and the partial use of the project results of the Ministry of Industry and Trade, TIP program – project number FR-TI2/746 - Rheological sliding joint with temperature-controlled viscoelastic properties.

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