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# CALCULATION OF TEMPERATURE IN SLIDING JOINT DESIGNED AS A PART OF FOUNDATION STRUCTURE

**Abstract**

In case of expected horizontal deformation of subsoil or foundation structure it is possible to use rheological asphalt sliding joint to eliminate internal forces caused with friction. Material characteristics of asphalt are temperature sensitive. In science literature it is possible to find data with temperatures expected in footing bottom, however it was decided to complement this information with temperatures measured in-situ in foundation slab for super-computer building in campus of VŠB-Technical University of Ostrava. In the paper measured and calculated temperatures are compared for the first days after concreting the foundation structure. Besides the temperature of environment also significant influence of heat of cement hydration are taken into account.

**Keywords**

Sliding joint, foundation structure, temperature measurement, temperature calculation.

## 1 INTRODUCTION

Friction in footing bottom due to horizontal deformation of terrain or foundation structure brings forth considerable values of internal forces in foundation structure and it is necessary to involve them into soil-structure interaction [2], [3]. To eliminate the friction it is possible to use rheological asphalt sliding joint. Faculty of civil engineering has provided research of shear characteristics of different types of asphalt belts for a few years. It was proved that the shear characteristics are strongly influenced with temperature [4], [5], [6]. Accurate design of sliding joint is related with estimation of temperature in footing bottom, whereas both short time and long time temperatures are important. Estimation of short time temperatures is important for friction elimination due to pre-stressing, temperature variation and creep and shrinkage which are significant especially if first days after concreting. Estimation of long time temperatures is important from the point of view of terrain deformation due to undermining and long –time creep and shrinkage.

## 2 TEMPERATURES MEASURED IN-SITU

### 2.1 Foundation structure description

Building of National Super Computer Centre is situated in campus of VŠB-Technical University of Ostrava. The building is founded on slab with thickness 400 mm and with stiffening

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ribs in upper part of foundation structure. Foundation slab was concreted in winter season in February 2013.

Equipment for measuring the temperatures is in the Fig. 1, more details also in [8]. Environmental temperatures and temperatures within the cross-section up to the depth 325 mm were measured. Due to technical parameters of measuring equipment it was not possible to measure the temperatures directly in footing bottom. In parallel with temperatures also strains of structures were measured. In the Fig. 2 there are temperatures measured in first 50 days after concreting the foundation slab. In the fig 3 there are temperatures measured in-situ in dependence with foundation coordinate. The measurements are still in progress, however with longer time intervals.

Fig. 1: Equipment for measuring the temperatures and strain in foundation slab

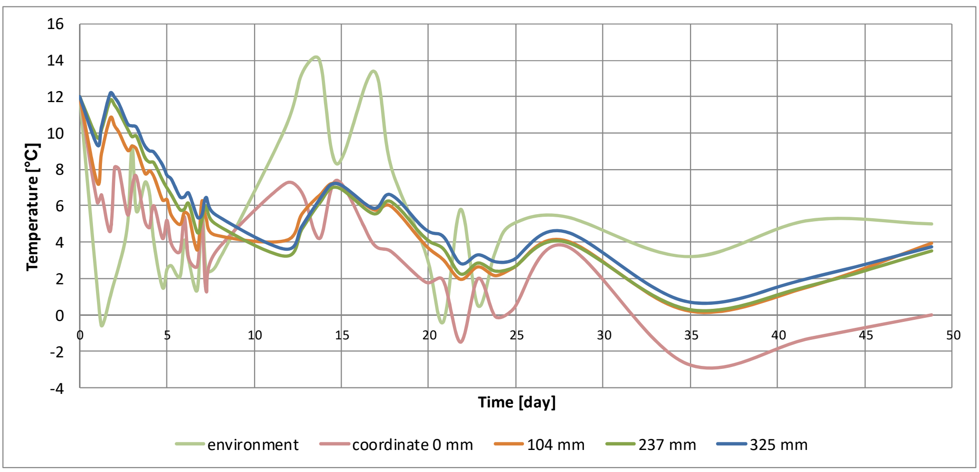


Fig. 2: Temperatures measured in-situ

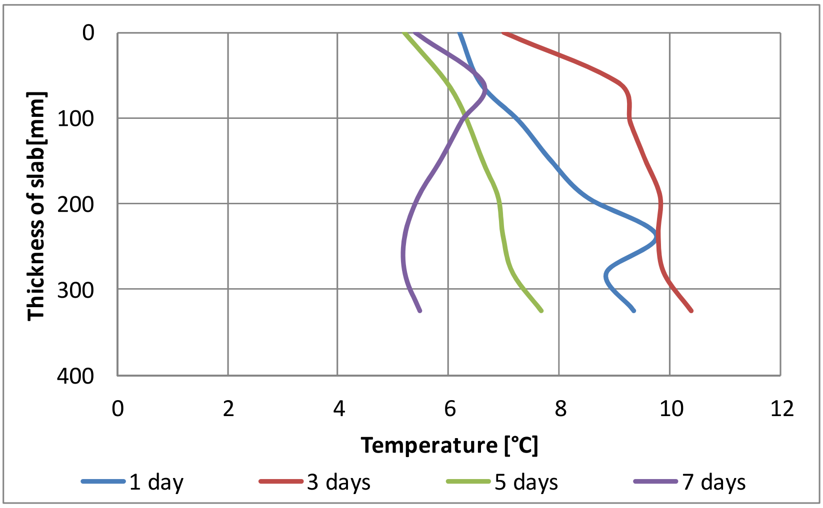

Fig. 3: Temperatures as function of foundation coordinate, measured in-situ

# 3 CALCULATION OF TEMPERATURES IN CROSS-SECTION OF FOUNDATION SLAB

## 3.1 Temperature of environment

For the calculation of temperatures within the foundation slab cross-section the temperature of environment according to (1) is considered. This formula was taken up from literature [9] because it is possible to take into account variation of temperatures over day.

$$T_e(t) = T_{med} + A_e.\sin\frac{\pi}{12}.t \tag{1}$$

where:

$T_{med}$ – is average temperature in winter season, recommended temperature 5° C is considered,

$A_e$ – temperature amplitude, recommended temperature 6° C is considered.

Temperature of environment measured in-situ is compared with temperature considered in calculation according (1) in the Fig. 4. Temperatures differ as expected, however temperature variation over day is notice able also in temperatures measured in-situ.

## 3.2 Heat of hydration

Number of dependences was derived for the development of the heat of hydration in time. In this paper the development according to ČSN 731208 [7], [10] is used. This model was chosen for simplicity, unlabored involvement into numerical calculations and relative availability of input parameters.

Variation of temperature in time is considered as exponential function according to (2), (3) and (4):

$$\Delta T_a(t) = \Delta T_a\left(1 - e^{-\beta t}\right) \tag{2}$$

$$\Delta T_a = \frac{m.Q_h}{c.\rho} \tag{3}$$

$$\beta = \beta_{10}.2^{\frac{T_{or}-10}{10}} \tag{4}$$

where:

$m$ – is amount of cement in 1 m$^3$ of concrete [kg.m$^3$],

$c$ – specific heat [J.kg$^{-1}$.K$^{-1}$],

$\rho$ – is the density of concrete [kg.m$^3$],

$Q_h$ – heat of hydration, appointed experimentally or according to the code [kJ.m$^{-3}$],

$T_{or}$ – initial concrete temperature [°C],

$\beta_{10}$ – basic value of coefficient $\beta$ for temperature 10° C [-].

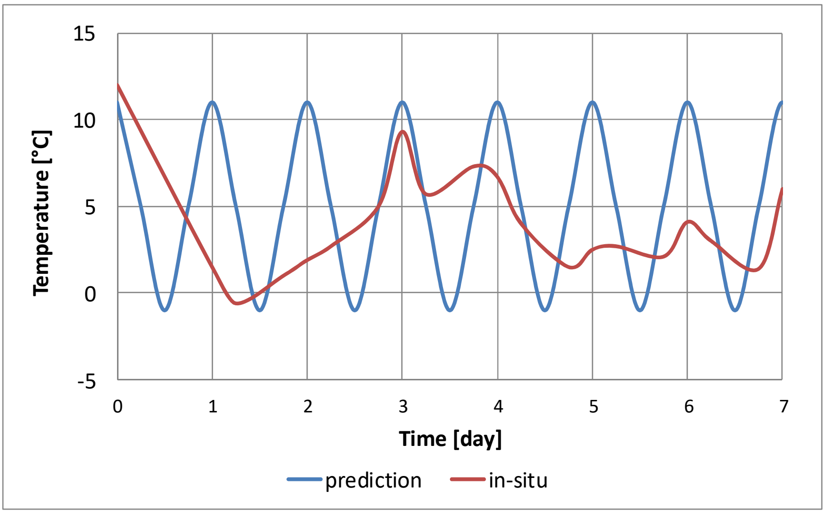


Fig. 4: Predicted and measured environmental temperatures

Deriving the function (2) the heat flow is settled and it can be used for numerical temperature calculation (5):

$$q(t) = c.\rho.\frac{\partial T}{\partial t} = c.\rho.\Delta T_a\left(0 + \beta.e^{-\beta t}\right) = c.\rho.\Delta T_a.\beta.e^{-\beta.t} \qquad (5)$$

Parameters for heat of hydration calculation of cement used for concrete of foundation slab was not possible acquire as the supplier refused to give information about it. It was found out that mixed cement was used. In the calculation minimal and maximal amount of cement and minimal and maximal value of heat of hydration is used according to EN 206 [11] a ČSN 731208 [10]. Coefficient $\beta_{10}$ which represents the rate of heat of hydration releasing is also considered with minimal value 0.15 for slow heat of hydration releasing and with maximal value 0.25 for rapid heat of hydration releasing. Minimal values of temperature were settled for cement amount $m$ = 300 kg.m$^{-3}$ and heat of hydration $Q_h$ = 260 kJ.m$^{-3}$ and maximal temperatures for amount of cement $m$ = 400 kg.m$^{-3}$ and heat of hydration $Q_h$ = 350 kJ.m$^{-3}$.

## 3.3 Calculated temperatures

Temperatures within the cross-section with taking into account predicted environmental temperature and heat of hydration were analyzed with NONSTAC software which solves numerically Fourier differential equation for one-dimensional temperature array[1].

In the Fig. 5 there are calculated minimal and maximal temperatures in footing bottom for slow and rapid rate of heat of hydration releasing. In the Fig. 6 measured and calculated temperatures at the coordinate 325 mm are compared. The coordinate 325 mm is the nearest to the footing bottom where there are temperatures measured in situ. Calculated temperatures represents curve for minimal amount of cement and low rate of heat of hydration releasing which with achieved temperatures and progress of function responds best with in-situ measured temperatures.

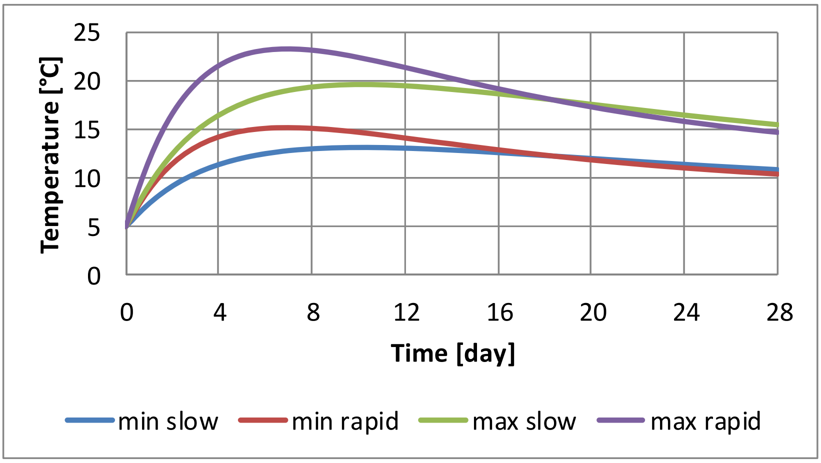


Fig. 5: Calculated minimal and maximal temperatures in footing bottom

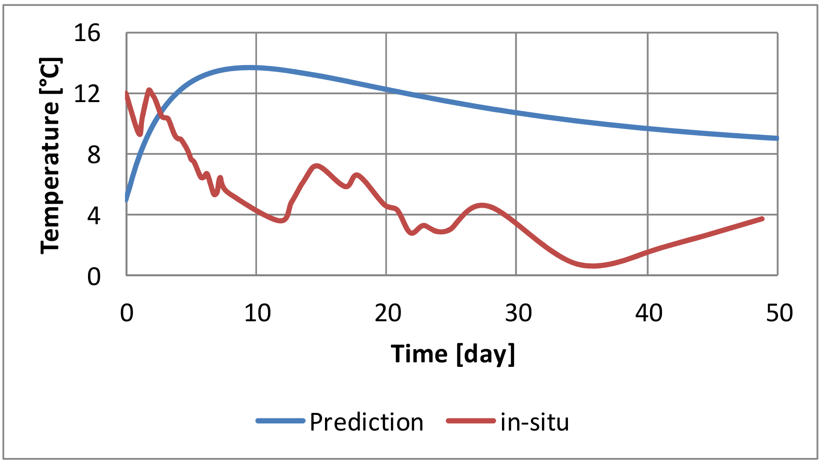


Fig. 6: Calculated and in-situ temperatures at coordinate 325 mm

### 3.4 Discussion

From the Fig. 6 it is evident that temperature calculated for coordinate 325 mm from slab surface is higher than measured in-situ. Similar difference is expected also in footing bottom. The difference was expected as the predicted and calculated environment temperature differ, Fig. 4. Other inaccuracies are caused by simple model of heat of hydration according to code [10], where in addition it was not possible to acquire accurate input parameters, i.e. cement heat oh hydration and amount of cement in 1 $m^3$ of concrete.

It is necessary to take into account the temperature difference while designing the rheological sliding joint as the material characteristics are temperature dependent.

## 4 CONCLUSIONS

Appropriate rheological sliding joint design is connected with estimation of temperature in footing bottom. Temperature affects shear deformations of asphalt belt and consequently also sliding joint shear resistance. In the paper temperatures measured in-situ in foundation slab of National Super Computer Centre and temperatures calculated on the basis of predicted environmental temperature using particular model of heat of hydration releasing are compared. Predicted temperatures in this case are higher than measured in-situ. Higher temperatures correspond with higher deformations and lower shear resistance. Above mentioned findings should be taken into account when designing the sliding joint.

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