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# TEMPERATURE DISTRIBUTION OF SLIDE JOINT IN REINFORCED CONCRETE FOUNDATION STRUCTURES

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**Abstract:** *In the paper temperature distribution in foundation structure is analyzed for different temperature regime of environment. Temperature distribution is analyzed numerically using Nonstac computer program. Nonstac computer program solves one dimensional temperature distribution and it is possible to input appropriate thermal characteristics as a function of temperature and to take into account heat of hydration development, variation of environment temperature and if needy in special cases e.g. purposeful warming of the foundation structure. Calculated temperatures will be used in future research for strain analysis in footing bottom with slide joint and consequently stress and strain of foundation structure.*

**Keywords:** ***Slide joint, foundation structure, temperature distribution.***

## 1. Introduction

Slide joints are used for elimination of friction in footing bottom caused by deformation of foundation structure owing to shrinkage, creep, pre-stressing and temperature variation or by subsoil deformation, owing to e.g. undermining, Fig. 1.

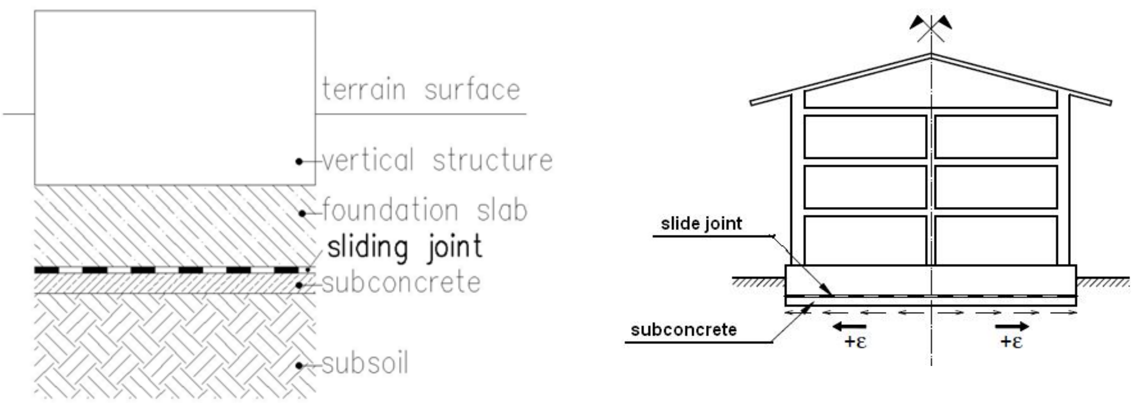


*Fig. 1: Schematic drawing of slide joint.*

Original slide joint design method dates from the eighties of last century and was primary focused on foundations on undermined area, material of slide joint was mainly asphalt belt. Currently number of new and potentially suitable material for slide joint is at disposal. Rheological shear characteristics of selected materials were tested at Faculty laboratory, VSB –TU Ostrava, some of the results are introduced in doctoral thesis (Maňásek,P., 2008).

One of the important factors, which affect the rheological shear resistance of slide joint, is the temperature. For that reason research and laboratory testing of selected materials continues and rheological shear characteristics are tested in dependence on temperature in air conditioned room. Experiments are in testing the operation, Fig. 2. Air-conditioned room with dimensions 1000 x 2500 x 2200 mm is made of polyurethane foam, thickness 125 mm. Temperature limit is from -20°C to +40°C, cooling is provided through cooling unit with vaporizer, heating through electric heater with

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centrifugal fan. Experimentally appointed function of slide joint resistance versus temperature should contribute to design optimization of slide joint and consequently also foundation structure.

*Fig. 2: Testing rheological shear characteristics in air conditioned room.*

## 2. Thermal actions

Analysis of temperature distribution in foundation structure enable estimating of temperatures, expected in slide joints for different temperature regimes, eventually with heat of hydration taking into account.

### 2.1. Environmental temperature

Temperature variation in building structures is given in ČSN EN 1991-1-5 (2005). Thermal action is expressed with maximal temperature $T_{max}$ in summer and minimal temperature $T_{min}$ in winter. Appropriate temperatures are for Ostrava region $T_{max}$ = 37°C and $T_{min}$ = -33°C. With considering solar radiation the temperature of the structure could be in summer up to $T_{max}$ = 67°C. Environmental average month temperatures are available also in standards for thermal protection of buildings.

It is also possible to make use of published measured temperatures in subsoil, e.g. average temperatures of environment at the depth 0.5 m and 1.0 m for different above see levels (Halahya, M., Sobotka, P., 1988), Fig. 2. Experiments with temperature measuring in subsoil are planed also at Department of Constructional Surrounding at Faculty of civil Engineering VSB-TU Ostrava.

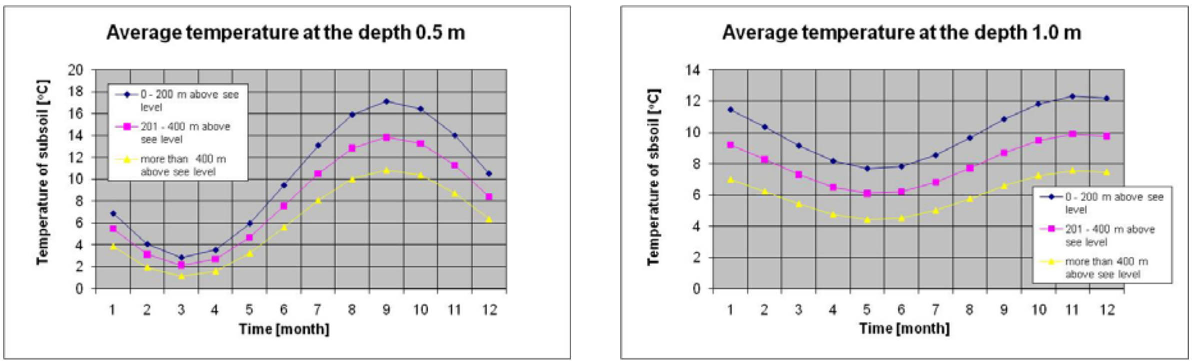


*Fig. 3: Measured temperatures in subsoil, (Halahya, M., Sobotka, P., 1988).*

Description of temperature variation through the day is given e.g. in textbook (Halahya, M. 1970). Temperature variation is expressed as sinus function (1):

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

where $T_{med}$ is average daily temperature, $A_e$ is temperature amplitude, $t$ is time. Average daily temperature and temperature amplitude is considered in summer $T_{med,sum}$ = 20.5°C, $A_{e,sum}$ = 6.7°C, in winter $T_{med,win}$ = 5.0°C, $A_{e,win}$ = 6.0°C. In summer solar radiation has to be taken into consideration.

Influence of solar radiation is expressed through solar radiation intensity $E_e$ which is defined similarly to temperature as sinus function. Result heat flow is determined by multiplying the radiation intensity with absorbing capacity for radiation.

### 2.2. 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 (2010) is used. Temperature variation $\Delta T_a(t)$ is considered according to exponential function (2):

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

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

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

where $m$ is weight of cement in 1 $m^3$ of concrete, $c$ is specific heat of concrete, $\rho$ is density of concrete, $Q_h$ is heat of hydration assigned by laboratory experiment or according to data in ČSN 731208 (2010), $T_{or}$ original temperature of concrete, $\beta_{10}$ basic value of coefficient for $T_{or} = 10°C$.

For the temperature distribution analysis it is important to get intensity of heat generation which is derivation of temperature variation (2), (5):

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

### 3. Temperature distribution – foundation slab

Computer program Nonstac solves numerically Fourier differential equation of one dimensional transient temperature distribution (6), Čajka (2010). It is possible to input appropriate thermal characteristics as a function of temperature, heat generation and variant environmental temperatures.

$$\frac{\partial T}{\partial t} = \frac{\lambda}{c.\rho}.\frac{\partial^2 T}{\partial x^2} + \frac{q}{c.\rho} \tag{6}$$

where $T$ is temperature, $t$ is time, $\lambda$ is heat conductivity, $\rho$ is density, $c$ is specific heat, $q$ is heat generation, e.g. heat of hydration.

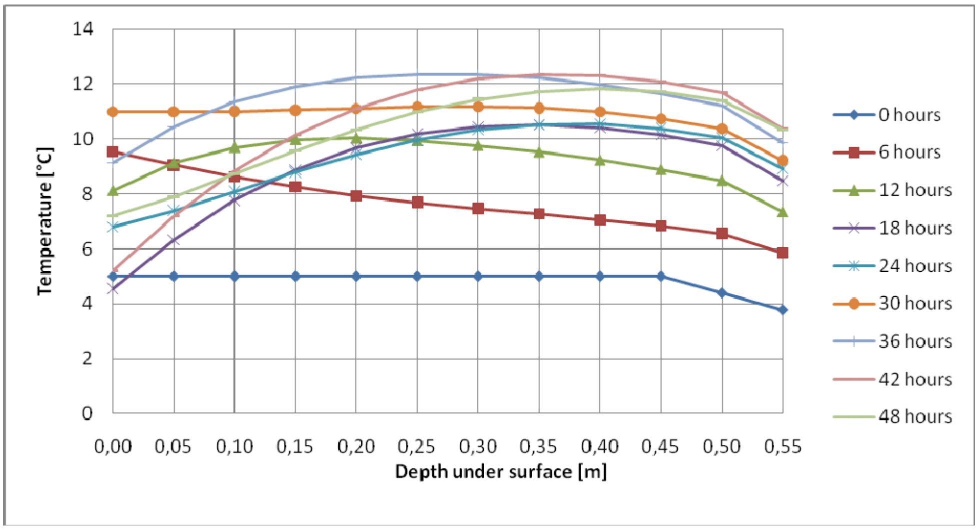


*Fig. 4: Temperatures in foundation slab – concreting in winter time.*

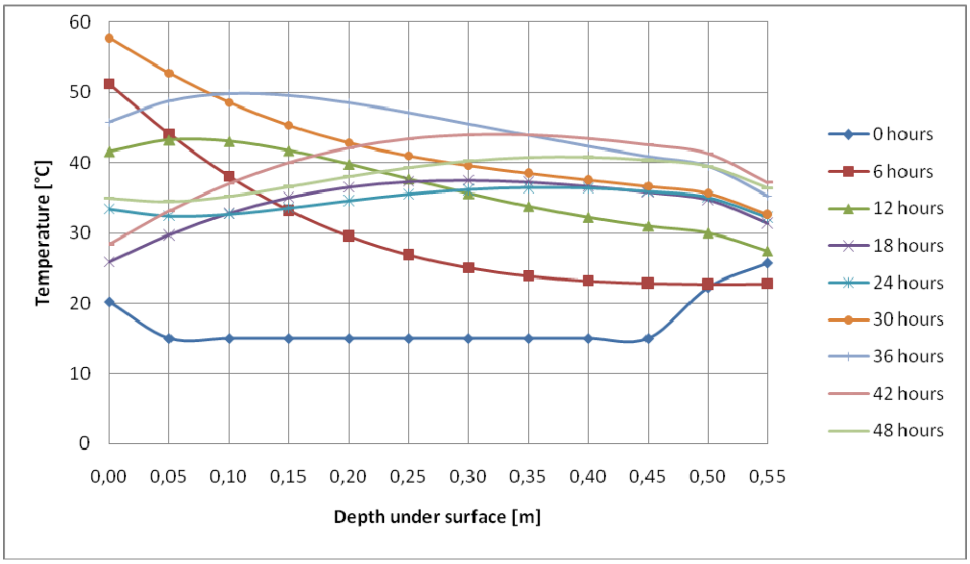


*Fig. 5: Temperatures in foundation slab – concreting in summer time.*

In the study example temperature distribution in foundation slab with thickness 550 mm is analyzed for 48 hours from concreting. Temperature distribution is considered as one-dimensional, environmental temperature varies for concreting in winter time, Fig. 4, and in summer time according to (1) Fig. 5. In summer time the intensity of solar radiation is taken into consideration.

## 4. Conclusions

In the paper the temperature distribution in foundation slab is analyzed using Nonstac computer program. Nonstac solves numerically one dimensional temperature array, enable to input appropriate thermal characteristics as a function of temperature, heat generation and variant environmental temperatures. Temperatures in foundation slab are analyzed for concreting in summer time and in winter time. Analysis of temperature distribution in foundation slab enable estimating of temperatures, expected in slide joints. Particular temperature is one of the significant factors, which affects rheological shear characteristics of slide joint material. Experiment of rheological shear characteristics as a function of temperature are in testing the operation. Experimentally appointed function of slide joint resistance versus temperature should contribute to design optimization of slide joint and consequently also foundation structure.


## Acknowledgement

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## References


Čajka, R. (2002) Influence of friction in the subsoil to strain of foundation structures. Inaugural dissertation, VSB-Technical university of Ostrava. (In Czech).

Čajka, R. (2010) Analysis of computer numerical solution of transient temperature distribution with temperature dependant material properties. (In Czech).

ČSN EN 1991-1-5 Eurocode 1(2005) Action on structures – Part 1-5: General actions – Thermal actions. ČNI Prague.

ČSN 731208 (2010) The design of waterworks concrete structures. UNMZ Prague. (In Czech).

Halahyja, M. (1970) Heat engineering, lighting, acoustic. ALFA Bratislava. (In Slovak).

Halahyja, M., Sobotka, P. (1988) Analysis of factors which affect the long-time temperature variation in subsoil. In journal Sanitary Engineering and air conditioning, volume 31, nb 6. Prague. (In Slovak).

Maňásek, P. (2008) Foundation structures with slide joint. Doctoral thesis, VSB-Technical university of Ostrava. (In Czech).