

Martina JANULÍKOVÁ¹, Radim ČAJKA², Pavlína MATEČKOVÁ³, Marie STARÁ⁴**MODELING OF FOUNDATION STRUCTURES WITH SLIDING JOINT USING
RESULTS OF ASPHALT BELTS LABORATORY TESTS****MODELOVÁNÍ ZÁKLADOVÝCH KONSTRUKCÍ S KLUZNOU SPÁROU
S VYUŽITÍM VÝSLEDKŮ LABORATORNÍCH ZKOUŠEK ASFALTOVÝCH PÁSŮ****Abstract**

Long-term objective of rheological sliding joints research is to contribute to updating the existing computational methods for their design. Sliding joints are applied in foundation structure to reduce the friction which is caused in footing bottom due to horizontal deformation loading (e.g. effect of undermining, pre-stressing). Accuracy of rheological sliding joints design depends on knowledge of the mechanical properties of used materials. The most common material for sliding joint are asphalt belts, which are tested at Faculty of civil engineering using own testing equipment and temperature controlled room. Currently, series of measurements have been carried out so that the results could be used for the numerical modeling. This papers aim is to present possible approaches to asphalt belt sliding joint numerical modeling in foundation structure and summarize their advantages and disadvantages.

Keywords

Sliding joint, asphalt belt, foundation structures, modeling of sliding joint.

Abstrakt

Dlouhodobým výzkumným cílem problematiky reologických kluzných spár je přispět k aktualizaci stávajících výpočetních metod pro jejich navrhování. Aplikace kluzné spáry do základové konstrukce se využívá pro snížení tření, které může v základové spáře vznikat od účinků vodorovných zatížení (např. od vlivu poddolování). Správnost návrhu reologické kluzné spáry závisí především na znalosti mechanických vlastností materiálu kluzné spáry, nejčastěji asfaltových pásů, které se na fakultě stavební testují s využitím vlastního měřicího zařízení a klimatizační komory. V současné době neustále probíhá řada měření a výsledky jsou využívány např. pro numerické modelování. Tento příspěvek si klade za cíl ukázat možné přístupy k modelování asfaltové kluzné vrstvy v základové konstrukci a stručně shrnout jejich výhody i nevýhody.

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Klíčová slova

Kluzná spára, asfaltový pás, základové konstrukce, modelování kluzné spáry.

1 INTRODUCTION

Correctness of rheological sliding joint design depends on knowledge of the mechanical response of used material. The most common material for the sliding joint is asphalt belt, see [1] to [5]. In 2007 first measurements for different types of asphalt belts were carried on own measuring equipment at laboratory temperature [6]. The basic principle of the test is on the Figure 1.

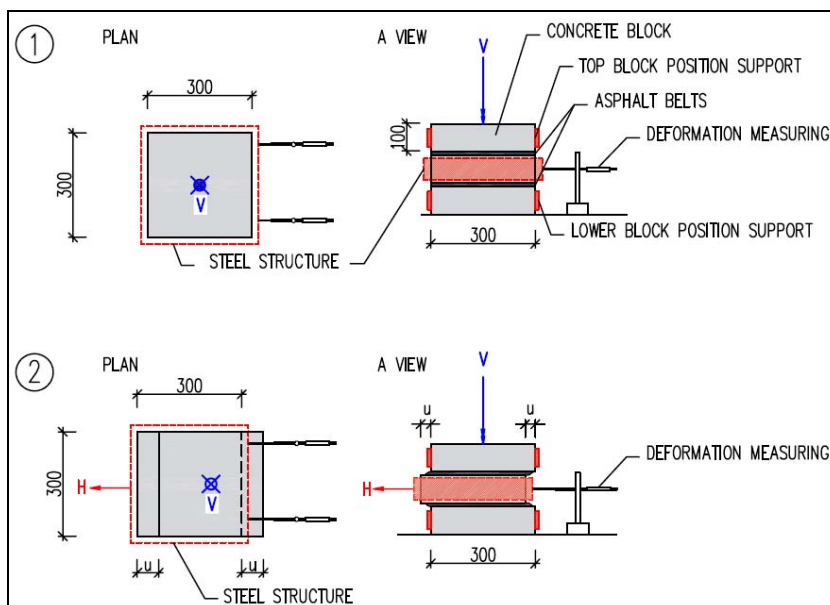


Fig. 1: Basic principle of the test

These measurements followed on measurements of asphalt belts from the 80th [7]. The original measuring equipment was placed in 2010 into temperature controlled room, which was designed and constructed specifically for investigation into the influence of temperature (Figure 2). Measurement methodology including the effect of temperature and some results from measurements were described in [8].



Fig. 2: Measurement equipment placed in temperature controlled room

2 RESULTS OF LABORATORY TESTS

The goal of these tests was to simulate the behavior of concrete structures with applied sliding joint exposed to horizontal deformation. The ambient temperature was regulated by air condition room. Values of deformation, which allows the asphalt belt at given temperature and given load combinations, were monitored throughout the 6 day measurement (Figure 3). Generally it could be stated that at higher temperatures there are larger deformations measured due to changes of mechanical properties of asphalt belts, and vice versa.

Measured deformations could be used for e.g. deriving the friction parameters C_{1x} C_{1y} (see [9] to [12].), which is possible to assign in commercial software as subsoil parameter and utilized in design practice.

The results could be also used for appointing the mechanical properties of asphalt belts, which are used as a basis for numerical modeling of foundation structures with sliding joint, see also [13] to [16].

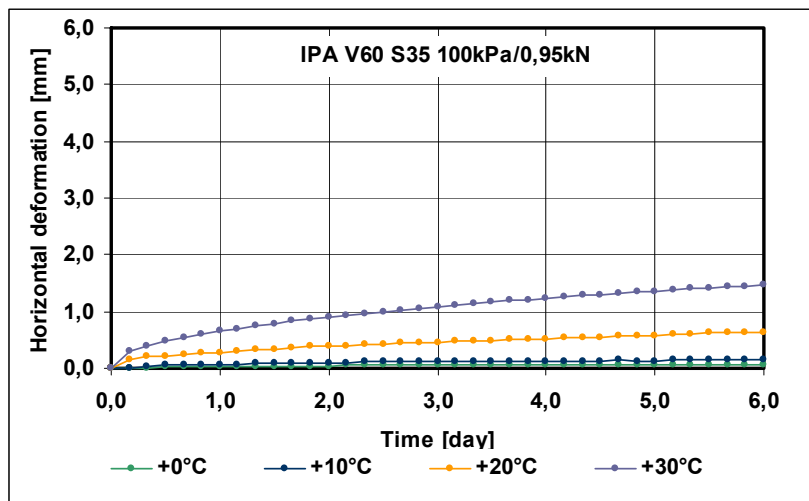


Fig. 3: Example of the primary results from laboratory testing of asphalt belts

3 NUMERICAL MODELING

For the numerical modeling of foundation structures with sliding joint FEM program ANSYS 12.0 was used. As illustrative example simple strip foundation in 2D was solved (Figures 4 and 6). Numerical model was created using two approaches. The first option is modeling asphalt belt layer in the real thickness and define the characteristic of this layer with viscoelastic material models. With this model changes in the mechanical properties of asphalt belts at a time can be reflected. Those can be defined with using the results of tests at different temperatures (Figure 4). The second option is to define the layer between foundation structures and concrete base layer with contact FEM elements (concrete base layer is always applied to protect the asphalt belt when applying the sliding joint) (Figure 6)

3.1 Asphalt as viscoelastic material

Asphalt is a material that shows viscoelastic properties in deformation and therefore in describing the material characteristics theory of rheology is often used [17]. This theory analyses material deformation in relation to time with the influence of mechanical factors. The basic principle of the theory of rheology is in replacement of real rheological material properties with properties, which could be defined physically and mathematically in more simplified way, e.g. liquid asphalt properties are idealized with Burges mass.

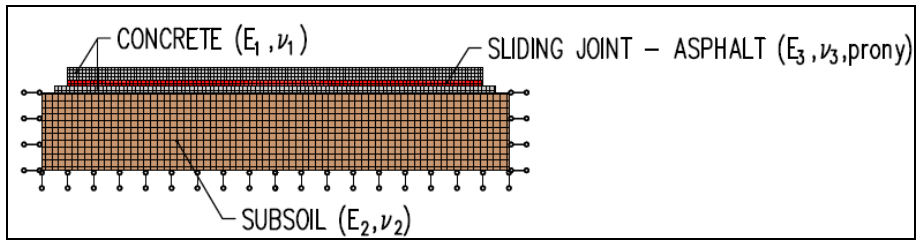


Fig. 4: Modeling of sliding joint as layer with viscoelastic properties

Asphalt belts as viscoelastic material in ANSYS software was idealized as nonlinear material, using Prony series equations with the rheological constants. These can be easily obtained using the laboratory tests results. Shear modulus as a function of time is appointed and rheological constant are settled automatically in ANSYS software. This way, material properties of sliding joint in relation to time are taken into account. The resulting numerical model consists of three materials - concrete, subsoil and asphalt layer. Asphalt belt should be given in its real thickness, but it is unsuitable given to numerical non stability in case of the small thickness comparing with other dimensions of the model. In this illustrative example the asphalt layer was considered higher than in reality and the height is divided into two elements. This simplification obviously affects the resulting stress. Another problem is considerable order difference in the modulus of elasticity of particular materials. The model is shown in Figure 4.

3.2 Defining asphalt layer with contact elements

Using of contact elements appears suitable option for mathematical modeling with regard to the ratio of asphalt layer and strip foundation dimensions. Characteristics of sliding joint can be defined for example by means of friction coefficient μ , which was considered simply depending on the vertical and horizontal stress as it assumes the Coulomb friction model (Figure 5).

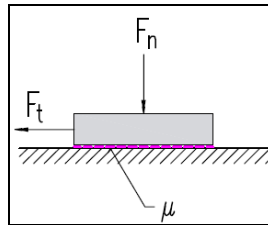


Fig. 5: Simplified model of friction

Simplified formula for calculating friction coefficient:

$$\mu = \frac{F_t}{F_n} \quad (1)$$

where:

F_t — is horizontal force,

F_n — is vertical force

At present authors are analyzing the possibility to define the contact elements using a dynamic coefficient of friction. Dynamic friction models are often used in cases of modeling phenomenon experimentally measured at speeds close to zero. In the Figure 6 there is the result model.

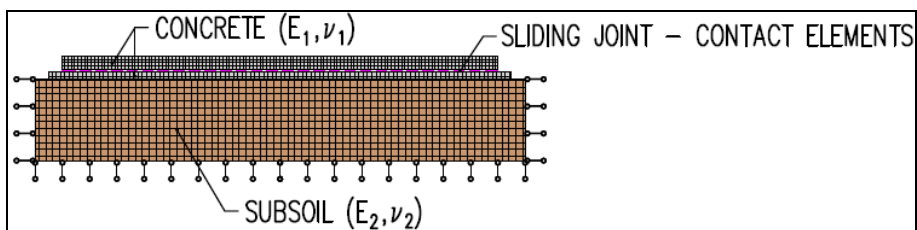


Fig. 6: Modeling sliding joint with using contact elements

4 COMPARISON OF RESULT OF MODELING

In the graph in the Figure 7 there are shear stresses in the sliding joint depending on the distance from the middle of foundation strip for different approaches of sliding joint modeling. Curve which shows shear stress without sliding joint according to current codes [18] is also presented for comparison. The curves in the Figure 7 show significant differences between the approaches to modeling. Although the courses of stress cannot be considered as final, mathematical modeling correctly reflects the smaller shear resistance with sliding joint especially in the model with contact elements. In the viscoelastic model there is significant increase of tension stress due to the simplifications. The question is which model is more suitable for calculation. In modeling with viscoelastic properties asphalt layer characteristics could be expressed more precisely also as a function of time. The disadvantage remains the necessity to increase the thickness of asphalt layers to unrealistic proportions which distorts the resulting courses of stress in footing bottom. Due to these inaccuracies and considerable simplification, it seems more suitable modeling of sliding joints using contact elements, but it is necessary to find an appropriate contact characteristics.

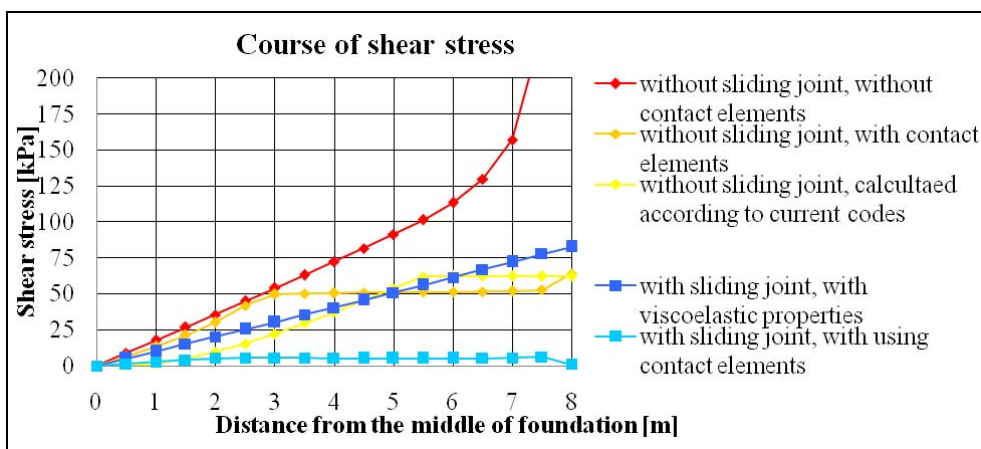


Fig. 7: Comparison of shear stress course

5 CONCLUSION

The aim of further research is implementation of test results, including the effect of temperature, in the mathematical modeling correctly, whether in the determination of the contact elements parameters or determination of material characteristics of the asphalt. On the one hand, it is advantageous to model the sliding joint as a layer with viscoelastic properties. On the other hand, the results can be significantly distorted due to the need to increase the thickness of layer and due to differences between modulus of elasticity of concrete and asphalt. Models with contact elements do not comprise viscoelastic properties of asphalt, but providing correct contact parameters expression it seems to be appropriate tool for modeling sliding joints. As both approaches have their advantages and disadvantages in the future both models will be developed.

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