Utilization of asphalt belt as sliding joint for friction elimination

MATECKOVA Pavlina, SMIRAKOVA Martina
Department of Building Structures
VSB – Technical University of Ostrava
L. Podeste 1875/17, Ostrava, 708 33
CZECH REPUBLIC
pavlina.mateckova@vsb.cz   http://www.fast.vsb.cz

Abstract: Foundation structures are usually exposed to dominant vertical load. In some cases there is also significant value of horizontal deformation load caused by horizontal terrain deformation on areas attached with underground mining or by horizontal deformation of foundation structure due to pre-stressing, creep, shrinkage, and temperature variation. The idea of sliding joints between subsoil and foundation structure, which eliminates the friction in footing bottom, made of asphalt belt has been analyzed at Faculty of Civil Engineering, VSB – Technical University of Ostrava in long term. The influence of vertical and horizontal load and the effect of temperature in temperature controlled room have been examined. Currently targeted heating of asphalt belt used in specimen of sliding joint was tested. In the paper there are test results of shear resistance of currently used asphalt belts, also with respect to temperature. Utilization of test results is also mentioned.

Key-Words: asphalt belt, undermined area, pre-stressing, sliding joint, horizontal subsoil deformation

1 Introduction

Underground mining always influence also landscape on surface. If there are buildings on the surface they are affected with terrain deformation which comprises terrain inclination, curvature, shift and horizontal deformation. Ostrava – Karvina region is specific with underground mining very close to densely inhabited area. About 20 years ago there were mines even in the city of Ostrava. Recommendations and rules for design of building structures on areas affected with underground mining have been therefore analyzed in long term and are reflected also in Czech code [2].

This paper is focused on deformation action caused by terrain horizontal deformation - expansion or compression. Through the friction between foundation structure and subsoil in footing bottom the foundation structure has to resist significant normal forces. The idea of sliding joint in footing bottom which eliminates the friction comes from the eighties of the last century. Bitumen asphalt belt was proposed and proven as suitable material for sliding joint. First experiments were carried out by Balcarek and Bradac [1] in 1980's. A concrete block weighing 2208 kg was placed on the asphalt belt on an inclined plane, and the displacement was measured for different tilt angles, and consequently different shear force T, Fig. 1. On the basis of experimental data the shear stress as a function of deformation rate was derived, which can be listed in still valid Czech code [2].

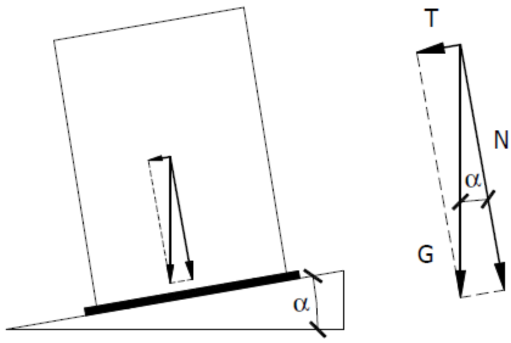

Fig. 1: Primary testing of sliding joint

2 Renewed Testing

Material characteristic of the bitumen belt has been changed significantly since the time of primary testing and this fact demanded new experiments. At VSB – Technical University of Ostrava unique equipment was designed for shear resistance measurement, Fig. 2. Renewed experiments for different types of bitumen belts started in 2008.

In between concrete blocks with dimension 300 x 300 x 100 mm 2 asphalt belt specimens are placed, Fig. 3. Specimens are exposed to vertical load and after one day delay, a horizontal load is also applied. Vertical load responds with load expected in footing bottom, horizontal load is between 0.5 kN and 2.0 kN so that the expected horizontal deformation responds with expected deformation load.

Displacement *u* of the middle concrete block is measured for 6 days, and sometimes also for more days. Within long term testing different types of asphalt belt were examined and the influence of vertical and horizontal load. Test results of different types of asphalt belt were presented in a few papers, e.g. [9, 10, 13, 14].

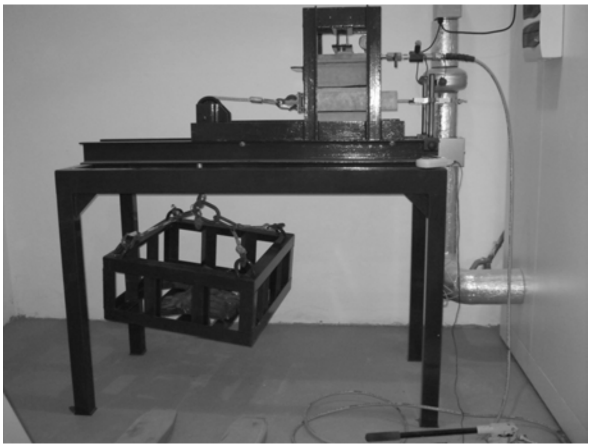

Fig. 2: New testing equipment

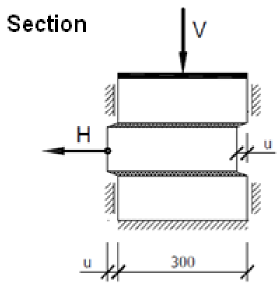

Fig. 3: Scheme of asphalt belt testing

2.1 Temperature influence

One of the important factors which affect the rheological shear resistance of slide joint is the temperature. For that reason laboratory testing was extended and rheological shear characteristics are tested by dependence on temperature in a temperature controlled room. The temperature limit is from -20°C to +40°C. The aim is to determine the slide joint shear resistance for temperatures expected in a footing bottom [11, 12].

Important are both the temperature in the first days after concreting, and also the long-term temperature. The temperature in the first days after concreting is influenced not only with environment temperature but also with heat of hydration. Sliding joint shear resistance in the time after concreting is important for elimination of cracks in the footing bottom due to shrinkage and possible pre-stressing. Long-term temperatures are important for calculating the shear resistance of the sliding joint to eliminate the long-term horizontal deformation due to undermining or creep [6].

It was proved that higher temperature leads to higher deformation and related lower shear resistance, both for the group of oxidized and SBS modified asphalt belts [7].

2.2 Target heating

Favourable asphalt belt shear characteristics at higher temperature lead to idea of temporary target heating of slide joint, e.g. during the foundation pre-stressing.

Asphalt belt sliding joint is part of foundation structure and its target heating in time of increasing horizontal deformation, (in case of undermining after months or years after building commissioning), is complex problem. Arrangement of heating device has to resist significant vertical and horizontal press and also endure action during foundation execution.

It was decided to examine SBS modified specimen with heating provided by power grid with electric resistance wire, in between two layers of asphalt belt. Safe low electrical voltage was used.

Specimen arrangement has gone through development process. In the beginning the power grid was placed between plastic layers and adapted power grid was placed between two layers of asphalt belt, Fig. 4. Target heating was successful, but the implementation in footing bottom is complicated and the measurement of deformations was affected with plastic layer.

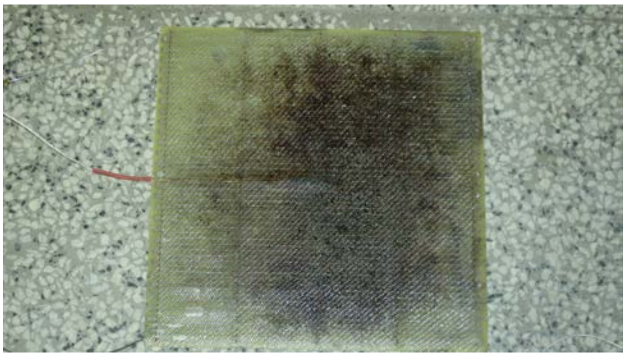

Fig. 4: Electric resistance wire between plastic layers

In the next step electric power grid was implemented directly between two layers of asphalt belt, Fig. 5. In this paper the test results of target heating provided with this type of power grid are presented.

Last step in power grid specimen preparation is the power grid prepared on plastic netting, Fig. 6.

Fig. 5: Electric resistance wire between two layers of asphalt belt

Fig. 6: Electric resistance wire prepared on plastic netting

3 Experiment Results

3.1 Temperature influence

In the Fig. 7 there are measured displacements for asphalt belt exposed to vertical load 500 kPa and horizontal load 2.0 kN.

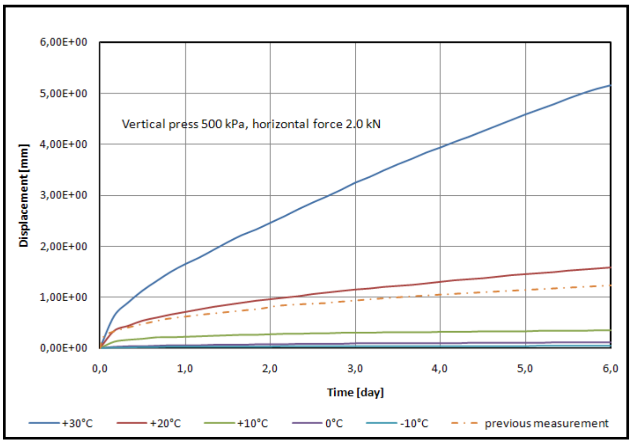

Fig. 7: Measured displacement, influence of temperature

2.2 Target heating

Specimens with power grid were exposed to vertical load 500 kPa. After one day delay also horizontal load 1.0 kN was applied, which causes the shear stress 5.6 kPa. Measuring equipment was placed in temperature controlled room with steady constant temperature 4°C. Horizontal deformation of middle concrete block was measured for over 100 days and in this period specimens were heated in four stages to the temperature 20°C.

The deformation rate responded the specimen heating and increased as expected. In the Fig. 8 is visible increasing of deformation rate in first and second heating in time 2 days and 7 days, in the Fig. 9 third and fourth heating in time 83 days and between 94 to 97 days.

With respect to heating of the specimen there was danger of middle block slipping and devaluation of specimen and consequently also whole testing. To reduce the risk of slipping the test was carried out with higher value of vertical load and lower value of horizontal load. This fact in combination with environment temperature 4 °C result in small deformation velocity in the stage without heating, e.g. in time 10 to 80 days the deformation is nearly zero, Fig. 8, 9.

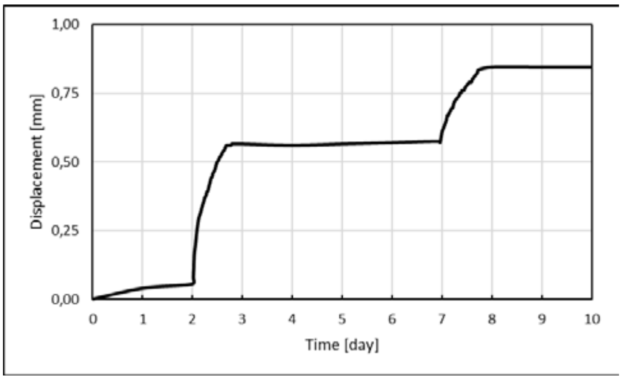

Fig. 8: Measured displacement, first and second heating

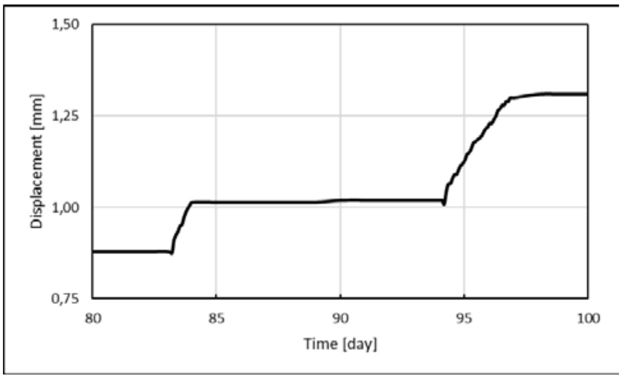

Fig. 9: Measured displacement, third and fourth heating

The deformation rate increased while the specimens were heated, i.e. shear resistance decreased. However, with repeated heating the deformation rate decreased.

4 Sliding Joint Design

4.1 Shear stress without sliding joint

Horizontal deformation of the subsoil or the foundation structure brings forth the shear stress in foundation bottom, which causes the normal forces in foundation structure. Simple method for appointing the shear stress and consequently the normal force bring forth CSN 73 00 39 [2], Fig. 10. Shear stress is settled as a function of horizontal deformation ε, dimensions of the foundation structure and oedometric modulus of subsoil.

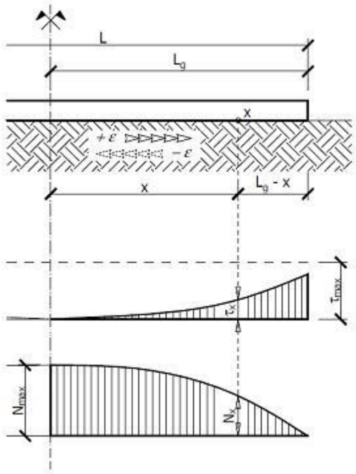

Fig. 10: Shear stress and normal force caused by friction in footing bottom

4.1 Simple sliding joint design

The shear resistance of bitumen asphalt belt is primarily dependent on deformation rate.

As the measurement of shear resistance for particular deformation rate is problematic, it is necessary to appoint experimentally the deformation rate for different shear stresses.

Using linear regression it is possible to appoint the shear resistance of a slide joint as a function of deformation rate, Fig. 11. Result function is dependent on type of asphalt belt, level of vertical load and expected temperature [4, 5, 15, 16].

The experience from the experiments shows also influence of asphalt belt age at the time of sliding joint activation.

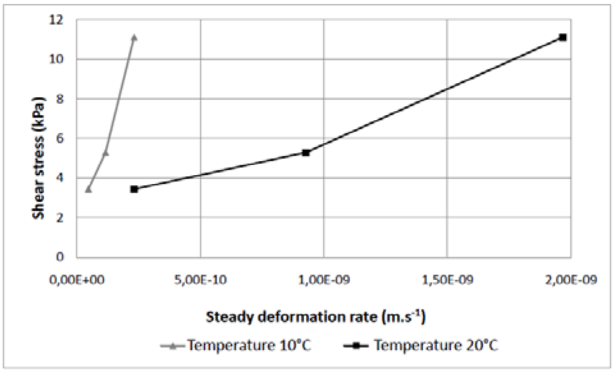

Fig.11: Shear stress as a function of deformation rate

4.2 Design in FEM analysis

One of the possibilities of modelling the sliding joint in FEM analysis is to appoint horizontal soil parameter C_{1x} and C_{1y} analogically to vertical parameter C_{1z} of one-parametrical model of subsoil, Fig. 12. Basic equations are listed (1), (2), more detailed description in [3, 7].

$$\sigma_z = C_{1z}.w \tag{1}$$

$$\tau_x = C_{1x}.u\,,\, \tau_y = C_{1y}.v \tag{2}$$

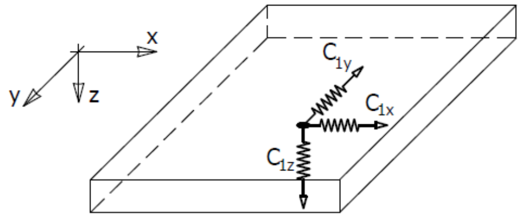

Fig. 12: Vertical and horizontal parameters of subsoil

4 Conclusion

In the paper the idea of using the asphalt belt as sliding joint for elimination of friction between foundation structure and subsoil is introduced. It was proved that higher temperature decreases shear resistance and this finding lead to idea of temporary target heating of slide joint, e.g. during the foundation pre-stressing or in time when the subsoil deformation due to undermining is expected.

It was decided to examine SBS modified specimen with heating provided by power grid with electric resistance wire, in between two layers of asphalt belt. Specimens were exposed to vertical load and also to shear stress through horizontal load for over 100 days and they were heated repeatedly in time 2 days, 7days, 83 days and 94 to 97 days.

The deformation rate increased while the specimens were heated, however, with repeated heating the deformation rate decreased.

In the paper possible utilization of test results is mentioned.

Though the bitumen sliding joint was successfully applied at a few buildings [8], sliding joints has not been widely used yet. The aim of experiments is to contribute to wider utilization of bitumen asphalt belt as sliding joints and thus enable to design more durable and sustainable building structures.

Acknowledgement

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