Modern Sliding Joints in Foundations of Concrete and Masonry Structures

M. Janulikova, P. Mynarcik

***Abstract*—**Using of sliding joint is one of the possible options to solution of problem associated with horizontal deformation of the subsoil which causes shear stress in the footing bottom. This horizontal deformation can arise from the effect of undermining but the same effect of foundation also has pre-stressing of foundation or creep or shrinkage of concrete. We can reinforce foundation or we can use the knowledge about sliding joints to solution these effects. Sliding joint is applied between foundation and concrete base layer and it is created from asphalt belt or another material which can help to reduce shear stress on the contact surfaces between foundation and subsoil. Today a lot of new materials exist which can be used for reducing shear stress in foundations. Different types of asphalt belts or other modern materials are tested at the Faculty of Civil Engineering VSB TU Ostrava at different loads and at different temperatures. The effect of ambient temperature is monitored to better description of temperature dependency of all materials. Long-term goal of this research is to simplify process of design buildings with sliding joint and to help designer with right choice of the most advantageous material. The results and conclusion from the test are presented in this paper.

***Keywords*—**Sliding joint, asphalt belt, foundation structures, footing bottom

I. Introduction

PROBLEMS with structures on undermined areas are very often solved in our region. We have several options how these problems can be solved. For example we can use the option of house pre-stressing (Figure 1a) or we can use the knowledge about sliding joint (Figure 1b). But the cheapest and the most effective solutions are often those which we apply beforehand. One of the options is to apply sliding joint into foundation structures. This paper is focused on the method of reducing shear stress using sliding joint.

The original method of using rheological sliding joint is from the 80^{th} and it is based on old oxidized asphalt belts which were in that time available. These belts were chosen because they show viscoelastic behavior. It occurs to slowly viscous flow under shear loading. Because of provide functionality it is needed to create sliding joint from the most advanced material which is available on market. The today´s market is very different than in time of formation of old method. This is the purpose why there are the new modern materials tested.

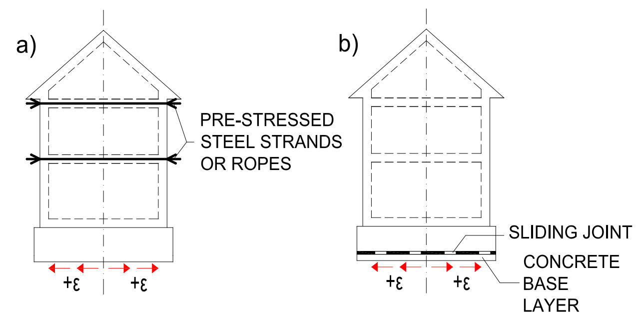

Fig. 1 Possible options to solution of horizontal deformation

II. The Basic Principle of Sliding Joint

On the undermined areas are settlement trough created (Figure 2). If the building is placed on undermined area, horizontal deformations can arise, which cause shear stress in the foundation (Figure 3a). If we create sliding joint between foundation and subsoil (Figure 3b), we can reduce this shear

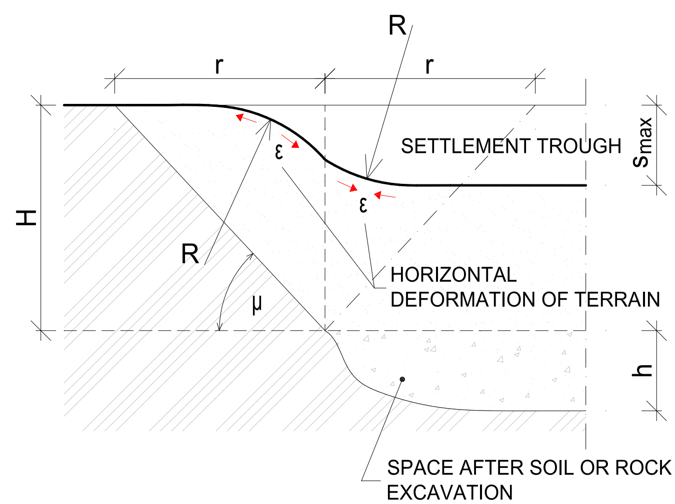

Fig. 2 Settlement trough

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stress very efficiently. Main purpose of sliding joint is to transfer shear stress so that the foundation itself would be loaded minimally.

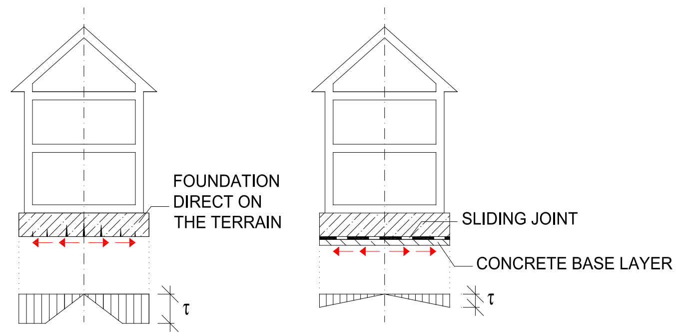

Fig. 3 The basic principle of sliding joint

III. Materials to Create Sliding Joint

To create sliding joint are often used asphalt belts because of their viscoelasticity properties. It was discovered there is a viscous flow in asphalt belts if they are loaded with slow horizontal load [1]. It is advanced for reducing of shear stress in the foundations because the stresses from horizontal deformations are transferred in the sliding joint.

But there are two basic categories of materials. The first category is set of materials based on asphalt - oxidized and modified asphalt belts. The old method of using rheological sliding joint is based on oxidized asphalt belts. The newer modified asphalt belts have better durability and strength than the oxidized belts but it has not have important for its function as material to create of sliding joint. The second category of materials is set of new modern foils which have for water insulation significantly better properties than older asphalt belts.

But the question is if the new modern materials are advantageous or disadvantageous to reduce shear stress in footing bottom in the comparison with asphalt belts. The basic difference between these two categories of material is

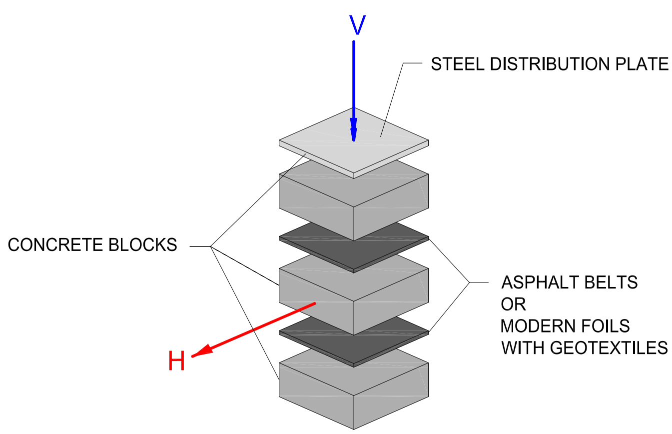

Fig. 4 The test sample

in behavior of material by shear loading. In the case of asphalt belt there is a viscous flow and in the case of new modern foils behavior of sliding joint is dependent mainly on coefficient of friction on the contact surfaces.

Different types of materials are tested at the Faculty of Civil Engineering in Ostrava because there is a lot of material with different properties. There is a lot of effect which can influence the behavior of sliding joint material. These include vertical and horizontal load, thickness and chemical composition of materials and the ambient temperature too. The modification of asphalt belts is very important factor too.

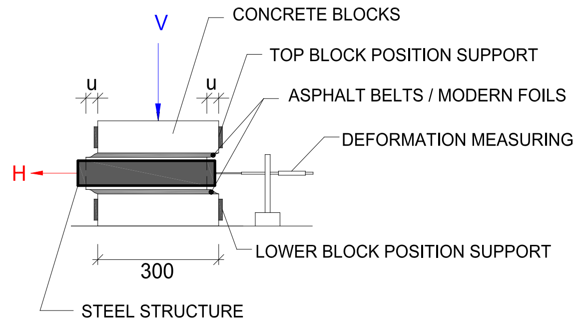

Fig. 5 The basic principle of the test

IV. Laboratory Tests

The aim of these tests is to simulate behavior of concrete structure with sliding joint. The test sample is on Figure 4 and

Fig. 6 The steel test equipment

it consists from three concrete blocks with two sliding joints.

These sliding joints are filled with test material (most often loosely placed asphalt belt or loosely place PE or PVC

Fig. 7 Air-conditioned room

insulation foil with two geotextiles). The scheme of loading and placing of the test sample is on the Figure 5. A steel structure is used for introducing vertical and horizontal load which is shown in Figure 6.

The vertical load is carried out using a hydraulic press through a steel load distribution plate and the horizontal load is carried out using a basket with weights, which is attached to the middle concrete block. The top and lower blocks are firmly fixed (Figure 5).

Table I Load combination

Combination	Vertical load [kPa]	Horizontal load [kPa]
1	500	5,28
2	500	11,1
3	100	5,28
4	100	11,1

Figure 6 shows the test equipment and Figure 7 shows the air-conditioned room where the test equipment is placed during whole test. An air-conditioned room was constructed due to the impact of the influence of ambient temperature and the steel test equipment was placed into this room. More information on the test can be found in [2, 3, 4, 5 and 6].

The tests are very time consuming because one test takes one week. If only two temperatures, two vertical forces and two horizontal forces (Table 1) are tested, it takes two months for one type of asphalt belt. If it is needed to test more temperatures or more sizes of load, it takes more time.

The test has two parts. In the first part the test sample is loaded with vertical load and after 24 hour it is introduced horizontal load on the middle concrete block. The entire test take 7days when is reached the steady deformation rate. During whole test it is monitored deformation of the middle block.

V. RESULTS FROM THE TESTS

A. Materials based on asphalt

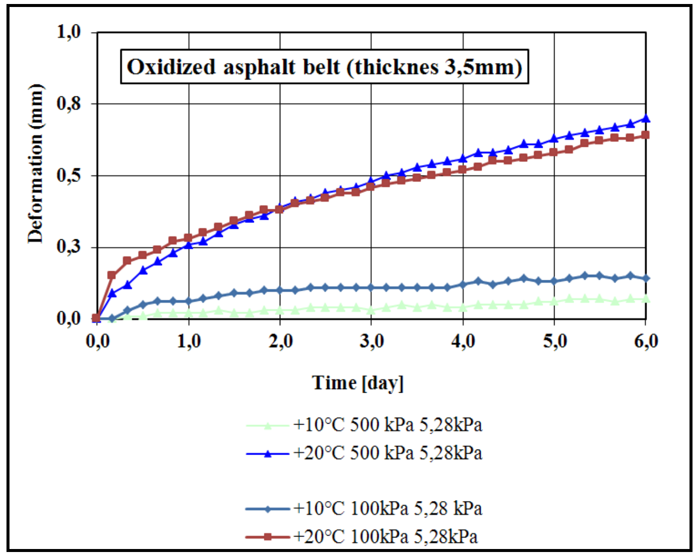

Fig. 8 Horizontal deformation for one set of measurements of deformations for oxidized asphalt belts

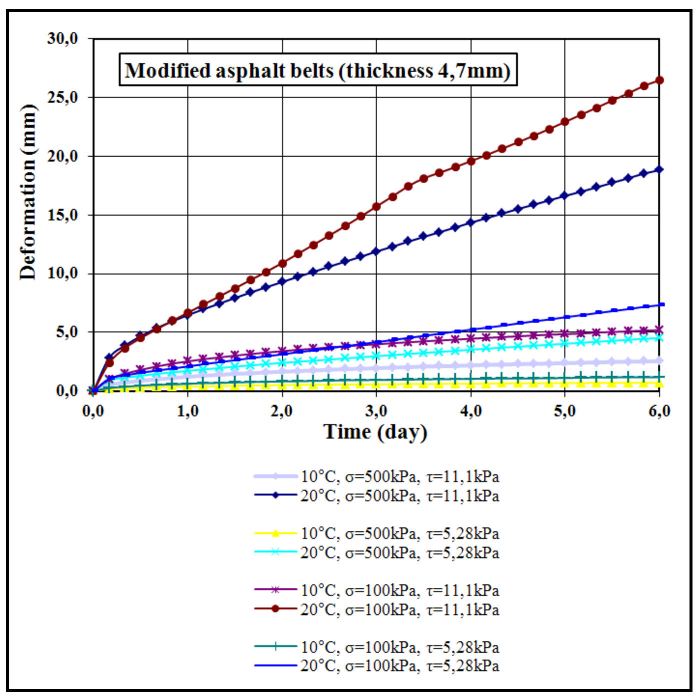

Fig. 9 Horizontal deformation for one set of measurements of deformations for modified asphalt belts

Asphalt belts often show behavior as viscoelastic substance. On the beginning of the loading there is the faster response to load and then gradually slows.

The tests also show that at higher temperature deformations are greater and vice versa. It is clear from Figure 8 and Figure 9, which shows horizontal deformation of the middle block of the test sample during the test at different temperatures.

Rheological properties of asphalt are evinced as a consequence of change of ambient temperature. There is a change of consistency of the asphalt belt from rigid to fluid. The deformation increases with increasing temperature. The graph on the Figure 10 compares deformation dependent on temperature at the end of test. It is clear that the dependency resulting deformations on temperature has an exponential character. This knowledge is very useful for this sliding joint where we can manage temperature. This allows better use of the sliding joint method for shear stress decreasing.

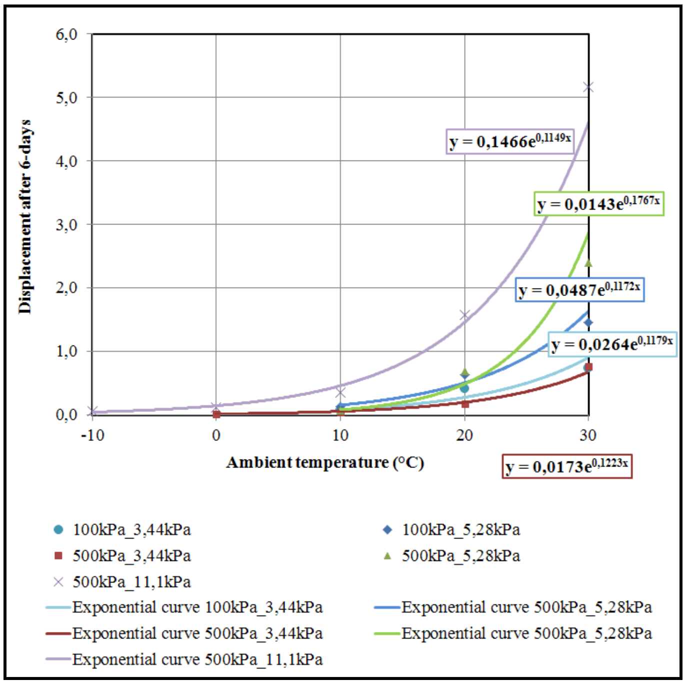

Fig. 10 Horizontal deformation for one set of measurements of deformations for modified asphalt belts

Other dependencies are calculated from the test results [7, 8, 9, 10] and it is made effort to use the gained knowledge to correct design of concrete structures.

B. New modern materials

Graphs on Figures 11 and 12 show total horizontal deformation on the middle concrete block during the test for different load combination. In the graphs are presented some result for oxidized belts, modified belts and for modern thin PVC foil with the thickness of 1,5mm.

It is necessary to remark that higher deformation means that the material is more pliant and a smaller shear resistance rise in the sliding joint. Then smaller deformation means higher shear resistance. It is clear from the graphs that a type of material plays a significant role. Generally the asphalt belts shows higher deformation than modern PVC foil and it means that classical asphalt belts exhibit smaller shear resistance in sliding joint as PVC foil. Another important fact is that properties of asphalt belts are strongly-dependent on temperature but properties of PVC foils are not.

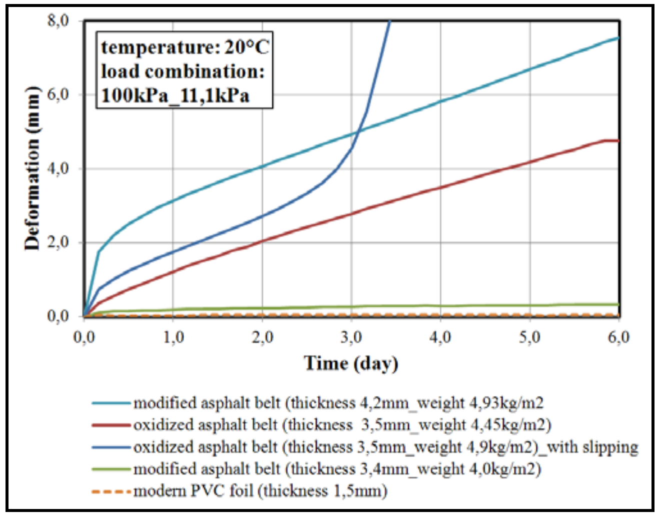

Fig. 11 Horizontal deformation for one set of measurements of deformations for asphalt belts and PVC foil

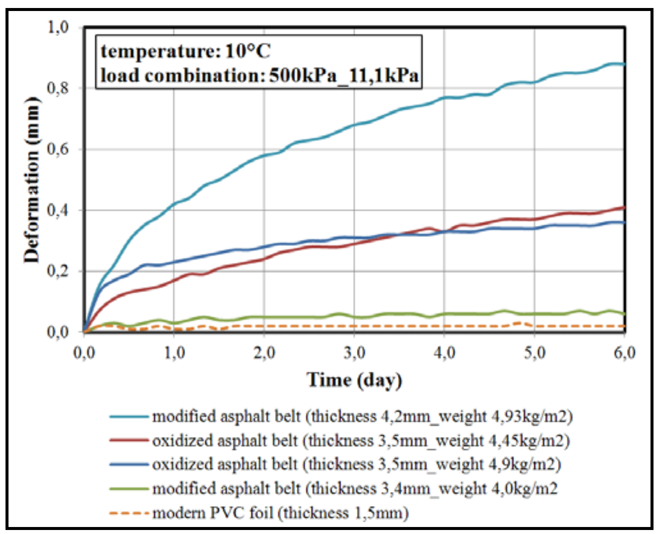

Fig. 12 Horizontal deformation for one set of measurements of deformations for modified asphalt belts

VI. DESIGN OF CONCRETE FOUNDATION STRUCTURES

Correct design is important for the concrete structures especially for the foundations on the undermined areas. The problem is to calculate shear stress in the foundation with sliding joint. The old method from the 80th exists but this method does not include all the asphalt belt properties.

The equation for calculate shear stress is:

$$\tau = (1{,}5 - 0{,}1 \cdot \Delta T) \cdot 10^9 \cdot v_u + 1{,}5$$

τ shear stress in the foundation bottom

v_u speed of deformation in the subsoil

This formula does not include composition of asphalt belt neither its modification nor its thickness. There is stated only minimum of thickness and weight of asphalt belts in the standard. It is too little because a lot of different materials exist on the market.

Another think is that this equation is valid only for asphalt belts and this formula is not usable for modern PVC or PE foils.

It would be appropriate to extend this formula to other characteristic of asphalt belts.

Another option is numerical modeling using finite element method and rheological material models which can be used to modeling asphalt layer behavior. For example viscoelastic material models can be used. Viscoelastic material model can be modeled in some software using nonlinear materials models. The knowledge of changes of material properties during loading is needed to create nonlinear material model. These changes of material properties (modulus of elasticity etc.) can be calculated from test results.

Models with using contact elements and friction coefficient can be used for new foils because there is behavior of material dependent mainly on friction coefficient and not on deformation of materials. This models can be also used for asphalt belts as simplification due to dimensional ratio of the sliding joint and whole structure (the thickness is negligible in proportion of structure size). More information about modeling using viscoelastic material models or contact elements can be found in [11-19].

VII. CONCLUSION

It was described the function of sliding joint and the advantages of its using. There were introduced basic materials to create sliding joint and also their behavior at the different type of input parameters.

The current results show that behavior of asphalt belt has viscoelastic character and that the behavior of asphalt belt is very dependent on ambient temperature. We can say that deformations are greater at higher temperature and vice versa. It is also clear that the dependency on temperature has exponential character. This knowledge is a very important finding for prediction of behavior of asphalt belt at a known temperature. Temperature management can help to use a sliding joint for higher loads because the higher pliancy of asphalt belt helps with reduction of shear stress in the sliding joint. This finding is also very important for masonry or concrete structures because this sliding joint can be used to reduce shear stress under a masonry or concrete structure by its pre-stressing if they need it to increase their service life. It offers us new options with research work with influence of temperature. If we would manage the temperature in the sliding joint, we can also manage the deformation and then shear stress can be managed too. It can be used if we assumed that the horizontal load will be greater.

Tests also show that the total deformations and also analogical shear response are dependent on thickness and type of material in sliding joint. Last but not least the currently test show that modern thin foils exhibit higher shear resistance and that means that they are not as advantageous to create sliding joint as classic asphalt belts. Another important fact is that properties of asphalt belts are strongly-dependent on temperature but properties of PVC foils are not. Temperature dependency is useful for sliding joint where we can influence shear response with help of temperature control.

But it is necessary to verify these assumptions with other tests with different types of materials.

The correct design of concrete structures is separate chapter and it will be solved further too. We have several options to solve this problem and it will take long time with regard to need to know their long-term behavior of asphalt belts as sliding joint in the concrete structures.

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REFERENCES

[1] V. Balcarek, J. Bradac, Utilization of bitumen insulating stripes as sliding joints for buildings on undermined area, Civil Engineering, 1982, in Czech

[2] R. Cajka, P. Mateckova, M. Janulikova, M. Stara, K. Burkovič, Time and temperature dependant behaviour of bituminous slide joints. In Global Thinking in Structural Engineering: Recent Achievements, Sharm El Sheikh, Egypt: International Assotiation for Bridge and Structural Engineeering (IABSE), 2012

[3] R. Cajka, Determination of Friction Parameters for Soil – Structure Interaction Tasks. Recent Researches in Environmental & Geological Sciences. Energy, Environmental and Structural Engineering, Series No. 4, Proceedings of the 7th WSEAS International Conference on Continuum Mechanics (CM ´12). Kos Island, Greece, July 14-17, 2012

[4] M. Janulikova, M. Stara, Numerical modeling of foundation structures with sliding joints. In The 9th fib International PhD Symposium in Civil Engineering. Karlsruhe, Germany: Karlsruhe Institute of Technology (KIT), 2012

[5] R. Cajka, M. Janulikova, P. Mateckova, M. Stara, Laboratory Testing of Asphalt Belts with the Influence of Temperature. Transactions of the VŠB – Technical University of Ostrava, Civil Engineering Series. Volume 11, Issue 2, Pages 1–6, ISSN (Online) 1804-4824, ISSN (Print) 1213-1962, DOI: 10.2478/v10160-011-0020-0, December 2011

[6] M. Janulikova, R. Cajka, P. Mateckova, V. Buchta, Laboratory Testing of Asphalt Belts Rheological Properties Exposed to Shear Loads. Transactions of the VŠB – Technical University of Ostrava, Civil Engineering Series. Volume 12, Issue 2, Pages 59–66, ISSN (Online) 1804-4824, ISSN (Print) 1213-1962, DOI: 10.2478/v10160-012-0018-2, January 2013

[7] R. Cajka, Horizontal Friction Parameters in Soil – Structure Interaction Tasks. Advanced Materials Research, Vol. 818 (2013), pp 197-205, Trans Tech Publications, Switzerland, DOI:10.4028/www.scientific.net/AMR.818.197

[8] R. Cajka, K. Burkovic, V. Buchta, Foundation Slab in Interaction with Subsoil. Advanced Materials Research, Vols. 838-841, (2014), pp 375-

380, Trans Tech Publications, Switzerland, DOI:10.4028/www.scientific.net/AMR.838-841.375

[9] R. Cajka, P. Mateckova, (2011) Temperature Distribution of Slide Joint in Reinforced Concrete Foundation Structures. 17th International Conference on Engineering Mechanics 2011, Svratka, May 09-12, 2011. Engineering Mechanics 2011, pp. 95-98, ISBN 978-80-87012-33-8, WOS: 000313492700017

[10] R. Cajka, Analysis of Stress in Half-space using Jacobian of Transformation and Gauss Numerical Integration. Advanced Materials Research, Vol. 818 (2013), pp 178-186, Trans Tech Publications, Switzerland, DOI:10.4028/www.scientific.net/AMR.818.178

[11] M. Janulikova, R. Cajka, P. Mateckova, M. Stara, Modeling of foundation structures with sliding joint using results of asphalt belts laboratory tests. Transactions of the VŠB – Technical University of Ostrava, Civil Engineering Series. Volume 12, Issue 1, Pages 1–7, ISSN (Online) 1804-4824, ISSN (Print) 1213-1962, DOI: 10.2478/v10160-012-0002-x, June 2012

[12] R. Cajka, M. Janulikova, P. Mateckova, M. Stara, Modelling of Foundation Structures with Slide Joints of Temperature Dependant Characteristics. In B.H.V. Topping, Y. Tsompanakis, (Editors), "Proceedings of the Thirteenth International Conference on Civil, Structural and Environmental Engineering Computing", Civil-Comp Press, Stirlingshire, UK, 2011

[13] Z. Boukria, and A. Limam, "Experimental Damage Analysis of Concrete Structures Using the Vibration Signature - Part I: Diffuse Damage (Porosity)", International journal of mechanics, 2012, ISSN: 1998-4448

[14] Z. Boukria, and A. Limam, "Experimental Damage Analysis of Concrete Structures Using the Vibration Signature - Part II: Located Damage (Crack)", International journal of mechanics, 2012, ISSN: 1998-4448

[15] D. Guida, F. Nilvetti, C. M. Pappalardo, Instability Induced by Dry Friction, International journal of mechanics, 2009, ISSN: 1998-4448

[16] Stella B. Bondi, Steven J. Makonis, Jr., Zia Razzaq, Resit Unal; Minimizing Uncertainty of Selected Composite Materials Using Various Mathematical Approaches, International journal of mechanics, 2013, ISSN: 1998-4448

[17] O. Sucharda, J. Brozovsky, Bearing Capacity Analysis of Reinforced Concrete Beams, International journal of mechanics, 2013, ISSN: 1998-4448

[18] M. Krejsa, R. Cajka, The foundation slab monitoring of the "National Supercomputing Center - IT4 Innovations" during construction. 11th International Probabilistic Workshop 2013 (IPW11), Brno, Czech Republic, November 6-8, 2013. ISBN 978-80-214-4800-1

[19] R. Cajka, Accuracy of Stress Analysis Using Numerical Integration of Elastic Half-Space (2013), Applied Mechanics and Materials, 300-301, pp. 1127-1135. Trans Tech Publications, Switzerland, ISSN: 16609336, ISBN: 978-303785651-2, DOI: 10.4028/www.scientific.net/AMM.300-301.1127