Analysis of model foundation slab focused on strain gauge measurement

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Abstract: - Interaction analysis between foundation structure and subsoil and related assessment of stress in the subsoil and internal forces in foundation structure are discussed in research conferences and scientific journals in the long term. Since 2012 research team at Faculty of civil engineering VSB - TU Ostrava has tested a few slabs with dimensions 2 x 2 m with thickness from 0.12 to 0.2 m. Complex testing comprises measurement of slab deformations, stress in the subsoil and measurement of stress in foundation slab using strain gauges. Slabs were made of plain concrete, reinforced concrete, pre-stressed concrete and fibre concrete. In the paper there are particular test results of stress measured in the foundation structure made of fibre concrete using strain gauges. Measured stresses are compared with stresses calculated using simplified soil-structure interaction model.

Key-Words: - soil-structure interaction, strain gauges, foundation, fibre concrete

1 Introduction

Long term research at Faculty of Civil Engineering VSB - TU Ostrava is focused also on buildings at undermined area. Analysis of soil structure interaction is an integral part of this research, both in the experimental field and in the consecutive mathematical modelling [2, 3, 6, 7].

On the yard of the Faculty of Civil Engineering, VSB -TU Ostrava testing devise was built up for testing of simple model foundation structures and related soil structure interaction [1, 4, 5].

It is possible to analyse experimentally foundations up to dimensions 2.0 m x 2.0 m. Mechanical load is applied using a hydraulic press which is placed between the tested slab and special steel frame structure, Fig. 1. Limit value of mechanical load is 1000 kN.

Complex testing comprises measurement of slab deformations in regular net of points, stress in the subsoil and measurement of stress in foundation slab using strain gauges [10. 11].

Since 2012 research team at Faculty of civil engineering VSB - TU Ostrava has tested a few slabs made of plain concrete, reinforced concrete, pre-stressed concrete and fibre concrete.

In the future it is planned to use the testing equipment also for applying the horizontal load for the analysis of the shear stress in footing bottom, eventually also with applied asphalt belt with function of sliding joint [8, 9].

Fig. 1: Testing devise – steel frame structure

2 Experiment description

2.1 Sample foundation slab

In this paper experiment results are presented which were measured with strain gauges in slabs made of fibre concrete. The slabs with dimensions 2 x 2 m with thickness 200 mm are made concrete with the same composition but different amount of wires. Slab S01 is made of fibre concrete with amount of wires 25 kg.m^{-3}, slab S02 with amount of wires 50 kg.m^{-3} and slab S03 with amount of wires 75 kg.m^{-3}. Concrete is imported with concrete mixers. It is then poured into shuttering to the desired height and compacted properly, Fig. 2.

2.2 Application of mechanical load

Mechanical load is applied in the middle of the foundation slab through the steel plates with dimensions 400 x 400 mm. Strutting to the steel structure is provided with specially designed steel blocks which are fastened with clips to the steel structure, Fig. 3.

Foundation slab is loaded in steps. Desired value of mechanical load is applied and ongoing deformations are measured for 30 minutes. After time delay next mechanical load is applied. Those steps are repeated until the load bearing capacity of foundation structure is exhausted up to limit load value.

Fig. 2: Concreting of tested foundation slab

Fig. 3: Application of mechanical load

2.3 Strain gauges

Strain gauges are placed on the plastic strips spacer to fix the position during concreting in the height 15 mm from footing bottom. Location of strain gauges is in the Fig. 4.

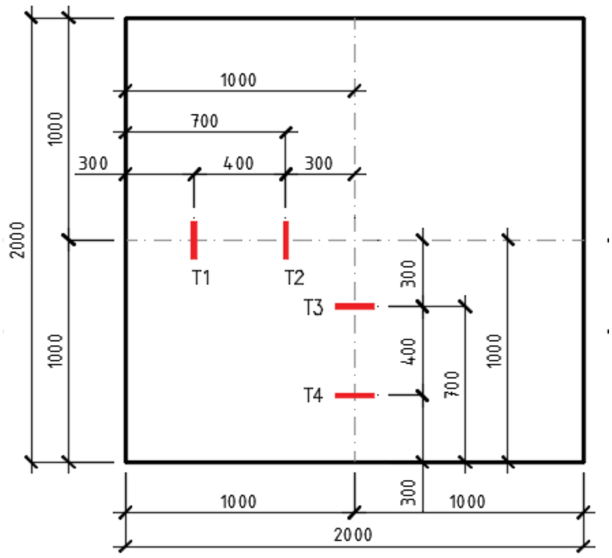

Fig. 4: Scheme of strain gauges position

2.4 Measured values

In the Fig.5 there are values of stress settled using strain gauges T1 and T4 in the slab S 01. Stresses are presented as a function of vertical mechanical load, throughout all the testing. In the chart there is distinct point of crack generation. After crack generation the stress measured by strain gauges grows sharply. In the following charts, Figs. 6-11 the test result are presented for the load before crack generation up to the load approximately 150 kN. In the Figs. 6 – 7 there are charts with stresses measured in slab S01 as a function of mechanical load, in the Figs. 8 – 9 there are registered test results measured in the slab S02 and in The Figs. 10 – 11 there are test results measured in the slab S03.

Measured result load carrying capacity for vertical mechanical load is registered in the Table 1.

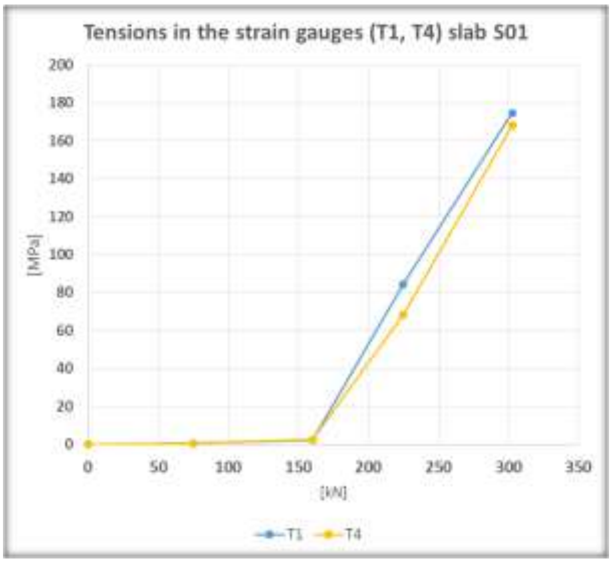

Fig.5: S01 - tensions in the strain gauges T1, T4

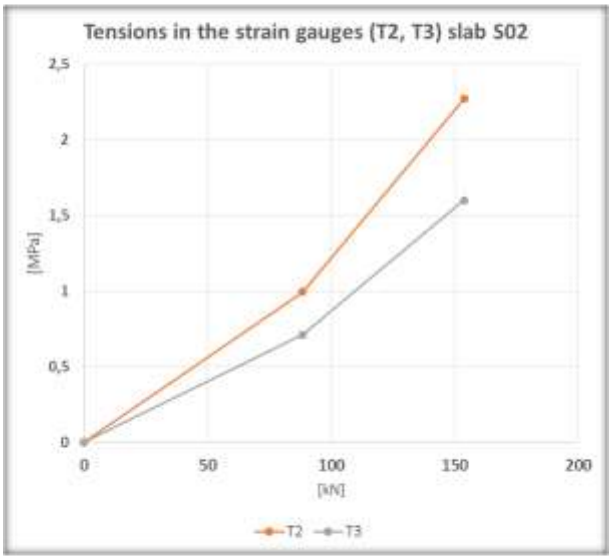

Fig.8: S02 - tensions in the strain gauges T2, T3

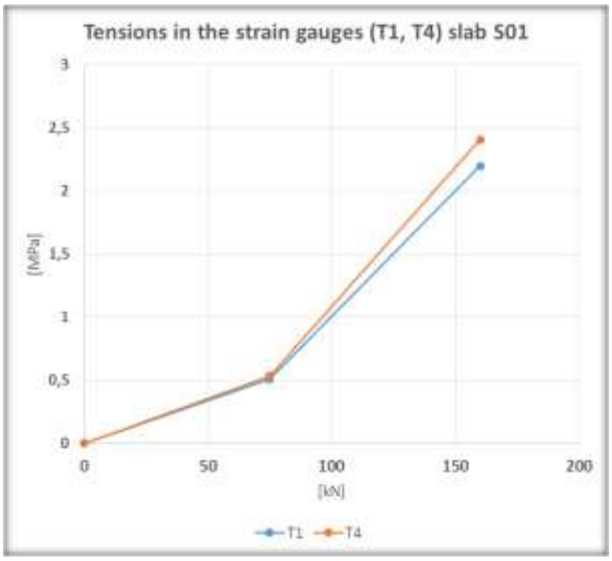

Fig.6: S01- tensions in the strain gauges T1, T4

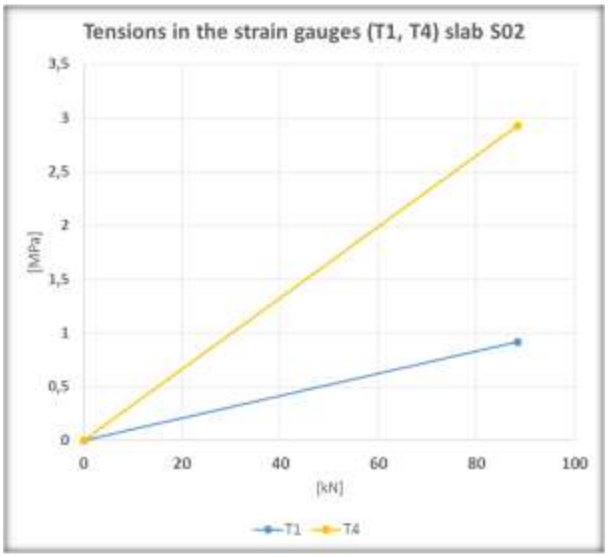

Fig.9: S02 - tensions in the strain gauges T1, T4

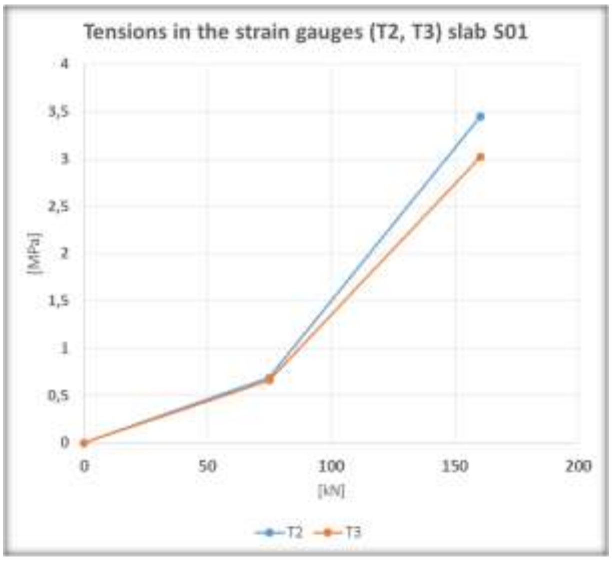

Fig.7: S01- tensions in the strain gauges T2, T3

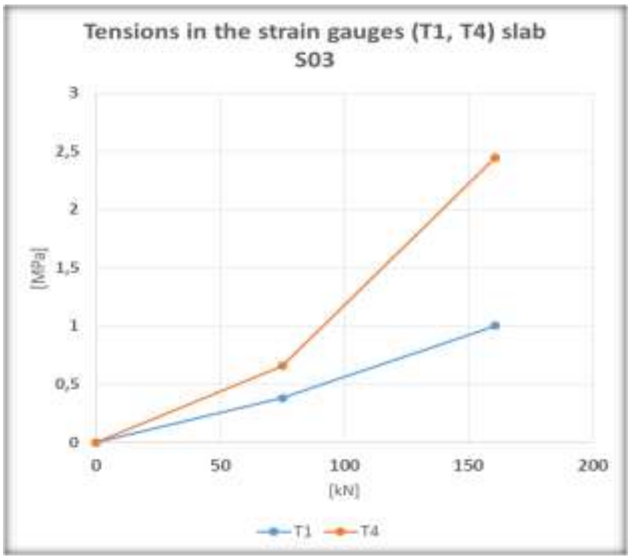

Fig.10: S03 - tensions in the strain gauges T1, T4

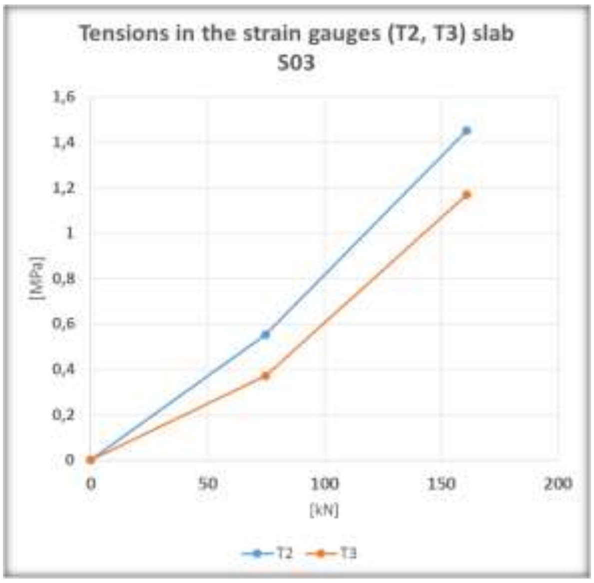

Fig.11: S03 - tensions in the strain gauges T2, T3

2.2 Measured values

Stress in the gauges T1, T4 are lower than stresses in gauges T2 and T3 responding to the simple model for foot foundation analysis.

At the value of vertical load approximately 150 kN stress in the strain gauges reached values of crack occurrence in all three slabs. The measured stress in this step is approximately 2 MPa - 3 MPa.

From this point, where the tensile strength of concrete is achieved, the tension in cross-section is transferred only with reinforcement wires in tension crack and test results are affected.

However, the data from gauges were registered up to the load about 300 kN. This value of vertical load leads to break of strain gauges and further data are not measured, Fig. 12.

Fig. 12: Damaged gauge after completing the test

Table 1: Ultimate vertical load

Slab	Amount of wires	Ultimate load
S01	25 $kg.m^{-3}$	371 kN
S02	50 $kg.m^{-3}$	525 kN
S03	75 $kg.m^{-3}$	642 kN

3 Numerical analysis

3.1 Simplified calculation

Tested slab was analysed as foot foundation. Vertical load is supposed to be spread as constant continuous stress in the subsoil. Maximal tension stress in the foundation as a function of coordinate is shown in the Fig. 14 for vertical load 75 kN and in the Fig. 16 for vertical load 150 kN.

3.2 FEM analysis

Tested slab was analysed also using software based on finite element method SCIA Engineer. Subsoil was supposed as one parametrical with stiffness 5 $MN.m^{-1}$. Value of vertical subsoil stiffness was determined with respect to experiment results so that the measured deformation in the middle of the foundation corresponds with calculated deformation. Tension in the foundation as a function of coordinate is shown in Fig. 13 for vertical load 75 kN and in the Fig. 15 for vertical load 150 kN.

3.3 Comparison of measured and calculated values

In Table 2 and Table 3 there are sequenced calculated and measured values of result stresses in particular slabs in locations of the strain gauges. Results are presented for first two steps of loading, i.e. 75 kN and 150 kN. Then, stress in all the strain gauges is influenced with crack occurrence and the results are affected.

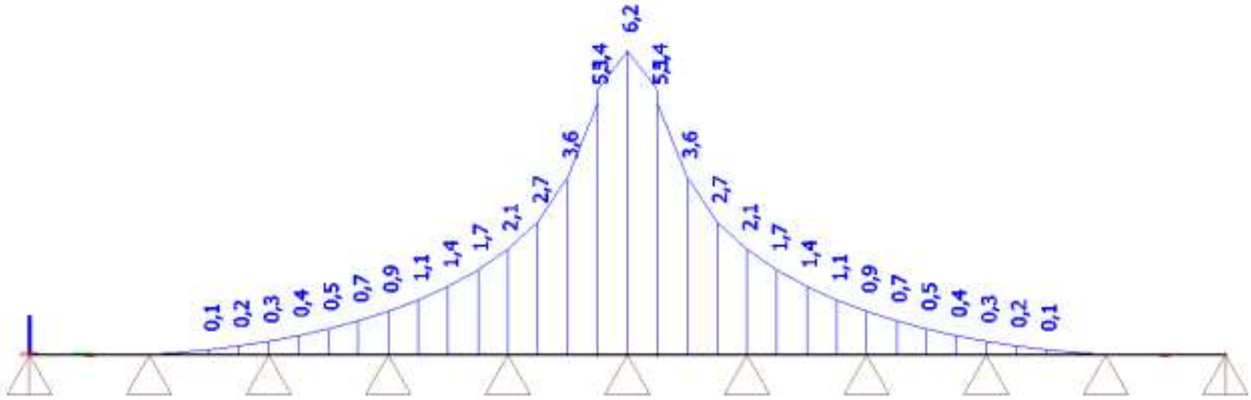

Fig. 13: Tension [MPa] in slab foundation by FEM analysis. Load of 75kN.

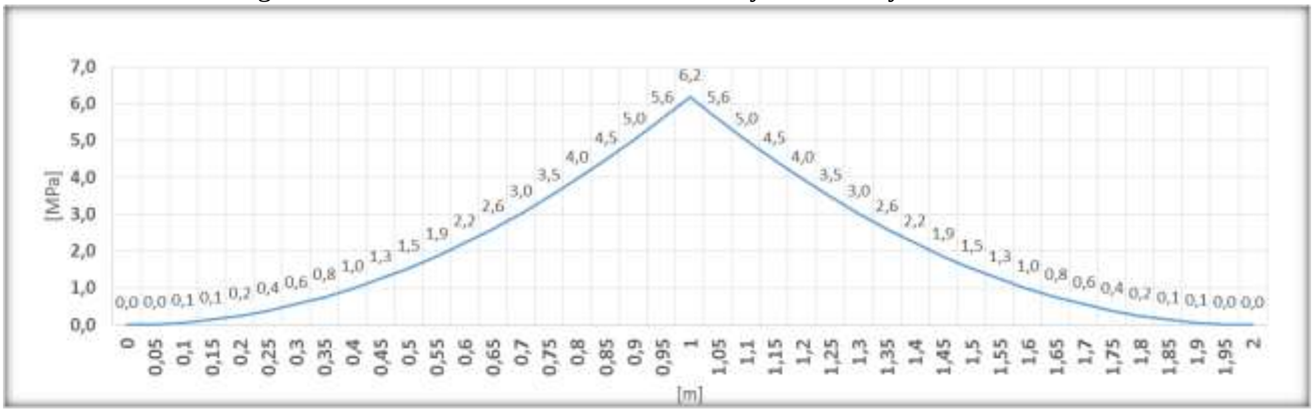

Fig. 14: Tension [MPa] in slab foundation by simplified calculation. Load of 75kN.

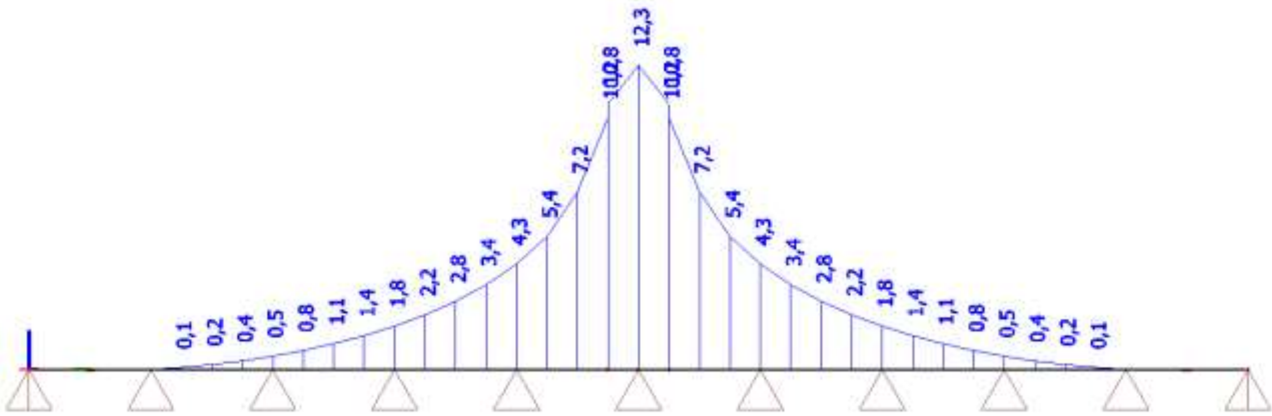

Fig. 15: Tension [MPa] in slab foundation by FEM analysis. Load of 150kN.

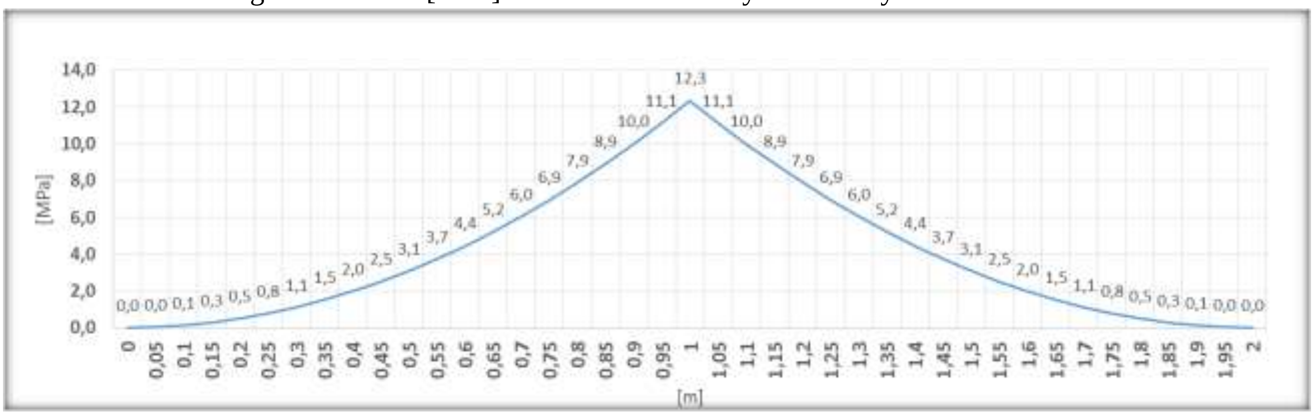

Fig. 16: Tension [MPa] in slab foundation by simplified calculation. Load of 150kN.

Table 2: Stress in the foundation, vertical load 75kN

Gauge number	T1 / T4	T2 / T3
	[MPa]	[MPa]
FEM analysis	0.10	1.40
Simplified calculation	0.56	3.02
Experimental test slab S01	0.51	3.02
Experimental test slab S02	0.91	0.96
Experimental test slab S03	0.38	0.45

Table 3: Stress in the foundation, vertical load 150kN

Gauge number	T1 / T4	T2 / T3
	[MPa]	[MPa]
FEM analysis	0.20	2.80
Simplified calculation	1.11	6.05
Experimental test slab S01	2.28	3.40
Experimental test slab S02	-	2.44
Experimental test slab S03	0.99	1.30

3.4 Discussion

There is difference between the tension stresses calculated in a simplified way and using FEM analysis. The difference is caused by concentration of load in the middle of the foundation in FEM analysis which is not possible to take into consideration in simplified calculation.

Comparing the calculated and measured values, in some cases the values are almost identical, e.g. simplified calculation and slab S01, load step 75 kN. In many cases the calculated tension responds with measurement roughly. Generally, for calculated values there is significantly higher difference between the tension in points close to the middle of the desk (T2,T3) and the tension in points close to the periphery (T1, T4) then in the measured values.

One of the reasons could be inaccurate model of subsoil or uneven origination of micro cracks in the foundation. Though the concrete compaction was done as carefully as possible there is still possibility of movement of the strain gauge during concreting.

4 Conclusion

In this paper testing of foundation slab exposed to vertical load is described. During the testing the foundation deformations, stress in the subsoil and tension in the cross-section were measured. Tension in the cross-section is measured using strain gauges.

In the paper there are measured values of tension in the bottom part foundation slab compared with values calculated using simplified model of subsoil and using FEM analysis. The measured and calculated values respond in a few cases, in many other respond only roughly.

For more accurate analysis it would be more favourable to use smaller load step in order to monitor the tension in the strain gauges in more steps. Relevant data can be obtained until the value of tensile strength is achieved. After exceeding this value the gauges are deformed in tensile cracks and the result values of tension are affected.

Besides refinement calculation there is factor of measurement inaccuracy, in extreme case affection of the gauge position during concreting.

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References:

[1] V. Buchta, M. Janulikova, R. Fojtik, *Experimental Tests of Reinforced Concrete Foundation Slab*, Procedia Engineering, 114, pp. 530-537, DOI: 10.1016/j.proeng.2015.08.102, 2015.

[2] R. Cajka, J. Labudkova, *Fibre Concrete Foundation Slab Experiment and FEM Analysis, Key Engineering Materials*, Vols. 627, pp 441-444, Trans Tech Publications, Switzerland, DOI:10.4028/www.scientific.net/KEM.627.441, 2015.

[3] J. Labudkova, R. Cajka, *Comparison of the Results from Analysis of Nonlinear Homogeneous and Nonlinear Inhomogeneous Half-Space*, Procedia Engineering, 114, pp. 522-529, DOI: 10.1016/j.proeng.2015.08.101, 2015.

[4] P. Mynarcik, *Measurement processes and destructive testing of fibre concrete foundation slab pattern*, Advanced Material Research, TTP, Switzerland, 1020, 221-226, ISSN (Online) 1662-8985, ISSN(Print) 1022-6680, DOI: 10.4028/www.scientific.net/AMR.1020.221, 2014.

[5] R. Cajka, V. Krivy, D. Sekanina, *Design and development of a testing device for experimental measurements of foundation slabs on the subsoil*, Transactions of the VŠB – Technical University of Ostrava, Civil Engineering Series, 11 (1), 1 - 5, ISSN (Online) 1804-4824, ISSN (Print) 1213-1962, DOI: 10.2478/v10160-011-0002-2, (2011)

[6] R. Cajka, J. Labudkova, P. Mynarcik, *Numerical solution of soil - foundation interaction and comparison of results with experimental measurements*, International Journal of GEOMATE, 11 (1), pp. 2116-2122, 2016.

[7] R. Cajka, J. Labudkova, *Finite element analyses of soil-foundation interaction and comparison with experimental measurements*, Civil-Comp Proceedings, 108, DOI:10.4203/ccp.108.7, 2015.

[8] M. Janulikova, *The New Options to Reduce Shear Stress into Foundation Structure, Procedia Engineering*, 114, pp. 514-521, DOI: 10.1016/j.proeng.2015.08.100, 2015.

[9] M. Janulikova, *Comparison of the shear resistance in the sliding joint between asphalt belts and modern PVC foils, Applied Mechanics and Materials*, 501-504, pp. 945-948, DOI: 10.4028/www.scientific.net/AMM.501-504.945, 2014.

[10] Cajka R., Burkovic K., Buchta V., *Foundation slab in interaction with subsoil, Advanced Materials Research*, Trans Tech Publications, Switzerland, 838-841, 375-380, ISSN (Online) 1662-8985, ISSN (Print) 1022-6680, DOI:10.4028/www.scientific.net/AMR.838-841.375, 2014.

[11] Mynarcik P., Labudkova J., Koktan J., *Experimental and numerical analysis of interaction between subsoil and post-tensioned slab-on-ground*, Jurnal Teknologi, 78, 23-27, (2016), ISSN 0127-9696, DOI: 10.11113/jt.v78.8530, 2016.