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# The Elastic Deformation of Soil Around Models of Rigid Slab and Raft

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Additional information is available at the end of the chapter

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## Abstract

Load tests and the results of the numeric modeling represent this chapter. Two kinds of foundation models were tested. Tests started during the year 2014 in the Faculty of Civil Engineering, VŠB–Technical University of Ostrava. Test equipment STAND, located in the campus of the Technical University, is primarily designed to test the interaction of the foundations and the subsoil. Presented are the data processed experimental measurement of the adjacent terrain around the foot and raft. The measured data will be verified by theoretical calculations using the MIDAS GTS based on the method of finite elements. Tests of several foundation constructions were carried out. The aim of this test was to verify the behavior of raft foundation by comparing to equivalent surface foundation and a pilot. Three types of foundation constructions were examined. Reinforced concrete foundation slab, raft foundation (made of reinforced concrete foundation slab supported by drilled reinforced concrete pilot), and a separate reinforced concrete drilled pilot. All these types of foundation constructions were constructed as models, in a reduced scale, approx. 1:10. The size had to be adjusted due to limited capacity of the testing device and financial reasons. The measurements were carried out by the STAND device in the area of VŠB-TU Ostrava. The values of load (vertical point force) and vertical deformations (subsidence) were measured with the individual tested models. Beside the main task, concerning the measuring of the behavior of the foundation constructions, there was also carried out measurement of the behavior of the adjacent terrain. The aim of this chapter is to compare the behavior of adjacent terrain near the model of rigid slab and the model of the raft. The measurement results are compared with the results of numerical modeling.

**Keywords:** slab-soil system, finite element method, settlement, measurement, foundation

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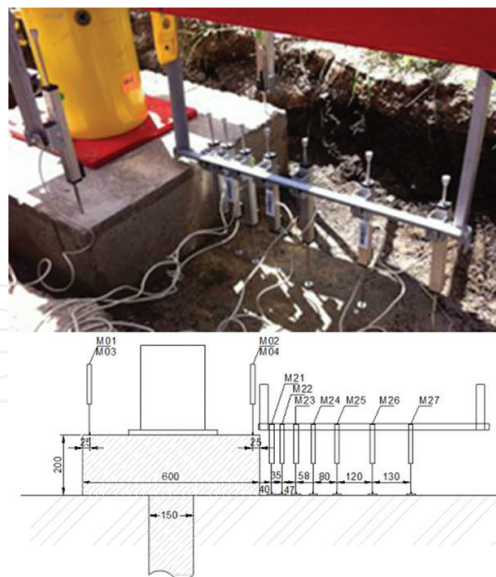
## 1. Measurement

STAND is a device (see **Figure 1**) which serves to research the interactions between the foundation constructions and the subsoil (Buchta et al., 2016; Cajka, 2014; Cajka et al., 2016a,b; Mynarcik et al., 2016). The loading equipment (hydraulic presses) can be freely anchored to the cross members. The position of the presses can be arbitrarily changed in the range of the ground area. The subsoil is a homogeneous clay with high plasticity and hard to firm consistency in the depth down to 5.0 m. All the measured models were subjected to a load test by vertical point force which was transmitted in the construction by steel boards of a hydraulic press. The load values (vertical point force) and vertical deformation (subsidence) of the individual tested models and foundation constructions were measured. Measurement of the raft was carried out in August 2014, and measurement of separate slab in July 2014. The hydraulic press was anchored by steel attachments and washers to the construction of the STAND. The beams for installation of the meters track were located on both sides of the press. Beams for installation of displacements sensors were supplemented by cross beams for adjacent terrain deformation measurements. For the measurement of the raft four displacement sensors were used, soil was measured by seven sensors (see **Figure 2**), to a distance of 600 mm.

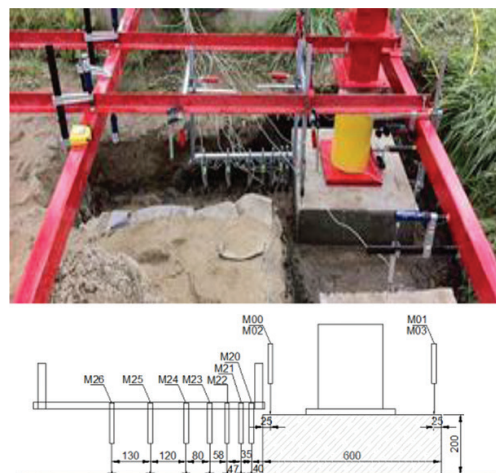


**Figure 1.** The STAND-measuring equipment.

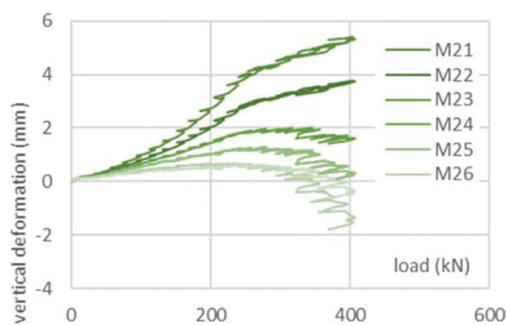
Four displacement sensors were used for the measurement of the slab; soil was measured by eight sensors. Seven sensors were placed to a distance of 600 mm. The last sensor was at a distance of 1.0 m from the foundation (see **Figure 3**). Cylinder pressure sensor and the displacement sensors were connected to the data bus. The measurements were carried out in 5-min cycles after 20 kN. The measurements were completed when there was a break of the plate and no more high pressure level in the hydraulic press could be achieved. After measuring the pressure in the press was released and creep of subsoil was measured. Deformation of the land around the raft (see **Figure 4**) and the slab (see **Figure 5**) are drawn in the following graphs. The graphs record the data of the individual sensors during the load tests. The graphs in **Figure 6** and **Figure 7** show pushing of the surrounding soil at the edges of the foundation, roughly up to 200–250 mm away (by raft) and roughly up to 100–150 mm away (by slab). Behind this line the soil is lifted by the push of the subsoil.



**Figure 2.** Raft model measurement with displacement sensors.



**Figure 3.** Slab model measurement with displacement sensors.



**Figure 4.** Load-deformation dependence of the raft.

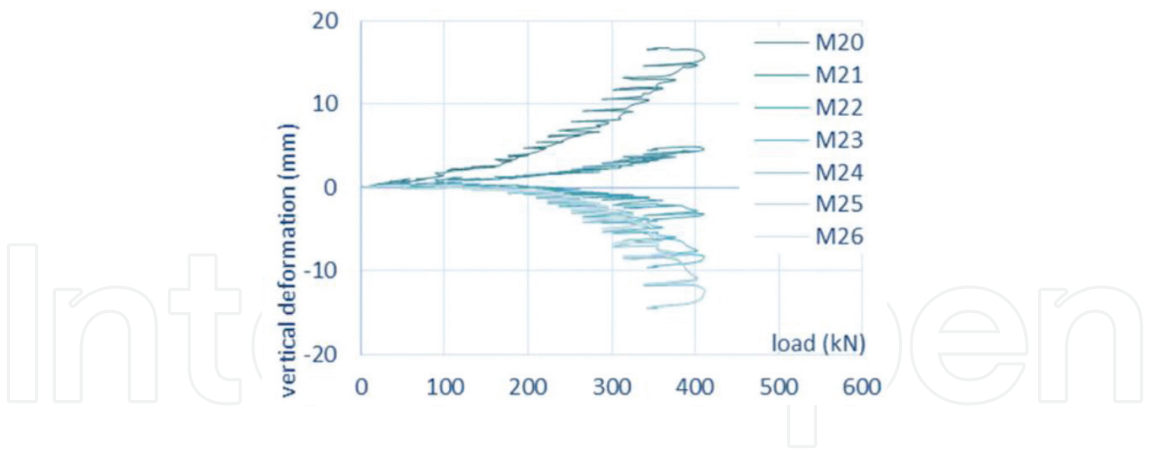


Figure 5. Load-deformation dependence of the slab.

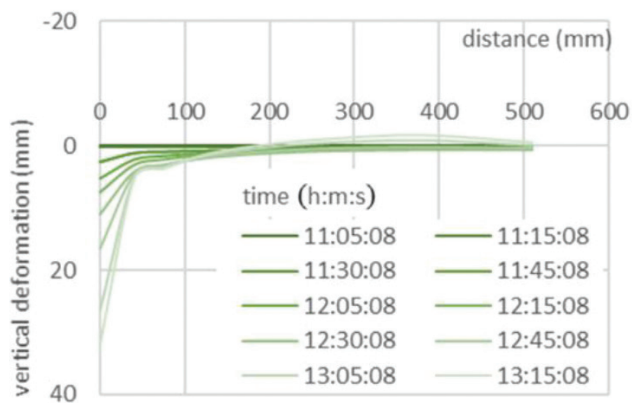


Figure 6. Deformation-time-distance-raft.

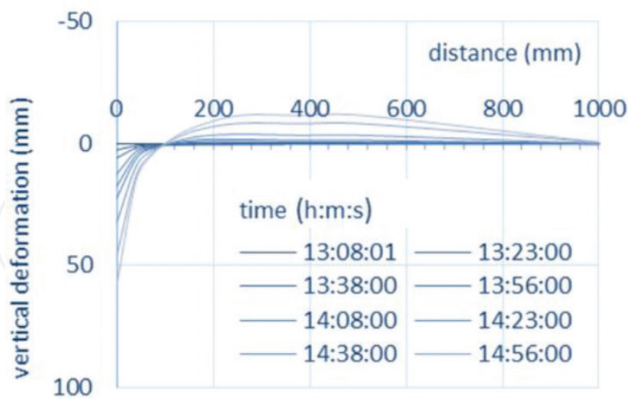


Figure 7. Deformation-time-distance-slab.

## 2. Mathematic modeling of the deformation of the terrain

The analysis of the behavior of the foundation slab and raft was carried out by the final element method, using software MIDAS GTS NX. A 3D model of the slab and the subsoil was made (Hrubesova et al., 2015). The model was used for the bedrock “Mohr-Coulomb,” which

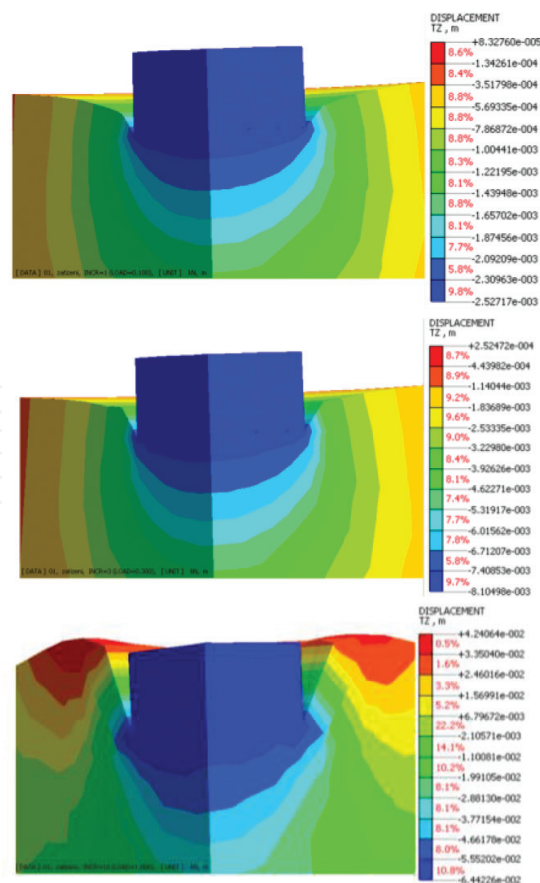


is usually used for analysis of the elastic behavior of the bedrock. The modulus of elasticity of concrete was considered at 27.0 GPa, and the compressive strength at 20 MPa. The point load entering the calculations corresponds with the force use data in the load test. It ranged equally from 0 to 400 kN. As the force was transmitted by the steel slab board measuring  $0.2 \times 0.2$  m, equal surface load rating from 0 to 10 MPa was used (Burkovic and Duris, 2015). The calculation was carried out excluding the influence of the groundwater.

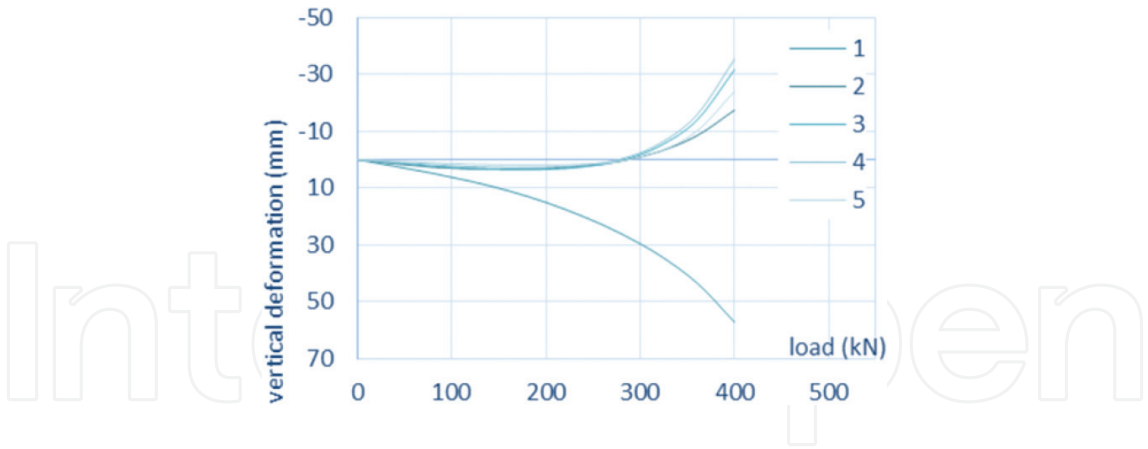
### 3. Slab foundation

Elastic behavior of the foundation slab material is assumed. The concrete slab and the subsoil were made by a hybrid network of final elements with automatically generated contact points between the slab and the subsoil. The calculation run in two phases (construction stage). In the first phase, the calculation of the weight of the slab itself and the subsoil was carried out and the deformations were then reset at zero.

The following phase of nonlinear analysis was carried out in 10 iteration steps. Clearly, schemes of vertical deformations of the terrain of separate iterative steps were received from the calculations in **Figure 8**. Graphs of deformations for comparison of the measured values were made from the adjacent points in **Figure 9**.



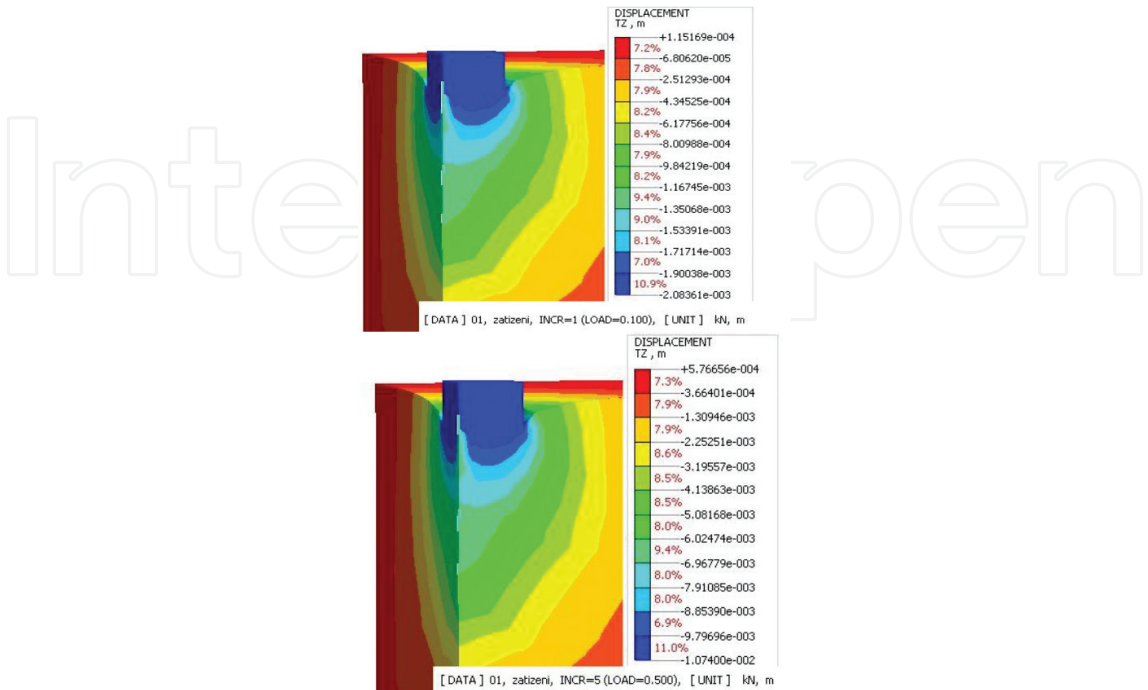
**Figure 8.** Deformation of the terrain—steps 1, 3, and 10.



**Figure 9.** Load-deformation dependence–slab.

**4. Raft foundation**

Feet and bedrock were made as the 3D element (box). The pilot was modeled as a 1D element (truss). The 3D element of the bedrock has been divided into a finite number of elements in the system (hybrid mesher). The material was used for shoe model of elastic behavior. The concrete was used for the pilot model of the behavior of an elastic material, which does not use with material nonlinearity (pile element) for defining the sheath of friction piles. The calculation took place in two stages (construction stage). The first phase was carried out with the calculation of the own weight of the shoe and the subsoil and deformation were subsequently cleared. The subsequent phase of nonlinear analysis was carried out in 10 iterative steps. Understandable schemes of vertical deformations of the terrain of separate iterative steps were received from the calculations in **Figure 10** and **Figure 11**. Graphs of deformations for comparison of the measured values were made from the adjacent points in **Figure 12**.



**Figure 10.** Deformation of the terrain–steps 1 and 5.

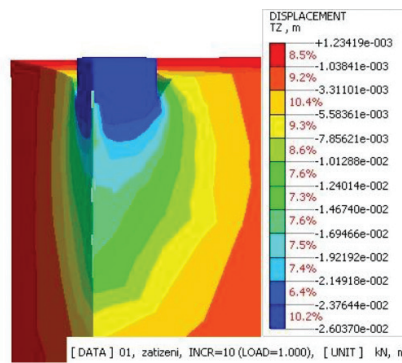


Figure 11. Deformation of the terrain-step 10.

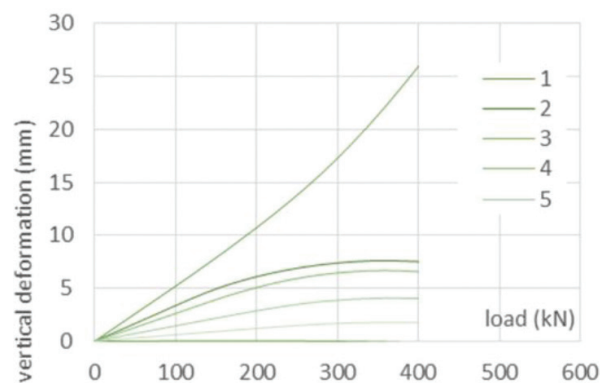


Figure 12. Load-deformation dependence-raft.

## 5. Comparison of measurements and conclusion

Understandable comparing graph was set from the data gained by the load test and the values gained from the calculations. You can compare the progress of the measured maximum values of adjacent terrain deformation. **Figure 13** shows recorded waveforms of the maximum deformation of adjacent terrain, slab, and raft. Furthermore, you can compare the values measured and calculated values of settlement adjacent terrain at the slab and raft in **Figure 14** and **Figure 15**.

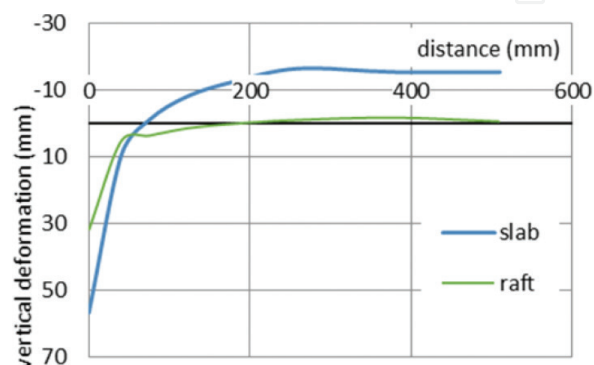


Figure 13. Maximum deformation of adjacent terrain.



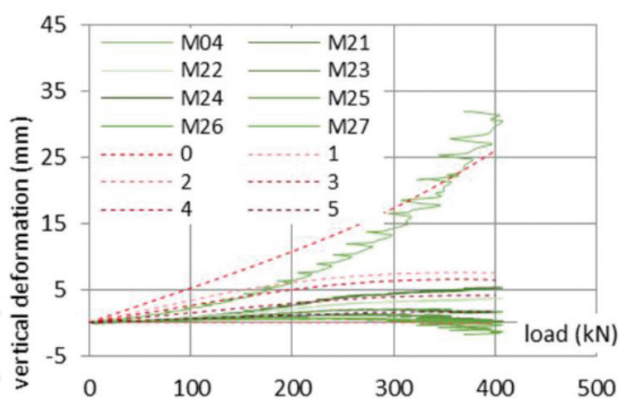


Figure 14. Comparison of results-slab.

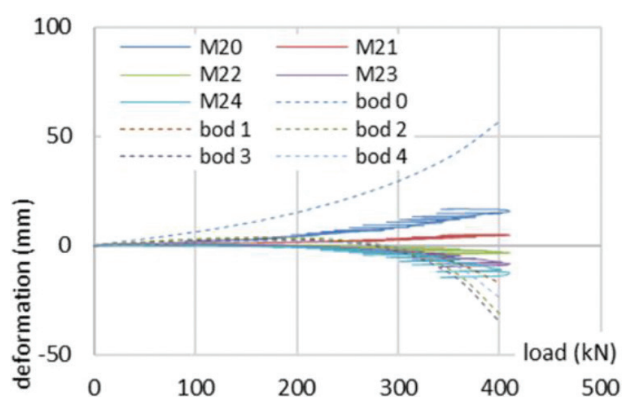


Figure 15. Comparison of results-raft (right).

These disproportions are caused by incorrect entering values as well as selected number of final elements and, above all, the behavior of the concrete foundation slab at the end of the experiment. The slab behaves in the calculation as a solid body.

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