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# EXPERIMENTAL MEASUREMENTS OF A MODEL OF PILE, SLAB AND RAFT FOUNDATION

**Abstract**

A design of the load-bearing capacity and settlement of a pilot base is usually based on the assumption that all of the load from the top of the building is transferred only by pilots. The influence of the adjacent connecting structures, which are in contact with the ground (pile cap, slab, block, belt, etc.), is usually ignored. The necessary data from the experimental measurement of the impact of these structures, concerning the overall bearing capacity of the foundations, was obtained on the test-load device (Stand), in the area of Faculty of Civil Engineering, VŠB-TU of Ostrava. The progress of the experiment and the results of the load tests are listed in this paper.

**Keywords**

Single pile, pile foundation, pile test, model pile, slab, base, piled raft foundations, load test, disconnected, stand.

## 1 INTRODUCTION

The aim of the experiment was to verify the behavior of a piled raft foundation by comparing with an equivalent slab base and pilots. Three types of foundations were examined: a drilled pilot, the slab on the subsoil and piled raft foundations consisting of the pilot and a slab of identical dimensions [1],[3],[4],[6],[10]. Measurements were carried out on models of reinforced concrete structures diminished roughly in a ratio of 1: 10. It was necessary to adapt the shape of the dimensions and capacity of the test Stand equipment [5].

## 2 EQUIPMENT STAND, CHARACTERISTICS

Equipment Stand [5], which has been built on the campus of the Faculty of Civil engineering, VSB-Technical University of Ostrava, is used to investigate the interaction between the base and the structure subsoil. It is also used for the purposes of geotechnical measurements. It is a steel frame built into the base strips. Bearing capacity of the foundations of the stand, including a hedge against pulling out is enhanced by a series of micro piles [5]. The basic structure was welded from steel profiles supplemented by two crossbars, whose position can be changed in the horizontal direction. 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 load capacity of this device is up to 1 000 kN.

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## 3 PREPARATION OF THE TEST SPECIMENS

Before the start of each specimen, the terrain under the test equipment was modified. The humus layer and cinder embankment was removed to solid ground. The subsoil is a homogeneous clay with high plasticity and hard to firm consistency.

### 3.1 Pilot

Pilot models were made in the morning on 15.3.2014, in sunny dry weather at a temperature of 10-12 °C. The pilots were made from concrete C16/20 X0, which was reinforced by inserting a threaded stainless steel rod. The pilot was made into the hole in the subsoil using gasoline earth auger/drill. The diameter of the bore hole was 150 mm, The length was given due to the possibilities of the drilling equipment and amounted to 850 mm.

Fig. 1: Implementation of pilot

### 3.2 Piled raft foundations

Piled raft foundations consisted of a single model of a concrete drilled piles associated with reinforced concrete slab. The slab was made over the existing pile with a diameter D = 150 mm, and the length h = 850 mm. Concrete C16/20 X0, reinforcing mash 6/100-6/100 was used.

Fig. 2: Realization of the concrete slab above the pile

### 3.3 Single base slab

The base slab was made from concrete C16/20 X0, the dimensions of 600x600x250 mm. Concreting was made into wooden shuttering on terrain. The slab was reinforced with reinforcing mash 6/100-6/100 mm at the bottom and the top of the surface. The mash was bent at the ends. The mixture was compacted by immersion vibrator.

Fig. 3: Realization of base slab

## 4 MEASUREMENT

All three elements were gradually subjected to a load test. The load and vertical deformation of the elements was measured. For the slab and Piled raft foundations also subsidence of the adjacent terrain was measured. At installation of the equipment and the involvement of the sensors, the experience of the preceding tests of baseboards [7], [8], [9] was used.

### 4.1 Measurement of single piles

The model of single pile was measured on 05.07.2014. With regard to the pushing on the head of piles, there were embedded steel washers. Subsequently, a hollow hydraulic press ENERPAC HOLL-OCILINDER, with manual pressurizing was installed and anchored to the attachment of the steel structure of the Stand. The sensor tracks were anchored to steel girders. Cylinder pressure and displacement sensors were connected to the bus ALMEMO 2590-4S V5. The measurements were done in cycles of 5 kN with a delay of 5 min between each loading cycle. The measurements were terminated as soon as the steel washers had reached the level of the surrounding terrain. After the end of the measurement, the pressure in the cylinder was released.

Figure 4: Measurement model of single pilot (with washers - left, measuring assembly - right)

### 4.2 Measurement of the piled raft foundations

The model of the piled raft foundations was measured on 15.7.2014. For the measurement the hydraulic press ENERPAC CLRG-2002 was used. The 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. Thus it was possible to measure the deformation of the foundation and adjacent terrain. Four displacement sensors were used for measuring of the settlement of foundation. The terrain was measured using eight sensors, located at a distance 600 mm from the foundation. All displacement sensor and the pressure sensor were connected to the data bus. The measurements were carried in five-minute cycles of 20 kN, and they took about 2 hours and 30 minutes and were terminated as soon as it was no longer possible to achieve the next level of pressure in the hydraulic cylinder. After the end of the measurements, the pressure in the cylinder was released. Subsequently the creep of subsoil was measured.

Fig. 5: Measurement on a model of the piled raft foundations
(overview, a detail measurement of adjacent terrain)

### 4.3 Measuring of separate slab

Measuring of the separate slab was made on 25 August 2014. The measurements were performed in a similar manner as the measurement of the piled raft foundations. We used hydraulic press ENERPAC CLRG-2002 anchored to Stand by steel adapters and washers. Beams for installation of displacements sensors were supplemented by cross beams for adjacent terrain deformation measurements. For the measurement of the slab four displacement sensors were used, soil was measured by eight sensors. Seven sensors were placed to a distance of 600 mm. The last sensor was distanced 1.0 m from the foundation. Cylinder pressure sensor and the displacement sensors were connected to the data bus. The measurements were carried out in five-minute cycles after 20 kN. The measurements were completed when there was a break of the plate (see Figure 6 on the right) 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. Measurements were carried out for 2 hours 25 minutes.

Figure 6: Measurement of model of slab (left – general view, right – the detail of terrain)

## 5 RESULTS OF MEASUREMENTS

The individual measurements produced data about the load models of foundations and their vertical deformation (settlement). The slab with a piled raft foundation provided extra data about the vertical surface deformation and adjacent terrain. From the datasets synoptic charts were compiled.

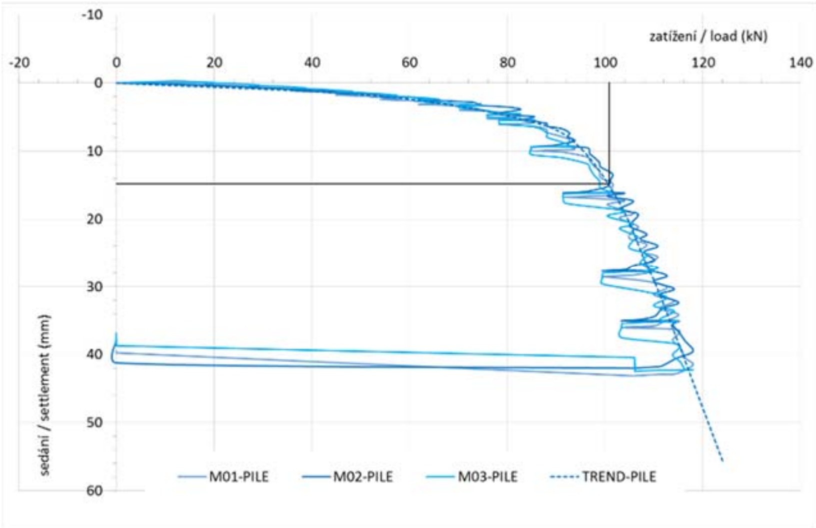


Figure 7: Results of measurements on the model of pile, load settlement addiction

As can be seen from the chart, the vertical load carrying capacity can be determined as $U_{def}$, for vertical deformation $s = 0{,}1.d$ (where d is the diameter of the piles, $\gamma_{fe} = 1{,}25$ to 1,3 is coefficient of operating conditions).

$$s = 0{,}1\ .\ d = 0{,}1\ .\ 150{,}0 = 15\ \text{mm};\ U_{ve} = 101{,}0\ \text{kN} \quad (1)$$

$$U_{def} = U_{ve} /\ \gamma_{fe} = 101{,}0 / 1{,}25 = 80{,}8\ \text{kN} \quad (2)$$

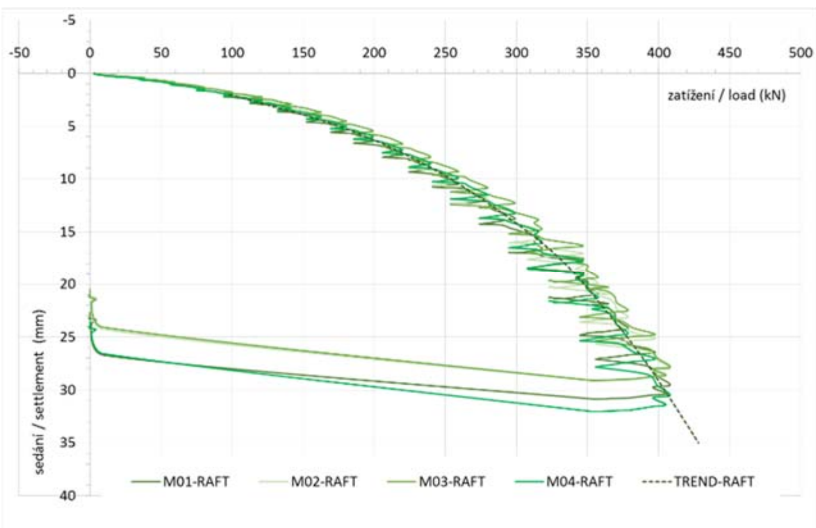


Figure 8: Results of measurement on the piled raft foundation model (load-settlement chart)

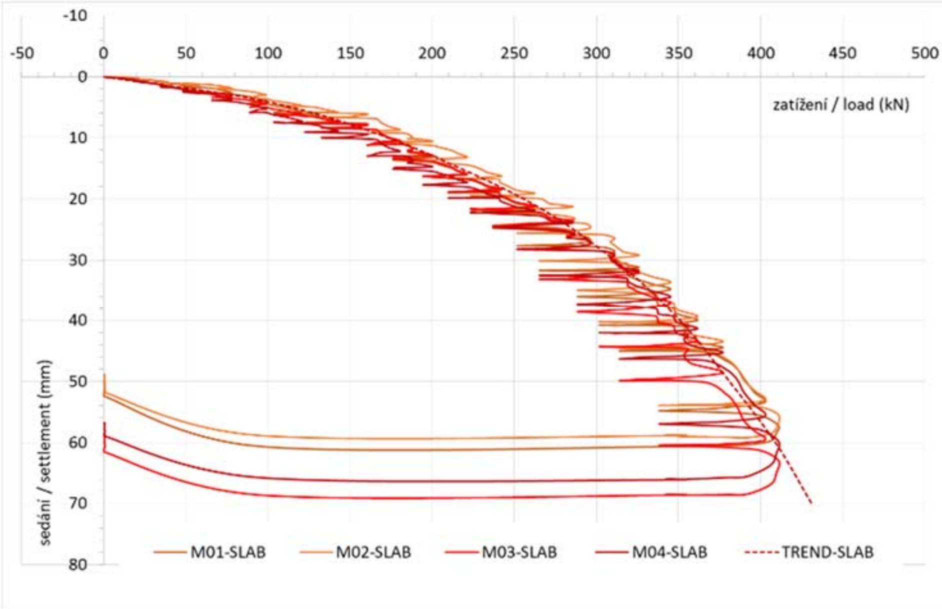


Fig. 9: Results of measurement on the slab model, (load-settlement chart)

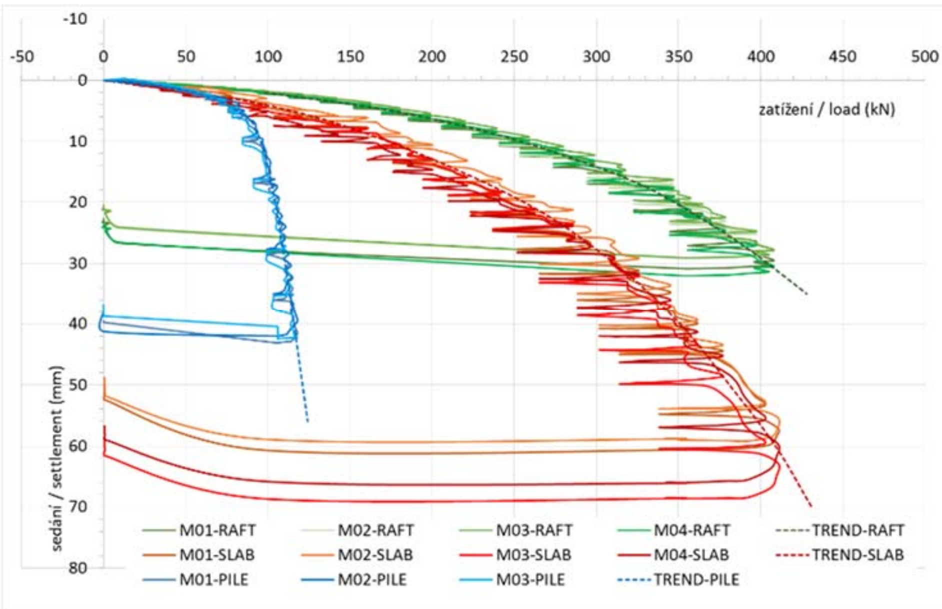


Fig. 10: Summary of the results of measurements on all three models (load-settlement chart)

The chart fig. 10 shows the vertical deformation (settlement) of all three types of foundations. The minimum deformation at maximum load shows the expected combined basis. A cumulative curve was constructed from the arithmetic sum of the trends of the average deformation of the model of separate piles and separate slab. In the chart fig. 11 it is marked in purple.

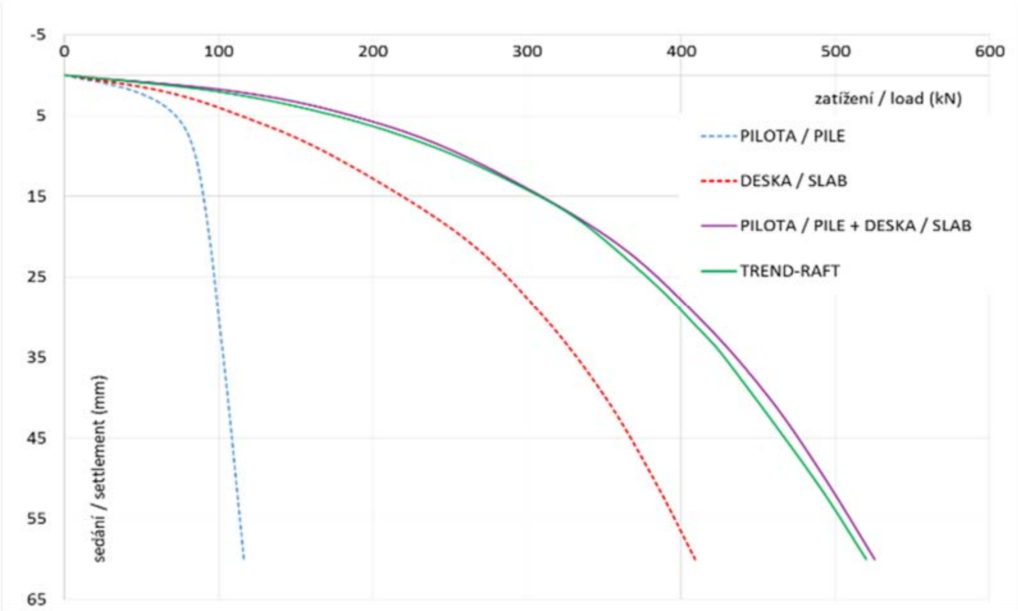

Figure 11: Comparison of the cumulative curve (pilot + slab) with a piled raft foundation

This curve in its shape roughly corresponds with the curve of the average trend of the combined base. That does not correspond with the premise of higher load-bearing capacity of a piled raft foundation due to the increase in the sheath friction of the piles by the slab overload.

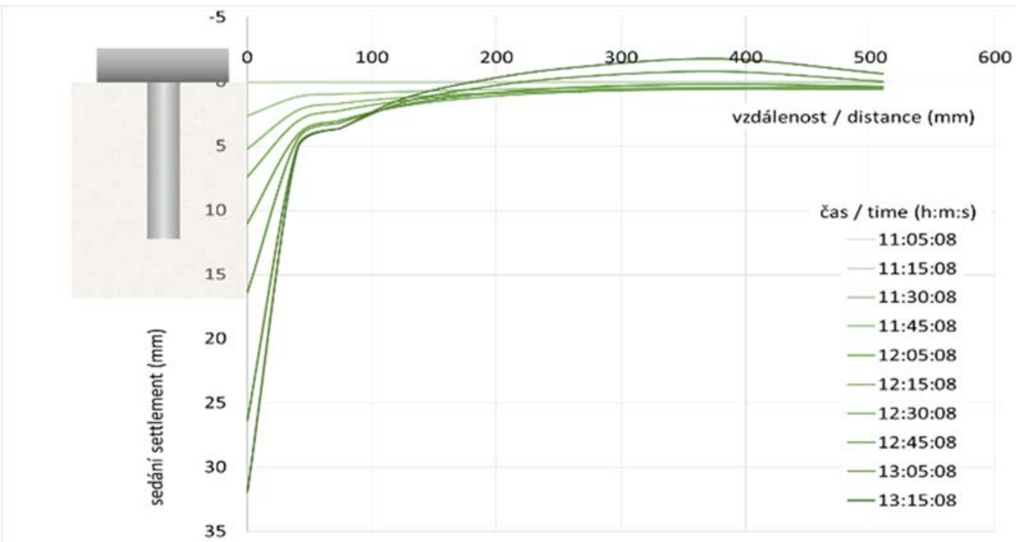

Figure 12: Deformation of the surface - piled raft foundation

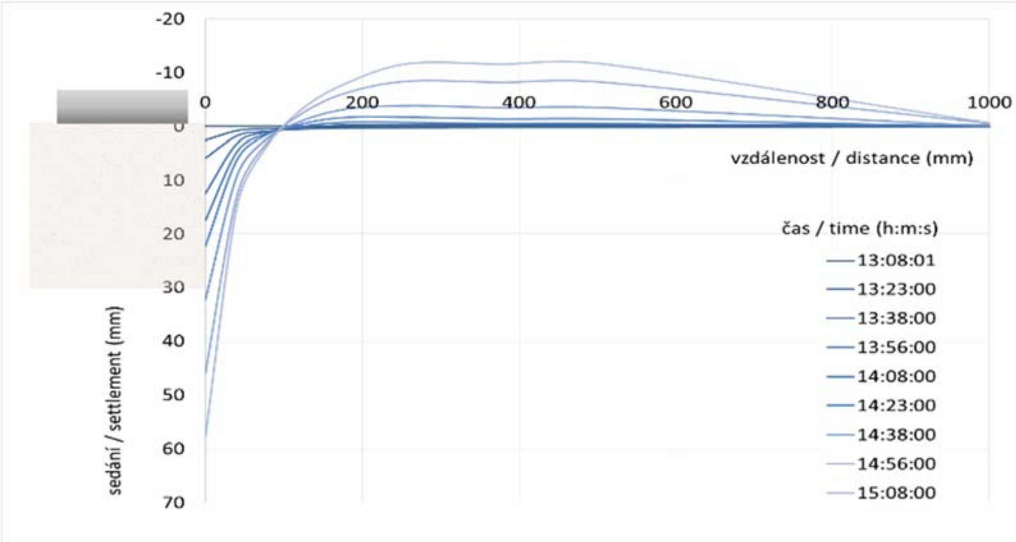


Figure 13: Deformation of the ground surface – slab

The other graphs below (Figs. 12 and 13) show the recorded vertical deformations of the foundation soil in the immediate surroundings of the examined piled raft foundation and the slab. The graphs show rutting of the surrounding soil at the edge of the foundations to a distance of about 100-150 mm. There is a lifting of the soil beyond this due to its displacement from the subsoil. For raft (Fig. 12), the boundary between the lifting and descending terrain is less evident.

## 6. CONCLUSION

The experiment examined the possibility of making and testing of models of foundation structures, mainly bored concrete pile on Stand devices [5]. A significant amount of data that will be used for comparison with theoretical calculations were obtained, especially with the calculations of foundation structures on the ground, means of numerical modeling, finite element method.

In a piled raft foundation, increased resistance in the skin friction piles overloading by slab was practically investigated. However, this increased carrying capacity was not proved on the model. The summed curve of trends of pilots and slab in its shape roughly corresponds with the average trend curve of piled raft foundation. It can therefore be concluded that for the soil and for the shape and dimensions of the foundation, settling of a combined basis is equal to the arithmetic sum of settlements of separate piles and the separate base plate (see Figure 11).

In addition to the results of the settlement patterns of foundation structures, experiments also have brought data on the behavior of the surface of the adjacent terrain. Graphical evaluation of these figures is shown in the above graphs of deformation (settlement) of surfaces of the adjacent terrain (see Figs. 12 and 13).


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