Experimental testing of post-tensioned concrete industrial floor model – subsidence analysis

Petr Mynarcik, Radim Cajka

***Abstract*—**The behavior of slab-on-ground constructions - subsidence of constructions and interaction between concrete structure and subsoil is one of the main research directions at the Faculty of Civil Engineering, VSB – Technical university of Ostrava Actually, scope of research is focused on concrete post-tensioned slab-on-ground. The article presents the process of a static load test on a post-tensioned concrete industrial floor model. The experimental model was designed as a cutout of a post-tensioned concrete industrial floor, and the static load test was conceived as a simulation of loading by base plate of a heavy rack. During the static load test, measurements focused on observation of subsidence and results of subscribed experiment were used for comparison with basic FEM model.

***Keywords*—**Post-tensioned concrete, Industrial concrete floors, Interaction between post-tensioned slab and subsoil, Sliding joint, Slab-on-ground, Prestressing bar

I. Introduction

CONCRETE industrial floors must fulfill a number of very specific requirements - adequate flatness, limited cracking and especially sufficient load capacity.

This paper focuses on the subsidence issue of post-tensioned concrete industrial floors and describes the process of experimental static load test on a large-dimension post-tensioned concrete industrial floor model.

II. Subsidence observation of concrete industrial floors and slab-on-ground constructions

The behavior of slab-on-ground constructions - subsidence of constructions and interaction between concrete structure and subsoil is one of the main research directions at the Faculty of Civil Engineering, VŠB – Technical university of Ostrava [1], [3]. Currently research focuses on post-tensioned concrete slabs-on-ground and industrial floors. For the experimental static load test a model of a post-tensioned industrial floor was concreted. The experimental model was designed as a cutout of

A post-tensioned concrete industrial floor and the static load test was a loading simulation of base plate of a heavy rack. The experiment served to give a better understanding and possible improvement of these technologies from the perspective of interaction with the subsoil

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III. Description of the post-tensioned concrete floor model

The basic dimensions of experimental model were 2000 x 2000 x 150 mm. The concrete type C35/45 XF1 was used for concreting.

Fig. 1 The steel formwork with ducts for prestressing bars

The experimental model was post tensioned by six fully threaded prestressing threadbars. The materials of the threadbars were made of low relaxation steel with designation Y 1050, and the diameters of these threadbars were 18 mm. The prestress force for each threadbar was 100kN. Threadbars were anchored by domed nuts and recessed anchor plates. The model was laid on homogenous subsoil. A sliding joint was placed between the contact surface of the concrete floor model and the subsoil [4]-[5]. This sliding joint was made of a combination of PVC foil and geotextile [6]-[7]. The experimental model was situated in an outdoor testing device ”STAND” [8].

Fig. 2 Post - tension process with use of hollow hydraulic cylinder

IV. Description of testing devices and measurements

The outdoor testing device ”STAND” consists of two frames. Crossbeams enable variability of the press machine location. The frames are anchored with screws into a steel grate based in the reinforced concrete strip foundations. The construction is anchored with 4 m long micro piles. The greatest possible vertical load is 1 MN [8]. The experimental static loading test consisted of the assembly of a set of measurements.

Experimental measurement line:

- Vertical deformation measurement (potentiometric position sensors);
- measurement of the vertical load
- (Built-in pressure sensors);
- strain measurement on the surface of the slab
- (Strain gauges);
  - strain measurement inside the slab
- (Strain gauges);
- measuring the stress on the interface of the slab and soil
- (Geotechnical pressure cells);
- Temperature inside and on the surface (temperature sensors).

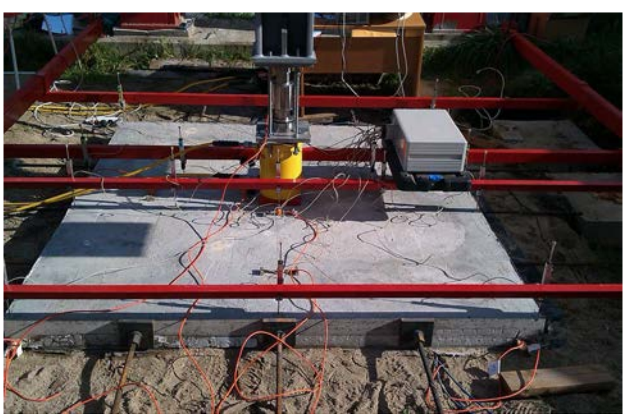

Fig. 3 The complete assembly for static load test

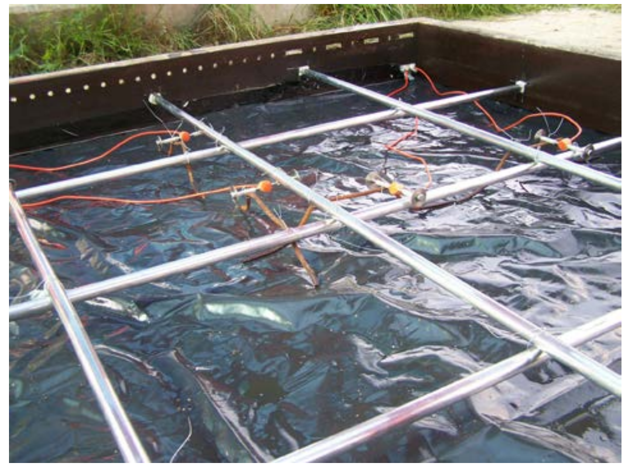

Fig. 4 Strain gauges for tension measurement inside the slab

Fig. 5 Installation of geotechnical pressure cells

V. Description of the subsoil attributes

The experimental model was implemented on a compacted gravel bed. Gravel bed layer thickness was 300 mm and was compacted on prime clay subsoil without greensward [9], [10]. The subsoil characteristics were determined by standard geotechnical measurements.

Subsoil attributes:

- Subsoil consists of loess loam with F4 consistency;
- thickness of subsoil layer is about 5 meters;
- volumetric weight of soil γ = 18.5 kN.m-3;
- poisson coefficient ν = 0.35;
- static Young’s modulus EDEF = 33.86 MPa;
- oedometric modulus of elasticity
- EOED= 4.27 MPa.

VI. Process of static load test

The vertical load was generated by a high tonnage hydraulic cylinder ENERPAC CLRG. The loaded equipment was placed between the experimental model and the steel extension fixed on ”STAND”. The hydraulic system was equipped with a pressure sensor. Potentiometric position sensors were installed on the surface of the concrete floor model. These gauges were connected to the same sensor station with automatic scanning and recording. The shape and size of the load area simulated the base plate of a heavy loaded rack. The dimensions of the load area were 200 x 200 mm. A fixed interval of loading - 75kN / 30 min was chosen for this experimental testing.

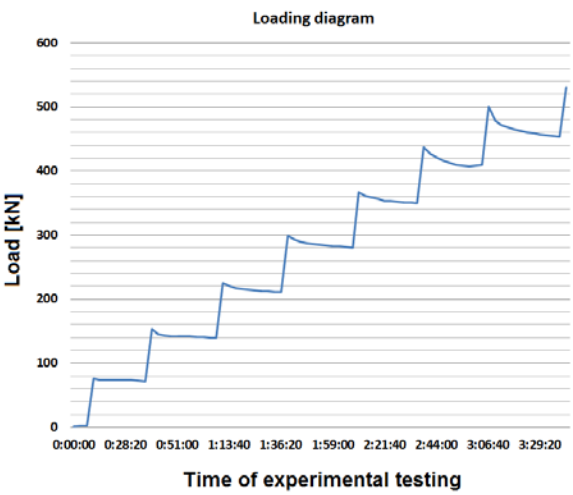

Fig. 6 The loading diagram of post-tensioned concrete industrial floor model

VII. RESULTS OF STATIC LOAD TEST AND SUBSIDENCE MEASUREMENTS

Potentiometric sensors situated on the non-contact surface recorded vertical deformations in particular positions. The deployment plan of potentiometric sensors is displayed in Fig.7.

The measured data was processed into graphs of vertical deformation development - subsidence.

The development of subsidence in the edge area of experimental model is represented by lines A-A´ and C-C´ (Fig. 8 and Fig. 10). From the graphs of edge area the lifting in corners of the experimental model is noticeable. The development of subsidence in the central area of experimental model is represented by lines B-B´ and D-D´ (Fig. 9 and Fig. 11). These graphs showed centralized subsidence in the central part of experimental model. The creation and progression of punching shear is also noticeable from graphs of lines B-B´ and D-D´.

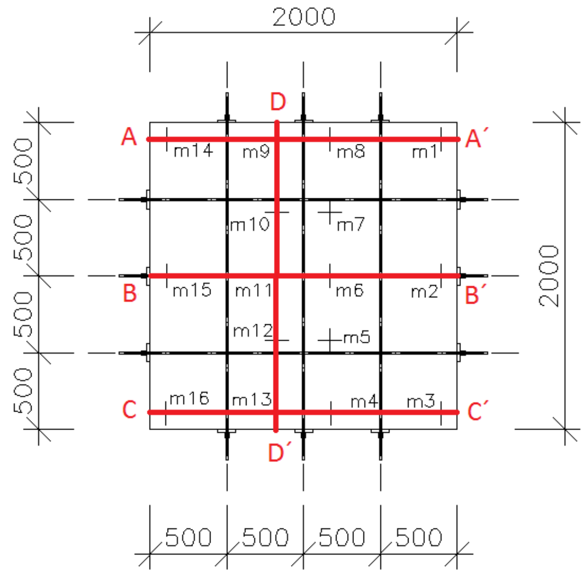

Fig. 7 Deployment plan of potentiometric sensors

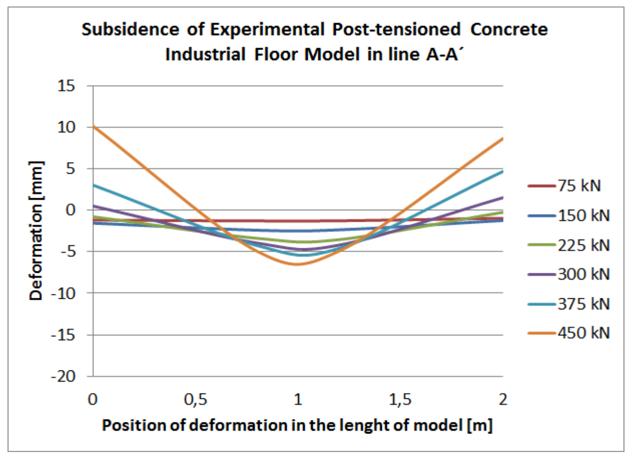

Fig. 8 Subsidence in the edge area of experimental slab model – line A-A´

(Potentiometric sensor - m14, m9, m8, m1)

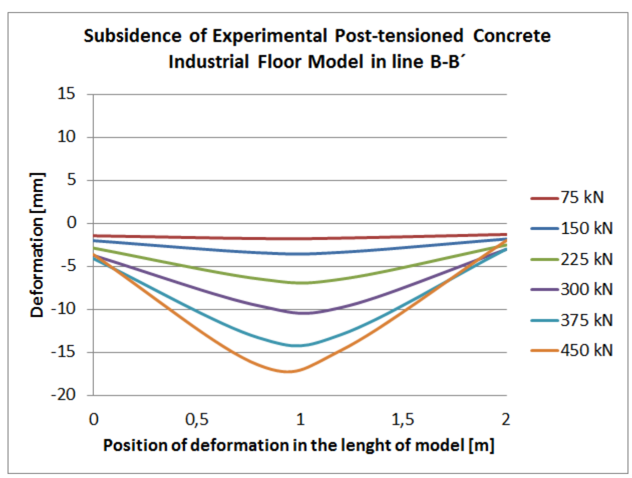

Fig. 9 Subsidence in the central area of experimental slab model – line B-B´

(Potentiometric - sensor m15, m13, m4, m3)

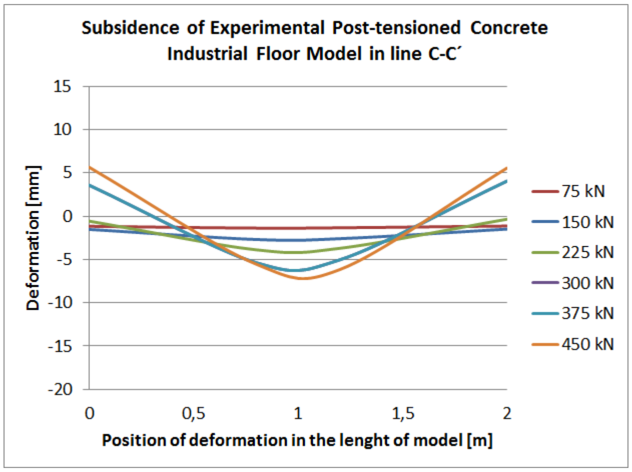

Fig. 10 Subsidence in the edge area of experimental slab model – line C-C´
(Potentiometric sensor - m16, m13, m4, m3)

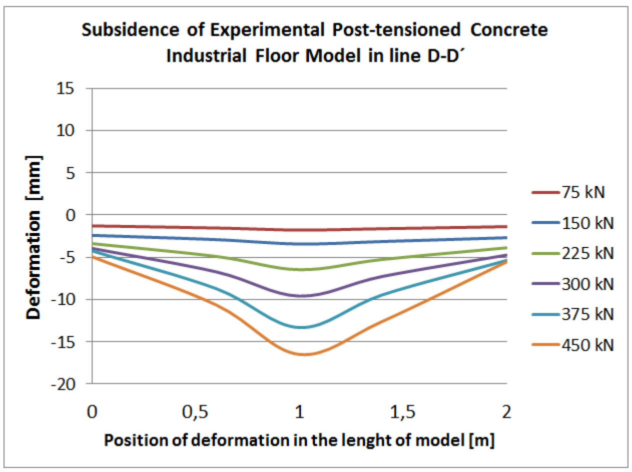

Fig. 11 Subsidence in the central area of experimental slab model – line D-D´
(Potentiometric sensor - m13, m12, m11, m10, m9)

VIII. Evaluation of Experimental Measurements

The experimental post-tensioned concrete industrial floor model resists the loads exerted after seven load cycles and induced maximal load level 525 kN. Loading process of experimental model was continuous testing. Subsidence of concrete slab was equally over the entire surface after three loading cycle. After third steps, central part of experimental model started outstrips edge parts. Concurrently at the same time, edge parts started lifting. The first significant cracks were detected after the fourth cycle. These cracks were located near anchors of middle threadbars. After the sixth cycle the first signs of punching shear were detected. The experiment was terminated at the moment when the model was severely damaged by punching shear.

Maximal vertical deformation measured on the experimental post-tensioned floor model:

Edge area: 10,12 mm (line A-A´)
Central area: 16,50 mm (line B-B´)

Fig. 12 Cracks near anchor of middle prestressing threadbar

Fig. 13 Punching shear damage under loading area of hydraulic press

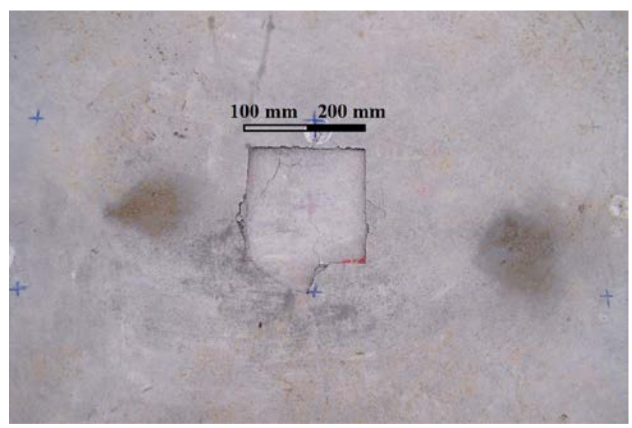

Fig. 14 Detail - punching shear damage

Subsidence at the central part (lines B-B´ and D-D´) was balanced in both directions. The location of the test pattern inside the test experimental STAND and the use of available handling techniques enabled to lift the test slab. Threadbars were used for anchorage for stretching hanging straps. A pair of chain hoists was hung on the STAND beams. The experimental model was lifted and allowed the course of cracks evaluation right on post-tensioned slab surface that was in contact with the subsoil. The crack cross is highlighted with red colour on Fig.15.

Fig. 15 Course of cracks on the contact surface of post-tensioned concrete industrial floor model

Main cracks on contact surface of post-tensioned model were situated in directions of middle ducts for prestressing threatbars. These cracks draw full cross to the boundaries of concrete slab. Signs of these cracks were observed near threadbar anchors after fourth loading cycle. Central crack meshes was signal of punching shear damage. Experimental model was sectioned to 8 sub sections after end of experimental measurement. Course of cracks along the height of slab were studied on this sub - sections. These minority measurements serve to specifications of basic control perimeter for calculation punching shear capacity.

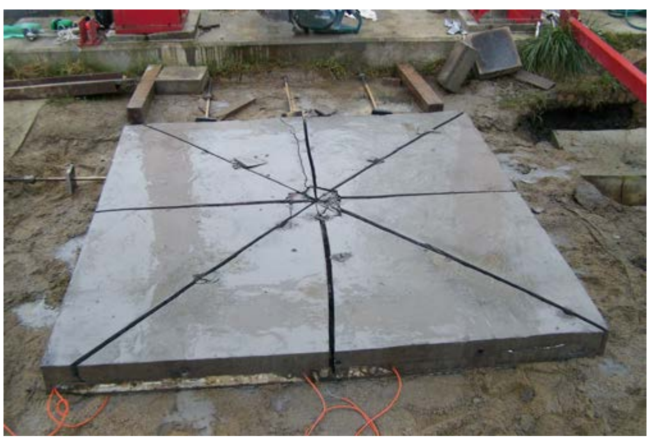

Fig. 16 Experimental model sectioned into 8 sub-sections

IX. FEM ANALYSIS

Results of subscribed experiment are used for comparison with FEM model. Problematic of interaction between subsoil and post-tensioned industrial floors or foundation structures is active research scope around the world [17]-[19]. Numerical model of experimental model was created with ANSYS finite element method software. Concrete post-tensioned model was created as a shell element with linear isotropic material properties. Subsoil was created as a solid element with isotropic elasto-plastic model aka "Drucker - Prager Model". Results of comparison between FEM model and real experiment results are divergent. Reason for divergence is difficult modelling of contact between concrete and subsoil. There are too many unknowns and variables quantities, because this problematic is combination of two different exercises with different ways of solution – concrete slab and subsoil Actually, harmonization of ANSYS model is in progress. Second direction of solve the interaction task is create the model in different FEM software and compare results. And finally, third direction of solving this task is creation of specialized FEM software for this specific modelling of interaction between concrete structure and subsoil. The results of experiment and results of FEM analysis in universal software are very important for this next step in research.

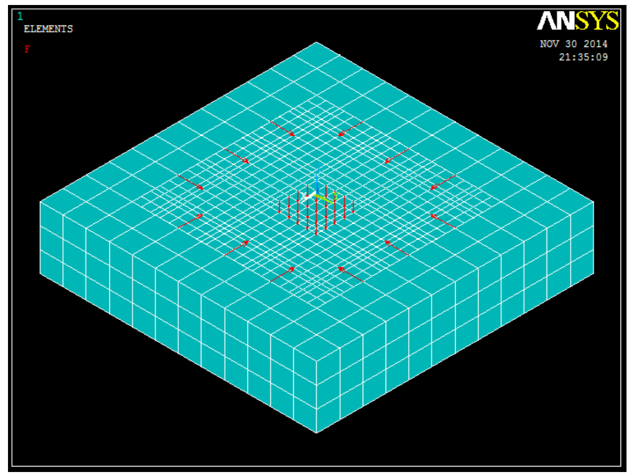

Fig. 17 FEM interaction model of post-tensioned concrete industrial floor model

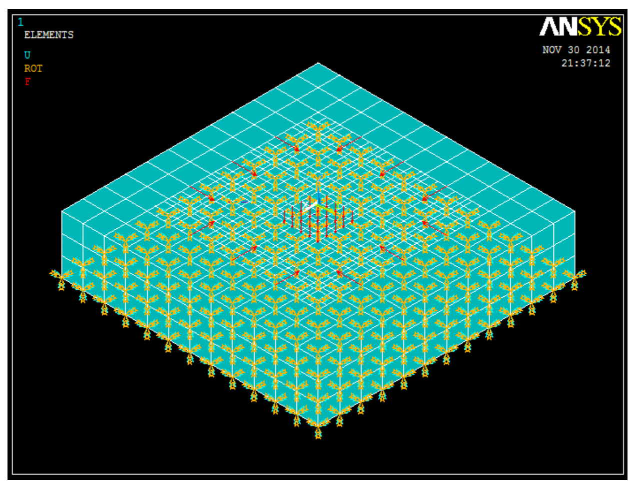

Fig. 18 Boundary conditions of FEM interaction model

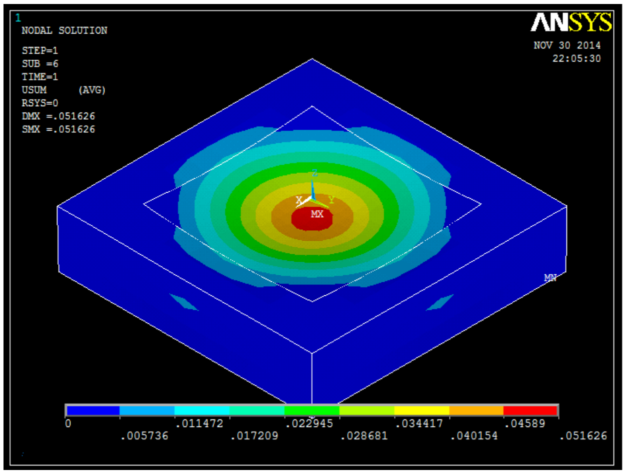

Fig. 19 Total vertical displacement of FEM interaction model

X. Conclusion

This experiment offers much information about the influence of post-tensioning on punching shear resistance [11]-[13]. The measured data will serve for the creation of a numerical model by the FEM (finite element method) [14]. Post-tensioning influences both the behaviour (crack opening, rotations) and strength of slabs subjected to concentrated loads. Post-tensioned members have stiffer responses (associated with lower extents and openings of the flexural cracks) and higher punching resistances for the same amount of non-post-tensioned flexural reinforcement [14]-[16].

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