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Experimental measurements of subsoil—structure interaction and 3D numerical models☆

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Summary Use of combination of experimental measurements, tests in situ and numerical modelling is optimal approach to obtain reliable results of subsoil—structure interaction. Input data for numerical analyses were obtained by experimental loading tests of three different types of concrete slabs. Loading was performed out using experimental equipment. The unique experimental equipment was constructed in the area of Faculty of Civil Engineering, VŠB-TU Ostrava. Analyses of interaction of reinforced concrete slabs with subsoil were solved by application of inhomogeneous half-space. The main focus was to verify the aptness of application of inhomogeneous half-space in relation to the slab deformations in comparison of different types of reinforcements of concrete slab.

Introduction

Geological profile can be different in various parts of the area under the foundations. Unambiguous description of geological profile is very difficult. Experimental measurements of subsoil—structure interaction are carried out throughout the world (Aboutalebi et al., 2014; Alani and Aboutalebi, 2012; Huang et al., 2013) and also in the Czech Republic and Slovakia. Methology, results and conclusions of the performed loading tests performed out at the Faculty of Civil Engineering, VŠB-TU Ostrava are described in (Cajka et al., 2014; Buchta and Mynarcik, 2014; Janulikova and Stara, 2013). Inadequate theoretical basics and an absence of appropriate calculation software also prevent the determination of an unambiguous solution of subsoil—structure interaction. Numerical modelling of the subsoil—structure interaction is also described in (Frydrysek et al., 2013; Janda et al., 2013; Kralik, 2013).

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Experimental loading test

In 2010, testing equipment was constructed in areal of the Faculty of Civil Engineering, VŠB — Technical University of Ostrava (Cajka et al., 2011). The testing equipment is used for experimental for monitoring of the stress—strain relationships of the interaction of the foundation structures and subsoil. The load is applied by a hydraulic press which pushes the test sample into subsoil. For more details about the structure of the test equipment see (Cajka et al., 2011). The testing equipment was used for testing of several different types of foundation slabs. The slabs are different, e.g. from the point of view of concrete mixture, reinforcement, slab dimensions and its thickness or size of the load area. In 2014, the steel-fibre reinforced concrete slab, the post-tensioned concrete slab and the reinforced concrete slab were loaded there. The ground plan dimensions of all slabs were 2000 mm × 2000 mm. Dimensions of the load area were 200 mm × 200 mm. All types of concrete foundation slabs were subjected to punching shear. The failure of the slabs by punching shear is also described in (Halvonik and Fillo, 2013).

Experimental loading test of the steel-fibre reinforced concrete slab

The dimensions of the steel-fibre reinforced concrete slab were 2000 mm × 2000 × 170 mm. The C25/30 concrete was used. The concrete was reinforced with scattered reinforcement. The reinforcement consisted of steel fibres 3D DRAMIX 65/60B6—25 kg m^{-3}. From the geologic point of view, the upper layer of subsoil consists of loess loam (F4). The thickness of the layer is approximately 5 m. The Poisson coefficient of the subsoil was $\mu = 0.35$ and modulus of deformability was $E_{def} = 2.65$ MPa. The loading was performed out sequentially in steps: 20 kN/60 min. Despite of assumptions, the slab did not fail even after nine loading cycles (the load was 180 kN) and the test was interrupted. During repeated loading test of the steel-fibre reinforced concrete slab was loaded with new cycle: 50 kN/30 min. The slab failed during the 6th cycle. The loading force was 250 kN. Fig. 1 shows casting of the slab and cracks at the lower surface of the failed steel-fibre reinforced concrete slab after its lifting up.

Experimental loading test of the reinforced concrete slab

The reinforced concrete slab dimensions were 2000 mm × 2000 mm × 120 mm. The C25/30 concrete was used. 38 steel bars of length 1.9 m and a diameter 8 mm was used for reinforcing of concrete slab. Steel bars were bound to grid with a mesh size 100 mm × 100 mm. Cover of concrete of 20 mm for the lower bars was achieved through concrete spacers. From the geologic point of view, the upper layer of subsoil consists of loess loam (F4). The thickness of the layer is approximately 5 m. 10 cm of the original soil was removed before experimental loading test of reinforced concrete slab. The footing bottom was filled with gravel fraction 0—4 mm along the edge of the surrounding terrain. Gravel was evenly compacted by vibrating plate. The Poisson coefficient of the subsoil was $\mu = 0.35$ and modulus of deformability was $E_{def} = 33.1$ MPa. The slab was loaded at half-hour intervals by vertical force of 50 kN. The slab was infringed at load of 350 kN. The slab was infringed by punching shear. Fig. 2 shows casting of the slab and cracks at the lower surface of the failed reinforced concrete slab after its lifting up.

Experimental loading test of the post-tensioned concrete slab

Post-tensioned concrete slab had the dimensions 2000 mm × 2000 mm × 150 mm. Concrete class C35/45 was used. Slab was post-tensioned by six threaded prestressing bars. The bars were from steel Y 1050 and their diameter was 18 mm. Each bar was tensioned by force of 100 kN. From the geologic point of view, the upper layer of subsoil consists of loess loam (F4). The thickness of the layer is approximately 5 m. The 300 mm layer of clay soil was removed before loading test of post-tensioned concrete slab. The footing bottom was filled with gravel fraction 0—4 mm to the edge of the surrounding terrain. The Poisson coefficient of the subsoil was $\mu = 0.35$ and modulus of deformability was $E_{def} = 33.86$ MPa. Loading was carried

Figure 1 Casting of the steel-fibre reinforced concrete slab and cracks at the lower surface of the failed steel-fibre reinforced concrete slab after its lifting up.