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EXPERIMENT E6/0,2 WITH LATERAL PASSIVE PRESSURE ROTATION ABOUT THE TOE

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Abstract: *The paper gives information on a repeated long-term experiment E6/0,2 with lateral pressure at rest and passive pressure during wall rotation about the top towards into tested granular mass. The experiment was successfully finished in the last year 2011 and (together with a previous experiment E5/0,2) it should prove gained results which appear distinct from a theory of EUROCODE 7-1 contemporaneously used. Both experiments monitored and registered both pressure components and mass deformation and displacements into the sandy mas.*

Keywords: ***Lateral earth pressure, pressure at rest, passive pressure, physical experiments, ideally non-cohesive sand, mass deformation, slip surface, bi-component pressure sensor.***

1. Introduction

A basic research of earth/lateral pressure based on physical and numerical experiments has begun in 1998 at the institute of the authors and it has continued. The physical research should prove behaviour of ideally non-cohesive granular mass during three basic types of structure movement towards active and passive directions The first research period in 1998-2000 aimed on active pressure and in 2001-2002 on the first long/term experiment with passive pressure (E3/0.2) but during this the first side glass tables cracked. Despite it the experiment went off successfully to finish. In the course of the second period was developed experimental equipment on the second and the third (contemporary) stages. The first experiment with passive pressure E3/0,2 (2001-2) was repeated like experiment E5/0,2 (2010) in a frame of the second research period such as a long-term operation test of the new experimental equipment. It brought similar results however, with lower pressure values. The experiment E5/0,2 had to be repeated and this, the last carried out experiment E6/0,2 is presented in the paper.

2. Experimental equipment

The actual advanced equipment (see Figs 1a,b) has the same size and it is fully controlled by two computers (the first for front wall movement and data monitoring and registration, the second for visual monitoring and photo registration) and reaches up very suitable characterizations: max. *active* wall movement of 300 mm, max. *passive* wall movement of 242 mm, arbitrarily *slow* front wall movement of velocity from of 3.684 to of >0 mm/min. i.e. arbitrarily slow movement, max. pressing force cca 2870 kN, 5 bi-component pressure sensors in front moved wall, 1 three-component sensor and 5 bi-component pressure sensors in back solid wall, 2 potential movement sensors, 1 optoelectronic movement sensor, 1 impulse summator, max. recording frequency 1000 Hz. The equipment can afford a huge quantity of data of 803 MB/day.

Deformation of the sample and displacements into it are monitored visually. Slip surfaces and uplifts of the sample mass are monitored through the right transparent side due to red strips into the mass (see Fig.1a). Locations of the strips are registered a stabile photo camera about per day during

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Fig. 1. Experimental equipment with transparent glass sides before experiment E6/,02 with non-cohesive sandy sample into:
a) Lateral view at right equipment side (left). The moved front wall with five bi-component pressure sensors is left, back stabile wall with six pressure sensors is right.
b) Front view at hardware facilities in front of the experimental equipment (right). Red frame bearing six black cameras is left.

the front wall movement. Also, the locations of the strips are measured manually in the time intervals. Displacements of black little globes located in front sample part in net of 50/50 mm are monitored by cameras set through the transparent left side (see in Fig.1b left). Visual registration data of cameras are stored separately in the second separate computer (see Fig.1b right). A detailed description of the equipment can be found in Koudelka P. and Bryscejn J. 2010.

3. Experiment E6/0,2

The experiment belongs to the set of basic physical experiments whose should repair and prove the lateral/earth pressure theory:
- *active pressure:* three repeated experiments with pressure at rest and active pressure (structure rotations about the toe and top and translative motion – carried out 1998 - 2000,
- *passive pressure:* three repeated experiments with pressure at rest and passive pressure (structure rotations about the toe and top and translative motion).

Thus, altogether two times six experiments without experiment E3/0.2 that was performed using the original simple equipment of which results probably will not be fully comparable.

The basic physical research for the more advanced theory and its development has continued from April 8, 2010 to be completed the experiments with pressure at rest and passive pressure, i.e. double repeated long-term experiments for rotations about the top and the toe and for translative motion. The firstly, the experiments E5/0,2 and E6/0,2 with rotation about the top and an ideally non-cohesive sand have been begun using a velocity of wall toe movement of 0.005 mm/min. (near to natural processes - 50 times faster than finger nail growth or 53 times faster than continental drift). The following repeated experiment E6/0,2 was entered 25.3.2011 on and finished successfully on 19.12.2011. A history of the experiment E6/0,2 see in Table 1. A detailed description of the equipment function during the experiment (operation test) can be found in Koudelka P., Valach J. and Bryscejn J. 2011. Contemporarily (in March 2012), the first experiment with *passive* rotation *about the toe* E5/0,1 is running from 28.2.2012.

3.1. Sample

The same material (quartz sand) under the same compaction is used for samples of all experiments. Principal physical properties of the sample were found as follows: unit weight γ= 15.697 kN/m^3, effective angle of shearing resistance ϕ_{ef} = 38.5°, effective cohesion c_{ef} = 0, residual angle of shearing resistance ϕ_r = 31°, structure-ground interface friction angle δ = 12.8°, moisture w = 0.3 %.

Table 1. History of experiment E6/0,2 - Rotation about the top

E5/0,2	Date			Movement		
Phase [1] [Note]	Start [day]	End [day]	Time [2] [h/m/s]	Direction [act./pas]	Dist. max. [3] [mm]	Velocity [mm/min]
0a	25.03.2011	25.03.2011	0:59:59	active	- 0.200	0.005
recons.1	25.03.2011	31.03.2011	-	-	- 0.200	0
a0	31.03.2011	31.03.2011	1:14:25	passive	- 0.020	0.005
recons.2	31.03.2011	07.04.2011	-	-	- 0.020	0
0p	07.04.2011	07.04.2011	1:40:16	passive	0.292	0.005
recons.3	07.04.2011	26.04.2011	-	-	0.292	0
p1	26.04.2011	03.05.2011	163:52:20	passive	47.950	0.005
recons.4	03.05.2011	01.09.2011	-	-	47.950	0
p2	01.09.2011	25.09.2011	578:02:28	passive	205.460	0.005

[1] Phases containing zero indicate movement in a branch of pressure at rest, similarly "a" branch of active pressure and "p" branch of passive pressure, Numbered phases "recons" indicate period's re-consolidation without a movement for research of time stability of the pressure.

[2] Time of continuous wall movement.

[3] Distance maximum of the wall toe at the phase end from its original position before the experiment start.

3.2. Hardware and software

The entire system is equipped with electronics and computers to enable controlling experiments and also proper data collection. It has single power plug 220V which leads to UPS which is backing up the crucial low-consumption devices and also the main computer. A stepper motor control unit is supplied from DC power source (40V/5A). Two kinds of software run on the main computer. InMotion program works with the stepper motor unit in two modes — program mode is used when the experiment is in progress and realizes slow steady motion of the front wall; the second mode is used for controlling the motor on demand for various purposes, e.g. during the setup of experiment. Program NextView is software which collects data from all sensors and saves it for later processing at desired sampling rate. It shows also actual data in both numerical and graphical manners. Signals of the pressure sensors, temperature sensor and analog potentiometric sensors are conditioned, amplified and led to 16bit A/D convertors, then via interfacing USB devices (BMCM) into the measuring computer. Two digital displacement sensors (resolution 10 nm), found next to potentiometric sensors, are connected into the PC via internal card. The second computer is used for controlling of a camera system.

4 Results

The experiment brought an extreme quantity of basic NextView data of *1.508 GB* (time data and sensor data without visual monitoring data and photos). The data quantity needs a special technology (software, approaches etc.) of which development is running. At all events, size of experimental results does not make it possible to transfer data in a suitable format and to analyze them in short time and of course, to present the complete results in one paper. Complete analyses and evaluations of particular aspects of the granular mass behaviour in detail will be present step by step further. A digest of the results follows below.

The front wall rotation about the top influences the maximal movement of the toe. The wall is very rigid and it behaves like solid structure and due to it movements of other wall points depend on the toe movement linearly according to their distance to the top. That is for all results are regarded to a relevant toe movement.

4.1. Data

Data collected during whole experiment as well as the rest phases are saved to disk in NextView's proprietary data format (.lfx). The sampling rate of these datasets differs. So, to be obtained human-understandable results, these data are exported to ASCII format first. This leads into huge amount of data (~68 GB), so the decimation process takes place here. It is done via several short scripts written in Matlab language. This lessens amount of the data reasonably, so it can be put into several well-arranged Excel tables. For this purpose, a macro in Excel was developed. The original data with high sampling rates will be used in subsequent evaluation process.

Very important movement of the front wall toe was measured using five independent techniques: potential movement sensors, optoelectronic movement sensor, impulse summator and the maximum distance of the toe after the experiment from its original location by electronic micrometer. There were not found significant differences. A position of the front wall top (not moved) was controlled by the second potential movement sensor. Movement values presented in the Paper are data according to the lower potential movement sensor in all experimental phases except of the last one (p2) for which are used data according to the measurement after the experiment by electronic micrometer.

4.2. Deformations and slip surfaces

Deformations of the red strips and displacements of the black little globes during the first three phases, i.e. both active and passive pressure at rest, and also changes of the sample surface, were not visible. A slight uplift of the lower strips could be monitored up the toe movement of 10-20 mm. The toe movement of 47,95 mm at the end of the fourth phase (p1 – movement for full passive pressure according to EC 7-1) appears to be critical and the red strips on right side of the sample shoved:

- A front part of the sample behind the front moved wall was uplifted yet in upper area (depth of 0 – 0.6 m) at the maximal values of 18–21 mm in distances about of 0.8 m from the wall. The uplift was visible to depth of 0.9 m and fell to of 8 mm on a level of 0.9 m.
- This wall movement appeared critical because simultaneously, *the first slight slip displacement* was monitored at the strip level of 0.9 m in a distance from the wall of 0.58 m.

This sample state is illustrates in Fig. 2 (photo is not so obvious).

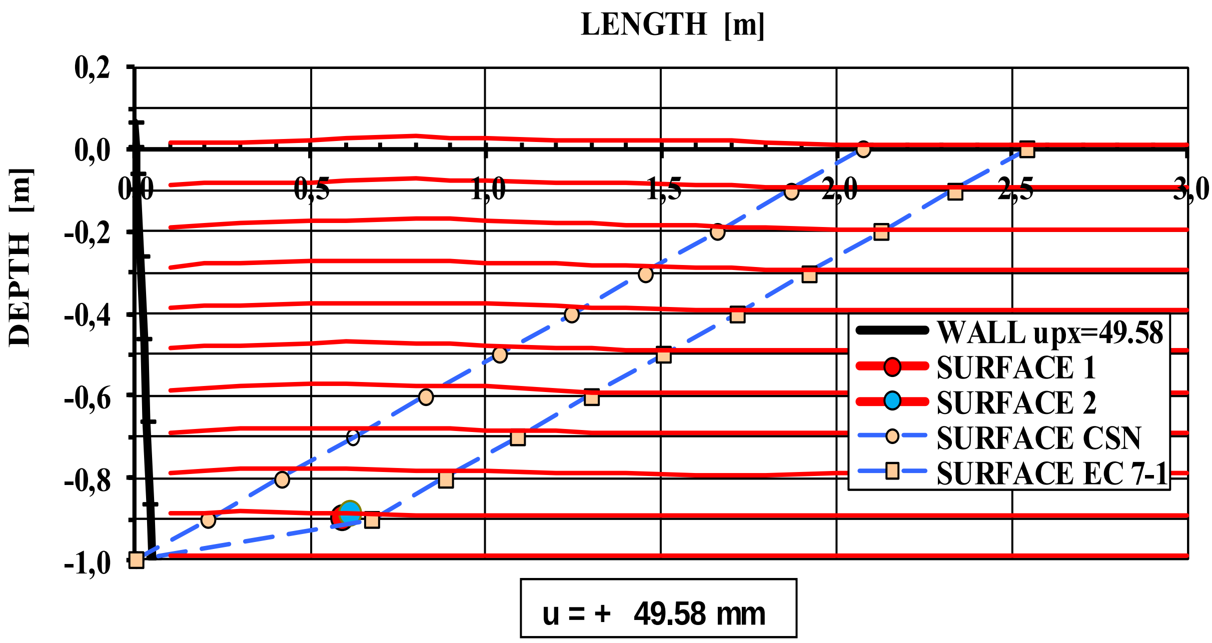

Fig. 2: Deformation of the sample front part according to the red strips and beginning the first slip surfaces Nos. 1, 2 in a strip of depth of -0,9 m comparatively to theoretical slip surfaces according to ČSN 73 0037 and EC 7-1 after passive movement of the toe of 49.58 mm.

4.3. Pressures

Pressure analyses will be performed after the data transformation in xls format that is running. Contemporarily, it can be stated the passive pressure maximum has been found after the toe wall movement of 124.3 mm and its value has been 102.4 kPa. This value is near to maximal passive pressure value of 107.8 kPa which had been found before during the experiment E5/0,2 after toe movement of 60.0 mm and the value of 102.3 kPa had been found after toe movement of 87.1 mm.

5 Conclusion

In spite of the analyses of data are not carried out a preliminary conclusion appears possible. Granular mass of the experiment E6/0,2 behaved similarly to the experiment E5/0,2. It can be seen obviously in figures of Figs. 3a,b which make it possible to compare visible mass changes (slip surfaces including) after experiments.

Fig. 3: View at right sides of the samples (granular masses of the same sand of size of 0.3 mm.
a) Experiment E6/0,2 after toe movement of 212.3 mm(left).
b) Experiment E5/0,2 after toe movement of 226.9 mm (right).

Both pressure results of the repeated experiments E5/0,2 and E6/0,2 appear similar too. Differences are in an interval of a temperature influence and could be caused also a bit of incorrectness of the masses.

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