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Experimental Stress Analysis

Operation Test of a New Experimental Technology for Research of Lateral Pressure

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Abstract: Hardware and software accessories of a original advanced experimental equipment was finished and debugged at the beginning of the last year. The equipment was constructed for a basic research of lateral pressure multi-phase granular materials and to verify a theoretically derived "*General* Lateral Pressure Theory" (GLPT). A number of technical tests of measuring components and computer controlling system were performed before the finish of the equipment development. Several quasi-experiments without a sample ended the equipment preparation at last. The first real experiment E5/0,2 with pressure at rest and passive pressure was used for an operation test of the new equipment. The paper deals with the experimental technology (apparatuses, hardware, software, etc.) and experiences of them during an extremely slow movement of front wall. Also, it is mentioned a visual monitoring, 3D scan technology including.

Keywords: Physical modeling, Operation test, 3D scanner

1. Introduction

The physical research of soil lateral pressure acting on moved wall has passed over more than ten years. The first complete double experiments (rotations about the toe and top, translative motion – altogether two times three experiments: E1/0,1,2,3 and E2/0,1,2,3) with *pressure at rest* and *active* pressure were carried out in period 1998-1999 and the first experiment with *pressure at rest* and *passive* pressure (rotation about the top – E5/0,2) in period 2001-2002 using original simple experimental equipment with hand drive. Side glass walls of the equipment crackled during the last mentioned experiment due to high pressures around an area of the moved wall toe.

The above mentioned initial research showed a great importance and an influence of time and dynamics of lateral soil pressure at the experiments. Merely, a repair of the original equipment would not be satisfying, it was necessary to develop a new more advanced technology. Due to out-of-the-way requirements the equipment development was arduous and continued about eight years in two stages till beginning 2010. Hardware, software and both driving and registering programs were debugged and technically tested in the last development period (05/2009-02/2010). Then the new advanced and sophisticated equipment need also an operation testing. It was decided to test the equipment by the first regular experiment with pressure *at rest* and *passive* pressure (E5/0,2).

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2. Motivation

There has been shown [1] and it is obvious that earth pressure concept of the EUROCODE 7 "Geotechnical design, Part 1: General rules" even eventual practice according to it are not adequate both to contemporary practice and opinion and also to contemporary possibilities. It involves incorrectness emerging from a former time lower knowledge and its ignorance is risky.

The research has formulated principal postulates of a new theory of earth pressure which is noted "General Lateral Pressure Theory" in contradistinction to the conventional earth pressure theory of the code (EC 7-1) or other standards. The differences between theoretical concepts are obvious looking following diagrams of the constitutive dependencies of *structure movement*/*lateral (earth) pressure*

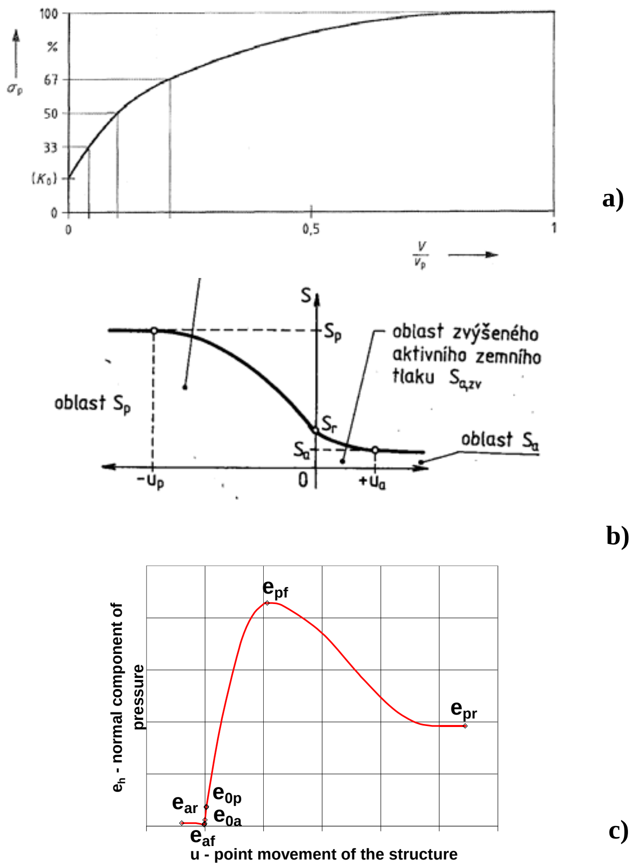

Fig. 1. The constitutive dependencies movement/pressure according to rules and the developed theory:
a) EC 7-1 - Dependence of pressure at rest and passive pressure on the maximal structure movement.
b) ČSN 73 0037 - Dependence of passive pressure, pressure at rest and active pressure (mirror image of the axis x = u) on the maximal structure movement.
c) GLPT - Dependence of active pressure, pressure at rest and passive pressure on movement of the given structure point.

The dependence according to Fig. 1c was developed from 1990 till 2004 and derived from numerical results of a number design analyses using at that time new Dependence Pressure Method (Zapletal, 1981) and later more advanced programs on the basis of results of the first experiment set (until 2002). The results were in discordance to the classical concept of earth pressure theory that time used too. Objections to the classic theory and postulates of the new theory were formulated step by step through the time however, it was necessary to verify them.

The objections and the theoretical concept of GLPT have been and are verified by physical experiments. Hitherto, a number of physical experiments have been performed. The first experiment collection with the aid of the first manual stage experimental equipment involved a complete set of repeated experiments with pressure at rest and active pressure and also the first experiment with passive pressure. The second experiment collection should verify a remaining part of GLPT in a range of passive pressure, passive pressure at rest including.

Fig. 2. Views at left lateral sides of the samples (the moved front wall is left) at the ends of the experiments with passive pressure during rotation about the top: a) (left) Experiment E3/0,2 with maximal movement of the toe of 158.8 mm. b) (right) Experiment E5/0,2 with maximal movement of the toe of 226.9 mm.

3. Operation test

The second collection has been started by the operation test with the long-term experiment E5/0,2 – pressure at rest and wall rotation about the top (8.4.2010). Both the operation test and the experiment were finished successfully in last year (13.10.2010). Contemporarily from 25.3.2011, the repeating and proving experiment E6/0,2 is running. Then the verifying of the whole theory need two couples of experiments with passive rotation about the toe and passive translative motion more. Experiences of the operation test are very important for all these following experiments.

Generally, an operation testing and its evaluation can be aimed at two different targets: 1) testing of plausibility of results, 2) testing of technology (reliability, correctness and accuracy, etc.). The paper object is the second target and first one is mentioned in the following paragraph.

3.1. Behaviour of the soil samples

The first experiment collection was carried out using the original experimental equipment and hand-made drive, i.e. irregular pulsing movement of the front wall. The movement of the new equipment can be considered like continual and it is very slow (velocity = 5 μ/min. – approx. average velocity of the whole experiment E3/0,2). Velocity of the moved wall/structure has an expressive effect for the soil mass although it is not well-known. Following Figs.1a, b make it possible to compare the last states of the same sandy masses after the repeating experiments E3/0,2 and E5/0,2 with different maximal rotations about the top. Behaviour both of the masses appears similar.

4. Control & registering systems

Entire experimental system consists of a mechanical part and a relatively complex electronics/computer part. The system has been evolved during last year significantly, extending its measuring and data collecting capabilities. This section is focused on some technical problems related to these changes.

The former system configuration, as described in [2], utilized a single PC running a stepper motor control program and a program for scanning and saving data from all sensors (LabView). System was equipped with multi-axial pressure sensors mounted on front and rear walls in contact with the sand body, two analog displacement sensors and a temperature sensor.

All sensors are connected via their signal amplifiers and conditioners to data scanning devices (BMC). Amplifiers and signals are grouped, three units in total, each working with 16 signal channels. These devices are controlled from the master program (LabView) and connected to PC via USB ports.

As mentioned in [2], the analog displacement sensors are of a potentiometer type and proved themselves as nonlinear. The maximum absolute error exceeds 1 mm (range about 300mm). The most precise information on trajectory can be derived from the number of revolutions of the stepper motor. It should be always known, as the motor controller program developed for each part of an experiment deals with steps and microsteps, with fixed ratio 200 steps per one revolution of stepper motor. Although this information is extensively used in offline data analysis of experiments, the actual information on displacement coming directly from mounted sensor, accessible in a live view during the experiment, should be as precise as it can be in order to operate smoothly both during experiment and setup phases. The value of displacement obtained in this way will differ from the value based on steps performed by the stepper motor, depending on the geometry and mechanical properties of all parts of the chain between the stepper motor and the measuring point.

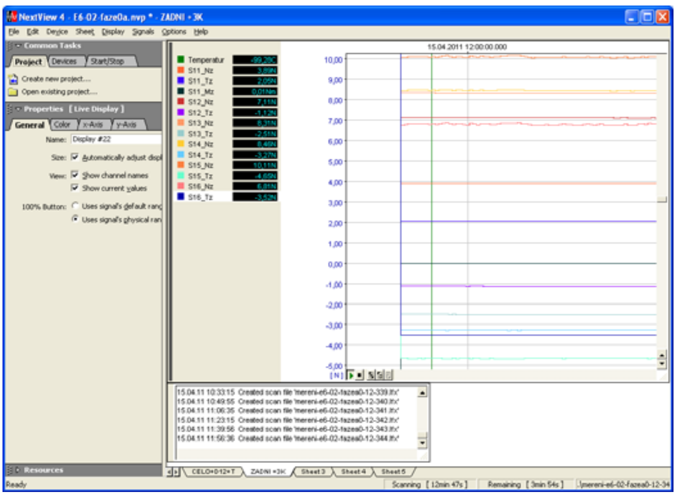

Fig. 3. A sample screen of LabView program shows live views of actually measured data

In order to obtain independent and precise information of displacements, the choose to enrich the installation with another one displacement sensor has been made. As the solution best suited for our purposes, after several consultations with BMC, a digital, optoelectronic sensor was chosen, with 10 nm resolution ability (Megatron NRI). This type of sensor is nearly insensitive to electrical interferences, yielding to higher degree of complexity of system status observations. Unfortunately, significant errors of sensor output in cases of very slow displacements, crucial for our studies, occurred. A genuine device for sensor testing and calibration has been designed and implemented, and these facts proved. The data scanning devices have been detected to be the reason of the above mentioned disfunctionality, in cooperation with BMC.

The data scanning device of the new sensor has been replaced with a measuring card embedded into the PC. Slow speed problems were solved, but synchronization problems between other external data scanning devices and the internal measuring card emerged. Unkind but effective measures have been taken: time windows (for our sample rate 15 minutes works) are repeatedly independently processed, with appropriate LabView option applied.

Grid of well visually recognizable markers is newly optically measured on the one longitudinal side of the sand body. Cameras and a PC provide us this way the current sand body geometry information.

5. Observation of sample's surface

In order to capture relation between slip lines observed on transparent sides and surface development, final state of the sample's surface was thoroughly analyzed. 3D scanner Leica ScanStation C10 (for more information see ref. [3]) was used for precise surface topography determination. The scanner is a sophisticated device utilizing precisely positioned laser with a femtosecond pulse duration and precise atomic clock for distance measurement via method called "duration of flight" of laser light. The result of measurement is a "cloud of points" that belongs to measured surface. This cloud of points is in extensive and time-consuming post-processing stage converted into a smooth surface, incorrectly determined points are excluded. The surface can be visualized and manipulated in several software tools. One of many ways, how to visualize the rendered surface is presented in Fig. 4.

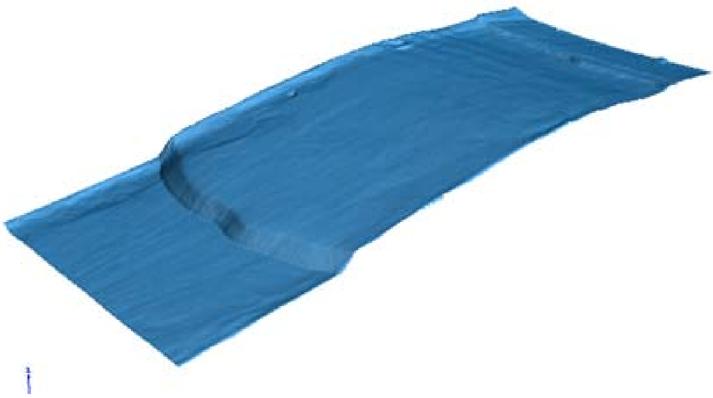

Fig. 4. Vizualization of sample surface

The digital model of surface can also be used for quantitative analysis, for example in Matlab. An example of surface profiles in several parallel cuts clearly illustrates that profiles in the middle of the sample protrudes more forward than the closer to sides ones (Fig. 5).

As the working principle of the scanner implies, the cloud of points is acquired on predefined division of space angle. This can be a serious issue when measured surface is positioned nearly parallel with ray of light direction, measured points are distributed unevenly, as depicts Fig. 6. Another drawback is a possibility partial obscurity of some surface areas for laser beam due to disadvantageous configuration of light direction and surface slope – consequence is incorrectly depicted surface.

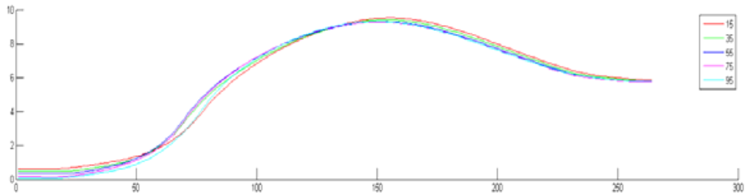

Fig. 5. Profile at various distances from the sides. Vertical scale is exaggerated

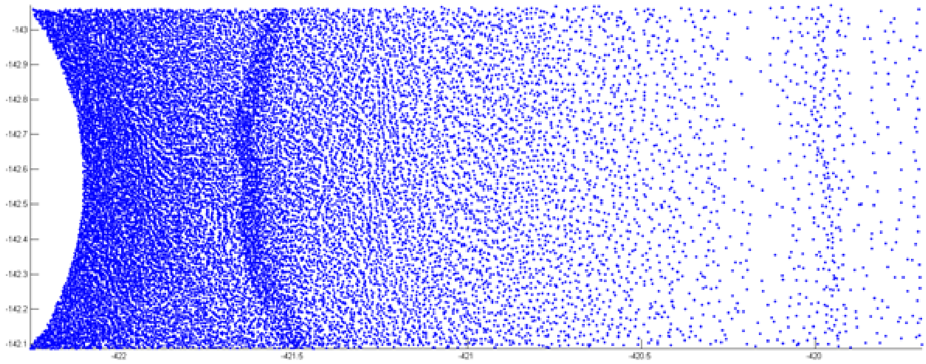

Fig. 6. Cloud of points acquired by laser scanner can be, as in this example, unevenly distributed

6. Discussion, conclusions

To conclude, 3D laser scanning is advanced technique yielding precise and detailed data of studied surface. But, on the other hand, it is also prohibitively expensive and labor-extensive technique that cannot be used on everyday basis in the laboratory conditions. Therefore in the planned experiments we assume to use simpler optical methods based on fringe projection, shadow moiré or digital image correlation. Such a method will provide us with a possibility to record surface development in time and to relate the surface processes with these captured on transparent sides.

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