Experimentální Analýza Napětí 2007

DEVELOPMENT OF EXPERIMENTAL EQUIPMENT FOR SLOW PROCESS DYNAMICS OF LATERAL PRESSURE – STATE IN APRIL 2007

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Abstract: *The experimental research of lateral pressure has been proceeding by means of physical as well as advanced numerical models. Original stand, pressure sensors were developed for the monitoring of both components of lateral pressure, i.e. normal and tangential (shear) ones. The front wall of the stand with the sensors is arbitrarily moved, the side glass walls make possible the visual monitoring of displacements and deformations within a tested soil mass. The research using this stand has brought some obviously new results of some which can be considered as substantial.*

Among others it was achieved so high passive pressure that the nearest glass side tables cracked but the experiment was successfully finished, however the stand renovation has been necessary. The second development stage of the stand involved a reconstruction the thicker glass side walls with regarding front wall and particularly development and carrying out a new concept of front wall engine motion drown by computer.

Keywords: *granular material, lateral pressure, active and passive pressure, pressure at rest ,residual pressure, experimental equipment, 2nd stage of the equipment development.*

1 Introduction

Physical research in the field of granular multiphase materials (geotechnics) on the world scale concentrates in the absolute majority of cases on centrifuge experiments. This technology has a number of advantages, such as relatively simple sample preparation (possibility of using more cohesive materials), experiment speed, high standard and accessories of technology which make it preferable. Some disadvantages includes high costs of not only the centrifuges themselves, but also the special building required for their operation and particularly the theoretical problems of the results of small models of cohesive granular multiphase materials obtained in the conditions of higher gravity and their similarity to the effective stress state. Basic research concerned with lateral pressure theory has not received attention; Kusakabe´s et al. research (2005) is solitary and rather exceptional. Also the theoretical problems of experiments in the higher gravity conditions has been afforded small, if any, attention.

Experimental research of lateral pressure of granular multiphase materials on an original equipment to handle samples of medium dimensions, i.e. samples 1.5 – 3.0 m long, 1.0 m wide and 1.2 m high, designed for this purpose, has been taking place for several years. The research concept is intended on an investigation near to the actual problem conditions (slow movement and lateral pressure dynamics including - compare to Schneebeli). This equipment makes it possible to measure both (normal and shear) stress components (Koudelka & Valach

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2002) any type of front wall movement by human force and visual observation of granular mass deformation through lateral glass walls. The research carried out with this equipment has brought about some unexpected and probably new results some of which may be considered essential.

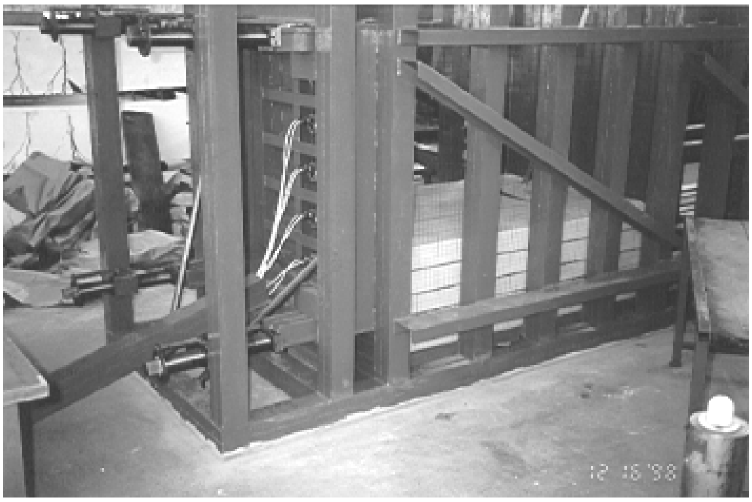

Fig. 1 Experimental equipment after the 1st development phase during the preparation of the first experiment E1 with active lateral pressure (specimen length 1.5 m). On the left side the movable front wall is provided with 4 bi-component pressure pick-ups, the upper is still missing.

The research comprised i.e. the investigation of time stability of both pressure components, i.e. normal and shear components. The experiments have shown the time instability of lateral pressure and the knowledge of its tendency. The research of lateral pressure history and of model masses and their dynamics during the slow structure movement processes required further development of experimental equipment. Moreover, it has come to light during the passive pressure research with dry industrial sand (size 0.3 mm) in 2002 that the primary special glass plates 10 mm thick in the sides were convenient for the research of active pressure, but unfortunately proved too weak for the research of passive pressure.

Therefore, it was necessary to increase the thickness of lateral glass walls, which necessitated the reconstruction of the whole equipment. This reconstruction covered also the improvement of the movement drive (replacement of manual with motor drive), movement sensing and further components of research technology.

2 Initial State – 1st Development Phase

The experimental equipment is of original design and both the technology and the equipment are undergoing constant development. The concept is open and is based on limited research resources and envisages successive equipment development in several phases, depending on the results of previous research phase on the one hand and on the funds available on the other.

The first phase covered the design and construction of the experimental equipment with the front wall movable in any required direction within 300 mm (+/- 150 mm inwards and outwards). The wall enables rotation at the toe or at the top as well as a regular movement, all

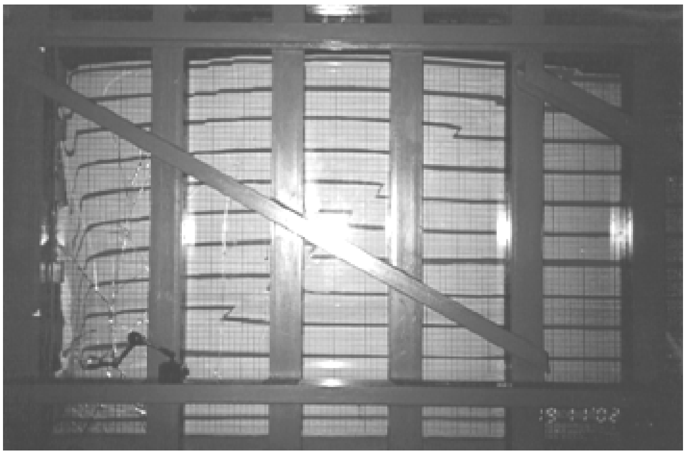

Fig. 2. The state of the ideally loose sand mass and the lateral glass wall in the passive lateral pressure experiment E3/2 during front wall rotation about the top (left) after the 158.8 mm toe movement in inward direction. It is possible to observe heavy cracks in the glass plate near the movable front wall; the greatest displacement is measured by a micrometer (lower left).

three movements in both directions. The outward movements (away from the granular mass) generate active lateral pressures, the inward movements (into the granular mass) generate massive lateral pressures. Front wall movement was generated by the turning of four high-precision screws (see Figure 1 left) actuated by long wrenches with an accuracy of some 0.025 mm.

The front wall movement was controlled by revolution meters of individual screws, the actual front wall movement was measured by four classical micrometers mounted on skids in wall corners. The accuracy of micrometer readings was 0.01 mm which is considered high accuracy in geotechnics.

The granular mass pressure in contact with the movable front wall was monitored by bi-component pick-ups according to the Czech patent of Šmíd-Novosad and a BMC station and amplifier which had proved very well (Koudelka & Valach 2002). The BMC "NextView" programme took care of recording and evaluation.

According to the initial idea a visual observation was intended as a supplementary activity. In the course of the experiments, however, it brought about a number of new information and, consequently, was developed from plain irregular photographing of changes in the red strata to continuous observation and documentation on both sides (red strata on one side, a 40/40 mm grid of black points consisting in glass beads made by Ornela a.s. on the other side - Koudelka & Valach 2000) and the monitoring of the deformation of the upper free surface of the granular mass (Valach & Koudelka 2005).

3 New State – 2nd Development Phase

This phase of development of the equipment comprised initially only the provision of front wall motor drive. However, due to the defects of lateral glass walls on both sides of the equipment and the necessity of their strengthening it was necessary to provide also a new, narrower front wall. The concept of this phase was expanded subsequently to include all necessary and possible modifications required for the optimization of the equipment. Lateral glass wall thickness was increased from 10 mm to 20 mm. The new front wall required by this thickness was redesigned to that it could be modified easily in case of further increase of wall

Fig. 3. Overall view of the computer-controlled front wall motor drive after the first development part and restructure of the moved front wall. The motor is on the left; the linear incremental position pick-ups near the skids cannot be seen.

glass wall thickness was increased from 10 mm to 20 mm. The new front wall required by this thickness was redesigned to that it could be modified easily in case of further increase of wall thickness, if required in the future. The front wall was also provided with special seal at the sides, as the ideally loose sand used in experiments behaves as a fluid around even very small openings and gaps. Also new high-precision movement screws were provided.

Fig. 4. Details of upper screws for front wall movement with skids and linear incremental position pick-up (left side view in 2006) and after the development in Apr.2007 due to the rupture of the little plate off very hard steel under a bearing steel globe (right – view down).

Also the front wall movement was totally redesigned. The wall displacement is generated by the rotary movement of four screws located in the corners of the wall. The motion of only the upper pair or of only the lower pair of screws can produce the wall rotation about the lower and the upper edge respectively. The screws are driven by a single two-phase stepping motor with a 1:30 worm gearbox. The torque is distributed to the screws by a roller chain with 1:5 transmission ratio. The overall transmission ratio between front wall displacement and the

 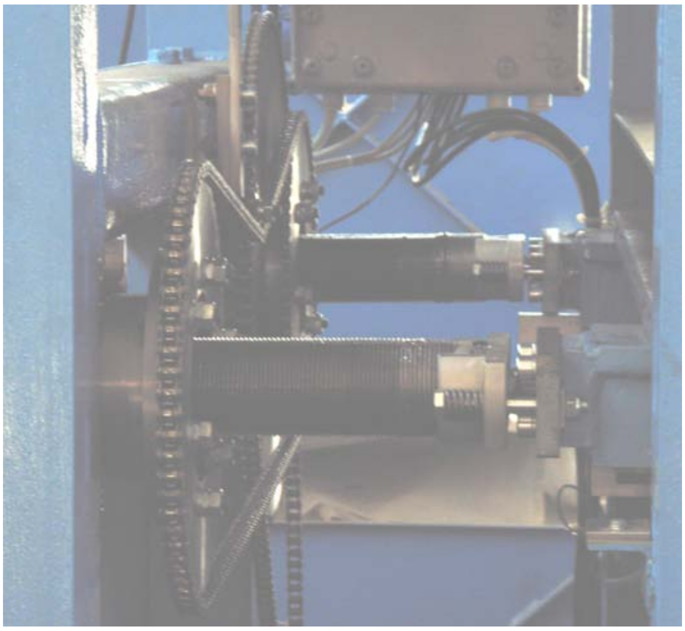

Fig.5 Two right side views at the restructured front part of the equipment in Apr. 2007. In the left picture can be seen the moving system (left) and the translative moved front wall (in picture centre). The right picture shows upper part of the moving system in detail. Details from the Fig. 4 (right) are at the ends of screws (right).

motor drive is 0.35 mm/rev., which makes it possible to produce a pressure force of as many as 40 kN for the maximum stepping motor torque of 3.25 Nm.

The stepping motor is controlled by a programmable unit which can be controlled by simple commands of the control software of an external PC. In this way it is possible to achieve any front wall movement within the velocity scope of 0–20 mm/min. incl. cyclic movements. The control of front wall position is derived indirectly from the inner position links of the stepping motor. For the measurements of the front wall position the equipment is provided with four linear incremental position sensors with a 10 μm resolution situated near the screws.

Table 1. Characterizations of the experimental equipment.

Property	1st phase value	unit	2nd phase value	unit
Equipment - length	3.920	m	3.920	m
- width	1.400	m	1.400	m
- height	2.386	m	2.386	m
Specimen - length	1.5 - 3.0	m	1.5 - 3.0	m
- width	1.000	m	0.980	m
- height	1.200	m	1.200	m
Max. active wall movement	- 150	mm	- 300	mm
Max. passive wall movement	+ 150	mm	+ 242	mm
Movement resolution	10 μm		10 μm	
Min.wall movement velocity	manual stepping		> 0 mm/min	
Max.wall movement velocity	manual stepping		20 mm/min	
Max. pressure force	manual		40 kN	
Max. measured pressure	163.16	kPa	-	

4 Conclusion

The first tests of the new motor drive of the experimental equipment were successful. The equipment has not been used for a new experiment yet, as also the movement screws have been redesigned and the IT development makes it necessary to innovate also hardware and software.

The new level of experimental equipment should increase substantially also the accuracy of experiments, particularly in time, and to expand experimental possibilities also to the field of dynamics of granular masses.

Acknowledgement: Financial support of related research projects Nos.103/1997/0702, 103/2002/0956, 103/2005/2130 and IAA 207/1302 was provided by the Grant Agency of the Czech Republic and the Grant Agency of the Academy of Sciences of the Czech Republic. The reconstruction of the equipment was participated in by the technical staff of the Institute of Theoretical and Applied Mechanics. The authors would like to thank all of them for support.

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