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Speedy partial process of lateral pressure in granular mass during consolidation – Experiment E5/0,2

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Abstract: The long-term experiment E5/0,2 with pressure at rest and passive pressure of ideally non-cohesive sand ran in 2010 and consist of a number of phases which brought huge quantity of data. The experiment contained also a phase of consolidation after passive wall rotation about the top with a toe movement of 15.6 mm. Movement velocity of the front wall toe was 0.005 mm/min. only. On the contrary, processes of the pressure components (normal and shear) were surprisingly quick. The Paper presents an analysis of a process of time pressure instability at the beginning and the end of a reconsolidation phase.

Keywords: Physical experiment; Granular non-cohesive material; Consolidation; Passive pressure at rest; Pressure instability; Speedy process.

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, i.e. pressure due to wall movement towards into the mass, (rotation about the top – E3/0,2) 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. During a necessary long experimental break (251 days) sample consolidated and due to it instability of lateral soil pressure was observed and registered (see [1] or [3].

The long-term experiment E5/0,2 with pressure at rest and passive pressure of ideally non-cohesive sand ran in 2010 and consist of a number of phases which brought huge quantity of data. The experiment contained also a phase of reconsolidation after passive wall rotation about the top with a toe movement of 50 mm. Velocity of the front wall movement was 0.005 mm/min. only. On the contrary, some processes of the pressure components (normal and shear) were surprisingly quick. For the present, three pressure processes in granular masses appear to be quick (relatively to other processes in the masses):

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- changes of pressure at rest due to imperceptible wall movements in a zero interval,
- processes due to temperature changes of the structure or the mass,
- processes due to a wall movement start or stopping .

The paper deals with the last process group that comes on as result of sudden wall movement stopping or beginning.

2. Experiment E5/0,2

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 rotation about the toe and top and translative motion),
- *passive pressure:* three repeated experiments with pressure at rest and passive pressure (structure rotation about the toe and top and translative motion).

Thus, it is altogether two times six experiments except of experiment E3/0,2 that was performed using the original simple equipment of which results probably will not be completely comparable due to cracked glass side tables near to the toe of rotated front wall. The experiments with active pressure were carried out firstly.

The basic physical research for the more advanced theory (GLPT) and its development has continued from April 8th, 2010 to be completed the experiments with pressure at rest and passive pressure, i.e. double repeated long-term experiments with rotations about the top and the toe and with translative motion. 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. The velocity appears to be near to natural soil, geological and other processes (56 times faster than continental drift or 50 times faster than finger nail growth). The experiment E5/0,2 was also the operation test of the new equipment. Both the operation test and the experiment were finished successfully in October 2010. A history of the experiment E5/0,2 see in Table 1. Analysed results are of the phase “recons. 4” (Tab.1 - thick frame). The experimental equipment

Table 1. History of experiment E5/0,2 - Rotation about the top

E5/0,2	Date			Toe movement		
Phase [1)] [Note]	Start [day]	End [day]	Time [2)] [h/m/s]	Direction [act./pas]	Max.dist. [3)] [mm]	Velocity [mm/min]
0a	08.04.2010	08.04.2010	1:01:00	active	- 0.270	0.005
recons.1	08.04.2010	15.04.2010	-	-	- 0.270	0
a0	15.04.2010	15.04.2010	1:09:05	passive	- 0.083	0.005
recons.2	15.04.2010	22.04.2010	-	-	- 0.083	0
0p	22.04.2010	22.04.2010	1:40:11	passive	0.768	0.005
recons.3	22.04.2010	03.05.2010	-	-	0.768	0
p1	03.05.2010	05.05.2010	52:11:53	passive	15.601	0.005
recons.4	05.05.2010	14.09.2010	-	-	15.601	0
p2	14.09.2010	13.10.2010	703:40:03	passive	226.890	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] Maximum distance of the wall toe at the phase end from wall original position before the experiment start.

see in Fig. 1 and a detailed description of the equipment and an equipment function during the experiment (operation test) can be found in [2] and [4]. The repeating and proving experiment E6/0,2 ran from 25.3.2011 to 19.12.2011.

Fig. 1. Experimental equipment before the experiment E5/0,2 during sandy sample preparation.

Fig. 2. Deformation of the sandy sample during the phase "recons. 4" after the toe movement of 15.6 mm (see uplift of red strips).

2.1. 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 follow: unit weight γ= 15.172 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 % (slightly deformed sample of the phase after the toe movement of 15.6 mm see in Fig. 2).

3. Pressure analysis

Original data, gathered by our measuring system using NextView software, were exported to ASCII format. Because of huge amount of these data (tens of gigabytes), a specialized program, written in Free Pascal (fpc/lazarus system) was used for preparation of data for graphing. Graphs were then created using Matlab. The stair-like nature of the graphs is due to resolution of used A/D converters (16 bit) in combination with relatively small range of displayed data. The sampling rate was 100 Hz, but the moving average of length 100 was applied to the data first.

The analysis concentrates on processes of examinant passive pressures in short time intervals around both limit points of the reconsolidation 4 (stop-up and start-up of the wall rotation about the top). Presented analysis part shows time histories of normal pressure component in the intervals containing about one hour

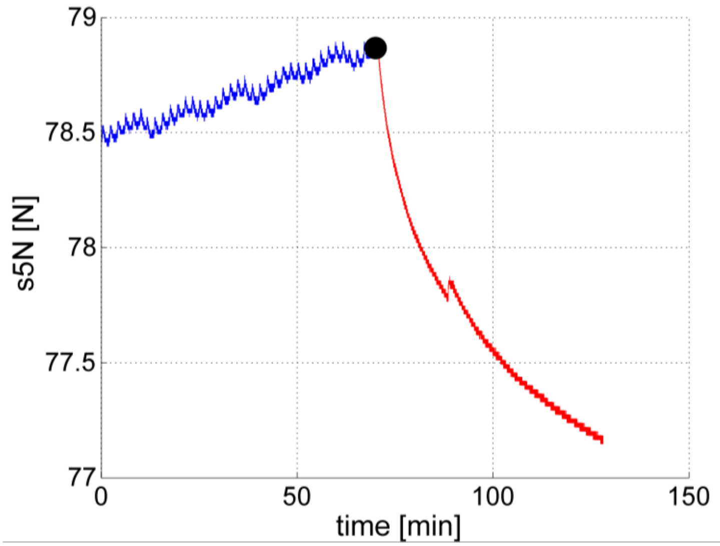

Fig. 3. History detail of normal component of the bi-component sensor 5 around the wall movement stop-up flash after the toe passive movement of 15.61 mm (thick black point above centre of the time axis). Left (blue) part shows the history during the last 70 minutes of wall movement before the reconsolidation phase 4. Right (red) part shows the history during the first 58 minutes of the mass reconsolidation.

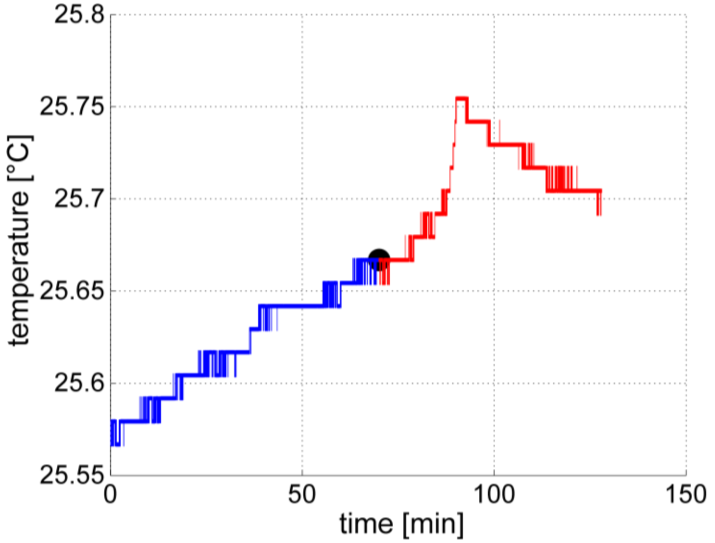

Fig. 3. Relevant history detail of temperature of the experimental equipment structure around the movement stop-up flash after toe passive toe movement of 15.61 mm (thick black point above centre of the time axis). Left (blue) history part shows the history during the last 70 minutes of wall movement before the mass reconsolidation phase 4. Right (red) history part shows the history during the first 58 minutes of the reconsolidation.

before and one hour after the relevant change flash (movement/rest and rest/movement).

Temperature plays an important role in lateral pressure processes taking their courses in the mass sample. This is a reason why one of parameters of presented graphs in Figs.4 and 6 is just temperature though temperature changes in the short time intervals are little.

The analysis around the end of the *first passive rotation* up to the toe movement of 15.6 mm has taken into account data more than one hour before (70 minutes) to less than one hour after (58 minutes) from the stop-up flash of the rotation. A toe displacement during the first half of the time interval was of 0.35 mm (zero in the second half) and a temperature change of the time interval is of 0.125 °C (see Fig.4). A history of normal pressure component of the sensor 5 (depth of 0.865 mm) is showed in Fig. 3 during 128 minutes of the interval. The stop-up flash is differentiated by a small circle. There can be seen two different speedy processes of passive pressure in time with stabile structure (without front wall movement):

a) A permanent pressure decrease immediately after the stop-up of the wall rotation that is not linear (see Fig.3). If we compare a continual velocity of a pressure increase during the wall rotation of 0.0055 N/min = 0.00278 kPa/min to a decrease velocity of the first 18,56 minutes after the wall rotation stop-up of 0.0588 N/min = 0.02995 kPa/min the first decrease velocity is 10.77 times speedier. An average decrease velocity during following 36.5 minutes, i.e till 58 minutes from the rotation stop-up, is of 0.01565 N/min = 0.00797 kPa/min and this is compared to the increase velocity of the phase "p1" 2.87 times speedier.

b) A quick accidental increase and a following slower decrease of temperature of the equipment structure of 0.05°C between 87^{th} and 91.5^{th} minutes (see Fig.4): The temperature changes caused after 91 sec a little quick increase of the relevant normal component of the pressure sensor 5 (see Fig.3). The maximal *absolute* pressure increment compared to pressure of the temperature increase beginning was of 0.091 N = 0.0463 kPa (i.e. 0.9269 kPa/°C) , the *relative* maximal pressure increment to a supposed pressure history without temperature change was about of 0.115 N = 0.0585 kPa (i.e. 1.05093 kPa/°C). The temperature increase was followed by a slower decrease to the same value like at the temperature increase beginning (before 58 minutes). The temperature influence and the increase of pressure normal component backed out steadily and almost simultaneously (time differences were of 1.5 and 2.6 min). An increasing pressure velocity due to temperature change was of 0.235 N/min = 0.1198 kPa/min. This process was 43.1 times quicker than the pressure increase due to the wall movement, 8 times quicker than the decrease after the wall movement stop-up but only 1.44 quicker than the increase velocity of pressure after the repeated wall movement start-up at the beginning the phase "p2".

The analysis around the beginning of the *second passive rotation* after of 132 days of the reconsolidation (phase 4) has taken into account data of 4 minutes before

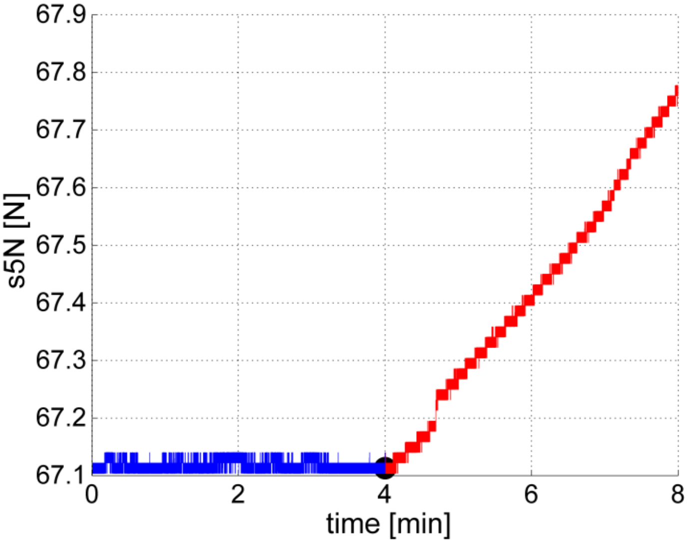

Fig. 5. History short detail of normal component of the bi-component sensor 5 around the movement start-up flash (thick black point close to centre of the time axis) after 132 days of the mass reconsolidation at passive toe movement of 15.61 mm. Left (blue) part shows the history during the last 4 minutes of the reconsolidation. Right (red) part shows the history during the first 4 minutes of wall movement of the phase “p2”.

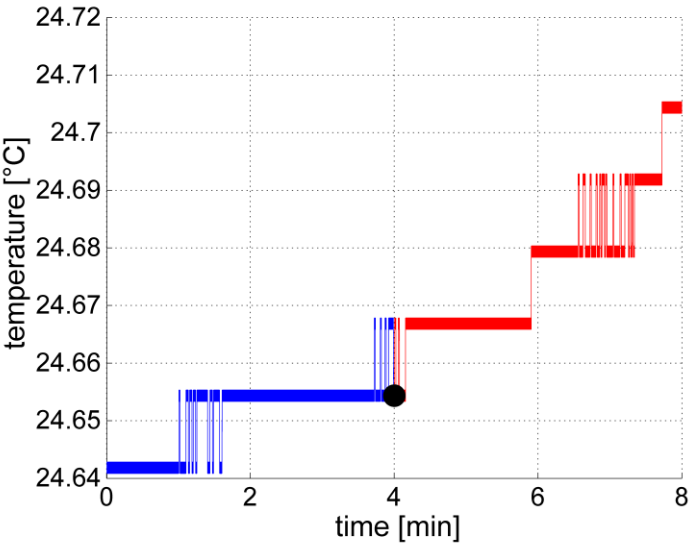

Fig. 6. History short detail of temperature of the experimental equipment structure around the movement start-up flash (thick black point close to centre of the time axis) after 132 days of the mass reconsolidation at passive toe movement of 15.61 mm. Left (blue) part shows the history during the last 48 minutes of the reconsolidation. Right (red) part shows the history during the first 4 minutes of wall movement of the phase “p2”.

and 4 minutes after the start-up flash (see Figs.5 and 6). Toe engine displacement during reconsolidation was zero and then after 4 minutes of the passive rotation (phase “p2”) of 0.020 mm. A temperature change of the time interval of 0.062 °C could be considered almost negligible (see Fig.6). A change of passive pressure at the reconsolidation end was not detectable in such short time interval. However, almost immediately, the presented normal component of the sensor 5 began to increase linearly of a velocity of 0,16375 N/min = 0.08340 kPa/min (see Fig.5). This velocity compared to the pressure increase at the end of the phase “p1” is 30 times higher and to the reconsolidation decrease 5.6 times higher.

4. Conclusions

Dynamics of processes in granular masses is very important both for theory and experimental practice but also for engineering practice. The paper presents the first analysis part of all both of preformed and considered experiments with passive pressure of uniform ideally non-cohesive granular masses. Data analysed till this time (Apr. 2012) can be a base for following conclusions:

1 The granular mass is very sensitive. It changes its behaviour due to start-up or stop-up and little structure temperature changes practically immediately.

2 Pressure increments due to toe movement velocity (0.005 mm/min) at the *beginning* of the wall movement after reconsolidation are much higher than pressure increments due to the same movement velocity during longer movement (compare Figs. 3 and 5). It appears to be a similar phenomenon to passive pressure at rest.

3 The course of the immediate pressure decrease after wall rotation stop-up is non-linear and probably similar to logarithmical curve like other dependencies of soil mechanics.

Fig. 7. Overall view at the experimental equipment under envelop against quick temperature changes whole time the experiment E5/0,2.

4 An influence of temperature of the equipment structure at the pressure normal components appears to be also practically immediate. The found value of 1.05 kPa/°C for the sensor No. 5 in depth of 0.865 m cannot be considered like proved because it was analysed from the slight and short temperature change. Anyway, the influence is not negligible though it is less than 1.5 %, former estimations indicated about of 5-7 %.

5 A used envelope of the experimental equipment with the samples is necessary (see Fig.7).

In the future, a difference between temperature of steel frame of the experimental equipment and granular mass can be also precisely measured by thermo camera [5]. Above presented conclusions will be further completed and specified according to results of further analyses.

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