22nd International Conference
ENGINEERING MECHANICS 2016
Svratka, Czech Republic, 9 – 12 May 2016

EXPERIMENT E7/0,3 – DISPLACEMENT PROCESSES IN NON-COHESIVE SAND MASS DURING ACTIVE TRANSLATIVE MOTION OF RETAINING WALL

P. Koudelka*

Abstract: *The first part of information on the new experiment denominated as E7/0,3 with* active *pressure of non-cohesive quartz sand on time behaviour of the mass was presented at the last Conference (P. Koudelka, 2015). The second part is object of this Paper. The experiment was performed at the Institute of Theoretical and Applied Mechanics in 2014. The moved rigid front wall of the experimental equipment was translatively moved towards active direction (out of the mass) at a position of supposed acting of active pressure value, then the wall motion was stopped and time pressure stability was monitored. After more than three months the wall was moved at the last position of 100 mm from original position before the experiment. The experiment ran four and a half months. The paper presents firstly results on the deforming mass through the course of the wall movement at a supposed position for active pressure mobilization of 1.357 mm and after the further movement. The experiment was repeated to be the results proved (Experiment E8/0,3). New results are analysed.*

Keywords: Retaining wall, active lateral earth pressure, non-cohesive material, sandy mass behaviour, wall movement modus, displacements.

1. Introduction

Long-term experiment E7/0,3 with *active* lateral pressure of sandy mass is a part of a long-term research of lateral earth pressure of non-cohesive granular masses at the Institute of Theoretical and Applied Mechanics running from 1998. A complete set of experiments with *passive* pressure ran in period 2010 - 2014 (P. Koudelka, 2013) when all three basic modes of wall movement (rotations about the top and toe, translative motion) were tested two times (experiment sets E5 and E6), altogether six long-term experiments using the same sand to be proved mass behaviour during each wall movement modus. The presented experiment E7/0,3 ran in the second half of 2014 year. A repeated same experiment E8/0,3 ran after in the first half of 2015 and its results are analysed.

Each of experiments brought huge volume of different data. Data of bi-component pressure sensors (normal pressure and friction), movement sensors and temperature sensor were registered digitally using record frequency of 1-100 Hz (max. frequency is of 1000 Hz), cameras of visual monitoring of small globule displacements in the mass on left side and surface of the mass registered pictures with record frequency 1 picture per minute. The digital registering is complemented and secured by "handmade" data registering of sensors and namely uplift/settlement of red sandy strips in the mass on right side and their disruptions which show slip surfaces in the mass much more preciously than globule displacement vectors on the opposite side. The Paper presents some results of an analysis of the strip registering ("handmade" data and photos).

2. Experimental equipment and techonology

Experimental equipment and technology were mentioned at the last Conference in the paper P. Koudelka (2015). A brief survey follows. It was availed the same developed advanced equipment with transparent side walls (glass) such as for the previous experiments with passive pressure (P. Koudelka, 2013) however, with shorter sandy sample space. Sizes of sandy sample were as follows: wide of 0.98 m, height

* Petr Koudelka, DSc.,PhD.,AEng.,CEng.: Institute of Theoretical and Applied Mechanics, Czech Academy of Sciences, Prosecká 76; 190 00, Prague; CZ, koudelka@itam.cas.cz

of 1.20 m, length of 1.375 m (previous experiments – length of 3.0 m). Numbers of bi-component pressure sensors in a front moved wall (5) and a stable back wall (6) were the same but more sensitive sensors for lower pressures were used. It is used the same sharp quartz material of size of 0.3 mm repeatedly and as well as for the experiment E7/0,3. Compaction of the mass was homogeneous and not too high similarly to previous masses using also a special exact compacting instrument (n*=47.0 %*, I_D = *0.55*, unit weight γ = *1494 kg/m*^{3}).

2.1. Experiment Flow

The **e**xperiment was in progress in three motional phases applying front wall translative motion and three reconsolidation phases (without a motion). The first motional phase tested an influence of *active* micro movement of the front wall from an original position of u *= 0 mm* to position of u *= -0.28 mm*, i.e. behaviour in a range of pressure at rest. The second motional phase followed after 5 days at wall position of u *= -1.36 mm*, i.e. supposed full mobilization position of *active pressure* according to EN 1997-1 (Annex C). Then time behaviour of the mass consolidated along of 97 days was monitored. The last motional phase at position of u *= 100.42 mm* made it possible to monitor behaviour of the mass in a range of full shear strength mobilization and further during destruction of the mass. Consolidation pressures of the failed mass were monitored 23 days after. A movement velocity of the front wall during all motional phases was of *0.0049 mm/min*., the same as during other experiments.

Fig. 1: View at the right side of the sample after active translative motions of the front wall (left):
a) Movement of 1.36 mm to left. Deformations are not yet visible.
b) Movement of 9.13 mm to left. Deformations and the first main slip surface are visible.
c) Movement of 74.04 mm to left. Displacements are very obvious in a frontal active mass part and create very complicated system of slip surfaces.

3. Results of slow processes in the mass

The wall motion velocity was very slow to be near to behaviour velocity of natural soil masses which, unfortunately, can vary in wide limits. The applied wall velocity about of 0.0049 mm/min. is about fifty times faster than a continental drift between Europe and America or grows of human nails only. The velocity corresponds approximately to behaviour of long term retaining structures under pressure of less cohesive soils.

3.1. The mass deformation

The mass shows two parts which are visibly distinct almost from the motion beginning. A frontal wedge shaped part touching the wall subsides according to the wall motion. A pure deformation process does not continue during a longer motion owing to a process of slip surface creating. It can be seen comparing Fig. 2a and Fig 2b, resp. less obviously in Fig. 1a (very slight subside) and Fig. 1b. Absolute wall motion values in figures are denominated like *u* and a note minus signifies active direction, i.e. out of the mass.

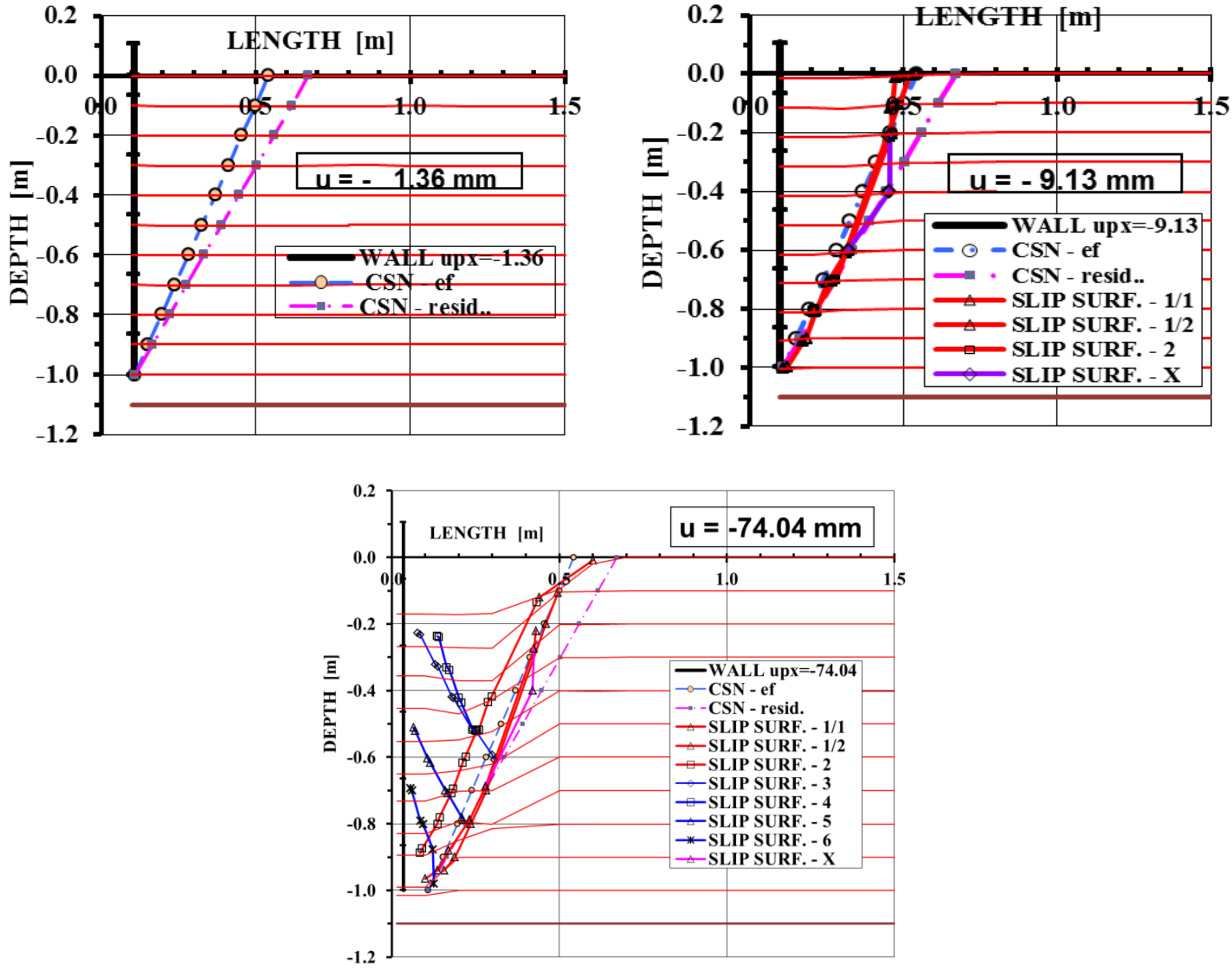

Fig. 2: Graphs of real drop of the red strips in the sample and real slip surfaces according to mass states in Figs. 1:
a) State after motion of 1.36 mm to left. Deformations are not yet visible.
b) State after motion of 9.13 mm to left. Deformations and the first main slip surface are visible.
c) State after motion of 74.04 mm to left - state of the frontal mass part destruction. Displacements are very obvious in a frontal active mass part and create very complicated system of slip surfaces.

Vertical thick full lines in figures demarcate positions of the wall and horizontal line marks give positions of the pressure sensors. Inclined lines in Fig. 2a are shear surfaces supposed according to the classic earth pressure theory (also by ČSN 73 0037) considering angle of effective shear strength (dashed blue line) and angle of residual shear strength (dash-dotted violet line).

The code EN 1997-1 presents in Annex C, Table C.1 values of ratios v_a/h for non-cohesive soils where v_a is the wall motion to mobilise active earth pressure and h is the height of the wall. The values depend on kind of wall movement and compaction of the soil. Translative motion values in cases of loose and dense soils are of *0,2,* resp. *0.05-0.1*. The mentioned compaction of the mass of $I_D = 0.55$ accords to approximately medium compacted soils and the motion value of *u=-1.36 mm* accords about to suppositions of the code for active pressure mobilisation. The mass deformation near after this value begins to be influenced due to displacements along slip surfaces creating themselves.

3.2. Slip surfaces

The first slip surface zone appeared before reaching of the wall motion value of *u=-9.13 mm*. The zone involves the slip surfaces 1 and 2. Unfortunately, an equipment structure post covers an area around length of *0.4 m* and a substantial part of histories of the slip surfaces was not visible (see Fig. 1b). Owing to this fact the missing part was interpolated. However, a more probable history of this part of slip surface 1 may be a history according to the slip surface X.

A further history of transfiguring of the mass begins by widening of the first slip surfaces zone (slip surface 1 and 2) and by slipping of the frontal mass part along the zone. Next slip surfaces create themselves outside the zone step by step (e.g. slip surface 2). The second opposite system of slip surfaces begins to create about of wall motion of *25 mm*. This system is very complex and it causes subsidence process of a middle part of the mass frontal part (Figs. 1c and 2c). This is after the point of the destruction process beginning.

4. Conclusion

Known wider physical experiments with lateral earth pressure appear sporadic. There can be mentioned an excellent research of lateral passive pressure in Cambridge presented by Roscoe (1970), unfortunately without detailed results for wall rotation about the top and not concerning with active pressure. Also, there can be mentioned experiments of Gudehus (1980) monitoring total forces acting on the whole wall.

Owing to this research situation the long term wide research at the institute can be useful and applicable for a putting more exactly of lateral earth pressure theory and practice.

5. Acknowledgement

The author thanks to Jan Bryscejn, EEng. for driving the equipment and data registering a transforming. Of course, exact collaboration of institute technicians was requisite and meritorious.

References

EN 1997-1: Eurocode 7: Geotechnical design – Part 1: General rules. CEN, Bruxeles 2004, 168 ps.

Gudehus G.(1980): *Materialverhalten von Sand: Anwendung neuerer Erkentnise im Grundbau.* Bauingenieur,55/9,351-359.

Koudelka, P. (2015) Experiment E7/0,3 – Displacement Processes in Non-cohesive Sand Mass during Active Wall Translative Motion, in: Proc. 21st IC on Engineering Mechanics 2015 (J. Náprstek & C. Fischer eds), Institute of Theoretical and Applied Mechanics, v.v.i., Praha, Czech Republic. ISBN 978-80-86246-42-0, ISSN 1805-8248, pp. 146-147.

Koudelka, P.(2013) Double Case of Passive Pressure Acting on Wall Rotated about the Top. Proc.7th IC on Case Histories in Geotechnical Engineering (#3.15b), Wheeling (Chicago, Ill.), Apr.29-May 4, 2013. S. Prakash, Missouri University of Science and Technology, Rolla, MO, USA. ISBN 1-887009-18-3 (Abs.v.), ISBN 1-887009-17-5, ps.10.

Roscoe, K.H. (1970): The Influence of Strains in Soil Mechanics. *Géotechnique 20*, No. 2, pp. 129-170.