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LATERAL PRESSURES OF GRANULAR MASS EXPERIMENT NO. 2

Petr Koudelka *

Abstract

In 1997 and 1998 an original special experimental equipment (including bicomponent tensors, a large stand and others) was designed and developed for the research of lateral pressure of granular materials. The retaining wall of the stand is measured and can be arbitrarily moved. In 1998 and the first half 1999 was made the first medium-term experiment with a mass of very dry flowing sand was made which has brought some little expected and new results. That was for the nearly same experiment was repeated in the second half 1999 exploiting three new more fitted tensors.

The paper presents information about the research and the experiment no. 2 (marked as E2) and shows measured lateral pressures of the granular mass due to three types of movements of the retaining wall, i.e. rotation about the toe, rotation about the top and, finally, translative motion. The results of the experiment were inputs for the proposal of amendment EC7-1 (EUROCODE 7 Part 1 "Geotechnical design"), Art. 9.5.

Key words: granular mass, lateral (earth) pressure, retaining wall (structure), bicomponent tensor, shear and slip surfaces, rotations about the toe and top, translative motion.

Introduction

No satisfactory procedures for the computation of dynamic earth pressures are known and the knowledge used for the computation of static earth pressures does not correspond with the significance of the problem, either. Its complicated character and the state of the solution of earth (lateral) pressures is testified to also by the fact that the valid preliminary issue of EUROCODE 7-1 (1994) defines formulae for the active pressure at rest (Jáky 1944) and neglets the passive pressure at rest (Pruška 1973).

An advanced numerical model based on a comprehensive nonlinear dependence, has shown that the Code limit movements (Art.8.5.4/2, last draft Art.9.5.4/2) do not correspond with mobilization of the peak shear strength (Koudelka 1996, 1998a, 1999b). Then the Code presents {Annex G} the sample procedure to determine the extreme {peak} values of earth pressures for the case of peak shear strength mobilization. It gives the coefficients K for the effect of material weight in 9 diagrams depending on frictional and geometrical parameters. Other coefficients {for load and cohesion} are calculated by approximate formulae. It is obvious that the actual theory of earth {more general "lateral"} pressures is not satisfactory.

Therefore, two research projects were proposed and started by the author institute with the support of the Grant Agency of the Czech Republic. The paper presents some important results of the physical modeling project. Some results of the numerical modeling project

* Petr Koudelka, PhD., UTSD, MSc, Institute of Theoretical and Applied Mechanics – Academy of Sciences of the Czech Republic, S.S.O. Address: Prosecká 76, Prague 9, 190 00. Tel.: +42.2.86882121, Fax. +42.286884634, E-mail: koudelka@itam.cas.cz, I-net: http://www.itam.cas.cz .

concerning with the comprehensive nonlinear constitutive dependence were presented (Koudelka 1990, 1992, 1996, 1998a, 1999b). The more detailed information about the experimental procedure see in Koudelka 1999c.

Concept of research

A special equipment for the research of bicomponent lateral pressures of multi-phase granular materials was designed and developed during the past three years in the Czech Republic by the Institute of Theoretical and Applied Mechanics {Academy of Sciences}. The research should contribute to the verification of the mathematical models (Koudelka 1998a,b, 1999b) and, also, to the drafting of a General Lateral (Earth) Pressure Theory. The measurements of lateral pressure are based on the Czech invention of bi-component tensors (Šmíd – Novosad) which enable simultaneous continuous measurements of normal and tangential components as well as dynamic pressures.

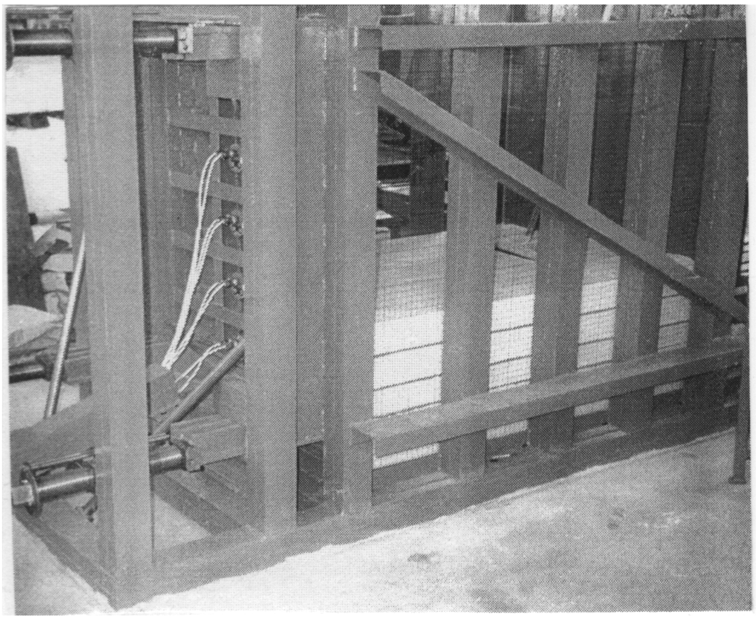

Figure 1 Experimental stand with transparent lateral sides. The retaining wall is the blue plane inside the structure on the left. Two red tensors can be seen placed in the retaining wall through the front side. The other one above is not in place.

At the end of 1998 and in the first half of 1999 the first experiment with the mass of a really non-cohesive material (very dry flowing sand) was made. Due to some little expected results the experiment was repeated in the second half of 1999 exploiting three new more sensible tensors. The tensors are numbered from top to bottom and were placed at the depths of 0.165, 0.365 m, 0.565 m, 0.765 m and 0.965 m below the surface of the mass.

The possibilities of the arbitrary movements of the retaining wall were used for 3 phases of the experiment with active lateral pressures again. One of the three basic movement types was active during each phase. Before the first phase, the experiment with the passive pressure at rest was made by a small translative motion 0.49 mm (experiment no.1 rotation about the toe max. 0.11 mm only). The experimental equipment and tested material have been described earlier (Koudelka 2000a). Thus, will be stated that the very dry (flowing) sand had following basic parameters : γ = 17,01 kN/m^3 (unit weight), ϕ'= 43,4^o (angle of internal friction). ;

The mass consolidated after the first and second phases during the time interval not shorter than three weeks. The retaining wall was not moved during the reconsolidation time and thus the mass was influenced by the conditions of the experimental hall only.

The values of each of the movements were 8.75 mm which, considering the height of the wall {1,0m} are many times higher than the EC7 Art. 8.5.4/2 as well as ČSN 73 0037

(Earth pressure acting on structures) requirements for the mobilization of maximal shear strength. The phases of the experiment and their relation to standard limit movements for active pressure are shown in the table below:

Phase	Type of movement	Wall height	Max. increment of phase		Standard active limit movements			
					EC 7		ČSN 73 0037	
		H	max u	u/H	u/H	u_{lim}	u/H	u_{lim}
		m	mm	-	-	mm	-	mm
1	Rotation about the toe	1,0	8.75	0,009	0,005	5	0,001-0,002	1 - 2
2	Rotation about the top	1,0	8.75	0,009	0,002	2	0,002-0,004	2 - 4
3	Translative motion	1,0	8.75	0,009	0,001	1	0,0005-0,001	0,5-1

Table 1. Tested movements and standards limit movements for supposed mobilization of active pressure {peak strength}.

Lateral pressures

The experiment has brought about a great number of results, which were processed and evaluated; their scope is extraordinarily large and extends beyond the limits of this paper. Some visual results of E2 have been presented (Koudelka-Valach 2000a) which have shown that behaviour of the perfectly noncohesive granular body which has been similar to E1 and at variance with the present concept of the earth pressure theory again. Also for E1, the publication of the pressure measurement results (normal components) during different movements of the retaining wall is prepared.

The scope of the paper makes it possible to present only a minor part of the E2 results. From the number of results we have selected the dependence of the normal pressure components on the different types of the retaining wall movements. The initial part of the experiment has concerned the proof of the real existence of an interval of the passive pressure at rest. The pressures during translative motion of the retaining wall in the region of the passive pressure at rest and on the rotation about the toe in the region of the active pressure can be seen in Fig.2. All tensors have showed the existence of an almost singular region of pressures within the narrow interval of displacements around zero during the gradual displacement of the wall to the passive side (into the mass) only 0.49 mm. Similar behaviour was observed in 4 tensors also during the small rotation of the top about the toe to about 0.25 mm to the active side. The actual movements of the individual tensors towards the active side were smaller because of the type of the movement and dependence on their distance from the axis of rotation (the toe). Thus, the movements of all tensors in the passive direction amounted about 0.49 mm and in the active interval of the rotation about the toe the movement of the upper tensor amounted to 0.22 mm, that of the lower tensor to 0.02 mm. During passive motion (into the mass) the pressure in four tensors rose steeply and after the change of the direction of rotation it dropped steeply to a value generally lower than that at the beginning of the experiment, before the movement of the wall. The dependence course has been similar as by E1.

During further rotation about the toe in active direction (phase E2/1) the pressure dropped more and more mildly until its drop stopped practically within the interval of the movement of the top of the wall between movement of the top 0.5 mm and 5 mm (Fig.3). In the course of further rotation at the top the pressure rose mildly in all tensors except for the first one. This phase of the experiment proceeded without any break. The break for the reconsolidation followed after the end of the phase but values of the pressure changed not too.

Next course of the normal component of pressure during both rotation about the top and translative motion (phases E2/2 and E2/3) shows Fig. 4 of which it is obvious the different behaviour of the mass due to each of both movement types. Note that the normal component pressure during rotation about the top depended on the movement of the toe. Thus, the actual movements of the individual tensors were smaller because of the type of the movement and dependence on their distance from the axis of rotation (the top). The similar courses of the pressure were measured also by corresponding phases of the experiment E1.

Conclusion

The results of the experiment E2 are very similar to the results of the experiment E1. The differences are very slight and most of them might be caused due to the more sensible tensors and the differences of their placing. Despite of these slight differences the experiment E2 proves the results of the experiment E1.

As the test results of E1 as the test results of E2 have shown the existence of two phenomena which have not been paid attention either in practice or in theory. Their number includes the existence of an almost singular interval of the value of the pressure at rest and, consequently, also the existence of the value of the passive pressure at rest, derived theoretically as early as in the 70s (Pruška.1973). Further it is the ascertainment of a mild increase of lateral pressure during major movements of the retaining wall which points to the existence of reduced shear strength towards residual value. This phenomenon cannot be too distinct in the case of the tested perfectly noncohesive sand, where the change of shear strength concerns only a minor reduction of the angle of internal friction.

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EXPERIMENT no. E2/0-1
ACTIVE AND PASSIVE PRESSURE AT REST

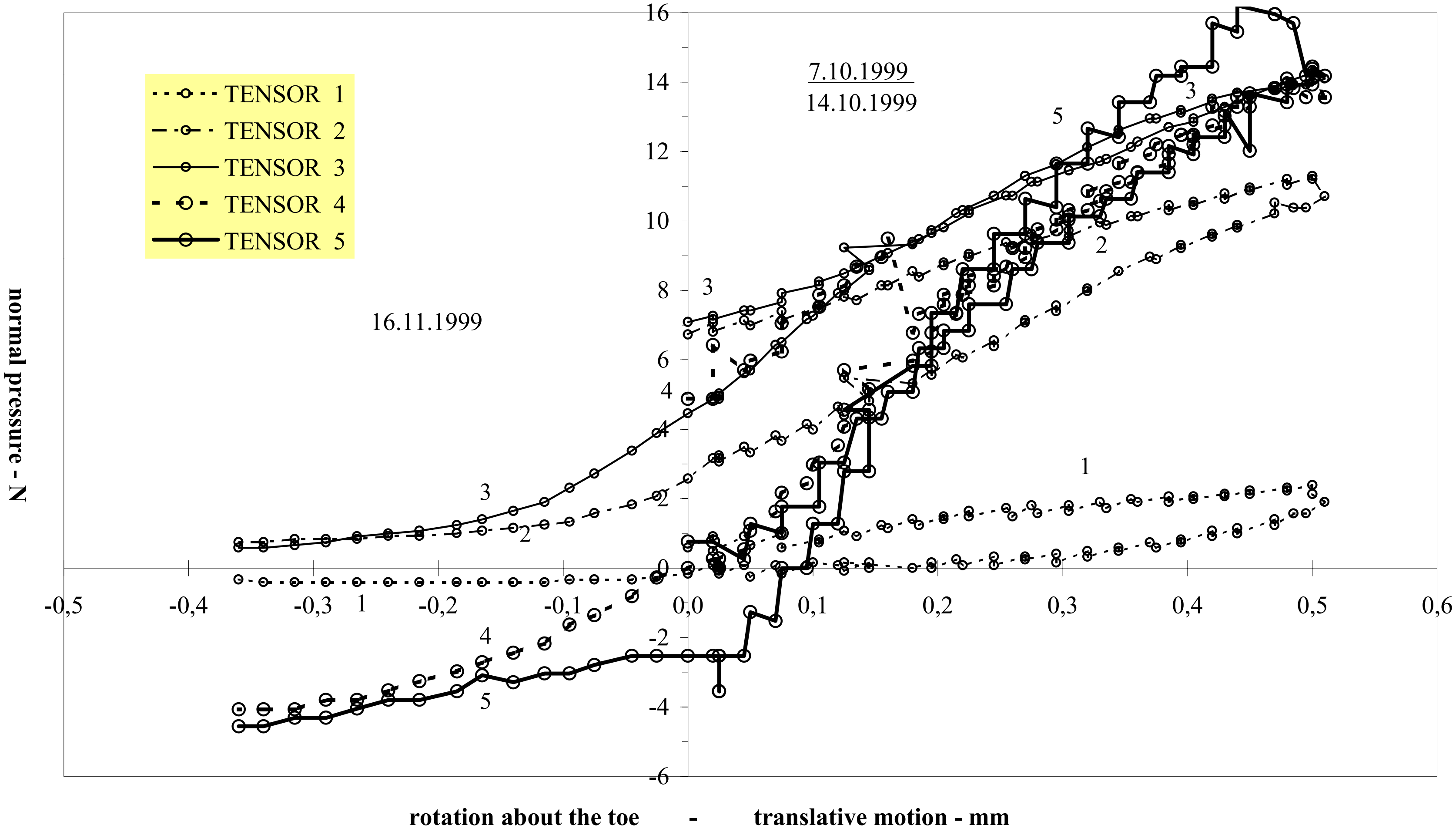

Fig. 2. Experiment 2 – Phase 0-1 – Measured normal components of the lateral passive and active pressure at rest depended on the movement of the top in detailed graph.

EXPERIMENT no. E2/0,1
PRESSURE AT REST+ROTATION ABOUT THE TOE +RECONSOLIDATION

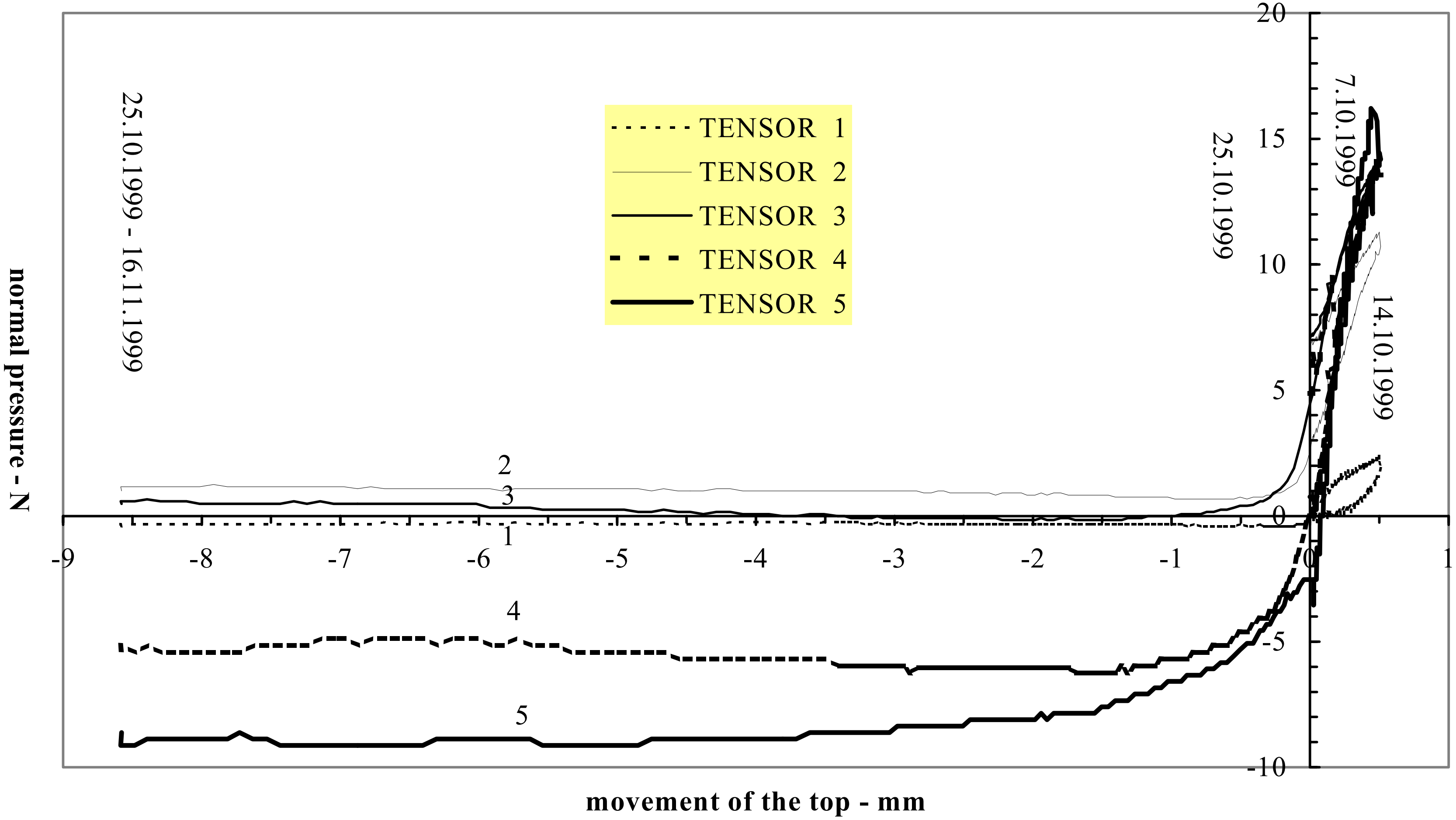

Fig. 3. Experiment 2 – Phase 0+1 – Measured normal components of the lateral passive and active pressure at rest depended on the movement of the top in total graph.

EXPERIMENT no. E2/2,3 - ROTATION ABOUT THE TOP + +RECONSOLIDATION + TRANSLATIVE MOTION+RECONSOLIDATION

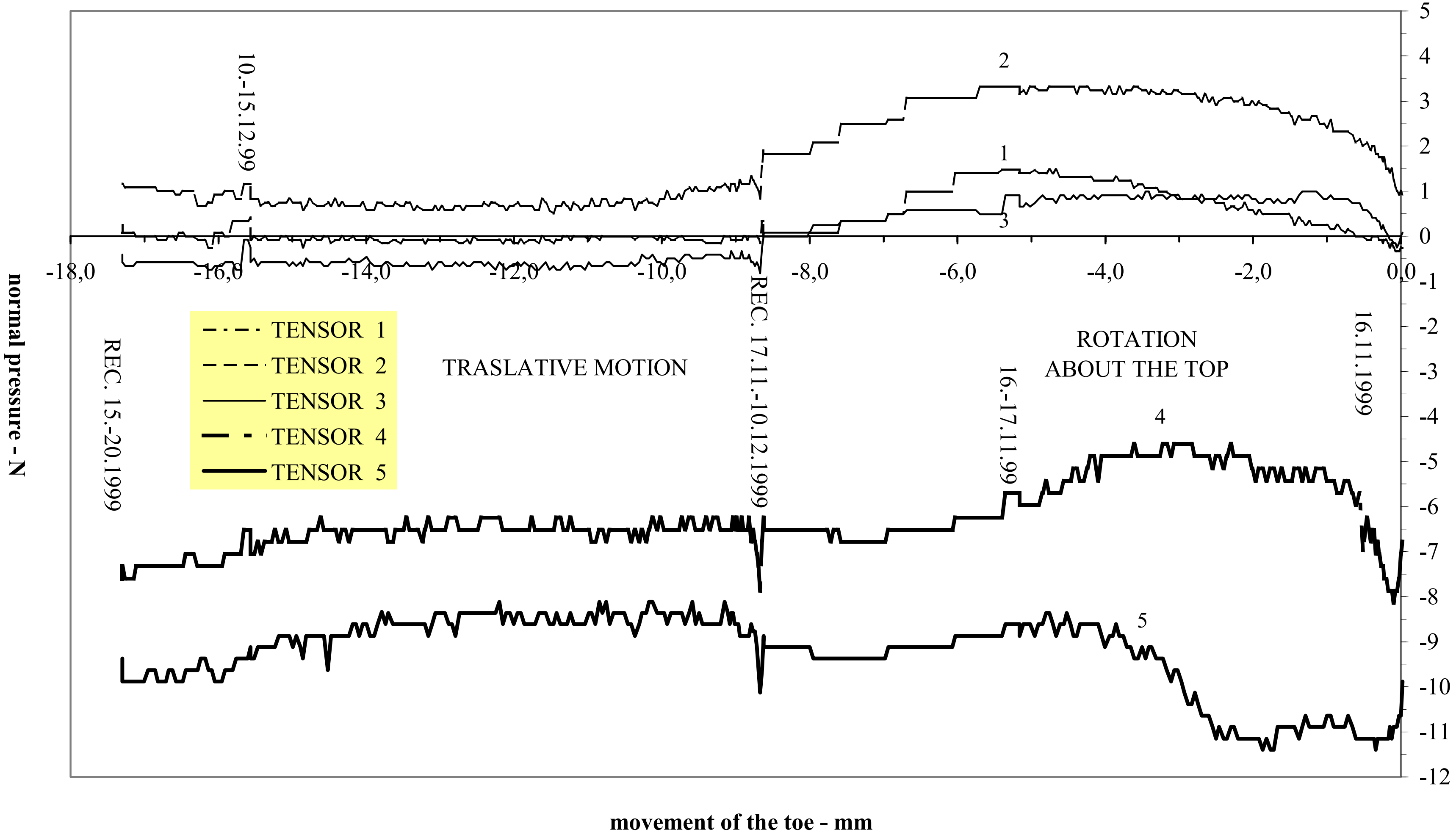

Fig. 4. Experiment 2 – Phases 2+3 – Measured normal components of the lateral passive and active pressure depended on the movement of the toe in total graph.