THE INFLUENCE OF TEETH ON THE EARTH-WORKING PROCESSES

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Summary The new experimental program of laboratory tests was presented, performed in a soil bin on cohesive soil. Model tools in a shape of an excavator's bucket equipped with teeth of different geometry were used in that study. The change in geometry simulated different subsequent stages of material wear. The experimental verification of the influence of teeth (number of teeth, and the position of teeth on the bucket's inside lip) on the efficiency of the digging cycle is discussed. Three different types of soil samples (dense, medium dense and loose) were used.

EXPERIMENTAL RESULTS

An experimental program was executed on the specialized laboratory stand equipped with a soil bin. The bin, the stand and sample preparation were precisely described in [1]. The bin dimensions were 2 m long x 0,6 m wide x 1,2 m deep. A mixture of 50% cement, 20% bentonite, 18% sand and 12% white vaseline was used to imitate a clayey soil. No water was added. Three different densities of the soil sample were used: loose, medium dense and dense sample. The loose soil sample used could be described by the Coulomb model with the following initial parameters: γ=16.2 kN/m^3, ϕ=27° and c=~15 kPa. For the medium dense soil sample the corresponding values were: γ=16.8 kN/m^3, ϕ=27° and c=~30 kPa, and for the dense soil sample: γ=17,2 kN/m^3, ϕ=27° and c=~45 kPa.

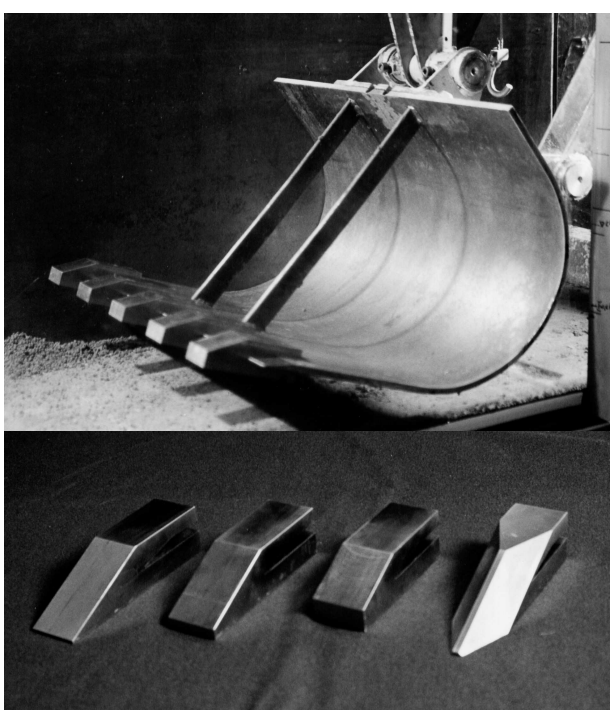

Figure 1. View of the excavator bucket and a set of teeth.

In the experiments the model of an excavator's bucket of the width equal to that of the soil bin was used. The bucket was equipped with teeth. The shape and size of each tooth corresponded to that which is produced for the small bucket excavator K-111 by Waryński Company. Their width was w=46 mm and they stand out 95 mm in front of the inside lip. The model with 1, 2, 3, 4, 5 and 6 symmetrically situated teeth was used, as well, as the model without any teeth and one wide tooth obeying width equal to the width of the soil bin (0,6 m). Several different shapes of teeth were used: "sharp tooth" (2 mm worn-out), 10 mm worn-out, 20 mm worn-out and the tooth with 3-dimensional shape (Figure 1). All tests were executed on the soil samples obeying horizontal free surface. The same trajectory consisting of two linear stages was used. During the first stage, the bucket moved horizontally with the cutting depth 175 mm until it was filled up with the soil. The bucket inclination was 5°. During this stage of the earth-working process subsequent shear bands are generated and within those shear bands material softening is observed. As a result, the observed earth-working force obeyed oscillatory character of peaks followed by drops of the force value. In the second stage of the trajectory the bucket was lifted and withdrawn out of the soil bin. In Figure 2 variation of horizontal force acting on the tool for the number of teeth equal 5 and the loose soil sample are presented for three different stages of the teeth wear. With progressing development of the teeth wear the horizontal component of the force is significantly increasing.

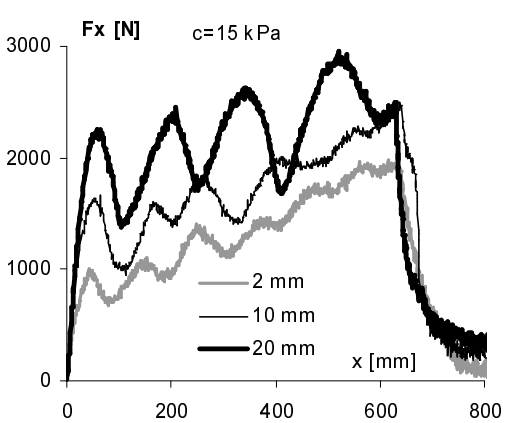

Figure 2. Horizontal force variations for the tools with 5 teeth and three different stages of the teeth wear.

In Figure 3 the variation of horizontal force for the tool equipped with various number of teeth (1, 3 and 5 teeth) is presented and compared with results for the wide tooth (0,6 m wide). In case of these tests the "sharp teeth" (2 mm worn-out) were used and tests were executed on the loose sample. As it was shown in

the previous paper by Maciejewski *et al.*[2] for the buckets with the number of teeth greater or equal to 4, the first and subsequent shear bands were not generated from the inside lip but from the line connecting the tips of the teeth (the range of the teeth spacing l was less then 3.26 w, where the w is the width of the single tooth). For the number of teeth exceeding 3 the line connecting the tips of the teeth played the role of the inside lip. It should be noticed, that the character of this test and the one performed for very wide tooth were similar, but the peak values of horizontal force were smaller. In the zone prior to the teeth the deformation pattern was identical like for the wide tooth, suggesting the existence of a plane strain condition within it. However, in the area surrounding the teeth the three-dimensional deformation pattern was observed. As a result some material was left behind the tool resulting in smaller peak values of the horizontal force component.

Thus, the deformation pattern in front of such an assembly of teeth was again the plane strain deformation pattern, which was observed by the authors for tools of the width equal to the width of the soil bin.

In Figure 4 the variation of horizontal force for the tool equipped with 5 sharp teeth is presented for three different densities of the soil sample.

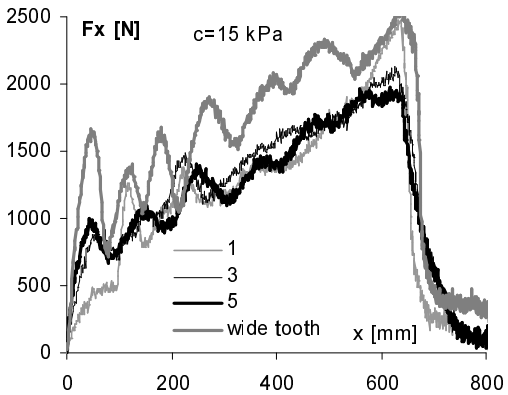

Fig. 3. Horizontal force variations for the tools with different number of teeth.

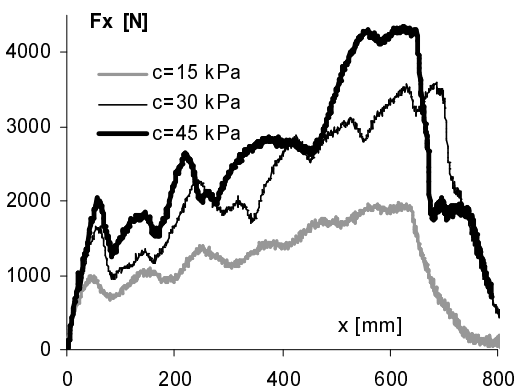

Fig. 4. Horizontal force variations for the tools with 5 teeth and different soil densities.

Conclusion

Periodic character of the digging process (observed for the cohesive soil with softening) manifested in the oscillatory character of force components and generation of the subsequent shear bands is independent of the shape of the tool, number of teeth and the degree of tool wear.

It was found, that for particular cohesive soil, corresponding to sandy clay for the teeth spacing l/w less then 3.26, the line connecting the tips of the teeth played the role of the inside lip. The teeth did not act as separate three-dimensional objects but as one wide tool built up from several modules. Thus, the deformation pattern in front of such an assembly of teeth was similar to the plane strain deformation pattern.

The wear of teeth, approximated to by the simple change of their geometry, has significant influence on the peak values of earth-working force. For wide teeth the influence of teeth wear on the earth-working force is observed for the whole range of the digging process not only for the peak values of force. The observed phenomena are independent from the soil density. However, for higher densities (higher cohesions) the differences between the peak and the minimum force values are more significant.

Acknowledgements

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References

[1]. Maciejewski, J.and Jarzębowski, A., Optimisation of tool trajectory in soil digging processes – laboratory tests. *J. Terramechanics* **39**, 3, 161-179, 2002

[2] Maciejewski, J., Jarzębowski, A., and Trąmpczyński, W., Study on the efficiency of the digging process using the model of excavator bucket. Proc. 14-th Int. Conf. ISTVS (CD), Vicksburg, MI, USA., 2002.