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MATERIAL POINT METHOD IN THREE-DIMENSIONAL PROBLEMS OF GRANULAR FLOW

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Three-dimensional gravitational flow problem of a granular material is considered. The dynamic, large strain problem still appears to be difficult in analysis although many well-developed computational methods are available. For example, the standard finite element method formulated in the Lagrangian description of motion is not sufficiently robust for analysis of granular flow processes due to the problem of large mesh distortions which deteriorates the accuracy of the approximate solution. A mesh re-zoning technique aided to the Lagrangian approach is not a comprehensive remedy to overcome the problem as it need mapping state variables from the distorted mesh to the newly generated one which is an additional source of computational errors. On the other hand, the use of an Eulerian formulation of the finite element method is disadvantageous because of inherent convective terms in equations of motion and troubles related to tracing of free surfaces.

In the present work, the considered problem is solved by the use of the material point method well-known in fluid mechanics as the particle-in-cell method [1]. The method has been applied successfully to two-dimensional problems of granular flow and some geotechnical problems [2]. In the material point method, state variables are traced for a set of points (called material points) representing subregions of the analyzed body on which the region initially representing the body is divided. The state variables are calculated by the use of a finite element mesh (called a computational mesh) which can be defined in an arbitrary way which means that the problem of mesh distortions is avoided. Due to the fact that two kinds of spatial discretisation are used—the material points and the computational mesh—the method reveals features of the arbitrary Lagrangian–Eulerian description of motion which makes the method very flexible in applications. Such problems like self-contact of the granular material and flow around obstacles are much easier to be solved than in other methods.

The results for a problem of collapsing sand wall are shown below. The wall has dimensions 2 m × 2 m in the xz-plane and is infinitely long in the y-direction. As the flow is plane, the results of the three-dimensional computations can be verified by the comparison with those obtained by the use of the two-dimensional material point model. Some phases of the flow are shown in Fig. 1. The last phase shown corresponds to the final configuration of the material. For comparison, the configuration of the granular body after reaching

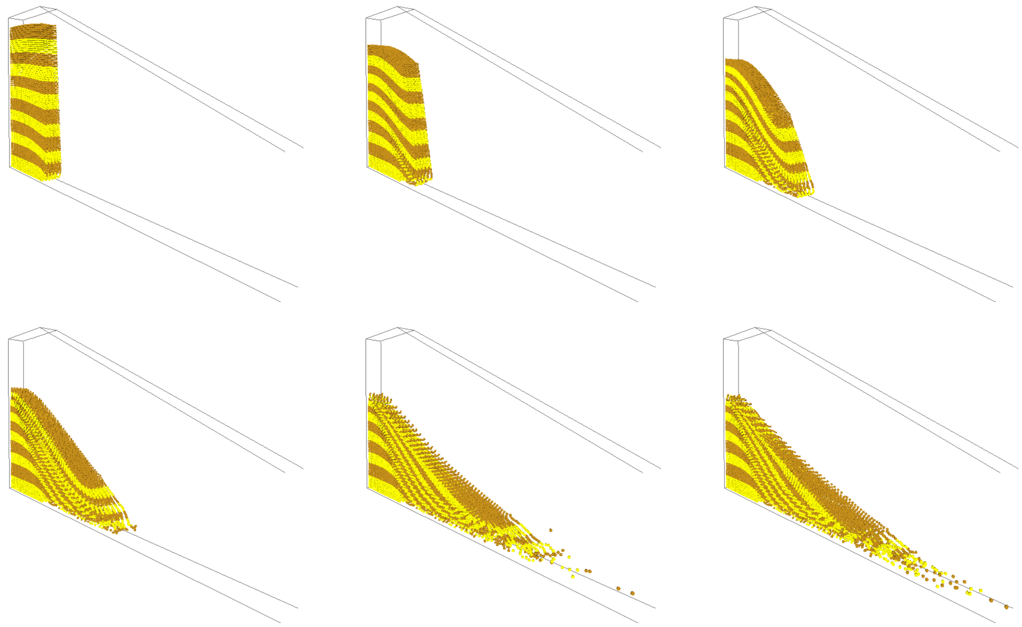

Figure 1: Several stages of deformation of collapsing wall

the equilibrium state obtained by the 2D computations is depicted in Fig. 2. Outlines of the computational grids applied in calculations are also shown in the figures. An elastic–viscoplastic constitutive model [2] is utilized in the calculations.

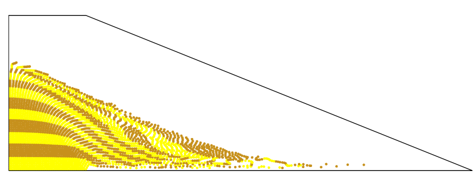

Figure 2: Final (equilibrium) stage calculated in 2D analysis

REFERENCES

[1] F.H. Harlow. The particle-in-cell computing method for fluid dynamics, in: B. Adler, S. Fernbach, M. Rotenberg (eds.), *Methods for Computational Physics*, Vol. **3**, Academic Press, 319–343, 1964.

[2] Z. Więckowski. The material point method in large strain engineering problems, *Comput. Methods Appl. Mech. Engrg.*, Vol. **193**, 4417–4438, 2004.