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TWO-PHASE MATERIAL POINT MODEL IN ANALYSIS OF EROSION PROBLEMS

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Modelling erosion is a challenging task of computational mechanics. The difficulties are related to the state transition involved in the phenomenon—a soil which behaves as a solid body at some stage of the physical process can be fluidized and then transported by a fluid. Due to large displacements and large strains as well as complexity of state transitions of the solid–fluid mixture, even so well-developed computational methods as the finite element method are not sufficiently effective in analysis of erosion problems. During the last decade, some point-based methods have been applied to solve the problem. It seems that one of the most successful method has appeared the particle finite element method [1].

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) which has been applied successfully to two-dimensional problems of granular flow and some geotechnical problems [2]. In the proposed approach, state variables are traced for two sets of points (called material points) representing subregions of two material phases: solid and fluid ones. The state variables are calculated by means of interpolation exploiting a finite element mesh (called a computational mesh) and two velocity vectors defined as degrees of freedom at nodes for both the material phases separately. The solid–fluid interaction forces are defined by Ergun's law. The mechanical behaviour of the soil is described by the use of an elastic–viscoplastic constitutive model while the fluid is treated as viscous and compressible liquid.

The described approach allows one to solve a seepage problem for a deformable or rigid porous body. The results for a seepage problem are shown below. A flow of water through a porous wall with a square cross-section is considered. It is assumed that water is stored on the left side of the wall at the beginning of the flow process. Four stages of the process are shown in Fig. 1. It is visible that the material point method enables one to find easily the evolution of a phreatic surface for water.

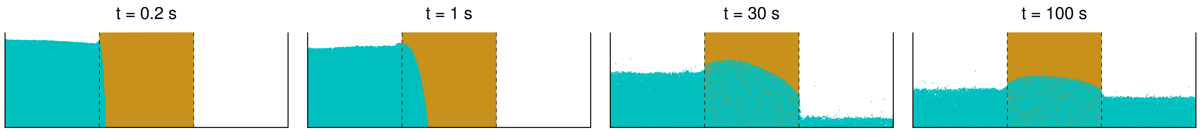

Figure 1: Seepage problem

The results for a more complex problem of a collapsing submerged sand wall are also shown. Initially, the wall cross-section has dimensions 1 m × 1 m and its top is located 0.5 m below the water surface. It is assumed that the wall is located in a basin the cross-section of which has dimensions 3 m × 1.5 m. A flow of granular material along the wall surface is observed. This kind of flow leads to reduction of the wall width and height and is called breaching. Such a kind of phenomenon is purposely induced in engineering practice, for example during dredging sea or river beds by the use of suction technique. Some phases of the considered breaching process are illustrated in Fig. 2 where—because of symmetry—only one half of the analysed area is shown. Only the position of material points representing the solid body (sand) is shown in the figure, an outline of the right half of the basin filled with water is shown as well. The field of mass concentration of the solid body is represented in the form of colour maps in the figure.

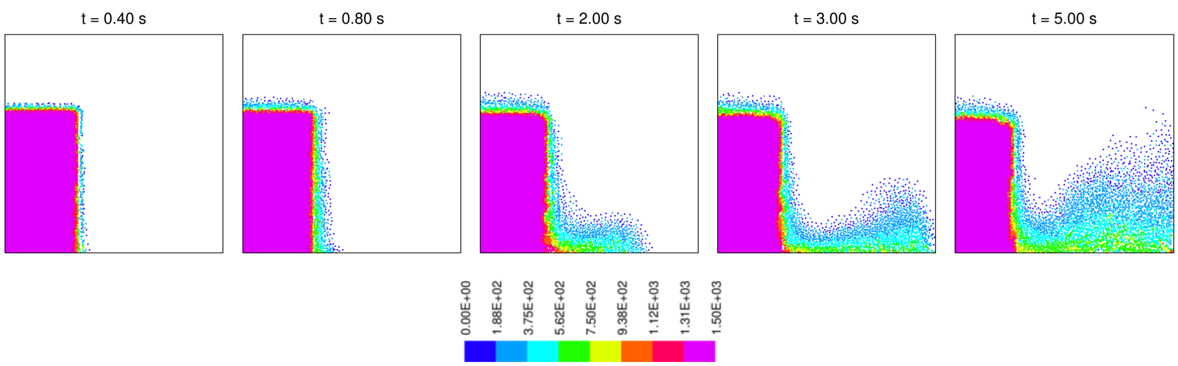

Figure 2: Breaching problem

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