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CIP-DEM COMBINED MULTI-PHASE SOLVER FOR A SOIL COMPACTION MECHANISM

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ABSTRACT

Before a construction of a large structure such as a water reservoir, usually a soil compaction procedure is executed. The soil surface is impacted repeatedly and instantaneously in the soil compaction process and it is empirically well known that the process can enhance soil's strength and improve water-shielding property. While there are not studies that detail a mechanism of the process clearly from a point of view of interactions between soil structures and pore fluid, many experiences have showed that the efficiency of the compaction strongly depend on water content in the soil, and there is an optimum water content which maximizes dry density of the soil after the compaction [1]. This dependency is known as the Proctor's principle.

In this work, in order to investigate the soil compaction mechanism in detail from a point of view of interactions between soil structures and pore fluid, we developed a two-dimensional CIP-DEM combined numerical model. The model can solve a multiphase flow consisting of the soil particles, pore water and air. In the model, while each soil particle motion is solved by the Discrete Element Method (DEM) [2], flow of the pore water and air within the soil structure is calculated by the Constrained Interpolation Profile (CIP) method which is proposed by Yabe *et al*. [3,4] for a multiphase flow analysis. In the solution of the pore fluid by the CIP method, interfaces between the pore water and air are traced by a color-function method and Continuum Surface Force (CSF) model [5] is used to calculate the effects of surface tension. Interactions between the soil particles and pore fluid are considered through affecting fluid's pressure to the soil particles in the DEM calculation and imposing a soil particle's velocity on the fluid motion in the CIP solution at each time step.

The developed numerical solver is applied to the two-dimensional soil compaction problems in a container surrounded by fixed walls. Initial placement of the soil particles is made by letting them pile up as closest packing and by thinning out them in random so that porosity (void ratio) becomes to be 30%. In order to represent the impacts to the soil surface during the compaction process, downward acceleration force is additionally

imposed on the particles in the top layer.

A series of numerical solutions is conducted in varying the water content at the start of a computation. Numerical results show that the dry density of the soil at the end of a compaction depends on the initial water content and a compressibility of the soil reaches a maximum at a certain value of the initial water content as stated in the Proctor's principle.

For the soil of rich water content, because the superfluous pore water narrows and blockades the channels for discharged pore air, compressibility of the soil becomes to be suppressed as increasing the water content. On the other hand, for the soil of poor water content, even so there are enough many void spaces connected with each other to supply efficient channels through that the pore air is discharged out easily in contrast to the rich water content soil, it is found that compressibility of the soil is suppressed as reducing water content as same as the soil of rich water content. Through a comparison with the numerical results calculated without the surface tension, it is verified that a strong skeleton-like structure is formed by the soil particles because the localized pore water constructs bridge structures between the soil particles and the soil particles are bonded each other due to the surface tension.

Indeed, when the water content is increased and the magnitude of imposed impact force exceed the surface tension per unit water volume, a drastic improvement of the soil compressibility is calculated. These facts suggest a reason why the maximum compressibility is observed at the optimum water content: the both two effects - the blocking effect of the pore air discharge for the rich water content, and the bonding effect of the surface tension for the poor water content - become to be relatively weak and thus the compressibility is improved drastically at the optimum water content.

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