Deformation analysis of fill dams due to level 2 earthquakes using PIV

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A lot of civil engineering structures have been severely damaged by Level 2 earthquakes. An agricultural fill dam in Fukushima prefecture was failed and washed out due to the Great East Japan earthquake in 2011 and a few people were killed in the downstream region. In order to increase the level 2 earthquake resistances, understanding the failure mechanism of fill dams is necessary. The fill dams normally consist of unsaturated and saturated geomaterials. Namely the parts of fill dams above or below the seepage surfaces respectively remain under unsaturated or saturated conditions. Then we should understand the mechanical properties of both saturated and unsaturated geomaterials. Especially it is very important to consider the unsaturated mechanical properties to understand deeply the failure mechanism of fill dams. In unsaturated geomaterials, pore water pressures are normally negative (suction) and the suction effects play important roles. Kohgo et al. (1993) clarified that there were two suction effects: 1) an increase in suction increases effective stresses and 2) suction enhances the internal confinement and an increase in suction increases yield stresses.

In this research we try to investigate the suction effects in the model levels of fill dams. So, several centrifugal shaking model tests were conducted. Two types of model materials: sandy soil and the soil mixed with silty soil named DL clay and No. 6 Silica sand were used. The dimensions of models in prototype were 6 m in height, 31.5 m and 1.5 m in base and crest widths and 12 m in depth after 30g centrifuge acceleration applied. The inclines of both slopes were 1:2.5. Accelerometers, pore water pressure and pore air pressure sensors were installed inside the model. Laser displacement sensors were set above the models. Input sine waves were applied by increasing their acceleration step by step. Before and after each shaking, photographs were taken using a digital camera mounted in front of the embankment model. These photographs were used to calculate inner displacements by using particle image velocimetry (PIV) technology. The displacement data might be used to estimate volumetric and shear strains within the embankments.

It was found that in the sandy model, the crest deformed roundly and vertically. Moreover, slip failures occurred in both slopes. On the other hand, in the mixed soil model, the whole embankment deformed downward but no slide was observed. The displacement vectors obtained from PIV could well reflect the differences of these deformations. The shear strains in the sandy soil model developed near the slops and finally the volumetric strains changed to dilation there while in mixed soil model both shear and volumetric strains developed at the center of the bottom of the embankment.

Applying PIV to deformation analysis in the fill dam model, the strain distribution could be obtained in detail. As a next step, we will try to discuss totally including the behavior of pore water pressures.

Keywords: Fill dam, Suction, Centrifugal model test, PIV