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HDS26-01 Room:203 Time:May 26 17:15-17:40

Numerical and Centrifuge Modelling of Submarine Landslides

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Submarine landslides can cause a significant damage to offshore structures. Their mechanism is not well understood due to the difficulty of direct observation of the phenomenon. In engineering perspective, assessing the risk of submarine landslides is necessary for further development of offshore areas. Estimating the extent and the impact of submarine debris flows is particularly important when designing subsea facilities. In the field of geotechnical engineering, physical and numerical modelling are often used to tackle these problems. The attempt here is to introduce recent research activities in physical and numerical modelling of submarine landslides.

One of the major discussions in numerical modelling of submarine landslides is how one can model the change in mechanical properties of the material during an entire flow event. Submarine landslides typically originate from collapse of seabed sediment. The flow process involves a phase transition of the material from solid to semi-fluid by shearing, mixing, and entraining ambient water. In the conventional equivalent fluid method based on Non-Newtonian fluid models, the change in material properties is neglected by assuming constant rheological parameters throughout the flow event. Often the rheological parameters are calibrated using the evidence of previous flow events. Such parameters may not represent the real physics involved in submarine debris flows.

The work by the author presented here aims to develop a new modelling framework for submarine landslides based on observations from conventional soil tests. Our modelling strategy is to extend the critical state concept in soil mechanics to a range of higher water content to account for the solid-fluid phase transition. The depth-averaged momentum conservation is solved by a numerical scheme known as the Material Point Method together with the developed constitutive model. Simulations are performed against evidence of a previous flow event. The capability of the numerical model is highlighted in a comparison with the conventional Bingham fluid model.

Another way to look into the mechanism of submarine landslides is physical modelling. Full-scale testing, however, is almost impossible for a submarine landslide event. In such situation, physical modelling can be a powerful tool to observe particular aspects of the phenomena. Physical models are usually constructed at much smaller scale than the prototype. Due to this, one has to carefully consider the scaling laws to extrapolate the observation in the model to the prototype. Among various scaling laws, that regarding to stress and strain is most important in geotechnical problems because of the non-linear, stress-strain behaviour of soil. One way to satisfy this scaling law is to increase the gravity, which can be achieved by applying centrifugal acceleration to the model.

The geotechnical centrifuge at the Port and Airport Research Institute (Japan) has a 10 m-beam with 1.6m x 1.6m platforms at both sides. A soil model is loaded at one side while a counter weight is loaded at the other side. The acceleration is applied by rotating the beam and it can be increased up to about 100 g. This means that the model can be scaled up by 100 times in size. Here, an example of the centrifuge modelling is presented. The aim of the tests is to observe the earthquake-induced slope failure and the transition to the gravity-flow. An underwater slope constructed in a model container was subjected to shaking while spinning the centrifuge. Several tests were performed with different sand/clay ratios and various slope angles. The results indicate the sand/clay ratio significantly influences the pore pressure dissipation during shaking and thus changes the flowability afterwards. Furthermore, the effects of the viscosity of the pore fluid and the osmotic pressure applied to the slope from the bed were examined. The detailed results will be presented at the oral/poster session.

Keywords: submarine landslies, centrifuge modelling, Material Point Method

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Seismic wave simulation for terrestrial and submarine landslide sources in and around the Kii peninsula, southwest Japan

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We deployed permanent seafloor stations in water depths of 1,900-4,400 m near the Nankai trough of southwest Japan in 2010. We observed seismic signals in the broadband seismometer of the seafloor station at a terrestrial landslide event caused by a typhoon passing over the Kii peninsula on September 4, 2011 (Nakamura et al., 2014). We simulated seismic waveforms for the event with the finite-difference method by using a three-dimensional structure model in and around the Nankai trough. From our simulations, we reproduced the features of the observed waveforms in terms of the arrival times of the main phases and the waveform as a whole.

We also simulated seismic waveforms at the seafloor stations for a submarine landslide event assuming the epicenter to be located in the middle of the large slump between the source area of the Tonankai and Nankai earthquakes. We assumed the source time function with a duration time of more than 50 s referring to the analysis results of the 2011 terrestrial landslide event presented by Yamada et al. (2013). Our simulation results show the prominent propagation of Rayleigh waves in the vertical component because of the shallow source location of the submarine landslide near the seafloor and the effective development of the waves. We also find the significant variations of the Rayleigh wave propagation depending on the presence of a seawater layer. This is because the phase and group velocities and the dispersion of Rayleigh waves can be affected by the thickness of a seawater layer. In our simulation, the maximum amplitude of the vertical component for the structure model with a seawater layer is four times greater than that for the non-seawater case at the seafloor stations. Our results indicate that a seawater layer should be correctly incorporated into source analyses such as the size of the submarine landslide and the mechanism analysis when we use waveform data observed at seafloor stations.

Keywords: submarine landslide, wave propagation, seafloor observation, Tonankai area, DONET