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海底地すべりに関する数値モデリングと遠心載荷模型試験
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.

キーワード: 海底地すべり, 遠心載荷, マテリアルポイントメソッド
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紀伊半島周辺における陸上及び海底地すべりによる波動伝播シミュレーション
Seismic wave simulation for terrestrial and submarine landslide sources in and around the Kii peninsula, southwest Japan

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海洋研究開発機構では、紀伊半島沖の水深 1,900-4,400 m の海底に 20 点から成る地震観測網を 2010 年に設置した。各海底観測点には広帯域地震計を備えており、観測点周辺で発生した微小地震や低周波微動によるシグナルをこれまでに捉えている。2011 年 9 月には、台風通過に伴って奈良県南部で発生した地すべりによるシグナルを海底で観測することができた（Nakamura et al., 2014）。本研究では、3 次元構造を用いて、地すべりに伴う波動伝播のシミュレーションを差分法で試みた。その結果、10 秒から 20 秒の帯域において、走時や波形形状など、海底観測波形を説明できるシミュレーション結果を得ることができた。

本研究では次に、海底地すべりの発生を想定した波動伝播のシミュレーションを試みた。潮岬沖海底谷を震央とし、震源時間関数は Yamada et al. (2013) による 2011 年 9 月の陸上地すべりの震源解析結果を参考にした。シミュレーションの結果、上下動成分でレイリー波を主成分とする顕著なフェイズの伝播を確認することができた。これは震源が海底付近にあるため、海底から数 km 以深で発生する通常の地震の場合と比べて、震源により近い場所で表面波が生成され、大きな振幅を伴って海底観測点まで伝播したためと考えられる。また、海水層の有無によって、レイリー波の波形形状や振幅に顕著な違いが生じることが分かった。これはレイリー波の位相速度や群速度、分散性が海水層の厚さに大きく依存していることと関係する。海水層を取り除き、空気層に置き換えた構造モデルの場合と比べ、海水層を取り入れたより現実に近いモデルのシミュレーションでは、振幅値が 4 倍以上大きくなる海底観測点があった。これらの結果は、海底観測点データを使った海底地すべりの規模やメカニズム推定などの震源解析を行うにあたって、海水層の影響を正しく考慮する必要があることを示唆する。

キーワード: 海底地すべり, 波動伝播, 海底観測, 東南海地震震源域
Keywords: submarine landslide, wave propagation, seafloor observation, Tonankai area, DONET