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A slope stability study for marine gas hydrate resource development

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There are lots of studies and hypotheses with regard to relationship between gas hydrates below sea floor and marine landslides. Most of them deal with large-scale phenomena related to global climate change in geological time frame. On the other hand, investigations to develop marine gas hydrates resource have started in countries such as Japan, US, Korea, India, etc.

The Japanese national program includes an offshore production test of gas from hydrates deposit in marine sediments in early 2013 at a location off Atsumi Peninsula, Pacific coast of the central Japan. The planned test is relatively small scale; production from a single well, duration is one to several weeks, and expected dissociated area is 10 to 100 meter radius from the well, that is completely different scale in area and involved energy from climate related events. However, possibility to influence the sea floor stability by the test cannot be denied. Meanwhile, small scale events in shallow depth, or natural events that are not caused by gas hydrate dissociation can damage production facilities such as pipelines. Therefore, more quantitative risk analysis than geological scale problem is necessary.

From those view points, as one subject of the Research Consortium for Methane Hydrate Resources in Japan (MH21), the authors have started a seafloor stability study to use the Eastern Nankai Trough as a model area. The area has complicated geology with knolls and anticlines in the active margin. Gas hydrate concentrated zones have been found in sandy layers of turbidite sediments. In early 2013, the first offshore production test by depressurization technique will be conducted at a location in the north slope of the Daini Atsumi Knoll in the area.

Near the location, we have found relatively large kilo-meter scale slide scars that might be created by uplift of the knoll and erosion to a seafloor valley. The base of the slide deposit is shallower than gas hydrate rich zone, gas hydrates in the area have played limited role in the occurrence of slides. Because the area is close to epi-centers of Tonankai Earthquakes that have happened every hundreds of years, the earthquakes might trigger the slides.

Therefore, we started a quantitative risk analysis of slope instability in the Atsumi Daini Knoll area. Firstly, bathymetry and structural geology information from seismic survey, and geotechnical information from core samples and geophysical logging data were analyzed. Moreover, micro-bathymetry and precise geology data were taken by side-scan sonar and sub-bottom profiler of AUV Urashima. Core samples and cone penetration test data from shallower formations than the gas hydrate concentrated zone in the area taken using DV Chikyu were utilized to obtain geotechnical information.

Using those information, the factor of safety (FoS) under static load was calculated using bathymetry data, and FoS under seismic load that was assumed from predicted Nankai metathrust earthquake (combination of Tokai, Tonankai, and Nankai quakes) was computed using 1D dynamic analysis. Also some numerical models are employed to evaluate effects of gas hydrate dissociation by production test and subsequent reduction of formation strength, mass movement by a possible expansion of slide area, and occurrence and propagation of Tsunami.

New data obtained are under tests and analyses, and their results will be used to update the model and results. A hazard map of slope instability in the Eastern Nankai Trough area will be made for the planning of future resource development.

Not only for gas hydrates but also other marine resources, public acceptance requires correct risk analysis, communication, and building of understanding. This slope stability study is one of those processes. There are still many uncertainties in the relationship between submarine slope instability and gas hydrate, so both viewpoints of basic science and practical risk analysis are necessary.

Keywords: methane hydrate, submarine landslide, geotechnical, tsunami