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Damage Evaluation of Rock Berm under Anchor Collision

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ABSTRACT

Rock berms were modeled using SPH (smoothed particle hydrodynamics) method to investigate their behaviors under collision of 10.5-ton stockless anchor. Two parameters (rock and berm sizes) were considered to figure out their effects on the structural responses (von-Mises stress and vertical displacement). We found that the dynamic behaviors are sensitive to the sizes; hence, it is required to control the rock and berm sizes to establish the safety of the rock berms. Nonetheless, the 10.5-ton stockless anchor gives no safety assurance due to its heavier weight and colliding energy accordingly. Safety is assured when the anchor weight is decreased.

1. INTRODUCTION

A rock berm is often used for protecting lifelines such as subsea pipelines and submarine power cables. In water environment, along with the environmental loads such as waves and currents, anchor collision is considered as an accidental load (Woo and Na 2014a). The consequence can be severer with a certain level of frequency; hence, the structural responses should be carefully understood. However, no study has been made to quantify the structural response under anchor collision because it is hard to deal with the individual behavior of each rock. Therefore, this study presents damage evaluation according to collision analysis of a rock berm by facilitating the smoothed-particle hydrodynamics (SPH) method. For the purpose, 10.5-ton stock anchor is considered as a colliding object and simulated to drop to so-called A-berm. Then, the dynamic collision analysis is carried out to capture the response characteristics. Finally, the associated damage evaluation is established using safety criteria, which is introduced in the study.

2. MATERIALS AND METHODS

Conventionally, the most popular anchor type was 2-ton stock anchor in shallow waters. However, recent trend of commercial vessels require heavier anchors; hence 10.5-ton stockless anchor is considered as a colliding object in the study. Fig. 1 shows

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a typical berm consisting of rocks in the upper region and sands (seabed) in the lower region. To model the A-berm shown in Fig. 2, it is required to use SPH method because of the rocks and their behaviors under anchor collision.

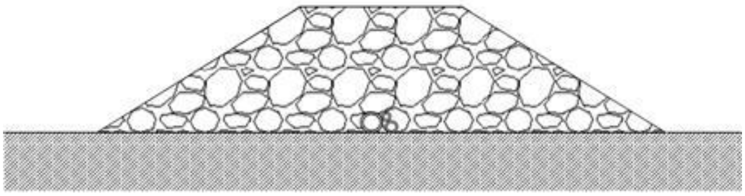

Fig. 1 Typical rock berm

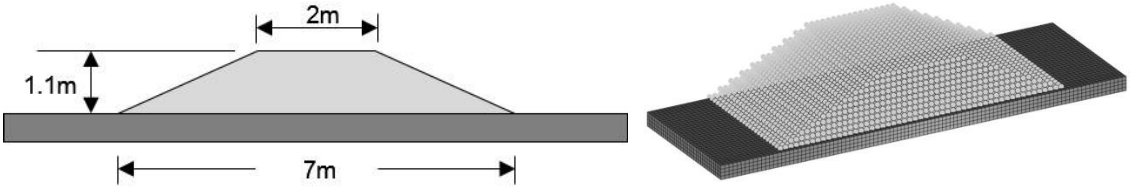

Fig. 2 A-berm

To simulate anchor collision, it is necessary to obtain the drag coefficient of the target anchor. This can be done by wind tunnel experiment or numerical flow analysis. Thanks to the modern computer technology, it is possible to accurately obtain the drag coefficient through CFD (computational fluid dynamics) and associated software package. We conducted the flow analysis for the drag coefficient and found that the drag coefficient is about 0.781 and then calculated the corresponding terminal velocity of 9.623 m/s (Woo and Na 2014b) by solving the associated equation of motion.

Consider the conservation of energy; we saved the calculation time by setting the initial velocity and distance equivalent to the terminal velocity (the maximum velocity when the acceleration becomes zero in water) of the 10.5-ton stockless anchor. Moreover, we assumed the bottom boundary is perfectly elastic because Woo and Na (2014b) showed that the bottom conditions are not sensitive to the ground conditions. Also, the vertical movements at the nodal points locating the utmost lower layer are fixed as structural boundary conditions.

Woo and Na (2014b) proposed the safety criteria of rock-berms under anchor collision. The criteria are based on the tensile strengths of a HPDE cable and polyurethane pipe that is frequently used outside the HPDE cable for the protection purpose. These are typically 27 MPa (σ_{L1}) and 12.1 MPa (σ_{L2}), respectively; hence the safety criteria can be expressed by $\sigma < \sigma_{L1}$ and $\sigma < \sigma_{L2}$. Here, σ indicates the von-Mises stress occurred in a rock-berm due to anchor collision.

Here, we established two cases for the collision analysis. The first one is the size of rocks. Two rock sizes are considered to investigate the responses accordingly. The second one is the rock-berm size. Three berm sizes are considered to study the responses as well.

3. COLLISION ANALYSIS RESULTS

Figs. 3 and 4 show the maximum von-Mises stresses and vertical displacements, respectively, according to SHP particle size (200 and 100 mm). As shown, the stress increases as the particle size decreases, while the displacement gives the reverse pattern. This indicates that the analysis results are sensitive to the particle size; hence, it is required to consider the average diameter of the rocks; otherwise the analysis results vary. Figs. 5 and 6 show the maximum von-Mises stresses and displacements when the berm height is increased. Moreover, the safety criteria are not satisfied all the cases, which indicate the berms do not provide the necessary protecting capability. Therefore, it is required to increase the berm size under 10.5-ton stockless anchor. It is found that the safety is accomplished if the anchor weight is increased such as 2-ton (not shown here).

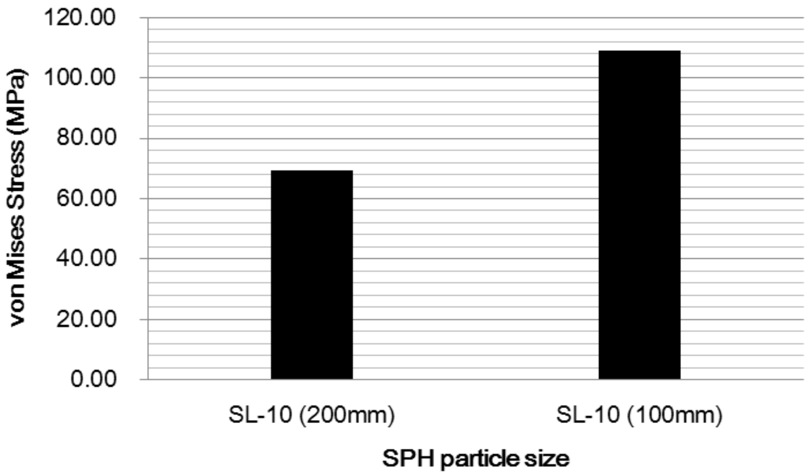

Fig. 3 von-Mises stress according to SPH particle size

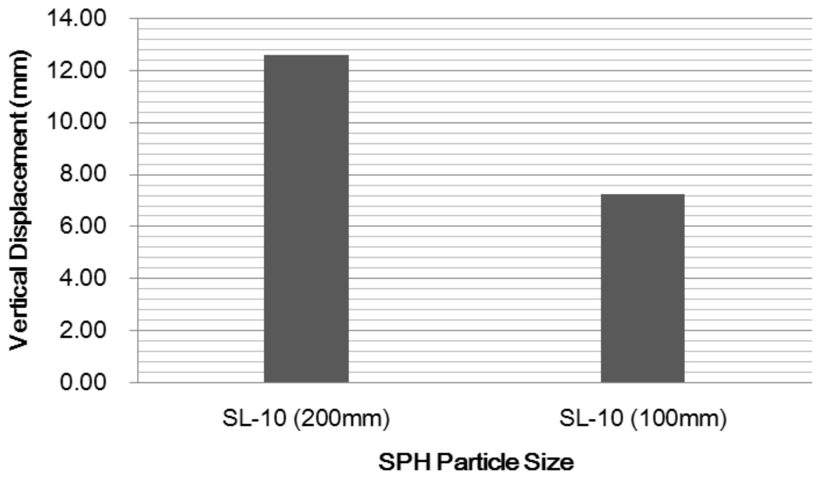

Fig. 4 Vertical displacement (mm) according to SPH particle size

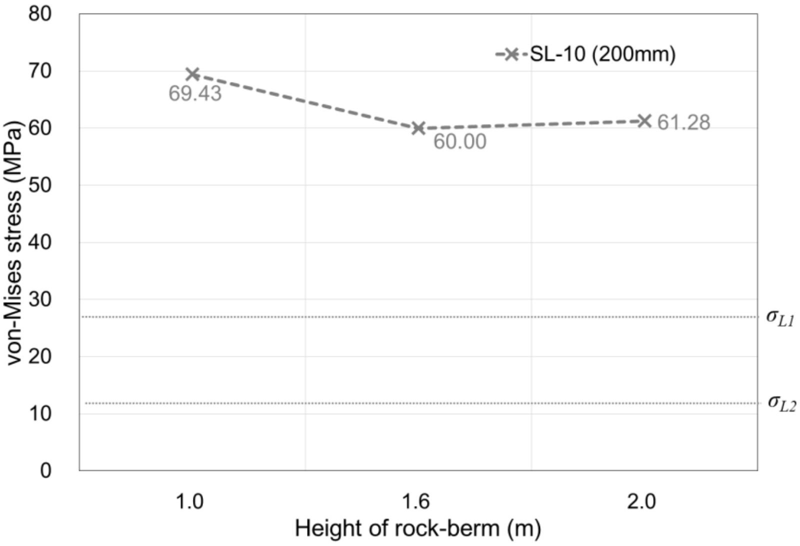

Fig. 5 von-Mises stress (MPa) according to SPH particle size and height of rock berm

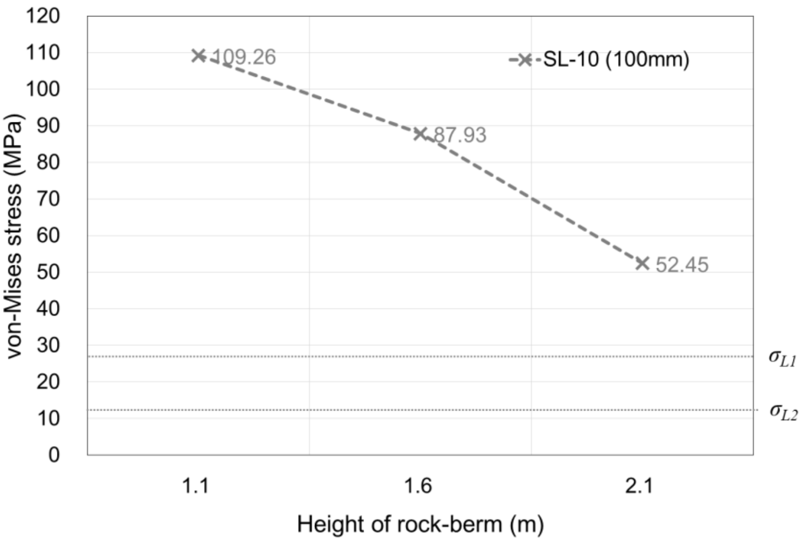

Fig. 6 Vertical displacement according to SPH particle size and height of rock berm

4. CONCLUSIONS

We found that the dynamic behaviors of rock-berms are sensitive to the sizes of rock and berm; hence, it is required to control the rock and berm sizes to establish the safety of the rock berms. Nonetheless, the 10.5-ton stockless anchor gives no safety assurance due to its heavier weight and colliding energy accordingly.

5. ACKNOWLEDGEMENT

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