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Analysis of Rubble Mound Foundation Failure of a Caisson Breakwater Subjected to Tsunami Attack

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ABSTRACT

Presently, there is no methodology to evaluate the deformation that the rubble mound of a caisson breakwater would suffer if it was attacked by a tsunami. The present paper proposes a methodology to evaluate this deformation based on the method of Esteban and Shibayama (2006), which originally was developed for wind waves. The method was verified by carrying out laboratory experiments using solitary waves and comparing the results to those obtained using the new methodology.

KEY WORDS: tsunami; reliability; risk assessment; tilting; deformation; rubble mound.

INTRODUCTION

The reliability of the different available tsunami counter-measures is being re-assessed following various recent disasters, with the effectiveness of hard and soft measures being compared in order to obtain the most suitable solutions. The development of these countermeasures is of paramount importance in order to prevent the loss of life and property that might occur as a result of these waves. Various researchers such as Shibayama et al, (2006), Sasaki (2006) and Jayaratne et al. (2006) have noted the effects that various types of coastal terrain have on the attenuation or magnification of the damage due to tsunami attack. However the degree of protection that the various natural or artificial coastal structures offer against tsunami attack is not yet properly understood. The 2004 Banda Aceh tsunami has highlighted how coastal forests do not always offer effective protection against tsunami attack as previously thought (it appears that if the tsunami height exceeds the height of the trees these are ripped from the ground and carried by the force of the wave). Hence it is not clear which is the best method to protect against tsunami attack and what degree or risk is related to the different methods of defence.

In Japan, sea dikes have been built along the coast to protect against tsunamis, high waves and storm surges, and numerous records (such as that of Naksuksakul (2006) for Kanagawa Prefecture) can be found of the construction of such structures. However, expected tsunami heights are often higher than the existing defences, and hence the damage due to a tsunami should be estimated in order to formulate a correct disaster prevention policy.

The wave force induced by the tsunami along with the scouring of breakwaters foundations are two of the major factors relating to the failure of coastal dikes. The force exerted by the tsunami would depend strongly on the shape of the wave, which in term depends on the depth of water and other factors.

Tanimoto et al. (1984) performed large-scale experiments on a vertical breakwater by using a sine wave and developed a formula for the calculation of the wave pressure. Ikeno et al (2001) conducted model experiments on bore type tsunamis and modified Tanimoto's formula by introducing an extra coefficient for wave breaking. Subsequently Ikeno et al (2003) improved the formula to include larger pressures around the still water level, where the largest wave pressure was observed to occur. Mizutani and Imamura (2002) also conducted model experiments on a bore overflowing a dike on a level bed and proposed a set of formulae to calculate the maximum wave pressure behind a dike. These formulas are however based on fixed structures, and no research has been done on the pressures applied to the rubble mound foundation and the deformation that it would suffer as a consequence. This research is important for the development of an effective risk management policy, as the reliability of the structures must be