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Laboratory Experiments on the Sliding Failure of a Caisson Breakwater Subjected to Solitary Wave Attack

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ABSTRACT

At present no methodology exists to evaluate the failure mode of a caisson breakwater subjected to a tsunami attack. The present paper investigates the sliding and tilting failure of a caisson breakwater subjected to a solitary wave attack, and establishes a relationship between the sliding and vertical movement. The vertical movement of the caisson is evaluated using the method of Esteban and Shibayama (2006), 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. The sliding failure will be discussed and a general expression for an upper bound limit to the sliding will be proposed.

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

INTRODUCTION

In order to correctly design structures to withstand tsunami attack it is necessary to evaluate how reliable they would be against a range of tsunami wave types and heights. 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. Researchers such as Shibayama et al, (2006), Sasaki (2006) and Jayaratne et al. (2006) have noted how various types of coastal terrain can attenuate or magnify 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 are not always as effective against tsunamis as previously thought. At present it is therefore not entirely clear which is the best method to protect against tsunami attack and what degree or risk is related to the different counter-measures available.

For the case of Japan, sea dikes have been built along the coast to protect against tsunamis, high waves and storm surges, and numerous studies (e.g. Naksuksakul 2006) can be found of the construction of such counter-measures. However, expected tsunami heights are often higher than the existing defences, and hence the potential damage due to a tsunami of a given height should be evaluated in order to formulate a correct disaster prevention policy.

The sliding/tilting failure induced by the wave force, 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.