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Pressure Exerted by a Solitary Wave on the Rubble Mound Foundation of an Armoured Caisson Breakwater

Miguel Esteban
United Nations University, Institute of Advanced Studies
Yokohama, Japan

Nguyen Danh Thao
Ho Chi Minh City University of Technology
Ho Chi Minh City, Vietnam

Hiroshi Takagi
Penta-Ocean Construction Co., ltd, International Construction Divistion,
Yokohama, Japan

Tomoya Shibayama
Yokohama National University, Department of Civil Engineering
Yokohama, Japan

ABSTRACT

Although a lot of attention has been paid to develop formulas and methodologies to assess the effect of wind waves on caisson breakwaters, there is still limited understanding of the loadings due to tsunami waves. More specifically, no methodology exists to determine the effect that a partially destroyed armour layer would have on the overall stability of an armoured caisson breakwater. Although Esteban et al. (2008) developed a method to estimate the deformation of a caisson breakwater subjected to solitary wave attack, this method is known the be greatly influenced by the presence of an armour layer in front on the caisson. Thus, laboratory experiments with solitary waves were carried out to clarify the failure mechanism of an armoured caisson breakwater against a comprehensive range a tsunami type events (bore-type, breaking and non-breaking). The results of the experiments show how the load which is exerted by the caisson onto the foundation depends on the depth of water in front of it, the shape of the armour layer and whether the wave strikes the caisson or the armour layer first. Of particular interest, it was found how the presence of armour (in particular a failed or partially constructed armour layer) can sometimes be detrimental to the stability of the caisson itself.

KEY WORDS: Tsunami; armoured caisson, tetrapod, sliding; 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. In order to evaluate the effectiveness of the hard solutions it is necessary to accurately estimate their reliability, i.e. what degree of protection they would offer against a range of tsunami wave types and heights.

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 defences. The force exerted by the tsunami would depend strongly on the shape of the wave, which in term depends on the depth of water, the wavelength, local bathymetry 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. Esteban et al. (2008) calculated the deformation of the rubble mound