Improvement of Prediction Models of the Toe Scour of a Seawall and the Topographical Change of a Wide Coastal Area due to Tsunami

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ABSTRACT

Tsunami causes large-scale erosion and scour, which may result in the destruction of coastal structures, often as a result of tsunami backflow. Considering that much more serious damage will occur after a seawall breaks, it is necessary for the prediction of damage to develop prediction methods of coastal erosion and scour. This paper proposes a numerical model for the topographical change due to tsunami. Moreover, prediction methods on the maximum scour depth due to tsunami backflow and its position in front of the seawall are also proposed.

KEY WORDS: Tsunami; Backflow; Toe scour; Topographical change; Hydraulic experiment; Numerical simulation; Prediction model.

INTRODUCTION

As typical examples of tsunami disasters, the records of the Chilean earthquake tsunami in 1960, Indian Ocean tsunami in 2004 and Great East Japan tsunami in 2011 are cited. Tsunamis cause large-scale topographical change in many coasts, which may result in the destruction of coastal structures and the damage of harbors. On the other hand, even if a seawall can withstand the incident wave, there is the case that the seawall is destroyed with toe scour by the tsunami backflow. Therefore, it is necessary to predict the damage due to tsunami to take countermeasures.

Takahashi et al. (1991, 1993a, 1993b) stated that it is not possible to neglect the suspended load transport in addition to bed load transport in predicting topographical change. Fujii et al. (1998), Takahashi et al. (1999) and Nishihata et al. (2007) considered suspended load entrainment and deposition, and improved the accuracy of topographical change prediction due to tsunami. Ca et al. (2010) developed a numerical model by means of which topographical change in an inundation zone can be predicted also. However, they couldn’t check the applicability of topographical change in the offshore zone because there were some artificial excavations of tin mines in the research area.

Horikawa et al. (1983) had conducted many small-scale experiments, and Noguchi et al. (1997) had also conducted some large-scale experiments, and they proposed formulae to get the maximum scour depth due to tsunami backflow. However, we cannot obtain the maximum scour depth, unless the thickness of a backflow on the seawall crown is known in the former, and unless the flow rate of the backflow is known in the latter. Through a numerical simulation of toe scour by the tsunami backflow, Goto et al. (2002) studied it with Moving Particle Semi-implicit (MPS) method. Their model is good in order to explain qualitative phenomena. However, this model requires a lot of calculation time and the quantitative accuracy is still insufficient. Ca et al. (2010) and Yamamoto et al. (2011) proposed formulae based on parabolic movement to estimate the maximum scour depth and its position from hydraulic experiments. However, the authors have not rightly considered the influence of the crown height of the seawall.

In this paper, we applied the numerical model of Ca et al. (2010) to Kesennuma Bay, Miyagi, Japan in connection with the observations collected after the Chilean earthquake tsunami in 1960, and we confirmed the reproducibility of the model by adjustment of the bed load coefficient. Then we applied the model to Patong Beach with relation to the effects induced by the Indian Ocean tsunami in 2004 to confirm the accuracy of the model. Moreover, we improved the formulae of Yamamoto et al. (2011) by considering the influence of the crown height of the seawall, and we applied the improved formulae to the results of our quasi-large-scale scour experiments to confirm the accuracy of the formulae.

NUMERICAL PREDICTION MODEL OF TOPOGRAPHICAL CHANGE DUE TO TSUNAMI

Application of the numerical model to Kesennuma Bay

We applied the numerical model of Ca et al. (2010) to Kesennuma Bay. The run-up of this model is calculated by solving the equations of the non-linear shallow water theory through a finite-difference approach based on the Crank-Nicolson method. The bed load transport is estimated using Eq. 1 (Ribberink, 1998).