MODELLING OF DEBRIS MOTION DRIVEN BY TSUNAMI WAVE BREAKING

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INTRODUCTION

When a giant tsunami approaches onshore, offshore vessels and other floating objects move following the current of the tsunami. Some of the waterborne debris are transported to tsunami inundation areas and those debris impact buildings. Thus, waterborne debris collision is one of the risks for damaging structures around tsunami inundation areas. In tsunami design zones, important infrastructures and buildings are designed taking debris impact loads to consideration.

For evaluations of debris impact loads, types of debris having the potential to impact and damage the structures are identified by considering debris impact hazard region. According to ASCE7-22, the debris impact hazard region shall be determined by the empirical model proposed by Naito et al. (2014) in a simple manner. Furthermore, numerical debris transport modelling using massless tracers also shall be permitted to use for the determination.

On the other hand, numerical debris tracking (nDT) modellings which solve the equation of motion of debris have been developed (e.g., Kihara and Kaida, 2019). The nDT modellings would be possible to determine not only the debris impact hazard region but also the impact speed. The nDT models are generally used by 1- or 2-way coupling with a two-dimensional nonlinear shallow water equation (nSWE) model because the flow information is necessary for the calculation of the hydrodynamic force on debris. Since the nSWE model does not accurately solve velocity profiles in wave breakings, effects of wave breaking on the debris motion cannot be simulated without the modelling of surface velocity profile.

In this study, a surface roller modelling is incorporated into the nDT model of Kihara and Kaida (2019) to simulate debris motions driven by tsunami wave breaking. To validate the model, simulations of hydraulic experiments focusing on the motion of offshore debris reported by the Nuclear Regulation Authority (NRA) of Japan are carried out (Oda et al., 2021).

SIMULATIONS OF OFFSHORE DEBRIS MOTIONS DRIVEN BY TSUNAMI WAVE BREAKING

The nDT model proposed by Kihara and Kaida (2019) calculates debris trajectories by solving the equation of motion of debris. The model considers the hydrodynamic force, impact force between debris and buildings, impact force among debris, and friction force on the bed. The nDT model can be used both for 1-way and 2way couplings with an nSWE model. One of the major characteristics of the nDT model is that debris diffusion due to various perturbations can be simulated by applying Monte-Calro simulations.

In order to simulate debris motions driven by tsunami wave breaking, the concept of the surface roller is modelled. The model first identifies the presence of tsunami wave breaking by observing the local slope of the water surface. If the local slope of the water surface exceeds 20 degrees, the model judges that the tsunami wave breaking is presence. Second, the wave breaking zone is determined by considering the local slope. Then, the velocity in the zone is assumed to be equal to wave celerity, and the hydrodynamic force on debris is calculated by substituting the wave celerity for the velocity.

The nDT model with the surface roller modelling was applied to the numerical simulations of the laboratory experiments of NRA (2019). In the experiment, debris models were initially located offshore and were transported onshore by a soliton wave (Figure 1). At onshore, a seawall was installed, and collision probability and force on the seawall were investigated.

By carrying out Monte-Calro simulations using the surface roller modelling implemented nDT model, uncertainties on model settings, such as the drag coefficient and the diffusivity, were considered. Simulations for two types of waves (We20 and We40) and three types of debris models were performed. The predicted relationship between the collision probability and the distance from the shoreline to the initial debris position is compared with the experimental results, showing good predictions.

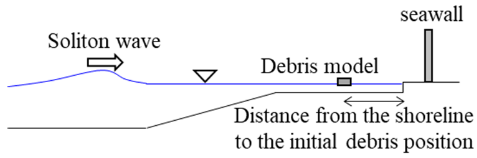

Figure 1 - Image of the hydraulic experiment.

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