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# 主 論 文 の 要 旨

論文題目 Development of Numerical Circular Wave Basin and Investigation of Tsunami-Structure Interaction（円形数値波動水槽の開発と津波・構造物相互作用に関する研究）

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## 論 文 内 容 の 要 旨

Since marine structures are operated under the real conditions of the open sea, accurate prediction of waves plays a key role in solving coastal and ocean engineering problems, especially for pre-designing hydraulic responses of coastal and offshore structures. In numerical or physical wave basins, the real sea waves, which consist of multi-directional and oblique waves, are generally generated by the snake-movement of the serpent wave generator according to the wave maker theory. There are two factors affecting the effective area of the reproduced wave field in the practical application of the multi-directional and oblique wave generations in three-dimensional wave basins, which are wave reflections and wave diffractions, for the re-reflected waves from wave generation paddles and side walls of the basin disturb the wave field after certain time of simulation and wave diffraction makes the generated wave be not able to preserve its energy.

To reproduce the multi-directional and oblique waves with larger effective test area, a numerical circular wave tank model is developed based on the two-phase incompressible flow model by solving the Navier-Stokes equations in cylindrical coordinates and tracking the free surface with the volume of fluid (VOF) method. Oblique waves are generated with a transparent wave generator, and the outgoing waves are numerically dissipated in a dumping zone at the outer edge of the wave basin. In this model, the finite volume method (FVM) is used to discretize the control equations over the zonal embedded grid system that is implemented to overcome the stability issue in the cylindrical coordinates. The computational components are stored according to the staggered grid arrangement. Velocities and pressure are coupled with the projection method. To solve the VOF convection equation over the zonal embedded grids, an algebraic CICSAM-VOF method is applied, which is proposed to track the free surface over unstructured grids. Validations of the two-phase incompressible flow model are carried out with the circular dam breaking problems in a circular basin and good agreements can be found from the computational results.

Oblique waves are successfully reproduced in the proposed circular wave basin. Comparisons of the numerical results with analytical results shows that this model can reliably reproduce oblique waves with enlarged effective area. This model is extended to multi-directional wave simulations by integrating the mass wave source of oblique waves. Two crossing waves are carried out as a case study in this thesis. As a result, the circular wave basin is numerically built for the generation of oblique and multi-directional waves.

Tsunami-bridge interaction is carried out based on numerical and experimental studies. The characteristic of wave forces acting on the bridge and the relationship between the bridge failure and wave forces are discussed. Usage of the developed circular wave basin to Tsunami-Bridge interaction will be carried out by applying unstructured grids to model a rectangular bridge in cylindrical coordinates.

In Chapter 1, the background of the study of three-dimensional waves is introduced and the goal to build the circular wave basin is presented.

In Chapter 2, a three-dimensional two-phase incompressible flow model in cylindrical coordinates is developed. In this model, the projection method is used to solve the Navier-Stokes equations over zonal embedded grids which are used to generate a smoothed grid system in the entire computational domain to avoid that too small time steps should be used in the computation. The free surface is tracked by the volume of fluid (VOF) method and the free surface tension is also considered with the Continuum Surface Force (CSF) method in this study. Two cases that a volume of water breaks inside the cylindrical tank have been used to validate the two phase model.

In Chapter 3, experimental and numerical studies on the tsunami and bridge interaction are carried out to analyze the bridge failures by evaluating tsunami forces acting on the bridge, since the recent events, the Indian Ocean tsunami in 2004 and the great East Japan tsunami in 2011, have brought the importance of investigation of bridge failures induced by tsunami.

In Chapter 4, the numerical circular wave basin is developed and applied to the investigation of oblique waves based on the two-phase incompressible flow model proposed in Chapter 2. Oblique waves are generated with a transparent wave source method and the outgoing waves are numerically dissipated by the artificial dumping zone. Based on this model, the interaction of oblique waves with a vertical cylinder is discussed.

Finally, the main conclusions and the intension for the future researches are presented in Chapter 5.