A MULTI-LEVEL TSUNAMI RUN-UP SIMULATION BASED ON 3D PARTICLE METHOD WITH A VIRTUAL WAVE MAKER

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論 文 名　：A MULTI-LEVEL TSUNAMI RUN-UP SIMULATION BASED ON 3D PARTICLE METHOD WITH A VIRTUAL WAVE MAKER
（仮想造波板を用いた 3D 粒子法によるマルチレベル津波遡上解析）

区　　分　：甲

論 文 内 容 の 要 旨

On March 11, 2011, a huge tsunami caused by a great earthquake devastated many infrastructures in the pacific coast of north eastern Japan. Due to a strong destructive power of tsunami reached at the coastal area and traveled inland, a multi-physics phenomenon was observed such as overturning of building, the collapse of breakwater and bridge washout. In order to solve the multi-physics phenomenon during tsunami disaster, a multi-level tsunami simulation is proposed to predict the tsunami waves, the damage level of infrastructure and effects of prevention and mitigation. In this study, a multi-level tsunami simulation based on the Smoothed Particle Hydrodynamics (SPH) method is developed to consider several levels of tsunami behavior. There are mainly three level simulations; a 2D tsunami propagation simulation from the epicenter to coastal line (Level-0), a 3D tsunami inundation simulation into coastal city area (Level-1) and a zooming simulation which can discuss the safety of structures at a high resolution (Level-2). To perform the above multi-level simulation, a zooming method that can connect between the tsunami propagation based on the 2D finite difference method and a tsunami inundation using 3D particle method is necessary. In addition, a zooming simulation between two different resolution models in the particle method is also required. Then, a virtual wave maker which satisfies an appropriate boundary condition on the boundaries of these different level simulations is proposed. The proposed virtual wave maker was verified and validated with several numerical tests and real case of tsunami inundation simulation in Utatsu area, which has critical damage on the bridges on March 11, 2011. To discuss this matter in details, this thesis was divided into six chapters.

Chapter 1 introduces an overview and the motivation of the study regarding the tsunami disaster and it impacts. The concept of the multi-level tsunami analysis is introduced in this chapter with the aim and several objectives to be achieve along this study.

Chapter 2 summarizes historical developments of Smoothed Particle Hydrodynamics (SPH), which is utilized for the 3D tsunami simulations in this thesis. The fundamentals mathematics of the conventional SPH is firstly described. And then, the extension to the incompressible flow solver (Incompressible SPH) is explained. In addition to the general topics of the ISPH, a stabilization method for the ISPH, which is original method in our research group, is introduced here.

Chapter 3 highlights a detailed description on solid boundary treatment formulations, which is used as the main tool to achieve the thesis motivation. In the beginning of this chapter, the types of existing solid boundary treatments are surveyed. The approach using fictitious boundary particle is selected as one of the type of boundary treatment that will be focus on. Then, the main part of this chapter is proposing the enhancement of existing boundary treatment which is called generalized fixed ghost particle approach (GFGP). The proposed Simplified GFGP (SGFGP) has several advantages in the robustness and in the computational cost. The last section in this chapter is focusing on the verification and validation of the proposed SGFGP boundary treatment. Validation tests not only for the hydrostatic pressure test with complicated obstacles in the water tank but also for hydrodynamic pressure tests in the dam-break problems are conducted to show accuracy and advantages of the proposed method.

Chapter 4 focus on a matrix arrayed virtual wave maker for a key issue of the multi-level tsunami simulations. The general functions of the virtual wave maker (VWM) are firstly defined. The first function of VWM is generation and/or removal of the water particle on the boundary of the multi-level tsunami simulations. New water particles are generated to resume a record of inflow conditions by the preliminary tsunami simulation at a lower level in the case of inflow condition, and outflow water particles are removed in the case of outflow condition. The next function of the VWM is to satisfy the reasonable boundary condition between two level simulations. Especially, smoothness of pressure field between two different level simulations is strongly required to prevent an artificial additional wave on the boundary of multi-level simulations. The SGFGP proposed in the Chapter3 can be arranged to satisfy the pressure Neumann condition on the boundary of multi-level simulations. There are several numerical tests were conducted to validate the proposed VWM with SGFGP as a coupler between two 3D particle models with the same resolution and also the application to a zooming simulation with 3D particle simulations.

In **Chapter 5**, multi-level of tsunami simulations is conducted here as the final target of this study. The coupling tsunami simulations between 2D shallow water equation based finite difference method at Level-0 with 3D particle simulation at Level-1 is conducted at the Utatsu area, where Utatsu Bridge was totally collapsed by Tohoku earthquake tsunami 2011. The proposed VWM can connect between 2D and 3D tsunami simulations without any artificial additional wave because of a precise boundary treatment with SGFGP. The simulated tsunami inundation area by the multi-level tsunami simulation shows a good agreement with the disaster report of Tohoku earthquake tsunami 2011. The small discrepancy is due to the resolution of the simulation model, but the smaller resolution model shows a convergence profile to the disaster report.

In **Chapter 6**, conclusions and recommendations for future works are presented.