EXAMINATION OF ANALYSIS METHOD FOR HYDRAULIC MODEL EXPERIMENT UTILIZING RGBD IMAGES AND DUALSPHYSICS

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INTRODUCTION

Reconstruction method of real objects into point cloud based on RGB images and Depth images (RGB-D Images) has been adopted in various fields. By utilizing such reconstruction method, it would be possible to efficiently measure the complex shape of objects, such as tetrapods, without directly contacting to them in the real experiment. However, the measurements of three-dimensional (3D) objects have rarely been used in hydrodynamic experiments. In the present study, the methodology was built to carry out hydraulic experiments and numerical simulations focusing on the displacement of complex objects. It was carried out by combining reconstructed 3D point cloud data acquired from Intel RealSense LiDAR Camera L515 (L515) and DualSPHysics. The result of displacement of the objects was investigated by numerical simulation and hydrodynamic experiments.

METHODS

In the hydraulic model experiment, the four tetrapods (wave breakers) were arranged along the Y-axis in the two-dimensional cross-sectional channel (Figure 1 and Figure 2), and regular waves acted on the objects. Wave heights at the three points in the channel were measured by wave gauges (WG), and displacement of the models was measured by comparing the photographs of the models before and after the wave was acted. The 3D point cloud data of the tetrapods located in the channel (Figure 3) were reconstructed from RGB-D Images obtained from L515 by Open3D (3D data processing libraries). Additionally, it was converted to an individual block (Figure 3) and STL format by CloudCompare (3D data processing libraries). In the numerical simulations, the point cloud data of individual blocks were imported into the same numerical experimental flume created in DualSPHysics, and the wave heights and displacements of the model's centers under the regular waves were analyzed. Two cases were set for rigid algorithm for blocks made by SPH and DEM model, respectively. Table-1 shows the calculation parameters for DualSPHysics, and Table-2 and 3 show the physical properties of each material for DEM model.

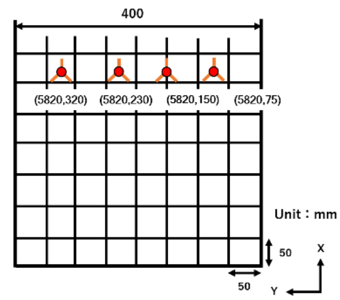

Figure 2 - Arrangement plan of tetrapod models

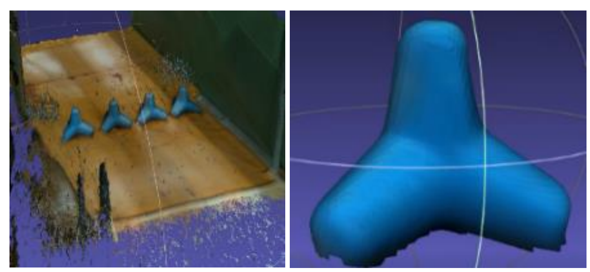

Figure 3 - Reconstructed 3D models of tetrapod (Left: tetrapods located in the flume, Right: individual block)

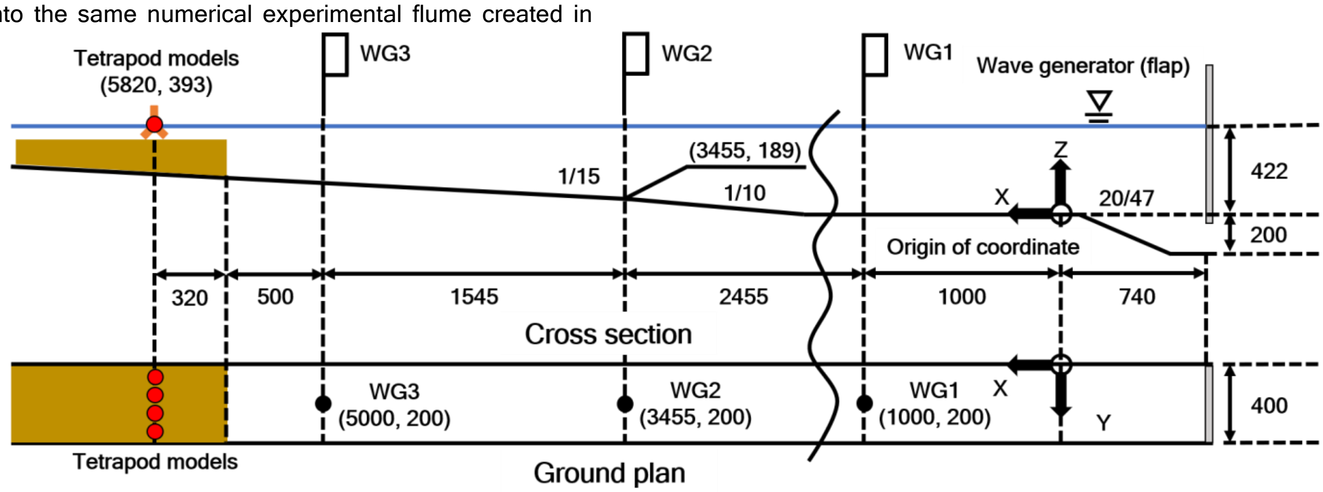

Figure 1 - Cross-section of two-dimensional channel in the hydrodynamic experiment

Table 1 - Parameters for DualSPHysics

Gravity in Z-axis direction (m/s2)	-9.81
Mass body of 3D model (kg)	0.0169
Dimension of 3D model (mm)	H50×W59×D55
Coefficient of smoothing length	1.2
Inter-particle distance (m)	0.007
Boundary	DBC
Step Algorithm	Symplectic
Kernel	Wendland
Visco Treatment	Artificial (0.01)
Rigid Algorithm	SPH / DEM
Time Max (s)	9.0
Time Out(s)	0.01
Water Depth (m)	0.673
Variable draft (m)	-0.125
Wave Height (m)	0.0653
Wave Period (s)	1.43

Table 2 - Young modulus and Poisson ratio of each material for DEM model

Material	Young Modulus (N/m2)	Poisson Ratio
Concrete	226421059.0	0.20
Steel	210000000000.0	0.35
PVC	3000000000.0	0.30
Grass	65000000000.0	0.23
Soft-wood	70000000.0	0.10

Table 3 - Restitution coefficient and kinetic friction coefficient of each material for DEM model

Material	Restitution Coefficient	Kinetic Friction Coefficient
Concrete	0.13	0.59
Steel	0.80	0.35
PVC	0.60	0.15
Grass	0.85	0.40
Soft-wood	0.50	0.75

RESULTS

Figure 4 shows the wave heights at the three points in the two-dimensional cross-sectional channel. Firstly, the results of SPH and DEM simulation were in fair agreement with the experimental results at the WG1. However, both SPH and DEM wave height results further from the wave generator showed an underestimation at the WG2 and WG3.

Figure 5 shows the comparison of experimental and numerical results for the displacements of the four tetrapod model's centers in the X-axis direction. The displacements caused by regular single wave and double waves, whose height of 6.53 (cm) and period of 1.43 (s), acting on the block models were used for the comparison. Firstly, the results of SPH simulation showed an overestimation of the displacements of blocks by 3~4 times compared with the experiment. On the other hand, under the single wave case using DEM model, the displacement of the one block agreed well with the experiment, and three blocks were underestimated with the experiment. However, the displacement of three blocks acted by double waves agreed well with the experiment while one block is overestimated.

Figure 4 - Wave Heights at the three points in the two-dimensional cross-sectional channel

These results show that the displacement of blocks in DEM model is in better agreement with the experiment than in SPH model case. This is probably because the repulsion forces and friction in the floor-block and block-block interaction were considered in DEM model (Tables 2 and 3). The reason for the underestimation of the three blocks under the single wave case using DEM model was mainly because of DBC that utilize for the boundary conditions (Table 1). DBC would not allow fluid particles to flow solid-to-solid due to particle-free gaps between wall particles and fluid particles, and water pressure between the tetrapods was not calculated. This could be potentially solved by mDBC (Modified dynamic boundary conditions; English et al. 2021) which is one of the boundary conditions for solving the boundaries between objects proposed by DualSPHysics. As the future task, the improvement of calculation accuracy for the displacement of real objects should be done by using the state-of-the-art solution for numerical simulation.

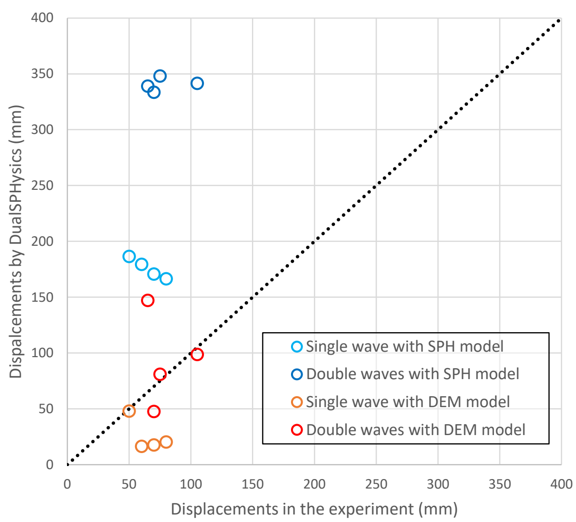

Figure 5 - Displacements of models in X-axis

CONCLUSION

The methodology to reproduce hydraulic model experiments utilizing 3D point cloud data constructed by RGB-D Images was developed. The result in the case of SPH and DEM shows that and simulation of displacement of four blocks was better to be reproduced by DEM model, which was fairly consistent with experimental results.

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