THREE-DIMENSIONAL FLUID-STRUCTURE ANALYSIS ON SEAWALL FAILURE INDUCED BY 2011 GREAT TOHOKU EARTHQUAKE TSUNAMI

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INTRODUCTION

The Great Tohoku Earthquake with a magnitude of 9.0 occurred off the pacific coast of Japan on March 11th, 2011, which was the largest earthquake in the recorded history of Japan. Tohoku region, which is located on the northern part of the main island of Japan, has been devastated by some tsunamis in the past. It is of extreme importance from the perspectives of tsunami disaster prevention and mitigation to comprehend the failure mechanisms of coastal structures and nonlinear interaction between fluid and structure. In this study, a three-dimensional fluid-structure analysis model is proposed to discuss seawall failure mechanism caused by tsunami. The utility of the model is verified by applying it to the failure phenomenon of seawalls broken by the 2011 Great Tohoku Earthquake Tsunami.

FLUID-STRUCTURE ANALYSIS MODEL

A three-dimensional fluid-structure analysis model was developed in this study to discuss tsunami-induced seawall failure mechanism. The model consists of a free open source software for computational fluid dynamics "OpenFOAM" (Open source Field Operation And Manipulation) and a Finite Element Method (FEM)-based structural analysis model "SeanFEM". "interFoam" in OpenFOAM was adopted in this study, which is a liquid-gas two phase model for incompressible and immiscible fluid. Structural analysis was conducted here by using the time variations of tsunami pressures acting on the structure calculated by OpenFOAM. Figure 1 shows a computational domain for a three-dimensional fluid analysis with OpenFOAM, which models topography near Kojirahama Fishing Port in Kamaishi of Iwate Prefecture broken by the 2011 Tohoku Earthquake Tsunami. Seawalls illustrated in Figure 2 were installed along the coastline before the tsunami attack. Initial tsunami height was set at 10m based on the preliminary horizontal two-dimensional tsunami analysis. The boundary condition for the seawall used in the structural analysis is also shown in Figure 2.

RESULTS AND DISCUSSIONS

Figure 3 shows the numerical results of tsunami behavior near the seawall. It is recognized that tsunami overflows the seawall and inundates the inland. Figure 4 shows the dynamic behavior of the seawall computed by the FEM-based structural analysis model, which is represented at ten-fold magnification. Moreover, Figures 4 indicates that the seawall does not move for a while after the tsunami attack, but begins to turn over in a clockwise direction, namely landward at the time of t = 30 ~ 40s that the pressure largely increases.

CONCLUSIONS

In this study, a three-dimensional fluid-structure analysis model was proposed in this study to discuss seawall failure mechanism caused by tsunami. As a result, the model can be said to be a useful computational tool for examining the failure mechanism of coastal structures.

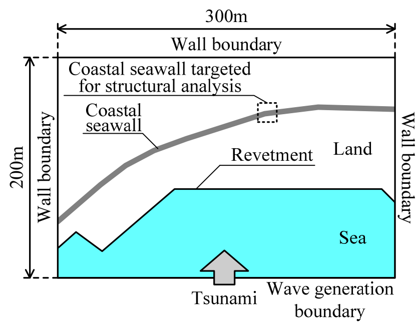

Figure 1 - Computational domain

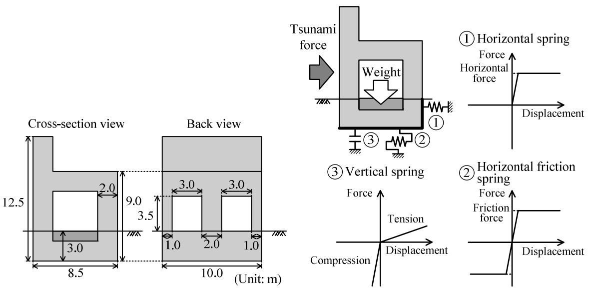

Figure 2 – Schematic and boundary condition of seawall

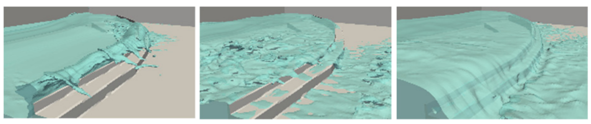

Figure 3 - Tsunami behavior near seawall

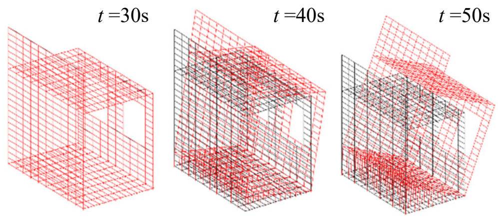

Figure 4 - Numerical result of seawall deformation
(Black line: original position)

REFERENCES

OpenFOAM Foundation (2013). http://www.openfoam.org /docs/user/.