TSUNAMI INUNDATION SIMULATIONS IN URBAN TOPOGRAPHY

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OBJECTIVES

The inundation of the 2011 Tohoku Earthquake Tsunami showed complex behavior over the land. According to the surveys of the Tohoku Earthquake Tsunami in 2011, the behavior of tsunami in urban areas was different from that in rural areas and the damage was not only dependent on the inundation heights but also the local momentums. The buildings are commonly excluded and smoothed off in the topography in the conventional inundation simulation but it's important to understand the local characteristics of tsunami run-up in urban areas. The purpose of this study is to understand and validate numerical models of tsunami in the urban area.

PHYSICAL AND NUMERICAL MODELS

The physical experiment as a benchmark for the numerical simulations was adopted by Park et al (2013). This experiment was an idealized representation of Seaside, Oregon, constructed at 1:50 scale. The elevation views of the physical model are shown in Figure 1. The buildings were positioned on the flat ground based on aerial imagery and field survey data. Time-dependent surface water levels and velocities were measured in the experiment. Measurement locations are divided into 4 lines. Line A is located on a city street parallel to the primary inundation flow direction and numbered sequential 1 to 9, as the measurement locations move inland. Line D is located mostly behind buildings and only had 4 measurement locations.

In this study, two numerical models are compared to the physical model results. These models are quasi-three dimensional (Q3D) Euler model and standard two dimensional (2D) nonlinear shallow water model. The Q3D model assumes hydrostatic but includes both vertical and horizontal turbulence mixing based on k-ε turbulence model. The numerical results considering the buildings are shown Figure 1. The buildings are included as topography because the roughness model is not applicable to the estimation of local tsunami behavior around the buildings. The smallest houses have approximately 4 by 6 grids for numerical stability. The offshore boundary conditions were given by the physical experiment.

RESULTS

Both 2D and Q3D models agreed well with the experimental results on the strait street from shorelines. However, the numerical models were differed from the experiment at the points behind large scale buildings as shown in Figure 1. The discrepancy with the experiment emerged where the vertical mixing is dominant. By the sensitivity test, it was confirmed that the arrival time and the maximum velocity in inland are more dependent on viscosity than bottom friction.

The difference between 2D and Q3D models became large especially in inland. Figure 2 shows time series of velocity along straight street from shoreline (left) to land and street behind of large building (right). The inundation depth and velocity of 2D models tented to be smaller than those of the Q3D model because 2D model allows for larger wave energy dissipation due to assumed vertical velocity profile and excluded vertical turbulence mixing and horizontal large scale vorticity behind of structures. The local diffraction and horizontal scale eddy behind of building give significant impact on local momentum and are sensitive to model. Additionally the inundation extent depends on the bottom friction parameterization rather than model itself.

CONCLUSIONS

The numerical simulations showed that both 2D and Q3D models are available to estimate the damage of the tsunami in city scale but the accuracy of inundation behavior depends on the local reflection and diffraction due to large scale buildings. Sensitivity tests showed the importance of appropriate modeling of viscosity considering of hydrodynamic forces on buildings. According to the comparison of Q3D model and 2D model, it is likely that the 2D model underestimates the inundation extent and local hydrodynamic forces during the tsunami inundation process.

REFERENCES

Hyongsu Park et al. (2013): Tsunami inundation modeling in constructed environments: A physical and numerical comparison of free-surface elevation, velocity, and momentum flux, Coastal Engineering, ELSEVIER, vol. 79, pp. 9-21.

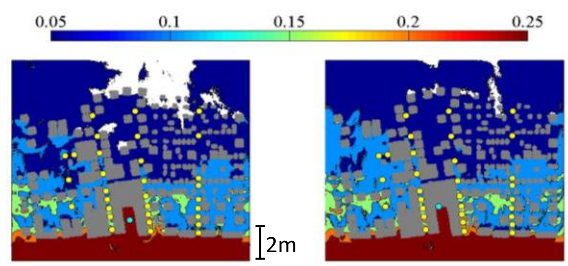

Figure 1 – Modelled inundation depth (left: 2D model right Q3D model, dots: location of wave gauges, unit m)

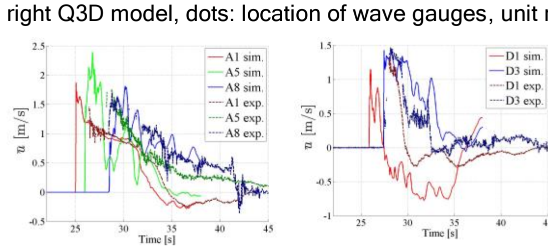

Figure 2 – Comparison of velocity from shoreline to land (left: line A for straight street, right: line D for behind of large building).