A NUMERICAL STUDY ON FLOOD INUNDATION IN A COASTAL URBAN AREA: APPLICATION TO CHANGWON CITY, KOREA

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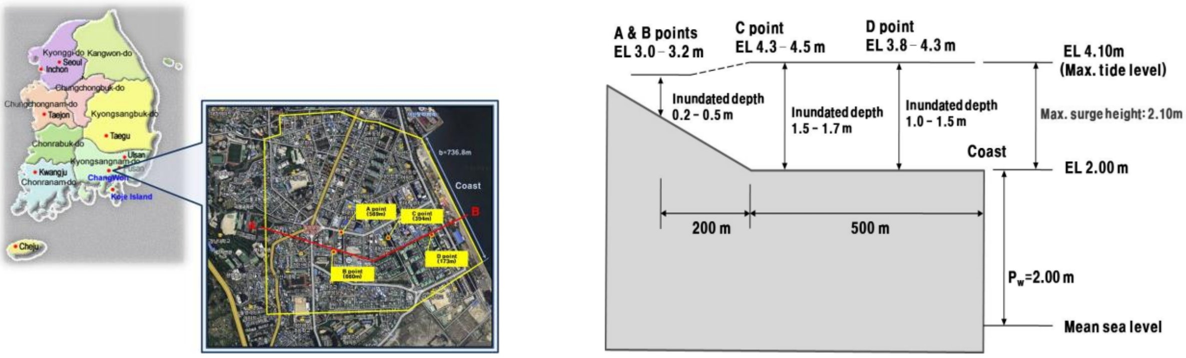
1. INTRODUCTION

In this study, the simulation and analysis for the inundation in a coastal urban area according to the storm surge height are carried out using a two-dimensional finite volume model with a well-balanced and HLLC schemes (Jeong, 2015). The target coastal urban area considered in this study is a part of the new town of Changwon city, Gyungnam province, Korea and this area was extremely damaged due to the storm surge generated during the period of the typhoon "Maemi" in September 2003. For the purpose of the verification of the numerical model applied in this study, the simulated results are compared and analyzed with the temporal storm surge heights observed at the tide station in Masan bay and inundation traces in an urban areas. Moreover, in order to investigate the influence of super typhoons possible in the future, the results simulated with the storm surge heights increased 1.25 and 1.5 times greater than those observed during the period of the typhoon "Maemi" are compared and analyzed.

2. SIMULATION RESULTS

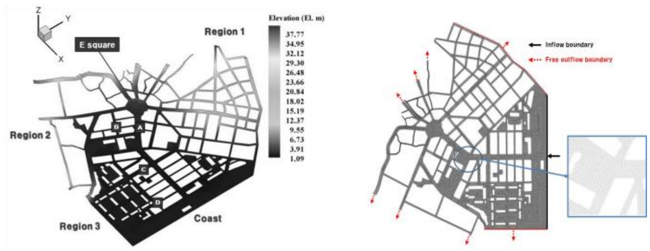
The target coastal urban area is a part of new town of Changwon city which is located on the southern coast of the Korea and Masan Bay (Figure 1(a)). This town was extremely damaged by high tides and storm surge during the typhoon "Maemi" from September 12 to 13 in 2003. The major points with records of inundation traces are A, B, C, and D, which are located at 660, 569, 394, and 173 m, respectively, from the coast. Figure 1(b) shows the cross-sectional diagram of the area along A-B line in Figure 1(a), and the range of inundated water depth surveyed at each point. Point D, which is the closet to the coast, was recorded to be inundated approximately 1.0~1.5 m, point C was inundated 1.5~1.7 m, and points A and B were inundated 0.2~0.5 m.



a) *b)*

Figure 1. *Target coastal urban area (a) and schematic cross-section along A-B line (b).*

Figure 2(a) represents the elevation distribution of the target area. The elevation along the coastal line varies from EL. 1.90 to EL. 2.10 m and the mean elevation is EL. 2.00 m. The elevation range of the urban area is between EL. 2.00 and EL. 39.90 m. The region from the coast to point C represents an almost flat terrain, but regions 1 and 2 become steeper with a mean slope of approximately 0.09. The elevation of point A is EL. 2.01 m, point B EL. 2.08 m, point C EL. 1.40 m, and point D EL. 1.24 m. Figure 2(b) shows the grid system of the target coastal urban area and boundary conditions. The grid system consists of 57,503 non-structural triangular cells and 32,885 nodes, and buildings are considered to be impermeable. Hence, the flow occurs only along the roads between buildings. The coastal line is considered as an inflow boundary condition, and the road exits connected with the boundary of the target coastal urban area are considered as free outflow boundary conditions.



a) *b)*

***Figure 2.** Elevation distribution (a) and grid system with boundary conditions (b).*

Figure 3 shows the spatial distributions of inundation depths with time for Typhoon "Maemi" case. The storm surge starts to inflow in from the coast, moves along the roads between buildings, stops moving around E square because of high slope, and then moves along other roads with relatively small slopes. With the first half of the buildings placed close and parallel to the coast, rapid increases in the water depth occurs, which means that buildings may become barriers that delay the movement of the storm surges flowing in from the coast. Since the beginning of the simulation, the

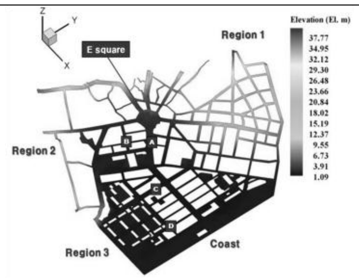
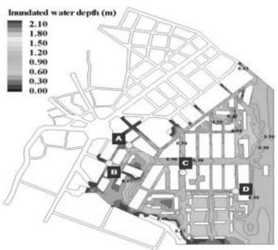
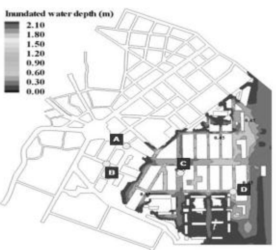
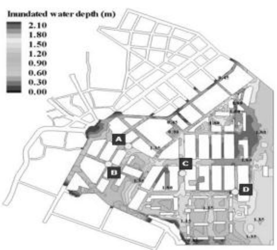
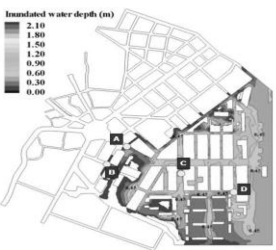
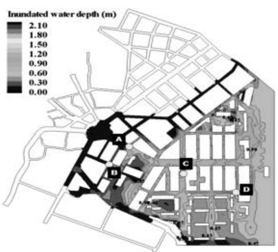
		**Time (sec)**	**Inundated water depth(m)**
		15,000 (4h 10m)	
Time (sec)	**Inundated water depth(m)**		
5,000 (1h 23m)		**21,000 (5h 50m) Max**	
10,000 (2h 47m)		**25,000 (6h 57m)**	

***Figure 3.** Spatial distribution of inundation depths with time for Typhoon "Maemi" case.*

inundation depth with time increases from 0.84 m after 5,000 seconds (1 hr 23 min), to 1.07 m after 10,000 seconds (2 hr 47 min), to 1.4 m after 15,000 seconds (4 hr 10 min), and up to 2.09 m after 21,000 seconds (5 hr 50 min), and then starts to decrease. After 25,000 seconds (6 hr 57 min), the inundation depth decreases down to 1.25 m.

Figure 4 shows the temporal variations of inundation depth for four points. In the case of point D, the maximum inundation depth is 1.22 m and occurs after 21, 204 seconds (corresponding to September 12, 21 hr 53 min) from the beginning of the simulation, which is 204 seconds (nearly 3 min) after 21,000 seconds when the maximum storm surge height occurred. In the case of point C, the maximum inundation depth is 1.71 m after 21,265 seconds (corresponding to 21 hr 54 min), which is estimated to have occurred approximately 60 seconds after the maximum storm surge height at point D occurred. For points A and B, the maximum inundation depths are 1.07 m and 0.79 m, respectively, and they occur after 21,308 and 21, 317 seconds, respectively, almost simultaneously since the beginning of the simulation. In the case of points C and D estimated in this study, the maximum inundation depth represents values within the range of, or considerably close to, the inundation traces shown in Figure 10(b), but in the case of point A and B, the maximum inundation depths are overestimated by approximately 0.5 m. Considering the uncertainty of the inundation

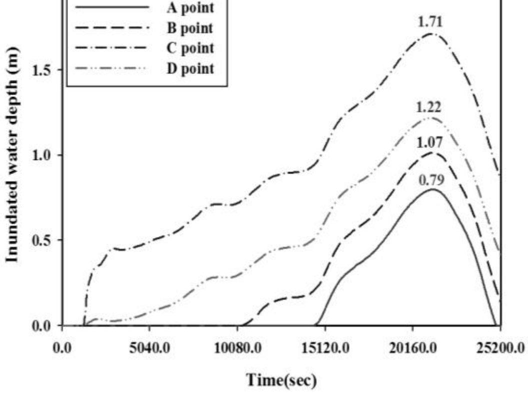


Figure 4. *Temporal variation of inundation depths at four points for Typhoon "Maemi" case.*

traces, however, the simulated results are comparatively appropriate. In the case of point D and C, the inundation starts after approximately 1,189 seconds (corresponding to 16 hr 19 min) and 1,254 seconds (corresponding to 16 hr 21 min), respectively. For points A and B, the inundation starts after 9,027 seconds (corresponding to 18 hr 30 min) and 14,328 seconds (corresponding to 19 hr 58 min), respectively.

3. CONCLUSIONS

Using the 2-dimensional numerical model and the data of storm surge heights observed from the tide station of Masan bay, we simulated and analyzed inundations caused by storm surges in a part of new town in Changwon city, Kyungnam Province, Korea. The main conclusions drawn in this study are as follows:

1. The maximum inundation depths for points D, C, A, and B in the target coastal urban areas are 1.22, 1.71, 1.07, and 0.79 m, respectively, and in the case of points D and C, the calculated values are considerably close to those from the surveyed inundation traces, whereas in the case of points A and B, the maximum inundation depths are overestimated by approximately 0.5 m. Considering the uncertainty of the inundation traces, however, the maximum inundation depth estimated in this research is appropriate in principle.
2. The storm surge starts to flow in from the coast, moves along the roads between the buildings in the urban area, stops moving around E square because of roads with high slope, and then moves along other roads with relatively small slopes. With the first half of the buildings placed close and parallel to the coast, rapid increases in the water depth occur, and the buildings in the urban area probably become barriers that delay the movement of the surges flowing in from the coast.

4. REFERENCE

[1] Jeong, W.C. (2015) "A study on simulation of flood inundation in a coastal urban area using two-dimensional well-balanced finite volume model", Natural Hazards, Vol. 77, No. 1, pp. 337-354.