

Hydraulic Analysis of Submergence Damage by Typhoon 9918

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ABSTRACT: The submergence damage of Typhoon 9918 attack at New Moji reclaimed land in Kita-kyushu city was analyzed using actual field survey and remote sensing data with GIS. Submergence of reclaimed land in the typhoon attack was caused by overtopping of seawater, outflow from the back ground, and water storage from rainfall. First, the quantity of wave overtopping was estimated using the Goda diagrams of wave overtopping. The storage amount of water at the target place was calculated from the topography provided by the surveys and remote sensing data with GIS. Next, the mean rainfall in the target place was calculated from rainfall data by the Meteorological Agency. Finally, water balance analysis was carried out to obtain time series of storage and drainage amount in the submerged area. As a result, this submergence damage was judged to occur not only by wave overtopping of high tide and high waves but also by local settlement in the reclaimed land and its incomplete drainage systems.

1. INTRODUCTION

Currently, the study about natural disaster became one of most important study in order to protect the lives and properties of victims. Various studies about disaster by high tide and high waves with an attack of typhoon have been done till now. These were inspected from the viewpoint of meteorology and coastal engineering. However, as for the study about rainfall, inflow from the back ground, and chronological order of submergence to be distributed broadly, the satisfactory accuracy is not guaranteed. Though these are big factors of submergence damage. The quantity of building a breakwater wave overtopping was demanded in this study. Furthermore, the rain and rainwater inflow and submergence conditions were estimated using remote sensing and GIS.

2. STUDY TARGETS

2.1. Typhoon 9918

Typhoon 9918 attacked north Kyusyu and Yamaguchi areas in the early morning of September 24, 1999. This typhoon resembled Typhoon 9119 in power and course in 1991 (Figure 1). However, such damage magnitude as Typhoon 5915 in 1959 was brought by this typhoon. Because the typhoon hit there at the

same time of flood tide and high tide.

Therefore, Typhoon 9119 hit it at ebb tide. In addition, it was one of cause that east wind was blowing a gale from the west Suo Nada sea. Significant wave height and significant wave period of the past maximum were observed off Kanda, Kita-kyushu where the center of typhoon passed (Hashimoto *et al.*, 2000; Sato *et al.*, 2000).

2.2. Study area

New Moji south area (about 180.6 ha), Moji district, Kita-kyushu city, Fukuoka prefecture, was the target in this study (Figure 2). This district was reclaimed land, and two banks were constructed. A bank of north side (No.1) has 814-m extension, and the bank of the south side (No.2) has 1,171-m extension (Total extension becomes 1,985m). However, these banks were destroyed at 10 points by the wave force of the typhoon invasion (Takahashi *et al.*, 2000). Much seawater invaded by wave overtopping and influence of collapse of banks. Therefore, this area suffered the serious inundation damage. The bank No.2 was divided into two (A and B) for convenience in this study (Figure 2). Especially, the bank No.2A that received the terrible damage was inspected. All the height was described with a value of the chart datum level (C.D.L) in the following sections and charts.

3. METHODS

The inundation of the coastal area by the typhoon invasion was formed by the inflow from seawater, rain, and the back ground. The causes of inundation in the study area were analyzed by the following methodology in this study. In addition, an estimate of storage discharge in a submergence area was carried out.

3.1. Estimate of inflow quantity deep water

The existing design standard of banks and dikes corresponds to the instructions by Goda (JSCE., 2001). Generally, quantity of wave overtopping is estimated with the diagrams of wave overtopping designed by Goda in Figure 3. (Goda, 1990). The quantity of wave overtopping was calculated using the following conditions in this study. The target was bank No.2A (The extension is 526.5m). One point of representative equivalent deep water waves in the offing wave height H_0' , in front of the bank was used. As for the representative equivalent deep water waves in the offing and the representative-period equivalent deep water waves in the offing were referred to data by Kita-kyushu-city harbor office (Table 1). The target time was 5:00 to 10:00 a.m., September 24. Most of collapse parts were at jointed concrete parts. The collapse time was not clear precisely. It was supposed to be before 7:00 a.m. Because the surge was the most prominent at that time. Those conditions were classed in standing straight banks without vanishing-wave tetrapods.

Data by Kanda, Simonoseki, and Kagumeyoshi meteorological observatory stations were used for rainfall in the study area (Table 2). The serial rainfall during Typhoon 9918 passage was added up every meteorological observatory. The rainfall of the study area was calculated with an isohyetal method. The penetration or the losses were not considered in this study by the following reasons. It was shown that study area was paved more than 60% from a result of supervised land cover classification with NVIR bands of Terra/Aster (Band 1, 2, and 3N, in Figure 7). Analysis about chronological order of water levels in the whole reclaimed land was not enough at this step, too.

Next, it is the method of rainwater inflow from the back ground as follows. Area of the basin where rainwater flowed into the target area was obtained by 50-m-mesh DEM. The run off coefficient was considered to be 0.8 because it was identified that background was immediate incline by DEM (JSCE., 1985).

3.2. Storage discharge

Storage discharge is a volume of between the ground and submergence surfaces. The ground level data were made by a result of ground elevation surveying in the target area. The submergence data were obtained by the flood damage reports. Ground elevation profiles of the target area were made from these.

4. RESULTS

4.1. Inflow quantity of water

Wave overtopping inflow calculated with values estimated by the Goda diagrams. The result was shown in Table 3. Inflow of seawater became about 2 times by collapse of banks. The estimated total amount of rainfall in the submergence damage was 55 mm, and it was about 27,000 m³ in the whole target area. The basin area of the reclaimed land was about 554,000 m² (Figure 4). This area exceeded the back area of bank No.2A. The estimated quantity of water that flowed into the back area of bank No.2A was about 6,000 m³. The rainwater storage discharge at the disaster increased by 30 % considering inflow from the back ground.

4.2. Storage discharge

Average submergence surface was obtained from the heights of ground and submergence (Figures 5 and 6). However, it was not maintained the same by influence of surge and non-distinctness of the measurement points. Average submergence surface was estimated as +67 m. The result was shown in Table 4. It was found out that most of the areas were flooded. In particular, the damage through East and West roads were terrible. The result of ground elevation surveying showed the tendency that roads sank lower than other spots. In the reclaimed land, seaward is lower than land side for drainage. However, some points became the topography like a hollow by subsidence. Drainages for rainwater drainage existed in the target area. However, there were no water gate or no countercurrent prevention functions. Accordingly the rainwater drainage in the target area was in bad condition. Most the rainwater concentrated into the target area. It was shown that the quantity of water was considerably large by results of this study.

5. DISCUSSION

It was evaluated about the submergence damage by Typhoon 9918 in the south area, New Moji, in this study. The main cause of inundation was wave overtopping and bank collapse, but the topography of reclaimed land and the back ground became causes of damage expansion, too. Improvement of estimate accuracy of submergence damage cause was proposed as a future theme. It is necessary to investigate elevation of ground, land covers of the target area, and rainwater drainage function more in detail in order to analyze surge of water in the inundation area particularly. NVIR bands of Terra/Aster were used for land cover classification in this study (Figure 8b). These bands detect presence of vegetation very well, but classification of pavement side and bareland not so well. Besides, Terra/Aster data have six SWIR bands (bands 4 to 9, Figure 8c) and five TIR bands (bands 10 to 14, Figure 8d). White pixels in Figure 8 were identified as bareland by actual ground truth. However, the reflections were obviously different in accordance with bands in the same bareland. Using those bands, a technique to estimate indispensable information such as permeability of the soil, the roughness, ground elevation, or soil moisture will be developed in future in order to investigate the submergence damage. Construction of non-routine water budget simulation in a target area at typhoon invasion will be executed. Finally, detailed reproduction at a disaster is carried out, and it will be contributed to inundation damage reduction in a coastal area more.

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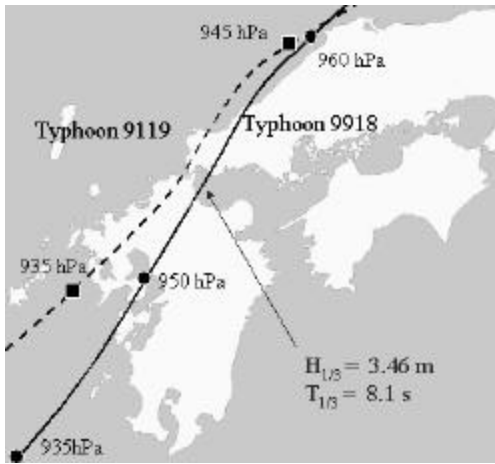


Figure 1 Courses of Typhoons 9918 and 9119

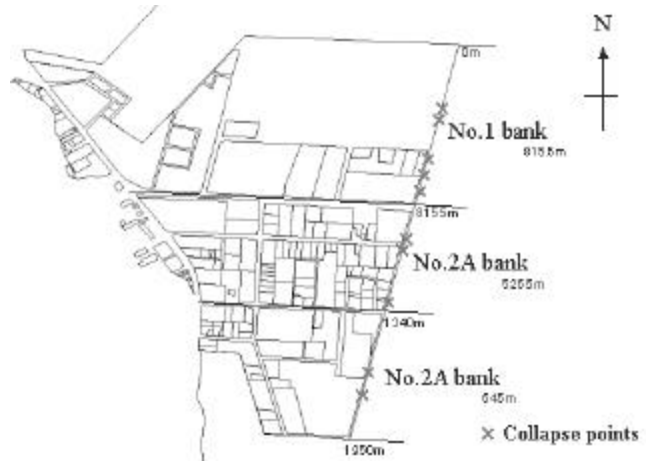


Figure 2 New Moji Port, south area

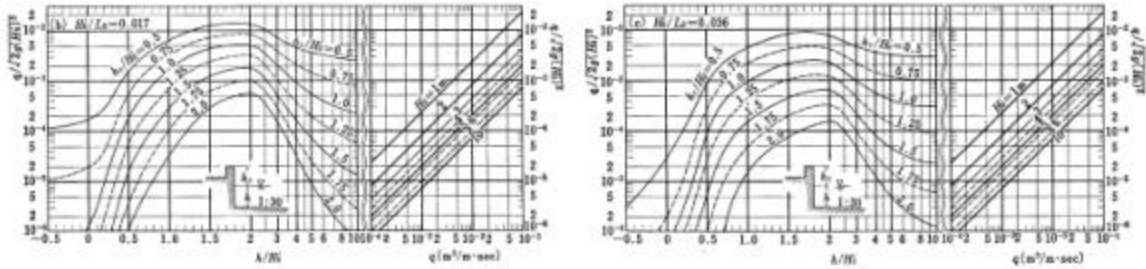


Figure 3 Goda diagrams for wave overtopping

Table 1 Parameters for estimate of wave overtopping

Time	Tide (m)	Frequency T (sec)	Wave length L_0 (m)	Depth h (m)	Equivalent deep water wave H_0' (m)	H_0'/L_0	h/H_0'	hc (m)	hc/H_0'
5:00	3.18	6.2	59.97	6.68	1.94	0.032	3.44	2.32	1.20
6:00	4.08	6.9	74.27	7.58	2.37	0.032	3.20	1.42	0.60
7:00	5.18	8.1	102.35	8.68	2.73	0.027	3.18	0.32	0.12
8:00	5.31	8.1	102.35	8.81	2.31	0.023	3.81	0.19	0.08
9:00	4.62	6.3	61.92	8.12	1.64	0.026	4.95	0.88	0.54
10:00	3.88	4.2	27.52	7.38	0.80	0.029	9.23	1.62	2.03

Table 2 Rainfall each meteorological observatory on September 24, 1999.

Time	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	Total
Shimonoseki	5	7	2	1	0	2	4	8	21	0	50
Yahata	10	3	2	2	0	3	9	19	16	1	65
Kagumeyoshi	3	1	1	1	0	4	9	29	12	1	61

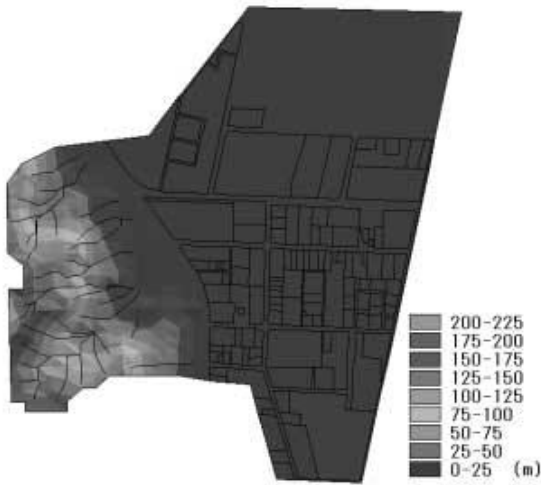


Figure 4 Basin area

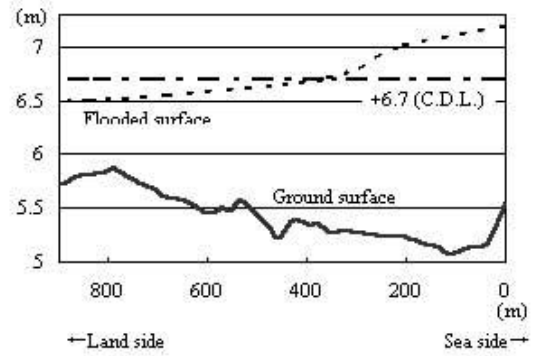


Figure 5 Flooded water and ground elevations

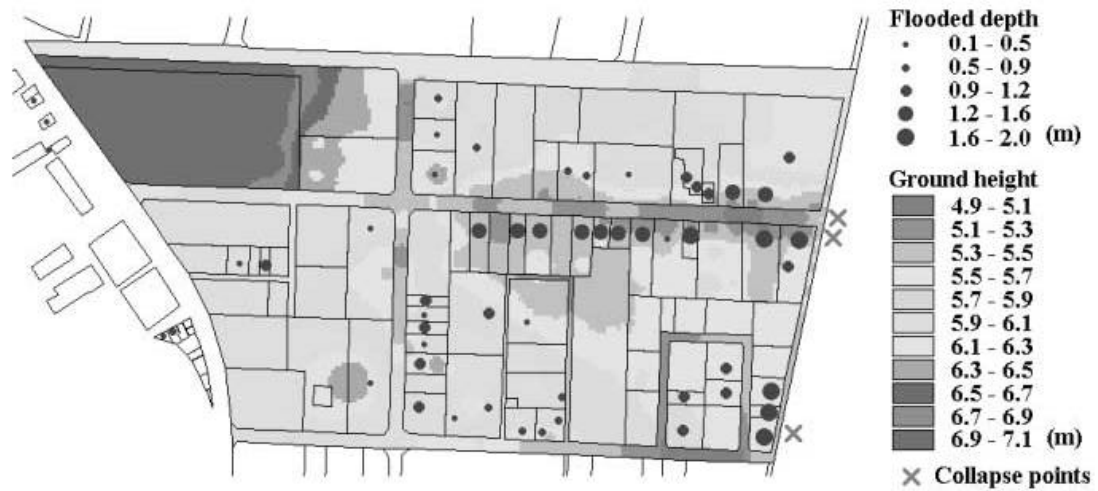


Figure 8 Ground elevation map

Table 3 Inflow from the sea

Time	No collapse section	Collapse section	Total
5:00	739	100	839
6:00	9,444	1,272	10,716
7:00	90,065	67,398	157,463
8:00	62,313	62,951	125,264
9:00	1,553	4,603	6,156
10:00	0	0	0
Total	164,114	136,323	300,437

Table 4 Estimated storage

Ground height (m)	Depth (m)	Area (m ²)	Quantity (m ³)
4.9-5.1	1.7	3,096	5,264
5.1-5.3	1.5	17,763	26,645
5.3-5.5	1.3	56,594	73,572
5.5-5.7	1.1	114,701	126,171
5.7-5.9	0.9	85,216	76,695
5.9-6.1	0.7	100,341	70,239
6.1-6.3	0.5	29,214	14,607
6.3-6.5	0.3	11,724	3,517
6.5-6.7	0.1	3,174	317
Total			397,025

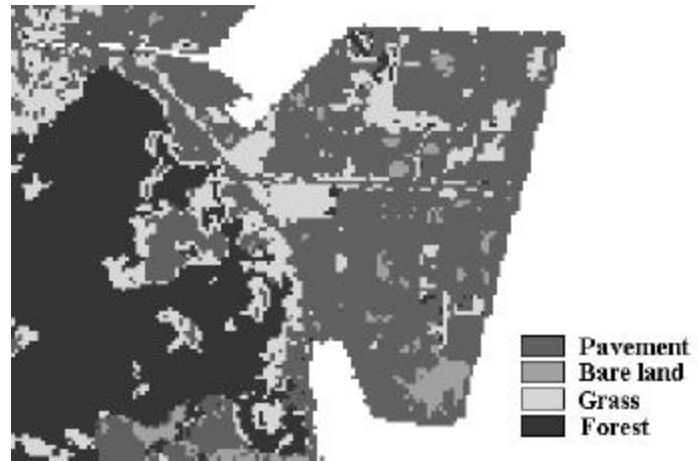


Figure 7 Land-cover classification of the study area

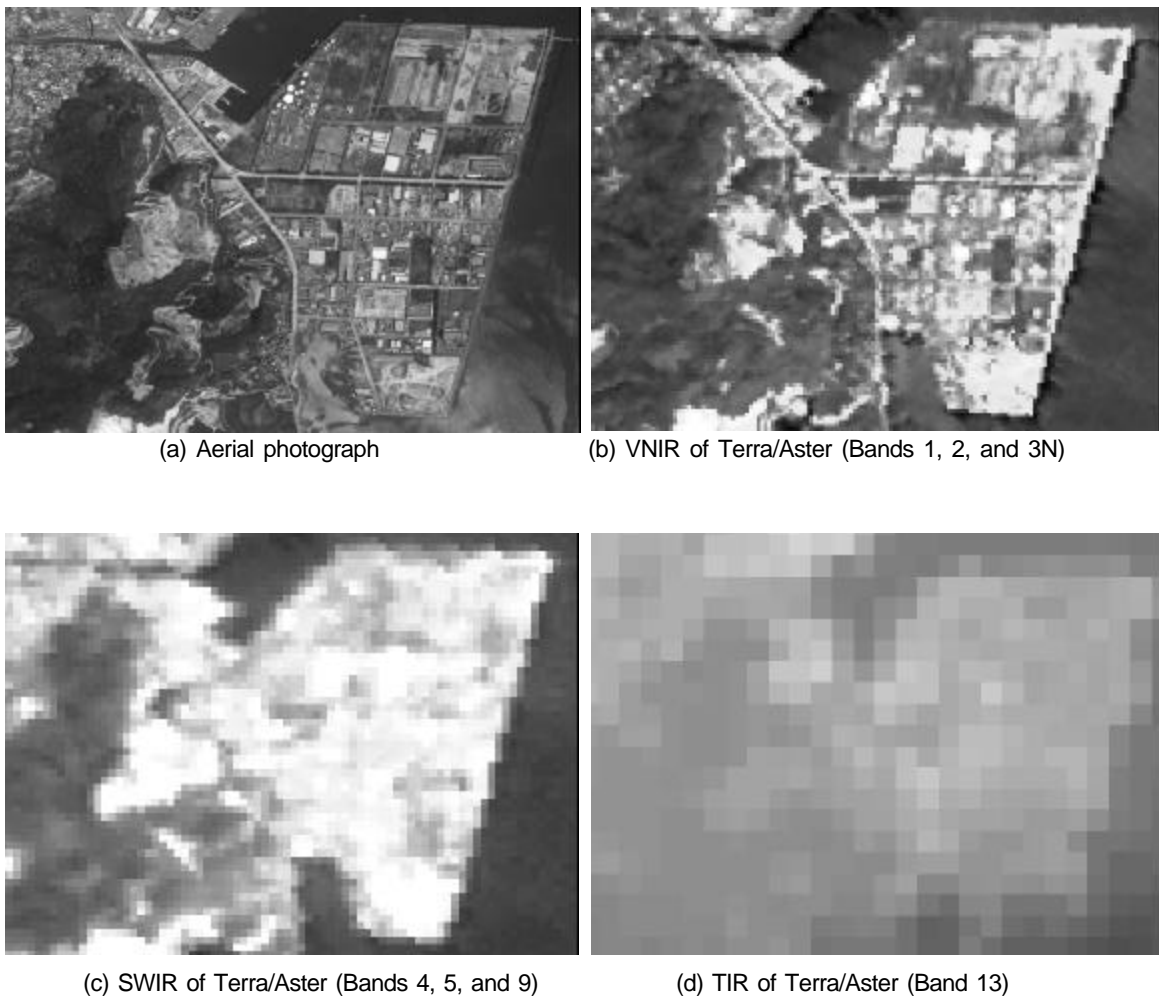


Figure 8 Various images of the study area