OVERWASHED SEDIMENT INTO THE GAMO LAGOON IN NANAKITA RIVER MOUTH AND EFFECTIVENESS OF THE OVERWASH PREVENTION CONSTRUCTION

Xuan Tinh Nguyen[1], Ryutaro Hirao[2], Hitoshi Tanaka[3]

ABSTRACT

Coastal overwash occurs primarily during severe storms. In the Japan, overwash is common during the Typhoon on a low sand dune or beach as well as on the barrier island between lagoon and sea. Overwashed sediment or washover can be transported very long inland and on barrier islands in their natural state, contributes to the maintenance of an island's sediment budget during severe storms. Overwash may damage or destroy bridges and roads or simply render roads impassable due to large depths of deposited sand. Overwash can lead to coastal breaching when the overwashing waves and currents open new inlets on barrier islands. The occurrence of storm is expected to increase because of the Global Warming Effects so the study about storm impacts is become very important for coastal management and engineers.

1. INTRODUCTION

Study area is located in the southern part of Sendai Port as shown in the Figure 1. This sandy beach is limited by Nanakita River mouth in the south and Sendai port in the north. However, this study will be focused on the sandy beach at the Gamo Lagoon as denoted by a dot-line in the Figure 1.

Overwash is often occurred during the extreme storms and it is the flow of water and sediment over the crest of the beach that does not directly return to the water body where it comes from such as ocean or lake. Washover is the sediment transported and deposited inland by overwash processes. There is a number studies on the overwash process such as Sallenger at el. (2000), and Donnelly at el. (2005). Most of them have classified the overwash processes into two main mechanisms of overwash, namely runup overwash and inundation overwash.

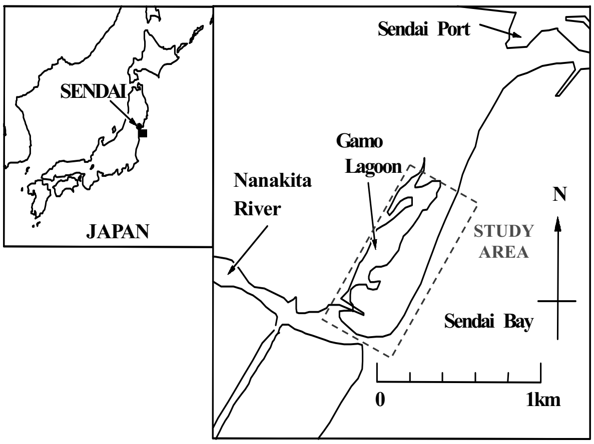

Figure 1: *Location of the study area on Japan map*

From 8th to 10th of October 2009, an extreme Typhoon number 18 was attacked to the Nanakita Beach in Japan. Figure 2 is the aerial photograph taken before one month of the typhoon and Figure 3 shows the aerial photograph was taken immediately 4 days after the typhoon. There a big amount of sediment was transported

[1] Post-doctor Fellow, Department of Civil Engineering, Tohoku University, 6-6-06 Aoba, Sendai 980-8579, Japan
[2] Undergraduate Student, Department of Civil Engineering, Tohoku University, 6-6-06 Aoba, Sendai 980-8579, Japan
[3] Professor, Department of Civil Engineering, Tohoku University, 6-6-06 Aoba, Sendai 980-8579, Japan

and deposited inland after as seen in Figures 3. The morphological change of this area suggested that the sediment was even reached to the Gamo Lagoon area. This intruded sediment may cause the smaller area of lagoon, thus it is definitely not good for the lagoon environment. This study is to evaluate the total deposited sediment by overwash processes in the Nanakita Beach and to discuss about the importance of constructions for preventing the wave overwash as well as sediment intrusion into the lagoon in this area.

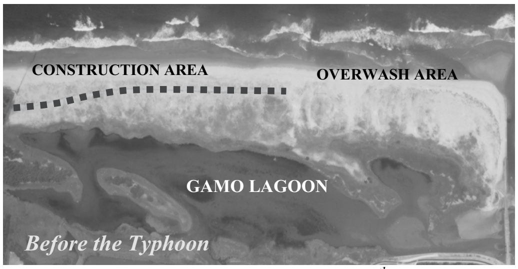

Figure 2: *Aerial photo of study area on 5th Sept. 2009*

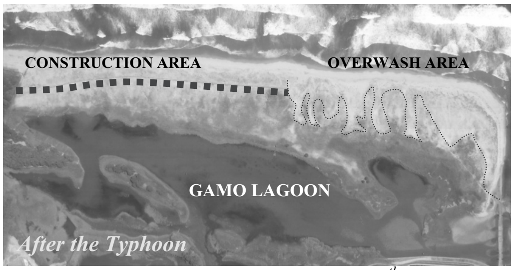

Figure 3: *Aerial photo of study area on 14th Oct. 2009*

2. DATA COLLECTION AND ANALYSIS

Cross-shore profile measurements

In order to estimate the impacts of Typhoon to the beach and calculate how much was the deposited sediment inland, the pre- and post-storm beach profiles as well as the hydrodynamics condition are appreciated. However, there were no historical data of the previous cross-shore profiles that available to use in this study area. Based on the evidence that the before surface beach layer was covered by vegetation and grass, the cross-shore profile holes were dug until reaching this grass layer and then measure the sediment thickness so that the previous beach surface was roughly known. An example of digging hole is shown in Figures 4. The average deposited sediment thickness is about 10 cm height.

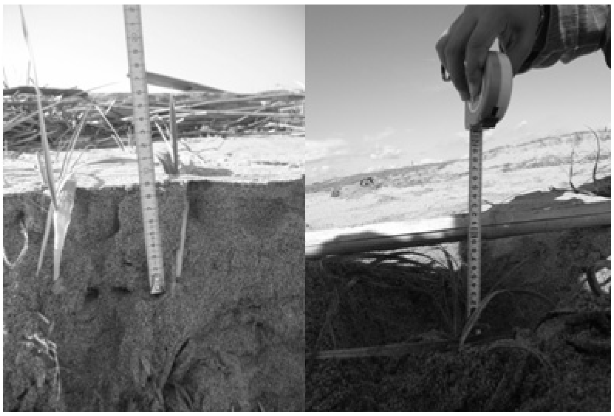

Figure 4: *Thickness of deposited sediment after the Typhoon*

The results of measured cross-shore profiles and location holes can be seen in the Figure 5. There were in total seven different locations occurring wave overwashing during the typhoon. The whole study area was divided by two area, namely construction area and overwash area as shown in Figures 2, 3.

Topographic field measurement

A field survey is also conducted to measure the topography of study area in order to get the shape of dunes and overwash fans morphology. The result is plotted and shown in Figure 6. It is clearly seen that overwash only occurred through the lower notch in between two dunes.

In the southern part near Nanakita River mouth, the elevation of topography is quite low and morphological changes suggested that this part was inundated during the typhoon.

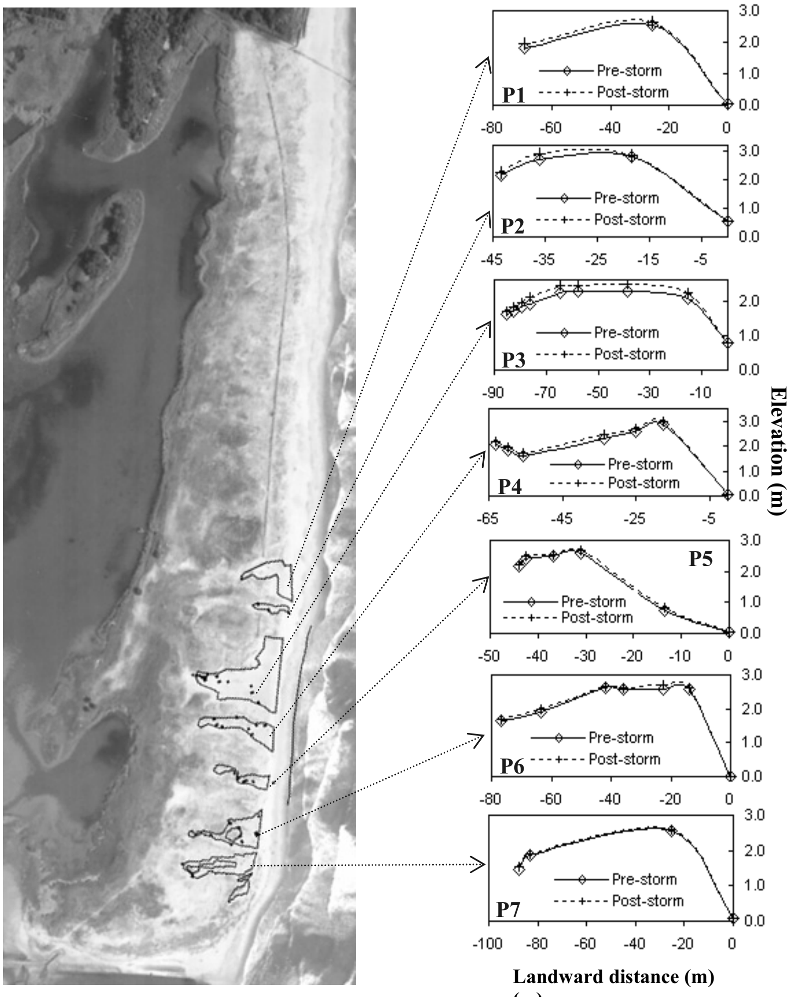

Figure 5: *Location of overwashed area and surveyed profiles*

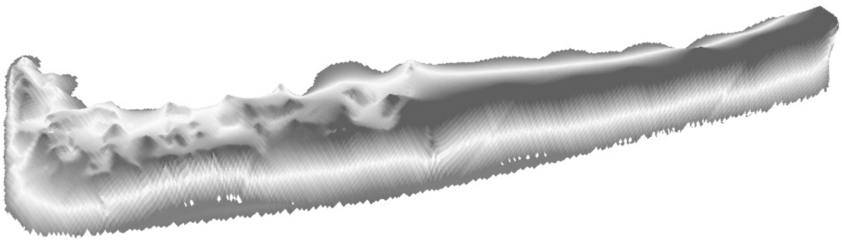

Figure 6: *Topography of the study area*

2.2 Hydrodynamics collection

The time series of hydrodynamic conditions of typhoon such as the wave height, wave period, and water level including storm surge height are of interest when estimating beach profiles response due to overwash and for developing and applying the empirical formula discussed in this study. The wave information is taken from the Sendai Port station which located in about 20m of water depth. The tidal level is obtained from the Ayukawa station. The time-series of Typhoon 18th hydrodynamic conditions are illustrated in Figure 7 and summarize of the maximum condition values are shown in the Table 1. where H_c is the dune crest height, R is wave runup height calculated by Larson Formula (2004) . The excess runup, ΔR, is difference in elevation between the wave runup heights plus storm surge height (Still Water Level) and the beach crest height. And the excess runup duration, t_D, is the time of excess runup occurrence.

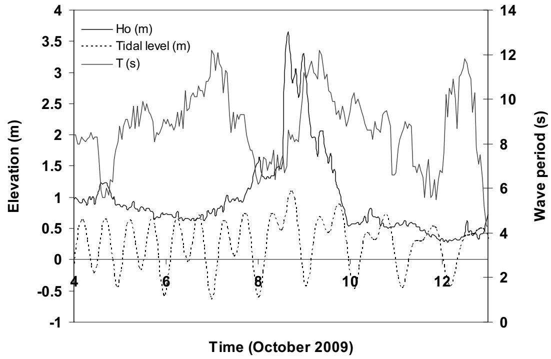

Figure 7: *Hydrodynamic condition of Typhoon No. 18*

Table 1: Summarize of maximum hydrodynamic values of the Typhoon 18 in 2006

Profile No.	*Wave height H (m)*	*Wave period T (s)*	*Beach crest height H_c (m)*	*Tidal level (m)*	*Runup height R (m)*	*Excess runup ΔR (m)*	*Excess runup duration t_D (s)*
Profile 1	3.65	8.6	2.56	1.09	3.24	0.68	126000
Profile 2	3.65	8.6	2.82	1.09	3.24	0.42	108000
Profile 3	3.65	8.6	2.07	1.09	3.24	1.17	248400
Profile 4	3.65	8.6	2.85	1.09	3.24	0.39	108000
Profile 5	3.65	8.6	2.56	1.09	3.24	0.68	122400
Profile 6	3.65	8.6	2.56	1.09	3.24	0.68	126000
Profile 7	3.65	8.6	2.54	1.09	3.24	0.7	126000

3. RESULTS AND DISCUSSIONS

3.1 Cross-shore overwashed sediment volume

Nguyen (2008) has developed an empirical formula for overwashed sediment volume by assuming this volume is proportional to the sediment transport rate multiplied by the excess runup duration (t_D).

$$Q = 0.0011 \frac{H_c}{R} \frac{t_D}{T} (R - H_c)^2 \qquad (1)$$

where Q is the cross-shore sediment transport volume (m^3/m), R is the wave runup height (m), and H_c the beach crest height (m) referenced to the still-water level, t_D is the overwash duration (s), T is the wave period (s), and an empirical coefficient, α = 0.0011, was calibrated using the field data sets from United States.

By applying the Equation 1 for seven cross-shore profiles and comparison with the measured volume, which is computed by integrating the area between two profiles, and the results are illustrated in the Figure 8. These shown that there is a well agreement between calculated and measured sediment volume. Most is felt in a factor of two.

3.2 Total of overwashed sediment volume

Using above seven measured overwashed sediment volumes and by multiplying to the overwash fan area, the total overwashed sediment volume, which deposited on the surface of Nanakita beach can be computed as approximately equal to 930 m^3. Since this typhoon is rather lower in magnitude compared to some previous events attack to this area but we still obtained significant deposited sediment inland direction. These indicated that this area was very frequently impacted by overwash and the sediment deposited further inland by overwash is a big concern issues for local coastal management and environment.

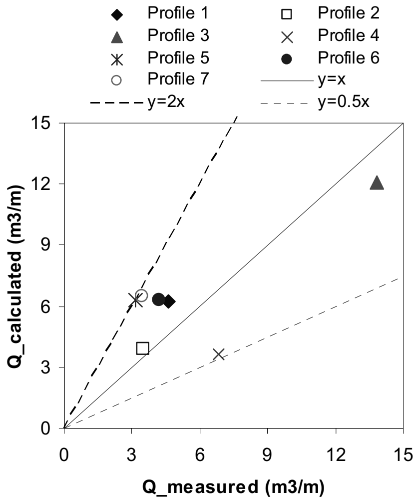

Figure 8: *Comparison with measured data*

3.3 Effectiveness of overwash prevention construction in this area

There are two different types of overwash prevention construction in this area. One is a hard-rock construction and the location can see in Figures 9 in the upper picture. Another small and separated construction is made from bamboo trees (Figure 9 in the lower picture). These bamboo constructions were built up in different directions to prevent the wind-induced sediment transportation inland.

As mentioned above, the topography of whole area was measured and Figure 10 is shown the results of long-shore elevation at the dune crest location. At the sites of construction, the elevation is designed as a constant level so that there were almost no sediment deposited on the back side of construction, even thought the structure elevation is not so high compared to the overwash area part (see Figure 10). This is because of constant level of construction and no v-notching places, which make the overwash can occur and sediment intrude to the inland direction. Therefore, the hard-construction is played in important roles to prevent wave overwash. Because of that this study recommends to further construct the hard-rock structure to the northern part and in the overwash area we might have to conduct the beach nourishment such as bring the transported and deposited sediment in the lagoon to the nearshore zone. Since the fresh sediment in overwash area is somehow important for the immigrating birds that living in the lagoon.

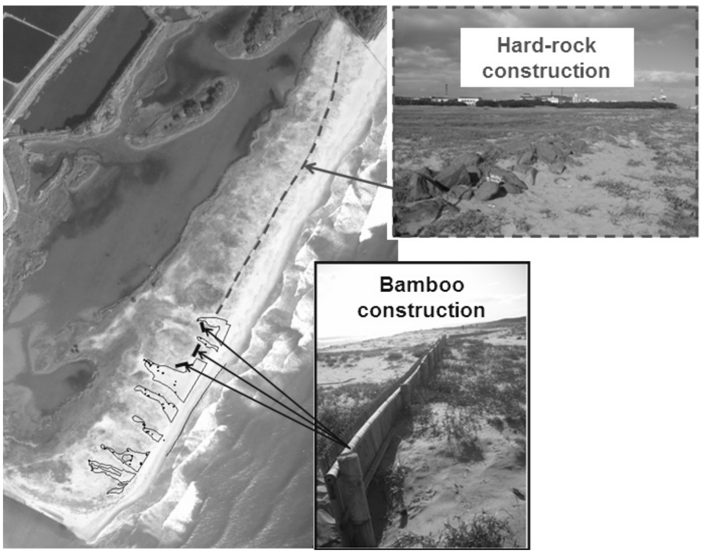

Figure 9: *Types and locations of construction in this area*

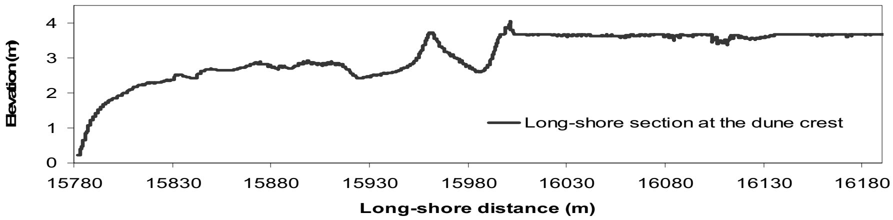

Figure 10: *Long-shore section of elevation at the dune crest location*

4. CONCLUSIONS

The cross-shore sediment volume calculated by new empirical formula is again in agreement with the measured volume and felt in a factor of two for the Nanakita data sets. This indicated that the new empirical formula is able to predict the overwashed sediment volume for any future storm events at a sandy beach.

The total overwashed sediment volume on the surface of the Nanakita Beach after the Typhoon number 18 in October 2009 was estimated about 930 m^3.

Since when the sediment reaches to the Gamo Lagoon side, the area of the lagoon will probably smaller and it is not good for the environment of lagoon. Therefore, a recommendation is to further build up a hard rock construction up to the northern part of Gamo Lagoon. In the southern part, which is closed to the Nanakita River mouth, we allowed overwash occurrence for some environmental reasons but the deposited sediment by overwash needs to move to the nearshore zone if it is necessary.

ACKNOWLEDGMENTS

This study can not be conducted without the financial support from Grant-in-Aid for Scientific Research from JSPS (No. 21-360230) and the first author is a Postdoctoral Fellow granted by JSPS (No. P09287). The authors would like gratefully appreciate their supports.

REFERENCES

Donnelly, C., N.C. Kraus and M. Larson (2006): State of knowledge on measurement and modelling of coastal overwash, Journal of Coastal Research, Vol. 22, pp. 965-991.

Larson, M., Wise, R.A., and Kraus, N.C., 2004: “Coastal Overwash. Part 2: Upgrade to SBEACH,” Regional Sediment Management Demonstration Technical Note, ERDC/RSM-TN-15, U.S. Army Engineer Research and Development Center, Vicksburg, MS

Nguyen, X.T., Donnelly C., Tanaka H., and Larson M., 2008: A new empirical formula for coastal washover sediment volume, Proceedings of 31st International Conference on Coastal Engineering, ASCE, pp.975-985.

Shallenger at el. 2000: “Storm impact scale for barrier islands,” Journal of Coastal Research Vol. 16(3), pp. 890-895.