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BACKSHORE EROSION DUE TO HIGH SWELL WAVES

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ABSTRACT: High swell has been known for the one of the main causes of beach erosion in the east coast of Korea. In this study, coastal topography changes due to high swells are simulated to find its effect on the backshore by using movable bed experiments and numerical experiments. Sea bottom topographical changes due to various incident waves were investigated using CSHORE model in the numerical experiments. Furthermore, the mechanism and the phenomena of beach erosion due to waves and high swells on the foreshore and backshore were analyzed and compared with movable bed hydraulic experiments.

Keywords: Beach erosion, long period high waves, C-SHORE

INTRODUCTION

Sandy Beach, which is located on the seashore, is an important tour resource for beach resorts and a valuable asset that maintains the natural environment and prevents natural disasters caused by high waves. But this important natural resource continues to disappear due to natural erosion and sedimentation (Kim and Yoo, 2003). In last few decades, Korea has gone through substantial developments in economical, social and cultural aspects. Along with these developments, living area has been expanded and tourist attraction has been damaged because of the sea level rise and the increased frequency of high-wave invasion due to the global warming. Particularly, significant beach deformation is resulted when high swell waves directly attack the seashore. It is because more energy is diffused onto the seashore and the level of wave rush is increased. In the case of South Korea East Sea, the frequency of high swell waves has been increasing annually that it requires an in-depth analysis in the beach deformation in order to solve various problems caused by coastal erosion. This study remodeled beach deformation caused by high swell waves and applied hydraulic model tests to examine its impact on the coast. Furthermore, this study made a comparative study with the results of the hydraulic model tests that was examined through C-SHORE model. Lastly, the characteristics of the erosion due to usual waves and the high swell waves on both foreshore and backshore were studied.

THE HYDRAULIC MODEL TEST

Test equipment

Hydraulic model test is equipped with 2-dimensional tidal wave water tank which simulates. The water tank, the length of 30m, the width of 1.0m, and the depth of 1.5m (Fig. 1), is composed of tempered glasses at the both sides for the best observation of the experiment. The wave-making machine employs pistons to make waves and works effectively when an experimenter puts then tentative spectrum value on recoil waves and component waves.

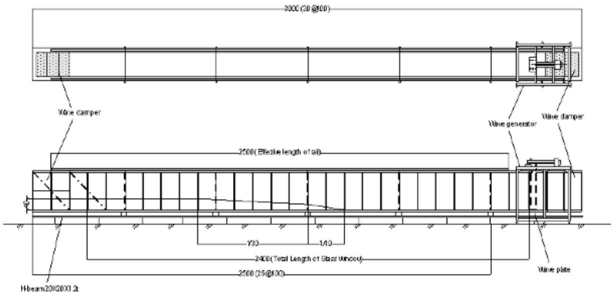

Fig. 1 2-Dimensional Wave Flume

The wave-making machine is not only able to absorb reflected waves but also minimizes the occurrence of reflected waves with its breaking materials and absorbing filters.

Condition and Structure of the Experiment

The 2-Dimentional hydraulic model test reconstructed an area in scale of 1:50 scale. The area is one of the most eroded beach profiles in G-Coast in East Sea where the erosion is active. The wave calculation in this experiment analyzes the result of 2006 wave calculation categorizing waves into the normal, erosive and a long-term high swell waves.

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The geographical features are described in 1:20 scale and it uses standard scale of average of 0.012mm particle. The experiments employ tidal waves for 0.5 hours, 1 hour, 2hours, 5hours, and 10hours. Then, this test compared the initial topography with the changes in the cross-section by using an ultrasonic equipment which calculates steep slope in the given time intervals

Table 1. Laboratory Experimental Conditions

Cases	$H_{1/3}$(m)	$T_{1/3}$(sec)	L(m)	$H_{1/3}/L$	Slpoe	C	Fo
Case01	0.02	0.84	1.101	0.018	0.05	17.098	1.190
Case02	0.02	1.13	1.992	0.010	0.05	14.058	0.884
Case03	0.04	0.84	1.101	0.036	0.05	34.196	2.380
Case04	0.04	0.13	1.992	0.020	0.05	28.117	1.769
Case05	0.06	0.84	1.101	0.055	0.05	51.294	3.571
Case06	0.06	0.13	1.992	0.030	0.05	42.175	2.654
Case07	0.06	1.41	3.101	0.019	0.05	35.442	2.127
Case08	0.08	1.13	1.992	0.040	0.05	56.234	33.539
Case09	0.08	1.41	3.101	0.026	0.05	48.590	2.836
Case10	0.10	1.41	3.101	0.032	0.05	60.737	3.546
Case11	0.10	1.69	4.456	0.022	0.05	53.893	2.958

Experimental wave used Dean's equation (1) and Horikawa & Sunamura's equation (2) on its eleven experiment proposals, and analyzed the tendency of erosion and sedimentation on its wave-prone respective area.

$$F_o = H_o/(V_f \cdot T) \quad (1)$$

$$C = H_o/L_o(\tan\beta)^{0.27} \cdot (d_{50}/L_o)^{-0.67} \quad (2)$$

In Equation (1), Fo signifies a Dean number, Ho signifies a deep-sea wave, T signifies a wave period. In this equation, sedimentation occurs, if Fo <1 whereas erosion occurs if Fo >1 (Shore Protection Manual, 1984). In Equation (2), C is the non-dimensional coefficient that determines erosion and/or sedimentation; Ho is a deep-sea wave, Lo is a deep-sea wavelength; tanβ is a beach slope; d is a sand median diameter. In the equation, sedimentation occurs if C <9 whereas Erosion occurs if C>18. If 9 ≤C ≤8, erosion and sedimentation occur in a periodic interval.(Sunamura and Horikawa, 1975).

Experiment result

As demonstrated in Fig. 2 and Fig. 4, erosion and/or sedimentation level on the coast results inconsistently due to the incident waves with different waves height intervals.

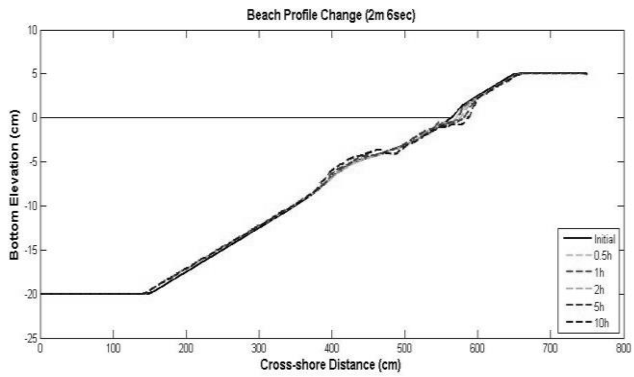

Fig. 2 Measured topography change of natural beach ($H_{1/3}$=2m, $T_{1/3}$=6sec, slope 1/20)

It is anticipated that even a common wave with $H_{1/3}$ = 2m and $T_{1/3}$= 6sec (Case 03) hits a seashore, the result could be detrimental and influential. In Fig. 2, the erosion on near shoreline and its sand creates a coastal sand bar.

A wave with $H_{1/3}$ = 3m and $T_{1/3}$= 10sec (Case 07) is an erosive wave that frequently hits seashore. It creates a relatively large coastal sand bar, especially on foreshore. The characteristic of the wave is height with relatively long wave period so that high energy level is transmitted to the coastal area resulting sand beach elimination and as time passes, the eroded area expands affecting both foreshore and near-shore eventually. As a result, a large amount of sedimentation occurs both on the foreshore and the near-shore which leads to a large scale of long-shore bar

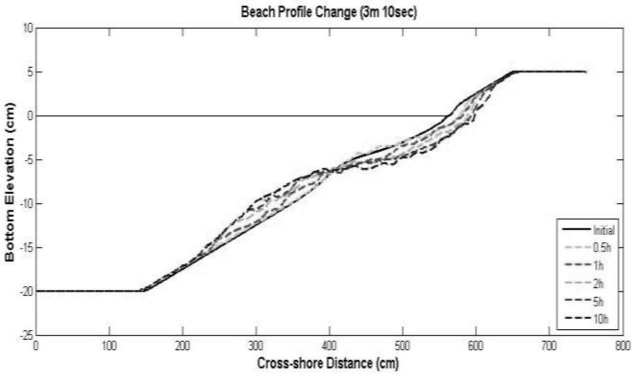

Fig. 3 Measured topography change of natural beach ($H_{1/3}$=3m, $T_{1/3}$=10sec, slope 1/20)

A wave with $H_{1/3}$ = 5m and $T_{1/3}$= 12sec (Case 11) has been verified that such run-up phenomenon caused by high swell waves affects the berm on the rear surface of backshore. In fact, pine forests exist around object sea area, the G-shore's berm, and it has been examined that high swell waves damages such pine forests.

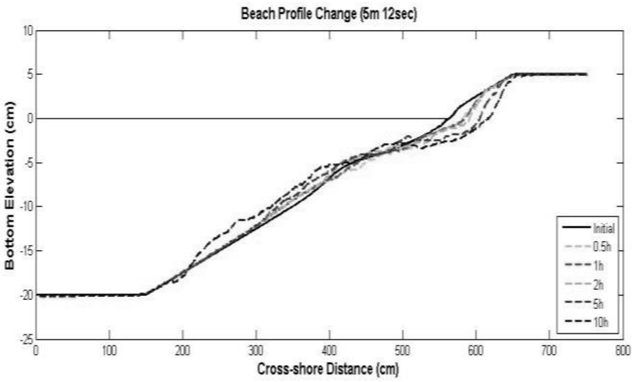

Fig. 4 Measured topography change of natural beach ($H_{1/3}$=5m, $T_{1/3}$=12sec, slope 1/20)

Through the hydraulic model test, it is confirmed that erosion occurs on the backshore berm and analogous erosion occurs in actual topography. Also the erosion may be exacerbated in time and the terminal range of the high swell waves may increase as well.

THE NUMERICAL MODEL TEST

Numerical Model

Although the SBEACH and CSCHORE model is representative in reconstructing the 2-dimensional, cross-sectional, coastal change, this study uses CSHORE model in order to be accurate in describing particular characteristics of each geographical features. (Cheon and Ahn, 2008), (Linh et al., 2009). CSHORE is composed of a wave-current model that is based on time-averaged continuity, cross shore, long shore momentum, wave action equation, a permeable model that demonstrates the porous flow and the energy loss, and the probability model about the wet and dry zone in the permeable and impermeable water. (Kobayashi et al., 2007).

As Fig. 5 demonstrates, the probability model on the wave's run-up phenomenon deal with the change of the coastal line. The change of coastal line is determined by the run-up line that is parallel to the channel height Z_b. The run-up interval estimates the instant height (η_r) that is created above the intersection of the run-up wire and the free surface elevation. The variance of η_r and the standard deviation σ_η can be calculated by using longitudinal variances of $\bar{\eta}(x)$ and $\sigma_\eta(x)$.

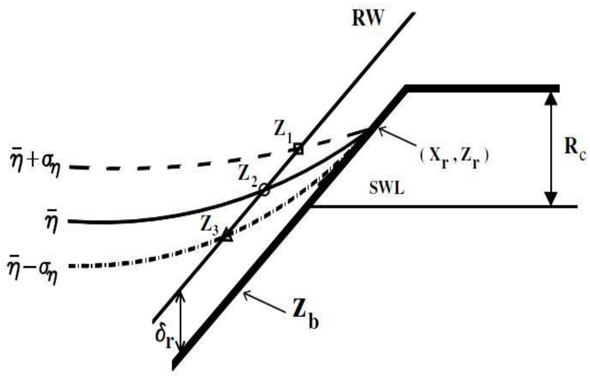

Fig 5. Definition Skech of Probabilistic Model for Irregular Wave Run-up

(DOCUMENTATION OF CROSS-SHORE NUMERI-CAL MODEL CSHORE 2009)

The probability of η_r that is in excess of, $(\bar{\eta}+\sigma_\eta)$, $(\bar{\eta})$ and $(\bar{\eta}-\sigma_\eta)$ is the same as the probability of η that is in excess of $(\bar{\eta}+\sigma_\eta)$, $(\bar{\eta})$ and $(\bar{\eta}-\sigma_\eta)$. The elevation of z_1, z_2 and z_3 which is the intersection of the $(\bar{\eta}+\sigma_\eta)$, $(\bar{\eta})$ and $(\bar{\eta}-\sigma_\eta)$can be calculated by the run-up$(z_b+\delta_r)$ line. The height estimated matched accordingly as below. The variance and the standard deviation $z_1 = (\bar{\eta}_r + \sigma_r)$, $z_2 = (\bar{\eta}_r)$ and $z_3 = (\bar{\eta}_r - \sigma_r)$, η_r is written in Equation 10 below.

$$\bar{\eta}_r = \frac{(z_1+z_2+z_3)}{3}\ ;\ \sigma_r = \frac{z_1-z_2}{2} \tag{3}$$

To explain the transmission from the wet zone (Pw= 1) to the wet and dry zone (Pw <1) in CSHORE model, $\bar{r}$, σ_η could be substituted through $(P_w\bar{h}+Z_b)$ and $P_w\sigma_\eta$ that is caused by the change of $Z_1+Z_2+Z_3$

Run-up height (R) is defined as Crest Height that is caused by the change of $\boldsymbol{\eta_r}$. Generally, the probability spread of the linear wave crest can be calculated by the spread of Rayleigh.

Although the calculation of the interrelationship between the filtration flow into the shore is necessary in order to describe the flow phenomenon in detail, this model did not include such calculation. (Kim, etc, 1997).

Experiment result

The numerical model test applies similar wave condition as the hydraulic model test and calculates the change on the cross section in each time interval. As Figures 6, 7 and 8 demonstrates, the results on of $H_{1/3}$ = 2m, $T_{1/3}$= 6sec, $H_{1/3}$ = 3m, $T_{1/3}$= 10sec and $H_{1/3}$ = 5m, $T_{1/3}$= 12sec are shown in figures below.

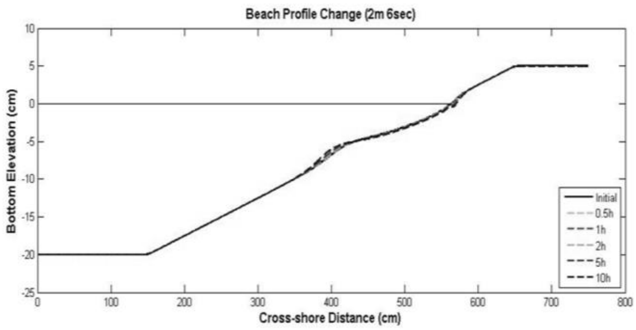

Fig. 6 Computed beach profile ($H_{1/3}$=2m, $T_{1/3}$=6sec)

As Fig demonstrates, a wave with $H_{1/3}$ = 2m and $T_{1/3}$= 6sec creates slight erosion near the surface of the sea level. Although the experiment creates long term waves, no significant change in coastal area is detected for erosion and/or sedimentation. Therefore, it is concluded the hitting of a wave with $H_{1/3}$ = 2m and $T_{1/3}$= 6sec on the coast makes no significant effect on the coastline.

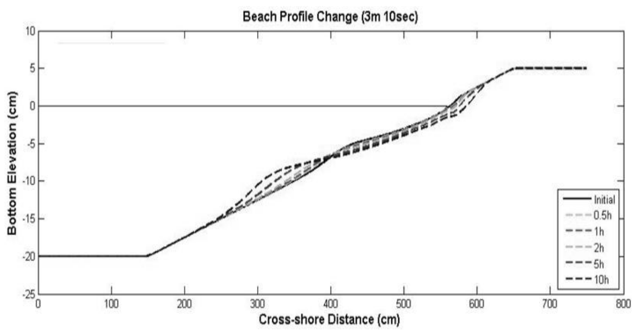

Fig. 7 Computed beach profile ($H_{1/3}$=3m, $T_{1/3}$=10sec)

In the case of wave with $H_{1/3}$ = 3m and $T_{1/3}$ = 10sec, a large portion of the topography is eroded because of a high-level run-up phenomenon. The land above the sea is especially vulnerable to erosion as the wave continuously hits the land. After 10 hours of waves making, a large amount of sand formed at a steep cross section. The wave affects a large scope of area; therefore, it creates significant erosion.

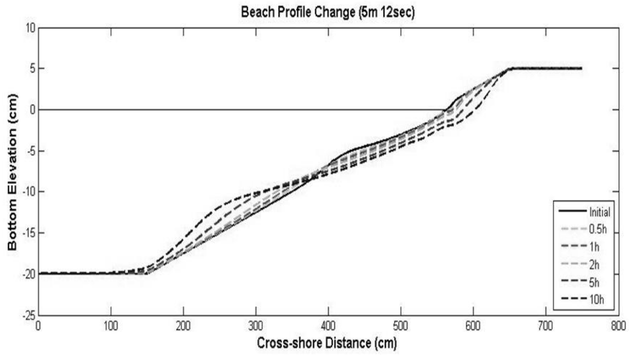

Fig. 8 Computed beach profile ($H_{1/3}$=5m, $T_{1/3}$=12sec)

The wave with $H_{1/3}$ = 2m, $T_{1/3}$ = 12 sec affects both the foreshore and backshore because of its high run-up phenomenon whose height is over 3m. As the period of wave-hitting increase, erosion becomes intensified resulting damages on the backshore berm. As the frequency of wave-hitting increases the coastal line significantly retreats. Therefore, it is confirmed that the hitting of high swell waves increases the height of the run-up phenomenon and expedites erosion.

THE ANALYSIS OF THE NUMERICAL AND HYDRAULIC MODEL TEST RESULTS

As analyzed above, the result from the numerical and hydraulic model test are similar in its tendency in erosion and sedimentation. Fig 9, 10 and 11 compared the changes in geographical features in 10-hours term after the waves hitting on the coastline. As Figures 9, 10 and 11 demonstrate, in all wave conditions, numerical model test shows more gradual topographical changes than the hydraulic model test.

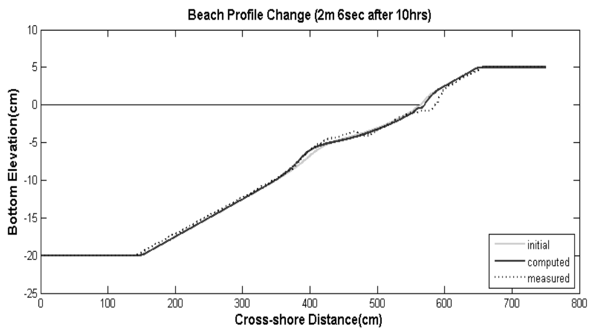

Fig. 9 Comparison between computed and measured data($H_{1/3}$=2m, $T_{1/3}$=6sec)

However, the numerical model test was not adequate in finding an acute result as in erosion and sedimentation that was accessible through the hydraulic model test.

In case of $H_{1/3}$ = 2m, $T_{1/3}$ = 10 sec, although the value from the hydraulic model test was bigger than the numerical model test, we can conclude that the tendency was mostly the same

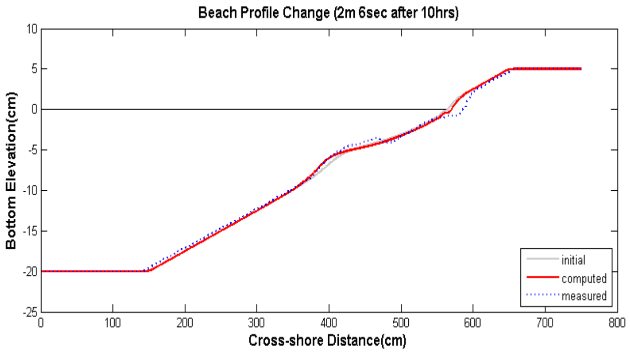

Fig. 10 Comparison between computed and measured data($H_{1/3}$=3m, $T_{1/3}$=10sec)

In case of $H_{1/3}$ = 3m, $T_{1/3}$ = 10 sec, although the value from the hydraulic model test was bigger than the numerical model test, we can conclude that the tendency was mostly the same.

As the Fig 11 demonstrates, the wave $H_{1/3}$ = 5m, $T_{1/3}$ = 12 sec reached into the coast line and the backshore due to its high level run-up phenomenon. Therefore, it created a large amount of loss of sand and a serious erosion. This result has been similarly confirmed by both the numerical and hydraulic model test.

The numerical and hydraulic model test results derived from the value ten hours after the wave hit the coastline demonstrated that there was a subtle difference between the coastal line and the outside of the shore, although the severity of erosion was similar

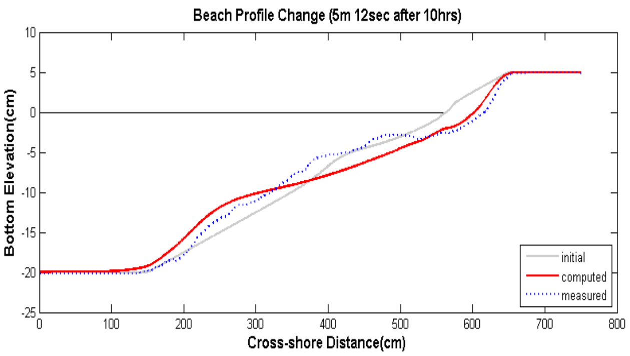

Fig. 11 Comparison between computed and measured data($H_{1/3}$=5m, $T_{1/3}$=12sec)

CONCLUSION

There have been a significant number of reports and researches about the foreshore erosion as it is such a significant phenomenon when a high swell wave hits the coastline. However, it was difficult to observe the erosive phenomenon that affects the backshore, and as a result, there were not much preceding researches on this topic. This research examined such mechanisms by using the numerical and hydraulic model tests to further examine the high swell waves that frequently attack East Sea of Korea. In its experiment, various types of waves were made, and the change in the geographical features, a.k.a. the steepness of the shore, the loss of the foreshore, and the distance of wave due to the run-up phenomenon found out to be the same based on two tests, the numeric and hydraulic model test. Particularly, the change in the foreshore and the backshore erosion were similar in nature, and it confirmed that both tests were great mechanisms to check the change of the geographical changes. After analyzing the erosion mechanism through numerical and hydraulic model tests, the wave' s hitting time and the change of the height of the run-up have a significant relationship with the backshore erosion. Because the frequency of the high swell wave' s hitting is predicted to be continuously increasing, further research on the solution to decrease the energy from the high swell wave should be forthcoming.

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