II－30 EXPERIMENTAL STUDY ON FORMATION OF RIVER MOUTH BAR DUE TO WAVES

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1. INTRODUCTION

Sand bars at river mouth influence extremely to flow features in the river and obstruct navigation and flood discharge. Under the combinative effect of waves, tide movement, long-shore and cross-shore current, and river flow, the river mouth morphology is changed frequently. Sediment is transported and deposited at the river mouth, forming sand bars at this area. The evolution of sand bar at river mouth relates closely to typical seasonal river discharge between winter and summer. In the summer, most of sand bars are flushed out of the mouth because of high river discharge and tidal current, and in the winter, slow river flow is a good factor for wave-induced current carrying and accumulating sediment into the river mouths. The formation process of sand bar depends on a lot of hydrodynamic factors from above actions that relate to the height, width of bars as well as their position. This study shows the formation of river mouth bars under the action of waves, water depth at river mouth.

2. EXPERIMENTAL CONDITION

A series of experiments were carried out in a two-dimensional wave flume, as shown in **Fig.**1. The length of the flume is 11.3m with 50cm height and 30 cm width. The flume was equipped a monochromatic wave generator, a filter was installed in front of the wave generator and wave absorbing works at the other end of the flume to filter out reflection wave. A model of river mouth was set in the flume with a uniform, smooth impermeable slope of 1/10 by sand with the grain size of 0.26mm. A level surface of sand was set at the height of 30 cm, 220cm long. A profiler was used to measure changes of bed surface, and a wave gauge was installed at the toe of slope to measure wave parameters before acting the slope. Seven cases of the experiment have been carried out with the difference of water depths in the mouth, from 0.5cm to 5cm, as shown in **Table** 1. In which, h_R is the water depth at the mouth, H_0 is the height of deep water wave, T is the wave period.

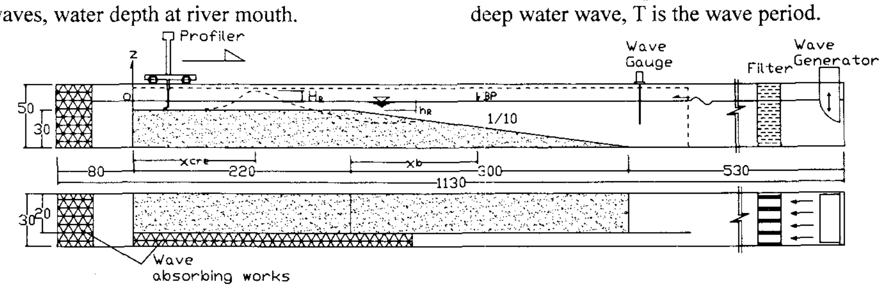

Fig.1 Experimental equipment

Table 1 Experimental conditions

Cases	h_R (cm)	H_0(cm)	T(s)
01	0.5	5.76	1.44
02	1.0	6.04	1.44
03	1.5	5.58	1.44
04	2.0	5.40	1.44
05	3.0	5.55	1.44
06	4.0	4.84	1.45
07	5.0	4.85	1.44

3. RESULTS AND DISCUSSION

3.1. Sand bar formation

The sand bar formation process of the Case 01 is shown in **Fig.**2. Under the action of waves, sediment at the bottom was agitated and transported into the river mouth and deposited there, and formed the bar. The changes of the bottom surface causes of the wave breaking point variation. The combinative actions of breaking wave and the wave-induced current have carried sediment into river mouth. The variation of wave breaking point relates directly to the position of sand bar. **Fig.**3 shows the relationship between the position of wave breaking point, bar crest and the water depth at river mouth, where, x_b and x_{cre} are the distances from the breaking point to the mouth and from the bar crest to the end of flume respectively, as the definition in **Fig.**1. The movement trend of bar crest was proportion to the one of breaking point, and moved into the river mouth when the water depth there increases.

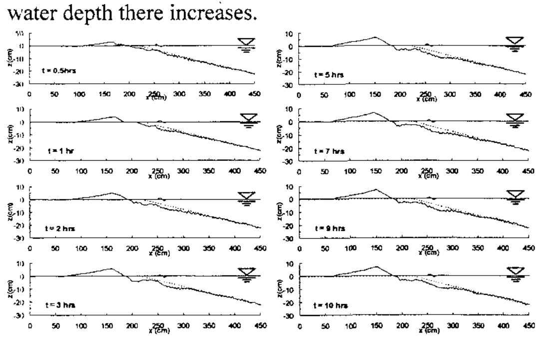

Fig.2 Time variation of the sand bar profile under wave action in the Case 01, h_R = 5mm

Fig.4 describes the changes of sand bar equilibrium due to the variation of water depth in the mouth. There were two types of sand bars formed in the experiment, one is emersed bar and the other is immersed bar. The increase of water depth at the mouth caused of the equilibrium bar change from emersed bars with fully developed to immersed bars. When fully developed states were attained, waves slid up and down the bar with little

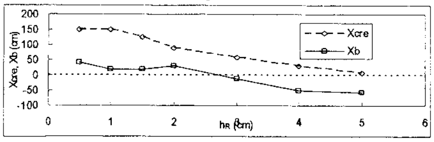

Fig.3 Changes of wave breaking point and equilibrium bar crest position

3.2. Height of sand bar

In case of small water depth in the river mouth, the sand bar was formed and emersed soon with fully developed height. The height of fully developed sand bar relates directly to the wave run-up processes. Wave run-up processes are responsible for the position and the height of the bar, that also relate closely to breaking waves as well as deep water wave characteristics. Okazaki and Sunamura (1994) predicted the height for collapsing and surging related berms on the uniform beach slope. Wada et al. (1998) proposed the relationship between the height of sand bar and deep water wave steepness as follows:

$$\frac{H_{R(F)}}{H_0} = 0.48\left(\frac{H_0}{L_0}\right)^{-13/20}\left(\frac{d}{H_0}\right)^{1/4}\phi \quad (1)$$

In which, $H_{R(F)}$ is fully developed height of sand bar, H_0 and L_0 are the height and length of deep water wave, d is grain size of sediment, ϕ is reduction factor due to the roughness and permeability of the slope.

$$\phi = exp(-0.04\, D_*^{0.55}) \quad (2)$$

$$D_* = \left[\frac{g}{\nu^2}\left(\frac{\rho_s}{\rho} - 1\right)\right]^{1/3} d \quad (3)$$

Where, g is the acceleration of gravity, ρ and ρ_s are the density of water and sediment respectively, ν is the kinematics viscosity of water. The fully developed bar height created in laboratory experiment was predicted via dimensionless bar height parameter, as shown in **Fig.**5.

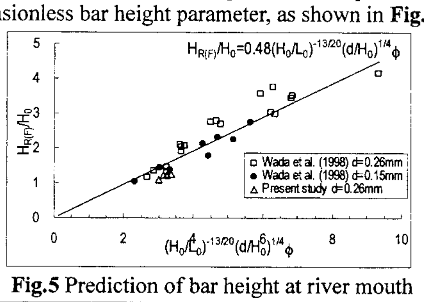

Fig.5 Prediction of bar height at river mouth

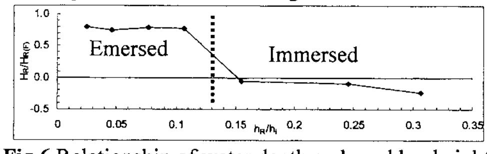

Fig.6 Relationship of water depth and sand bar height

The formation of the bar in laboratory experiment was classified into two types; emerged and immerged bars. bubble production, without marked step formed. The sediment at the bottom moved slightly with the motion of water. The deeper water level at the mouth created immersed bar there. Sediment was transported further into the mouth and accumulated on a large area.

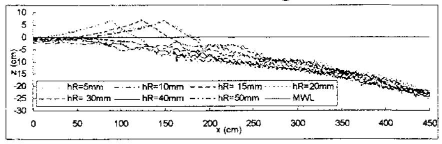

Fig.4 Relationship of equilibrium bar crests and water depths

The influence of water depth at the river mouth on the height of sand bar is shown in **Fig.**6. This effect leaded to the difference of emerged and immersed bars. The water depth at the mouth changes together with the critical water depth for inception of surface layer movement. In **Fig.**6, H_R is the sand bar height, h_R the water depth at the mouth, h_i the critical water depth for inception of surface layer movement that can be obtained from equation (4).

$$\left(\frac{H}{H_0}\right)^{-1}\sinh\left(\frac{2\pi h_i}{L}\right) = \alpha\frac{H_0}{L_0}\left(\frac{L_0}{d}\right)^n \quad (4)$$

In which, $\alpha = 1.77$, $n = 1/3$, and L, H are the wave length and height at the position of critical water depth for the inception of surface layer movement, Sato and Tanaka (1962). The decrease of water depth at the mouth as well as the increase of the critical water depth for inception of surface layer movement created the evolution of sand bar strongly to the emersed bar. On the contrary, the increase of water depth at the mouth or the decrease of the critical water depth for inception of surface layer movement leaded to the formation of sand bar at river mouth being immersed, and reduced the height of sand bars. As the result in **Fig.**6, the demarcation between emersion and immersion of sand bar formation was proposed at the point of $h_R/h_i = 0.13$.

4. CONCLUSIONS

This study showed that the depth of water in river mouth impacts directly to the formation of san bar, besides wave parameters and sediment diameter. Sand bars change from emersed to immersed bars and their crests trend into the mouth when water depth at the mouth increase. The demarcation between immersed and emersed bar is proposed $h_R/h_i = 0.13$.

ACKNOWLEDGEMENT

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