INVESTIGATION OF DEPTH OF CLOSURE INFLUENCED BY COASTAL STRUCTURE

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1. INTRODUCTION

Study on depth of closure (h_c) theory is widely investigated by many researchers. Their approach is appropriate to understand how to determine h_c location, and also its necessity on field application. Its concept was firstly introduced by Hallermeier (1981). He defined the boundary between shoal zone and littoral zone as h_c.

Due to the fact that longshore variation of h_c exists, the study of h_c determination becomes more interesting. One example was brought by Francois et al (2004). The study utilized midterm bathymetry data and proposed longshore variation of h_c. Furthermore, its result was confirmed analytically.

In relation with influence of structure to wave reflection it was concluded in Rhitpring and Tanaka (2006) that position and angle of breakwater are important factor that influence wave reflection. However, there is lack of the study which explains relation between influence of wave reflection and variation of h_c.

Study area in this study is Yuriage Port. It is located in the southern part of Sendai Coast, downstream of Nattori River as seen in Fig.1. In this area, jetties were constructed in 1970's. Approximately 700m breakwater was installed after that. Bathymetry data were obtained from field measurement conducted by government during 1983 to 1997. However considering its accuracy only data during 1994 to 1997 is used in this study. Wave data from 1991 to 2003 is applied. Its direction is predominant on South East (SE) direction.

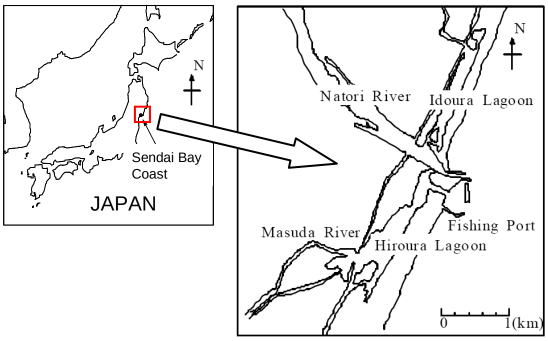

Figure 1. Study area, Yuriage Port

This study purpose is to analyze reflection factor due to coastal structure and its influence to longshore variation of h_c. For that purpose, relation of longshore variation of h_c to bottom shear stress will also be discussed. Furthermore, Shields parameter will be analyzed as correlation with sediment transport process.

2. METHODOLOGY

2.1. Hydrodynamic model

Hydrodynamics condition in Yuriage Port is simulated using Boussinesq model by Peregrine (1967). This model is used considering its ability to observe non-linear phenomenon and also influence of reflection factor for wave condition.

Governing equation are statements of conservation mass and momentum as seen in Eq. 1 and 2. Furthermore surface elevation, bottom velocity outside boundary layer in x and y direction is obtained.

$$\frac{\partial \eta}{\partial t} + \nabla[(h+\eta)\mathbf{u}]\cdot = 0 \qquad (1)$$

$$\frac{\partial u}{\partial t} + (\mathbf{u}\cdot\nabla)\mathbf{u} + g\nabla\eta = \frac{1}{3}h^2\nabla(\nabla\cdot\frac{\partial \mathbf{u}}{\partial t}) \qquad (2)$$

Where **u** is horizontal velocity at an arbitrary depth *(u,v)*, η is surface elevation, h is local water depth, ∇ is horizontal gradient operator $(\partial/\partial x, \partial/\partial y)$, g is gravity coeffcient.

2.2. *Bottom shear stress and Shields parameter approach*

Considering its definition in correlation with sediment movement, bottom shear stress (τ_{0max}) parameter becomes important factor that can be observed. Using maximum orbital velocity (u_{bmax}) that was obtained from wave modeling, τ_{0max} can be calculated using following expression:

$$\tau_{0\max} = \frac{\rho}{2} f_{cw} u_{b\max}{}^2 \qquad (3)$$

Where ρ is water density, f_{cw} is wave-current friction coefficient derived by Tanaka and Thu (1994), u_{bmax} is the maximum wave–induced velocity just outside boundary layer obtained from wave modeling.

Furthermore dimensionless Shields parameter (τ_0*) is calculated using expression as follows:

$$\tau_0{}^* = \frac{\tau_{0\max}}{(\rho_s - \rho)g d_{50}} \qquad (4)$$

Where ρ_s is sediment density, d_{50} is mean particle diameter (=0.026cm).

3. RESULTS AND DISCUSSION

To propose longshore variation of h_c, bathymetry data series are used. By overlaying these data and taking several cross sections, h_c location and its value is predicted. Standard deviation (σ) becomes one of the parameter that also needs to be considered. For Yuriage Port, σ is 0.1. Longshore variation of h_c is shown in Fig. 2.

From Fig. 2, by comparing with previous study conducted by Nomura (1986) and Uda (1997), the longshore variation of h_c is deeper. Interesting phenomenon occurred in the area near the structure. In that region, h_c is deeper, and it is getting shallower as the distance increase. This phenomenon occurs due to influence of breakwater to the wave condition. The influence of wave reflection is higher in the area near structure than the area far from structure.

Keywords: bed shear stress, coastal structure, depth of closure, Shields parameter
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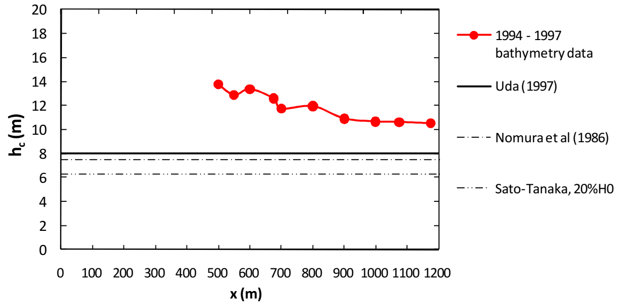

Figure 2. Longshore variation of h_c, Yuriage Port

Representative wave height, 20% wave height in deep area (H_0), H=1.15m and corresponding wave period, T=7.55sec are utilized to observe hydrodynamics condition in Yuriage Port. Wave condition is assumed as regular wave. Simulation is carried out using dx=dy=5m and dt=0.1sec.

Spatial variation of u_{bmax} can be seen in Fig. 3. The higher velocity can be observed in the shallow area. This is due to the natural shoaling and refraction. Similar phenomenon can also be observed in the area near the structure. Due to the reflection phenomenon occurred in that location, wave height is higher and velocity is higher too. Longshore variation of h_c is overlaid on the velocity distribution. Using h_c location, it is confirmed that h_c location is laid on u_{bmax}=0.4m/sec.

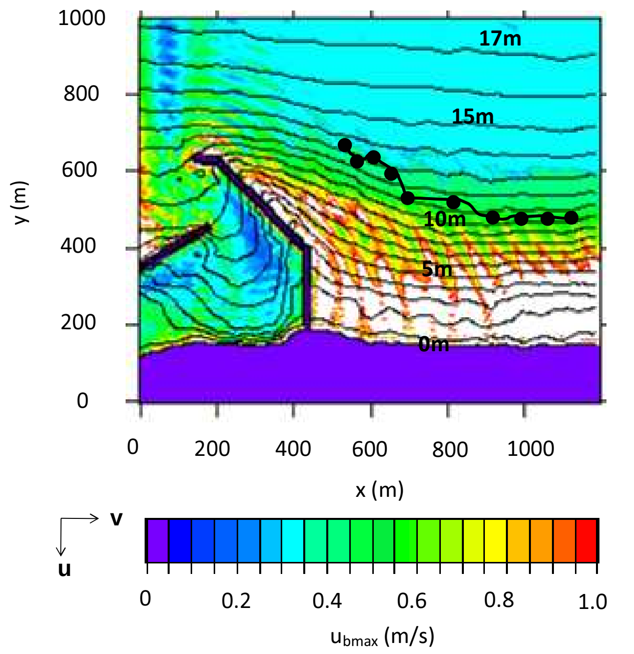

Figure 3. Maximum orbital velocity, Yuriage Port

τ_{0max} under wave-current combined motion is calculated using u_{bmax} that was obtained from the previous result. Furthermore τ_0* is obtained as shown in Fig. 4.

By overlying longshore variation of h_c and the confirmed h_c location, it can be observed that h_c is laid on value τ_0* =0.14. As seen in Fig. 4 in the area near structure, as consequent higher velocity, it produces higher τ_{0max} . In relation of τ_{0max} to τ_0* , higher τ_0* is obtained.

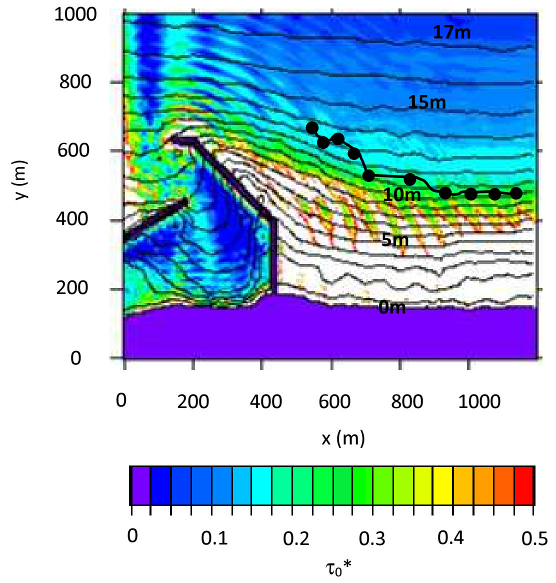

Figure 4. Shields parameter, Yuriage Port

4. CONCLUSION

By observing longshore variation of h_c, it is concluded that h_c in the area near structure is deeper than area far from structure. u_{bmax} is obtained using wave modeling. By overlaying h_c location to u_{bmax} spatial variation, it is obtained that h_c is overlaid on u_{bmax}=0.4m/sec. Furthermore, dimensionless Shields parameter is calculated. By overlaying this result with longshore variation of h_c, it is obtained that h_c is laid on τ_0*=0.14.

ACKNOWLEDGEMENT

The authors gratefully acknowledge to Grant-in-Aid for Scientific Research from JSPS (No. 21-360230) and in particular to Dr. Kanayama, from Penta-Ocean Institute of Technology, Coastal and Ocean Engineering Group for his support and assistance.

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