Proceedings of the Sixth International Conference on Asian and Pacific Coasts (APAC 2011)

December 14 – 16, 2011, Hong Kong, China

COMPUTER SIMULATION OF YEONG-IL MAN NEW HARBOR FOR SEICHE REDUCTION

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The seiche motion due to long waves at Young-il man new harbor in Korea have occurred frequently which produced undesirable wave and ship oscillation in the harbor, especially during the season with waves coming from the east-northeast direction. This paper presents results of a computer simulation study for exploring seiche reduction measure at Yeong-il man new harbor. Several resonant modes are clearly seen from simulation results that resonant periods are 35s~45s and 6min~14min. This study make set up a target resonant periods for seiche reduction measure which is 35s~45s. These periods have a bad effect on small sized ship motion at Young-il man new harbor. It is seen that the seiche reduction measure is effective when the quay wall replace to the energy dissipating structure.

1. Introduction

Yeong-il Man new harbor, where is located in the Yeong-il bay in the southeast of Korea, is one of the largest commercial harbors in Korea. The pier structure and the loading and unloading facilities are capable of handling 24 ships concurrently which handle 23 million tons yearly (Figure 1).

Due to its location and the coastline orientation, Yeong-il bay has been found to provide fairly good protection against typhoons coming from the south. However, resonant motion due to long period waves have occurred frequently which produced undesirable wave and ship oscillation in the harbor, especially during the season with waves coming from the northeast direction.

This paper presents results of a computer model study for analysis of harbor resonance motion and exploring the effectiveness of resonance reduction measure.

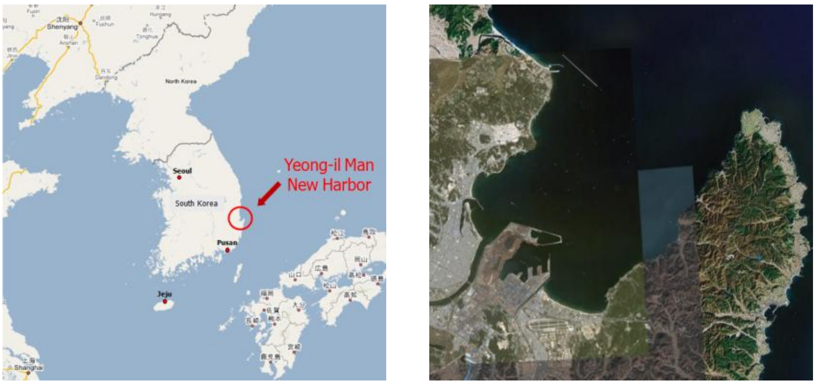


Figure 1. Location map and the air photo of Yeong-il man new harbor.

2. Numerical Model

MIKE21 EMS model applied to the Yeong-il man new harbor for this study. The computer model is able to consider the effect of refraction, diffraction and energy dissipation at partial reflecting boundaries. This model use ADI method to obtaining finite difference solution (Madsen and Larsen, 1987).

The Elliptic Mild-Slope Wave Module of MIKE21 solves the mild-slope wave equation expressed in two horizontal dimensions (MIKE BY DHI, 2009).

$$\nabla(C \cdot C_g \nabla \varsigma) - \frac{C}{C_g} \cdot \frac{\partial^2 \varsigma}{\partial t^2} = 0 \tag{1}$$

Where, C is the phase celerity, C_g is the group velocity, ς is the surface elevation above datum and ∇ is the horizontal gradient operator.

By introducing the pseudo fluxes P^* and Q^*, this equation can be rewritten as a system of first order partial differential equations, which are similar to the mass and momentum equations governing nearly horizontal flow in shallow water.

$$\begin{gathered} \frac{\partial P^*}{\partial t} + CC_g \frac{\partial \xi}{\partial x} = 0 \\ \frac{\partial Q^*}{\partial t} + CC_g \frac{\partial \xi}{\partial y} = 0 \\ \frac{C_g}{C} \frac{\partial \xi}{\partial t} + \frac{\partial P^*}{\partial x} + \frac{\partial Q^*}{\partial y} = 0 \end{gathered} \tag{2}$$

The harmonic time variation can be extracted from the equations by using as follows.

$$
\begin{aligned}
\xi &= S(x,y,t)e^{i\omega t} \\
P^* &= P(x,y,t)e^{i\omega t} \\
Q^* &= Q(x,y,t)e^{i\omega t}
\end{aligned}
\tag{3}
$$

Now the remaining time variation in S , P and Q is a slow variation, which is due to the solution procedure i.e. iteration towards a steady state). This leads to the following set of equations, which have been generalized to include internal wave generation, absorbing sponge layers, partial reflection and transmission from breakwaters and other structure, bed friction and wave breaking.

$$
\begin{aligned}
\lambda_1 \frac{\partial S}{\partial t} + \lambda_2 S + \frac{\partial P}{\partial x} + \frac{\partial Q}{\partial y} &= SS \\
\lambda_1 \frac{\partial P}{\partial t} + \lambda_3 P + C_g^2 \frac{\partial S}{\partial x} &= 0 \\
\lambda_1 \frac{\partial Q}{\partial t} + \lambda_3 Q + C_g^2 \frac{\partial S}{\partial y} &= 0
\end{aligned}
\tag{4}
$$

where

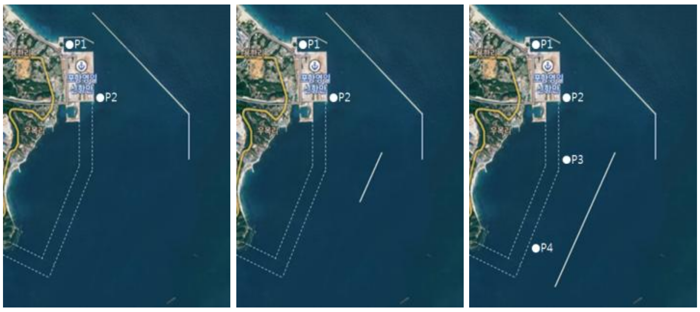
$$
\begin{aligned}
\lambda_1 &= \frac{C_g}{C} \\
\lambda_2 &= \frac{C_g}{C} \cdot i\omega + f_s \\
\lambda_3 &= \frac{C_g}{C} \cdot \omega(i + f_p) + f_s + e_f + e_b
\end{aligned}
\tag{5}
$$

The symbols P, Q, S are complex function of x , y and t , ς is surface elevation above datum, SS is source magnitude per unit horizontal area, f_p is linear friction factor due to energy loss in porous media, f_s is linear friction factor due to energy loss in sponge layers.

3. Computer Simulation of Seiche motion

3.1 Conditions of Computer Simulation

Computer simulation carried out according to the harbor layout change which are the present stage (north breakwater constructed 4130 m), first stage (add construct south breakwater 1300 m) and final stage (extension of south breakwater 2100 m) in Figure 2. The interesting areas for study on harbor resonance selected in four points that are P1 in fishery harbor, P2 in container terminal, P3 and P4 in future expansion area. The computational wave periods picked out from 30 sec to 5 minute in infra gravity waves which have effected on the moored ship motion and from 5 minute to 100 minute in long waves. Incident wave directions are NE and ENE that shown a lot of appearance ratio around harbor area. The grid points of finite differential model are contained 540(east) and 680(north) meshes, that the grid spacing is 20 m. The time interval is 0.1 sec in infra gravity waves and 1.0 sec in long waves.

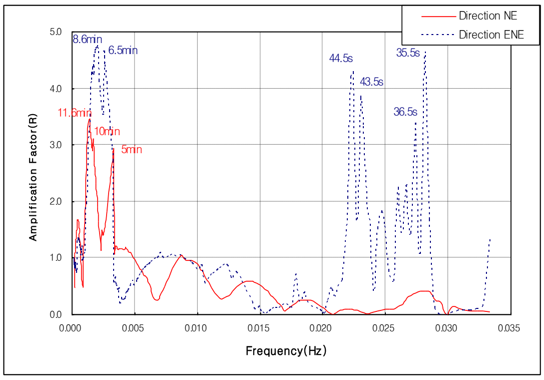


(a) present stage (b) first stage (c) final stage

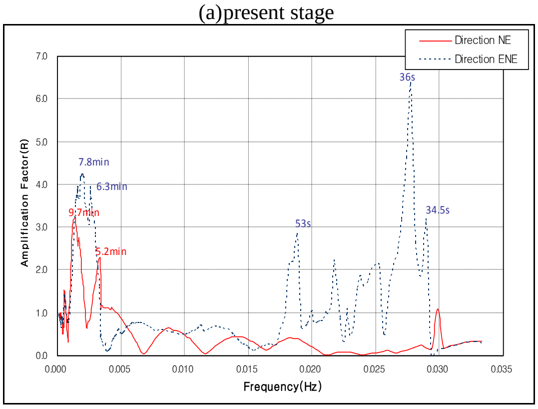
Figure 2. Harbor layout for computer simulation.

3.2 Results of Computer Simulation

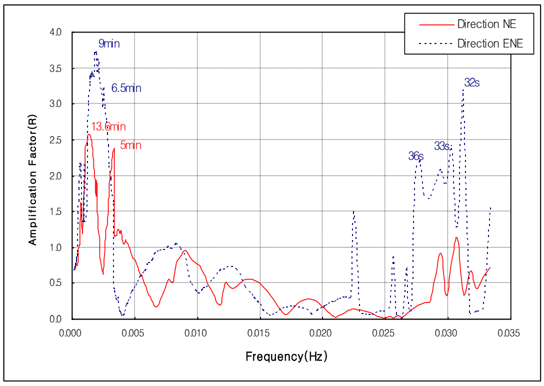
On investigation it was found that the large seiche motion occurred at P1 in fishery harbor. But, the seiche motion didn't occur at P2, P3 and P4 where are located in opened area. The amplification factor response curves with wave frequency at P1 show in Figure 3. It covers the wave periods from 100 minutes to 30 sec. The ordinate is the amplification factor defined as the wave height at point P1 divided by the incident wave height. The abscissa is the wave frequency with unit Hz. Several resonant modes clearly seen from simulation result of the present stage layout which the resonant periods are 35 sec ~ 45 sec and 5 minute ~ 12 minute in Figure 3(a). At this time, the amplification factors have shown 4.7 at 35.5 sec and 4.8 at 8.6 minute. The result of first stage layout shows several resonant modes which the resonant periods are 34 sec ~ 53 sec and 5.2 minute ~ 9.7 minute, and the amplification factor shows 6.35 at 36 sec and 4.2 at 7.8 minute in Figure 3(b). Also, the results of final stage layout shows several resonant modes which the resonant periods are 32 sec ~ 36 sec and 5 minute ~ 14 minute, and the amplification factor shows 3.2 at 32 sec and 3.7 at 9 minute in Figure 3(c). The amplification factor showed a very high when the wave direction is ENE than NE direction.



(a)present stage



(b) first stage



(c) final stage

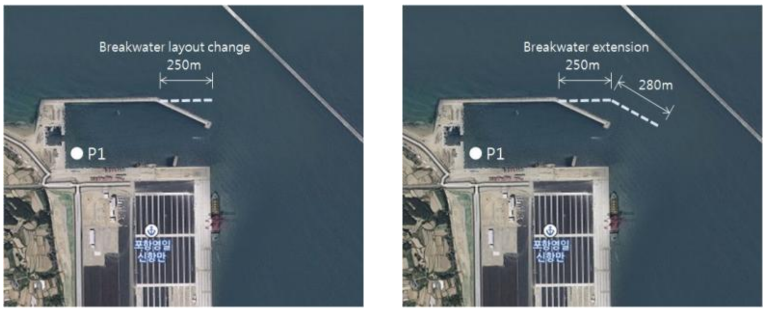
Figure 3. Results of response curve at P1 with harbor layout change**.**

4. Seiche Reduction Measure

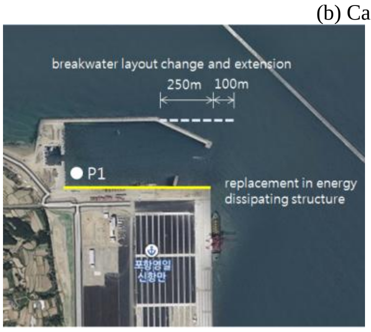
It is found that the position P1 in fishery harbor shows the large seiche motion when infra gravity waves and long waves come from ENE direction. This study investigates a seiche reduction measure when infra gravity waves less than wave period 1 minute propagated to harbor, because mostly the small sized ships are berthing in this harbor.

We have investigated a several measures including harbor layout change and extension. Case 1 of the reduction measures set up the breakwater layout change in 250 m, Case 2 is the breakwater layout change in 250 m and extension 280 m, and Case 3 is the breakwater layout change in 250 m and extension 100 m as well as replacement of the quay wall into an energy dissipating structure (Figure 4). The most effective measure, that are breakwater layout change in 250 m and extension 100 m as well as replacement of the quay wall into an energy dissipating structure.

Figure 5 is shown the comparison of response curve between before and after seiche reduction measure. Figure 5(a) is shown the Case 1 that the response curves of before and after reduction measure almost same because the breakwater layout is little changed. Figure 5(b) is shown the Case 2 that the amplification factor of after reduction measure reduced on resonant period 43.5 sec and 44.5 sec because of the breakwater extension effect.

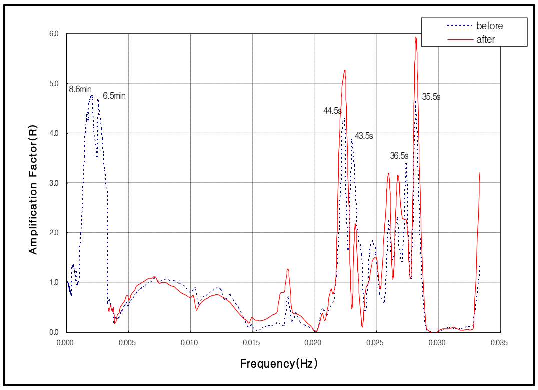


(a) Case 1 (b) Case 2

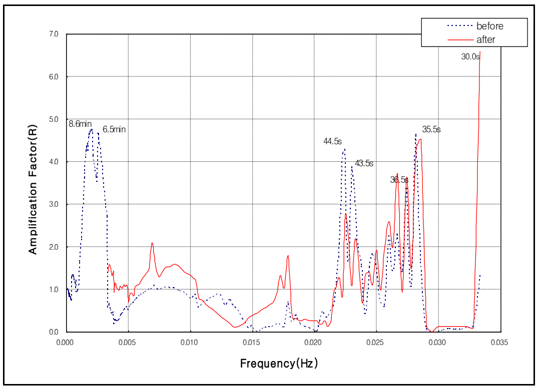


(c) Case 3

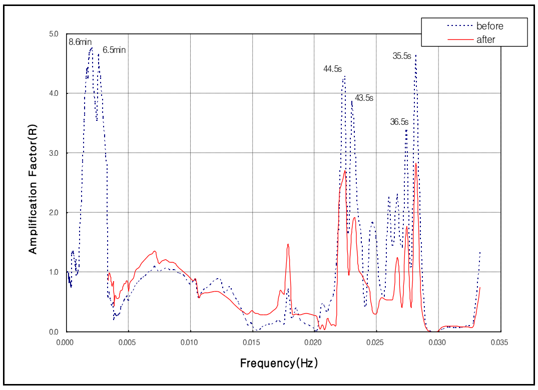
Figure 4. Harbor layout changes for seiche reduction



(a) Case 1



(b) Case 2



(c) Case 3

Figure 5. Comparison of response curve between before and after seiche reduction measure.

Figure 5(c) is shown the Case 3 that is the most effective reduction measure. In Case 3, the amplification factor 4.7 reduced into 2.84 on wave period 35.5 sec, and the amplification factor 3.9 reduced into 1.7 on wave period 43.5 sec because of effect that the quay wall replaced of energy dissipating structure.

5. Conclusion

The fishery harbor where is located in Yeong-il man new harbor have shown the large seiche motion when an infra gravity waves and long waves come from east-northeast direction. The seiche motion did not changed in case of breakwater layout change only. But, it is found that the seiche reduction measure is very effective in case of replacement of the quay wall into an energy dissipating structure. If the reflectivity of energy dissipating structure keep in 70 % then the amplitude factor is able to reduce in 40 % when an infra gravity waves with wave period 35 sec ~ 45 sec are incident to small harbor.

Acknowledgements

This research was supported by Basic Research in Science and Engineering Program (No. 2010-0023136) through the National Research Foundation (NRF) funded by the Ministry of Education, Science and Technology of Korea. This support is greatly appreciated.

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