Possibility of Seiche of Pohang New Port due to Edge Waves under Ever Present Amplitude Modulating Swell of Narrow Band Width

Nagoya University, Student Member, YongHwan Cho
University of Seoul, Korea, YongJun Cho
Nagoya University, JSCE Member, Tomoaki Nakamura
Nagoya University, JSCE Member, Norimi Mizutani

1. Introduction

Pohang New Port suffers from inherent seiche problems and the development of remedial measures is the urgent task for Korean economy. Recently, as a first step to solve these problems, Korean Ministry of Land, Transportation and Maritime (MLTM) has carried out field surveys of relatively long period (August 23, 2008 ~ August 28, 2009). In the field survey, they concluded from spectral analysis of waves and meteorological data that locally-generated wind waves of 10 s caused most of the downtime. However, these conclusions presumably left huge rooms to argue, because any obvious signal components over higher frequency band was not found and energy densities of the component which MLTM claimed as major driving force of seiche were too low. In this study, we first assume that Pohang seiche has been induced by edge waves generated under amplitude modulating swells of narrow bandwidth and proceed to verify possibilities of this assumption using numerical simulation based on the non-linear shallow water (NSW).

2. Numerical simulation

As a wave model, NSW was adopted to explain the nonlinear interaction of incoming swells and edge waves. The computational domain is discretized by uniformly-spaced 740 x 555 nodal points with 54 m. An open boundary was placed far offshore, i.e., 20 km off Janggi-cape, to minimize effects of scattered waves coming from the inside of computational domain. The water depth was uniformly distributed from 1 m at Pohang Old Port to 228 m offshore and waves are internally generated from the line source separated from the open boundary by 1134 m. The water depth along the line source was distributed around 193 m. The numerical simulation was implemented for 16 different random waves equally spaced from 300 s to 600 s with the each spectrum of which was narrowly banded.

3. Numerical results and discussions

We present contour plots of instantaneous water surface elevation (Fig. 1) and vector plots of velocity for T_p= 480 s (Fig. 2) for which the harbor response is the most energetic. Three anti-nodes and corresponding nodal lines formed in the Young-Il bay are detected based on the contour plots of water surface elevation (Figs. 1, and 2). The anti-nodes 1 and 2 have typical characteristics of standing waves easily found on the seashore cliff in nature. On the other hand, the

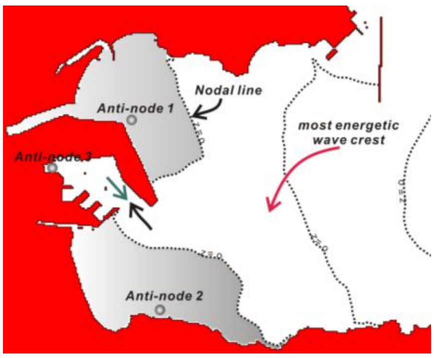

Fig. 1 The location of anti-nodes and nodal line of partial standing waves

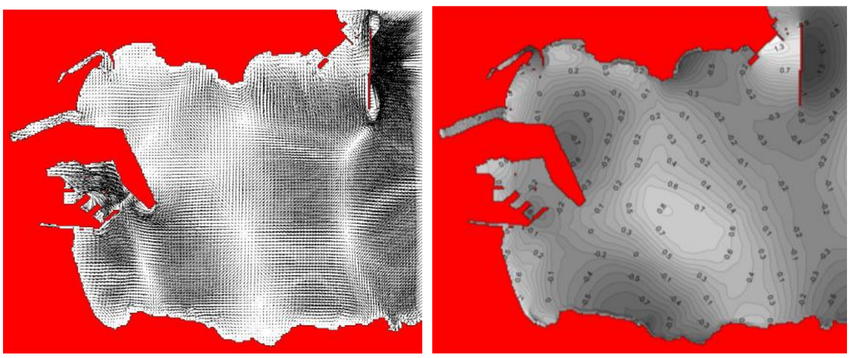

Fig. 2 Vector plot of velocity field and contour plot of water surface elevation when wave front is formed near the entrance of Pohang New Port for T_p=480 s

anti-node 3 is moving back and forth due to multiple reflected waves coming from the quay walls in the rear side, but it is shown that the anti-node 3 has general features of standing waves. Even though the anti-nodes 1, 2 and 3 belong to independent wave system partially blocking by the outer breaker of Pohang New Port, it seems that the anti-node 1, 2 and 3 are on phase, and they reach their crests and troughs almost simultaneously. In the case where water levels are retreating to trough from their crests, standing waves formed in the south-eastern area below Pohang New Port are moving toward the mouth of Pohang New Port. At this moment, other standing waves in the inner area of Pohang New Port are also moving toward the entrance. After that, these two different standing waves encounter each other near the mouth of Pohang New Port, and finally a new wave front begins to appear near the entrance of Pohang New Port. With the new wave front formed in this way, the seiche in the open basin mode in Pohang New Port is near completion. It turns out that the wave front near the entrance prevents the radiation of the wave energy trapped in the inner area of Pohang New Port to Young-Il bay, and, in the end, the sea state of Pohang New Port becomes more energetic.

It is considered that the edge waves are not observed apparently from classical First Fourier Transform (FFT) methods having limitation to harmonic analysis. In this rationale, observed time series of water elevation are decomposed to three Intrinsic Mode Functions (IMFs) at T_p= 480 s making marine condition of Pohang New Port more energetic based on an Empirical Mode Decomposition (EMD) method (Fig. 3). The 1st IMF means a normal wave condition formed by approaching narrow-banded waves with T_p= 480 s in the Young-Il bay. On the other hand, in the 2nd and 3rd IMF, long wave components were observed, especially extreme long waves exist in the 3rd IMF.

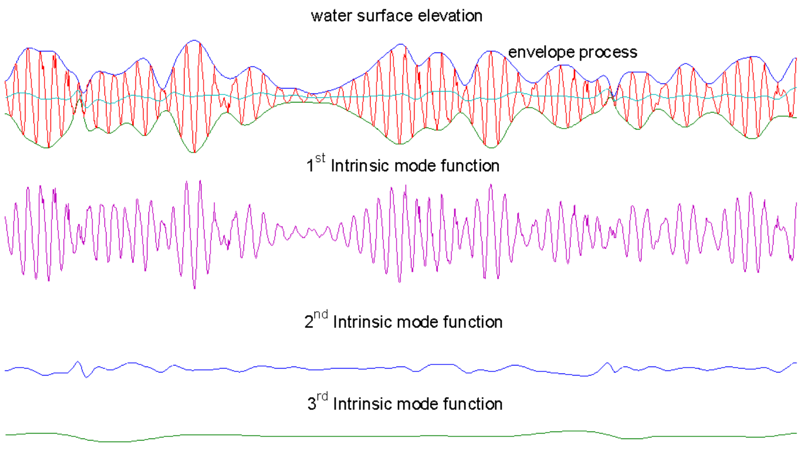

Fig. 3 Intrinsic Mode Function for T_p=480s

4. Conclusion

In this study, it is found from numerical results that T_p= 480 s is the primary resonance period of Pohang New Port as in previous studies. In addition, it is also shown that the sea state of Pohang New Port can become very forceful once exposed to waves with T_p= 440-520 s. It seems that this seiche of Pohang New Port is induced by relatively long waves formed in Young-Il bay through sub-harmonic resonance. It is concluded that these relatively long waves causing the seiche are edge waves formed under narrow-banded swell approaching from the far offshore as Mei (1989) points out. However, these highly non-linear edge waves are extremely difficult to detect using classical FFT methods. To overcome the limitation of spectral analysis mentioned above, EMD method for nonlinear phenomenon proposed by Huang et al. (1998) to decompose edge waves, and partially succeed in detecting the edge waves. However, further research is required to decompose clearly long wave components for verifying edge waves. Detail of the results will be presented in the conference.

[Reference]

Mei, C. C., 1989. The applied dynamics of ocean surface waves, World Scientific.

Huang, N. E., Shen, Z., Long, S. R., Wu, M. C., Shin, H. H., Zheng, Q., Yen, N. C., Tung, C. C. and Liu, H. H.,1998. The empirical mode decomposition and the Hibert spectrum for nonlinear and non-stationary time series analysis. Proc. R. Soc. Lond. A, 454: 903-995