RECOVERY OF SURFACE WAVES FROM BOTTOM PRESSURE BY NEURAL NETWORK WITH BISPECTRUM

Hiyori Yoshino, The University of Tokyo, yoshino-hiyori-867@g.ecc.u-tokyo.ac.jp
Noriaki Hashimoto, Coastal Development Institute of Technology, hashimoto_n@cdit.or.jp
Yoshihiko Ide, Kyushu University, ide@civil.kyushu-u.ac.jp
Koji Kawaguchi, Port and Airport Research Institute, kawaguchi@p.mpat.go.jp
Masao Mitsui, Sonic Corporation, masao-mitsui@u-sonic.co.jp

INTRODUCTION

The Nationwide Ocean Wave Information Network for Ports and Harbors (NOWPHAS) conducted by the Port and Harbor Bureau of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) in Japan, uses a Doppler Wave Meter (DWM) as a standard equipment for wave observation. Depending on the situation, the system supplements the missing data by estimating surface waves based on water pressure data as appropriate.

Meanwhile, in the case of cargo handling in harbors, the significant wave height is generally used as a criterion. It has been reported that even under conditions where wave heights are considered calm, there are many cases where large ship motions occur, causing problems with cargo handling operations. Since large ship motions occur when the long-period wave component is close to characteristic period of the vibration system consisting of the hull and mooring cables, it is necessary to examine the frequency domain based on spectra instead of the significant wave height.

Therefore, in this study, the frequency-domain analysis was used as the basis for the estimation of surface waves from bottom pressure waves. The transfer function that relates the two wave quantities is estimated to convert the pressure wave to a water surface wave. The purpose of this study is to develop a method for estimating surface waves that can be used not only during storms, but also for examining the marginal loading wave conditions for long period waves at all times.

METHOD

The transfer function from pressure waves to surface waves in linear theory is expressed by Equation (1).

$$S_\eta(f) = |H(f)|^2 S_p(f) \qquad \text{............(1)}$$
$$H(f) = \rho g \cosh kz / \cosh kd$$

Here $S_\eta(f)$ and $S_p(f)$ is power spectrum of water surface waves and pressure waves respectively, f is frequency, $H(f)$ is transfer function, ρ is water density, g is gravitational acceleration, k is wave number, z is arbitrary water depth and d is water depth which observatory equipment is located.

On the other hand, the transfer function estimated from observations is affected by not only nonlinearity but also multi-directionality as pointed out by Hashimoto et al. (1993) and does not necessarily match the transfer function estimated by linear theory. In addition to this, the coexistence of incident and reflected long-period waves in coastal region makes it difficult to develop an accurate estimation method that incorporates all these factors by a theoretical approach based on progressive wave theory.

Therefore, neural networks were employed as a transfer function estimation method. In the estimation process, bicoherence of pressure data was taken as the input value to the neural network. This is a squared normalized version of bispectrum and represents the extent of phase coupling among pressure components which were influenced by nonlinearity and multi-directionality of coastal waves. Then the transfer function between surface waves and pressure waves estimated with observation data was taken as output value. To be precise, the transfer function normalized by the one estimated by linear theory was used as output value, to accurately estimate nonlinearity and multi-directionality effects.

RESULT AND CONCLUSION

An example of the transfer function estimated by the neural network and a comparison of the applied results with the observed values at Port Hitachinaka (d=30m) are shown in Figure 1. As can be seen from Figure 1, the results show good accuracy at the spectral level of the surface waves. It should be noted that highly accurate estimation was possible even for the long-period wave component shown in red dots. Similar result was shown in the application for Port Nakagusuku (d=50m). We expect that proposed method will be useful in port cargo handling management as well as estimating surface wave spectrum.

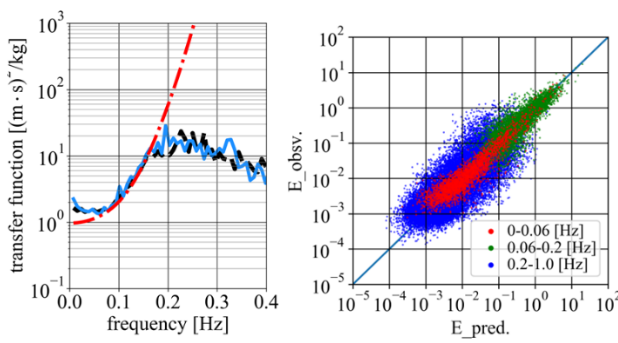

Figure 1 - (left) Comparison of transfer function. (Blue line is result by neural network and black line is observed one. Red line is from linear wave theory.) (right) Comparison of the value of water surface spectrum each frequency, observed ones (vertical axis) versus converted ones (horizontal axis) from hydraulic spectrum using estimated transfer function (2000/9, Port Hitachinaka)

REFERENCES

Hashimoto, N., T. Nagai, T. Asai and K. Sugawara (1993): Surface Wave Recovery from Subsurface Pressure Record on the Basis of Weakly Nonlinear Directional Wave Theory, Report of the Port and Harbour Research Institute, vol. 32, no. 1, pp. 27-51.