Expected Overtopping Probability Considering Real Tide Occurrence

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Abstract

A new calculation method of expected overtopping probability of rubble mound breakwater considering real tide occurrence has been proposed. A calculation method of expected overtopping probability of rubble mound breakwater was proposed by Kweon and Suh (2003). In their calculation, the fluctuation of tidal elevation was expressed by the sinusoidal change that yields the uniform distribution of occurrence frequency.

However, the realistic distribution of tidal elevation should influence on the overtopping chance. In this study, the occurrence frequency of tidal elevation obtained from the real sea is included. The tidal elevation used in this study is collected from the east coastal part of Korean peninsular. Analyzing the annual data of the tidal fluctuation measured hourly during 355 days, the distribution of occurrence frequency is formulated utilizing by the normal distribution with one peak.

Among the calculation procedures of annual maximum wave height, wave height-period joint distribution, wave run-up height and occurrence frequency of tide, only the annual maximum wave height is again chosen randomly from normal distribution to consider the uncertainty. The others are treated by utilizing the distribution function or relationship itself.

It is found that the inclusion of the variability of tidal elevation has great influence on the computation of the expected overtopping probability of rubble mound breakwater. The bigger standard deviation of occurrence frequency is, the lower the overtopping probability of rubble mound breakwater is.

KEY WORDS: overtopping probability, reliability analysis, real sea, occurrence frequency of tidal elevation, annual maximum wave height, wave height-period joint distribution, wave run-up height

1. INTRODUCTION

The reliability design method has been developed for breakwater designs since the mid-1980s. Now the reliability analysis has been an essential technique for the performance design of coastal structures. Because of the variety of social demands on the sea environment, a lot of informations for performance design have to be offered.

In Europe, van deer Meer (1988) proposed a probability approach for the design of breakwater armor layers, and Burcharth(1991) introduced the partial safety factors in the reliability design of rubble mound breakwaters. Recently Burcharth and Sörensen (1999) established the partial safety factor systems for rubble mound and vertical breakwater by summarizing the results of the PIANC Working Groups.

On the other hand, in Japan the expected sliding distance of a caisson of a vertical breakwater (Shimosako and Takahashi, 1999; Goda and Takagi, 2000) or the expected damage of the armor blocks of a horizontally composite breakwater (Hanzawa et al., 1996) during its lifetime is estimated through the Monte Carlo simulations by taking the uncertainties of various design factors into computation.

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However, these methods have mainly focused on the stability investigation of the breakwater. Among the design procedures of rubble mound breakwater, determination of the crest elevation is one of the important factors. Kweon and Suh (2003) proposed an estimation method of the expected overtopping probability for the rubble mound breakwater. The crest elevation of rubble mound has been designed by the allowable overtopping rate (m3/sec/m). The study proposes an estimation method of the overtopping probability as a first step for the overtopping rate.

In this study, for the more realistic estimation of the overtopping probability, the occurrence frequency of tidal elevation collected from real sea is included.

2. OCCURRENCE FREQUENCY OF TIDAL ELEVATION

In order to get some distribution of the variability of tidal elevation in the field, we analyzed the tidal elevation data provided in the homepage of the National Oceanographic Research Institute (http://www.nori.go.kr). The tidal elevation data has been made at every one hour during 355 days. It provides the fluctuation of tidal elevation at 17 locations around South Korea. Among these we used the data at the locations along the east coast of Korea, or Mukho and Busan, where the design wave heights corresponding to return period of 50 years are almost same but have different occurrence frequency of tidal elevations as shown Fig. 1 and Fig. 2. The elevations of tidal fluctuation are subtracted from the mean values of themselves calculated with the total number of 8760 each other.

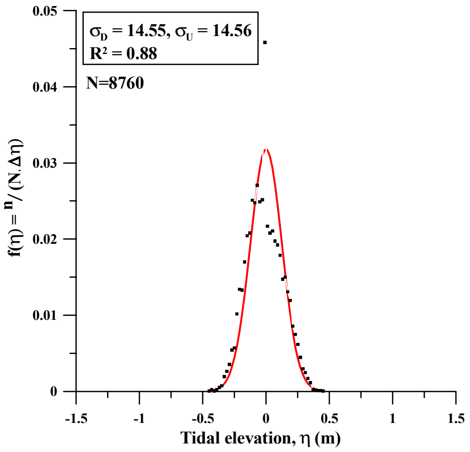


Fig. 1 Occurrence frequency of tidal elevation at Mukho region

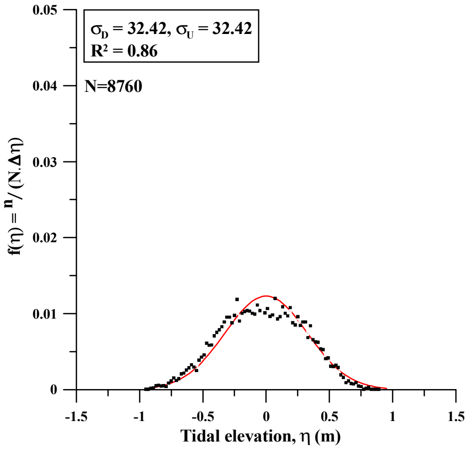


Fig. 2 Occurrence frequency of tidal elevation at Busan region

The two series of tidal elevation shown in Fig. 1 and Fig. 2 are fitted with the normal distribution. The series of tidal elevation taken zero mean are fitted by the following expression:

$$f(\eta) = \frac{1}{2}\left[\frac{1}{\sigma_D\sqrt{2\pi}}\exp\left(-\frac{1}{2}\left(\frac{\eta-\mu_D}{\sigma_D}\right)^2\right)+\frac{1}{\sigma_U\sqrt{2\pi}}\exp\left(-\frac{1}{2}\left(\frac{\eta-\mu_U}{\sigma_U}\right)^2\right)\right] \quad (1)$$

in which, η is the tidal elevation, μ_D the mean of lower elevation, μ_U the mean of higher elevation, σ_D the standard deviation of lower elevation, σ_U the standard deviation of higher elevation.

As shown in Fig. 1 and Fig. 2, they have one peak shape and zero mean. Mukho has σ_D=14.55, σ_U=14.56 and Busan has σ_D=32.42, σ_U=32.42. The standard deviation of Busan is greater than that of Mukho.

COMPUTATIONAL PROCEDURE

VARYING OF CREST ELEVATION

The crest elevation has been determined by the design tidal level and design wave height in Korea. The existing method for determining the crest elevation is:

$$h_c^* = \alpha^* + \beta^* H_{1/3} \quad (2)$$

in which, h_c*is the height from the mean sea level to the crest elevation, the design tidal level, the varying values from 0.6 to 1.2, *H*0the design wave height at a specific site.

However the characteristics of occurrence frequency are different at each region, its effect could not be considered in deterministic method. Fig. 3 shows conceptual comparison of existing method for crest elevation and change of tidal elevation. In this study, the crest elevation is varied by the existing concept as shown in eq. (2) for the easy understanding and comparison. Changing the crest elevation, the analysis of overtopping probability is conducted.

There is discrepancy of the time scale between tidal change and the attack of maximum wave height. In this study, maximum wave height is divided into the individual wave extended by joint distribution of height and period. The individual wave is coupled with the tidal elevation in every case. If the run-up height calculated with tidal elevation and wave is higher than that of the set crest one, the multiplication value of corresponding probabilities of tidal elevation and wave is accumulated.

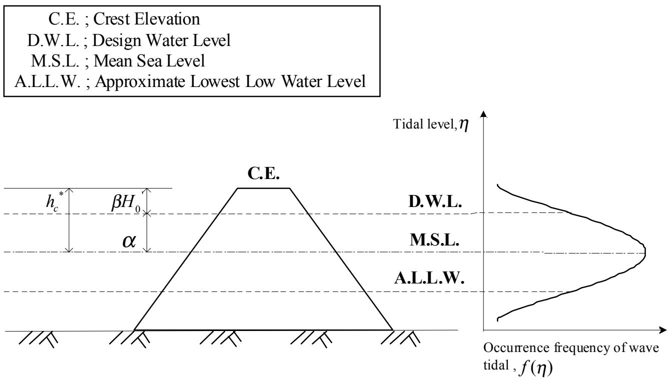


Fig. 3 Crest elevation and occurrence frequency of tidal elevation

OFFSHORE WAVES

The offshore wave height is usually determined by referring to the extreme wave height distribution, which is constructed with the extreme wave data of long-term observations or hindcasts. In the present study, the following Gumbel distribution function is employed for the annual maximum wave heights:

$$F(x) = \exp - \left[- \exp \left(- \frac{x - B}{A} \right) \right] \quad : -\infty < x < \infty \tag{3}$$

where x stands for the annual maximum significant wave height, A and B are the scale and location parameters, respectively.

The parameters used in the study were estimated by Kim (2004) based on the hindcasted data. Table 1 shows the conditions of extreme wave heights.

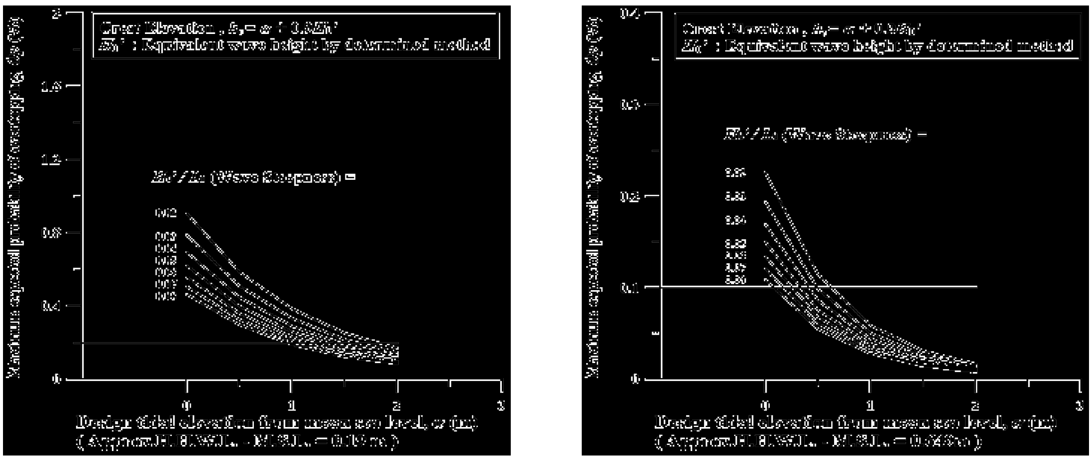
Table 1 The extreme wave height with estimated parameters

Site	Return period (Years)	Extreme wave height (m)	Scale parameter (*A*)	Location parameter (*B*)
Mukho	50	6.996	0.999	2.798
Busan	50	6.983	0.523	3.298

As shown in Table 1, the extreme wave heights are almost same with each other.

ILLUSTRATIVE EXAMPLES

In this section, we present the effect of occurrence frequency of tidal elevation on the expected overtopping probability. Fig. 4(a) and (b) show the computational results of expected overtopping probability according to occurrence frequency.



(a) Mukho (b) Busan

Fig. 4 Expected overtopping probability of Tetrapod slope (Mukho and Busan)

The Fig. 4(a) and (b) show the effect on the occurrence probability of tidal elevation. The Fig. 4(a) for Mukho region which has higher deviation of tidal elevation as shown in Fig. 1 has bigger overtopping probability comparing to that of Busan region. Making a comparison of Fig. 4(a) and Fig. 4(b), the expected overtopping probability becomes smaller by the increasing of standard deviation of tidal elevation.

CONCLUSIONS

It is found that the inclusion of the variability of tidal elevation has great influence on the computation of the expected overtopping probability of rubble mound breakwater. The bigger the deviation of occurrence frequency of tidal elevation is, the smaller the expected overtopping probability is.

ACKNOWLEDGEMENTS

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REFERENCES

Burcharth, H. F. (1991). Introduction of partial coefficient in the design of rubble mound breakwaters. *Proc. Conf. on Coastal Structures and Breakwaters*, Inst. of Civil Engrs., London, pp. 543-565.

Burcharth, H. F. and Srensen, J. D. (1999). The PIANC safety factor system for breakwaters. *Proc. Int. Conf. Coastal Structures '99*, A. A. Balkema, Spain, pp. 1125-1144.

Goda, Y. (2000). *Random Seas and Design of Maritime Structures*, 2nd edn., World Scientific, Singapore, 443p.

Goda, Y. and Takagi, H. (2000). A reliability design method of caisson breakwaters with optimal wave heights. *Coastal Engrg. J.* **42**: 357-387.

Hanzawa, M., Sato, H., Takahashi, S., Shimosako, K., Takayama, T. and Tanimoto, K. (1996). New stability formula for wave-dissipating concrete blocks covering horizontally composite breakwaters. *Proc. 25th Int. Conf. on Coastal Engrg.*, American Soc. of Civil Engrs., Orlando, pp. 1665-1678.

Kim, J-D (2004). Characteristics on the extreme value distributions of deep water waves in marginal seas around Korea. Master thesis, Wonkwang university.

Kweon, H.M. and Suh K.D. (2003). Reliability analysis of the expected overtopping probability of rubble mound breakwater. ISOPE, 493-496

Shimosako, K. and Takahashi, S. (1999). Application of deformation-based reliability design for coastal structures. *Proc. Int. Conf. Coastal Structures '99*, A. A. Balkema, Spain, pp. 363-371.

van der Meer, J. W. (1988). Deterministic and probabilistic design of breakwater armor layers. *J. Waterway, Port, Coastal and Ocean Engrg.* **114**: 66-80.