CHAPTER 113

Short Term Wave Overtopping Rate of Block Armored Seawall

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Abstract

The characteristics of short term over topping rate for a deepsea block armored seawall are investigated experimentally. Two series of experiments were conducted. One is a series that seawall has low crown height and a wave grouping effect is investigated. Another experiment is a series that it has a high crown height and slope effect of armor unit is studied. From these experiments, we have to consider the short term wave overtopping rate for the design of drainage facilities of deepsea structure such as an artificial island.

Introduction

Recently, Many ideas of offshore artificial island have been planning in Japan and many studies on a design method for deepsea seawall or deepsea breakwater have been started. In a concerning research, it is pointed out that excess wave overtopping maybe lead artificial island to ruin. Therefore it is very important in the construction of artificial island to estimate accurately of overtopping rate of seawall.

Usually, In order to estimate the wave overtopping rate, the Goda's diagrams (Goda, 1987) are used. This diagram illustrates the relationship between a mean overtopping and a crown height. It has been pointed out that short term overtopping rate is important for the design of drainage facilities behind the seawall (Kimura and Seyama, 1984). Moreover it is suggested that the short term overtopping rate become several ten times of mean wave overtopping rate and large amount of water comes into the drainage facilities in short time (Inoue et al., 1989).

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However, Goda's diagram is illustrated only for the time average of total overtopping quantity and this diagram dose not include an effect on the slope of block armor unit. In this study, we study the characteristics of short term wave overtopping rate on the block armored seawall experimentally.

Experiments

Experiments were conducted by using the wave flume with dimension of 0.6m in width, which is partly divided from a wave basin of 5m in wide, 34m in length and 1.2m in depth. At an end of basin, rubbles banked in 1: 5 slope in order to reduce reflected waves. The wave flume shows in Figure 1. Model seawall were set up in the flume.

Two series of experiments for the wave overtopping were carried out. In these experiments, it is supposed that a prototype water depth in front of the seawall is 22.5m. Considering the wave flume dimensions, the model scale of series one and two are assumed to 1/85.7 and 1/87.5 respectively.

One of two experiments is a series that seawall has low crown height and a wave grouping effect is investigated. A typical model section in Series-one is shown in Figure 2. Both a vertical and a block armored seawall are used in this series. The water depth in front of a model seawall was 26.3 cm. Sea bed slope in front of a model seawall is 1/100. The tetrapods (58.9g) were used as armored blocks and the same size blocks

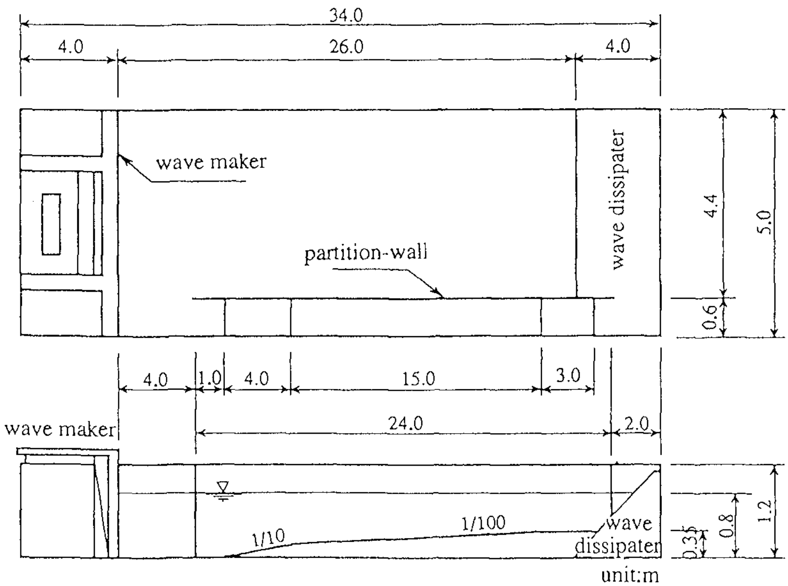


Figure 1 Experimental setup.

were used in all section. A crown height was 10.5 cm. It is 9m in prototype scale and the slope of armor units is 1:4/3.

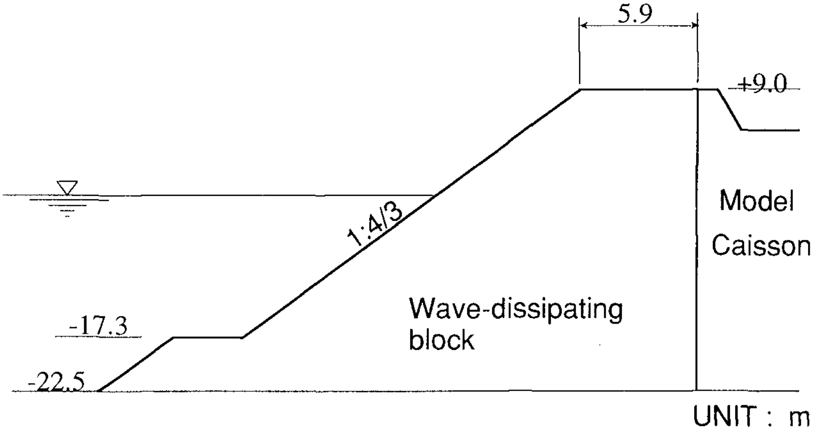


Figure 2 Typical model seawall (for series 1)

Irregular waves which have Wallops type spectrum were act on model seawall.
Wallops type wave spectrum is shown below.

$$S(f)=\beta H_{1/3}^{2}T_{p}\left(T_{p}f\right)^{-m}\exp\left[-\frac{m}{4}\left(T_{p}f\right)^{-4}\right] \tag{1}$$

$$\beta \cong \frac{0.6238m^{(m-2)/4}}{4^{(m-5)/4}\Gamma\left[(m-1)/4\right]}\left[1+0.7458(m+2)^{-1.057}\right] \tag{2}$$

$$T_{p} \cong T_{1/3}/\left[1-0.283(m-1.5)^{-0.684}\right] \tag{3}$$

where m : Spectral shape factor, $H_{1/3}$: Significant wave height, $T_{1/3}$: Significant wave period, T_p : Peak wave period, $\Gamma()$: Gamma function.

The shape factor m become small, the bandwidth of wave spectrum becomes narrow, while the m is large, the band widths of wave spectra become wide. In the case that m is 5, Wallops type wave spectrum corresponds to Modified Bretschneider-Mitsuyasu type wave spectrum modified by Goda.

The experimental cases were shown in Table 1. In this series, 24 runs of experiment were conducted. The three types of spectral shape factor m= 3,5 and 9 were selected. The wave period was 1.73 second and five kinds of wave height were used. The wave height normalized by the crown height were changed from 0.65 to 1.42.

Table 1 Experimental case for series 1.

$T_{1/3}$(s)	$H_{1/3}$/hc	vertical seawall			block armored seawall		
		m=3	m=5	m=9	m=3	m=5	m=9
1.73 (16.0)	0.60	○	○	○	○	○	
	0.74	○	○	○	○	○	
	0.89	○	○	○	○	○	
	1.04	○	○	○	○	○	
	1.19	○	○		○	○	

Table 2 Experimental case for series 2.

$T_{1/3}$ (sec)	$H_{1/3}/h_c$	Slope of block armour units				
		1:4/3	1:1.6	1:1.8	1:2.0	1:2.5
1.28	0.456	○				
	0.548	○	○	○	○	○
	0.639	○	○	○	○	○
	0.684	○	○	○	○	○
	0.730	○				
	0.812	○	○	○	○	○
	0.913	○	○	○	○	○
1.71	0.456	○				
	0.548	○	○	○	○	○
	0.593	○				
	0.639	○	○	○	○	○
	0.684	○	○	○	○	○
	0.730	○				
	0.776	○				
	0.821	○	○	○	○	○
	0.913	○	○	○	○	○
2.14	0.456	○				
	0.548	○	○	○	○	○
	0.593	○				
	0.639	○	○	○	○	○
	0.684	○	○	○	○	○
	0.730	○				
	0.821	○	○	○	○	○
	0.913	○	○	○	○	○

Another experiment is a series that it has a high crown height and slope effect of armor unit is studied. Assuming an actual wave overtopping condition, the mean wave overtopping rate set below $0.05 m^3/m/s$ in prototype scale in the condition that the significant wave height normalized by crown height is 0.684, and significant wave period is 16s in this series. The crown height was 16 cm in experimental scale (it is 14m in prototype scale). Therefore these experiments were conducted under the relatively high crown height and low wave overtopping rate condition. The slopes of armor units which were used in the experiment were 1:4/3, 1:1.6, 1:1.8, 1:2.0 and 1:2.5. The tetrapods (36.8g) were used as armored blocks and the same size of block was used in all section. The Wallops type wave spectra were also used in this series. In this series, the shape factor of incident wave spectra is selected m = 5. The wave heights normalized by the crown height were changed from 0.46 to 0.91 and three wave periods 1.28s, 1.71s and 2.14s in experimental scale were used, which were 12s, 16s and 20s second in prototype scale respectively. Experimental condition is shown in Table 2. Eighty-four runs of experiments were conducted.

Short term over topping rate measurement.

In order to get the short term overtopping rate, a time dependent weight of water was measured using the measurement apparatus which was used by Sekimoto et al. (1994). This apparatus is consist of a water tank which was supported by four load-cells and was set just behind the seawall. The instantaneous wave over topping rate was defined as a change rate of water weight per unit time.

We defined a maximum wave overtopping rate as a maximum value of moving average of instantaneous overtopping rate over a time interval as shown below. The duration of average is to be n times significant wave period, where n is 1,3 and 5 in this study. Using this instrument, the short term wave overtopping rate can be measured accurately (Sekimoto et al., 1994).

$$q_n(t) = \frac{1}{nT_{1/3}} \int_{-nT_{1/3}/2}^{nT_{1/3}/2} q_i(t+\tau)\,d\tau \quad ,n = 1,3,5 \tag{4}$$

$$q_{n-\max} = Max[q_n(t)] \tag{5}$$

where, $q_i(t)$: Instantaneous wave overtopping quantity, $q_n(t)$: n-waves mean overtopping rate, $q_{n\text{-max}}$: n-waves maximum overtopping rate (short term wave overtopping rate), $T_{1/3}$: Significant wave period.

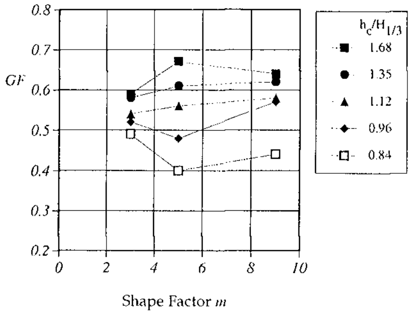


Figure 3 The relationship between spectral shape factor m and groupiness factor.

Results

Figure 3 shows the relationship between spectral shape factor m and groupiness factor. There is no clear relationship in both. In the case of high wave height, wave breaking is occurred and groupiness factor is relatively small.

In Figure 4, the mean wave overtopping rate normalized by wave height is plotted against the spectral shape factor m. In this figure, the wave height is measured on the position of seawall in the condition that the model seawall dose not set up. On the left hand side of this figure, the results of vertical wall type seawall are shown and on the right hand side the results of block armored seawall are shown. The mean wave overtopping rate have tendency of increase while spectral band width become narrow. However, this tendency is not so strong.

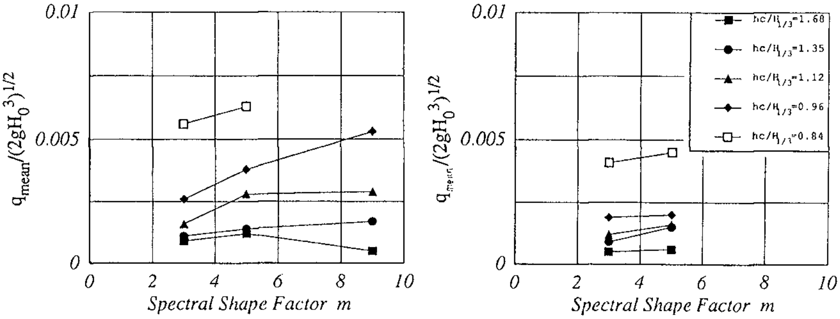
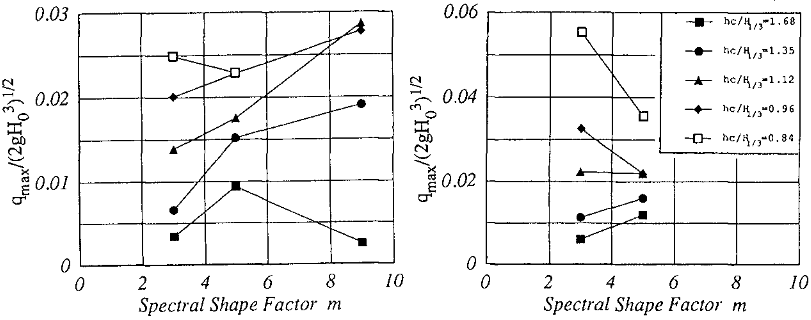
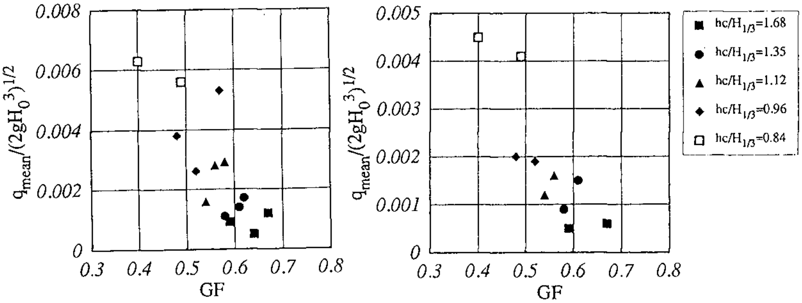


Figure 4 The relationship between the mean wave overtopping rate and the spectral shape factor.



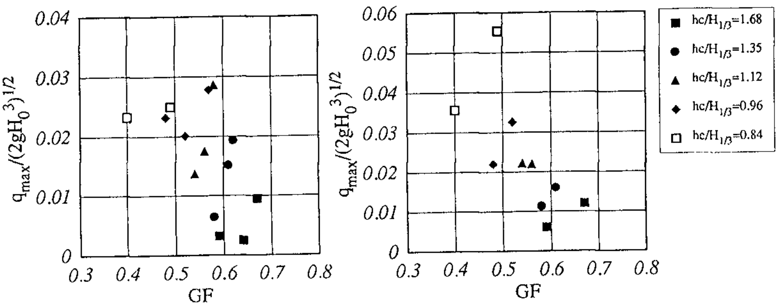
(a) Vertical Seawall (b) Block armored Seawall

Figure 5 The relationship between the maximum wave overtopping rate and the spectral shape factor.



(a) Vertical Seawall (b) Block armored Seawall

Figure 6 The relationship between the mean wave overtopping rate and the groupiness factor.



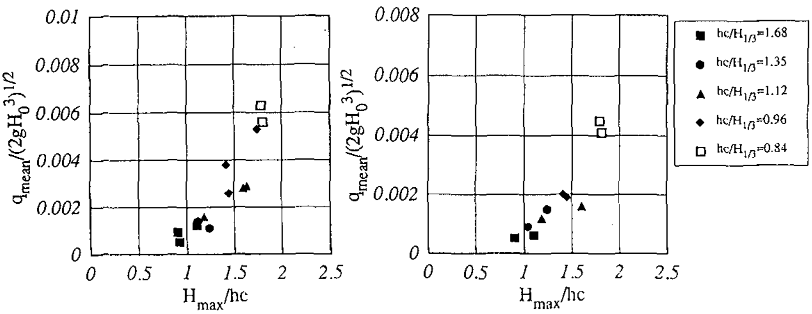
(a) Vertical Seawall (b) Block armored Seawall

Figure 7 The relationship between the maximum wave overtopping rate and the groupiness factor.

Figure 5 shows the maximum wave overtopping rate in the same manner as Figure 4. The maximum wave overtopping seems depends on the shape factor except for the case of high waves. In the case of high wave height, wave breaking effect may be appeared.

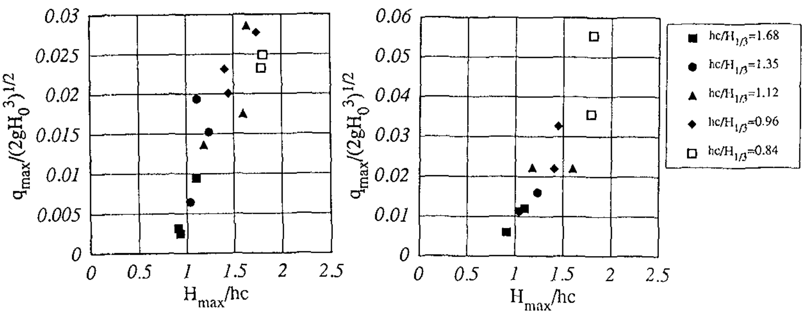
The relationship between wave-overtopping rate and groupiness factor is compared in Figure 6 and Figure 7. On the left hand side of this figure, the results of vertical wall type seawall are shown and on the right hand side the results of block armored seawall are shown. The results show the strong relationship between both is available. In the case of the same wave height, the wave overtopping also increase as the wave groupiness increase.

We also compared the maximum wave height in a wave train with wave overtopping rate. The maximum wave height in this figure is measured at the location of model seawall before the model seawall was set up. The left-hand side and right-hand side of this figure are indicated in the same manner as previous figures.



(a) Vertical Seawall (b) Block armored Seawall

Figure 8 The relationship between the mean wave overtopping rate and the maximum wave height.



(a) Vertical Seawall (b) Block armored Seawall

Figure 9 The relationship between the maximum wave overtopping rate and the maximum wave height.

Figure 8 shows the case of mean wave overtopping rate. The mean wave overtopping rate has one to one correspond to maximum wave height. In the results of maximum wave overtopping rate (Figure 9), we can clearly see the same relationship. This relationship is very natural and shows that once we know the maximum wave height in front of seawall, we can accurately estimate the wave overtopping rate not only the mean overtopping rate but also the short term wave overtopping rate.

Next, we investigated the slope effect on the wave over topping.

The relationship between the mean wave overtopping rate and an inverse of the slope in each wave period had investigated by Sekimoto et al. (1994). According to this study, the tendency of these relationships is similar to the results of Saville's runup experiment(1952). That is the mean overtopping rate is small when the slope is steep. As the slope becomes mild, the mean overtopping rate becomes large. The slope further becomes mild, the mean overtopping rate decreases.

This reason can be accounted for the wave deformation on the slope of blocks. In the case of steep slope, wave deformation does not occur on the slope because of the short slope length. As the slope becomes mild, the wave height increases due to wave shoaling. In the case that slope is further mild, the wave energy is dissipated due to the wave breaking on the slope and the energy loss in the armor units. In the case that the same wave act on the seawall, the mean overtopping rate has not same volume when the slope of armor units is not same. Especially in the case of the 1: 1.8 slope, the mean overtopping rate was seven times as large as that in the case of the 1: 2.5 slope.

We investigated the relationship between the maximum wave overtopping rate and the slope of armor unit in Figure 10. In this figure, the wave overtopping rate was indicated in prototype scale. The almost same relationship to the mean wave overtopping rate is available in this figure. However, the maximum wave overtopping rate is more variable quantity than the mean wave overtopping rate, in the sense of statistics.

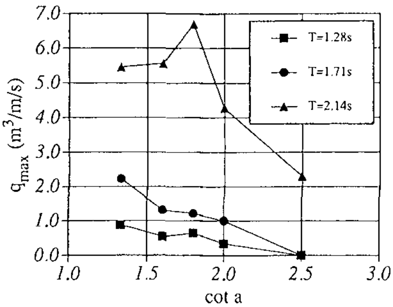
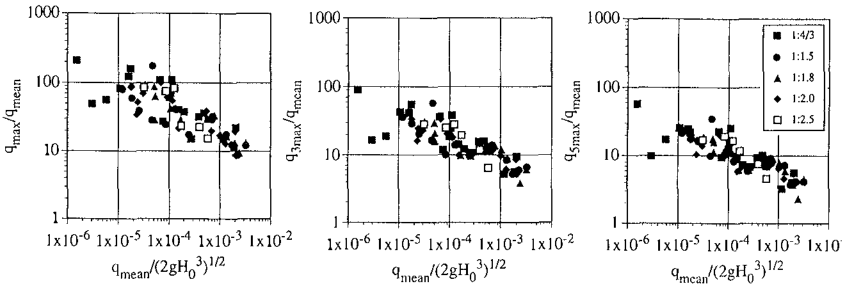


Figure 10 The relationship between the maximum wave overtopping rate and the slope of armor unit.



(a) Maximum (b) Three waves average (c) Five waves average

Figure 11 The relationship between the short term wave overtopping rate and the mean wave overtopping rate.

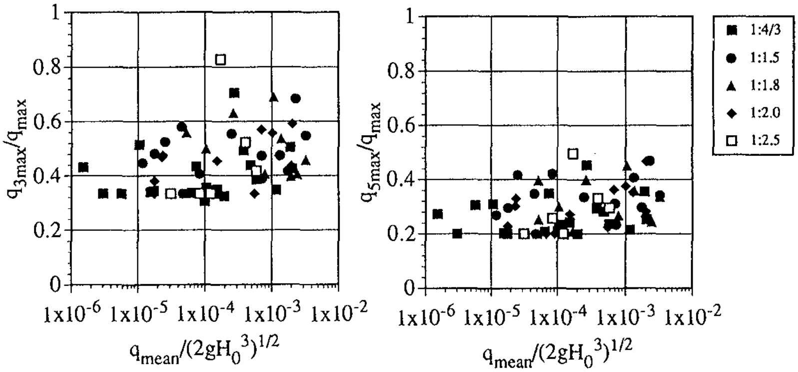
Therefore the maximum wave overtopping rate shows more complicated feature than mean wave overtopping rate.

Figure 11 shows the relationship between the short term wave overtopping rate and the mean wave overtopping rate. In this figure, vertical axis is the ratio of short term overtopping rate to the mean wave overtopping rate and horizontal axis is taken normalized mean wave overtopping rate. Three types of short term wave overtopping rate were taken in these figures. The q_{max} means the maximum wave overtopping rate which is the maximum value of the average of wave overtopping quantities during one wave. The q_{3max} means the maximum value of the average of wave overtopping quantities during three waves. The q_{5max} means during five waves.

From this figure, we find that the ratio becomes large as the mean wave overtopping rate becomes small. The maximum wave overtopping rate shows 10 to 170 times the mean wave overtopping rate. The maximum overtopping rate during three waves shows 5 to 100 times the mean wave overtopping ratio. The maximum overtopping rate during five waves indicated 3 to 50 times.

It shows that the large amount of water flows over seawall in short time and we have to consider short term wave overtopping in the design of drainage facilities just behind the seawall.

Figure 12 shows the relationship between the short term wave overtopping rates against the mean wave overtopping rate. The data of maximum overtopping rate during three waves were distributed from 0.333 to 0.8 times the maximum wave overtopping rate. In the case of maximum overtopping rate during five waves, it becomes from 0.2 to 0.5. It is natural that scattering of this ratio become small when the duration time for average is large. In the case of small rate of wave overtopping, the number of overtopped waves including the wave by which the maximum wave overtopping rate was occurred is only one. In the case of large rate of



(a) Three waves average (b) Five waves average

Figure 12 The relationship between the short term wave overtopping rates against the mean wave overtopping rate.

wave overtopping, the number of overtopped waves including the wave when the maximum wave overtopping rate was occurred is one to three.

Conclusions

The main results obtained from this study were shown below.

(1)The mean wave overtopping rate is not so affected by the spectral band width in this experiment.

(2)The short term wave overtopping rate is affected by the spectral band width, except for the case that the wave breaking obviously occurred.

(3)The wave overtopping rate strongly related to the Groupiness Factor.

(4)The wave periods become longer, the short term wave overtopping rate become larger.

These results were similar to the case of mean overtopping rate.

(5)The maximum wave overtopping quantity, which is defined as the maximum value of wave overtopping for one wave, becomes more than 100 times of the mean wave overtopping rate in the case of high crown height. In the design of drainage facilities, it has to be considered that huge amount of water flows in short time.

(6)The mean overtopping rate and the maximum wave overtopping rate were clearly affected by the slope of block armor unit. This is a same tendency of previous experiments of Saville's wave run-up on composite slopes. The slope effect in the wave overtopping has to be considered in design of sea wall.

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