CHAPTER 143

Experiments on a non-wave overtopping type seawall

Keisuke Murakami*, I.Irie† and Y.Kamikubo‡

Abstract

A new type of seawall is proposed in this study. The seawall has a deep circular arc cross section and allows no wave overtopping any more. The critical crest elevation of the seawall, which defined as the minimum crest elevation on which the wave overtopping dose not occur at all, is investigated through the wave tank experiments. The wave pressures and wave forces acting on the seawall are also measured, and the characteristics of the wave pressure distribution and wave forces are examined.

1. Introduction

The landward area of a seawall provides an excellent space for various use so long as it is protected from the wave overtopping. Recently, the coastal areas are planned for land use which is very sensitive to the spray falls such as the electronic power plant and the airport, and the very small quantity of the wave overtopping rate is allowed. Furthermore the reduction of the seawall height is also required to afford unobstructed view as well as to save the cost. Though some types of seawall were proposed for the purposes of the reduction of the rate of wave overtopping and the height of seawall (Inoue, 1974; Takata, 1979; Kono, 1993), those could not release the land from hazard by the wave overtopping thoroughly.

In this study, a new type of seawall is proposed(referred as *Flaring Shaped Seawall* (*FSS*) ; see **Fig.-1**). The seawall has a deep circular arc cross section and no wave overtopping is allowed any more. The critical crest elevation of the *FSS*,

*Research Associate, Dept. of Civil Eng., Kyushu Univ., Fukuoka, 812-81, JAPAN
†Professor, Ditto
‡Graduate Student, Ditto

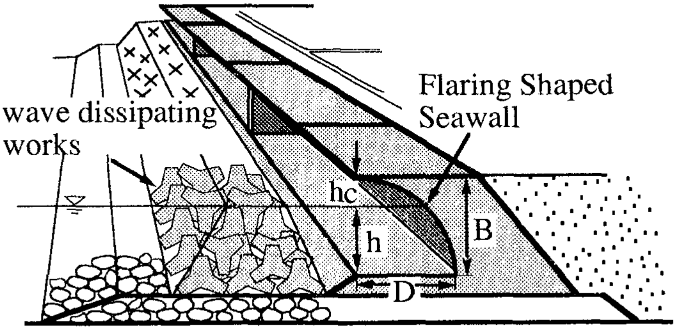

Fig.-1: Conceptual sketch of the *FSS*

which defined as the minimum crest elevation on which the wave overtopping dose not occur at all, was investigated through wave tank experiments, and the required crest elevation which satisfies the non-wave overtopping condition was examined. The wave pressures and uplift wave forces acting on the *FSS* were also measured through wave tank experiments and characteristics of the wave pressure were discussed by classifying the wave colliding patterns in front of the *FSS*.

2. Experimental conditions

2.1 Measurement of the critical crest elevation

As shown in **Fig.-2**, the experiments were conducted with two-dimensional wave tank of $28m$ in length, $0.5m$ in height and $0.3m$ in width. The water depth was maintained at $h_0 = 35cm$ and the impermeable slope with $1/20$ was installed at the end of the wave tank. Four types of seawall with the same seawall

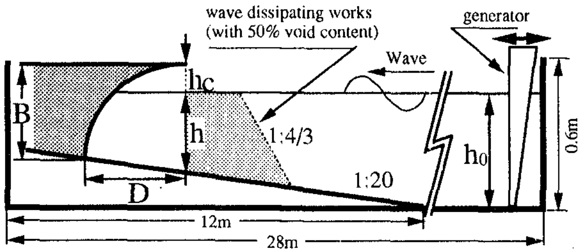

Fig.-2: Schematic of wave tank facility

Table-1: Wave conditions for the measurement of the critical crest elevation

$B(cm)$	D/B	H_0/L_0	$H_0(cm)$
15	0	0.012	4,6,7,8,9
		0.036	
	0.5	0.012	
		0.036	
	1.0	0.012	
		0.036	
	2.0	0.012	
		0.036	

height, $B = 15cm$, and the different arc depth, D/B =0, 0.5, 1.0 and 2.0, were tested. The tip of these seawall was made with a thin plate and its thickness did not affect to the wave overtopping. The critical crest elevation depends on the configurations of the wave dissipating works such as crest elevation, crown width, location and void content(e.g.,Yamamoto,1984, Takayama,1988, Sasajima,1993). In this study, the wave dissipating works with 50% void content was installed in front of the seawall and its crest elevation was coincide with the still water level. The wave dissipating works was made by using 1/25 scale model of $2t$ type blocks, and these blocks were piled one upon another in the layers.

Table-1 shows the incident wave conditions, where H_0 and L_0 indicate the incident wave height and wave length respectively. Two kinds of incident wave steepness of H_0/L_0 = 0.012 and 0.036 were used in this experiment, and the incident wave height, H_0 was changed in the range from $4cm$ to $9cm$. With changing the location of the seawall and incident wave height, the critical crest elevation, h_c for these incident wave condition was measured. The critical crest elevation was obtained by observing whether the wave overtopping occur or not.

2.2 Measurement of the wave pressure

The experiments were conducted with two-dimensional wave tank of $20m$ in length, $1.2m$ in height and $0.6m$ in width. The water depth was maintained at h_0 =$85cm$. Four types of seawall with the combinations of the different seawall height, B =$22.5cm$ and $36.4cm$, and the different relative arc depth, D/B =1.0 and 0.5 were tested. The wave dissipating works with 50% void content and crest elevation in the still water level was installed in front of the seawall.

Table-2 shows the incident wave conditions. The incident wave steepness of H_0/L_0 =0.036 was used in this experiment, and the incident wave height, H_0 was changed in the range from $4cm$ to $13cm$. With changing the location of the seawall and incident wave height, the wave pressure distributions on the seawall were measured by the pressure gauges of $8mm$ diameter attached on the face of

Table-2: Wave conditions for the measurement of the wave pressure

B (cm)	D/B	h (cm)	H_0 (cm)	B (cm)	D/B	h (cm)	H_0 (cm)
22.5	0.5	11	6,8,10,11,12,13	36.4	0.5	27	7,9,11,13
		13	6,8,10,11,12,13			30	3,5,7,9
		15	6,8,10,12,13			32	4,5,6,7
		18	4,6,8,9,10				
	1.0	11	6,8,10,11,12,13		1.0	24	7,9,11,13
		13	6,8,10,11,12,13			27	7,9,11,13
		15	6,8,10,12,13			30	7,9,11,13
		18	4,6,8,9,10			34	3,4,5,6

the seawalls. The output signals were recorded in the digital data recorder with $1000Hz$ sampling frequency.

3. Characteristics of the critical crest elevation

Fig.-3 shows the characteristics of the critical crest elevation, h_c/H_0 for the incident wave steepness of $H_0/L_0 = 0.012$ on which the wave dissipating works are installed in front of the seawall. **Fig.-4** also shows the characteristics of h_c/H_0 for H_0/L_0 =0.036. In these figures, the symbols ○, ◇, and △ show the results of the *FSS* with D/B = 0.5, 1.0 and 2.0 respectively. The symbol ● also shows the results of the conventional upright seawall which has the same seawall height as other *FSS*. The thick line in **Fig.-4** shows the relative crest elevation of the upright seawall with wave absorber proposed by Goda(1985) for H_0 = 2m as a model scale of 1/20. The wave overtopping rate, q =2 × $10^{-4}(m^3/m \cdot sec.)$ was employed as a level where the wave overtopping rate can be considered negligible.

The critical crest elevation, h_c/H_0 of the conventional upright seawall increase linearly with increase of the relative water depth, h/H_0. On the other hand, the critical crest elevation of the *FSS* decrease with increase of h/H_0, and the differences of the critical crest elevation between *FSS* and conventional upright seawall become larger. The *FSS* checks the wave overtopping more effectively than the upright seawall, and the crest elevation, h_c of the *FSS* can be reduced to about a half of the offshore wave height even under the non-wave overtopping condition.

Fig.-5 and **Fig.-6** show the critical crest elevation for H_0/L_0 =0.012 and 0.036 on which the wave dissipating works is not installed in front of the seawall. Though the characteristics of the critical crest elevation are similar to the results shown in **Fig.-3** and **Fig.-4**, the differences of the critical crest elevation between

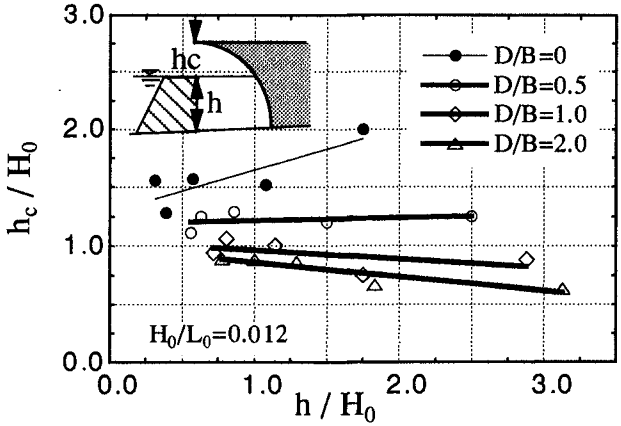

Fig.-3: Critical crest elevation for $H_0/L_0 = 0.012$ (with wave dissipating works)

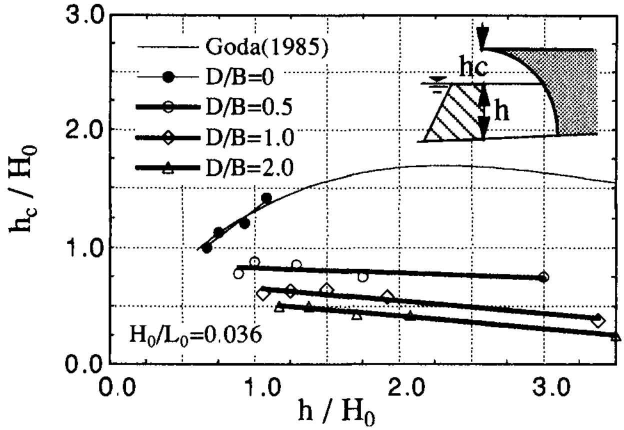

Fig.-4: Critical crest elevation for $H_0/L_0 = 0.036$ (with wave dissipating works)

the *FSS* and upright seawall become significant because h_c/H_0 of the upright seawall increase rapidly with increase of h/H_0.

Comparing with the results of D/B =0.5, 1.0 and 2.0 in **Fig.-3** and **Fig.-4**, the checking capability of the wave overtopping becomes higher along with the increase of the relative circular arc depth, D/B. **Fig.-7** shows the relationship between the critical crest elevation and relative arc depth, D/L_0. h_c/H_0 decreases monotonously with increase of D/L_0. So that, the *FSS* with deep arc depth relative to the incident wave length is effective for the prevention of the

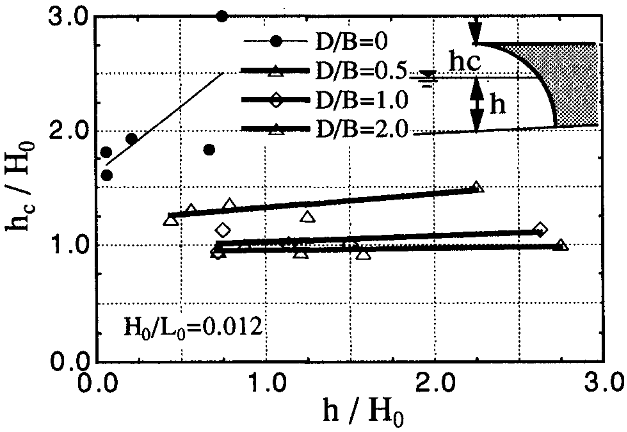

Fig.-5: Critical crest elevation for $H_0/L_0 = 0.012$ (without wave dissipating works)

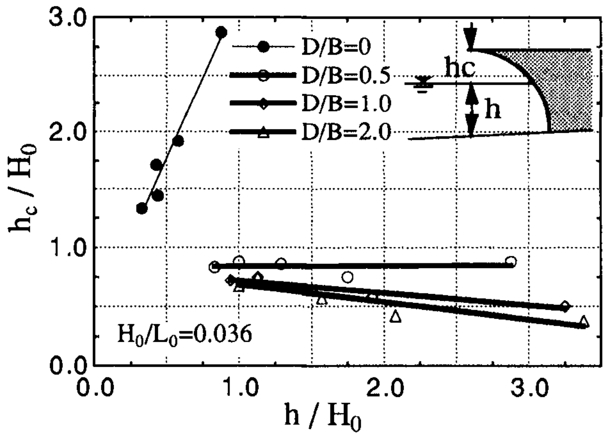

Fig.-6: Critical crest elevation for $H_0/L_0 = 0.036$ (without wave dissipating works)

wave overtopping.

The critical crest elevation, h_c/H_0 is deeply related to h/H_0, D/B, H_0/L_0, H_0/h_0, $\tan\beta$ and f_D, where f_D means a wave damping rate by the wave dissipating works. The linear multiple regression analysis was carried out with using above factors to obtain the approximate equation for h_c/H_0, and the equation was obtained as follows:

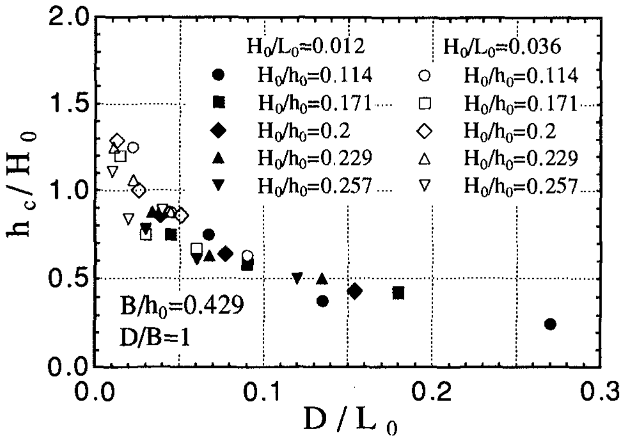

Fig.-7: Relationship between h_c/H_0 and D/L_0

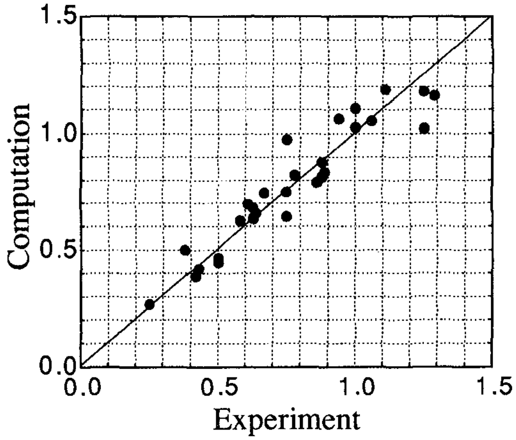

Fig.-8: Results of the regression analysis

$$\frac{h_c}{H_0} = -0.24\frac{h}{H_0} - 0.18\frac{D}{B} - 11.59\frac{H_0}{L_0} - 2.63\frac{H_0}{h_0} + 2.17 \tag{1}$$

where $\tan\beta$ and f_D are constant in this study.

Fig.-8 shows a result of the regression analysis. The computed results show fairly good agreements with experimental ones, and h_c/H_0 is estimated with high correlation coefficient of γ =0.95 by Eq.(1).

4. Wave pressure acting on *FSS*

Fig.-9 and **Fig.-10** show the wave pressure distributions on the *FSS* of D/B =1.0 and 0.5 at different water depth,h/h_0, where the seawall height is B =22.5cm. The lateral axis shows the location of the wave pressure gauges and coordinate z is taken upward from the still water surface. Each symbol in

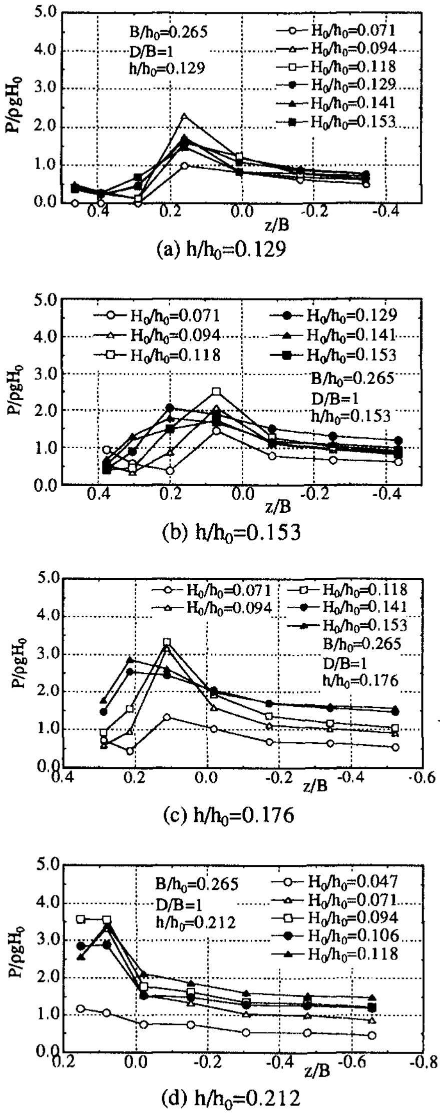

Fig.-9: Wave pressure distributions on *FSS* of D/B = 1.0

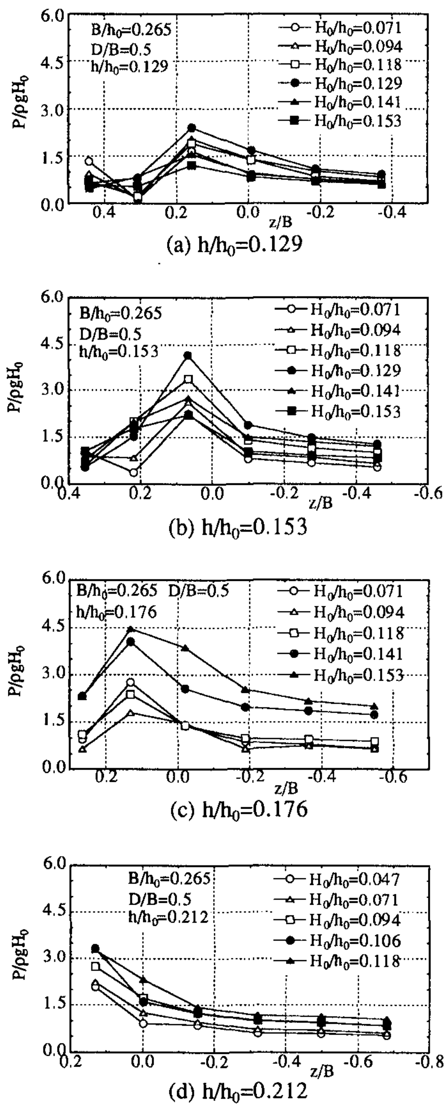

Fig.-10: Wave pressure distributions on *FSS* of D/B = 0.5

the figures mean the difference of the incident wave height, H_0/h_0.

The patterns of the wave pressure distribution are varied with the incident wave height, H_0/h_0 and the water depth, h/h_0. The maximum wave pressure appears between $z/B = 0$ and 0.2, and the pressure in the range from $P_{max}/\rho g H_0 = 1.2$ to 4.5 were observed. The values of the maximum wave pressure closely relate to the wave colliding patterns in front of the *FSS*.

Fig.-11 and **Fig.-12** show the variation of the maximum wave pressure,

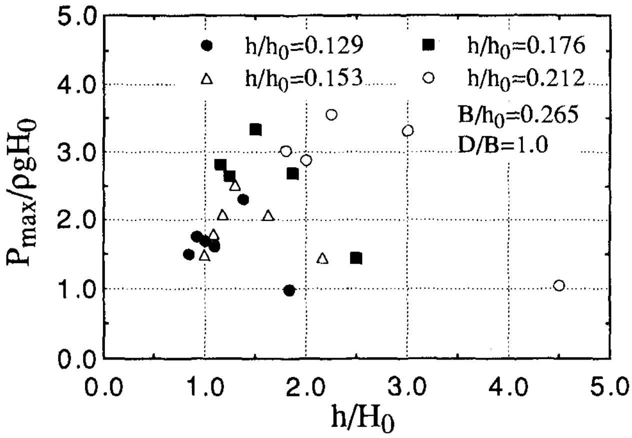

Fig.-11: Variation of the maximum wave pressure to the relative water depth, h/H_0 $(D/B = 1.0)$

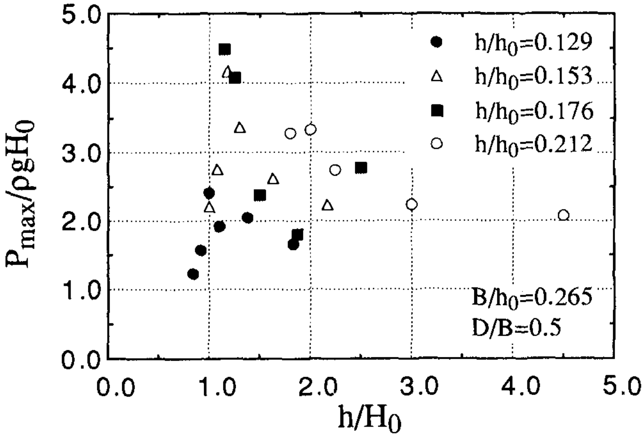

Fig.-12: Variation of the maximum wave pressure to the relative water depth, h/H_0 $(D/B = 0.5)$

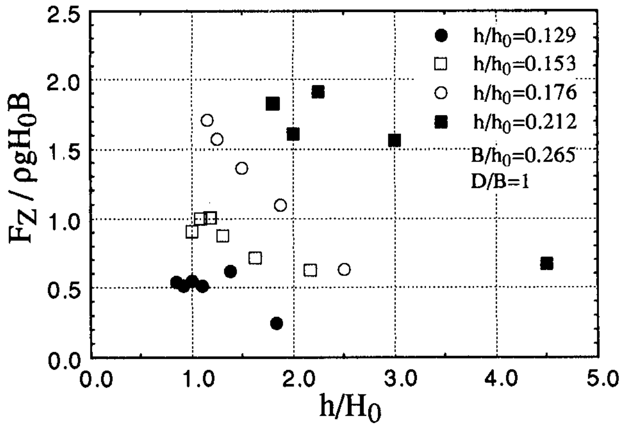

Fig.-13: Variation of the vertical wave force to the relative water depth, h/H_0 $(D/B = 1.0)$

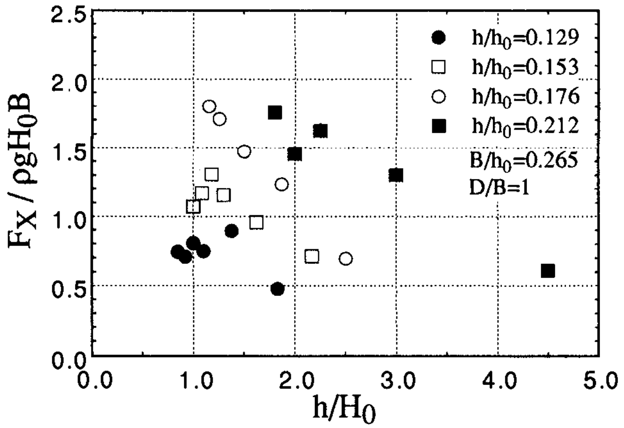

Fig.-14: Variation of the horizontal wave force to the relative water depth, h/H_0 $(D/B = 1.0)$

$P_{max}/\rho g H_0$ to the relative water depth, h/H_0 for $D/B = 1.0$ and 0.5. In the range of the small relative water depth, h/H_0, the maximum wave pressure is relatively small, because the incident waves break on the offshore side of the wave dissipating works and fully dissipated waves attack the seawall. With increase of h/H_0, the maximum wave pressure increases because the wave breaking point approaches to the seawall. The maximum value of $P_{max}/\rho g H_0$ appears when the waves break just in front of the seawall. After taking the maximum value, the maximum wave pressure decreases with increase of h/H_0. In the range of the large relative water depth, h/H_0, the maximum wave pressure becomes small because the waves attack the seawall without wave breaking.

Fig.-13 and **Fig.-14** show the vertical and horizontal wave forces acting on the *FSS* of D/B =1.0. The profiles of the wave pressure at each measuring point were assumed to be synchronized, and the wave forces were obtained by integrating the maximum wave pressures along the seawall face.

The variations of the vertical wave force are similar to that of the horizontal wave forces. The magnitude of the vertical wave force takes nearly the same value of the horizontal wave force, and the vertical force acting on the *FSS* is relatively larger than that on the upright seawall. The same tendencies were observed in the *FSS* of $D/B = 0.5$. In that case, the values of the vertical wave force took about 50%~60% of the horizontal wave force.

5. Conclusions

A new type of seawall (*FSS*) with deep circular arc cross section was proposed. The relative critical crest elevation of the *FSS* was extremely smaller than that of the conventional upright seawall, and the crest elevation could be reduced to about a half of the offshore wave height even under the non-wave overtopping condition. Further, the critical crest elevation of the *FSS* was estimated with fairly good correlation coefficient by using the approximate equation obtained from the experimental results.

The characteristics of the wave pressure were investigated. The values of the maximum wave pressure deeply related to the wave colliding patterns in front of the seawall, and those values change with the relative water depth, h/H_0.

The maximum wave pressure appears near the still water surface and this pressure causes the large vertical wave force. The increase of the vertical wave force reduces the stability of the seawall, and a new type of wave dissipating works which could reduces the maximum wave pressure effectively must be investigated in further studies.

References

Inoue,M.: Hydraulic characteristics of seawall with inverted slope, Proc. 21th Conf. on Coastal Eng. in Japan, pp.417-421, 1974. (in Japanese)

Takata,A., Y.Yoshida, H.Fujilkawa: Relationships of sectional forms of seawall and wave overtopping, Proc. 26th Conf. on Coastal Eng. in Japan, pp.285-289, 1979. (in Japanese)

Kono,T., S.Takano, H.Tsuda: Comparison of wave overtopping rate between seawalls with various kind of cross section, Proc. 40th Conf. on Coastal Eng. in Japan, pp.681-685, 1993. (in Japanese)

Yamamoto,M., Y.Nishi: Developments of the seawall having remote absorber to reduce overtopping, Proc. 31th Conf.on Coastal Eng. in Japan, pp.537-541, 1984. (in Japanese)

Takayama,T., N.Ikeda, T.Nagai, M.Takayama: Model tests on the reduction of wave overtopping rate by a broad submerged breakwater, Proc. 35th Conf. on Coastal Eng. in Japan, pp.587-591, 1988. (in Japanese)

Sasajima,T., K.Yamanaka, K.Kimura, Y.Mizuno, S.Kikuchi: Study on hydraulic characteristics of double alignment breakwater, Proc. 40th Conf. on Coastal Eng. in Japan, pp.645-649, 1993. (in Japanese)

Goda,Y.: Random seas and design of maritime structures, University of Tokyo Press, 1985.