CHAPTER 142

WAVE PRESSURES ON SLIT-TYPE BREAKWATERS

by

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ABSTRACT

For severe storm waves with periods of 7.0 sec to 14.0 sec and heights of 6.3 m to 9.0 m, it was proved that the resultants of the maximum simultaneous pressures exerted by breaking waves on the slit-type breakwaters with the optimum relative chamber width of 1/L = 0.05 to 0.07 were in most cases less than 70 per cent of those exerted on the conventional composite-type breakwaters.

INTRODUCTION

The experimental results in the previous study (2) showed that the resultants of the maximum simultaneous pressures exerted on the slit-type breakwaters by breaking waves with periods of 6.0 sec and 7.0 sec and heights of 3.3 m to 4.3 m were less than about 60 per cent of those exerted on the conventional composite-type breakwaters, while the resultants of the maximum simultaneous pressures exerted on the slit-type breakwaters by non-breaking or standing waves were a little less than or approximately equal to those on the conventional composite-type breakwaters.

For more severe storm waves with periods of 7.0 sec to 14.0 sec and heights of 6.3 m to 9.0 m, the resultants of the maximum simultaneous pressures exerted on the slit-type breakwaters located at a water depth of 16.0 m by breaking and non-breaking waves are presented herein, compared with those on the conventional composite-type breakwaters. Finally the optimum relative chamber width, 1/L, for the slittype breakwater is shown.

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EXPERIMENTAL EQUIPMENT AND PROCEDURES

The experiments were carried out at a scale of 1/25 in a 100 mlong wave channel of 2 m-height and 1.2 m-width with a wind blower at the Harbor and Coastal Engineering Laboratory of Osaka City University.

Cross-Sections of Breakwater Model. — As the basic crosssection of the breakwater models used in the experiments, the south breakwater in the Port of Kashima (1) was selected, as shown in Fig. 1. The breakwater, 2,900 m in overall length, was constructed in 1969 at water depths from about 9 m to 20 m below the Datum Line (D.L.), and was severely hit by storm waves in January of 1970, the characteristics of which were hindcast to be $H_{1/10} = 10$ m and $T_{1/10} = 10$ sec to 12 sec. The vertical walls of reinforced concrete caisson were slid toward harbor-side by 0.24 m to 1.81 m. The experiments (1), which were conducted at a scale of 1/25 at the same wave channel as used at this experiment, showed that the maximum resultant pressure of $P_e = 193$ t/m was exerted by a wave with H = 9.6 m and T = 8 sec, and the value was confirmed by the maximum resultant pressure of $P_{cal} = 202$ t/m which was obtained by the wave-pressure formula (1).



FIG. 1.- Cross-Section of Kashima South Breakwater

The five cross-sections of breakwater model were used in the experiments, as shown in Figs. 2 to 6 and Table 1. As known from Figs. 2 to 6 and Table 1, the width of wave chamber, 1, was changed to be 6 m and 10 m. Fig. 7 shows the profile of the model sea bed and the position of a wave recorder for offshore waves.

Void Ratios of the Slit-Type Box Wave Absorber. — The void ratios of the slotted vertical front-wall and slotted horizontal bottom-wall of the wave absorber were constant $\lambda = 0.24$ and $\lambda' = 0.15$, respectively (2).

Conventional Composite-Type Breakwater. ——— The cross-sections of conventional composite-type breakwater were made by attaching a iron plate to the sea-side of the vertical front-wall of the slit-type breakwater from the top to the bottom.

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Cross- Section (1)	Width of wave chamber l in meters (2)	Top width of rubble- mound B in meters (3)	Berm (4)	Top of rubble- mound in meters (5)	Sea bottom in meters (6)	Crown of caisson in meters (7)
I	10.0	8.0	With	D.L 8.5	D.L 16.0	D.L.+ 5.0
11	6.0	7.0	With	D.L 8.5	D.L 16.0	D.L.+ 5.0
111	6.0	8.0	Without	D.L 8.5	D.L 16.0	D.L.+ 5.0
IV	6.0	12.0	Without	D.L 8.5	D.L 16.0	D.L.+ 5.0
v	6.0	6.0	Without	D.L 8.5	D.L 16.0	D.L.+ 5.0

TABLE 1.- Cross-Sections of Slit-Type Breakwater used in the Experiments











FIG. 4.- Cross-Section III

FIG. 5.- Cross-Section IV



FIG. 6.- Cross-Section V



FIG. 7.- Profile of the Model

Figs. 8 and 9 show the positions of wave pressure gauges installed in the breakwater.





FIG. 9.- Positions of Pressure Gauges

Characteristics of Waves used in the Experiments. ——The heights and periods of the waves used in the experiments were H = 6.3 m to 9.0 m and T = 7.0 sec to 14.0 sec. The wind velocity was constant 38 m/sec through the experiments. Table 2 summarizes all the conditions tested.

Tidal level	Wind velocity	Incide	nt wave	Steepneee	Crose-Section	
in meters (1)	in metere per eccond (2)	Period in seconde (3)	Wave height in metere (4)	H/L (5)	ueed in experiment (6)	
		7.0	6,8	0.099	II	
			6.3	0.076	IV	
		8.0	7.0	0.084	11	
			8.0	0.096	I∿V	
	38	10.0	6.9	0.062	IV	
D.L.± 0.00		10.0	8.7	0.078	$\mathbf{I} \sim \mathbf{V}$	
(L.W.L.)		12.0	7.0	0.050	IV	
		12.00	9.0	0.065	III , IV	
) .	14.0	7.0	0.042	IV	
			8.7	0.053	ι ∿ ν	
		8.0	7.8	0.094	I, II	
	0	10.0	8.6	0.077	Ι, Π	
		14.0	8.6	0.052	Ι, Π	
		8.0	8.0	0.094	IV	
D.T. A. 0.75	38	10.0	8.7	0.077	IV	
		12.0	9.0	0.064	IV	
		14.0	8.7	0.051	IV	

TABLE 2.- Conditions tested in the Experiments

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EXPERIMENTAL RESULTS AND ANALYSIS

Maximum Simultaneous Wave Pressure and Maximum Wave Pressure Intensity for Breaking Waves. ——— Wave pressures exerted on five points of the slotted vertical front-wall (shown by Fl to F7 in Fig. 9) and on five points of the vertical solid back-wall (caisson) (shown by Bl to B7 in Fig. 9) were simultaneously measured. The maximum simultaneous wave pressures exerted on the slotted vertical front-wall and those on the solid back-wall do not simultaneously occur, and the former always occurred earlier than the latter. However, when the intensity of the wave pressure was small, the change of the maximum simultaneous pressures in a short time was so little that both maximum simultaneous pressures may be approximately considered to simultaneously occur. Therefore, for such cases the sum of both maximum simultaneous pressures was taken as the maximum simultaneous pressure exerted on the slit-type breakwater, as denoted by P_{e max}(slit) (2).

When wave pressures are so strong as in the cases of this experiment, however, the maximum simultaneous pressures change rapidly even in a short minute. The experiment showed that the resultant of the maximum simultaneous pressures exerted on the slit-type breakwater, $P_{e\max}(\text{slit})$, was the sum of the resultant of the maximum simultaneous pressures exerted on the slit-type breakwater, of the pressures simultaneously exerted with those of the back-wall on the slotted front-wall. Figs. 10 to 14 show the vertical distributions of the maximum simultaneous pressures exerted by strong breaking waves on the slit-type breakwaters with the cross-sections of I to V and those on the conventional composite-type breakwaters with the same cross-sections as I to V for comparison, respectively.

The resultants of the maximum simultaneous pressures on the slittype breakwaters, $P_{e\max}(\text{slit})$, and those on the conventional composite-type breakwaters, $P_{e\max}(\text{compos.})$ are summerized in Tables 3 to 7 for the breakwaters with the cross-sections of I to V, respectively. These tables also show the resultants of the maximum simultaneous pressures obtained by the wave pressure formulas for conventional composite-type breakwaters, $P_{C\max}(\text{compos.})$ (3). The wave pressure formulas used for breaking waves were those for composite-type breakwaters with low rubble-mounds such as $0.40 \leq h_1/h_2 < 0.75$, and the resultants of the maximum simultaneous pressures for standing waves were calculated by use of P_{A}' and P_{A} (4).

Figs. 15 and 16 summerize the ratios of $P_{e \ max}(slit)$ over $P_{c \ max}(compos.)$ and $P_{e \ max}(slit)$ over $P_{C \ max}(compos.)$ for breaking waves. It may be stated from these figures that the ratios of $P_{e \ max}(slit)/P_{e \ max}(compos.)$ for breaking waves are within 0.48 to 0.81 in Fig. 15 and the ratios of $P_{e \ max}(slit)/P_{C \ max}(compos.)$ are 0.44 to 0.77 in Fig. 16, and in most of the cases of breaking waves both the ratios are less than 0.70.

According to Figs. 10 to 14, the maximum wave pressure intensities on the slotted front-walls and the solid back-walls of the slit-type breakwaters reduce to less than 60 % of those on the conventional solid caissons of composite-type breakwaters, and the reduction of the pressure-intensity becomes larger as the intensity of shock pressure exerted on the caisson of composite-type breakwater becomes higher.

Effect of the Top-Width of Base-Rubble-Mound. Effect of the top-width of the base-rubble-mound of the slit-type breakwater, B, on the wave pressures was tested by changing B = 6.0 m (section V), B = 8.0 m (section III) and B = 12.0 m (section IV). The experimental results are listed in Tables 7, 5 and 6, respectively. According to Tables 5 to 7, it may be stated that the top-width, B, has little effect on wave pressure for the slit-type breakwater, while the effect is remarkable for the conventional composite-type breakwater.

Maximum Simultaneous Wave Pressure for Standing Waves. ----- The maximum simultaneous wave pressures exerted on the slit-type breakwaters by standing waves and partial standing waves were almost same as or a little less than those for conventional composite-type breakwaters, when the heights of the top of vertical wall of composite-type breakwater from the still water level, H_{C} , were 2.5 m to 5.6 m which were comparable to the heights of incident waves, H = 3.3 m to 4.3 m (2). However, in the cases where the heights of incident waves were so large as H = 7.0 m to 9.0 m, compared with $H_{\rm C} = 5.0$ m (constant), there was caused a large quantity of wave-overtopping over the vertical walls of the composite-type breakwaters, which resulted in reduction of the resultant of the maximum simultaneous pressures, Pe max(compos.). Therefore the values of Pe max(compos.) measured in these cases were less than P_{C} max(compos.) calculated by the wave pressure formulas of P_A and P_A (4). Since the heights of composite waves generated at the sea-side of the slit-type breakwaters were smaller than those generated at the sea-side of the conventional composite-type breakwaters, the quantity of wave-overtopping over the slit-type breakwaters was smaller than that in the composite-type breakwaters. This fact results in some cases where $P_{e max}(slit)$ were a little larger than $P_{e max}(compos.)$ and nearly same as or slightly smaller than P_{C max}(compos.) calculated by the formulas of P_{h}' and P_{h} , as shown in Tables 3 to 7.

Upward Pressure on the Slotted Bottom-Wall. ——— The upward pressures exerted on the slotted horizontal bottom-wall by the waves transmitted underneath the wave absorber were as large as $p_u = 4.0 \text{ t/m}^2$ to 8.0 t/m² which were nearly same as the intensities of the horizontal wave pressures exerted at the same level as the slotted bottom-wall on the solid back-wall. However, when the trough of a receding wave came considerably down below the bottom-wall, the wave severely hit upward on the bottom-wall at the time of upward moving, and the intensities of the upward pressures reached up to $p_u = 9.3 \text{ t/m}^2$ to 13.4 t/m² which were much larger than the intensities of horizontal wave pressures

exerted at the same level on the solid back-wall. However, when the slotted bottom-wall was installed so as to be located a little lower than the lowest trough of the design wave, the intensities of the upward pressures reduced to $p_u = 8.5 \text{ t/m}^2$ to 7.2 t/m², respectively. These experimental results are shown in Table 8.

OPTIMUM CHAMBER WIDTH FOR WAVE PRESSURE

As has already been mentioned, it was proved that the change of the width of wave chamber from 1 = 6.0 m to 10.0 m had no definite and noticeable effect on the intensities and their vertical distributions of the maximum simultaneous wave pressures exerted on the slit-type breakwaters by breaking waves and non-breaking waves.

As known in Tables 3 to 7, all of the largest breaking wave pressures for the slit-type breakwaters with cross-sections I to V were exerted by breaking waves with periods of 8.0 sec to 10.0 sec, which had wave-lengths of L = 83 m to 112 m. Therefore, for the width of wave chamber 1 = 6.0 m, the ratios of 1/L, which was designated as relative wave chamber width, were 0.07 to 0.05. In the previous experiments (2), largest breaking wave pressures were exerted by breaking waves with a period of 7.0 sec, which had wave lengths of L = 61 m to 66 m. Since there were no noticeable differences between the maximum simultaneous pressures exerted on the slit-type breakwaters with different widths of wave chamber, 1 = 3.75 m and 5.50 m, the wave chamber width was decided 1 = 3.70 m for the slit-type breakwater in the Port of Osaka, which has been under construction since 1977. As the period of the design wave is 7.0 sec, and its wave lengths are L = 61 m to 66 m, the ratio of 1 and L is about 0.06.

Therefore it may be stated that the optimum relative wave chamber width, $(1/L)_{opt}$, is 0.05'to 0.07, on an average 0.06, for slit-type breakwaters. More definitely and clearly speaking for the purpose of practical design, the optimum wave chamber width, 1, would be 3.70 m or so for moderate waves with heights equal to or less than about 5.0 m and periods equal to or less than about 7.0 sec, and l = 6.0 m or so for larger waves with heights larger than 5.0 m till about 10.0 m and periods larger than 7.0 sec till about 15.0 sec.

REFLECTION COEFFICIENT OF SLIT-TYPE BREAKWATER

The heights, H_C , of the composite waves, generated at one to two wave lengths offshore of the slit-type breakwaters and composite-type breakwaters, were measured by visual observation through the glass wall of the wave channel in all the experiments. The coefficients of reflection of both the breakwaters, K_R , obtained from H_C , are shown in Tables 3 to 7. The values of K_R in the slit-type breakwaters are about 0.10 to 0.30 for breaking waves, and about 0.50 to 0.70 for non-breaking waves, while K_R in the composite-type breakwaters are about 0.50 to 0.60 for breaking waves and about 0.70 to 0.80 for non-breaking waves.

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Fig. 17 shows relationships between K_R and T as well as K_R and 1/L for the cross-section V of breakwater (l = 6.0 m) when the incident waves are H_I = 8.0 m to 9.0 m. The theoretical curve shown in Fig. 17 was obtained so as to K_R = 0.20 at $1/L \approx 0.15$.

CONCLUSIONS

It may be stated that the most outstanding characteristics of the slit-type breakwater, which denotes a special composite-type breakwater attached a slotted box-type wave absorber to the sea-side vertical wall of the caisson near the still water level, is to be able to reduce the resultants Pe max(slit) of the maximum simultaneous shock pressures exerted by breaking waves to less than 70 % of those exerted on the conventional composite-type breakwaters, Pe max(compos.), or P_{c max} (compos.) which denotes the resultant of the maximum simultaneous pressures calculated by the wave pressure formulas for breaking waves (3). The point of action of these resultant pressures should be taken at the still water surface. The effect of width, 1, of the wave chamber of the box-type wave absorber on the wave pressures is not so sensible as the effect on reflection coefficient, and the optimum relative chamber width, 1/L, would be 0.05 to 0.07, on an average 0.06. It may be stated, therefore, for practical design that the optimum chamber width, 1, would be 3.70 or so for moderate design waves with heights equal to or less than about 5.0 m and periods equal to or less than 7.0 sec, and 1 = 6.0 m or so for larger waves with heights larger than 5.0 m till about 10.0 m and periods larger than 7.0 sec till about 15.0 sec.

For non-breaking waves the $P_{e \max}(\text{slit})$ could be obtained from $P_{c \max}(\text{compos.})$, which denotes the resultant of the maximum simultaneous pressures calculated by the wave pressure formulas for non-breaking or standing waves (3) (4).

The top of the slotted vertical front-wall of the slit-type breakwater should be taken at the same level as the crown of the solid caisson wall for ordinary cases, and the slotted horizontal bottom-wall be installed at such a level as a little lower than the lowest trough of the design wave at the slit-type breakwater to avoid high upward pressures exerted from underneath the bottom-wall.

The void ratio of the slotted vertical front-wall should be $\lambda = 0.24$ or so and that of the slotted horizontal bottom-wall be $\lambda' = 0.15$ or so.

The coefficients of reflection, ${\rm K}_{\rm R},$ of the slit-type breakwaters which have the optimum chamber width, 1, as described here, and the void ratios of λ = 0.24 and λ' = 0.15 are about 0.10 to 0.30 for breaking waves and about 0.50 to 0.70 for non-breaking waves. These values of ${\rm K}_{\rm R}$ are smaller than about 0.50 to 0.60 for breaking waves and about 0.70 to 0.80 for non-breaking waves in the conventional composite-type breakwaters.

TABLE 3.- Comparison of the Maximum Simultaneous Pressures on a Slit-Type and a Composite-Type Breakwater (Cross-Section I) Chamber width l=10.0 m, Top of base rubble-mound, D.L.-8.5 m, Top width of base rubble-mound, B=8.0 m, w₀=1.03 t/m³, With berm

· h							
Upward pressure Pu in tons	per square meter (16)	4. 6 ∿ 6.0	5.8 v 7.0	6.5 ∿ 8.6	4.0 ~ 4.9	5.6 ~ 7.3	6.1 v 7.6
s of c ure (slit)	/Pc max (15)	0.63	0.55	1.01	0.56	0.52	0.81
Ratic wav press Pe may	/Pe max (14)	0.68	0.53	1.32	0.72	0.60	1.14
Pe max(slit) Pe max(slit) in tons	meter (13)	84.4	89.7	133.7	73.4	83.8	106.7
Pc max in tons	meter (12)	133.6	162.8	(A') 132.9	130.3*	161.0	(a') 131.3
Max.res Solid Pe max in tons	meter (11)	124.4	170.0*	101.3	101.5*	140.3	93.7
cient tion	Slit (10)	0.10	0.30	0.39	0.10	0.27	0.40
Coeffi of reflec K _R	Solid (9)	0.58	0.70	0.75	0.62	0.72	0.76
t of site ters	slit (8)	80 80	11.3	12.1	8.6	10.9	12.0
Heigh compo wav HC	Solid (7)	12.6	14.8	15.2	12.6	14.8	15.1
H/L	(9)	0.096	0.078	0.053	0.094	0.077	0.052
ave Wave length I	meters (5)	83.4	111.8	165.7	83.4	111.8	165.7
cident w Wave height H	meters (4)	8.0	8.7	8.7	7.8	8.6	8.6
In Period T in	seconds (3)	8.0	10.0	14.0	8.0	10.0	14.0
Wind velocity in meters per	second (2)		38			0	
Tidal level in	meters (1)			D.L.‡ 0	(L.W.L.)	2	·

* : denotes breaking wave pressure measured

****** : denotes breaking wave pressure calculated

(A'): denotes the resultant of the max. simultaneous pressures calculated by the formula $P_{A'}$

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TABLE 4.- Comparison of the Maximum Simultaneous Pressures on a Slit-Type and a Composite-Type Breakwater (Cross-Section II) Chamber width 1=6.0 m, Top of base rubble-mound, D.L.-8.5 m, Top width of base rubble-mound, B=7.0 m, w_0=1.03 t/m³, With berm

Upward pressure D,,	in tons	per square meter (16)	I	1	5.5	7.5	8.1	4.7	6.1	8.0
s of Ve sure	(slit)	/Pc max (15)	0.77	0.73	0.61	0.72	1.04	0.61	0.64	1.02
Ratio	Pe max	/Pe max (14)	0.73	0.62	0.55	0.81	1.21	0.48	0.65	1.26
s pressures Slit-type Pe max(slit)	in tons	meter (13)	70.4	72.5	78.7	109.1	137.6	76.6	96.4	133.6
sult.wave wall Pc max	in tons per	meter (12)	91.3*	** 8.66	128.2	152.0*	(A') 132.9	125.0	150.3*	(A') 131.3
Max.re: Solid Pe max	in tons Der	meter (11)	96.5*	117.8*	142.8*	134.2*	113.5	160.6	147.4	106.0
icient E stion	~	slit (10)	0.19	0.23	0.29	0.53	0.68	0.32	0.59	0.66
Coeff: o: reflec	X	Solid (9)	0.50	0.69	0.60	0.68	0.78	0.53	0.70	0.79
it of site e	ters	slit (8)	8.1	8.6	10.3	13.3	14.6	10.3	13.7	14.3
Heigh compc wav	H H	Solid (7)	10.2	11.8	12.8	14.6	15.5	9.II	14.6	15.4
	H/L	(9)	660.0	0.084	0.096	0.078	0.053	0.094	0.077	0.052
ave Wave length	чų	meters (5)	68.7	83.4	83.4	111.8	165.7	83.4	8.111	165.7
cident w Wave height	н ц	meters (4)	6.8	7.0	8.0	8.7	8.7	7.8	8.6	8.6
In Period	ti ti	seconds (3)	7.0	8.0	8.0	10.0	14.0	8.0	10.0	14.0
Wind velocity in	meters	second (2)			38				0	
Tidal level	in	meters (1)				D.I.+0	(T.W.L.)	:		

* : denotes breaking wave pressure measured

** : denotes breaking wave pressure calculated

(A'): denotes the resultant of the max. simultaneous pressures calculated by the formula $P_{\mathbf{A}}^{'}$

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TABLE 5.- Comparison of the Maximum Simultaneous Pressures on a Slit-Type and a Composite-Type Breakwater (Cross-Section III) Chamber width 1=6.0 m, Top of base rubble-mound, D.L.-8.5 m, Top width of base rubble-mound, B=8.0 m, w_0=1.03 t/m³, Without berm

Interd	pressure	Pu in tons	per square	f meter (16)	ع	1	J	8.1				
os of	ve	sure v(slit)		/Pc max (15)	0.77	0.63	06.0	86.0				
Rati	PM	pres Pe ma		/Pe max (14)	0.69	0.65	0.93	1.23				
e pressures	Slit-type	Pe max(slit) in tons	per	meter (13)	102.5	102.1	122.0	130.3				
sult.wave	wall	Pc max in tons	per	meter (12)	133.6	162.8*	(A') 136.0	(A') 132.9				
Max.res	Solid	Pe max in tons	per	meter (11)	148.5*	156.1*	131.4	106.2				
cient	· · · ·	tion		Slit (10)	0.26	0.52	0.49	0.68				
Coeffi	ç	reflec K _R		Solid (9)	0.55	0.63	0.57	0.78				
t of	site	U	ters	slit (8)	10.1	13.2	13.4	14.6				
Heigh	compo	wav H _C	in me	Solid (7)	12.4	14.2	14.1	15.5				
		H/L		(9)	0.096	0.078	0.065	0.053				
ave	Wave	length L	'n	meters (5)	83.4	111.8	139.1	165.7				
cident w	Wave	height H in		meters (4)	8.0	8.7	0.6	8.7				
Ĕ		Period T	'n	seconds (3)	0.8	10.0	12.0	14.0				
Wind	Wind relocity in I meters		рег	second (2)		00 M						
	Tidal	Tevel	ų i	meters (1)		D.L.† 0	(L.W.L.)					

* : denotes breaking wave pressure measured

** : denotes breaking wave pressure calculated

(A'): denotes the resultant of the max. simultaneous pressures calculated by the formula $P_{A'}$

TABLE 6.- Comparison of the Maximum Simultaneous Pressures on a Slit-

Type and a Composite-Type Breakwater (Cross-Section IV)

Chamber width 1=6.0 m, Top of base rubble-mound, D.L.-8.5 m, Top width of base rubble-mound, B=12.0 m, w_0=1.03 t/m³, Without berm

1					·	•••				-		
Upward	pressure	Pu in tons	per square	meter (16)	4.0	4.9	4.9	7.0	5.7	7.2	6.1	8.5
os of	Ratios of wave pressure Pe max(slit)		/Pc max (15)	0.44	0.61	0.59	0.66	0.70	0.61	0.80	0.81	
Rati			/Pe max (14)	0.52	0.60	0.67	0.62	11.1	0.64	1.13	1.03	
e pressures	pressures Slit-type e max(slit) in tons		per	meter (13)	47.6	66°3	75.6	122.5	74.7	118.2	86.4	107.0
sult.wave	wall	Pc max in tons	per	meter (12)	108.6	163.9*	127.5*	186.2*	(A') 106.0	194.8	(A') 107.5	(A') 132.9
Max.re	Solid	Pe max in tons	per meter (11)		91.2*	166.9*	111.6*	199.0*	67.4	184.2*	76.6	104.1
icient	<u>ч</u>	ction		slit (10)	0.24	0.25	0.34	0.43	0.51	0.49	0.54	0.61
Coeff	•	refle		Solid (9)	0.59	0.60	0.61	0.63	0.67	0.61	0.63	0.72
ht of	osite	e 0 0	eters	Slit (8)	7.8	10.0	9.5	12.5	10.6	13.4	10.8	14.0
Heig	comp	т А А	in m	Solid (7)	10.0	12.8	11.1	14.2	11.7	14.5	11.4	15.0
		H/L		(9)	0.076	0,096	0.062	0.078	0.050	0.065	0.042	0.053
ave	Wave	Length	'n	meters (5)	83.4	83.4	111.8	111.8	139.1	139.1	165.7	165.7
cident w	Wave	neight K	'n	meters (4)	6.3	8.0	6.9	8.7	7.0	0.6	7.0	8.7
8	Inc.	reriod	ŗ	seconds (3)	8.0	8.0	10.0	10.0	12.0	12.0	14.0	14.0
Wind	velocity	meters	per	second (2)				38				
	Tidal v level in in meters (1)						D.I.+ 0	(-T-M-T)				

* : denotes breaking wave pressure measured

** : denotes breaking wave pressure calculated

(A'): denotes the resultant of the max. simultaneous pressures calculated by the formula $P_{\mathbf{A}}$

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TABLE 7.- Comparison of the Maximum Simultaneous Pressures on a Slit-Type and a Composite-Type Breakwater (Cross-Section V)

chamber width l=6.0 m, Top of base rubble-mound, D.L.- β .5 m, Top width of base rubble-mound, B=6.0 m, w_0 =1.03 t/m³, Without berm

per square meter (16)	5.5	I	I	7.9
/Pc max (15)	0.67	1.05	0.82	66*0
/Pe max (14)	0.72	1.05	1.12	1.40
per meter (13)	86.5	102.0	110.8	130.9
per meter (12)	128.2	(A) 97.6	(A') 136.0	(A') 132.9
meter (11)	119.5*	97.6	98,8	93.8
slit (10)	0.31	0.49	0.54	0.57
Solid (9)	0.61	0.75	0.81	0.76
Slit (8)	10.5	13.0	13.9	13.7
solid (7)	12.9	15.2	16.3	15.3
(9)	0.096	0.078	0.065	0.053
meters (5)	83.4	111.8	139.1	165.7
meters (4)	8.0	8.7	0.6	8.7
seconds (3)	8.0	10.0	12.0	14.0
per second (2)			38	
meters (1)		0.L.+ 0	(T.W.L.)	_
	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$

* : denotes breaking wave pressure measured

** : denotes breaking wave pressure calculated

(A) : denotes the resultant of the max. simultaneous pressures calculated by the formula \mathbb{P}_{A}

(A'): denotes the resultant of the max. simultaneous pressures calculated by the formula ${\tt P}_{\rm A}{\tt '}$

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TABLE 8.- Up-Lift Pressures on the Bottom-Wall of Slit-Type Breakwater (Cross-Section IV)

Chamber width 1=6.0m, Top of base rubble-mound, D.L.-8.5m, Top width of base rubble-mound, B=12.0m, w₀=1.03t/m³, Without berm

Upward	pressure	pu	in tons	per square	meter	(10)		4.9		4.9		7.5		7.0		13.4		7.2		9.3	8,5	
ave pressures	Slit-type	Pe max(slit)	in tons	per	meter	(6)		6 6. 3		I		122.5		ł		118.2		ł		107.0	I	
resultant w	wall	Pc max	in tons	per	meter	(8)	*	163.9	+	157.1	*	186.2	*	179.9	*	194.8	*	191.6		132.9	138.8	
Maximum	Solid	Pe max	in tons	per	meter	(1)	*	166.9		I	*	0.661		I	*	184.2		I		104.1	ı	
			H/L			(9)		0.096		0.094		0.078		0.077		0.065		0.064		0.053	0.051	
	Wave	length	ч	in	meters	(2)		83.4		85.1		8.111		113.0		139.1		140.6		165.7	170.0	
cident wave	Wave	height	н	'n	meters	(4)	8.0						8.7				0.6				8.7	
ц		Period	64	r in (3)			0.8			10.0		12.0			14.0							
Wind	velocity	ų.	meters	per	second	(2)		38			0	35				38		38		88		
	Tidal	level		in	meters	(1)	-	D.L. 1 0.00		D.L. + 0.75		(L.W.L.)		c/.0 + .I.d	• • • •	D.L. 2 0.00		D.L. + 0.75		D.L. ± 0.00	D.L. + 0.75	

* : denotes breaking wave pressure measured

****** : denotes breaking wave pressure calculated

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FIG. 17.- Relationships Between $K_{\rm R}$ and T (1/L)

APPENDIX - REFERENCES

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