Transmission-Reflection Wave on Curtainwall Pile Breakwater with and without Bottom Protection

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Abstract: The quay is ideally free from wave interference so ships can dock to rise and fall of passengers or loading and unloading goods safely and comfortably. The harbours that open directly to the ocean without being protected by breakwaters are quite vulnerable to unfriendly weather when very high wind speed occurs high sea waves rise very high can lead to the process of relying on the ship on rise and fall of passengers or loading and unloading goods cannot be done safely and comfortably. Generally the size of the gravitational breakwater increases with the depth of the water, starting from the base of a large foundation and requiring an enormous amount of construction material if it is built in deep water, so this breakwater type are expensive in deeper water.The curtainwall pile breakwater is one of partially barrier breakwater types, that requires less concrete per-unit run and capable of transmitting less wave energy. Research on curtaianwall-pile breakwater (CPB) and the same types has been done by many researchers, but there is no research on CPB equipped with protection base to protect the pile from wave scouring. The experimentally study has be done in wave flume with physical model. The size of the wave flume are length 15 meters, depth 0.45 meters, and wide 0.30 meter that equipped with wave maker, damper, and wave probe. The purpose of study investigate transmission wave coefficient (K_t) and reflection wave coefficient (K_t) CPB effect of the bottom protection with low rubble-mound. Based on the result of study is known that the curtainwall pile breakwater (CPB) with bottom protection give transmission wave coefficient (K_t) more less (decrease value: 0.04 – 0.22) than CPB without bottom protection and give reflection wave wave coefficient (K_r) larger (increase value 0.07) depend value of h/d. The generally curtainwall pile breakwater (CPB) without bottom protection, if the value h/d and H/L increase, transmission wave coefficient (K_t) will decrease and reflection wave coefficient (K_r) will increase. The value K_t = 0.91 – 0.42 and K_r = 0.26 – 0.65 depend h/d and H/L.

1 INTRODUCTION

There are 2 types of breakwaters, namely full protection breakwaters and partial protection breakwaters (Ahmed, 2011). Full protection breakwaters such as rubblemound, caisson, and combination breakwaters, while partial protection breakwaters such as submerged breakwaters, detached breakwaters, pipe breakwaters, floating breakwaters and peneumatic breakwaters. Gravity breakwaters that use upright stacks of rocks or caisson are often used to obtain a calm pond for ships and protect port facilities from sea wave attacks. In general, the size of gravity breakwaters increases with the depth of water, starting from the bottom of large foundations and requiring a very large amount of construction material if built in deep waters (Suh et al., 2006 and 2007). The construction of gravitational breakwaters becomes very expensive with increasing water depth (size and volume increases) and the width of the pond also decreases with the size of the structure. Gravity breakwater cannot be built on soft soils, where hard soil structures are deep enough.

One solution to the problems is the curtainwall pile breakwater (CPB) or pile support skirtwall breakwater (PSSB). The basic concept of CPB is to become a wave barrier around the surface area where the movement of water particles is larger, while the bottom is unobstructed (slot). Pile support structure of breakwater allows through outflow so that water circulation is very good and fish and organisms can go in and out through the CPB so that this type of

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breakwater is environmentally friendly. In soft soil with deep hard soil conditions, curtainwall pile breakwater (CPB) can be an alternative allaternative (Laju et al., 2011). There are many Research on the wall-pile breakwater (CPB) and the same types have been done by many : Koraim (2015), Ahmed and Schlenkoff (2014), Zang and Li (2014), Najedkazem and Gharabi (2012), Laju et al. (2011), Liu and Li (2011), Rageh et al. (2009), Ji and Suh (2008), Suh et al. (2006 & 2007), and Nelami and Rajendran (2002). Najedkazem and Gharabi (2012) proposed a coefficient of friction consisting of hydrodynamic characteristics for estimation. Liu and Li (2011) examined the hydrodynamic performance of the CPB with double walls to obtain reflection, transmission and wave force coefficients. The study of Ji and Suh (2008) conducted a study with irregular waves on many wall CPB in order to obtain reflection and transmission wave coefficients. There is no reseach CPB. There has been no previous studies on CPB combined with bottom protection.

The purpose of this study investigate of the reflection wave coefficient value (K_r) and he reflection wave coefficient value (K_r) of CPB combination botton protection is compared to CPB without bottom protection with CPB function from relative curtainwall depth (h/d) and wave steepness (H/L).

Sea waves do not transfer mass, but transfer energy. The rate of energy transport is called energy flux (F). Waves propagate through barriers such as curtainwall pile breakwaters (CPB), some of their energy will be reflected by the barrier, some will be forwarded to the rear of the structure through the structural gap and some will be damped. Generally, the concept of flux energy (F) which attack curtainwall pile breakwater (CPB) is illustrated in Figure 1 and a description of wave flux energy (F can be shown in equation 1 and equation 2, according to the concept of Paotonan and Yuwono (2011).

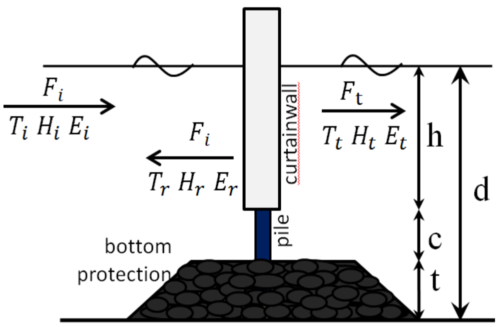

Figure 1: Definition sketch.

Where, $E=\frac{\rho.g.H^2}{8}$; $n=\frac{1}{2}\left(1+\frac{kd}{\sin 2kd}\right)$; $k=\frac{2\pi}{L}$; E= wave energy, H= wave heigt, C= wave propagation, T= wave period and L= wave length.

$$F_i = F_r+F_t+F_d \text{ then } F_d = F_i-(F_r+F_t) \quad (2)$$

$$F_d = \frac{1}{8}\rho.g.H_i^2\sqrt{gd} - \left(\frac{1}{8}\rho.g.H_r^2\sqrt{gd} + \frac{1}{8}\rho.g.H_t^2\sqrt{gd}\right) \quad (3)$$

$$\frac{H_d^2}{H_i^2} = 1-\left(\frac{H_r^2}{H_i^2}+\frac{H_t^2}{H_i^2}\right) \quad (4)$$

$$K_{Ed} = 1-(K_{Er}+K_{Et}) \text{ or } K_d{}^2 = 1-\left(K_r{}^2+K_t{}^2\right) \quad (5)$$

Where, H_i, H_r, H_t, K_{Ed}, K_{Er} dan K_{Et} successively are incident wave height, reflection wave height, transmission wave height, energy dissipation coefficient, reflection energy coefficient, transmission energy coefficient and K_r, K_t, K_d equation can be seen in Equation 6-8.

$$K_r = \frac{H_r}{H_i} \quad (6)$$

$$K_t = \frac{H_t}{H_i} \quad (7)$$

$$K_d = 1-(K_r^2+K_t^2) \quad (8)$$

The incident wave attack the barrier of partial protection, the reflection wave height is smaller than the height of the incident wave height. The reflected wave partial protection, which is characterized by upper envelope and lower envelope of the wave. Sketch envelop wave concepts of Dean and Dalrymple (1999) can be illustrated in Figure 2.

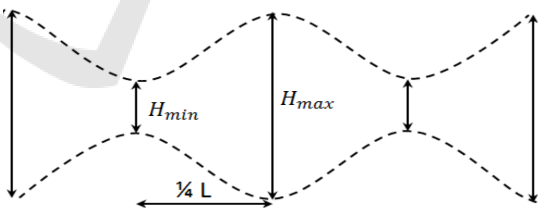

Figure 2: Envelope in a partial standing wave system.

The incident wave height (H_i) and the reflection wave wave (H_r) in the reflection wave that atact the partial protection breakwater, where the distance between H_{mak} and H_{min} is ¼ L (Dean and Dalrymple, 1) is defined Equation 9 and 10.

$$H_i = \frac{(H_{mak}+H_{min})}{2} \quad (9)$$

$$H_r = \frac{(H_{mak}-H_{min})}{2} \quad (10)$$

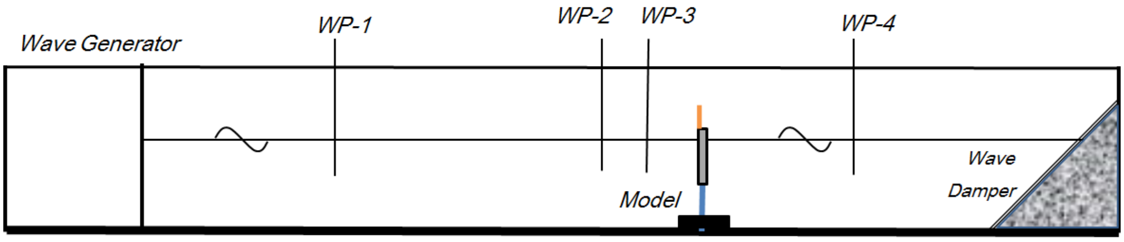

Figure 3: Sketch of experimental setup.

(a) (b)

Figure 4: CPB: a. CPB without bottom protection a. CPB with bottom protection.

According to the concept of Koraim (2015) to find the value of H_{mak} as far as L (for example waves when being modeled at the peak, at the same time the wave reaches the peak, as far as one wavelength) and H_{min} is obtained at the position ¼ L of the reflected wave (as far as 1.25L from the physical model).

2 RESEARCH METHODOLOGY

This research is an experimental research using physical models in a wave flume laboratory equipped with wave generators and wave dampers. Wave height recording uses a wave probe equipped with WTM (wave tide meter) and a computer to get the wave height. The wave flume sketch and the laying of the wave probe are shown in Figure 3.

The wave flume used in the study was 30 cm wide, 45 cm high, 15 m long and a water depth at the study of 20 cm. WP-1 (wave probe-1) is used to measure the incident wave height that be generated from wave generator, WP-2 and WP-3 measure the incident wave height and reflection wave height, and WP-4 measures the transmission wave height. Wave probe placement: WP-1 is located between the wave generator and the model for measuring the incident wave height, WP-2 and WP-3 are placed in front of the model with distances as far as L and 1.25 L to measure the reflection wave height (mixed wave height at H_max and H_min) as in the Koraim (2015) study, and WP-4 was placed in back beetwen model and wave damper to measure transmission wave height.

The depth of curtainwall (h/d) range 0-0.70 of curtainwall pile breakwater (CPB) was combinated with bottom protection (t/d = 0.20) and CPB without bottom protection (t/d= 0). Value h/d CPB respectively 0 (base curtainwall position on SWL), 0.10, 0.30, 0.50 and 0.70 below surface water level (SWL). Waves generated at the wave flume are regular waves with wave steepness (H/L) range 0.0097 - 0.0285. The wall material of the CPB model is acrylic, piles of CPB model are round woods, while the bottom of the pile is split with size: 5-10 mm as shown in Figure 4.

Dimensional analysis of transmission height wave (H_t) and transmission height wave (H_t) on CPB with

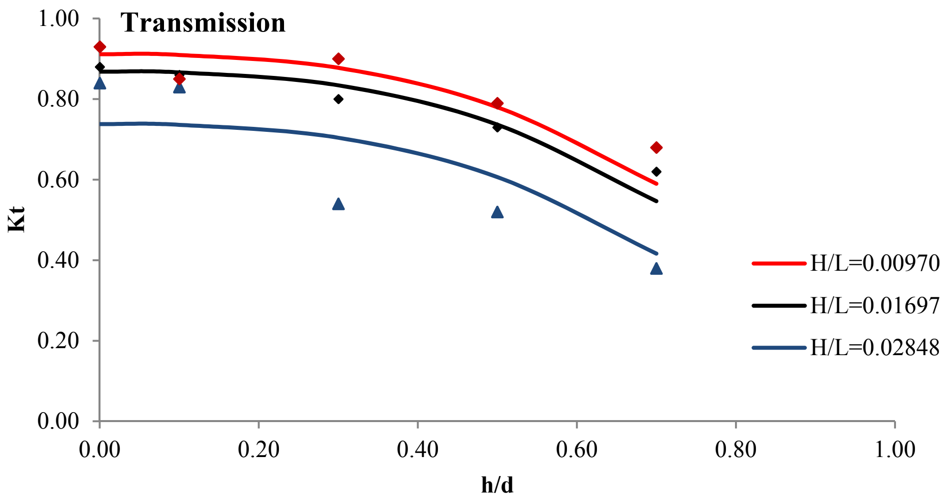

Figure 5: Effect of relative curtainwall depth on $\boldsymbol{K_t}$ (t/d=0).

bottom protection H_t= f (h, t, d, T, H_i, g) and H_r= f (h, t, d, T, H_i, g) with dependent parameter is H_t or H_r, the independent parameters are h, t, d, T, dan H_i, others parameter is g.

Based on result dimensioanal analysis, the formula is shown in Equation 11 and 12 respectively.

$$K_r = \frac{H_r}{H_i} = f(\text{H/L, h/d, t/d}) \text{ or } K_r = \frac{H_r}{H_i} = f(\frac{gT^2}{H_i}, \text{h/d, t/d}) \quad (11)$$

$$K_t = \frac{H_t}{H_i} = f(\text{H/L h/d, t/d}) \text{ or } K_t = \frac{H_t}{H_i} = f(\frac{gT^2}{H_i}, \text{h/d, t/d}) \quad (12)$$

In this study it that CPB for function of bottom protection height (t/d) is CPB with bottom protection, just one bottom protection condition (t/d=0.20).

3 RESULTS AND ANALYSIS

In this study the parameters that be reseached are reflection coefficient value (K_r) and transmission coefficient value (K_t) of curtaianwall pile breakwater (CPB) without bottom protection (t/d = 0) and curtaianwall pile breakwater (CPB) with bottom protection function of relative curtainwall depth (h/d) and wavesteepness (H/L).

Transmission coefficient (K_t) value of curtaianwall pile breakwater (CPB) without the bottom protection (t/d= 0) function of relative curtainwalldepth (h/d) and wave steepness (H/L) shown on Table 1, while the graph of effect of relative curtainwall depth (h/d) K_t shown in Figure 5.

Table 1: Transmission wave coefficient (K_t) function from h/d and H/L (t/d=0).

H/L	**h/d**				
	0	**0.10**	**0.30**	**0.50**	**0.70**
0.0097	0.93	0.85	0.90	0.79	0.68
0.0170	0.88	0.86	0.80	0.73	0.62
0.0285	0.84	0.83	0.54	0.52	0.38

Equation line is resulted statistical analysis using the SPSS program with multivariate non-linear data on Table 1 shown on Figure 5.

The reflection wave coefficient (K_r) of curtaianwall pile breakwater (CPB) without bottom protection (t/d= 0) on function of the relative curtainwalldepth (h/d) and wavesteepness (H/L) are displayed on Table 2, while the graph of the K_r relationship to the function h/d and H/L is shown in Figure 6.

Table 2: Reflection wave coefficient (K_r) fuction of h/d and H/L (t/d=0).

H/L	**h/d**				
	0	**0.10**	**0.30**	**0.50**	**0.70**
0.0097	0.26	0.33	0.34	0.40	0.58
0.0170	0.32	0.32	0.35	0.40	0.60
0.0285	0.32	0.35	0.44	0.55	0.78

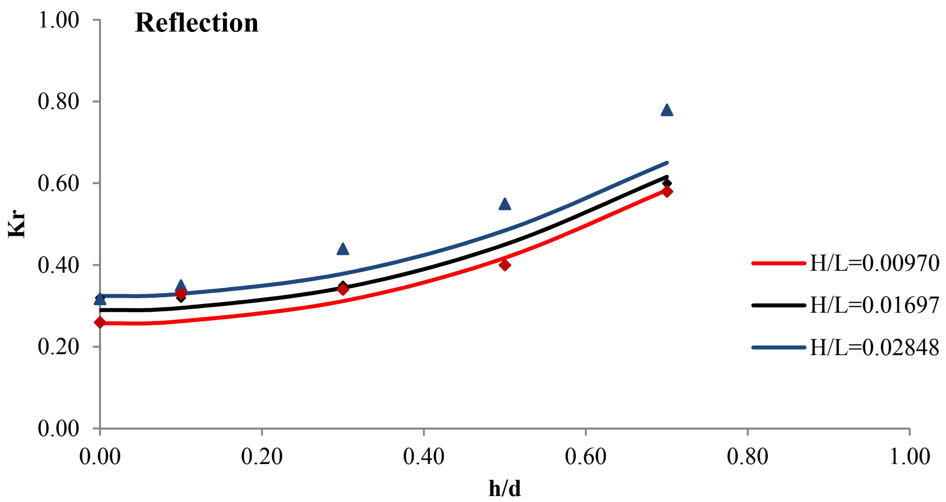

Figure 6: Effect of relative curtainwall depth on K_r (t/d=0).

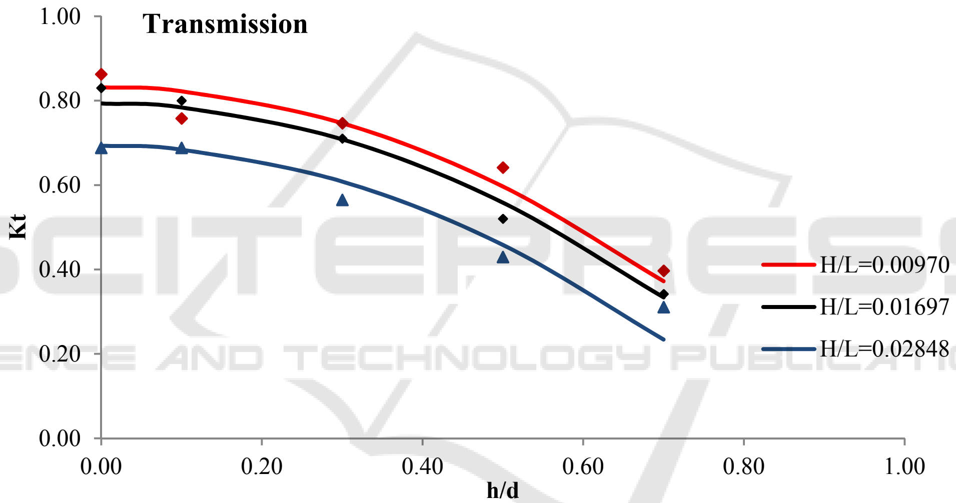

Figure 7: Effect of relative curtainwall depth on $\boldsymbol{K_t}$ (t/d=0.20).

Equation line statistical analysis using the SPSS program with multivariate non-linear data on Table 2 shown on Figure 6.

Table 3: Reflection wave coefficient (K_t) fuction of h/d and H/L (t/d=0.20).

H/L	**h/d**					
	0	**0.10**	**0.30**	**0.50**	**0.70**	**0.80**
0.0097	0.86	0.76	0.75	0.64	0.40	0.19
0.0170	0.83	0.80	0.71	0.52	0.34	0.17
0.0285	0.69	0.69	0.56	0.43	0.31	0.09

The transmission coefficient (K_t) value of curtaianwall pile breakwater (CPB) with the bottom protection (t/d = 0.20) function of relative curtainwall depth (h/d) and wavesteepness (H/L) shown on Table 3, while the graph of the K_t relationship to the function h/d and H/L is shown in Figure 7.

Equation line statistical analysis using the SPSS program with multivariate non-linear data on Table 3 shown on Figure7.

The reflection wave coefficient (K_r) of curtaianwall pile breakwater (CPB) with the bottom protection (t/d= 0.20) on function of the relative curtainwall depth (h/d) and wavesteepness (H/L) are displayed on Table 4, while the graph of the K_r

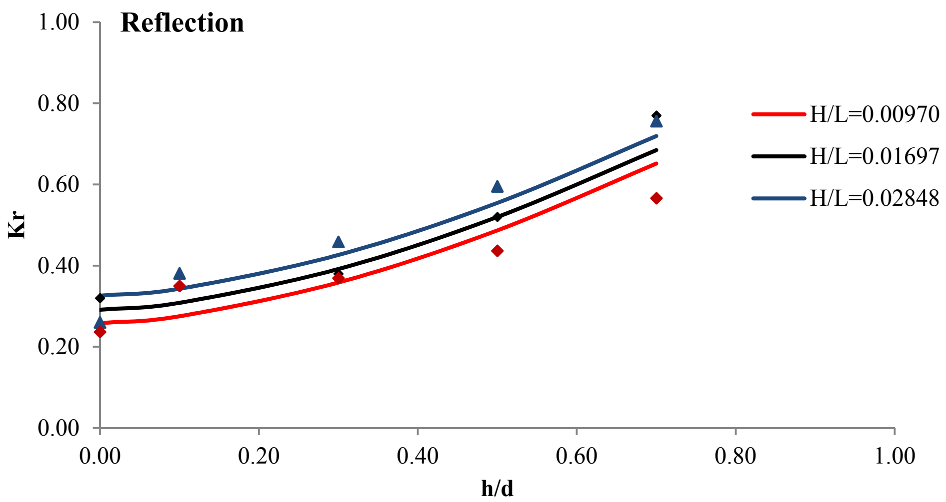

Figure 8: Effect of relative curtainwall depth on $\boldsymbol{K_r}$. (t/d=0.20).

relationship to the function h/d and H/L shown in Figure 8.

Table 4: Reflection wave coefficient (K_r) fuction of h/d and H/L (t/d=0.20).

H/L	**h/d**					
	0	**0.10**	**0.30**	**0.50**	**0.70**	**0.80**
0.0097	0.24	0.35	0.37	0.44	0.57	0.73
0.0170	0.32	0.35	0.38	0.52	0.77	0.80
0.0285	0.26	0.38	0.46	0.60	0.76	0.83

Equation line statistical analysis using the SPSS program with multivariate non-linear data on Table 4 shown on Figure 8.

Based on Figure 5 graph effect of relative curtainwall depth (h/d) on transmission wave coefficient (K_t) of CPB without bottom protection obtained that the transmission wave coefficient (K_t) decrease with increasing relative curtainwall depth (h/d) and wave steepness (H/L). The transmission wave coefficient (K_t) value ranges from 0.91-0.42 depending on relative curtainwall depth (h/d) and and wave steepness (H/L). The decreasing in transmission wave coefficient (K_t) ranges from 0-0.32 depending on relative curtainwall depth (h/d). The transmission wave coefficient (K_t) value decrease with increasing relative curtainwall depth (h/d) which curtainwall deeper causes the slot height of CPB to be reduced by increasing curtainwall causing the wave's ability to pass CPB that become transmission wave decreases and transmission wave coefficient (K_t) value decreases. If the wave steepness (HL) increases, increasing elevation wave peak and wave height while fixed slot height, thus incident wave pass through CPB that become transmission wave decrease and transmission wave coefficient (K_t) value decrease.

Based on Figure 6 graph effect of relative curtainwall depth (h/d) on reflection wave coefficient (K_r) of CPB without bottom protection obtained that reflection wave coefficient (K_r) decrease with increasing relative curtainwall depth (h/d) and wave steepness (H/L). The reflection wave coefficient (K_r) value ranges 0.26-0.65 depending on the value relative curtainwall depth (h/d) and wave steepness (H/L). The increasing in the reflection wave coefficient (K_r) value ranges 0-0.33 depending on the relative curtainwall depth (h/d). The increasing relative curtainwall depth (h/d) so that curtainwall) of CPB becomes the wave barrier increase will increasing reflected wave. The wave steepness (H/L) increases, increasing elevation wave peak and wave height while fixed slot depth of CPB below the curtainwall, thus the incident wave (H_i) passes through CPB will be reflected wave increase and reflection wave coefficient (K_r) increase.

Based on Figure 7 graph effect of relative curtainwall depth (h/d) on transmission wave coefficient (K_t) of CPB with bottom protection (t/d=0.20) obtained that the transmission wave coefficient (K_t) decrease with increasing relative curtainwall depth (h/d) and wave steepness (H/L). The transmission wave coefficient (K_t) value ranges from 0.83-0.23depending on relative curtainwall depth (h/d) and and wave steepness (H/L). The decreasing in transmission wave coefficient (K_t)

ranges 0-0.46 depending on relative curtainwall depth (h/d). The transmission wave coefficient (K_t) value decrease with increasing relative curtainwall depth (h/d) which curtainwall deeper causes the slot height of CPB to be reduced by increasing curtainwall causing the wave's ability to pass CPB that become transmission wave decreases and transmission wave coefficient (K_t) value decreases. If the wave steepness (HL) increases, increasing elevation wave peak and wave height while fixed slot height, thus incident wave pass through CPB that become transmission wave decreas and transmission wave coefficient (K_t) value decrease.

Based on Figure 8 graph effect of relative curtainwall depth (h/d) on reflection wave coefficient (K_r) of CPB with bottom protection (t/d=0.20) obtained that reflection wave coefficient (K_r) decrease with increasing relative curtainwall depth (h/d) and wave steepness (H/L). The reflection wave coefficient (K_r) value ranges 0.26 - 0.72 depending on the value relative curtainwall depth (h/d) and wave steepness (H/L). The increasing in the reflection wave coefficient (K_r) value ranges 0-0.39 depending on the relative curtainwall depth (h/d). The increasing relative curtainwall depth (h/d) so that curtainwall) of CPB becomes the wave barrier increase will increasing reflected wave. The wave steepness (H/L) increases, increasing elevation wave peak and wave height while fixed slot depth of CPB below the curtainwall, thus the incident wave (H_i) passes through CPB will be reflected wave increase and reflection wave coefficient (K_r) increase

Transmission wave coefficient (K_t) of CPB with bottom protection (this study t/d=0.20) when be compared with transmission wave coefficient (K_t) of CPB without bottom protection increase than transmission wave coefficient (K_t) of CPB without bottom protection. The increasing of the transmission wave coefficient (K_t) value of CPB with the bottom protection ranges 0 - 0.07 depending on the value of relative curtainwall depth (h/d), shown in Figure 5 and Figure 7. Equation line statistical result analysis using the SPSS program with multivariate non-linear data on Table 3 shown on Figure 7, defined equation 13.

$$K_t = -0.935\left[\frac{h}{d}\right]^{1.992} - 160.23\left[\frac{H}{L}\right]^{1.946} + 0.851 \qquad (13)$$

with R^2= 0.979 and R^2 is determination coefficient, where K_t is influenced on h/d dan H/L parameters by 97.9 % and the equation line shown on Figure 7

Reflection wave coefficient (K_t) of CPB with bottom protection (this study t/d=0.20) when be compared with reflection wave coefficient (K_r) of CPB without bottom protection decrease than reflection coefficient (K_t) of CPB without bottom protection. The increasing of the transmission wave coefficient (K_t) value of CPB with the bottom protection ranges 0 - 0.07 depending on the value of relative curtainwall depth (h/d), shown in Fig 5 and Figure 7. Equation line statistical result analysis using the SPSS program with multivariate non-linear data on Table 4 shown on Figure 8, defined Equation 14.

$$K_{r=} = 0.699\left(\left[\frac{h}{d}\right]^{1.613} + \left[\frac{H}{L}\right]^{0.237}\right) + 0.036 \qquad (14)$$

4 CONCLUSION

The wave incident, transmission, and reflection characteristics of CPB, curtainwall, and bottom protector are experimentally studied under normal regular waves. The influence of different wave and structure parameters on CPB are studied e.g. the wave length and height, curtainwall depth, and the bottom protection height (t/d=0.20).

As a whole, the transmission coefficient (K_t) decreases with relative curtainwall depth (h/d) and wave steepness (H/L) increasing while reflection coefficient (K_r) takes the opposite trend. The transmission coefficient (K_t) of CPB without bottom protection range 0.91-0.42 and reflection coefficient (K_r) range 0.26-0.65 depends on relative curtainwall depth (h/d) and wave steepness (H/L). The transmission coefficient (K_t) of CPB with bottom protection (t/d=0.20) range 0.83-0.23 and reflection coefficient (K_r) range 0.26-0.72 depends on relative curtainwall depth (h/d) and wave steepness (H/L). Comparison between transmission coefficient (K_t) and reflection coefficient (K_r) of CPB without bottom protection and transmission coefficient (K_t) and reflection coefficient (K_r) of CPB without bottom protection of CPB without bottom protection is obtained that transmission coefficient (K_t) CPB with bottom protection (t/d=0.20) has a lower (range 0.04 – 0.22) and reflection coefficient (K_r) is higher (range 0 – 0.07) compared to CPB without bottom protection depends on relative curtainwall depth (h/d).

It is recommended that the curtainwall pile breakwater (CPB) can be combined with the bottom protector based on the results of the study, the curtainwall pile breakwater (CPB) that be combined bottom protection can be applied to reduce the transmission wave height. The results of this research can be used to design the dimensions of the CPB to obtain the expected transmission wave coefficient (K_t) value must be required that wave steepness (H/L) range 0.010 – 0.030, relative curtainwall depth (h/d) range 0-0.70 and t/d = 0.20.

NOMENCLATURE

The following symbol have been adopted for use in this paper :

C	: propagation wave	$[m/s]$
d	: water depth	$[m]$
H	: wave height	$[m]$
H_i	: incident wave height	$[m]$
H_r	: reflection wave height	$[m]$
H_t	: transmission wave height	$[m]$
h/d	: relative curtaiwall depth	$[-]$
H/L	: wave steepness	$[-]$
K_r	: reflection wave coefficient	$[-]$
K_t	: transmission wave coefficient	$[-]$
L	: wave length	$[m]$
T	: wave period	$[s]$
t/d	: relative the bottom protection height	$[-]$
t	: the bottom protection height	$[m]$

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