RESEARCH PAPER

THE PERFORMANCE OF PERFORATED SCREEN SEAWALL IN DISSIPATING WAVES, MINIMIZING REFLECTED WAVE AND RUN-UP/RUN-DOWN

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Abstract

Perforated screen seawall was considered as one of the multi function coastal structures that can be dissipating the wave energy and reducing both the reflected wave height and the wave run-up/run-down simultaneously. Physical model with 1:20 geometric scale has been conducted in 16 m length, 1.20 m width and 1.00 m high of a wave flume to simulate the models. Three models are distinguished on the perforated screen density ie. S = 0.5B; S = B and S = 1.5B (S is spacing perforated gaps and B is width of the closing part) set in a slope of 45º have been simulated by 3 variations of wave height and wave length (H_i & L). The results indicated that the higher density of the perforated screen rising the wave dissipation capability, minimizing both the wave reflection and run-up/run-down. Wave steepness parameter (H_i/L) and the density of perforation (S/B) either individually or jointly in non dimensional parameter is significantly influenced on wave reflection and dissipation. The maximum deduction of wave run-up about 30% - 60% by high to low density of perforated screen was found in around 2.5 of Irribaren number. The Empirical obtained equations for K_d and K_r both in relationship with BH_i/SL and the curves of R_u/H and R_d/H in the relationship with I_rS/B can be used for prototypes design purpose.

Key words: perforated screen, run-up/run-down, reflection, dissipation.

INTRODUCTION

General Background

As a maritime country with a long coastline, Indonesia currently is facing serious and complex coastal problems. The fact shown that many coastal management policies were wrong, causing damaging effects on the surrounding environment. Many cases of coastal development are not environmentally friendly that not only fail to solve the problem, but even resulting other problems in the vicinity. Many of coastal structures such as seawall and revetment newly constructed by stone masonry and/or concrete are found collapsed due to scouring on the toe or overtopping by wave and seepage or piping problems at the bottom of the structure. One of the causes the damage described above was run-up/run-down of waves on the wall. Run-up will produce overtopping and run down will reach the foot layer of structures when not equipped with a toe protection, causing scour in the foot. Beside increasing the crest of revetment/seawall and installing toe protection, then an another alternative that can be done by installing a perforated layer (screen) in front of a wall that serves to reduce run-up and run-down of the wave and at the same time have the ability to reduce the wave height. Therefore, it is expected that the wave reflection at the wall also becomes small. This paper presents the results of the laboratory scale model study in the Department of Civil Engineering Hasanuddin University, Indonesia, which aims to determine the effect of the density of screen structure to the reflection and dissipation of the waves as well as run-up/run-down the wave at revetment wall.

Literature Study

Complementary of revetment structure in the form of perforate screen wall with horizontal grating beams inspired by some previous research on the perforated breakwater suggested by Takahashi et al (1996), who examined the perforated wall Caisson and the result is quite effective to reduce the wave energy. Allsop (1995) in Thomson et al (2000) examined the single and double screen wall breakwater with the results of the wave transmission and reflection were small enough. Ariyarathne (2007) and Suh et al (2005) tested the perforated breakwater model, where the structure created a massive structure starting from the bottom up to the top of the breakwater with the perforations are at the top. The result shows that the reflection, transmission and energy dissipation depends on the parameter B/L, where B is the width of the structure and L is the wave length. For the wave conditions tested, the energy dissipation ranged from 56% to 78%, and over 75% of the cases tested, the dissipated energy above of 69%. This means the structure is very effective for wave energy dissipation. While the reflection coefficient decreases with increasing value of B/L to about 0.225 and then started to rise again. Minimum reflection coefficient occurs at $B/L \approx 0.2$ to 0.25. Rageh and Koraim (2009) examined the breakwater forms a vertical wall with a horizontal slit. From the results of the breakwater model study that can dissipate the incoming waves up to 50% with the placement of breakwater at h/L about 0.25 to 0.35 where h is the water depth and L is the wave length. Wurjanto et al. (2010) and Laju et al

(2005) examined the effectiveness of perforated skirt breakwater (PSB) in the category of long waves and found that the greater the value breakwater draft (*s*), then the smaller the value of the transmission coefficient (K_t) or the greater of the energy dissipation occurs. The smaller the coefficient K_t means better functioning of the breakwater. In the structure of revetment such known as the strengthening structure for the beach slope, it should also be optimized the functions to reduce or minimize wave reflection. In addition, it is also necessary that run-up and run-down the waves can be reduced as low as possible to obtain an efficient construction.

Run-up and run-down the waves on shore protection wall is one important aspect that needs attention because it will have an impact on the high structures crest and scour potential at the foot of the structure by a run-down wave. Run-up depends on the shape and roughness of the structure, the depth of water at the foot of the structure, the slope of coastal profil at front of the structure, and the characteristics of the wave. Various studies on wave runup has been done in the laboratory. The results in the form of graphs that can be used to determine the height of the runup. The experimental results are most commonly used in the determination of the wave runup height of the structure is the result of the experiment Irribaren.

To explain the phenomenon of ocean waves, scientists have developed several theories, namely wave linear theory (Airy wave theory, Small-amplitude wave theory) and non-linear wave theory (Finite-amplitude wave theories) among others Stokes wave order 2, order 3, order 4 onwards, Cnoidal waves, waves Dean Stream Function and Solitary waves. To determine the most appropriate theory to the problems faced, used graphics application wave theory based on the value ratio *H/d* and *d/L* (Triatmodjo, 1999).

The revetment structures are located on the shoreline and generally interact with the shallow water waves, so that the corresponding wave theory is the theory of cnoidal waves. In order to facilitate the analysis, however, the Airy wave theory can be used. It is based on the results of Thaha (2001), who studied shallow ocean waves on a clump of mangroves obtained results that the application of Cnoidal wave theory is not significantly different from Airy wave theory. For that wave length (*L*) can be calculated using the following equation (Sorensen, 2006).

$$L = \frac{gT^2}{2\pi}\tanh\left(\frac{2\pi}{L}d\right) \tag{1}$$

By using the method of iteration then Equation (1) can be solved to determine the wavelength. Equation (1) require deep water wave length (L_o) such as present in the following equation:

$$L_0 = 1{,}56\,T^2 \tag{2}$$

where, T = wave period,

d = water depth.

Wave reflection is the reflecting wave from the structure wall which is expressed by wave reflection coefficient (K_r). Reflection coefficient (K_r) is the ratio between H_r with H_i and dissipation coefficient (K_d) = 1-K_r-K_t, where K_t is considered 0 because no waves through the revetment. Incoming wave height (H_i) and wave reflection (H_r) in the model is determined by the maximum and minimum measured wave height (H_{max} and H_{min}) at several measurement points. H_i defined as $(H_{max}+H_{min})/2$ and H_r is $(H_{max}-H_{min})/2$ (Dean and Dalrymple, 19920.

To determine the amount of wave run-up and run-down, the Irribaren number determined by the following equation:

$$Ir = \frac{tg\,\theta}{(H/L_0)^{0,5}} \tag{3}$$

with,

Ir : Irribaren number,

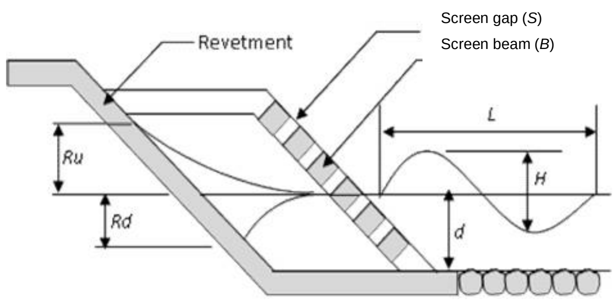
θ : revetment slope angle,

H : incident wave height

L_0 : deep water wave length.

Methodology of Study

Research was conducted experimentally at the Ocean Hydrodynamics Laboratory of Hasanuddin University with a physical model simulation using 1:20 geometric scale. Screened revetment model forming by scenes of horizontal beams with a slope of 45º (see Figure 1) was made in 3 variations of beam gap there are 0.5*B*; *B* and 1.5*B*, where *B* is thickness of beam. Calibrated model is placed at the end of wave flume and than simulated by several calibrated wave height and wave period. The measured parameters are actual incident wave height and period (H_i & T), reflection wave height (H_r) and wave run-up/run-down (R_u and R_d). The data analysis includes computation of H_i, L, H_r, H_d and Ir continues to formulating reflection coefficient (K_r) and relative run-up/run-down (R_u and R_d).



Gambar 1. Typical section of perforated screen seawall model.

The results are consists of empirical equations and graphs presenting the relationship between a dimensionless parameter that combines the characteristics of the wave and the characteristic structure of the screen. The limitation of study just examines of angle of 45º, the influence of the distance between the seawall and the screens were not studied, but as the approach taken 1/3 of the maximum wave length.

RESULTS AND DISCUSSION

Wave dissipation capability

Computations analysis are based on the law of wave height conservation in which incoming wave height is the sum of wave transmission, reflection and dissipation or $H_i = H_t + H_d + H_r$. In the case study that no any wave transmitted through revetment, then H_t otherwise 0 so that the dissipation wave height can be calculated by $H_d = H_i - H_r$ or in the form of coefficients $K_d = 1 - K_r$. The results were presented in the relationship between the density of screen structure (S/B) with K_r and K_d using wave steepness (H_i/L) as wave characteristics. Figure 2 presents the relationship between K_r and H_i/L in 3 kinds of screen density and compared with K_r without screens. Figure 3 presents the relationship K_d and H_i/L also on 3 kinds of density with K_d without screen for comparison.

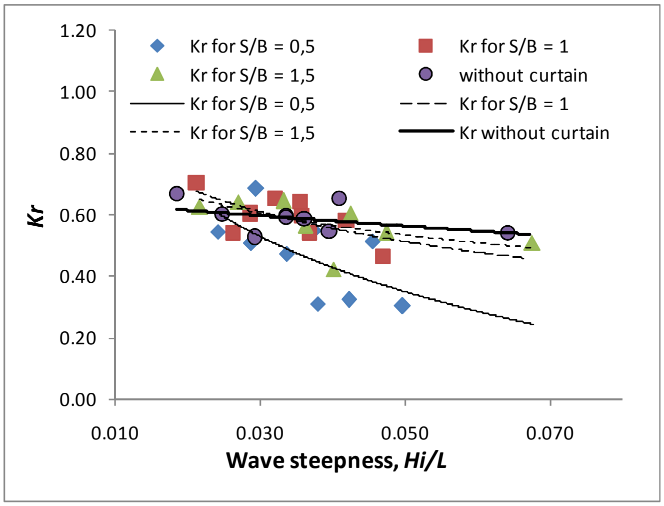


Figure 2. Relationship H_i/L with K_r.

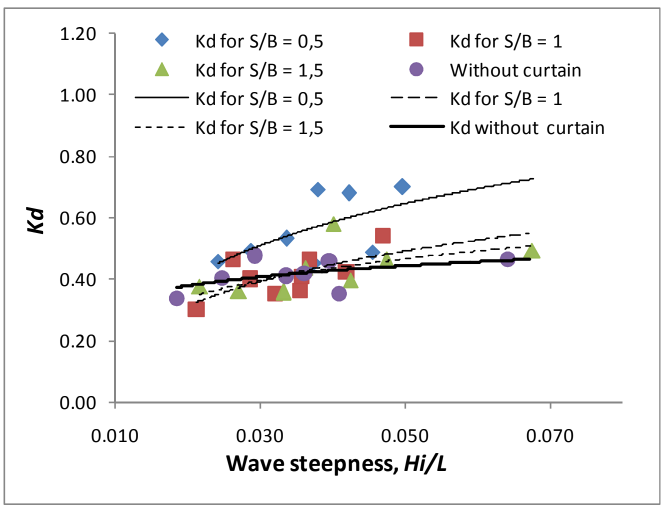


Figure 3. Relationship H_i/L with K_d

Figure 2 shows the effect of the screen density (*S/B*) to the wave reflection in front of the model, where the high density of the screens or the smaller *S/B*, the smaller the wave reflection coefficient (K_r) or the smaller height of the reflected wave. The distribution gap of both the data and the regression curve between *S/B* = 0.5 with *S/B* = 1 is much larger than the gap between the *S/B* = 1 with *S/B* = 1.5. This suggests that the screen density effect is non linear to the wave reflection and the space of S/B = 1.5 showed a narrow margin with K_r without screen. This suggests that the effect of mentioned density is not significant anymore. Figure 3 shows the opposite effect of screen density (S/B) to wave dissipation that occurs in the model, where the high density of the screens or the smaller dimension of S with respect to B, the greater the wave dissipation coefficient (K_d) or the larger the wave height dissipated. The gap distribution of the data and the regression curve between S/B = 0.5 with S/B = 1 is much larger than the gap between the S/B = 1 with S/B = 1.5. This suggests that the screen density effect is not linear on the wave dissipation and screen space of S/B = 1.5 showed a narrow margin with an average K_d without screens. This shows that the density effect is not significant anymore. Figure 4 present the effect of the combination parameter between H_i/L and S/B to K_r and K_d, then used a dimensionless parameter BH_i/SL. Figure 6 presents the relationship BH_i/SL with K_r and K_d.

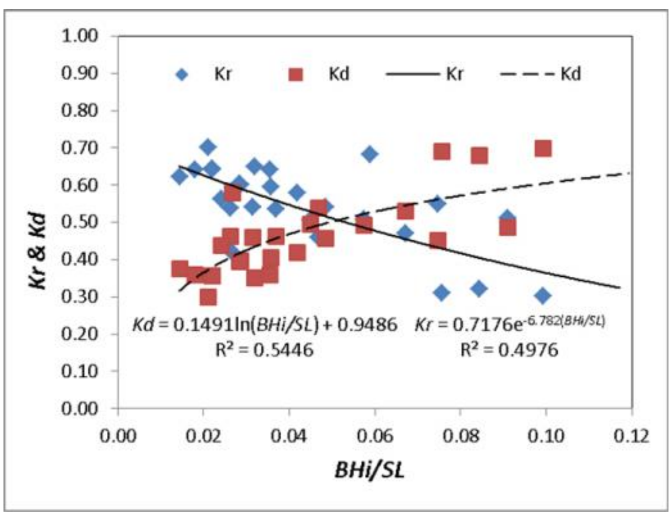


Figure 4. Relationship BH_i/SL with K_r and K_d.

Figure 4 shows the relationship between non dimensional parameter that contains the density of screen (B/S) and wave steepness (H_i/L) with K_r and K_d, where K_r decreases exponentially with increasing the value of BH_i/SL and K_d increases logarithmically with increasing value of BH_i/SL. Empirical approach to the relationship between two parameters were obtained as follows:

$$K_r = m \exp^{-n\left(\frac{BH_i}{SL}\right)} \qquad (4)$$

$$K_d = p \; ln\left(\frac{BH_i}{SL}\right) + q \qquad (5)$$

With H_i = incoming wave height; B = width of barrier beam; S = spacing of beam and m, n, p and q is constant. Both equations are valid for a 45 º slope of screened seawall with a screen distance about 1/3L. The equation can be used to make design prototypes for field application.

Run-up/Run-down (R_u and R_d) of Wave

Study on wave run-up and run-down over the revetment wall was conducted to determine the effect of the screen density (*S/B*), the wave characteristics (H_i and L) and revetment slope angle (θ) against of R_u and R_d. The results will be useful in designing the revetment crest. Irribaren number (*Ir*) is a common used parameter to describe the magnitude of the run-up and run-down (see Equation 3). *Ru* and *Rd* values themselves are made dimension-less and using in relative to the incident wave height (*H*). The results are presented in the relationship between Irribaren number (*Ir*) with obtained *Ru/H* and *Rd/H*. The relationship is plotted with several previous graphs as presented in Figure 5.

In Figure 5 there are 6 curves that consist of 3 curves of run-up and 3 other curves for run-down (Test-1; Test-2 and Test-3). Test-1 is the result of run-up and run-down of the density of *S/B* = 0.5 (high density), Test-2 present the result for *S/B* = 1 (moderate den-sity) and Test-3 is the result for *S/B* = 1.5 (low density). The data of Test-1 results indicate both *Ru* and *Rd* increased linearly until the Irribaren number reaches about 13 value of. Test-1 gives *Ru* and *Rd* are small yield compared to the smooth slope wall, crushed stone, quadripod and doloz where *Ir* values ranging up to 8 for *Ru* and *Ir* arround 4 for *Rd*. From Test-2 results that can be seen the value of *Ru* and *Rd* increased linearly until the number of *Ir* about 8 and became constant thereafter. Value of test-2 showed that the moderate density of the screen (*S=B*) for *Ir* value up to 4 giving R_u and R_d value smaller than the smooth wall, crushed stone and quadripod, whereas the exceeded value of *Ir* produce *Ru* averagely between smooth wall with other Irribaren curves.

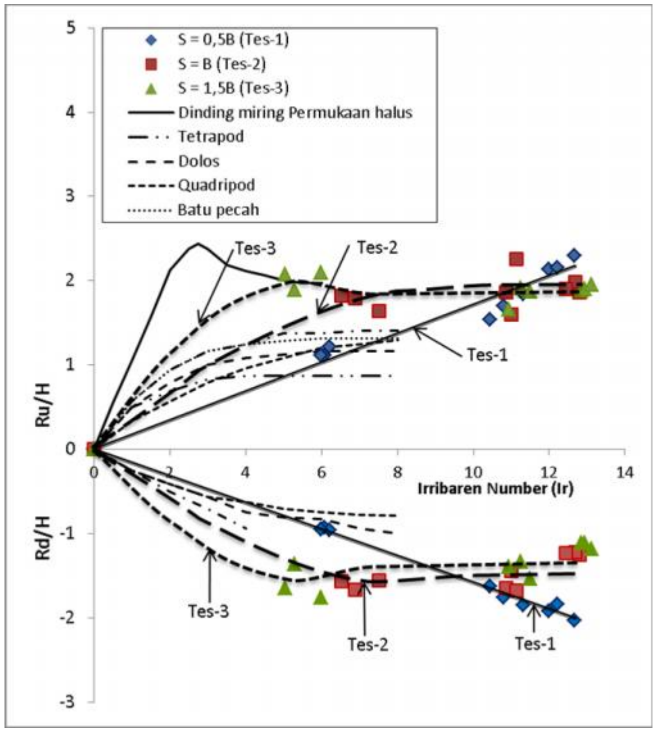


Figure 5. Relationship between I_r with R_u/H and R_d/H.

For the value of *Rd*, Test-2 shows greater value of *Rd* compare to others Irribaren curves. In Test-3, the *Ru* and *Rd* values increased linearly up to I_r ranges 5-6 and then decreased thereafter and constant at the value of I_r arround 7. The constant value of R_u is equal to a constant value of smooth wall curve. Thus the chart of test-3 gives an indication of similarity to smooth wall curve despite the greater value of I_r. It can be said that the low density (S = 1.5B) indicated a relatively small effect on reducing the value of R_u. For field prototypes design purpose, that can be used the relationship between R_u and R_d with all examined influencing parameters in the form of dimensionless relationship as shown in Figure 6.

Figure 6 shows that the maximum mean of R_u is about 2H for the value of dimesionless $I_r.S/B$ arround 7 and R_u become constant at 1.8H in values of $I_r.S/B \geq 10$. The maximum mean of R_d is about 1.75H for the value of $I_r.S/B$ arround 7 and R_d become constant at 1.4H in values of $I_r.S/B \geq 11$.

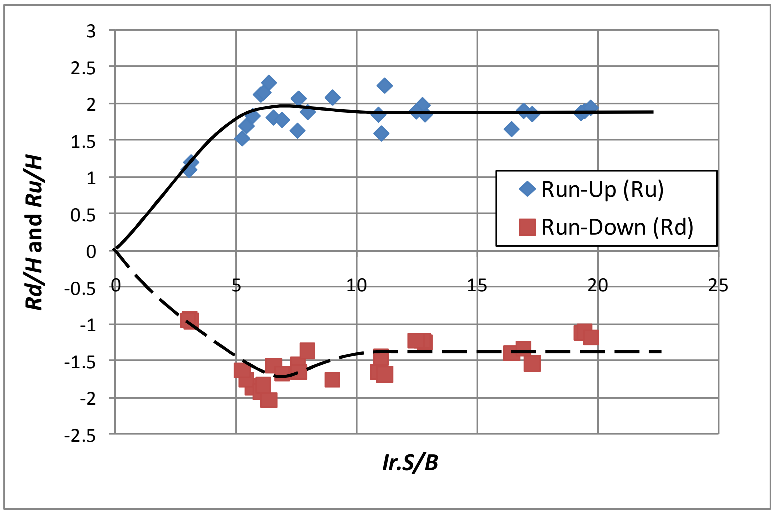


Figure 6. Relationship between $Ir.S/B$ with R_u/H and R_d/H.

CONCLUSIONS AND RECOMMENDATIONS

1. The addition of perforated screen in front of sea wall can be increased the effectiveness of the structure in absorbing the waves energy and reducing both for wave reflection and run-up/run-down of wave.
2. The higher the density of perforated screen (S/B is smaller) the greater wave absorber capability and produced smaller wave reflection, and vice versa. Low tested screen density ($S = 1.5B$) was no longer significant effect on K_r and K_d.
3. The K_r decreases exponentially and K_d increases logarithmically with increasing the value of BH_i/SL.
4. Wave runup (R_u) can be reduced up to 60% in the I_r ranging from 0 up to 11 for all tested screen density. The maximum deduction of wave run-up about 30% - 60% for $0.5B$ to $1.5B$ screen density occurred at 2.5 of I_r.
5. The Empirical obtained equations for K_d and K_r in the relationship with dimensionless parameter BH_i/SL and the I_rS/B curves in the relationship with the R_u/H and R_d/H can be used for prototypes design purpose.

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