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Sea Wave Transmission at the Mangrove Forest of *Rhizophora* Sp

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ABSTRACT

One of the benefits of the Rhizophora sp. mangrove forest in the coastal area is its capability in attenuating the forces of incident waves towards the shore line so that the coastal erosion can be minimized. This study aimed to analyze characteristics of sea waves: wave period (T_i), wave height (H_i) and wave transmission (H_t) through the clumps of Rhizophora sp. at a certain porosity (N_p). These characteristics are used in predicting value of the transmission coefficient (K_t). The study began with the making of the canal sized of 30 m x 6.5 m x 1 m; measurement of root diameter, root length and length of the submerged trunk; measurement of wave height, periode of incident wave, and the transmitted wave by using the SBE (Sea Bird Electronics) gauge at an interval distance of 10 m. The results showed that the transmission coefficient is inversely proportional to the value of wave steepness ($H_i\ (gT_i^2)^{-1}$) and porosity (N_p). The ability in minimizing sea wave value at Rhizopora sp. class is 57,73 % on the porosity 0,9828.

KEYWORDS : *porosity, Rhizophora sp., transmission coefficient, wave transmission*

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I. INTRODUCTION

Long beach conditions and characteristics of typical environment suggest any potential benefits in supporting the sustainable coastal environment [1,2]. The coastal areas are vulnerable to changes due to the transition position between land and sea as well as the high intense uses of the coastal resources [3]. Dynamic changes occur in many coastal areas, such as coastal erosion resulting abrasion and sedimentation that adds the mainland coast [4]. The erosion and sedimentation are the result of human activities in coastal areas such as residential, farms, and other events that cause a reduction or even loss of natural ecosystem in coastal areas such as mangrove forests. Abrasion will continue if the natural processes in coastal areas, damaged the green belt of mangrove as a natural coastal protection. It could ultimately threaten the life in coastal areas [3,5,6]. Many studies have shown that mangroves can attenuate the incident of winds and waves [7]. Distinctive characters of the existing environment in the coastal mangrove forests suggest very important roles e.g. physically mangrove forests protect the coast from the waves of the sea and coastal erosion [6]. Mangrove forests are also able to restrain sea water intrusion and catch the sediment loads [8]. Coastal areas face the threat of abrasion due to the mangrove forest barrier are losses. As a result, the land are gradually eroded and threaten any residential locations and other land occupied in coastal areas.The sea waves have complex and complicated behavior, consider by both of physical and mathematical aspects [4]. The phenomena of sea waves incident toward the main coastline through mangrove forests also need any physical and mathematical solutions, it is quite complicated. These phenomena resulted in the ecological, economic and social dynamic of the coastal habitat. Mangrove forest in the coastal areas, particularly in the Village Nguling Penunggul which is also the estuary of the Laweyan river are able to protect the coast from sea waves [9]. However, despite the benefits of the mangrove forest has been known for many years ago, yet a little information about the effectiveness of mangrove in attenuating the incident sea waves. Therefore it is necessary to study the sea wave attenuation in mangrove forest of *Rhizophora* sp. This study develop a natural wave tank similar to the wave tank in the laboratory.equipped with data acquisition tools for recording any relevant informations and wave data in the field.

This study aims to analyze characteristics of incident sea waves, included time period of wave, wave height, and wave transmission, to calculate value of the transmission coefficient and the wave steepness; and to analyze relationship between the transmission coefficient and the steepness of the wave through the grove of *Rhizophora* sp.

II. RESEARCH METHODS

The field surveys and laboratory works were conducted during December 2012 in the mangrove forest village of Penunggul - Nguling district, Pasuruan regency. This location is the largest mangrove forest in the Nguling and suggest the fairly uniform type of *Rhizophora* sp. and *Avecennia* sp. [10]. The coastal areas suggest a gently sloping contours so that the reflected waves from the shoreline can be minimized. The tools that is used to investigate characteristics of sea waves are 2 units of SBE 26 (Sea Bird Electronics), stopwatch, laptop and writing tools. The natural laboratory wave tank was equipped with the meter roll of 25 meter, rubber rug size of 1 m x 30 m, bamboo sticks, nail battens, saws, hammers, wire, roller, and other supporting equipments such as wooden ship, watchtower, emergency lights, and batteries.

2.1. Stages of data collection as follows:

2.1.1. Record physical characteristic of the *Rhizophora* sp. mangrove: A number of trees, the circle of stem and root, the length of stem and root [11], which are obtained at each density of mangroves in a different canal volume. Size of the Canal A: 1 m x 10 m x 6.5 m, Canal B: 1 m x 20 m x 6.5 m; and Canal C: 1 m x 30 m x 6.5 m. All of these canals along the mangrove forest are perpendicular to the direction of incident wave. Collection of these datas are conducted at low tide. Furthermore, data obtained were used to determine the porosity value in each of the canal Fig (1).

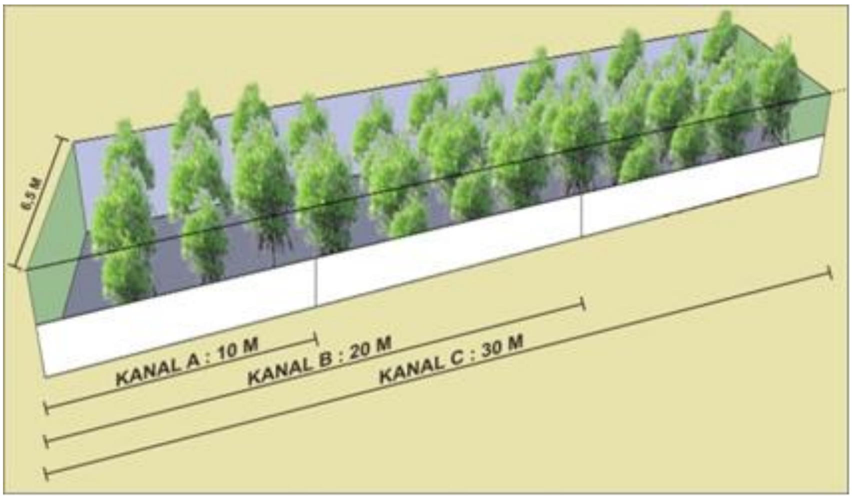

Fig (1): Model of the natural wave tank laboratory

2.1.2. The incident wave period (T_i), wave height (H_i), and the transmission wave height (H_t) measured according to the canals. The SBE 26, Sea Gauge Tool were employed to observe propagating wave to the shoreline with. These datas are analyzed with Seasoft Software For Waves [11].

2.1.3. Sea wave transmission coefficient is calculated by comparing the results of incoming wave height and transmitted wave height . while the wave steepness is calculated by comparing the results of measurements of wave height and wave period in squares.

2.1.4. Graphs showing the relationship between sea wave transmission coefficient (K_t) with T_i, H_i with K_t, K_t with wave steepness ($H_i / (gT_i^2)$), were presented for each canal.

2.1.5. The relationship between transmission coefficient (K_t) and wave steepness ($H_i / (gT_i^2)$) was presented for the third canal.

2.1.6. Regression analysis was used to derive a general equation for the wave attenuation in *Rhizophora* sp. mangrove forest [13]

2.1.7. The wave attenuation regression analysis involved the normalization test, homogeneity and multicollinearity test [13].

2.2. Data were analyzed in the following stages:

2.2.1. The porosity value (N_p) of clumps of *Rhizophora* sp. is calculated by the following formula [14]:

$$N_p = 1 - \frac{V_t}{V_0} \quad \text{.......(1)}$$

N_p: porosity values (-), V_t: volume of submerged stems and roots of *Rhizophora* sp. (m^3), V_0: total control volume (m^3), N_p = 1 indicates the absence of mangroves, and N_p = 0 indicates the fully reflective walls.

2.2.2. Sea wave transmission coefficient was calculated by the following formula [15]:

$$K_t = \frac{H_t}{H_i} \qquad (2)$$

K_t: transmission coefficient (-), H_i: Height of incident wave (m), and H_t: Height of transmission wave (m).

2.2.3. The wave steepness (H_i / (gT_i^2)) (Park, 1999)

$$wave\ steepness = \frac{H_i}{gT_i^2} \qquad (3)$$

H_i: wave height (m), g: gravity acceleration (m/s^2), and T_i: period of the incident wave (s).

III. RESULTS AND DISCUSSION

Nguling districts have several coastal villages. These villages are located near the estuary of the Penunggul Laweyan river and have a stretch of mangrove forests. The existence of mangrove forests have been felt by the coastal communities as the coastal protection from waves and produce any alternative sources of livelihood of the organisms taken from forest ecosystems such as mangrove crabs, shellfish and fish. Besides, the people also exploit mangrove seedlings to nurseries and reforestation efforts. Based on the observations and interviews with the local ecosystems, there are two types of mangrove, i.e. *Rhizophora* sp. and *Avicennia* sp. Both of them suggested any ecological benefits from exposure to protect coastal sea waves. The condition doesn't happen in the absence of mangrove forests. Benefits of coastal protection from waves are increasingly felt as the more extensive mangrove area and forest cover [10]. Characteristics and benefits of mangrove forests in reducing wave canal focused on observations made as in Fig (2). Canal observations made on *Rhizophora* sp. clump in order to create a condition when the sea waves are coming in and are transmitted more focused on a particular area so that the SBE 26, Sea Gauge tool, can be more accurate in recording the data wave characteristics.

Fig (2): Field laboratory wave tank nature clumps *Rhizophora* sp.
(Source: Author's Photo December 2012)

The results of field measurements in the form of physical data on clumps of mangrove *Rhizophora* sp. are the number of trees, circumference of the trunk and roots, stems and roots. The control volume for 1 m water depth in each area of the canal listed in Table (1).

Table (1) : Volume control in each canal.

Canal	Volume of canal (m^3)	Volume of control *Rhizophora* sp. (m^3)
A	65	0,52
B	130	2,17
C	195	3,35

Table (1) shows the canal volume of 65 m^3, the volume of the stem, and roots of *Rhizophora* sp. 0.52 m^3, the canal area of 130 m^2 stem and root volume of 2.17 m^3 *Rhizophora* sp. While in the canal area of 195 m^2, stem and root volume 3.35 m^3 *Rhizophora* sp. The density of *Rhizophora* sp. clumps increase toward the shoreline as they are tend to grow *Rhizophora* sp close to the shoreline. Previous study shows that the porosity values are increasing with the extent of the canal toward the shoreline [14].

The results of measurements with SBE 26 SeaGauge in forest waters mangrove Penunggul Village includes incoming wave period (T_i), wave height (H_i), and the transmitted wave height (H_t). These data are used to calculate the transmission coefficient (K_t) and wave steepness ($H_i / (gT_i^2)$). The results of Thaha (2003) show that the main parameters that influence the transmission and attenuation of waves through a clump of mangroves is the relative density of mangroves, clump thickness, and wavelength. This study analyzes the effects of parameter period, incident wave height, wave height transmission of the transmission coefficient, and wave steepness [2]. Wave data on mangrove forest *Rhizophora* sp. is measured using the SBE 26 SeaGauge to record wave period (T_i), wave height (H_i) and the transmission wave height (H_t) for each canal as presented in Table (2).

Table (2): Wave Period on high tides in clumps *Rhizophora* sp.

Canal	T_i (det)	H_i (m)	H_t (m)
A	0,7343	0,2026	0,1316
B	0,0621	0,2270	0,1445
C	0,8994	0,2069	0,1106

Wave period (T_i) influence on the transmission coefficient (K_t) can be generated [12]. Comparisons between wave periods (T_i) with the value of the transmission coefficient (K_t) in the mangrove forest species *Rhizophora* sp. each canal displayed in Fig (3).

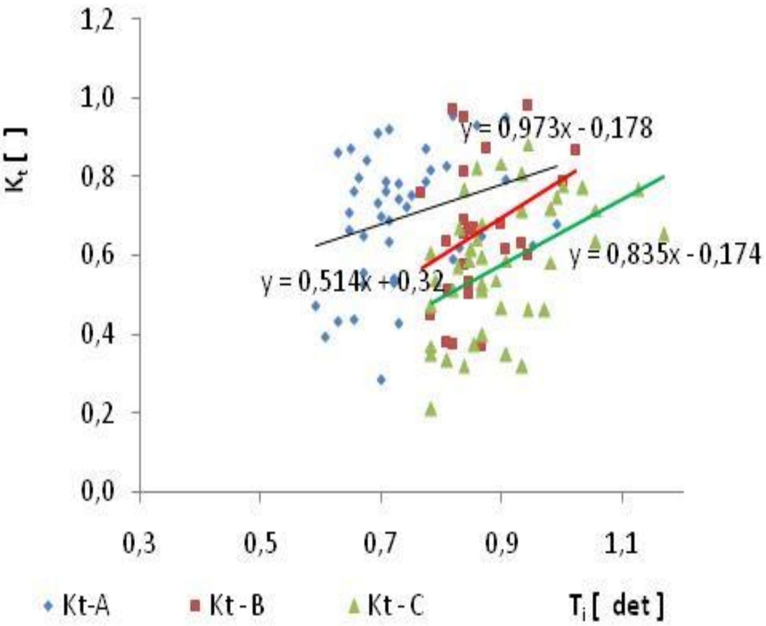

Fig (3) : Relationship between the wave period (T_i) and the transmission coefficient (K_t) at mangrove forests of *Rhizophora* sp. for each canal type.

Fig (3) shows that the results of the comparison measurements of the transmission coefficient in the canals . The wave period at each canal has a tendency to an increase proportional to the wave period (T_i). Each canal leads to an increase in the value of the transmission coefficient (K_t). This study empirically proven by Hashim, *et al*., (2013), that the greater the wave period, the more increasing the value of the transmission coefficient [12]. Wave height (H_i), that has an influence on the transmission coefficient (K_t) is generated in Fig (4). Relationships between wave height (H_i) and the transmission coefficient (K_t) in the mangrove forest species *Rhizophora* sp. for each canal are displayed.

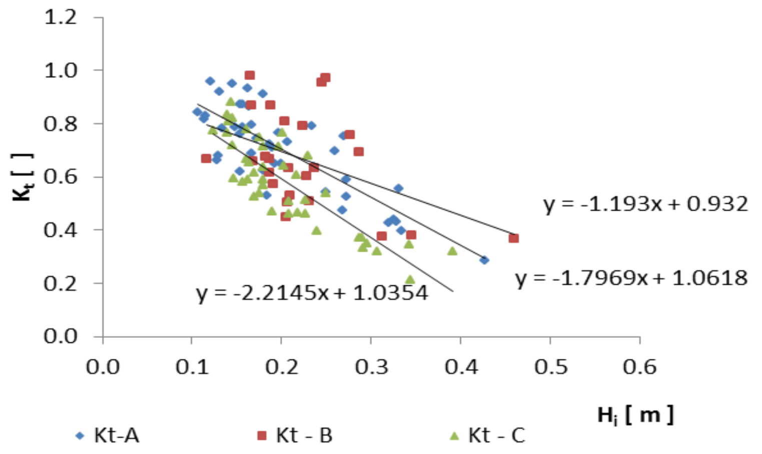

Fig (4) : Relationship between the incident wave height (H_i) and the transmission coefficient (K_t) in the mangrove forest of *Rhizophora* sp.

Fig (4) above shows that the the measured transmission coefficient, at each canal, has a tendency inversely proportional to the wave height, which means an increase in wave height (H_i) each canal leads toreduction of the transmission coefficient (K_t). This is also consistent with the research of Hashim *et al.*, (2013), the greater the wave height (H_i) will cause a decrease in the value of the transmission coefficient (K_t) [12]. Due to friction with the sea waves, mangrove roots and stems are submerged in sea water. It causes the wave energy reduced and resulting in changes in incoming wave height and period. High sea wave that came through the mangrove forests experienced a wave damping according to the arrangement of the roots and stems [2]. It has an impact on the size of the transmission coefficient (K_t) in the area. Wave attenuation in mangrove forests can be seen from the relationship of the transmission coefficient (K_t) and wave steepness (H_i / (gT_i^2).

Comparison of transmission coefficient (K_t) and wave steepness (H_i / (gT_i^2)) *Rhizophora* sp. clumps on each canal for each canal in the mangrove *Rhizophora* sp. clumps listed in Table (3).

Table (3) : Comparison of transmission coefficient (K_t) and wave steepness (H_i / (gT_i^2)) *Rhizophora* sp. clumps on each canal.

Canal	K_t	$H_i/(gT_i^2)$
A	0,2843 - 0,9572	0,0134 – 0,0928
B	0,3682 - 0,9817	0,0166 – 0,0625
C	0.2105 - 0.8833	0,0112 – 0,0574

The processing of wave data were summarized in Table (3), the relationship between wave transmission to wave steepness on each canal, for all data shown in Fig (5).

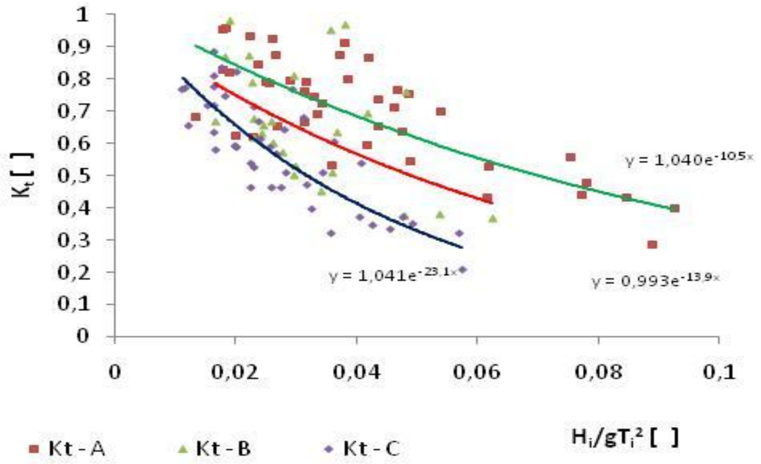

Fig (5) : Relationship between the wave steepness (H_i/gT_i^2) and the transmision coefficient (**K_t**).

In Fig (5), it is observed that a declining trend of the transmission coefficient (K_t) in line with the increment of the wave steepness (H_i / (gT_i^2)) value. On canal A, it shows the transmission coefficient (K_t) ranged from 0.2843 to 0.9572 and wave steepness ranged from 0.0134 to 0.0928, with the equation obtained K_t =1,040 $e^{-10,5 H_i / (gT_i^2)}$. Canal B produces the equation K_t = 0,993 $e^{-13,9 H_i / (gT_i^2)}$ with the value of the transmission coefficient (K_t) ranged between 0.3682 to 0.9817 and wave steepness ranged from 0.0166 to 0.0625. While canal C shows the transmission coefficient (K_t) ranged between 0.2105 - 0.8833 and wave steepness ranged from 0.0112 to 0.0574 with the equation K_t = 1,041 $e^{-23,1 H_i / (gT_i^2)}$. Results of measurement and data processing waves through the clumps of *Rhizophora* sp. shows the transmission coefficient (K_t) decreased with increasing wave steepness. The empirical results of a similar study reported by Quartel *et al.*, (2006) showed that the value of the transmission coefficient increases with the decreasing slope of the wave [17]. Otherwise the value of the transmission coefficient decreases with the increasing wave slope [18]. So it can be concluded that the larger the wave steepness, the result in transmission coefficient is getting smaller.

3.1 Porosity of Mangrove Forest

Porosity is the ratio of void volume to total volume [19]. Porosity of mangrove forest is the ratio between the volume of observation canals reduced by the total volume of roots and stems are submerged in water. Porosity values obtained by direct measurement of the stems and roots of mangroves in each area of mangrove forest along the canal on the direction perpendicular to the direction of sea coastline. Measurement results then tabulated and processed to obtain porosity values.

Table (4) : Porosity values in mangrove forest type *Rhizophora* sp.

Canal	Volume of canal (m^3)	Volume tree and root (m^3)	Porosity
A	65	0,52	0,9920
B	130	2,17	0,9833
C	195	3,35	0,9828

Table (4), shows the canal volume 65 m^3 with the porosity value of 0.9920. In the canal volume of 130 m^3, the porosity value of 0.9833. While in the canal volume of 195 m^3, the porosity value of 0.9828. Porosity values have a tendency to decrease toward the shoreline [14]. Porosity of the surface state is inversely proportional to the density of the stems. The porosity of mangrove forest *Rhizophora* sp. showed in Table (5) for each canals along with their averaged wave transmission and wave steepness.

Table (5) : Porosity value comparison, K_t and H_i/gT_i^2

Canal	Porosity	K_t	$H_i\ (gT_i)^{-2}$
A	0,9920	0,6977	0,0411
B	0,9833	0,6612	0,0319
C	0,9828	0,5773	0,0276

Table (5) shows that the porosity values reduced with the decreasing transmission coefficient (K_t) and steepness (H_i/gT_i^2). This is consistent with the research by Sidek and Wahab (2007), an increase in the transmission coefficient (K_t) when the value of the variable porosity increase [15]. Relationship between variables that affect the formation process of the transmission wave can be determined by using the method of statistical analysis using regression modeling. Wave data obtained from measurement results include wave height, incoming wave period, wave transmission, and high porosity values each canal in the grove *Rhizophora* sp..The data were, calculated and analyzed with SPSS method to obtain the transmission coefficients K_t (-), in *Rhizophora* sp. influence by the following variables : , H_i incoming wave height (m), T_i incoming wave period (s), and g acceleration of gravity (m/s^2) and N_p porosity (-).

3.2 Calculated Transmission Coefficient vs Measured Transmission Coefficient

It is necessary to justify the proposed equation models by comparing to the measured data. By plotting the values of transmission coefficient obtained by proposed equation (Kt-calc) along with those obtained from field measurements (Kt-meas), one can compare the deviation of the value from the ideal line (identical values of transmission coefficient). This presented in Fig (6).

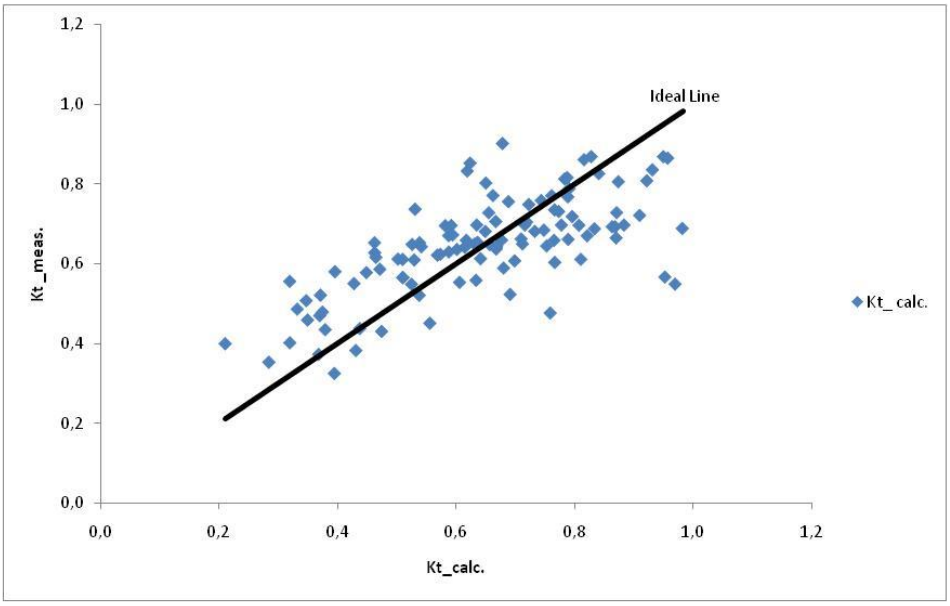

Fig (6) : The relationship between the calculated transmission coefficient (K_t_calc.) and the measured transmission coefficient (K_t_meas.)

The proposed equation was also compared to the equation models from similar studies. The equation models proposed by Bao (2011) at Hoang Tan, Tien Lang, and Can Gio, Vietnam compared with the proposed equation in this study is shown in Fig (7) [20].

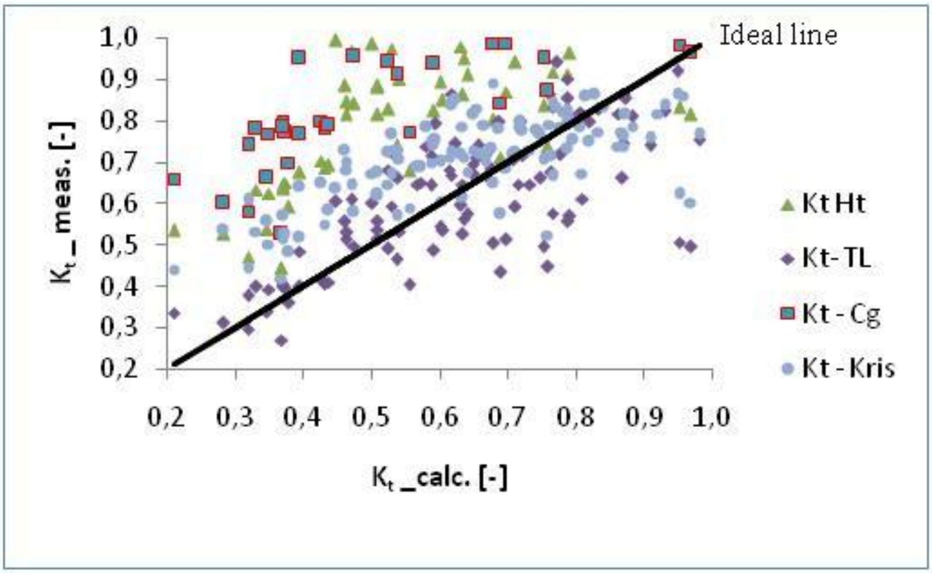

Fig (7) : Relationship between the measured transmission coefficient and the calculated transmission coefficient based on the four models:

K_t - Ht : study transmission coefficient (Bao, 2011 in HoangTan).
K_t - TL : transmission coefficient research (Bao, 2011 in Tien Lang).
K_t - Cg : transmission coefficient research (Bao, 2011 in Can Gio).
K_t - Kris : transmission coefficient (this study, 2013)

Fig (7), shows that the ratio of the point spread between the researchers showed a tendency to be in a straight line interval (best-fit trend line). This condition indicates that the model equations obtained transmission coefficient has a data distribution that tends to approach the prediction line (on a best-fit line).

IV. CONCLUSIONS

4.1. The characteristics of wave on clumps of *Rhizopora* sp. as follows : the time period between the incident waves: from 0.0621 to 0.8994 sec; wave height between: 0.2026 to 0.2270 m, and the wave height transmitted between: 0.1106 to 0.1445 m.

4.2. The value of the transmission coefficient (K_t) equal: from 0.2105 to 0.9817 and wave steepness (H_i / (gT_i^2)) of 0.0112 to 0.0928.

4.3. The increase in wave period (T_i) in the grove *Rhizophora* sp. showed a tendency to an increase in the value of the transmission coefficient (K_t). While the increase in wave height (H_i) on *Rhizophora* sp. clusters have a tendency to cause a decline in the value of the transmission coefficient (K_t).

4.4. Grove *Rhizophora* mangrove forest in the village of porosity Penunggul 0.9828 to 0.9920 have the ability to reduce waves according to the mathematical equation models:

$$K_t = 1 - \left\{ e^{0,936} \left(\frac{H_i}{gT_i^2} \right)^{0,771} N_p^{-55,990} \right\}$$

4.5. The attenuation capability of sea waves through the *Rhizophora* sp. is useful in preserving coastal ecosystems. There are a few suggestions for the future as follows:

4.5.1. There should be a further research related to effects of sea water density, soil type, and slope of the beach alleged effect on the value of transmission coefficient.

4.5.2. Need to develop advanced manufacturing laboratory wave tank rather than comprehensive natural equipped with measuring equipment as well as the speed and direction of wind flow, viscosimeter, which is expected to show up the next Natural Hydrodynamics Laboratory.

4.5.3. In the preparation of spatial planning of coastal areas, especially in planning the conservation and rehabilitation of mangrove forests, consider more about aspects of wave characteristics in the area.

4.5.4. The rehabilitation conditions damaged on coastal sea wave activity and the occurrence of tidal mangrove trees need a planting as coastal protection.

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