EEFECTS ON WAVE BREAK, SEA DIKE PROTECTION OF THE TREE PLANTING FORMULA IN THE COASTAL SALINITY INUNDATED AREAS

Assoc. Prof. Dr. Vuong Van Quynh - Forestry University of Vietnam

1. Introduction

The coastal areas of Vietnam have a great potential for economic development including agriculture, forestry, fisheries, particularly seafood and aquatic culture. Thanks to the economic development, many households would get some income of hundreds of million VND per year. However, these are the areas most subject to disasters caused by heavy sea waves. Waves can result in dyke destruction, bridge, road, building, and irrigation system damages, causing salinity submerged agricultural land, bringing about partial or complete loss of productive fields, ponds, aquaculture areas, etc.

One of the most effective solutions to break the sea wave and concurrently contribute positively to the economic development and environmental protection in the coastal areas is to do mangrove afforestation. This article presents some research results on the mangrove forest ability of creating wave break effects with a partial funding support from a research project named "Research on finding solutions for tree planting to protect sea dykes, contributing to improve the coastal environment in provinces from Quang Ngai to Kien Giang".

2. Research Methodology

Energy and destructive power of the ocean waves is determined by many factors, but mainly depends on the height of the waves. Effects of mangrove forest on wave breaking is actually making elimination of the wave fluctuation, reducing the height and the devastation of the waves. The breakwater effect of mangrove forest is more related to density, tree size and the forest strip width. Therefore, the authors studied the effects of the forest on wave breaking through the analysis of wave height changes around trees and when trespassing deeply into the mangrove strips.

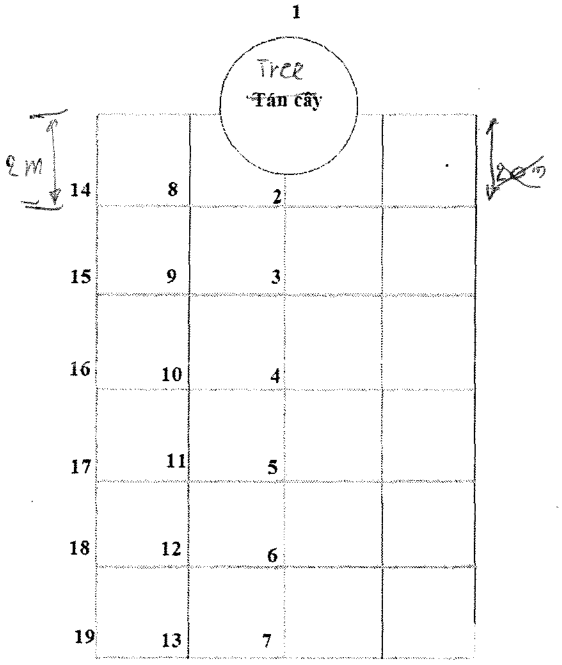

Figure 1. *Outline of the locations designed for taking wave hight measurements behind each individual tree*

To study the wave break capacity of each mangrove forest tree, this research selected 6 standard pilot trees growing relatively independent and took investigation on the wave height at 19 locations spaced 2 m from each other (Figure 1) around each tree. The analysis results allowed to make mathematical models reflecting the impact rules of each individual tree on wave height, with the aids of computers the researchers built up models of mangrove forests with different density and size and successfully determined the wave break effects for each specific case. Based on the analysis of wave break capacity of mangrove forest and the maximum wave height in Vietnam this research project suggested standard structure of wave beak mangrove forest.

To study the wave break capacity of the mangrove forest band, the research group established 21 survey transects for investigating the sea wave height in many areas. The transects are oriented perpendicularly to the coastline. On each transect we determined 7 points for investigating the sea waves. The first point was located at the outer edge of the mangrove forest strip. The remaining points were designed to distribute along the transect, equally spaced

20 m into the forest. In each transect, the survey team did take five measurements of the wave height at different times. Parameters of forest structure were collected by means of silviculture investigations carried out right at the typical standard plots designed for each wave survey transect. Wave height was investigated by a pole engraved lines of centimeter unit.

The management and analysis of the silviculture data collected from the typical standard plots was conducted accordingly to the statistical methods [2], the processing of wave data was implemented using regression analysis methodologies and algorithms with the aid of computers [1].

3. Research results and discussion

3.1. Impacts of mangrove forest on sea wave characteristics in the Southern coastal salinity inundated flats based on the mathematical models using the field survey data

Characteristics of the sea wave height and wave height reduction requirements in the study area

In order to analyze the characteristics of the largest wave height in the coastal localities, the research group did make inventories of the maximum wave height observed at the time of 6:30, 12:30 and 7:00 every day during the whole period ranging from January 1, 2004 to December 31, 2005 at five marine stations: Quang Ninh, Hai Phong, Thanh Hoa, Da Nang, and Vung Tau. The results show that the maximum wave height in the project area ranges from within 3 meters to 5 meters.

Requirement to reduce the wave height to protect the sea dikes was determined via interviewing staff and residents using and doing management of the sea dikes serving for production and life. Results showed that most of the opinions were agreed that for the safety of dams and other civil works, the wave height behind the forest strip needs to be maintained at a level not exceeding 30 cm.

Structural characteristics of mangrove forests

The statistical results of forest investigations conducted at the standard mangrove forest plots were recorded in Table 1.

Table 1- Some silviculture inventory criteria of different mangrove forest types.

Dominant tree species	*Diameter at Breast height (cm)*	*Canopy diameter (m)*	*Tree stem height below branches (m)*	*Total tree height (m)*	*Density (number of trees/ha)*	*Forest canopy cover level (%)*
Mangrove apple /Berembang *(Sonneratia caseolaris (L.) Engl.)*	12,09	2,83	1,59	6,38	2.027	74
Mangrove *(Rhizophora apiculata Blume)*	9,75	2,84	6,16	11,31	4.142	77
Rheed 's caper/Thorn caper *(Capparis Micracantha, Capparis Henryi)*	7,59	2,41	3,63	7,58	2.974	75

Black Mangrove or River Mangrove/ Aegiceras *(Aegiceras corniculatum)*		1,51		1,64	8.063	83
Pisang-pisang *(Kandelia candel)*	7,49	1,45	0,68	2,22	13.613	93

Based on the data shown in Table 1, it is possible to make some remarks as below:

- The upper storey composition of mangrove forest is relatively simple, in the project areas there were 24 species discovered, but mainly consisted of five species namely Mangrove apple, Mangrove, Thorn caper, Black Mangrove, and Pisang-pisang.
- The growth situation of the existing species is clearly different. The average height of the forest states having the dominant species varied from 1.64 to 11.31m, the average diameter of the Berembang forest was largest, there were some trees having over 30 cm in diameter. Average diameter of Mangrove species was relatively large. Aegiceras was the smallest species, mostly like shrub land with very small diameter. The average height of the mangrove forests was 11m. The next were Thorn caper and Mangrove apple forests. Aegiceras and Pisang-pisang forests have minimum height, usually under 3m.

Density of the forest tends to change oppositely to the height and diameter, or size of trees. Aegiceras and Pisang-pisang forests have the greatest density, average density of trees in Aegiceras forest was approximately 10,000 trees/ha, of Pisang-pisang forests was 13,000 trees/ha while the density in Berembang forest reached only about 2,000 trees/ha and in mangrove forest reached more than 4,000 trees/ha.

The canopy cover levels in the forests were not very much different. In the forest of bigger tree species like Mangrove, Mangrove apple, and Thorn caper, the forest canopy cover reached more than 75%, while this number was 80% in Aegiceras forest and 90% in Pisang-pisang forest.

Sea wave height characteristics of mangrove forest strip

The analysis results showed that the reduction of the sea wave as reaching deep into the forest belt conformed to the exponential laws. The chart below is an example of the decline of the wave when entering deeply into the mangrove forest belt.

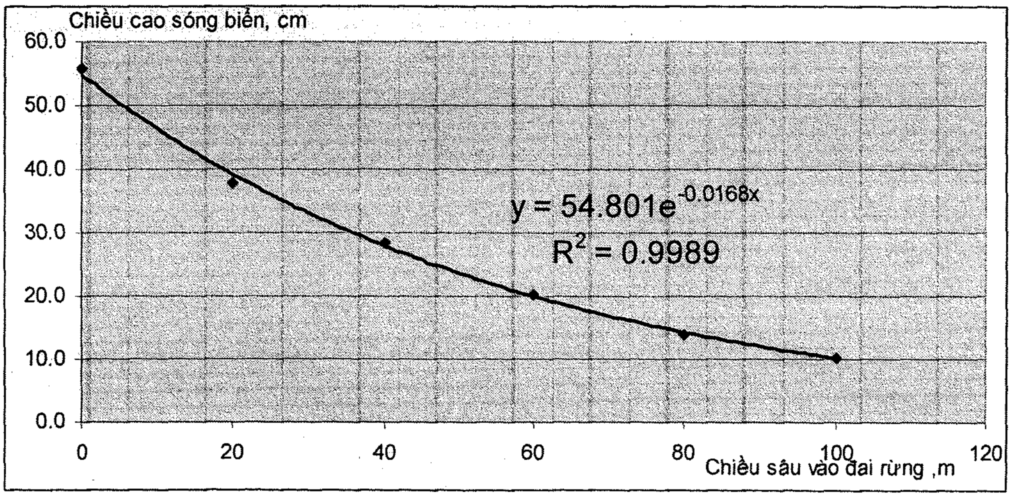

Figure 2- *Sea wave height distribution when reaching into the forest belt, observed at the first time measurement in transect number 1 of Mangrove forest in Can Gio*

Data analysis at all investigation times on the designed survey transects indicated that the relationship between wave height and distance length orienting deep in the forest belt conformed to the form of exponential equation $\mathbf{hs = a * e^{b*d}}$ with correlation coefficient R = 0.96. Where, hs is the height of the wave at the d meter position in the forest belt, a and b are the parameters of the equation.

Simulation equation when the wave goes deep into strip of mangrove forest.

The data analysis showed that the value of the parameters a and b in the equation simulating the relationship between the wave height and distance depth in the mangrove forest is variable depending on various factors.

Parameter **a** depends mainly on the wave height in front of the forest belt, **a** was calculated by the following formula:

$$\mathbf{a} = 1.0249\ (\mathbf{hs1}) - 0.9777\ ,\ R2 = 0{,}99$$

Where, **hs1** is the wave height in front of a forest belt, in cm.

Parameter b depends primarily on the characteristics of forest structure and was calculated using the following formula:

$$\mathbf{b} = 0.048066 - 0.0016 * \mathbf{Hvn} - 0.00177 * \ln(\mathbf{N}) - 0.00777 * \ln(\mathbf{TC}),\ R = 0{,}85$$

Where, **Hvn** is the average total height of trees in the mangrove forest, calculated in meter unit, **N** is the density of mangrove trees, taken into account only the trees at 1 m tall or above, (the number of trees / ha), **TC** is forest canopy cover of the dominant story, calculated in %.

General integrated equation determining the wave height at different locations in the forest belt can be written as follows:

$$\mathbf{hs = (1.025\ (hs1) - 0.977) * exp\{[0.0481 - 0.0016 * Hvn - 0.00177 * ln(N) - 0.00777 * ln(TC)] * d\}}$$

To analyze the confidence level of this equation, the authors conducted a statistical comparison of the wave height data computed from the synthesis equation mentioned above and the actual wave height data recoded from all 678 investigated cases. Chart 3 shows the relationship between wave height calculated theoretically based on the equation and the actual wave height with a very high determination coeffient ($R^2 = 0.92$).

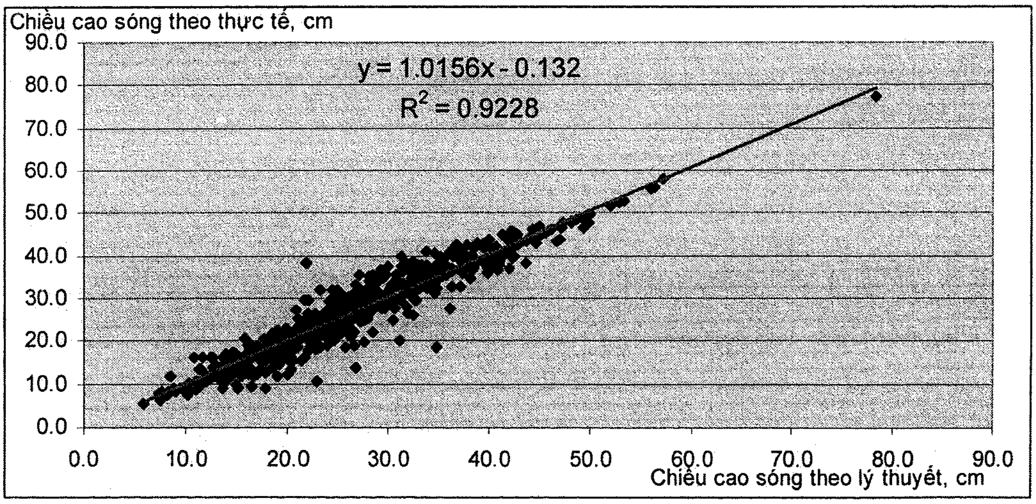

Figure 3 - *The compatibility of data on wave height calculated by the synthesis equation with wave height recorded by 678 actual measure times.*

Applying the statistical method for making interval estimate of the recurrent equation, the researchers identified that the estimate error of the wave height according to the distance depth into the forest belt ranged from an average of 1-2%.

3.2. Influences of structure, area, height, and distribution of mangrove trees strip on wave break effect using a physical model.

Mangrove forest tree characteristics and water break capabilities

The standard trees used to study the wave break capacity were Mangrove apple- one of the fast growing tree species widely planted in coastal protection forest strips. Their sizes characteristics were recorded in the following Table.

Table 2. Size characteristics of the standard trees

Order	DBH (cm)	Canopy Diameter (m)	Height (m)
1	10	2.5	3.2
2	13	3.5	3.3
3	12	3.0	3.5
4	16	4.2	3.5
5	15	4.0·	3.5
6	19	4.5	3.7
TB	14	3.6	3.4

These are medium sized trees in the forest. They have thick canopy, relatively compact layout which is convenient for conducting experimental measurements of the wave height. The diameters ranged from 10 to 19cm, canopy diameters from 2.5 to 4.5 m, and heights from 3.2 - 3.8m.

The relationship between stem diameter and canopy diameter as well as the relationship between canopy diameter and height of the standard trees are very close (Figure 4). Therefore, it is possible to use canopy diameter of the standard trees as indicators generally reflecting the general size of standard trees.

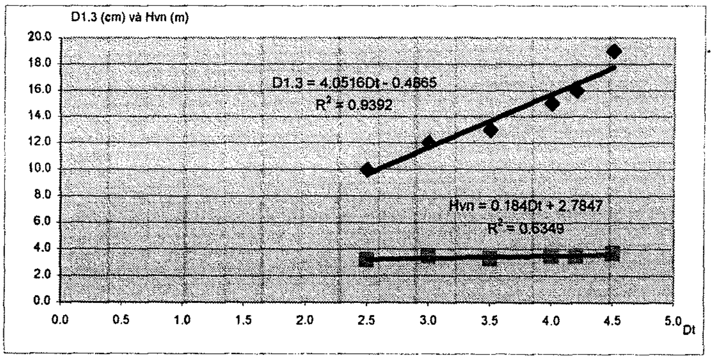

Figure 4. *Relationship between canopy diameter (Dt) with stem breast height diameter (D1.3) and forest tree height (Hvn)*

Physical model reflecting the influences of mangrove trees on the sea wave height

- Wave height around the standard trees

The wave height around standard trees was measured at 19 locations as shown in Figure 1. The results of data analysis allowed to come up with some comments as below:

- Value of the wave height at 1 meter in front of standard tree is the greatest, it decreased gradually to the rear and lateral of the standard trees.
- The decrease level of wave height behind the standard trees is associated with the trunk diameter, canopy diameter and height of the standard trees, but most close relationship was found with the their canopy diameter.
- Wave height at a position behind the standard trees is in close relation with wave height in front of the standard trees as well as the vertical distance and horizontal distances to the standard trees.
- It is possible to use multivariate equations for simulating the characteristics of wave height distribution behind and lateral positions of the standard trees as below:

$$Hs = Hs0 - \{0.71202 - 0.431635802*kcn - 0.02703732*(kcd-2.6924*\mathrm{Ln}(Dt) - 3.9761)^{\wedge}2 + 0.155077776*\mathrm{Ln}(Hs0) + 0.888855106*\mathrm{Ln}(Dt)\},\ R = 0.87.$$

Where: Hs is the wave height measured at any position behind the standard trees presented in centimeters, kcn is the horizontal distance from measured position to the longitudinal line spacing from the standard trees to the rear following the spread orientation of the wave and was measured in meters, kcd is the distance (in meters) on the vertical axis measured from the standard trees to the horizontal axis passing through the measured positions, Dt is the diameter (in meters) of the tree canopy, Hs0 is the wave height (in centimeters) measured at a distance of 1 meter in front of the standard trees.

Wave break effects of mangrove forest in different models of structure, area, height, and distribution of mangrove trees strips.

Based on the empirical equations, maximum coastal wave height (5 m) and the need to reduce wave height for protecting the sea dikes, the research group established models simulating wave height reduction in the mangrove forest in relation with different tree densities and different tree sizes. There are two principles to be applied in modeling: (1) – the reduction extent of the wave height at any position behind each row of trees is the total reduction of the wave height resulted in by the individual trees on that row, (2) - wave height at the back of this tree row is the wave height of the front of the next tree row.

The determined results of the wave height in different mangrove forest models having densities ranging from 400 to 1600 trees/ha and average canopy diameter of 2 - 3m were recorded in the following Table.

Table 3. Wave height at distances d in the mangrove forest belt having tree density N and different canopy diameter Dt

Order No.	d (m) distance	Density (number of trees/ha)								
		Dt = 2 m (canopy diam)					Dt = 3 m			
		1600	1250	830	500	400	1250	830	500	400
1	0	500.0	500.0	500.0	500.0	500.0	500	500	500	500
2	20	428.7	449.9	465.2	479.6	480.9	437.5	457.6	472.4	473.2
3	40	371.4	394.6	426.6	456.8	466.7	368.2	410.3	440.8	451.8
4	60	303.1	340.3	388.5	434.1	452.4	300.6	363.7	409.5	430.1
5	80	231.7	287.2	350.8	411.6	432.1	234.8	317.9	378.4	400.7
6	100	180.1	235.6	313.5	389.4	418.1	171.0	272.8	347.7	379.7
7	120	120.1	185.5	276.8	367.3	404.0	109.9	228.5	317.3	358.5
8	140	59.5	137.4	240.7	345.5	383.9	52.8	185.0	287.2	329.8
9	160	19.3	91.9	205.3	323.9	370.1	3.2	142.6	257.5	309.4
10	180	0.0	49.9	170.6	302.5	356.3	0.0	101.5	228.2	288.7
11	200	0.0	13.0	136.9	281.4	336.5	0.0	62.2	199.4	260.8
12	220	0.0	0.0	104.3	260.5	323.0	0.0	25.5	171.1	241.1
13	240	0.0	0.0	73.0	240.0	309.3	0.0	0.0	143.4	221.1
14	260	0.0	0.0	43.6	219.8	290.0	0.0	0.0	116.4	194.2
15	280	0.0	0.0	17.0	199.9	276.8	0.0	0.0	90.2	175.4
16	300	0.0	0.0	0.0	180.3	263.4	0.0	0.0	65.0	156.3
17	320	0.0	0.0	0.0	161.2	244.4	0.0	0.0	41.2	130.6
18	340	0.0	0.0	0.0	142.5	231.6	0.0	0.0	19.2	113.0
19	360	0.0	0.0	0.0	124.2	218.4	0.0	0.0	0.9	95.2
20	380	0.0	0.0	0.0	106.5	200.0	0.0	0.0	0.0	71.4
21	400	0.0	0.0	0.0	89.4	187.6	0.0	0.0	0.0	55.6
22	420	0.0	0.0	0.0	72.9	174.8	0.0	0.0	0.0	39.8
23	440	0.0	0.0	0.0	57.2	156.9	0.0	0.0	0.0	19.3
24	460	0.0	0.0	0.0	42.1	145.0	0.0	0.0	0.0	7.3
25	480	0.0	0.0	0.0	27.9	132.6	0.0	0.0	0.0	0.0
26	500	0.0	0.0	0.0	14.7	115.5	0.0	0.0	0.0	0.0
27	520	0.0	0.0	0.0	2.5	104.2	0.0	0.0	0.0	0.0
28	540	0.0	0.0	0.0	0.0	92.4	0.0	0.0	0.0	0.0
29	560	0.0	0.0	0.0	0.0	76.2	0.0	0.0	0.0	0.0

Tree density N/ha

yellow

turquoise

30	580	0.0	0.0	0.0	0.0	65.8	0.0	0.0	0.0	0.0
31	600	0.0	0.0	0.0	0.0	54.7	0.0	0.0	0.0	0.0
32	620	0.0	0.0	0.0	0.0	40.1	0.0	0.0	0.0	0.0
33	640	0.0	0.0	0.0	0.0	30.7	0.0	0.0	0.0	0.0
34	660	0.0	0.0	0.0	0.0	21.2	0.0	0.0	0.0	0.0
35	680	0.0	0.0	0.0	0.0	9.3	0.0	0.0	0.0	0.0
36	700	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0
37	720	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38	740	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	760	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	780	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

In the table above, colored yellow are areas of mangrove forest having lower wave break performance effects than requirement, while the turquoise areas are areas where wave break effects of mangrove forest meets the requirements for dike and other civil works protection.

3.3. Comparison of calculated data and actual surveyed/investigated data on the effect of the mangrove forest on reducing wave height in Southern coastal areas.

The difference between wave break effect of mangrove forest in the physical models and wave break efficiency of the forest belt in practice.

- The effect on wave break of mangrove forest belt determined from actual investigation data

Based on the close relationship equation between wave height and the distance going deep into the forest belt $\mathbf{hs = a*e^{b*d}}$ we are able to build the formula for calculating the necessary width of the breakwater forest belts as follows:

$\mathbf{d = [ln(hs)-ln(a)]/(b)}$,

In which: **hs** is the wave height needed to be reduced behind the forest belt, **a** is the maximum wave height in coastal areas and **b** is a parameter depending on the structural characteristics of mangrove forest.

Assuming the wave height in front of a forest belt (a) is 500cm, the height of waves behind the forest belt (hs) required to be 30cm, the research group determined the necessary width **d** of the forest belt according to the parameter **b**, the results were presented in Table 4.

Table 4- Required width of wave break forest belt according to parameter b

Parameter b	***Required width of wave break forest belt* (m)**	**Parameter b**	***Required width of wave break forest belt* (m)**
-0,0010	2.813	-0,011	256
-0,0012	2.345	-0,012	234
-0,0014	2.010	-0,013	216
-0,0016	1.758	-0,014	201
-0,0018	1.563	-0,015	188
-0,0020	1.407	-0,016	176
-0,0022	1.279	-0,017	165
-0,0024	1.172	-0,018	156
-0,0026	1.082	-0,019	148
-0,0028	1.005	-0,020	141
-0,0030	938	-0,021	134
-0,0032	879	-0,022	128
-0,0034	827	-0,023	122
-0,0036	782	-0,024	117
-0,0038	740	-0,025	113

-0,0040	703	-0,026	108
-0,0042	670	-0,027	104
-0,0044	639	-0,028	100
-0,0046	612	-0,029	97
-0,0048	586	-0,030	94
-0,0050	563	-0,031	91
-0,0060	469	-0,032	88
-0,0070	402	-0,033	85
-0,0080	352	-0,034	83
-0,0090	313	-0,035	80
-0,0100	281		

Calculated results in Table 4 shows that in the fluctuation extent of coefficient b in mangrove forest from -0.001 to -0.035, the wave break forest belt width necessarily required will range from 2.80 m to 80.00 m. With the average value of parameter b of mangrove forest in Southern region from 0.0110 to 0.0150, the minimum width required for breakwater forest belt is 190-250m.

- The effect on wave break of mangrove forest belt determined by physical models

The results of wave height in the mangrove forest belt determined by physical models in Table 3 shows that when the distance to the forest belt increases, wave height decreases gradually, the decrease extent depends on the density of forest trees. With a requirement of wave height behind the forest belt to be smaller than 30 cm and common density of forest from 830 to 1600 trees/ha, when the forest canopy diameter Dt ≈ 2 m, wave break forest belt width needed to be maintained is from 160 to 280 meters, while the average diameter of tree canopy Dt ≈ 3 m the forest belt width will be ranging from 180 to 220m.

The comparison between effectiveness on wave break of the actual mangrove forest and forest belts simulated by using the physical models showed no significant difference at all. This result confirms the accuracy of the law governing the reduction of the wave height of mangrove forest identified in this research project.

Wave height prediction in the mangrove belts

The research results mentioned above indicated that we can use two methods for predicting wave height in mangrove forest: (1) – By using the numerical tables already calculated the wave height in the mangrove forest based on density, forest canopy diameter and wave height in front of the forest strips (similar to Table 3) and (2) - By using the synthesis equation simulating the wave height when it goes deep into the mangrove forest strips. However, based on the correlation coefficient reflecting the accuracy of the empirical equations, the research group recommended that it is better to use the synthesis equation simulating the wave height when it goes deep into the mangrove forest strips.:

$$\mathbf{hs = (1.025\ (hs1) - 0.977)*exp\{[0.0481-0.0016*Hvn-0.00177*ln(N)-0.00777*ln(TC)]*d\}}$$

Wave break mangrove forest standard

Standards of wave break mangrove forests can be understood as the criteria and thresholds of the forests to ensure the wave height behind them to be 30 cm or less - a safety level for sea dikes and other civil works.

Based on the research results mentioned above, it is possible to set up the standards of breakwater forest using two criteria: structure coefficient of the mangrove forest (C) and the width of mangrove forest band (d).

Structure coefficient C of mangrove forest is determined by the reverse of the parameter b, $C = -b$, or $C = (0.0016*hvn+0.00177*\ln(N)+0.00777*\ln(TC))-0.048066$. The larger the coefficient C the higher the wave break capacity of forest belt, the smaller the required width of the forest belt.

The value set of the structure coefficient C and the required width necessary to ensure the wave height behind the forest belt which was determined smaller than 30 cm are the breakwater standards of mangrove forest. They are determined on the basis of using the equation reflecting the law of wave height reduction in the forest belt, the maximum wave height in front and wave height requirement behind the forest belt. From the results of the study it is easily to set a formula for determining the structure standard C of the mangrove forest belt based on the width of the forest belt. $C= [\ln(30)-\ln(100)]/(- d)$. Results determining the structure standard of mangrove forest are recorded in Table 5.

Table 5. Structure standard C of breakwater mangrove forest

Order No.	Width of the forest belt d (m)	Standard of structure coefficient C	Order No.	Width of the forest belt d (m)	Standard of structure coefficient C
1	100	0.02813	16	850	0.00331
2	150	0.01876	17	900	0.00313
3	200	0.01407	18	950	0.00296
4	250	0.01125	19	1000	0.00281
5	300	0.00938	20	1050	0.00268
6	350	0.00804	21	1100	0.00256
7	400	0.00703	22	1150	0.00245
8	450	0.00625	23	1200	0.00234
9	500	0.00563	24	1250	0.00225
10	550	0.00512	25	1300	0.00216
11	600	0.00469	26	1350	0.00208
12	650	0.00433	27	1400	0.00201
13	700	0.00402	28	1450	0.00194
14	750	0.00375	29	1500	0.00188
15	800	0.00352			

The data indicate that one of the structure standards of mangrove forest is to ensure that the structure coefficient C will not be less than coefficient C looked up from the table corresponding to each certain width of the forest strip, this standard is not fixed but changes accordingly to the width of the forest strip.

4. Conclusion

The maximum sea wave height in the study areas ranged from 3 meters to 5 meters, for the safety of sea dikes, dams and other civil works, the wave height behind the forest strip required to be not exceed 30 cm.

The species composition of mangrove forest in the project areas of this research is relatively simple, the most dominant species are five species namely Mangrove apple, Mangrove, Thorn caper, Pisang-pisang, and Black Mangrove. Average height of mangrove forest ranged from 1.64 to 11.31m, average stem diameter from 8-12 cm, canopy diameter from 1.4-2.8m, average density from 2,000 to 13,000 trees/ha. The forest cover varied from 75% to 90%.

The main reduction of the sea waves when they go deep into the forest belt conformed to the exponential law $\mathbf{hs = a*e^{b*d}}$. It is possible to use the general synthesis equation to determine the wave height when it goes deep into the forest belt with an average error of 1-2%.

- Wave height at 1 meter in front of the standard trees has the greatest value, it decreased gradually to the rear and side to side of the standard trees. We can use multivariate equations to simulate the characteristics of wave height distribution in the rear and side to side of the standard trees based on the kcn, including the horizontal distance, vertical distance, canopy diameter and height of waves at 1 meter in front of the standard tree's canopy.

Based on the empirical equations simulating the wave height reduction law behind individual trees, maximum coastal wave height (5 m) and the need to reduce wave height to protect sea dykes we can set up a reduction model of wave height in the mangrove forest with different densities and tree sizes.

- No significant difference between the reduction effectiveness on the wave height of the actual mangrove forest belts and simulated forest belts based on the physical models. This fact confirms the accuracy of the law governing the reduction of the wave height of mangrove forest identified in this research project. We can predict the wave height in different locations in the mangrove forest belt based on the simulation equation shown as below:

$$hs = (1.025\ (hs1) - 0.977)*\exp\{[0.0481-0.0016*Hvn-0.00177*\ln(N)-0.00777*\ln(TC)]*d\}$$

The structure standard of mangrove forest is to ensure that the structure coefficient C will not be less than coefficient C looked up from the table corresponding to each certain width of the forest strip, this standard is not fixed but changes accordingly to the width of the forest strip.

References

1- Vương Văn Quỳnh et al. Science and technology report "Research on determining forest area necessarily required for localities, Ha Tay, 2007.

2 - Nguyễn Hải Tuất, Ngô Kim Khôi. "Statistical analysis of empirical research data in agriculture and forestry using the computer," Agricultural Publishing House, Hanoi 1996