Rhizophora apiculata as Coastal Defense against Disaster; A review of their strength

University of Miyazaki Student Member Akhmad Adi Sulianto
University of Miyazaki Associate Professor Keisuke Murakami

1. Introduction

Recently, coastal forests have been considered by many parties as one of the mitigation measures against extreme events, such as tsunamis and storm waves. In some degree, coastal forest vegetation's are generally sufficient to withstand extreme winds, storms, and salt sprays. Several reports and surveys (field observations, experienced damage, and satellite images) have apparently shown evidence that coastal forests have played an important role as a natural protection against tsunami (Forbes, 2007). Ecologically, *mangrove* is used for the green belt around coastal area. It's used for the wave breaker. The researches had shown that mangrove especially the *Rhizophoraceae* family has the potentials to reduce *tsunami* waves. Istiyanto *et* al. (2003) concluded that *Rhizophora* spp., reflected, continued and absorbed the *tsunami* wave energy by changing the height of the wave. Mazda and Wolanski (1997) and Mazda and Magi (1997) added that *mangrove* vegetation, especially its roots could absorb *tsunami* wave energy by reducing the height of wave while passed through *mangrove*. Despite this recognition, the strength of *Rhizophora apiculata* is still poorly researched. Hence, it is important to analyze the strength of *Rhizophora apiculata* especially their stilt root.

Figure 1. *Rhizophora apiculata*

2. Concept and Method

The research uses experimental research placed in laboratory. It is to seek the stilt root's material strength through physical tests; (1) compressive stress, (2) tensile stress, and (3) shear stress. The test results are compared with concrete, and wood's material strength. The comparison shows whether *Rhizophora apiculata* is capable to be used as defense as well as other coastal protection e.g. breaks water and seawall. The basic method of this research is using the *Uniaxial stress* expressed by:

Figure 2. Physical testing machine.
(a) device to test the samples, (b) device to measure the forces

$$\sigma = \frac{F}{A}$$

Where:
σ = sigma (N/m^2), F = force (N), A = area (m^2).

The equation is used for the basic method because the *testing machine* used it in operation. The main difference is the unit used by the machine to define force; it is kilogram force (Kgf). 1 Kgf = 9.80665 N.

3. Result and Discussion

The result shows the value of forces that *Rhizophora apiculata's stilt roots* able to receive. The tensile stress value is the highest with sigma average value 81,920 MPa. The parallel fiber compressive stress has 56,928 Mpa. The shear test has 11,409 Mpa, and the perpendicular fiber compressive stress has the lowest sigma average value 8,558 Mpa.

Table 1. Result of Physical Test of *Rhizopora apiculata*

		Tensile stress	Compressive stress		Shear stress
			Parallel fiber	Perpendicular fiber	
Sample 1	Sample sub total	3 pieces	3 pieces	-	3 pieces
	Highest σ	114.859 MPa	56.553 MPa	-	9.999 MPa
	Lowest σ	60.559 MPa	52.029 MPa	-	5.394 MPa
	Average σ	87.752 MPa	54.682 MPa	-	7.440 MPa
Sample 2	Sample sub total	1 pieces	4 pieces	8 pieces	6 pieces
	Highest σ	-	71.062 MPa	44.089 MPa	19.068 MPa
	Lowest σ	-	45.905 MPa	2.075MPa	6.810 MPa
	Average σ	67.003 MPa	58.613 MPa	8.559 MPa	13.393 MPa
Sum (Seek value)	Sample sub total	4 pieces	7 pieces	8 pieces	9 pieces
	Highest σ	114.859 MPa	71.062 MPa	44.089 MPa	19.068 MPa
	Lowest σ	60.559 MPa	52.029 MPa	2.075 MPa	5.394 MPa
	Average σ	**81.920 MPa**	**56.928 MPa**	**8.558 MPa**	**11.409 MPa**

Compare to concrete grade specification based on international standard of compressive stress of concrete, it clearly be seen that compressive stress of *Rhizophora apiculata's* stilt roots is more than concrete's maximum standard (Table 2). Moreover, coastal structures usually are categorized to K 350 that have compressive stress about 29 MPa. It is mean that *Rhizophora apiculata* has strong root and could be able to be natural defense as coastal protection. Tensile stress of *Rhizophora apiculata's stilt roots* is below minimum standard requirement of steel's grade. But it is strong enough to hold a force of 80 tons/m^2, it is equivalent with 8 times trailer's load (1 trailer load = ± 10 tons). Meanwhile, compare with the quality of wood grade base on wood as structural material, *Rhizophora apiculata's* stilt root could be categorized as wood with medium standard that have compressive stress among 49 MPa to 58.8 MPa (Table 3).

Table 2. *Rhizophora apiculata's* σCS average compared with concrete's f 'c

	Rhizophora apiculata's stilt roots	Concrete's grade [5]	f 'c	Usability
Less than requirement				
Minimum standard		K 125	10,5 MPa	Working floor, wet land concrete
		K 250	21 MPa	Paving block, non-bridge structure
Medium standard		K 350	29 MPa	Diaphragm, bridge floor, reinforced concrete girder, box culvert, column
		K 500	40 MPa	Pre-stressed concrete at bridge girder
Maximum standard		K 600	50 MPa	Circle pre-stressed concrete pile
More than requirement	**σCS average = 56,928 MPa**			

Table 3. *Rhizophora apiculata's* σCS average compared with Wood's σCS wood

	Wood's grade[6]	σCS_{Wood}	*Rhizophora apiculata's* stilt roots
Less than requirement			
Minimum Standard	Very weak	< 34.3 Mpa	
	Weak	34.3 – 49 Mpa	
Medium standard	**Medium**	**49-58,8 Mpa**	**σCS average = 56,928 MPa**
	Strong	58.8 – 73.5 Mpa	
Maximum standard	Very Strong	>73.5 Mpa	
More than requirement			

Both of table 2 and table 3 show that *Rhizophora apiculata's stilt roots* material strength in compressive stress is above the concrete's maximum standard and could be categorized in the medium of wood's grade. The result also indicated that *Rhizophora apiculata's stilt roots* material strength in tensile stress is under the minimum requirement standard of steel's tensile stress. But it is above 80 MPa, which means it is strong enough to hold a force 80 tons/m^2, it is a huge force that equivalent with 8 times trailer's load (1 trailer load = ± 10 tons).

The conditions above are strong enough to approve that *Rhizophora apiculata* is capable to be used as coastal protection such as break water and seawall. The principal structure of coastal protection is loaded by compressive strength 56,928 MPa is more than strong enough to be used as alternative coastal structures beside seawall and breakwater. Therefore, we propose the greenbelt barrier instead of the hard system like breakwaters because they cost high expense. The greenbelt is composed of the mangroves trees with enough stability against tsunami pressure and it may be grown up in the residential vegetation of the coastal areas such as *Rhizophora apiculata*.

4. Conclusion

Rhizophora apiculata's stilt roots material strength in compressive stress is above the concrete's maximum standard and categorized in the medium of wood's grade. The grade of *Rhizophora apiculata's stilt roots* material strength are their tensile stress more than their compressive stress parallel fiber and their shear stress more than their compressive stress perpendicular fiber. *Rhizophora apiculata* is capable to be used as coastal protection because it has compressive strength. 56,928 Mpa and the wood have long lasting about 50 years.

References

1. Forbes K., J. Broadhead. 2007. "The role of coastal forests in the mitigation of tsunami impacts", Food and Agriculture Organization of the United Nations (FAO), FAO, Bangkok, 20 pp.
2. Istiyanto D.C., K.S. Utomo, & Suranto. 2003, "Pengaruh Rumpun Bakau Terhadap Perambatan Tsunami di Pantai", Seminar Mengurangi Dampak Tsunami: Kemungkinan Penerapan Hasil Riset, BPPT – JICA, 11 March 2003, Yogyakarta (in Indonesia).
3. Mazda, Y., Magi, M., Kogo, M. and Hong, P.N. 1997. Mangroves as a coastal protection from waves in the Tong King Delta, Vietnam. Mangroves and Salt Marshes 1: 127-135.
4. Mazda, Y. Wolanski, E. and Ridd, P.V. 2006. The Role of Physical Processes in Mangrove Environments Manual for the preservation and utilization of mangrove ecosystems.
5. Official rules for Concrete Structures, Materials and Workmanship: Concrete B 5, 1965.
6. Wagiman dan M Nasroen Rivai. 1975. *Kayu Sebagai Bahan Bangunan* (in Indonesia).