EFFECTIVENESS OF HYBRID ENGINEERING COMBINATION OF CEMENTED PVC AND USED TIRES, PROTECTING MANGROVE VEGETATION AND PREVENTING ABRASION ON KALIWLINGI BEACH, EAST BREBES, BREBES REGENCY, CENTRAL JAVA, INDONESIA

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ABSTRACT *Brebes Regency has experienced severe coastal abrasion, leading to significant mangrove deforestation, particularly in Kaliwlingi Village, where 186 ha of land has been lost. This research aims to develop and implement a hybrid engineering approach for Wave Breaking Equipment (APO) to protect the coastline and mangrove ecosystems. The study, conducted from July to September 2023, involved field observations at three stations, assessing mangrove vegetation and hydrodynamic conditions. Two dominant mangrove species,* Rhizophora mucronata *and* Avicennia marina*, were identified, with an average density of 4,166 trees/ha. Hydrodynamic analysis revealed the influence of tidal currents on erosion, necessitating the embedding of hybrid structures at a depth of at least 1.07 m for stability. The APO was constructed using locally available materials such as bamboo, wood, and PVC reinforcements. The study highlights the effectiveness of hybrid engineering in mitigating coastal abrasion and emphasizes the role of mangrove conservation in shoreline protection.*

Keywords*: Coastal abrasion, mangrove conservation, hybrid engineering, wave breaking equipment, Brebes Regency, hydrodynamic analysis.*

INTRODUCTION

Background

Brebes Regency has a coastline of approximately 63 kilometers. The area of mangrove area of Brebes Regency in 1983 was recorded at 2,327 ha, reduced to 505.2 ha (2000), 274.00 ha (2010), 243.20 ha (2015) [1], and increased to 370.62 ha (2018) due to reforestation factors [2], [3]. The length of the coastline of the East Brebes region is about 15 km and the existence of mangroves at several points of the coast has been eroded by sea currents from 1963 to 2009 covering an area of 812 ha. [4]. Kaliwlingi Village Beach, East Brebes experienced abrasion along 7 km covering 186 ha. or 30% of the area of abrasion in Brebes Regency [6]. The mangrove forest on the coast of East Brebes in 1996 was 51.84 ha., through reforestation increased to 114.30 ha. (2000), but reduced again abrasion to 43.29 ha. (2007), and increased again to 163.62 ha. (in 2010), 286.38 ha. (in 2015), and to 475.65 (in 2019) due to reforestation [5]. Another source states that the area of mangroves in Kaliwlingi Village, East Brebes in 2008-2013 increased by 101.25 ha. from 48.42 ha. (2008) to 149.67 ha. (in 2013), increasing again to 333.9 ha. (2018)[7]. Mentioned the results of reforestation of mangrove forests on Kaliwlingi beach, East Brebes from 2004 - 2024 reached 445 ha.

Mangrove ecosystems have a very strategic role due to their ecological and economic functions. From the ecological side, mangrove ecosystems are able to act as a buffer for the dynamics of coastal fisheries resources and other fauna and flora, protectors against abrasion / physical degradation of the coast, new renewable energy sources, and carbon traps that are very effective in reducing the level of air and water pollution. Economically, mangrove forest areas can be a source of food, beverages, craft products, medicinal / medical ingredients, cosmetics, as well as driving the economy of the people through mangrove ecotourism. Based on this, the existence of mangrove forests and coastal stability as mangrove areas need to be protected properly. One way that can be done is to protect the coast from abrasion in the form of Wave Breaking Equipment (APO). One type of APO that is efficient in its procurement is hybrid engineering, because it is made from simple materials such as wood and bamboo which are easily found around the coast and relatively cheap. However, it is necessary to conduct a study to obtain a hybrid engineering APO installation technique that is effective in surviving the onslaught of waves / ocean currents, and is able to protect the beach and the existence of mangroves with all its ecological and economic functions.

Research Objectives and Novelty

The expected purpose and novelty of this research is to obtain a hybrid engineering design and installation technique that is effective in reducing coastal abrasion and protecting mangrove vegetation.

METHOD

This research was conducted in July-September 2023 in Kaliwlingi beach area, Brebes District, Brebes Regency, Central Java Province, Indonesia. The research was experimental in nature by observing the condition of mangrove vegetation at 3 selected observation stations and measuring ocean currents on the beach. The data obtained is then used to design the design and installation techniques of hybrid engineering that are effective in preventing/reducing abrasion and protecting existing mangrove vegetation.

RESULTS AND DISCUSSION

Mangrove Forest Condition in Kaliwlingi Beach

The observation results showed that in the three observation stations there were 2 types of mangrove vegetation that were found and suitable for planting in the coastal area of Brebes Regency, namely: Rhizophora mucronata, and Avicennia marina. This is in accordance with the opinion of [7], which states that the type of mangrove planted to retain coastal abrasion is Rhizophora spp. and if for greening alone can be planted Avicennia spp. R. mucronata type which is called bangka by the locals and spread almost evenly and dominate along the coast, waterways and pond bunds on Pandansari beach, Kaliwlingi, Brebes District, Brebes Regency as presented in Figure 1. The A. marina is not always found at each observation station.

Figure 1. Rhizopora mucronata at Kaliwlingi beach, Brebes

a. Mangrove Forest Density

Based on the results of research on the density of mangrove forests in the 10-year-old core zone, presented in Table 1 and Figure 2.

Table 1. Mangrove Forest Density Data Based on Research Results.

Mangrove type	Tree density (ind/4 m^2)								
	Station 1 Muddy			Station 2 Sandy			Station 3 Muddy Sand		
	Tr 1	Tr 2	Tr 3	Tr 1	Tr 2	Tr 3	Tr 1	Tr 2	Tr 3
Rhizophora marinna	2	[illegible]	3	[illegible]	2	0	3	1	1
Avicennia marina	0	0	0	0	1	0	0	0	1

Information: Tr: transect

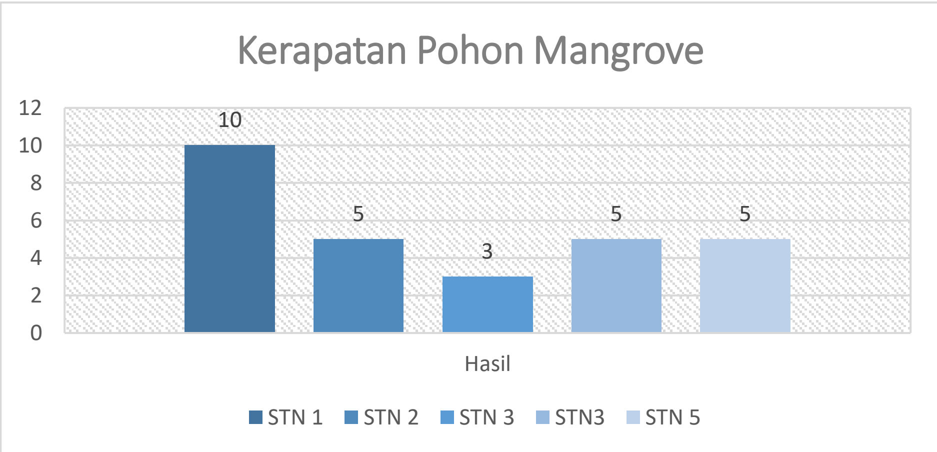

Figure 2. Graph of Mangrove Tree Density at 5 Stations

The average number of mangrove trees at each station is 5 trees, with a density of 5 ind/m2 or 4,166 ind/ha. The results of the statistical analysis showed that there was no difference in the density of mangrove forests at each station.

b. Mangrove Trees Size

The size of the mangrove trees at each observation station has a size range of 5.00–13.50 cm, as presented in Table 2 and Figure 3.

Table 2. Differences in the Size of the Rhizophora Mangrove Vegetation Stems (cm)

Sta	Sediment Texture	Mangrove tree size (cm)					Average	SD
		1	2	3	4	5		
1	Substrate Muddy	8,30	8,50	10,40	9,50	8,00	8,94	0,99

2	Substrate Sandy	8,50	10,00	10,00	5,00	8,00	8,30	2,05
3	Substrate Muddy sand	7,00	8,00	11,00	11,00	13,50	9,50	2,60

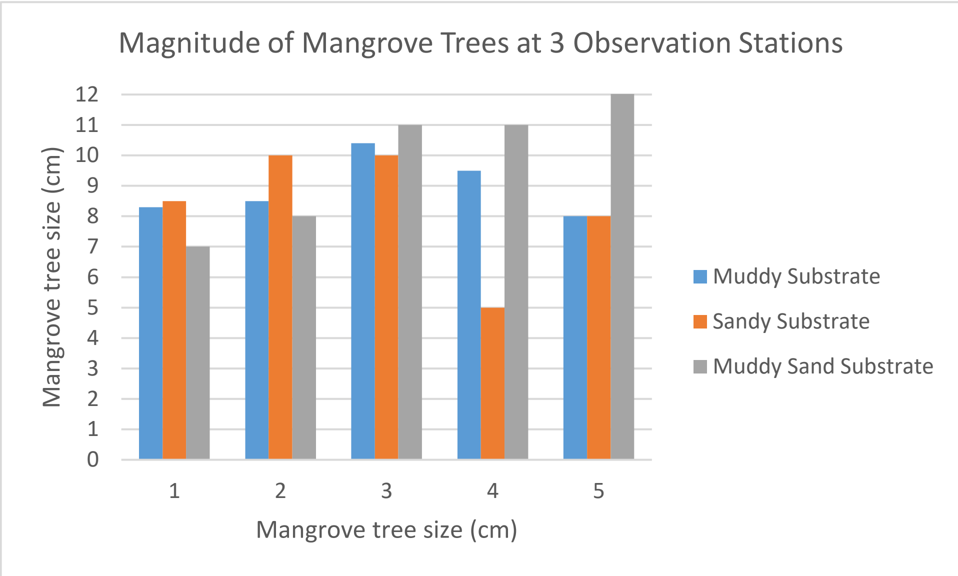

Figure 3. Graph of Mangrove Tree Magnitude at 3 Observation Stations

Hydrodynamic Conditions And Calculations For Hybrid Engineering Installation

Increasing the effectiveness of hybrid engineering installation requires careful calculation of the energy of ocean currents/waves striking the shore. This is related to the depth at which the hybrid engineering is anchored or installed. The energy that holds the hybrid engineering legs must be balanced with the energy of the currents/waves that hit them. The influential ocean currents are horizontal ocean currents in the form of ocean waves on the beach and vertical currents in the form of tidal currents and upwelling. Vertical currents in the coastal waters of eastern Brebes tend to be dominated by tidal currents rather than upwelling due to shallow and sloping coastal waters.

The influence of tidal currents as a vertical water movement in the coastal waters of East Brebes needs to be taken into account considering the shape of the East Brebes coastal area which resembles a large bay so that strong tidal currents are possible. It is as stated by [6] that in coastal waters, especially in bays or narrow straits, the movement of ups and downs of water levels will cause tidal currents. Usually the direction is more or less alternating, for example if the water level moves up the water flows in, while when the water level moves down the current flows out. These tidal currents in certain places are quite strong and in other areas the tidal strength is usually less than 1.5 m/s, and in the open sea the tidal strength is less than 0.5 m/s.

a. **Ocean Waves/Currents**

The results of observations of ocean current/wave motion at the research site are presented in

Table .

a. The first observation

Observation Location: Pantai Dukuh Pandansari, Ds. Kaliwlingi, Kec. Brebes, Kab.Brebes

date : July 2, 2023

Hours : 10.30 – 15.30

No	Wave Frequency			Wave Height			v	P	H
	N	t (sec)	F (Hz)	H_{maks} (cm)	H_{min} (cm)	R (m)	(m/s)	(Watt)	(m)
1	5	25	0.20	63	29	0.17	0.21	1.90	0.78
2	10	46	0.22	64	28	0.18	0.25	2.53	1.03
3	15	79	0.19	63	28	0.18	0.22	2.23	0.91
4	20	85	0.24	64	30	0.17	0.26	2.35	0.96
5	25	112	0.22	63	29	0.17	0.25	2.26	0.92
6	30	135	0.22	64	31	0.16	0.22	1.76	0.72
7	35	144	0.24	65	31	0.17	0.26	2.35	0.96
8	40	150	0.27	63	28	0.17	0.29	2.62	1.07*
Average									
	22.50	97	0.23	63.63	29.25	0.17	0.25	2.26	0.92

b. The second observation

Observation Location: Pantai Dukuh Pandansari, Ds. Kaliwlingi, Kec. Brebes, Kab.Brebes

date : July 23, 2023

Hours : 12.30 – 15.30

No	Wave Frequency			Wave Height			v	P	h
	N	t (sec)	F (Hz)	H_{maks} (cm)	H_{min} (cm)	R (m)	(m/s)	(Watt)	(m)
1	10	44	0.23	65	31	0.17	0.26	2.35	0.96
2	13	56	0.23	65	30	0.18	0.26	2.63	1.07*
3	14	60	0.23	62	28	0.17	0.25	2.26	0.92
4	17	73	0.23	65	30	0.18	0.26	2.63	1.07*
5	20	97	0.21	63	28	0.17	0.22	1.98	0.81
6	23	114	0.20	64	29	0.17	0.21	1.90	0.76
7	26	121	0.22	65	30	0.18	0.24	2.43	0.99
8	29	130	0.22	64	29	0.17	0.23	2.07	0.85
Average									
	19	86.88	0.22	64.13	29.37	0.17	0.25	2.26	0.92

c. The third observation

Observation Location: Pantai Dukuh Pandansari, Ds. Kaliwlingi, Kec. Brebes, Kab.Brebes

date : August 12, 2023

Hours : 10.30 – 14.30

No	Wave Frequency			Wave Height			v	P	h
	N	t (sec)	F (Hz)	H_{maks} (cm)	H_{min} (cm)	R (m)	(m/s)	(Watt)	(m)
1	10	45	0.22	62	29	0.17	0.24	2.17	0.86
2	12	51	0.24	61	29	0.16	0.24	1.92	0.78
3	14	57	0.25	64	30	0.17	0.26	2.35	0.96
4	16	69	0.23	63	28	0.18	0.26	2.63	1.07*
5	18	81	0.22	61	29	0.16	0.22	1.76	0.72
6	20	92	0.22	64	32	0.16	0.22	1.76	0.72
7	23	102	0.23	65	30	0.18	0.26	2.63	1.07*
8	25	110	0.23	66	32	0.16	0.23	1.84	0.75
<u>Average</u>									
	17.25	75.88	0.23	63.25	29.88	0.17	0.25	2.26	0.92

Description:

* = highest value

N = number of waves

t = wave time (seconds)

F = wave frequency (Hz)

Hmax = maximum wave height (cm)

Hmin = minimum wave height (cm)

R = wave amplitude (m)

v = wave speed (m/s)

b. Calculation of Hybrid Engineering Depth

The calculation of the hybrid engineering embedment depth is carried out as follows

$$\text{Frequency (F)} = \frac{N}{t}$$

$$\text{Amplitude (R)} = \frac{Hmax - Hmin}{2}$$

$$\text{Wave speed (v)} = 2\,\pi\,f\,R$$

Power per meter of wavefront (P) = $$\frac{1}{32}\,\dot{\rho}\, g\, R^2\, v$$

where :

P (wave power)

$\dot{\rho}$ (seawater density) = 1020 kg/m3

g (gravitational force) = 9.81 m/s2

Volume of measuring cup 500 ml (0.5 liter = 0.5 dm3 = 0.0005 m3)

Weight of empty measuring cup 220 grams (0.220 kg),

Weight of measuring cup filled with seawater = 0.730 kg

Water weight = 0.730 - 0.220 = 0.510 kg

Density of seawater ($\dot{\rho}$) = 0.510 kg/0.0005 m3 (1020 kg/m3)

The balance between the strength of the hybrid engineering planting and the wave power hitting the beach can be met if the potential energy of the mangrove vegetation planting is equal to the wave power per meter of wavefront.

P = E pot

E pot = mgh so that h = P / mg

where :

E pot = potential energy (kg/m.dt2)

g = gravitational force (9.81 m/s2)

h = depth of hybrid engineering (m)

m = weight of one leg of hybrid engineering = 2.50 kg

The highest value of h in the three observation times is 1.07 m so that the legs of hybrid engineering need to be plugged into the subgrade of coastal waters at least 1.07 m deep so as not to collapse by the waves of the sea.

Construction of Hybrid Engineering Breakwater (APO)

The wave breaker (APO) installed at the research site is a hybrid engineering APO made from local raw materials (bamboo and wood). The APO construction was chosen to be a triangular construction model, with one of the sharp ends installed facing the direction of the waves. This is with the calculation and hope that APO will be stronger to withstand the waves and waves of the sea. Based on feedback from the Research Partners, the APO was strengthened/enhanced by the installation of PVC pralon casted with cement on the inside of the PVC. In addition to this, on the inside of the APO triangle, a pile of used outer tires was also given a wooden stake on the inside of the tire to keep the tire from shifting places. The tire piles were not tied and were arranged to move up and down (vertically) to effectively capture sediment/silt carried by waves and ocean waves towards the APO. The materials and APO to be modified are presented in Figure 4 and Figure 5.

Figure 4: Raw materials for the wave breaking device

Figure 5. Breakwater tool

Hybrid Engineering Installation Location

The planned location of the hybrid engineering installation is in the coastal waters of Dukuh Pandansari, Kaliwlingi Village, Brebes District, Brebes Regency, Central Java, with coordinates 109o04'49.1” East; 6o49'0.4” LS. The location at these coordinates is a mutual agreement between researchers, partners, and research beneficiaries. Kaliwlingi beach waters is a sloping beach, there are sandbanks in the beach waters, fine-grained grayish beach sand. The height of the beach is ±3 m with a width of ±25 m. It has experienced abrasion of ±500 meters from the shoreline to the land (1992-2003) with a coastal abrasion rate of ±55 m/year. On the Kaliwlingi beach there are damaged mangroves and there are mangroves from reforestation. In the location used for the research, the mangroves were in an open condition facing the direction of the incoming sea waves so that some of the mangrove vegetation began to be damaged again and endangered by abrasion.

Figure 6. Beach and mangroves are eroded at Pandansari beach, Kaliwlingi Village

Research Activity Partners

The research partner is the Community Mangrove Forest Conservation Group (KMPHM) of Kaliwlingi Village, Brebes District, Brebes Regency.

Figure 7: Coordination of the research team with research partners and handover of research funds

CONCLUSION

The study found that *Rhizophora mucronata* and *Avicennia marina* are the dominant mangrove species in Kaliwlingi Beach, with *R. mucronata* playing a key role in coastal protection. The mangrove density averaged 5 ind/m², and tree sizes ranged from 5.00–13.50 cm. Hydrodynamic analysis showed that tidal currents significantly influence the area, requiring hybrid engineering structures to be embedded at least 1.07 meters deep for stability. A hybrid breakwater (APO) using bamboo, PVC, and tires was designed to reduce erosion, which has reached ±55 meters per year. Collaborative conservation efforts with local communities are crucial for coastal protection and mangrove restoration.

REFERENCES

Sugianto, D. N., Widada, S., Wirastriya, A., Ismanto, A., Hartati, R., Widianingsih, W., ... & Suripin, S. (2020). Framework for Plans Permeable Breakwater Eco-Friendly Building Identification and Characteristics Materials Construction Study Case at Demak Village.

Perricone, V., Mutalipassi, M., Mele, A., Buono, M., Vicinanza, D., & Contestabile, P. (2023). Nature-based and bioinspired solutions for coastal protection: an overview among key ecosystems and a promising pathway for new functional and sustainable designs. *ICES Journal of Marine Science*, *80*(5), 1218-1239.

Yang, Y., Jalalah, M., Alsareii, S. A., Harraz, F. A., Thakur, N., Zheng, Y., ... & Salama, E. S. (2024). Plastic waste and microplastics (MPs) formation: Management, migration, and environmental impact. *Journal of Environmental Chemical Engineering*, 112926.

Abbas, M. (2021). *Resilience based restoration of mangrove ecology in the Kingdom of Bahrain* (Master's thesis, Eesti Maaülikool).

Goreau, T. J. (2024). Indigenous/endogenous sea peoples: climate change adaptation and environmental regeneration prospects. In *Traditional Knowledge and Climate Change: An Environmental Impact on Landscape and Communities* (pp. 189-252). Singapore: Springer Nature Singapore.

Al Alwan, B., Ismail, B., El Jery, A., & Badawi, A. K. (2024). State-of-the-art strategies for microplastics mitigation in aquatic environments: identification, technological innovations, and prospects for advancement. *Journal of Water Process Engineering*, *61*, 105336.

Tayebi, S. T., Sambucci, M., & Valente, M. (2024). Waste Management of Wind Turbine Blades: A Comprehensive Review on Available Recycling Technologies with A Focus on Overcoming Potential Environmental Hazards Caused by Microplastic Production. *Sustainability*, *16*(11), 4517.

H. Purnomo, et al., Community-based fire prevention and peatland restoration in Indonesia: a participatory action research approach, Environ. Dev. 50 (2024) 100971. October 2022.

K. Kismartini, A. Roziqin, N. Authori, A stakeholder analysis for sustainable development of Maritime Village in Semarang coastal community, Indonesia, Public Adm. Policy 26 (3) (2023) 321–334.

Y. Zhao, Y. Li, Blue transition for sustainable marine fisheries: critical drivers and evidence from China, J. Clean. Prod. 421 (June) (2023) 138535.

K.L. Leo, C.L. Gillies, J.A. Fitzsimons, L.Z. Hale, M.W. Beck, Coastal habitat squeeze: a review of adaptation solutions for saltmarsh, mangrove and beach habitats, Ocean Coast Manag. 175 (December 2018) (2019) 180–190.

Y. Fern´andez-Palacios, et al., Status and perspectives of blue economy sectors across the Macaronesian archipelagos, J. Coast Conserv. 27 (5) (2023).

F. Yulianda, Coastal rehabilitation efforts through community perception : a case study in Karawang Regency , Indonesia, AACL Bioflux 14 (1) (2021) 72–90.

A. Miedtank, J. Schneider, C. Manss, O. Zielinski, Marine digital twins for enhanced ocean understanding, Remote Sens. Appl. Soc. Environ. 36 (2024) 101268. August 2023.

R. Patel, Securing development: uneven geographies of coastal tourism development in El Salvador, World Dev. 174 (2024) 106450. October 2023.

S. Narwal, M. Kaur, D.S. Yadav, F. Bast, Sustainable blue economy: opportunities and challenges, J. Biosci. 49 (1) (2024).

A. Midlen, Enacting the blue economy in the Western Indian Ocean: a ‘collaborative blue economy governmentality, Environ. Plan. E Nat. Sp. 7 (2) (2024) 627–653.

M. Khan, Y.C. Chang, A. Bibi, Navigating Pakistan’s Maritime Industry potential in context of blue economy: an analysis of the necessity for ratification of maritime labour convention 2006, Mar. Pol. 165 (May) (2024) 106150.

A.A. Rami, M. Faiq, A. Aziz, N.A. Muhamad, Characteristics and success factors of rural community leadership in Malaysia : a focus group analysis, Pertanika J. Sci. Technol. 29 (3) (2021) 1591–1609.

C.R. Priadi, et al., Policy and regulatory context for self-supplied drinking water services in two cities in Indonesia: priorities for managing risks, Environ. Dev. 49 (November 2023) (2024) 100940.