

CompariSonal AnalySiS of Fly Ash (CaSh Study at PLTU Port Ratu)

Ismail ^{a,1,*}, Ardin Rozandi ^{a,2}, Danang Purwanto ^{a,3}, Tsulis Iqbal Khairul Amar ^{b,4}, Matrunevich Oksana Viktorovna ^{c,5}

^a Civil Engineering Study Program, Nusa Putra University, Sukabumi Indonesia

^b Civil Engineering Study Program, Muhamadiyah Surakarta University, Surakarta Indonesia

^c Rostov State Transport University, Rostovskogo Strelkovogo Polka Narodnogo Opolcheniya Sq., 2, Rostov-on-Don, 344038

¹ ismail_ts18@nusaputra.ac.id; ² ardin.rozandi@nusaputra.ac.id; ³ danang.purwanto@nusaputra.ac.id; ⁴ tsulisibalka@nusaputra.ac.id;

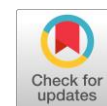
⁵ oks.marunevich@mail.ru

* Corresponding Author

Received 06 November 2020 ; revised 10 November 2020 ; accepted 12 November 2020

ABSTRACT

Fly ash can include toxins from high levels of bottom ash in some circumstances, such as burning of solid waste to generate power (resource recovery facilities or waste-to-energy conversion), and combining fly ash and bottom ash together delivers corresponding quantities of contaminants. Under some conditions, fly ash can be classified as non-hazardous waste, but if it is not blended, it can be classified as hazardous waste. The goal of this research was to find out about the differences between fly and bottom ash, as well as the influence of fly ash on bottom ash in terms of avoiding abrasion. In addition, the study's goal was to see how fly ash affected coconut fiber's resistance to abrasion. This study employed a quantitative technique in which the researcher used primary data sources such as questionnaires and observations, as well as secondary data sources such as prior studies. The findings revealed that fly ash had no effect on bottom ash in terms of avoiding abrasion. Furthermore, it is well known that neither fly ash nor bottom ash are effective against coconut fiber. Fly ash has a coarser texture than bottom ash, according to the findings. The regression test revealed that there was no difference between fly ash and bottom ash, as well as coconut coir, in terms of reducing abrasion.



KEYWORDS

Fly ash
Bottom ash
Coconut coir
Abrasion



This is an open-access article under the [CC-BY-SA](https://creativecommons.org/licenses/by-sa/4.0/) license

1. Introduction

Indonesia is the largest archipelagic country in the world which has approximately 17,508 islands connected by straits and seas, and has a coastline of 81,000 [1]. Approximately 75% of cities in Indonesia are located on the coast with a population of more than 100 million people. This causes the coastal area to develop rapidly to meet various human needs including; residential areas, ports, industrial areas, fisheries, agriculture, and tourist areas. This indicates that the coast and the ocean have an important role for life. As a result, coastal areas in Indonesia experience many problems such as erosion, abrasion, sedimentation, and saltwater intrusion [2]. The beach is a complex environment that is influenced by the intensity of marine processes, fluvials and their movements. The type of beach as a reflection of the mechanism of the erosion process, land origin acceleration, and washing. In this case, the authors approach the characteristics of the coast and the wave flux method based on the prediction of wind speed data[3].

The southern coast of Java is a coastal area that is directly adjacent to the open sea, namely the Indian Ocean, this boundary directly forms the characteristics of the oceanographic parameters that occur in the southern coast of Java, in addition to oceanographic parameters, the southern sea also forms a unique geology that forms different oceanographic conditions compared to other seas [4]. The southern coast experiences more abrasion and has the characteristics of deeper waters because it borders the Indonesian Ocean which has larger currents and waves than the Java Sea (Pradipta, 2016)[5].

The coastal area is a transitional area between sea and land. This condition causes coastal areas to be under pressure from various activities and phenomena that occur on land and at sea. Phenomena that occur on land such as flood erosion and activities carried out such as residential development, clearing of forests for rice fields, pond construction and so on ultimately have an impact on coastal ecosystems. Similarly, phenomena in the ocean such as tides, storm waves and so on [6].

Abrasion is an event of retreat of the coastline in coastal areas that are vulnerable to activities that occur on land and at sea [7]. Activities such as logging of mangrove forests, sand mining, as well as the phenomenon of high waves, and sea tides have the impact of abrasion or coastal erosion [8]. Erosion that occurs on the mainland of the coastal area causes sediment transport to move from its place of origin and along the direction of the incoming wave, thereby affecting changes in the coastline. Abrasion is a problem for ecosystems and settlements in coastal areas. The impact of abrasion is the decline of the coastline which can threaten the buildings and ecosystems behind the coastline [9]. Mitigation efforts need to be carried out to avoid casualties, as well as the impact of potential disasters, so that steps and preparedness are obtained before a disaster occurs. *In overcoming abrasion, fly ash and bottom ash are generally applied. As is known, fly ash is used more often because it is said to be more effective than bottom ash.* Abrasion resistance can occur when the material used also has a high pressure [10].

Fly ash is a residue or waste from the coal combustion process which is currently being used as a partial replacement for cement or as a substitute for fine aggregate in the manufacture of concrete [11]. While bottom ash is a type of ash used to process a combustion used in PLTU. Bottom ash is basically better known for its larger size than fly ash. Bottom ash is said to be more reliable to make the pozzolanic reaction ineffective while fly ash is more effective. *In addition, the use of bottom ash provides lower pressure and abrasion resistance when compared to fly ash.*

In addition, fly ash can also be used to increase the durability of concrete, one of which is resistance to sulfate [12]. Fly ash is a by-product (waste) from industry which has a fairly high silica (Si) content. Silica (Si) and Calcium (CaO) are one of the main ingredients needed to produce portland cement. Fly ash is categorized as a hazardous material, so if it is to be used as a material, it must be processed first so that the content of harmful substances in fly ash can be controlled (PP. No. 101, 2014). Control of hazardous substances in fly ash can be done by geopolymerization. Fly ash is a residue from the combustion of coal in power plants. Fly ash has a melting point of about 1300 °C and has a density between 2.0 – 2.5 g/cm³ [13].

In addition, many infrastructure developments can also utilize fly ash as a basic material or mixture for road construction and various other uses [14]. The effort to utilize fly ash is in accordance with the implementation of priority programs on the Making Indonesia 4.0 road map that has been launched by the government. Fly ash from coal combustion at PLTU Palabuhanratu which is currently planned as the main material for the abrasion-resistant embankment will later be used for internal and external civil purposes at PLTU Palabuhanratu. On the other hand, PLTU Palabuhanratu, which is located in Sukabumi Regency, West Java, as one of the largest sources of fly ash in Indonesia, is located near the coast, thus creating an opportunity to be able to utilize fly ash from PLTU Palabuhanratu in the construction of seaside buildings, one of which is the Embankment. Therefore, this study was conducted to find the right method in utilizing fly ash from the Palabuhanratu PLTU in the manufacture of embankments to prevent abrasion. Make maximum use of fly ash and reduce the use of cement as much as possible.

Fly ash is solid waste resulting from the combustion process in the furnace at the PLTU which is then carried out by the remnants of combustion and captured using an electrostatic precipitator [15]. Fly ash consists of inorganic materials contained in coal that have undergone fusion during combustion. This material solidifies while in the exhaust gases and is collected using an electrostatic precipitator. Because these particles solidify while suspended in the exhaust gases, fly ash particles are generally spherical in shape. The fly ash particles collected in the electrostatic precipitator are usually silt (0.074 – 0.005 mm) in size. This material is mainly composed of silicon dioxide (SiO₂), aluminum oxide (Al₂O₃) and iron oxide (Fe₂O₃).

Fly ash is a material produced from the coal combustion process in power generators, so all of its properties are also determined by the composition and properties of impurity minerals in coal and the

combustion process [16]. In this coal combustion process, the melting point of coal ash is higher than its combustion temperature. And this condition produces ash which has a very fine grain texture. Coal fly

ash consists of fine grains which are generally solid or hollow spheres. The particle size of fly ash resulting from burning bituminous coal is smaller than 0.075mm [17]. The density of fly ash ranges from 2100 to 3000 kg/m³ and the specific area (measured according to the Blaine air permeability method) ranges from 170 to 1000 m²/kg).[18]

Based on the research background and the formulation of research problems that have been discussed and put forward by the author above, then the purpose of this study is (1) to determine the characteristics between fly ash and bottom ash through the comparison method), (2) determine the effect of fly ash on bottom ash in preventing abrasion and (3) determine the effect of fly ash on coconut fiber in preventing abrasion.

2. Method

In making research successful, it is necessary to determine a method used in research. In carrying out this research, the researcher uses a quantitative method which is a method in which the researcher uses a survey to obtain data that can produce statistical values[19]. In this study, researchers used multiple regression analysis techniques where the X1 variable is Fly Ash and X2 is Bottom ash while the Y variable used in this study is Decrease).

The research "Comparative analysis of fly ash (case study at PLTU Pelabuhanratu)" includes several stages. The stages of research carried out include.

- Literature study and data collection. Preparation in the form of a literature study using various previous research results as a reference without reducing creativity and freedom in conducting research tests.
- Analyze the need for tools and materials, analyze and provide the tools and materials needed in research.
- Analysis of the effectiveness of the materials used.
- Analyze the results, analyze the survey results and identify the results of the analysis.
- Conclusion, draw conclusions from research results

In the preparation of this research, there are several work steps which are arranged in a flow chart in “Fig 1”) “Figure.1”

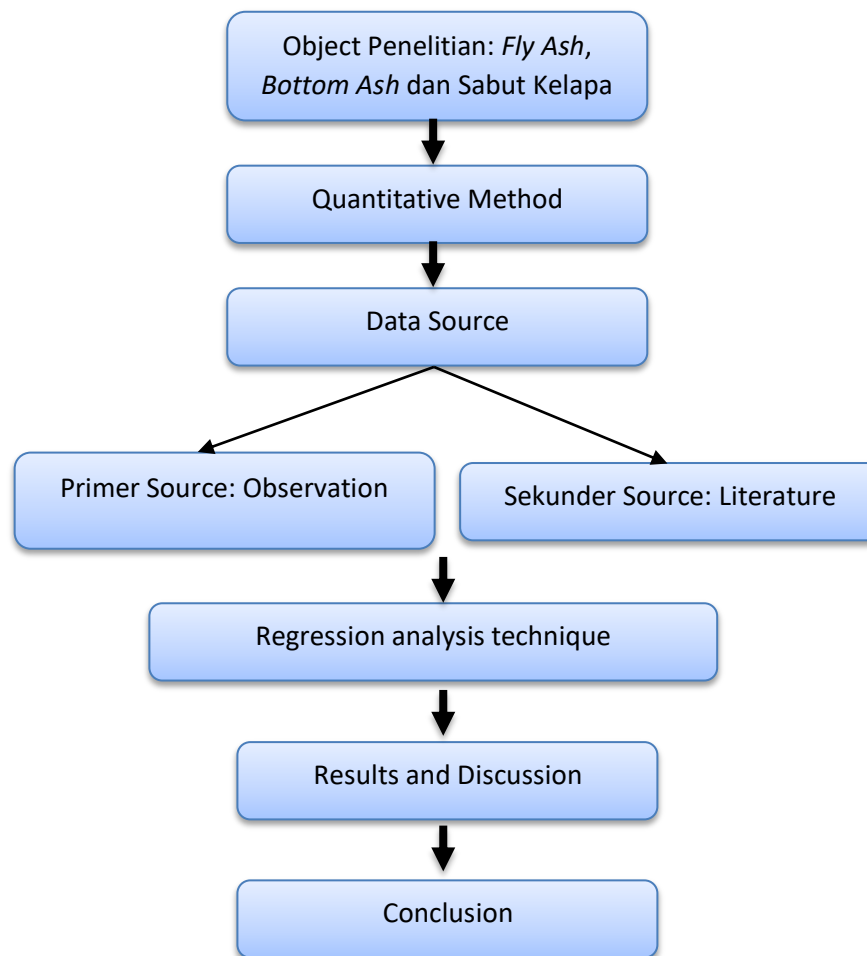


Fig. 1.Flowchart

In this study, data collection was carried out using two types of data, namely primary and secondary. Primary data collection is done using observation, while secondary sources use literature studies. This research was conducted at PT. Indonesia Power PLTU Pelabuhan Ratu on "Fig.2" from 01 July 2021 – 30 August 2021.



Fig. 2.Site Research

3. Results and Discussion

In Table.1. are the results of the analysis of the characteristics of fly ash and bottom ash in PLTU Pelabuhan Ratu:

Table 1. Composition of Fly Ash and Bottom Ash

Parameter	Fly Ash		Bottom Ash	
	Unit	Results	Unit	Results
Silicone Dioxide (SiO ₂)	%wt	49.08	%wt	64.61
Aluminium Trioxide (Al ₂ O ₃)	%wt	28.31	%wt	19.10
Iron Trioxide (Fe ₂ O ₃)	%wt	9.55	%wt	7.28
Calcium Oxide (CaO)	%wt	6.56	%wt	2.73
Magnesium Oxide (MgO)	%wt	1.53	%wt	1.12
Potassium Oxide (K ₂ O)	%wt	0.76	%wt	1.00
Sodium Oxide (Na ₂ O)	%wt	0.38	%wt	0.51
Sulphur Trioxide (SO ₃)	%wt	0.63	%wt	1.23
Loss on Ignition (LOI)	%wt	0.20	%wt	3.52

The table above is the composition of fly ash and bottom ash. If the two ingredients are mixed with other ingredients, then of course the percentage will be reduced. This is because there has been a mixing process with other ingredients.

Table 2. Volume Ash from PLTU

Ash Volume	Hourly Ash Volume		Daily Ash Discharge (t/d)		Annual Ash Discharge (104/a)	
Item	Design Coal	Worst Coal	Design Coal	Worst Coal	Design Coal	Worst Coal
Fly Ash Volume	8.34	22.74	200.16	545.76	5.846	15.938
Bottom Ash Volume	2.09	5.68	50.16	136.32	1.465	3.981
Total Ash Volume	10.43	28.42	250.32	682.08	7.311	19.92

In "Table.2" it can be seen that the use of Fly ash is better than bottom ash. This can be seen from the design value of coal and worst coal which has a higher number compared to bottom ash in "table 2". Fly ash is better known as a mixture of fine coal while bottom ash is mixed with sand and shards in the ocean area. This causes the quality of bottom ash to decrease. Large volume levels present a problem where it is necessary to provide a place for stockpiling to occur [20].

According to Farhan & Nugraha (2021), fly ash and bottom ash have different textures when the control process occurs [21]. In fly ash, there is a crack that makes the texture a little harder. Whereas in bottom ash there are no shards, even the texture is smoother. The granules in fly ash have a greater density than bottom ash. This makes bottom ash slower to occur. So it can be concluded that the smoother the texture used, the more difficult the material can be weathered.

According to Gan et al., (2018) the gradation of bottom ash can only reach the highest percentage, which is 80 percent, so that the density of bottom ash combined with other materials decreases. In his research, rock ash was used as a mixture material [22].

The following is a comparison of the weight of the oxide composition in fly ash and bottom ash in "Table 3"

Table 3. Comparison of the Weight of Fly Ash and Bottom Ash . Oxide Composition

	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	Ti ₂ O ₂	CaO	MgO	K ₂ O	Na ₂ O	SO ₃	MnO ₂	P ₂ O ₅	LOI
Fly Ash	34.29	16.62	15.38	0.73	18.18	7.52	1.35	2.97	1.63	0.17	0.25	0,36
Bottom Ash	34.39	10.02	18.41	0.65	21.16	9.70	0.90	0.24	0.66	0.22	-	3.54

The table above is a comparison of the weights of fly ash and bottom ash. The highest yield was obtained by SiO₂ with a percentage of more than 30 percent. However, P₂O₅ does not get a percentage yield on bottom ash. So based on "Table 3" it can be seen that the use of fly ash is superior to bottom ash.

The test was carried out in the composition of 100% fly ash, which can be seen in "Table 4" decreasing every week.

Table 4. Depreciation of Fly Ash and Bottom Ash

% Shrinkage								
Test	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Fly Ash	98%	96%	93%	91%	89%	87%	84%	82%

The table above is the shrinkage data that occurs by combining 100 fly ash in the first sack. The following is "Table 5" with the percentage of each composition

Table 5. Processing Data *Fly Ash and Bottom Ash*

		X1	X2	Y
% FA	Kg	Kg FA	kg BA	Shrinkage
5	44,5	2,23	42,28	7,23
10	44,5	4,45	40,05	7,45
15	44,5	6,68	37,83	7,67
20	44,5	8,90	35,60	6,03
25	44,5	11,13	33,38	6,12
30	44,5	13,35	31,15	6,34
35	44,5	15,58	28,93	6,45
40	44,5	17,80	26,70	6,59
45	44,5	20,03	24,48	6,78
50	44,5	22,25	22,25	6,9
55	44,5	24,48	20,03	6,95
60	44,5	26,70	17,80	6,03
65	44,5	28,93	15,58	6,45
70	44,5	31,15	13,35	6,59
75	44,5	33,38	11,13	5,34
80	44,5	35,60	8,90	5,23
85	44,5	37,83	6,68	5,2
90	44,5	40,05	4,45	5,21
95	44,5	42,28	2,23	5,21

The table above is data that was processed by researchers through SPSS to show evidence of the effect of variables X1, X2 on Y. The percentage of fly ash used for this study started from 5 percent to 95 percent. Each percentage of fly ash uses a similar weight of 44.5 kg.

In "Table 6" is data that has been processed through SPSS)

Table 6. Regression Coefficient *Fly Ash and Bottom Ash*

Model	Coefficients ^a				
	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1	(Constant)	5.215	.242	21.537	.000
	BA	.049	.010	.779	.000

Based on "Table 6", it can be seen that the t value obtained is 5.125 where the result is greater than the alpha value of 0.05. So based on this, it can be concluded that there is no significant effect between fly ash and bottom ash in preventing abrasion. The following is a linear regression equation that can be formulated in this study.

$$Y = 5.215 + 0.049X_2$$

Through the value of the constant or variable for the decrease in fly ash, namely 5.215, it can be concluded that, X₂, namely bottom ash which is added by 0.049, will decrease by 5.215. So it can be concluded that the decrease that occurs is 52 percent when fly ash and bottom ash are used simultaneously.

These results are in line with research conducted by A Rivai et al., (2020) where it is said that the use of fly ash has decreased for seven days[13].

The following is "Table 7" comparison of bottom ash with coconut fiber:

Table 7. Comparison of bottom ash with coconut fiber

	Bottom Ash	Coconut Coir Waste
Water content	5%	12%
Ash	52%	3%
Volatile Compound	4%	68%
Carbon Content	39%	17%
Sulphur	0.46%	0.12%
Calorific Value	3255 kkal/kg	3950 kkal/kg

Based on "Table 7" above, it can be seen that the calorific value of bottom ash is 3255 kcal/kg, this value indicates the potential of bottom ash to be used in the textile industry. Based on this, it can be concluded that bottom ash can be used to be mixed in making briquettes.

The following "Figure 3" shows a graph of biobriquettes:

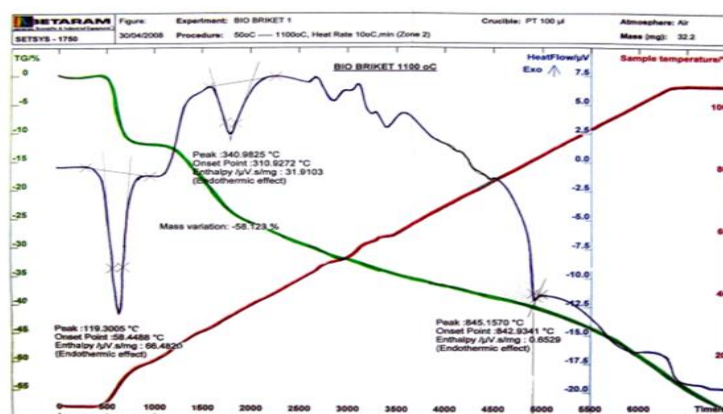


Fig. 3.Biokriket Chart

Through the results of the tests carried out, it appears that bottom ash cannot make briquettes form optimally. However, it actually makes the briquettes to be destroyed. As is known, coconut fiber has a less strong texture so that when the two are put together it will provide better strength in pressure [23]. According to Bayuaji et al., (2015), coir mixing between fly ash and coconut coir can give stronger results in cement formation [24]. The following "Table 8" is the composition used by researchers in the manufacture of cement through the use of fly ash and coconut.

Table 8. Evindance of Fly Ash is more needed than Bottom Ash

N o.	Kebutuhan (%)			Kebutuhan Massa (gram)			
	Semen	Fly Ash	Sabut Kelapa	Air	Semen	Fly ash	Sabut Kelapa
1	100	0	0	14,73	108,97	0	0
2	90	0	10	14,74	98,07	0	4,37
3	80	0	20	14,75	87,18	0	8,73
4	70	0	30	14,76	76,28	0	13,1
5	90	5	5	14,77	98,07	4,23	2,18
6	80	5	15	14,78	87,18	4,23	6,55
7	80	10	10	14,79	87,18	8,46	4,37
8	80	15	5	14,80	87,18	12,68	2,18
9	70	5	25	14,81	76,28	4,23	10,91
10	70	10	20	14,82	76,28	8,46	8,73
11	70	15	15	14,83	76,28	12,68	6,55
12	70	20	10	14,84	76,28	16,91	4,37
13	70	25	5	14,85	76,28	21,14	2,18

Based on the results of the research conducted, it can be seen that the use of fly ash is greater than the use of other materials. In this study, cement used 30 percent of the composition of coconut fiber and fly ash. On research, it is known that the amount of coco coir used is 25 percent while the amount of fly ash used is 5 percent. Hawari & Lizar (2021) have conducted a study involving the mixing of fly ash, bottom ash and coconut coir [25]. Based on the results of this study, it is said that the mixture of fly ash and bottom ash has decreased due to the presence of less effective asphalt content. Through the test, it was stated that the VMA value in fly ash obtained an increasing value, as well as bottom ash. This is due to the pozzolanic properties contained in the two types of ash.

Here is "Table 9" with each composition percentage:

Table 9. Data on Fly Ash and Coconut Coir

% FA	Kg	Kg FA	kg SK	Penurunan
5	27,5	1,38	26,13	16,45
10	27,5	2,75	24,75	16,25
15	27,5	4,13	23,38	16,05
20	27,5	5,50	22,00	16,25
25	27,5	6,88	20,63	15,67
30	27,5	8,25	19,25	15,53
35	27,5	9,63	17,88	15,45
40	27,5	11,00	16,50	15,33
45	27,5	12,38	15,13	15,23
50	27,5	13,75	13,75	14,76
55	27,5	15,13	12,38	14,65
60	27,5	16,50	11,00	14,44
65	27,5	17,88	9,63	14,35
70	27,5	19,25	8,25	13,89
75	27,5	20,63	6,88	13,56
80	27,5	22,00	5,50	13,06
85	27,5	23,38	4,13	13,06
90	27,5	24,75	2,75	13,05
95	27,5	26,13	1,38	13,05

Based on the data above, the researchers used fly ash percentages ranging from five percent to 95 percent with a weight of 27.5 Kg. In this case, the researchers made a comparison of fly ash against coconut fiber. The researcher used an increasing weight of fly ash for each percentage and using a decreasing weight of coconut coir for each percentage of fly ash. So, based on "Table 9", it can be seen that the decline occurred steadily starting from 16.45 to 13.05.

In "Table 10" is data that has been processed through SPSS

Table 10. Regression Coefficient of Fly ash and Coconut Coir

Model	Coefficients ^a				
	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	12.652	.093		136.156	.000

Based on the data that has been processed through the use of SPSS, the researchers obtained the t value for coconut coir amounted to 25,629 which was tested for a decrease in. Therefore, through the t value obtained, where there is a number greater than the alpha value, it is concluded that there is no significant effect between fly ash on the use of coconut fiber in reducing abrasion. So, the regression equation that can be formulated is as follows:

$$Y=12.652+0,152X_2$$

Based on the regression equation, the constant value which is the variable for reducing fly ash gets the number 12,652 with the X_2 variable, namely coconut husk, which is 0.152. So it can be concluded that the addition of coconut fiber by 0.152 will experience a decrease in fly ash by 12.652 or by 12 percent.

Based on these tests, it can be said that the results of the study are not in line with the research of Bayuaji et al., (2015) which states that the combination of fly ash and coconut fiber can give results that affect the materials used [24]. However, in the research of Hawari & Lizar (2021), it is said that there is a decrease when fly ash and coconut fiber are used to overcome abrasion [25].

4. Conclusion

Based on the results of the tests that have been carried out, it can be concluded that the use of fly ash in the prevention of Abrasion does not have a significant effect, as well as when combined with the use of coconut fiber. In this case, the usage will decrease. As is well known, the character of fly ash is harder due to the presence of cracks, while bottom ash has a very fine texture (As is known, the character of fly ash is harder due to the presence of cracks, while bottom ash has a very fine texture. By Therefore, it can be concluded that the use of a harder texture will be better because there will be a decrease (Therefore, it can be concluded that the use of a harder texture will be better because there will be a decrease. Therefore, it can be concluded that the use of a harder texture will be better because there will be a decrease.. In this case, it is necessary to understand that the softer and more liquid the ash is used, the less effective it will be (In this case, there needs to be an understanding that the softer and more liquid the ash used, the less effective it will be. Through multiple regression testing, it was found that the addition of bottom ash of 0.049 can give a decrease in fly ash of 5.215 (Through multiple regression testing, it was found that the addition of bottom ash of 0.049 can provide a decrease in fly ash of 5.215. Meanwhile, the use of coconut husk which is added by 0.152 will decrease fly ash by 12.652 (Meanwhile, the use of coconut husk which is added by 0.152 will give a decrease in fly ash by 12,652.

References

- [1] S. Puryono, S. Anggoro, S. Suryanti, and I. S. Anwar, "Pengelolaan pesisir dan laut berbasis ekosistem," 2019. Available at: [Google Scholar](#)
- [2] N. Badwi, I. I. Baharuddin, and I. Abbas, "Dampak strategi pengendalian bencana abrasi di pantai Kabupaten Maros Provinsi Sulawesi Selatan," 2019. Available at: [Google Scholar](#)
- [3] D. Setiady and L. Sarmili, "Proses Akresi dan Abrasi berdasarkan Pemetaan Karakteristik Pantai dan Data Gelombang di Teluk Pelabuhan Ratu dan Ciletuh, Kabupaten Sukabumi, Jawa Barat," *Jurnal Geologi Kelautan*, vol. 13, no. 1, 2016. doi: [10.32693/jgk.13.1.2015.260](#)
- [4] G. Minarrohman, "Simulasi arus dan distribusi sedimen secara 3 dimensi di pantai selatan jawa," Institut Teknologi Sepuluh Nopember, 2017. doi: [/10.12962/j23373539.v6i2.24607](#)
- [5] G. Minarrohman, "Simulasi arus dan distribusi sedimen secara 3 dimensi di pantai selatan jawa." Institut Teknologi Sepuluh Nopember, 2017. doi: [10.12962/j23373539.v6i2.24607](#)
- [6] Z. Pinto, "Kajian Perilaku Masyarakat Pesisir yang Mengakibatkan Kerusakan Lingkungan (Studi Kasus di Pantai Kuwaru, Desa Poncosari, Kecamatan Srandakan, Kabupaten Bantul, Provinsi DIY)," *Jurnal Wilayah dan lingkungan*, vol. 3, no. 3, pp. 163–174, 2015. doi: [10.14710/jwl.3.3.163-174](#)
- [7] F. Firdaus, M. Chaerul, and S. Gusty, "Analisis Pengurangan Risiko Bencana Abrasi Pantai di Kecamatan Galesong Utara Kabupaten Takalar," *Syntax Literate; Jurnal Ilmiah Indonesia*, vol. 7, no. 4, pp. 3965–3977, 2022. Available at: [Google Scholar](#)

- [8] G. J. Utomo, W. Atmodjo, D. N. Sugianto, R. Widiaratih, and A. Ismanto, "Efektifitas Struktur Kerapatan terhadap Laju Sedimentasi dan Jenis Sedimen pada Hybrid Engineering di Desa Timbulsloko, Demak, Jawa Tengah," *Indonesian Journal of Oceanography*, vol. 4, no. 1, pp. 47–58, 2022. Available at: Google Scholar [Google Scholar](#)
- [9] H. Nugroho, A. K. Indriastuti, E. Yulipriyono, M. A. Wibowo, and F. Hermawan, "Penanganan Erosi Pantai dengan Penanaman Mangrove di Desa Bedono Kecamatan Sayung Kabupaten Demak," *Pasopati*, vol. 2, pp. 53–59, 2020. Available at: [Google Scholar](#)
- [10] M. K. Abda, "Mitigasi Bencana terhadap Abrasi Pantai di Kuala Leugekecamatan Aceh Timur," *Jurnal Samudra Geografi*, vol. 2, no. 1, pp. 1–4, 2019. Available at: [Google Scholar](#)
- [11] K. E. Ghozali, A. Yonathan, A. Antoni, and D. Hardjito, "PENELITIAN AWAL PEMANFAATAN FLY ASH DAN BOTTOM ASH PLTU SURALAYA DALAM PEMBUATAN BETON DI LINGKUNGAN PANTAI," *Jurnal Dimensi Pratama Teknik Sipil*, vol. 7, no. 2, pp. 177–184, 2018. Available at: [Google Scholar](#)
- [12] M. W. Kusuma, E. S. Sunarsih, and T. L. A. Sucipto, "PEMANFAATAN LIMBAH KACA SEBAGAI PENGANTI SEBAGIAN VOLUME PASIR DAN FLY ASH 20% SEBAGAI BAHAN PENGANTI SEMEN DITINJAU DARI KUAT TEKAN DAN BERAT JENIS BETON DALAM LINGKUNGAN AGRESI SULFAT 5%," *Indonesian Journal Of Civil Engineering Education*, vol. 6, no. 2, pp. 24–31. Available at: [Google Scholar](#)
- [13] B. Oktaviastuti and Y. Yurnalisdel, "Studi Kuat Tekan Beton Geopolymer Dengan Fly Ash Sebagai Perkerasan Kaku Di Pesisir Pantai," *Fondasi: Jurnal Teknik Sipil*, vol. 9, no. 2, pp. 201–214, 2020. Available at: [Google Scholar](#)
- [14] G. Dirgantara, "PENGARUH ABU TERBANG SEBAGAI FILLER TERHADAP KARAKTERISTIK MARSHALL CAMPURAN AC-WC= THE EFFECT OF FLY ASH AS A FILLER ON CHARACTERISTICS OF MIXED MARSHALL AC-WC," Universitas Hasanuddin, 2022. Available at: [Google Scholar](#)
- [15] A. P. Bagaskara, "Analisis Perencanaan Transportasi Limbah Pembakaran Batubara Pembangkit Listrik Tenaga Uap (PLTU): Studi Kasus Wilayah Sumatera," Institut Teknologi Sepuluh Nopember, 2018. Available at: [Google Scholar](#)
- [16] C. D. Prasetyo, E. S. Sunarsih, and T. L. A. Sucipto, "KAJIAN PEMANFAATAN LIMBAH KACA SEBAGAI PENGANTI AGREGAT HALUS DAN FLY ASH 30% DARI BERAT SEMEN DITINJAU DARI KUAT TARIK BELAH, DAYA SERAP DAN POROSITAS BETON," *Indonesian Journal Of Civil Engineering Education*, vol. 6, no. 2, pp. 65–77. Available at: [Google Scholar](#)
- [17] D. Chandra, "ANALISA PENGARUH AKTIVATOR KALIUM DAN KONDISI MATERIAL PADA BETON GEOPOLYMER DARI LIMBAH B3 FLY ASH BATUBARA TERHADAP KUAT TEKAN," *JURNAL REKAYASA*, vol. 11, no. 1, pp. 1–16, 2021. Available at: [Google Scholar](#)
- [18] N. H. Haryanti, "Uji Abu Terbang PLTU Asam Asam Sebagai Bahan Pembuatan Bata Ringan," *Jurnal Fisika Flux: Jurnal Ilmiah Fisika FMIPA Universitas Lambung Mangkurat*, vol. 11, no. 2, pp. 127–137, 2017. Available at: [Google Scholar](#)
- [19] D. Sugiyono, "Metode penelitian pendidikan pendekatan kuantitatif, kualitatif dan R&D," 2013. Available at: [Google Scholar](#)

-
- [20] H. Winarno, D. Muhammad, and Y. G. Wibowo, "Pemanfaatan limbah fly ash dan bottom ash dari pltu sumsel-5 sebagai bahan utama pembuatan paving block," *Jurnal Teknik*, vol. 11, no. 1, pp. 1067–1070, 2019. Available at: [Google Scholar](#)
- [21] M. Farhan and C. Nugraha, "Pengaruh Penggunaan Fly Ash dan Bottom Ash sebagai Cover dalam Pencegahan Pembentukan Air Asam Tambang Menggunakan Metode Free Draining Column Leach Test," *Rekayasa Hijau: Jurnal Teknologi Ramah Lingkungan*, vol. 5, no. 2, pp. 136–149, 2021. Available at: [Google Scholar](#)
- [22] A. I. Gan, H. Sutikno, Antoni, and D. Hardjito, "Optimasi Penggunaan Fly Ash Dan Bottom Ash Pltu Suralaya Dalam Pembuatan Paving Block Mutu Tinggi," *Jurnal Dimensi Pratama Teknik Sipil*, pp. 8–15, 2018. Available at: [Google Scholar](#)
- [23] S. Rismayani and A. S. Tayibnapis, "Pembuatan bio-briket dari limbah sabut kelapa dan bottom ash," *Arena Tekstil*, vol. 26, no. 1, 2011. Available at: [Google Scholar](#)
- [24] R. Bayuaji, R. W. Kurniawan, and A. K. Yasin, "Material Inovatif Ramah Lingkungan : Pemanfaatan Komposit Abu Serabut Kelapa dan Fly Ash pada Pasta Semen," *Jurnal Aplikasi*, vol. 13, pp. 15–20, 2015. Available at: [Google Scholar](#)
- [25] F. Hawari and Lizar, "Analisis Pengaruh Penggantian Filler Abu Sawit Fly Ash Dan Bottom Ash Terhadap Karakteristik Perkerasan Lentur (AC-WC)," *Jurnal Inovtek Seri Teknik Sipil dan Aplikasi*, vol. 3, no. 1, pp. 1–6, 2021. Available at: [Google Scholar](#)