Engineering Journal issn: 0125-8281

Article

Eco-Friendly Production of Decorative Concrete Blocks Using Coal Fly Ash and Coconut Husk Fiber Admixtures: Mixture D-Optimal Design Optimization

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Abstract. The present study investigates the production of decorative concrete blocks using coal fly ash and coconut husk fiber as admixtures to cement and sand. Using the Mixture D-optimal design, the decorative concrete blocks with a volume of 3,350 cm^3 were produced by varying the amount of coal fly ash (2.33-28.33 wt.%) and coconut husk fiber (3-9 wt.%) while using a constant amount of 10% of cement and 58.67% of sand throughout the study. These were cured for 28 days and tested in terms of compressive strength, density, and water absorption capacity. Results revealed that the density of the produced decorative block at optimum conditions was 1153.27 kg/m^3, which is lighter than the commercial one, which was 1165.39 kg/m^3 because of the raw materials used. Meanwhile, a high water absorption capacity was recorded at 24.79%. Furthermore, the recorded compressive strength of 0.467 MPa of the produced block is higher than the commercial one with 0.453 MPa, which means that this can replace them, considering its lower production cost. This study presents an innovative approach to utilizing industrial waste materials and producing a new product that can reduce solid waste generation and environmental pollution.

Keywords: Circular economy, decorative concrete block, coal fly ash, coconut husk fiber, D-optimal design.

ENGINEERING JOURNAL Volume 28 Issue 7
Received 24 April 2024
Accepted 30 June 2024
Published 31 July 2024
Online at https://engj.org/
DOI:10.4186/ej.2024.28.7.1

DOI:10.4186/ej.2024.28.7.1

1. Introduction

The global surge in waste production is alarming, posing a significant threat to the environment and human health [1], [2]. The daily waste production rate in urban areas has reached 2.01 billion tons, equivalent to 0.74 kilograms per person per day [3]. This upward trend is projected to increase by 70% from 2016 to 2050 [4]. Improper disposal of these wastes leads to various pollution types, including soil, air, water, and ecological damage [5]. Hence, waste management is a global concern that requires innovative solutions. This study focuses on two types of waste materials: coal fly ash and coconut husk fiber, which were utilized to produce low-cost decorative concrete blocks.

Coal fly ash, a by-product of coal power plants, is an environmental concern that causes soil, air, and water pollution [6]. Global coal fly ash production rates have reached 600 million tons annually and are still increasing [7], [8]. Coal fly ash is commonly disposed of in landfills, leading to significant environmental problems over time [9]. The utilization of this waste material in various industries has been investigated, such as building materials [10], [11]. Its high pozzolanic properties that bind component materials make it a viable alternative to traditional building materials [12].

Coconut husk fiber is another waste material from coconut plantations worldwide [13]. The coconut fruit contains 40% coconut husks containing 30% fiber [14]. The Philippines, a tropical country with the largest plantation of coconut trees worldwide, is one of the top coconut-producing countries [15]. Coconut husk fiber has been utilized in building materials as a natural fiber that can be used as reinforcement in composite materials [16]. The waste from coconut husk disposal has become a significant environmental problem in countries where coconut plantations are prevalent [13].

Decorative concrete blocks have become widely used in buildings such as hotels, condominiums, and other indoor infrastructures, providing permanent ventilation [17]. Commercially available decorative concrete blocks are expensive, limiting their use to high-end buildings. Using coal fly ash and coconut husk fiber to produce low-cost decorative concrete blocks could be a sustainable and innovative solution to the waste problem. This study aims to evaluate the capacity and durability of coal fly ash and coconut husk fiber in producing decorative concrete blocks and compare them with commercially available blocks in terms of compressive strength, density, and water absorption capacity.

2. Materials and Methods

2.1. Collection of Raw Materials for Making Decorative Block

Coal fly ash and coconut husk fiber were the raw materials used to make decorative blocks. The coal fly ash was collected at Del Monte Philippines, Incorporated in Bugo, Cagayan de Oro City, near enough to reach Claveria, Misamis Oriental. The coconut husk fiber was taken from Pelaez Coconut Plantation at Medina, Misamis Oriental. Blending these two materials was investigated to see if it could enhance and refine the properties of the decorative concrete block.

2.2. Experimental Design

Mixture D-optimal of the Design Expert 7.0 software was used to generate the experimental runs. Coal fly ash and coconut husk fiber were the two mixture components. The ranges of low and high components are shown in Table 1.

Table 1. Experimental Range of Low and High Admixture Percentages in Making Decorative Concrete Block.

Admixture	Low (wt. %)	High (wt. %)
Coal fly ash	22.33	28.33
Coconut husk fiber	3.00	9.00
Cement	10.00	10.00
Sand	58.67	58.67

Using the values of the independent variables in Table 1, thirteen runs were generated as expressed in weight percent (wt. %) shown in Table 2.

Table 2. Experimental Runs with Values of Independent Variables.

Run	Component A: Coal fly ash (wt. %)	Component B: Coconut husk fiber (wt. %)	Component C: Cement (wt. %)	Component D: Sand (wt. %)
1	28.33	3.00	10.00	58.67
2	28.33	3.00	10.00	58.67
3	24.78	6.55	10.00	58.67
4	28.33	3.00	10.00	58.67
5	28.33	3.00	10.00	58.67
6	24.01	7.32	10.00	58.67
7	23.16	8.17	10.00	58.67
8	26.93	4.40	10.00	58.67
9	26.23	5.10	10.00	58.67
10	25.52	5.81	10.00	58.67
11	22.33	9.00	10.00	58.67
12	22.33	9.00	10.00	58.67
13	22.33	9.00	10.00	58.67

n=4 (where n stands for the number of replications).

The proportion of 10% cement, 58.67% sand, and 0.55 ratio for water-cement were held constant for all the samples [18], [19]. The researchers added two raw materials: coconut husk fiber (CHF) and coal fly ash (CFA) as partial replacements.

2.3. Preparation of Raw Material

After collection, the coal fly ash and coconut husk fiber were separately characterized by their moisture content, ash content, and particle size. The moisture content of the coconut husk fiber and coal fly ash was determined following the ASTM D 2974 procedure (Standard Test Method for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils) with some modifications. The particle size of the two raw materials was characterized. It was done by sieving the coal fly ash (CFA) with 20 mm holes, and the coconut husk fiber (CHF) was cut into 5-10 mm lengths and sieved. The determination of ash content of the sieved CFA was analyzed using a muffle furnace. A 100 g CFA sample was furnaced at 440 °C at 2-hour intervals to get a constant weight of the ash used to compute its ash content. Meanwhile, the moisture content of CHF was determined by obtaining the difference in the mass of the samples after drying in an oven for a 1-hour interval at 100 °C until the mass remained constant [20].

Additional materials, such as sand and cement, were used in the mixing process to bind concrete blocks. Ordinary Portland Cement was the type of cement used in the mixing. These materials were easy to find because of their local availability.

2.4. Procedures for Making Decorative Block

A graduated cylinder with a volume of 9π was used as a measuring tool to get the equivalent measurement of mixture components. By ratio and proportion, the amount of each component was computed by multiplying the volume of the decorative concrete block molder (3350 cm^3) with the percentage of each component divided by the volume of the graduated cylinder used. The amount of each component was weighed manually in terms of kilograms.

The coal fly ash and coconut husk fiber, including sand and cement, were collected in a concrete mixer. The dry components were mixed first until they became homogenous, and a 0.55 ratio of cement: water was used to mix the aggregates thoroughly [21], [22]. The proportion used was prepared based on the levels in experimental runs, as shown in Table 2, using the Mixture D-optimal design. The wet mixtures were poured into the rectangular molder with a volume of 3350 cm^3 and the aggregates were evenly distributed. The mixture was removed from the molder, considering the set time for concrete mixtures was 3-5 mins [23]. Samples were cured for 28 days through water spraying [24]. Figure 1 shows the appearance of the molder.

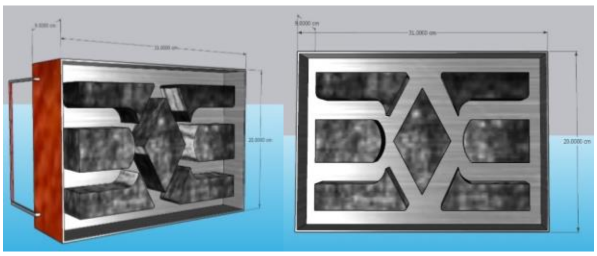

Fig 1. Rectangular Decorative Block Molder.

2.5. Properties of Block Analysis

The sample for compression was tested using ASTM C140 Standard Test Method for Sampling and Testing Concrete Masonry Units and Other Related Units at LYL Development Corporation: Material Testing and Quality Control Section in KIMWA Compound, Baloy, Cagayan de Oro City, Philippines.

The density test was conducted at the Agrivironmental Laboratory of the University of Science and Technology of Southern Philippines-Claveria. Density follows the formula shown in Eq. (1).

$$\rho = \frac{m}{v} \tag{1}$$

where m is the mass of the block after letting it dry in a typical environment, while v is the volume of the block.

The test for water absorption was conducted in compliance with ASTM C 642 [25] at the Agrivironmental Laboratory in USTP-Claveria and was computed using Eq. (2).

$$water\ absorption = \frac{w_m - d_m}{d_m} \times 100 \tag{2}$$

where w_m is the mass of the wet block, and dm is the mass of the dry block. The blocks were immersed in water for 24 h and drained for 1 min. All wet samples were weighed as w_m. After that, samples were dried in an oven with an interval of 2 h until two consecutive weights of the last weighted specimen showed an increment of loss not greater than 0.2%. Then, d_m was recorded as the mass of the sample.

2.6. Statistical Analysis

Using Analysis of Variance (ANOVA) of the Mixture D-optimal design, the gathered data were statistically analyzed to determine the optimum conditions needed to produce the decorative concrete blocks with the best properties. One sample t-test was also employed to compare the properties of the commercial decorative blocks and the composite one with CFA and CHF partial replacements.

3. Results and Discussion

3.1. Properties of Coal Fly Ash and Coconut Husk Fiber

The properties of coal fly ash (CFA) and coconut husk fiber (CHF) were determined using the standard methods and were presented in Table 3. Meanwhile, the percentage mass of the oxide component of the coal fly ash was adopted from the study of Samadhi et al. [26], presented in Table 3 for reference purposes.

Table 3. Properties of Coal Fly Ash and Coconut Husk Fiber.

Material	%-mass of oxide component [26]									Physico-chemical Properties		
	Al_2O_3	SiO_2	CaO	Fe_2O_3	MgO	Na_2O	K_2O	P_2O_5	SO_3	Moisture Content	Ash Content	Particle Size
CHF	-	-	-	-	-	-	-	-	-	83.2 ±1.39%	-	≤ 20 mm
CFA	21.1	50.7	15.8	3.71	2.29	1.24	2.09	0.52	1.91	-	82±1.73%	≤ 20 mm

As presented in Table 3, the moisture content of the coconut husk fiber, 83.2±1.39%, indicates that it has higher water absorptivity when mixed in the concrete mixture. CHF contribute to the strength development in concrete by enhancing moisture retention during the curing process, which facilitates more effective hydration of cement. This property is similarly observed in the study of Mazlee, where he noted that higher moisture content leads to higher mechanical properties generally and compressive strength in particular [27]. On the other hand, the ash content of the coal fly ash is 82±1.73% for every 100 g of furnaced sample, which enhances the strength and durability of the concrete, considering its fine particles, which then fill the voids of the concrete matrix. Ash content refers to the inorganic residue that remains after a material has been completely incinerated [28], [29]. In concrete technology, incorporating ash as a pozzolanic material (one that reacts with calcium hydroxide to form cementitious compounds) can improve the strength and durability of the concrete while also mitigating the environmental impact associated with the production of traditional Portland cement [30]. Also, one of the advantages of using fine particles such as coal ash in the concrete mixture is that it will help improve the mechanical properties as it eventually provides fast hydration [31]. Pozzolanic materials, such as coal ash, react with calcium hydroxide (CH) produced during cement hydration to form additional calcium silicate hydrate (C-S-H) gel. This reaction contributes to the densification of the microstructure, leading to enhanced strength and durability of the concrete [32]. The pozzolanic reaction is a key mechanism in the development of strength in concrete [33]. By providing additional reactive materials that can participate in the hydration process, pozzolanic materials like coal ash contribute to the formation of more C-S-H gel, which is the primary binding phase in concrete. This increased C-S-H gel formation leads to improved mechanical properties, such as compressive strength and durability, as the concrete matures over time [34], [35], [36].

3.1. Decorative Block Mixture Components

The combinations generated by the Mixture D-Optimal design in terms of composition percentage were carried through the experiment to produce a decorative block with a volume of 3350 cm^3. Table 4 shows the design-generated mixture components and their equivalent amount in terms of the mass of the materials (kg).

Table 4. Equivalent Measurement of Mixture Components.

Run	Equivalent Mixture Components			
	A. CFA (kg)	B. CHF (kg)	C. Cement (kg)	D. Sand (kg)
1	0.40	0.02	0.40	2.95
2	0.40	0.02	0.40	2.95
3	0.34	0.03	0.40	2.95
4	0.40	0.02	0.40	2.95
5	0.40	0.02	0.40	2.95
6	0.34	0.04	0.40	2.95
7	0.33	0.04	0.40	2.95
8	0.36	0.03	0.40	2.95
9	0.36	0.03	0.40	2.95
10	0.35	0.03	0.40	2.95
11	0.29	0.05	0.40	2.95
12	0.29	0.05	0.40	2.95
13	0.29	0.05	0.40	2.95

3.2. Physical and Mechanical Properties of Decorative Block

Table 5 presents the results of the physical and mechanical properties of decorative blocks produced following the mixture suggested by the Mixture D-Optimal Design.

As shown in Table 5, run 5 attained the highest compressive strength of 0.409 MPa, while the mixture of run 1 acquired the lowest compressive strength of 0.136 MPa. According to Babu et al. [37], when the amount of coal fly ash replacement increases to 20-35%, the concrete's compressive strength best increases. However, a further increase in the percentage of coal fly ash more than the maximum percentage may decrease the concrete's compressive strength. On the other hand, Abdullah et al. [38] added that concrete's compressive strength would increase when coconut husk fiber's content levels were only up to 9%. Hence, to obtain higher compressive strength when combining the two components, coconut husk fiber must be minimized up to 9% while the percentage replacement of coal fly ash must be maximized to as much as 20-35%.

In terms of water absorption, run 12 gained the highest water absorption of 26.86%. It can be noted that this run contains the highest amount of CHF, which is similar to the study of Nadzri and Shamsul [38]. They reported that the increase in the amount of CHF significantly increases the water absorption capacity of the block due to its organic matter content. The American Standard for Testing Materials C140 (ASTM) states that low permeability is an essential property of good quality in concrete [39]. It restrains water entry and is not prone to freezing and thawing. Also, to have a good decorative concrete block, it is best to produce with low absorptivity to avoid micro-cracking inside the decorative concrete block [40].

The mixture of run 2 obtained the highest density of 1177.01 kg/m^3, while run 5 attained the lowest density of 1138.66 kg/m^3. According to Hung Mo et al. [41], a lower density of lightweight concrete block leads to economic savings in design flexibility, transportation, and handling costs. Also, Harshavardhan et al. added that less dense concrete could result in a more durable product that can resist negative environmental impacts. Low-density concrete is lightweight, reducing transportation and placement costs [42].

The results presented in Table 5 of our study exhibit variations in compressive strength, density, and water absorption that do not al`ign with typical expectations. Generally, higher density in construction materials such as concrete or decorative blocks is expected to correlate with increased compressive strength due to better particle packing and reduced porosity, which in turn usually corresponds with lower water absorption. However, the data in this study shows a complex relationship that cannot be explained by these conventional understandings alone. The discrepancies could be explained by the intricate interplay of material composition, microstructure, curing conditions, and environmental factors. The composition of decorative blocks, including aggregate types, binder content, and air void characteristics, plays a crucial role in determining mechanical properties independent of bulk density. Variations in the size and distribution of aggregates can also significantly impact the load-bearing framework within the block, thereby affecting compressive strength. Furthermore, curing conditions, such as the environment and duration of curing, are critical for strength development in cementitious materials, and any inconsistencies in these conditions can lead to variations in density and strength [43].

In addition, Ranchhood et al. emphasized that proper compaction is essential to address air voids, which is why the concrete reduces its strength while increasing density and permeability, thus making it more durable. Also, it ensures that the forms will be compacted entirely to increase the concrete's durability and minimize shrinkage [44]. On the other hand, some results are distant from others. One reason might be the block was compacted manually. The other one is that maybe the fiber was stiff because it lacked water in the mixture, so the packing became difficult at high fiber contents; thus, voids were introduced.

Table 5. Physical and Mechanical Properties of the Decorative Block.

Run	Testing Result		
	Compressive Strength (MPa)	Water Absorption (wt. %)	Density (kg/m^3)
1	0.136	25.32	1165.67
2	0.249	25.30	1177.01
3	0.222	22.61	1145.22
4	0.201	21.07	1144.78
5	0.409	24.71	1138.66
6	0.235	22.01	1139.25
7	0.225	23.57	1146.27
8	0.200	22.94	1158.21
9	0.223	23.81	1151.71
10	0.211	22.37	1141.19
11	0.186	25.77	1164.18
12	0.220	26.86	1157.76
13	0.321	24.58	1161.71

Table 6. Analysis of Variance of Reduced Mixture Quadratic Model for Compressive Strength.

Source	**Sum of Squares**	**df**	**Mean Square**	**F value**	**P-value Prob > F**
Model	6.262E-003	2	3.131E-003	18.06	< 0.0029[a]
Residual	1.040E-003	6	1.733E-003		
Lack of Fit	4.620E-004	5	9.240E-005	0.16	0.9456[b]
Pure Error	5.780E-004	1	5.780E-004		
Cor Total	7.302E-003	8			
R^2 = 0.8576					

a=*significant;* b=*not significant*
**Runs 2, 4, 5, and 13 were ignored since results were considered outlier data*

Table 7. Analysis of Variance of Reduced Mixture Cubic Model for Water Absorption.

Source	**Sum of Squares**	**df**	**Mean Square**	**F value**	**P-value Prob > F**
Model	22.40	3	7.47	20.10	<0.0008 [a]
Residual	2.60	7	0.37		
Lack of Fit	1.77	4	0.44	1.59	0.3669 [b]
Pure Error	0.83	3	0.28		
Cor Total	25.00	10			
R^2 = 0.8960					

a=*significant;* b=*not significant*
**Runs 4 and 13 were ignored since results were considered outlier data*

Table 8. Analysis of Variance of the Reduced Mixture Cubic Model for Density.

Source	**Sum of Squares**	**df**	**Mean Square**	**F value**	**P-value Prob > F**
Model	789.63	3	263.21	27.49	<0.0007 [a]
Residual	57.45	6	9.57		
Lack of Fit	36.47	4	9.12	0.87	0.5969 [b]
Pure Error	20.97	2	10.49		
Cor Total	847.07				
R^2 = 0.9322					

a=*significant;* b=*not significant*
**Runs 1 and 3 were ignored since results were considered outlier data.*

Table 9. Predicted and Actual Results of the Decorative Block.

Experi-ment	Coal fly Ash (wt. %)	Coconut Husk Fiber (wt. %)	Water Absorption (wt. %)	Density (kg/m^3)	Compressive Strength (MPa)
Predicted (D-Optimal)	22.77	8.56	24.73	1152.09	0.214
Actual (validation)	22.77	8.56	24.79± 0.19	1153.27 ±1.27	0.467±0.04

3.3. Analysis of Variance of the Properties of Decorative Blocks

The fit summary analysis of the three properties resulted in reduced mixture quadratic and reduced mixture cubic as the best-fit model in predicting its values.

The analysis of variance (ANOVA) of the reduced mixture quadratic model for compressive strength of the decorative block interpreted in Table 6 shows a model p-value of <0.0029, which indicates that the model generated is significant. The model p-value means that there was a <0.29% possibility of error due to the unanticipated data movement. The lack of fit p-value of 0.9456 indicates that the lack of fit was not significant. This signified that the values generated from the model were true and accurate.

The ANOVA of the reduced mixture cubic model for the water absorption of the decorative block interpreted in Table 7 shows a model p-value of <0.0008, indicating that the generated model is significant. The model p-value means that there was a <0.08% probability of error that could occur due to inconsistent value discrepancy of data. The values the model can develop were true and accurate since the lack of fit p-value was 0.3369, which shows that the lack of fit was insignificant.

The reduced mixture cubic model for density had a p-value of <0.0007, which shows that the model produced was sturdy, as shown in Table 8. This also indicates that there is strong evidence against the null hypothesis and that the independent variables significantly affect the dependent variable. Meanwhile, the lack of fit p-value of 0.5969 implies that the lack of fit was not significant, signifying that the model fits the data well.

3.4. Optimum Conditions in Decorative Block Production

The Design Expert 7.0 software generated optimum conditions through numerical optimization. The compressive strength and density were maximized, being the main objective of the study was to achieve a higher compressive strength within the compactness of the decorative block. Water absorption was minimized since the study aims to reduce the water absorption capacity.

The mixture component, such as coal fly ash, was minimized since it is costly in terms of energy consumption. In contrast, coconut husk fiber was maximized since the availability of the waste is abundant. The mixture components of the combination were replicated three times, and the result of the predicted vs. actual is presented in Table 9

3.5. Raw Materials Used in Making a Decorative Block

The component of the decorative block at the optimum condition with its equivalent weight and volume is indicated in Table 10.

Table 10. Components of One Decorative Block at Optimum Conditions.

Raw Material	Component Mixture (wt. %)	Equivalent Mass / Volume (kg)
Coal Fly Ash	22.77	0.3072
Coconut Husk Fiber	8.56	0.0456
Sand	58.67	2.9530
Cement	10.00	0.3952

As shown in Table 10, one decorative block was composed of 22.77 wt.% coal fly ash, which is equal to 0.3072 kg; 8.56 wt.% coconut husk fiber, which was equivalent to 0.0456 kg; 58.67 wt.% of sand equal to 2.953 kg; 10 wt.% of cement equivalents to 0.3952 kg; and 59.25 wt.% water equivalent to 1.656 L. Similar mixture components, as suggested in Table 9, must be applied to attain an optimum condition of the decorative block.

3.6. Comparison of Decorative Block Properties to the Commercial

The comparability of the produced decorative block to the commercial decorative block is one of the objectives of the study. Table 11 indicates the probability values in comparing the decorative block produced at the optimum condition to the commercial values of water absorption (25.447%), density (1165.39 kg/m^3), and compressive strength (0.453 MPa).

Table 11. Comparison of the Physical and Mechanical Properties of the Produced Decorative Block and the Commercial Decorative Block.

Parameter	Compressive Strength (MPa)	Water Absorption (wt. %)	Density (kg/m^3)
Commercial	0.453	25.45	1165.39
Experimental Results			
Mean	0.467	24.79	1153.27
StDev	0.04	0.19	1.27
SE Mean	0.02	0.11	0.73
t-value	0.59	-6.11	-16.50
p-value (mean > commercial)	0.3075	0.0129	0.0018

The results show that the experimental blocks have a lower water absorption percentage and density compared to the commercial blocks. The water absorption of the experimental blocks was found to be 24.79%, which is significantly lower than that of the commercial blocks at 25.45%. These results have important implications for the manufacturing and use of concrete blocks. The concrete blocks' higher water absorption and density may make them more susceptible to damage and degradation over time. In contrast, the experimental blocks' lower water absorption and density may indicate that they are more durable and resistant to wear and tear. Moreover, the experimental blocks have a significantly lower density of 1153.27 kg/m^3 than the commercial blocks at 1165.39 kg/m^3. This could be attributed to using lightweight aggregates in the experimental blocks, which have been shown to reduce concrete density. These findings are consistent with a related study by Alfar et al., which cited that the lightweight admixtures contributed to the lesser density of the product [45]. Furthermore, reducing the water absorption of concrete can improve its durability and resistance to weathering and corrosion, which can have significant economic and environmental benefits.

Regarding the compressive strength, the experimental blocks have a slightly higher mean value of 0.467 MPa compared to the commercial blocks at 0.453 MPa, but the difference is not statistically significant, although the experimental blocks do show a trend towards higher compressive strength. This finding may suggest that the compressive strength of concrete is affected by various factors such as the water-cement ratio, curing conditions, and aggregate properties. On a positive note, the compressive strength may not be statistically significant, but the result suggests that the experimental blocks may have the potential to perform better than the commercial blocks in terms of compressive strength, given their higher value. Yet, further research would be necessary to confirm this trend. Nonetheless, considering the load it can handle, these results provide input on the right application of the produced blocks.

3.7. Environmental and Economic Analysis

The incorporation of coal fly ash and coconut husk fibers into the production of decorative concrete blocks represents a significant shift towards sustainable construction practices. The use of coal fly ash, a by-product of coal combustion, in place of a portion of cement in concrete production significantly reduces the greenhouse gas emissions associated with cement manufacturing [30]. Cement production is one of the largest sources of industrial CO_2 emissions globally. Integrating coal fly ash not only helps in reducing the carbon footprint but also mitigates the environmental damage caused by the disposal of ash in landfills. Coconut husk fibers are typically considered agricultural waste. Repurposing these fibers for concrete production helps in waste diversion from landfills and reduces the environmental burden of disposal. By converting these by-products into valuable construction materials, the production process promotes a circular economy model, thereby enhancing overall sustainability.

On the economic perspective, incorporating coal fly ash as a partial substitute for cement can result in significant cost savings, as fly ash is usually less expensive than cement. The cost of coconut husk fibers is also relatively low, given that they are a waste product. This can decrease the overall material costs for concrete block production, making it an economically attractive option for manufacturers. The enhanced properties imparted by the admixtures—such as improved durability and better thermal insulation—can lead to long-term savings for end-users. Buildings constructed with these blocks may require less energy for heating and cooling, and the increased durability of the blocks reduces maintenance costs over time.

4. Conclusion

The study provides practical implications that coal fly ash and coconut husk fiber can effectively be admixtures in producing attractive concrete blocks. Using these waste products minimizes solid waste and pollution and gives the construction industry an economically and environmentally viable answer. The research demonstrated that altering the proportions of coal fly ash and coconut husk fiber while keeping cement and sand constant produced a decorative block with the desired compressive strength, water absorption, and density. The generated block exhibited a better compressive strength than the commercial block, demonstrating its potential as a substitute. The study also found that the manufactured block had a better water absorption capacity, making it appropriate for managing pollution in streams in building projects. In addition, due to the study's raw materials, the reduced density of the created decorative block compared to the commercial block provides an added benefit for ventilation in residential structures. The findings of this study demonstrate the considerable potential for using coal fly ash and coconut husk fiber in the building industry. It offers a cost-effective alternative to conventional construction materials while presenting a sustainable and creative method to decrease solid waste and environmental damage. The findings of this study imply that future research could investigate the potential use of these waste materials in other construction applications, thereby contributing to sustainable development and environmental protection.

Acknowledgment

The authors would like to acknowledge the support of the College of Engineering and Technology faculty of the University of Science and Technology of Southern Philippines Claveria (USTP Claveria). Also, to Del Monte Philippines, Incorporated, and Pelaez Coconut Plantation for the provision of the raw materials.

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DOI:10.4186/ej.2024.28.7.1

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DOI:10.4186/ej.2024.28.7.1

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