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Utilizing Corn Cob Ash and Bauxite as One-Part Geopolymer: A Sustainable Approach for Construction Materials †

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Abstract: This research focused on creating sustainable geopolymer mortar using waste materials such as corn cob ash (CCA) and bauxite. The CCA was obtained by burning corn cobs in an open environment and then further treated at 600 °C to remove carbon impurities. The resulting ash was ground to improve reactivity and used as a binder. Sodium silicate was used as an activator for geopolymerization. The geopolymer was prepared by combining the binder with fine aggregate, ground bauxite, and CCA in different proportions. The curing process involved heating the samples at 70 °C for 24 h followed by ambient temperature curing. Compression testing was conducted at 7, 14, and 28 days to assess the strength and durability of the geopolymer mortar. Testing was performed according to ASTM standards.

Keywords: geopolymer; corn cob ash; bauxite; construction; materials

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1. Introduction

Concrete is the most used building material all around the world. Concrete is a composite material composed of fine and coarse aggregate bonded together with cement. Many researchers have tried to reduce the harmful environmental effects of cement by replacing it with supplementary cementations materials such as rice rusk ash, fly ash, ground granulated blast furnace slag, and corn cob ash (CCA) [1]. Pakistan produced almost 7.9 million tons of corn from 2021–2022 and this production is increasing every year at a rate of 4.97% [2]. One possible way of utilizing CCA is its use as secondary cementitious material (SCM). Studies have shown that CCA possesses all the properties which would make it suitable to be used as an SCM [3]. Bauxite is a naturally occurring rock which is rich in alumina. It is found in abundance in the Kotli AJK region. The purpose of using bauxite with CCA in this research is that it will not cause any sudden depletion of natural resources as no other industry utilizes it and it is considered waste. It is easily mineable as it is soft rock and contains 45–50% Al_2O_3, not more than 20% Fe_2O_3, and 3–5% Silica [4].

This research will be limited to only the synthesis of one-part geopolymer mortar (GM). Different mass ratios of CCA and bauxite will be used to find the optimum combination of CCA and bauxite that can be adopted for preparation of a high-strength geopolymer. The research aims to contribute to sustainable construction practices and explore the potential of agricultural waste materials in geopolymer technology.

2. Research Methodology

The research was conducted as per the following procedures and details:

2.1. Materials Preparation

Corn cob was burnt in an open environment before burning in a controlled environment at 600 °C for 2 h. The obtained ash was crushed in a jar mill and then passed through sieve No. 200. Bauxite was jar milled and passed through sieve No. 200.

2.2. Mortar Preparation

Mix design for GM is shown in Table 1 below:

Table 1. Mix design for GM.

Material	Percentage by Weight (%)
CCA	10, 20, 30 percent weight of binder
Bauxite	90, 80, 70 percent weight of binder
Sand	50
Activator (Sodium Silicate)	10% the weight of binder
Water-to-Binder Ratio	0.3
Super Plasticizer	2% the weight of binder

Cubes were cast for different tests according to mix design.

2.3. Curing

Curing was conducted at the high temperature of 70 °C in an oven for 7, 14, and 28 days.

2.4. Tests

Sieve analysis was conducted on fine aggregates (ASTM C136-05) [5]. Temperatures of mortar mixes were checked (ASTM C1064) [6]. Initial setting time of GM was noted through Vicat needle apparatus in accordance with ASTM Standard C191 [7]. Slump test was conducted on all the cubes of GM (ASTM C143) [8]. Compressive strength test was performed to check the compressive strength of GM in a universal testing machine (UTM) (ASTM C109) [9]. Cubes were observed for appearance of cracks.

3. Results

3.1. Sieve Analysis of Fine Aggregates

The sand was obtained from Lawrencepur quarry. Sieve analysis was conducted to determine the fineness modulus of the sand. Equation (1) was used to find the fineness modulus. Fineness modulus helps in determining the particle size of sand. It affects the mechanical properties of the GM. The sieves were arranged in the following way according to their openings per linear inch: 4, 8, 16, 30, 50, 100, Pan.

The fineness modulus is given by:

$$\text{Fineness Modulus} = \frac{\Sigma \text{ Percent cumulative retained on sieve upto 160 micro meter}}{100} \tag{1}$$

The fineness modulus was calculated as 2.54, which was within limits. Fineness modulus for fine aggregate should be within the range 2.3 to 3.2.

3.2. Temperature of the Mortar

Temperature plays a crucial role in the hydration and curing process of construction materials. In this research, the temperature range of 15.6 °C to 26.7 °C suggests that the curing conditions were controlled within an acceptable range, promoting proper hydration and curing of the GM.

3.3. Setting Time of the Mortar

Initial setting times for different mortar mixes are presented in Table 2 below:

Table 2. Initial setting times of different mortars.

Sample ID	Initial Setting Time (min)
C10B90	40
C20B80	60
C30B70	75
OPC	35

3.4. Compressive Strength

Compressive strength for all the GM mixes were checked by testing them with the universal testing machine. A total of three cubes were tested for determination of strength for one day. The average of three cubes was taken as the strength of that day. Beside GM cubes, OPC mortar cubes were also tested for the sake of comparison. Compressive strengths of different mix designs are shown in Table 3. After compressive tests, it was found that the compressive strength of C20B80 cubes was the highest of all. It was 62 percent more than that of OPC at 28 days of curing. It can be seen in Table 3 below that the compressive strengths of all the GM cubes were greater than those of OPC mortar cubes.

Table 3. Compressive strengths of different mix designs.

GM Mix	Compressive Strength at Different Curing Ages (MPa)					
	7 Days	% Difference in Compressive Strength as Compared to OPC	14 Days	% Difference in Compressive Strength as Compared to OPC	28 Days	% Difference in Compressive Strength as Compared to OPC
C10B90	16.5	43.47	18.2	51.67	19.5	52.32
C20B80	18.1	57.39	19.6	63.34	20.76	62.18
C30B70	14.3	24.34	15.5	29.17	17.2	34.37
OPC	11.5	Nil	12.0	Nil	12.80	Nil

3.5. Cracks

It can be seen in Figure 1 that no cracks were observed in GM cubes. The absence of cracks in the GM cubes is a positive outcome, indicating that the mortar exhibited good structural integrity and resistance to cracking under the tested conditions. It suggests that the mixture proportions, including the binder-to-sand ratio and the incorporation of waste materials like corn cob ash and bauxite, were appropriate and resulted in a cohesive and robust mortar. Furthermore, the absence of cracks in the GM cubes may also be attributed to the curing conditions employed during the testing. The curing process, including the temperature and duration, likely played a significant role in allowing the mortar to develop its strength and preventing the formation of cracks.

Figure 1. Geopolymer cubes.

4. Conclusions

The following conclusions can be drawn from the conducted study:

1. One-part geopolymer can be developed locally in Pakistan by using corn cob ash and bauxite.
2. The mix design with 20 percent corn cob ash and 80 percent bauxite gave the most optimum results.
3. One-part geopolymer resulting from corn cob ash and bauxite has huge potential for replacing OPC.
4. The geopolymer developed in this research has compressive strength higher than that of normal ordinary Portland cement.

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References

1. Singh, R.P.; Vanapalli, K.R.; Cheela, V.R.S.; Peddireddy, S.R.; Sharma, H.B.; Mohanty, B. Fly Ash, GGBS, and silica fume based geopolymer concrete with recycled aggregates: Properties and environmental impacts. *Constr. Build. Mater.* **2023**, *378*, 131168. [CrossRef]
2. Lyddon, C. Focus on Pakistan. WorldGrain, 20-Sep-2021. Available online: https://www.world-grain.com/articles/15862-focus-on-pakistan (accessed on 7 May 2023).
3. Adesanya, D.A.; Raheem, A.A. Development of corn cob ash blended cement. *Constr. Build. Mater.* **2009**, *23*, 347–352. [CrossRef]
4. Ye, J.; Zhang, W.; Shi, D. Effect of elevated temperature on the properties of geopolymer synthesized from calcined ore-dressing tailing of bauxite and ground-granulated blast furnace slag. *Constr. Build. Mater.* **2014**, *69*, 41–48. [CrossRef]
5. *ASTM C136-05*; Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates. ASTM: West Conshohocken, PA, USA, 2017. Available online: https://www.astm.org/c0136-05.html (accessed on 31 May 2023).
6. *ASTM C1064/C1064M*; Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete. ASTM: West Conshohocken, PA, USA, 2017. Available online: https://www.astm.org/c1064_c1064m-17.html (accessed on 31 May 2023).
7. *ASTM C191*; Standard Test Methods for Time of Setting Hydraulic Cement by Vicat Needle--eLearning Course. ASTM: West Conshohocken, PA, USA, 2010. Available online: https://www.astm.org/astm-tpt-185.html (accessed on 31 May 2023).
8. *ASTM C143/C143M*; Standard Test Method for Slump of Hydraulic-Cement Concrete. ASTM: West Conshohocken, PA, USA, 2015. Available online: https://www.astm.org/c0143_c0143m-12.html (accessed on 31 May 2023).
9. *ASTM C109/C109M*; Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens). ASTM: West Conshohocken, PA, USA, 2020. Available online: https://www.astm.org/c0109_c0109m-20.html (accessed on 31 May 2023).