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Research Article

The Impact of Replacing Cement with a Mixture of Rice Husk Ash and Bagasse Ash on the Compressive Strength of High-Performance Concrete

Muhammad Azhari[1]*, Muttaqin Hasan[2], Aulia Rachman[1], Khairul Amna[1], Rafiqa Muhnita Yusputri[2], Vreslisawati Sagala[3]

[1] Department of Civil Engineering, Universitas Malikussaleh, Aceh Utara, Indonesia, 24353
[2] Department of Civil Engineering, Universitas Syiah Kuala, Banda Aceh, Indonesia, 23111
[3] Department of Civil Engineering, Universitas Sumatera Utara, Medan, Indonesia, 20151
*Corresponding Author: muhammadazhari@unimal.ac.id | Phone: +62821-6570-9035

ABSTRACT

Bagasse ash and rice husk ash are quite smooth and have high active silica content. This forms the basis for using these ashes as substitutes for cement. In addition to being easy to find, the use of bagasse ash and rice husk ash waste is also a recent innovation to realize environmentally friendly building material technology. The purpose of this research is to determine the effect of using a combination of bagasse ash and rice husk ash as a cement substitute based on compressive strength and to compare the results with previous research. Portland cement, fine aggregate, coarse aggregate, water, superplasticizer, and a mixture of bagasse ash and rice husk ash are the materials utilized in this study as a cement replacement. The proportion variations are 0%, 5%, 10%, and 15% of the cement volume. The results of this study indicate that varying the percentage of this ash combination as a cement substitute affects the compressive strength of high-quality concrete. The most optimal compressive test results at the ages of 28 and 56 days were obtained with the 5% variation. This experienced an increase of 14.49% and 22.92% from the control concrete.

Keywords: rice husk ash; bagasse ashes; the compressive strength of concrete; the concrete environment; cement substitute

1. INTRODUCTION

The expansion of concrete building development has been accompanied by a related increase in concrete manufacturing, according to an article published by the Indonesian Ministry of Industry. An increase in the need for cement, with cement consumption reaching 48 million tons in 2011, an increase of 17.7% over 2010. Due to the imbalance between the supply and demand for cement, Indonesia continues to import cement to satisfy its infrastructure development requirements. The most common wastes in Indonesia are rice husk ash and bagasse ashes. Using rice husk ash and bagasse ash as an alternative cement replacement is a good way to address waste issues in the environment since both are excellent substitutes. One of the constituents of cement is silica (SiO_2), which is found in waste. This research aims to assess the impact of using a mixture of rice husk ash and bagasse ash as a cement replacement that may increase the compressive strength of premium concrete by making it denser.

This research was conducted at the Construction and Building Materials Laboratory of Civil Engineering, Syiah Kuala University, Banda Aceh. In this study, the composition of high-quality concrete consisted of cement, water, split (crushed stone), sand, superplasticizer, bagasse ash, and rice husk ash, with the concentrations used being 0%, 5%, 10%, and 15% of the cement volume, with a combination of bagasse ash and rice husk ash of 50% each. The test specimens for one variable were 3 pieces for the testing age of 28 days and 56 days, so that the total number of test specimens was 24 pieces with cylindrical test specimens measuring 10 cm in diameter and 20 cm in height.

The results of the study showed that the compressive strength value of the control concrete at the test age of 28 days was 52.26 MPa, while at the test age of 56 days it was 56.76 MPa. In concrete that uses a combination of bagasse ash and rice husk ash as a partial cement substitution, the largest increase in concrete compressive strength is found in the percentage variation of 5%. The value of compressive strength obtained at the test age of 28 days was 63.27 MPa with a percentage increase in concrete compressive strength of 14.49% from the control concrete. At the test age of 56 days, the value of concrete compressive strength obtained was 68.46 MPa with a percentage increase in concrete compressive strength of 22.92% from the control test specimen. Based on the calculation of the analysis of variance of the high-strength concrete compressive strength test, the Fo value of the percentage of partial cement substitution in concrete is 37.28, and the Fo table value is 3.24, so that the Fo value > Fo table. This demonstrates that the proportion of the combination of rice husk ash and bagasse ash used as a cement replacement in high-strength concrete varies. has an impact on the concrete's compressive strength.

2. RESEARCH METHOD

2.1 Materials and equipment

2.1.1 Materials

This research employed a combination of Portland cement, fine aggregate, coarse aggregate, water, superplasticizer, and bagasse and rice husk ashes. a cement alternative composed of 50% rice husk ash and 50% bagasse ashes, with varying volumes of 0%, 5%, 10%, and 15%. The cement used was Type I Portland Cement produced by PT. Lafarge Cement Indonesia. Visual inspection was performed to ensure the packaging bags were untearable and the grains were free of hard lumps. The fine aggregate used, with a size of less than 5 mm, was sourced from Krueng Aceh, and the coarse aggregate (split) used, with a maximum size of 10 mm, was imported from PT. Lhoknga Beton, Aceh Besar. The aggregates were physically tested to determine their quality. The bagasse ash used is obtained from the combustion of sugarcane fiber from sugar factory waste in Takengon at a temperature of 619°C. Meanwhile, the rice husk ash comes from the residue of the rice husk combustion process at the Lam Ateuk Rice Factory in Aceh Besar. The bagasse and rice husk ash are ground and sieved through a No. 200 sieve before being used as a cement substitute. The water used for the concrete mixture is clean, free from mud, salts, and harmful compounds that could alter the properties of the cement and damage the concrete. The superplasticizer used is Sika Viscocrete-10 at 1.5% of the cement weight.

2.1.2 Equipment

A German-made Ton Industries Compressive Testing Machine with a maximum capacity of 100 tons, a compressometer, and data are used in this investigation. The logger includes a scale, a thermocouple, a slump flow test apparatus, an oven, and a 10 x 20 cm cylindrical test specimen mold. a rubber hammer, a concrete mixer (molen), and a set of scales made by Maruto Japan that are nearly identical to the ASTM standard sieve location. The Construction and Building Materials Laboratory, Faculty of Engineering, Unsyiah, has all of this gear on hand.

2.2 Material inspection

The chemical composition of rice husk ash and bagasse ash was examined at the Banda Aceh Industrial Baristand Laboratory. The coarse and fine aggregates were examined at the Building Materials Construction Laboratory, Faculty of Engineering, Syiah Kuala University. The physical properties of the coarse and fine aggregates were assessed, including specific gravity, absorption, bulk density, and sieve analysis.

2.3 Concrete mix design

The stage for planning the composition of the concrete mix design is calculated based on the volume ratio. For the design of a high-quality concrete mix, it is planned with a w/c value of 0.3. The percentage of additives (a combination of bagasse ash and rice husk ash) used is 0, 5, 10 and, 15 % of the cement volume with each mixture of 50% bagasse ashes and 50% rice husk ashes. The superplasticizer used is the Viscocrete-10 type, as much as 1.5% of the cement weight. The concrete mix design can be seen in **Table 1.**

Table 1. Design of 1 m^3 conventional concrete mix with w/c 0.3.

Material	Quantity (Kg)
Water	180
Cement	600
Bagasse ash	-
Rice husk ash	-
Sand (0-2 mm)	831,588
Split (6-10 mm)	831,588
Superplasticizer	9

2.4 Preparation and maintenance of test objects

2.4.1 Preparation of test objects

Before casting, each material is weighed according to the mixture ratio obtained from the concrete mix design. Mixing of concrete mortar is done by sequentially inserting high-quality concrete forming materials into the mixer, namely crushed stone, sand, cement, rice husk ash, bagasse ash, water, and superplasticizer. After homogeneous mixing, a slump flow test is carried out, after which the mortar test specimen is inserted into a cylindrical mold in stages in three layers. Each layer is compacted 25 times with a drop height of about 30 cm. After the mold is full, the side of the mold is tapped with a rubber hammer so that the mortar becomes solid. After the test specimen is (2-4) hours old, the surface is leveled using cement paste (capping) with w/c 0.3.

2.4.2 Test object maintenance

After the test specimens were 24 hours old, the cylinder molds were removed, and the specimens were cured by soaking them in a soaking tank for 25 and 53 days. After 27 and 55 days of curing, the specimens were removed from the tank and dried before testing the following day.

2.5 Compressive strength testing

Compressive strength testing is conducted at 28 and 56 days using a 10 cm diameter, 20 cm high cylinder. Specimens are taken from the soaking tub, weighed, and measured the day prior to testing. Testing employs a Ton Industries No.254/14/1970 machine, with a 100-ton capacity, made in Germany, and follows SNI 03-6805-2002 standards. Axial strain under each load is measured by a transducer installed on the compressometer. Load and strain values are recorded by a data logger. The maximum value is noted when the load decreases or when the specimen cracks or fails.

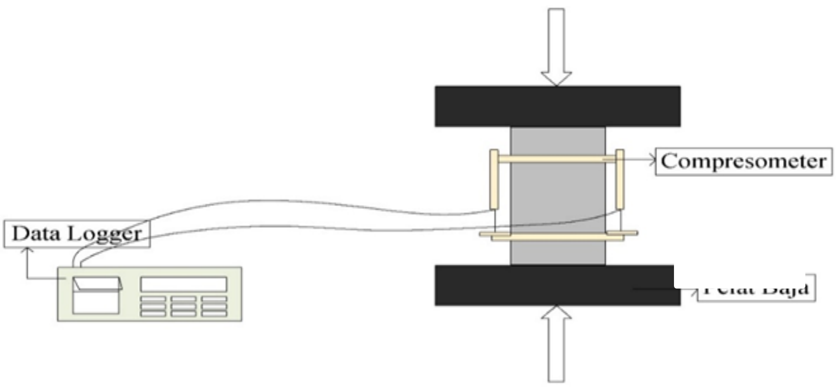

Figure 1. Cylinder compressive strength test

3. RESULTS AND DISCUSSION

3.1 RESULTS

3.1.1 Examination of the chemical elements of sugarcane bagasse ash and rice husk ash

The results of the parameter examination of bagasse ashes and rice husk ashes were conducted by the Testing Laboratory of the Banda Aceh Industrial Research and Standardization Center. The physical property values can be seen in the Table 2 and Table 3.

Table 2. Examination of bagasse ash parameters.

Test parameters	Test results (%)
SiO_2	42,47
Fe_2O_3	1,02
Al_2O_3	1,69
CaO	5,01

Table 3. Examination of rice husk ash parameters

Test parameters	Test results (%)
SiO_2	65,70

3.1.2 Physical properties of bagasse ash and rice husk ash

The results of the examination of the physical properties of bagasse ash and rice husk ash are shown in Table 4.

Table 4. Examination of the physical properties of bagasse ash and rice husk ash.

No	Physical examination	Bagasse ash	Rice husk ash	unit
1	Bulk Density	1,042	0,423	g/l
2	Specific Gravity	-	-	-
3	SSD	1,77	1,47	g/l

3.1.3 Concrete mix design

The concrete mix design is planned for high-quality concrete with a design compressive strength of 60 MPa and w/c of 0.3. The results of the concrete mix composition calculations can be seen in Table 5.

Table 5. Concrete Mix Design 1 m^3 with w/c 0.3.

Material (Kg)	Cement substitute			
	0%	5%	10%	15%
Water	180	175,630	171,257	166,886
Cement	600	570	540	510
Bagasse ash	0	8,429	16,857	25,286
Rice husk ash	0	7	14	21
Sand (0-2 mm)	831,588	836,653	842,895	849,137
Split (6-10 mm)	831,588	836,653	842,895	849,137
Superplasticizer	9	8,79	8,6	8,34

3.1.4 High quality concrete compressive strength test results

Compressive strength testing was conducted at 28 and 56 days of concrete curing. This test aimed to compare the compressive strength of control concrete with concrete using cement substitutions of 5%, 10%, and 15% of the cement volume and the addition of Viscocrete-10 superplasticizer at 1.5% of the cement weight. The compressive strength results at 28 and 56 days of testing can be seen in Figure 2.

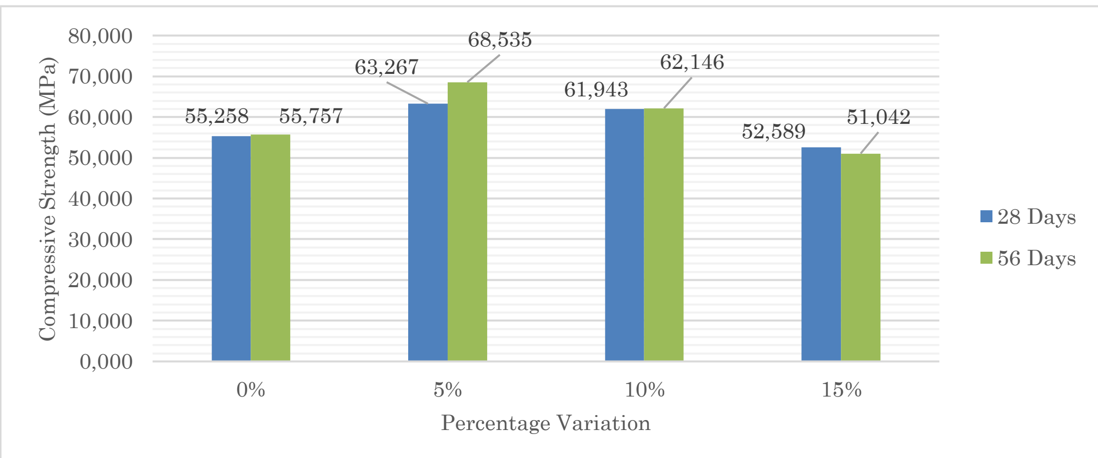

Figure 2. Comparison chart of high quality concrete compressive strength at 28 and 56 days.

a. 28-Day Compressive Strength Test Results

The first stage of compressive strength testing was conducted during the 28-day curing of the specimens. The data from this compressive strength test included concrete load and strain data. The concrete compressive strength test results are shown in Table 6.

Table 6. Results of concrete compressive strength testing at 28 days.

Age	Percentage	Name of Test Object	Dimension (mm)		Area	Burden	Compressive Strength	Average Compressive Strength
(Days)	(%)		Height	Diameter	(mm²)	(N)	(MPa)	(MPa)
28	0	111	203,0	100,5	7938,0	451105,9	59,10	55,26
		112	202,8	101,7	8123,3	411879,3	52,73	
		113	203,4	102,3	8224,8	426589,3	53,94	
	5	211	201,2	100,5	7927,5	470719,2	61,75	63,27
		212	202,0	100,5	7927,5	500139,2	65,61	
		213	202,0	101,5	8086,1	485429,2	62,43	
	10	311	202,0	100,6	7943,2	456009,2	59,70	61,94
		312	202,0	100,5	7932,7	470719,2	61,71	
		313	200,5	100,4	7916,9	490332,5	64,41	
	15	411	202,8	100,4	7916,9	402072,7	52,82	52,59
		412	201,8	100,5	7932,7	416782,6	54,64	
		413	202,5	100,3	7906,4	382459,4	50,31	

b. Compressive Strength Test Results at 56 Days

The second stage of compressive strength testing was conducted when the specimens had reached 56 days of curing. The data from this compressive strength test consisted of concrete load and strain data. The concrete compressive strength test results are shown in **Table 7**.

Table 7. Results of concrete compressive strength testing at 56 days.

Age	Percentage	Name of Test Object	Dimension (mm)		Area	Burden	Compressive Strength	Average Compressive Strength
(Days)	(%)		Height	Diameter	(mm²)	(N)	(MPa)	(MPa)
56	0	121	202,1	102,0	8171,3	446202,6	56,79	55,76
		122	201,4	100,4	7911,7	411879,3	54,14	
		123	200,6	100,1	7874,9	426589,3	56,34	
	5	221	202,0	100,4	7911,7	500139,2	65,74	68,53
		222	201,5	100,5	7927,5	544269,1	71,40	
		223	202,0	100,3	7895,9	519752,5	68,46	
	10	321	201,8	100,3	7895,9	456009,2	60,06	62,15
		322	201,5	100,4	7916,9	470719,2	61,84	
		323	202,5	100,3	7901,2	490332,5	64,54	
	15	421	202,8	100,3	7906,4	367749,4	48,37	51,04
		422	201,8	100,5	7927,5	416782,6	54,68	
		423	201,3	100,6	7943,2	382459,4	50,07	

3.1.5 Stress-strain relationship of high strength concrete

The stress-strain data of high-quality concrete with a combination of bagasse and rice husk as cement substitutes were obtained from the results of cylinder compressive strength tests. Based on this data, a graph of the concrete stress-strain relationship was created and obtained by calculating the stress and strain for each 1-ton load increase interval until the test specimen was destroyed.

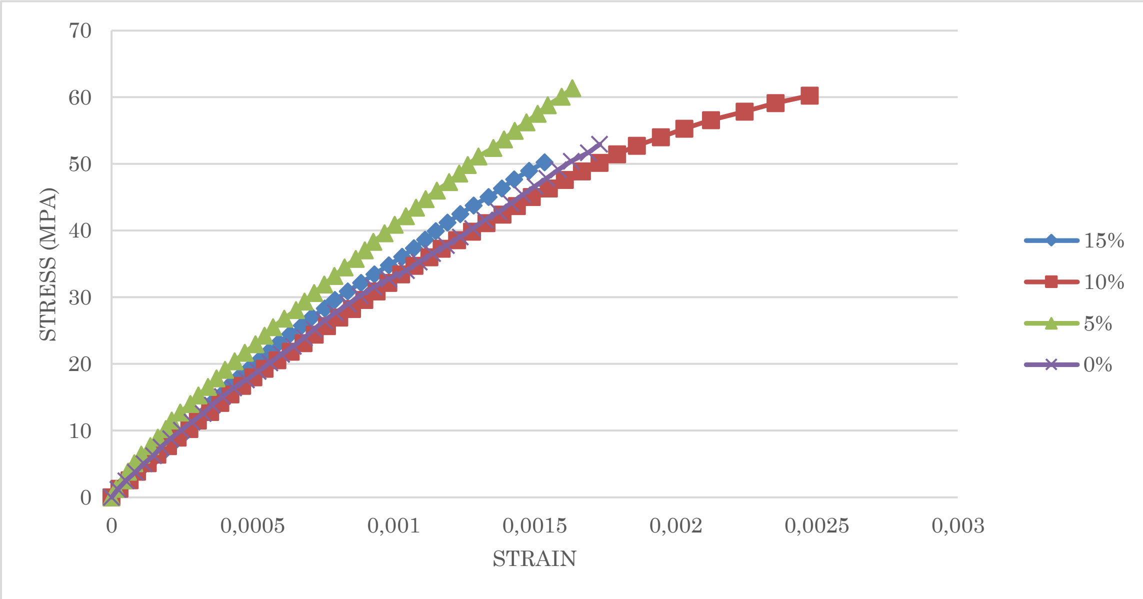

Figure 3. Concrete stress-strain graph at 28 days test age.

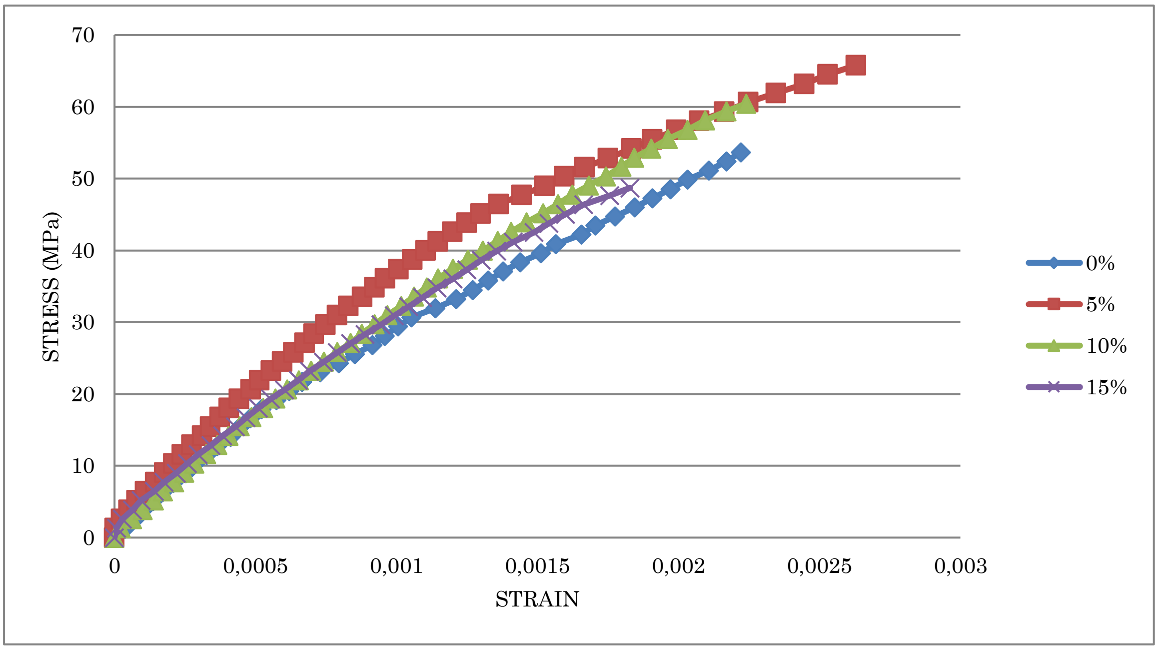

Figure 4. Concrete stress-strain graph at 56 days test age.

3.1.6 **DISCUSSION**

3.1.7 Discussion of physical properties of materials

The results of the physical properties of aggregates in the laboratory indicate that the aggregates used in this study meet the requirements as high-quality concrete forming materials. The aggregate volume weight value exceeds 1.2 kg/l, and the specific gravity value ranges from 2.5 - 2.8 for split and 2.0-2.7 for sand, while the absorption value also meets the requirements, which is between 0.4 - 1.9. In the mixed aggregate gradation graph, the percentage of aggregate produces a good aggregate mixture distribution in concrete, because the aggregate distribution data results in zone 3 for a good grain arrangement. From laboratory examinations, namely by testing the physical properties of bagasse ash and rice husk ash, the specific gravity value is obtained, which does not match the specific gravity of cement. But the chemical elements contained in bagasse ash contain silica (SiO_2) of 42.47% and rice husk ash contains silica elements (SiO_2) of 65.70%. The silica element, if reacted with free lime $Ca(OH)_2$, will increase the bond strength between the cement paste and aggregate the strengthening the concrete. Therefore, bagasse ash and rice husk ash can be a good alternative cement substitute in forming high-quality concrete mixtures.

3.1.8 Discussion of concrete mix design

The concrete mix design was carried out using the weight and volume comparison method by (Aulia, 2005). The calculation of the mix composition for 1 m3 of high-quality normal concrete (without the addition of bagasse ashes and rice husk ashes and superplasticizer) and high-quality concrete using cement replacement variations of 5%, 10%, 15% of the cement volume (each variation with a mixture composition of 50% bagasse ash and 50% rice husk ash) with the addition of viscocrete-10 type superplasticizer of 1.5% of the cement weight. The calculation of the substitution percentage was taken because the specific gravity of bagasse ash and rice husk ash that had been tested was in accordance with their respective specific gravity. Therefore, the weight of cement, bagasse ash, and rice husk ash used had different.

3.1.9 Variance analysis

The calculation of variance analysis aims to determine the effect of environmental conditions on the compressive strength of concrete at different ages and, different variations can be seen in Table 8.

Table 8. Results of concrete compressive strength testing at 56 days.

Variant Source	Sum of Squares	Degrees of Freedom	Mean Square	Fo	Fo Table
Age	7,33	1	7,33	1,13	4,49
Percentage	723,44	3	241,15	37,28	3,24
Interaction	38,32	3	12,77	1,97	3,24
Error	103,48	16	6,47		
Total	872,58	23			

Based on the table above, the following results were obtained:

1. In the concrete compressive strength test, the Fo value for concrete age was 1.13 < Fo table = 4.49. This indicates that concrete age has no effect on concrete compressive strength.
2. In the concrete compressive strength test, the Fo value for the percentage of partial cement substitution in concrete was 37.28 > Fo table = 3.24. This indicates that the percentage of partial cement substitution in concrete affects concrete compressive strength.
3. In the concrete compressive strength test, the Fo value for concrete interaction was 1.97 < Fo table = 3.24. This indicates that concrete interaction has no effect on concrete compressive strength.

4. CONCLUSION

The use of a combination of rice husk ash and bagasse ash as a partial cement replacement in high-strength concrete significantly improves compressive strength, with the optimal replacement level at 5%. At 28 days, compressive strength increased by 14.49%, resulting in an overall strength improvement of 22.92% compared to the control concrete without replacement. Replacement levels up to 10% still enhance strength, but beyond 10%, compressive strength decreases. Failure patterns observed include cone-shattering and shearing, typical of high-strength concrete with these additives. Statistical analysis indicates that the replacement percentage significantly affects compressive strength, while the strength gain between 28 and 56 days is not statistically significant. Therefore, the combination of rice husk ash and bagasse ash can be optimally used as a cement substitute up to 10% to improve the performance of high-strength concrete.

RECOMMENDATIONS

The findings of this investigation suggest that using rice husk ash and bagasse ash as partial cement replacements has promise as an environmentally friendly option. Though they are a friendly building material, their use should be limited to no more than 10% of the cement volume and be thoroughly blended in order to get the best outcomes. of fresh concrete, which is supported by chemical composition testing of both materials in order to facilitate their use in practical field applications and research.

AUTHOR'S CONTRIBUTIONS

All authors were involved in the discussion of the findings and made contributions from the beginning to the conclusion of the manuscript

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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