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Mechanical Properties of Concrete By Substituting Sawdust with Ground Glass

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Abstract

This study aimed to evaluate the mechanical properties of concrete by substituting sawdust with ground glass in proportion to the weight of fine aggregate. These materials can be used again in the building sector, but they are often thrown away, which harms the environment. The modulus of elasticity, tensile strength, flexural strength, and compressive strength of 216 concrete samples were evaluated. To conduct these experiments, three experimental groups were made by adding sawdust in percentages of 10%, 15%, and 30% and powdered glass in percentages of 10%, 20%, and 30%. A control group of concrete samples was made without any additives. According to the analyzed results, the concrete's mechanical properties were enhanced by substituting 20% ground glass and 10% sawdust. This resulted in increases of 2.65% for compressive strength, 1.68% for flexural strength, and 6.51% for modulus of elasticity, corresponding to the design of f'c= 280 kg/cm². Similarly, the tensile strength test showed a drop of 3.18%. From the foregoing, it may be inferred that the concrete's mechanical qualities are only slightly improved using sawdust and powdered glass instead.

Keywords: Concrete, Ground glass, Mechanical properties, Sawdust.

1 | Introduction

One of the most significant ecological and social issues facing all nations today is the issue of waste disposal [1]. Concrete and other building and demolition trash in India are disposed of abroad rather than through professional recycling [2]. Recycling may be done in various ways. Owing to this crucial problem, some building waste materials, such as leftover concrete aggregates, can be recycled several times and used for new projects [3].

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Cement, aggregates, water, and admixtures are among the elements used in the production of concrete; aggregates make up the majority of the ingredients. Waste glass has a great deal of potential for use in the concrete building industry. Raw materials, including sand, soda ash, limestone, and rubble, were used to make glass containers [4]. Good-quality sand supplies are running low, particularly in India, as the demand for sand rises in the contemporary developing globe. Consequently, the lack of natural resources like sand will be made up for by sawdust, which is regarded as a waste product [5].

Sawdust and cow dung are waste materials frequently utilized in the concrete technology industry [6]. In general, sawdust can be used as an aggregate in concrete production [7], and it can be used in construction. It lowers the product's cost and CO_2 emissions, and it offers a means of reducing environmental byproducts by using it to improve ecosystem sustainability [8]. A by-product of wood-cutting operations like sawing, milling, etc., is sawdust, also known as wood residue. It is made out of tiny wood shavings and is available in different densities, hues, chemical compositions, and particle sizes [9].

Cellulose, lignin, hemicelluloses, and extractives are among its primary constituents [10]. The necessity for this study is further supported by the paucity of studies conducted locally and nationally. Concrete's ability to take on nearly any shape while still fresh is one of its essential characteristics [11]. One of the materials with the greatest potential for recycling and repurposing is waste glass [12].

By replacing the fine aggregate in concrete with ground glass and sawdust, the mechanical behavior of the mixture was assessed; the tensile, elastic, compression, and bending moduli were examined; tensile strength is the highest force a material can sustain before permanently deforming or breaking [13]; bending is a crucial property of materials since it establishes their capacity to withstand loads that tend to bend them; compressive strength is "a measure of the ability of concrete to resist the loads that tend to compress it, that is, the ability of the material or structure to withstand loads on its surface without any cracking or deflection"[14]; The amount of deformation that happens in a material when a force is applied to it is determined by its modulus of elasticity. Deformation decreases with increasing modulus of elasticity [15].

Concrete with 5% SDA replacement provides comparable workability and compressive strength to regular concrete, according to Meko and Ighalo [16]. But it's crucial to recognize that as the proportion of replacement rises, workability falls [16]. According to Alabduljabbar et al. [17], the standard sample's compressive strength was 65.8 MPa after 28 days; the assessed property dropped by 26.1% when substitutes were increased from 0% to 100%. Although the findings are deemed suitable for construction, the initial flexural strength values were 4.2 MPa and did not rise when sawdust was substituted for fine aggregate [17].

The substitution of 5% GWP gives the base concrete strength, according to Folagbade and Olatunji [18], but it has no discernible impact on compressive strength. According to Batool et al. [19], a 10% replacement of fine aggregates is the ideal amount to use. This increases the tensile strength by 14% while decreasing the compressive strength [1], [9].

According to Edem et al. [20], the maximum strength of concrete was attained when 20% of the sand was substituted with iron filings and glass particles. Lastly, the adoption of glass particles in concrete manufacturing will enhance waste management and resource conservation; concrete samples containing glass particles consistently enhance flexural strength at all replacement levels [20], [21].

From the slump experiments, the more glass and crushed brick are added to concrete, the less workable it becomes [22]. As the amount of glass in the hardened concrete rose, the concrete's compressive and tensile strength declined in comparison to the control concrete [22]. According to Rabiu and Damdelen [8], the standard sample's compressive strength increased after 28 days; however, sawdust resulted in noticeably lower strength and no discernible tensile strength [8]. The findings of Poma's research in Peru show that the glass's fineness modulus of the fine aggregate, which came out at 2.81%, was within the allowed range. It was concluded that the resistances between 230 and 235 kg/cm², which are ideal values in comparison to a design of 210 kg/cm², were attained when 2% and 3% of powdered glass were added to the aggregate [23]. According to Codina [24] kit, the qualities of concrete improve with increasing ground glass substitution. For example, if 10% ground glass is substituted for fine aggregate, the concrete will reach its maximum strength after 28 days [24].

2|Methods

2.1|Cement

The general-purpose gray Portland cement type I, whose specifications meet the minimal physical and strength standards outlined in ASTM C150 and NTP 334.009, was utilized.

2.2|Aggregates

Fine aggregate from the Pátapo – La Victoria quarry, located in the district of Pátapo, province of Chiclayo, department of Lambayeque, and coarse Aggregate (AG) from the Tres Tomas quarry, located in the district of Mesones Muro, province of Ferreñafe, department of Lambayeque, both of which are located in Peru, were used in this study. The aggregates were physically characterized, and the selected materials met the requirements and protocols of the ASTM C136 standard.

2.3|Ground Glass (Vm)

A frequent by-product of crushing recycled glass from bottles and demolished buildings is ground glass, which is then thrown away.

2.4|Sawdust (As)

A by-product of the wood-sawing operation is sawdust. The material, is frequently sold as a by-product for various uses, was gathered from the several carpentry businesses where this job is done.

Fig. 1. Sampling of ground glass.

Fig. 2. Sampling of sawdust.

2.5 | Mix Design

Considering the dosage derived from the mix design, twenty-seven samples of standard concrete were created for the various laboratory tests in resistances of 280 kg/cm² on the various curing days. Following the samples were created by adding sawdust (10%, 15%, and 30%) and powdered glass (10%, 20%, and 30%) based on the weight of fine aggregate.

Table 1. Combination dosage for concrete f'c=280 kg/cm² + ground glass.

Material	Designation			
	CP	**CVM10**	**CVM20**	**CVM30**
"Cement (kg/m³)"	436	436	436	436
"Fine aggregate (kg/m³)"	700	700	700	700
"Coarse aggregate (kg/m³)"	1017	1017	1017	1017
"Water (lt)"	201	201	201	201
"Vm (%)"	-	10%	20%	30%
"Vm (kg/m³)"	-	70.00	140.00	210.00

Table 2. Combination dosage for concrete f'c=280 kg/cm² + Ground glass.

Material	Designation			
	CP	**CVM20AS10**	**CVM20AS15**	**CVM20AS30**
"Cement (kg/m³)"	436	436	436	436
"Fine aggregate (kg/m³)"	700	700	700	700
"Coarse aggregate (kg/m³)"	1017	1017	1017	1017
"Water (lt)"	201	201	201	201
"Vm (%)"	-	20%	20%	20%
"Vm (kg/m³)"	-	140.00	140.00	140.00
"As (%)"	-	10%	15%	30%
"As (kg/m³)"	-	70.00	105.00	210.00

Table 3. Description of combination codes.

Code	Designation
“CP”	“Standard concrete f'c= 280 kg/cm²”
“CVM10”	“Standard concrete f'c= 280 kg/cm² + 10% Ground glass”
“CVM20”	“Standard concrete f'c= 280 kg/cm² + 20% Ground glass”
“CVM30”	“Standard concrete f'c= 280 kg/cm² + 30% Ground glass”
“CVM20AS10”	“Standard concrete f'c= 280 kg/cm² + 20% Ground glass + 10% Sawdust”
“CVM20AS15”	“Standard concrete f'c= 280 kg/cm² + 20% Ground glass + 15% Sawdust”
“CVM20AS30”	“Standard concrete f'c= 280 kg/cm² + 20% Ground glass + 30% Sawdust”

2.6|Experimental Procedure

The following ASTM rules were followed when conducting the experiments outlined in the experimental procedure: unit weight, settlement, and temperature are tested in the fresh condition: 1) compressive strength, flexural strength, tensile strength, and modulus of elasticity are tested in the hardened state, and 2) for testing, all of the manufactured samples were cured for 7, 14, and 28 days. Concrete cylindrical specimens measuring 150 mm in diameter and 300 mm in height were prepared for the tests of compressive strength, tensile strength, and modulus of elasticity; similarly, concrete beams measuring 150 mm x 150 mm x 500 mm were prepared for the test of flexural strength.

Accordingly, it was possible to identify the ideal percentage of ground glass and sawdust for the implementation of the concrete mix designs after analyzing the mechanical properties of the experimental concrete with the percentages of ground glass (10%, 20%, 30%) and sawdust (10%, 15%, and 30%) about the weight of fine aggregate, as illustrated in Tables 4, 5, 6 and 7.

3|Results and Discussion

3.1|Compressive Strength of Concrete

Resistance decreased when 10%, 20%, and 30% of fine aggregate was substituted for ground glass relative to its weight. Specifically, a 10% substitution resulted in a 13.56% decrease in resistance, a 20% substitution produced a 3.15% decrease, and a 30% substitution produced the largest decrease, reducing up to 19.51% in comparison to the base sample after 28 days of curing. These findings concur with those of Folagbade and Olatunji [18], who assessed different replacement percentages and found that even concrete combinations with GWP and SDA individually did not produce values greater than those of the basis sample, Meko and Ighalo [16] acquired compressive strength of 33.9 N/mm² after 21 days for the sample with 5% replacement, whereas Poma [23] produced values between the ranges of 230 to 235 kg/cm² by incorporating 2% and 3% ViM for the aggregate.

Edem et al. [20] suggest that the maximum strength of concrete may be achieved by substituting 20% of the sand with iron filings and RVi particles. Strength was shown to rise when 10% of sawdust was replaced with 10%, 15%, and 30% of fine aggregate relative to its weight, and to decrease as the amount of replacement rose. In particular, a 2.65% increase in resistance was noted when 10% sawdust was substituted; an 8.70% decrease was obtained when 15% sawdust was substituted; and the largest decrease, up to 9.73% in comparison to the base sample, was obtained when 30% sawdust was substituted at 28 days of curing.

This is supported by Meko and Ighalo [16], who found that the sample with 5% replacement had a compressive strength of 33.9 N/mm² after 21 days, whereas Folagbade and Olatunji [18] assessed different substitution percentages, including concrete combinations with GWP and SDA separately. However, according to Folagabade and Olatunji [18], these samples did not yield results that were greater than the basic sample. Similarly, Batool et al. [19] observe that 10% of the compressive strength is lost when 10% is substituted. Similarly, Rabiu and Damdelen [8] note that the conventional sample's compressive strength improves after 28 days, but it drastically decreases when sawdust is added.

3.2 | Tensile Strength of Concrete

Similar to the previously mentioned properties, this one also showed a decrease in strength; specifically, a 13.72% decrease in strength was noted when 10% ground glass was substituted, a 10.34% decrease when 20% was substituted, and the largest decrease, up to 17.20% in comparison to the base sample, was obtained when 30% ground glass was substituted at 28 days of curing. According to him, flexural and compressive strengths between 230 and 235 kg/cm² are attained by adding 2% and 3% of MV for the fine aggregate [23].

As the percentage of substitution increased, the strength decreased with the addition of sawdust; specifically, a 10% substitution resulted in a 3.18% decrease in strength; a 15% substitution produced a 21.97% decrease; and, at 28 days of curing, a 30% substitution produced the largest decrease, reducing up to 23.96% in comparison to the base sample. This is in line with research by Batool et al. [19], which suggests that a 10% sawdust substitution for fine aggregates might be the best option and increase tensile strength by 14%.

Table 4. Concrete's compressive strength after adding sawdust and powdered glass.

Sample	Compressive Strength fc = 280kg/cm²		
	7 Days	14 Days	28 Days
"CP"	217.23	243.63	293.8
"CVM10"	190.7	216.7	253.97
"CVM20"	199.23	232.73	284.53
"CVM30"	182.6	197.4	236.47
"CVM20AS10"	212.67	243.5	310.6
"CVM20AS15"	191.57	220.6	268.23
"CVM20AS30"	180.5	219.13	265.2

However, scientists like Rabiu and Damdelen [8] disagree, claiming that substantial results were not obtained in terms of tensile strength when sawdust was substituted. According to Alabduljabbar et al. [17], substituting sawdust for fine aggregate did not result in an improvement in strength values. Their findings are deemed suitable for building, nonetheless [17].

Table 5. Concrete's tensile strength after adding sawdust and powdered glass.

Sample	Tensile Strength fc = 280kg/cm²		
	7 Days	14 Days	28 Days
"CP"	17.4	29.27	33.53
"CVM10"	14.93	25.37	28.93
"CVM20"	16.17	26.5	30.07
"CVM30"	13.53	24.13	27.77
"CVM20AS10"	17.5	28.3	32.47
"CVM20AS15"	14.37	24.33	26.17
"CVM20AS30"	14.37	22.43	25.50

Table 6. Concrete's flexural strength after adding sawdust and powdered glass.

Sample	Flexural Strength fc = 280kg/cm²		
	7 Days	14 Days	28 Days
"CP"	34.43	39.20	49.67
"CVM10"	30.13	33.23	41.83
"CVM20"	32.73	35.57	47.03
"CVM30"	28.83	32.6	40.37
"CVM20AS10"	35.3	38.17	50.5
"CVM20AS15"	30.13	32.03	44.4
"CVM20AS30"	27.73	28.5	41.27

Table 7. Concrete's modulus of elasticity after adding sawdust and powdered glass.

Sample	Modulus of Elasticity fc = 280kg/cm2		
	7 Days	14 Days	28 Days
"CP"	234,339	267,874	292,316
"CVM10"	208,251	235,487	262,998
"CVM20"	221,710	249,341	279,064
"CVM30"	189,374	211,354	225,020
"CVM20AS10"	247,813	269,652	311,346
"CVM20AS15"	201,908	222,288	256,004
"CVM20AS30"	190,709	210,759	245,804

4 | Flexural Strength of Concrete

Similar to the previously mentioned properties, this one also showed a decrease in strength; specifically, a 13.72% decrease in strength was noted when 10% ground glass was substituted, a 10.34% reduction was obtained when 20% ground glass was substituted, and the largest decrease, up to 17.20% in comparison to the base sample, was obtained when 30% ground glass was substituted at 28 days of curing. According to his findings [23], flexural and compressive strengths were attained between 230 and 235 kg/cm2 when 2% and 3% of ViM were used as the fine aggregate. The findings demonstrated that when sawdust was substituted for fine aggregate, strength increased by 10% and decreased as the proportion of replacement increased.

Resistance increased by 1.68% when 10% substitution was taken into account; decreased by 10.60% when 15% replacement was made; and decreased by 16.91% when 30% substitution of sawdust was made. These results were achieved after 28 days of curing. The results are somewhat at odds with those of Alabduljabbar et al. [17], whose study found that the initial flexural strength values were 4.2 MPa and that the substitution of sawdust for fine aggregate did not increase but rather decreased by 26.1%; however, their findings are still deemed suitable for use in construction.

5 | Modulus of Elasticity

According to the results, this property also showed negative results; at 28 days of curing, a 10.03% strength drop was observed when 10% ground glass was substituted, a 4.53% decline when 20% ground glass was substituted, and the largest drop, up to 23.02% in comparison to the base sample, occurred when 30% ground glass was substituted. Sawdust was found to boost strength when a 10% substitution was made, and strength decreased as the proportion of substitution rose. When 10% was substituted, strength increased by 6.51%; when 15% was substituted, strength decreased by 12.42%; and when 30% sawdust was substituted, after 28 days of curing, the most notable reduction was achieved, reaching a reduction of up to 15.91% in comparison to the basic sample.

6 | Conclusion

To improve the qualities of traditional concrete, the current study substituted Vm for fine aggregate in the mix at percentages of 10%, 20%, and 30%, respectively. The findings of the experiment led to the deductions that the usage of the designs of f'c=280 kg/cm^2, modified samples were made by replacing 10%, 20%, and 30% of the weight of fine aggregate with ground glass, and the usage of the designs of f'c=280 kg/cm2, modified samples were made by replacing 10%, 15%, and 30% of the weight of fine aggregate with sawdust.

The analysis showed that the substitution of sawdust in the concrete was more beneficial in all properties. Nevertheless, considering the two materials in question (ground glass and sawdust), the ideal percentage of addition was 20% ground glass and 10% sawdust (CVM20AS10) at 28 days of curing.

Author Contributions

ABA: conceptualization, writing-original draft, method, analysis**;** AOA: conceptualization, method, supervision; FNU: literature, discussions. The authors read and approved the final manuscript.

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Conflicts of Interest

The authors declare that there is no competing interest.

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