IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.301

Volume 3, Issue 2, July 2023

Utilizing Pulverized Glass as a Partial Replacement for Fine Aggregates in Cement Mortar

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Abstract: *Mortar plays a pivotal role in the construction industry, underscoring the significance of comprehending its quality and the intricate interplay of its mixture in shaping performance outcomes. The utilization of waste glass as an innovative alternative to conventional fine aggregates in mortar mixtures is instrumental in enhancing structural safety. In light of this, the present study is dedicated to investigating the efficacy of waste glass incorporation in bolstering both compressive and flexural strength. This inquiry delves into the intrinsic qualities and strength attributes of concrete mortars, scrutinizing the influence of pulverized waste glass content. The range of powdered waste glass inclusions encompasses 0%, 10%, 15%, 20%, 25%, 30%, 50%, and 60% by weight in relation to the sand component of the mortar mixture. The experimental design involves the fabrication of a total of 72 mortar cubes, where 48 specimens are earmarked for conducting assessments of compressive and flexural strength. Compressive and flexural strength evaluations are conducted on the mortar samples after 7, 14, and 28 days of both moist and water curing protocols. The outcomes of these tests unveil the effectiveness of incorporating powdered waste glass as an aggregate within mortar mixtures, particularly at the 25% replacement mark. Intriguingly, the investigation highlights that concrete mortars imbued with 25% waste glass content exhibit superior strength in comparison to the other examined samples. Additionally, the study underscores that the strength outcomes for replacements of 25% and 10% successfully meet the prescribed strength requirements for cement mortar outlined in accordance with ASTM standards.*

Keywords: compressive strength, flexural strength, cement mortar, pulverized glass, replacement

I. INTRODUCTION

Mortar, a fundamental component of construction, plays a pivotal role in binding masonry units, rendering stability to structures, and distributing loads across surfaces. Comprising a mixture of cementitious materials, aggregates, and water, mortar's composition and properties significantly influence the overall strength, durability, and aesthetics of constructed elements. The selection and proportioning of mortar constituents are critical to achieving desired performance characteristics in various applications, from historical preservation to modern construction projects [1, 2, 3].

A considerable body of research has been dedicated to the investigation of mortars, resulting in the formulation of various mixtures. Researchers have explored diverse avenues, including the incorporation of alternative aggregate forms and deviations from standard mix ratios tailored to specific construction contexts. The integration of fine recycled aggregates into mortar formulations is closely associated with the attainability of desired properties in the resulting mixture [4, 5].

The continual growth of the global population has spurred an unprecedented surge in the demand for modern construction materials. To meet the needs of the ever-expanding construction industry, significant quantities of natural aggregates and cement are extracted on a large scale to accommodate new developments and the maintenance of buildings and vital engineering infrastructure. However, this intensive extraction of natural resources has ushered in a concerning trend of depleting Earth's finite resources, consequently heightening the potential for environmental degradation. Concurrently, the accelerated proliferation of population growth compounds these challenges by generating substantial amounts of environmental waste, underscoring the intricate web of concerns linked to sustainable development [6, 7, 8, 9].

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The utilization of waste materials in construction practices has garnered significant attention in recent years, driven by the imperative to achieve sustainable and environmentally friendly solutions. One such innovative approach involves the incorporation of pulverized glass as additives in mortar formulations. Pulverized glass, derived from discarded glass products, presents an opportunity to reduce waste accumulation, conserve natural resources, and enhance the properties of mortar. This introduction delves into the rationale behind utilizing pulverized glass as an additive in mortar, exploring its potential benefits and addressing associated challenges [10, 11].

A multitude of research endeavors has been undertaken to explore the incorporation of powdered glass waste as aggregates within mortar mixtures. These studies have been instrumental in presenting an avenue for the mitigation of glass waste and the concurrent reduction of mineral aggregate consumption in construction practices [12,13]. This experimental inquiry has captured the attention and curiosity of the researcher, aiming to assess the caliber and efficacy of mortar mixtures containing powdered waste glass.

II. MATERIALS AND METHODS

2.1 Materials

The following materials used in this research were as follows:

Table 1 illustrates the foundational framework for the standardized procedure employed in the study, facilitating the determination of material quantities to ensure accurate and reliable outcomes.

TABLE 1: STANDARDSPECIFICATIONFORTHENEEDED MATERIALS

Materials Needed	ASTM Standard
Cement	ASTMC1329
Sand	ASTMC144
Pulverized Waste Glass	SieveNo.16
Water	ASTMC1062

Presented in the table 2 provided are the requisite material quantities for the design mix, accounting for the specific quantity of glass intended to substitute the sand component. The mix adheres to a water-cement ratio of 0.56.

TABLE 2: QUANTITIES OF MATERIALS NEEDED

Design Mixture	Cement(kg)	Sand(m^3)	Pulverized Glass(m^3)	Water/Cement Ratio	Total Weight(m^3)
1:4	0.00625	0.025	0	0.56	0.03125
10% replacement	0.00625	0.0223	0.0025	0.56	0.03125
15% replacement	0.00625	0.0213	0.0038	0.56	0.03125
20% replacement	0.00625	0.20	0.005	0.56	0.03125
25% replacement	0.00625	0.019	0.0063	0.56	0.03125
30% replacement	0.00625	0.18	0.008	0.56	0.03125
50% replacement	0.00625	0.013	0.013	0.56	0.03125
60% replacement	0.00625	0.01	0.015	0.56	0.03125

2.2 Methods

The following methods were adopted in this research were as follows:

2.2.1 Mixture proportion: 1:4 (cement: fine aggregates: fine aggregates) were used in the mix. A water-cement ratio of 0.56 was also used for the mix.

2.3 Laboratory tests

- Specific Gravity and Water Absorption Measurement: The specific gravity and water absorption values are essential characteristics of fine, crucial for mix design calculations. The recognized ASTM C128 test method was employed to ascertain the specific gravity.
- Sieve Analysis: Fine aggregate particles were subjected to sieve analysis using the established ASTM C136 standard test method.

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- Slump Test: Individual slump tests were conducted for the design, adhering to the prescribed ASTM C143 standard test method.
- Compressive Strength Test: The concrete's compressive strength was determined after conventional curing periods of 7, 14, and 28 days. The standardized ASTM C39 test method was employed for this assessment.
- Curing methods:Moist curing and water curing are used in the study.

III. RESULTS AND DISCUSSION

Table 3 displays the mean compressive strength of the mortar after 7-day, 14-day, and 28-day periods of moist curing. As depicted in the table, the compressive strength at a 25% replacement rate surpasses that of 20% and 35% replacements. Notably, a marginal variance in compressive strength is observed between 20% and 25% replacements. Conversely, compressive strength experiences a decline as the replacement percentage rises for 50% and 60% replacements.

TABLE 3: COMPRESSIVE STRENGTH OF THE MORTAR (MOIST CURING)

Design Mixture	Average Compressive Strength of Mortar, MPa		
	7 days	14 days	28 days
0% replacement	14.95	12.25	16.50
10% replacement	9.45	10.16	14.10
15% replacement	9.65	10.32	12.90
20% replacement	6.97	9.23	12.58
25% replacement	6.89	8.39	12.62
30% replacement	7.55	9.12	11.02
50% replacement	6.24	6.33	9.46
60% replacement	1.75	1.89	2.5

Table 4 exhibits the average compressive strength of the mortar following 7-day, 14-day, and 28-day durations of water curing. As illustrated within the table, the compressive strength achieved at a 25% replacement rate exceeds that of 20% and 35% replacements. Significantly, a minor discrepancy in compressive strength is observable between 20% and 25% replacements. Conversely, compressive strength demonstrates a reduction with escalating replacement percentages, specifically evident in 50% and 60% replacements. Noteworthy is the observation that the water curing approach yields slightly elevated compressive strength compared to moist curing, despite an initial decrease – this increase becomes apparent over time.

TABLE 4: COMPRESSIVE STRENGTH OF THE MORTAR (WATER CURING)

Design Mixture	Average Compressive Strength of Mortar, MPa		
	7 days	14 days	28 days
0% replacement	16.3	11.72	18.39
10% replacement	10.8	9.63	15.99
15% replacement	11	9.79	14.79
20% replacement	8.32	8.7	14.47
25% replacement	8.24	7.86	14.51
30% replacement	8.9	8.59	12.91
50% replacement	7.59	5.8	11.35
60% replacement	3.1	1.36	4.39

Presented in Table 5 are the average flexural strength values of the mortar following 7-day, 14-day, and 28-day durations of moist curing. As portrayed in the table, the flexural strength achieved at a 25% replacement rate outperforms that of both 20% and 35% replacements, registering an average strength of 2.67 MPa. It's worth noting a subtle distinction in flexural strength between 20% and 25% replacements. However, an inverse trend is evident as the replacement percentage escalates, resulting in a diminishing flexural strength, particularly notable in the context of 50% and 60% replacements.

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TABLE 5: FLEXURAL STRENGTH OF THE MORTAR (MOIST CURING)

Design Mixture		**Average Flexural Strength of Mortar, MPa**	
	7 days	**14 days**	**28 days**
0% replacement	4.73	5.4	6.75
10% replacement	3.26	3.72	4.65
15% replacement	2.5	2.85	3.55
20% replacement	1.86	2.12	2.65
25% replacement	1.89	2.15	2.69
30% replacement	1.305	1.40	1.74
50% replacement	0.98	1.06	1.3
60% replacement	0.87	1.01	1.15

Table 6 presents the average flexural strength values of the mortar after being subjected to 7-day, 14-day, and 28-day periods of water curing. As shown in the table, the flexural strength achieved at a 25% replacement rate outperforms that of both 20% and 35% replacements. Importantly, a subtle difference in flexural strength is discernible between 20% and 25% replacements. Conversely, there is a reduction in flexural strength as the replacement percentage escalates, particularly notable in the context of 50% and 60% replacements. It is noteworthy that the employment of water curing yields slightly higher flexural strength compared to moist curing, despite an initial decline – this enhancement becomes more evident over time.

TABLE 6: FLEXURAL STRENGTH OF THE MORTAR (WATER CURING)

Design Mixture		**Average Flexural Strength of Mortar, MPa**	
	7 days	**14 days**	**28 days**
0% replacement	6.53	7.2	8.55
10% replacement	5.06	5.52	6.45
15% replacement	4.3	4.65	5.35
20% replacement	3.66	3.92	4.45
25% replacement	3.69	3.95	4.49
30% replacement	3.105	3.2	3.54
50% replacement	2.78	2.86	3.1
60% replacement	2.67	2.81	2.95

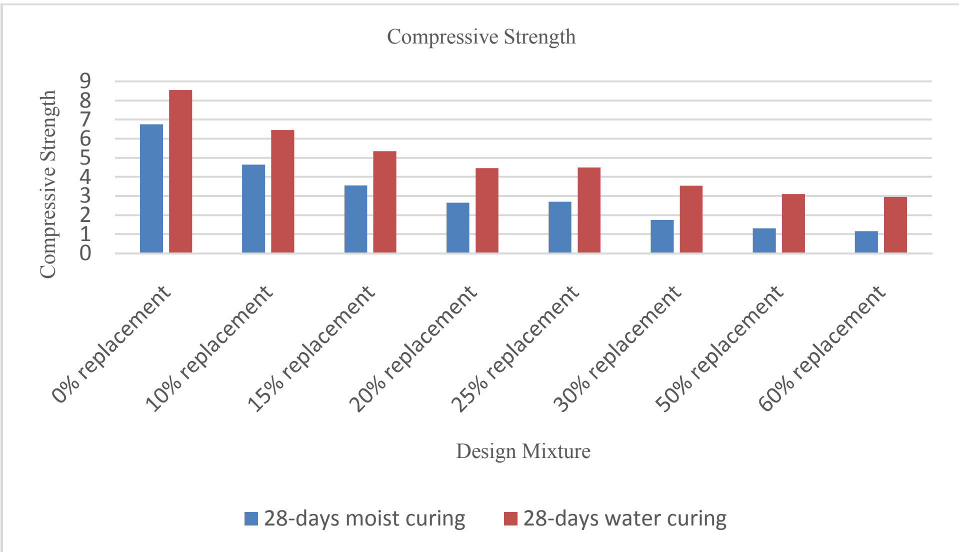

Figure 1. Comparison of Compressive Strength on Curing Method

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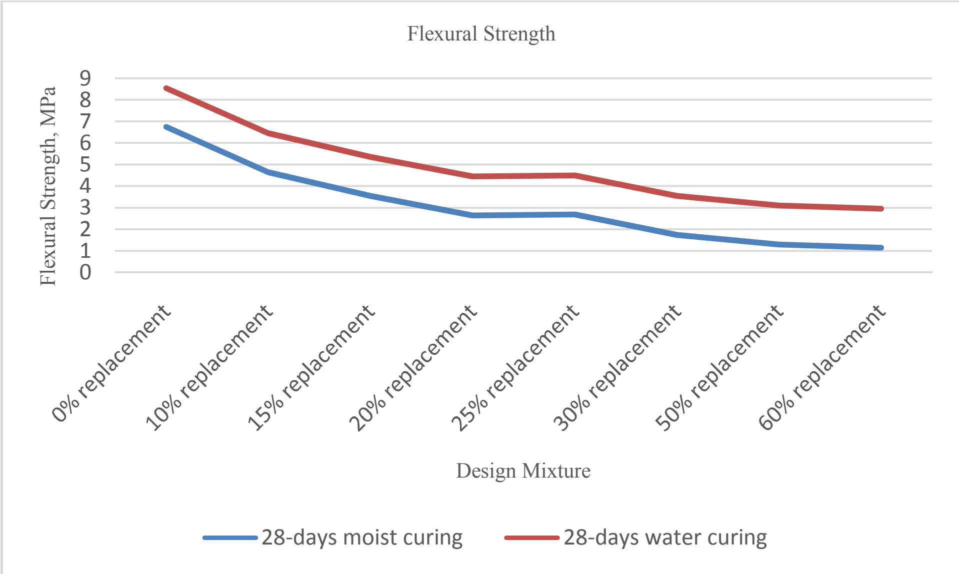

Figure 2. Comparison of Flexural Strength on Curing Method

Figure 1 and Figure 2 present a comparative analysis of compressive strength and flexural strength under both moist curing and water curing methods. The observation reveals a marginal increase in both flexural and compressive strength when employing the water curing approach in comparison to moist curing.

Shown in Table 7 the minimum compressive strength of mortar with the minimum curing periods. This minimum requirement serves as the basis if the resulting compressive strength based on % replacement of pulverized glass can be accepted for partial replacement for fine aggregates.

TABLE7: PHYSICALPROPERTIESOFMORTARCEMENTS(ASTMC 1329)

Mortar cement type	**Compressive Strength minimum Mpa(Psi)**	
Exterior, ator below grade	7 Days	14Days
	9.0 (1300)	12.4 (1800)

IV. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

- It was observed that pulverized glass can be use as replacement to fine aggregates for the mortar mixture.
- It was also observed that the maximum allowable percent replacement of pulverized glass based only on the design mixture is 25% which passes to the required minimum compressive strength of cement mortar based on ASTM standards.
- The design mix can be recommended to be used for mortar for block laying and brick making.

4.2 Recommendations

- For the future development and betterment of this study, the researcher recommends the following:
- To incorporate other replacement materials such as rubber cubes as partial replacement for coarse aggregates and other material for fine aggregates replacement such as fiber glass and steel wires.
- To explore the inclusion of additional chemical additives within the mixture to assess their impact on concrete strength while incorporating partial replacements of the aggregates.

V. ACKNOWLEDGMENT

The author expresses his gratitude to the author's family for their continuous support during the research process.

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