*IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*
*e-ISSN: 2278-1684, p-ISSN: 2320-334X, Volume 21, Issue 6 Ser. 2 (Nov. – Dec. 2024), PP 01-05*
*www.iosrjournals.org*

# Experimental Investigation Of Lightweight Concrete Using Coconut Shells And Crushed Glass As Partial Aggregates

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***Abstract:***
*The growing demand for natural aggregates in concrete production has led to concerns regarding the environmental impact and depletion of resources. This research investigates the mechanical properties of concrete modified with coconut shells and crushed glass as partial substitutes for conventional aggregates, aiming to promote sustainable construction practices. Various replacement levels (0%, 6%, 12%, 18%, 24%, and 30% by weight) were tested in M30 concrete mixes using Ordinary Portland Cement (OPC) and natural aggregates. The findings reveal significant alterations in concrete properties due to these substitutions. While coconut shells led to a modest reduction in early strength and workability-with a maximum impact value increase to 32.53%—they provided adequate strength for applications with lower surface wear, peaking at a crushing value of 40.03%. Conversely, crushed glass demonstrated superior mechanical performance, achieving an impact value of 35.16% and contributing positively to both early compressive strength (25.11 N/mm²) and long-term strength (37.73 N/mm²). Additionally, the inclusion of glass resulted in better abrasion resistance, with maximum values reaching 42.53%, compared to 41.20% for coconut shells.*

***Keyword:*** *Coconut shell, Crushed Glass, lightweight concrete, Compressive strength, Non-destructive Test.*

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Date of Submission: 18-11-2024 Date of Acceptance: 28-11-2024

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## I. Introduction

Concrete has long been a cornerstone of construction due to its strength, durability, and versatility. As urbanization accelerates, the demand for concrete in infrastructure projects continues to rise. A promising approach to meet this demand sustainably is the use of waste materials—both biodegradable (e.g. coconut shells) and non-biodegradable (e.g. crushed glass)—as partial substitutes for conventional aggregates. Recent research highlights the potential of these waste-based aggregates to enhance concrete's mechanical properties and durability, providing an eco-friendlier solution for concrete production.

One study explored the use of synthetic lightweight aggregates made from plastic waste, reducing concrete's density and improving its insulation, making it ideal for lightweight construction [1]. Another study found that glass waste improved compressive strength and durability, while a third demonstrated that coconut shells lowered concrete's weight with minimal strength loss. These studies paved the way for sustainable concrete solutions, showing that waste materials can address both environmental concerns and structural needs [2][3]. One study found that soda-lime glass, a common waste product, greatly enhanced the durability and surface hardness of concrete, making it suitable for wear-prone structures [4]. Additionally, the combination of coconut shells and expanded polystyrene beads reduced concrete density while maintaining compressive strength, making it ideal for non-load-bearing applications. These results underscored the potential of glass and coconut shells in diversifying concrete applications while reducing waste disposal impact.

In 2021, research shifted toward optimizing concrete's mechanical properties using waste materials [5]. One study showed that fine glass powder enhanced both compressive and flexural strength, indicating its potential for structural applications [6]. Another study focused on coconut shell aggregates, noting improvements in tensile strength, while combining coconut shells with industrial by-products like foundry sand resulted in high-performance concrete with enhanced durability and reduced shrinkage, demonstrating the synergistic benefits of combining different waste materials [7][8]. Advances in 2022 concentrated on optimizing the proportions of waste materials for improved concrete performance. One study found that combining recycled concrete aggregate with crushed glass improved both strength and durability [9]. Another study discovered that replacing fine aggregates with glass powder boosted tensile and flexural strength, while substituting coarse aggregates with glass lowered strength. The study recommended replacing 20% of both fine and coarse aggregates with glass for optimal performance [10]. Additionally, a separate study found that replacing fine aggregates with coconut shells improved permeability and chloride resistance, making concrete more suitable for coastal environments [11]. The objective of this study is to investigate the mechanical properties, such as compressive and tensile strength, of M30-grade concrete with partial replacements of coarse aggregates by coconut shells and crushed glass.

## II. Experimental Procedure

Concrete cubes (150 mm x 150 mm x 150 mm) and cylinders (150 mm diameter x 300 mm height) were cast for a series of tests. Each mix was replicated three times to ensure statistical reliability. The specimens were cured in water for 28 days to achieve adequate strength prior to testing for NDT. The compressive strength of the concrete cubes was assessed at both 7 days using a universal testing machine. The composition of concrete incorporating the replacement materials is detailed in Table 1.

The table 1, present the mix proportions for two series of concrete mixes: M30/MCS and M30/MGP. Each series explores the effects of replacing a portion of coarse aggregate with coconut shells. The control mix, labeled **M30**, contains 100% cement, aggregate, and sand with no coconut shell replacement. In both series, the cement and sand contents remain constant at 100%, while the aggregate content is gradually reduced as the percentage of coconut shell replacement increases.

**Table 1** Mix Formulation of concrete with Replacement materials

| Mix | Cement | Aggregate | Sand | Coconut Shell |
|---|---|---|---|---|
| M30 | 100% | 100% | 100% | 0% |
| MCS06 | 100% | 94% | 100% | 6% |
| MCS12 | 100% | 88% | 100% | 12% |
| MCS18 | 100% | 82% | 100% | 18% |
| MCS24 | 100% | 76% | 100% | 24% |
| MCS30 | 100% | 70% | 100% | 30% |
| **Mix** | **Cement** | **Aggregate** | **Sand** | **Glass Pieces** |
| M30 | 100% | 100% | 100% | 0% |
| MGP06 | 100% | 94% | 100% | 6% |
| MGP12 | 100% | 88% | 100% | 12% |
| MGP18 | 100% | 82% | 100% | 18% |
| MGP24 | 100% | 76% | 100% | 24% |
| MGP30 | 100% | 70% | 100% | 30% |

## III. Results And Discussion

Coconut shell and glass pieces have distinct impacts on the mechanical and durability properties of concrete. Coconut shell aggregates exhibit moderate impact and abrasion resistance, indicating suitability for applications with lower surface wear requirements.

**Impact value of coarse aggregates mix with coconut shell and glass pieces**

The figure 1 illustrates the impact value of coarse aggregates when mixed with coconut shell particles. It provides insights into the toughness of the aggregate mix by showing how well it can withstand sudden shocks or impacts. Higher impact values suggest greater brittleness, while lower values indicate better resilience, helping to assess the coconut shell's viability as a partial aggregate replacement. This figure 2 presents the impact value for coarse aggregates mixed with glass pieces, similar to the analysis in Figure 2 for coconut shells. The impact value here helps to evaluate the brittleness or durability of glass as a replacement material in concrete aggregates.

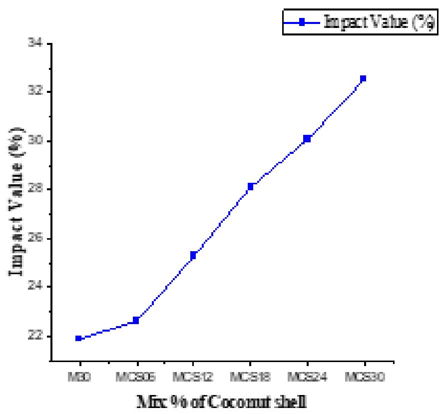


**Fig. 1**

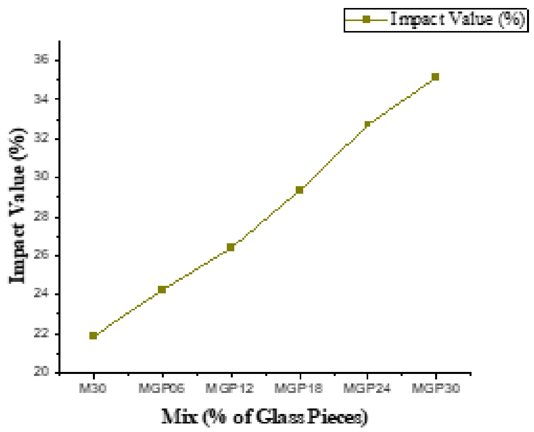


**Fig. 2**

**Abrasion value of coarse aggregates mix with coconut shell and glass pieces**

The figure 3, shows the abrasion resistance of coarse aggregates containing coconut shell. Abrasion value indicates the aggregate's ability to resist surface wear due to friction. A lower abrasion value would be preferable, as it implies higher durability for applications where surface wear could be a concern. The figure 4, shows the abrasion value for coarse aggregates with glass pieces. Abrasion testing reveals the wear resistance of the aggregate mix when exposed to surface friction. It helps determine if glass pieces could be effective in applications requiring resistance to surface wear.

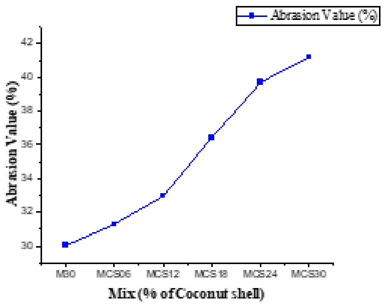


Fig. 3

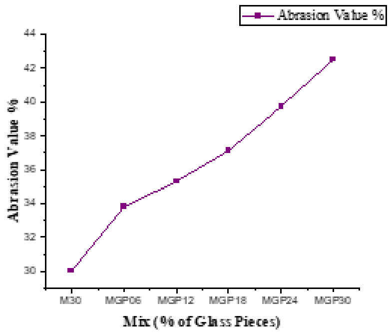


Fig. 4

**Crushing value of coarse aggregates mix with coconut shell and glass pieces**

The figure 5, displays the crushing value of coarse aggregates mixed with coconut shell. The crushing value reflects the strength of the aggregate under compression. A lower value indicates a stronger and more durable material, essential for structural applications. The figure 6, illustrates the crushing value of coarse aggregates mixed with glass pieces. It gives an understanding of the compressive strength of glass-mixed aggregates, allowing for a comparison with coconut shell-mixed aggregates.

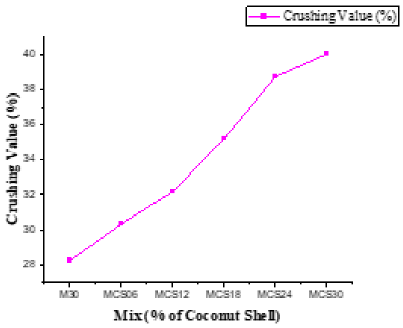


Fig. 5

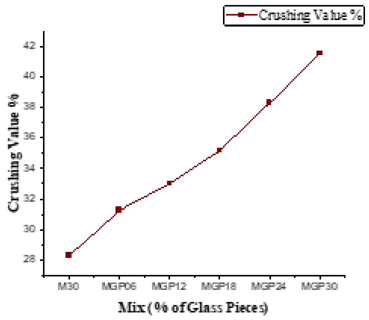


Fig. 6

**Slump test outcomes**

The figure 7, shows the slump test results for concrete samples made with different replacement materials. The slump test assesses workability and consistency, which are crucial for ease of placement and compaction of concrete. It compares the slump for concrete containing coconut shells versus glass pieces.

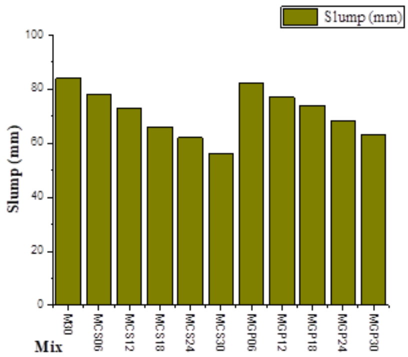


Fig. 7

**Compressive strength of concrete by using coconut shell and glass pieces as replacement material (7 days)**

The figure 8 displays the 7-day compressive strength of concrete with coconut shell as a replacement material. Early compressive strength data help evaluate the material's suitability for applications that require initial strength gain. The figure 9 displays the 7-day compressive strength of concrete using glass pieces. The results here can be compared to Figure 10 to assess the relative early strength performance of glass versus coconut shell as replacement materials.

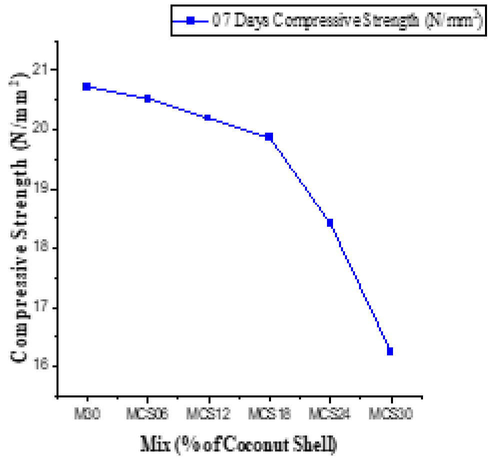


**Fig. 8**

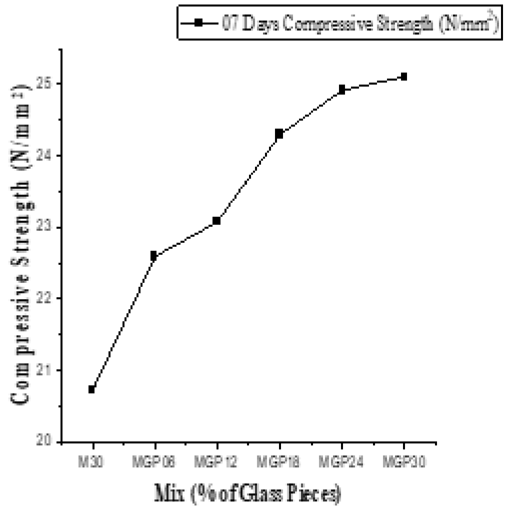


**Fig. 9**

**Rebound hammer result of concrete by using coconut shell and glass pieces as replacement material (28days)**

The figure 10, illustrates the surface hardness of concrete with coconut shell replacement, as measured by the rebound hammer test. Surface hardness data are relevant for durability considerations, especially for exposed surfaces. The figure 11, shows the rebound hammer results for concrete with glass pieces, providing comparative insights into surface hardness relative to coconut shell.

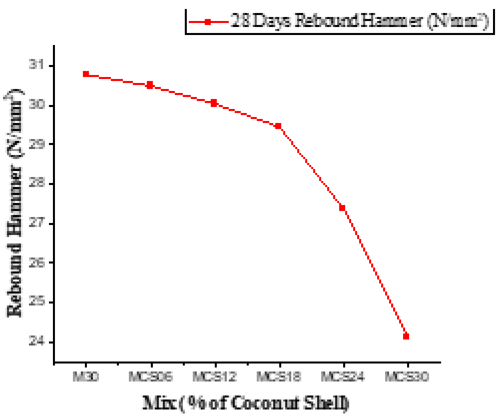


**Fig. 10**

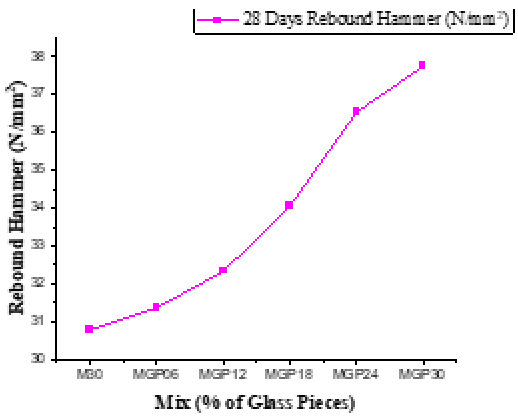


**Fig. 11**

## IV. Conclusion

This study investigates the impact of incorporating coconut shell (CS) and crushed glass (GP) into concrete mixtures, aiming to reduce environmental impact while meeting specified structural performance criteria, with a target compressive strength of 30 N/mm² after 28 days.

The followings are significant outcomes in this research:

- CS aggregates had a 48.60% increase in impact value, while GP aggregates showed a higher 60.62% increase, indicating greater brittleness.

- CS aggregates had a 37.15% increase in abrasion resistance, while GP aggregates had a higher 41.57% increase, showing reduced wear resistance due to lower toughness.
- CS aggregates had a 41.64% increase in crushing value, while GP aggregates had a higher 47.09% increase, suggesting glass's greater impact on compressive strength.
- Workability decreased more with 30% CS (33.33% decrease in slump) compared to 30% GP (25% decrease), due to CS's lower density and irregular shape.
- At 7 days, CS reduced compressive strength by 21.62%, while GP increased it by 21.18%, highlighting glass's superior early-strength contribution.
- Non-destructive testing confirmed the findings, with CS reducing compressive strength and GP increasing it, further supporting glass's superior strength.

In conclusion, coconut shell reduces compressive strength and workability, while glass improves early and long-term strength, especially in compressive and tensile properties. Both materials reduce abrasion and crushing resistance, with glass causing a more significant decrease. Glass is better suited for applications requiring high strength and durability, while coconut shell is more appropriate for non-structural uses where workability is prioritized.

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