



Partial Replacement Of Cement With Nano-Silica And Coarse Aggregate With Coconut Shell

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Abstract: The increased need for sustainable construction materials has spurred the demand for new alternatives to conventional concrete ingredients. This study ventures into the partial replacement of cement by nano-silica and coarse aggregate by coconut shell to develop an eco-friendly, cost-efficient concrete mix. Nano-silica, being highly pozzolanic in nature and having a very fine particle size, increases the mechanical strength and sustainability of concrete. Coconut shells, which are agricultural by-product, can serve as a lightweight, eco-friendly, and alternative to coarse aggregates. The purpose of this project is to investigate the workability, compressive strength, and durability properties of nano-silica (e.g., 2%) and coconut shell (e.g., 10%) in concrete. The present research works on the properties of concrete as a green concrete alternative using nano-silica in an eco-friendly aggregate system. In India, coconut shell deposition is around 80,000 tonnes' annually, which is 6.7% of total agricultural waste. Gravel manufacturing requires crushing, which emits CO₂, which is an issue for the environment. Meanwhile, to minimize waste dumping coconut shell can be used effectively as coarse aggregate in lightweight concrete. The conventional concrete was fully replaced by Coconut shell coarse aggregate and crushed gravel sand (M sand) as fine aggregate in plain Portland cement. Nano-silica in concrete improve the strength properties of concrete. Additionally, it is an attempt made to develop the concrete by replacing partial cement with Nano sized particles, which meets the various structural properties of concrete like compressive strength and tensile strength. It is expected that the final outcome of the project will positively contribute overall to the application of Nano-silica concrete in civil engineering construction work.

KEYWORDS: Nano-silica; Coconut shell; Compressive strength; Impact; Strength; Toughness; Admixture; Workability.

I. INTRODUCTION

Concrete is the most common construction material used globally because it is very strong, hard, and versatile. Yet, manufacturing cement one of the main components of concrete is one of the largest carbon dioxide emitters and contributes about 8% of global emissions. Likewise, excessive reliance on natural aggregates is resulting in natural resource depletion and environmental degradation. In order to mitigate such problems, researchers and engineers are exploring the utilization of substitute materials that can be utilized for partial or complete replacement of conventional concrete ingredients without compromising performance.

This study investigates partial substitution of cement with nano-silica and coarse aggregate with coconut shell. Nano-silica, with its very small particle size and high surface area, improves the microstructure of concrete and hence the strength and durability of the concrete. Coconut shell, a readily available agricultural

waste material, provides a light, environmentally friendly substitute for normal coarse aggregates. Employing such materials not only conserves waste and resources but also fosters the culture of environmental-friendly construction.

The purpose of this research is to study the physical and mechanical characteristics of concrete when cement is partially replaced by nano-silica and coarse aggregate by coconut shell. The study is looking for optimum percentages of replacement that ensure good performance while advocating for sustainability in construction activities.

Coconut shell coarse aggregate changes some properties of the concrete mix and concrete. Due to the roughness of aggregate grain surfaces, the mobility of the concrete mix is decreased but adhesion of the aggregate to the cement–sand matrix increases. Studies on thermophysical properties of concrete with coarse coconut aggregate indicate that increasing the percentage of aggregate from 0% to 40% in concrete leads to the reduction of thermal conductivity by three times. It needs to be noted that the use of coconut shell aggregate should not reduce the strength properties of concrete.

OBJECTIVE

1. To explore the feasibility of nano-silica as a replacement of partial cement and coconut shell as a partial replacement of normal coarse aggregate in concrete.
2. To design and test different concrete mix designs by varying the percentage of replacement of nano-silica 2% and coconut shell 10% to identify the optimal combination.
3. To test the fresh properties of concrete, such as workability and slump value, for different levels of replacement.
4. To test the hardened properties of concrete, such as compressive strength, split tensile strength, at 7, 14 days of curing.
5. To find the comparison of mechanical behavior of the modified concrete with normal concrete to test its suitability for structural application.
6. To investigate the density and weight savings of concrete brought about by incorporating lightweight coconut shell aggregates.
7. To support sustainable development goals through promotion of the use of industrial and agricultural wastes and therefore reducing the cost of construction as well as reducing environmental impact.
8. To encourage new material research in civil engineering through envisioning the applicability of nanomaterials and waste organic.

II. COCONUT SHELL AS COARSE AGGREGATE

The replacement of coarse aggregates in concrete with coconut shells is an innovative and eco-friendly method. Coconut shells are robust and have low weight, providing various benefits including lower costs, efficient waste disposal, and the ability to create lightweight concrete. The replacement ratio is usually between 5% and 20%, ranging from 10% to 15% for optimal durability and cost advantage. Nonetheless, coconut shell concrete can have lower workability and compressive strength compared to normal mixes and is thus well suited for non-load-bearing applications like partition walls, paving blocks, light roofs, and precast components.



Fig 1: Coconut Shell

IV. NANO SILICA AS FINE AGGREGATE

Nano-silica behaves as a reactive pozzolanic material if used as a partial cement replacement. In the current work, 2% of cement is substituted with nano-silica for improving the concrete properties. Due to its extremely fine particle size and high surface area, nano-silica enhances the hydration reaction, and hence extra calcium silicate hydrate (C-S-H) gel is produced. This enhances the production of higher early strength, reduced porosity, and a more dense concrete matrix, which leads to more durable and crack-resistant concrete.



Fig 2: Nano Silica

V. RESULTS AND DISCUSSION

Testing of Concrete

In order to evaluate the performance of concrete with partial replacement of cement by nano-silica and coarse aggregate by coconut shell, the following tests were conducted.

I. Workability Test (Slump Cone Test):

This test was conducted to determine the workability of fresh concrete. A slump cone of standard dimensions was used. Fresh concrete was filled in three layers and each layer was tamped with 25 strokes. The slump was measured immediately after lifting the cone.

Mix Name	% of Replacement	Trial no	Slump Cone Value (mm)	Average Slump Cone Test (mm)
M20	0	1	79	79
		2	78	
		3	79	
M20	10%CS+2%NC	1	81	87.66
		2	89	
		3	93	

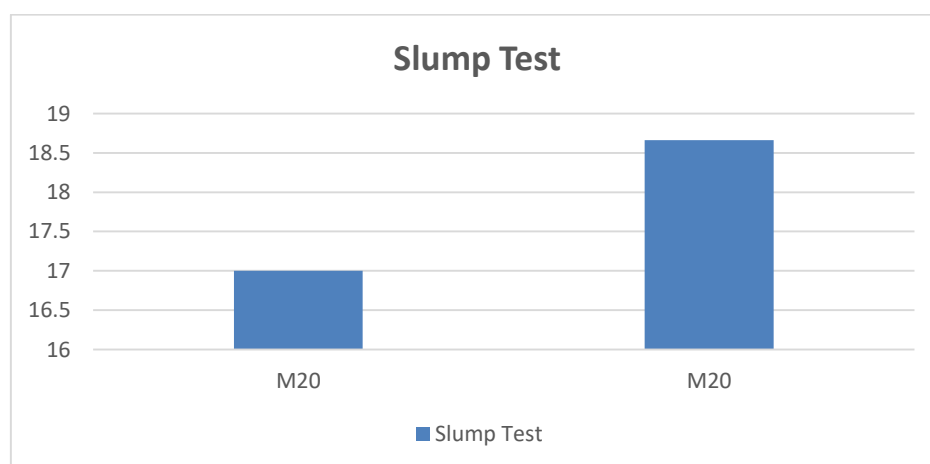


Fig 3. Tensile Strength test for 14 days

II. Compressive Strength Test:

Concrete cubes of 150 mm × 150 mm × 150 mm were cast and cured for 14 days. After curing, the specimens were tested using a Compression Testing Machine (CTM). The cubes with nano-silica and coconut shell showed adequate compressive strength, confirming suitability for M20 grade.

Compressive Strength(N/mm^2) – Load(P)/Cross Sectional Area(A)



Fig 4: Compressive Test

Result:

For 7 days,

Mix Name	% of replacement	Trial no	Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
M20	0	1	390	17.33	17.55
		2	395	17.55	
		3	400	17.77	
M20	10%CS+2%NC	1	430	19.11	19.33
		2	435	19.33	
		3	440	19.55	

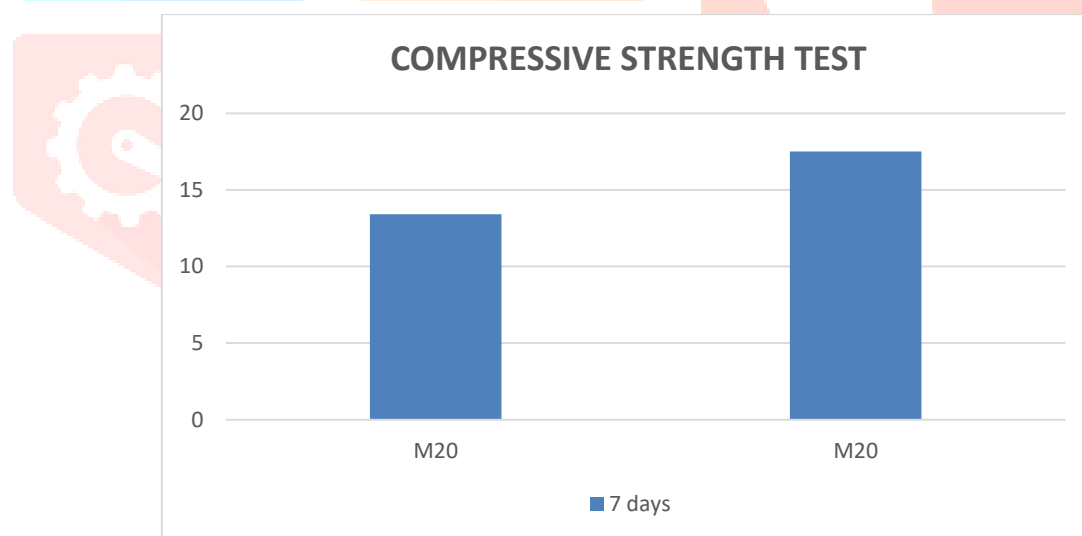


Fig 5. Compressive Strength test for 7 days

For 14 days,

Mix Name	% of replacement	Trial no	Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
M20	0	1	475	21.11	21.33
		2	480	21.33	
		3	485	21.55	
M20	10%CS+2%NC	1	520	23.11	23.33
		2	525	23.33	
		3	530	23.55	

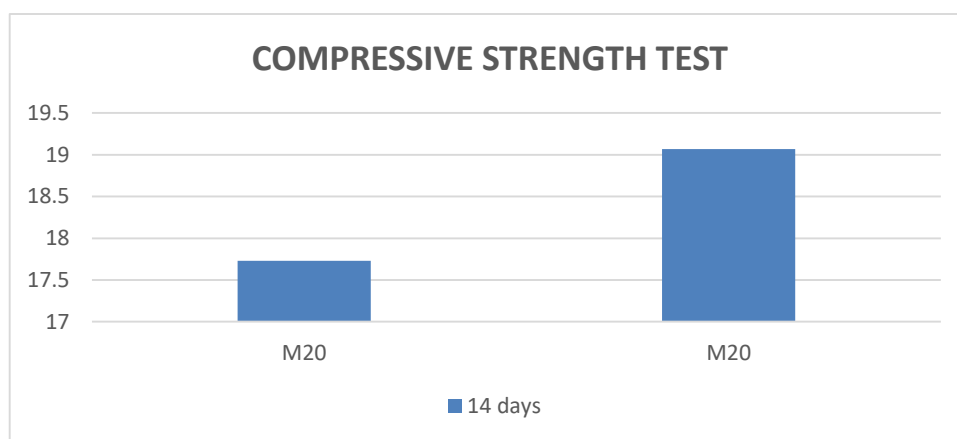


Fig 6.Compressive Strength Test for 14 days

III. Tensile Strength Test:

The test specimen was placed in the centering jig with packing strip and/or loading pieces carefully positioned along diametrically vertical planes at the top and bottom of the specimen. The maximum diametrical load applied was recorded. The measured splitting tensile strength(T) of the specimen was calculated using the following formula

$$T = 2P / (\pi DL)$$

Result

For 7 days,

Mix Name	% of replacement	Trial no	Load (KN)	Tensile Strength (N/mm ²)	Average Tensile Strength (N/mm ²)
M20	0	1	210	1.47	1.50
		2	215	1.50	
		3	220	1.53	
M20	10%CS+2%NC	1	250	1.75	1.78
		2	255	1.78	
		3	260	1.82	

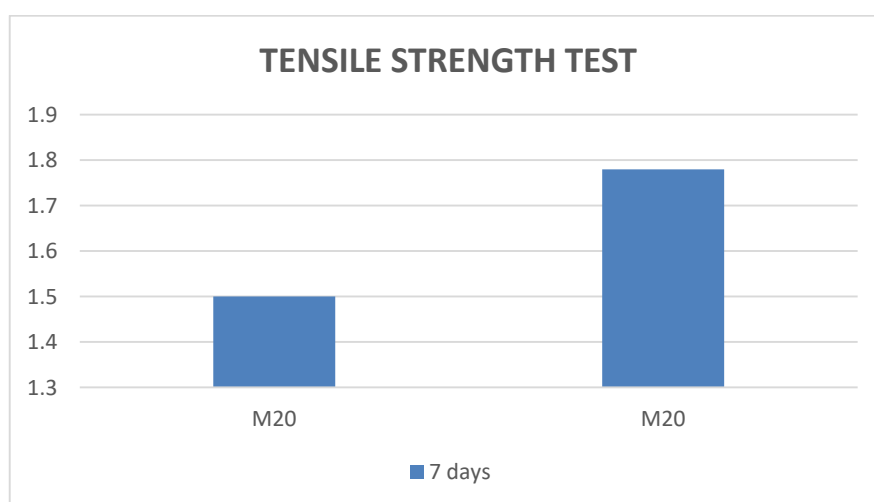


Fig 7.Tensile Strength Test for 7 days

For 14 days,

Mix Name	% of replacement	Trial no	Load (kN)	Tensile Strength (N/mm ²)	Average Tensile Strength (N/mm ²)
M20	0	1	270	1.89	1.92
		2	275	1.92	
		3	280	1.95	
M20	10%CS+2%NC	1	310	2.16	2.20
		2	315	2.20	
		3	320	2.23	

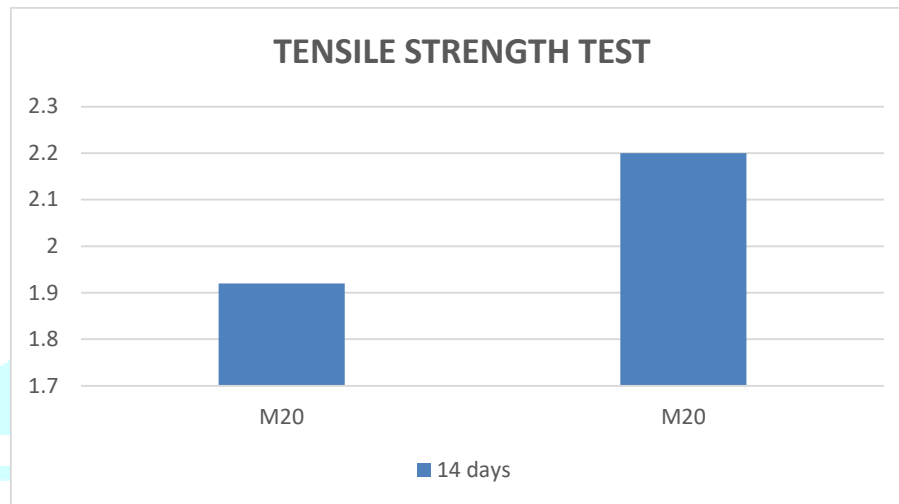


Fig 8. Tensile Strength Test for 14 days

III. CONCLUSION

This study opens up several promising directions for future research and development. Further investigations can focus on increasing the replacement levels of nano-silica beyond 2% and coconut shell beyond 10% to determine the optimal mix for maximum performance without compromising strength and durability. Long-term durability studies, such as resistance to chemical attacks, freeze-thaw cycles, and chloride penetration, are necessary to understand the behavior of this modified concrete in aggressive environments. The application of this concrete in structural elements can also be explored, especially in lightweight and low-cost construction. Additionally, combining nano-silica and coconut shell concrete with chemical admixtures like superplasticizers may enhance workability and strength, making the mix more versatile for practical use.

Moreover, detailed environmental impact assessments and life-cycle analyses can provide insights into the sustainability benefits of using industrial waste materials like nano-silica and agricultural waste like coconut shells. Economic feasibility studies can help evaluate the cost-effectiveness of this replacement approach at a commercial level. The material can also be tested for use in precast elements such as blocks, pavers, and panels, where lightweight and durable properties are desirable. Field trials and large-scale applications would further validate its performance, while tests under various climatic conditions can ensure its adaptability. Finally, studies on bond strength with reinforcement can help assess its suitability for structural applications, especially in reinforced concrete structures.

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