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Climate Change and the Push for Sustainable Practices Impact Analysis on Environment, Agriculture, Health, and Society with a Case Study on Recycled Aggregate-Coconut Shell in Concrete

Pravin Ankushrao Nikam[1], Dr. Arun Kumar Dwivedi[2], Dr. S. P. Ahirrao[3]

[1]Assistant professor, Department of Civil Engineering, SND College of Engineering & Research Centre, Yeola, Maharashtra, India.
[2]Professor, Department of Civil Engineering, Sandip University, Nasik, Maharashtra, India.
[3]Professor, Department of Civil Engineering, K.B.S'S College of Engineering & Technology, Jalgaon (M.S.),Maharashtra, India.
Email: pravin.nikam@sndcoe.ac.in

This research examines the multifaceted effects of climate change on the environment, agriculture, management, health, and society while emphasizing the critical need for sustainable practices. With rising global temperatures, shifting precipitation patterns, and extreme weather events, industries must adopt eco-friendly solutions to mitigate environmental impacts. One such approach is utilizing agricultural waste, like coconut shell, as a substitute for traditional materials in construction, reducing the environmental footprint and aiding waste management. The findings demonstrate how recycling agricultural by-products can reduce resource extraction pressures and foster sustainable growth across sectors.

Keywords: Aggregate, Concrete, Economy, Environment, Management, Recycle, Trash, Waste.

1. Introduction

Climate change is widely recognized as one of the most critical challenges of the 21st century, with far-reaching consequences for both natural and human systems. Rising global temperatures, increased atmospheric carbon dioxide levels, and a notable shift in climate patterns are leading to severe environmental, social, and economic disruptions. Scientists and policymakers warn that without urgent intervention, climate change could intensify, putting ecosystems, food security, health, and economic stability at risk. To address these concerns, there is a growing focus on sustainable practices across multiple sectors, from agriculture to construction, as key measures to mitigate environmental impact and promote resilience.

The environmental impacts of climate change are extensive, affecting ecosystems, biodiversity, and resource availability. Rapidly changing weather patterns disrupt natural ecosystems, causing biodiversity loss and threatening species that cannot adapt to these new conditions. These environmental shifts have a domino effect, affecting agricultural productivity, water availability, and soil health, further endangering food security. As the world grapples with these interconnected crises, it becomes evident that sustainable practices must be adopted at every level to slow the progress of climate change and preserve essential ecosystems.

One industry that stands out for its environmental footprint is construction, which relies heavily on natural resources and contributes to greenhouse gas emissions. The construction sector is a major consumer of non-renewable resources such as sand, gravel, and crushed stone, which are essential for creating concrete and other building materials. Traditional methods of extracting and processing these materials lead to environmental degradation, including habitat destruction, soil erosion, and water pollution. Furthermore, the high energy demands of these processes contribute to carbon emissions, exacerbating climate change. Given these concerns, researchers and industry leaders are increasingly looking for sustainable alternatives to reduce the sector’s environmental impact.

A promising area of research focuses on the use of agricultural by-products, like coconut shells, as a substitute for conventional aggregates in concrete. Coconut shell aggregate offers a sustainable alternative that not only reduces the need for mined resources but also provides a solution for managing agricultural waste. Coconut shells, typically discarded as waste, are abundant in tropical regions and present an eco-friendly solution for the construction industry. Studies indicate that using coconut shell as a coarse aggregate in concrete can produce a durable, lightweight material with comparable strength properties for specific applications. This approach also provides additional economic benefits, as farmers can sell what was once considered waste, adding value to their agricultural activities.

Integrating coconut shell aggregate in concrete aligns with the principles of the circular economy, which emphasizes reducing waste and making the most of existing resources. By recycling coconut shells, the construction industry can minimize its environmental footprint while also supporting waste reduction initiatives. This practice addresses two major issues: the scarcity of natural aggregates and the growing need for sustainable waste management solutions. The results of experimental investigations have shown that concrete containing coconut shell aggregate exhibits enhanced workability, impact resistance, and durability for low-load applications. The introduction of sustainable materials like coconut shell aggregate can reshape construction practices, making them more compatible with global sustainability goals and climate action targets.

In addition to its environmental benefits, coconut shell concrete also holds promise for economic and social sustainability. The practice of recycling agricultural waste into building materials can create new economic opportunities for rural communities, especially in tropical countries where coconuts are widely cultivated. By transforming coconut shells from waste into a valuable construction material, the industry can reduce production costs and provide an additional income stream for farmers. This innovative approach can also contribute to social equity by making affordable, eco-friendly housing options more accessible in resource-limited areas. Through case studies and experimental evidence, this paper highlights how agricultural by-products can contribute to a more sustainable and socially responsible construction industry.

As climate change continues to intensify, industries worldwide must adopt sustainable practices to mitigate environmental degradation. The construction sector, in particular, has the potential to lead in this transformation by utilizing alternative materials and reducing its dependence on finite natural resources. The study presented here examines the application of coconut shell aggregate as an environmentally and economically viable solution, encouraging a shift towards sustainable building materials. By leveraging coconut shell aggregate in concrete, the construction industry can contribute to global efforts to reduce carbon emissions, conserve natural resources, and address the challenges of climate change. This case study exemplifies how sustainable practices not only reduce environmental impact but also promote resilience and adaptation in the face of a changing climate.

Also the construction industry is facing increasing challenges due to the depletion of natural resources and environmental concerns associated with the extraction and use of traditional aggregates. In response to these issues, there is a growing interest in exploring sustainable alternatives such as coconut shell as a replacement for conventional aggregates in concrete.

Figure 1 Various Impact of climate Change

According to a study [1], coconut shell can be used as an alternative to coarse aggregate in concrete, producing lightweight concrete. The use of coconut shell as a substitute for aggregate is cost-effective and eco-friendly, and can help to resolve the problem of shortage of conventional material such as coarse aggregate. Coconut shell exhibits more resistance against crushing, impact and abrasion, compared to crushed granite aggregate. The study focuses on four different replacement levels, namely 0%, 10%, 15%, and 20% by weight of conventional coarse aggregate. A series of experiments including compressive strength, flexural strength, and durability tests are conducted to evaluate the mechanical and physical properties of the resulting concrete.

The examination of sustainable substitutes such as paper/fibre, waste plastic, post-consumer glass, and concrete debris is becoming more popular [2], [3]. The circular economy also applies to ashcrete, which uses coal ash to produce a sustainable aggregate for concrete[4]. Experimental investigation was to examine the characteristics of concrete built with coconut shell as a partial replacement for traditional coarse aggregates. In order to compare the attributes of concrete mixes containing various amounts of coconut shell to those of control concrete, or concrete that contains no coconut shell, the goal of the investigation was to determine the mixes' density and compressive strength. [5].

Figure 2 Coconut shell supply[5].

Effects of Climate Change on the Environment

Climate change significantly impacts the environment, causing biodiversity loss and ecosystem degradation. Rising temperatures, altered precipitation patterns, and extreme weather events disrupt habitats, endangering species and leading to decreased biodiversity. Many ecosystems, including coral reefs and forests, suffer from this stress, weakening their resilience and ecological functions. Additionally, water resources face increasing strain as higher evaporation rates, shifting rainfall, and droughts reduce freshwater availability. This intensifies competition for water, affecting agriculture, human health, and overall environmental sustainability.

Biodiversity Loss and Ecosystem Degradation

Climate change accelerates habitat loss, species extinction, and ecosystem degradation. Rising temperatures and unpredictable weather patterns disrupt biodiversity, affecting plant and animal survival. Species adapted to specific climates struggle to cope with rapid changes, leading to a loss of biodiversity that destabilizes ecosystems. Efforts to minimize resource extraction through sustainable practices, like using coconut shell as a substitute in concrete, contribute to preserving natural habitats by reducing quarrying and mining activities.

Water Resource Strain

Changes in rainfall patterns and prolonged droughts strain freshwater supplies, impacting ecosystems, agriculture, and human populations. With sustainable construction materials reducing the need for mined aggregates, practices like coconut shell recycling help conserve water resources by promoting eco-friendly alternatives in water-intensive industries. Such practices exemplify how industries can contribute to water conservation and climate adaptation.

Impact on Agriculture

Crop Yields and Food Security

Agriculture is highly susceptible to climate change due to its reliance on predictable weather patterns. Extreme temperatures, prolonged droughts, and unseasonal rains disrupt crop cycles, leading to reduced yields and compromised food security. Smallholder farmers in tropical and subtropical regions, already vulnerable to climate variability, face increased risk of crop failure.

Soil Degradation

Climate change exacerbates soil erosion, salinization, and nutrient depletion, diminishing soil productivity. Sustainable agricultural practices, including crop diversification, agroforestry, and recycling agricultural by-products, like coconut shells, help counteract soil degradation. For instance, coconut shells, when utilized in other sectors like construction, indirectly support sustainable agriculture by providing farmers an alternative income source while promoting waste reduction.

Management and Economic Implications

Resource Management

Climate change forces industries to rethink resource management strategies. The need to reduce dependence on finite resources has led to innovative recycling and reuse strategies across sectors. For instance, using coconut shells as a partial aggregate in concrete manufacturing reduces the reliance on mined aggregates, which are resource-intensive. In this study, coconut shell usage in concrete was tested at different replacement levels (0%, 10%, 15%, and 20%), with results showing that such sustainable replacements can enhance workability without drastically compromising structural integrity.

Economic Benefits of Sustainability

Sustainable practices can yield economic benefits by lowering material costs and reducing waste management expenses. For example, coconut shells, an agricultural waste product, are readily available and inexpensive compared to traditional aggregates. Results from the study showed that coconut shell concrete exhibited comparable workability, with increased slump values and sufficient compaction factor values, making it suitable for specific non-load-bearing applications. Embracing such practices aligns with climate resilience strategies, offering economic advantages while promoting ecological sustainability.

Health Impacts

Respiratory and Cardiovascular Illnesses

Climate change has increased the frequency and intensity of air pollution events, aggravating respiratory and cardiovascular diseases. High temperatures, combined with emissions from industrial processes, create harmful pollutants that degrade air quality. Sustainable practices, such as recycling waste materials like coconut shells, contribute to lowering industrial emissions by reducing the energy demand for material extraction and processing.

Vector-Borne Diseases

Warmer temperatures and altered rainfall patterns create favorable conditions for the spread of vector-borne diseases such as malaria and dengue. As climate zones shift, these diseases are appearing in previously unaffected regions. Mitigating climate change through sustainable practices can contribute to stabilizing temperatures and, indirectly, to controlling the spread of such diseases.

Societal Impacts

Climate-Induced Migration

Extreme weather events displace millions, leading to increased migration and associated social challenges. Coastal and agrarian communities are particularly vulnerable, as rising sea levels and failed crops force people to relocate. Adopting sustainable practices can mitigate the severity of these impacts by reducing carbon emissions and promoting resilient infrastructure, helping communities adapt to climate changes.

Social Inequality

Climate change disproportionately affects low-income communities, which often lack the resources to adapt to environmental changes. These populations are more likely to live in vulnerable areas and have limited access to healthcare and infrastructure. Sustainable construction practices, such as coconut shell concrete, can make housing more affordable and accessible by reducing construction costs and environmental burdens.

Case Study: Coconut Shell as Aggregate in Concrete

In the quest for sustainable materials, using agricultural waste like coconut shell as an aggregate in concrete offers a promising solution. This study explored the impact of replacing traditional aggregates with coconut shell in concrete at varying levels to assess workability, compressive strength, and tensile strength.

Methodology

The study followed IS standards for material testing and concrete mix design, incorporating 0%, 10%, 15%, and 20% coconut shell by weight in M20-grade concrete procedure detailed in Fig 3. Testing included slump and compaction factor tests to evaluate workability, along with compressive and split tensile strength tests at 7, 14, and 28 days.

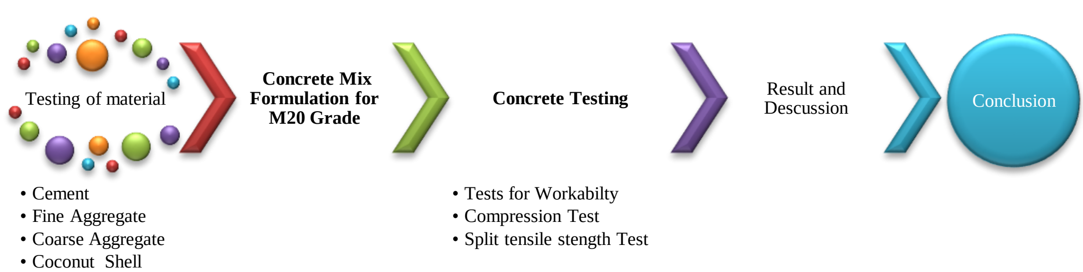


Figure 3 Methodology.

The methodology involves randomly collecting cement samples for physical tests. Fine aggregate samples are obtained and analysed for particle size distribution, specific gravity, and water absorption. Coarse aggregate samples are collected, and sieve analysis, specific gravity, and water absorption tests are conducted. Coconut shell samples are analysed for size, shape, specific gravity, and water absorption. The mix design of M20 grade concrete is determined based on target compressive strength, water-cement ratio, and proportions of materials with iterative adjustments. Concrete testing includes slump and air content tests for fresh concrete and compression and split tensile strength tests for hardened concrete. The results are discussed in terms of coconut shell's influence on concrete strength, workability, and environmental benefits. The study concludes that coconut shell can be a feasible partial replacement for coarse aggregate in M20 grade concrete with potential sustainability and cost-effectiveness benefits.

Experimental investigation

The current investigation was conducted using concrete of grade M20, which has a typical strength of 20 MPa. As required by Indian regulations, the mix design was carried out[11], [12]. A complete set of 72 cubes of concrete were studied in this experiment. To ascertain the characteristics of the substances, tests were conducted in accordance with Indian Standards. Two stages of the investigation were completed. In the first part, the mix design for M20 grade control concrete that is, concrete without coconut shell was done at the maximum weight-to-cement ratio of 0.55. Subsequently, the w/c ratio and the quantity of the remaining components were maintained, and the CA was replaced with the CS in the following volumetric ratios: (i) 0%, (ii), 10%, (iii), and (20%), respectively. At 7 and 28 days, tests for compression strength and split tensile strength were conducted.

Material Used

In the present study, common Portland cement, potable water, natural sand, and crushed coarse aggregates were utilised. The traditional crushed coarse aggregate was partially replaced with waste coconut shell. More information on the materials used is given in the section below.

Cement

In this investigation, ordinary Portland cement of grade 53 was employed. Cement tests were conducted in compliance with IS Code standards. [13] , and the results are shown in the Table 4.1.

Table 1 Cement Testing Results..

Sr. No.	Details of Testing		Test Outcomes	Standards Criteria As per [13]
1	Standard Consistency Test (%)		33	
2	Setting Time Test			
	a)	Initial setting Time Test	54	30 Minimum
	b)	Final setting Time Test	268	600 Maximum
3	Soundness Test (mm)			
	Le-Chatelier expansion T		1.5	10 (Max)
4	Compressive Strength (Mpa)			
	a)	72±1h (3 days)	31.2	≥ 27
	b)	168 ±1h (7 days)	41.8	≥ 37
	c)	672 ±1h (28 days)	53.8	≥ 53
5	Fineness Test			
	a)	By sieve of 90 µ (%)	6	10 (Max)

Fine Aggregate (FA)

In this investigation, sand from nature that conformed to Zone I was used as fine aggregate. It was put through a number of tests to ensure compliance with the guidelines. [14], [15] to determine its characteristics. Table 2 displays the fine particle sieve analysis. And Table 4 shows the test results regarding its characteristics Finely Crushed Aggregates.

Table 2 Sand Fine Aggregate Analysis via Sieve.

IS sieve size	Cumulative percentage retained	Cumulative Percentage passing	Recommendation of IS 383:1970 [14] for Zone1
10 mm	-	100	100
4.75 mm	1.1	94.49	90-100
2.36 mm	20.1	74.59	60-95
1.18 mm	52.9	44.1	30-70
600µ	96.5	31.5	15-34
300µ	99.3	0.7	5-20
150µ	100	00	0-10

Coarse aggregates (CA)

As per Granular materials with particles no larger than 20 millimetres, such as gravel or crushed stone, are referred to as “coarse aggregate.” These aggregates are frequently used in the manufacturing process to improve the structural strength and other qualities of concrete. The precise size of 20mm is selected based on the planned application and engineering specifications of the concrete mix. This size of coarse aggregate can improve the workability, durability, and overall performance of concrete in a variety of construction applications. Crushing strength and impact strength of Coarse aggregate are shown in Table 3.

Table 3 Coarse Aggregates Characteristics

Description Specific	Test Results	Recommendation of IS 2386 Part IV [16] and IS 383 [14]
Crushing Value	14.380	Not more than 30%
Impact Value	13.280	Not more than 30%
Abrasion Value (Los Angeles)	15.521	Not more than 30%

Throw trash coconut shells (Cs)

Throw trash the coconut shells (CS) shown in Figure 4 is an abundant by product generated from various coconut-related industries such as coconut processing and coconut-based product manufacturing. Instead of being discarded or incinerated, waste coconut shells can be repurposed and used for various applications, making them a valuable resource in the context of sustainability and waste management. Recycling and utilizing CS can contribute to environmental preservation and reduce the burden on landfill sites. Characteristics of coconut shell are shown in Table 4.4. As we seen that the water absorption is high in untreated coconut shell so we treat the coconut shell with epoxy polymer we observed that the water absorption of coconut shell is specifically reduced shown in Figure 4.2.

Figure 4 Waste Coconut shells.
Before Tretment

Smooth Inside

Rough Exterior Surface

After Treatment

Smooth Shiny Inside

Shiny
Rough

Figure 5 processed coconut shell

Table 4 Aggregates' Characteristics

Description Specific	CA	Sand	Shelled coconut (CS)	Processed Shelled coconut (CS)
Specific gravity	2.68	2.65	1.53	1.53
Water absorption (%)	0.4	1.01	24	4.52
Bulk density (loose) in kg/l	1.429	1.426	0.732	0.732

Bulk density (rodded) in kg/litre	1.532	1.552	0.793	0.793
Surface texture	Rough	Rough	Rough exterior surface with a smooth inside	Smooth shiny inside and shiny rough exterior
Shape	Angular	Angular	Flaky	Flaky

The Mix of Concrete Design for M20 Grade

According to Indian requirements IS 10262:2009 [11], For the control mix, which was devoid of coconut shell, the M20 mix design was used. The target slump value for the concrete mix was 60 mm. Waste coconut shell (CS) was substituted for traditional crushed coarse aggregate (CA) in coconut shell concrete at varying volume percentages: 0%, 10%, 15%, and 20%. The intention was to monitor how these replacements affected the concrete's compressive strength and Split tensile strength.

Table 5 Quantities of ingredients per m^3 of concrete.

Ingredients	% of CS in the total volume of coarse aggregate			
	0	10	15	20
Water (kg)	190	190	190	190
W/C ratio	0.45	0.45	0.45	0.45
Cement (kg)	422	422	422	422
Natural sand (kg)	672	672	672	672
Standard coarse aggregate weight (kg)	1105	995	939	884
Coconut waste with shells (kg)	Nil	111	166	221

Slump cone Test

The slump cone test as per IS code 1199:1559 [12] results for concrete samples with varying replacement ratios of coarse aggregate by coconut shell are as follows: 0% replacement resulted in a slump cone value of 60 mm, 10% replacement resulted in 68 mm, 15% replacement resulted in 75 mm, and 20% replacement resulted in 86 mm. as shown in Table 3.6 which is graphically shown in Figure 3.

Table 6 Slump Cone Test Result

Sr. No.	W/C ratio	Percentage of Coconut shell replaced	Height of Mould H_1 (mm)	Height of subsided concrete H2 (mm)	Slump H1-H2 (mm)
1.	0.45	0	300	240	60
2.	0.45	10	300	232	68
3.	0.45	15	300	225	75
4.	0.45	20	300	214	86

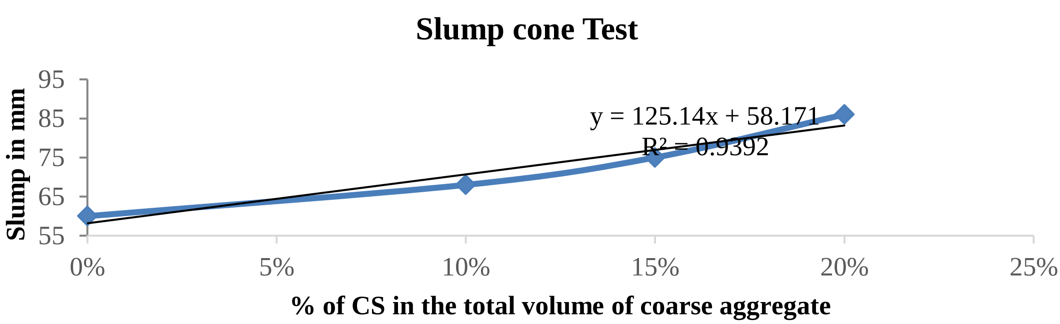


Figure 6 Slump Cone Test Results.

Compaction factor test

The Compaction Factor Test as per results IS code 1199:1559 [12] shown in Table 4.7 which is graphically shown in Figure 4.4. Reveals interesting findings regarding the replacement of coarse aggregate with coconut shell in concrete. At 15% and 20% replacements, the compaction factor values are the same at 0.79, suggesting a possible saturation point where further increases in replacement have little impact on workability. However, a slightly lower compaction factor of 0.77 at 10% replacement indicates an optimal ratio for achieving the best workability without compromising other properties. Concrete mixes with up to 20% replacement maintain relatively consistent workability, making them suitable for compaction and placement. Nonetheless, higher replacements may compromise concrete strength, necessitating a balance between workability and mechanical properties based on project needs.

Table 7 Compaction factor test.

Sr. No.	% of concrete replaced	Wt. of partially compacted concrete, W2	Wt. of fully compacted concrete, W3	Mass of partially compacted concrete, W2-W1	Mass of fully compacted concrete, W3-W1	C.F. (W2-W1) (W3-W1)
1.	0	17.48	19.85	7.26	9.63	0.75
2.	10	17.69	19.91	7.47	9.69	0.77
3.	15	17.91	19.99	7.69	9.70	0.79
4.	20	17.93	19.87	7.71	9.65	0.79

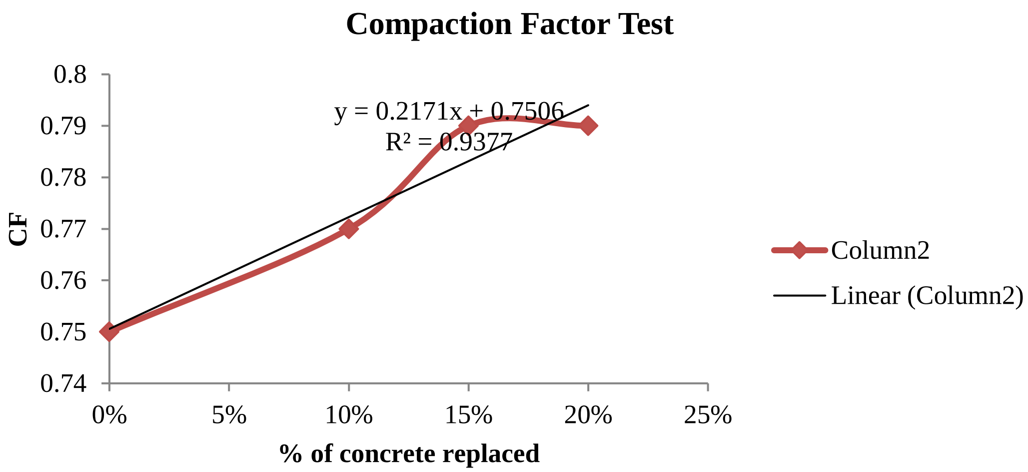


Figure 7 Compaction factor test.

Compressive strength result

The compression test was conducted according to IS 516:1959 [17].The test results are shown graphically in Figure 4.6. It was found that at 0% replacement of coconut shell by coarse aggregate, the test results were 15.35, 19.83 and 24.31 Mpa respectively on 7, 14 and 28 days of testing. At 10% replacement of coconut shell by coarse aggregate, the test results were 13.66, 18.44 and 21.69 Mpa respectively on 7, 14 and 28 days of testing. At 15% replacement of coconut shell by coarse aggregate, the test results were 10.8, 14.56 and 17.134 Mpa respectively on 7, 14 and 28 days of testing. At 2% replacement of coconut shell by coarse aggregate, the test results were 8.1, 10.94 and 12.86 Mpa respectively on 7, 14 and 28 days of testing.

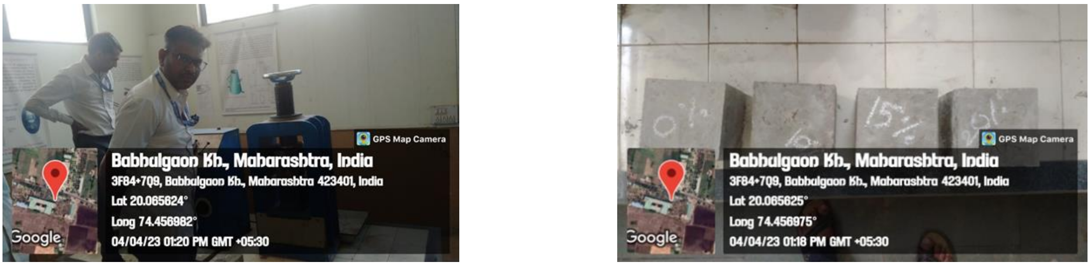
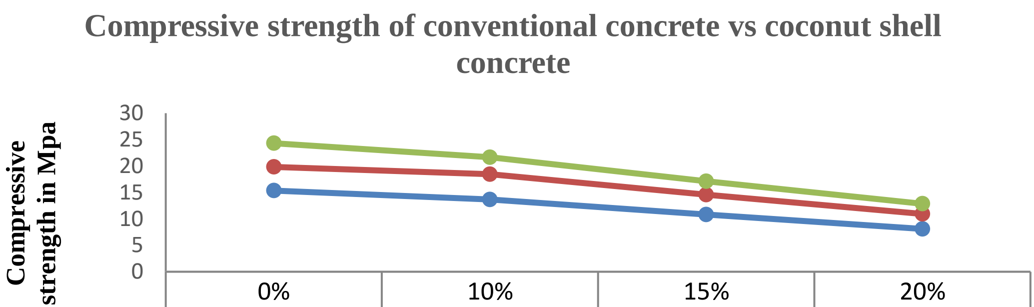


Figure 8 Testing at Snd Coe & Rc Yeola.



	0%	10%	15%	20%
7 days	15.35	13.66	10.8	8.1
14 days	19.83	18.44	14.56	10.94
28 days	24.31	21.69	17.134	12.86

Figure 9 Compressive Strength Test Results

Split Tensile Strength test.

The Split Tensile Strength test was conducted according to IS 5816-1999 [18] .The test results are shown graphically in Figure 4.7. It was found that at 0% replacement of coconut shell by coarse aggregate, the test results were 3.61, 4 and 4.94 Mpa respectively on 7, 14 and 28 days of testing. At 10% replacement of coconut shell by coarse aggregate, the test results were 2.8, 3.7 and 4.4 Mpa respectively on 7, 14 and 28 days of testing. At 15% replacement of coconut shell by coarse aggregate, the test results were 2.5, 2.9 and 3.8 Mpa respectively on 7, 14 and 28 days of testing. At 20% replacement of coconut shell by coarse aggregate, the test results were 2.3, 3 and 3.4 Mpa respectively on 7, 14 and 28 days of testing.

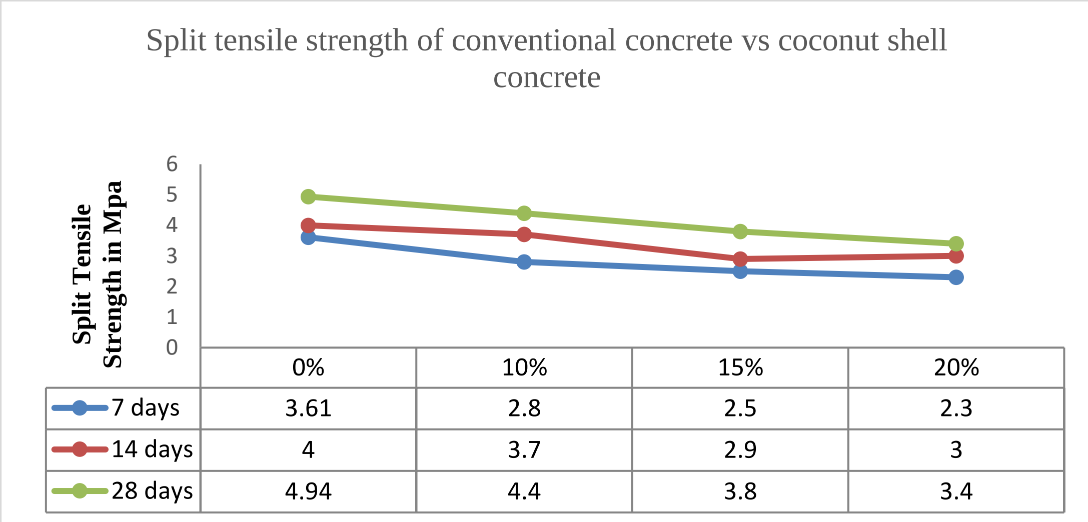


Figure 10 Split Tensile Strength test

2. Results & Discussion

Workability: Increased coconut shell content improved workability, indicated by higher slump values, with the highest replacement (20%) yielding an 86 mm slump compared to the control mix's 60 mm.

Compressive Strength: Compressive strength decreased with higher coconut shell content. At 28 days, control samples achieved 24.31 MPa, while 10%, 15%, and 20% replacements yielded 21.69 MPa, 17.13 MPa, and 12.86 MPa, respectively.

Split Tensile Strength: Similar trends were observed in tensile strength, with the control achieving 4.94 MPa at 28 days, and replacements showing reduced values, with 20% replacement resulting in 3.4 MPa.

The findings suggest that coconut shell can serve as an aggregate in applications where high strength is not critical, such as lightweight construction or non-load-bearing walls. This use of agricultural waste supports circular economy principles, reducing the environmental impact of concrete production while providing farmers with an additional income source from otherwise discarded materials.

3. Conclusions

Climate change impacts every aspect of human and natural systems, from the environment and agriculture to health and social stability. Sustainable practices, such as reusing agricultural by-products, offer viable solutions to mitigate climate effects. The case study on coconut shell aggregate in concrete demonstrates how industries can incorporate waste materials into production processes, reducing environmental impacts and promoting resilience against climate change. Future research should explore optimizing coconut shell treatment to enhance its compatibility in concrete, expanding its application in sustainable construction.

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