International Journal on Science and Technology (IJSAT)
E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

Experimental Study on Coconut Fiber Reinforced Concrete with Partial Replacement of Coarse Aggregate by Coconut Shell

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ABSTRACT

this study, the potential of using coconut shell as coarse aggregate replacement and coconut fiber as reinforcement in M 25 grade concrete with a water to cement ratio of 0.45 is examined. The goal is to create a sustainable, environmentally friendly and cost-efficient building material. Experiments were performed to investigate the compressive, split tensile and flexural strengths of the concrete after 7 and 28 days of curing. Researchers are looking on substitute materials that lessen their impact on the environment without sacrificing structural integrity as a result of the growing demand for environmentally friendly and sustainable building materials. The effects of using coconut fiber as a reinforcing agent and coconut shell as a partial substitute for coarse aggregates in concrete mix design are examined in this study. Coconut fiber, which is made from the husk of the coconut, improves the tensile strength and crack resistance of concrete, while coconut shell, an agricultural waste product, provides a lightweight and sustainable substitute for traditional aggregates.

This study investigates the performance of Mix grade concrete with respect to workability and mechanical strength for practical construction applications. The slump values obtained were within the desirable range, indicating adequate workability suitable for slab and beam casting in residential buildings. Experimental results show a positive relationship between compressive strength and both flexural and split tensile strengths, confirming overall strength enhancement with increasing compressive strength. The improved homogeneity and reduced bleeding contributed to better surface integrity and crack resistance. Based on the observed strength characteristics and workability, the developed concrete mix is found to be suitable for house construction as well as for road and pavement applications. The study demonstrates that an optimized mix design can effectively balance workability and strength requirements, ensuring reliable structural performance

Keywords: Compressive Strength, Split Tensile Strength, flexural strength, Workability, coconut shell aggregate replacement, coconut fiber Reinforced, Relationship between Compressive Strength and Flexural Strength and split tensile strength test

1. INTRODUCTION

Concrete emerges as a composite material through the combination of cement with water and particles. More concrete is utilized worldwide than any other man-made substance. Concrete stands as the second most utilized material after water in global usage. The yearly concrete production reaches 7.23 billion tons. The annual production of one ton equals the number of people living on Earth. The expansion of infrastructure development and building activities worldwide leads to increased concrete production which demands its essential ingredients of aggregates and cement and water and admixtures. The majority of concrete production depends on conventional aggregate sources. Traditional coarse aggregates such as granite used in large-scale concrete production for construction projects cause natural stone reserve depletion and environmental damage which results in ecological disturbances The extraction and processing of aggregates represent a major environmental issue.

The use of alternative waste materials in concrete production serves two purposes: environmental protection and sustainable building material development. Various waste materials including rubber, fly ash, glass, bottom ash and artificial sand have replaced natural aggregates in construction. Research indicates that coconut shell waste from agricultural activities can function as coarse aggregate in concrete production according to some studies.

Concrete stands as the leading construction material globally because it demonstrates exceptional compressive strength alongside durability and multiple application possibilities. The manufacturing process of conventional concrete depends on non-renewable natural aggregates while producing substantial carbon emissions. Scientists investigate the use of agricultural waste products and alternative materials in concrete production to solve environmental problems and enhance sustainability.

2. OBJECTIVES

- To investigate the effect of replacing coarse aggregates with coconut shell 10% (10 mm coarse aggregate) on the physical and mechanical properties of concrete.
- To analyze the influence of coconut fiber addition (e.g., 1%, 2%, 3%,4% and 5% by weight of cement) on the compressive strength split tensile strength and Flexural strength of concrete.
- To assess the workability of coconut shell and coconut fiber concrete mixes.
- To compare the performance of the modified concrete with conventional concrete to determine suitability for structural or non-structural applications
- To promote the use of agricultural waste materials in concrete, aiming to reduce environmental impact and encourage sustainable construction practices.
- To develops a concrete mix with adequate workability suitable for slab and beam casting in house construction.
- To study the relationship between compressive strength and flexural strength of concrete.
- To evaluate the relationship between compressive strength and split tensile strength.
- To assess the suitability of the concrete mix for road and pavement applications based on strength performance.
- To examine the effect of fiber addition on overall strength behavior and crack resistance.

3. REVIEW OF LITERATURE

“**Ali et al. (2013),** the addition of coir fiber improves tensile and flexural strength, particularly at low percentages (0.5%-2%). It also delays crack propagation and enhances post-cracking behavior, making the concrete more ductile and durable. The fibers are biodegradable and readily available, which adds environmental and economic value. Research combining both materials is emerging, showing that the synergistic effect of coconut shell and coir fiber can lead to a balanced concrete mix with improved ductility and reduced environmental impact. However, optimal mix proportions and long-term durability aspects still require further study.”

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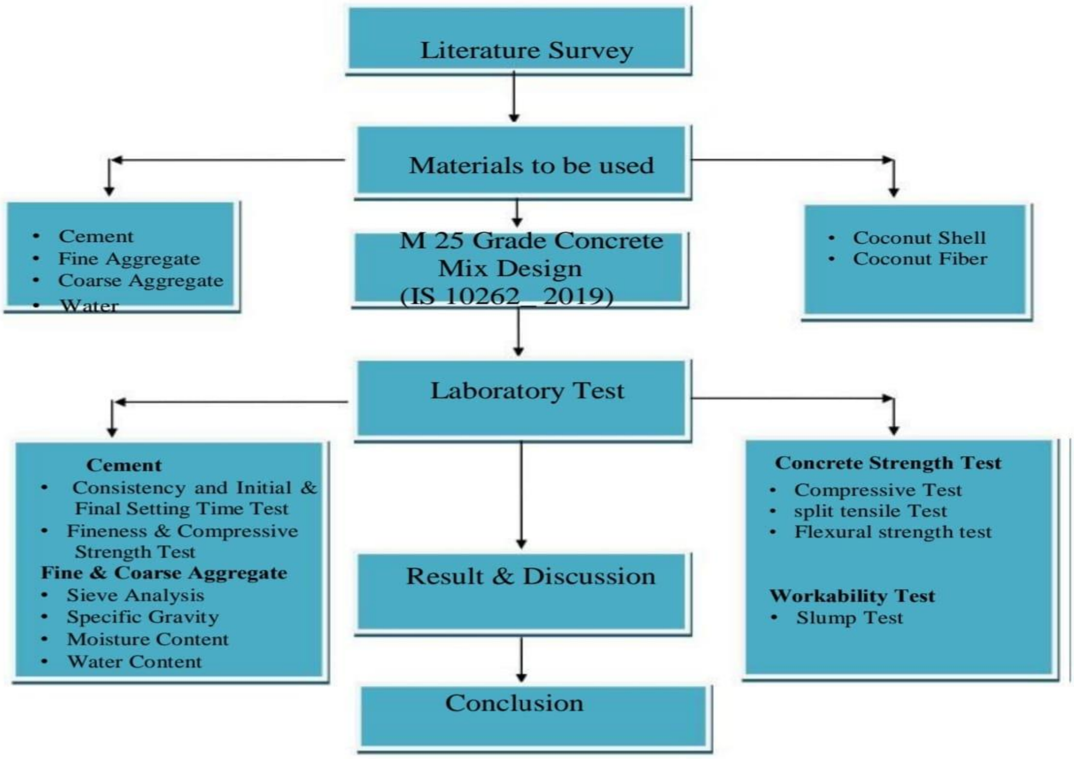
“R. Thenmozhi and Balasubramanian 2014’’The research investigates the potential of this study. The research investigates the potential of using 10% coconut shell aggregate (CSA) as a substitute for coarse aggregate in self-compacting concrete. The research investigates concrete (SCC) with 25% fly ash (FA) that uses super plasticizer and additives for its preparation. viscosity modifying agent. The SCC with normal aggregate containing FA25% is taken as (SCC), the research includes a reference section which contains 10% coconut shell aggregate substitution for coarse aggregate in the same mixture. The research investigates fresh and hardened properties of M25 SCC and SCC-CSA materials through laboratory tests. experiments. The southern region of India serves as a substitute for coarse aggregate materials which scientists use to create a specific concrete known as SCC-The paper presents a verification and discussion of FA-CSA for structural component applications. The research indicates that the technology has the potential to be used for the ago- waste known as CSA. The product immediately decreases the amount of regular natural stone which people use. The material serves two purposes because it separates aggregates while enabling the combination of CSA with large quantities of fly ash. The system operates through thermal power stations which protect our mother earth together with its environment through the design uses precious materials in a way that reduces the amount of normal aggregate required.”

“Damodaran Reddy et al (2014) The research project investigates how partial M30 grade concrete replacement affects the flexural and compressive strength properties of concrete. The research demonstrates that Coconut shell aggregate functions as an acceptable construction material while it helps decrease environmental damage from solid waste accumulation. The testing process for beams includes both their inspection and their property evaluation to determine their physical and mechanical characteristics. The primary goal exists to promote the utilization of these "seemingly" waste materials for building construction in affordable residential projects. The test results indicate that CSC with 25% coarse aggregate substitution maintains properties which match the nominal mix while CSC with 50% coarse aggregate substitution demonstrates properties that match lightweight concrete for use in framed structures and flooring tiles and thermal insulation concrete applications.”

“D.M. Perthane et al (2014) in his report he studies about the strength properties of coir. He used M20 concrete in this study. The split tensile strength and workability is taken at 7days, 14 days and 28 days. Based on the result obtain he says that the feasible and tension force become more when the coconut fibers is more. The combined concrete of 1%, 2%, 3%, 4% &5% substitution of coir at 28 days tension force shows the values as 2.68, 2.90, 3.11, 3.25, and 2.33 respectively. This proved that Coconut fibers is also applicable to be used in building construction which also act as the initiative steps for the utilization of eco-friendly"

"**C. Kaviarasi et al (2016)** studied upon the effect of coconut fiber in concrete. In this experiment he carried out to determine the compressive strength, split tensile strength and flexural strength. The coir length used here are 7 and 15 cm. The curing for concrete is done at the age of 7 and 28 days. Coconut fibers are replaced cement by 2, 4 and 6 percent. The design mix used here is M25 and water cement ratio used is 0.48. 2% of 10 to 15 cm long is casted and then 4% and 6% respectively of 10 to 15cm is also casted. From the result he concludes that coir improves the compressive strength to a certain level because coir expansion captures the miniaturized scale break present in the solids. Fibers of 25 mm long gives the greatest compressive strength and provides 0.75% expansion of coir fibers.

4. METHODOLOGY



MATERIALS USED

S.no.	Material	Description / Properties
1	**Cement**	Ordinary Portland Cement (OPC) 43 grade
2	**Fine Aggregate**	Natural river sand passing through 4.75 mm sieve, clean and well-graded.
3	**Coarse Aggregate**	Crushed angular aggregates of size 20 mm and 10 mm, conforming to IS 383.

4	**Coconut Shell (CS)**	Crushed, clean, dry coconut shells used as partial replacement of coarse aggregate. (12.5passing and 4.75 retaining)
5	**Coconut Fiber(CF)**	Brown coir fibers are thicker, stronger, and typically longer (3–10mm)
5	**Water**	Potable tap water, free from salts and impurities, used for mixing and curing.

Mix Design of M25 Grade Concrete (IS 10262-2019)

Grade of concrete	M 25
Characteristic compressive strength of concrete at 28 days	31.6 N/mm^2
Grade of cement	Ordinary Portland Cement (OPC) 43 grade
Type of exposure	Moderate
Size of coarse aggregate	20mm
Design mix target slump	75- 100 mm
Specific gravity of cement	3.15
Specific gravity of water	1.0
Specific gravity of fine aggregate	2.65
Specific gravity of coarse aggregate	2.72
Water/ cement Ratio	0.45
Water absorption of coarse aggregate	0.80%
Water absorption of fine aggregate	0.60%

1. Target Mean Strength

$$f'ck = fck + 1.65S$$

Where, $f'ck$= target average compressive strength at 28 days,

fck = characteristic compressive strength at 28 days,

S = standard deviation = 4 N/mm^2 (from Table 1, IS 10262: 2019)

Therefore, target strength=25+1.65*4=31,6 N/mm^2.

2. Selection Of Water Cement Ratio

The maximum water-cement ratio required for M25 grade concrete can be found in Table 5- IS (456.2000)

Exposure = Moderate

Maximum W/C ratio = 0.50

Water cement ration depends upon exposure (As per table 5 of IS 456-2000 page 20)

Adopted W/C ratio = 0.45

Maximum water content for 20mm aggregate to get 50mm slump is given in Table 2 of (IS10262. 2019)

From above table, For aggregate = 20mm and Slump = 50mm.

Maximum Water Content (50mm Slump) = 186 kg

186 kg of water is required to get a slump of 50mm but we need slump of 75mm as per our specifications. Clause 4.2 recommends increasing the water content by 3% to obtain an additional slope of 25 mm from the 50 mm slope

The weight of cement for the mix design of M 25 grade concrete can be calculated from the water-cement ratio and the water content Therefore as per clause 4.2 For aggregate = 20mm, Slump = 75mm

Water-content for 75mm Slump = 186+(0.03*186)

= 191.58 kg

Adopted Water Content = 0.45

Calculation Of Cement

The weight of cement for the mix design of M25 grade concrete can be calculated from the water cement ratio and the water content

Adopted Water Cement Ratio = 0.45

Cement required= Water Content / W-C Ratio

= 191.58/0.45

= 425.73 kg/m^3

3. Calculation Coarse Aggregate and Fine Aggregate

Coarse aggregate ratios for different Zones of Fine aggregates are given in Table 3 of (IS10262-2019)

From above table, For aggregate = 20mm, Fine aggregate= Zone II and Water-cement ratio = 0.50

Coarse Aggregate ratio = 0.62 (For w/c = 0.5)

Water cement ratio = 0.50=0.62 (IS10262-2019table 5)

But actual W/C ratio = 0.45

So, it is less by= 0.50-0.45= 0.05

As W/c ratio is reduced it is desirable to increase coarse aggregate preparation to reduce Fine aggregate

Coarse aggregate increase at the rate of 0.01 for every decrease is w/c ratio of 0.05 (IS 10262 2019 CL 5.5.1)

So, for decrease of every 0.05 w/c ratio= coarse aggregate increase by= 0.01

Therefore, For aggregate = 20mm, Fine aggregate= Zone II and Water-cement ratio = 0.45

Coarse Aggregate ratio (For W/C =0.5) =0.62 (Table3-IS10262)

Coarse Aggregate ratio (For W/C =0.45) = (0.62+0.01) = 0.63

Final Fine Aggregate ratio (1-0.63) = 0.37

4. Mix Calculations

Volume of concrete = 1 m3

Volume of cement = (mass of cement / (specific gravity of cement * 1000))

= (425.73 / (3.15* 1000)) = 0.135 m^3

Volume of water = (mass of water / (specific gravity of water * 1000))

= (191.58 / (1 * 1000)) = 0.191 m^3

Volume of Entrapped Air = 0.01m^3

Volume of all in aggregate = (a - (b + c + d))

= 1 – (0.135 + 0.191 + 0.01) = 0.66 m3

Mass of coarse aggregate =

(Volume of all in aggregate* volume proportion of coarse aggregate * specific gravity of coarse aggregate * 1000)

= 0.66 * 0.63 *2.72* 1000 = 1130.97kg/m^3

Grade of Concrete	**M 25**
Cement	425.73kg/m^3

Mass of fine aggregate =

(Volume of all in aggregate * volume proportion of fine aggregate * specific gravity of fine aggregate * 1000)

=0.66 * 0.37* 2.65* 1000= 647.13 kg/m^3

Fine aggregate = 647.13 kg/m3

Coarse aggregate = 1130.97 kg/m3 (55% 20 mm and 45% 10mm)

Water = 191.58 kg/m3

Water cement ratio = 0.45 Mix

Proportion = 1:1.52:2.65 (by weight)

Table 4.4 Show the M25 mix design of Concrete

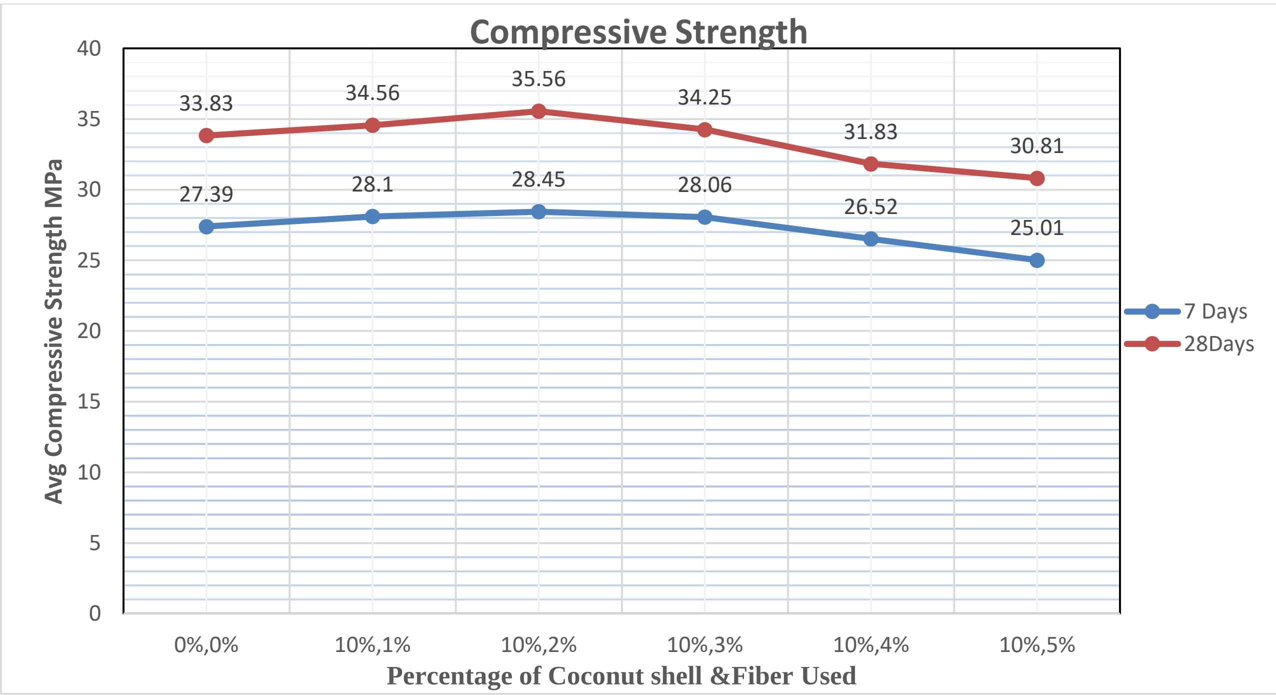
Aggregates	Fine aggregates	1130.9 kg/m^3	647.13 kg/m^3
Coarse aggregates • 20 mm aggregates (55%) • 10mm aggregates (45%)		1130.9 kg/m^3 621.99 kg/m^3 508.95 kg/m^3	
Ratio of mix proportion		1 :1.52: 2.65	
Water / Cement ratio		**0.45**	
Replacement% of coconut shell **(12.5 passing and 4.75) retained)**	Amount of coconut shell in Kg/m^3	add Percentage of Coconut Fiber	Amount of Coconut Fiber in Kg/m^3
10%	50.89	1%	4.25
10%	50.89	2%	8.51
10%	50.89	3%	12.77
10%	50.89	4%	17.02
10%	50.89	5%	21.28

International Journal on Science and Technology (IJSAT)
E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

RESULTS & DISCUSSION

Table 6.15 Compressive Strength test results

S no	% Replacement Coconut shell	% Coconut Fiber	7 Days	28 Days	Average Strength 7days	% Increment (7days to	Average Strength 28 days
1	0%	0%	24.65	33.25	27.39	23.5%	33.83
			27.39	33.80			
			30.13	34.45			
2	10%	1%	25.29	33.75	28.10	23.5%	34.56
			28.10	34.56			
			30.91	35.38			
3	10%	2%	25.61	34.70	28.45	25,0%	35.56
			28.45	35.60			
			31.30	36.38			
4	10%	3%	25.25	33.50	28.06	22.10%	34.25
			28.06	34.30			
			30.87	34.95			
5	10%	4%	23.87	30.50	26.52	20.00%	31.83
			26.52	31.80			
			29.17	33.19			
6	10%	5%	22,51	29.25	25.01	23.2%	30.81
			25.01	30.75			
			27.51	32.43			



Graph 6.16

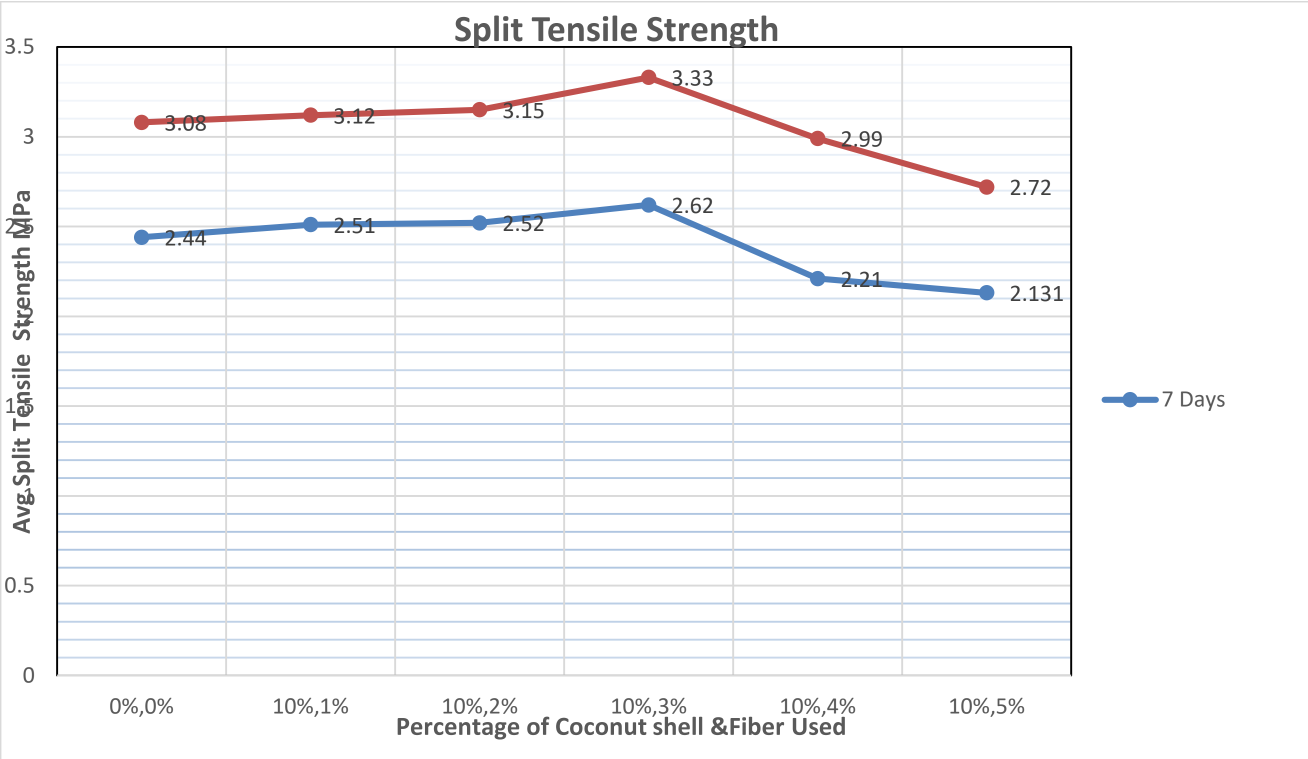
Table 6.15 Split Tensile Strength test results

S no	% Replacement Coconut shell	% Coconut Fiber add	7 Days	28 Days	Average Strength 7 days (MPa)	% increment (7days to 28days)	Average Strength 28 days (MPa)
1	0%	0%	2,270	3.090	2.440	26,2%	3.080
			2.440	3.110			
			2.610	3.050			
2	10%	1%	2.330	3.09	2.510	24.3%	3.120
			2.511	3.15			
			2.690	3.12			
3	10%	2%	2.340	3.11	2.520	25.0%	3.150
			2.512	3.16			
			2.771	3.17			
4	10%	3%	2.441	3.290	2.620	27.1%	3.330
			2.621	3.330			
			2,801	3.380			
5	10%	4%	2.061	2.99	2.210	25.6%	2.990
			2,221	3.01			
			2.360	2.97			
6	10%	5%	1.981	2.52	2.131	27.9%	2.72
			2,131	2.88			
			2.281	2.77			

S no	% Replacement Coconut shell	% Coconut Fiber add	7 Days	28 Days	Average Strength 7 days	% increment (7days	Average Strength 28 days
1	0%	0%	5.26	6,25	5.38	20.1%	6.46
			5.37	6.46			
			5.51	6.67			
2	10%	1%	5.29	6.35	5.39	21.5%	6.55
			5.40	6.55			
			5.50	6.75			
3	10%	2%	5.42	6.50	5.52	21,7%	6.72
			5.53	6.72			
			5.61	6.94			
4	10%	3%	4.93	6.63	4.95	27.5%	6.51
			4.94	6.52			
			4.98	6.72			
5	10%	4%	4.89	5.80	4.88	22.5%	5.98
			4.86	5.97			
			4.89	6.16			
6	10%	5%	4.55	5.00	4.56	12.9%	5.15
			4.57	5.15			
			4.58	5.30			

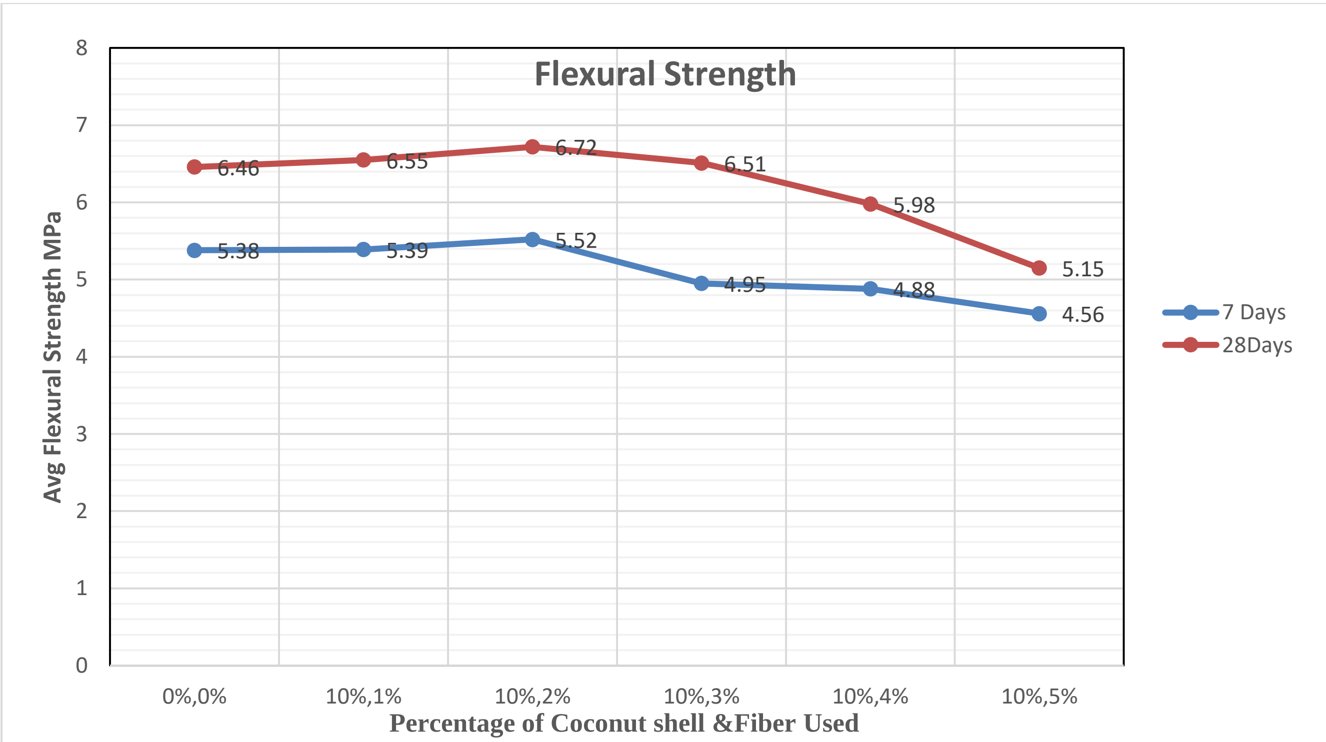
S no	% Replacement Coconut shell	% Coconut Fiber add	7 Days	28 Days	Average Strength 7 days	% increment (7days	Average Strength 28 days
1	0%	0%	5.26	6,25	5.38	20.1%	6.46
			5.37	6.46			
			5.51	6.67			
2	10%	1%	5.29	6.35	5.39	21.5%	6.55
			5.40	6.55			
			5.50	6.75			
3	10%	2%	5.42	6.50	5.52	21,7%	6.72
			5.53	6.72			
			5.61	6.94			
4	10%	3%	4.93	6.63	4.95	27.5%	6.51
			4.94	6.52			
			4.98	6.72			
5	10%	4%	4.89	5.80	4.88	22.5%	5.98
			4.86	5.97			
			4.89	6.16			
6	10%	5%	4.55	5.00			
			4.57	5.15			

			4.58	5.30	4.56	12.9%	5.15



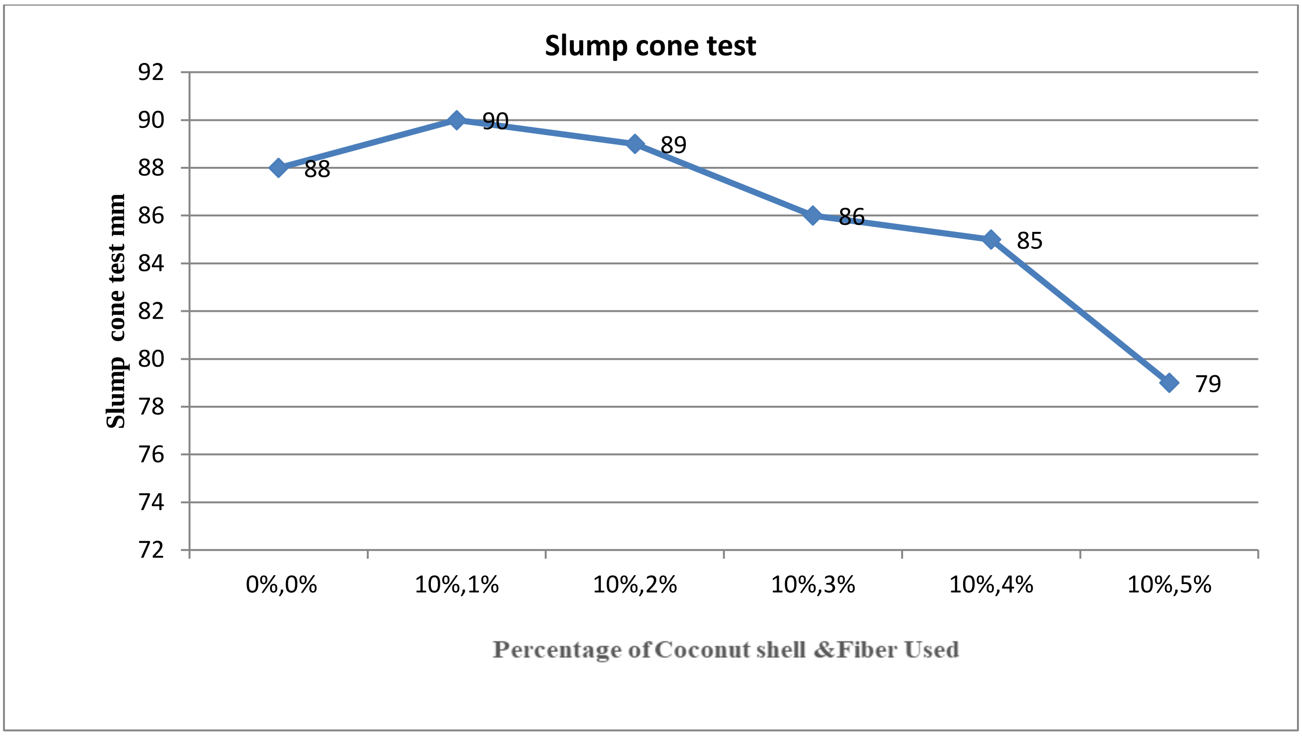
Graph 6.17

Table 6.15 Flexural Strength test results



S.no.	Coconut Shell Replacement %	Coconut Fiber %	Slump
1	0%	0%	88mm
2	10%	1%	90mm
3	10%	2%	89mm
4	10%	3%	86mm
5	10%	4%	85mm
6	10%	5%	79mm

Graph 6.18
Table 6.15 Test Results of slump Cone Test



Graph 6.19

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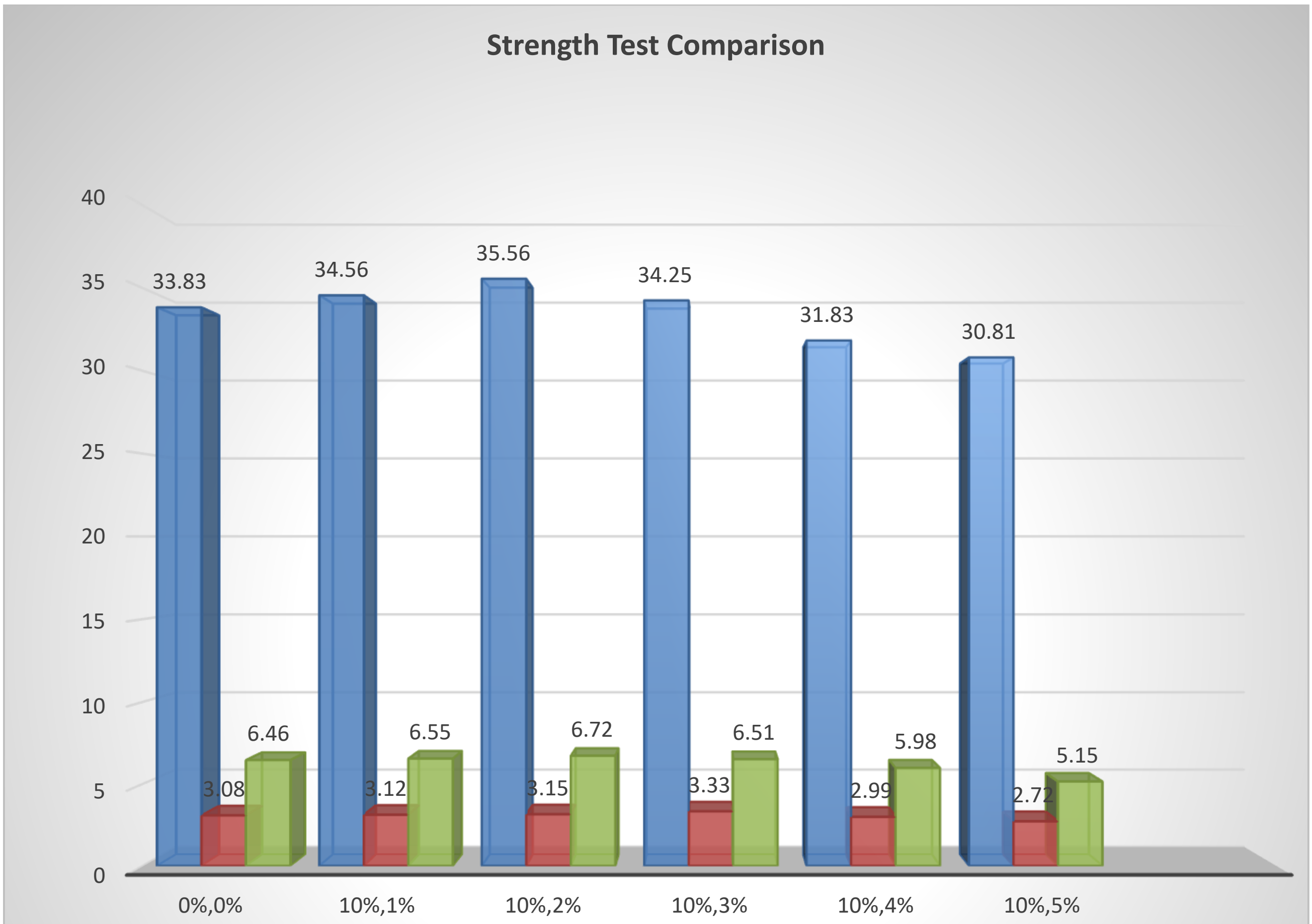
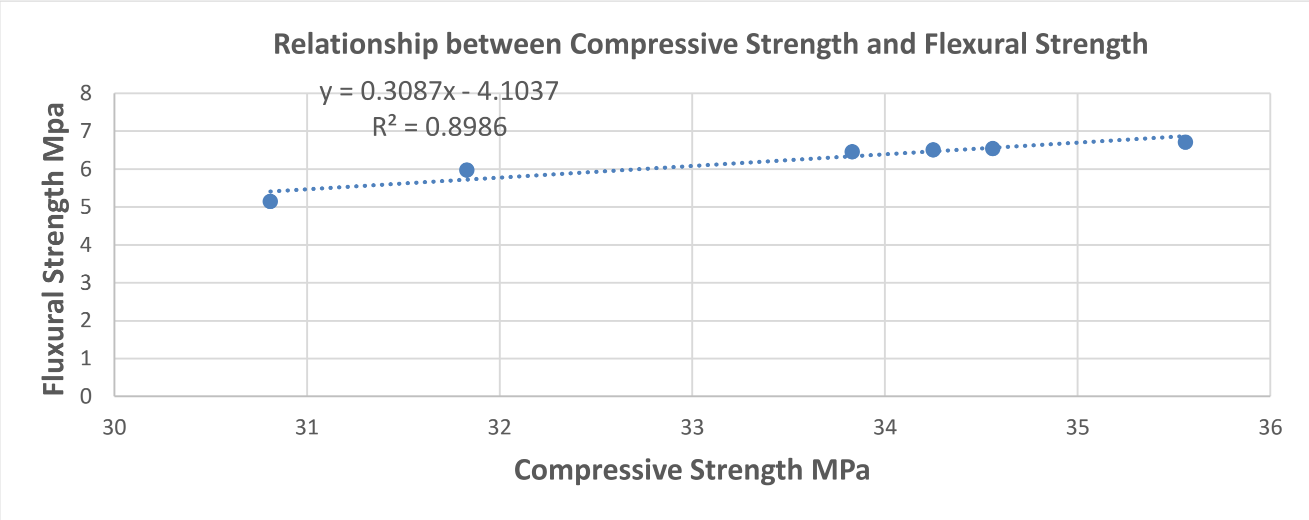
Strength Test Comparison



	0%,0%	10%,1%	10%,2%	10%,3%	10%,4%	10%,5%
Campressive Strength Test	33.83	34.56	35.56	34.25	31.83	30.81
Splits Tensile Strength	3.08	3.12	3.15	3.33	2.99	2.72
Flexural Strength Test	6.46	6.55	6.72	6.51	5.98	5.15

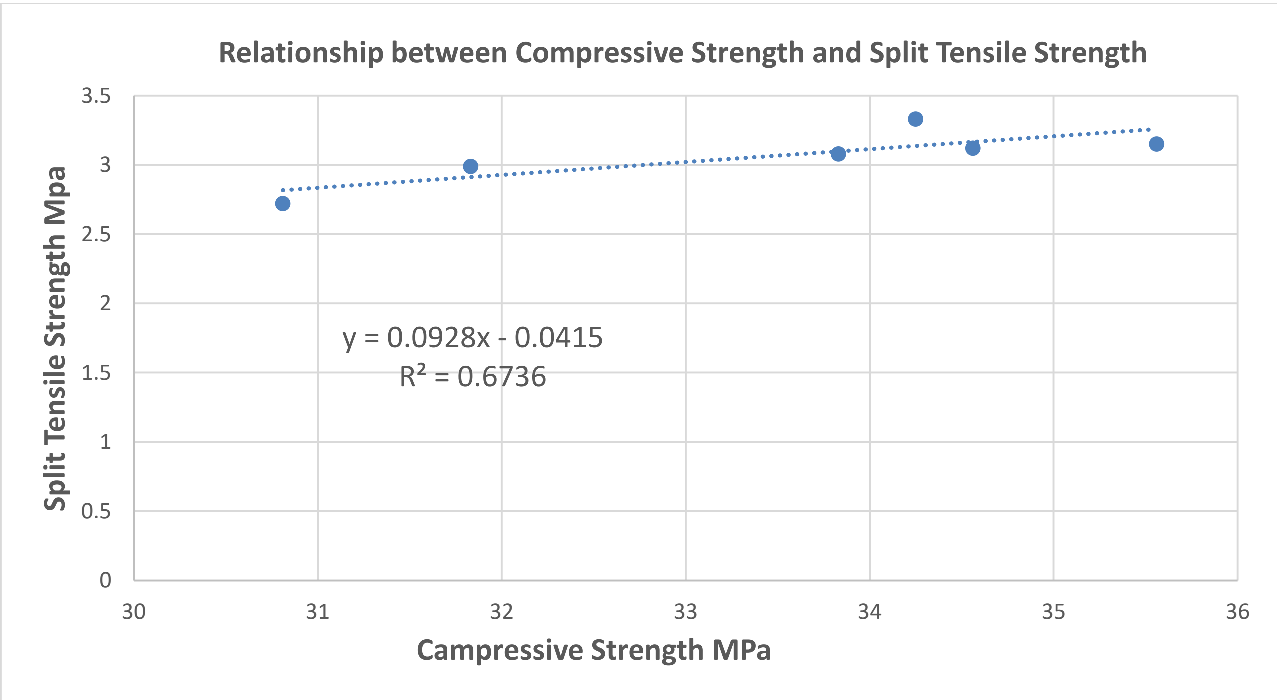
Graph 6,20

Relationship between Compressive Strength and Flexural Strength



Graph 6.21

Relationship between Compressive Strength and Split Tensile Strength



Graph 6.22

CONCLUSION

- The study demonstrates that coconut shell and coconut fiber can be effectively used in concrete mix design to develop a more sustainable, eco-friendly, and cost-effective construction material.
- Replacing coarse aggregates with coconut shell reduces the overall weight of the concrete and promotes the use of agricultural waste, while the inclusion of coconut fiber enhances the concrete's tensile strength, flexural strength, and resistance to cracking.
- Though the compressive strength may slightly increase with higher coconut Fiber content, the improved ductility and toughness from coconut Shell balance the mechanical properties. This makes the modified concrete suitable for load bearing and structural applications.
- Based on the experimental work it can be concluded that for 7 and 28 days curing up to 10% of coconut shell and 2% of coconut fiber can be used in concrete because it provides good strength. For flexural strengths up to 10% coconut shell and 2% of coconut fiber shows good results whereas for split tensile strength, up to 10% of coconut shell and 3% of coconut fiber replacement can be made in concrete
- Optimal Coconut fiber and coconut shell content is crucial to balance strength gains with acceptable workability. A Reduction in bleeding improves the surface integrity of concrete, improves its homogeneity and reduces the probability of cracks
- The results indicate a positive relationship between compressive strength and both flexural and split tensile strengths; flexural strength shows a strong correlation with compressive strength, while split tensile strength exhibits a moderate correlation, confirming that an increase in compressive strength generally enhances the overall tensile performance of M25 concrete.
- The study confirms that M25 concrete exhibits a positive relationship between compressive, flexural, and split tensile strengths, making it suitable and reliable for Rural Road and pavement applications due to its adequate load-carrying capacity and structural performance.
- The concrete mix provides adequate workability within the required slump range and sufficient strength characteristics, making it suitable for house construction, particularly for slab and beam casting with proper placement and compaction.

FUTURE SCOPE

- Study the long-term durability of Mix concrete in residential slabs and beams under different environmental conditions.
- Investigate the effect of varying fiber content on crack control and deflection behavior in slabs and beams.
- Evaluate shrinkage and creep characteristics to assess long-term serviceability of house structures.
- Analyze the performance of M25 concrete with different curing methods for slab and beam elements.
- Explore the use of supplementary cementitious materials to improve sustainability and cost efficiency in residential construction.
- Conduct full-scale slab and beam casting trials to validate laboratory results under site conditions.
- Future research can focus on evaluating the long-term durability and fatigue performance of coconut shell and coconut fiber–reinforced concrete under repeated traffic loads, studying abrasion and skid resistance for pavement surfaces, optimizing mix proportions for rigid pavement applications,

assessing crack propagation and impact resistance, and validating laboratory findings through full-scale Rural road construction trials under field conditions.

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