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Improvement Of Strength Of Concrete With Partial Replacement Of Coarse Aggregate With Coconut Shell And Coir Fibres

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Abstract: The present study investigates the viability of replacing some of the coarse material in concrete with coconut shell and incorporating coconut fiber as an additive to produce lightweight aggregate concrete. This strategy tries to alleviate the high price of traditional building materials. and the excessive exploitation of natural resources. The research objectives involve assessing the properties of coconut shell for use in reinforced concrete, evaluating the workability and strength of concrete with varying proportions of coconut shell and fiber, and analyzing the cost implications of producing eco-friendly concrete. The results of the experiments show that adding coconut fibre to concrete increases its strength by a certain amount, beyond which it decreases. Furthermore, replacing coarse aggregate by 10% coconut shell reduces the density and breaking strength of the concrete, while increasing its slump. These findings suggest that using coconut shell in place of certain coarse aggregate may result in a lightweight concrete material that is less strong and less dense. The study also identifies an optimal amount of coconut fiber that can be added to the concrete mix to maintain its strength. Overall, this study offers insightful information about using coconut shell and fibre to produce concrete, highlighting the need for careful selection and optimization of these materials to ensure the desired properties of the concrete.

Key Words: Coarse Aggregates, Coconut Shell, Coir Fibers ,Cement, Fine Aggregates.

I.INTRODUCTION

Coconut shells and coconut fibers are sustainable and eco-friendly materials that can be used as aggregates and reinforcement in concrete. Coconut shells are the outer hard coverings of the coconut fruit, while coconut fibers are obtained from the husk of the fruit. Both materials are abundant and can be sourced from coconut-producing countries, making them an attractive alternative to traditional construction materials. Coconut fibres may be utilised as a reinforcing agent and coconut shells can be used as a substitute for coarse gravel in concrete in the building sector. Light and having a high intensity-to-weight ratio are coconut shells, which makes them suitable for use in less weight concrete applications. On the other hand, coconut fibers are known for their high tensile strength and low density, making them ideal for reinforcing concrete.

Every year, millions of tons of solid waste from coconut shells are generated, and this amount is expected to increase over time. To solve this problem, different coconut waste products have been employed as partial or full replacements for coarse aggregates in the making of concrete, including the husk of coconuts, the shell of a coconut, coir fibre, and coconut shell powder. Agricultural waste products like coconut shell and coir fibre may be used successfully in concrete, according to studies. More than 96 nations cultivate coconut, with India alone dedicating 2.076 million hectares to the crop and producing 16.837 million tonnes of coconuts annually. In addition to enhancing the quality of the concrete, the use of these materials encourages the correct disposal of agricultural wastes like coconut fibre and shell, minimising the environmental effect.

Fig. 1.1: Coconut shell

The two forms of coir fiber—brown fibres taken from mature coconuts and white fibres taken from young coconuts—are separated from the coconut's outer shell. Brown fibers are mainly used in the construction industry. The coir industry in India produces a significant amount of coir fiber waste, estimated to be around 7.5 million tons annually. Coir fibres provide a number of benefits, including being moth-proof, resilient to rot and fungus, resistant to high temperatures and sound, heatproof, non- absorbent, long-lasting, secure, and able to revert to their initial form following extensive usage. Coir fibres are also compostable and harmless. They also possess property-based benefits, such as being difficult to burn, moisture-resistant, sturdy, completely free of static electricity, and easy to clean.

Fig. 1.2: Coconut fiber

Table 1.1: Properties of Coconut shell and Coconut fiber

S.No	Coconut shells	Coconut fiber
1.	Due to its excellent strength and modulus characteristics, thismaterial has a great potential.	Coconut fiber has excellent tensile strength, which makes it an ideal material for reinforcing concrete.
2.	Water absorption was found bemaximum for 35 Wt.%	Additionally, it was established thatthe husk of coconut released roughly 87% of its phosphate and 10% percent its total nitrogen.
3.	Significantly stronger.	4-6 times stronger to withstand tension compared to other fibers.
4.	65%cellulose in a coconutshell.	Higher amount of potassium.
5.	Biodegradable and compostable.	Biodegradable and compostable
6.	Heat and fire resistance.	Commonly known as coir.

Table 1.2 – Comparison of Physical and Mechanical Properties of Conventional Materials vs. Coconut Shell and Coconut Fiber

Property	Conventional Coarse Aggregate (Crushed Stone)	Coconut Shell (CS)	Conventional Fiber (Steel/Glass/Polypropylene)	Coconut Fiber (Coir)
Bulk Density (kg/m³)	1500–1700	550–650	Steel: ~7800 Glass: ~2500 PP: ~910	1150–1250
Water Absorption (%)	0.5–2.0	18–24	Steel/Glass: <0.5 PP: <0.1	8–12
Compressive Strength (MPa)	N/A (aggregate only)	N/A (aggregate only)	N/A (fiber only)	N/A (fiber only)
Tensile Strength (MPa)	N/A	N/A	Steel: 500–2000 Glass: ~2000 PP: 300–600	100–250
Modulus of Elasticity (GPa)	50–70	1.0–2.0	Steel: 200 Glass: 70–80 PP: 3–5	4–6
Elongation at Break (%)	N/A	N/A	Steel: ~3–4 PP: 15–25	15–40

Thermal Conductivity (W/m·K)	2.5–3.0	0.29–0.40	Steel: 50 Glass: 1.0 PP: 0.22	0.045–0.06
Biodegradability	No	Yes	No	Yes
Environmental Impact	Quarrying leads to habitat loss	Waste utilization, reduces landfill	High embodied energy (steel/glass)	Renewable, low embodied energy
Cost Factor	High in non-local areas	Low in coconut-producing regions	Moderate to high	Low in coconut-producing regions

1.1 SCOPE OF PRESENT INVESTIGATION

- Strength is improved by using the shell of coconut and coir fibre.
- Concrete may be made for less money by using coconut shells or other discarded resources from nature.
- To build an ecofriendly concrete with the help of coconut shells and coir.

1.2 OBJECTIVES OF THE PROJECT

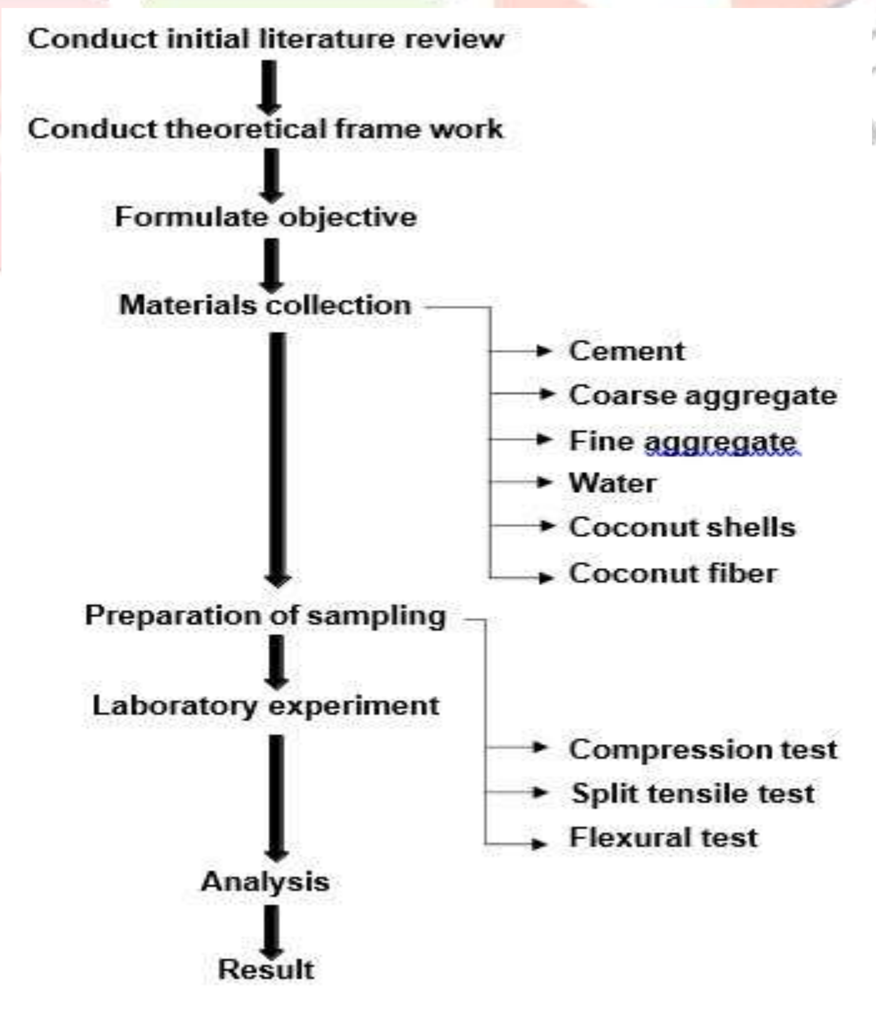
- To identify the characteristics of coconut shell that will be utilised in reinforced concrete
- To determine the workability of the concrete made with coconut shell and coconut fiber in different proportions.
- To determine the compressive strength of the concrete made with coconut shell and coconut fiber in different proportions.
- To determine the split tensile strength of the concrete made with coconut shell and coconut fiber with different proportions.
- To determine the flexural strength of the concrete made with coconut shell and coconut fiber with different proportions.

II. LITERATURE REVIEW

S.No	Study (Author)	Year	Mix / Replacement Details	Key Strength Findings
1	Gunasekaran et al., “Mechanical & bond properties of coconut shell concrete”	2011	CS used as coarse aggregate (varied %); standard mixes	CS concrete achieves structural-grade strengths; reductions vs. conventional but workable with proper design; flexural & split-tensile reported.
2	Kanojia & Jain, “Performance of coconut shell as coarse aggregate”	2017	Up to 40% CS replacing coarse aggregate	Strength decreases with higher CS; large drop at 40% (not recommended for strength-critical members).
3	Purnachandra Sai et al., “Concrete made with coconut shells	2018	CS as coarse aggregate; CF = 0–3% (by binder); M40; fly ash 10–30%	Adding coir fibre improved strength vs. CS-only; best

	and coir fibre (IJCIET)”			performance at low CF dosages; synergy with fly ash observed.
4	Verma et al., “Use of Coconut Shell as Partly Substitution of Coarse Aggregate”	2019	CS partial replacement (levels varied)	Compressive strength drops as CS% rises; recommends low-to-moderate CS for acceptable strength.
5	IRJET review/case, “Optimum use of Coconut Shell…”	2020	CS at several levels	Max compressive strength reported near 10% CS; higher levels reduce strength notably.
6	Raja et al., “Shrinkage & Strength of Concrete with CS”	2021	CS = 5%, 10%, 15% (M30)	Baseline 28.3 MPa (0% CS); mixes with CS maintained practical strengths; shrinkage behavior reported.
7	Tangadagi et al., “Strength characteristics with CS”	2021	CS partial replacement	Study targets optimum CS to enhance strength; identifies limited CS content advisable.
8	Bari et al., “Brick aggregate concrete… (incl. CS)”	2021	Normal-strength concretes including CS	Confirms viability of CS within lightweight/normal-strength range; careful proportioning needed.
9	Ahmad et al., “Coconut fiber in concrete (review)”	2022	CF (various dosages, often 0.5–2% by cement)	CF improves tensile/flexural performance by crack control; may reduce workability; proper dosage is key.

III. METHODOLOGY



Concrete made with coconut shell and coconut fiber involves several steps. First, the materials used in the concrete are tested to determine their suitability for use. After that, the mix is created in accordance with industry standards to get a sufficient amount of water. The coconut shells are used as a lightweight aggregate, replacing some of the coarse aggregate in the mix, while the coconut fibers are used as reinforcement, in the form of processed fibers or raw fiber meshes coated with coconut oil. Slump tests are carried out to make sure the mix is usable and the mixing procedure is carried out carefully enough to prevent bleeding. Before testing, the cubes are carefully dried in the sun after being adequately cured for seven to twenty-eight days. To assess if employing coconut shells and fibres as an alternative to conventional materials is successful, the strength qualities of the resultant concrete are contrasted to those of regular concrete.

In a prior work, the strength characteristics of standard concrete and concrete reinforced with coconut shell and fibre were compared, and the influence of fibre form on strength was explored. Tests were conducted using raw and processed coconut fibre meshes of 5 cm x 5 cm and covered with the oil of coconut at 4%, 5%, and 6% fibre contents, respectively. The appropriateness of ingredients for concrete was initially assessed using material testing. To guarantee there was no bleeding, the mix was created in accordance with IS 10262: 2009, and the procedure for mixing was followed as per protocol. The cubes were dried before testing after being cured for seven days and 28 days, respectively, in order to verify workability.

IV. MIX DESIGN

Mix ID	Water (kg)	Cement (kg)	Sand (kg)	Natural CA (kg)	Coconut shell (kg)	Coconut fiber (kg)	w/c
Mix 1 — Conventional M25	**197**	**438**	**631**	**1095**	—	—	0.45
Mix 2— 10% CS + 0.3% fiber	**197**	**438**	**631**	**987**	**47**	**1.31**	0.45
Mix 3 — 10% CS + 0.5% fiber	**197**	**438**	**631**	**987**	**47**	**2.19**	0.45
Mix 4 — 10% CS + 0.7% fiber	**197**	**438**	**631**	**987**	**47**	**3.07**	0.45

Table 4.1 : Mixes and its proportions

Mix	Grade	Proportion of mix
Mix 1	M 25	Conventional mix
Mix 2	M 25	Concrete with 10%of coconut shells and 0.3%of coconut fiber
Mix 3	M25	Concrete with 10%of coconut shells and 0.5%of coconut fiber
Mix 4	M25	Concrete with 10%of coconut shells and 0.7%of coconut fiber

V. RESULTS

Concrete made with coconut shell and coconut fiber has gained attention as a sustainable alternative to conventional concrete due to its low environmental impact and high strength. Here are some general points to consider when analyzing and discussing this type of concrete:

Compression test, split tensile tests, and bending test are common methods used to determine the strength of concrete. In compression testing, a sample of the concrete is subjected to breaking forces until it fails. Split tensile testing involves applying tensile forces perpendicular to the axis of a cylindrical sample. Bending testing involves bending a sample of the concrete to determine its strength under bending stresses.

These tests are typically conducted at specific time intervals, such as 7 and 28 days after casting the concrete. The test findings can be utilised for comparing various mix designs or to assess how adding components like coconut shell and fibre would affect the durability and strength of the concrete.

5.1 Compression test results

Table 5.1: Compression test values for 7-days test

S.No	Mix code	Weight in kg	Load in KN	Avg load	Compression strengthN\mm^2
1	Mix 1	8.54	330	376.67	16.75
2		8.94	300		
3		8.61	500		
4	Mix 2	8.16	300	310	13.77
5		8.21	330		
6		7.63	300		
7	Mix 3	8.26	320	330	14.66
8		7.93	320		
9		7.79	350		
10	Mix 4	7.86	300	293.34	13.03
11		7.98	310		
12		7.78	270		

Table 5.1 displays the results of compression tests conducted on various concrete mixture after seven days of curing. The weight of each mix is also provided alongside the corresponding compression strength values.

Following a seven-day curing period, the bursting strength of every one of the 4 concrete mixtures—the control mixture M25 and the three containing various amounts of coconut shells and fiber—was measured. Using compression testing equipment, the break strength values were calculated and expressed in units of N/mm2.

The seven-day compression test results provide an initial indication of the strength of each concrete mix and allow for comparison of the effectiveness of incorporating coconut shell and fiber into the mix.

28 days compression test

A common technique for determining the cracking strength of concrete is the 28-day compression test. For this test, a concrete specimen that is cylindrical or cubical is cast and treated under particular circumstances. After 28 days of treatment, a testing device is used to apply a breaking force to the specimen.

A vertically mounted specimen is loaded steadily with force until it breaks on a testing device. The specimen's breaking strength is computed by dividing its maximum load by its cross-sectional area. The highest load that the sample can sustain is recorded.

Table 4.2: Compression test values for 28-days test

S.No	Mix code	Weight in kg	Load in KN	Avg load	Compression strengthN\mm^2
1	Mix 1	8.62	670	700	31.28
2		8.48	720		
3		8.58	710		
4	Mix 2	8.66	590	590	26.4
5		7.98	580		
6		7.59	600		
7	Mix 3	8.24	680	666.67	29.89
8		8.1	650		
9		8.45	670		
10	Mix 4	7.92	570	553.34	24.72
11		7.82	540		
12		7.66	550		

Table 5.2 presents the compression test results for a 28-day testing period along with the corresponding weight of each mould. The table displays the breaking strength values for each mix, indicating the load capacity of the concrete specimens after 28 days of curing. The weight of each mix used for the test is also provided.

By dividing the highest load the concrete sample can support by the cylinder's cross-sectional area, one may calculate its breaking strength. The 28-day compressive test findings are used to confirm that the concrete used in building satisfies the project's necessary strength requirements.

Fig. 5.1: Graph for compression strength

5.2 Split tensile strength results

7 days Split tensile strength test

Table 5.3: Split tensile test values for 7-days test

S.No	Mix code	Weight in kg	Load in KN	Avg load	Compression strength N\mm²
1	Mix 1	13.19	180	167.5	1.18
2		13.54	155		
3	Mix 2	11.97	120	125	0.88
4		12.19	130		
5	Mix 3	12.02	150	150	1.06
6		12.39	150		
7	Mix 4	11.68	110	115	0.81
8		11.73	120		

Table 5.3 presents the split tensile test results obtained for each mix at 7-days, along with the corresponding weight of the mix used. The split tensile test measures the tensile strength of concrete by applying a load perpendicular to the direction of the concrete's surface. The results of the test are recorded in megapascals (MPa), and indicate the ability of the concrete to resist cracking under tensile stress.

A common test procedure for determining the tensile strength of cylinder or cube farm concrete samples with a grade of M 25 is the 7-day tensile strength split test. After seven days of curing, the test entails applying a splitting tensile strain to the cured specimen using a testing equipment. The specimen's maximum load tolerance is noted, and the split tensile strength is computed by dividing the greatest load by the cross-sectional region of the specimen. This test is frequently employed in building projects to check if the concrete satisfies particular strength standards and to evaluate the solidity of the concrete.

28 days Split tensile strength test

Table 5.4: Split tensile test values for 28-days test

S.No	Mix code	Weight in kg	Load in KN	Avg load	Compression strength N\mm^2
1	Mix 1	13.66	280	290	3.01
2		13.20	300		
3	Mix 2	12.07	240	250	2.47
4		12.23	260		
5	Mix 3	12.27	270	275	2.81
6		12.02	280		
7	Mix 4	11.52	230	225	2.29
8		11.88	220		

Table 4.4 presents the split tensile test results for the concrete specimens containing coconut shell and coconut fiber aggregates, with corresponding weights for each mix, after the 28 days of curing. The table shows the split tensile strength values in MPa for each mix, along with the corresponding weights of the specimens.

In the 28-day split tensile strength test, a cylindrical or cubical concrete specimen is cast and cured under specific conditions. After 28 days of curing, the specimen is subjected to a splitting tensile force using a testing machine.

The load required to fracture the specimen is recorded, and the split tensile strength is calculated by dividing the maximum load by the cross-sectional area of the specimen. This test is commonly used in construction projects to ensure that the concrete meets specific strength needs and to assess the structural integrity of the concrete.

The test is typically performed by a certified laboratory technician in accordance with standard testing procedures, and the results are reported to the client or contractor. The information obtained from the test can be used to verify compliance with regulatory requirements, assess the excellence of the concrete , and evaluate the suitability of the concrete mix for various applications.

Overall, the 28-day split tensile strength test is an important for evaluating the tensile strength and durability of concrete and is a widely accepted and standardized test method in the construction industry

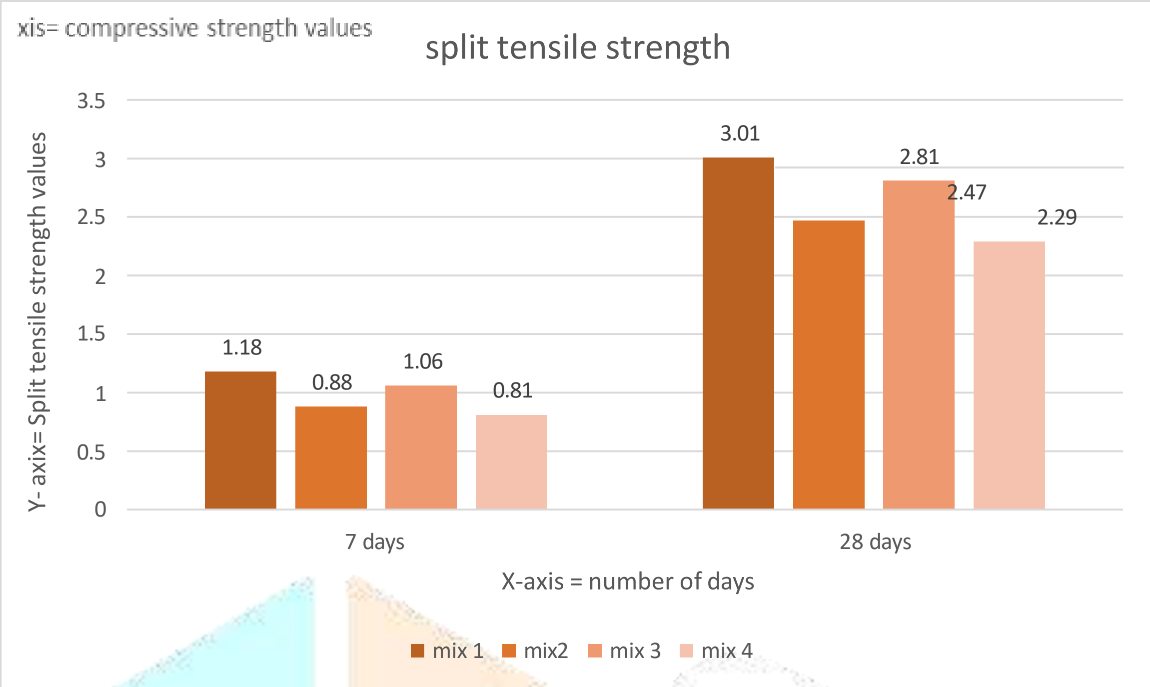


Fig. 5.2: Graph for Split tensile strength

5.3 Flexural strength results

7 days Flexural strength test

Table 4.5: Flexural test values for 7-days test

S.No	Mix code	Weight in kg	Load in KN
1	Mix 1	12.86	6
2	Mix 2	11.24	5
3	Mix 3	12.16	6
4	Mix 4	11.52	5.5

Table 5.5 presents the values of the bending test conducted on specimens of each mix at 7 days of age, along with the weight of each mix.

The seven-day bending strength test is used as an indicator of the overall strength of the concrete, as it allows for an early assessment of the strength of the material. This test is particularly important for applications where the concrete will be subjected to bending or other types of stress that can cause it to fail.

28 days Flexural strength test

The 28-day bending strength test is another commonly used test in the building industry to evaluate the strength of concrete. It is similar to the seven-day bending strength test, but the difference is in the duration of the curing. The test involves subjecting a concrete beam or cylinder to a load that creates a bending moment, just like in the seven-day test.

However, instead of testing the concrete after just seven days of curing, the 28-day bending strength test is performed after the concrete has cured for a full 28 days. This extended curing period allows the concrete to reach its fullstrength potential, which means that the test results are more representative of the long-term performance of the material.

The 28-day bending strength test assures that the concrete being utilised has the necessary strength to sustain the stresses it will be exposed to over time, which makes it a crucial quality control measure for building projects. If the concrete satisfies the strength criteria stipulated in the building and design plans, it will be determined by the test results.

Table 5.6: Flexural test values for 28-days test

S.No	Mix code	Weight in kg	Load in KN	Compression strength N\mm^2
1	Mix 1	12.92	7.6	2.05
2	Mix 2	11.52	6.5	1.73
3	Mix 3	111.89	7.5	1.94
4	Mix 4	11.67	6.3	1.59

Table 4.6 displays the results of the bending test performed on specimens of every mix after 28 days of age, accompanied by the corresponding weight of each mix. The completion of the 28-day bending strength test indicates that a concrete specimen has been cured for a full 28 days and subjected to a bending moment until failure. The force required to cause the concrete to fail has been measured, and the resulting value is used to determine the bend or flex strength of the material.

In order to make sure that the concrete utilised in a project is durable enough to sustain the stresses it will be exposed to over time, the 28-day bend test is an essential quality control tool in the construction industry. The results of the tests are used to confirm that the concrete satisfies the strength specifications stated in the design and building plans.

The completion of the 28-day bending strength test is an important milestone in the construction process, as it allows the project team to verify that the concrete has achieved the required strength and can be safely used in the construction of the project. If the results of the test indicate the concrete does not meet the required strength, corrective measures can be taken before the construction continues.

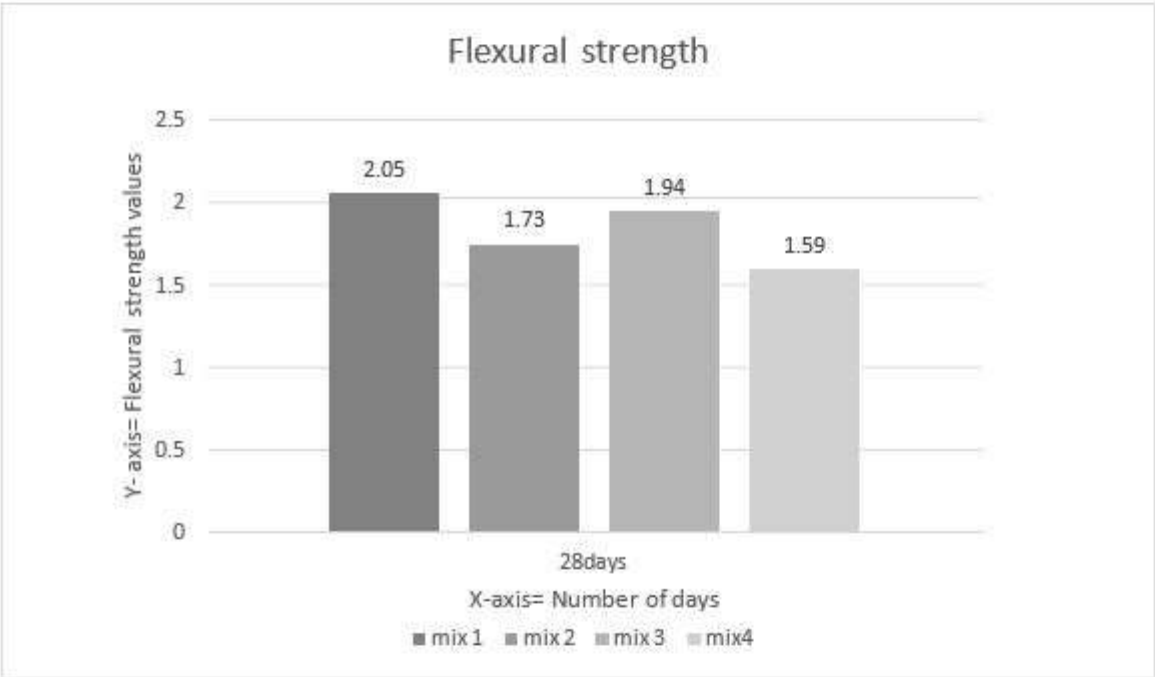


Fig. 4.3: Graph for Flexural strength

VI. CONCLUSION

6.1 GENERAL

The project focuses on the partial substitution of traditional coarse particles in concrete with coconut shell and fibre. In the experiment, concrete specimens with varying amounts of coconut shell and fibre were subjected to a number of tests, including those for breaking strength, split tensile strength, and bending strength. The tests' findings demonstrated that while the strength values of the coconut shells and fibre concrete were lower than those of conventional concrete, they were still within acceptable bounds for structural application. Additionally, the density of the concrete was reduced as a result of the inclusion of coconut shells and fibre, suggesting a potential usage for it in light concrete applications. The experiment demonstrates the possibilities of employing coconut fibre and shell as sustainable substitutes for traditional coarse aggregates in the manufacture of concrete.

6.2 CONCLUSION

In light of the research study observations, the following inferences are possible:

- It was determined from the testing results that adding coconut fibre to concrete boosted its strength by a specific amount. The results showed that adding coconut fibre up to a 0.5% percentage boosted the concrete's strength. The reason for this increase was that the coconut fiber acted as a reinforcement material, enhancing the bond between the cement paste and the aggregate. However, beyond this percentage, the strength of the concrete gradually decreased. This was because the excessive amount of coconut fiber led to a non-homogeneous mixture, resulting in a weaker concrete structure. The concrete's workability deteriorated as the amount of coconut fibre in the mixture
- As the coconut fibre content of the concrete increased, its workability decreased. This is because coconut fiber is a relatively stiff and coarse material, which can make it difficult to mix uniformly with the other ingredients in the concrete. As the proportion of coconut fiber increases, the mixture becomes more and more heterogeneous, resulting in a decrease in workability.This can make it challenging to place and compact the concrete properly, leading to potential defects and reduced overall strength.
- From a strength perspective, the use of coconut fiber in concrete showed a good impact in the experiments. However, the results were not significantly higher than those obtained with conventional concrete mixes, and were deemed only satisfactory.
- Based on the analysis of cost estimation values for the quantities required to produce 1 cubic meter of each type of concrete, it was found that the cost of producing sustainable or eco-friendly concrete was slightly higher compared to conventional concrete. Since coconut shell and fibre are not frequently utilised in the creation of normal concrete, the greater expense of adding them to the concrete mix might be the cause of this. However, it is important to note that the difference in cost was not significant and could be offset by the potential environmental benefits of using sustainable materials in construction.

6.3 LIMITATIONS

- As the percentage of coconut fiber increases, the concrete becomes more difficult to mix, place, and finish. The quality and quantity of coconut fiber can vary depending on factors such as location, season, and processing methods. This can make it difficult to obtain a consistent material for construction.

- Different sizes of coconut shells could have varying effects on the concrete, and using only one size may not fully represent the potential of using coconut shells in concrete.

- Plasticizers are commonly added to concrete mixes to improve their flow and workability, making it easier to place and compact the concrete. Without a plasticizer, the mixture can become more stiff and difficult to work with, making it harder to achieve proper compaction and potentially leading to defects and reduced strength.

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