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Improvement of Strength of Concrete with Partial Replacement Of Course Aggregate With Coconut Shell and Coir Fibres

Anju Mary Ealias [1], Rajeena A P [2], Sivadutt S [3] Asst. Prof. Life John [4] and Asst. Prof. Anju Paul [5]

[1,2,3] *B.Tech student,* [4,5] *Assistant professor Dept. of Civil Engineering, Toc H institute of science & technology, CUSAT, INDIA*

Abstract : *Coconut shell and coir fibres are the natural materials which is abundantly available in tropical regions. Wastes generated by industrial and agricultural processes have created disposal and management problems which pose serious challenges to efforts towards environmental conservation. A considerable amount of coconut shells and fibres remain in the environment as waste, so utilization of these materials for construction will be an important step to improve sustainability and eco-friendly construction. In addition to that it will help to produce light weight and economically profitable materials in construction field. The current study examined the suitability of partial replacing of coarse aggregate with coconut shell and coir fibres. To compare the above, test for compressive strength, splitting tensile strength, temperature resistance, water absorption, electrical resistance, chemical resistance, pH test of sample were performed. The specific gravity, bulk density and water absorption of coconut shell and fibres were analyzed. A study on the economic aspects was also carried out. The addition of fly ash helps to increase the strength and workability of concrete. The results obtained from above will be compared with conventional concrete of same mix.*

Keywords: *coconut shell, coir fibres, compressive strength, electrical resistivity, fly ash, pH, splitting tensile strength, temperature resistivity, water absorption.*

I. Introduction

1. General

The growing concern of resource depletion and global pollution has challenged many researchers to seek and develop new materials relying on renewable resources. These include the use of by-products and waste materials for building construction. Aggregates categorized under this section are those directly used without the need for processing.

The high cost of conventional building materials is a major factor affecting construction in India. In developing countries where abundant agricultural and industrial wastes are discharged, these wastes can be used for various purposes in construction industry. This will have double the advantages, reduction in the cost of construction material and also as a means of disposal of wastes. Thus the approach is logical, worthy and attributable. Therefore an attempt has been made in this study to utilize the coconut shell and coir fibres as partial replacement of coarse aggregate in the development of light weight concrete. Coir fibres and coconut shells are new materials in the field of construction, so a study on various strength, chemical and durability properties of these materials is required. Also suitable measures have to be adopted for attaining the target strength.

2. Description Of Materials

2.1 Coconut Shell

Coconuts are referred to as "man's most useful trees", "king of the tropical flora" and "tree of life". Global production of coconut is 51 billion nuts from an area of 12 million hectares. South East Asia is regarded as the origin of coconut.

Although the lignin content is higher and the cellulose content is lower, coconut shells are similar in chemical composition to hard wood. Coconut shell has good durability characteristics, high toughness & abrasion resistant properties. Coconut shell which is crushed in appropriate sizes (Fig. 1) can be used in concrete. Literature study shows 10% replacement is optimum.

2.2 Coir Fibres

Coconut fibres (Fig. 2) are extracted from the outer shell of a coconut. There are two types of coconut fibres, brown fibres extracted from matured coconuts and white fibres extracted tender coconuts. Brown fibres are thick, strong and have high abrasion resistance, which is used commonly.

There are many advantages of coconut fibres eg. they are moth-proof, fungi and rot resistant, provide excellent insulation against temperature & sound, not easily combustible, unaffected by moisture and dampness,

tough, durable, resilient, springs back to shape even after constant use, totally static free and easy to clean. Coir fibres were added 3% by the weight of cement and in 5 cm length.

Fig 1: Crushed Coconut Shell

Fig 2: Coir fibre

II. Review Of Literature

R. Nagalakshmi[1] conducted an experimental study to assess the strength characteristics on M 25 concrete with partial replacement of cement with fly ash and coarse aggregate with coconut shell. The 20% of fly ash is replaced with cement and simultaneously by replacing 10%, 20% and 30% of coconut shell as coarse aggregate for concrete of grade M 25. Examined strength characteristics such as compressive strength, splitting tensile strength and flexural strength of concrete mix are found for 7 days, 14 days, 28 days & 56 days of curing period, results are analyzed and compared with the regular mix. The results found were comparable with that of conventional mix. The result concludes that the compressive strength, splitting tensile strength and flexural strength of the concrete reduced with increasing percentage of the coconut shell replacement.

Study conducted by K. Gunasekaran[2] about utilization of coconut shell as coarse aggregate in the development of light concrete. In this study, coconut shell is used as lightweight aggregate in concrete. The properties of coconut shell and coconut shell aggregate concrete is examined and the use of coconut shell aggregate in construction is tested. Moisture content and water absorption were 4.20% and 24% respectively and these values are more compared to conventional aggregate. Coconut shell exhibits resistance against crushing, impact and abrasion compared to conventional aggregate. There is no need to treat the coconut shell before use as an aggregate except for water absorption. From the results, use of coconut shell aggregate concrete as structural lightweight concrete is recommended. Coconut shell aggregate is a potential construction material and simultaneously reduces the environmental problem of solid waste.

Majid Ali and Nawawi Chouw[3] conducted a study on coir fibres and rope reinforced concrete beam under dynamic loading. In order to acquire knowledge for designing low-cost but safe housing in earthquake prone regions, the dynamic properties of coconut fibre reinforced concrete (CFRC) structural members is investigated. The outcome of the research will be used in the analysis of CFRC buildings under earthquake loading in the future. Natural coconut fibres having a length of 7.5 cm and a fibres content of 3% by weight of cement are used to prepare CFRC beams. Coir having a diameter of 1cm and tensile strength of 7.8 MPa is added as the reinforcement. Compressive strength, splitting tensile strength, modulus of elasticity and rupture for CFRC are investigated. The workability of CFRC is a major problem because of the presence of fibres.

III. TESTING OF MATERIALS

Testing of concrete is done to determine the various properties of concrete when the coarse aggregate is partially replaced by coconut shell and coir.

Material properties such as specific gravity, density and water absorption of coconut shell and coir fibres were tested as per IS: 2386 (part III) – 1963. Strength properties were analyzed by conducting compressive strength test as per IS: 516 - 1959 (reaffirmed 1999) and splitting tensile strength test as per IS: 5816 - 1999. Nature of concrete was determined by pH test using pH paper. Durability characteristics such as water absorption, chemical, temperature and electrical resistivity properties were investigated. Also density and feasibility study was conducted. The strength property of concrete having coir fibres and coconut shell was improved by the addition of fly ash as per IS: 3812 (part I) – 2003.

IV. Results And Discussions

1. Bulk Density Test

The bulk density in compacted state is more as compared to the loose which shows that the bulk density greatly depends on the degree of compaction or how densely it is packed**.**

TABLE 1: Bulk Density of Coconut shell

DESCRIPTION	**Quantity**
Volume of vessel (A)	1.5000 m^3
Weight of empty vessel (B)	1.9835 kg
Weight of sample + vessel without compaction (C)	2.7568 kg
Weight of sample + vessel with compaction (D)	2.8969 kg

Bulk density of coconut shell, Loose $= \frac{C-B}{A}$ = 515.53 kg/m^3

Bulk density of coconut shell, Compacted $= \frac{D-B}{A}$ = 608.93 kg/m^3

Aggregates with bulk densities less than 1120 kg/m^3 are called Lightweight. From experiment, the bulk density of coconut shell is less than 1120 kg/m^3, so that which helps to produce Light-Weight concrete.

2. Specific Gravity And Water Absorption Test On Construction Materials

TABLE 2: Specific Gravity and Water Absorption of Coconut shell

DESCRIPTION	Quantity
Weight of sample + vessel + water (A)	5.793 kg
Weight of vessel + water (B)	5.539 kg
Weight of air dried sample (C)	1.068 Kg
Weight of oven dried sample (110ºC) (D)	0.843 Kg

Specific gravity of coconut shell $= \frac{D}{C-(A-B)}$ = 1.03

Water absorption of coconut shell $= \frac{(C-D)\times 100}{D}$ = 26.69%

Specific gravity of coconut shell is less than aggregate and the water absorption of coconut shell is greater than aggregate. So the coarse aggregate cannot be fully replaced by coconut shell. Only partial replacement is possible.

TABLE 3: Specific Gravity and Water Absorption of coir fibres

DESCRIPTION	Quantity
Weight of sample + vessel + water (A)	5.5530 kg
Weight of vessel + water (B)	5.5390 kg
Weight of air dried sample (C)	0.0850 Kg
Weight of oven dried sample (110ºC) (D)	0.0496 Kg

Specific gravity of coir fibres $= \frac{D}{C-(A-B)}$ = 0.69

Water absorption of coir fibres $= \frac{(C-D)\times 100}{D}$ = 71.37%

Specific gravity of coir fibre is less than aggregate and coconut shell. The water absorption of coir fibre is greater than aggregate and coconut shell. Coir fibres are used for enhancing tensile strength of concrete.

3. Compressive Strength Test

TABLE 4: Compressive Strength of Cubes

CONCRETE MIX	DESCRIPTION		COMPRESSIVE STRENGTH (N/mm^2)		
			7 days	14 days	28 days
M 25	Conventional concrete		16.25	25.74	32.01
	Coarse aggregate replaced by	Coconut shell	12.75	20.85	22.10
		Coconut shell + coir	8.92	12.43	14.82
M 30	Conventional concrete		28.45	31.62	36.06
	Coarse aggregate replaced by	Coconut shell	17.34	25.31	27.89
		Coconut shell + coir	11.34	18.38	20.47

Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. It always increases with age and curing. Strength is the stress required to cause fracture of the material. Compressive strength is affected by the factors such as effect of materials, mix proportions and curing conditions.

Coarse aggregate replaced by 10% coconut shell attains 65% to 80% strength of conventional concrete and coarse aggregate replaced by 10% coconut shell & 3% coir by the weight of cement attains 45% to 60% strength of conventional concrete.

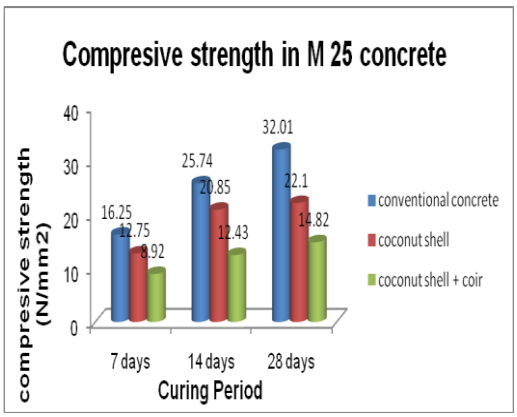

Fig 6: Graph Showing Compressive Strength in M 25 Concrete

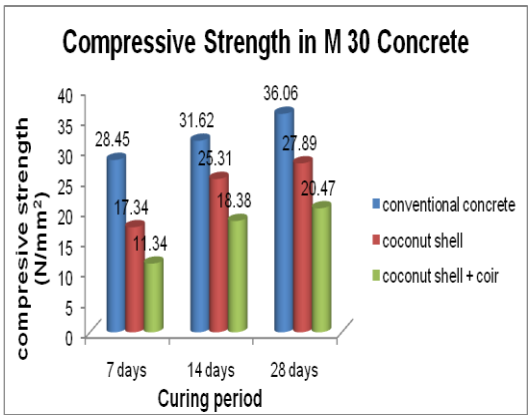

Fig 7: Graph Showing Compressive Strength in M 30 Concrete

4. Ph Test

When salt (pH of roughly 6 to 7) or other acids are introduced onto the concrete, they enter into small pores and micro-cracks of the concrete and attack the surrounding materials which lowering their pH. When the pH is lowered, the ability of cement to hold things together is compromised.

Concrete having partial replacement of coarse aggregate with 10% coconut shell and 10% coconut shell + 3% coir in M 25 and M 30 concrete gives pH value 12. This results shows that the concrete is alkaline in nature.

5. Water Absorption Test

The increase in weight as a percentage of the original weight is expressed as its absorption (%). The average absorption of the test samples shall not be greater than 5% with no individual unit greater than 7%.

TABLE 5: Water Absorption of Cubes

CONCRETE MIX	COARSE AGGREGATE REPLACED BY	WATER ABSORPTION (%)				
		0.5 hr	1 hr	24 hr	72 hr	168 hr
M 25	Coconut shell	4.80	5.28	5.32	5.91	6.42
	Coconut shell + coir	5.91	6.47	6.78	6.93	7.42
M 30	Coconut shell	4.46	4.65	4.76	4.86	6.11
	Coconut shell + coir	5.60	6.06	6.43	6.30	7.03

From test results, the addition of coconut shell and coir increases the water absorption property of concrete. Water absorption of concrete having coconut shell + coir is more than concrete with coconut shell, which exceeds limit of 7% water absorption in M 25 and M 30 concrete.

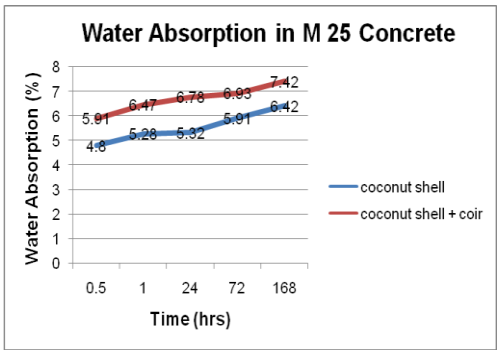

Fig 8: Graph Showing Water Absorption in M 25 Concrete

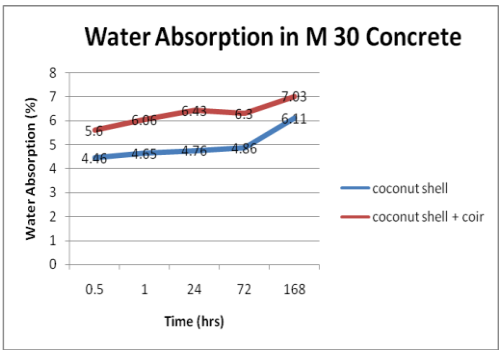

Fig 9: Graph Showing Water Absorption in M 30 Concrete

6. Electrical Resistivity Test

Conventional concrete is not electrically conductive in nature. The electric resistivity of normal weight concrete ranges between 6.54 – 11 kilo-ohm-meter.

TABLE 6: Electrical Resistivity of Cubes

CONCRETE MIX	COARSE AGGREGATE REPLACED BY	ELECTRICAL RESISTIVITY (kilo-ohm-meter)		
		7 days	14 days	28 days
M 25	Coconut shell	11.25	11.25	11.25
	Coconut shell + coir	11.25	11.25	7.50
M 30	Coconut shell	11.25	11.25	11.25
	Coconut shell + coir	11.25	11.25	7.50

Electrical resistivity of concrete having coconut shell and coir is 11.25 kilo-ohm-meter, which is nearer to the electrical resistivity of conventional concrete. After 28 days curing concrete with coconut shell + coir having electrical resistivity of 7.50 kilo-ohm-meter. It is comparable with conventional concrete.

7. Temperature Resistivity Test

TABLE 7: Temperature Resistivity of Specimens

CONCRETE MIX	DESCRIPTION		COMPRESSIVE STRENGTH (N/mm^2) After 28 day curing
M 25	Conventional		10.28
	Coarse aggregate replaced by	Coconut shell	4.87
		Coconut shell + coir	4.05
M 30	Conventional		12.92
	Coarse aggregate replaced by	Coconut shell	5.50
		Coconut shell + coir	5.11

The rise in temperature causes a decrease in the strength of concrete. However, the rate at which the strength decrease depends on the rate of increase in the temperature of the fire and the insulating properties of concrete. The change in concrete properties due to high temperature depends on the type of coarse aggregate used.

8. Chloride Test

When chloride present in sufficient amounts, may initiate or accelerate the corrosion of metals such as steel embedded in or contacting a cement system such as mortar, grout or concrete. The rate of ingress of chlorides into concrete depends on the pore structure of the concrete, which is affected by factors including materials used, construction practices and age.

TABLE 8: Chloride Penetration of Cubes

CONCRETE MIX	COARSE AGGREGATE REPLACED BY	CHLORIDE PENETRATION (%)		
		0-10 mm	10-30 mm	30-50 mm
M 25	Coconut shell	31.6	21.6	19.9
	Coconut shell + coir	31.6	19.9	18.3
M 30	Coconut shell	33.3	24.9	23.3
	Coconut shell + coir	33.3	24.9	19.9

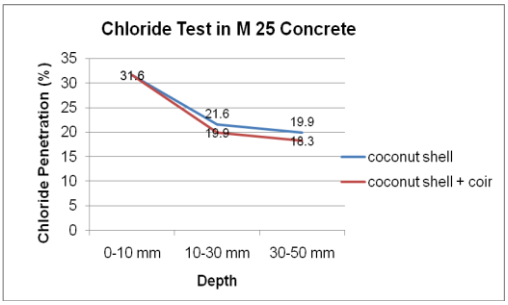

Fig 10: Graph Showing Chloride test in M 25 Concrete

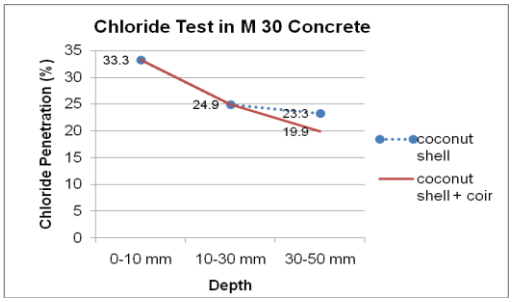

Fig 11: Graph Showing Chloride test in M 30 Concrete

The permeability of concrete is obviously related to the pore structure of the cement paste matrix. This will be influenced by many factors such as water-cement ratio and type of aggregate used on concrete. The addition of coconut shell and coir fibres makes the concrete matrix more porous so that penetration of chloride ion will be more. Percentage of chloride penetration is more in surface and it will reduce to inner depth. The inclusion of supplementary cementing materials serves to subdivide the pore structure.

9. Sulphate Test

Sulphate attack on ordinary Portland cement matrix is generally characterized by sulphate ions with cement hydration products and it causes expansion, cracking and spalling of concrte. The form and extent of damage to concrete will depend on the sulphate concentration, the type of cations in the sulphate solution.

TABLE 9: Compressive Strength of Cubes after Sulphate Attack

CONCRETE MIX	**COARSE AGGREGATE REPLACED BY**	**Compressive strength (N/mm^2) After 28 day curing**
M 25	Coconut shell	13.85
	Coconut shell + coir	10.28
M 30	Coconut shell	24.43
	Coconut shell + coir	18.34

10. Splitting Tensile Strength Test

Generally concrete is not designed to resist direct tension; the knowledge of tensile strength is of value in estimating the load under which cracking will develop.

TABLE 10: Splitting Tensile Strength of Cylinders

CONCRETE MIX	**DESCRIPTION**		**SPLITTING TENSILE STRENGTH (N/mm^2)**		
			7 days	**14 days**	**28 days**
M 25	Conventional		1.89	2.34	3.21
	Coarse aggregate replaced by	Coconut shell	1.43	1.89	2.15
		Coconut shell + coir	1.20	1.67	1.94
M 30	Conventional		1.93	2.51	3.71
	Coarse aggregate replaced by	Coconut shell	1.47	2.05	2.50
		Coconut shell + coir	1.23	1.91	2.10

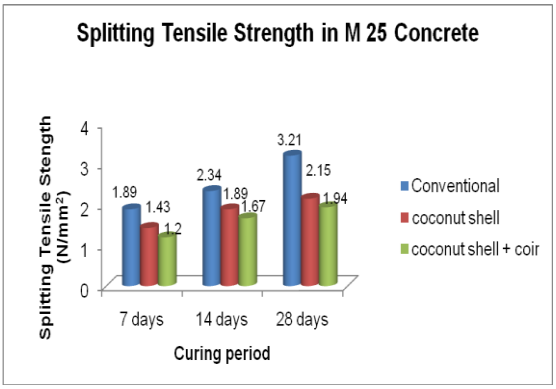

Fig 12: Graph Showing Splitting Tensile Strength in M 25 Concrete

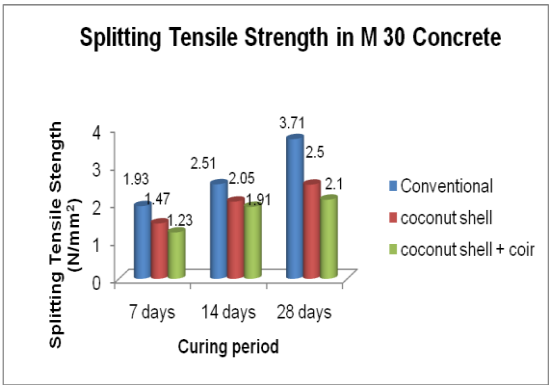

Fig 13: Graph Showing Splitting Tensile Strength in M 30 Concrete

As per IS 456 : 2000, the tensile strength can be estimated from compressive strength. Tensile strength is equal to $0.7\sqrt{fck}$ N/mm^2 where fck is characteristics strength of concrete. Addition of coconut shell and coir fibres in concrete reduces the tensile strength of concrete due to large amount of voids present in matrix.

11. Density Of Concrete

Density of normal concrete is in the order of about 2400 kg/m^3. The density of light weight concrete will be less than about density 1900 kg/m^3 and high density concrete have unit weight ranging from about 3360 kg/m^3.

TABLE 11: Density of Concrete

DESCRIPTION		MASS (kg)	VOLUME (m^3)	DENSITY (kg/m^3)
Conventional concrete		8.4	0.00337	2488.89
Coarse aggregate replaced by	Coconut shell	7.9	0.00337	2340.74
	Coconut shell + coir	7.2	0.00337	2133.33

When coconut shell and coir fibres added to the concrete, it reduces the density of concrete. So the material is comparable to light weight concrete

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12. Improvement Of Strength By Using Fly Ash

Fly ash is the modern pozzolona which helps to improving the performance of concrete. This helps to increases the strength properties of concrete.

TABLE 12: Compressive Strength of Cubes Containing Fly Ash

CONCRETE MIX	COARSE AGGREGATE REPLACED BY	COMPRESSIVE STRENGTH (N/mm^2)	
		7 days	28 days
M 25	conventional	16.42	28.74
	Coconut shell	15.20	25.91
	Coconut shell + coir	10.82	23.36
M 30	conventional	20.98	30.17
	Coconut shell	18.43	28.84
	Coconut shell + coir	12.70	27.10
M 35	conventional	23.57	34.84
	Coconut shell	20.76	32.19
	Coconut shell + coir	13.10	29.35
M 40	conventional	25.01	41.47
	Coconut shell	23.96	38.03
	Coconut shell + coir	13.47	35.05
M 45	conventional	27.93	45.67
	Coconut shell	24.63	42.45
	Coconut shell + coir	14.15	37.92
M 50	conventional	31.66	56.13
	Coconut shell	25.01	52.94
	Coconut shell + coir	14.40	45.42

Addition of fly ash helps to improve the strength of concrete with partial replacement of coarse aggregate with coir fibres and coconut shell. Compressive strength of concrete having coarse aggregate replaced by coconut shell reaches 90 – 95% of conventional concrete and coarse aggregate replaced by coconut shell + coir fibres reaches 80 – 90% of conventional concrete.

Significant improvement in strength is due to fly ash consist of particles with 2.2 kg/m^3 relative density which is more efficient void filler than Portland cement with relative density of 3.15 kg/m^3. Spherical shape of fly ash particles also allowed them to flow freely in mixtures and fill the forms more completely during vibration.

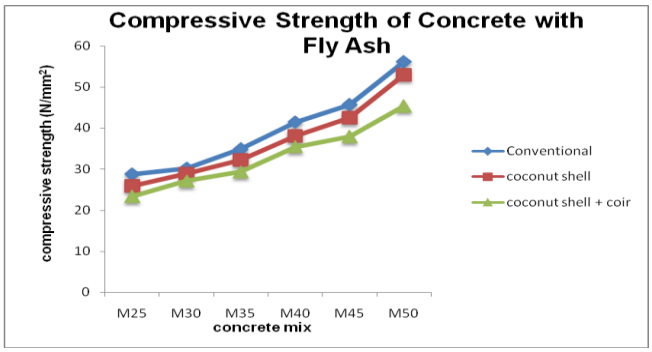

Fig 14: Graph Showing Compressive Strength of Concrete with Fly Ash

TABLE 13: Compressive Strength of Concrete With and Without Fly Ash

CONCRETE MIX	DESCRIPTION		COMPRESSIVE STRENGTH (N/mm^2) After 28 day curing	
			WITHOUT FLY ASH	WITH FLY ASH
M 25	Coarse aggregate replaced by	Coconut shell	22.10	25.91
		Coconut shell + coir	14.82	23.36
M 30	Coarse aggregate replaced by	Coconut shell	27.89	28.84
		Coconut shell + coir	20.47	27.10

Fly ash having advantages of greater strength, increases durability, increase workability, improve finishing etc. Void filling property of fly ash helps to improve the strength of concrete by reducing the voids in the concrete matrix having coconut shell and coir fibres.

Improvement in strength of concrete having coconut shell + coir fibres are found to be more as compared to coconut shell alone. Because of the addition of coir fibres creates more voids in concrete matrix and also reduces the workability of concrete.

13. Feasibility Study

To evaluate cost of conventional concrete, concrete replaced by coarse aggregate with 10% of coconut shell, concrete replaced by coarse aggregate with 10% of coconut shell and 3% of coir fibres for 1 cu.m separately.

TABLE 14: Cost of Conventional Concrete for 1 Cu.m

DESCRIPTION	QUANTITY REQUIRED (m^3)	RATE (Rs/m^3)	TOTAL COST (Rs)
Cement	0.1159	10951.00	1269.22
River sand	0.2476	2648.25	655.71
Aggregate	0.4217	706.20	297.8
Labour	1	3500	3500
Wastage of materials			300
Total			6022.73

TABLE 15: Cost of Concrete Replaced by Coarse Aggregate with 10% of Coconut Shell for 1 Cu.m

DESCRIPTION	QUANTITY REQUIRED (m^3)	RATE (Rs/m^3)	TOTAL COST (Rs)
Cement	0.1159	10951.00	1269.22
River sand	0.2476	2648.25	655.71
Aggregate	0.3795	706.20	268.00
Coconut shell	0.0421	190.02	8.00
Labour	1	3502.50	3502.50
Wastage of materials			300
Total			6003.43

Amount saved = 6022.73 - 6003.43

= 19.3 Rs/m^3

TABLE 16: Cost of Concrete Replaced by Coarse Aggregate with 10% of Coconut Shell and 3% of Coir Fibres for 1 Cu.m

DESCRIPTION	QUANTITY REQUIRED (m^3)	RATE (Rs/m^3)	TOTAL COST (Rs)
Cement	0.1159	10951.00	1269.22
River sand	0.2476	2648.25	655.71
Aggregate	0.3760	706.20	265.53
Coconut shell	0.0421	190.02	8.00
Coir fibres	0.0034	882.35	3.00
Labour	1	3506.50	3506.50
Wastage of materials			300

Total	6007.96

Amount saved = 6022.73 - 6007.96
= 14.77 Rs/m^3

The usage of coconut shell and coir fibres in construction field initiates low cost construction as well as waste management.

V. Conclusion

The use of coconut shell and coir fibres as partial replacement of coarse aggregate should be encouraged for sustainable and eco friendly construction. By the utilization of agricultural waste materials in concrete tends to low cost construction and waste management.

The results conclude that the concrete with coarse aggregate partially replaced with coconut shell and coir fibres shows lesser strength but can recommended for low cost construction with addition of fly ash. Strength properties of concrete having coconut shell and coir fibres improve to 80% – 95% by the addition of fly ash.

VI. Future Scope

- This study can be extended by using coconut shell under different physical conditions such as tender coconut shell, dried coconut shell etc.
- Seismic analysis of structure made by concrete with partial replacement of coarse aggregate with coir fibres and coconut shell can be carried out.
- Addition of coconut shells and coir fibres on reinforced concrete can be studied.

Acknowledgement

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