Experimental Study on the Rigid Pavement with Comparison of Polyester and Coconut Fiber as a Partial Replacement of Cement

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Abstract— This project work involves an experimental investigation of the artificial and natural fibers those are polyester and coconut fibers on the mechanical properties of the concrete used in the rigid pavement. In this experimental study involves two types of concrete mixes were prepared individually. Polyester fiber of 0.5% to 2.0% and coconut fiber of 0.5% to 2.5% by weight of cement were added to the mixes. After that a comparative analysis has been carried out for conventional concrete to that of the fiber reinforced in relation to their compressive, split tensile and flexural properties. In this study the observation shows that, the percentile of fiber content increases from 0%, 0.5%, 1%,1.5% for polyester fiber and 0%,0.5%,1.0%,1.5%,2.0% for coconut fiber in concrete mixes. By the experimental work the compressive, split tensile and flexural strengths are proportionally increased both polyester and coconut fiber usage. It is observed that the optimum dosages of polyester fiber is 1.5% and coconut fiber is 2.0% by weight of cement. In this project cost analysis is also determined for conventional concrete and fiber reinforced using experimental test reports. By analyzing the cost it was found that polyester reinforced concrete pavement increases to 49.77% and coconut reinforced concrete pavement decreases to 4.20% when compared to conventional concrete.

Key words: Coconut Fiber, Compressive Strength, Fiber Reinforced Concrete, Flexural Strength, Polyester Fiber, Split Tensile Strength

I. INTRODUCTION

A pavement is the layered structure on which vehicles travel. The main purpose of pavement is to provide a comfortable and durable surface for vehicles, and to reduce stresses on underlying soils. In a developing country such as India, the traditional system of bituminous pavement is widely used. Locally available cement concrete is a better substitute to bitumen which is the by product in distillation of imported petroleum crude. It is a known fact that petroleum and it's by products are dooming day by day.

The properties of concrete like strength and durability are varied by making appropriate changes in its ingredients like cementious material, aggregate and water and by adding some special ingredients. Hence concrete is very well suited for a wide range of applications. However Concrete has a brittle character, weak in tension, limited fatigue life, not capable of accommodating large deformations, low impact strength.

Cement concrete is characterized by brittle failure, the nearly complete loss of loading capacity, once failure is initiated. This type of failure, can be overcome by the inclusion of a small amount of short randomly distributed fibers (artificial and natural) and can be practiced among others that remedy weaknesses of concrete.

By this we can minimize the shrinkage cracking, and increases durability and resistance.

The presence of micro cracks at the mortar-aggregate interface is responsible for the inherent weakness of plain concrete. The weakness can be removed by addition of fibers in the concrete mix. There are different types of fibers are used in traditional composite materials to increase the concrete mix toughness, or ability to resist crack growth. The main purpose of fibers are used to transfer loads at the internal micro cracks. This type of concrete is called fiber-reinforced concrete (FRC). When concrete cracks, the randomly oriented fibers start functioning, arrest crack formation and propagation, and thus improve strength and ductility. Thus fiber-reinforced concrete is a composite material essentially consisting of conventional concrete or mortar reinforced by fine fibers.

Polymer fiber reinforced concrete pavements satisfies two of the much demanded requirements of the pavement material in India economy and reduced pollution. It also has several other advantages like longer life, low maintenance cost, fuel efficiency, good riding quality, increased load carrying capacity and impermeability to water over flexible pavements.

A. Objectives of the study

1) The main objective is to investigate the mechanical properties of concrete by adding polyester fiber and coconut fiber in concrete mixes.
2) To find out the optimum percentage of fiber content for polyester and coconut fibers to be added in concrete in relation to their mechanical properties
3) To find the thickness of pavement based on fiber material
4) Finally comparing the cost of pavement with and without using fibers.

II. EXPERIMENTAL PROGRAM

A. Materials Used

1) Cement:

Ordinary Portland cement of grade 53 is used for this experimental work.

2) Fine Aggregate:

The material which passes through BIS test sieve number 4 (4.75mm) is termed as fine aggregate usually natural sand is used as a fine aggregate at places where natural sand is not available crushed stone is used as fine aggregates. The sand used for the experimental works was locally procured and confirmed to grading zone II, sieve analysis of the fine aggregate was carried out in the laboratory as per IS 383-1970 and results are provided.

3) Coarse Aggregate:

The material which is retained on BIS test sieve number 4 (4.75mm) is termed as coarse aggregate. The broken stone is generally used as a stone aggregate. The aggregate is collected from stone crushing unit near Anandapuram located at a distance of 20 Km from Visakhapatnam.

4) Polyster Fibre:

Fig 1: Polyster Fibre

The Polyester fibers are available in monofilament form and belong to the thermoplastic polyester group. The Polyester fibers are temperature sensitive and above normal service temperature their properties may be altered. The polyester fiber is produced from Reliance industries Ltd., Mumbai. The type of polyester fiber is CT 2024. The constant dosages of 0.5% fibers up to 2.0% are used by weight of cement. The length of fiber is 8mm and its diameter is 0.014mm.

5) Coconut fiber:

Coconut fibers were extracted from coconut seeds and chopped into 10 mm in length. In the recent past, there has been growing interest in studying the properties of coconut fibers and coconut fiber reinforced composite. The coconut fiber is produced from Amalapuram East Godavari district. The diameter of fiber is 100-400 micrometer and elastic of modulus is 19-24 Gpa

Fig 2: Coconut Fibre

Description	Polyester fiber	Coconut fiber
Alkali resistance	Polyester fibre by nature is damaged by concentrated alkali action. No proven data of long term alkali resistance.	Coconut fiber by nature is damaged by concentrated alkali action.
Dispersion	Polyester fibers have density of 1.36gm/cm^3 which is significantly lower than that of concrete causing to float up & form bunches at the surface.	Coconut fiber have density of 1.2gm/ cm^3 which is significantly lower than that of concrete causing to float up
Tensile strength	550 Mpa	120-200Mpa
Elastic modulus	10 Gpa	19-24Gpa
Abrasion resistance	Low	Low

Table 1: Properties of fibres

B. Mix Design

The mix proportion chosen for this study is M20 grade with water-cement ratio of 0.5. In this test total 90 Cubes of standard size 150x150x150mm and 90 Cylinders of standard diameter 150mm and height 300mm and 90 Prisms of size 500x100x100mm were casted and cured for 7,14 and 28 days and tested as per code IS: 516-1959. The mix proportion chosen for this study is given in Table II.

Water	Cement	Fine Aggregate	Coarse Aggregate (60% + 40%)
150	300	737.91	1245.8 (747.48 + 498.3)
0.5	1	2.4	4.2

Table 2: Mix proportion (Kg/m^3) and mix ratio

III. TESTS AND RESULTS

The different tests were conducted in the laboratories as shown in below. It consists of mixing of concrete in the laboratory by replacing Polyester fiber as cement with proportions (by weight) of Polyester fiber added to concrete mixtures were as follows: 0% (for the concrete mix), 0.5%, 1.0%, 1.5% & 2.0% and Coconut fiber as Cement with proportions (by weight) of Coconut fiber added to concrete mixtures were as follows: 0% (for the concrete mix), 0.5%, 1.0%, 1.5%, 2.0% & 2.5% Concrete samples were prepared and cured in the laboratory, and are tested, to evaluate the concrete fresh and harden properties like compressive strength, Split tensile strength and flexural strength requirements.

A. Slump Cone Test:

Slump cone test was conducted to determine the workability of concrete.

Grade of Concrete	% of Polyester Fiber	Slump (mm)
M20	0	110
	0.5	99
	1.0	92
	1.5	82
	2.0	68

Table 3: Slump values for different % of polyester fiber

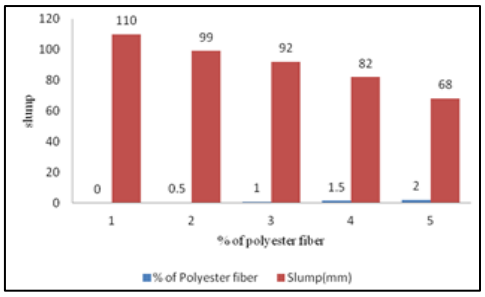

Fig 3: Variation of Slump in polyester fiber

Grade of concrete	% of Coconut fiber	Slump(mm)
M20	0	110
	0.5	102
	1.0	93
	1.5	84
	2.0	72
	2.5	69

Table 4: Slump values for different % of coconut fiber

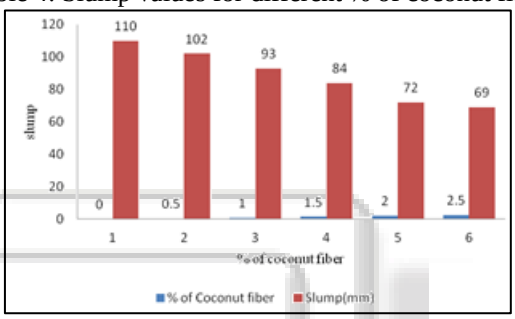

Fig 4: Variation of Slump in Coconut fiber

1) Description:

From the fig:3&4,It is observed that from the above results as the percentage of fiber increases the slump of the concrete is decreasing. This may be due to the fiber, as the percentage of fiber increases they obstructing the flow of the concrete.

B. Mechanical Characteristics of PFRC

1) Compressive Strength of PFRC

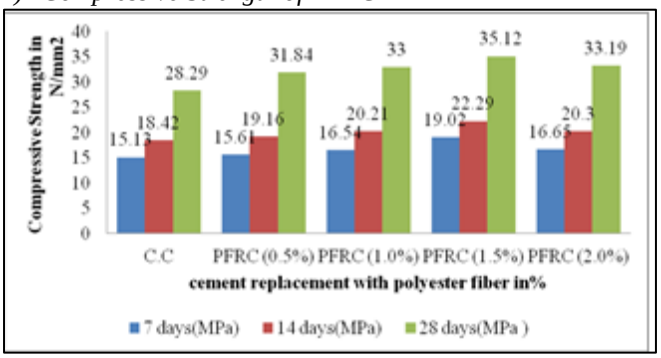

Fig. 5: Compressive strength values of C.C and PFRC at 7, 14 and 28 Days

a) Description:

- From the fig:5 It is observed that compressive strength of the concrete increases to 12.54%, 16.64% and 24.14% when % of fiber increases from 0.5%, 1.0% and 1.5% for PFRC when it is compared with conventional concrete at 28 days.
- It is observed that compressive strength values decreased as the percentage of fibers increases beyond 1.5%.

2) Split tensile strength PFRC

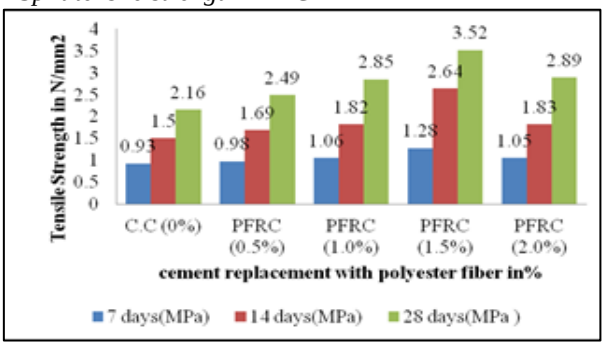

Fig 6: Split tensile strength values of C.C and PFRC at 7, 14 and 28 Days

a) Description:

- From the fig:6, It is observed that split tensile strength of the concrete increases to 15.27%, 31.94% and 62.96% when % of fiber increases from 0.5%, 1.0% and 1.5% for PFRC when it is compared with conventional concrete at 28 days.
- It is observed that split ensile strength values decreased as the percentage of fibers increases beyond 1.5%.

3) Flexural Strength of PFRC

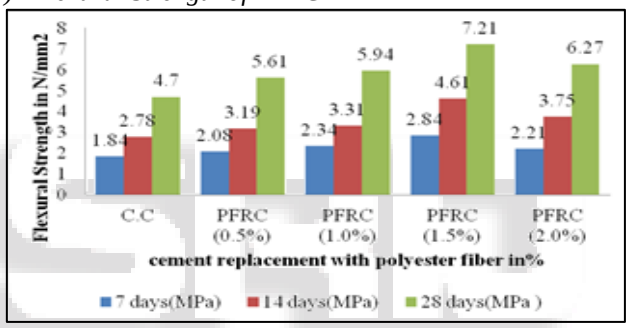

Fig 7: Flexural strength values of C.C and PFRC at 7, 14and 28 Days

a) Description:

- From the fig:7 It is observed that flexural strength of the concrete increases to 19.36%, 26.38% and 53.40% when % of fiber increases from 0.5%, 1.0% and 1.5% for PFRC when it is compared with conventional concrete at 28 days.
- It is observed that flexural strength values decreased as the percentage of fibers increases beyond 1.5%.

C. Mechanical Characteristics of CFRC

1) Compressive Strength of CFRC

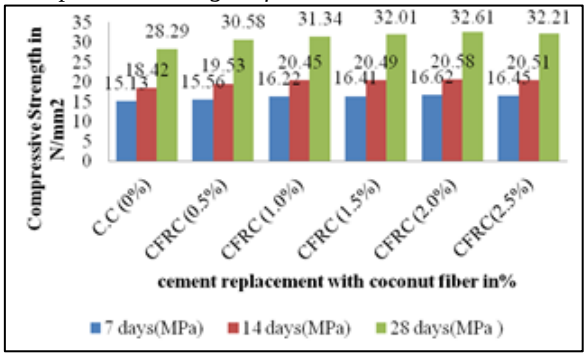

Fig 8: Compressive strength values of C.C and CFRC at 3, 7 and 28 days

a) Description:

- From the fig:8, It is observed that compressive strength of the concrete increases to 8.09%, 10.78%,13.14%,15.27% when % of fiber increases from 0.5% to 2.0% for CFRC when it is compared with conventional concrete at 28 days.
- It is observed that compressive strength values decreased as the percentage of fibers increases beyond 2.0%.

2) Split tensile strength CFRC

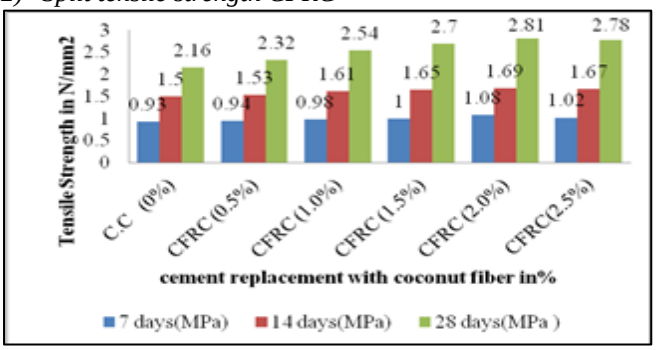

Fig. 9: Split tensile strength values of C.C and CFRC at 7, 14 and 28 Days

a) Description:

- From the fig:9, It is observed that split tensile strength of the concrete increases to 7.40%, 17.59%,25%,30.09%when % of fiber increases from 0.5% to 2.0% for CFRC when it is compared with conventional concrete at 28 days.
- It is observed that split tensile strength values decreased as the percentage of fibers increases beyond 2.0%.

3) Flexural Strength of CFRC

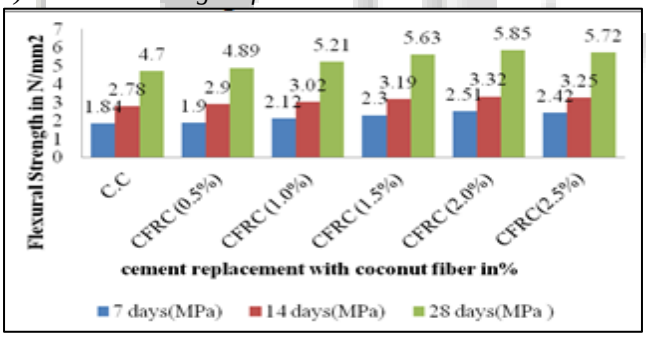

Fig 10: Flexural strength values of C.C and CFRC at 7, 14 and 28 Days

a) Description:

- From the fig:10, It is observed that flexural strength of the concrete increases to 4.04%, 10.85% ,19.78%,24.46%when % of fiber increases 0.5% to 2.0% for CFRC when it is compared with conventional concrete at 28 days.
- It is observed that flexural strength values decreased as the percentage of fibers increases beyond 2.0%.

IV. COST COMPARISON

A. Cost Comparison of C.C pavement with FRC Pavement

A cement concrete pavement is to be laid with following dimensions. Quantity and cost of each material for that stretch is calculated and compared for conventional concrete and polyester fiber reinforced concrete in this section.

1) Cost for conventional concrete

Length of the pavement = 1m.
Width of the pavement = 3.75m.
Thickness of the pavement = 31cm.
Total volume of concrete required to fill the surface course = L×b×h.
= 1m×3.75m×0.31m.
=1.162m^3.

S. no.	Material	Quantity (kg)	Rate per kg in Rs.	Cost in Rs.
1	Cement	348.6	6.4	2231.04
2	Fine aggregate	856.6	0.5	428.3
3	Coarse aggregate (20mm)	870.1	1.24	1070.924
4	Coarse aggregate (10mm)	580.07	0.80	464.056
5	Super plasticizer	2.52	60	151.2

Table 5: Estimation of materials for conventional concrete

Total cost in Rupees for 1.162m^3 of concrete for a stretch of 1m×3.75m×0.31m = 4345.52 /-

2) Cost for polyester fiber reinforced concrete

Length of the pavement = 1m.
Width of the pavement = 3.75m.
Thickness of the pavement = 25cm.
Total volume of concrete required to fill the surface course = L×b×h.
= 1m×3.75m×0.25m.
=0.937m^3.

S. no.	Material	Quantity (kg)	Rate per kg in Rs.	Cost in Rs.
1	Cement	276.88	6.4	1772.032
2	Fine aggregate	690.78	0.5	345.39
3	Coarse aggregate (20mm)	701.62	1.24	870.00
4	Coarse aggregate (10mm)	467.75	0.80	374.2
5	Super plasticizer	2.033	60	121.98
6	Fibers (polyester)	4.21	400	5167.60

Table 6: Estimation of materials for PFRC

Total cost in Rupees for 0.937 m^3 of concrete for a stretch of 1m×3.75m×0.25m = 8651.2 /-

3) Cost for coconut fiber reinforced concrete

Length of the pavement = 1m.
Width of the pavement = 3.75m.
Thickness of the pavement = 29cm.
Total volume of concrete required to fill the surface course = L×b×h.
= 1m×3.75m×0.29m.
=1.0875m^3.

S.no.	Material	Quantity (kg)	Rate per kg in Rs.	Cost in Rs.
1	Cement	319.725	6.4	2046.24
2	Fine aggregate	801.73	0.5	400.86
3	Coarse aggregate (20mm)	814.3	1.24	1009.73
4	Coarse aggregate (10mm)	542.87	0.80	434.29
5	Super plasticizer	2.35	60	141
6	Fibers(coconut)	6.52	7	45.64

Table 7: Estimation of materials for CFRC

Total cost in Rupees for 1.0875m^3 of concrete for a stretch of 1m×3.75m×0.29m = 4162.9 /-

V. CONCLUSIONS

1) It is observed that the concrete slump values are decreasing with the increasing fiber percentage. The reduction in slump with the increase in the fiber will be attributed to presence of fibers which causes obstruction to the free flow of concrete.
2) It is observed that the optimum dosage of polyester fiber is 1.5% and coconut fiber is 2.0%.
3) From the results it is observed that 0.5% addition of polyester fiber increases the compressive, split tensile and flexural strength by 12.54%, 15.27% and 19.36% respectively, when it is compared with conventional concrete with the same fiber content at 28 days.
4) From the results it is observed that 1.0% addition of polyester fiber increases the compressive, split tensile and flexural strength by 16.64%, 31.94% and 26.38% respectively, when it is compared with conventional concrete with the same fiber content at 28 days.
5) From the results it is observed that 1.5% addition of polyester fiber increases the compressive, split tensile and flexural strength by 24.14%, 62.96% and 53.40% respectively, when it is compared with conventional concrete with the same fiber content at 28 days.
6) From the results it is observed that 0.5% addition of coconut fiber increases the compressive, split tensile and flexural strength by 8.09%, 7.40% and 4.04% respectively, when it is compared with conventional concrete with the same fiber content at 28 days.
7) From the results it is observed that 1.0% addition of coconut fiber increases the compressive, split tensile and flexural strength by 10.78%, 17.59% and 10.85% respectively, when it is compared with conventional concrete with the same fiber content at 28 days.
8) From the results it is observed that 1.5% addition of coconut fiber increases the compressive, split tensile and flexural strength by 13.14%, 25% and 19.78% respectively, when it is compared with conventional concrete with the same fiber content at 28 days.
9) From the results it is observed that 2.0% addition of coconut fiber increases the compressive, split tensile and flexural strength by 15.27%, 30.09% and 24.46% respectively, when it is compared with conventional concrete with the same fiber content at 28 days
10) Addition of polyester fiber of 1.5% in concrete results in decrease of pavement thickness by 19.36%
11) Addition of coconut fiber of 2.0% in concrete, the pavement thickness is decreased by 6.41%
12) Construction cost of the pavement is increased by 49.77% by using polyester fiber
13) Construction cost of the pavement is reduced by 4.20% by using coconut fiber.

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