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An experimental study on coconut fibre reinforced concrete with partial replacement of fine aggregate by plastic waste

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Abstract - *This project gave us an idea of how we can use naturally available raw materials like coconut fibres to increase the tensile strength of the concrete and also partially replace fine aggregates by plastic waste and obtain an economical and eco-friendly concrete. Also the concrete obtained with optimum usage of coconut fibres and plastic waste is workable and can be employed in the future. In this experimental study, coconut fibres in the range of 2.5%, 5% and 7.5% was added to the concrete and fine aggregate was replaced by 5%, 10% and 15% of plastic waste for M-20 grade concrete. The various tests like slump test for determining the workability and tensile strength test and compressive strength test were carried out. The results show that increase in coconut fibre percentage increases strength and decreases workabilty, whereas, increase in plastic waste decreases strength as well as workability. The optimum strength was obtained for concrete with 7.5% addition of coconut fibre by mass of cement and 5% replacement of fine aggreagte by plastic waste.*

Key Words: Coconut fibres, Plastic waste, Workability , Split tensile strength, Compressive strength.

1. INTRODUCTION

Concrete is the most widely used construction material all over the world. Concrete is nothing but the mixture of cement, fine aggregate, coarse aggregate, water etc with proper proportion. Since concrete is weak in tension and flexure and good in compression. Concrete is typically reinforced with steel or synthetic fibres like carbon, glass. Despite their advantages the high material costs, the high energy consuming process by the production and their adverse environmental impact has initiated the search of new environmental friendly and sustainable alternatives. Researchers have used natural fibres as an alternative for steel or synthetic fibres in concrete. Natural fibres include coconut, sisal, jute, date, palm, bamboo, cotton, sugarcane fibres etc. They are cheap and locally available. Compared to steel fibres, they are also easy to use or handle because of their flexibility, especially when high percentage of fibres is involved. They are biodegradable, non-abrasive and there is no concern with health and safety during handling. When fibres are added to concrete it is called fibre reinforced concrete. Fibre reinforced concrete is known for its tensile properties. Natural fiber such as coconut fiber has certain physical and mechanical characteristics that can be utilized effectively in the development of reinforced concrete material. Coconut fibre is extracted from the outer shell of a coconut. There are two types of coconut fibres, brown fibre extracted from matured coconuts and white fibres extracted from immature coconuts. Coconut fibres are stiff and tough and have low thermal conductivity. In engineering, brown fibres are mostly used. In most cases, coconut fibers are dumped as agricultural waste so can be easily available in large quantity hence making them cheap. The advantage of using such fibres provides generally a low cost construction and the elimination of the need for waste disposal in landfills. Utilization of these fibres in concrete leads to an effective solid waste management technique. The introduction of fibres is a solution to develop concrete with enhanced compressive strength and split tensile strength, which is a new form of binder that could combine portland cement in bonding with cement. Coconut fiber being low in density reduces the weight of the fiber reinforced concrete. Cement, sand and aggregate are essential needs for any construction industry. Fine aggregate (sand) is a major material used for preparation of mortar and concrete and plays a major role in mix design. In general, consumption of natural sand is high, due to large use of concrete and mortar. Hence the demand of natural sand is high in developing countries to satisfy the

rapid infrastructure growth. In the present scenario the scarcity of fine aggregate is increasing day by day, in order to counteract this problem, fine aggregate is partially replaced by plastic waste material. In recent time significant research is underway to study the possibility of disposal of these wastes in mass concrete where strength of concrete may not be major criteria under consideration, such as heavy mass of concreting in PCC in pavements. If plastic wastes can be mixed in the concrete mass in some form, without significant effect on its other properties or slight compromise in strength, we can consume large quantities of plastic waste by mixing it in the concrete mass. Plastic is one component of municipal solid waste (MSW) which is becoming a major research issue for its possible use in concrete especially in self compacting concrete and light weight concrete. Although some of these materials can be beneficially incorporated in concrete, both as part of the cementitious binder phase or as aggregates, it is important to realize that not all waste materials are suitable for such use. Disposal of plastic waste in an environment is considered to be a big problem due to its very low biodegradability and presence in large quantities. Use of plastic has a dual advantage. By reusing waste plastic as a sand-substitution aggregate in concrete gives a good approach to reduce the cost of materials and solve some of the solid waste problems posed by plastics. The proposed concrete which is made up by adding plastic in concrete may help to reuse the plastic bag as one of the constituent's material of concrete, to improve the certain properties of concrete. With partial replacement of fine aggregate by plastic wastes and the use of coconut fibres in concrete, this concrete thus obtained can be economical and eco-friendly.

1.1 Objectives of Study

The objectives of this project are:

1. To optimize partial replacement of fine aggregate by plastic waste based on strength criteria.
2. To determine the effect of coconut fibres on the tensile properties of concrete.
3. To effectively recycle the plastic waste for eco-friendly concrete.
4. To decrease the environmental pollution by reusing the hazardous waste material.
5. To estimate the cost-effectiveness by using plastic waste and coconut fibres.

2. MATERIALS AND METHODOLOGY

The different properties of the raw materials used in the concrete have great influence on the characteristic strength of the concrete. Therefore, is it of utmost important to conduct basic material tests on the raw materials used for concrete. The following are the materials used for the concrete:

1. Cement
2. Fine aggregate
3. Coarse aggregate
4. Coconut fibre
5. Plastic waste
6. Water

2.1 Cement

The type of cement to be used for this experiment is ordinary Portland cement of grade 53. Cement is a binding substance that is used for construction which hardens, sets and adheres to all other materials and binds them together. The basic tests were conducted on cement to know the physical properties such as specific gravity, standard consistency and initial setting time as per standard procedure. The physical properties of cement are tabulated in the Table -1.

Table -1 Physical properties of Cement

Properties	Values
Specific gravity	3.1
Standard consistency	33%
Initial setting time	33 minutes

2.2 Fine Aggregate

The main function of fine aggregates in concrete is to fill the voids of the coarse aggregate and to operate as a workability agent. Basically, fine aggregate fills up the spaces left in-between the larger particles

present in the concrete and locks the larger particle together. The river sand of size below 2.36 mm was used as fine aggregate in this experimental work. The basic physical properties of fine aggregate are tabulated in Table -2.

Table -2 Physical properties of Fine Aggregate

Properties	Values	Test conforming to
Specific gravity	2.6	IS 2368 (Part III)-1963
Water absorption	0.9 %	
Sieve analysis	Zone II	IS 383-1970

2.3 Coarse Aggregate

Crushed stone or gravel particles that are 10mm down-size is used. The major reason for the usage of coarse aggregate is to fill up the larger voids and thereby decrease the amount of cement paste required and reduce the shrinkage that might occur in the future. The basic physical properties of coarse aggregate are tabulated in Table -3 conforming to IS 2386 (Part III) -1963.

Table -3 Physical properties of Coarse Aggregate

Properties	Values	IS code requirements
Specific gravity	2.79	–
Water absorption	0.2 %	0.6 % maximum
Aggregate impact value	8.975 %	< 10 % exceptionally strong

2.4 Coconut Fibres

Coconut fibre is a natural fibre extracted from the husk of coconut and can be used in concrete as reinforcement to increase tensile properties. The basic physical properties of coconut fibres are tabulated in Table -4.

Table-4 Physical properties of Coconut Fibres

Properties	Values
Specific gravity	0.25
Water absorption	0.25 %

2.5 Plastic Waste

Plastic Waste is obtained by shredding plastic from Plastic Shredding Machine. The plastic waste are of size less than 1 cm. Plastic Waste is used as a partial replacement to sand in concrete.

Table -5 Physical properties of Plastic Waste

Properties	Values
Specific gravity	0.58

2.6 Water

Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. Portable water is generally considered satisfactory for mixing concrete. Portable water which is available in the concrete laboratory was used in this experimental work.

2.7 Concrete Mix Designations

The different properties of concrete depend up on the material properties, mixing method, compaction method, curing method etc. A mix design of M20 grade of concrete was calculated as per the guidelines of IS10262-2009 with constant water-cement ratio of 0.5 according to the properties obtained from test results for this research work. The mix design for CFRC was the same as that of plain concrete, except more water was added because of fibre addition to make CFRC workable and different contents of fibres

were added and the same amount of aggregates was deducted from the total mass of aggregates. All materials were taken by mass of cement. Trial mixes of 2.5%, 5% and 7.5% of coconut fibres by mass of cement was calculated. Also, trial mixes of 5%, 10%, and 15% of fine aggregate replacement with plastic was calculated. In order to compare the results of various concrete mixes, control mix was made without the replacement of materials.

Table -6 Various Mix Designations

Mix Designations	Types of mixes
M	Control mix
M1	2.5%CF
M2	5%CF
M3	7.5%CF
M4	7.5% CF + 5% PW
M5	7.5% CF + 10% PW
M6	7.5% CF + 15% PW

2.8 Results and Discussions

The various basic material tests were conducted and concrete tests like compressive strength test and tensile strength test were conducted on various concrete mixes to know the strength of the concrete in this experimental study. The various test results obtained from these tests are tabulated in table as well as in the graphical form.

2.8.1 SLUMP TEST RESULTS

Slump Test is conducted for various concrete mix containing coconut fibre. The study on slump test helps us to know the amount of water required to obtain a concrete mix with good workability. The slump value for concrete with 2.5%, 5%, 7.5% coconut fibre and concrete having 7.5% coconut fibre with 5%, 10%, 15% plastic waste is obtained.

Table -7 Slump values of various concrete mixes

Mix Designations	Slump (mm)
Control Mix	72
2.5% CF	58
5% CF	45
7.5% CF	33
7.5% CF + 5% PW	30
7.5% CF + 10% PW	22
7.5% CF + 15% PW	13

The control mix has a slump value of 72 mm. It is observed that concrete with 2.5% coconut fibre has better slump than 5% and 7.5%. Also, with increase in the amount of coconut fibre, the slump decreases. Thus, lesser the amount of coconut fibre better will the workability. It is observed that concrete with 7.5% coconut fibre and 5% plastic waste has better slump than 7.5% coconut fibre with 10% plastic waste and 7.5% coconut fibre with 15% plastic waste. Also, with increase in the amount of plastic waste, the slump decreases. Thus, lesser the amount of plastic waste better will the workability.

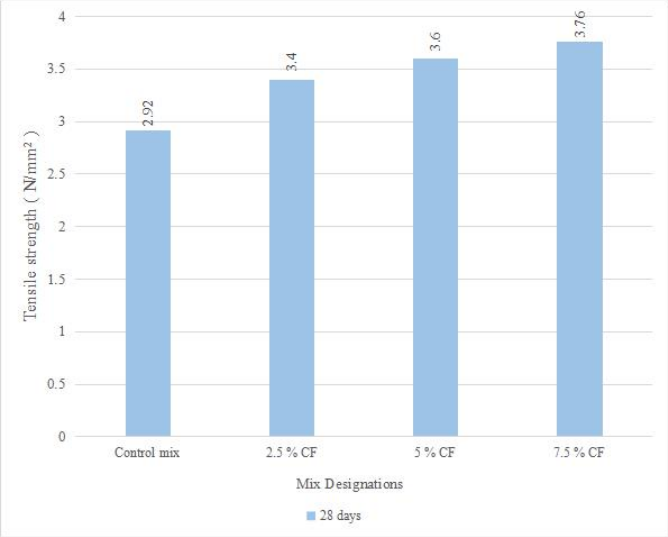
2.8.2 SPLIT TENSILE STRENGTH TEST RESULTS

Split tensile strength test for 28 days was conducted on various concrete specimens in order to know the tensile property of concrete consisting of coconut fibres. It is important to know the tensile strength of the concrete since it acts as a resistance towards the tensile stresses acting on it. The test was carried out on cylindrical specimen of diameter 150 mm and height 300 mm and was tested in Compressive Testing Machine (CTM) between the 2 plates. The load was gradually applied until the specimen fails. The peak load of the various concrete is tabulation in Table -8 and graphically represented in Figure -1.

Table -8 Tensile strength of various concrete mix containing coconut fibres

Mix designations	Compressive strength (N/mm^2), **28 days**
Control mix	2.96
2.5%CF	3.4
5%CF	3.6
7.5%CF	3.76

Figure -1 Tensile strength of various concrete mix containing coconut fibres



The split tensile strength of various concrete mix containing coconut fibres 2.5% , 5% , 7.5 % and control mix is represented in the Figure 6.3. From the figure it is known that tensile strength of concrete consisting of coconut fibres is more than the control mix. Also, with increasing amount of coconut fibre the tensile strength increases. The tensile strength obtained for concrete mix containing 7.5 % coconut fibre is more than 5 % and 2.5 %. Therefore, concrete containing 7.5 % coconut fibre is having maximum tensile strength.

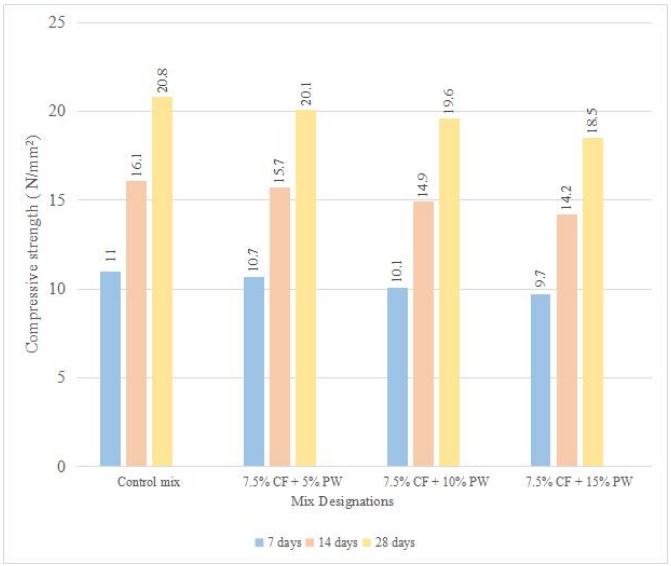
2.8.3 COMPRESSIVE STRENGTH TEST RESULTS

Compressive strength test for 7 days was conducted on various concrete specimens in order to know the compressive property of concrete consisting of coconut fibres and plastic waste. It is important to know the compressive strength of the concrete since it acts as a resistance towards the compressive stresses acting on it. The test was carried out on rectangular block of length 19.6 mm, width 9.7 mm and height 5.3 mm and was tested in Compressive Testing Machine (CTM) between the 2 plates. The load was gradually applied until the specimen fails. The peak load of the various concrete is tabulation in Table -9 and graphically represented in Figure 2.

Table -9 Compressive strngth of various concrete mixes at 7, 14 and 21 days.

Mix designations	Compressive strength (N/mm^2)		
	7 days	**14 days**	**28 days**
Control mix	11	16.1	20.8
7.5%CF+5%PW	10.7	15.7	20.1
7.5%CF+10%PW	10.1	14.9	19.6
7.5%CF+15%PW	9.7	14.2	18.5

Figure -2 Compressive strength of various concrete mixes at 7, 14 and 21 days



The compressive strength of various concrete mix containing coconut fibres 7.5% with plastic waste of 5% , 10% and 15% control mix is represented in the Figure -4. From the figure it is known that compressive strength of concrete consisting of coconut fibres and plastic waste is less than the control mix. Also, with increasing amount of plastic waste the compressive strength decreases. The compressive strength obtained for concrete mix containing 7.5% coconut fibre with 5 % plastic waste is more than 7.5% coconut fibre with 10% and 15% plastic waste. Therefore, concrete containing 7.5% coconut fibre and 5% plastic waste is having maximum compressive strength.

3. CONCLUSION

i. The addition of coconut fibres in the concrete, increase the tensile strength of the concrete pavement block as amount of coconut fibres increase. Although, due to the fibrous nature of coconut fibre the workability decreases with increase in amount of coconut fibre. The concrete pavement block is cost effect since coconut fibres are freely available.

ii. The replacement of fine aggregate by plastic waste in the coconut fibre reinforced concrete, shows slight reduction in compressive strength and workability. However, it shows enough sustainability against stress acting on it. Also, concrete pavement block is proved to be cost effective. Thus, plastic waste proves to be a good replacement for fine aggregate.

iii. The study shows that concrete pavement block containing 7.5% of coconut fibre and 5% of plastic waste is cost effective and has maximum tensile strength, compressive strength and workability. Thus, pavement block with addition of coconut fibre and partial replacement of fine aggregate by plastic waste is sustainable.

iv. Since the experimental study on concrete pavement block is based on utilizing waste materials like coconut fibre and plastic waste, which otherwise is burnt or thrown away, the concrete pavement block thus reduced environmental pollution.

v. Plastic waste which is hazardous material has faced many problems in its disposal, is being re-used in the concrete pavement block, thus making the pavement block eco-friendly and cost effective.

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