Evaluation of natural and artificial fibre reinforced concrete using waste materials

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***Abstract*- Considering global warming issues in the environment, recently there has been a rapid growth in research and innovation in the natural fiber composite (NFC) area. Interest is warranted due to the advantages of these materials compared to others, such as synthetic fiber composites, including low environmental impact and low cost and support their potential across a wide range of applications. Much effort has gone into increasing their mechanical performance to extend the capabilities and applications of this group of materials. In this research paper aims to provide an overview of the factors that affect the mechanical performance and durability performance of artificial fiber composite & natural fiber composite and details achievements made with them. Researchers have conducted studies on the effect of natural fibers on the mechanical and physical behavior of concrete to investigate the extent of improvement. The composite achieved considerable strength and toughness of the composite.**

***Keywords*- Artificial fibre reinforced concrete, Waste Materials, Synthetic Fiber, Natural Fiber, Concrete**

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I. INTRODUCTION

I.1 GENERAL INTRODUCTION

The construction industry is developing with the invention of different materials to make tasks efficient; reduce time and cost; improve durability, quality and performance of structures during their life time. This leads to the development of special concrete such as polymer concrete for high durability, fiber reinforced concrete for preventing cracks in concrete, high and ultrastrength concrete for applications in tall buildings and bridges, light weight concrete for reducing foundation loads and high performance concrete for special performance requirements. Since Ethiopia"s share in the annual fiber reinforced concrete production is null, this thesis concerns about developing fiber reinforced concrete.

Fibres are thread like materials which can be used for different purposes. Fibres produced by plants (vegetable, leaves and wood), animals and geological processes are known as natural fibres. Researchers have used plant fibres as an alternative source of steel and/or artificial fibres to be used in composites (such as cement paste mortar and/or concrete) for increasing its strength properties. These plant fibres, herein referred as natural fibres, include coir, sisal, jute, Hibiscus cannabinus, eucalyptus grandis pulp, malva, ramie bast, pineapple leaf, kenaf bast, sansevieria leaf, abaca leaf, vakka, date, bamboo, palm, banana, hemp, flax, cotton and sugarcane.

Waste materials in the form of polyethylene and tires cause environmental pollution which leads to various health problems. Polyethylene and waste tires can be recycled and used effectively in the concrete as reinforcement in the fiber form. Polyethylene is a synthetic hydrocarbon polymer which can improve the ductility, strength, shrinkage characteristics etc.

1.2 OBJECTIVES OF THE PROJECT

- The present work is aimed at using two polymeric waste materials, such as polyethylene and tire fibers as reinforcement in concrete.
- The study investigates various properties of fresh and hardened mortar reinforced with natural fibers (jute) and synthetic fibers.
- The general objective of this study is to characterize the physical and mechanical properties in the hardened state and list the benefits obtained by the concept of jute fiber reinforced concrete over conventional reinforced concrete by studying the effect of fiber on the compressive strength.
- The main goal of the study is to utilize waste materials polyethylene and tire to achieve greater concrete strength properties in order to recycle them into something very useful and helping in reducing the environmental impact that the both of them have.

II. LITERATURE REVIEW

Amit Rai and Dr. Y.P Joshi [1] reported that FRC is an effective way to increase toughness, shock resistance and resistance to plastic shrinkage cracking of the mortar. These fibers have many benefits. Steel fibers can improve the structural strength to reduce the heavy steel reinforcement requirement. Freeze thaw resistance of the concrete is improved. Durability of the concrete is improved to reduce in the crack widths. Polypropylene and Nylon fibers are used to improve the impact resistance. Many developments have been made in the fiber reinforced concrete and Fiber addition improves ductility of concrete and its post-cracking load-carrying capacity.

A.M. Shende et. al. [2] introduced Steel fibres of 50, 60 and 67 aspect ratio. Result data obtained has been analyzed and compared with a control specimen (0% fibre). A relationship between aspect ratio vs. Compressive strength, aspect ratio vs. flexural strength, aspect ratio vs. Split tensile strength represented graphically. It is observed that compressive strength, split tensile strength and flexural strength are on higher side for 3% fibres as compared to that produced from 0%, 1% and 2% fibres. All the strength properties are observed to be on higher side for aspect ratio of 50 as compared to those for aspect ratio 60 and 67. It is observed that compressive strength increases from 11 to 24% with addition of steel fibres.

G. Murali et. al. [3] studied the influence of addition of waste materials like lathe waste, soft drink bottle caps, empty waste tins, waste steel powder from workshop at a dosage of 1% of total weight of concrete as fibres. The lathe waste, empty tins, soft drink bottle caps were deformed into the rectangular strips of 3mm width and 10mm length. Experimental investigation was done using M25 mix and tests were carried out as per recommended procedures by relevant codes. The results were compared with conventional concrete and it was observed that concrete blocks incorporated with steel powder increased its compressive strength by 41.25% and tensile strength by 40.81%. Soft drink bottle caps reinforced blocks exhibited an increase in flexural strength of concrete by 25.88%. The specimen with steel powder as waste material was found to be good in compression which had the compressive strength of 41.25% more than the conventional concrete.

R. Kandasamyand R. Murugesan [4] studied the influence of addition of polythene fibbers (domestic waste plastics) at a dosage of 0.5% by weight of cement. The properties studied include compressive strength and flexural strength. The studies were conducted on a M20 mix and tests have been carried out as per recommended procedures of relevant codes It was concluded that it increases the cube compressive strength of concrete in 7 days to an extent of 0.68%, increases the cube compressive strength of concrete in 28 days to an extent of 5.12%, increases the cylinder compressive strength of concrete in 28 days to an extent of 3.84% increases the split tensile strength to an extent of 1.63% and the increase in the various mechanical properties of the concrete mixes with polythene fibers is not in same league as that of the steel fibres.

III. PROPOSED METHODOLOGY

Use of Waste polyethylene and tires:

Plastics are very strong and non-biodegradable in nature. The chemical bonds in plastics make it extremely sturdy and impervious to ordinary common techniques of degradation. The daily use of plastics has increased very rapidly and it has become a common habit of people to just throw out the plastic and causing environmental pollution. Over 1 billion tons of plastic have been produced since 1950s, and the same is likely to remain as such for many years. These wastes get mixed with MSW or they are simply thrown causing nuisance to the society. There is a big need of recycling of the plastics as well waste tires because we don't have any other option of disposing them without securing environment from pollution. For example, there are two processes for the disposal of wastes: land filling and incineration. If the wastes are simply dumped, they cause soil and water pollution and if they are incinerated, they cause air pollution. Hence, there is a need to recycle the wastes into something useful which will not hamper the environment and the process in which it is used.

Jute:

Jute is one of the natural fibers to reinforce the concrete. It is an important bast fiber with a number of advantages. It has high specific properties, low density, less abrasive behavior to the processing equipment, good dimensional stability and harmlessness, abundant available, easy to transport, has superior moisture retention capacity. Being made of cellulose on combustion, jute does not generate toxic gases. Due to its low density combined with relatively stiff and strong behavior, the specific properties of jute fiber can be compared to those of glass and some other fibers. Its production needs much less energy. It can be substitute of asbestos cement composite, which is a serious hazard to human and animal health and is prohibited in industrial countries.

Methodology:

In this experimental study, Cement, sand, coarse aggregate, water and natural & artificial fibers were used.

1. Cement: Ordinary Portland cement of 53 grade was used in this experimentation conforming to I.S12269: 1987
2. Coarse aggregates: Locally available, maximum size 20 mm, specific gravity 2.79
3. Sand: Locally available sand zone I with specific gravity 2.28, water absorption 2% and fineness modulus 2.92, conforming to I.S. – 383-1970.
4. Water: Potable water was used for the experimentation.
5. Chemical Admixture Type: Super Plasticizer
6. In case of natural fiber reinforced concrete fibers are added. For this experiment 2 types of fiber are chosen. The fibers to be used in the concrete mix are: Jute
7. In case of polymer fiber reinforced concrete fibers are added. For this experiment 2 types of fiber are chosen. The fibers to be used in the concrete mix are:

1. Polyethylene fiber
2. Tire (Nylon) fiber

Material Used-

AGGREGATE: Aggregates are inert granular materials such as sand, gravel or crushed stone that, along with water and Portland cement, are an essential ingredient in concrete. For a good concrete mix, aggregates need to be clean, hard, strong particles free of absorbed chemical or coatings of clay and other fine materials that could cause the deterioration of concrete. The purpose of the aggregates within this mixture is to provide a rigid skeletal structure and to reduce the space occupied by the cement paste. Both coarse aggregates (particle sizes of 20mm to 4.75 mm) and fine aggregates (particle sizes less than 4.75 mm) are required but the proportions of different sizes of coarse aggregate will vary depending on the particular mix required for each individual end use. The mere fact that the aggregates occupy 70-80 per cent of the volume of concrete, their impact on various characteristics and properties of concrete is undoubtedly considerable

COARSE AGGREGATE:

Aggregates most of which retained on 4.75-mm BIS Sieve are known as coarse aggregates. The various types of coarse aggregates described as:

● Uncrushed gravel or stone which results from natural disintegration of rock.

● Crushed gravel or stone when it results from crushing of gravel or hard stone.

● Partially crushed gravel or stone when it is a product of the blending of above two The graded coarse aggregate is demarcated by its nominal size i.e. 40 mm, 20 mm, 16 mm and 10 mm.

CEMENT: The Portland pozzolana cement is a kinker blended cement which is produced by either intergrinding of OPC clinker along with gypsum and pozzlanic materials in certain proportions or grinding the OPC clinker,gypsum and pozzolanic material separately and thoroughly blending them in certain proportions. Pozzolana is a natural or artificial material containing silica in a reactive form. It may be further discussed as siliceous or siliceous and aluminous material which in itself possesses little, or no cementitious properties but will in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties. It is essential that pozzolana be in a finely divided state as it is only then that silica can combine with calcium hydroxide (liberated by the hydrating Portland cement) in the presence of water to form stable calcium silicates which have cementitious properties.

FINE AGGREGATE (SAND): Aggregates most of which passes 4.75-mm BIS Sieve known as fine aggregates.

● **Natural sand** - Fine aggregates resulting from the natural disintegration of rock and which have been deposited by streams or glacial agencies.

● **Crushed stone sand** - Fine aggregates produced by crushing hard stone.

● **Crushed gravel sand -** Fine aggregates produced by crushing natural gravel. According to the size, the fine aggregates may be classified as coarse, medium or fine aggregates. Depending upon the particle size distribution, the fine aggregates are divided into four grading zones as per BIS: 383-1970 that are zone I, zone II, zone III and zone IV. The grading zones become finer from grading zone I to grading zone IV. The sand confirming to zone II was used.

WATER: Fresh and clean tap water was used for casting the specimens in the present study. The water was relatively free from organic matter, silt, oil, sugar, chloride and acidic material as per BIS: 456-2000.

ADMIXTURES: The admixture is a chemical compound mixed with other ingredients of concrete before or during mixing to make concrete achieve certain required properties. Chemical admixtures are generally used for following reasons:

- Reduce the cost of construction.
- Modify properties of hardened concrete.
- To retain quality of mix during transportation and placing.
- Achieve certain properties after or before time.

FIBERS: These are short discrete materials, may be metallic or polymeric, used as composing reinforcement for concrete structures. These are mixed with other components of concrete to form the matrix and add certain properties to it. These are generally used to:

- Improve tensile strength
- Increase impact, crushing and abrasion resistance.
- Increase flexural and shear strength.
- Reduce the effect of temperature change on concrete.
- Polymer fibers are corrosion resistant and can be used in saline environment.

MATERIAL PREPARATION:

The materials used in the concrete mix are:

1. 53 grade OPC.
2. Zone – iii sand as fine aggregate.
3. 10mm and 20mm coarse aggregate.
4. Sikament – 170 admixture
5. Polyethylene fiber
6. Tire fiber
7. Jute

PREPARATION OF FIBERS-

The polythene used in Amul milk packets is used as raw material for preparation of the fiber. These polythene packets are collected; they are washed and cleaned by putting them in hot water for 3- 4 hours. They are then dried. Similarly waste tires are collected. The steel wires inside them are striped out of the tires. They are washed in hot water and then dried. The dried polyethylene packets and the tires are cut into pieces of size 30mm x 6mm size. This is to ensure that when the fibers are mixed with the cement and aggregate the mixing will be proper and the fibers will be randomly distributed over the concrete matrix evenly.

Jute fiber: Jute is a natural fiber. Jute fibers were collected from local market called Betul, The length of jute used in the reinforced concrete is 5mm, 15mm and 25mm manually cut by scissor.

MIX DESIGN:

The proportion of concrete mix is to be designed to ensure the workability of concrete and to make the concrete possess the required strength, toughness and durability at the hardened condition.
The design mixes M30, M35 and M40 are carried out in accordance to codes IRC 44:2008.
The specifications of material used are

1. Cement :- OPC 43 grade
2. Fine aggregate :- Zone 3
3. Coarse aggregate :- Crushed rock (10mm and 20mm)
4. Admixture :- Plasticizer

a. The water cement ratio for design was chosen in between 0.4 to 0.45.
b. The coarse aggregates 10mm and 20mm are used in ratio 90 to 10.
c. In case of fiber introduced concrete, the polyethylene fibers and tire fibers each are used in 1.5% v/v of concrete mass.

Table 3.1: Mix design

Grade of Concrete	Water	Cement	Fine Aggregate	Coarse Aggregate (10 mm)	Coarse Aggregate (20 mm)	Admixture
M30	0.45	1	2.1	3.06	0.34	0.019
M35	0.43	1	1.6	2.7	0.3	0.022
M40	0.4	1	1.8	2.7	0.3	0.023

Specific gravity of polyethylene = 0.94
Specific gravity of tire (without steel wires) = 1.14

For cubes of size 150mm x 150mm x 150mm

- Polyethylene fiber used = 47.56gms
- Tire fiber used = 57.65gms

Table 3. 2. Mix proportions for the Jute Fiber

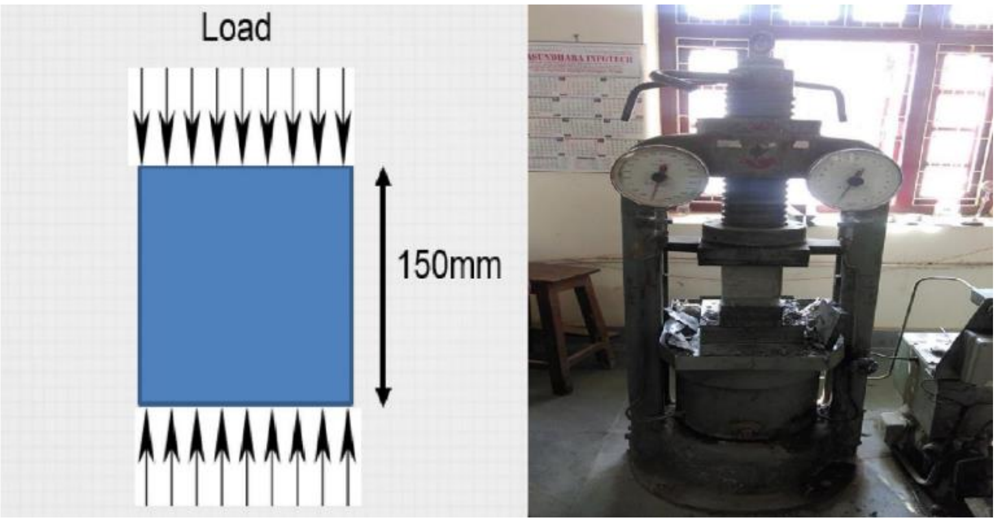
Mix designation	Cement quantity(kg/m³)	W/C Ratio	Water (liter/m³)	Fine aggregate (kg/m³)	Coarse aggregate (kg/m³)	Jute fiber(kg/m³)
Control	430	0.45	195	462	1274	0
L5V0.5	430	0.45	195	462	1274	215
L5V1	430	0.45	195	462	1274	430
L5V2	430	0.45	195	462	1274	860
V0.5L5	430	0.45	195	462	1274	215
V0.5L15	430	0.45	195	462	1274	215
V0.5L2	430	0.45	195	462	1274	215

For instance, a concrete mix designated by L5V0.5 is considered as a concrete mix with length 5mm which incorporates 0.5% of fiber volume and V0.5L15 designate concrete mix incorporating 0.5% of fiber volume with length of 15mm. the ratio of cement, sand and coarse aggregate were 1: 1.07: 2.96. The water content to cement ratio used for the mix was 0.45.

CASTING AND CURING:
Standard sized cubes (150mm x 150mm x 150mm) are casted for compression test of concrete.
A. Cubes
1. 3 numbers of M30 conventional concrete
2. 3 numbers of M35 conventional concrete
3. 3 numbers of M40 conventional concrete
4. 3 numbers of M30 fiber introduced concrete
5. 3 numbers of M35 fiber introduced concrete
6. 3 numbers of M40 fiber introduced concrete

TEST OF CONCRETE-

Compressive strength test: The compressive strength test is the most important test done on the concrete as it determines the characteristic strength of the concrete which represents the resistance of concrete against crushing load. The casted cubes are tested for compressive strength in the compression testing machine.



[Fig.3.1: Compressive strength test]

Procedure:

1. The bearing surface of the machine is cleaned.
2. The specimen is placed in the machine in such a manner that the load applied shall be to the opposite sides of the cube face towards the bearing.
3. The specimen is aligned centrally on the base plate of the machine.
4. The removable portion of the machine is rotated so that its bottommost part touches the surface of the cube.
5. The machine is started to apply load on the cube without any shock.
6. The load is applied continuously at a rate of 140Kg/cm^2/minute.
7. After the specimen fails, the load at failure is noted down
8. The removable part of machine is rotated in opposite direction and the broken sample is taken out of the machine.
9. The bearing surface of the machine is again wiped clean.

The similar testing is done for both conventional concrete and fiber introduced concrete cube specimens and their 28 days strength was calculated by formula:

fck = P/A

Where P = failure load

A = Surface area onto which load is applied

= 150mm x 150mm

= 22500mm^2

IV. RESULTS AND DISCUSSION

Table 4.1: Compressive strength of conventional concrete cubes

Grade of Concrete	Specimen No.	Failure Load (Tons)	Compressive Strength (N/mm^2)	Mean Compressive Strength (N/mm^2)
M30	1	83	36.89	
	2	84	37.31	37.17
	3	84	37.31	
M35	1	95	42.22	
	2	97	43.11	42.66
	3	96	42.66	
M40	1	104	46.22	
	2	108	48.00	46.96
	3	105	46.66	

Table 4.2: Compressive strength of fiber introduced concrete cubes

Grade of Concrete	Specimen No.	Failure Load (Tons)	Compressive Strength (N/mm^2)	Mean Compressive Strength (N/mm^2)	Strength Gain (%)
M30	4	99	44		
	5	99	44	43.85	17.93
	6	98	42.56		

M35	4	111	49.33		
	5	112	49.78	49.48	15.98
	6	112	49.78		
M40	4	124	55.11		
	5	122	54.22	54.57	16.1
	6	122	54.22		

Table 4.3: 14 day compressive strength results of mix series I for Jute Fiber Concrete

Mix Design	Mean 14th day Compressive Strength (MPa)	Standard deviation	Relative compressive strength, σ gain or loss (%)
Control	17.50	0.09	N/A
L5V0.5	23.30	1.00	33.14
L5V1	18.60	1.99	6.29
L5V2	16.70	0.57	-4.57

Table 4.4: 14 day compressive strength results of mix series II for Jute Fiber Concrete

Mix Design	Mean 14th day Compressive Strength (MPa)	Standard deviation	Relative compressive strength, σ gain or loss (%)
Control	17.50	0.09	N/A
V0.5L5	23.30	1.00	33.14
V0.5L15	12.92	1.19	-26.17
V0.5L25	11.50	0.31	-34.29

CONCLUSION

From the above study it may be concluded that the use of fibers in the concrete which is generated from agricultural activities in rural and urban areas construction material.it modifies beneficially the cracking behavior of concrete and cement matrices. This results in stronger, safe and economical structures in rural areas where these are freely and easily available. The workability is adversely affected by fibre addition. The fibre addition improves significantly the crack resistance. Also, the crack width is reduced. The fracture toughness of natural fibre composites is greatly improved. The compressive strength of natural fibre composites is not affected much upto certain fibre content. In general, the tensile strength of natural fibre composites is improved significantly. The fibre inclusion, in general, significantly improves the flexural strength and ductility of matrices. The bond of natural fibres in composites is satisfactory. The fibre inclusion greatly enhances the impact strength of composites.

The following inferences have been drawn from the experiments done on concrete with polyethylene and tire fibers:

1. There is a gain of 17.93%, 15.98% and 16.1% in compressive strength of M30, M35 and M40 grade concrete respectively.

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