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Study on Experimental Behavior of Plastic Based Fiber as Secondary Reinforcement in Concrete Pavement

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Abstract: Nowadays, the use of fibers of various materials such as polyethylene, polyester and polymer in concrete has increased extensively as reinforcement supplement material for production of high strength concrete. The incorporation of these material in concrete not only helps in improvement of desired properties of concrete but also helps in the mitigation of disposal issue of such non-biodegradable substances. Various such materials like plastics, different grades of single use polyethylene and rubber tyres cause environmental pollution which leads to environmental and health problems. Many of these can be used as supplement to reinforce the concrete such as PET and polyethylene in fibre form. In this paper the author has studied the effect of addition of mix of different proportion of polyethylene fibre (milk packet), PET (plastic bottle) and Recron 3S as replacement of fine aggregate on concrete properties such as compressive strength, flexural strength, split tensile strength, workability. The proportions of the mixtures used were based on the dry volume of cement (0%, 0.2%, 0.4% and 0.6%).
Keywords: LDPE, LLDPE, PET, RECRON 3S polyester fiber, Compressive Strength, Flexural strength test, Shear strength test.

I. INTRODUCTION

Since the invention of cement, concrete is the most abundantly used construction material all over the world. It is typically a mixture of cement, fine aggregate (generally sand) and coarse aggregate with different water content to produce a thick, workable mix which could be easily worked upon. It is practically irreplaceable by any other construction material due to its vast application across different construction projects throughout the world. concrete is so vastly used due to its properties such as excellent compressive strength, its ability to be molded in any shape, its flexural strength and tensile strength. Concrete is brittle in nature and thus adequate ductility is provided to it by use of reinforcement in form of steel rebars. Traditionally, concrete has low ductility, impact resistance, and abrasion resistance, and is prone to cracking on the surface due to its brittleness.

A. Properties of Cement

Cement is world's most common used man-made material, constituents used in its manufacture are limestone ($CaCO_3$), silica (SiO_2), alumina (Al_2O_3) and iron oxide (Fe_2O_3) at different proportion along with some special chemicals or ingredients depending upon the use of concrete. These substances are heated at high temperatures these very ingredients in solid form which is pulverized and mixed in form of fine powder referred to as cement. The main ingredient of cement is limestone which is used for long time as binding material since the time of Indus Valley civilization. Their towns were well known for their permanent house and excellent drainage system both of which used limestone extensively as binding material. Later, the technique of burning limestone was adopted by the Greeks and Romans further developed the addition of volcanic ash to burnt limestone to enhance its properties called pozzolana named after the city of Pozzuoli at the Bay of Naples, known for the best quality of flyash.

The essential properties of concrete include workability defined as ease with which freshly prepared concrete can be transported and placed under desired time and compacted to a dense mass. Workability is measured by different tests depending on the viscosity of concrete but generally the most common and widely accepted test method is slump test. Setting of concrete is then process when concrete changes it's state from fresh to hard. During the setting of concrete, the water present react with the different constituents of cement causing Also thermal shrinkage due to change in the temperature of concrete mix and surrounding and also within the concrete mass from the time of placing to hardening i.e., it will be fully installed. In addition, thermal expansion occurs when concrete is stacked in layers and the upper layer is poured before the lower layer is completely cured, causing thermal expansion of the lower layer. Finally, the water-cement ratio is defined as the ratio of water to cement in a mixture. Since an increase in the water-cement ratio reduces the strength of the concrete, this has a great effect on the concrete mixture.

B. Plastic Waste

Yearly plastic usage worldwide is presenting a global rise, triggering major environmental concerns owing to low biodegradability and abundance in plastic quantity. The cause for such growth can be attributed to the user-friendly properties of plastic such as strength, lightweight, durability, low density, long life, and low cost. Use of plastic has become an integral part of our lives, in industrial, automotive, packaging, medical delivery systems, housing and other uses. The future of our environment dependent largely on our ability to efficiently recycle and reduce the use of plastics. Recently, noticeable research is ongoing to look for the possibility of decreasing the plastic waste by including the properties of recycled plastics in concrete

It is estimated that approximately 100 million midsize tires reach the end of their life each year. According to UNEP Executive Director Inger Andersen, “By 2050, our landfills will contain about 1 billion tonnes of plastic. Change is needed." This statement represents the dangerous reality of this scenario. The COVID-19 pandemic has reduced our reliance on plastics and thus further undermined efforts to reduce plastic pollution. PPE kits, masks, gloves, disinfectants Mass production and disposal of dispensers, etc. Created a "Plastic Pollution Pandemic" scenario. Plastic production has increased exponentially in recent years, leading to a corresponding increase in plastic waste. Most of our plastic waste ends up in landfills or waterways. on figs. Figure 1.2 shows recent global plastics production. Since plastic has become an integral part of our lives, a sustainable solution to reducing plastic pollution is to reduce production and maximize recycling and reuse.

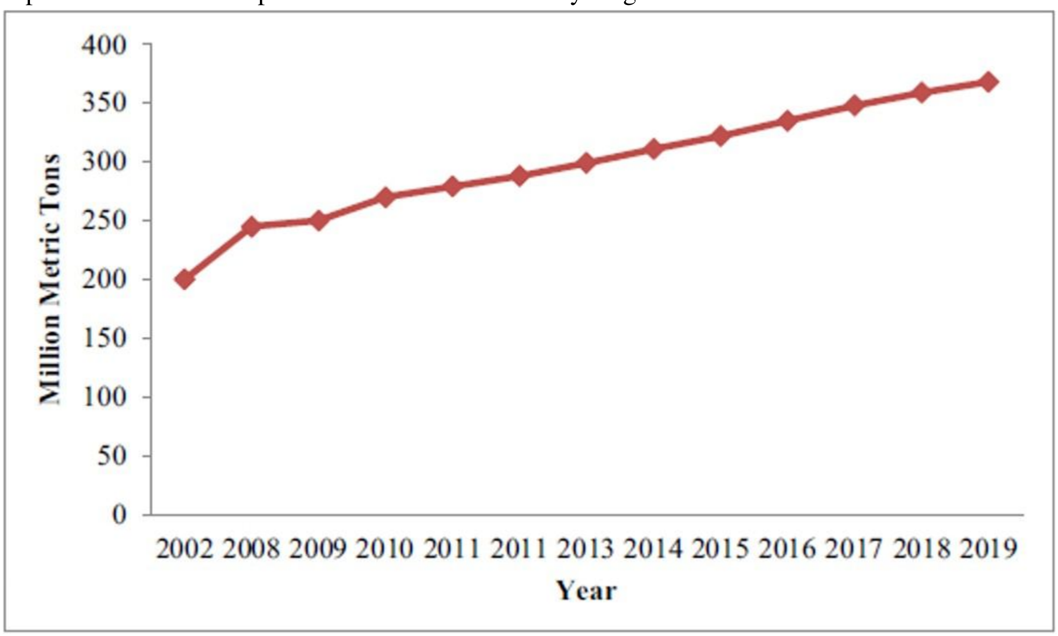

Fig. 1 Worldwide production of plastic

C. Problem with plastic waste

The biggest problem associated with plastic waste is its non-biodegradability, there is no perfect solution to the plastic materials that have worn out its useful life. For many years the reuse of plastic has been advocated as the solution but it has its limitations. In order to make plastic reusable many a time its form has to be changed or it has to undergo certain procedure such as cleaning and treating it with chemicals which ultimately create problems for the environment.

One of the most abundantly used method to deal with plastic waste worldwide is landfilling but it has its limitation and adverse effects too. Landfill areas are prone to toxic pollution rendering biodiversity present in area to plenish Also it contains toxic and soluble components also the possibility of accidental fires in such area is very deadly, plastic is flammable and when it burns uncontrollably it creates vast amount of greenhouse gases alongwith many poisonous and toxic gas which are very harmful for humans as well as flora and fauna around .After combustion, the plastic turns into a semi-solid-liquid state, which easily sticks to the surrounding material, the soil, and seeps through the ground surface into the groundwater supply, negatively affecting groundwater supplies and pipelines. Provides domestic water. But millions of tonnes of plastic have been buried in the ground for a long time, not only slowly destroying the environment, but also acting like a biohazard volcano that could erupt in a very unfavourable form on other days.

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D. Recycled plastic

Rubber Tyre wastes were previously used as paving material, however, only a part of these wastes can be recycled. Other alternatives are for formation of artificial reef but investigations presented this method not to ne so beneficial and useful Tyre waste could be used for cement manufacture in kilns for energetic purposes and for producing carbon black through tyre pyrolysis, thermal decomposition of these wastes without oxygen for producing by-products having low cost. Many research shows that replacing some quantity of aggregate in concrete with plastic material may result in more enhanced propertied of concrete such as ductility, water resistance, impact resistance, sound and thermal insulation etc., Rubber aggregates can be obtained from waste plastic by two different technologies first by mechanical grinding (at ambient temperature) or cryogenic grinding i.e.at temperatures below the glass transition temperature. The first method obtains rubber crumb instead of large aggregate, the second method obtains rubber crumb instead of fine aggregate. Since the demand for cement is likely to increase by several orders of magnitude with current construction rates around the world, this means that the amount of concrete will increase linearly, which is an excellent way to reuse PET waste.

E. Fiber Reinforcement

Adding pulp fibers is a common practice, used in old traditional structures. This is done primarily to reduce the brittleness of the hardened rock material. Fibers have been a viable option for concrete reinforcement for decades, and several studies have been conducted to verify the benefits of fibers in improving the mechanical properties of composites. Many other composite materials are gaining popularity due to their ductility and strain hardening properties. In order to improve the behavior after cracking, irregular short fibers are mixed with normal concrete.

Adding fibers can improve post-peak ductility, tensile strength before cracking, breaking strength, toughness, impact strength, flexural strength, fatigue strength, etc. The ductility of VVK depends on the ability of the fibers to crack as strain increases. The addition of polypropylene fibers reduces the unit weight of concrete, thereby reducing the concrete's own weight and providing increased strength. Along with natural fibers such as horsehair and straw, short fibers have been used for centuries to strengthen fragile materials such as cement and bricks. Today, a large number of different types of fibers are commercially available. Some basic materials are steel, glass, synthetic materials (polypropylene, carbon, nylon, etc.) and a small amount of natural fibers. With steel fibers, steel wire and metal clips were first used to improve the properties of concrete in the early 1900s. Research into the use of steel fibers as additives began around the 1960s and since then there has been considerable growth in research, development, application and commercialization. Typically, the fiber volume in steel fiber reinforced concrete (SFRC) is about 0.

5% to 1.5%. When the proportion of SFRC is (<1%), the compressive, tensile and flexural strengths increase slightly, since the concrete matrix essentially cracks under the same stresses and strains as ordinary concrete.

Fig. 2 Types of fiber reinforcement

II. PROBLEM IDENTIFICATION

Since the inception of concrete as a building material, researchers have attempted to improve its performance by making it more durable, resilient, environmentally friendly and cost-effective, and with the advent of advanced technologies to fundamentally improve the performance of the concrete, to understand and improve concrete The application of characteristic fibers in concrete as a reinforcing material has begun. There are many varieties of fibers available, which have been developed for use in laboratories, but their range is limited due to the time and effort required to research and produce such modern fibers, making them not only expensive but also environmentally unsustainable. The best way to solve this problem is to use environmentally harmful materials that are good for us. This approach solves many problems at the same time, such as those related to improving the properties of concrete, eliminating these hazardous plastic wastes and improving the properties of concrete. Concrete can be mixed with different materials, but their proportions have different effects on the same parameters such as compressive strength, tensile strength and flexural strength.

If the amount of fibers is low, it may not cause any improvement in properties, but if the ratio exceeds a certain value, the same or any other performance will be reduced. Likewise, if the plastic is used in fiber form, the form in which the plastic is used in the mix is equally important and the effect will be different from the same plastic used in pallet form, albeit in the same amount. As a result, multiple questions arise about the correct dosage, the correct form of plastic to use, and the impact on different properties. India has an extensive network of roads across the country, most of which are rural roads or LVRs.

III.MATERIAL CHARACTERIZATION

The concrete was prepared in the laboratory by design of mix following the procedure of IRC 44:2017 "Guidelines for the design of pavement cement concrete mix". The selection of the mix was based on the recommendations of SP 62 "Guidelines for the design and construction of cement concrete pavements for low volume ratio roads", which states that the minimum strength of LVR rigid pavements should be M30. Concrete is made by mixing cement, water, coarse aggregate, fine aggregate and admixtures in specified proportions to achieve the minimum strength required. The reinforcing fibers used are polyethylene fibers from used milk cartons and PET from broken bottles.

TABLE I
PROPERTY OF CEMENT

Property	Result	Code used
Fineness Specific Surface (m^2/kg)	357	IS 4031 (part I)
Specific Gravity (G)	2.81	IS 2720 (part III)
Soundness (in mm)	2	
Consistency	28.6	
Initial setting time (in min)	127	
Final setting time (in min)	361	

TABLE 2
PROPERTY OF AGGREGATE

Property	Result	Code used
Elongation Index	20.19	IS 2386 (Part I)
Flakiness Index	13.23	
Fineness modulus	4.64	
Specific gravity	2.8	IS 2386 (Part III)
Water absorption (%)	0.89	
Bulk density (kg/m3)	1600	
Water absorption (%)	0.4	
Los Angeles Abrasion value (%)	23.5	
Aggregate impact value (AIV)	21.7	
Aggregate crushing value (ACV)	21.4	
Grading		

TABLE 3
PROPERTY OF FINE AGGREGATE

Property	**Result**	**Code used**
Silt content (%)	1	IS 2386 (Part II)
Bulk density loose state (kg/m^3)	1536	IS 2386 (Part III)
Bulk density compacted state (kg/m^3)	1689	
Specific gravity	2.42	
Water absorption (%)	0.21	
Fineness modulus	2.36	IS 383:1970
Grading		

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A. Reinforcing Fiber

1) *LDPE:* LDPE fibers are obtained from waste polyethylene bags in milk. Pick up discarded milk packets at the store every week. On collection, the plastic is first washed in hot water to remove any residual product from the surface, then left to dry in the absence of moisture, once all moisture is removed, the milk bags are cut to about 5-10mm in diameter. width and length 20-40mm. The use of unequal lengths and widths to provide better interlocking and adhesion to concrete, allowing the reinforcement to form a strong matrix within the concrete mass, limiting cracks large and small.

Fig. 3 Shredded milk packets

2) *PET:* The fiber of PET was obtained from the waste plastic bottles. Disposed plastic bottles were collected on weekly basis from the stores. The plastic bottles upon collection were first washed in hot water to remove any and all residual product from its surface, then it was left to dry in absence of moisture, once all the moisture is removed the plastic bottles are cut in small strips width around 5-10 mm and length 20-40 mm. Non-uniform length and width is adopted so as to provide better interlocking and adhesion with concrete so the reinforcement should be able to form strong matrix within the concrete mass able to restrict both small and large cracks.

Fig 4. Acquired plastic bottles

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3) *Recron:* Recron structural fibers are available online. During the collection process, the fibers are first washed in hot water to remove all residue from their surface, and after all the moisture is removed, they are left to dry without moisture. Recron fibers do not require any modification of their dimensions and can therefore be used directly. An easy way to comply with IJRASET paper formatting requirements is to use this document as a template and simply type your text into it.

Fig 5. Recron Fiber

This study used M 30 grade concrete and was designed in the laboratory in accordance with IS 44:2017 guidelines. After the concrete mix is designed, reinforcement is added in varying percentages of the volume of cement used in the mix. A detailed analysis of the concrete mix design is provided in the appendix, while the final mix and fiber mix for unreinforced and fiber reinforced concrete are listed in Table 4

TABLE 4
MIX DESIGN OF CONCRETE

Volume of Fiber(%)	Weight in (kg.)				w-c ratio	Mix proportion (by weight)
	Cement	Fine aggregate	Coarse aggregate	Fiber		Cement: F.A: C.A: Fiber
0	423	469	1283	0	0.44	1: 1.11: 3.03: 0.00
0.2	423	445.25	1283	8.78	0.44	1: 1.05: 3.03: 0.02
0.4	423	421.75	1283	17.45	0.44	1: 0.99: 3.03: 0.04
0.6	423	389.75	1283	26.42	0.44	1: 0.94: 3.03: 0.06

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IV. KEY FINDINGS AND RESULTS

A. *Workability*

As evident from the graph, the workability of concrete decreases with increase in the percentage of fibers. It may be attributed to the fact that presence of fiber in more quantity covers more surface area in the mix. Since the fibers are added in expense of cement, with increase in quantity of fiber same cement content is required to cover more surface area. Also, the fiber length is used in this research is more as compared to fibers available in the market or conventionally treated fibers and it has been found that long length fibers are more prone to reduce the workability as compared to short fibers.

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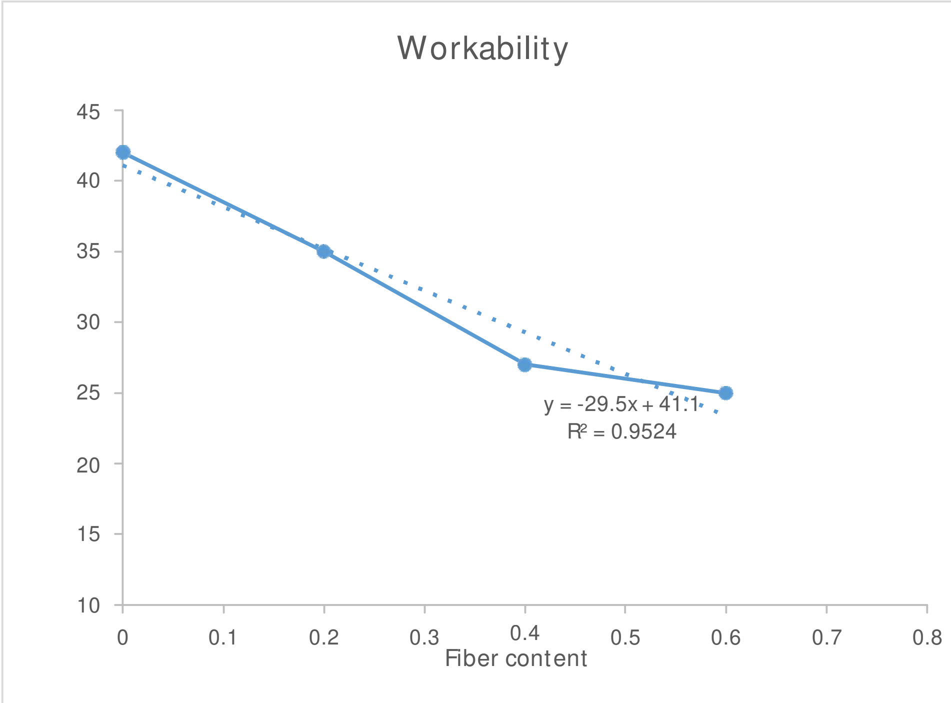

Fig. 6 Workability of fiber reinforced concrete

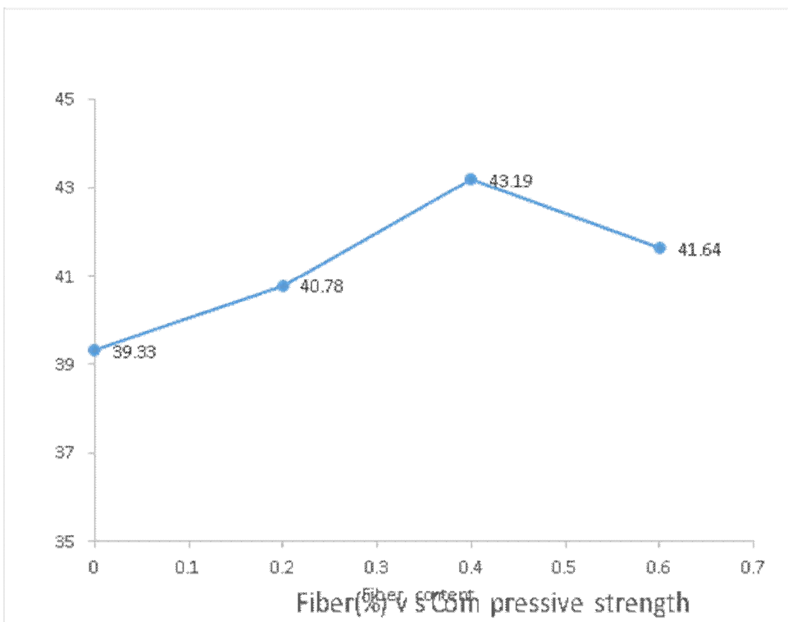

Fig. 7 Fiber content vs compressive strength

The graph between fiber content and compressive strength shows that as the fiber content increases, the compressive strength of concrete increases up to 0.4% fiber. As the fibers were added, the compressive strength began to decrease, probably due to less surface area available for good bonding of the cement and aggregates in the mix. This result is similar to that of other authors for the reinforcement of different fibrous materials in concrete. Many authors suggest 0. 3% was taken as the optimum value for polymer reinforcement, and the same result was found in this experiment. It is suggested that the optimum amount of reinforcement to increase the compressive strength is 0.4%, and the compressive strength will decrease if the amount of reinforcement exceeds this value. For 0, the greatest increase in compressive strength was recorded at around 9.81%. Reinforced with 4% fiber.

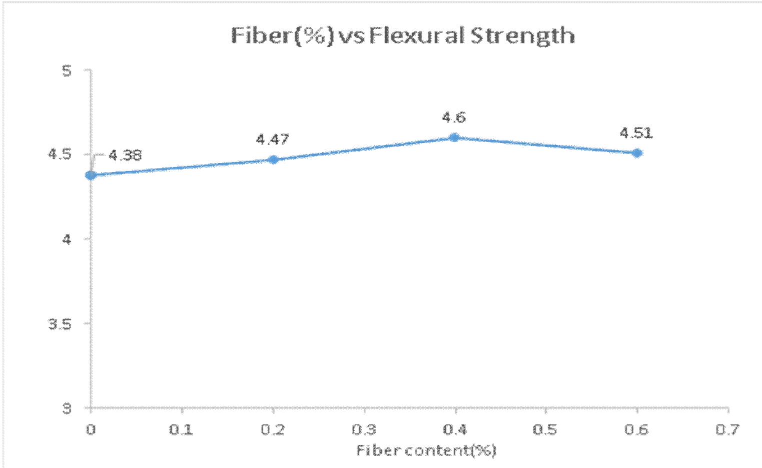

Fig. 8 Fiber content (%) vs Flexural Strength

Flexural strength is the most important property because rigid pavements are designed for flexural strength. Tests have shown that with the influence of polyethylene fibers up to 0.4%, the flexural strength of concrete increases, and beyond 0.4%, the strength tends to decrease. The flexural strength depends essentially on the capacity of the particles of the mixture to transmit loads in compression (upper half above the neutral axis) and in tension in the lower half (below the neutral axis), in a function of material-to-material combination strength to charge as efficiently as possible without failure. As the fiber content increases, the area where the cement covers the aggregate and forms a bond decreases, so if the fiber content increases beyond a certain percentage, the strength also decreases. It was also observed in the experiment that as the flexural strength increased, the ability of the specimen to resist crack initiation and the tendency of cracks to propagate inwards at low loadings decreased as fiber content increased. The greatest increase in flexural strength was reported when the fiber content was 0.4%, with an increase in flexural strength of nearly 5.02%.
The test results show that the tensile strength increases with increasing fiber content up to 0.4% fiber reinforcement, with the fiber content being higher as the tensile strength decreases. The increase in tensile strength was the highest compared to the increase in other properties such as compressive and flexural strength. An increase in tensile strength of 12 has been reported for a fiber content of 0.4%. 93%. The reason for this increase may be the inherent tensile strength of polyethylene. Because it is also malleable when mature, it is not very effective in increasing compressive strength, but it works well when tensile stress is applied to the specimen. Concrete itself is also low in tension, so increased tensile strength means better resistance to shrinkage cracking, reduced temperature sensitivity and increased durability.

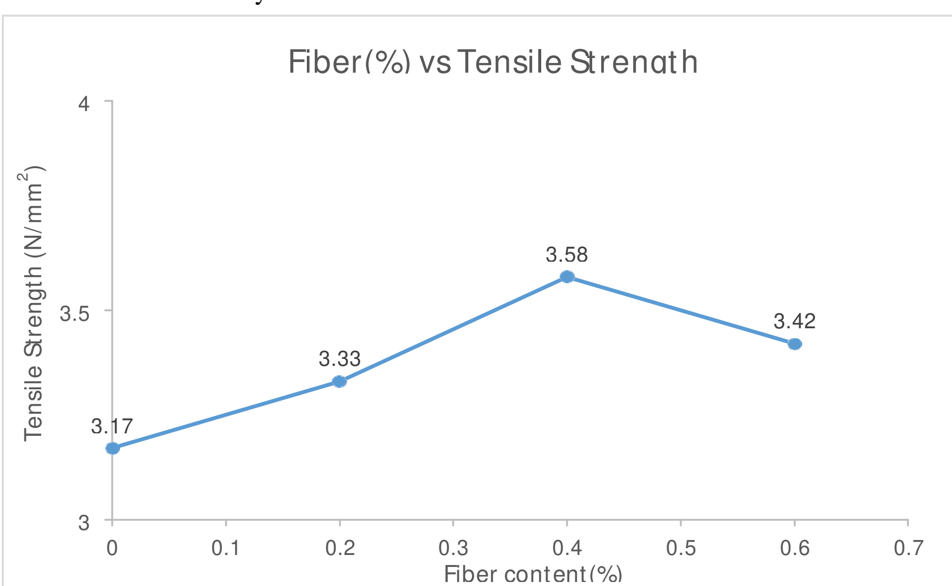

Fig. 9 Fiber content (%) vs tensile Strength

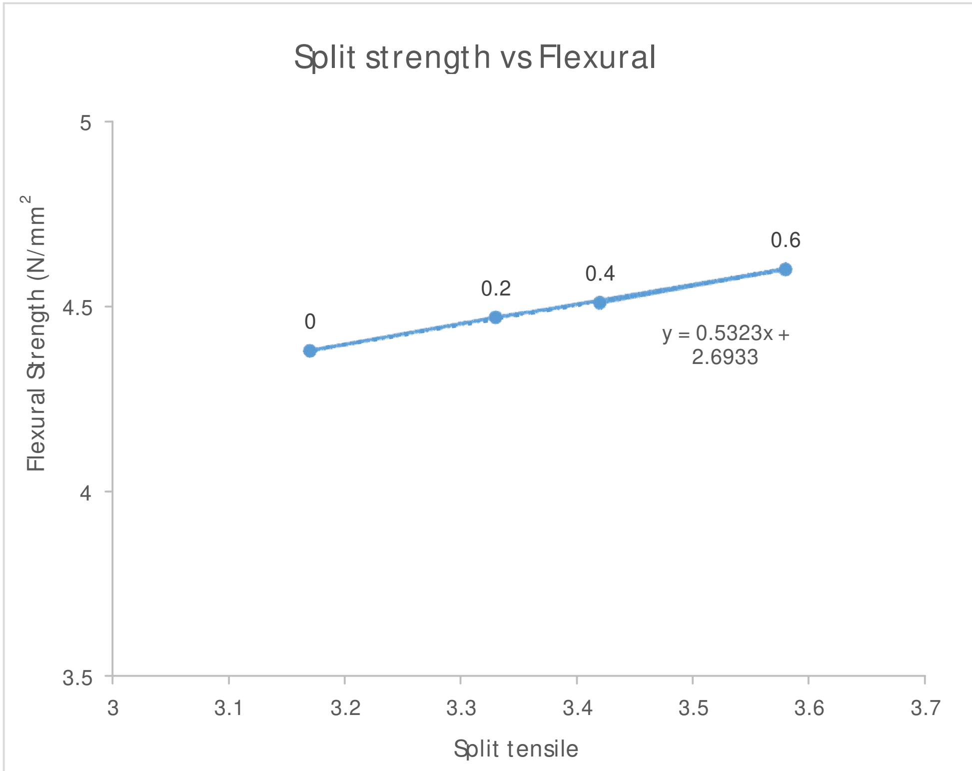

Fig. 10 Split tensile strength vs Flexural strength

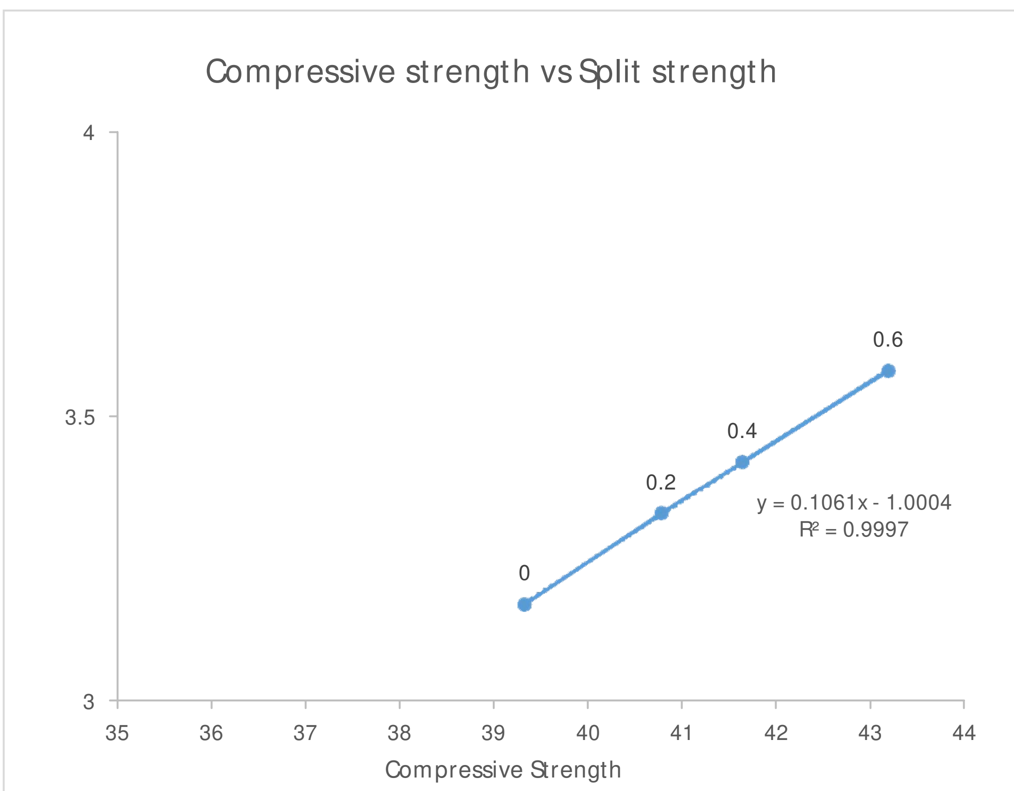

Figure 11 Graph between Compressive strength and split tensile strength

The graph between split tensile strength vs flexural strength and compressive strength vs split tensile strength of fiber reinforced concrete is different from normal behaviour. It was observed that with increase in fiber content both Split and flexural strength decreases but the relation between split and flexural strength and compressive and split strength increases with excellent R^2 value of linear equations indicates that only compressive strength may be used to find split tensile strength which could be used to find flexural strength and find the appropriate fiber content to find the required fiber content and check the accuracy of the fiber content selected.

V. CONCLUSION

After thorough research and detailed experimentation on various aspects of Concrete for pavement it was found that polythene, PET, Recron 3S mix can be used as fiber reinforcement to enhance the properties of concrete. It not only helps the pavement concrete to become more durable and long lasting which in turn reduce the cost in terms of maintenance and repair but also helps immensely in solving the wide spread problem of plastic. Although the government has taken various praiseworthy steps towards the mitigation of plastic waste problem such as ban on production, reuse of plastic motivation to jute and cloth bag etc., but still the plastic waste already present in our ecosystem which continues to harm our environment can be effectively used in our favor by this method.

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