ENRICHMENT OF THE STRENGTH CHARACTERISTICS OF FIBRE REINFORCED CONCRETE BY USING INDUSTRIAL WASTE POLYMER AS FIBRE

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Abstract - *The increasing amount of waste material from industry is a concerning reality that has began the sustainability issues of the environment and ecology of earth surface. The production of fibre in the industry accounts for the global warming by releasing the carbon dioxide and other harmful gases in the atmosphere during its manufacturing. It also process waste at the time of manufacturing and using on the field. Therefore, formulation of concrete with industrial waste can help in minimizing the environmental and ecological problems. In this study fibre (waste polypropylene fibre) was used as an additional material of cement concrete. Polypropylene fiber (PPF) is a synthetic hydrocarbon polymer which was added to enhance the strength of the concrete i.e. compressive and split tensile strength. In this study, we prepared number of specimens by varying percentage of industrial waste polypropylene fiber i. e. (0%, 0.25%, 0.5%, 0.75% and 1.00%). The density of Fibre Reinforced Concrete (FRC) was tested immediately after preparing the concrete mix whereas the compressive strength and the split tensile strength of the Fibre Reinforced Concrete (FRC) were tested after 7 and 28 days of curing. Results indicate that the density of fresh Fibre Reinforced Concrete (FRC) slightly or negligibly decreases from 2397 kg/cm^3 to 2393 kg/cm^3 with the addition of polypropylene fiber. The addition of waste polypropylene fiber increases the strength of Fibre Reinforced Concrete (FRC) for all curing ages up to a certain point. After that, there is an abrupt reduction in the strength of the Fibre Reinforced Concrete (FRC). The addition of 0.5% polypropylene fiber is recommended for the maximum strength with minimum coefficient of brittleness. The addition of 0.5% waste polypropylene fibre increase the compressive strength around 10% and 17% split tensile strength of the Fibre Reinforced Concrete (FRC).*

Key Words: Polypropylene fiber, Fibre Reinforced Concrete, Rice Husk Ash, polyethylene terephthalate, Fibre Reinforced Mortar.

1. INTRODUCTION

1.1 Background

Cement concrete is the most broadly used construction material in the world. There is a concern to know more about it and to improve its properties. Using waste and recycled materials in cement concrete mixes becoming increasingly important to manage and treat both the solid waste generated by municipal waste and industry.

Plastic is one of the most important innovations of 20th century substance or material. The amount of plastic consumed annually has been growing gradually and becomes a serious environmental trouble. For solving the disposal of large amount of recycled plastic material, use of plastic in concrete industry is considered as reasonable application.

According to some researcher used plastic material particles included as aggregate in the cement concrete mix and determined their physical, chemical, and mechanical properties. The outcome proved that the addition of polymeric materials in fractions 10% in volume inside of a cement matrix does not involve a significant variation of the cement concrete mechanical features.

Some researcher calculated the use of consumed plastic bottle waste as a partial replacement of the fine aggregate within composite materials for building applications. The study demonstrates that the plastic bottles shredded into small PET particles may be used successfully as a partial replacement of the fine aggregate in cementitious a concrete composite, which appears to present an attractive low-cost material with consistent or reliable properties and which would help out to resolve some of the solid waste troubles created by plastics production. Hence in this study, the opportunities to use the waste plastic in cement concrete mixes have been investigated and compared with control samples. In this section, only the cases where the plastic is used as fibrous material in concrete are presented. The different properties of the various types of fibrous waste material are represented. Finally, the possible future studies on the industrial waste polymer as fibrous material in the cement mortar and cement concrete mix are evaluated in this work.

1.2 Objectives of Our Proposed Research Work

The very important objective of this research work is to build up a sustainable and eco friendly solution for the use of industrial waste fibre in concrete by introducing them as fibrous material for producing a cement concrete mix. This research work or thesis is conducted to attain the following objectives:

1. To study the physical and mechanical performance of industrial waste polymer fibre used in the concrete mixtures.
2. To prepare the various proportions of polymer modified concrete using industrial waste fibre.
3. To determine the optimum use of industrial waste fibre in the cement concrete mix, which produces the best concrete of having better properties like compressive strength, split tensile strength and density.
4. To inspect the opportunity of using industrial waste fibre in cement concrete mixture.
5. To determine the compressive strength, split tensile strength of the polymer modified concrete which is made of industrial waste fibre.

2. LITERATURE REVIEW

(Manaswini C, Vasu Deva, 2015) reviewed that with growing creation of industrial waste, waste utilization can save us money and is claimed to be of great usefulness by researchers when added to concrete in the form of fibres. We can use metallic fibres and waste PP, PET, HDPE fibres as reinforcement of standard concrete. We know that, both these products are available in large quantity and at a cheaper cost; we can access effects of the incorporation of waste metallic fibres (WMF) and polypropylene fibres (WPF) on the fresh and hardened concrete properties. Numbers of experiments have been performed to observe the performance of FRC in compression, tension, shear, flexure in the extreme environments etc. By the detailed study on this paper we can say that there is almost a 41.25% increase in the compressive strength when waste metal fibres are used. Also we can say that, addition of fibres Reduce plastic disposal problem and it provides Sustainable, durable and economical construction.

According to (Amit Rai, Dr. Y.P Joshi, 2014) in normal cement concrete, micro-cracks develop before structure is loaded because of drying shrinkage and other causes of volume change. When a structure is loaded, the micro cracks open up and propagate because of the development of such micro-cracks, results in inelastic deformation in the concrete structure. Fibre reinforced concrete (FRC) is cementing concrete reinforced mixture with more or less randomly distributed small fibres. In the FRC, a numbers of small fibres are dispersed and distributed randomly in the cement concrete structure at the time of mixing, and thus improve concrete properties in all directions. The fibers help to transfer the load to the internal micro cracks. FRC is cement based composite material that has been developed in the recent years. It has been successfully used in construction with its exceptional flexural and tensile strength, resistance to the spitting, impact resistance and outstanding permeability and frost resistance. It is an effective way to increase the toughness, shock resistance and resistance to the plastic shrinkage cracking of the mortar. These fibers have many more benefits. Steel fibers can improve the structural strength to decrease in the heavy steel reinforcement requirement. Freeze thaw resistance of the concrete is also improved. Durability of the concrete is improved to reduce in the crack widths. Polypropylene and Nylon fibers are used to advance the impact resistance. Many developments have been made in the fiber reinforced concrete (FRC).

In the research program of (Pravin V Domke, 2012) to reduce the impact on the atmosphere due to agricultural and industrial waste products such as Rice Husk Ash (RHA) and (coconut fibers) COIR which are the waste products of paddy industry and agricultural industry. Use of these materials in the normal concrete is not only improves the compressive strength of the cement concrete but also leads to the appropriate disposal of these materials, resulting in reducing the impact of these resources on the environment. It is found that the rice husk ash is obtained by burning of rice husk in a controlled way, which is highly reactive pozzolonic material and the coir having excellent mechanical and physical properties to be utilized in effective way in improvement of composite materials. This research paper describes about the results obtained from the comprehensive investigation done on the partial replacement of cement with RHA cement concrete and shows evidently up to how much percentage the cement can be replaced by RHA and COIR.

Many other references are available on the use of waste plastic as aggregate, filler or fibre replacement in the preparation of cement mortar and cement concrete mix (Siddique et al. 2008).

Tam and Tam (2006) stated that technology is being developed that will allow building materials to be increasingly infused with recycled plastic element in order to increase the strength, durability and impact resistance, and improve appearance.

Jo et al. (2006) investigated the mechanical properties such as flexural strength and compressive strength of polymer concrete using an unsaturated polyester resin based on recycled PET, which participates to dropping the cost of the material and saving energy.

Cement concrete mix volume contains from 65%–80% aggregate and it plays a significant role in concrete properties such as dimensional stability, workability, strength, and durability, so the use of waste materials in cement concrete mix as fibre can effect in the amount of waste materials extremely. Lightweight fibrous material is an important material in reducing the unit weight of cement concrete mix. A work has already been done on the use of plastic waste as polyethylene terephthalate (PET) bottle such as Light weight fibrous material (Choi et al 2005).

In other research, by Assunc¸a˜o et al. (2004) used sodium polystyrenesulfonate produced from waste polystyrene cups as an admixture in the cement concrete mix. The results proved that NaPSS can be used acceptably either as a plasticizer or as an admixture for reduction of water in cement concrete mix. The slump increase of cement concrete was up to around 300% with 0.3% content of NaPSS per weight of cement in the mix.

The fruitful use of waste material represents a means of reducing some of the troubles of solid waste management (Davis and Cornwell, 1998). The recycle or reuse of wastes is very significant from different points of view. It helps to save and sustain naturally available resources that are not replenished, it reduces the pollution of the environment and it also helps to keep and recycle energy production processes. Wastes from different sources and industrial by-products should be considered as potentially precious resources which required suitable treatment and application. Plastic wastes are among these wastes; their disposal has ill effects on the environment due to their long biodegradation period, and therefore one of the logical methods for reduction of their negative effects is the application of these materials in other industries and other constructional activities (Hassani et al., 2005). Concrete plays a very important role in the advantageous use of these materials in the construction activities. Although some of these materials can be constructively included or use in concrete, both as part of the fibrous material or as aggregates, it is important to understand that not all waste materials are suitable for such type of use (Anon., 2003). Cement Concrete contains several flaws and micro cracks. The rapid spreading of micro cracks under an applied load is considered accountable for the low tensile strength of cement concrete. It is logical to assume that the tensile strength as well as the flexural strength of cement concrete can be significantly increased by introducing closely spaced fibres. These fibres would capture the spreading of the micro cracks, thus delaying the beginning of the tensile cracks and increasing the tensile strength of the material (Yin and Hsu, 1995).

The enhanced presentation of fibre reinforced concrete over its unreinforced equivalent comes from its better capacity to absorb energy during rupture or cracking, while a plain unreinforced matrix fails in a brittle material at all occurrences of cracking stress. This energy-absorption characteristic of fibre reinforced concrete is often termed ''toughness'' Banthia and Trottier (1995).

In the research by Rebeiz and Fowler (1996) found that very good flexural strength can be achieved with reinforced polymer concrete (PC) using unsaturated polyester resins based on recycled polyethylene terephthalate (PET).

Soroushian et al. (1995) stated that polypropylene is used only as synthetic fibres to improve the toughness of cement concrete mix. Hınıslıog˘lu and Ag˘ar (2004) investigated the opportunity of using various plastic wastes containing high density polyethylene (HDPE) as polymer additives to asphalt concrete mix. The result shows that the waste HDPE-modified bituminous binders present superior resistance against permanent deformations due to their high stability and high organize amount; it also contributes to the recycling of plastic wastes as well as in protection of the atmosphere.

The relations between the fibre and cement matrix, as well as the structure of fibre reinforced cementitious material are the necessary properties that have an effect on the performance of a cement based fibre composite material or a mixture. However, to know these properties, the need for calculating or analyzing the fibre contribution and the prediction of the composite's performance is necessitated. Such considerations are the following:

1- The matrix composition of the mixture.
2- Type, geometry and surface characteristic of the fibres.
3- The condition of the matrix before and after the failure.
4- The length efficiency and orientation of fibres through the cement matrix.
5- Optimum volume dosage of fibres in the cement concrete mix.

This chapter discusses the mechanism of fibre-matrix relations, where various models are used and compute the bonding between the fibres and cement mixture. As the bonding of fibre and the matrix plays a very important role in the composite behaviour. Also, this chapter presents a review of literature related to the examination and tests done for Fibre Reinforced Concrete (FRC) in general with a importance of civil engineering application.

2.1 Properties of Fibre Reinforced Concrete Materials:-

The mechanical behaviour of Fibre Reinforced Concrete materials are dependent on the structure of the composite material, which is both the properties of the cement concrete and the properties of the fibre type used in the cement mixture. Hence, composites analysing and forecast on their performance in various loading conditions, such internal organization or structure of the composite must be characterized. The properties that measured were divided into three groups:

1. The structure of the cement concrete matrix.

2. Shape, geometry and the distribution of fibres in the cement concrete matrix.

3. The structure and the interface between the fibre and cement concrete matrix.

2.2 The Structure And Main Constituents of The Fibre Reinforced Concrete Mixture

2.2.1 Cement

The cement in the mixture commonly consists of Portland cement. However, in some cases, the binding material can be manufacture by non-Portland cement materials. The fibre reinforced cement paste or mortars normally used for cladding or shelling, which generally applied in thin sheet components, such as asbestos cement. Fibres used in these applications acts as a primary reinforcement element and the range of fibre volume dosage rate are from 5% to 20% by the volume. For fibre reinforced concrete (FRC), the fibres act as secondary reinforcing element, which the fibre volume dosage rate is much lower (less than 2% by volume), mainly used for controlling the crack in the structure.

The most commonly used cement in any cement concrete mixing purpose is called Ordinary Portland Cement (OPC). Other available cement types are as follows:

1- High strength cement
2- Portland pozzolana cement
3- Low heat cement
4- Sulphate resisting cement
5- Shrinkage resisting cement.

All these type of cement can be used in to produce Fibre Reinforced Concrete (FRC). However, the hardened cement paste contains various sizes of air voids in their structure. This shows that the microstructure exhibits the volume changes in the hardened cement concrete paste were from the effects of creep and shrinkage at the movement of water in the cement matrix. Additionally, the hydration of the cement paste creates a highly alkaline environment with pH value ranges from 12 to 12.5. Such degree of alkalinity property in the cement matrix must be taken into consideration when selecting the type of fibre used.

2.2.2 Aggregate Used In Concrete

Aggregates which uses in plain cement concrete are appropriate for Fibre Reinforced Concrete (FRC), as these aggregates were categories in two types:

I) Fine aggregates (sand)
II) Coarse aggregates

Fine aggregates are required in both Fibre Reinforced Mortar (FRM) and Fibre Reinforced Concrete (FRC). As the types of fine aggregate been manufactured and used were based on maximum grain size and particle size distribution. The fine aggregates available in the used of fibre reinforced mortar (FRM) and concrete can be natural, crushed or manufactured fine aggregate (sand).

Coarse aggregates used can be of normal-weight, lightweight or heavyweight type. The usage of heavyweight aggregate is restricted to the specific construction conditions. As known that these aggregates contains in fibre reinforced concrete (FRC) were successfully used in the field applications such as pavements and in concrete slab, where the strength of these structure were improve by the used of fibres in the concrete mix. Aggregates used in the cement concrete have a major effect on the properties of cement concrete. Such properties of the aggregates that may influence the concrete are density, particle shape, grading, porosity, cleanliness and alkali reactivity of the aggregates. The details of the coarse aggregates were shown in Table-2.1.

Table-1 Type of Coarse Aggregate, Source And Their Density

Type of Coarse Aggregate	Source	Density (Kg/m^3)
Normal Weight	Natural Gravel Or Crushed Stone	2240
Light Weight	Expanded Clay Or Blast Furnace Slag	1440-1760
Heavy Weight	Quarried	2300-2400

2.2.3 Water Used In Concrete

The quality of water is very important as it can influence the setting time of fresh concrete and the strength of hardened Fibre reinforced concrete (FRC). In addition, it causes the risk of corrosion of the fibres, especially to steel fibres but not in case of polymer fibre. On the other hand, water is required for the heat of hydration process of cement and moulding and placing of cement concrete in the required shape and location. (Balaguru and Shah 1992) stated that the adequate water for the heat of hydration process requires a minimum water/cement ratio of 0.28. Water that is fit for drinking is appropriate for cement concrete used. If there is a high concentration of sodium, high suspended solids or potassium salts contain in the water, the water can't be used for cement concrete mixing. Concern on the water must be taken to avoid pollution of water, such as split admixtures.

2.2.4 Fibres Used In Concrete

The introduction of fibres was brought in as a solution to develop cement concrete in view of enhancing its flexural strength and tensile strength, which are a new type of binder that could combine Ordinary Portland Cement (OPC) in the bonding with cement matrix. Fibres are most commonly discontinuous, randomly distributed throughout the cements matrix. The term of 'Fibre reinforced concrete' (FRC) is prepared with cement, aggregates of various sizes, which incorporate with discrete, discontinuous fibres (Bentur et. al, 1990). Most common types of fibres are as follows:

I) Steel fibres
II) Glass fibres
III) Polypropylene/Synthetic fibres.

These usages may modify in cement concrete for special applications. The selection of fibre mostly depends on their properties, cost, effectiveness and availability. Special types of fibres such as carbon and Kevlar, natural fibres, mineral fibres, and asbestos fibres may use in harsh environmental condition. These differences and usage of fibres depends on the requirement of behaviour and properties for a cement concrete, permitting the increase the precise effects and mechanical properties.

Fibre geometry are as follows:-

I) Hooked end fibres

II) Deformed fibres

III) Deformed wires

IV) Fibre mesh

V) Wave-cut fibres

VI) Large end fibres

2.2.4.1 Steel Fibres

Steel fibres are broadly used in civil engineering applications and cement concrete reinforcement, due to its relative easy availability, low cost and better performance in its application with conventional steel reinforcement. (Bentur and Mindness, 1990) stated that the early study and researches on fibre reinforced concrete (FRC) in 1950's to 1960's primarily were the behaviour of steel fibre reinforced concrete (SFRC). Steel fibres significantly increase toughness of the cement concrete, which mainly is used for crack and shrinkage controls, to serves as secondary reinforcement for the pavements, slabs, pipes, tunnels and channel. Its potentially increases the toughness, minimizes the cracking due to temperature changes and resistance due to the extreme loading and environment such as abrasion, blasting, impact and fatigue.

2.3.6 Admixtures Used In Concrete

According to IS: 9103 covers the following types of admixtures:

(a) Accelerator

(b) Retarder

(c) Water reducing admixtures (Plasticizers)

(d) Air entraining admixtures

(a) Accelerator

These admixtures when added to the cement concrete, mortar and in grouting process, it increases the rate of hydration of hydraulic cement, reduces the setting time and accelerates the hardening or development of strength of cement concrete or mortar. These admixtures function by interaction with C_3S (Tri-calcium silicate) component of the cement thus increasing the reaction between cement and water.

Advantages

i) It reduces the setting time of cement and therefore increases the rate of gain of strength.

ii) It enables the earlier release precast members from moulds thus speeding up the production.

iii) It reduces segregation and increase density and compressive strength of concrete.

iv) Cures concrete faster and therefore uniform curing in winter and summer can be achieved.

v) Early use of concrete floors by accelerating the setting of cement concrete.

vi) Reduces water requirements, bleeding, shrinkage and time required for initial setting.

Effect of Use of Accelerator

Table- 2 below shows typical test results provided by M/S. Asian laboratories, New Delhi.

Mix details: OPC 350 kg/cum., Zone 2 sand 26%, 5-20 mm crushed aggregates 74%, Dosage: 1% by weight of cement.

Table-2 Result Shows the Effect of Accelerator on Concrete

Concrete	Cement Kg/m³	Water Kg/m³	Reduction In Water Content (%)	W/C Ratio	Slump (mm)	Compressive Strength kg/cm²		
						3 Days	7 Days	28 Days
Reference concrete	350	210	Nil	0.6	55	88.5	163.4	253
Concrete with Accelerator	350	178.5	15.0	0.51	60	135	216	304

From the results of above Table-2 it is seen that by the use of accelerator in cement concrete mixture of similar slump and cement content, the better strength at the early and final stage with enhanced workability can be achieved even at reduced W/C ratio.

(b) Retarder

This variety of chemical admixtures reduces the initial speed of reaction between the mix of cement and water and thus retards the speed of setting of cement concrete. It works by coating the surface of C_3S (Tri calcium silicate) components, thus, delaying this reaction with the water. Reaction products are slow to form as such the setting and hardening of cement concrete are delayed reducing early compressive strengths. Since the rate of stiffening of cement concrete can be very speedy in our hot climatic conditions, adequate time for the cement concrete is essential for the transportation and placement operation before setting takes place. In such conditions retarding admixtures can be very functional. Retardation in setting period up to 8 to 10 hours is achievable by appropriate use of retarders. The delay in hardening of cement concrete caused by the retarders can be broken to achieve an architectural finish of the exposed aggregate surface: the retarder is applied to the inner surface of the formwork so that the hardening of the adjoining cement is late or delayed.

Advantages

i) It increases the workability, cohesion and the setting time, provides safety against delays and facilitates maintaining the workability cement concrete for long period.

ii) In the huge construction, better workability of the cement concrete all over the placing period and prevention of cold joints is ensured by adding retarders in the cement concrete.

iii) Extended setting time minimize risks of long distance delivery in hot weather condition, improves pump ability of cement concrete by increased setting period and improved workability of cement concrete.

iv) Reduces bleeding and segregation where poor sand grading are necessary.

v) Reduces unfavorable environmental effects of various nature on cement concrete and surrounded steel by considerable reduction in permeability.

(c) Plasticizer (Water Reducer) Admixtures:-

Plasticizer is a material, which increases or improves the workability of freshly mixed cement concrete without increasing the water cement (W/C) ratio or maintains workability with a reduced amount of water, is termed as water reducing admixture. As their name implies, the function of water reducing admixture is to reduce the amount of water in the mixture, usually in the range 5 to 10%, sometimes (in cement concrete of very high workability) upto 15%. therefore, the reason of using a water reducing admixture in a cement concrete mixture is to permits a reduction in the water cement (W/C) ratio while retaining the preferred workability or, alternatively, to improve or increase its workability at a given water/cement (W/C) ratio. The actual reduction in the amount of water depends on the dose or range of admixtures, type of aggregate used, ratio of cement, cement content, fine aggregate and coarse aggregate etc. Therefore, the trial mixes containing an actual material to be used on the job are significant to attain optimum properties.

Chemical admixtures may also used to enhance or improve the certain properties such as workability of the fresh concrete and the compressive strength of concrete. The most common chemical admixture used is water-reducing admixture. This chemical admixture was developed to improve the workability of the concrete at a low water/cement ratio. The workability of a cement concrete matrix normally reduced with addition of fibre. With the use of water-reducing admixtures, it is possible to maintain the workability concrete without adding extra water. In addition, extra water reduces the compressive strength, increase the shrinkage and have the tendency to build up or develop cracks in the concrete surface. As a result, these problems influence the durability of fibre reinforced concrete (FRC) once it hardens. So it is desirable to minimum (reducing) the amount of water used in the concrete mix.

Advantages

i) They increase the workability of the cement concrete without decreasing the compressive strength or without changing water/cement ratio. This is particularly useful when cement concrete pores are limited either due to congested reinforcement or due to thin sections.

ii) High strength of concrete can be achieved with the same cement content by reducing water/cement ratio.

iii) A saving in the quantity of cement (approx. upto 10%) can be achieved keeping the same water/ cement ratio and workability.

iv) We can improve the compressive strength of concrete around 9%-15 % with use of superplasticizer (Hirendra Pratap Singh et. al, 2016).

Table-3 Results Shows the Effect of Using Plasticizers on Strength, Quantity of Cement in Concrete

Description of Mix	Dosage % Cement Wt.	Cement kg/m3	W/C Ratio	Slump mm	Compressive Strength N/mm2		
					3 Days	7 Days	28 Days
Reference	---	300	0.6	70	18	26	34
Plasticizers	0.2	300	0.6	100	18	28	37
	0.3	300	0.6	120	17	27	35
Strength Increase	0.2	300	0.56	70	21	32	41
	0.3	300	0.54	70	23	33	44
Cement Saving	0.2	280	0.6	70	19	28	36
	0.3	270	0.6	70	19	27	35

From the above Table-3 it is seen that one of the following advantages can be gained at a time:-

i) Reduced cement content helps in maintaining the same water/cement ratio and workability. This will lead to economy.

ii) Reduced water/cement ratio helps in maintaining the same water content and same workability. This will lead to increase in strength.

iii) Increased workability helps in maintaining the same water-cement ratio and cement content. This is especially required when workability retention for pumping or other activity is needed.

Range of Dosage = 250 ml – 1000 ml / bag of (Hirendra Pratap Singh et. al, 2016) weight of cement (different doses for different products) are recommended by manufacturers; however, it shall be fixed as per design requirements and after site trials.

(d) Air Entraining Admixture

The air entraining admixtures were introduced to improve the resistance of concrete to freeze thawing cycling for exposed structures. This admixture was required for exposed fibre reinforced concrete such as pavements or tunnel linings, as the fibre reinforced concrete as risk as the plain concrete. Air entrainment admixture overcomes the deficiencies in sand gradings, reduce the bleeding of concrete and improve the workability of the fresh concrete. However, care must be considered with air entrainment admixtures when the levels of air are high (about 8% to 10%), where it will results in loss of strength. Set accelerating admixtures used to increase the rate of strength development at early stage and reduce the initial setting time of concrete in cold weather. Furthermore, it reduces the possibility on corrosion of fibres, especially to steel fibres. These admixtures usually used for shotcreting application as to speed up the setting process. Set retarding admixtures slow down the setting of concrete, as usually used in hot weather to maintain the workability of the concrete during the placing. Furthermore, this admixtures cause reduction in the heat of hydration of a concrete. So, set retarding admixtures generally used with the combination of water reducing admixtures.

Advantages

i) Increases durability

ii) It Reduces the segregation and bleeding because of :

a) Attachment of air bubbles with cement constituent part and linking them.

b) Increase in inter particle attraction caused by adsorption of air entrainer.

c) Bubble acting as extra fine filler and improved total surface area of constituents relative to water volume.

d) Water flow between cement particles is restricted.

iii) Workability improved due to action of air bubbles as ball bearing which helps out the movement of particles each other.

3. MATERIALS AND TESTS PERFORMED ON THEM

3.1 Materials used in our work

The materials those were used in our thesis work are as follows:-

1. Binding material i.e. Cement
2. Fine aggregate (Sand)
3. Coarse aggregate
4. Industrial waste polypropylene fibre
5. Potable water.

3.1.1 Tests performed on Cement

There were various tests performed on cement that is selected by us for our experimental work those tests are as follows:-

Table-4 the tests results of setting time performed in laboratory on our cement sample

S. No.	Particulars	Result values after test	Requirements of IS:1489-1991 (Part-1)	
1.	Normal Consistency (%)	32	---	---
2.	Setting Time (minutes)	---	---	---
3.	I. Initial Setting Time	150-170 Minutes	30 Minutes	Minimum
4.	II. Final Setting Time	210-300 Minutes	600 Minutes	Maximum

Table-5 test results for compressive strength of cement

S. No.	Days	Characteristics compressive strength from our tests (N/mm²)	Value specified by BIS: 8112-2013 for OPC 43
1	3	23.60 N/mm2	23 N/mm2
2	7	34.88 N/mm2	33 N/mm2
3	28	46.85 N/mm2	43 N/mm2

3.1.2 Test performed on aggregate

3.1.2.1 Specific gravity

Specific gravity is a ratio that relates the density of the coarse aggregates or compacted specimen, as in this study, to the density of water (Mindess et al, 2003). The specific gravity of coarse aggregates normally used in road construction ranges from about 2.5 to 3.2 with an average value of about 2.70. Though high specific gravity of an aggregate is considered as an signal of high strength, it is not possible to judge the suitability of a sample of road aggregate without finding the mechanical properties such as aggregate impact value (AIV) and abrasion values.

Table-6 Specific Gravity of aggregates used in our concrete mix

S. No.	W_1 (gm)	W_2 (gm)	W_3 (gm)	W_4 (gm)	S.G.
1	646	944	1650	1464	2.66
2	646	946	1652	1464	2.68
3	646	946	1650	1464	2.63
4	646	944	1650	1466	2.61
5	646	948	1652	1464	2.65
6	646	946	1650	1464	2.63

3.1.2.2 Water Absorption

Water absorption value generally ranges 0.1 to about 2 percent for coarse aggregates normally used in road surface course. Indian Road Congress (IRC) and Ministry of Road Transport and Highways (MORTH) have specified the maximum water absorption values as 1.0 percent for aggregates used in bituminous surface dressing. As per MORTH specifications, the maximum permissible water absorption value is 2.0 percent for the coarse aggregates to be used in bituminous macadam base course, dense bituminous macadam binder course, semi-dense bituminous concrete surface course and bituminous concrete surface course. (Highway Materials and Pavement Testing- S.K. Khanna, C.E.G. Justo, A. Veeraragavan).

Table-7 Water absorption of test samples

S. No.	W_1	W_2	% Water absorption
1	2000	2030	1.5
2	2000	2026	1.3
3	2000	2026	1.3
4	2000	2028	1.4
5	2000	2026	1.3
6	2000	2028	1.4

Average water absorption of these sample found = 1.367 %.

3.1.2.3 Aggregate Impact Test

Aggregate Impact Value (AIV) Test has been designed to evaluate or calculate the toughness or the resistance of the stones aggregates to breaking down under repeated application of impact loading. Aggregate impact value (AIV) indicates a relative measure of the resistance of aggregate to impact loading. The aggregate impact test apparatus and the procedure have been standardized by the Bureau of Indian Standards (BIS).

Table-8 for Aggregate Impact Value Test Results

S. No.	W_1 (gm)	W_2 (gm)	AIV
1.	400	54	13.5
2.	400	56	14.0
3.	400	54	13.5
4.	400	52	13.0
5.	400	56	14.0

The Average AIV of the sample was found = 13.60.

4. MIX DESIGN AND TESTING OF PREPARED SAMPLES

4.1 Concrete Mix Design

The mix calculations per unit volume of concrete according to IS code shall be as follows:

1- Volume of concrete = 1 m^3 eq. 1

2- Volume of cement = $\frac{\text{Mass of cement}}{\text{Specific gravity of cement}} \times \frac{1}{1000}$

$\frac{359}{3.15} \times \frac{1}{1000}$ = 0.114 m^3 eq. 2

3- Volume of water = $\frac{197}{1} \times \frac{1}{1000}$ = 0.197 m^3 eq. 3

4- Volume of all aggregate = [eq. 1 – ({eq. 2 + eq. 3})] = 0.689 m^3 eq. 4

5- Mass of coarse aggregate = (eq. 4) x Volume of coarse aggregate x Specific gravity of coarse aggregate x 1000
= 0.689 x 0.61 x 2.65 x1000
= 1113.77 kg

6- Mass of fine aggregate=(eq. 4) x Volume of fine aggregate x Specific gravity of fine aggregate x 1000
= 0.689 x 0.39 x 2.72 x1000
= 730.89 kg

Table-9 Proportion of different materials in our mix

Cement	Fine Aggregate	Coarse Aggregate	Water
359	730.89	1113.77	197 liters
1	2.036	3.102	0.55

4.2 Preparation of Trial Mixes

Based on the concrete mix design by Bureau of Indian Standard (BIS) method, four trials mixes were prepared. Two trials mixes were prepared with W/C ratio of 0.55 and other two mixes were prepared with W/C ratio of 0.50. The 6 cubes were casted for each mix and were tested at 7 and 28 days. The mix proportions for various constituents have been summarized in Table-10

Table-10 Prepared trial mixes

Mix No.	W/C	Slump (mm)	Water (l/m3)	Cement Kg/m^3	Sand Kg/m^3	Coarse Aggregate Kg/m	Average Cube Strength	Average Cube
M-I	0.55	50	186	338	749.7	1142.4	15.30	25.48
M-II	0.55	100	197	359	730.89	1113.77	15.50	26.75
M-III	0.50	50	186	372	724.6	1143.4	14.45	24.55
M-IV	0.50	100	197	394	700.8	1113.9	14.98	25.90

The Mix-B was selected as the design mix because its average cube strength is very close to the target mean strength of the concrete with appropriate content of cement among all the mixes.

4.3 Prepared Mixes For Testing of The Compressive Strength

We prepared the various mixes of concrete for the testing of compressive strength with the variable percentage (0.25%, 0.50%, 0.75% and 1.00%) of polypropylene fibre.

Table-11 Prepared mixes for tests of compressive strength of concrete

Mix No.	W/C ratio	Slump (mm)	Fibre Content in % of cement wt	Water (l/m^3)	Cement Kg/m^3	Sand Kg/m^3	Coarse Aggregate Kg/m^3
Mix-I	0.55	100	0.00	197	359	730.89	1113.77
Mix-II	0.55	100	0.25	197	359	730.89	1113.77
Mix-III	0.55	100	0.50	197	359	730.89	1113.77
Mix-IV	0.55	100	0.75	197	359	730.89	1113.77
Mix-V	0.55	100	1.00	197	359	730.89	1113.77

5. TEST RESULTS AND DISCUSSION

5.1 Unit weight (Density) of fibre reinforced concrete

For the determination of unit weight of fibre reinforced concrete, we use a mould having diameter 15 cm and height 20 cm. In this test we compact the fibre reinforced concrete using the ramming rod which was used in the slump cone test and free fall of this rod taken 45 cm the material was filled in five layers, each layer being given 25 blows.

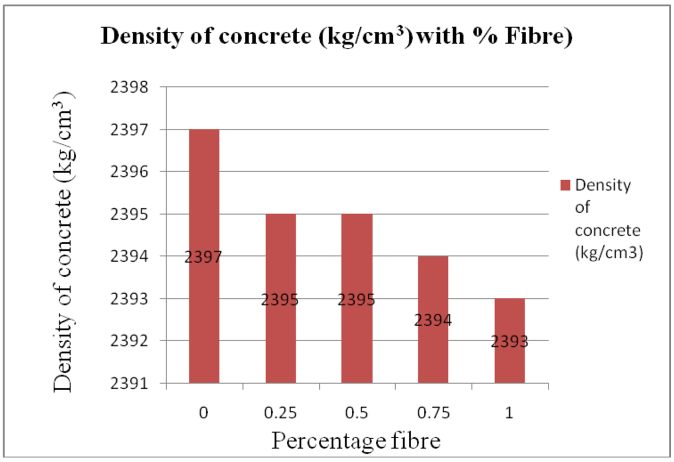
Volume of this cylinder = $\pi r^2 h$
Volume of this cylinder = $3.14 \times (7.5)^2 \times 20 = 3534.29\ cm^3$

Table-12 Density of fresh fibre reinforced concrete

S. No.	W/C Ratio	Fibre quantity (%)	Weight of empty mould (kg)	Weight of mould filled with water (kg)	Weight of mould filled with FRC (kg)	Density of concrete (kg/cm^3)
1	0.55	0	2.340	5.870	8.472	2397
2	0.55	0.25	2.340	5.870	8.465	2395
3	0.55	0.50	2.340	5.870	8.462	2395
4	0.55	0.75	2.340	5.870	8.460	2394
5	0.55	1.00	2.340	5.870	8.458	2393

By these observations we found that the density of fresh fibre reinforced concrete is in the range between 2393 - 2397 kg/cm^3 and it was observed that if we increase the percentage of polypropylene fibre in the mix it slightly or in negligible range reduces the density of fresh fibre reinforced concrete.

Graph-1 Density of FRC with variable fibre percentage



5.2 Compressive strength of fibre reinforced concrete

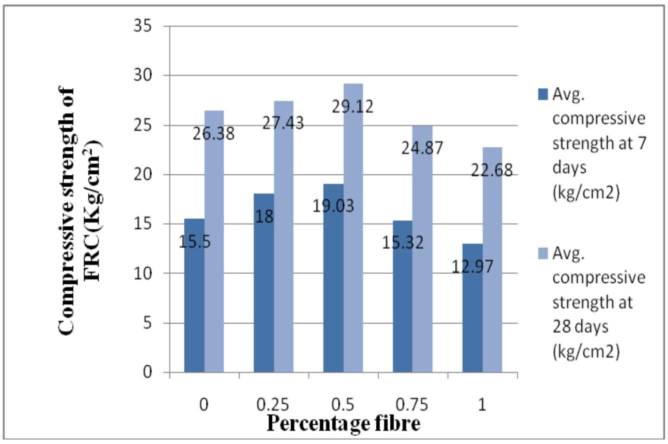
The compressive strength of all the prepared mixes was determined at the ages of 7 and 28 days for the various addition levels of polypropylene fibre with cement concrete. The values of average compressive strength for different mixes prepared by addition of polypropylene fibre (0%, 0.25%, 0.50%, 0.75% and 1.00%) at the completion of different curing periods (7 days and 28 days) are given in the various Tables below.

The fibre reinforced concrete strength tests conducted in this research involved the compressive strength test and split tensile strength test. A total of five mixes prepared with cement, sand, coarse aggregate and with different percentage of polypropylene fibre. The specimens tested had dimensions of 150 mm X 150 mm X 150 mm cubes. The specimens were placed in a curing tank for a period of 7-days and 28-days before tests were conducted as specified in IS code. When the specimens were examined after they were broken, it was found that the majority of the failures occurred because of the aggregates and cement paste bond not because of the aggregate.

Table-13 Combine table for compressive strength of fibre reinforced concrete

S. No.	Fibre (%)	Avg. compressive strength at 7 days (kg/cm^2)	Avg. compressive strength at 28 days (kg/cm^2)
1	0	15.50	26.38
2	0.25	18	27.43
3	0.50	19.03	29.12
4	0.75	15.32	24.87
5	1.00	12.97	22.68

Graph-2 Combine test results of compressive strength



By these test results we can say that compressive strength of fibre reinforced concrete can be increased approximately 10% by adding waste propylene fibre 0.50% of the weight of the cement content. It is also clear by these results that more than 0.50% waste propylene fibre start reducing the compressive strength of FRC.

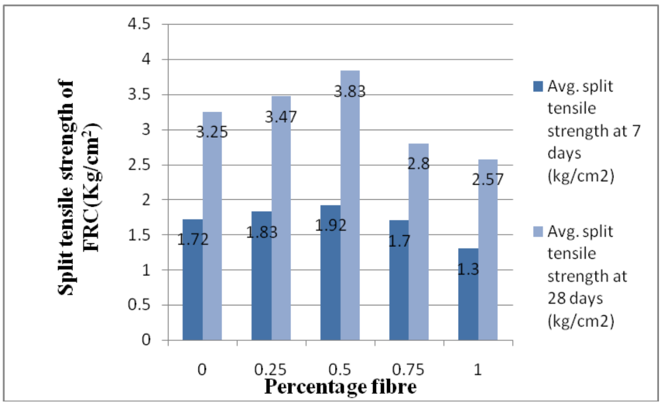
5.3 Split tensile strength of fibre reinforced concrete

To determine the split tensile strength of FRC, we prepare the various cubes with variable percentage of polypropylene fibre of having dimension 15 cm diameter and 30 cm height. We test these cubes after 7 days and 28 days curing.

Table-14 Combine table for split tensile strength of fibre reinforced concrete

S. No.	Fibre (%)	Avg. split tensile strength at 7 days (kg/cm²)	Avg. split tensile strength at 28 days (kg/cm²)
1	0	1.72	3.25
2	0.25	1.83	3.47
3	0.50	1.92	3.83
4	0.75	1.70	2.80
5	1.00	1.30	2.57

Graph-3 Combine test results of split tensile strength



By these test results we can say that split tensile strength of fibre reinforced concrete can be increased approximately 17.85% by adding waste propylene fibre 0.50% of the weight of the cement content. It is also clear by these results that more than 0.50% waste propylene fibre start reducing the split tensile strength of FRC.

6. CONCLUSION AND RECOMMENDATION FOR FUTURE WORK

6.1 Conclusion

After the detail analysis of the test results we can say that the addition of waste polypropylene fiber significantly affect the 7 and 28 days compressive strength and split tensile strength of the Fibre Reinforced Concrete (FRC). From the critical difference, it can be clearly seen that the addition of waste polypropylene fiber in certain amount i. e. 0.50% of the weight of cement increases the compressive strength up to 10 % as well as split tensile strength increases around 17 % than conventional concrete. Experimental results also shows similar trend. Hence, the results of statistical analysis are equivalent to the experimental results. From the experimental investigation this research work can be concluded as follows:-

1. The addition of waste polypropylene fibre does not affect very much the density of concrete mix.
2. The gradual increase seen in the compressive strength of Fibre Reinforced Concrete (FRC) at 7 days and 28 days curing with 0.25% and 0.50% addition of fibre but after that it starts reducing the compressive strength with increase of fibre addition.
3. The gradual increase seen in the split tensile strength of Fibre Reinforced Concrete (FRC) at 7 days and 28 days curing with 0.25% and 0.50% addition of fibre but after that it starts reducing the split tensile strength with increase of fibre addition.
4. The addition of waste polypropylene fiber increases the strength of concrete for all curing ages up to a certain point. After that there is an abrupt reduction in the strength of the Fibre Reinforced Concrete (FRC). Because at higher dosage, concrete loses its ability to make a proper bond.
5. The mix which was prepared with the addition of 0.50% fibre with 0.55 W/C ratio posses the maximum compressive as well as tensile strength. Therefore this mix is recommended for maximum strength.

6.2 Recommendation for future work

Further research and investigations were highly recommended and should be carried out to understand more mechanical properties of fibre reinforced concrete. Several recommendations for future studies are mentioned below:

1. The addition of fibre in concrete reduces the workability of the concrete so the effect of superplasticizer on FRC can be checked by preparing the test samples with addition of superplasticizer.

2. More investigations and laboratory tests should be done to study on the mechanical properties of fibre reinforced concrete (FRC). Such application of fibres was recommended in testing on concrete slabs, beams and walls or conducting more tests such as abrasion, shatter, shear, impact, blasting or creeping of concrete.

3. The combination of two or more short fibres may tend to provide more efficient mechanical properties of structure. So further investigation can be carried out by the combination of different types of short fibres into the concrete mix.

4. The mechanical properties of fibre reinforced concrete may be different in various temperatures. So the tests on freeze-thawing conditions were recommended for future study.

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