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DURABILITY OF FIBER REINFORCED CONCRETE OF MARINE STRUCTURES

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Abstract

The usefulness of fiber reinforced concrete (FRC) in various civil engineering applications is indisputable. Fiber reinforced concrete has so far been successfully used in slabs on grade, shotcrete, architectural panels, precast products, offshore structures, structures in seismic regions, thin and thick repairs, crash barriers, footings, hydraulic structures and many other applications. This paper presents a brief state-of-the-art report on mechanical properties and durability of fiber reinforced concrete.

Civil infrastructure around the world the problem is at the apparent lack of durability in our construction materials, inability on part of the owners to provide timely maintenance, absence of advanced condition assessment tools and lack of long-lasting, cost effective repair materials and technologies. This paper will present data to support the argument that fiber reinforced concrete (FRC) is an ideal material for achieving these goals. The paper also discusses fiber reinforced concrete materials carrying Polypropylene Triangular Fibers. This material can help us to develop intelligent infrastructure with elegantly integrated sensing.

Keywords
Fiber reinforced concrete, toughness, polypropylene triangular, Durability

I. Introduction

Compared to other building materials such as metals and polymers, concrete is significantly bleeding, plastic settlement, thermal and shrinkage strains and stress concentrations imposed by external restraints. Under an applied load, distributed micro-cracks propagate, coalesce and align themselves to produce macro-cracks. When loads are further increased, conditions of critical crack growth are attained at the tips of the macro-cracks and unstable and catastrophic failure is precipitated. Under fatigue loads, concrete cracks easily, and cracks create easy access routes for deleterious agents leading to early saturation, freeze-thaw damage, scaling, discoloration and steel corrosion.

The micro and macro-fracturing processes described above can be favorably modified by adding short, randomly distributed fibers of various suitable materials. Fibers suppress the formation of cracks. The concerns with the inferior fracture toughness of concrete are alleviated to a large extent by reinforcing it with fibers of various materials. The resulting material with a random distribution of short, discontinuous fibers is termed fiber reinforced concrete (FRC) and is slowly becoming a well accepted mainstream construction material. Significant progress has been made in the last thirty years towards understanding the short and long-term performances of fiber reinforced cementatious materials, and this has resulted in a number of novel and innovative applications.

II. Literature Review

S.C.Yaragal[7] have studied the effects of fibers in concrete for moment-curvature relationship, cracking characteristics and ductility and also confirmed the veracity of the assumptions of elastic and plastic theories of flexure. A.P.Singh[1] found the addition of steel in form of short and discrete fibers to plain concrete to enhance its engineering properties like compressive, tensile, flexural and shear strength and also its toughness and ductility. S.P.Singh[8] has studied Flexural fatigue strength of concrete reinforced with steel-polypropylene hybrid fibers. Manote Sappakittipakorn[6] conducted a test on loaded RC beams and studied the corrosion effects after adding fibers. Dr.J.Premalatha-madurai[3] has studied the Effect of steel fibers and longitudinal reinforcement inn effective moment of inertia of reinforced high strength fibrous concrete beams. Dr.G.Mohankumar[2] have studied the increase in split tensile strength in HFRC. Dr.Lalu mangal.Arun[4] Edwin conducted tests on the effect of fiber in concrete in terms of compressive strength , Poisson's ratio , split tensile strength and flexural strength and modulus of elasticity. Dr. P.Srinivasa Rao[5] found the effects of glass fibers to improve the durability of self compacting concrete.

III. Mix Design and Testing Consideration

The concentration of fibers can affect the mix's workability because of the relatively high surface area of fibers that must be coated with mortar (cement, fine aggregates, and water). An increase in the amount of fine aggregate to coarse aggregate ratio cement, and/or a high-range, water-reducing admixture (super plasticizer) will typically improve workability. Batch operators should resist the temptation to just add water to improve workability, because this causes many additional problems unrelated to fiber reinforcement. Fiber manufacturers have developed coarse-filament fibers in order to reduce the surface area of the fibers and, consequently, the demand for water. In addition to the normal battery of fresh concrete tests, the inverted slump-cone test can be performed (ASTM C995). This test measures the time it takes for the uncompacted concrete to flow through a slump cone with a vibrator inserted into the cone. Also, quality-control personnel should be aware that fibers will reduce slump (ASTM C143) from 25 to 100 mm. It may be necessary to perform flexural toughness testing (ASTM C1018) and/or residual strength testing (ASTM C1399) when using a FRC mix.

IV. Structural Consideration

Currently, the concrete industry is under pressure to improve productivity and efficiency. The use of fiber reinforcement has been suggested as a means of reducing the amount of primary standard reinforcing steel required in a particular product. Engineer should not replace reinforcing steel with fiber reinforcement and expect the concrete to behave in the same manner. Standard steel reinforcement and fiber reinforcement are two completely different materials. Reinforcing steel, including rebar and WWR, are continuous reinforcing elements that are placed discreetly in the concrete to provide tensile resistance in specific areas. This makes the placement of reinforcing steel critical. Because fiber reinforcement is discontinuous and is dispersed randomly throughout the concrete mix, placement of fibers is not as critical. This discontinuity and random orientation typically does not allow enough bond strength to develop in the concrete to fully utilize the fibers' tensile strength. For optimal performance, however, both fiber and standard reinforcement should be used together, making use of the beneficial properties of both.

Currently, performance testing of final products is the best indicator of the structural capabilities of Fiber-reinforced concrete. According to Mel Galinat of Synthetic Industries, no standard design methodology currently exists for FRC in the United States. An appropriate structural design approach would be completely different than that currently used for design of reinforced-concrete structures (e.g., ACI 318-99).

Mixing of FRC can be accomplished by several methods, with the choice of method depending on the job requirements and the facilities available. It is important to have a uniform dispersion of the fibers and to prevent the segregation or balling of the fibers during mixing .Balling of the fibers during mixing is related to a number of factors. The most important factors appear to be the **Aspect Ratio** of the fibers, the volume percentage of fibers, the maximum size and gradation of the aggregates, and the method of adding the fibers to the mixture. As the first three of these factors increase, the tendency for balling increases. The fiber strength, stiffness, and the ability of the fibers to bond with the concrete are important fiber reinforcement properties. Bond is dependent on the aspect ratio of the fiber. Typical aspect ratios range from about 20 to100, while length dimensions range from 6.4 to 76 mm. There are currently 200,000 metric tons of fibers used for concrete reinforcement. Following Table shows the existing commercial fibers and their properties.

V. Properties Of Fibers Used As Reinforcement In Concrete

Table 1: Propeties of Fibers

Material	**Polypropylene**
Specific Gravity	0.91
Alkali Resistance	Excellent
Chemical Resistance	Excellent
Acid & Salt Resistance	High
Denier	1050
Tensile Strength	0.67 KN/sq mm
Modulus (Young's)	4.0 KN/sp mm
Melt Point	>1650 celsius
Ignition Point	6000 celsius
Absorption	Nil
Density-Bulk	910 kg/m^3 (approx.)
Density-Loose	250-430 kg/ m^3 (approx.)
Dosage (Normal)	0.25% - 0.40% by wt. of cement
Fibre Cut Length (mm)	6, 12, 15, 20, 24, 30, 40, 60 & 120
Form	Fibrillated (Mesh)
Colour	Natural
Dispersion	Excellent

VI. Durability of Fiber Reinforced Concrete

In the last decade, there has been a considerable increase in the interest of FRC. For concrete secondary reinforcement in the construction industry. The fibres are an interesting material for concrete reinforcement. A great deal of research has been addressing durability of fibers in concrete in recent years. The required service life of concrete reinforcement is usually in the order of 50 to 100

years, and as results is desirable within only one or a few years.
Accelerated ageing is generally used to speed up the degradation. Typically, changes in mechanical properties after exposure in alkaline solutions at an elevated temperature are determined, and considered a measure of the Durability. So far most of the durability research conducted in this field has been qualitative, comparing different FRP types to determine which perform better.
For this new material to be generally accepted by the building industry, a good durability must be proven also in quantitative terms. Therefore a big challenge for researchers within this field is to determine the deterioration rate, and thereby the service life of fibers in concrete. This knowledge is needed to be able to choose proper safety factors, taking account for the deterioration due to environmental influence, for fiber design guidelines.

- The approach for service life prediction used in this project will discussed and some experimental results obtained so far will research work of durability of FRC.
- Collect and prepare all materials for concrete as per mix design.
- testing of all materials as per IS standards
- Prepare mix design of M30 concrete
- Mix different % of fibers with concrete as per mix design.
- Casting of cube
- The experimental program is designed to study the loss of weight and loss of compressive strength and permeability behavior of conventional concrete and polymer triangular fibers reinforced concrete 28 days curing in pure water specimens after immersing them in different solutions of NaCl, $MgSO_4$ and Na_2SO_4 for 90 days

VII. Research work of fiber reinforced concrete

- The main objective of the present study the properties of fiber reinforced concrete and to compare with those of conventional concrete and environmental effecr in durability of concrete..
- The properties to be studied will be studied will be compressive strength.

Table 2: Properties of Materials

Cement	0PC 53 Grade
Coarse aggregate	local crushed stone aggregate below 20 mm size and 10 mm grit
Sand	zone II Natural river sand
Chemical admixture	Rheobuild 819 (RM) to improve workability
Water:	distilled /potable/mineral water.
Fibres	triangular polypropylene 12 mm
Solutions	NaCl, $MgSO_4$ and Na_2SO_4

Table 3: Results of sand

Fineness modulus	2.63
Silt contents	1.98%
Specific gravity	2.58
Water absorption	1.59

(Sieves analysis as per IS 383-1970)

VIII. Chemical admixture

As per manufacturer's certificate and technical guideline and as per IS 9103: 1999 Concrete Admixtures – Specification

- **Water**:- potable /distilled/mineral water
- **Fiber**: - polypropylene triangular shape 12 mm long as per manufacturer's specifications and technical guideline.
- **Solutions** :- NaCl, $MgSO_4$ and Na_2SO_4 as per manufacturer's specifications

IX. OPC 53 Grade Cement testing research work

Consistency Test
The standard consistency of cement was tested and found 27 %. The fixed quantity of cement,course aggregate, fine aggregate(sand),admixture and water with variable percentage of polypropylene fiber of triangular shape and 12 mm length. The first 15 cubes were casted without fibers. The second batch was with fiber of 0.15 % of cement and after that 0.20%, 0.25%,0.30%,0.35%,0.40% of polypropylene fiber were casted.(Each of 15 Nos.)

Table 4: Test Results of Cement

Description	Result Obtained	Test methods	I.S. Requirement (I.S. 12269-1987)
Fineness	269 m^2/kg	IS-4031-P-2	Should not be less than 225 m2/kg
Consistency	27 %	IS-4031-P-4	-
Initial setting time	96 Min.	IS-4031-P-5	Should not be less than 30 mts.
Final setting time	235 min.	IS-4031-P-5	Should not be more than 600

			mts.
3 days comp. strength	33.3 N/mm^2	IS-4031-P-6	Should not be less than 27 N/mm2
7 days comp. strength	43.6 N/mm^2	IS-4031-P-6	Should not be less than 37 N/mm2
28 days comp. strength	55.8 N/mm^2	IS-4031-P-6	Should not be less than 53 N/mm2

Mix proportions of conventional concrete:-
As per IS 10262-2009 mix design for M30 prepared by trial and error and minimum water cement ratio decided for maximum compressive strength. After deciding quantity of each ingredients the casting of concrete as conventional and with different percentage of polypropylene fibers in moulds for compressive strength tests.

X. DURABILITY TEST PROCEDURE

Sodium Sulphate resistance of conventional concrete and polypropylene fiber reinforced concrete:
Sodium Sulphate resistance of conventional concrete determined by immersing C.C.Cubes of size 150x150x150 mm in 8% sodium sulphate (Na2SO4) solution. The effect on conventional concrete and polypropylene fiber reinforced concrete (PFRC) specimens measured as percentage reduction in weight and compressive strength at 90 days.
Magnesium Sulphate resistance of conventional concrete and polypropylene fiber reinforced concrete:
Magnesium Sulphate resistance of conventional concrete will be determined by immersing 150x150x150 mm test cubes in 10% magnesium sulphate (MgSO4) solution. the effect on conventional concrete and polypropylene fiber reinforced concrete (PFRC) specimens measured as percentage reduction in weight and compressive strength at 90 days.

Acid Attack on conventional concrete and polypropylene fiber reinforced (PFRC):
Marine environment attack determined by immersing C.C.Cubes of size 150x150x150 mm individually in7% sodium chloride (NaCl) solutions. The deterioration of conventional concrete and polypropylene fiber reinforced concrete (PFRC) specimens measured as percentage reduction in weight and compressive strength at 90 days.

Fig1 C.C cubes without fibers

Table 5: Compressive strength of C.C.Cubes (M30)

% fiber	7 days	28 days	90 Days in NaCl (loss)	90days in Na_2SO_4 (gain)	90days in $MgSO_4$ (loss)
00	22.59	33.36	30.10	36.45	18.80
0.15	23.96	34.80	32.30	38.90	22.30
0.20	28.08	46.34	43.10	52.93	27.10
0.25	28.57	48.64	45.70	55.65	31.56
0.30	28.91	50.10	47.45	57.45	36.70
0.35	27.72	39.16	37.20	52.22	35.22
0.40	27.18	38.62	36.70	50.34	34.84

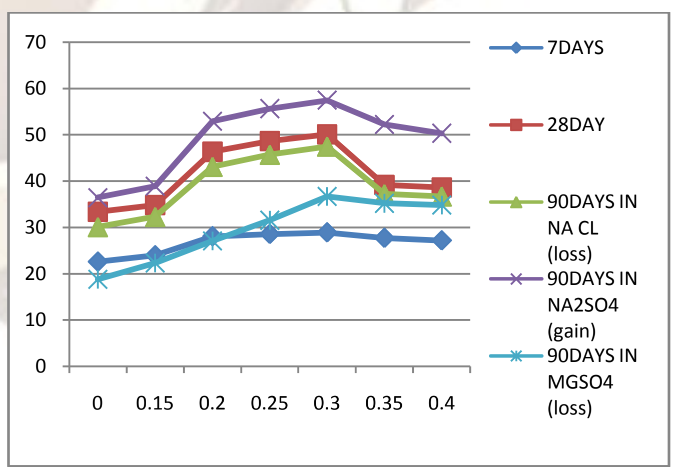

Fig 2 graphs showing compressive strength

The three cubes were tested on 7 days period, other three cubes were tested on 28 days and remaining nine cubes were immersed in chemical solution of NaCl, $Na2SO_4$, $MgSO_4$ to research the marine environment effect on fiber reinforced concrete after 28 days curing in pure water . These cubes were kept for 90 days. Than compressive strength were checked and compared with other results of specimens.

XI. Conclusions

(1) Addition of polypropylene triangular fibers improved durability of concrete. The loss in weight and loss/gain in compressive strength of the cube specimens improved with age.
Compressive strength of concrete increases with increase in fiber dosage upto 0.3%, then it start decreasing. So the optimum percentage fiber found from experiment is 0.3%.

(2) Higher the durability, higher will be the resistance to marine structures Attacks. The polypropylene fibers bridge the cracks and minimize interconnecting voids. This resulted in dense concrete. Therefore this can be used for water retaining structures like water tanks, swimming pools, which ought to be designed as impermeable.

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