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An Investigation on the Durability Properties of Textile Fibre Reinforced Concrete under Sulphate attack

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Abstract – *The main objective of this experimental program is to study the durability properties of textile fibre reinforced concrete under sulphate attack. 0.5% of polypropylene, polyester and nylon fibres are added to the concrete. After 28days of curing period different textile reinforced concrete specimens are immersed in $MgSO_4$ solution for 90days.*

***Key Words*: Textile fibre reinforced concrete, Sulphate attack, polypropylene fibre, polyester fibre, Nylon fibre, $MgSO_4$.**

1. INTRODUCTION

Concrete is one of the most versatile building materials. It can be cast to fit any structural shape from a cylindrical water storage tank to a rectangular beam or column in a high rise building. The advantages of using concrete include high compressive strength, good fire resistance, high water resistance, low maintenance, and long service life.

The disadvantages of using concrete include poor tensile strength, low strain of fracture and formwork requirement. The major disadvantage is that concrete develops micro cracks. It is the rapid propagation of these micro cracks under applied stress that is responsible for the low tensile strength of the material. Hence fibres are added to concrete to overcome these disadvantages.

1.1 Fibre reinforced concrete

To improve the fracture toughness of concrete fibres of various materials may be used. The resulting material with a random distribution of short, discontinuous fibres is termed as fibre reinforced concrete(FRC).

The addition of fibres in the matrix has many important effects. The improved mechanical characteristics of Fibre Reinforced Concrete (FRC) are its superior fracture strength, toughness, impact resistance, flexural strength and resistance to fatigue. Improving fatigue performance is one of the primary reasons for the extensive use of Steel Fibre Reinforced Concrete(SFRC)in pavements, bridge decks, offshore structures and machine foundation, where the composite is subjected to cyclically varying load during its lifetime.

The main reasons for adding steel fibres to concrete matrix is to improve the post cracking response of the concrete, i.e., to improve its energy absorption capacity and apparent ductility and to provide crack resistance and crack control. Also, it helps to maintain structural integrity and cohesiveness in the material. The initial researches combined with the large volume of follow up research have led to the development of a wide variety of material formulations that fit the definition of fibre reinforced concrete.

Fibre's tensile strength, modulus of elasticity, stiffness modulus and mechanical deformations provide an excellent means of internal mechanical interlock. This provides a user friendly product with increased ductility that can be used in applications of high impact and fatigue loading without the fear of brittle concrete failure. Thus, FRC exhibits better performance not only under static and quasi-statically applied loads but also under fatigue, impact, and impulsive loading.

Textile-reinforced concrete (TRC) is a type of reinforced concrete in which the usual steel reinforcing bar is replaced by textile material. TRC represents an interesting new construction material, additional advantage compared to steel or fibre reinforced concrete. This material has low weight and high bearing capacity. The textile fibre materials are polyester, polypropylene, nylon, Kevlar, rayon, etc.

1.2 Durability

Durability of hydraulic-cement concrete is defined as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration (ACI). Durable concrete will retain its original form, quality, and serviceability when exposed to its environment. Concrete is an inherently durable material. Reinforced concrete structures are expected to be maintenance-free during their service lives. However, there is evidence of premature deterioration of modern structures. The resultant costs to the economy reach 3 - 5% of GNP in some countries (and up to 50% of construction budgets). This occurs because existing knowledge is not adequately applied.

The common durability problems in concrete are:

- Corrosion of steel in reinforced concrete
- Sulphate and other chemical attack
- Alkali aggregate reaction (more of a material problem than environmental)
- Freezing and thawing damage
- Carbonation

2. OBJECTIVES OF THE WORK

Textile reinforcement is an alternative reinforcement material consisting of natural and synthetic fibres. When textile reinforcement is incorporated into concrete, it is termed as Textile Reinforced Concrete. Textile reinforcement possess low weight and high bearing capacity.

The main objective of this experimental investigation is to study the behaviour of textile fibre reinforced concrete under sulphate attack. Different fibres used in the experimentation are Polypropylene fibre, Polyester fibre and Nylon fibre.

To achieve the above objective, following experiments are conducted.

- To find out the workability characteristics of textile fibre reinforced concrete.
- To find out the strength characteristic of textile fibre reinforced concrete such as compressive strength, tensile strength, flexural strength, shear strength and impact strength.
- To find out the resistance of textile fibre reinforced concrete to sulphate attack.

3. MATERIALS AND METHODOLOGY

3.1 Cement

In this work, 43 grade OPC conforming to IS: 8112 – 1989 was used with the brand name of Zuari. The physical properties of cement are listed below by conducting tests on cement in laboratory.

Table 1: Physical properties of cement

Properties	Result	Permissible limits as per IS 8112:1989
Fineness	4%	It should not be more than 11%
Normal consistency	32%	<34%
Specific gravity	3.15	
Initial setting time Final setting time	43 min 360 min	Should not be less than 30 minutes Should not be less than 600 minutes

3.2 Fine aggregate

In this experimental work sand used is collected from river Tungabhadra. The properties of sand used are as follows,

Particle shape, size =Round 4.75mm and downsize

Specific gravity =2.64

Water absorption =1.0%

3.3 Coarse aggregate

The specific gravity of coarse aggregate was found to be 2.68. Aggregate were collected from crusher at Nellogal, Haveri district.

Table 2: Physical properties of coarse aggregate

Physical properties	Results
Particle shape, size	Angular 20mm down size
Fineness modulus of 20mm aggregate	6.89
Specific gravity	2.68

3.4 Water

Water actively participates in the chemical reaction with cement. So, water is an important ingradient of concrete for making good concrete mix and to enhance the strength characteristics. According to IS: 456-2000, water for concrete should be of portable quality (pH-6.8 to 8.0). Ordinary tap water, which is fit for drinking, was used in preparing concrete and also for curing in this investigation.

3.5 Polypropylene fibre

In this project Recron 3s fibre CT-2424 is used and it is developed after extensive research at Reliance Technology Centre. It is brought from Aahana enterprises, Chamarajpet, Bengaluru. CT-2424 is monofilament fibre specially designed to supply integral secondary reinforcement of concrete.. The fibres having 6mm and 12mm length are commonly used for concrete mix. In our research work fibre dosage was fixed as 0.5% per m^3 volume of concrete mix. Polypropylene fibres of length 12mm and diameter of 25micron are used. These micro fibres prevent crack formation and provide reinforcement.

Table 3: Specifications of polypropylene fibre

Specifications	Value
Material	Polypropylene riangular fibre
Type	CT 2424
Filament Diameter	25 Microns
Cut Length	12mm
Tensile strength	600kg/cm^2
Melting point	>250^0C
Dispersion	Excellent
Acid resistance	Good
Alkali resistance	Good
Electrical conductivity	Low
Thermal conductivity	Low

3.6 Nylon

Nylon is a strong, light synthetic fiber. Nylon thread is made from the polymerization of an amine and an acid chloride. The thread is lifted from the interface of two immiscible liquids. It is strong and elastic. In this work the nylon fibrer is brought from Aahana enterprises, Chamarajpet, Bengaluru and having 12 mm length and 0.024 mm average thickness i.e. having aspect ratio 500. The nylon fibre was added by 0.5% of volume.

Table 4: Properties of nylon fibre

Properties	Values
Length	12 mm
Diameter	24 micron
Density	1.14 g/cc
Tenacity	6.0-8.5 g/den
Elongation at break	15-45%
Elasticity	Very good
Melting point	215^0C
Resilience	Good

3.7 Polyester fibre

Polyester is a synthetic polymer made of purified terephthalic acid or dimethyl terephthalate and monoethylene glycol. Polyester fiber has good elasticity and toughness, and it can be used as a filler for sound absorption. Polyester fiber resists the stretching and shrinking and resistant to most of chemicals. In this work the polyester fibrer is brought from Aahana enterprises, Chamarajpet, Bengaluru and having 12 mm length and 0.024 mm average thickness i.e. having aspect ratio 500. The polyester fibre was added by 0.5% of volume.

Table 5: Properties of polyester fiber

Properties	Values
Length	12 mm
Diameter	24 micron
Density	1.3g/cc
Water absorption	0.1%
Refractive index	1.58-1.64
Flammability	self-extinguishing

3.8 Magnesium sulphate (MgSO4)

Magnesium sulphate is a widely used inorganic compound which is also called as Epsom salt or bath salts. In this experimental work Magnesium sulphate is brought from Pharma Foods, Kumta, Uttara Kannad district, Karnataka. The properties of magnesium sulphate are given in table.

Table 6: Properties of Magnesium sulphate

Test parameter	Test Standard	Test results
Description	Colourless crystals or White crystals	Colourless crystals
Solubility	Freely soluble in water	Freely soluble in water
Identification	Positive for magnesium & Sulphate	Passes test
Acidity/Alkalinity	NMT 0.2ml of 0.01M NaOH	0.11 ml of 0.01M HCL is required
Arsenic	NMT 5ppm	Less than 5ppm
Heavy metals as Pb	NMT 5ppm	Less than 5ppm
Iron	NMT 100ppm	Less than 100ppm
Chloride	NMT 300ppm	Less than 300ppm
Assay as $MgSO_4$	NLT 99.0% NMT105.0%	99.93%

4 Mix Proportions

Following table gives the mix proportion as per IS10262-2009

Table 7: Mix proportion

Water	Cement	Fine aggregate	Coarse aggregate
197 Litre/m^3	438 kg/m^3	655.96 kg/m^3	1129.46 kg/m^3
W/C- 0.45	1	1.497	2.578

5. EXPERIMENTAL PROCEDURE

In this work conventional concrete, with nylon fibre(0.5%), concrete with polypropylene fibre (0.5%) concrete with polyester fibre (0.5%) specimens are prepared. The specimens are cured for 28days. After 28days specimens are tested for compressive strength, split tensile strength, flexural strength, shear strength and impact strength. Then the specimens are immersed in

$MgSO_4$ solution for 90days. After 90days compressive strength, split tensile strength, flexural strength, shear strength and impact strength tests are conducted to check the durability under sulphate attack.

And finally the results are compared to investigate the durability properties of textile reinforced concrete under sulphate attack.

6. EXPERIMENTAL RESULTS

6.1 Workability test results

Table 8 Workability test results

Description of textile fibre reinforced concrete	Slump (mm)	Compaction factor	Vee-Bee degree (sec)
Conventional concrete	20	0.86	29
Polypropylene fiber reinforced concrete	0	0.76	38
Polyester fiber reinforced concrete	0	0.80	35
Nylon fiber reinforced concrete	0	0.78	36

6.2 Compressive strength test results

Table 9 gives the comparative overall results of compressive strength with and without sulphate attack. Table also gives the percentage increase or decrease of compressive strengths. Graphical representation of variation of compressive strength is given in figure.1

Table 9 Comparative overall results of compressive strength

Description of textile fiber reinforced concrete	Without sulphate attack		With sulphate attack		% decrease of compressive strength when subjected to sulphate attack
	Compressive strength (N/mm^2)	% Increase or decrease of compressive strength w.r.t conventional concrete	Compressive strength (N/mm^2)	% increase or decrease of compressive strength w.r.t conventional concrete	
Conventional concrete	30.35	-	20.89	-	31.16
Concrete with Polypropylene fiber	33.48	10.13	23.77	13.78	29.00
Concrete with Polyester fiber	32.44	6.89	22.58	8.08	30.39
Concrete with Nylon fiber	31.53	3.89	22	5.31	30.22

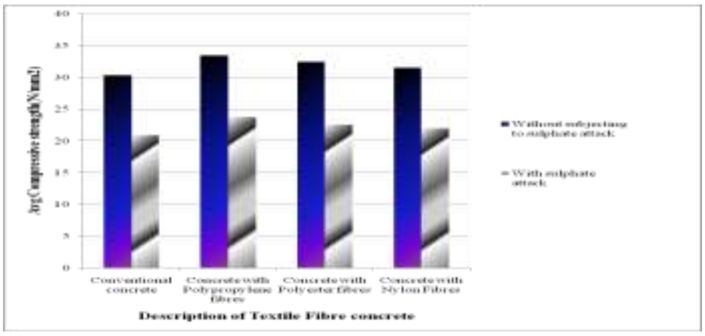

Figure -1 Graphical representation of variation of compressive strength

6.3 Split tensile strength test results

Table 10 gives the comparative overall results of split tensile strength with and without sulphate attack. Table also gives the percentage increase or decrease of split tensile strengths. Graphical representation of variation of split tensile strength is given in figure 2

Table 10 Comparative overall results of tensile strength

Description of textile fiber reinforced concrete	Without sulphate attack		With sulphate attack		Percentage decrease of split tensile strength when subjected to sulphate attack
	Split tensile strength (N/mm^2)	Percentage increase or decrease of split tensile strength w.r.t conventional concrete	Split tensile strength (N/mm^2)	Percentage increase or decrease of split tensile strength w.r.t conventional concrete	
Conventional concrete	2.40	-	1.98	-	17.50
Concrete with Polypropylene fiber	3.11	29.58	2.26	14.14	27.33
Concrete with Polyester fiber	2.69	12.08	2.12	7.07	21.18
Concrete with Nylon fiber	2.55	6.25	2.07	4.54	18.82

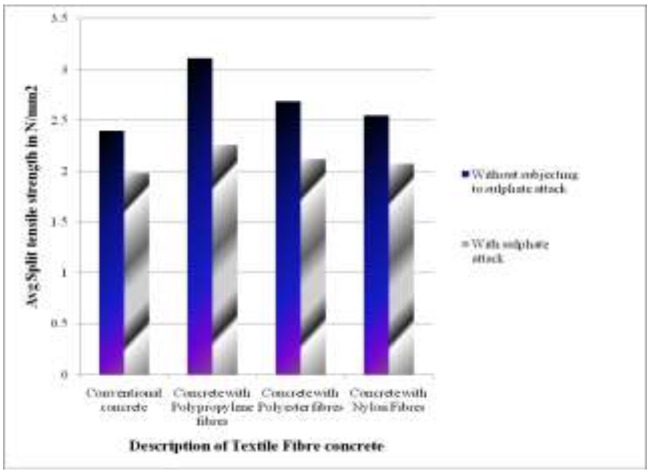

Figure.2 Graphical representation of variation of split tensile strength

6.4 Flexural strength test results

Table 11 gives the comparative overall results of flexural strength with and without sulphate attack. Table also gives the percentage increase or decrease of flexural strengths. Graphical representation of variation of flexural strength is given in figure.3

Table 11 Comparative overall results of flexural strength

Description of textile fiber reinforced concrete	Without sulphate attack		With sulphate attack		Percentage decrease of flexural strength when subjected to sulphate attack
	Flexural strength (N/mm^2)	Percentage increase or decrease of flexural strength w.r.t conventional concrete	Flexural strength (N/mm^2)	Percentage increase or decrease of flexural strength w.r.t conventional concrete	
Conventional concrete	5.92	-	5.03	-	15.03
Concrete with Polypropylene fiber	10.63	79.56	7.68	52.68	27.75
Concrete with Polyester fiber	8.08	36.48	7.13	41.74	11.75
Concrete with Nylon fiber	7.60	28.37	6.80	35.18	10.52

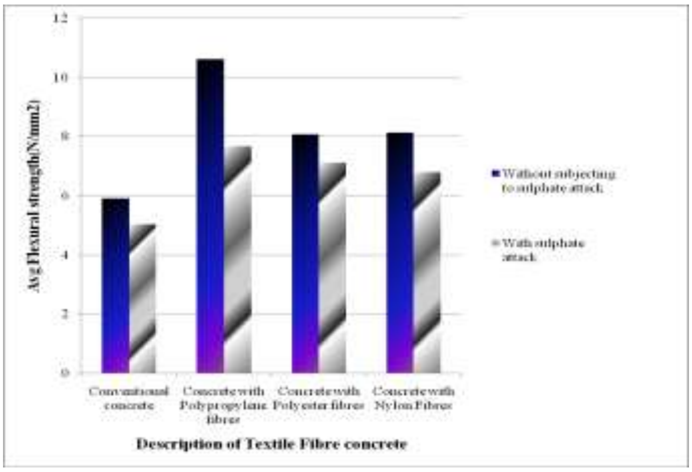

Figure 3 Graphical representation of variation of flexural strength

6.5 Shear strength test results

Table 12 gives the comparative overall results of shear strength with and without sulphate attack. Table also gives the percentage increase or decrease of shear strengths. Graphical representation of variation of shear strength is given in figure.4

Table 12 Comparative overall results of shear strength

Description of textile fiber reinforced concrete	Without sulphate attack		With sulphate attack		Percentage decrease of shear strength when subjected to sulphate attack
	Shear strength (N/mm²)	Percentage increase or decrease of shear strength w.r.t conventional concrete	Shear strength (N/mm²)	Percentage increase or decrease of shear strength w.r.t conventional concrete	
Conventional concrete	4.26	-	3.88	-	8.92
Concrete with Polypropylene fiber	9.81	130.28	7.77	100.25	20.79
Concrete with Polyester fiber	8.15	91.31	7.22	86.08	11.41
Concrete with Nylon fiber	7.59	78.16	6.67	71.90	12.12

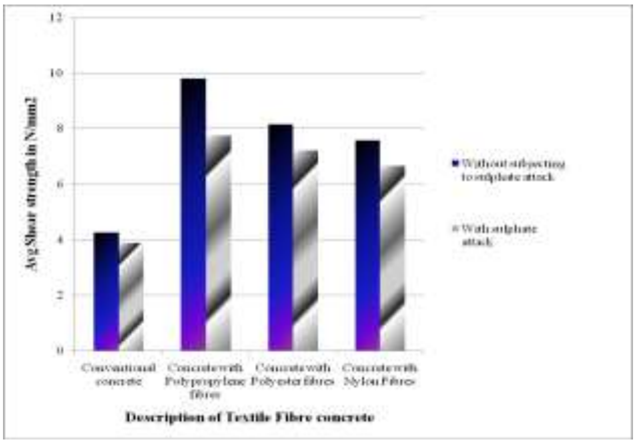

Figure.4 Graphical representation of variation of shear strength

6.6 Impact strength test results

Table 13 gives the comparative overall results of impact strength for final failure with and without sulphate attack. Table also gives the percentage increase or decrease of impact strengths. Graphical representation of variation of impact strength is given in figure.5

Table 13 Comparative overall results of impact strength

Description of textile fibre reinforced concrete	Without sulphate attack		With sulphate attack		Percentage decrease of impact energy when subjected to sulphate attack
	Impact energy for final failure (N-m)	Percentage increase or decrease of impact energy w.r.t conventional concrete	Impact energy for final failure (N-m)	Percentage increase or decrease of impact energy w.r.t conventional concrete	
Conventional concrete	2337.00	-	2301.38	-	1.52
Concrete with Polypropylene fiber	2907.00	24.39	2522.25	9.5	13.23
Concrete with Polyester fiber	2572.13	10.06	2403.38	4.43	6.56
Concrete with Nylon fiber	2394.00	2.43	2362.25	2.64	1.33

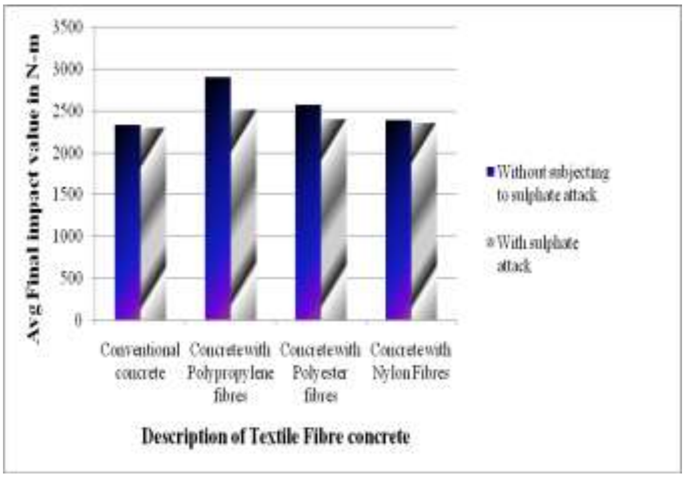

Figure 5 Graphical representation of variation of impact energy

CONCLUSIONS

Following conclusions are made based on the experimentation conducted on textile fibre reinforced concrete.

1) Workability of textile fibre reinforced concrete is seriously affected.
2) Compressive strength of textile fibre reinforced concrete is higher than the conventional concrete. Among the textile fibres, polypropylene fibres have shown better performance in compressive strength as compared to polyester and nylon fibres.
3) Tensile strength of textile fibre reinforced concrete is higher than the conventional concrete. Among the textile fibres, polypropylene fibres have shown better performance in tensile strength as compared to polyester and nylon fibres.
4) Flexural strength of textile fibre reinforced concrete is higher than the conventional concrete. Among the textile fibres, polypropylene fibres have shown better performance in flexural strength as compared to polyester and nylon fibres.
5) Shear strength of textile fibre reinforced concrete is higher than the conventional concrete. Among the textile fibres, polypropylene fibres have shown better performance in shear strength as compared to polyester and nylon fibres.
6) Impact energy strength of textile fibre reinforced concrete is higher than the conventional concrete. Among the textile fibres, polypropylene fibres have shown better performance in impact energy strength as compared to polyester and nylon fibres.

7) Compressive strength of textile fibre reinforced concrete is higher than the conventional concrete when subjected to sulphate attack, thereby proving the resistance to sulphate attack. Among the textile fibres, polypropylene fibres have shown better performance in sulphate attack as compared to polyester and nylon fibres.
8) Tensile strength of textile fibre reinforced concrete is higher than the conventional concrete when subjected to sulphate attack, thereby proving the resistance to sulphate attack. Among the textile fibres, polypropylene fibres have shown better performance in sulphate attack as compared to polyester and nylon fibres.
9) Flexural strength of textile fibre reinforced concrete is higher than the conventional concrete when subjected to sulphate attack, thereby proving the resistance to sulphate attack. Among the textile fibres, polypropylene fibres have shown better performance in sulphate attack as compared to polyester and nylon fibres.
10) Shear strength of textile fibre reinforced concrete is higher than the conventional concrete when subjected to sulphate attack, thereby proving the resistance to sulphate attack. Among the textile fibres, polypropylene fibres have shown better performance in sulphate attack as compared to polyester and nylon fibres.
11) Impact energy strength of textile fibre reinforced concrete is higher than the conventional concrete when subjected to sulphate attack, thereby proving the resistance to sulphate attack. Among the textile fibres, polypropylene fibres have shown better performance in sulphate attack as compared to polyester and nylon fibres.
12) Textile fibre reinforced concrete when subjected to sulphate attack exhibits less compressive strength as compared to the textile fibre reinforced concrete which is not subjected to sulphate attack.
13) Textile fibre reinforced concrete when subjected to sulphate attack exhibits less tensile strength as compared to the textile fibre reinforced concrete which is not subjected to sulphate attack.
14) Textile fibre reinforced concrete when subjected to sulphate attack exhibits less flexural strength as compared to the textile fibre reinforced concrete which is not subjected to sulphate attack.
15) Textile fibre reinforced concrete when subjected to sulphate attack exhibits less shear strength as compared to the textile fibre reinforced concrete which is not subjected to sulphate attack.
16) Textile fibre reinforced concrete when subjected to sulphate attack exhibits less impact energy strength as compared to the textile fibre reinforced concrete which is not subjected to sulphate attack.

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