MECHANICAL BEHAVIOUR OF TEXTILE REINFORCED CONCRETE

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ABSTRACT- *"Our World is made of concrete". As a Civil Engineer we all know that Concrete is strong only in Compression and weak in Tension. In order to increase the Tensile strength of the Concrete, it is being reinforced with steel, which unfortunately also has the drawback of being susceptible to corrosion and fatigue. It will further increase the maintenance and repair cost of the structure. And it is clear that we urgently need high performance construction materials to adequately meet our needs. An innovative concept to eliminate these drawbacks is the textile reinforcement of concrete. For past many years leading scientists have been working with the idea of improving the world of concrete by using high performance fibres, developing so called "Textile Reinforced Concrete (TRC)". The objective of this project is to study the various properties of Textile Reinforced Concrete (TRC). AR-Glass fibre mesh of 145 GSM is used. Specimens were casted with and without the fibres in the range of increase of fibre layers of 3, 4 and 5. Tests were conducted to study the Flexural strength of the beam. Beam specimens were casted using the 500mm×100mm×100mm beam mould. Among 4 beams casted, 3 were casted with fibre mesh and the another beam were casted without fibre mesh i.e. PCC beam. The tests were conducted by the method of three point loading system on the beam. And the interaction between the Cementitious Matrix and the Textile fibre mesh were determined. The results are compared between Textile Reinforced Concrete (TRC) and the Conventional Concrete. In which the PCC beam shows the Modulus of Rupture value as 7.75 N/mm^2 , the beam casted with 3 layers of AR-Glass Fibre mesh embedded in the Cementitious Matrix shows Modulus of Rupture value as 10.5 N/mm^2 , the beam casted with 4 layers of AR-Glass Fibre Mesh embedded in Cementitious Matrix shows the Modulus of Rupture value as 13.25 N/mm^2 and the beam casted with AR-Glass Fibre Mesh of 5 layers embedded in the Cementitious Matrix shows the Modulus of Rupture value as 11.5N/mm^2 . Based on the results obtained, the Flexural Strength of the Concrete increases about 70.6 % in the case of beam reinforced with 4 layers of AR-Glass Fibre Mesh when compared to the Conventional Concrete.*

Keywords: **Alkaline Resistant Glass Fibre, Cementitious Matrix, Flexural Strength.**

1. INTRODUCTION

Concrete is a composite material composed of Cement, Fine aggregate, Coarse aggregate and water. Concrete has relatively high Compressive Strength, but significantly lower Tensile Strength. As a result without compensating, Concrete would fail from Tensile stresses even when loaded in Compression. Therefore, a Tensile Reinforcing material is used in the cases where the Concrete is subjected to Tensile stresses. Reinforced Concrete is the most common form of Concrete. The reinforcement is often Steel (Mesh, Spiral, Bars and other forms), which unfortunately also has major drawbacks of being susceptible to corrosion and fatigue. Textile Reinforced Concrete (TRC) is a type of Reinforced Concrete in which the fabric cage is used as a Tensile Reinforcing material in the Concrete. The woven fabrics with high Tensile strengths and elongation properties are reinforced into the Concrete. The most commonly used Fibres for making the fabrics are Jute, Glass Fibre, Kevlar, Polypropylene, Polyamides (Nylon) etc. The Fabric weaving is done either in a coil fashion or in a layer fashion. As a result, the Concrete Reinforced with Textile Fibres becomes flexible from the inner side along with high strength provided by the outer materials. Uses of Textile reinforced materials are extensively increasing nowadays with the improvement in materials science and Textile technology. To withstand vibrations, sudden jerks and torsion in Bridges and Road Guards, they are prepared using Kevlar or Jute Reinforced Concrete.

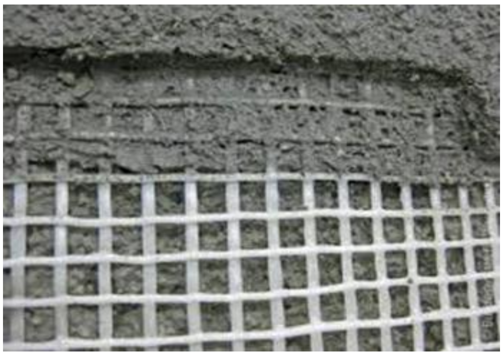

Fig.1-Textile Reinforced Concrete

Textile Reinforced Concrete consists of Hair thin filaments (continuous filaments) made of Alkali-Resistant Glass (AR-Glass) form the base material for the textile reinforcements. They have a diameter between 5 and approximately 30 micrometre, depending on the material. From thousands to tens of thousands of these filaments are combined into what are called rovings. Then the rovings are processed into lattice-like non-woven fabrics on textile machines. Bundling the filaments with their small diameters causes microscopic hollow spaces to form between the fibres, so small that even the finest Concrete particles cannot penetrate them. The Concrete would only reach the outer filaments, while the Concrete does not reach the core filaments. This means that only the outer edge filaments would absorb the load. The core filaments on the other hand remain free of strain, resulting a very low load factor of only 30-35% for the rovings. To use textiles efficiently, they have to be impregnated into Fine grined Cementitious Matrix. The impregnation mix is far finer than the Concrete, can penetrate the core of the roving and is able to activate the inner filaments for load dissipation as well. Impregnation with Epoxy Resin or Styrene-Butadiene has proven particularly effective for improving the quality of composite material. Impregnating the Glass or Carbon Fibre Reinforcement therefore makes it possible to systematically achieve the required characteristics, such as tensile stresses at break and permanency. In addition to the high tensile stresses at break, Epoxy Resin impregnation is particularly well suited for the production of robust, dimensionally stable reinforcement- important factors for the work flows in prefabricated component plants and Concreting.

2. MATERIALS USED

2.1 Cement

The Cement used in this project is Portland Pozzolana Cement.

2.2 Class F Fly Ash

Class F Fly Ash is used in this project. Class F Fly Ash is designated in ASTM C 618 and originates from anthracite and bituminous coals. It consists mainly of Alumina and Silica. Class F Fly Ash can be used as a Portland Cement replacement ranging from 20-30% of the mass of the Cementitious materials.

2.3 M-Sand

In this project, Karur crushed M-sand was used. Manufactured Sand (M-Sand) is a substitute of river sand for Concrete construction. Manufactured Sand is produced by crushing the hard granite rock. The crushed sand of cubical shape is washed and graded as a construction material. IS 383-1970 (Reaffirmed 2007) recognizes Manufactured Sand as “Crushed Stone Sand”. M-Sand can also be used for making masonry mortar and shall confirmed to the requirements of IS 2116-1980 (Reaffirmed 1998)-“Specification of Sand for Masonry Mortars”.

2.4 Silica Fume

Silica fume is a by product of producing Silicon metal or Ferrosilicon alloys. Concrete containing Silica Fume can have very high strength and can be very durable. Silica Fume consists primarily of amorphous (non-crystalline) Silicon dioxide ($SiO2$). The individual particles are extremely small, approximately 1/100th the size of an average Cement particle. Because of its fine particles, large surface area and high $SiO2$ content, Silica fume is very reactive Pozzolana when used in Concrete. The quality of Silica fume is specified by ASTM C 1240 and AASHTO M 307.

2.5 Super Plasticizer

Superplasticizer, also known as high range water reducers used where well-dispersed particle suspension is required. Their addition to Concrete or Mortar allows the reduction of the Water-Cement ratio, not affecting the Workability of the Mixture and enables the production of Self-Consolidating Concrete and High Performance Concrete. TEC MIX 550 Superplasticizer is used in this project. With a relatively low dosage (0.15%-0.30% by Cement weight) they allow a water reduction up to 40 %, due to their chemical structure which enables good particle dispersion.

2.6 AR-Glass Fibre

Fig.2-AR-Glass Fibre

Alkali-Resistant Glass Fibre Mesh of 145 GSM (Gram per Square Metre), Size of 1m×50m is used in this project. AR-Glass Fibres are manufactured from a specially formulated glass composition with an optimum level of Zirconium (ZrO_2) to be suitable for use in Concrete. The higher the Zirconium content in the fibre the better the resistance to Alkali attack. The Fibres add Strength and Flexibility to the Concrete resulting in a strong yet light weight. High Mechanical Strength and excellent Tensile Strength. The Glass Fibre products are able to bear high loads without significant deformation. It reduces shrinkage in the Concrete. It exhibits excellent Workability characteristics.

2.7 Water

Water fit for drinking is generally considered for making Concrete. Water should be free from acid, oils, alkalis and other organic compounds. Water plays two roles in the production of Concrete, which are as mixing water and curing water. The amount of water in Concrete controls many Fresh and Hardened properties in Concrete including Workability, Compressive Strength, Permeability and Water Tightness, Durability and Weathering.

3. PROPERTIES OF MATERIALS

Table-1: Properties of Cement

S. No	Property	Result
1.	Specific Gravity	**3.16**
2.	Normal Consistency	**34%**
3.	Initial Setting Time (min)	**35**
4.	Final Setting Time (min)	**610**

Table-2: Properties of Fine Aggregate (M-Sand)

S. No	Property	Result
1.	Specific Gravity	**4.79**
2.	Fineness Modulus	**2.78**

4. MIX DESIGN

Mix Design is the process of selecting suitable materials to attain the various properties of Concrete such as Workability, Durability and Strength. In other words, the process of determining relative quantity of materials like Cement, Fine Aggregate, Coarse Aggregate and Water is called the mix design of Concrete. Proportion of Concrete should be selected to make the economical use of the available materials to produce Concrete for required quality. Many methods have been recommended for mix proportioning of Concrete all over the world. Among those methods, IS 10262-2002 Code was selected. The design of mix for the present work by this method is given below.

4.1 Concrete Matrix in TRC

The Concrete Matrix applied in TRC differs from that typically used in conventional steel reinforced concrete. Fine-grained concrete also defined as mortar is typically prescribed for TRC, where the maximum aggregate size is typically <2mm. Self compacting and highly flowable concrete is primarily needed to adequate penetrate the openings of the textile reinforcement structure to allow for adequate bond and load transfer from the concrete to the reinforcement. This minimal aggregate size could however increase shrinkage and the need for larger quantities of cement paste; as such, a slight increase in maximum aggregate size to 4-6 mm could be considered while bearing in mind the desired design thickness of the TRC structure. Moreover, the matrix should be designed chemically compatible with the selected reinforcement, i.e. in terms of alkalinity, while providing the required strength properties, mechanical behaviour and suitable characteristics for the specimen geometry and production method. For instance, the concrete matrix could also be designed such that the alkalinity and hydration kinetics be altered or by modifying the morphology at the interface of the textile reinforcement by means of polymer coating along with Nano clay. Additions of silica fume or high alumina cement, for example, can be incorporated in the mix to lower the alkalinity. For the past several decades, there have been concerns about the sustainability and reduction of CO_2 gas emissions as a consequence of cement production. According to statistics from 2013, the production causes the generation of approximately 700 kg CO_2 per ton of cement which is why the substitution of cement with pozzolanas like fly ash been explored.

4.2 Cementitious Binder and AR-Glass fibre

In general, the applied mixes were Self-Compacting with a water-cement ratio of 0.4 and a maximum aggregate size of 4mm. The chemical admixture applied was a Polymer based Super plasticizer which reduces the surface tension of water during mixing, thus allowing the Concrete consistency to increase without additional water. Using high range water-reducing admixtures gives way to the reduction of water-cement ratio, which in turn increases the strength of the Concrete. Mineral admixtures in the form of natural pozzolanic materials, e.g. fly ash and silica fume, were also included as Concrete components in this work. These admixtures are primarily applied to improve the workability of fresh Concrete.

4.3 Mix Proportioning of Conventional Beam

Grade Designation = M25

Mass of cement in (kg/m^3) = 320

Mass of water in (kg/m^3) = 138

Mass of fine aggregate

in (kg/m^3) = 751

Mass of Coarse aggregate

in (kg/m^3) = 1356

Mass of admixture in (ml) = 1.5

Water Cement Ratio = 0.40

4.4 Mix Proportioning of TRC Beam

Table-3: TRC Beam Mix Proportioning

Cementitious Binder Materials	Quantity
Portland Pozzolana Cement	400 g
Class F Fly Ash	100 g
Silica Fume	50 g
Fine Aggregate (M-Sand)	1500 g
Super Plasticizer	0.15 %-0.30 % by Cement weight (in ml)
Water-Cement Ratio	0.4

5. RESULTS AND DISCUSSION

5.1 Experimental Program

In order to study the interaction of Textile Fibre (AR-Glass Fibre) with Concrete under Flexure, 4 Beams were casted respectively. The experimental program was divided into four sections. The first beam was casted as PCC Beam with Cement, M-Sand, Coarse Aggregate, Fly Ash and Super plasticizer. The another 3 Beams were casted as TRC beam by using AR-Glass Fibre Mesh and Fine grained cementitious matrix. The Beams were casted in the order of increase of Fibre mesh layer in each beam.

5.2 Experimental set up

Flexural Test evaluates the Tensile Strength of Concrete indirectly. It tests the ability of Concrete beam or slab to withstand failure in bending. The results of Flexural test on Concrete expressed as a Modulus of Rupture which denotes as (MR) in MPa or psi.

The Flexural test on Concrete can be conducted using either three point load test (ASTM C78) or Center point load test (ASTM C329). The Modulus of Rupture value obtained by centre point load test arrangement is smaller than three point load test configuration by around 15 percent. Furthermore, modulus of rupture is about 10-15 % of Compressive Strength of concrete. The load applying block was made into contact with the surface of the specimen at the three point between the supports. The first crack load and the corresponding deflection were noted.

The Modulus of Rupture (fb) $=Pl/bd^2$, N/mm^2

P - Load acting on the Beam

l - Span of the Beam

b - Breadth of the Beam

d - Depth of the Beam

5.2.1 Modulus of Rupture of PCC Beam

PCC beam of size 500 mm × 100 mm ×100mm comprises of Cement, Fine Aggregate (M-Sand), Coarse Aggregate of size less than 12.5 mm and water is casted and cured for 28 days and then it is tested for determine its Flexural Strength.

5.2.2 Modulus of Rupture of Beam Reinforced with 3 layers of AR-Glass Fibre

Textile Reinforced Concrete Beam of size 500 mm × 100 mm × 100 mm comprises of Cement, Fine Aggregate (M-sand), Fly Ash, Silica Fume with three layers of AR-Glass fibre of 145 GSM embedded in it with 25 mm spacing from the bottom. It is casted, cured for 28 days and then it is tested to determine its Flexural Strength.

5.2.3 Modulus of Rupture of Beam Reinforced with 4 layers of AR-Glass Fibre

Textile Reinforced Concrete Beam of size 500 mm × 100 mm × 100 mm comprises of Cement, Fine Aggregate (M-sand), Fly Ash, Silica Fume with four layers of AR-Glass fibre of 145 GSM embedded in it with 20mm spacing from the bottom. It is casted, cured for 28 days and then it is tested to determine its Flexural Strength.

Fig.3-TRC Beam

5.2.4 Modulus of Rupture of Beam Reinforced with 5 layers of AR-Glass Fibre

Textile Reinforced Concrete Beam of size 500 mm × 100 mm × 100 mm comprises of Cement, Fine Aggregate (M-sand), Fly Ash, Silica Fume with five layers of AR-Glass fibre of 145 GSM embedded in it. It is casted, cured for 28 days and then it is tested to determining its Flexural Strength.

Fig.4-TRC Beam after Failure

5.3 Graphical Representation of Test Results

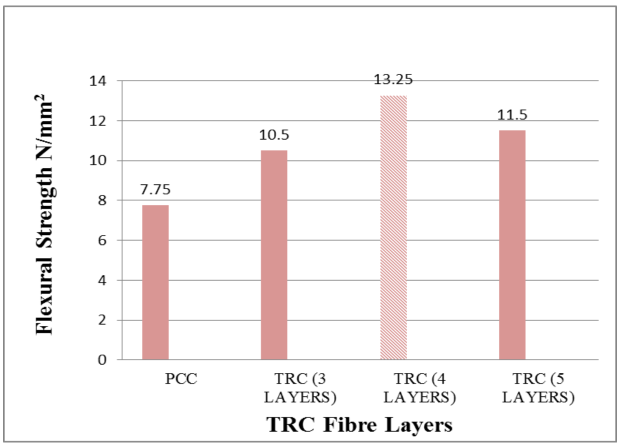

Fig.5- Flexural Strength of Beam

Table-4: Modulus of Rupture test result comparison

SPECIMEN TYPE	FIRST CRACK LOAD IN KN	28 DAYS MODULUS OF RUPTURE (N/mm2)
PCC	15.5	7.75
TRC (3 layers of AR-Glass Fibre)	21	10.5
TRC (4 layers of AR-Glass Fibre)	26	13.25
TRC (5 layers of AR-Glass Fibre)	23	11.5

5.4 Discussion

The tests were carried out on each mix to evaluate the Modulus of Rupture of Concrete. From the results obtained, the Flexural Strength of Conventional Concrete at 28 days was 7.75 N/mm^2 and the Flexural Strength increases when the 4 layers of TRC AR-Glass Fibre Mesh was added to the Concrete, which shows the Flexural Strength at 28 days of about 13.25 N/mm^2. Increase in strength when compared to Conventional Concrete is 70.6%.

6. CONCLUSIONS

The following results are concluded based on the experimental results discussed in the previous chapters.

- Addition of Fibre to concrete increases the tensile strength of the concrete.

- The addition of Fibre to Concrete significantly increases its toughness and makes the concrete more ductile as observed by the modes of failure of specimens.

- The load bearing capacity of the concrete can be increased by adding Fibres of having high GSM (Gram Per Square Metre) , thus increases the strength of the concrete.

- Textile Fibre Reinforced Concrete can be suggested for rehabilitation of deteriorated structures and Strengthening of existing RC structures.

It is concluded that the Strength increases with the increase in thickness of the Fibrous material used. The experimental result shows that the Flexural Strength of the Conventional Concrete at 28 days was found to be 7.75 N/mm2. In which, the beam reinforced with 4 layers of AR-Glass Fibre shows the Flexural Strength of about 13.25 N/mm2. Increase in strength when compared to Conventional Concrete is about 70.6%.

REFERENCES

1. **Anna Volkova and Alexey Paykov(2016),**"Flexural Behaviour of textile Reinforced Concrete", Journal of Material Science and Technology, Volume 4, Issue 7, Pp. 130-140.

2. **Amir Si Larbi, Raphael(2015),**"Development of Textile Reinforced Concrete (TRC) to retrofit Reinforcement Concrete Structures", Materials Journal, Volume 20, Issue 8, Pp. 65-73.

3. **Barak Fishbain, oded Rabinovitch, Yiska Goldfeld(2015),** "Sensory Carbon fiber based textile-reinforced concrete for smart Structures", Journal of Intelligent Material systems and Structures, Volume 8, Issue 5, Pp. 87-96.

4. **Barzin Mobasher, Yiming Yao(2015),** "Experimental Investigation and Modelling of the Temperature effects on the tensile behaviour of textile reinforced refractory Concretes", Cement and Concrete Composites, Volume 75, Issue 11, Pp. 51-61.

5. **Catherine G. Papenicalaou, Dionysios A. Bournas(2007),** "Textile-Reinforced Mortar versus Fiber Reiforced Polymer confinement in Reinforced concrete column", Structural Journal, Volume 104, Issue 6, Pp. 740-748.

6. **Hendrick L. Funke, Lothar Kroll, Sandra Gelbrich(2015),** "Development of Effective Textile-Reinforced Concrete Noise Barrier", Journal of Materials Science Research, Volume 4, Issue 3, Pp. 71-82.

7. **Holger Wallbaum, Karin Lundgren, Katarina Malaga and Natalie Williams Porta(2015)** "Sustainable Potential of Textile-Reinforced Concrete", Journal of Materials in Civil Engineering, Volume 27, Issue 7, Pp. 261-273.

8. **Junes.A, Si Larbi.A,(2016)** "An Experimental and theoretical study of Sandwich Panels with TRC facing: Use of metallic connectors and TRC Stiffness", Engineering Structures, Volume 113, Pp. 174-185.

9. **Nagesh R. Iyer, Ramachandra Muthy. A, Smita Gopinath,(2016)** "Strengthening of RC beams with textile reinforced concrete overlays produced using textile reinforced concrete Prototyping technology", Indian Concrete Journal, Volume 9, Issue 9, Pp. 25-31

10. **Lil He, Xu Shilang,(2007)** "Bond Properties and Experimental methods of textile reinforced Concrete", Journal of Wuhan University of Technology and Materials Science, Volume 22, Issue 3, Pp. 529-532.