10th International Conference on Recent Innovations in Science, Engineering and Management
Dhruva Institute of Engineering and Technology, Nalgonda, Telangana State (ICRISEM-17)
7th July 2017, www.conferenceworld.in ISBN: 978-93-86171-53-5

TECHNICAL USAGE OF FIBER REINFORCED CONCRETE (Glass Fiber)

Mrs V.Aparna

Asst.Prof in Civil Engineering Department, Dhruva Institute of Technology (India)

ABSTRACT

Normal concrete is strong in compressive strength possesses a very low tensile strength, limited ductility and title resistance to cracking. The low resistance to tensile crack propagation in turn results in low fracture toughness, limits resistance to impact and explosive loading internal micro cracks are leading present in the concrete due to drying, shrinking and poor tensile strength, eventually leading to brittle fracture of concrete. Hence fibers are added to concrete to overcome these disadvantages.

I. FIBER REINFORCEMENT CONCRETE (RFC)

Concrete is week in tension and has a brittle character. The concept of using fibers to improve the characteristics of construction materials is very old. Early application includes addition of straw to mud bricks, horse hair to reinforce plaster and asbestos to reinforce pottery.

Use of continuous reinforcement in concrete (rein forced concrete) increases strength and ductility, but requires careful placement and labor skill. Alternatively, introduction of fiber indiscrete form in plain or reinforced concrete may provide a better solution. The modern development of fibers reinforcement concrete (FRC) started in the early sixties. Addition of fibers to concrete makes it a homogeneous concrete and isotropic material.

II. GLASS FIBERS REINFORCED CONCRETE (GFRC)

Concrete is weak in tension and has a brittle character. The concept of using fibers to improve the characteristics of construction materials is very old. Early applications include addition of straw to mud bricks, horse hair to reinforce plaster and asbestos to reinforce pottery. Use of continuous reinforcement in concrete (reinforced concrete) increases strength and ductility, but requires careful placement and labor skill. Alternatively, introduction of fibers in discrete form in plain or reinforced concrete may provide a better solution. The modern development of fiber reinforced concrete (FRC) started in the early sixties (1J. Addition of fibers to concrete makes it a homogeneous and isotropic material. When concrete cracks, the randomly oriented fibers start functioning, arrest crack formation and propagation, and thus improve strength and ductility. The failure modes of FRC are either bond failure between fiber and matrix or material failure. In this paper, the state-of-the-art of fiber reinforced concrete is discussed and results of intensive tests made by the author on the properties of fiber reinforced concrete using local materials are reported.

III. DEFINITION

Glass fiber reinforced concrete is the term applied to products manufactured using cement/aggregate slurry thoroughly mixed with alkali-resistant (AR) glass fiber reinforcement.

Types of fibers

The fibers can be broadly classified into two groups

1. Low modulus, high elongation fibers
2. High Strength, high modulus fibers

IV. LOW MODULUS, HIGH ELONGATION FIBERS

Nylon, polypropylene, plastic are some of the low modulus high elongation fibers which are capable of large energy absorption characteristics. They do not lead to strength improvement but impart toughness, resistance to impact and explosive loading.

Ex: rayon etc.

V. HIGH STRENGTH, HIGH MODULUS FIBERS

High Strength, high modulus fibers are Glass, Carbon and Steel. These fibers impart primary characteristics of strength and stiffness to composite and varying degrees of dynamic properties.

Fibers Material	Tensile Strength N/mm^2	Young's Modulus (10^3N/mm^2)	Specific Gravity
Steel	275-2758	200	7.86
Glass	1034-3792	69	2.5
Asbestos	551-965	89-138	3.2
Nylon	758-827	4.31	1.1
Polypropylene	551-758	3.45	0.90

Table: Types of Fibers and its properties

VI. GLASS FIBERS

Glass-reinforced plastic (GRP) is a composite material or fiber reinforced plastic of a plastic reinforced by fine glass fibers. Like graphite-reinforced plastic, the composite material is commonly referred to as fiberglass. The glass can be in the form of a chopped strand mat (CSM) or a woven fabric. As with many other composite materials (such as reinforced concrete), the two materials act together, each overcoming the deficits of the other. Whereas the plastic resins are strong in compressive loading and relatively weak in tensile strength, the glass fibers are very strong in tension but tend not to resist compression. By combining the two materials, GRP becomes a material that resists both compressive and tensile forces well. The two materials may be used uniformly or the glass may be specifically placed in those portions of the structure that will experience tensile loads.

Glass fibers lose a proportion of their pristine strength when placed in a Portland cement environment. AR fibers have a superior performance to other types, and are likely to retain long term tensile strengths of about 1000-1200 N/mm2 at ambient temperatures in a cement environment.

VII. EFFECT OF FIBERS IN CONCRETE

Fibers are usually used in concrete to control plastic shrinkage cracking and thus reduce bleeding of water. Some types of fibers produce greater impact, abrasion and shutter resistance in concrete. Increase in the aspect ratio of the fibers usually segments the flexural strength and toughness of the matrix. However, fibers which are too long tend to “ball” in the mix and create workability problems.

Adding steel fibers to the concrete will reduce the slump. It is important therefore to increase the slump of the concrete with super plasticizer to above the level required for placing the concrete prior to adding the fibers. The amount by which the slump should be increased will depend up the type of fibers used and the dosage rate.

The main difference between dewatered and non-dewatered GRC is the difference in density which has two effects. Firstly although the fiber content by weight is the same, the higher density of the dewatered board gives a higher fiber volume fraction giving higher strengths. Secondly the dewatered board has better compaction and reduced porosity giving better fiber/matrix bond strength.

VIII. FACTORS AFFECTING PROPERTIES OF FIBERS REINFORCED CONCRETE

Fiber reinforced concrete is the composite material containing fibers in the cement matrix in an orderly manner or randomly distributed manner. Its properties would obviously, depends upon the efficient transfer of stress between matrix and fibers. The factors are briefly discussed below

- **Relative Fibers Matrix Stiffnes:** The modulus of elasticity of matrix must be much lower than that of fiber for efficient stress transfer. Low modulus of fiber such as nylons and polypropylene are, therefore, unlikely to give strength improvement, but the help in the absorption of large energy and therefore, impart greater degree of toughness and resistance to impart. High modulus fibers such as steel, glass and carbon impart strength and stiffness to the composite. Interfacial bond between the matrix and the fiber also determine the effectiveness of stress transfer, from the matrix to the fiber. A good bond is essential for improving tensile strength of the composite.
- **Volume of Fibers:** The strength of the composite largely depends on the quantity of fibers used in it. Use of higher percentage of fibers is likely to cause segregation and harshness of concrete and mortar.
- **Aspect Ratio of The Fibers:** Aspect ratio is defined as length to diameter of the fibers.
- Aspect ratio = length / diameter.
- Another important factor which influences the properties and behavior of the composite is the aspect ratio of the fiber. Increase in aspect ratio increases the ultimate concrete linearly. Aspect ratio may vary 20 to 100. Aspect ratio of steel fibers greater than 100 is not recommended, as it will cause inadequate workability, formation of mat in the mix and also non uniform distribution of fibers in the mix**.**
- **Orientation of fibers:** One of the differences between conventional reinforcement and fibers reinforcement is that in conventional reinforcement, steel bars are oriented in the direction desired while fibers are randomly oriented. The fibers alignment parallel to the applied load gives more tensile strength and toughness than randomly distributed or perpendicular fibers.
- **Workability and compaction of concrete:** Incorporation of steel fibers decreases the workability considerably. This situation adversely affects the consolidation of fresh mix. Even prolonged external vibration fails to compact the concrete. The fibers volume at which this situation is reached depends on the length and diameter of the fibers. Another consequence of poor workability is non-uniform distribution of the fibers. Generally, the workability and compaction standard of the mix is improved through increased w/c ratio or by the use of some kind of water reducing admixtures.

- **Size of coarse aggregate:** Maximum size of the coarse aggregate should be restricted to 20mm, to avoid appreciable reduction in strength of the composite. Fibers also in effect, act as aggregate. Although they have a simple geometry, their influence on the properties of fresh concrete is complex. The inter-particle friction between fibers and aggregates controls the orientation and distribution of the fibers and consequently the properties of the composite**.**
- **Mixing:** Mixing of fibers reinforced concrete needs careful conditions to avoid balling of fibers, segregation and in general the difficulty of mixing the materials uniformly. Increase in the aspect ratio, volume percentage and size and quantity of coarse aggregate intensify the difficulties and balling tendency. Steel fibers content in excess of 2% by volume and aspect ratio of more than 100 are difficult to mix.
- **Freeze-thaw cycles:** Due to freeze-thaw cycles the initial Young's modulus drops with almost 80% for plain concrete and 30 to 40% for FRC which causes decrease in flexural strength.

IX. ADVANTAGES

Fiber reinforced concrete has started to find its place in many areas of civil infrastructure applications where the need for repairing increased durability arises.

- Also FRC are used in civil structures where corrosion can be avoided at the maximum.
- Fibers reinforced concrete is better suited to minimize cavitations' /erosion damage in structures such as sluice-ways navigation locks and bridge piers.
- Compare to plain concrete, fibers reinforced concrete is much tougher and more resistant to impact.
- Well compacted and cured, concretes containing steel fibers seems to possess excellent durability as long as fibers remain protected by cement paste
- Main purpose of GFRC is to increase the energy absorption capacity and toughness of the material, but also increases tensile and flexural strength of concrete. Shrinkage can decrease by 10-15% when high dosages of steel fibers are incorporated.

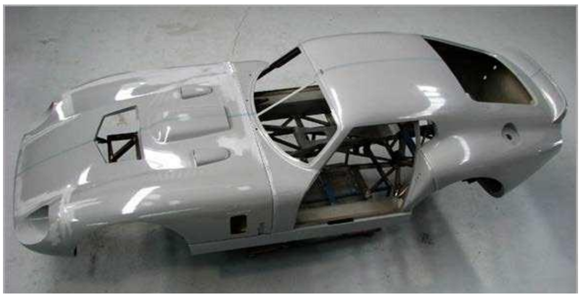
X. DISADVANTAGES

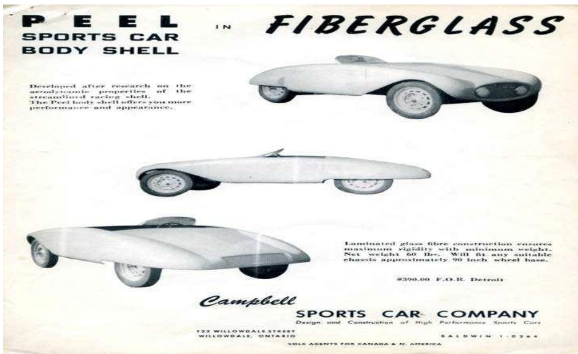
The main disadvantage associated with the fibers reinforced concrete is low workability. The process of incorporating fibers into the cement matrix is labor intensive and costlier than the production of the ordinary concrete.

XI. APPLICATIONS OF GLASS FIBER

11.1 Automotive Market

The automobile industry is one of the largest users of glass fiber. Polymer matrix composites containing glass fibers are used to make external body panels, bumper beams, pultruded body panels and air ducts, engine components, etc. Parts made are much lighter than metallic ones, making the automobile more fuel efficient.

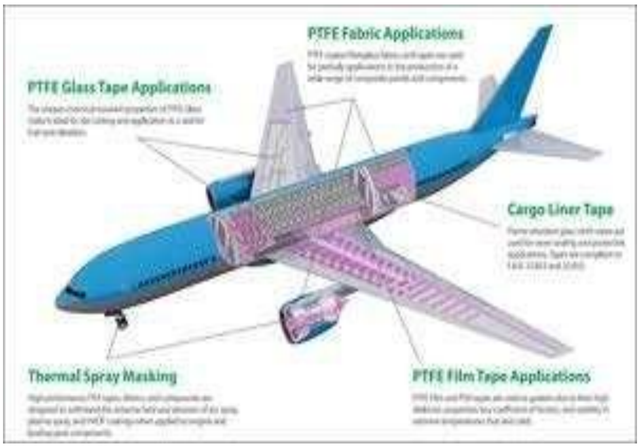




11.2 Aerospace Market

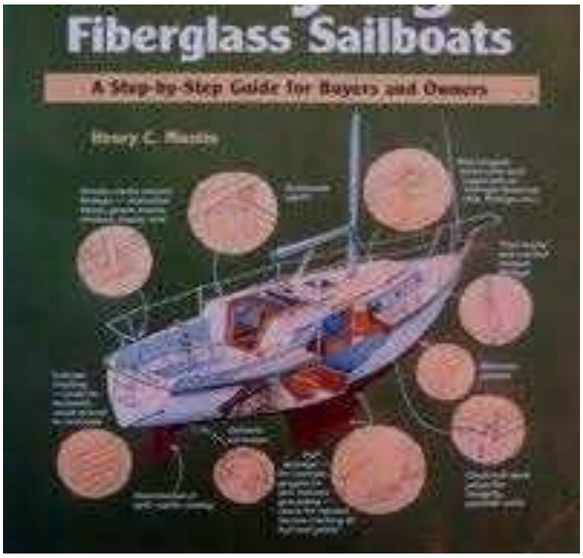
Glass fiber reinforced composites are used to make aircraft parts such as wings, helicopter rotor blades; engine ducts etc. glass fiber has a relatively low elastic modulus. Hence it is more common to use glass fiber reinforced polymer composites in the interior of an airplane rather than in primary structural parts.

• The radar transparency characteristics of glass have given it some key uses in the radar evading stealth technologies.



11.3 Marine Market

• Sailing boats and hulls and decks of commercial fishing boats and military mine hunters are frequently made of glass fiber reinforced polymers. Glass fiber reinforced polyester is commonly used in making boats of all sizes.



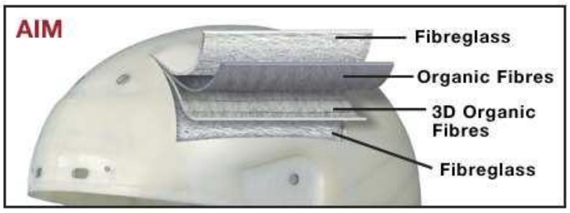
XII. CIVIL CONSTRUCTION

• Typical applications include the use of glass fibers in polymeric resins for paneling, bathtubs and shower stalls, doors, windows etc. glass fibers are also used as reinforcement in a variety of house hold items such as paper, tapes, lampshades etc. Some special alkali resistant glass fibers have been developed for reinforcement of cement and concrete. Commonly steel bars are used for such purposes.

ISBN: 978-93-86171-53-5

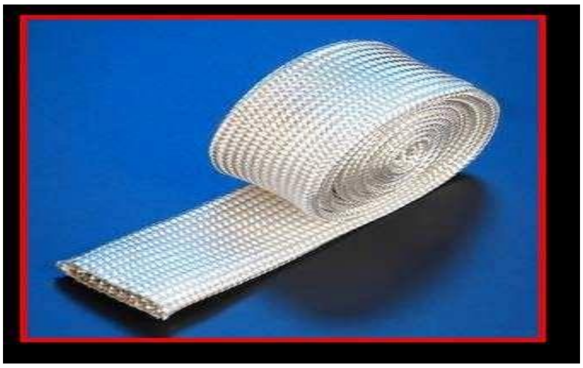
12.1 Sporting Goods

• The sporting goods industry was one of the first to make use of glass fiber reinforced composites. Examples include bicycle frames, tennis, rackets, golf club shafts, cricket bats, skis, etc.



12.2 Electrical/Electronic Market

• Glass fibers are used extensively in printed circuit boards, industrial circuit breakers, conduits for power cables. Etc.



12.3 Composition & properties of glass fibers

Typical Chemical Composition of E & S Glass in %

SiO2	54.3	64.2
Al2O3	15.2	24.8
CaO	17.2	0.01
B2O3	8.0	0.01
MgO	4.7	10.3
Na2O	0.6	0.27
BaO		0.2.0
FeO		0.21
Others		0.03

Property	E-Glass	S-Glass
Specific gravity	2.54	2.49
Tensile strength (MPa)	3450	4590
Tensile modulus (GPa)	72	86
Diameter range (microns)	3 to 20	8 to 13
CTE (per million per C)	5	2.9

XIII. CONCLUSION

[1] Under the limitation of the experimental work, the following conclusions are made

[2] Maximum increase in Compressive strength obtained is 46.8N/mm2 at 1% glass fiber replacement with Aspect ratio 65.

[3] Compressive strength of concrete at 0.5% and 1.5% are observed to be less when compared to 1% replacement.

[4] From the above result shows the concrete with glass fiber got more compressive strength compare with normal concrete mix at a range between 1% to 1.5% of glass fiber mix in to the concrete.

[5] By increasing of glass fiber content by weight of cement the mechanical properties of concrete are going to be decreased.

[6] Generally glass does not increase tensile strength.From the Experimental study glass fiber used in concrete does not increase the variation of tensile strength.

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