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Studies on Strengthening of Structures with FRC

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Abstract: Cement concrete reinforced with steel bars is an extremely popular construction material.

In spite of its great popularity in the building industry Constant maintenance and repair is needed to enhance the life span of those structures. On the material scale, concrete has a very low tensile strength and almost no ductility. On the structural scale, the engineers are faced with time-consuming and expensive reinforcing process, with large self-weight of the concrete structures and also with durability problems. Therefore, the development of new, high-performance types of concrete is necessary, in order to improve the structural quality and the construction process in general. There are many ways to minimize maintenance and the failure of the concrete structures made of steel reinforced concrete. The tradition approach is to adhesively bond mixing of fibre composites in the structural concretes termed as Fibre Reinforced Composites (FRC) helps to increase the tensile strength and Toughness of the conventional concrete.

The Fiber reinforced composite (FRC) is a composite material consisting of hydraulic cement, sand, coarse aggregate, water and fibers. In this composite material, short fibers are randomly distributed throughout the concrete mass. The behavioral efficiency of this composite material is far superior to that of plain concrete and many other construction materials of equal cost. With this advantage, the use of FRC has steadily increased during the last two decades and its modern field of application involves pavement of highways and airports, earthquake-resistant and explosive-resistant structures, mine and tunnel linings, bridge deck overlays, hydraulic structures, rock-slope stabilization. Extensive research work on FRC has established that the addition of various types of fibers such as glass, steel, synthetic, and carbon, in plain concrete improves strength, toughness, ductility, post-cracking resistance, etc. Literature survey indicated that very limited study has been conducted on Fiber reinforced concrete. So, this paper reviews the developments of FRC and its necessities to strengthen the conventional concrete structures.

1. INTRODUCTION

The concept of using fibers as reinforcement in construction is not new. Fibers have been used as reinforcement since ancient times. Historically, horsehair was used in mortar and straw in mud bricks etc. In early 1900s, asbestos fibers were used in concrete, and in the 1950s the concept of composite materials came into being and fiber reinforced concrete was one of the topics of interest. Also Portland cement is undergoing several modifications to suit to the ever changing construction needs. In the last few decades, for example, the concern for repair and up gradation of damaged concrete structures along with the need for durability is making researchers look more closely at the use of such steel, glass and synthetic fibers and polypropylene fibers with conventional concrete for strengthening the concrete structures.

There is huge potential of application of the FRC and very attractive proposition for rehabilitation and up gradation of damaged concrete structures due to earth quacks, cyclones etc. The intention of this paper is to present an overview of the topic. This will include a discussion of how to approach a concrete repair to strengthen, as well as introducing some of the commonly used repair techniques and materials.

Effect of fibers in Concrete: Fibers are usually used in concrete to control plastic shrinkage and drying shrinkage cracking. They also reduce the permeability of concrete and thus reduce bleeding of concrete. Some types of fibers produce greater impact and abrasion resistance in concrete. Actually fibers alone do not increase the flexural strength of concrete, so it cannot be replaced in the place of structural steel reinforcement.

The amount of fibers added to a concrete mix is measured as a percentage of the total volume of the composite (concrete and fibers) termed volume fraction (V_f). V_f typically ranges from 0.1 to 3%. Aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter (d). Fibers with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the modulus of elasticity of the fiber is higher than the matrix (concreteor mortar binder), they help to carry the load by increasing the tensile strength of the material. Increase in the aspect ratio of the fibre 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.

Some recent research indicated that using fibers in concrete has limited effect on the impact resistance of concrete materials. This finding is very important since traditionally people think the ductility increases when concrete reinforced with fibers. The results are pointed out that the micro fibres are better in impact resistance compared with the longer fibres.

Typical concrete problems are: poor quality concrete

- Corrosion related deterioration
- Freeze thaw damage
- Earthquake damage
- Design related problems
- Substandard workmanship
- Environmentally related problems

Poor quality concrete: The quality of concrete in a structure will force the long-term performance. Good durable, properly-consolidated concrete, placed with the minimum of honeycombing and internal shrinkage, will provide an environment that should protect the embedded reinforcing for years before repairs are required.

Corrosion-related deterioration: Corrosion of embedded reinforcing steel is the most common cause of concrete deterioration. When the iron in steel is exposed to water, oxygen, and chlorides, it oxidizes and produces corrosion. The oxidized metal can expand up to 10 times its original volume, resulting in intense bursting forces in the surrounding concrete. This will eventually lead to cracking and delamination.

Freeze-thaw damage*:* Freeze-thaw damage is more likely to occur in poor quality concrete. This is a problem is considered in the colder climates with a wide variation of temperature on a daily basis.

Earthquake damage*:* This is a problem here in India as well as at various other locations throughout the world. There are some methods to modify and/or strengthen existing structures to meet current earthquake standards.

Design-related problems*:* Improper designs or detailing can rarely result in deterioration to that structure. For example, lack of proper expansion joints in large concrete tanks will result in significant cracking.

Substandard workmanship*:* Misplaced reinforcing, for example, is a common problem in concrete structures. This often results in severe cracking, and eventually leads to delamination because of corrosion.

Environmentally-related problems*:* Structures located along seacoasts, or in northern climates where dicing salts are used, for example, often have serious problems with corrosion of the underlying reinforcing steel because of its contact with chlorides.

The Fibre reinforced mortar/ concretes give out solution to the above problems and in particular the behavior of the fibre reinforced polymer composites (FRP) very popular in recent years to strengthen Earth quack damaged structures. This popularity has arisen due to the need to maintain and upgrade essential infrastructure in all parts of the world, combined with the well-known advantages of FRP composites, such as good corrosion resistance and ease for site handling due to their light weight. The continuous reduction in the material cost of FRP composites has also contributed to their popularity.

FRP composites also offer many advantages over other materials especially in seismic retrofitting applications; FRP composites can potentially enhance the flexural strength, shear strength, toughness, and ductility of RC members. By means of a wrap method, FRP composites protect the RC columns from the major failure modes. Basically there are two types of fibres.

1 Metallic fibre reinforced (Steel)

2. Non metallic fibre reinforced: Theses are of type's polypropylene fibres (FRP), Glass fibre, Asbestos fibres, Carbon Fibres (CFRP), Organic Fibres, Vegetable fibre reinforcing composites.

Generally the steel fibres are used in high performance and high strength concretes. HPFRC high performance fibre reinforced concrete is produced by the addition of either short discrete steel fibers or continuous long fibres to the cement based matrix. In fiber reinforced concretes different types of discrete fibres used or hooked end steel, straight steel, corrugated steel and polypropylene fibres. The maximum quantity of hooked-end fibres that can be added without causing balling is limited to 1% by volume. Compare to plain concrete the addition of 1% by volume of hooked fibres increased the first cracking strength by 15% to 90% and static flexural strength by 15% to 30%. Compared on equal basis on 1% by volume, the hooked end steel fibres, contribute the highest enhancement and the straight fibres provide the least enhancement of concrete properties [7].

In practice fibre content is normally reckoned by weight of fibre for unit volume of concrete. It is the product of volume fraction Vf (volume of fibres for unit of volume of concrete) and specific gravity of the fibres. It is generally accepted that the type and amount of currently used do not significantly enhance the first cracking tensile strength of the fibre reinforced composite. Many of the current applications of FRC involves the use of fibres in composites can be ranging up to 15% of steel, glass and synthetic fibres to the considerable enhancement of the tensile load carrying capacity of the matrix. This may be attributed to the fact that fibres suppress the localization of the micro-cracks into macro-cracks and consequently the tensile strength of matrix increases.

Abhijit mukerjee et al [3] the non metallic fibers have strengths that are 10 times more than that of steel fibers. The ultimate strain of non metallic fibers is also very high. Besides, the density of FRP materials is approximately one third that of steel. Due to its corrosion resistance FRCs can be applied on the surface of the structure without worrying about its deterioration due to environmental effect. They in turn protect the concrete core from environment attack. FRPC sheets, being flexible, can be wrapped around the joints very easily.

The FRP bonding methods are commercially available in several forms to suit different application needs. However, the most effective bonding system used in seismic retrofits is a FRP composite 'wrap'. The wrap is made of layers of fibers pre-impregnated with resin. Some companies designed a machine called the Robo-Wrapper that constructs a hoop-wrapped jacket around a RC column using drag of continuous carbon fiber pre-impregnated with resin. It is a programmable with two-axis machine that can wrap pre-preg drag to accurate dimensions around highway and bridge columns. The machine rotates around the column while it moves up and down, encasing the entire column with carbon fiber pre-preg. Because the carbon fiber is continuous, the wrap created provides uniform confinement of the concrete. This ensures to no weak spots where the shear strength and flexural strength would be low. The same company also designed a radiant heat oven, which cures the resin at high temperatures. During the cure, the resin cross-links and forms a hard shall. The resin also acts

as an adhesive and bonds to the concrete forming a tight structure around the entire cross section of the column. Two main machines, the Robo-I and the Robo-II, are used to retrofit RC columns of all sizes.

When the work has finished a detailed report showing what was done, such as jacket thickness in specific areas, etc., can be reviewed with the data given by the machine. Seismic retrofits performed using the Robo-Wrapper have improved the ductility and strength of substandard RC columns[5]. This FRP composite application is an example of how time and cost efficient for strengthening the structures which are disintegrated or damaged due to earth quacks etc.

[Tarricone 1995] Many Departments of Transportation (DOTs) in the United States (e.g. Nevada, Pennsylvania and west Verginia DOTs) have adopted fiber wrapping as reliable and cost effective method for column retrofitting. They stated that the use of wrap saved the Vermount Department of Transportation $8000(U.S) as compared to using the conventional steel jacketing method.[8]

2. CONCLUDING REMARKS

According to Recent studies the fibre reinforced composites are a very attractive proposition for up gradation and strengthening the damaged structures. FRCs offer many advantages over other materials in seismic retrofitting applications, including enhanced mechanical properties and lower installation costs. However uncertainties about the durability of FRPs as their long- term performance data are limited.

AS the design methods are developed, their publicity and possible inclusion of Indian standards are required.

Limited knowledge of the material properties and application procedures.

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