SIFCON: A SUSTAINABLE APPROACH

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***Abstract*—** Concrete is no longer a material consisting of cement, aggregates, water and admixtures but it is an engineered material with several new constituents performing satisfactorily under different conditions. Today it can be perfectly customized for particular applications and contains diverse materials. Development of modern civil engineering causes an urgent need to develop higher performance engineering materials possessing high strength, toughness, energy absorption and durability. Since concrete is weak in tension, steel reinforcement is present in concrete which transfers the tensile load. An alternative to increasing the load carrying capacity of concrete in tension is the addition of fibres which improves tensile strength and provides ductility. Well-dispersed fibers in the concrete act to bridge the cracks that develops in the concrete. But the limitation of Fibre Reinforced concrete is the fibre concentration, as it is increased along with fibre aspect ratio (length/diameter), it becomes difficult to mix and place these materials. This situation places bounds on the improvements in the engineering properties of concrete (flexural strength, flexural toughness index, impact resistance and fatigue resistance) that can be gained through the use of steel fiber. To overcome this, Slurry Infiltrated Fiber Concrete (SIFCON) is one of the recently developed construction material that can be considered as a special type of high performance fiber reinforced concrete (HPFRC) with higher fiber content. SIFCON possessed the characteristics of both high strength as well as ductility which is an important parameter for sustainable structures.

***Keywords*—** *High Performance Fiber Reinforced Concrete, SIFCON, High Strength, Durability, Sustainability*

I. INTRODUCTION

The composition of concrete is no longer limited to conventional material consisting of cement, aggregates, water and admixtures rather now it is an engineered material with several new types of constituents being used under different conditions. Today it can be perfectly customized for particular applications and contains diverse materials. One of the major advances made in the field of construction is the production of high performance materials. Development of modern civil engineering causes an urgent need to develop higher performance engineering materials possessing high strength, toughness, energy absorption and durability.

Fiber reinforced concrete (FRC) is one of the conventional engineering materials used in several structural applications in order to enhance the structural resistance/performance of the structure under different loading combinations. High or ultrahigh strength concrete with very high compressive strength values remains basically a brittle material. The inclusion of adequate fibers improves tensile strength and provides ductility. The incorporation of fibres in a cement matrix leads to an increase in the toughness and tensile strength, and an improvement in the cracking and deformation characteristics of the resultant concrete. A significant amount of research has been conducted on fibre-reinforced concrete over the past thirty to forty years. High performance construction materials provide far greater strength, ductility, durability, and resistance to external elements than traditional construction materials, and can significantly increase the longevity of structures in the built environment and can also reduce maintenance costs for these structures considerably. These most significant high performance construction materials include high performance concrete, high performance steel, fiber reinforced cement composites, FRP composites, etc. Slurry infiltrated fibrous concrete (SIFCON) is one of the high performance material. As the fibre concentration is increased long with fibre aspect ratio (length/diameter), it becomes difficult to mix and place these materials. In practice it has been found that the amount of fibre must be kept fewer than 2% volume and aspect ratio must be kept under 100. This situation places bounds on the improvements in the engineering properties of concrete (flexural strength, flexural toughness index, impact resistance and fatigue resistance) that can be gained through the use of steel fibres. In 1978, Lankard began an investigation to incorporate larger amounts of steel fibres in steel fibre reinforced cement based composites. The result of this investigation led to the development of new cement composite called “Slurry Infiltrated Fibre Concrete (SIFCON)” in which steel fibres up to 20% by volume could be used.

II. SLURRY INFILTRATED FIBER CONCRETE (SIFCON)

Slurry infiltrated fiber concrete (SIFCON) is a relatively new special type of high performance (steel) fiber-reinforced concrete (HPFRC). The technique of infiltrated layers of steel Fibers with Portland cement based materials was first proposed by H. Haynes in 1968. Lankard then in 1979, modified the method used by Haynes and proved that if percentage of steel Fibers in cement matrix could be increased, one could get a material with very high strength properties which he called as SIFCON. Dr. Lankard had done some pioneer work in the development of the material, as well as some applications using the material in the paving and metal fabrication industries. SIFCON possessed the characteristics of both high strength as well as ductility. SIFCON is made by pre-placing short discrete fibers in the molds to its full capacity or to the desired volume fraction, thus forming a network as shown in *Fig.1*. The fiber network is then infiltrated by a fine liquid cement-based slurry or mortar as shown in *Fig. 2*. The fibers can be sprinkled by hand or by using fiber-dispending units for large sections. Vibration is imposed if necessary during placing the fibers and pouring the slurry. The steel fiber content can be as much as 20 % by volume. In conventional fiber reinforced concrete (FRC), where fibers are mixed together with other ingredients of concrete, this percentage is limited to only about 2 % for practical workability reasons. Because of its high fiber content, SIFCON has unique and superior mechanical properties in the areas of both strength and ductility. High range water reducing admixtures are used to provide suitable slurry viscosity while maintaining a low water cement ratio. Once the slurry infiltration is completed, the method of curing of SIFCON is the same as for any concrete material. The matrix fineness must be designed so as to properly infiltrate the fiber network formed in the mold. Otherwise large pores may form leading to substantial reduction in the mechanical properties. Additives such as high range admixtures such as super plasticizer are used for improving the flowing characteristics of SIFCON.

The main differences between FRC and SIFCON, in addition to the clear difference in fiber volume fraction, lies in the absence of coarse aggregates in SIFCON which, if used, will hinder the infiltration of the slurry through the dense fiber network. Furthermore, SIFCON contains relatively high cement and water contents when compared to conventional concrete. All steel fiber types namely straight, hooked and crimped can be used. The Fibers are subjected to frictional and mechanical interlock in addition to the bond with the matrix. The matrix plays the role of transferring the forces between fibers by shear, but also acts as bearing to keep fibers interlocked. SIFCON is one such high performance material that possesses excellent mechanical properties coupled with greater energy absorption characteristics. Ever since its invention, SIFCON has attracted many researchers and structural engineers. This composite can be considered as a special Fiber Reinforced Concrete.

Fig 1. Placing of fibers

Fig 2. Pouring of Slurry

III. ADVANTAGES AND APPLICATIONS OF SIFCON

Although SIFCON is still a relatively new material, the composite has been used successfully in a number of areas, especially for applications where high strength or high ductility or both are needed.

- These include a large variety of earthquake resistant structures, military installations, explosive and penetration-resistant structures.
- In addition to many other uses such as airport pavements, parking lots and bridge decks, SIFCON possess excellent durability, energy absorption capacity, impact and abrasion resistance and toughness.
- Modulus of elasticity (E) values for SIFCON specimens is higher when compared with plain concrete.
- The balling problem of steel fibers with increase in fiber volume in SFRC can be resolved by SIFCON, because of its fiber alignment.
- Deflection for SIFCON will be very less compared to conventional concrete structural components.

Since properties like ductility, crack resistance and penetration and impact resistance are found to be very high for SIFCON when compared to other materials, SIFCON should be considered as an efficient alternative construction material for applications where concrete or conventional SFRC cannot perform as may be expected/required by the user or in situations where such unique properties as high strength and ductility are required. SIFCON is best suited for application in the following areas:-

- Pavement rehabilitation and precast concrete products
- Overlays, bridge decks and protective revetments
- Seismic and explosive-resistant structures
- Security concrete applications (safety vaults, strong rooms etc)
- Refractory applications (soak-pit covers, furnace lintels, saddle piers)
- Military applications such as anti-missile hangers, under-ground shelters

- Sea-protective works
- Primary nuclear containment shielding
- Aerospace launching platforms
- Repair, rehabilitation and strengthening of structures
- Rapid air-field repair work

IV. VARIOUS STUDIES

The fact that ultimate stress is required to fail Fibre Reinforced Concrete in flexure and tension is governed by fiber volume fraction, aspect ratio, fiber orientation; the increase in failure stress can be achieved by increasing these parameters. The behavior of SIFCON under different loading conditions was investigated by several researchers using different types of fibers in varying fiber volume fractions and aspect ratios, experimentally and analytically.

HalitYazici et al.[1] investigated the effects of steel fibre alignment and partial replacement of high volume mineral admixtures such as Flyash(FA) and Ground Granulated Blast Furnace Slag (GGBFS) on the mechanical properties of SIFCON. Ordinary Portland cement was partially replaced by 50% of FA or GGBS in SIFCON slurries and alignment of steel fibres in two different forms of orientation (random orientation and one direction orientation). Test results showed that replacement of FA and GGBS positively affected the strength characteristics but the incorporation of mineral admixtures enhances the durability characteristics and orientation of fibres alignment is an important factor for excellent performance of SIFCON. Sudarsana Rao et al.[2] studied the performance of Slurry infiltrated fibrous concrete two way slabs under punching shear. It is observed that the first crack strength was increased with increased percentage of fibre content in punching shear. Murat Tuyan et al.[3] investigated Pull-out behaviour of single steel fiber from SIFCON matrix and concluded that increasing the diameter of the fibre and improving the curing conditions increased matrix–fibre bond and an increasing bond strength. The pull-out toughness was increased by increasing embedded length of fibre. It has been observed that hooked end fibres have shown better interface bond compared to the smooth fibres. Sundarsana Rao et al.[4] studied the behaviour of slurry infiltrated fibrous concrete slabs under impact loading. The test was conducted by using impact testing machine with steel ball drop weight. The results reveals that SIFCON slabs with 12 % fibre content exhibits excellent performance in strength and toughness characteristics compared to Fibre reinforced concrete, Reinforced cement concrete and plain cement concrete slab specimens. JayeshKumar et al.[5] studied the experimental investigations on partial substitution of cement with fly ash in concrete mix design. Cement was partially replaced with flyash in the range of 0%, 10%,20%,30% and 40% for making concrete mix design normal and high strength concrete mix. The Compressive strength and split tensile strengths were decreased with increased percentage of flyash content, but cost of concrete decreased due to reduction of quantity of cement. . Arunachalam et al.[6] studied and performed the experimental investigation on high performance fly ash concrete in normal and aggressive environment. An Experimental investigation was conducted on mechanical properties of High strength Concrete with partial replacement of fly ash (25% and 50%) and without replacement of flyash (control specimen) under normal and aggressive environment. Iralda et al.[7] studied the action of atmospheric agents against reinforced concrete. In aggressive atmospheric conditions, more concentration of sulphates causes degradation of concrete structures and corrosion of steel reinforcement. This study concluded that to protect the reinforced concrete structures from the careful study of stability design, preventive measures. Jose Aguiar et al.8 investigated on the performance of concrete in aggressive environment. Surface treatments act as a barrier between the surrounding and to prevent the entry of water and harmful substances into the concrete.

V. DURABILITY OF SIFCON

Durability ensures that the structure will retain its structural and aesthetic capabilities for many years. The carbon footprint of a structure is minimized when the need to replace it is eliminated completely. SIFCON is one such type which provides long service life, safety, energy efficiency and lower maintenance of the structure. Various experiments have led to conclude this fact. In one such experiment led by Adel Mohamed Gilani, showing the durability aspect of SIFCON which involves resistance to frost, corrosion, penetration, carbonation and chemical attack. It was found that the higher is the fiber content the lower is the shrinkage. The absorption range was 4 % to 7 % in the case of mortar SIFCON, which is relatively close to the 3.5 % absorption recorded in the low permeability reference concrete. Generally speaking, SIFCON, especially mortar SIFCON, had shown good durability characteristics in spite of its apparent high absorption. For the effects of fiber content, it was found that increasing it will result in improved durability. On the other hand, there were no definite relationships between the fiber shape and the durability aspects studied. In some aspects, hooked fibers have shown better results, while in some others the use of crimped fibers was proven to be slightly more successful.

VI. SIFCON A SUSTAINABLE APPROACH

Sustainability is the ability to persevere. Sustainable development is an example of resource use that aims to meet human needs while preserving the environment so that these necessities can be met in the present, as well as for future eras. One of the basic requirement for any structure be sustainable is that it should be durable, it should have the ability to function satisfactorily in changing conditions without any detrimental effect on itself and to the surrounding environment. The fundamental meaning of sustainable is durable, and by surviving 20 centuries, concrete structures such as in the Roman Empire, the zenith being the Pantheon in Rome have shown that they are, indeed, durable.

Concrete needs special attention to protect it from the aggressive environment which leads to distress in the structures in the form of reinforcement corrosion, carbonation and other durability related problems. The weak tensile capacity of concrete causes it to crack in the service condition itself. Concrete needs special attention to protect it from the aggressive environment which leads to distress in the structures in the form of reinforcement corrosion, carbonation and other durability related problems. The weak tensile capacity of concrete causes it to crack in the service condition itself. Most of the design codes consider the concrete in the tension zone as a cracked. Structurally this cracked section though can function safely it is the environment that surrounds the structure which induces distress in the members resulting in reduction in life of the structure. SIFCON is a type of fibre concrete with very high percent of steel fibres, the high amount of steel fibre makes SIFCON stronger in tension, though not strong enough to replace the steel and not economical to replace concrete, it enhances the cracking load of the section considerably, enabling the section to remain un-cracked at service loads.

VII. REFERENCES

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