Properties of Glass Fiber Reinforced Concrete: A Review

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Abstract: Traditional concrete shows very less ductility, poor tensile strength, less resistance against crack and high dead load of structural element. To overcome these drawbacks and make structural element lightweight, glass fibers are introduced in concrete which is known as Glass fiber reinforced concrete (GFRC). GFRC is a combination of cement, sand and glass fibers which is use to improve the strength. This paper consists of review on study that has been conducted on GFRC. Properties like compressive strength, split tensile strength, flexural strength, behavior on chloride attack and sulphate attack are covered here. The variation in mechanical properties using glass fibers in concrete has been identified and discussed in this paper.

Keywords: **Fiber reinforced concrete, alkali glass resistant fiber, chloride attack, sulphate attack**

I. INTRODUCTION

Glass fiber reinforced polymer (GFRP) was hardly considered as good material in building construction around 1930s. Revolution of glass fiber reinforced polymer happened in 1960-70s when engineer use it in Disney land's "House of the Future". After that the use of GFRP increased, and all the engineers around the world start considering it as a good option for construction. Till 1994 in construction work around 600 million pound of GFRP was used. [2014]. Invention of Glass Fiber Reinforced Concrete (GFRC) happened in Russia during Second World War, but till 1970 it was not used properly. Traditional concrete shows weaker behavior on tension side than compression one. In order to enhance the load carrying capacity on tension side of an element glass fiber has been added. By addition of glass fiber, properties like toughness, ductility, flexural and tensile strength will be get enhanced than traditional concrete. Quantity and type of glass fiber will decide the amount of enhancement in results. Micro cracks can be controlled by including glass fiber as there is a rise in tensile strain. 65% of worldwide production of fiber is use in concrete only. In this new modern age of technology we have numerous types of fibers like: acrylic, aramid, nylon, glass, polyester, polypropylene, steel, polyethylene etc. Glass Fibers is the one that have more benefit in terms of fire resistant and strength.

After a series of tests it was established that by adding fiber with small size, closely spaced, and equally dispersed concrete becomes more stable for static as well as dynamic loading. Fibers with round shape are more likely to have better flexural, tensile and impact strength, they also show improvement in toughness and ductility. One of the newest member in the list of fiber is Alkali Resistant Glass Fiber which provides resistance against chemical better properties then old fibers and very high energy absorption. [2013]

II. MECHANICAL PROPERTIES OF GLASS FIBER REINFORCED CONCRETE

To understand the effect on the glass fiber reinforced concrete, one needs to investigate the mechanical properties of traditional concrete first and the compare it with the properties of glass fiber reinforced concrete.

Gowri and Angelinemary [2013] observed the effects of glass fibers on concrete with glass wool fiber's mechanical properties. The experiment was conducted on cubes for compressive tests. The concrete mixes were designed with the glass wool fibers of aspect ratio 125 in the addition ratio of 0.025%, 0.05% and 0.075% by the total volume of the concrete. From the obtained results it was concluded that when fiber content rises from 0.025% to 0.075% concrete compressive strength get increase and the failure patterns were also studied and it illustrated that development of cracks is very high in concrete without fibers rather than along with glass wool fibers.

Muthuswamy K. et al. [2013] did experimental work on high performance hybrid fiber reinforced concrete by adding three kind of fibers: polyester, glass and steel fibers with addition of super plasticizer for workability and Silica fume with small replacement of cement as mineral admixture. Result showed concrete with glass fiber had higher strength than concrete with polyester but had lower strength then concrete containing steel fibers.

Jayaraman and Senthil [2014] studied the optimization of using nano-silica as constituent material and added M-sand instead of natural sand in high Performance Concrete. Concrete mix was designed with 0.75% is replaced by nano-silica with cement and 100% replacement with M-Sand of F.A. The cubes were casted with different mixes and normal mix. From the obtained results it was suggested that by incorporation of nano-silica leads to a significance increase in durability and characteristics strength of the concrete and self-weight of mix with nano-silica is much less when compared to the other mixes.

Kamal et al. [2014] investigated the strength and behavior of beam which have polypropylene fibers and steel what makes it a ultra high strength concrete. The steel fibers had aspect ratio of 65 while polypropylene fiber had 12.5 as aspect ratio which was used in the concrete mix. The fibers were mixed in concrete by a measured fraction of 40 kg of steel fibers and 1kg of polypropylene fibers by volume. 2 point loading test was conducted over the beam specimen and the results illustrated by using of polypropylene fiber and steel increment in compressive strength as 6% and 2.5% in contrast to the normal mix concrete without fiber. It was also noticed that the rise in ultimate load get high by 48 and 15 percent when steel and polypropylene fiber were added in concrete.

Sangeetha [2011] proposed that rise in glass fiber's percentage as 0.1%, 0.2% and 0.3% by concrete weight. Total 128 samples were casted, mould of size 15 X 15 X 15 cm were used to cast cubes for characteristics strength tests. The percentage rise in characteristics strength was found out 23%.

According to Bentura and Diamond [1987] durability of glass fiber reinforced concrete can be enhanced by including silica fumes in strands of glass fiber. This paper reports that addition of silica fume (micro silica) directly in the glass fiber strand before including them into cement and it showed effective improvement in composite's durability. Next step is to submerge strands in slurry of micro-silica. Composites composed from that sustained its flexural strength in a span of 5 months ageing duration. This study also showed that the toughness decreases as time increases and shunned below 93.50%.

Alsayed et al. [2000] observed behavior of glass fiber reinforced plastic bars and use them as stiffening substance in concrete element. In this paper author did two different series of work and examined their reliability according to the modification. Due to the increase in work of fiber reinforced plastic new codes should be develop or some improvement must be done in current codes. Out of two series, first one is use to examine the validity of alteration in service load and flexural load deflection model.

According to Langlois et al. [2007] work on carbon yarn and alkaline resistant glass reinforced mortar's performance. Main purpose of this experimental setup was to observe carbon yarn and alkaline resistant glass feasibility. Flexural test and bond flexural test were performed at different age of sample after casting by varying volume of carbon yarn. Results showed that as we increase the carbon yarn quantity ductility as well as strength of mortar increases. Yarn effectiveness based on yarn's structure, pyramid of micro metric was for carbon yarn while strands of mill metric were for glass yarn. They also found out that there was an accretion in cracking strength with time in mortar of carbon yarn but loss in ductility as well as in strength in mortar of glass yarn.

According to Murthy et al. [2012] observation on glass fiber not just enhance concrete's property but help to use waste product of glass for different places and recycle them. In this paper report author found out that beam's flexural strength raised by 30% with use of just 1.5% of glass fiber. They also found out that as we increase the quantity of glass fiber there is depletion in slump test.

Wang et al. [2014] observed that flexural properties of epoxy syntactic foam reinforced by short glass fibers with concrete. The experiment was further processed with the usage of short glass fibers of 3mm in length with the addition ratio varying from 0% to 1.5% to the total weight percentage of the concrete and also with glass fiber mesh of 0.6mm covering over it with varying layers. The flexural test investigation was done over the beam specimen comprising of sizes 5 x 10 x 190 mm^3. Results showed that the concrete foams reinforce by 0.5% of weight glass fiber and 2 layers of glass fiber mesh enhanced the flexural properties and during flexure, the fiber glass mesh on the tensile side is also stopping the micro crack propagation.

Zhu et al. [2009] worked on composites of alkali resistance glass fiber reinforced cement and studied their behavior. Their observation entails to test 2 non-identical fabric content. Alkali resistance fibers with strong fabric concrete showed very good behavior in hardening. Specimens were tested under 3 point bending condition. Result showed about 22-25 MPa range for tensile strength while strain capacity in order of 2 to 5% and static conditions.

Harle and Meghe [2013] indicated that glass fibers show very small creep at normal room temperature, show very brittle behavior in terms of stress and strain but have very good elastic modulus as well as tensile strength. Glass fiber can be found out in different type of shapers but mostly they are in straight and rounded shape of diameter about 5×10^{-4} to 15×10^{-4} cm range.

Kumari et al. [2013] studied the pattern of shear resistance in shear zone of silica coated glass fiber reinforced polymer bars and flats. In test samples water-cement (w/c) ratio of 0.52 was used for the mix of 1:1.5:3. Results showed that silica coated glass fiber reinforced polymer beam had high failure load then theoretical failure loads. Glass fiber reinforced polymer beam were also found to be very ductile in nature and had very high tensile strength.

Gobinath et al. [2013] used M-sand for the replacement of fine aggregate and also substitute silica fumes in place of cement to observe concrete's strength. Split Tensile tests over the cylinder specimen were conducted to find the strength behavior on 7th and 28th day respectively. The results concluded that M-sand fulfilled the requirement of aggregate like shape, strength, angularity in the concrete. They also suggested that adoption of M-sand for replacement by 50% of natural sand is encouraging based on test results.

Barluenga and Hernandez [2007] studied the effect of alkali resistant glass fiber in traditional concrete and observed the new cracking pattern on different time age of test sample. Two different type of alkali resistant glass fiber were used in experimental setup. Different type of test were conducted in this paper, some of them are: test for free shrinkage by providing air flow on the test specimens, compressive strength, cracking of slab by double restraining and flexural strength.

Gornale et al. [2012] investigated reinforced concrete's strength aspect by mixing glass fiber in test samples. Test were done to understand the pattern of change in compressive, split tensile, flexural strength. They observed the workability of reinforce concrete falls with addition of glass fiber but this problem can be solve by using super-plasticizers. There was a moderate rise in flexural and compression strength in initial stage but a sudden rise in split tensile strength when equated to plain concrete.

Investigation was done by Joe et al. [2013] to study the behavior of High Performance concrete when M-sand in included in samples. The work done by various replacement levels of natural sand by M-Sand with various ratio by it varying as 30%, 40%, 50% & 60%on M 30 mix of concrete. The tests such as compression, split tensile and flexural strength tests were conducted over cube, cylinder and prisms for the optimum results. Chemical admixtures such as Super plasticizers and viscous modifying agents were also added to the concrete mix to reduce the segregation. The test results illustrated that that 50 percent replacement of fine aggregate with M-sand gives maximum strength to the concrete which resulted in compressive, split tensile, and flexural strength.

Experimental work done by Petersen et al. [2015] to study the behavior of alumina tri hydrate filler with fire-retardant glass fiber-reinforced polymer materials. The investigation was conducted over a thin mortar panel with E glass fiber and alumina tri-hydrate and tests such as compression, tension, flexural and shear tests were conducted over the specimen. The test results illustrated that control specimen was found out to be best in every test besides flexure, because it was about 3% less than the sample that have 25% of alumina tri-hydrate. While in test for compression it was about 25% and 19% more for 50% and 25% of alumina tri-hydrate. Sample with 50% of alumina tri-hydrate had very low maximum stress then control specimen.

III. SULPHATE AND CHLORIDE ATTACK ON GLASS FIBER REINFORCED CONCRETE

In the beginning test were done on E-glass fiber but they were not much effective due to alkaline attack on concrete which had adverse effect on durability and strength. This leads to the invention of alkali resistant glass fiber to enhance the properties of concrete. Dispersed glass fiber was first considered as reinforcement by Biryukovich et al. [1965]

Stucke and Majumdar [1976] investigated the micro-structure of glass fiber reinforced super sulphate cement. They used electron micro scope to scan and understand glass fiber better. Their report was mainly on micro structure of 1 to 5 years old glass reinforced concrete casted with super sulphate cement and cem-fil alkali resistant glass fiber. According to their study fiber becomes integral part of samples, it was also reported the amount of pull out glass fiber in wet stage is high but as the time pass out decreases very much.

Boddy et al. [2001] studied the permeability of chloride in concrete which have very high reactive metakaolin. When clay (kaolinite) is kept under very high temperature to create pozzolanic properties, that clay is known as Metakaolin. Water-cement ratio was kept around 0.35 to cast 6 different combinations which have 0, 8 and 12% substitution of Portland cement by highly reactive metakaolin. Parameters under consideration were permeability of chloride, bulk diffusion, migration of chloride and resistivity shown by concrete after long term like 140 day ors 1 and 3 year respectively. Result showed that all concrete samples had better strength with addition of highly reactive metakaolin, observation from 140 days sample was that due to low water-cement ratio and high quantity of metakaolin reduces permeability, diffusion but give rise in migration of chloride and resistivity. They also observed as the quantity of metakaolin increase, resistance also increases in all samples.

Huang et al. [2005] did experimental work to understand the performance of hydrochloric acid and damage cause by them on different type concrete. After casting, samples were cures for about 360 day then were treated with hydrochloric acid for 24 hour by varying its ration from 5% to 20%. Compression, flexural, loss in dynamic modulus and mass loss test were conducted in series of tests. They observed as the percentage of hydrochloric acid increases all concrete's properties reduces. Sample of normal mix as well as high mix showed same pattern of loss in compressive strength.

Experimental examination by Chotithanorm et.al [2007] was done to understand the effect of fly ash variation in specimen and observe it's oppose to penetration of chloride in concrete. Mainly 3 type of fly ash were used standard, 10% and 45% fine potion fly ash. All tests were done according to ASTM C1202. Result showed that the main factor was fineness of fly ash means more the fineness of fly ash more will be the resistance offered against penetration of chloride.

Talah et al. [2011] studied the effect chloride on high performance concrete that contain pozzolana cement. they observed deplition of chlorine ion's permeability and absorption of water in sample reports natural pozzolana shows good property then traditional concrete and also acceptable for high performance concrete. Deterioration of concrete was mainly happened due to sulphate attack and diffusion of chloride. The capability to withstand this sort of attack which are classified as diffusivity and permeability, are known as "durability indicators".

Rao et al. [2012] did experimental work to study the behavior of concrete with alkali resistant glass fiber and observe their durability and resistance from the acid attack. Result showed that sulphate had not much action over test samples while permeability of chloride was very low in contrast to traditional concrete.

IV. CONCLUSION

This article summarized that glass fiber reinforced concrete is a very useful and strong material that can be used in construction. After using GFRC around 25-30 percent enhancement in compressive strength. It helps to make the precast elements lightweight, so the cost of transportation decreases effectively in pre cast construction. Tensile and Flexural strength also get improved by using GFRC which makes structural element resistant against cracking and more durable. By using alkali resistant glass fiber concrete shows better performance against chloride and sulphate attack, they also make concrete impervious, enhance first crack load and crack pattern. Standard codes on GFRC are old now, new technique and fibers have been introduced so it should be revise as soon as possible. As GFRC is the future of construction in whole world more research on it needs to be done. It can be used everywhere even inside water because of its alkali resistant property which otherwise makes concrete invulnerable.

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