

Glass Fibre Reinforced Concrete for Construction – A Review

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Abstract— The review dynamically signifies the various components and characteristics indulged in the analysis of Glass Fibre Reinforced Concrete. Fundamentally, GFRC is a fibre based concrete in which fibre are uniformly distributed and partially oriented along with other material such as cement, aggregates, sand, water, fly ash, etc. These fibres reinforce the concrete internally. Furthermore, it possesses various properties which enhance the workability of concrete up to a certain level along with its compressive, flexural and tensile strength. Apart from fibre, various other admixtures are significantly added in the concrete mix to overcome the concrete deficiencies such as weak in tension, highly porous, susceptible to cracking and chemical attacks. The length of glass fibre may vary depending upon their requirement for the specific objective. They may be applied either by spraying or by pouring.

Keywords— Glass fibre reinforcement, fibre reinforced concrete, compressive strength, flexural strength, flyash, alkali resistant glass fibre.

I. INTRODUCTION

Concrete has manifested an integral part of our life's as it can be witnessed anywhere around us. Concrete is a building material which is rich in diversity and availability. Reinforced concrete is used in areas where a demand of high tensile strength is required along with precast concrete which can easily create in any form according to the demand. Large and heavy structures like dams, bridges, tunnels are completed to withstand for longer time period by the involvement of concrete. Concrete for now has ever been involved with many other building materials in order to enhance its properties such is the Glass Fibre Reinforced Concrete. Fundamentally, GFRC is a fibre based concrete in which fibre are uniformly distributed and partially oriented along with other material such as cement, aggregates, sand, water, fly ash, etc. These fibre reinforce the concrete internally. The length of glass fibre may vary depending upon their requirement for the specific objective. They may be applied either by spraying or by pouring. GFRC is significantly used in building countertops, construction or renovation of exterior facades of building, drainage works, architectural works such as cladding etc.

II. LITERATURE REVIEW

A number of researches have been conducted on GFRC during the recent years. The work of various researchers have been studied and presented below:

- ❖ Gupta et al. (2017) analyzed the effect on compressive and flexural strength of M25 grade of concrete after the addition of alkali resistant glass fibre and observed that the inclusion of the glass fibre into the mixture of concrete replacing the cementitious material did not improve its compressive and flexural strength. However at the age of 28 days, the values of the mix with 2% of glass fibre are comparable to the controlled concrete mix having no glass fibre at all.
- ❖ An experimentation on the properties of reinforced glass fibre and ground granulated blast furnace slag concrete was carried out by Kumar Shantveerayya and Nikkam Vikasin (2016) which concluded that the concrete workability increases and decreases in accordance to the inclusion of Ground Granulated Blast Slag and glass fibre. Slump value gets gradually increase up to 45% in 0.33% and 0.67% of glass fibre along with the addition of GGBS and then further decreases. The split tensile strength and compressive strength value of cube exhibit efficacious strength with the addition of GGBS from 0% to 45% in 0.33% of glass fibre and 0% to 30% in 0.67% of glass fibre. However further more addition of GGBS may result in decreasing the value of cubes.
- ❖ In an experimental study on glass fibre concrete by Khan et al. (2016), it was culminated out that after the addition of glass fibre, the workability of concrete increases by 1%. There was also an increment of M-20 grade concrete in compressive, flexural and split tensile strength at 7 and 28 days regarding to the 1% increase in workability. A gradual increase in the compressive strength of glass fibre concrete was also observed as compared to the normal concrete. Further, workability decreases from 1% due to addition of glass fibre. The flexural strength, compressive strength and split tensile strength remains very high at 1% for 7 days.
- ❖ Subramani and Mumtaj (2015) conducted an experimental investigation Of Partial Replacement of Sand with Glass Fibre which deduces out that the strength of concrete with 10% of glass fibre was higher than compared to that of the conventional mix. The optimum intensity to be sustained for the higher value of strength and durability at 7 days was acquired with sand replacement amount of 10% of glass fibre in variant mixes. The coefficient of permeability of Concrete mix with glass fibre remains negligible and without glass fibre increased significantly. Fibres in the concrete

help in depleting the pores, hence creating erratic pore structures which increase the impermeability of concrete. Cementitious materials fracture energy remarkably increases with the addition of glass fibre.

- ❖ A Study on the increment of Concrete Tensile Strength due to glass fibre was governed by Pitroda et al. (2015) which stated that the flexural strength, compressive strength and split tensile strength of concrete increases with the addition of glass fibre in order to overcome the deficiency of taking loads and tension, thereby enhancing its durability and mechanical properties.
- ❖ A research work conducted by Singh and Kumar (2014) illustrated the effect of fibre on properties of concrete which clarified that with 0.5% of glass fibre in concrete will result in greater compressive and flexural strength. However, flexural strength may significantly increase to 60% as compared to its nominal mix with addition of 0.7% of glass fibre.
- ❖ An experimental study on glass fibre reinforced concrete moderate deep beam was carried out by Rathi et al. (2014). The study showed increase in the split tensile and compressive strength with a maximum value coming at the inclusion of 0.75% glass fibre and an average increase value of 24.73N/mm^2 and 11.88N/mm^2 respectively. With the inclusion of 0.75% of glass fibre results in abating stirrup requirement as the shear stress of beam increases. The ultimate load carrying capacity of beam increases till 1% fraction of glass fibre than starts to gradually decrease but attains a maximum value at 0.75% of glass fibre. Properties like balling effect and heterogeneity manifested at higher value of glass fibre like 0.75% and 1%.
- ❖ Krishna and Venkateswara (2014) deduce the effect of glass fibres in rigid pavement. The study proclaimed that 0.2% of fibre in concrete possess the optimum value of compressive, flexural and split tensile strength increasing from 12.2N/mm^2 to 20.4N/mm^2 , 19.48N/mm^2 to 53.96N/mm^2 and 17.05N/mm^2 to 43.77N/mm^2 at 28 days. The pavement thickness decrease economically better than the plain cement concrete.
- ❖ Dawood and Hamad (2013) carried out a study on the high performance lightweight concrete reinforced with Glass Fibre which manifested that the increase of glass fibre percentage result in reduction of the workability of concrete. Lightweight concrete with less than 0.6% of glass fibre will have an increment in its compressive strength whereas with more than 0.6% will result in the decrement of its workability. However, flexural strength promptly increases with the addition of 0.6% glass fibre with or without super-plasticizer.
- ❖ Ravikumar and Thandavamoorthy (2013) investigated on strength and fire resistant properties of glass fibre concrete which concluded that when compared to the flexural, compressive and split tensile strength of conventional concrete, with the 0.5% addition of glass fibre, the value increased to 13%, 42% and 20%. Therefore, reinforcing concrete with glass fibre increase its strength by 1.78 times the normal concrete. Heating the concrete for 2 hours at 300°C decreases its compressive strength. The compressive strength without and with addition of 0.5%, 1% of glass fibre after heating decreases to 32% and 25%, 10% to its original strength.
- ❖ Manjunatha and Ashwini (2013) analyzed the performance of glass fibre reinforced self-compacting concrete and concluded that the flow capability and passing capability of SCC with the increase in the aspect ratio decreases and volume fraction of glass fibre. Glass fibre moreover is highly lucrative in axial-tension which increases its tensile strength. The flexural strength and compressive strength was found out to be the most at the addition of 0.5% of glass fibre whereas split tensile strength at 0.75%. The volume fraction and aspect ratio of glass fibre for concrete to perform in the most lucrative manner in terms of compressive and flexural strength was found to be at 0.5% and 1285 whereas for split tensile strength at 0.75% and 1285.
- ❖ In an experimentation study on reinforcing efficiency of low volume class fly ash concrete with glass fibre carried out by Sivakumar and Sounthararajan (2013), it was observed that with 25% of fly ash and 0.3% of fibre in concrete possess the optimum value of flexural and compressive strength, which further emits the enhanced mechanical characteristics of concrete. It also exhibits significant ultrasonic pulse velocity of variant mix composition which improves its hardening effect as well.
- ❖ Deshmukhet et al. (2012) conducted a research experiment on the effect on Ordinary Portland cement with the addition of glass fibre concrete and exhibits the mechanical properties and durability of concrete is optimum at 0.1% fraction of fibre. The compressive strength marginally increases while flexural and split tensile strength increases significantly with further increase of glass fibre.
- ❖ Alam et al. (2012) conducted experimentation on Properties of Glass Fibre Reinforced Concrete. Alkali resistant glass fibre doesn't affect the workability of the concrete while it notably enhances its compressive and tensile strength. The slump value varies barely but significantly for different grades of concrete mixes. Compressive and tensile strength had a prolific improvement with the addition of glass fibre up to a limit.
- ❖ Murthy et al. (2012) examine the performance of fibre reinforced concrete and conclude that glass fibre being a waste of glass industry have a substantial role in the improvement of the properties of concrete in future. It increases the compressive strength up to a marginal value but flexural strength was increased up to 30% in the test conducted. Hence, it plays a crucial role for the development.
- ❖ Quadri et al. (2012) analyze the strength aspects of glass fibre reinforced concrete which concluded out that with further addition of fly ash in the concrete mix, the workability decreases which can be overcome by further addition of plasticizers or super-plasticizers. They also observed that there is a moderate increase in the early stages of strength for compression and flexural whereas the ultimate strength of split tensile strength had a sudden increase of the glass fibre reinforced concrete when compared to plain concrete. Concrete of grade M-20, M-30 and M-40 were tested for their split tensile strength, compressive strength and flexural strength at 3, 7 and 28 days and it was concluded out after keen

observation that the variant strength increases from 20% - 30%, 25% - 30% and 25% - 30% respectively when compared to plain concrete.

- ❖ A research study on glass fibre reinforced concrete use in construction was conducted by Shakor and Pimplikar (2011) which affirmed that the compressive strength increases up to a limit of 1.5% fraction of glass fibre in concrete as observed in the test. The decrease in the strength after exceeding the limit is due to the increasing weight of glass fibre which affects the cohesiveness between the particles of concrete. Glass fibre has to be precisely mixed under a minute, as it breaks down into smaller fractions which don't provide the optimum result.
- ❖ Rao et al. (2010) scrutinize the effect of fly ash based concrete with glass fibre and deduced that the performance of concrete degrades with addition of fly ash and moderately increases with fibre addition. Concrete with 0.3% of glass fibre has the optimum strength value in differentiation to the control mix.
- ❖ Experimentation was conducted to seek out the strength properties of glass fibre concrete by Rao et al. (2010). They deduce out that the addition of glass fibre in the concrete mix may lead to a reduction in bleeding which further result in the enhancement of its homogeneity, surface integrity and reducing the probability of cracks. There was also an increase of 20% - 25% in compressive strength, 15% - 20% in flexural and split tensile strength as compared with 28 days of various grades of concrete mixes.
- ❖ Awang and Noordin (2002) analyzed the effect on the compressive strength of lightweight foamed concrete when mixed with alkaline-resistant glass fibre and observed that the workability of various mixes used in the experiment varied between 18cm to 20 cm and the foamed concrete effuse significant workability procured from the various mixes. The dry density from a target value of 900 kg/m³ and 1000 kg/m³ varied from 912 kg/m³ to 924 kg/m³ and 1015 kg/m³ to 1070 kg/m³. The study also shows the compressive strength is mainly dependent on the cement content and the fine aggregate grading and is also affected by the inclusion of fibre content in the foamed concrete. A range of 0.2% and 0.4% was recommended as the suitable percentage of fibre to be used for the optimization of strength. The concrete tends to absorb more water with the inclusion of glass fibre. The method and time of mixing have to be controlled and not to be over mixed as it may result into the shattering of bubbles which leads to the increase in density and over mixing may also lead to the dispersion of glass fibre into smaller filaments resulting in the increase of water absorption of concrete. This can be controlled by providing protective rendering when exposed to weather.

All the literatures studied during the present work have been summarized in the table below:

Table 1: Summary of the Literature Survey

S. NO.	TITLE OF MANUSCRIPT (YEAR)	RESEARCHERS	WORK DONE	TYPE OF GLASS FIBRE USED
1	Effect of alkaline-resistant glass fibre on compressive strength of lightweight foamed concrete (2002)	Hanizam Awang, N M Noordin	Compressive Strength Test, Flexural Strength Test, Split Tensile strength Test is done for 7 & 28 days for 0.2, 0.4 & 0.6% of Glass Fibre in M30 Grade of concrete and found that the compressive, flexural and split tensile strength is coming highest at 28 days on 1% of glass fibre.	Alkali Resistant Glass fibre
2	Effect of Glass Fibres on Flyash Based Concrete (2010)	Rama Mohan Rao, Sudarsana Rao, H, Sekar, S.K	Compressive Strength Test, Flexural Strength Test, Split Tensile strength Test is done for 7, 28 & 56 days for 0, 0.1, 0.2 & 0.3% of Glass Fibre in M30 Grade of concrete and found that the compressive, flexural and split tensile strength is coming highest at 56 days on 0.3% of glass fibre.	E- Glass fibre
3	Strength Properties Of Glass Fibre Concrete (2010)	Chandramouli K, Srinivasa Rao P, Pannirselvam N, Seshadri Sekhar T and Sravana P	Compressive Strength Test, Flexural Strength Test, Split Tensile strength Test is done for 28, 56, 90 & 180 days for 0.03% of Glass Fibre in M20, M30, M40 & M50 Grade of concrete and found that the compressive, flexural and split tensile strength is coming highest at 180 days in all the grades.	Cem-Fil Anti-Crack High Dispersion

4	Glass Fibre Reinforced Concrete Use in Construction (2011)	Eng. Pshtiwan N. Shakor, Prof. S. S. Pimplikar	Compressive Strength Test, Flexural Strength Test, is done for 7, 28 days for 0.11, 1.5 & 2% of Glass Fibre in M60 Grade of concrete and found that the compressive and flexural strength is coming highest at 28 days on 0.75% of glass fibre.	Alkali Resistant Glass fibre
5	Strength Aspects of Glass Fibre Reinforced Concrete (2012)	Avinash Gornale, S Ibrahim Quadri, S Mehmood Quadri, Syed Md Akram Ali, Syed Shamsuddin Hussaini	Compressive Strength Test, Flexural Strength Test, Split Tensile strength Test is done for 3, 7 & 28 days for 0.03% of Glass Fibre in M20, M30, M40 Grade of concrete and found that the compressive, flexural and split tensile strength is coming highest at 28 days in all the grades.	Cem-Fil Anti-Crack High Dispersion
6	Performance of Glass Fiber Reinforced Concrete (2012)	Yogesh Iyer Murthy, Apoorv Sharda, Gourav Jain	Compressive Strength Test is done for 7, 28 days and flexural strength test is done for 28 days for 0, 0.5, 0.7, 0.9, 1.2 & 1.5 % of Glass Fibre in M30 Grade of concrete and found that the compressive and flexural strength is coming highest at 28 days on 1.5% of glass fibre.	E- Glass fibre
7	Effect of Glass Fibres on Ordinary Portland cement Concrete (2012)	Deshmukh S.H., Bhusari J. P, Zende A. M	Compressive Strength Test, Flexural Strength Test, Split Tensile strength Test is done for 3, 7, 28 & 90 days for 0, , 0.03, 0.06 & 0.1% of Glass Fibre in M20 Grade of concrete and found that the compressive, flexural and split tensile strength is coming highest at 90 days on 0.1% of glass fibre.	Cem-Fil Anti-Crack High Dispersion
8	Experimental Study on Properties of Glass Fibre Reinforced Concrete (2012)	Md.Abid Alam , Imran Ahmad, Fazlur Rehman	Compressive Strength Test and Split Tensile strength Test is done for 28 days for 0, 0.02, 0.04 & 0.06% of Glass Fibre in M20 & M30 Grade of concrete and found that the compressive and split tensile strength is coming highest at 28 days on 0.6% of glass fibre in both the grade.	Cem-Fil Anti-Crack Alkali-Resistant High Dispersion
9	Performance of Glass Fibre Reinforced Self Compacting Concrete (2013)	Manjunatha J.K ,Ashwini B.T	Compressive Strength Test, Flexural Strength Test, Split Tensile strength Test is done for 7 & 28 days for 0, 0.25, 0.5, 0.75 & 1% of Glass Fibre in M40 Grade of concrete and found that the compressive, flexural and split tensile strength is coming highest at 28 days on 0.5% of glass fibre.	Cem-Fil Anti-Crack Alkali-Resistant High Dispersion
10	Reinforcing efficiency of glass fibres in low volume class F fly ash concrete (2013)	V. M. Sounthararajan and A. Sivakumar	Compressive Strength Test, Flexural Strength Test, Split Tensile strength Test is done for 7 & 28 days for 0, 0.1, 0.2, 0.3, 0.4 & 0.5% of Glass Fibre in M40 Grade of concrete and found that the compressive, flexural and split tensile strength is coming highest at 28 days on 0.3% of glass fibre.	Alkali Resistant Glass fibre

11	High performance lightweight concrete reinforced with Glass Fiber (2013)	Eethar Thanon Dawood , Ali Jihad Hamad	Compressive Strength Test, Flexural Strength Test is done for 7 & 28 days for 0.06,0.2,0.4 & 0.6 % of Glass Fibre in M25 Grade of concrete and found that the compressive and flexural strength is coming highest at 28 days on 0.6% of glass fibre.	Alkali Resistant Glass fibre
12	Glass Fibre Concrete: Investigation on Strength and Fire Resistant Properties (2013)	C. Selin Ravikumar and T.S. Thandavamoorthy	Compressive Strength Test, Flexural Strength Test, Split Tensile strength Test is done for 7 & 28 days for 0.5 & 1% of Glass Fibre in M25 Grade of concrete and found that the compressive strength is coming highest at 28 days on 1% of glass fibre.	Alkali Resistant Glass fibre
13	Effect Of Fiber On Properties Of Concrete (2014)	Vinay Kumar Singh, Dilip Kumar	Compressive Strength Test, Flexural Strength Test is done for 28 days for 0.225, 0.075, 0.375 & 0.525% of Glass Fibre in M30 Grade of concrete and found that the compressive and flexural strength is coming highest at 28 days on 0.525% of glass fibre.	E- Glass fibre
14	Experimental Study on Glass Fiber Reinforced Concrete Moderate Deep Beam (2014)	V.R.Rathi, A.V.Ghogare ,S.R.Nawale	Compressive Strength Test, Flexural Strength Test, Split Tensile strength Test is done for 28 days for 0, 0.25, 0.5, 0.75 & 1% of Glass Fibre in M25 Grade of concrete and found that the compressive, flexural and split tensile strength is coming highest at 28 days on 0.75% of glass fibre.	E- Glass fibre
15	Effect of Glass Fibers In Rigid Pavement (2014)	K. vamshi krishna, J. Venkateswara Rao	Compressive Strength Test, Flexural Strength Test, Split Tensile strength Test is done for 3, 7 & 28 days for 0.1, 0.2 & 0.3% of Glass Fibre in M20 Grade of concrete and found that the compressive, flexural and split tensile strength is coming highest at 28 days on 0.2% of glass fibre.	Polyester Glass Fibers
16	Experimental Investigation Of Partial Replacement Of Sand With Glass Fibre (2015)	T.Subramani , A.Mumtaj	Compressive Strength Test, Flexural Strength Test, Split Tensile strength Test is done for 7, 14 & 28 days for 0.1% of Glass Fibre in M30 Grade of concrete and found that the compressive, flexural and split tensile strength is coming highest at 28 days.	E- Glass fibre

17	A Study on Glass Fibre as an Additive in Concrete to Increase Concrete Tensile Strength (2015)	Ronak Prakashkumar Patel, Jayraj Solanki, Dr. Jayeshkumar Pitroda	Compressive Strength Test, Flexural Strength Test, Split Tensile strength Test is done for 28 days for 0.03, 0.06 & 0.1% of Glass Fibre in M20 Grade of concrete and found that the compressive, flexural and split tensile strength is coming highest at 28 days on 0.1% of glass fibre.	E- Glass fibre
18	An Experimental Study on the Properties of Glass Fibre Reinforced and Ground Granulated Blast Furnace Slag Concrete (2016)	Kumar Shantveerayya, Vikas Nikkam	Compressive Strength Test, Flexural Strength Test, Split Tensile strength Test is done for 3, 7 & 28 days for 0.33 & 0.67% of Glass Fibre in M25 Grade of concrete and found that the compressive, flexural and split tensile strength is coming highest at 28 days on 0.67% of glass fibre.	E- Glass fibre
19	Experimental Studies on Glass Fiber Concrete (2016)	J.D.Chaitanya kumar, G.V.S. Abhilash, P.Khasim Khan, G.Manikanta sai	Compressive Strength Test, Flexural Strength Test, Split Tensile strength Test is done for 7 & 28 days for 0.5, 1, 2 & 3% of Glass Fibre in M20 Grade of concrete and found that the compressive, flexural and split tensile strength is coming highest at 28 days on 1% of glass fibre.	E- Glass fibre
20	Partial Replacement of Cement by Flyash & Glass Fibre in Light Weight Fibre Reinforced Concrete (2017)	Sakshi Gupta, Aakash, Abhimanyu Ramola, Jatin Arora, Anand Saini	Compressive Strength and Flexural Strength is done for 7, 14 & 28 days for 0, 1, 1.5, 2, 2.5, 3% of Glass Fibre in M25 grade of concrete and found that the compressive and flexural strength is coming highest at 28 days on 2% of glass fibre	Alkali Resistant Glass fibre

III. ADVANTAGES, DISADVANTAGES & PRACTICAL APPLICATIONS

After careful review of the literatures, it was found that there are a number of advantages of using GFRC along with their practical applications. Also, if there are advantages of certain type of concrete, it is always accompanied by certain demerits which were seen from various literatures studied. The advantages, disadvantages and the practical applications of GFRC are discussed below:

Advantages:

- ❖ As compared to the traditional mix GFRC is 75% lighter in volume.
- ❖ It provides high level of strength to weight ratio because of its tensile nature.
- ❖ It does not crack easily and can be easily moulded.
- ❖ Currently, GFRC is highly used in walls and ceilings and is also used for external restoration work.
- ❖ GFRC is easy to apply and no requirement of heavy duty machinery while application.

Disadvantages:

- ❖ Cost of GFRC is more than that of concrete.
- ❖ GFRC may lose its strength, over a long period of time. So this point should be noted at design stage.
- ❖ GFRC is made precast rather than on site, so forward planning is needed.
- ❖ It can collapse under stress because of its non-ductile nature.
- ❖ GFRC is applied by pouring and mixing or spraying. GFRC is not easy to mix by your own

Practical Applications:

- ❖ GFRC is excellent for new buildings exteriors and restoration projects of the facades of old buildings.
- ❖ It is also used to construct walls and ceilings within the buildings.
- ❖ GFRC is used extensively in landscaping and water features.
- ❖ It is excellent for sculptures as well as prefabricated rocks and boulders; because of its ability to be poured in almost any cast.
- ❖ GFRC is used by landscape artists for one piece waterfalls, landscape sculptures, boulders, cremation urns and memorial stones.

IV. CONCLUSION

After an extensive study of the various literatures on glass fibre reinforced concrete, it was found that GFRC is an excellent concrete that can be put to various applications. It was seen from the work of a number of researchers that the workability of the concrete increased up to a certain degree of value and then started to decrease. However, the compressive strength significantly increased as compared to flexural and tensile strength which resisted at a certain point which was clearly defined. It was also seen that the use of super plasticizers might enhance the workability and the addition of low alkali cement augmented the durability characteristics of the concrete. Thus, GFRC is significantly used in building countertops, construction or renovation of exterior facades of building, drainage works, architectural works such as cladding and other applications.

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