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EFFICIENCY OF GLASS FIBER REINFORCED CONCRETE IN CONSTRUCTION

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ABSTRACT

Several minute and fine glass fibers combined together form a glass fiber. It is also known as "fiberglass" in the present world. In the year 1932, "Russell Games Slayter of Owens-Corning" invented this construction material. It was initially used as "thermal building insulation". The mechanical characteristics of glass fiber are equally similar to the other fibers like carbon fiber & polymers. When used in composites, it is less fragile & cheaper even though it is not rigid or strong as carbon fiber. To produce a very strong and comparably lightweight fiber-reinforced polymer (FRP) composite element called "glass-reinforced plastic (GRP)", glass fibers are used as a reinforcing agent for many polymer products (Shafei, B., et al 2021). This element is poor thermal insulator and it contains little gas or air. When thin strands of silica-based or other formulation glass are extruded into many fibers with small diameters, glass fiber is formed which are suitable for textile processing. Fine fibers are formed by heating & drawing glass for many years but the application of this glass fiber in textile industry is recent. As a staple, most of the glass fibers are manufactured upto this time. E-glass is "aluminoborosilicate glass with less than 1% w/w alkali oxides" (Yuan, Z. & Jia, Y., 2021). It is the most familiar form of glass fiber which is employed in present times and is used for glass reinforced plastics. This research paper presents the critical evaluation of the glass fiber reinforced concrete and examines the efficiency of it.

***KEY WORDS**: glass fiber reinforced concrete, efficiency, performance, fiberglass, application*

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INTRODUCTION

Glass-fiber reinforced concrete or GFRC is "a type of fiber-reinforced concrete containing fibrous material which increases its structural integrity". Small discrete fibers are equally dispersed and unsystematically aligned in GFRC. If the alignment, fiber elements, mixture, geometries, densities, dispersion varies, the nature of glass fiber reinforced concrete also varies. Instead of steel, glass fibers are used in this concrete for reinforcement. 1/2" to 3/4" is the common size of the cast which is usually thin (Zaid, O., et al 2021). One of the major plus in this concrete is the prevention of rusting as steel is not used for reinforcement. Hence, no effort has to be taken to add thickness for the concrete to prevent rusting. They can weigh a fraction of the weight of traditional precast concrete with the thin, hollow construction of GFRC products.

Based on the glass content, production methods & mix design, the characteristics of GFRC vary as an engineered component. There is higher tensile strength in the glass fiber when compared to the steel. The strength of the concrete increases when the fiber content added to the mixture is more. 6,000 to 8,000 psi will be the strength, when five percent glass fiber is added to the mix.

Accelerated aging tests in the real life installations & laboratory is the general test conducted to test the quality of the glass fiber reinforced concrete. The durability of the glass fiber reinforced concrete is as high as the pre-cast concrete. GFRC can outperformance than other concrete as it can adapt to different environments even in the high moisture or salt spray as there is no concern for corrosion. It weathers more like a "quality architectural pre-cast concrete" as the surface of GFRC is a "portland concrete" (Kasagani, H. & Rao, C.B.K., 2018).

Architectural precast cladding panels were the main application in which glass fiber reinforced concrete was employed for last thirty years. Statues, crowns, domes, fireplace surrounds and columns are some of the myriad ornamental treatments in which glass fiber reinforced concrete are used. To produce artificial rocks, water features and cliffs, super-strong mix is employed by the contractors for many years. With the help of concentric chopper gun & rotor/stator pump, glass fiber reinforced concrete is mixed and applied through spray. Using a premix spray gun & peristaltic pump, it can also be hand-laminated or sprayed as a premix.

The thickness of the glass fiber reinforced concrete cast products is usually between 1/4 inch and 1 inch which is very thin when compared to the conventional wet-cast concrete. The thickness of the regular concrete is usually between three and six inches (Madhkhan, M. & Katirai, R., 2019). As the flexural strength of the glass fiber reinforced concrete is five times higher than precast concrete, the precast concrete is heavier than glass fiber reinforced concrete. This is mainly caused by the addition of the glass fibers to the mixture of the concrete.

COMPOSITION OF GLASS FIBER REINFORCED CONCRETE

Glass fibers which have huge strength and are surrounded by a cementitious medium is possessed by the elements of the glass fiber reinforced concrete. The pure individual chemical properties are maintained by both the environment & fibers in this shape. If the elements are used individually, the enhancement in the resultant characteristics of the concrete cannot be achieved. The fibers are kept in a particular direction & position by the enclosed matrix and the load is carried by the central properties of the glass fibers.

The normal environmental damage is prevented by the medium provision as it shifts the load of the fibers. Either in irregular or constant lengths, the incorporation of the glass fibers into the matrix can be done. Laminate is the "most widespread shape in which glass fiber reinforced composites are used in structural applications" (Faleschini, F., et al 2020). A matrix and fine fiber layers are consolidated into the desired size to attain this form. A range of mechanical properties of the composite materials is created by using the stacking sequence of the layers and orientation of fiber in each layer.

Even though it weighs only $1/3^{rd}$ of the real solid concrete weight, there is combination of all these elements to make the glass fiber reinforced concrete look like a solid concrete. Where the durable & lightweight concrete is required, this makes it useful for the indoor or outdoor applications. Domes, decorative structures, planters, fountains are some of the applications in which glass fiber reinforced concrete is used.

CONSTITUENT MATERIALS OF GFRC

There are five essential constituent elements of GFRC are listed below.

1. Cement
2. Fine Aggregates
3. Coarse Aggregates
4. Water
5. Glass fibers

- **Cement**

Cement is one of the important constituent elements of glass fiber reinforced concrete. For experimental program, "ordinary Portland cement 53 grade" is usually employed. The physical properties of the cement are tested whether it is in accord with standards of IS.

- **Fine Aggregates**

From the bed of the river, the fine aggregates is obtained and used for the experimental purpose. Through 4.75mm sieve, fine aggregates are passed. They have a specific gravity of 2.68. According to IS 383.2, the fine aggregates belonged to Zone II.

- **Coarse Aggregates**

Based on the needs to create durable and good concrete, the coarse aggregates were used as non-reactive. The required grading for coarse aggregates was obtained by a definite mix proportion & two separate gradings. Maximum size of 12.5mm & a minimum 10mm is the size of one grade and maximum size was 20mm & minimum 12.5mm is the size of other grade. For cylinders, prisms & casting cubes, this combination is used. The bailing effect of concrete mix is prevented by this (Elshamandy, M.G., et al 2018).

- **Water**

For creating the mixture of concrete, ordinary tap water is used. It should be potable for washing & drinking and safe. The water used for the mixture of concrete should be pure and without any impurities. If there are impurities in the water, it will affect the quality of the concrete. Hence, the contaminated water is avoided for the concrete mixture.

- **Glass Fibers**

From extremely fine fibers of glass, glass fiber is produced. This type of glass fiber is also called as fiber glass. The properties of the glass fiber produced are strong in nature, light in weight and robust elements. “Chemically inert, hydrophobic, and lightweight” are the main properties of the glass fiber which is common type of the synthetics.

“Fine fibrils of rectangular cross-section” is formed by chopping of a particular length as tapes & films which are the “continuous cylindrical monofilaments” produced from it (Meda, A., et al 2019). Cracking is subsidized and the plastic shrinkage is reduced by the glass fiber reinforced concrete than steel reinforcement even 0.1% of glass fiber is added to the volume of concrete.

ADVANTAGES OF GLASS FIBER REINFORCED CONCRETE

GFRC is an engineered element. Based on the fiber content, design of mixture & techniques employed during the manufacture, the characteristics of the concrete changes. Because of its various characteristics, the usage of glass

fiber reinforced concrete has become more famous (Guérin, M., et al 2019).

- Glass fiber reinforced concrete last long to the same duration of the pre-cast concrete. It can be tested in actual installations & in laboratory.
- As the steel reinforcement is absent, glass fiber reinforced concrete can perform well in adverse environment like moisture or salts as there won't be any corrosion.
- The installation of the glass fiber reinforced concrete is simple and can be done quickly.
- The weight of the glass fiber reinforced concrete is less when compared to the other concretes.
- Any shape can be casted with the help of glass fiber reinforced concrete because of its unique properties.
- The elements which are possessed by the glass fiber reinforced concrete are unlikely to burn.
- The concrete acts as thermal regulator and shield the elements from the flame heat when exposed to fire.
- When compared to solid concrete, the glass fiber reinforced concrete is 75% to 90% less in weight, thin & strong.
- The load applied on the structure is reduced as the weight is less and it helps in rapid & easy installation.
- Flexibility in design is allowed, transportation expenditure is minimized and the impact on environment is reduced by the tough & light weight element.
- Seismic loads are endured by the improved capacity provided by the superior strength.
- When compared to normal concrete, glass fiber reinforced concrete are more resistant to freeze thaw & less vulnerable to weather effects.

APPLICATION OF GLASS FIBER REINFORCED CONCRETE

The total composition of glass fiber is two hundred to four hundred individual filaments. In order to form a stand, it is lightly bonded. To use it for several applications, these stands are cut into different lengths. Thin-sheet products manufacture is done with the help of mortar matrices reinforcing or cement which are the major industrial application of glass fibers (Gravit, M., et al 2021). The usage of two percent of 25mm length fiber is permitted by the traditional mixing techniques of concrete. "e-glass" is the most familiar form of glass fibers which are employed for normal applications. Physical characteristics like moisture movement are enhanced by adding polymers in the glass fiber mixes.

In the place where attractive, strong, fire retardant element, light is needed, glass fiber reinforced concrete is used. GFRC can be employed in manufacturing architectural products like "wall panels, window surrounds, column covers, soffits, cornices, brackets, quoins, railings, pilasters, copings, domes, site furnishings, planters, bollards,

urns and tables" (Kasagani, H. & Rao, C.B.K., 2018).

LITERATURE REVIEW

The fibers impact on the different strength of M20 grade concrete, density and workability is analyzed. Based on the weight of the cement, there is 0.5 to 4.5% variation in the fiber content. "Compressive strength, flexural strength, split tensile strength, and bond strength" are the different strengths which are investigated for this study. For compressive and bond strengths, cubes of 150 mm are casted. For flexural strength, beams of 100 × 100 × 500 mm are casted. For split tensile strength, cylinders of 150 mm diameter 300 mm length are casted. They are tested for duration of 28 days after curing in water. It is found that there is reduction in the workability of the wet mix if the fiber content is increased. As observed from the study of load-deflection behavior, there is increase in ductility of concrete in the glass fiber reinforced concrete. Because of the addition of glass fibers in the concrete, a notable enhancement in different strength is observed. It is noted that optimum fiber content is strength dependent (Ghugal, Y.M. & Deshmukh, S.B., 2006).

To meet the requirement to adopt the present one to account for the engineering properties of FRP materials or to produce a fresh design code, fiber reinforced plastic (FRP) bars are increasing used to reinforce concrete structures. To prevent rupturing of the tensile reinforcement, some modifications are suggested for ACI model for computing flexural strength, service load deflection & the minimum reinforcement. "The validity of the suggested modifications" is checked by conducting two series of tests. "The validity of the modifications made into the flexural and service load deflection models" was checked by the first series. "The accuracy of the modification suggested into minimum reinforcement model" is checked by the second series (Memon, M.S. & Sheikh, S.A., 2005).

With the help of the "ultimate design theory", the prediction of the flexural ability of the beams reinforced by glass fiber reinforced concrete bars can be done as per the results of the first series. The actual deflection of these beams is underestimated by the present ACI model for computing the service load deflection is also presented. "The measured deflection under service load, and the simpler of the two pertains better predictions than those of the models available in the literature" is correctly estimated by the two suggested models for predicting service load deflection. The agreement between the recorded & predicted behavior of the test specimens is revealed by the results of the second series. "The validity of the proposed model for calculating the required minimum reinforcement for beams reinforced by GFRP bars" is also suggested by it (Alsayed, S.H., et al 2000).

"The experimental results of full-scale circular concrete columns reinforced with glass-fiber-reinforced-polymer

(GFRP) bars and confined with GFRP discrete hoops subjected to combined axial compression loads and bending moments" is presented in this research study. Based upon the force equilibrium & strain computability to broaden the parametric study, the findings of the experimental work were incorporated with a theoretical analysis. Along with reinforcement ratio & reinforcement concrete strength, there was usage of highest & lowest bounds of the mechanical elements of glass fiber reinforced concrete (Meng, W. & Khayat, K.H., 2016).

The review of the compressive strength contribution of glass fiber reinforced concrete was done and analyzed. At the time of peak loads, there were development of tension strains & compression up to −0.003 & 0.008 as per the results. At the time of fewer loads, there were failure on the tension side & compression upto −0.015 & 0.0135. The buckling of longitudinal GFRP bars was avoided up to or even past the peak load by the "confinement provided by GFRP discrete hoops (9.5 mm) spaced at 80 mm" till the occurrence of failure. To avoid tension failure, one percent is the minimum glass fiber reinforced concrete longitudinal reinforcement ratio as per the results of the theoretical & experimental tests provided that the mechanical elements are in accordance with the extent of standard & codes (Hadhood, A., et al 2017).

The realization of using glass as a construction element was made in the year 1940. Later, it was developed to the addition of zirconium dioxide for rough alkali condition in the year 1960. The new glass fibers are used to improve the durability of the elements. To meet various demands, the glass fiber reinforced concrete was produced and employed in different applications. Based upon the accuracy of the production methods & the quality of the elements, there is change in the mechanical & physical characteristics of glass fiber reinforced concrete. It was presented by the tests on the glass fiber reinforced concrete & scientific studies (Dadvar, S.A., et al 2021).

Where there is a requirement of fire resistant, attractive, light, weather resistant, strong & impermeable element, glass fiber reinforced concrete can be employed. The entire construction can be built with less cost with the help of advanced technology. The investigation made on the glass fiber reinforced concrete has revealed that it is more effective and excelling in performance than other concretes. At present, it has become more common material which is used for construction (Iskender, M. & Karasu, B., 2018).

The usage of "alkali-resistant glass fibers (ARGFs)" as reinforcement is an essential way to enhance the performance of the concrete. "The problems of the cracking of the partition wall and lining seepage in Laoshan Tunnel, Qingdao, China" is the base for this study. "High dispersion (HD) and high performance (HP); and the compressive strength (CS), tensile strength (TS), flexural strength (FS), and impervious performance (IP) of concrete" are investigated with the help of the two forms of glass fibers which are selected for this study (Song, J.H., et al 2020).

There is improvement in the "tensile strength (TS), flexural strength (FS), and impervious performance (IP) of concrete" even though there is decrease in the compressive strength (CS) of graded glass fiber reinforced concrete (G-GRC). When compared with ordinary concrete, there is increase in "the tensile strength (TS), flexural strength (FS), and impervious performance (IP) of concrete" by 15.86%, 14.90%, and 31.58% for the 0.6 and 5 kg/m3 density of "High dispersion (HD) & high performance (HP)". The results indicate that there is enhancement in the mechanical elements of concrete and 22.29% increase in the tension-compression ratio. The construction of the Laoshan tunnel was built based on this result and the application turned to be successful (Wang, Q., et al 2021).

RESEARCH OBJECTIVE

The main aims of this research paper are given below.

- → To study about the glass fiber reinforced concrete in detail
- → To analyze the forms, applications, nature, properties of the glass fiber reinforced concrete
- → To determine the efficiency of the glass fiber reinforced concrete which is majorly used in the construction.

SIGNIFICANCE OF THE STUDY

This study brings out the detailed analysis about the glass fiber reinforced concrete. The nature, forms, properties, applications of the glass fiber reinforced concrete is discussed in this study. The efficiency of the glass fiber reinforced concrete which is used in the most of the construction works is presented. There is a huge research gap found in this research topic. Even though there are many research studies performed based on the glass fiber reinforced concrete, there is less studies which has the subject of the efficiency of the glass fiber reinforced concrete. Thus, this research paper contributes a new dimension about this research topic and adds value to the research society.

RESEARCH METHODOLOGY

In this research paper, secondary data collection is done. All the literary sources regarding the efficiency of the glass fiber reinforced concrete is studied and analyzed in detail. The main source of the all the data is Google scholar. The research papers, journals, thesis related to the glass fiber reinforced concrete were selected from the external source. After the selection of the data, it was formatted into a table with the necessary details like author name, title of the study, year of the publication, source, etc. From the list in the table, the title of the study is analyzed and the screening is done to choose the research papers which are relevant to this study i.e. the efficiency of the glass fiber reinforced concrete.

After finalizing the list of the secondary data, the research papers are analyzed in detail. The tests conducted, the materials taken for the test and the result of the tests are studied. After analyzing the above details in the selected secondary data, the result for this study is presented whether there is improvement or enhancement in employing glass fiber reinforced concrete. This research study abides all the ethical standards followed in a research. Proper citation is given for the secondary data collected for this research study. This paper is conducted with the proper guidance from the expert in this field.

RESULT OF THE STUDY

The result of the study indicates that if the glass fiber is added to the mixture of concrete, there is an increase in the compressive strength, flexural strength, Schmidt rebound hammer number, split tensile strength value and ultra-sonic pulse velocity. For 0.8% glass fiber, there is 14% increase in the compressive strength. For 0.8% glass fiber, there is 7.84% increase in flexural strength. For 0.8% glass fiber, there is 14% increase in schmidt rebound hammer number. For 0.8% glass fiber, there is 37% increase in split tensile strength value. For 0.8% glass fiber, there is 24% increase in ultra-sonic pulse velocity. The properties of concrete in general are enhanced when glass fiber is added to the concrete mixture.

Another research study indicates the same point which is the addition of glass fiber increases the compressive strength, flexural strength, split tensile strength, ductility. For 5% of glass fiber, there is 29.60% increase in the compressive strength. For 4% of glass fiber, there is 52.54% increase in the flexural strength. For 5% of glass fiber, there is 51.16% increase in split tensile strength. It is also found that addition of glass fiber also increases ductility and it reduces the workability of concrete. When compared to normal concrete, the crack width of glass fiber reinforced concrete is less. It enhances other properties and overall strength. Hence, it is proved that the glass fiber improves the quality of concrete when it is added to the mixture.

DISCUSSION

The glass fiber reinforced concrete is less in weight when compared to other concrete which is a major plus point. It is 75% less in weight when compared to the traditional concrete. It has high strength as the flexural strength of glass fiber reinforced concrete is around 4000 psi. The reinforcement in glass can be done internally and other types of reinforcement are not required as it is hard to place difficult shapes. There is no requirement of vibration for sprayed glass fiber reinforced concrete. Consolidation is attained easily for poured glass fiber reinforced concrete. This type of glass fiber does not require costly equipment.

Glass fibers are so strong in nature and it cannot crack easily. The surface of the concrete doesn't have voids or bug holes as it is sprayed on it. It can easily adapt into any form or shape when poured or sprayed into a mold. The glass fibers have more endurance power. It is also sustainable as it uses low amount of cement than traditional concrete. When compared to traditional concrete, glass fiber reinforced fibers are more costly but it is very effective.

CONCLUSION

It is concluded that the glass fiber reinforced fibers are more efficient in performance than the traditional concrete as it has several properties. If the quantity of the glass fiber enhances, there is reduction in the workability of concrete. When the glass fiber is added, there is increase in ductility and the strength of the concrete also increases by many folds. Most of the scholars suggest the usage of glass fiber in the concrete. Glass fibers are now employed in various applications throughout the world. Some of the projects in which glass fibers are commonly used are architectural cladding, renovation works, acoustic screens & barriers, tunnel lining panels & bridge, construction work, drainage & water works. It is successfully used in several applications because of the efficiency of the glass fiber.

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