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Enhancing Concrete Performance: A Study on the Optimal Proportion of Glass Fiber

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ABSTRACT:

This project is about observing the effect of putting glass fiber into M40 grade concrete which already has 30% fly ash as a substitute for cement, called control mix. We look into six different mixes for every type of fiber from 0.1% to 0.5%, making nine cubes for each mix sample. After curing times of 7, 14 and 28 days, we do compression strength tests on them. The results show that the concrete mix with 0.5% glass fiber has the highest compression strength, compared to control mix. The values are 39.7 MPa, 41.63 MPa, 42 MPa ,43.11MPa and .48MPa for glass fiber contents of 0.1% up until 0.5% respectively which shows an increase in strength as more fibers are added into it Comparison between two different concretes mixed; one is normal and other includes glass fiber - we see how typically the latter type of concrete displays greater resistance against compression than former one does indicating a clear effect from both amount and kind on mechanical properties in this material.

KEYWORDS : - Fly Ash, Glass Fiber, M40, Optimum Percentage, Testing, Workability.

INTRODUCTION :

Concrete with glass fibers is a sort of compound material that consists of cement, fine aggregates, water, chemical admixtures and glass fibers. The addition of glass fiber to a concrete mixture can greatly improve the strength and endurance of the resulting material. The correct proportion of glass fiber within a concrete mix is very important in order to attain an ideal equilibrium between performance level, cost efficiency and ease in working process.

Glass fiber concrete (GFC) is a new type of composite material that shows better mechanical properties and durability than regular concrete. But, it's very important to find out the best percentage of glass fibers in the mix for getting maximum benefits without losing cost-effectiveness or manageability. The search for this perfect ratio comes from wanting to balance many different things like how strong it is, how long-lasting it can be, how easy or hard it is to work with and also thinking about money matters. This endeavor requires a deep comprehension of both glass fibers' features, complexities in concrete mix designing and the demands for particular use. When experts find out what is the best amount of glass fibers to add, it allows engineers and concrete producers to combine their strengths in a way that will create an ideal reinforced material while also guaranteeing high-level strength, flexibility and durability for the GFC produced.

Glass fiber is very important to maintain the cost-effectiveness of construction projects. It can provide a cheaper alternative compared to the usual steel reinforcement, possibly resulting in considerable money savings. Moreover, concrete strengthened with glass fibers has better ability to resist cracks. This means there will be less need for repairs and upkeep over time. Additionally, the advantages in economy are not only restricted to the production stage. With its lighter weight compared to traditional concrete, glass fiber-reinforced concrete can lessen expenses related with transporting pre-made elements and permit slimmer designs or less usage of total concrete. Furthermore, glass fibers improve the durability of concrete which could lengthen life expectancy for structures and decrease costs needed for replacements. Glass fiber's cost-effectiveness is not always consistent, it changes based on certain factors. However, when used as an alternative to other materials in the construction industry, it has the potential to save money and enhance performance.

This study expands on past research, which already established that a specific amount of fly ash in the concrete mix is good for both performance and environment. We know that when 30% fly ash replaces cement, it keeps the workability of the mixture. In this part, we concentrate on determining best dosage for fiber reinforcements - glass fibers - to improve mechanical characteristics of concrete as much as possible.

This study is about the influence of various fiber types and contents on a high-grade concrete known as M40. The experiment will create two sets of concrete specimens, ranging from 0.1% to 0.5%, into the design mix for these samples. One separate sets of specimens will be formed: Five concrete mixes (G1 to G5) are made with increasing percentages of glass fibers within this range. This research study examines how different types and amounts of fibers affect a high-grade concrete referred to as M40. The experiment plans to make two groups, starting from 0.1% up until 0.5%, into the design mix for these samples. In this research study, we are investigating how different fiber types and amounts can impact a type of superior-quality concrete called M40. Our plan is to divide it into two groups ranging from 0-point one percent all the way up until point five percent in terms of design mix for these samples. The research project is looking at how various kinds and quantities of fibers might influence what's known as "superior quality" concrete labeled M40 in specific circumstances where they are included inside its composition mixture or recipe for making it happen? The plan includes forming two groups which differ by their size increases starting from very little (point one) percent going all away until big amount such as five zero points five percentage - both fall within range set out beforehand in rules that governs procedure itself). In each group there will be one separate collection made up total six items: three cubes measuring hundred millimeters on every side; three beams long six hundred plus thirty centimeters with cross sectional area exactly ten square centimeters at midpoint between supports). The goal our investigation has been set accordingly - it aims merely towards determining if changes occurring due inclusion certain kind/amounts could bring beneficial effects when added inside final structure's makeup recipe so we can have better comprehension about what may happen during future real-life application scenarios involving similar materials? We hope results obtained would provide us more understanding regarding potential benefits linked with using different sorts/quantities involved here thus helping make decisions related selection process far clearer than before! These exemplars will be tested in three main time periods: after 7 days, 14 days and finally, 28 days from the day they were cast.

2. MATERIALS AND MIX PROPORTION

2.1 MATERIAL

2.1.1 CEMENT

The mix of concrete used in this study was created using UltraTech OPC 53-grade cement, a commonly utilized kind for construction works because it is strong and reliable. This cement follows the Indian standard (BIS IS:12269-1987) for quality. It is known for its toughness, durability and ease of use which makes it a versatile choice in many building uses.For checking the performance, they must have done tests on cement for some important properties. These include finding out how quickly it hardens (setting time), how well it mixes with water (consistency), and how finely ground its particles are (fineness). The detailed results of these tests might be shown in a different table for more information.

The cement gets hard in 35 minutes, has a typical consistency of 33%, and a fineness modulus measuring at 4% along with specific gravity that is about 3.15.

The physical and chemical test are given in the table 2.1.1(a) and table 2.1.1(b)

PHYSICAL TEST: -

Sr. No.	Tests and properties of cement	Test Data
1	Primary setting time	35 minutes
2	Ultimate setting time	35 minutes
3	Standard consistency	33 %
4	Fineness modulus	4 %
5	Specific gravity	3.15

Table 2.1.1(a)

CHEMICAL TEST: -

Sr no.	Properties	Test results	Requirement As 3812 (Part 1)-2013)
1	Loss on Ignition - (% by mass)	2.6	4.0 maximum
2	Chloride Content – (% by mass)	0.003	0.1 maximum
3	Sulphuric Anhydride	3.27	3.5 maximum
4	Magnesia	4.36	6.0 maximum
5	Insoluble residue	2.65	5.0 maximum

Table 2.1.1(b)

2.1.2 FLY ASH

Fly ash refers to a type of fine powder composed of spherical particles. It gets made when coal is burned at power plants that use this fuel, and has various benefits for improving concrete production like enhancing strength and workability.

Normally, if the specific gravity of fly ash is found to be around 2.2 g/cc, it indicates a significant amount of calcium oxide (CaO) - this makes it fall under Class C fly ash. This kind usually has more calcium oxide and comes from places with higher levels of calcium like bituminous and lignite coals; it might also display some pozzolanic characteristics which are helpful for concrete applications. Class C fly ash, known for its cementitious properties, works as a supplementary cementitious material.

The physical and chemical test are given in table 2.1.2

Sr no.	Properties	Test results	Requirement As per 3812 (Part 1)-2013)
1	Loss on Ignition - %	0.320	5.0 max
2	Silicon dioxide (SiO_2) in Percent by mass	62.02	35 min
3	Calcium Oxide (CaO) Content -%	1.46	--
4	Magnesium Oxide (MgO) Content -%	Below 0.5	5.0 max
5	Total Sulphur as Sulphur trioxide (S03) in percent by mass	Below 0.1	3.0 max
6	Chloride Content -%	0.03	0.05 max
7	Silicon Dioxide (SiO_2) +Aluminum oxide (AL_2O_3) +Iron oxide in percent by mass	94.02	70% min
8	Specific gravity	2.2	
9	Fineness test	30 gm	
10	Normal consistency	35%	

Table 2.1.2

2.1.3 GLASS FIBER

The width of these thin, glass fibers is 14 microns (filament diameter) and they are available in two lengths: 6 or 12 millimeters. They are manufactured from a particular type of glass that does not get damaged by chemicals (Alkali Resistant Glass Fiber) and has a large surface area for bonding well with concrete - it covers 105 square meters per kilogram; its specific gravity is 2.6.

The photo of glass fiber is given in Fig 2.1.3(a)

Fig 2.1.3(a)

2.1.4 AGGREGATE

Coarse aggregate has a specific gravity of 2.87. In simpler terms, this means the coarse aggregate is slightly heavier than water (water has a specific gravity of 1). Coarse aggregate is typically gravel or crushed rock used in concrete.

Fine aggregate has a specific gravity of 2.5. This means the fine aggregate is also denser than water, but slightly lighter than the coarse aggregate. Fine aggregate is usually sand used to fill gaps between the coarse aggregate particles.

2.2 MIX COMPOSITION

This study is about the effect of various kinds and amounts of fibers on top-quality concrete (M40). The mix design for this type of concrete, as per IS 10262:2019 and curing method according to ASTM C192 (2019), was used to make ready all specimens made from concretes. After making the mixtures, we poured them into steel molds that had been oiled with suitable lubricant before putting in place. Cube samples with dimensions of 150mm x 150mm x 150mm were made for measuring the compressive strength. (Fig 2.2. (i) shows cube sample)

Fig 2.2.(i)

The mix of concrete will have 30% fly ash, which is mixed with cement as a part replacement. The remaining 70% will be the ordinary cement and this mix of fly ash works as control group for comparisons. We will make two groups of concrete samples to study how fibers affect it: Six mixes made from different amounts of glass fiber - starting at 0.1% and going up to 0.5%, all based on total volume in each mix. The mixture for making the concrete has been decided, it contains 30% fly ash that is mixed with cement to serve as a partial replacement and we use remaining amount (70%) which is just regular cement in this case where no substitute has been added yet so far - these percentages are what make up our control group; now we prepare two sets or groups of concretes specimens to experiment about effect on those materials when adding fiber: In first set there are Six mixes created by changing quantity glass fiber from small value like one-tenth percent (0.1%) till reaching half percent (0.5%), everything based upon whole amount in every single mixture's volume. We test concrete cubes at 7, 14 and 28 days for seeing how well they can resist forces that squeeze them (like when weight pushes down).

The mix design used for the experiment had same combinations of cement, sand, aggregates, water and fly ash. It also included various combinations of glass fibers which were denoted by different codes such as G1, G2, G3, G4 and G5. These mixes contained 0.1%, 0.2%, 0.3%, 0.4% or 0.5% glass fiber respectively in comparison to normal concrete mix M for better understanding and comparison between them.

Mixes	Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	Fly ash (kg)	Water (kg)	Glass fiber (kg)	Glass fiber content in %
1) M	17.46	20.33	39.85	5.76	6.98	-	-
2) G1	17.46	20.33	39.85	5.76	6.98	0.017	0.1%
3) G2	17.46	20.33	39.85	5.76	6.98	0.035	0.2%
4) G3	17.46	20.33	39.85	5.76	6.98	0.052	0.3%
5) G4	17.46	20.33	39.85	5.76	6.98	0.070	0.4%
6) G5	17.46	20.33	39.85	5.76	6.98	0.087	0.5%

Material quantity of glass fiber is given in table 2.2.1

3 COMPRESSIVE STRENGTH TEST ON CUBES AND IT'S RESULT

3.1 COMPRESSIVE STRENGTH TEST ON CUBES

Compressive strength test of concrete specimens was done in line with Indian Standard code IS 516: 1959, which gives guidelines for the testing of concrete. To measure the compressive strength of each mix, we generally carried out this experiment on three concrete cubes. We used a testing machine that applies increasing compressive force until the cube fails (fig 3.1. (i) shows failure of cube sample). The compressive strength was determined in force by area units. The tests of compressive strength were done on various curing periods for different mixes. Mixes M, G1, G2, G3, G4 and G5 were tested at 7, 14 and 28 days of curing.

$$\text{Compressive strength} = \frac{Failure\ load(N)}{Cross\ setional\ area(mm^2)}$$

Fig 3.1.(i)

Ordinary Portland Cement (OPC) grade 53 is used, with a 30% replacement of fly ash based on the mass of cement. For casting 9 cubes, a total of 120.51 kg of concrete is needed, incorporating glass fibers.
In total mixes, the following materials are used:

Cement:	14.00 kg
Fine aggregate:	21.18 kg
Coarse aggregate:	41.51 kg
Fly ash:	6.00 kg
Water:	7.27 kg

With an additional 20% for wastage.

Glass fiber percentages vary across the mixes: 0.1%, 0.2%, 0.3%, 0.4%, and 0.5%, equivalent to 0.014 kg, 0.028 kg, 0.042 kg, 0.056 kg, and 0.070 kg, respectively.

3.2 RESULT

The compressive strengths of glass fibers are given in Table 3.2.(a), and their graphical representation is shown in Fig 3.2.(i).

ID		Cement (%)	Fly Ash (%)	Glass Fiber (%)	Compressive Strength (Mpa)			Workability (mm)
					7 Days	14 Days	28 Days	
M40 (M)		70	30	0.0	23.02	31.7	38.8	
M40-G1		70	30	0.1	27.55	33.48	39.7	170
M40-G2		70	30	0.2	27.85	37	41.63	160
M40-G3		70	30	0.3	28.59	37.33	42	145
M40-G4		70	30	0.4	32.15	37.48	43.11	130
M40-G5		70	30	0.5	32.29	41.33	48.48	120

Table 3.2(a)

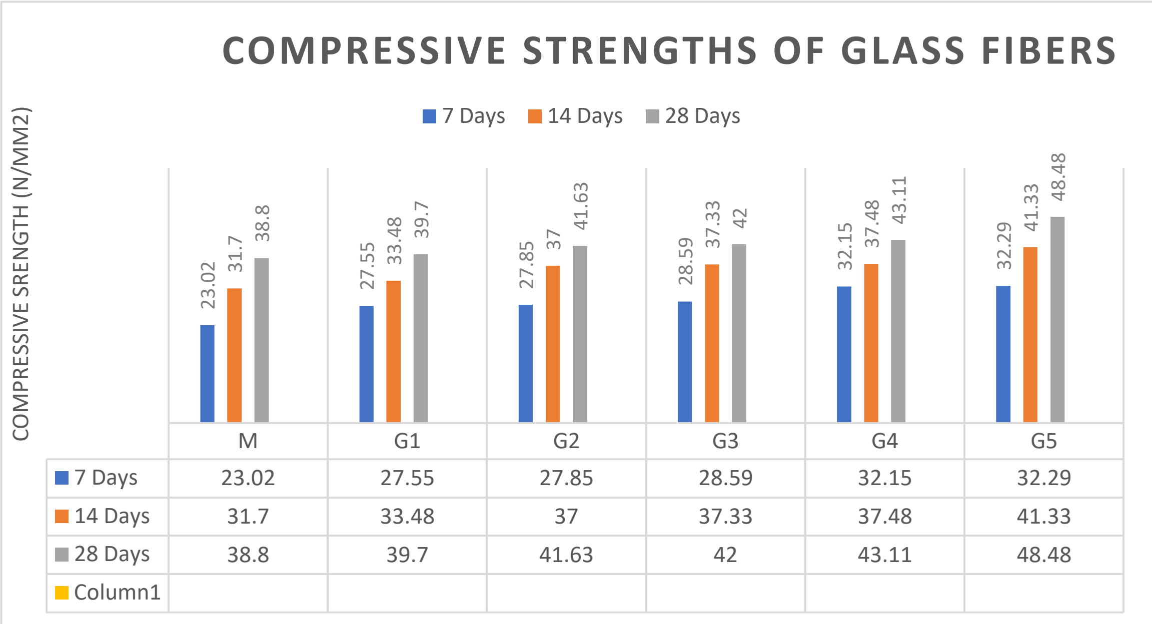
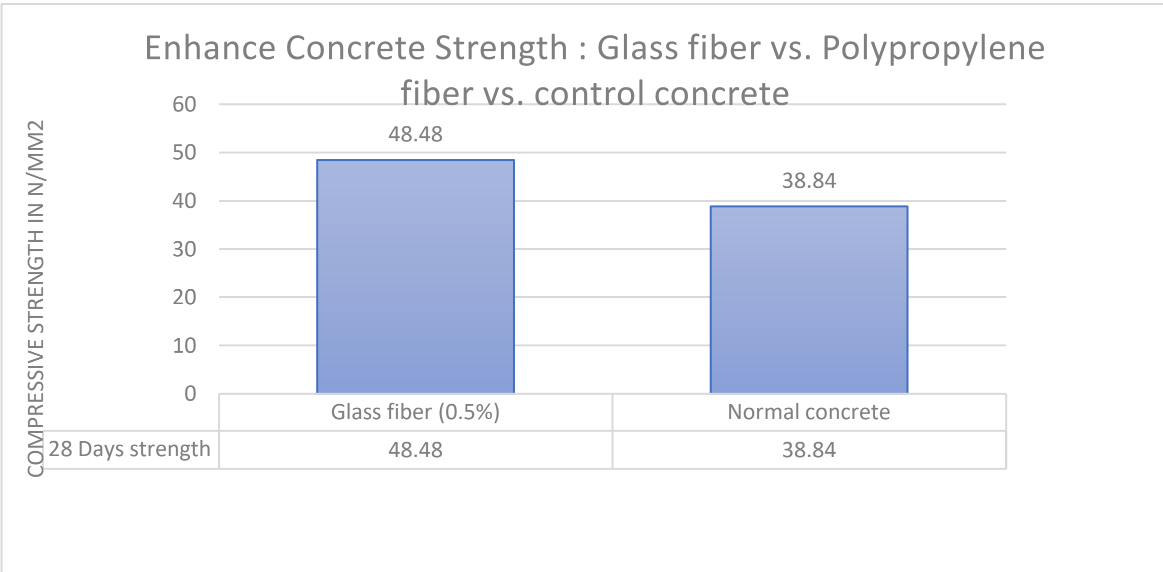


Fig 3.2.(i)

The presented results on table 3.2(a) indicate that incorporating glass fibers leads to a progressive increase in compressive strength as the fiber content increases up to 0.5%. The concrete mix containing the highest glass fiber content (0.5%) exhibits the strongest performance, reaching a compressive strength of 48.48 MPa. This suggests that glass fibers effectively improve the concrete's ability to resist compressive forces

3.4 CONCLUSION



Remarkable results were shown in the test. Concrete mixes that held glass fibers experienced a steady rise in compressive strength as more fibers were added. The most notable achievement was the M5 mix (0.5% glass fiber) reaching an impressive 48.48 MPa after 28 days of curing. This is a big improvement, showing the strong strengthening effect of glass fibers with a 24.82% increase compared to the control specimen.

The investigation reveals that fiber types improve the workability and compressive strength of fly ash concrete. However, glass fibers generally lead to a more significant enhancement in compressive strength compared to normal concrete at the investigated content levels.

DECLARATION OF COMPETING INTEREST

The people who wrote this research paper say they do not have any conflicts of interest. This refers to situations where someone might think their viewpoint could be affected due to personal relations or financial benefits connected with the study's subject matter. Such interests include receiving money for research, being related to companies that make fly ash, glass fibers, polypropylene fibers or concrete and having personal relationships with individuals or organizations involved in these activities.

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2. The maximum expansion allowed by IS 4031 (Part 3):1988 is 10mm or 0.8 percent for the "Le Chatelier" method and autoclave test, respectively.
3. Cement fineness can be determined using both the IS sieve no. 9 sieve method and the Blaine's air permeability method as described in IS 4031 (part 2): 1988.
4. IS 383:2016, titled "Specification for Coarse and Fine Aggregates from Natural Sources for Concrete
5. The mix design is done as per IS 10262:2019.
6. According to Clause 2.1 on page 4 of IS 2386 (Part 1): 1963, the fineness modulus of an aggregate is calculated
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