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Measuring Improvement in Fly Ash Based Concrete Impregnated with Glass Fiber

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Abstract: In cement and concrete, fly ash has been utilized as a mineral additive. Utilizing it offers a number of benefits, including enhanced workability and strength characteristics as well as environmental advantages linked to waste disposal and lower carbon dioxide emissions. Constantly 1.5%, 2.5%, and 3.5% of the cement's weight is reinforced with alkali-resistant glass Fibers. Glass Fibers improved split and flexural strength without increasing compressive strength and served as an effective crack arrester. For this study, concrete of M30 grade is utilized. Studying fly ash's viability as a mineral additive to replace cement and provide extra glass fibre reinforcement in concrete is the primary goal of this project. Concrete's several structural qualities, such as its compressive, split, and flexural strength, are satisfied by the use of glass Fibers as extra reinforcement and fly ash as a partial substitute for cement. The complete investigation came to the conclusion that the best combination of all the mixes was 10% FA + 3.5% GF, which gave the most tensile strength; 10% FA + 3.5% GF showed greater flexure strength; and 10% FA showed good compressive strength at 28 days compared to standard concrete. After seven days, fly ash blends no longer exhibit improved compressive strength or split tensile strength.
Keywords: Fly Ash (FA), Alkali Resistance Glass Fiber (GF), Workability, Compressive Strength, Split Tensile Strength, Flexural Strength.

I. INTRODUCTION

The development of environmentally friendly and sustainable building materials has gained popularity in recent years. One such substance is geopolymer concrete, which has advantages over conventional Portland cement-based concrete in terms of the environment. Glass fibers can also improve the characteristics of concrete and lessen problems like bleeding and hairline fractures. Concrete can be made more ductile by including discontinuous fibers that are randomly distributed throughout the matrix. According to GFRHSC's investigation, fly ash may easily replace GFRC in construction projects based on open-plan construction (OPC) and provides additional advantages for nearly all building applications, including residential, commercial, and building slabs, columns, beams, and other RCC constructions. Large-scale construction projects and circumstances where the local environment and soil quality seriously harm structures constructed using conventional cements are the two main instances where it is recommended. Glass fiber has a maximum strength of 3000 N/mm².70–80 GPA elastic modulus, minimal creep at room temperature, and around 50 N/mm² of stiffness. It has been demonstrated that cement sand mortar containing 5% glass fiber is suitable for premix applications and does not result in balling.

Circumstances where the local environment and soil quality seriously harm structures constructed using conventional cements are the two main instances where it is recommended.

Because this material is less dense than steel, it is perfect for molding the facades of structures. It is possible to use fly ash in pervious concrete. Utilizing fly ash offers several benefits. Using fly ash, a byproduct of burning coal in power plants, reduces the energy required to produce cement. The purpose of this investigation is to examine how glass fiber reinforced concrete behaves when cement is replaced with fly ash. should look into the cubes, cylinders, and prisms' mechanical characteristics in order to get the best results while looking into split and compressive tensile strength. to contrast the selected outcomes.

II. OBJECTIVES OF STUDY

The goal of research on glass fiber and fly ash additions to concrete is to better understand and optimize characteristics related to flexibility are as follows:

1) To design concrete mix of M35 grade.
2) To design concrete mix with addition of fly ash and glass fiber at different dosages and combinations.

3) To determine the workability of fresh concrete impregnated with a combination of fly ash and glass fiber and compare with the reference mix.
4) To evaluate compressive, flexural and tensile strength of concrete and compare with the reference mix.

III. LITERATURE REVIEW

A lot of work in the field of Glass fibre concrete using different types of replacement material has been done. The work done by various researchers is presented here.

Tajne and Bhandari (2014) [1] clearly define how adding glass fibre to regular concrete affects it. They concluded that adding glass fibre to the concrete mix mitigated the bleeding deficit in the concrete. At 28 days, there is an increase in the compressive and flexural strengths of the concrete mixes containing varying grades of glass fibre, ranging from 12% to 18% and 16% to 20%, respectively.

Dayalan J. (2017) [2] conducted a thorough investigation into the strength properties of glass fibre reinforced concrete and came to the conclusion that GFRC made with Portland Pozzolana Cement is a superior substitute for complex structures because it increases the concrete's compressive, flexural, and tensile strengths as glass fibre content increases. In marine and hydraulic constructions, steel reinforcement is very susceptible to corrosion. This is mitigated by the characteristics of glass fibre, which increase its tensile strength and reduce the need for larger, more readily corroded areas of steel reinforcement. Additionally, since the addition of glass fibre increases the concrete's compressive and tensile strength and prevents the elements that cause deterioration, an additional layer of glass fibres -infused concrete can be added to the maritime and hydraulic structure. the framework and inflict additional pain on it. increasing the structure's lifespan in the process.

Patel et al. (2013) [3] glass fibres can be added to concrete as an addition to boost its tensile particles to remain sealed together rather than separated. With the inclusion of glass fibre, the concrete's 28-day compressive, flexural, and tensile strengths increased. The inclusion of 0.1% glass fibre did, however, seem to improve the mechanical and durability qualities while only slightly increasing the compressive strength.

Srinivasa R, et al. (2010) [4] Glass fibres was added to the concrete in this experiment at a rate of 0.03% by volume of concrete. A comparative analysis was done to demonstrate the efficacy of using glass fibres and not using them. When compared to 28 days strength, the increase in compressive strength for all grades of concrete mixes ranged from 20 to 25%. When compared to 28 days strength, the flexural and split tensile strengths for all the grades of concrete mixes ranged from 15% to 20%.

Pitroda J, & coworkers (2012) [5] In the range of 0%, 10%, 20%, 30%, and 40% by weight of cement for M-25 and M-40 mix, fly ash has been substituted for cement. The outcome showed that, after 28 days of curing, FA may be utilised as a 10% replacement for cement. When fly ash is substituted with cement, compressive strength decreases. Compressive strength and split strength decrease as fly ash percentage rises.

Shamsuddin H. and associates (2012) [6] Glass fibres was added to the concrete in this experiment at a rate of 0.03% by volume of concrete. A comparative analysis was done to demonstrate the efficacy of using glass fibres and not using them. It's been noticed that adding glass fibres to concrete reduces its workability. When comparing the flexural strength and split tensile strength of M-20, M-30, and M-40 grade concrete at 3, 7, and 28 days to the strength of plain concrete at 28 days, the results show that the respective values are 20% to 30%, 25% to 30%, and 25% to 30%.

Kartikey T. and associates (2013) [7] He proposed that adding fly ash to structural concrete enhances its qualities when it partially replaces cement. The investigation examined the characteristics, strengths, and qualities of three different grades of concrete: M15, M20, and M25. Fly ash was employed at 20%, 40%, and 60% cement for each of these grades. The workability of concrete enhanced with an increased percentage of fly ash when cement was partially replaced with it. Three cubes were evaluated for compressive strength for each concrete grade. The highest strength of 14.48 N/mm^2 for M15 grade at 20% replacement, 14 N/mm^2 for M20 grade at 20% replacement level, and 14.05 N/mm^2 for M25 grade at 20% replacement was achieved After 28 days of curing, the experiment ultimately determined that fly ash supplementation up to 20% demonstrates stronger strength than 40% and 60% for all three grades.

IV. INFERENCES FROM LITERATURE REVIEW

Following inferences have been drawn from the literature survey:

A general overview of my dissertation work is provided in this chapter. Materials like fly ash, glass fibre, coarse and fine aggregate, and other components of fly ash-based glass fibre reinforced concrete have been targeted for my projects. A brief description of the characteristics of the building materials has also been provided, along with the benefits and drawbacks of glass fibre concrete.

1) In majority of the literatures, the cementitious material is replaced partially. The main purpose of partial replacement of cementitious material is to cut down the expenses incurred during the procurement of cement at the time of construction.
2) Find the ideal amount of glass fibre and fly ash to add to the concrete mix to increase flexibility without sacrificing strength or durability.
3) Examine the effects of fly ash and glass fibre's particle size and distribution on the concrete's flexibility. Improved flexibility could result from homogenous distribution and smaller particles.
4) Examine any chemical reactions that may exist between glass fibre, fly ash, and other concrete ingredients that may impact the material's flexibility. Chemical bonding processes or hydration reactions may be examples of this.
5) Examine the entire mix design, taking into account the ratios of water, fly ash, glass fibre, cement, and aggregates, in order to maximise flexibility while still fulfilling performance specifications.
6) Think about how temperature and moisture content during the curing process affect the development of flexibility in fly ash and glass fibre-containing concrete.
7) Examine the effect of adding fly ash and glass fibre on mechanical qualities, such as tensile strength, ductility, and modulus of elasticity, which are measures of flexibility.
8) To comprehend the orientation and distribution of glass fibre within the concrete matrix and how it affects flexibility, perform micro structural analysis.
9) Analyse the durability of flexibility gains in concrete using fly ash and glass fibre additions over an extended period of time, taking shrinkage and creep into account.

V. RESEARCH METHODOLOGY

1) Preparation of design mix of M35 grade using relevant IS code.
2) OPC 43 grade shall be used as binder.
3) Preparation of different concrete mixes by keeping the percentage of fly ash fixed or 30% and varying the percentage of glass fibers.
4) Different percentages of glass fibers are 0%, 1.5%, 2.5%, and 3.5%.
5) Comparative study of compressive, flexural, split tensile strength of concrete mix thus, prepared shall be made.

For each mix group, set of three cubes of 150x150x150mm size will be used for determining compressive strength, set of three cylinders of size 150x300 mm for split tensile strength and beam of size 100 x100x500 mm mould for flexural strength. The specimen would be cured and tested at 7 and 28 days as per IS requirements.

VI. MATERIALS AND PROPERTIES

A. Glass Fiber

Alkali-resistant glass fibres, cement, fine sand, water, and a polymer—typically acrylic polymer—combine to form GFRC, a composite material. The glass fibres offer extra tensile strength and flexibility to the concrete, acting much like standard concrete's steel reinforcement. Here are some important properties of glass fibre when used in concrete.

Technical data sheet 24 mm glass fibre	
Sizing code	Japan 7065
Product Description	AR Glass fibre
Specific Gravity	2.68
Softening Point	2.68
Filament dia	14 mic.

B. Cement

The experimentation employed cement that complied with IS: 269 - 2015, namely Ordinary Portland Cement (OPC) 43 grade of Ultratech. When it comes to concrete, cement has the following crucial qualities:

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Properties of Cement

Test Name	Test Value
Specific Gravity	3.15
Consistency	29%
Initial Setting Time	43 min
Final Setting Time	310 min

Fig.1 Initial setting time experiment on Victas Apparatus

C. Coarse Aggregate

For the various design mixes of Porous Concrete, nominal size aggregates of 10 mm and 20 mm were taken into consideration. They have hard flat surfaces and well-defined angular edges because they are naturally occurring. According to IS: 2386 (Part I) - 2016, a sample must weigh at least 500 g in order to be used for screening nominal size aggregates. To comprehend the gradation, a sieve analysis was conducted on a sample of 2 kg coarse particles.

Basic Properties of Coarse Aggregates

Properties	Coarse Aggregate
Specific gravity	2.724
Water absorption	0.401%

D. FLY ASH

The residue that remains after burning coal is called fly ash, and it is created when the coal's gaseous emissions are effectively cooled. It resembles fine-grained glass powder in certain ways. The chemical components of this residue, however, may differ from one another. Fly ash is commonly found in the chimneys of power plants and has a variety of industrial uses.

Basic Properties of Fly ash

Properties	Fly ash
Specific gravity	2.2
Fineness	2.28%

E. Water

Ordinary portable water was used in this investigation both for mixing and curing.

F. Superplasticizer (SP)

Conplast SP430g8 is used as a super plasticizer. It is a chloride free, chemical admixture. It is used to maintain w/c ratio and enhance the workability of concrete mixes.

Fig.2 Admixture conplast sp430g8

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G. Concrete Mix Design

Mix proportion used in this study is 1:1.46:2.79 (M35) with water-cement ratio of 0.4 and super plasticizer of 1%

1) Batching and mixing of materials

In this experiment, machine mixing and weight batching are used. The table displays the percentage of FA that replaces regular cement, the amount of glass fiber added, and their respective material weights.

Mix proportion per cubic Meter

Mix Names	Cement (kg/m3)	FA (kg/m3)	Fine Aggregate(kg/m3)	Coarse Aggregate (kg/m3)	Water (L/m3)	Glass fiber (kg/m3)	Admixture(kg/m3)
M	431	0	629	1203	172	0	4.35
M1	381	44	623	1193	172	6.53	4.35
M2	376	44	623	1192	172	10.88	4.35
M3	372	44	623	1192	172	15.23	4.35
M4	337	87	618	1182	172	6.53	4.35
M5	333	87	618	1182	172	10.88	4.35
M6	328	87	618	1182	172	15.23	4.35
M7	294	131	612	1171	172	6.53	4.35
M8	289	131	612	1171	172	10.88	4.35
M9	284	131	612	1171	172	15.23	4.35

2) Testing of Specimen

Compressive strength test were carried on cubes, split tensile strength test on cylinders and flexural strength test on beams as shown in figure

Fig.3 Compressive & Flexural strength test

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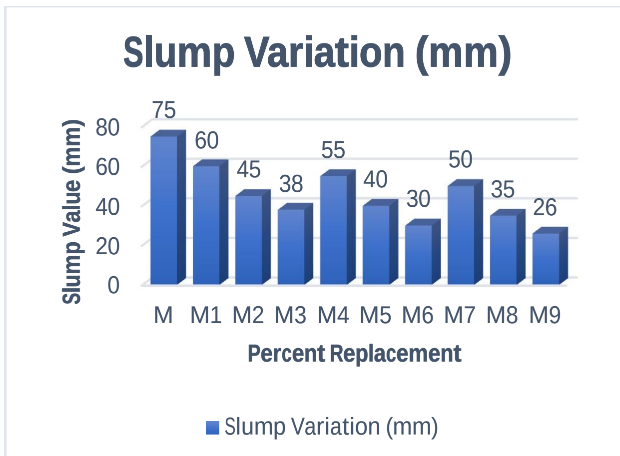
Fig.4 Split Tensile strength Test

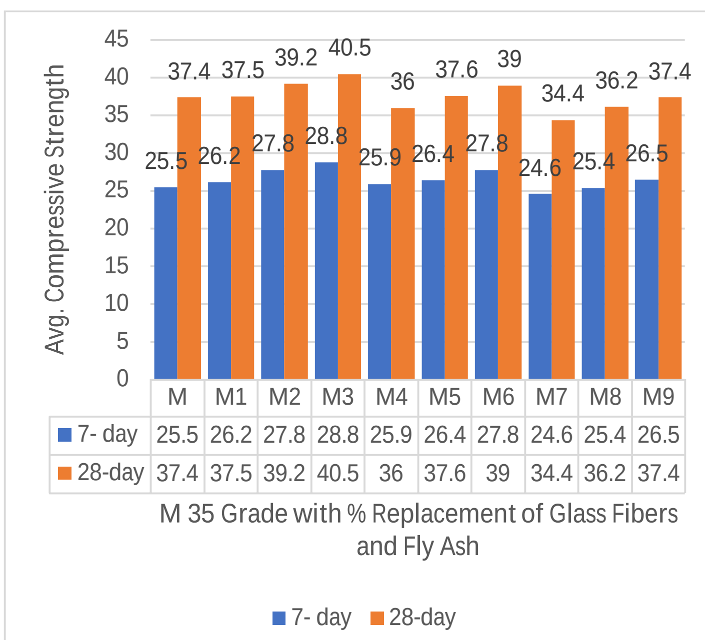
VII. RESULTS AND DISCUSSION

A. Slump Variation

The above variations in slump values are shown in Table 4.1 and Figure 4.1 respectively indicates that these values do not follow a continuous trend rather, it shows variable trend reaching maximum at 30%Flyash &1.5%Glass Fiber replacement level. The percentage change in slump values of grade M35 are recorded as -6.67%, -20%, -33.33%, +0%, -13.33%, -26.67%, +6.67%, -6.67%, -20%, from the reference value of control mix.



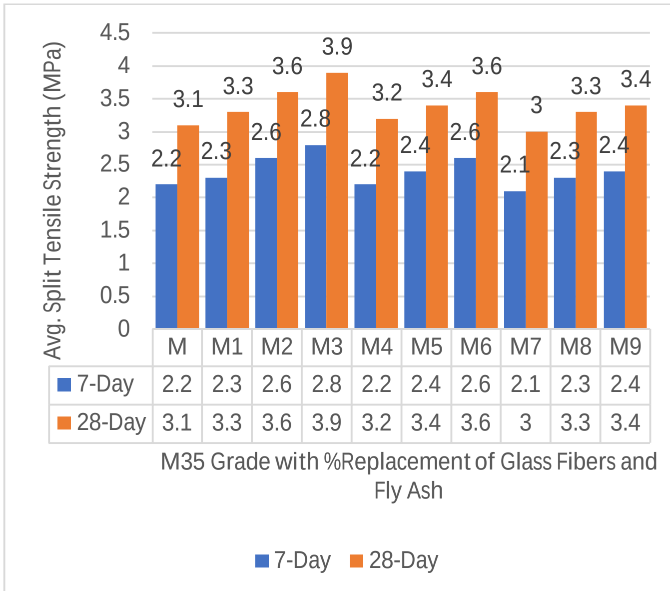
B. Compressive Strength Test



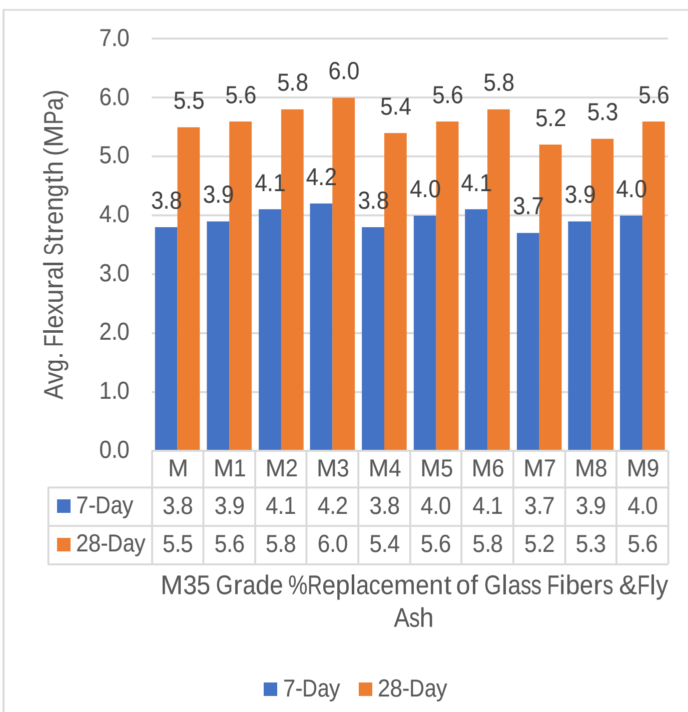
After a period of 28 days, with proper curing and quality control, the percentage change recorded in the values of compressive strength of the specimen corresponding to RL of replaced fly ash ad glass Fiber as against the control mix is +0.27%, +5.88%, +8.29%, -3.74%, +0.54%, +4.28%, -8.02%, +3.21%, +0%, respectively

C. Split Tensile Strength Test

The variations recorded in Split tensile strength value follows a similar trend as is the case with compressive strength. This hints that the replaced component is having similar effect on different strength parameters of concrete. After a period of 28 days, with proper curing and quality control, the percentage change from the level of control mix as recorded during test conducted is +6.45%, +16.13%, +25.8%, +3.23%, +9.68%, +16.13%, -3.23%, +6.45%, +9.68% corresponding.



D. Flexural Tensile Strength



In comparison to the control mix, the percentage change in the flexural strength values of the specimen corresponding to the RL of replaced fly ash and glass fibre after 28 days of appropriate curing and quality control is +1.81%, +5.45%, +9.09%, -1.81%, +1.81%, +5.45%, -5.45%, -3.64%, and +1.81%, respectively.

VIII. CONCLUSION

The conclusions drawn from various tests conducted on grade M35 are listed below:

1) When glass fibres and fly ash are substituted for the control mix, the compressive strength, split tensile strength, and flexural strength all exhibit a similar trend of strength variation. There is a dip in values that progressively rises to 10% fly ash before beginning to decline from 20% to 30% fly ash, with the biggest decline occurring from 30% fly ash and 3.5% glass fibres.
2) The aforementioned fluctuations in slump values, which are respectively, suggest that these values do not exhibit a consistent pattern but rather a fluctuating one that peaks at the 10% flash and 1.5% glass fibres replacement level. In comparison to the reference value of the control mix, the slump values of grade M35 show percentage changes of -6.67%, -20%, -33.33%, +0%, -13.33%, -26.67%, +6.67%, -6.67%, and -20%.
3) The percentage change in the specimen's compressive strength values corresponding to the RL of replaced fly ash and glass fibres compared to the control mix after 28 days of appropriate curing and quality control is +0.27%, +5.88%, +8.29%, -3.74%, +0.54%, +4.28%, -8.02%, +3.21%, and +0%, respectively.
4) The trend of the fluctuations in the split tensile strength value is similar to that of the compressive strength. This suggests that the substituted component is affecting the various concrete strength characteristics in a comparable way. The percentage change from the level of the control mix as recorded during the test is +6.45%, +16.13%, +25.8%, +3.23%, +9.68%, +16.13%, -3.23%, +6.45%, +9.68%, respectively, after 28 days of appropriate curing and quality control.
5) The percentage change in the flexural strength values of the specimen corresponding to the RL of replaced fly ash and glass fibres as compared to the control mix after 28 days of appropriate curing and quality control is +1.81%, +5.45%, +9.09%, -1.81%, +1.81%, +5.45%, -5.45%, -3.64%, and +1.81%, respectively.

IX. RECOMMENDATIONS FOR FITURE WORK

1) Optimization Studies: To strike a balance between workability, strength, and durability, future study should concentrate on maximizing the ratios of fly ash to glass fibres. To identify the best mix designs, sophisticated statistical approaches such as response surface methodology (RSM) might be employed.
2) Long-Term Performance Evaluation: Research on the aging behaviour, durability, and structural integrity of concrete containing fly ash and glass fibres under various environmental circumstances can be conducted over an extended period of time.
3) Alternative Fibers and Additives: To further improve the qualities of concrete, the performance of hybrid fibres systems that combine glass fibres with other materials like polypropylene or basalt fibres should be studied.
4) Structural Applications: Although laboratory experiments yield useful information, practical uses in structural components such as beams, slabs, and columns must be investigated. The practical applicability of this mix design will be validated through testing under load-bearing situations.
5) Environmental Impact Analysis: A thorough grasp of the concrete mix's environmental advantages over traditional concrete can be obtained through a life cycle assessment (LCA).
6) Investigation of Fly Ash Sources: Future research can look at how different fly ash compositions affect the performance of concrete because the qualities of fly ash might alter depending on where it comes from.

X. FUTURE SCOPE

1) Optimized Mix Design: To improve performance for particular applications, more study can concentrate on adjusting the ratios of fly ash to glass fibres.
2) Long-Term Performance: Research can be done on the durability and performance over an extended period of time in a variety of environmental circumstances, including sulphate exposure, chloride attack, and freeze-thaw cycles.
3) Hybrid Fibers: Glass fibres may work in concert with other fibres types (such as steel or polypropylene) to improve a variety of qualities.
4) Advanced Uses: The produced concrete may be investigated for use in certain applications, such as pavements, precast concrete components, and constructions that need to be extremely durable.

5) Field Trials: To confirm laboratory findings and assess the viability of applying this mixture in practical situations, extensive field testing have to be carried out.
6) Including Other Waste Materials: To further improve sustainability, more research might look at the usage of other industrial by-products such slag, silica fume, or recycled aggregates.
7) Nano Additives: To obtain greater strength and durability, fly ash and glass fibres can be combined with nano-silica or other nanomaterials.
8) Structural Analysis: To guarantee safe design and application, the performance of structural members constructed with this concrete should be evaluated under actual loading circumstances.

XI. LIMITATIONS

1) Delays in Strength Development: Adding fly ash may cause delays in early strength development and initial setting time, making it unsuitable for projects with tight deadlines.
2) Challenges with Fiber Dispersion: It can be difficult to distribute glass fibres uniformly and may call for specialized mixing methods.
3) Cost Implications: Adding glass fibres raises production costs, which may restrict its application in applications with tight budgets.
4) Durability Issues: When exposed to extremely alkaline environments, glass fibres may be vulnerable to the alkali-silica reaction (ASR), which could compromise their long-term durability.
5) Moisture Sensitivity: Fly ash and glass fibres may raise the need for water; therefore the water-to-cement ratio needs to be carefully managed.

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