Experimental Study on Partial Replacement of Cement by Metakaolin in Glass Fibre Reinforced Concrete

1Karthik Prabu .P, 2Arun .A
1Research Scholar, Department of Civil Engineering, Mahendra Engineering College, Mallasamudram
2Research Guide, Department of Civil Engineering, Mahendra Engineering College, Mallasamudram

Abstract
Concrete is a sufficiently fragile material when introduced to standard loads and effect loads. The adaptability of cement is around one 10th of its compressive quality. As requirements are for these qualities, legitimate dependable individuals couldn’t keep uploads and adaptable loads that happened on solid bars and pieces. Trustworthy individuals are fortified with consistent continuing bars to withstand flexible squares and make up for the nonappearance of flexibility and quality. The presentation of strands is consistently taken as a reaction to stirring up its flexural and inflexible nature. Fiber braced cement (FRC) is concrete made of concrete concretes, totals, and discrete stimulating fiber. Strands appropriate for propping concrete have been passed on from steel, glass, and ordinary polymers (created filaments). Exactly when substantial parts, oneself emphatically masterminded strands begin working, get break headway and causing, and improve quality and pliability.

I. Introduction
In this paper, tests were facilitated to analyze quite far, and the quality of glass fiber supported concrete. The various strands and Metakaolin mixes will be done. Glass fiber will be used in concrete to form thread upheld concrete. The ideal rate was fixed as 0.4 % to the substantial ness of cement by anticipating squares, chambers, and significant stones with fluctuating degrees of fiber, such as 0%, 1%, 2%, and 3%, and taking the rate which will vivify most ridiculous worth. Metakaolin is a thing validating organizing necessities concerning physical and delivered properties. The Solid will be unstuck with Metakaolin by 5%, 10%, 15%, 20%, 25%, and 30% to cement’s sub spatial ness. The 3D squares, chambers, and pearls were cast of 150x150x150mm, 150mm appraisal x 300mmhigh, 700 x150x150mm. Superplasticizer will be joined for better worth, and ideal evaluation was obliged by using the swamp cone test. As necessities are obvious, quality and the quality test will be driven.

Fibers in Concrete
Filaments can be portrayed as a bit of continuing material having unequivocal dimensional credits. The most basic breaking point describing a fiber is its Aspect degree. "Edge degree" is the length of fiber disengaged by a proportionate width of the thread. The properties of fiber propped concrete are a considerable amount of influenced by such a fiber. Filaments are partner fortification material and go about as part arresters. The desire to spread breaks starting from inner blemishes can accomplish overhauls in the association’s static and dynamic properties. Passageway recently advanced the likelihood that post breaking of cement can be improved by merging fiber in 1910. In any case, the little movement was made to improve this material until 1963 when Romualdi and Batson 1969 flowed their model paper regarding the issue. Beginning now and for a significant length of time, there has been a flood of energy for fiber braced concrete, and a few enamoring tests have been done. Strands are taken as such a spread that joins Portland concrete in the holding with robust frameworks. Strands are commonly broken, self-self-assertedly went on all through the concretes systems. Several sorts of strands, for example, steel, fibrillated polypropylene, nylon asbestos, polyester, coir, jute, sisal, kenaf, glass, and carbon have been attempted, and these are accessible in a game plan of shapes, sizes, and thickness Fibers can be thoroughly be portrayed into two get-togethers as Low Modulus High Elongation Fibers and High Modulus Fibers.
a) Low Modulus High Elongation Fibers
This social occasion joins high extending fibers with immense energy absorption characteristics and is prepared to give durability and insurance from impact and risky loadings. Threads generally associated with this social event are nylon, polypropylene, polyethylene, rayon, acrylic, and polyester strands.

b) High Modulus Fibers
This social occasion joins strands suitable for conveying strong composites; they give quality and immovability to the composite to changing degrees and resistance under extraordinary loadings. Strands associated with this social occasion are steel, carbon, asbestos, standard fibers, etc.

Glass-Fiber Reinforced Concrete
Glass fiber is made up of 200-400 individual filaments gently appended to make up a stand. These stands can be hacked into various lengths or joined to make texture tangle or tape. Using the conventional mixing techniques for normal healthy, it is ridiculous to hope to mix more than about 2% (by volume) of fibers of a length of 25mm.

The multiple glass fiber devices have reinforced the substantial or mortar cross-sections used to make small sheet things. The boy and mainly used verities of glass strands are e-glass used. In the fortified plastics and AR glass E-glass, it has deficient assurance from salts present in Portland solid where AR-glass has improved acid neutralizer safe characteristics. Polymers have similarly incorporated the mixes to enhance some physical properties, for instance, sogginess advancement. Glass-fibre reinforced concrete

Metakaolin
Metakaolin is the anhydrous ensured sort of the mud mineral kaolinite. Minerals that are well off in kaolinite are known as china earth or kaolin, generally used to gather porcelain. The atom size of met kaolin is tinier than solid particles, yet not as sufficient as silica fume.

Metakaolin is a pozzolan, likely the best pozzolanic material for use in concrete. It is a thing that is created for help rather than a result and is molded when china mud, the mineral kaolin, is warmed to a temperature someplace in the scope of 600 and 800°C.
The T-O soil mineral kaolinite doesn't contain interlayer cations of interlayer water. The temperature of dehydroxylation depends upon the assistant layer stacking demand. Messed up kaolinite dehydrated late someplace in the scope of 530 and 570 °C, mentioned kaolinite someplace in the range of 570 and 630 °C. Dehydroxylated messing up kaolinite shows higher pozzolanic development than ordered. [1] The dehydroxylation of kaolin to metakaolin is an endothermic cycle because of the colossal proportion of energy expected to dispose of the artificially strengthened hydroxyl particles. Over the temperature extent of dehydroxylation, kaolinite changes into metakaolin, a complex unclear structure that holds some long-ago demand due to layer stacking. [2] Much of the aluminum of the octahedral layer ends up being tetrahedrally and octahedrally coordinated. [3] In solicitation to convey a pozzolan (reinforcing cementitious material), practically complete dehydroxylated must be reached without overheating, i.e., through and through stewed at this point not devoured. This makes an indistinct, significantly pozzolanic state while overheating can cause sintering, shape a dead devoured, nonreactive unyielding, containing mullet and a disfigurement Al-Si spinel. [4] Reported ideal activation temperatures vary someplace in the scope of 550 and 850 °C for moving ranges. In any case, the range 650-750 °C is most generally quoted. [5] In assessment with other earth minerals, kaolinite shows a sweeping temperature stretch among dehydroxylation and recrystallization, very much wanting the metakaolin plan and the use of thermally started kaolin muds as pozzolans.

Concrete Application

Considered to have doubled the reactivity of most different pozzolans, metakaolin is a substantial admixture for solid/concrete applications. Supplanting portland concrete with 8–20% (by weight) metakaolin produces a solid blend that displays favorable designing properties, including the filler impact, the quickening of OPC hydration, and the pozzolanic response. The filler impact is prompt, while the pozzolanic response's impact happens somewhere in the range of 3 and 14 days.

II. Literature Review

Venkateswaraludu Dampa (2018) A self-compacting concrete (SCC) is the one that can be set in the casing and can encounter hindrances by its weight and without the need for vibration. Since its first improvement in Japan in 1988, SCC has expanded more broad affirmation in Japan, Europe, and the USA because of its common unquestionable central focuses. The critical favoured situation of this strategy is that SCC advancement offers the opportunity to restrict or discard vital circumstance issues in annoying conditions. It goes without reiterating a comparative kind of significant worth control test on strong, which uses both time and work. Advancement and setting end up being faster and easier. It murders the necessity for vibration and diminishing uproar pollution. It improves the filling furthest reaches of significantly stopped up assistant people. SCC gives better quality, especially in the people having support obstruct or decreasing permeability and improving the durability of concrete. The essential purpose of this examination is to research the feasibility of using SCC by dissecting its principal properties and strength characteristics, for instance, water maintenance, shrinkage, and sulfate resistance. An expansive composing study was coordinated to examine the current circumstance with data on self-cementing concrete's durability execution. In any case, because it usually requires a more significant substance of spread and compound admixtures stood out from customary healthy, its material cost is usually 20-half higher, which has been a massive obstacle to a more overall execution of its usage. There is creating evidence that solidifying high volumes of mineral admixtures and small scale fillers as a midway replacement for Portland concrete in SCC can make it reasonable. Regardless, the sturdiness of such SCC ought to be illustrated. This investigation work contains (i) headway of a proper mix for SCC that would satisfy the plastic state; (ii) anticipating strong models and testing them for compressive quality, shrinkage, water ingestion, sulfate resistance. Close by sums, stable, admixtures, and included substances conveyed by the local suppliers were used in this work. The significance of this work lies in its undertaking to give some introduction data of SCC to cause to see the possible use of SCC.

Experimental Work

Outline of Present Work

In this current examination, polyester fiber was used in concrete for the formation of fiber fortified concrete. The ideal rate was fixed as 4 % to cement's weight by anticipating 3D squares, chambers, and gems with contrasting degrees of fiber, such as 0%, .01%, 0.2%, and 0.3%, and taking the rate which strengthened most noteworthy worth. Metakaolin is a thing insisting on planning requirements in the phrasing of physical and compound properties. Concrete was replaced with Metakaolin by 5% to the greatness of cement. By taking 0.1% of fiber and 5% replacement of Metakaolin shapes, chambers and gems were cast of size 150x150x150mm, 150mm expansiveness x 300mm high, 700x150x150mm. Superplasticizer was incorporated for better usefulness, and ideal estimations were directed by using a swamp cone test. Consequently, extraordinary quality and durability tests were driven. The going with tests was performed. The various mixes are to be done.
Test Results and Discussions

Test Results of Cement

| % of cement replaced By Metakaolin (%) | Consistency (%) |
|---------------------------------------|-----------------|
| 0                                     | 31              |
| 5                                     | 36              |

It is observed here that the consistency percentage is increasing as the percentage of Metakaolin increases as a cement replacement, but the change is not so abrupt.

| % of Metakaolin with cement Replacement | 3 days strength (MPa) | 7 days strength (MPa) |
|----------------------------------------|----------------------|----------------------|
| 0                                      | 15.98                | 23.15                |
| 5                                      | 19.6                 | 27.12                |

It was observed that 3 days and 7 days compressive strength increases about 25% and 43% that is from 15.98 MPa to 23.15 MPa and 19.6 to 27.12 respectively, as Metakaolin percentage increases from 0 to 5%.

Effect on Slump and Compaction Factor

| Parameters | Slump (mm) | Compaction Factor |
|------------|------------|-------------------|
| 0% of Metakaolin | 106 | 0.9 |
| 5% of Metakaolin | 48 | 0.85 |
| 5% of Metakaolin + SP | 114 | 0.92 |

Slump and Compaction factor value was influenced by replacement of cement with Metakaolin.

Test Results of Hardened Concrete

Optimum Dosage of Fibers

| Fibre percentage | Compressive strength at 7 days (N/mm²) | Split tensile strength at 7 days (N/mm²) | Flexural strength at 7 days (N/mm²) |
|------------------|----------------------------------------|------------------------------------------|-----------------------------------|
| 0%               | 23.02                                  | 2.46                                     | 3.75                              |
| 0.1%             | 25.6                                   | 2.84                                     | 3.98                              |
| 0.2%             | 30.1                                   | 3.31                                     | 5.56                              |
| 0.3%             | 27.56                                  | 3.02                                     | 5.12                              |

Compressive Strength of Cube

| Parameters | 7 days compressive strength (N/mm²) | 28 days compressive strength (N/mm²) |
|------------|-------------------------------------|-------------------------------------|
| OPC        | 23.02                               | 30.86                               |
| OPC+Metakaolin | 29.78                               | 33.28                               |
| OPC+ Nylon Fiber | 27.36                               | 31.23                               |
| OPC+ Nylon Fiber+Metakaolin | 30.81                               | 36                                  |
Comparison of Compressive Strength of Cubes and Cylinders

Table 6 Test Results of Comparison of Compressive Strength of Cubes and Cylinders

| Parameters          | Cube compressive strength at 60 days (N/mm$^2$) | Cylinder compressive strength at 60 days (N/mm$^2$) |
|---------------------|-----------------------------------------------|--------------------------------------------------|
| OPC                 | 35.62                                         | 38.33                                            |
| OPC+Metakaolin      | 55.95                                         | 53.71                                            |
| OPC+ Nylon Fiber    | 48.21                                         | 43.5                                             |

Split Tensile Strength

Table 7 Test Results of Split Tensile Strength of Concrete

| Parameters                        | 7 Days Split Tensile Strength (N/mm$^2$) | 28 Days Split Tensile Strength (N/mm$^2$) |
|-----------------------------------|------------------------------------------|-------------------------------------------|
| OPC                               | 2.43                                     | 3.95                                      |
| OPC+Metakaolin                    | 2.70                                     | 4.44                                      |
| OPC+ Nylon Fiber                  | 3.11                                     | 4.96                                      |
| OPC+ Nylon Fiber+Metakaolin       | 2.89                                     | 4.73                                      |

Flexural Strength

Table 8 Test results of flexural strength of concrete

| Parameters                        | 7 days flexural strength (N/mm$^2$) | 28 days flexural strength (N/mm$^2$) |
|-----------------------------------|-------------------------------------|-------------------------------------|
| OPC                               | 3.87                                | 5.73                                |
| OPC+Metakaolin                    | 4.04                                | 6.08                                |
| OPC+ Nylon Fiber                  | 4.46                                | 6.75                                |
| OPC+ Nylon Fiber+Metakaolin       | 4.78                                | 7.17                                |

Table 9 Test results of modulus of elasticity

| Parameters                        | Modulus of Elasticity(Gpa) |
|-----------------------------------|-----------------------------|
| OPC                               | 22.14                       |
| OPC+Metakaolin                    | 23.45                       |
| OPC+ Nylon Fiber                  | 31.08                       |
| OPC+ Nylon Fiber+Metakaolin       | 26.87                       |

Table 10 Poisson's Ratio

| Parameters                        | Poisson’s Ratio |
|-----------------------------------|-----------------|
| OPC                               | 0.105           |
| OPC+Metakaolin                    | 0.161           |
| OPC+ Nylon Fiber                  | 0.166           |
| OPC+ Nylon Fiber+Metakaolin       | 0.336           |

Table 11 Density of Cubes and Cylinders

| Parameters                        | Density of cubes at 60 days(Kg/m$^3$) | Density of cylinders at 60 days(Kg/m$^3$) |
|-----------------------------------|----------------------------------------|-------------------------------------------|
| OPC                               | 2534.23                                | 2379.63                                   |
| OPC+Metakaolin                    | 2567.89                                | 2455.13                                   |
| OPC+ Nylon Fiber                  | 2524.17                                | 2427.23                                   |
| OPC+ Nylon Fiber+Metakaolin       | 2493.96                                | 2319.89                                   |

Durability Tests

Table 12 Acid Resistance Test

| Parameters                        | Loss of weight at 30 Days(%) | Loss in compressive strength at 30 days(%) |
|-----------------------------------|-----------------------------|-------------------------------------------|
| OPC                               | 4.32                        | 13.65                                     |
| OPC+ Metakaolin                   | 2.46                        | 6.98                                      |
| OPC+ Nylon Fiber                  | 3.23                        | 11.86                                     |
| OPC+ Nylon Fiber+Metakaolin       | 1.46                        | 5.58                                      |
### Table 13 Alkaline Attack

| Parameters                        | Loss in weight at 30 days (%) | Loss in compressive strength at 30 days (%) |
|----------------------------------|-------------------------------|--------------------------------------------|
| OPC                              | 4.06                          | 10.41                                      |
| OPC + Metakaolin                 | 2.49                          | 7.11                                       |
| OPC + Nylon Fiber                | 2.92                          | 8.56                                       |
| OPC + Nylon Fiber + Metakaolin   | 1.81                          | 5.21                                       |

### Table 14 Freeze and Thaw

| Parameters                        | Compressive strength (Mpa) |
|----------------------------------|-----------------------------|
|                                 | Without freeze and thaw     | Cubes at -18°C                  |
| OPC                              | 39.02                       | 24.55                          |
| OPC + Metakaolin                 | 46.88                       | 36.12                          |
| OPC + Nylon Fiber                | 52.02                       | 48.01                          |
| OPC + Nylon Fiber + Metakaolin   | 57.65                       | 42.78                          |

### Table 15 Initial Surface Absorption Test (ISAT)

| Parameters                        | Average Rate of Penetration of Water (Ml) |
|----------------------------------|------------------------------------------|
| OPC                              | 17.6                                     |
| OPC + Metakaolin                 | 10.4                                     |
| OPC + Nylon Fiber                | 14.8                                     |
| OPC + Nylon Fiber + Metakaolin   | 12.1                                     |

### Table 16 Water Absorption and Porosity

| Parameters                        | Saturated Water Absorption at 60 Days (%) | Porosity at 60 days (%) |
|----------------------------------|------------------------------------------|-------------------------|
| OPC                              | 2.34                                     | 3.24                    |
| OPC + Metakaolin                 | 2.22                                     | 2.34                    |
| OPC + Nylon Fiber                | 2.46                                     | 4.06                    |
| OPC + Nylon Fiber + Metakaolin   | 1.98                                     | 2.21                    |

### III. Conclusion

In this current examination with the specified time and lab set up, managing the cost of has been taken to enlighten Metakaolin’s utilization in fiber fortified cement in agreement to their proficiency. It was inferred that with the supplanting of concrete with Metakaolin, the consistency increments about 18.46%. The utilization of Metakaolin, which consumed appropriately in controlled temperature, improves the quality of mortar. Quality improvement isn’t critical. With the utilization of super plasticizer, it is conceivable to blend in with low water to solidify proportion to get the ideal quality.

- The most extreme compressive quality of shapes and chambers at 28 and 60 days were gotten for the blend OPC+RHA and increment in rate was 25.66% for blocks at 28 days, 55.15%, and 40.56% for 3D squares and chamber at 60 days.
- In split elasticity, the most extreme quality was obtained for the blend OPC+ Nylon FIBER. It was about 27.98% and 25.56% at seven days and 28 days individually. Along these lines, expansion is found to have a better impact on split elasticity contrasted with Metakaolin.
- For the situation of flexural quality, the most excellent quality was acquired for the mix OPC+ Nylon. It was about 26.87% and 25.42% at seven days and 28 days separately.
- From the stress-strain diagram plotted, the modulus of the flexibility of cement was found. The worth was discovered to be most significant in the mix in which fiber just was included and least in 5 % of Metakaolin substitution.
- The most extreme estimation of Poisson’s proportion is 0.336, which was acquired for the blend OPC+FIB+ Metakaolin and the least worth is 0.161 for the mix OPC+FIB.
- In the correlation of thickness of shapes and chambers for 60 days. The most excellent worth was acquired for the mix OPC + Metakaolin. The qualities are 2567.89Kg/m3 for solid bodies and 2493.98Kg/m3 for chambers. Accordingly, the expansion of RHA builds the thickness of cement.
- From the strength considers, specifically corrosive assault and necessary assault, It has been seen that there is an expansion in opposition for the mix OPC + Metakaolin + FIB.
• The joining of RHA improved protection from corrosive assault. This is because of Metakaolin’s silica, which joins with calcium hydroxide and decreases mixes defenseless to corrosive assault.

• The loss of compressive quality of shapes was 5.46% at 30 days for the mix OPC+ Metakaolin + FIB. This mix gives better corrosive obstruction.

• The loss of compressive quality of shapes was 5.43% at 30 days for the mix OPC + Metakaolin + FIB. This mix gives better soluble obstruction.

• The porousness of water was diminished by the expansion of Metakaolin and fiber, which gave the least estimation of 1.96 and, in this way, influences better sturdiness. By expanding Metakaolin and fiber, the volume of pores in solid abatements, and accordingly lessening the entrance of water.

• The least porosity esteem was acquired for the mix OPC + Metakaolin + FIB, and the worth is 2.22 at 60 days, which is 33.2% lower than OPC.

• In the instance of beginning surface assimilation test (ISAT), the permeability of water was diminished by Metakaolin’s expansion. This is because of the physical and synthetic properties of Metakaolin.

• The maximum estimation of compressive quality acquired after the freeze and defrosted cycles was 48.36 for the mix OPC+FiB, and it was practically 49.19 % expanded contrasted with ordinary cement.

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