Experimental studies on ECC by using Glass Fibers.

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Abstract - ***An Engineered Cementitious composite is a high ductile cementitious composite which possess high crack resistance, tensile strain capacity which surpasses property of normal concrete. Engineered Cementitious Composites are kind of a Fiber Reinforced Concrete, but in ECC the fiber percentage is optimized to get the better performance and absence of coarse aggregates reduces transition zone effect thus altering behaviour of ECC. As the bond between the fiber and the matrix is foundation to play an important role in behaviour of ECC. In this experiment an attempt is made to study the interaction of Glass fibers with the matrix prepared by incorporating the different mineral admixture such as Metakaolin and fly ash. In this experiment flexural tests were carried out to examine the behaviour with different fibers with percentage varying between 1% to 2% in the interval of 0.25% and their interaction with different mineral admixtures. It is observed that the control mixes show no deflection whereas glass fiber in Metakaolin with 1% of fibers had shown a good deflection and the same fibers in fly ash shown good deflection at fibers content of 2%.***

Key Words: *ECC, glass fibers, fly ash, metakaolin .*

1. INTRODUCTION

Concrete is the most popular construction material because of its special properties such as versatility, durability and easy to handle, due to these special properties more than 11.4 billion tons of concrete consumed annually worldwide. Ordinary Portland cement, though costly and energy intensive is the most widely used ingredient in the production of concrete mixes.

The creation of ECC is mainly motivated on micromechanical interactions that occur between ingredients and way of processing. Interaction occurs between fibers and matrix is recognized as key factor which governs ECC behaviour, resulting in interfacial zone modification techniques so as to design desired properties. Fiber ruptures in ECC are prevented and pull-out of fiber from matrix is achieved by the use of suitable mineral admixtures. Thus improving tensile strain capacity 3-7% for ECC containing 2% fiber by volume. Micromechanical interaction recounts macroscopic properties of the microstructure of composite, and forms spine for ECC material design theory. Especially, books for microstructure tailoring of ECC along with material optimization. The Micromechanical models were constructed on the basis of fracture mechanics and deformation mechanism these are the parameters which are provide an opportunity for tailoring micromechanical parameters so as to control failure mode, tensile strength and various other parameters.

2.OBJECTIVES

- To investigate the properties of ingredients of Engineered Cementitious composites (ECC)
- To investigate the Mix Design procedure of ECC
- To investigate the hardened properties of the ECC

3.INGREDIENTS OF ECC CONCRETE

3.1 Ordinary Portland Cement

Ordinary Portland cement (often referred to as OPC) is the general type of cement in use around the world ,because it is the basic key ingredient for making concrete, mortar, stucco and most of the grouts specially prepared for specific purpose. It is made by intergrinding of argillaceous and calcareous materials .

Physical properties of OPC

1. Fineness

Particle fineness of Portland cement affects rate of hydration, which affects the rate of strength gain. Smaller is the particle size, the greater is the surface area-to-volume ratio, means more area is available for the reaction of water-cement per unit volume.

2. Soundness

The ability of a hardened cement paste to retain its shape after setting is known as soundness. The cement samples containing excessive amounts of free lime are subjected to volume change. Soundness of cement is determined by using Le chartliars equipment.

3.Consistency

The ability of cement paste to flow is known as consistency. The cement paste consistency is determined by using Vicat aglassratus when the plunger penetrates by 10±1 mm and the corresponding water-cement ratio is reported as the Std consistency of cement.

4. Setting Time:

Initial setting time is defined as the time that elapsed from the instant of adding water until the pastes behave as plastic material thus offering resistance against the penetration. Whereas final setting time referred to be the time that is required for the cement paste to reach a certain state of hardness to bear some load and is tested by using Vicat apparatus.

5. Specific gravity:

The particle density which is measured by excluding the air between particles of OPC is found to be in the range of 3.1 to 3.25. The density of cement is determined by density bottle apparatus and here kerosene is used.

3.2 Sand

- Good river bank sand in absence of any earthy matter and organic matter.
- Particles are angular in shape passing 250 micron and retaining 150 micron standard sieve.
- Sample is washed in water to get free from silty and earthy and other organic content and dried over a period of 48 hours of sunlight.

3.3 Water

Water which fits for drinking purpose is considered for mixing the ingredients, and should be free from suspended impurities and foreign matters such as acids, alkalis. Water plays two key roles in a concrete mix. Firstly, it chemically reacts with constituents of cement to form paste where paste holds aggregates in suspension phase until paste hardens. Secondly, it act as lubricant in mixing of ingredients.

3.4 Flyash

In the coal powered power generating plants the exhaust gases which comes out after burning is treated with electrostatic precipitators and the fine particles that collected in it is known as flyash and the ash which doesn't comes out with the exhaust flue gases is termed bottom ash. Fly ash constitutes substantial amount of silicon dioxide (SiO_2) in the form of both amorphous and crystalline form and calcium oxide (CaO), both being effective ingredients in many coal-bearing rock strata.

3.5 Super plasticizer

This is used to improve the rheological properties of fresh concrete. Super plasticizers are the additives to fresh concrete which helps in dispersing constituents uniformly throughout the mix. This is achieved by their deflocculatiion action on cement particles by which water entrapped is released and is available for workability. Super plasticizer increases slump properties from 5cm to 20cm without addition of water and thereby reducing the water requirement by 15 to 20 percent. This results in improvement of vital properties like density, water tightness. Where sections are having closer reinforcements, the use of super-plasticizer increase workability and no compaction is required. The permeability of concrete is key property which contributes to durability ,the use of superplasticizer increases workability maintaining low water to cement ratio. The permeability of cement paste reduces considerably with reduction in water to cement ratio. Thus super plasticizer can be used effectively to improve various properties of concrete and to avoid defects like honeycombing.

3.6 Glass Fiber (GF)

Fibers are normally used in concrete to control the cracking due to both plastic shrinkage as well as drying shrinkage. Glass fibers which are possessing high tensile strength and their surface is not treated with any chemicals and they are susceptible for alkali environment of matrix this makes us to do an experimental study by selecting these fibers.

Fiber type	Tensile strength (MPa)	Young's modulus (GPa)	Fiber elongation (%)	Specific gravity
Glass fiber	2200	80	0~4	2

EXPERIMENTAL INVESTIGATIONS ON ECC

3.2 TEST RESULTS OF MATERIALS

3.2.1 Cement

IS mark 43grade cement (Brand – ultra tech) was used for all ECC mixes. The cement used was fresh and without any lumps. Testing of cement was done as per IS:12269-1987. The various tests results conducted on the cement are reported bellow

Table 3.2: Properties of cement

Sl. No.	Particulars	Test Results found
1	Fineness of the cement	4%
2	Specific gravity	3.1
3	Normal consistency %	31%
4	Initial setting time (min)	55min.
5	Final setting time (min)	355min

3.3 MIX DESIGN

There is no standard procedure for calculating the mix design for ECC. The mix design procedure was mainly based on the micromechanical modelling of composite materials, various authors have proposed the different mix proportions of ECC based on workability criteria. The Std mix design procedure adopted by most of the scientists are the mix design proposed by Dr.Victor.c.li

Major physical properties of ECC

Compressive Strength (MPa)	**First Crack Strength (MPa)**	**Ultimate Tensile Strength (MPa)**	**Ultimate Tensile Strain (%)**	**Young's Modulus (GPa)**	**Flexural Strength (MPa)**	**Density (g/cc)**
20 – 95	3 – 7	4 – 12	1 – 8	18 – 34	10 – 30	0.95–2.3

Table 3.3: Mix design for experimental work on ECC taken

	Cement	**Fly Ash/ Metakaolin**	**Sand**	**Water**	**HRWR***	**Fiber (Vol %)**
Ratio	1.0	1.2	0.8	0.56	0.012	0.02
Kg/m3	587	704.6	469.9	299.7	17.31	Based on density of fiber
Per cube	166gms	199gms	132.8gms	87.89ml	5ml	11.32 gms for 2%GF

Note: the water content for meta kaolin based mix is 105ml.

Beams of sizes of 304.8mmx76.2mmx12.2mm casted.

- For GF

% of fiber's	1%	1.25%	1.5%	1.75%	2.0%
For fly ash					
14 days	3	3	3	3	3
28 days	3	3	3	3	3
56 days	3	3	3	3	3
For Metakaolin					
14 days	3	3	3	3	3
28 days	3	3	3	3	3
56 days	3	3	3	3	3
Control mixes for metakaolin and fly ash =12 no's					
Total no's	12	12	12	12	12

Totally 150 no's of beams are casted.

4.0 RESULTS AND DISCUSSIONS

4.1 Control mix

The control mixes are prepared using the cement, sand and water and with mineral admixtures and without fibers. The results of control mixes are tabulated in table 3

Table 4.1.Control mix results with flyash

Load (kN)	Deflection (mm)
0	0
0.1	0

Table 4.2.Control mix results with metakaolin

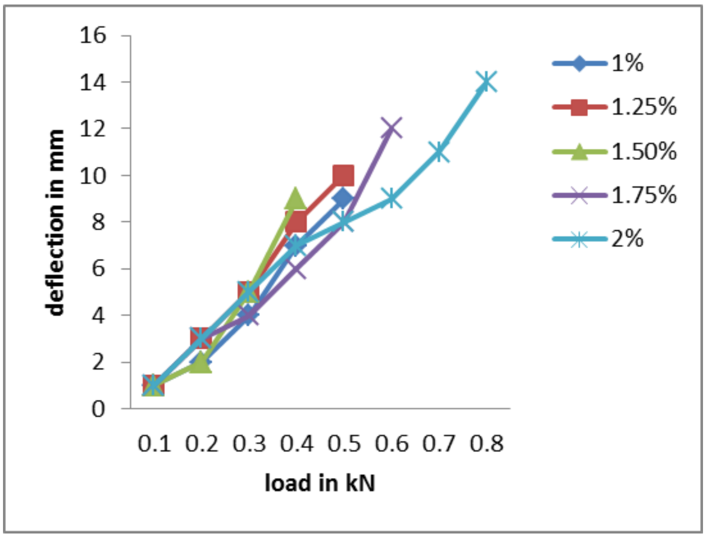
Load (kN)	Deflection (mm)
0	0
0.1	0
0.2	0

In the absence of fibers the control mixes doesn't show any deflections in flexure testing machine and load taking capacity is around 0.1kN for control mix of flyash and 0.2kN for control mix with metakaolin.

4.3 Fly ash based mix with glass fiber

Table 4.6. Fly ash based mix with varying percentage of Glass fiber for 14 days.

LOAD(kN)	Deflection in mm with varying % of glass fibers				
	1%	1.25%	1.5%	1.75%	2%
0.00	0	0	0	0	0
0.10	1	1	1	1	1
0.20	2	3	2	3	3
0.30	4	5	5	4	5
0.40	7	8	9	6	7
0.50	9	10		8	8
0.60				12	9
0.70					11
0.80					14

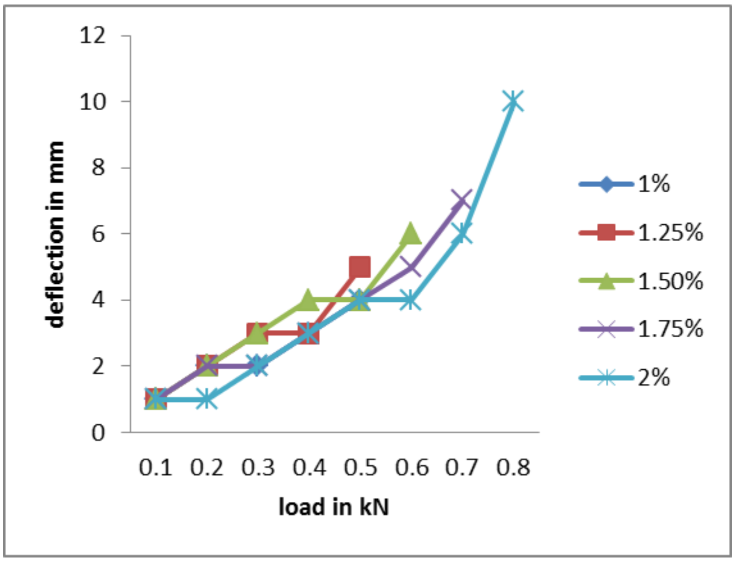


Graph.4.4.Load verses deflection of Fly ash based mix with varying percentage Glass fiber for 14days.

Mixes prepared using cement, water, flyash, sand, glass fiber and super plasticizer, the result of the mixes are as shown in the table 4.6 and the graph of load v/s deflection is shown in the Graph 4.4, and control mixes prepared using cement, water, sand and flyash without the glass fiber shows sudden failure without deflection. It is observed visible cracks are not appeared till 0.4kN and sudden failure of specimen is observed at 0.5kN for 1% of fibers and mixes prepared with 1.25% of fibers, visible cracks are not appeared till 0.6kN of loading and mixes prepared with 1.5% of polypropylene fibers visible cracks are not appeared till 0.7kN of loading. Further for the specimens with 1.75% of polypropylene fibers had carried almost same load as 1.5% fibers but giving more deflections and specimens with 2% of fibers resulted in carrying more load showing good deflection, flyash in mix makes matrix smooth this allows specimens to deflect more under small loading and glass fibers tensile capacity is very high resulting in more load taking capacity.

Table 4.7. Fly ash based mix with varying percentage of Glass fiber for 28 days.

LOAD(kN)	Deflection in mm with varying % of glass fibers				
	1%	1.25%	1.5%	1.75%	2%
0.00	0	0	0	0	0
0.10	1	1	1	1	1
0.20	2	2	2	2	1
0.30	2	3	3	2	2
0.40	3	3	4	3	3
0.50	4	5	4	4	4
0.60			6	5	4
0.70				7	6
0.80					10

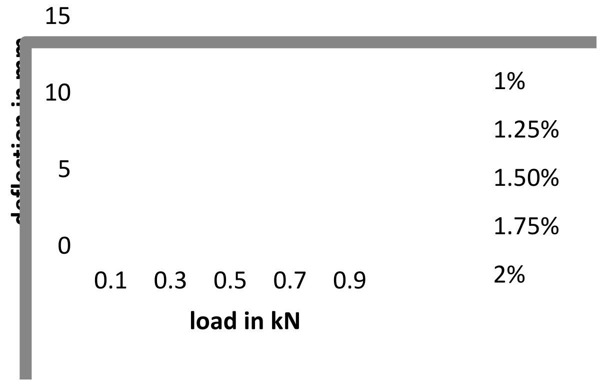


Graph.4.5.Load verses deflection of Fly ash based mix with varying percentage of Glass fiber for 28days.

It is observed visible cracks are not appeared till 0.4kN and sudden failure of specimen is observed at 0.5kN for 1% of fibers and mixes prepared with 1.25% of fibers, visible cracks are not appeared till 0.5kN of loading and mixes which are prepared with 1.5% of polypropylene fibers visible cracks are not appeared till 0.6kN of loading. Further for the specimens with 1.75% of polypropylene fibers had carried almost same load as 1.5% fiber but giving more deflections and specimens with 2% of fibers has resulted in carrying more load showing good deflection, flyash in mix makes the matrix smooth this allows the specimens to deflect more even under small loading and glass fiber tensile capacity is very high and resulted in more load taking capacity.

Table 4.8. Fly ash based mix with varying percentage of Glass fiber for 56 days.

LOAD(kN)	Deflection in mm with varying % of glass fibers				
	1%	1.25%	1.5%	1.75%	2%
0.00	0	0	0	0	0
0.10	1	1	1	1	1
0.20	1	2	1	2	1
0.30	2	2	2	2	2
0.40	4	3	3	3	3
0.50	6	4	4	4	4
0.60		5	5	6	5
0.70		6	6	7	6
0.80			7	8	9
0.90					10
1.00					12



Graph.4.6.Load verses deflection of Fly ash based mix with varying percentage of Glass fiber for 56days.

It is observed visible cracks are not appeared till 0.4kN and sudden failure of specimen is observed at 0.5kN for 1% of fibers and mixes prepared with 1.25% of fibers, visible cracks are not appeared till 0.5kN of loading and mixes prepared with 1.5% of polypropylene fibers visible cracks are not appeared till 0.6kN of loading. Further for specimens with 1.75% of polypropylene fibers had carried almost same load as 1.5% fiber but giving more deflections and specimens with 2% of fibers resulted in carrying more load with more deflection, flyash in mix makes the matrix smooth this allows the specimens to deflect more under small loading and glass fiber tensile capacity is very high and resulted in more load taking capacity and its percentage of elongation is very less this caused specimens to deflect less.

4.5 Metakaolin based mix with glass fiber

Table 4.12. Metakaolin based mix with varying percentage of Glass fiber for 14 days

LOAD(kN)	Deflection in mm with varying % of glass fibers				
	1%	1.25%	1.5%	1.75%	2%
0.00	0	0	0	0	0
0.10	0.5	0.5	0.5	0	0
0.20	1	1.5	1	0.5	0.5
0.30	3	2	2	1	1
0.40	5	3	2.5	2	2
0.50	6	5	3.5	3	2.5
0.60	7	7.5	5	3.5	3.5
0.70	9	8	7.5	5.5	4
0.80	12	8.5	8	6	6
0.90		11	8.5	7	7
1.00			9.5	7.5	
1.10				8	

Mixes prepared by using cement, metakaolin, sand, and glass fiber with varying percentage, water and super plasticizer, result of mix are shown in the table 4.12 and the graph of load v/s deflection is shown in Graph 4.10. The control mixes prepared by using the cement, sand and water without Metakaolin and fiber shows the sudden failure without any deflection. It is observed, Specimen prepared by using metakaolin doesn't show good yield in deflection and brittle failure is observed in

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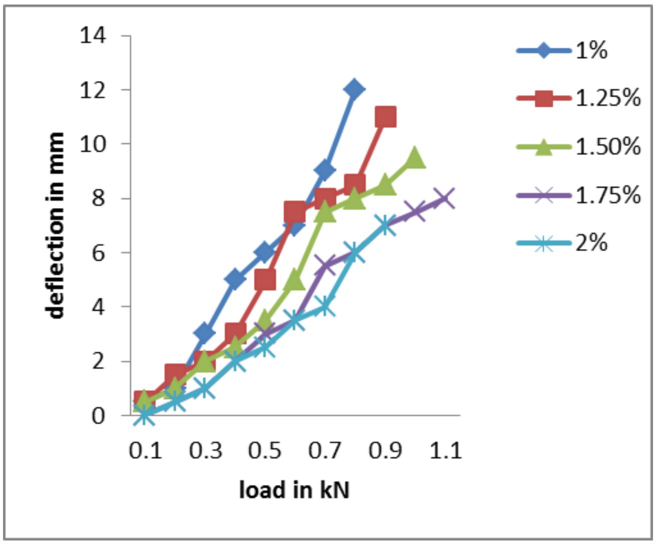
almost all specimens, and the specimen with 1.75% of fibers was found to be the one which yielded more by comparatively taking more load than other specimens which are prepared with metakaolin and glass fibers.

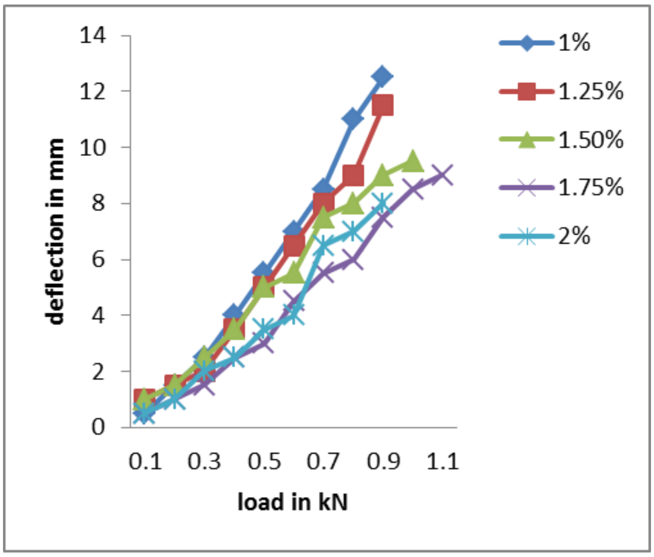


Graph.4.10.Load verses deflection of Metakaolin based mix with varying percentage of Glass fiber for 14days.

Table 4.13. Metakaolin based mix with varying percentage of Glass fiber for 28 days

LOAD(kN)	Deflection in mm with varying % of glass fibers				
	1%	1.25%	1.5%	1.75%	2%
0.00	0	0	0	0	0
0.10	0.5	1	1	0.5	0.5
0.20	1.5	1.5	1.5	1	1
0.30	2.5	2	2.5	1.5	2
0.40	4	3.5	3.5	2.5	2.5
0.50	5.5	5	5	3	3.5
0.60	7	6.5	5.5	4.5	4
0.70	8.5	8	7.5	5.5	6.5
0.80	11	9	8	6	7
0.90	12.5	11.5	9	7.5	8
1.00			9.5	8.5	
1.10				9	

Mixes prepared by using cement, metakaolin, sand, and glass fiber with varying percentage, water and super plasticizer, result of mix are shown in the table 4.12 and the graph of load v/s deflection is shown in Graph 4.10. The control mixes prepared by using the cement, sand and water without Metakaolin and fiber shows the sudden failure without any deflection. It is observed, Specimen prepared by using metakaolin doesn't show good yield in deflection and brittle failure is observed in almost all specimens, and the specimen with 1.75% of fibers was found to be the one which yielded more by comparatively taking more load than other specimens which are prepared with metakaolin and glass fibers.



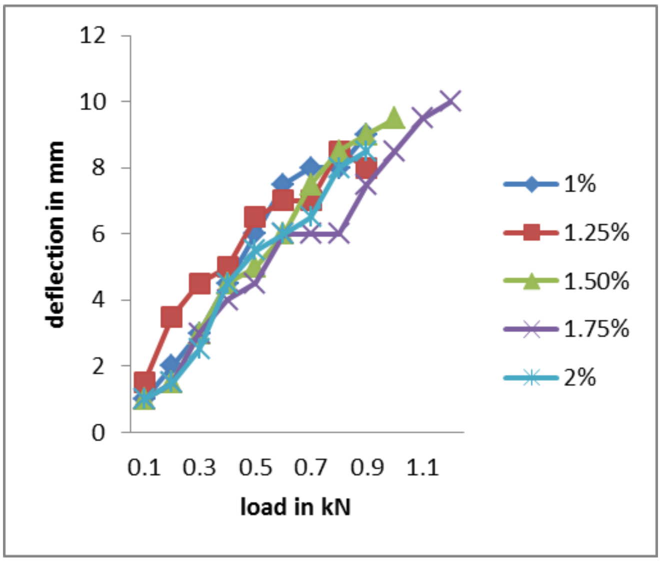
Graph.4.11.Load verses deflection of Metakaolin based mix with varying percentage of glass fiber for 28days.

Table 4.14. Metakaolin based mix with varying percentage of Glass fiber for 56 days

LOAD(kN)	Deflection in mm with varying % of glass fibers				
	1%	1.25%	1.5%	1.75%	2%
0.00	0	0	0	0	0
0.10	1	1.5	1	1	1
0.20	2	3.5	1.5	1.5	1.5
0.30	3	4.5	3	3	2.5
0.40	4.5	5	4.5	4	4.5
0.50	6	6.5	5	4.5	5.5
0.60	7.5	7	6	6	6
0.70	8	7	7.5	6	6.5
0.80	8	8.5	8.5	6	8
0.90	9	8	9	7.5	8.5
1.00			9.5	8.5	

1.10				9.5	
1.20				10	

It is observed, the specimens prepared using metakaolin doesn't show good yield in deflection and brittle failure is observed in almost all specimens .Specimen with 1.75% of fibers is yielded more by comparatively taking more load than the other specimens which are prepared with metakaolin and glass fibers.



Graph.4.12.Load verses deflection of Metakaolin based mix with varying percentage of Glass fiber for 56days.

It is observed, specimens prepared by using metakaolin doesn't show good yield in deflection and the brittle failure is observed in almost all specimens .The specimen with 1.75% of fibers is yielded more by comparatively taking more load than other specimens which are prepared with metakaolin and glass fibers.

CONCLUSION

Following conclusions were drawn from this experimental work.

- The experimental work had been carried out with glass fibers and with mineral admixtures such as fly ash and Metakaolin and the fiber is varied in between 1% to 2% at the interval of 0.25%.
- The Metakaolin based mix requires more water than the fly ash based mix to get the good workable mix because of high volume compared to fly ash. The water requirement is in the order of 1.2 times the water required for fly ash.
- The glass fibers performed better in metakaolin based mix, poor ductility and improved load taking capacity is observed in metakaolin based mix. The use of metakaolin results in early high strength and held the fibers tight resulting in very poor ductility.
- Optimum percent of glass fibers in fly ash based mix is found at 2% and for metakaolin based mix it is found at 1%.

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