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Strength Appraisal of Fibre Reinforced Concrete with Partial Replacement of OPC with Mineral Admixtures (Fly Ash, GGBS, Metakaolin)

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Abstract: *Concrete consumption has becomes multi-fold over last few decades, and such usage of concrete has increased on large scale world over. Concrete ingredients used are becoming more costly day by day and also demand for the same is increasing widely all over. The present experimental investigation is aimed to compare the glass fibre reinforced concrete on partial replacement opc with mineral admixtures (Fly ash, GGBS &Metakaolin) with concrete grade of M30. The mix proportioning for M30 grade was done according to the IS:10262-2009. The work is focused on replacing the opc i.e. Fly ash20%+GGBS20%, Fly ash20%+Metakaolin20%, Matakaolin20%+GGBS20% by mineral admixtures with and without Alkali Resistant (AR) glass fibres0.5%, 1.0% content. And also maintaining less water-cement ratio used water reducing admixture (super plasticizer). The maximum compressive strength and split tensile strength of concrete is observed for the mix with opc replaced by mineral admixtures Fly ash20%+GGBS20% @1.0% glass fibres(Mix M2) is increased by 2.55% and 9.11%. The split tensile strength of concrete mix is increased by 8.01% and31.33%. when compared with compressive strength and split tensile strength of control concrete at 7 and 28 days respectively.*

Keywords: *Alkali Resistant(AR)glass fibres, Workability,Pozzolana, Fly Ash, GGBS, Metakaolin, Super Plasticizer, Compressive Strength, Split Tensile Strength.*

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I. Introduction

Concrete is the most widely used man-made construction material in the world. It is obtained by mixing cementitious materials, water, aggregate and sometimes admixtures in required proportions. Fresh concrete or plastic concrete is freshly mixed material which can be moulded into any shape hardens into a rock-like mass known as concrete. The hardening is because of chemical reaction between water and cement, which continues for long period leading to stronger with age. The utility and elegance as well as the durability of concrete structures, built during the first half of the last century with ordinary Portland cement (OPC) and plain round bars of mild steel, the easy availability of the constituent materials (whatever may be their qualities) of concrete and the knowledge that virtually any combination of the constituents leads to a mass of concrete have bred contempt. Strength was emphasized without a thought on the durability of structures.

FIBRE REINFORCED CONCRETE

Concrete is strong in compression and weak in tension. Concrete is brittle and will crack with the application of increasing tensile force. Once concrete cracks it can no longer carry tensile loads. In order to make concrete capable of carrying tension at strains greater than those at which cracking initiates, it is necessary to increase the tensile strength. To increase the tensile and flexural strength, fibres are added in concrete. The addition of fibres to concrete will result in a composite material that has properties different from those of un-reinforced concrete. The extent of this variation depends not only on the type of fibres, but also on the fibre dosage. The incorporation of fibres into a brittle concrete can have the effect of controlling the growth and propagation of micro cracks as the tensile strain in the concrete increases. Care is needed in using fibre as additive in concrete. The use of fibres in concrete has increased with the development of fast-track construction. In fact, nearly 65 per cent of the fibres produced worldwide is currently used in concrete. It offers increasing toughness and ductility, tighter crack control and improved load-carrying capacity. Different types of fibres are available in the market for reinforcing concrete and they are: steel, glass, acrylic, aramid, carbon, nylon, polyester, polyethylene, polypropylene, etc..

GLASS FIBER REINFORCED CONCRETE

Glass fibre–reinforced concrete is (GFRC) basically a concrete composition which is composed of material like cement, sand, water, and admixtures, in which short length discrete glass fibers are dispersed. Inclusion of these fibres in these composite resultsin improved tensile strength andimpact strength of the material.GFRC has been used for a period of 30 years in several construction elements but at that time it was not so popular, mainly in non-structural ones, like facingpanels (about 80% of the GRC production), usedin piping for sanitation network systems, decorativenon-recoverable formwork, and other products.At the beginning age of the GFRC development, one of the most considerable problems was the durability of the glass fiber, which becomes more brittle with time, due to the alkalinity of the cement mortar. After some research, significant. Improvement have been made, andpresently, the problem is practically solved with the new types of alkali-resistant (AR resistance) glass fibers and with mortar additives that prevent the processes that lead to the embrittlement of GFRC.

Improvement in Concrete Properties by Glass Fibers

- Compressive strength –Increased about 20 – 30%
- Tensile strength–It is improved compared to conventional concrete
- Flexural Strength–Increased about 25 – 30%
- Split Strength –Increased up to 25 – 30%

Applications of fiber reinforced concrete

1. Runway, Aircraft Parking, and Pavements
2. Tunnel Lining and Slope Stabilization
3. Thin Shell, Walls,4444 Pipes, and Manholes
4. Dams and Hydraulic Structure

II. Experimental Programme

MATERIAL PROPERTIES

CEMENT: Normal consistency-32%, Specific gravity-3.15, Compressive strength-3,7,28 days 25.3MPa,36.8MPa,52.5 MPa,Fineness-1.3%, Soundness-1.5mm, Initial setting time-90min, Final setting time-270min

FINE AGGREGATE,COARSE AGGREGATE-Specific gravity-FA 2.85,CA-2.85, Bulk density loose-FA-1728kg/m^3 CA -1544kg/m^3,Bulk density compacted -FA-1805kg/m^3, CA-1605kg/m^3 ,Water absorption –FA-1.05% ,CA –NIL, Fineness modulus-FA-2.64, CA-7.62

SUPER-PLASTICIZER (MasterRheobuild920SH)- State – Liquid,Color - Dark Brown,Density - 1.20,Chloride content - 0.074,Chemical Name - Naphthalene formaldehyde polymers,P^H - 8.40,Dry material content - 39.36

Alkali Resistant (AR) Glass Fibers-Appearance –White, Size-18mm, Diameter - 14µm,Aspect ratio - 857:1, Density - 2.7 g/cm^3 ,Tensile strength - 1700 MPa,Elastic modulus -72 GPa, Elongation at break - 2.3%, Zirconia content - 16.7%, Melting point- 1450^{0}C, Refractive index - 1.561
Fly ash – Color- Dark gray, Bulk density -1041kg/m^3 , Sp. Gravity-2.1, Fineness-336 m^2/kg
GGBS – Color-Off white, Bulk density- 1280kg/m^3 , Sp. Gravity- 2.8, Fineness-340 m^2/kg
Metakaolin – Color-Off white, Bulk density- 785kg/m^3 ,Sp. Gravity- 2.7, Fineness -356 m^2/kg

Table1: Chemical Properti44e4s Of Fa,Ggbs,Mk,Argf

PROPERTY	FLY ASH	GGBS	METAKAOLIN	AR GLASS FIBERS
SiO_2	61.5%	37.73%	52.86%	54.88%
Al_2O_3	21.80%	14.42%	44.10%	15.38%
Fe_2O_3	8.50%	1.11%	0.45%	10.54%
CaO	2.68%	37.74%	0.28%	8.39%
MgO	0.6%	8.71%	0.20%	4.9%
LOI	1.1%	1.41%	0.85%	-

III. Test Results

Table3: Compressive, Split tensile strength values of various mixes

MIX	COMPRESSIVE STRENGTH N/mm^2		SPLIT TENSILE STRENGTH N/mm^2		Slump value (mm)
	7 days	28 days	7days	28days	
C1	24.5	36.29	2.58	2.92	32
A1	26.44	41.02	2.80	3.19	30
A2	28.21	44.12	3.083	3.731	31
M1	26.04	46.81	3.22	4.410	45
M2	28.93	48.14	3.330	4.90	42
M3	25.45	46.5	3.194	4.378	43
M4	28.84	46.62	3.325	4.486	39
M5	26.23	45.7	3.168	4.163	40
M6	28.83	46.52	3.24	4.593	38

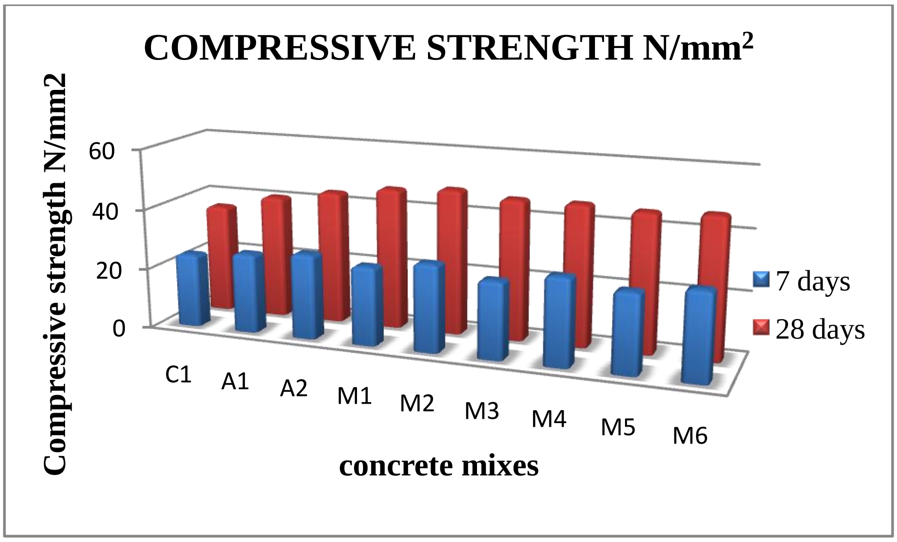

Fig 1:7,28-day Compressive strength of concrete with different mixes

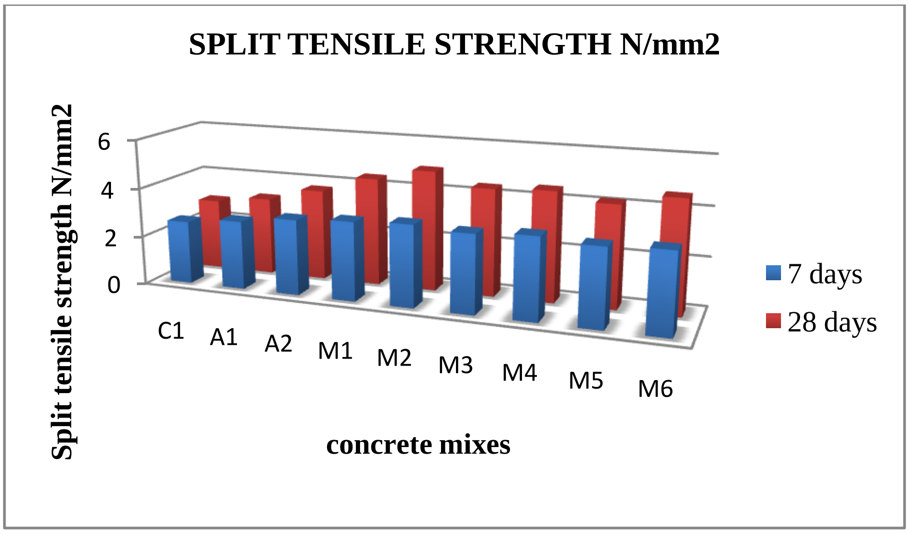

Fig 2:7,28-day Split tensile strength of concrete with different mixes

The nine different types of concrete mixes are as described below
C1 (Conventional mix): OPC100% + F.A + C.A
A1: OPC100% + F.A + C.A + Fibers @ 0.5% by weight of binder
A2: OPC100% + F.A+ C.A + Fibers @ 1.0% by weight of binder

Mixes with cement replaced Mineral Admixtures by (Flyash + GGBS +Metakaolin)
M1: OPC60% + 20%Flyash + 20%GGBS + F.A + C.A +Fibers @0.5% by weight of binder
M2: OPC60% + 20%Flyash + 20%GGBS + F.A+C.A +Fibers @1.0% by weight of binder
M3: OPC60% + 20%Flyash + 20%Metakaolin + F.A+C.A +Fibers @0.5% by weight of binder
M4: OPC60% + 20%Flyash + 20% Metakaolin + F.A+C.A +Fibers @1.0% by weight of binder
M5: OPC60% + 20% Metakaolin + 20% GGBS + F.A+C.A +Fibers @0.5% by weight of binder
M6: OPC60% + 20% Metakaolin + 20% GGBS+ F.A+C.A +Fibers @1.0% by weight of binder

IV. Discussions

For conventional mixes with fiber content

- As the Conventional concretemix(C1),glass fibers are added mixes (A1,A2)withrespect to the @0.5%,1.0% compressive strength is increases by 7.91% & 15.14% for 7 days respectively.
- As the Conventional concretemix(C1),glass fibers are added mixes (A1,A2) with respect to the @0.5%,1.0% compressive strength is increases by 13.03% & 21.57% for 28 days respectively.
- As the Conventional concrete mix(C1),glass fibers are added mixes (A1,A2) with respect to the @0.5%,1.0% split tensile strength is increases by 8.52% & 19.49% for 7 days respectively.013852002015641
- As the Conventional concrete mix(C1),glass fibers are added mixes (A1,A2) with respect to the @0.5%,1.0% split tensile strength is increases by 9.24% & 27.73% for 28 days respectively.

For mixes partial replacement of opc by mineral admixtures(Flyash, GGBS, Metakaolin) with glass fibers@0.5%,1.0% respectively

- As compare the opc (A1) and replacement by mineral admixturesFlyash+20% of GGBS (M1), 20% of Flyash + 20% of Metakaolin (M3) & 20% of Metakaolin +20% of GGBS (M5**)** including fiber content added @0.5% by weight of binder compressive strength is decreases by 1.52%, 3.75%, 0.8% and split tensile strength increases by 15%, 14.07%, 13.14% for 7 days respectively.
- As compare the opc (A1) and replacement by mineral admixturesFlyash+ 20% of GGBS (M1), 20% of Flyash + 20% of Metakaolin (M3) & 20% of Metakaolin +20% of GGBS (M5)including fiber content added @0.5% by weight of binder compressive strength is increases by 14.11%, 13.35%, 11.4% and split tensile strength increases by 38.24%, 37.24%, 30.5% for 28 days respectively.
- As compare the opc (A2) and replacement by mineral admixturesFlyash+ 20% of GGBS (M2), 20% of Flyash + 20% of Metakaolin (M4) & 20% of Metakaolin +20% of GGBS (M6)including fiber content added @1.0% by weight of binder compressive strength is increases by 2.55%, 2.23%, 2.19% and split tensile strength increases by 8.01%, 7.84%, 5.87% for 7 days respectively.
- As compare the opc (A2) and replacement by mineral admixturesFlyash+20% of GGBS (M2), 20% of Flyash + 20% of Metakaolin (M4) & 20% of Metakaolin
- +20% of GGBS (M6)including fiber content added @1.0% by weight of binder compressive strength is increases by 9.11%, 5.66%, 5.43% and split tensile strength increases by 31.33%, 20.23%, 23.1% for 28 days respectively.

Table3: Cost analysis for all the mixes (kgs)

Mix	C1	A1	A2	M1	M2	M3	M4	M5	M6	Actual cost
Cement	425	425	425	255	255	255	255	255	255	50
Cost	2975	2975	2975	1785	1785	1785	1785	1785	1785	350
F.A	740	740	740	740	740	740	740	740	740	45
Cost	2137	2137	2137	2137	2137	2137	2137	2137	2137	130
C.A	1350	1350	1350	1350	1350	1350	1350	1350	1350	60
Cost	2025	2025	2025	2025	2025	2025	2025	2025	2025	90
Fly ash	-	-	-	85	85	85	85	-	-	80
Cost	-	-	-	121.42	121.42	121.4	121.4	-	-	85
MK	-	-	-	-	-	85	85	85	85	70
Cost	-	-	-	-	-	121.4	121.4	121.4	121.42	100
GGBS	-	-	-	85	85	-	-	85	85	70
Cost	-	-	-	109.28	109.28	-	-	109.28	109.28	90
Fiber @0.5%	-	2.125	-	2.125	-	2.125	-	2.125	-	0.5
Cost	-	1700	-	1700	-	1700	-	1700	-	800
GF @1.0%	-	-	4.25	-	4.25	-	4.25	-	4.25	1
Cost	-	-	3400	-	3400	-	3400	-	3400	800
Total cost	7137.77	8787.77	10487.77	7847.365	9547.365	7859.5	9559.5	7878.475	9578.475	1645

% Difference	-	23.11 %	46.93%	10.71%	8.96%	10.57%	8.86%	10.35%	8.68%	

COST ANALYSIS
FOR MIXES WITH FIBER CONTENT @0.5%

- For mix with fibres added @0.5% of weight of binder to conventional concrete(C1) cost increased by 23.11%
- As the opc(A1) is replaced by mineral admixtures 20%Fly Ash+20%GGBS (Mix M1) cost decreases by 10.71%
- As the opc (A1) is replaced by mineral admixtures 20%Fly Ash +20%Metakaolin (Mix M3) cost decreases by 10.57%
- As the opc(A1) is replaced by mineral admixtures 20%Metakaolin+20%GGBS (Mix M5) cost decreases by 10.35%

FOR MIXES WITH FIBER CONTENT @1.0%

- For mix with fibres added @1.0% of weight of binder to conventional concrete(C1) cost increased by 46.93%
- As the opc (A2) is replaced by mineral admixtures 20%Fly Ash+20%GGBS (Mix M2) cost decreases by 8.96%
- As the opc (A2) is replaced by mineral admixtures 20%Fly Ash+20%Metakaolin (Mix M4) cost decreases by 8.86%
- As the opc (A2) is replaced by mineral admixtures 20%Metakaolin+20%GGBS (Mix M6) cost decreases by 8.68%

V. Conclusions

- Based on the research studies the following conclusions can be made:
- It has been observed that the workability of concrete decreases with the addition of mineral admixtures and further decreasing by adding glass fibers. However, requisite workability has been achieved by using super – plasticizers.
- The glass fibers are added in the wet concrete i.e. after adding water to the dry mix, otherwise it will stick to the surface of mixer. Care should be taken while mixing the glass fibers with concrete.it should be not allowed to mix more than 2 minutes, otherwise it will segregate.
- To compare the compressive strength of conventional concrete with adding glass fibers and opc replaced by mineral admixtures concrete mix of compressive strength is decreases of at the 7 days because pozzolans obtained early strength is very less.
- But 28 days compressive strength mineral admixtures concrete mix get more strength compare to conventional concrete mix because of Long term process pozzoloans are getting more strength.
- The percentage increases of compressive strength of concrete mix with replacement of opc(Mix A2) by 20% flyash + 20%GGBS @1.0% glass fibers (Mix M2)when compared with 7,28 days compressive strength of control concrete withglass fibers is observed as 2.55% , 9.11%
- The percentage increases of split tensile strength of concrete mix with replacement of opc(Mix A2) by 20% flyash + 20%GGBS @1.0% glass fibers (Mix M2)when compared with 7,28 days compressive strength of control concrete with glass fibers is observed as 8.01% ,31.33%
- It was observed that, the percentage increase in the strength of glass fibers reinforced concrete increases with the age of concrete.
- Plain concrete fails suddenly once the deflection corresponding to the ultimate flexural strength is exceeded, on the other hand, fiber-reinforced concrete continue to sustain considerable loads even at deflections considerably in excess of the fracture deflection of the plain concrete.
- It shows that the presence of fibers in the concrete acts as the crack arrestors.
- The ductility characteristics have improved with addition of glass fibers. The failure of fiber concrete is gradual as compared to that of brittle failure of plain concrete.

VI. Scope For The Future Work

- The research work on pozzolanic materials and fiber along with pozzolanas is still limited. But the promises a great scope for future studies.
- Percentage and actual fineness of mineral admixtures requires as partial cement replacement for good strength development.

- The benefit of using fiber is that it is non-corrosive. The strength is very good. The heat resistance power is very good which is extremely impotant of every structure.
- The partial replacement of opc with mineral admixtures gives the required strength values for the concrete construction purpose and the cost of the mineral admixtures becomes very cheap if available locally or near places.
- Mineral admixtures and glass fibers percentage increases and also observed the compressive strength and split tensile strength properties and also observe durability properties.

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