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The Effect of Alkaline Solution of Varying Molarity and Hookedend Steel Fibres on Split Tensile Strength(SPTS)(f_{ct}) of Fibre Reinforced Geopolymer Concrete(FRGPC)

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Abstract: ***This article mainly aims the study the effect of alkaline solution of varying molarity [1]" and the percentage of volume fraction of steel fibres[2]" of 0%, 0.5%, 0.7%, 0.9% and 1.1% (R_0, R_5, R_7, R_9 and R_{11}),different ratios of GGBS to Flyash on Split Tensile Strength of GPC is studied. The combination of Sodium Hydraxide (NaoH) of different molarity (8M,10M and 12M) and Sodium Silicate (Na_2Sio_3) used are alkaline activators. The Modified Binder Index(B_{mi}) [3]" is introduced to express the effect of Binder Index(B_i) [4]" and hooked end Steel Fibre Effect on Split Tensile Strength (f_{cv}) of SFRGPC. In the experimental program total 180 cylinders of its size 100mm dia and 200mm length for each variation were cast and tested after 7days and 28days of ambient curing for average strength. The effect of Molarity, GGBS to Flyash ratio and Steel Fibres on the SPTS (f_{cv}) of SFRGPC is presented in this paper.***

INDEX TERMS—. ***Fly ash, Steel fibres, Ground Granulated Blast furnace slag (GGBS), Split Tensile Strength(f_{ct})(SPTS)*** (f_{ct})***, Modified Binder Index (B_{mi}).***

I. INTRODUCTION

Concrete is one of the most expansive building construction material, which is usually associated with Portland cement as the main component for making concrete. Among the green house gases CO_2 contributes about the 65% of global warming – (McCaffrey [5]). The cement industry is accountable for about 7% of all CO_2 release as the manufacture of one ton of Portland cement release approximately one tone of CO_2 into the atmosphere (Davidovits [6]). One of the efforts to produce more environment friendly concrete is to minimize the use of OPC by replacing cement in concrete with Fly ash and other mineral admixtures. The Geopolymer concrete is produced using fly ash, GGBS and alkaline activator.

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The steel Fibers are commonly used to improve the tensile strength, flexure capacity and fracture toughness. Hooked end Fiber is minor piece of reinforcing material having different Geometric shapes.
The steel fiber if often described by a parameter called aspect ratio. It is defined as a ratio of its length to its diameter (D) . Generally steel and carbon fibers are used to increase the fracture toughness and flexure capacity(Bending) of the structural concrete . An investigational program is conducted to examine the properties of steel Fiber reinforced Fly ash based Geopolymer concrete. The effect of fly ash, GGBS, fiber content and Molarities on Split Tensile Strength (f_{ct}) is considered in the present study.

II. EXPERIMENTAL INVESTIGATION

Experimental Program consisted of casting and testing cylinders of size 100mm dia and 200mm length for finding out the Split Tensile Strength(fct) of the FRGPC, based on GGBS and Fly ash. Two different Fly ash to GGBS proportions (40%F: 60%GGBS and 60%F: 40%GGBS) are used in the present study. The ratio of (Na_2Sio_3) solution to $(NaoH)$ solution is kept as 2.5 [7]. Fine aggregate to Total aggregate ratio is taken as 32% . In the present investigation NaoH and Na_2Sio_3 are used as alkaline activators. Three different molarities of NaoH solution (8M, 10M and 12M) [1] were considered to prepare different GPC mixes. The average Split Tensile Strength (f_{ct}) of hooked end Steel Fibre Reinforced Geopolymer Concrete is obtained by testing the cylinders after 7days and 28days of ambient curing.

A. Materials

Low calcium, Class F dry fly ash, follow to IS 3812(part 1:2003)[9] , is obtained from Kothagudem Thermal power station, Bhadradri Kothagudem Dt, Telangana, India .Fine aggregate is used as Natural Godavari river sand was used .. The gradation of the sand by using sieve analysis as per IS 383 (1970)[11]. Fineness modulus of sand was found to be 2.50.Coarse aggregate were used as Crushed granite stones of size 12 mm and 10 mm. The bulk specific gravity in oven dry condition coarse aggregate 12 mm and 10mm and water absorption of the coarse aggregate 12 mm and 10mm as per IS 2386 (Part III, 1963) [10] were 2.35 and 0.28% respectively. GGBS conforming to IS 12089:1987 is obtained from Blue way exports supplier, Vijayawada, Andhra Pradesh, India.

Specific gravity of fly ash is 2.17 and Specific gravity of GGBS 2.90. Chemical composition details are shown in Table 1. Tap water was used in the experimental work for preparation of alkaline solution. Super Plasticizer Conplast Sp-430 was used to obtain the desired workability. Hooked end steel fibers made with low carbon steel has a length of 30 mm and diameter 0.6 mm thus giving an aspect ratio of 50 were used .Tensile strength of the hooked end fibers is 1450Mpa.

B. Preparation of Alkaline Solutions

Three different molarities of NaoH solutions (8M,10M and 12M) were prepared one day before casting .The alkaline activators were prepared by mixing NaoH (8M ,10M and 12M) with Na_2Sio_3 Solution. The solution thus mixed, was stored for 24hours at room temperature before casting. The quantities of NaoH pellets used for preparation of (NaoH) Alkaline liquid, is given in table 2.

C. Mix proportions

The steel fibre Mix proportions were given in table 3.The Density of GPC is assumed as 2400 kg/m^3. The ratio of Alkali liquid to fly ash ratio was fixed as 0.36[8] and also Na_2 Sio_3 and NaoH ratio is taken as 2.5 [7] .The quantities of all ingredients are given in table 4.

Table 1: The Fly Ash And Ggbs Chemical Composition

Material	Fly Ash	GGBS
SiO2	60.12	34.16
Al2O3	26.63	20.1
Fe2O3	4.22	0.81
SO3	0.32	0.88
CaO	4.1	32.8
MgO	1.21	7.69
Na2O	0.2	nd
LOI	0.85	

Table 2: Mix Proportions Of Alkaline Liquid

Alkaline liquids	8 moles/L	10 moles/L	12 moles/L
Sodium hydroxide pellets (NAOH),(grams)	262	314	361
Water (grams)	738	686	639

Table 3:FIBRE MIX PROPORTIONS IN SFRGPC

Fiber designation	Volume fraction (%)	Weight(kg/m^3)
R0	0	0
R5	0.5	39.25
R7	0.7	54.95
R9	0.9	70.65
R11	1.1	86.35

TABLE 4:
GPC MIX PROPORTIONS:FRGPC MATERIAL MIX PROPORTIONS

FA:GGBS	GGBS/FA		Materials in Kg/m^3							
		Molarity	Coarse Agg	Fine Agg	Fly ash	GGBS	NaoH Solution	Sodium Silicate	Super Plasticizer	Extra water (10% of the binder)
40:60	1.5	8M	1100	517.45	230.08	345.12	59.10	148.25	11.50	57.52
60:40	0.666	8M	1100	517.45	345.12	230.08	59.10	148.25	11.50	57.52
40:60	1.5	10M	1100	517.45	230.08	345.12	59.10	148.25	11.50	57.52
60:40	0.666	10M	1100	517.45	345.12	230.08	59.10	148.25	11.50	57.52
40:60	1.5	12M	1100	517.45	230.08	345.12	59.10	148.25	11.50	57.52
60:40	0.666	12M	1100	517.45	345.12	230.08	59.10	148.25	11.50	57.52

***D.* Casting of Steel Fibre Reinforced GPC:**

The solids constituents of the Geopolymer concrete were dry mixed for about three min. After 24 hr . Preparation of alkaline solution along with additional water and the super plasticizer were added to the dry mix solids. The cylinders were cast in three layers, compacting each layer by uniform tamping and vibrate about 10 seconds. The demoulding of specimens was done after 24 hours and kept for ambient curing. A total of 180 cylindrical specimens, comprising of three identical specimens for each variation were cast.

Table 5 THE VARIATION OF SPLIT TENSILE STRENGTH OF (FRGPC) (Fly Ash 60% :GGBS40%) and (Fly Ash 40% GGBS60%)

Sl. No.	Mix	Molarity (M)	R0			R5			R7			R9			R11		
			7D	28D	7/28 R	7D	28D	7/28 R	7D	28D	7/28 R	7D	28D	7/28 R	7D	28D	7/28 R
1	(Fly Ash 60 % : GGBS 40%)	8M	0.189	0.209	0.904	0.305	0.348	0.876	0.314	0.393	0.798	0.334	0.435	0.767	0.43	0.542	0.817
		10M	0.197	0.216	0.912	0.349	0.383	0.911	0.383	0.416	0.92	0.433	0.494	0.876	0.482	0.57	0.84
		12M	0.216	0.239	0.904	0.373	0.408	0.914	0.415	0.467	0.888	0.483	0.532	0.907	0.562	0.636	0.883
2	(Fly Ash 40%:GGBS 60 %)	8M	0.209	0.221	0.945	0.348	0.441	0.846	0.393	0.422	0.931	0.435	0.494	0.88	0.57	0.614	0.928
		10M	0.219	0.226	0.969	0.368	0.419	0.878	0.405	0.443	0.914	0.454	0.536	0.847	0.581	0.62	0.937
		12M	0.249	0.262	0.95	0.384	0.424	0.905	0.434	0.56	0.775	0.547	0.597	0.916	0.632	0.711	0.888

Split Tensile Strength (f_{ct})

The Geopolymer concrete specimens for Split Tensile Strength were tested on Universal Testing Machine of capacity 1000KN. The maximum loads applied on various specimens were recorded as per IS 516-1956[5]. Three identical specimens of each variation were trial for average SPTS(f_{ct}). A total of 180 cylinders using different Fly ash to GGBS proportions and different molarities were tested after 7 and 28 days of open air curing. The test results are shown in table 5.

B. Result and Discussions

The o difference of SPTS(f_{ct}) of Steel fiber reinforced GPC with increase in volume fraction of Hooked end Steel fibres from 0.5% to 1.1%, for different molarities and GGBS to fly ash proportions is shown in following figures. (Fig.1toFig.4) .

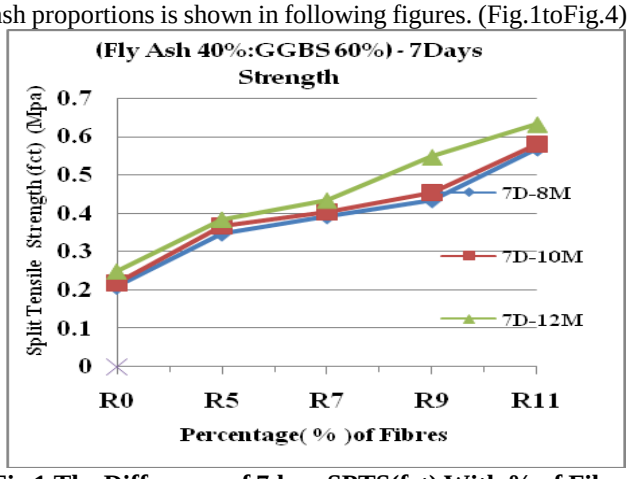

Fig 1.The Difference of 7days SPTS(fct) With % of Fibres (Different Molarity 8M, 10M and 12M)

A.Testing

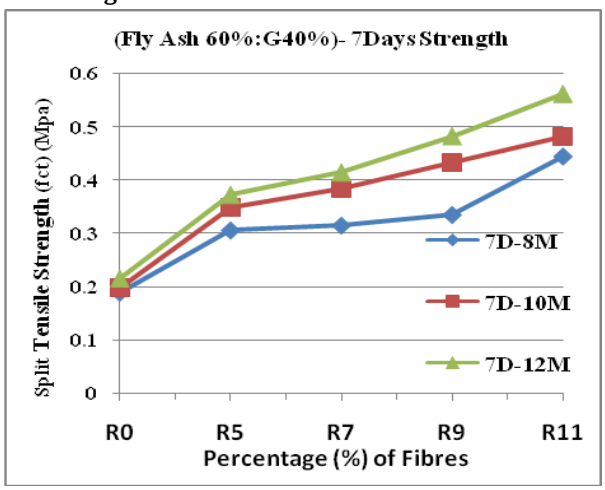

Fig 2 .The Difference of 7days SPTS(fct) With % of Fibres (Different Molarity 8M, 10M and 12M)

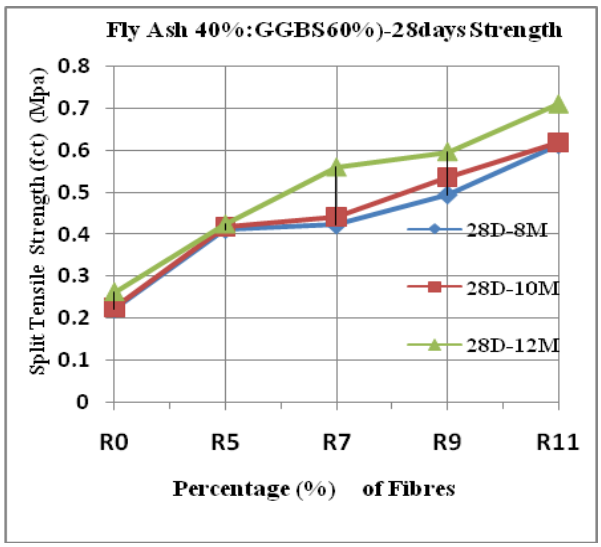

Fig 3.The Difference of 28 days SPTS(fct) With % of Fibres (Different Molarity 8M, 10M and 12M)

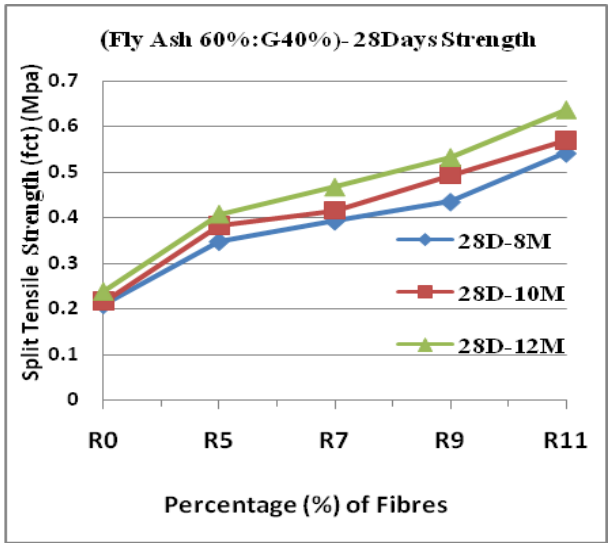

Fig 4.The *Difference* of 28 days SPTS(fct) With % of Fibres (Different Molarity 8M, 10M and 12M)

From figures 1 to 4, it is perceive that the SPTS(f_{ct}) FRGPC increased with increase in the volume fraction of fibres. It is also observed that the SPTS(f_{ct}) of FRGPC increased with increase in molarity of alkaline activator and the increase in the %of GGBS .The increase in Split tensile Strength is observed to be higher up to 0.5% (R_5) volume fraction of fibres.

C.Binder Index (Bi)

The binder index was defined as the product of Molarityof alkaline activator solution and GGBS to (Fly ash + GGBS) ratio.

Binder Index (Bi) = Molarity x [GGBS / (GGBS + Fly ash)]..... *eq (1)*

In the present study the Modified Binder index(B_{mi})[3] has been used to study the combined effect of GGBS, Fly ash, molarity of Alkaline Activator and Fiber effect on SFRGPC.

D. Modified Binder Index (Bmi)

The Modified Binder index is an empirical formula connecting the fibre effect and binder index. Fibre effect is incorporated multiplying the volume fraction of steel fibre and tensile strength of Steel fibre. The Modified Binder Index (B_{mi}) is formulated as follows.

$(B_{mi}) = B_i \times (\sqrt{f_{eff}})$; ------ eq (2)

Where $f_{eff} = f_{tr} \times V_{fr}$ (f_{eff} = Fibre effect) ;

f_{tr} = Tensile Strength of steel fibre;

V_{fr} = Volume fraction of Rigid fibre;

Table 6:
FIBRE INDEX

Sl.No.	% of Fibre	$f_{eff} = f_{tr} \times V_{fr}$	($\sqrt{f_{eff}}$)
1	0	1450x0=0	0
2	0.5	1450x(0.5/100) =7.25	2.692
3	0.7	1450x(0.7/100)=10.15	3.185
4	0.9	1450x(0.9/100)=13.05	3.612
5	1.1	1450x(1.1/100)=15.95	3.993

Table:7
Split Tensile Strength 7daysand 28 Days And Modified Binder Index

S.NO	% GGBS	% Fibres	Molarity (M)	Binder Index (Bi)	Modified Binder Index (B_{mi})	7 Days SPTS (f_{ct}) **(Mpa)**	28Days SPTS (f_{ct}) **(Mpa)**
1	40%	0	8	3.2	0	0.189	0.209
2	40%	0.5	8	3.2	8.614	0.305	0.348
3	40%	0.7	8	3.2	10.19	0.314	0.393
4	40%	0.9	8	3.2	11.55	0.334	0.435
5	40%	1.1	8	3.2	12.77	0.443	0.57
6	60%	0	8	4.8	0	0.209	0.221
7	60%	0.5	8	4.8	12.92	0.348	0.411
8	60%	0.7	8	4.8	15.28	0.393	0.422
9	60%	0.9	8	4.8	17.33	0.435	0.494
10	60%	1.1	8	4.8	19.16	0.57	0.614
11	40%	0	10	4	0	0.197	0.216
12	40%	0.5	10	4	10.76	0.349	0.383
13	40%	0.7	10	4	12.74	0.383	0.416
14	40%	0.9	10	4	14.44	0.433	0.494
15	40%	1.1	10	4	15.97	0.482	0.542
16	60%	0	10	6	0	0.219	0.226
17	60%	0.5	10	6	16.15	0.368	0.419
18	60%	0.7	10	6	19.11	0.405	0.443
19	60%	0.9	10	6	21.67	0.454	0.536
20	60%	1.1	10	6	23.95	0.581	0.62
21	40%	0	12	4.8	0	0.216	0.239

22	40%	0.5	12	4.8	12.92	0.373	0.408
23	40%	0.7	12	4.8	15.28	0.415	0.467
24	40%	0.9	12	4.8	17.33	0.483	0.532
25	40%	1.1	12	4.8	19.16	0.562	0.636
26	60%	0	12	7.2	0	0.249	0.262
27	60%	0.5	12	7.2	19.38	0.384	0.424
28	60%	0.7	12	7.2	22.93	0.434	0.56
29	60%	0.9	12	7.2	26	0.547	0.597
30	60%	1.1	12	7.2	28.74	0.632	0.711

The values of 7 and 28 days SPTS(f_{ct}) and Modified Binder Index (B_{mi}) were ploted as shown in fig.9

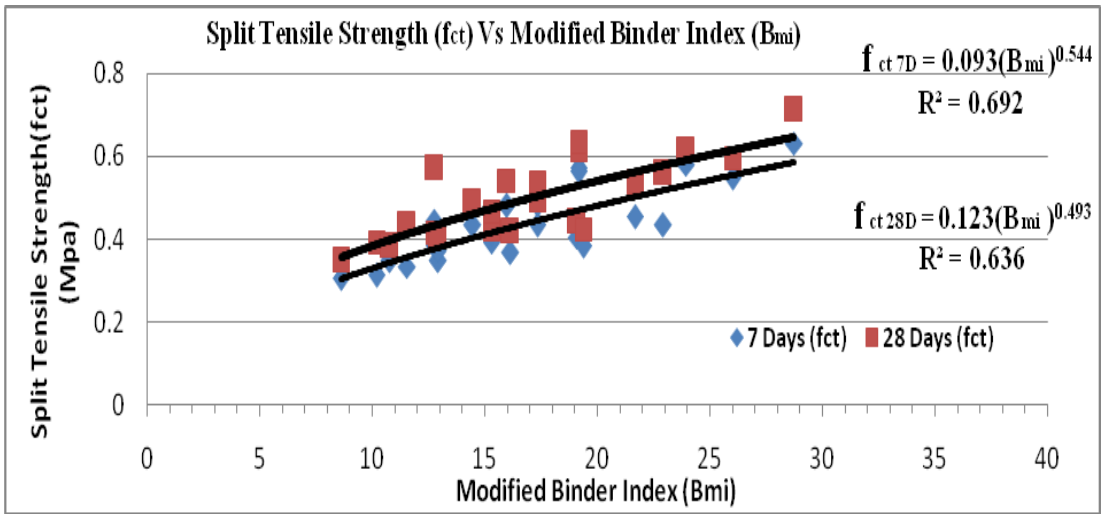

Fig.9. Effect of Modified Binder Index (B_{mi}) on Split Tensile Strength (f_{ct}) of Fibre Reinforced Geopolymer Concrete

From fig.9 it is observed that the compressive strength and Modified Binder Index (B_{mi}) have a non linear relation

It is observed that the Modified Binder Index combined the effects of Binder index (B_i) and Fibre effect (f_{eff}) reasonably well in predicting the Split Tensile Strength (f_{ct}). The following best fit curve equations (3) and (4) give the relation between the 7days and 28days Split Tensile Strength (f_{ct}) with Modified Binder Index (B_{mi}) along with the correlation coefficient (R^2).

$$f_{ck7} = 0.093\,(B_{mi})^{0.54} \text{-} R^2 = 0.692 \quad \text{-- eq (3)}$$

$$f_{ck28} = 0.123\,(B_{mi})^{0.4} \text{---} R^2 = 0.6\ldots. \quad \text{eq (4)}$$

III. CONCLUSIONS

1. The 7days and 28 days Split Tensile Strength(SPTS) (f_{ct}) of Steel Fibre Reinforced Geopolymer Concrete increased with increase in Molarity of Alkaline Activator.
2. The Split Tensile Strength(SPTS) (f_{ct}) of Steel Fibre Reinforced Geopolymer Concrete is higher for Fly Ash to GGBS proportions (40:60) compared to (60:40).
3. The Split tensile Strength (SPTS) of FRGPC increased with increase in the % of Fibres from 0.5% to 1.1%.
4. The increase in Split Tensile Strength (SPTS) of FRGPC is higher up to 0.5% volume fractions of fibres.
5. There is a non linear relation between Modified Binder Index (B_{mi}) and Split Tensile Strength (SPTS) (f_{ct}) for Steel Fibre Reinforced Geopolymer Concrete.
6. The Modified Binder Index (B_{mi}) which combines the effect of Molarity, GGBS to Fly Ash ratio and Fibre effect give good prediction of Split Tensile Strength(SPTS) (f_{ct}) of Fibre Reinforced Geopolymer Concrete (FRGPC).

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