ABRASION RESISTANCE OF POLYPROPYLENE FIBER REINFORCED GEOPOLYMER CONCRETE.

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Abstract: Geopolymer are manufactured by activation of alkaline liquids, materials such as Fly ash, GGBS etc. The abrasion resistance is an important objective termed under long term durability properties of concrete. The disintegration of concrete surfaces originates in various types of wear such as cavitations and erosion & abrasion when exposed to different temperatures. Abrasion resistance is a type of durability test conducted for circular moulds it can be described as rubbing or scraping, of objects present on the concrete surface[6][10]. This is a type of scraping that is observed in highway pavements, building floors, or other surfaces like airport runways which friction forces are applied due to relative movemement between the wearing objects and surfaces. Concrete abrasion resistance is majorly impacted by a number of factors like strength of concrete, physical, properties of aggregates, which are used. A large number of previous literature have resulted that concrete abrasion resistance depends upon the compressive strength of the concrete. The factors such as alkaline liquid to binder ratio, sodium silicate to sodium hydroxide ratio and quality of aggregates which affect the strength of concrete, therefore, should also influence abrasion resistance. In present experimental work the specimens for abrasion resistance are casted by incorporating polypropylene fibers of 12mm length. The test results showed that the fiber reinforced geopolymeric composites had better performance characteristics than plane geopolymeric materials.

Key words- cement concrete, geopolymer, abrasion, compressive strength, polypropylene fibers.

I INTRODUCTION

The development of infrastructure using special concretes has been growing from past few decades. the demand and requirement for geopolymer concrete as construction material is been increasing in present trends .The reason for choosing special concrete is to minimize the Production of Ordinary Portland cement which is composed of highly harmful energy containing pollutant i.e. is CO_2 which leads to deterioration of environment.**[2]** The amount of non renewable natural resources such as carbon dioxide (CO_2) is liberated during production of one ton of Portland cement .The environmental effects Concerned with production of Portland cement, demands for a need of developing alternate materials replacement of cement which is most widely used. [The development of fly ash and slag based geopolymer concrete is indexed as eco friendly Concrete which exhibits less harmful pollutants the amount of CO_2 .Liberated in geopolymer concrete production is negligible. The wide availability of byproducts such as fly-ash produced by thermal power plants gives a benefit that it can be used as binder material. Davidovits (1988) had suggested that the alkaline Solutions can be used as it reacts with the Silicon (Si) & Aluminum (Al) in byproduct material such as Fly ash, Ground granulated blast furnace slag (GGBS) for production of desired grade of fiber reinforced geopolymer concrete **[1].** Geopolymer concrete do not demand any Portland cement in its production. However the binder produced by the chemical reaction of alkaline solutions with a existing material which is rich in Silica & Alumina results in formation of geopolymer past which binds the loose coarse & fine aggregates & other existing materials together to form geopolymer concrete paste.**[6]** The mechanical characteristics of fiber reinforced geopolymer concrete is carried out using the methods available in concrete technology such as ,compressive strength ,split tensile strength ,flexural strength. Geopolymer concrete composites are good construction materials regarding strength & durability considerations. Also bond strength of Geopolymer concrete with rebar is seemed to be higher than cement concrete.**[2][3][4]** The water absorption of fly ash geopolymer is less than 4% which is low Water to geopolymer solid ratio is the most active parameter to increase strength, & to decrease the water absorption. Fiber reinforced concrete is new composite material in which fibers are introduced in geopolymer matrix as reinforcement to improve the tensile properties and to arrest the cracks.

II MATERIALS

2.1 Coarse Aggregate:

Locally available coarse aggregate of 20mm size possessing good toughness sourced from crushed granite has been used in production of geopolymer concrete.

2.2 Fine Aggregate:

Locally available river sand sieved with 4.75mm was used in production of GPC.

Table.1 Properties of Aggregates:

Property	**Coarse Aggregate**	**Fine Aggregate**
Specific gravity	2.86	2.59
Water absorption	0.35%	0.9%
Fineness modulus	6.95	2.42
Bulk density Kg/m^3	1660	1585
Source	Crushed granite stone	Sea Shore

2.3 Sodium Hydroxide (NaOH):

Sodium Hydroxide pellets of 98% purity was used in manufacturing of geopolymer concrete which acts a major role in geopolymerization it is been used as alkaline activators which has a capability to bind the aggregates together to form desired geopolymer concrete paste.

2.4 Sodium Silicate (Na_2SiO_3):

Sodium Silicate in the form of gel it enhances the working ability of geopolymer concrete the mixture of alkaline solution i.e. Sodium hydroxide & sodium silicate solution together results in production geopolymer concrete

Table.2 Properties of Sodium Silicate-

Specific gravity	1.65
Molar mass	112.06 gram/mol
Na_2O	12.80%
SiO_2	28.46%
Water (by mass)	58.70%
Weight ratio (SiO_2 to Na_2O)	2.5
Molarity ratio	0.94

Table.3 Properties of Sodium Hydroxide-

Molar mass	40 gr/mol
Appearance	White
Density	2.25 gr/cc
Melting point	315^{o}C
Boiling point	1380^{0}C
Amount of heat liberated when dissolved in water	268 cal/gr

2.5 Super plasticizer SP430:

Conplast SP430 (NE) is supplied as a brown liquid instantly dispersible in water. Conplast SP430 (NE) has been specially formulated to give high water reductions up to 20- 25% without loss of workability or to produce high quality concrete of higher grades by reducing the permeability complies**:** with **IS 9103:1999** and **BS:5075 Part 3 and ASTM-C-494** Type 'F' as a high range water reducing admixture and Type G at high dosage.

Table.4 Properties of Conplast SP430:

Specific gravity	1.20-1.22
color	brown
chloride content	nil
air entrainment	1.50%
max dosage	0.6-1.5 liter for 100 kgs of cement

2.6 Fly-Ash:

Low calcium based Class F fly ash is obtained from Navyug Plant located in patancheru Hyderabad is used as binder in equal proportions in geopolymer concrete mix.

2.7 GGBS:

Ground granulated blast furnace slag is obtained from kakatiya power plant located in Warangal.

Table.5 Chemical Properties of fly-ash & GGBS.

Particulars	Class F fly ash	GGBS
% Silica(SiO_2)	65.6	30.61
% Alumina(Al_2O_3)	28.0	16.24
% Iron Oxide(Fe_2O_3)	3.0	0.584
% Lime (CaO)	**1.0**	**34.48**
% Magnesia (MgO)	**1.0**	**6.79**
% Titanium Oxide (TiO_2)	**0.5**	**-**
% Sulphur Trioxide (SO_3)	**0.2**	**1.85**
Loss on Ignition	**0.29**	**2.1**

Table.6 Physical Properties of Fly-ash & GGBS.

Property	Fly-ash	GGBS
Specific gravity	2.21	2.82
bulk density Kg/m^3	540-860	100-1200
appearance	grey	Grayish white
Particle size	30 microns	25 microns
Fineness(m^2/kg)	360	400

2.8 Polypropylene fibers-

Polypropylene fiber, a synthetic carbon polymer, is produced as continuous monofilaments, with circular cross section. Polypropylene fiber 0.0075 diameter, 12 mm length, and aspect ratio (L/D) is 1600. 0.91 g/cm^3 density were used. Polypropylene fibers are tough but with low tensile strength and modulus of elasticity. The role of polypropylene fibers in geopolymer concrete is to reduce crack width. These type of fibers are usually recommended for Plastic shrinkage reinforcement in concrete. It helps in uniform distribution throughout the concrete mix and gives excellent finish ability.

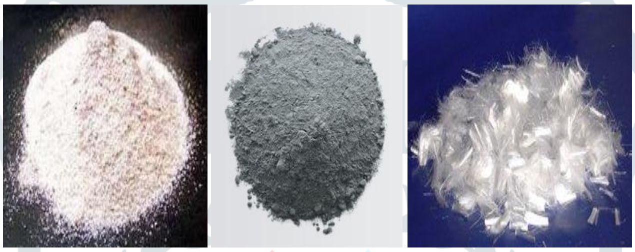

Figure.1 GGBS FLY-ASH PPF

Table.7 Properties of Polypropylene Fibers:

Property	›ropylene fibers
Type	Macro filament
Cut length	12mm
Diameter	0.0045
Tensile Strength	550-700 MPa
Density	0.91 gm/cm^3
color	white
ıgation at failure	21%
Modulus of elasticity (GN/m^2)	3.5-6.8
Electric conductivity	low

III EXPERIMENTAL PROCEDURE:

Abrasion resistance is confined with C1138- 1997, standard test method for Abrasion resistance of concrete which was indexed by the ASTM Committee .The abrasion machine is shown in fig 2. This test method involves a strategy in obtaining the resistance of OPC & GPC specimens subjected to abrasion with water which progresses the abrasive action performed on specimens.. The control specimens without inclusion of fibers the OPC specimen was cured in curing tank and GPC specimen was curing in oven. The abrasion resistance test procedure exhibits the behavior of wearing action in water, containing steel balls of different sizes that produce motion through which the friction is produced. **[3]** The abrasion apparatus consists of drilling machine with a chuck capable of fixing and rotating the agitation paddle under test condition at a speed of 1100-1200 rpm and the test container is attached with a pipe having internal diameter of 305 mm and height 460 mm. It is adjusted with water tight base and in number of five - six blocks of 25 mm screws are fixed on the base of test container. **[5]** The agitation paddle is made up of steel according to ASTM C1138 M-05. The nominal size and quantity of steel balls used are 1.0, 0.75, 0.50 inches and 10, 35 and 25. These balls have a fine texture without any damages.**[7]** The specimens which had to be tested are introduced into the container with the surface to be tested opposing upside and in normal to the direction of drill shaft and the center of the specimen then upper part of the agitation paddle included in drill press. A rotating knob is attached to adjacent side of machine by which the surface of the specimen makes the paddle rotated at a required speed for every 6-12 hrs of duration. After removing the specimen from the test container, weight of the abrasion specimen in air and water were recorded. Testing totaling 72 hrs exhibits excellent abrasive properties.

3.1Mix design for Polypropylene fiber reinforced geopolymer concrete:

The common variance between Geopolymer concrete and ordinary Portland concrete is the binder. The Al and Si oxides in low calcium fly ash with react the alkaline solution to form geopolymer paste that binds the coarse aggregate, fine aggregate and other un-reacted material together to form geopolymer concrete paste in OPC the aggregate occupied **70-80%** of the total mass of concrete. So the assumed aggregate percentage was **78%.[4]**The ratio of binder i.e. fly-ash, GGBS to alkaline solution ratios is assumed **to 0.40**. The ratio of sodium silicate to sodium hydroxide solution was taken **as 2.5** for all the mixtures because the sodium silicate is cheaper than the sodium hydroxide pellets based solution. The molarity concentration of NaOH solution was taken as **12M** for all consecutive mixes. The water reducer used was naphthalene based super plasticizer Forsec SP 430(8). Extra water content was added according to demand for settling of geopolymer concrete paste**.[2]**

Figure 2. Abrasion apparatus

Table.8. 3.2 Mix Proportions for Abrasion Moulds

Grade of concrete	**CC**	**FRCC**	**GPC**	**FRGPC**
Cement (kg/m^3)	400	400	377.18	377.18
Fine Aggregate (kg/m^3)	660	660	655.2	655.2
Coarse Aggregate (kg/m^3)	1168.3	1168.3	1216.8	1216.8
Water (kg/m3)	160	140	150	120
S.P (kg/m^3)	2	2	3.5	3.5
W/C ratio	0.45	0.45	0.4	0.4
polypropylene fibers	0	0.02%	0	0.02 %

CC: Cement concrete,
FRCC: fiber reinforced cement concrete,
GPC: Geopolymer Concrete,
FRGPC: fiber reinforced GPC.

(a) CC-40 FRCC-40 (b)

Fig.3 (a) & (b) Abrasion Specimens CC & FRCC before & after wearing action

GPC 40 (c) FRGPC 40 (d)

Fig.3 (c) & (d) Abrasion Specimens GPC & FRGPC before & after wearing action.

IV RESULTS AND DISCUSSIONS

6.2 Compressive Strength:

Compressive strength is the most important property of concrete. The specimens were tested on 2000kN As **per IS: 10086-1982**. The geopolymer concrete mixes were formulated in such a way that the fibers were added partially with And Fly and GGBS were included in the mix at equal volumes. The incorporation of polypropylene fibers as it yielded the highest strength in tests.**[10]** The geopolymer Concrete with the addition **of 0.02%** of polypropylene fibers yields the highest strength and the control mix without the addition of fibers resulted in relatively lower strengths which are still above the desired 40MPa.The increase in the compressive strength could be attributed to the fibrous nature of polypropylene fibers. The compressive strengths of all cubical specimens of 150x150x150mm were evaluated at the end of 7 and 28 days. As shown in table **[9].**

Table.9 Compressive Strength Results

Mix id	**7 days**	**28 days**
M0 (0%)	26.11	43.95
M1 (0.01%)	32.32	51.32
M2 (0.02%)	**37.52**	**55.8**
M3 (0.03%)	34.5	48.25
M4 (0.04%)	28.15	39.8

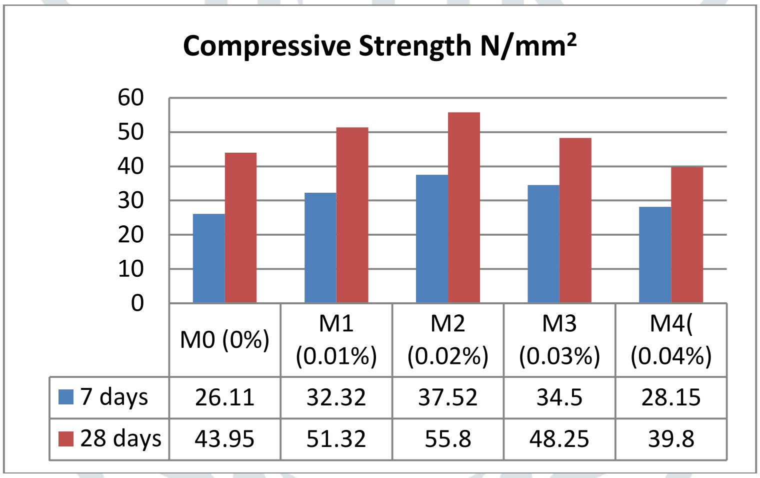

Figure.4 Compressive Strength Variations

6.3 Abrasion Resistance:

Abrasion resistance refers to the ability of materials and structures to withstand the wearing activity. It is a strategy of erosion or rubbing away the contact surface of concrete by means of friction. Abrasion resistance resists the wear caused due to mechanical action. the resistant materials are useful for both at when materials are at motion and static condition. The Moto of abrasion resistance of concrete is to determine the toughness of aggregate and strength of aggregate bonded together in the concrete matrix. Abrasion resistance can be controlled by usage of surface hardeners, lubricants covering the material with coating agents, sliding and impinged or resurfacing the concrete elements.**[8]** The nature of abrasion depends on Hardness of Material's hardness, Velocity and mass of the particles in motion. However, the use of polypropylene and basalt fibers can improve the flexural ductility, toughness, split tensile strength, and long-term durability of geopolymer concrete Fiber reinforced composites are defined as composites incorporated with short, & discontinuous fibers .In the present experimental study for evaluating the abrasion resistance of fiber reinforced geopolymer concrete . The Diameter of 150*150*150 mm cubical specimens was used to test compressive strength. Dia of 300 mm × 100 mm circular discs were used for water abrasion test. The test was performed with respect to confined ASTM code no. 1138 specimens subjected to heating curing at 60°c for 24hrs and then left for ambient condition for 90days.

The Abrasion loss can be calculated as follows:

Volume of the specimen at any time can be computed using

$V\ V_t = (W_{air} - W_{water}) / G_w$

where W_{air} is the mass of the specimen in air at the desired time in kg, W_{water} is apparent mass of the specimen in water at the desired time in kg, G_w is the unit weight of water, kg/m^3

The volume of concrete lost at the end of any time increment of testing as follows:

$VL_t = V_i - V_t$

Where VL_t = Volume of material lost by abrasion at the end of the test increment in question, m^3.

V = volume of specimen before testing, m^3 and i

V_t = volume of the specimen at the end of the test increment in question, m^3

Table.9 Abrasion results for CC specimen without fibers [a]

duration	mass Air	mass water	Vt	VLt	Avg. depth of abrasion(mm)
0	15.655	12.102	3.553	-	-
12	15.089	11.786	3.303	0.25	3.053
24	14.876	11.596	3.28	0.023	3.257
36	14.542	11.429	3.113	0.167	2.946
48	14.189	11.219	2.97	0.143	2.827
60	13.986	11.142	2.844	0.126	2.718
72	13.702	10.968	2.734	0.11	2.624
					17.425

Table.10 Abrasion results for CC specimen with fibers [b]

duration	mass Air	mass water	Vt	VLt	Avg. depth of abrasion(mm)
0	14.925	11.952	2.973	-	-
12	14.488	11.745	2.743	0.23	2.513
24	14.213	11.686	2.527	0.216	2.311
36	13.932	11.598	2.334	0.193	2.141
48	13.633	11.485	2.148	0.186	1.962
60	13.302	11.332	1.97	0.178	1.792
72	13.002	11.168	1.834	0.136	1.698
					12.417

Table.11 Abrasion results for GPC specimen without fibers [c]

duration	mass Air	mass water	Vt	VLt	Avg. depth of abrasion(mm)
0	15.98	11.862	4.118	-	-
12	14.81	11.486	3.324	0.794	2.53
24	14.486	11.296	3.19	0.134	3.056
36	14.142	11.118	3.024	0.166	2.858
48	13.789	10.909	2.88	0.144	2.736
60	13.486	10.742	2.744	0.136	2.608
72	13	10.568	2.432	0.312	2.12
					15.908

Table.12 Abrasion results for GPC specimen with fibers [d]

duration	mass Air	mass water	Vt	VLt	Avg. depth of abrasion(mm)
0	13.825	11.852	1.973	-	-
12	13.428	11.645	1.783	0.19	1.593
24	13.176	11.566	1.61	0.173	1.437

36	12.942	11.498	1.444	0.166	1.278
48	12.623	11.335	1.288	0.156	1.132
60	12.482	11.332	1.15	0.138	1.012
72	12.202	11.168	1.034	0.116	0.918
					7.37

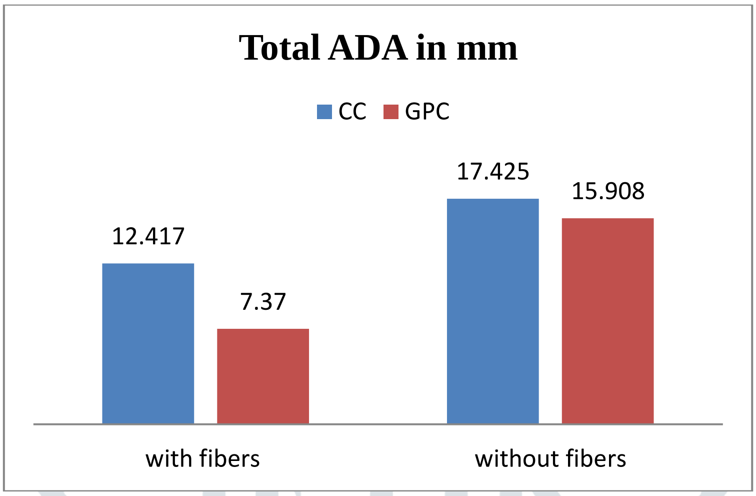

Figure.4 Total abrasion Variations

VII CONCLUSIONS

The final experimental results have shown that the incorporations of polypropylene fibers results in improving the abrasion resistance is more in geopolymer concrete than cement concrete . In this study, it was found that the most reliable that optimal condition was obtained with the incorporation of polypropylene fibers at **0.02 %** by volume. The fibers plays a significant role in imparting the abrasion resistance to geopolymer concrete in present investigation comparative study abrasion resistance for optimal mix was carried out. Cement concrete with fibers without fibers and geopolymer concrete with and without fibers were evaluated .the optimal condition was obtained for FRGPC i.**e. 7.37mm** wear for normal GPC specimen was obtained as **16.895mm**. for cement concrete without fibers as **17.425mm** and with fibers as **12.417mm** polypropylene fibers of 12mm plays a major role in arresting the cracks appeared during the wearing action of steel balls in apparatus The abrasion resistance, with the 12mm fibers in geopolymer concrete has proven to be more reliable than cement concrete specimens. The experimental analysis shows that geopolymer concrete is more efficient than cement concrete against abrasion.

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