Experimental Investigation on Properties of Geopolimer Concrete Paver Block with the Inclusion of Polypropylene Fibers

Rismy Muhammed, Deepthy Varkey

Abstract— This paper presents results of an experimental program to determine mechanical properties of Polypropylene Fibre Reinforced Geopolymer Concrete (PFRGPC) pavers which contains fly ash, alkaline liquids, fine & course aggregates & polypropylene fibers. Alkaline liquids to fly ash ratio were fixed as 0.35 with 100% replacement of ordinary Portland cement (OPC) by fly ash. Alkaline liquid consists of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) solutions. The ratio of Sodium hydroxide solution to Sodium silicate solution was fixed to 2.50. Polypropylene fibers Recrone 3S were added to the mix in volume of concrete. In this paper represent the results of the geopolymer paver block with the mix proportion of M 40 grade and polypropylene fibre with the different percentage rate. Test results indicate that by the addition of PPF by 0.2% it gives good results for abrasion resistance and flexural strength at 28 days respectively. Based on the test results, it was observed that the PFRGPC have relatively higher strength than GPC & OPC pavers.

Index Terms— Polypropylene Fiber, Compressive strength, Abrasion resistance, Flexural strength, Water absorption, Density, Weight loss in acid solution, Weight loss in acid solution.

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1 INTRODUCTION

Ordinary Portland Cement (OPC) is conventionally used as the primary binder to produce concrete. But the amount of carbon dioxide released during the manufacture of OPC due to the calcinations of lime stone and combustion of fossil fuel is in the order of 600 kg for every ton of OPC produced. In addition, the extent of energy requires to produce OPC is only next to steel and aluminum. On the other hand, the abundant availability of fly ash world wide creates opportunity to utilize as substitute for OPC to manufacture concrete. Binders could be produced by polymeric reaction of alkali liquids with the silicon and the aluminum in the source materials such as fly ash and rice husk ash and these binders are termed as Geopolymer. In Geopolymer Concrete, fly ash and aggregates are mixed with alkaline liquids such as a combination of Sodium Silicate and Sodium Hydroxide. Large volume of fly ash is being produced by thermal power stations and part of the fly ash produced is used in concrete industry, low laying area fill, roads and embankment, brick manufacturing etc. The balance amount of fly ash is being stored in fly ash ponds. Use of fly ash as a value added material as in the case of geopolymer concrete, reduces the consumption of cement. Reduction of cement usage will reduce the production of cement which in turn cut the CO2 emissions.

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In this project Interlocking pavers are manufactured geopolymer product that is individually placed as per the requirement. Polypropylene fiber is used in this construction as a secondary reinforcement which arrests cracks, increases resistance to impact/abrasion and greatly improves quality of construction.

Geopolymer concrete can be manufactured by adopting the conventional techniques used in the manufacture of Portland cement concrete. In this experiments:

1) The fly ash and the aggregates were first mixed together dry in pan mixer for about three minutes.
2) The alkaline liquid was mixed and the extra water, if any.
3) The liquid component of the mixture was then added to the dry materials and the mixing continued usually for another four minutes.
4) The fresh concrete could be handled up to 120 minutes without any sign of setting and without any degradation in the compressive strength.
5) The fresh concrete was cast and compacted by the usual methods used in the case of Portland cement concrete.
6) Fresh fly ash-based geopolymer concrete was usually cohesive.
7) The workability of the fresh concrete was measured by means of the conventional slump test.

Curing: Heat-curing of low-calcium fly ash-based geopolymer concrete is generally recommended. Both curing time and curing temperature influence the compressive strength of geopolymer concrete.

After casting the specimens:

1) Specimens were kept in rest period in room temperature for 2 days. The term 'Rest Period' was coined to indicate the time taken from the completion of casting of test specimen to the start of curing at an elevated temperature.
2) The geopolymer concrete was demoulded and then placed in an autoclave for steam curing for 24 hours at a temperature of 60oC.
3) The cubes were then allowed to cool in room temperature for 24 hours.

Advantages of Fibre Geopolymer concrete:

- The Fly ash is an easily available material and Compared to cement it is of low capital cost.
- The chemical compounds used are easily available in the local market.
- The Fibre geopolymer concrete is a green concrete since there is no CO_2 emission.

1.1 Objective of Study

The objectives of the present study are:

- To study the effect on the properties of paver block by adding the different percentage of polypropylene fibres.
- To study the effect on abrasion resistance and Flexural Strength by adding polypropylene fibre in paver blocks.
- To increase the life span of paver block.

1.2 Literature Review

Radhakrishna et.al (2015) [1] has determined geo-polymer masonry as sustainable Building material by complete elimination of cement by using fly ash, blast furnace slag as binders and River sand replaced with m-sand and other recycled aggregates. Industrial by-products class F fly ash and slag were used as binders. They were cured in open air by conserving water. Venugopal K et.al (2015) [2] has studied geo-polymer masonry with complete elimination of cement is achieved without compromising the strength and durability. This study use of marginal materials fly ash, blast furnace slag as binders. River sand can be replaced with M-sand as fine aggregates. Tejas.Ostwal1.et.al.(2014).[3]: In this study geo-polymer blocks prepared by without the use of cement. The materials used are Fly ash (Class F), Ground granulated blast furnace slag (GGBS), Quarry dust and sand. The mass reduction of GPC block due to hydrochloric acid resistance at the end of 84 days is found to be 0.72%. Chandan Kumar1 et.al (2014)[4] In this paper studied higher concentration of sodium hydroxide solution results in higher compressive strength of fly ash-based geopolymer concrete. As the curing temperature in the range of 40˚C to 100 ˚C increases, the compressive strength of fly ash-based geopolymer concrete also increases and increase in strength beyond 24 hours is not significant. Subhash.V.Patankar et.al (2014)[5] : This paper presented the effect of concentration of sodium hydroxide, temperature, and duration of oven heating on compressive strength. Kishan L.J and Radhakrishna (2013) [6] :This paper presents comparative study of cement concrete and geo-polymer masonry blocks. S.D. Muduli et.al (2013) [7] : The goal of this study is to provide effect of NaOH concentration in manufacture of geo-polymer fly ash building brick. The raw mix consisting of 87% of fly ash and alkaline activator had been used. Finally, it is found that the geo-polymerization process is a green technology as it aims for 100% utilization of waste materials.

Research results have shown the following:

- Higher concentration (in terms of molar) of sodium hydroxide solution results in higher compressive strength of geopolymer concrete.
- Higher ratio of sodium silicate solution-to-sodium hydroxide solution ratio by mass, results in higher compressive strength of geopolymer concrete.
- The slump value of the fresh geopolymer concrete increases when the water content of the mixture increases. Superplasticizers may assist in improving workability.
- As the H2O-to-Na2O molar ratio increases, the compressive strength of geopolymer concrete decreases.

1.3 Experimental Program

The experimental program consisted of the following steps:

- Preliminary investigation of materials used.
- Development of mixed design for OPC paver blocks based on IS 10262:2009 confirming to the standards of IS 15658:2006 and hence to arrive at the base proportion.
- Development of GPC paver blocks of the above base proportions with different strengths of activators and steam curing at 60°C for 24 hours
- Studies on mechanical and physical properties on paver blocks on 28th day as per IS 15658:2006
- The base proportion was 1:1.2:2 with a water to cement ratio of 0.35 using codal provisions. In geopolymer paver blocks, cement was replaced by fly ash and water is replaced by activator alkaline solutions.
- Polypropylene fibers Recrone 3S were added to the mix in volume of concrete with the different percentage rate. In layers contain the polypropylene fiber (PPF) of 0.1%, 0.2%, 0.3%, 0.4%, and 0.5% in each mixes proportion by

weight. Tests were determined at 3 day, 7th day and 28 days.

Sl.No	Mix	Concrete Mix Propotion
1	OPC	M40 Conventional concrete paver block
2	GPC	M40 Geopolymer concrete paver block
3	GPC1	GPC + 0.1% addition of polypropylene fiber (PPF)
4	GPC2	GPC + 0.2% addition of polypropylene fiber (PPF)
5	GPC3	GPC + 0.3% addition of polypropylene fiber (PPF)
6	GPC4	GPC + 0.4% addition of polypropylene fiber (PPF)
7	GPC5	GPC + 0.5% addition of polypropylene fiber (PPF)

PPF: Polypropylene Fibre

1.4 Development of geopolymer concrete mixes and casting

Based on base proportion of OPC mix as show in table I, the geopolymer mix of fly ash, fine aggregate and course aggregate was taken. Ratio of alkaline liquid to fly ash was taken as 0.35. Ratio of sodium silicate to sodium hydroxide was taken as 2.5. The concentration of sodium hydroxide.was.10M.

Table 1.Base proportions for geopolymer mix

Sl No	Specimen	Cement (kg/m^3)	Flyash (kg/m^3)	FA (kg/m^3)	CA (kg/m^3)	Water (kg/m^3)	Na_2SiO_3 Solution (kg/m^3)	Naoh Solution (kg/m^3)	%of PPF
1	OPC	530	-	636	1060	185.5	-	-	-
2	GPC	-	530	636	1060	-	132.5	53	0%
3	GPC1	-	530	636	1060	-	132.5	53	0.1%
4	GPC2	-	530	636	1060	-	132.5	53	0.2%
5	GPC3	-	530	636	1060	-	132.5	53	0.3%
6	GPC4		530	636	1060	-	132.5	53	0.4%
7	GPC5		530	636	1060	-	132.5	53	0.5%

2 MATERIALS AND PROPERTIES

1.Cement :The cement used for the study is Ordinary Portland cement (OPC- 53 grade) conforming to IS: 12269-1987. The manufacture of the cement is Dalmiya. Properties of Ordinary Portland cement is tabulated in table 5.1.

Table 5.1.Properties of OPC -53 Grade

Property	Value
Standard consistency	31%
Specific gravity	3.17
Initial setting time	60 minutes
Final setting time	450 minutes

2..SodiumHydroxide:Commercially available sodium hydroxide flakes with a purity of 98% were used.

3.Sodium Silicate : Commercially available sodium silicate solution supplied to the industries was used.

4.Flyash : Fly ash for the experiment was obtained from Local suppliers. Low calcium class F flyash of Specific gravity 2.35 (Passing 45µ) was used

5. Polypropelyne Fiber (Recrone 3S) :

PPF for the experiment was obtained from Local suppliers

No	PROPERTY	VALUE
1	Cross Section	Triangular
2	Diameter	0.03-0.04 mm
3	Cut Length	6 & 12 mm
4	Elongation	>100 %
5	Moisture Flat	<1 %
6	Melting Point	150-160 °C
7	Specific Gravity	0.9 Cc/gm
8	Tensile Strength	140-690 N/mm^2
9	Elastic Modulus	3450-4825 N/mm^2

Source: Manufactured by Reliance Industries Limited, Hoshiarpur Manufacturing Division, Dharmashala Road, Punjab, India.

6.Coarse Aggregate (CA): Crushed stone from granite was used as course aggregate. Material passing 10mm sieve and retained on 4.75mm were used. Specific gravity was 2.7.

7. Fine Aggregate (FA): Quarry sand was used as fine aggregate. Material passing 4.75mm sieve and retained on 75 µm sieve was used. And specific gravity was 2.67.

8.Water: Tap water was used for mixing and curing. It was free from deleterious materials confirming to IS 456-2006 [29] and IS 3025-1964[30]specification

3 RESULTS AND DISCUSSIONS

3.1 Hardened properties

3.1.1.Compressive strength

Table 2: Compressive Strength

Mix Designation	3 days Compressive strength	7 days Compressive strength	28 days Compressive strength
OPC	35.32	41.5	49.32
GPC	49.2	49.66	50.1
GPC1	49.9	50.51	51.05
GPC2	50.9	52.38	53.12
GPC3	48.67	50.9	52.3
GPC4	48.5	50.2	50.2
GPC5	46.32	48.65	49.99

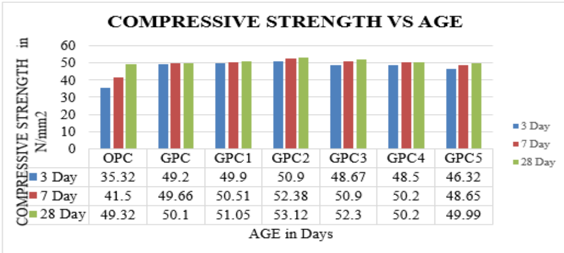

Fig. 1. Compressive strength Vs age graph.

3.1.2 Abrasion Resistance

Table 3. Abrasion resistance test at 28 days

Mix Designation	28 day abrasion value(mm)
OPC	2.10
GPC	1.85
GPC1	1.80
GPC2	1.72
GPC3	1.75
GPC4	1.76
GPC5	1.79

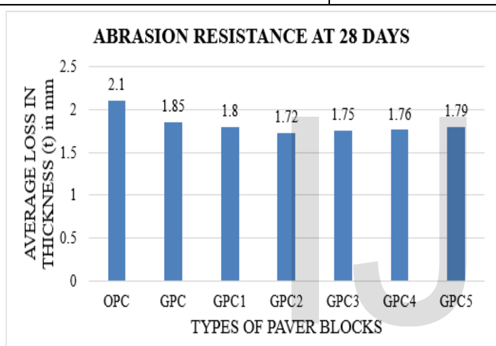

Fig. 2.. Abrasion resistance at 28 days

3.1.3. Flexural strength

Table 4. Flexural strength test at 28 days

Mix Designation	28 day flexure strength(N/ mm^2)
OPC	10.63
GPC	12.34
GPC1	14.21
GPC2	14.43
GPC3	14.75
GPC4	14.80
GPC5	14.72

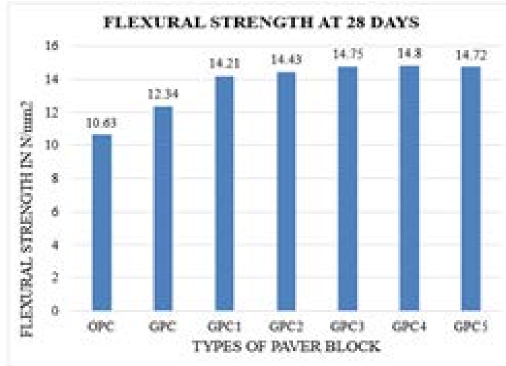

Fig. 3. Flexural strength at 28 days graph

3.1.4. Water absorption

Table 5. water absorption test at 24 hours

Mix Designation	24 hours water absorption (%)
OPC	2.6
GPC	2.4
GPC1	2.1
GPC2	2.0
GPC3	2.2
GPC4	2.3
GPC5	2.5

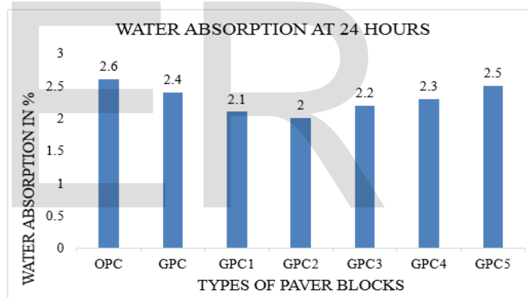

Fig. 4. Water absorption at 24 hours

3.1.5 Density

Table 6. Density

Mix Designation	Density (kg/m^3)
OPC	2503
GPC	2524
GPC1	2536
GPC2	2548
GPC3	2554
GPC4	2556
GPC5	2558

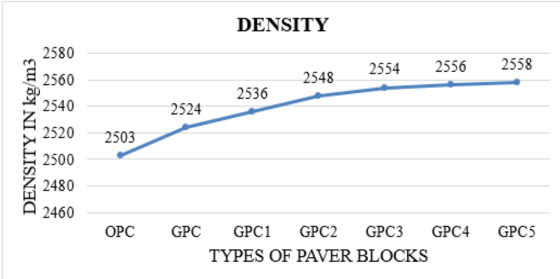

Fig. 5. Density variation of mixes

3.1.6 . Weight loss in acid solution

Table 7. Weight loss in acid solution

Mix Designation	30 day weight loss in acid solution (H_2SO_4) (%)
OPC	3.01
GPC	1.86
GPC1	1.80
GPC2	1.73
GPC3	1.65
GPC4	1.60
GPC5	1.59

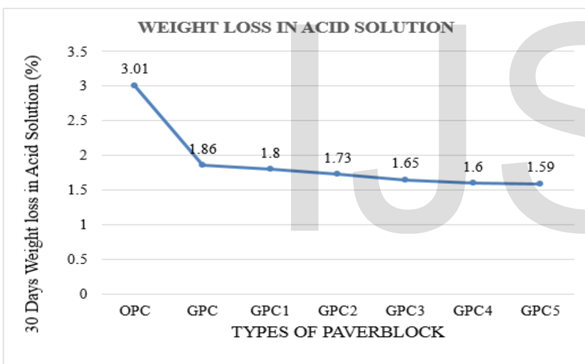

Fig. 6. weight loss in acid solution variation of mixes

3.1.7 . Weight loss in alkali solution

Table 8. Weight loss in alkali solution

Mix Designation	30 day weight loss in alkali solution (NaOH) (%)
OPC	2.20
GPC	1.73
GPC1	1.61
GPC2	1.43
GPC3	1.32
GPC4	1.23
GPC5	1.20

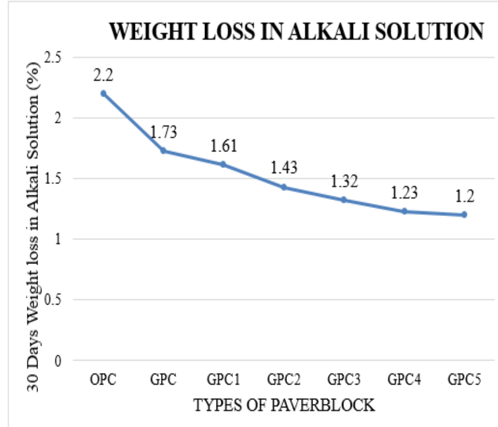

Fig. 7. weight loss in alkali solution variation of mixes

4. CONCLUSIONS

1. The Low calcium fly ash based Geopolymer concrete has excellent compressive strength within short period (3 days)
2. Inclusion of polypropylene fibers in Geopolymer concrete shows considerable increase in compressive, abrassion resistance & flexural strength of GPC with respect to GPC without fibers.
3. The abrasion resistance of paver block at 28 days improves the results up to 45% of paver block. In abrasion resistance minimum abrasion results obtained by adding 0.2% polypropylene fibre in paver block.
4. Flexural strength is increased very highly Maximum results obtain in a sampleGPC4 i.e. PPF has added 0.4% by weight.
5. Compressive strength, and abrasion resistance of with polypropylene GPC concrete increases with respect to increase in percentage volume fraction of polypropylene fibers up to 0.2% by weight.

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