Experimental Study on Geopolymer Concrete using Fly Ash, Bagasse Ash and Metakaolin with Pet Fiber

Tanveer Singh Bains, Khushpreet Singh

ABSTRACT: The continuous reduction in raw resources in the construction industry has reached the alarming stage such that the usage of waste by-products from various industries has become the necessity. Fly ash has been used in construction industry from the last decade but there is a need for more experimental studies with other material as a substitution. Polyethylene terephthalate, known as PET has been widely used for developing plastic bottles. Although it has umpteenth uses, it has serious issues of biodegradability. Hence, researchers are also trying to investigate the properties of PET fibers as construction material.This experimental work has been done to examine the fully replacement of cement in concrete with fly ash, bagasse ash and metakaolin. Total 4 mixes were prepared for this study and strength parameters were explored. Cement was replaced fully with 70% fly ash, 20% metakaolin and 10% bagasse ash. PET fibers were also added with the varying proportion of 2%, 3% and 4%. The obtained concrete mixeswere tested for its compressive strength, split tensile strength and flexural strength at 7 days and 28 days. It can be concluded from the present investigation that the Geopolymer containing 3% PET fibers is more effective in strength than the other mixes.

Keywords: Bagasse Ash, Fly ash, Geopolymer Concrete, Metakaolin.

I. INTRODUCTION

Concrete is a composite mixture comprises of fine and coarse particles known as aggregates mixed and bonded together with a cement (cement paste) with the help of fixed proportion of water forms a liquid slurry that can be easily transported and placed at the required position. The cement reacts with aggregates and water chemically and tends to form hard mass which is called concrete. Sometime, pozzolans or superplasticizers are added in the mixture to improve the physical and chemical properties of the mix. The concrete is poured with reinforcing mesh (called as rebar) inserted to provide tensile strength, yielding reinforced concrete as concrete is weak in tensile property.

Portland cement is the widely used type of cement in construction industry. It acts as a baseto concrete, mortar etc. It entailsvarious constituents like calcium silicates (alite, belite), aluminates and ferrites –calcium, silicon, aluminum and iron as they will react with water chemically. Portland cement, pozzolanic cement etc.are made by heating limestone along with clay or shale and grinding this product to form clinkersin the presence of sulfate like gypsum. Geopolymer is a concrete which replaces the cement with suitable replacement material which gives a sustainable and environmentally friendly concrete. The term geopolymer was invented by Davidovits (1991) [1]. Geopolymer is a kind of material which is synthesized from various materials of geological origin (e.g.,metakaolin) or industrial waste products like fly ash and iron slag, which entails silica and alumina with alkaline activators. In some survey, it was concluded that the generation of geopolymer containing fly ash requires almost 60% less energy and emission of CO2 is reduced 80% less when compared to manufacturing of OPC. [2].Till date, extensive research works on geopolymer concrete have been carried out worldwide which promotes geopolymer concrete as an incredible sustainable material for future[3,4,5]. As the modern world is marching towards the new construction techniques, the study of replacement of ingredients of the concrete becomes essential. As the raw material almost reaches its limit and cannot be used lavishly by not thinking its alternative. Investigations are going on to replace the cement, aggregates by waste product of various industries. Flyash, bagasse ash and metakaolin, being the common one, has been found out to be the best option to replace the cement either partially or fully.

II. OBJECTIVE

The main objective of the present experimental study is to investigate the geopolymer concrete by fully replacement of cement with fly ash, bagasse ashand metakaolinalong with the varying proportion of PET fibers. After obtaining the various mixes containing various proportion of PET fibers, strength parameters such as compressive strength, flexural strength and split tensile strength of concrete specimen was examined and the result were compared between the obtained mixes.

Revised Manuscript Received on May 06, 2019

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III. MATERIAL USED AS AN REPLCEMENT TO CEMENT

Fly Ash

Fly ash also called flue ash, or pulverized fuel ash, is a result of coal combustion that is comprised of fine particles of burned fuel. Ash that falls to the bottom of the boiler is called bottom ash. Fly ash, generally, collected by electrostatic precipitators or any other type of particle filtration machine before these flue gases reach the chimney. The constituents of the ash can vary depending upon the source and composition of the coal which is being burnt, but in general, fly ash entails silicon dioxide (SiO2) (amorphous and crystalline), aluminum oxide and calcium oxide.

Bagasse Ash

Bagasse ash is a waste-product of sugarcane industry which is found when the sugarcane bagasse is burnt. Sugarcane bagasse is obtained from the extraction of all sugar from sugarcane. Disposal of sugarcane bagasse is creating the big issue to environment by creating environmental problems near the sites of sugar industry. The production generates large amount of bagasse as a waste, which is used as fuel to boilers. The final product of this burning is residual sugarcane bagasse ash (SBA). The usage of SBA has been very critical to concrete as it can help in replacing the cement. Various proportions of SBA can be used to replace the cement which results in increasing the strength of concrete and imparts workability.

Metakaolin

It is a refined kaolin clay which is burnt (Calcinated) under very scrutinized circumstances in order to create an amorphous alumina silicate which can easily react with concrete. The particle size of metakaolin is very fine than the particle size of cement which is the main reason it can replace cement in concrete as it can act as a marvelous pore filling material. Metakaolin is also called supplementary cementitious material.

Table 1: Chemical Composition of Fly Ash, Bagasse Ash and Metakaolin.

Composition	Fly ash Mass (%)	Bagasse ash Mass (%)	Metakaolin Mass (%)
CaO	05.01	05.90	00.78
SiO_2	59.57	59.63	52.68
Al_2O_3	19.87	01.57	45.80
Fe_2O_3	06.01	06.69	02.14
MgO	07.23	02.11	00.16
SO_3	00.05	03.25	-
K_2O	00.19	07.94	00.62
Na_2O	00.29	00.58	00.26

Figure 1. Fly Ash, Bagasse Ash, Metakaolin and PET fibres.

IV. CONCRETE MIX PROPORTION

Present study entails the different proportions of PET fibers in geopolymer concrete. In order to examine the combined effect of PET fibers along with the fly ash (FA), bagasse ash (BA)and metakaolin (MK), different mixes were prepared and moulded for various tests. M30 grade of concrete was designed as per the Indian standard design code.

Various design mixes are mention in the table 2 and the quantities which were used for moulding1 cube (150mm x 150mm x150mm), 1 beam (100mm x 100mm x 500mm) and 1 cylinder (150mm diameter and 300mm height) is shown in table 3.

Design Mix	FA	MK	BA	PET
M1	70%	20%	10%	-
M2	70%	20%	10%	2%
M3	70%	20%	10%	3%
M4	70%	20%	10%	4%

Table 2. Design Mix Proportion

Ingredients	For 1 Cube	For 1 Cylinder	For 1 Beam
Fly Ash	0.89 kg	1.402 kg	1.32 kg
Metakaolin	0.255 kg	0.400 kg	0.378 kg
Bagasse Ash	0.1275 kg	0.200 kg	0.189 kg
Fine Aggregate	1.86 kg	2.936 kg	2.77 kg

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Coarse Aggregate	4.36 kg	6.85 kg	6.47 kg
Sodium Hydroxide	0.16 kg	0.26 kg	0.25 kg
Sodium silicate	0.41 kg	0.675 kg	0.62 kg
Superplasticizer	0.025 kg	0.040 kg	0.0375 kg
PET (2%)	0.0372 kg	0.0581 kg	0.0554 kg
PET (3%)	0.0558 kg	0.0881 kg	0.0831 kg
PET (4%)	0.0744 kg	0.117 kg	0.1108 kg

Table 3. Quantities of Various Ingredients.

V. RESULTS AND DISCUSSION

For compressive strength, 150mm x 150mm x150mm cubes were tested at 7 days and 28 days in CTM (Compression Testing Machine). Curing was done by two methods: oven dry curing and room temperature curing. The results of compressive strength are being represented in figure 2 and 3.

Therefore, it can be concluded that mix M3 (containing 3% PET) shows maximum compressive strength (34 MPa) at 28 day from all the design mixes when curing is done with oven dry method. But at 7 day, M4 shows maximum strength of 23 MPa with oven dry curing.

Table: 4. Compressive strength of geopolymer concrete with oven dry curing.

	7 Day	28 Day
M1	18	28
M2	19	32
M3	22	34
M4	23	27

Table: 5. Compressive strength of Geopolymer concrete with room temperature curing.

	7 Day	28 Day
M1	16	23
M2	15	24
M3	18	27
M4	16	25

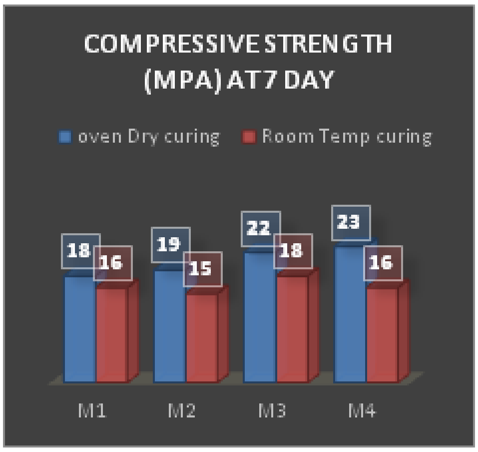

Figure 2. Compressive Strength (Mpa) at 7 Days

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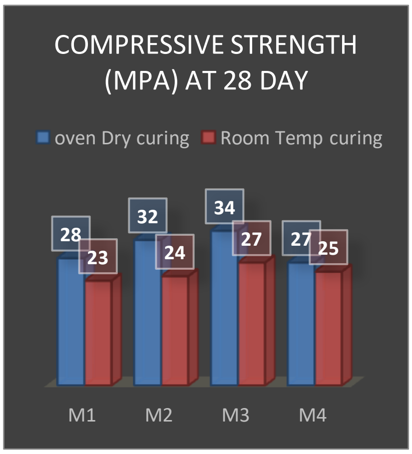

Figure 3. CompressiveStrength (Mpa) at 28 Days.

For Flexural strength, 100mm x 100mm x 500mm beam were tested at 7 days and 28. Again curing was done by two methods for these specimen: oven dry curing and room temperature curing. The results of Flexural strength at 7 day and 28 day are being represented in figure 4 and 5.

Therefore, from the test results it can be concluded that mix M3 (containing 3% PET) shows maximum flexural strength (7.75 MPa at 7 days and 11 MPa at 28 day) from all the design mixes when curing is done with oven dry method. With room temperature curing, maximum strength can be seen with the mix M3 (9 Mpa at 28 days).

Table: 6. Flexural strength of Geopolymer concrete with oven dry curing.

	7 Day	28 Day
M1	5	8.75
M2	7.25	10
M3	7.75	11
M4	5.5	9

Table: 7. Flexural strength of Geopolymer concrete with Room Temperature curing.

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	7 Day	28 Day
M1	3.75	5.75
M2	5.5	7
M3	5	9
M4	4	7.5

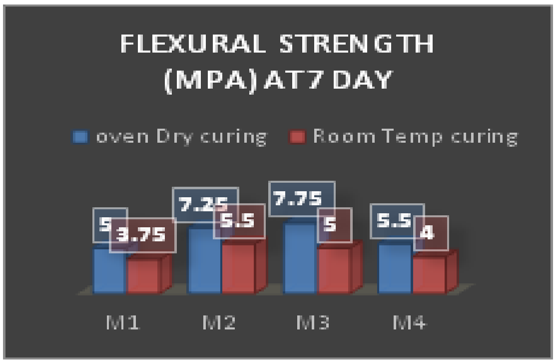


Figure 4. Flexural Strength (Mpa) at 7 Days.

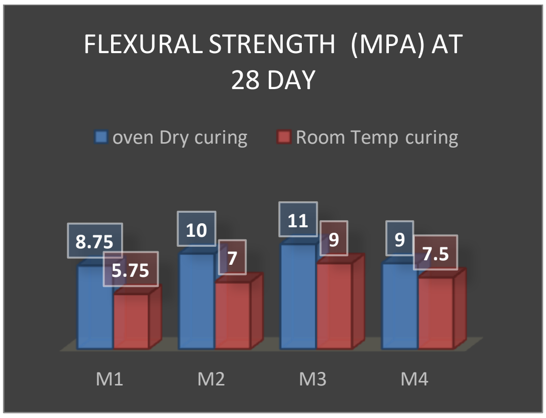


Figure 5. Flexural Strength (Mpa) at 28 Days.

For Split tensile strength, cylindrical specimens of 150mm diameter and 300mm height were tested at 7 days and 28. The results of Split TensileStrength at 7 days and 28 days are being represented in figure 6 and 7.

Hence, it can be concluded that mix M3 which entails 3% PET fibers shows maximum strength of 2.5 MPa at 7 days and 2.9 MPa at 28 days with oven dry curing.

Table: 8. Split tensile strength of Geopolymer concrete with Oven dry curing.

	7 Day	28 Day
M1	1.12	1.49
M2	1.99	2.39
M3	2.5	2.9
M4	1.9	2.2

Table: 9. Split tensile strength of Geopolymer concrete with Room Temperature curing.

	7 Day	28 Day
M1	0.99	1.1
M2	1.88	2
M3	1.77	2.2
M4	1.5	1.7

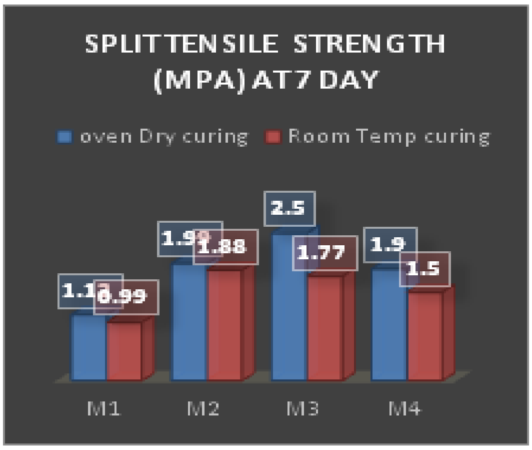


Figure 6. Split Tensile Srength (Mpa) at 7 Days.

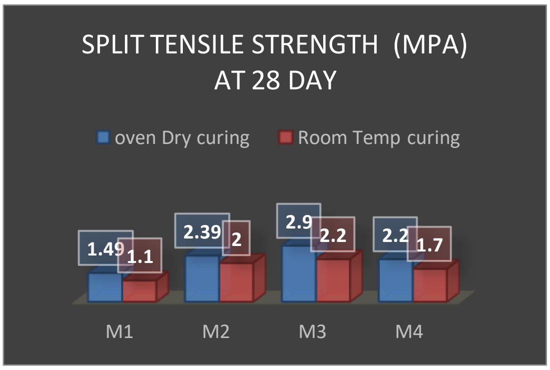
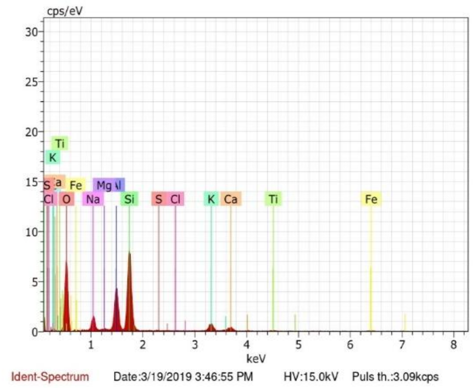


Figure 7. Split Tensile Strength (Mpa) at 28 Days.



Spectrum: test 3920

Element	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (3 Sigma) [wt.%]
Oxygen	K-series	45.57	48.56	59.82	18.12
Silicon	K-series	21.40	22.81	16.01	2.80
Aluminium	K-series	10.15	10.81	7.90	1.54
Carbon	K-series	4.80	5.12	8.40	4.07
Sodium	K-series	4.40	4.69	4.02	0.98
Iron	K-series	1.19	1.27	0.45	0.34
Calcium	K-series	2.12	2.26	1.11	0.35
Potassium	K-series	3.34	3.56	1.79	0.46
Magnesium	K-series	0.23	0.25	0.20	0.15
Chlorine	K-series	0.05	0.05	0.03	0.10
Titanium	K-series	0.55	0.59	0.24	0.20
Sulfur	K-series	0.04	0.04	0.03	0.10
	Total:	93.84	100.00	100.00	

Figure 9.Spectrum graph and details of Concrete Mix.

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VI. CONCLUSION

The final conclusions from present investigation of Geopolymer concrete with PET fibers are:

- The maximum compressive strength (34 MPa) was achieved with Geopolymer concrete containing 3% PET fibers with oven dry curing.
- It was noticed that design mix M3 showed maximum flexural strength (11MPa) which contains 3% PET fibers. Oven dry curing was used to achieved the maximum strength.
- Results of split tensile strength showed maximum strength with 3% PET fibers when oven dry curing method is adopted.
- Moreover, oven dry curing was found better curing technique than room temperature curing as all the strength parameters are higher in oven dry method than room temperature method.

In the gist, it can be concluded that from all the deign mixes of geopolymer obtained, maximum strength parameters were achieved with 3% of PET fibers. Therefore, this proportion can be used in producing geopolymer concrete for sustainable development.

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