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COMPRESSIVE STRENGTH AND MICROSTRUCTURE STUDIES ON CEMENT ADDED GEOPOLYMER CONCRETE

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ABSTRACT

Geopolymer results from the reaction of a source material that is rich in silica and alumina with alkaline liquid. It is essentially cement free concrete. This material is being studied extensively and shows promise as a greener substitute for Ordinary Portland Cement concrete in some applications. Research is shifting from the chemistry domain to engineering applications and commercial production of geopolymer concrete. It has been found that geopolymer concrete has good engineering properties with a reduced global warming potential resulting from the total replacement of Ordinary Portland Cement.In this work, low-calcium fly ash-based geo-polymer and cement is used as the binder to produce concrete. The fly ash-based geo-polymer and cement paste binds the loose coarse aggregates, fine aggregates and other un-reacted materials together to form the cement added geo-polymer concrete, with or without the presence of admixtures. The manufacture of geo-polymer concrete is carried out using the usual concrete technology methods. To evaluate whether cement added geopolymer concrete can be cured as a normal concrete or not. The present study is about finding optimum percent of cement to be added to know the compressive strength. To study the microstructure of Cement added Geopolymer Concrete (XRD analysis).

Keywords: *Concrete, Fly-ash, Geopolymer, Compressive strength, XRD analysis*.

I. INTRODUCTION

General

The development of Geopolymer concrete is the result of the concern for two environment-related situations, viz. the high amount of carbon dioxide released into the atmosphere during the production of Ordinary Portland cement (OPC), and the abundant availability of fly ash, a by-product from power stations worldwide. The rate of production of these two by-products is increasing with increasing demand for infrastructure development, and hence proper attention and action to be taken to minimize the impact on the sustainability of our living environment. Sustainable development is a concept that has several definitions. The most common one declares that today's generation should not compromise the ability of future generations to meet their needs. The three pillars of sustainable development are economic and environmental protection as well as social development. It is known that the Earth's capacity to support people is determined by natural constraints and human priorities.

On the other hand, when fly-ash is used as a partial replacement of OPC, in the presence of water and in ambient temperature, fly-ash reacts with the calcium hydroxide during the hydration process of OPC to form the calcium silicate hydrate (C-S-H) gel. The development and application of high volume fly-ash concrete, which enabled the replacement of OPC up to 60% by mass has been a significant development.

Cement Added Geopolymer Concrete

In this work, low-calcium fly ash-based geo-polymer and cement is used as the binder to produce concrete. The fly ash-based geo-polymer and cement paste binds the loose coarse aggregates, fine aggregates and other un-reacted materials together to form the cement added geo-polymer concrete, with or without the presence of admixtures. The manufacture of geo-polymer concrete is carried out using the usual concrete technology methods. As in the case of OPC concrete, the aggregates occupy about 75-80 % by mass, in cement added geo-polymer concrete. The silicon and the aluminium in the low-calcium fly ash (ASTM Class F) react with an alkaline liquid that is a combination of sodium silicate and sodium hydroxide solutions to form the geo-polymer paste that binds the aggregates and other un-reacted materials.

Aims Of The Research
The aims of this study were:
- Toinvestigate the advantage of mixing Cement in Geopolymer concrete to avoid curing at high temperatures.
- To evaluate whether cement added geopolymer concrete can be cured as a normal concrete or not.
- To find optimum percent of cement to be added to know the compressive strength.
- To study the microstructure of Cement added Geopolymer Concrete (XRD analysis).

II. MATERIAL
The following materials were used in the study of strength of geopolymer made with cement as replacing material.
1. .Fly-ash
2. .Ordinary Portland Cement (53 Grade)
3. Fine aggregate
4. Coarse aggregate
5. Alkaline solution (NaOH + Na2SiO3)
6. Super plasticizer (CONPLAST SP-430)
7. Distilled Water

Fly-ash
In the present experimental work, low calcium Class F fly-ash was used which is obtained from Ramagundam Thermal Power Stationin Telangana (RTPS). Specific-gravity of fly-ash was found to be 577 kg/m3.

Alkaline Liquids
The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate. Alkaline liquid plays an important role in the polymerisation process. Reactions occur at a high rate when the alkaline liquid contains soluble silicate, either sodium or potassium silicate, compared to the use of only alkaline hydroxides. To activate the fly ash, a combination of sodium hydroxide solution and sodium silicate solution was chosen as the alkaline activator. Sodium-based activators were chosen because they were cheaper than Potassium-based activators.

Ordinary Portland Cement
53 Grade Cement is a prime brand cement with a remarkably high C3S (Tri Calcium Silicate) providing long-lasting durability to concrete structures. 53 Grade OPC is a higher strength cement to meet the needs of the consumer for higher strength concrete.

Fine Aggregate
In the present investigations, river sand available in the local market was used as fine aggregate.The physical properties of fine aggregate such as gradation, specific gravity and bulk density were tested in accordance with IS: 2386-1963.

Coarse Aggregate
The coarse aggregate used in the investigations was of two sizes i.e., 20mm and 10mm. The crushed coarse aggregate was obtained from the local crushing plants. The physical properties of the coarse aggregate such as gradation, fineness modulus, specific gravity and bulk density were tested in accordance with IS: 2386-1963 and IS : 383-1970.

III. MIX DESIGN

1. Mix Design Of Geopolymer Concrete

In the design of geopolymer concrete mix, coarse and fine aggregates together were taken as 76% of entire mixture by mass. This value is similar to that used in OPC concrete in which it will be in the range of 75 to 80% of the entire mixture by mass. Assuming the aggregates to be in surface saturated dry condition and the unit weight of concrete is 2400 Kg/m^3. By assuming the ratios of alkaline liquid to fly ash 0.4. The ratio of sodium silicate solution to sodium hydroxide solution was fixed as 2.5. Combined aggregates are assumed to consist of 70% coarse aggregate and 30% fine aggregate. 70% coarse aggregate of 20mm and 30% coarse aggregate of 10mm are taken.Mass of combined aggregate = 76% of 2400 Kg/m3 = 1824 Kg/m^3

Table 3.1 Mix Proportions for 1 m3 of concrete for 14M NaOH solution

Weight of flyash	400 Kg
Alkaline solution/ Fly ash ratio	0.4
$Na_2SiO_3/NaOH$ ratio	2.5
Mass of NaOH	45.714 Kg
Mass of Na_2SiO_3	114.286 Kg
Mass of combined aggregates	1824 Kg
Mass of coarse aggregate (70% of combined aggregate)	1276.8 Kg
Mass of coarse aggregate 20mm (70% of CA)	893.76 Kg
Mass of coarse aggregate 10 mm (30% of CA)	383.04 Kg
Mass of fine aggregate	547.2 kg
Mass of super plasticizer	8

Na_2SiO_3:NaOH:Flyash:Sand:CA(20mm):CA(10mm) = 0.285:0.114:1:1.61:2.093:0.897

2. Different Mixes Considered

- Mix – I (NGPC) Weight of flyash = 400 Kg
- Mix – II (5% CGPC) Weight of flyash = 380 Kg , Weight of Cement = 20 Kg
- Mix – III (10% CGPC) Weight of flyash = 360 Kg , Weight of Cement = 40 Kg
- Mix – IV (15% CGPC) Weight of flyash = 340 Kg , Weight of Cement = 60 Kg
- Mix – V (30% CGPC) Weight of flyash = 280 Kg , Weight of Cement = 120 Kg

IV. RESULT & DISCUSSION

The test results cover the workability of fresh cement added geopolymer concrete, effect of curing time on the compressive strength of the cement geopolymer concrete, effect of the age on the compressive strength of oven, ater cured cement added geopolymer specimens. The test specimens were made using cement added geopolymer concrete

1. **Workability results**

Table 4.1 showing Slump values for different mixes

Mix	NGPC	5% CGPC	10% CGPC	15% CGPC	30% CGPC
Slump (mm)	145	142	140	137	135

2. **Compressive Strength Test results**

MIX-I (NGPC)

Table 4.2 showing variation of compressive strength of oven cured GPC specimens with age

*	Age of the specimen (days)	Curing method	Compressive strength (MPa)
1	7	Oven	39
2	14	Oven	39.7
3	21	Oven	40.2
4	28	Oven	41
5	60	Oven	41.7
6	90	Oven	42.9
7	120	Oven	44.2
8	180	Oven	45.2

MIX – II (5% CGPC)

Table 4.3 showing variation of compressive strength of oven and water cured Cement added GPC specimens with age

S.No	Age of the specimen (days)	Compressive strength (MPa)	
		Oven	Water
1	7	39.8	40.3
2	14	40.7	41.2
3	21	41.4	42
4	28	42.3	42.8
5	60	43	43.6
6	90	44.2	44.8
7	120	45	45.6
8	180	46.4	46.9

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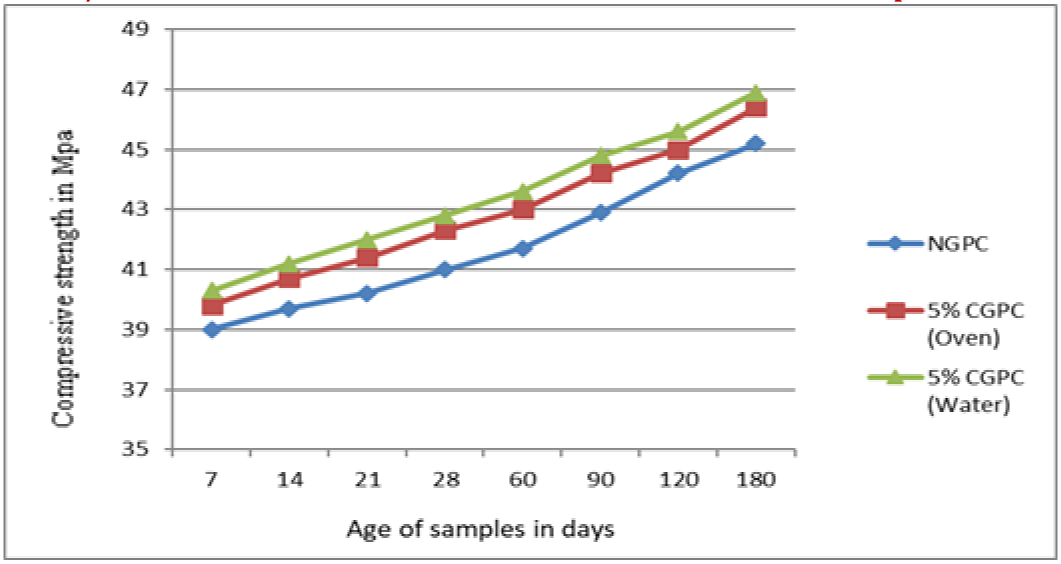

Fig. 4.1 Comparison between Compressive strengths of NGPC and 5% CGPC

Mix – III (10% CGPC)

Table 4.4 showing variation of compressive strength of oven and water cured Cement added GPC specimens with age

S.No	Age of the specimen (days)	Compressive strength (MPa)	
		Oven	Water
1	7	41.4	42
2	14	42.2	42.8
3	21	43	43.5
4	28	43.8	44.2
5	60	44.5	45
6	90	45.7	46.1
7	120	46.5	47
8	180	48	48.6

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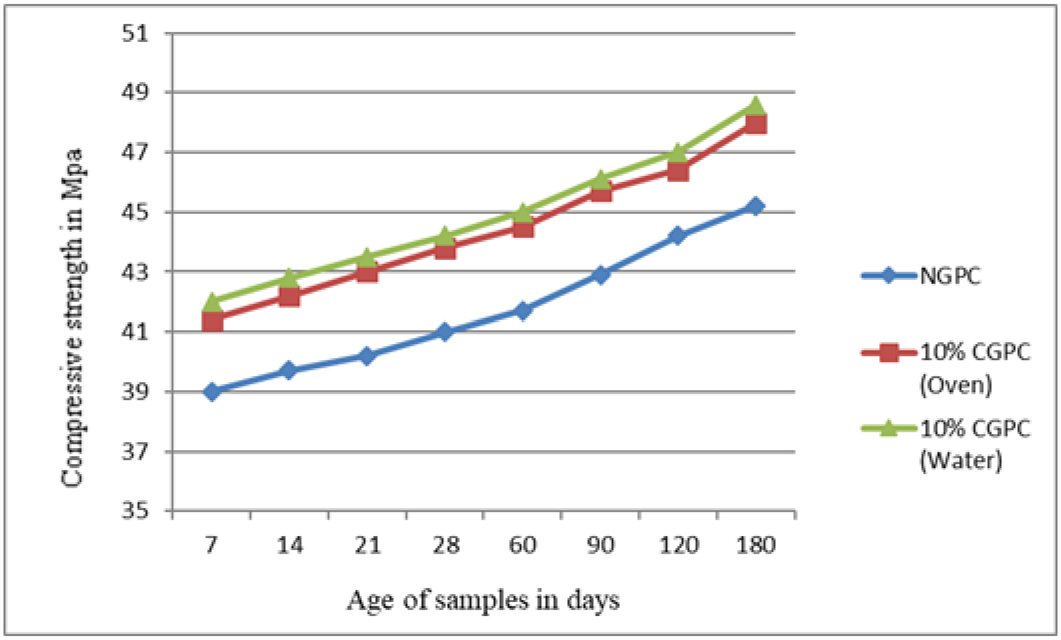

Fig. 4.2 Comparison between Compressive strengths of NGPC and 10%CGPC

Mix – IV (15% CGPC)

Table 4.5 showing variation of compressive strength of oven and water cured CGPC specimens with age

S.no	Age of the specimen (days)	Compressive strength (MPa)	
		Oven	Water
1	7	42.2	42.6
2	14	43	43.2
3	21	43.7	44
4	28	44.5	45
5	60	45.3	46.1
6	90	46.5	47
7	120	47.2	48
8	180	48.5	49.2

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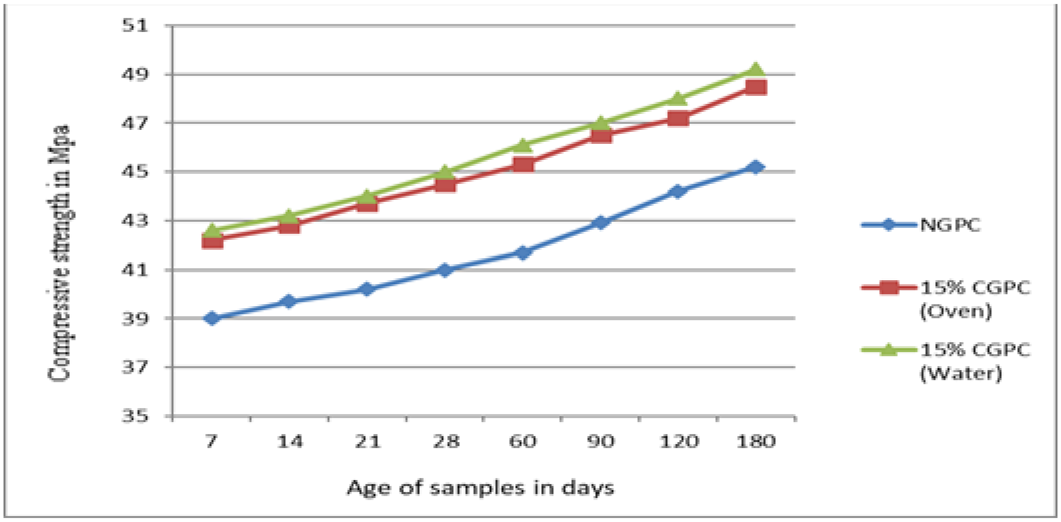

Fig. 4.3 Comparison between Compressive strengths of NGPC and 15%CGPC

Mix – IV (30% CGPC)

Table 4.6 showing variation of compressive strength of oven and water cured Cement added GPC specimens with age

S.No	Age of the specimen (days)	Compressive strength (MPa)	
		Oven	Water
1	7	44.8	45.3
2	14	45.6	46.1
3	21	46.4	46.9
4	28	47.2	47.8
5	60	48	48.5
6	90	48.8	49.3
7	120	49.6	50.2
8	180	50.5	51

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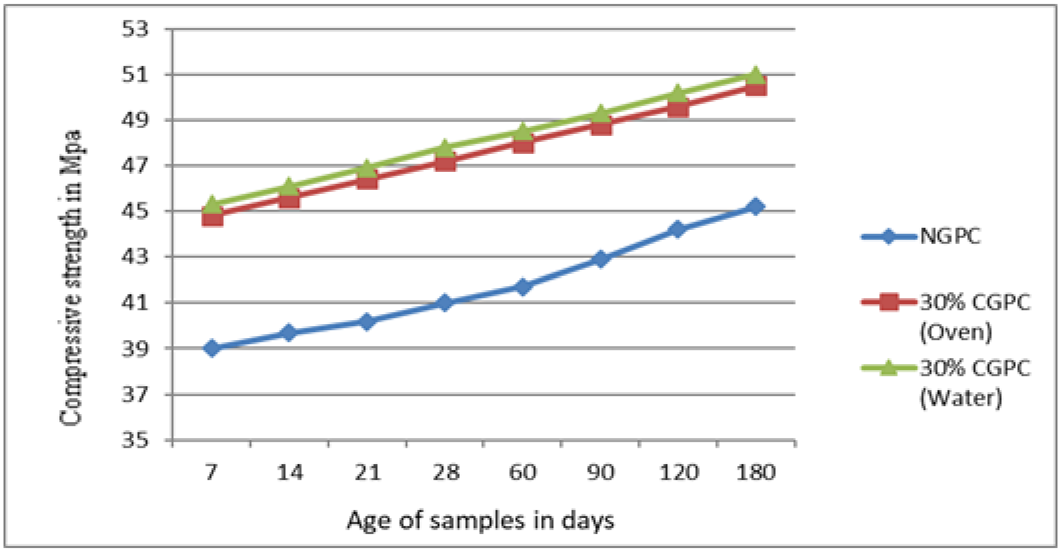

Fig. 4.4 Comparison between Compressive strengths of NGPC and 30% CGPC

3. X-Ray Diffraction Analysis

Powder diffraction patterns are typically plotted as the intensity (Counts per second) of the diffracted X-rays vs. the angle 2θ. By measuring the 2θ values for each diffraction peak, we can calculate the d-spacing (the distance between the diffracting planes) for each diffraction peak. By using Debey-Scherrer's we can calculate the average size of the particle, from the above equation as and values are constant in the present XRD studies, it is clear that the size of the particle is inversely proportional to the base width of the XRD peaks.

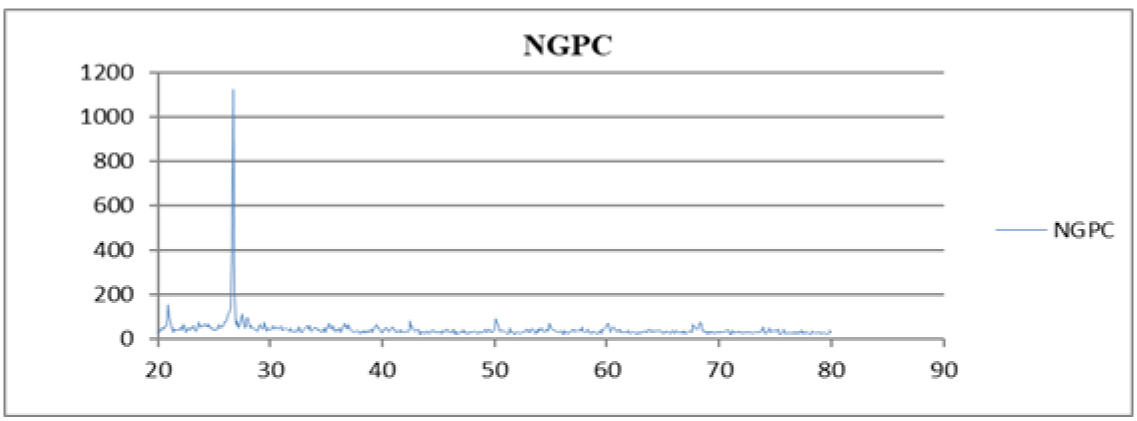

Fig 4.5 X-ray powder Diffraction Analysis for NGPC at 28 days

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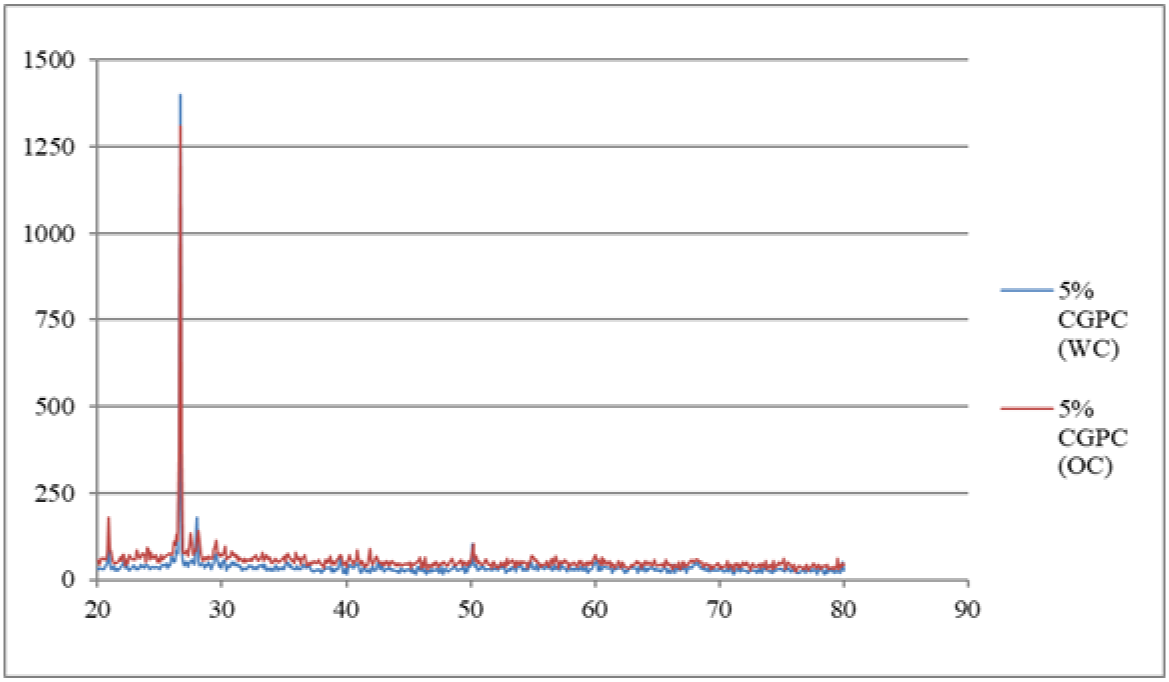

Fig 4.6 X-ray powder Diffraction Analysis for 5% CGPC oven and water cured at 28 days

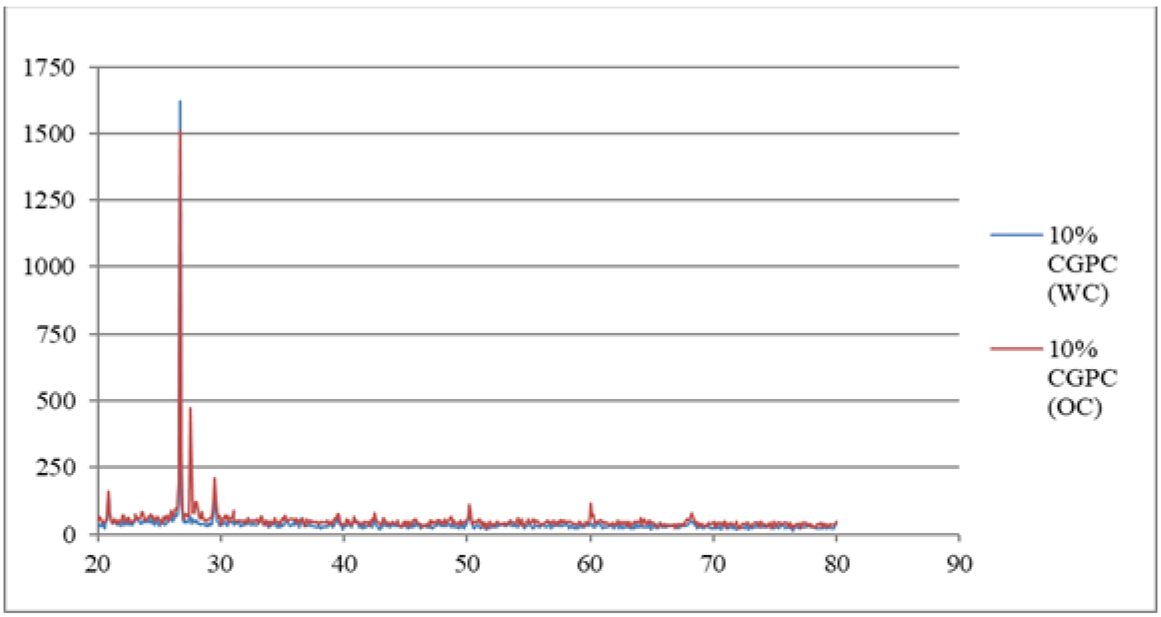

Fig 4.7 X-ray powder Diffraction Analysis for 10% CGPC oven and water cured at 28 days

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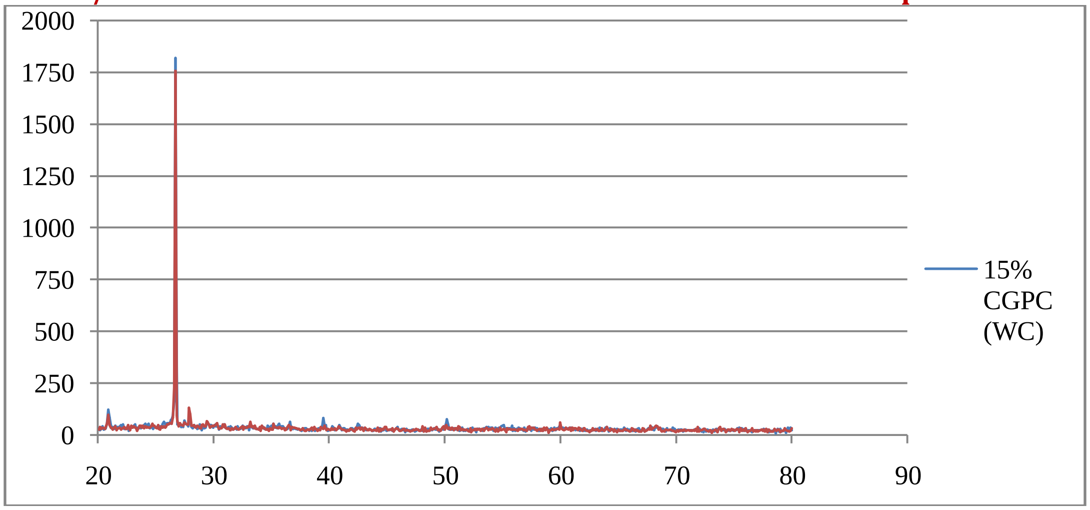

Fig 4.8 X-ray powder Diffraction Analysis for 15% CGPC oven and water cured at 28 days

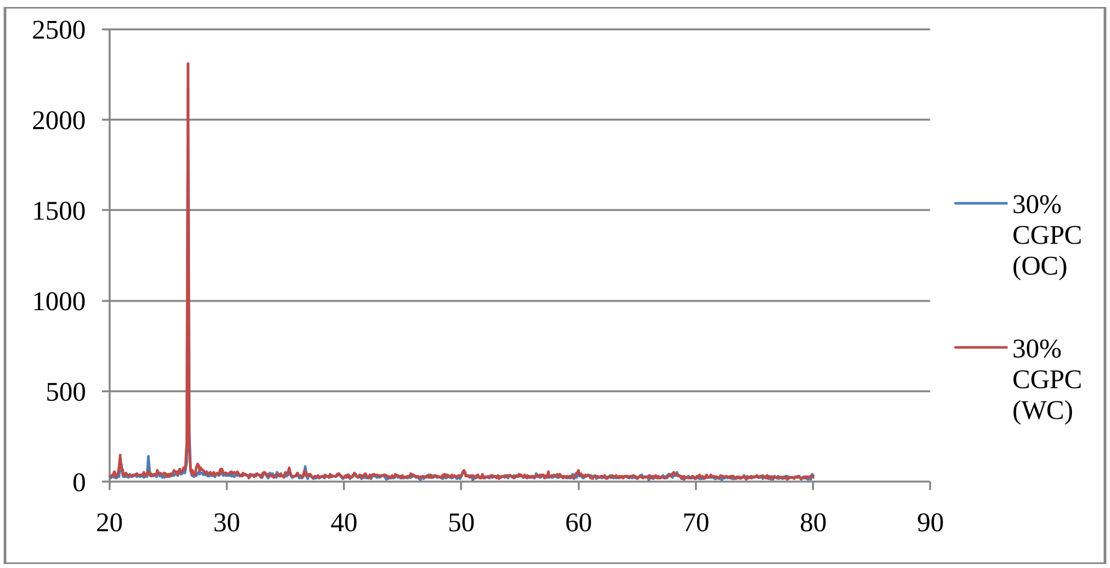

Fig 4.9 X-ray powder Diffraction Analysis for 30% CGPC oven and water cured at 28 Days

V. CONCLUSION

- When flyash is replaced by cement for making of geopolymer concrete, normal curing is giving more strength compared to temperature curing at 60^{o}C.
- Higher concentrations of sodium hydroxide (14 M) solution results in a higher compressive strength of geopolymer concrete for all mixes.
- The addition of naphthalene based super plasticizer, up to 2% of fly ash by mass, improves the workability of the fresh fly ash based geopolymer concrete. However, there is a slight degradation in the compressive strength of hardened concrete when super plasticizer dosage is greater than 2%.
- There is no substantial gain in the compressive strength of heat cured fly ash based geopolymer concrete with age.
- 5% Cement added Geopolymer Concrete (CGPC) water curing samples gives better results when compared to temperature cured Normal Geopolymer Concrete.

- Practically, in field it is not possible for temperature curing at 60°C. So by replacing fly ash with cement with certain percentage (water cured) it can achieve more strength compared to temperature cured Normal Geopolymer Concrete.
- From the XRD patterns, for Normal Geopolymer Concrete as the peak width is large the diameter of the particle will be less this shows that NGPC is less hydrated to that of CGPC

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