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Influence of aggregae quarry dust on strength characteristics of GGBFS Geo-polymer concrete

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Abstract —*The major problem in the world is facing the environmental pollution. In the construction industry mainly the production of Ordinary Portland Cement (OPC) will causes the emission of pollutants as CO2 results environmental pollution. We can increasing the usage of industrial by-products in our construction industry and reduce the pollution effect on environment. This paper discusses various combinations of Ground Granulated Blast Furnace Slag (GGBFS) and Aggregate Quarry Dust (AQD) as source materials (which is the by-product of steel industries and Quarry process respectively), to produce geo-polymer concrete at ambient temperature. It has been generally accepted that elevated temperature is required for polymerization process and producing geo-polymer concrete which is consider a drawback affecting its application. In this paper variation of source materials i.e. replacement of GGBFS with AQD as 10% interval is done to achieve compressive strength for medium grade of concrete of M-25. Oven and ambient curing is done for that. It is found that geo-polymer concrete with GGBFS in AQD as increases it gains strength and shows good strength at 3,7 and 28 days even at ambient curing with increase in GGBFS content. Rate of gain of strength is slower at ambient temperature while only slag based geo-polymer concrete has higher strength at oven curing.*

Keywords-*GGBFS, AQD, Oven Curing, Ambient Curing, Compressive Strength*

I. INTRODUCTION

Environmental pollution is the biggest hazard to the human race on our earth today. That means adding impurity to environment. There are many reasons which cause that type of pollution. In our cement industry, cement is the main ingredient for the production of concrete. But the production of cement means the production of pollution because of the emission of CO_2 during the production. There are two different sources of CO_2 emission during production of cement. Combustion of fossil fuels to operate the rotary kiln is the largest source & other one is the chemical process of calcining limestone into lime in the cement kiln.[1] In India about 2,069,739 thousands of metric tons of CO_2 is emitted in the year 2010. The cement industry contributes about 5.5% of total global carbon dioxide emissions. [2] And also, the raw materials such as lime stone, clay and other minerals which are using for manufactured the cement. Quarrying of these raw materials is also causes environmental degradation.

On the other side the demand of concrete is increasing day by day for the ease of preparing and fabricating in all type of convenient shapes. So to overcome this problem, the concrete to be used should be environmentally friendly. To produce environmental friendly concrete, we have to replace the cement with the industrial by-products such as GGBFS (Ground Granulated Blast Furnace Slag) and AQD (Aggregate Quarry Dust) etc. The term geo-polymer was first coined by Davidovits in 1978 to proposed that an alkaline liquid which can react with the silicon (Si) and aluminum (Al) in a source material of geological origin or industrial by product can be used to produce binders. Since chemical reaction in this process is of polymerization therefore, he coined it as “Geo-polymer” [3]. So geo-polymer constitutes of two main compounds namely source materials and alkaline liquids. The alkaline liquids are made from soluble alkaline metals which are mainly sodium or potassium based. Sodium Hydroxide (NaOH) or Potassium Hydroxide (KOH) and Sodium Silicate or Potassium Silicate are mostly used alkaline liquid. Binder is the primary difference between concrete produce using Portland cement and geo-polymer concrete. Geo-polymer incorporate of silicon and aluminum atoms bonded via oxygen into a poly condensation reaction between alumina silicate binder and an alkaline silicate solution such as a mixture of an alkali metal silicate and metal hydroxide is obtained. As like Portland cement concrete, the course and fine aggregates occupy about 75% to 80% of mass of geo-polymer concrete. Therefor the influence of that aggregates, such as angularity, grading and strength are considered to be the same as in case of Ordinary Portland concrete.[4]

Fly ash (FA), GGBFS (Ground Granulated Blast Furnace Slag) and AQD (Aggregate Quarry Dust) are the most common industrial by-products used as binder materials. Due to its latent hydraulic properties GGBFS has been widely used as cement replacement material, while fly ash has been used as a pozzolanic material to enhance the physical, chemical and mechanical properties of cements and concretes. Increasing emphasis on the environmental impacts of construction materials such as Portland cement has provided abundant trust in recent years to the increased utilization of waste and by-product materials in concrete.

A major advancement towards increasing the beneficial use of industrial waste products and reducing the adverse impacts of cement production we can use the activation of alumina silicate materials such as fly ash, blast furnace slag, and metakaolin using alkaline solutions to produce binders free of Portland cement.

It has been reported that fly ash and ground granulated blast furnace slag (GGBFS) are very effective as starting materials for cement-free binder concretes because of the soluble silica and alumina contents in these materials that undergo dissolution, polymerization with the alkali, condensation on particle surfaces, and solidification that eventually provides strength and stability to these matrices.[4]

This study aims to coordinating geo-polymer concrete using combination of GGBFS and AQD. And here AQD was replaced in varying percentages by GGBFS to understand the effect on Compressive strength. [5]

II. EXPERIMENTAL PROGRAM

2.1. Materials

Aggregate Quarry Dust (AQD) in this study is the by-product of Quarry Process and obtained from Nearest Source of that (passing from 90 µm IS sieve). Ground Granulated Blast Furnace Slag (GGBFS) used is obtained from Stallion Energy Pvt. Ltd. The chemical and physical properties of GGBFS and AQD used are shown in the Table-I and Table-II respectively [6] A mixture of Sodium Hydroxide (NaOH) with Sodium Silicate (Na_2SiO_3) which are most commonly used alkaline activators. For preparation of alkaline liquids, Sodium Hydroxide with the 98 percentage purity in the form of flakes and Sodium Silicate were obtained from local manufacturer. Locally available 20mm and 10 mm crushed aggregates have been used as course aggregate, locally available river sand is used as fine aggregate in the mixes [7, 8]

"Table 1. Chemical Property of GGBFS"

Sr. No	Property	Value
1	Loss on Ignition %	0.70
2	Silica (SiO_2) %	35.47
3	Aluminum (Al_2O_3) %	14.27
4	Calcium oxide (CaO) %	35.89
5	Iron oxide (Fe_2O_3) %	2.41
6	Sulphide sulphur as SO_3 %	1.58
7	Magnesium oxide (MgO) %	8.06

"Table 2. Chemical Property of AQD"

Sr. No	Property	Value
1	Silica (SiO_2) %	62.48
2	Aluminum (Al_2O_3) %	18.72
3	Calcium oxide (CaO) %	4.83
4	Iron oxide (Fe_2O_3) %	6.54
5	Magnesium oxide (MgO) %	2.56

2.2. Mix Design and Specimens Preparation

In this paper Geo-polymer Concrete was casted for M 25 grade of Compressive strength. As there are no code provisions for mix design of geo-polymer concrete, the density of the geo-polymer concrete is assumed as 2370 to 2480 kg/m³ (Based on Literature). That mix design shown in Table 3 details the quantities used for casting different mix with varying percentage of GGBFS and AQD. The ratio of alkaline liquid to GGBFS the as 0.4 mass of GGBFS and mass of alkaline liquid was found out. By taking the ratio of Sodium Silicate solution to Sodium Hydroxide solution was 2.5, find out the mass of Sodium Silicate solution to Sodium Hydroxide solution. The total volume occupied by the aggregates (course and fine aggregate) is assumed to be 75% of the total mass of concrete (in this 35% of fine aggregate and 60:40 ratio of 20mm & 10mm aggregate respectively of remaining). 10% Extra water required for workability and a GLENIUM 8784 based super plasticizer of about 1% of the mass of GGBFS. Using the above procedure the mix has been designed. [5]

"Table 3. Mix Design"

Materials		**Different mixes**			
		Mix-1 (kg/m^3)	Mix-2 (kg/m^3)	Mix-3 (kg/m^3)	Mix-4 (kg/m^3)
Coarse Aggregate	20 Mm	702	702	702	702
	10 mm	468	468	468	468
Fine Aggregate		630	630	630	630
Aggregate Quarry Dust		428.57	385.7	342.85	300
GGBFS		0	42.86	85.72	128.57
Sodium Hydroxide Solution		48.98 (14M)	48.98 (14M)	48.98 (14M)	48.98 (14M)
Sodium Silicate Solution		122.45	122.45	122.45	122.45
Extra Water		42.86	42.86	42.86	42.86
Super-Plasticizer		4.29	4.29	4.29	4.29

2.3. Compressive Strength Test

The Compressive Strength of that Geo-polymer concrete has been evaluated on Hydraulic Testing Machine. For the compressive strength test, Cubes of size 150mm ×150mm×150mm are tested in Compression in according with the test procedures gives in IS : 516-1959[9].

III. Results and Discussion

In this investigation of work, to study the compressive strength properties of geo-polymer concrete for different mixes were prepared by percentage replacement of AQD with GGBFS and that all results are presented below.

"Table 4. Compressive Strength for Oven Curing"

Mix	3 days (MPa)	7 days (MPa)	28 days (MPa)
Mix-1 (0%)	8.14	9.84	12.49
Mix-2 (10%)	18.11	21.3	26.68
Mix-3 (20%)	23.28	27.82	35.4
Mix-4 (30%)	28.35	32.12	39.65
Control Concrete	12.7*	22.14*	31.65*

**Normal curing procedure id followed*

Here different curing techniques were applied on the casted specimen i.e., Oven curing and Ambient curing. Control concrete was casted as according to IS 10262:2009 and cured in normal curing as water.

It is observed in Table 4. & Table 5, as the GGBFS content increases in oven curing and ambient curing that increases compressive strength also. However, the strength gain from that is little slow at later stages.

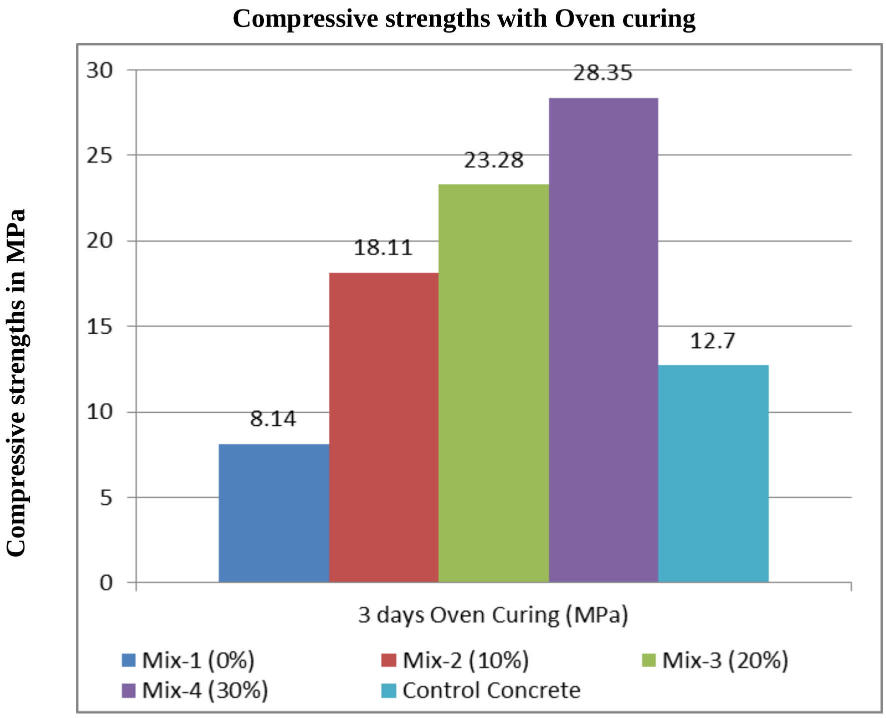
Table 5. Show s results for ambient cured samples for 3 days, 7days and 28 days respectively for combination of AQD and GGBFS.

"Table 5. Compressive Strength for Oven Curing"

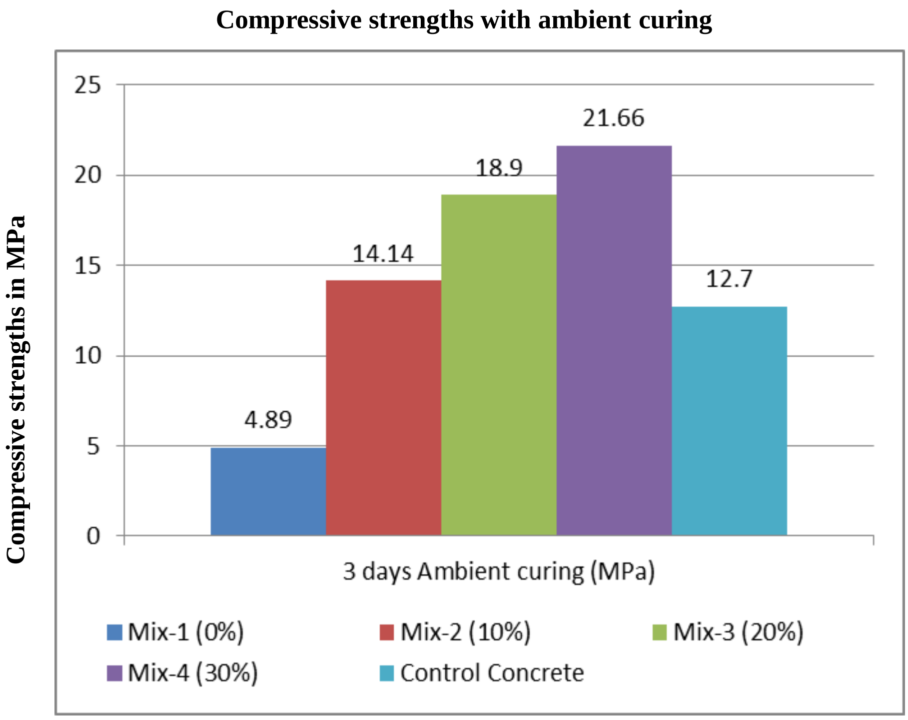
Mix	3 days (MPa)	7 days (MPa)	28 days (MPa)
Mix-1 (0%)	4.89	6.28	7.1
Mix-2 (10%)	14.14	18.32	21.64
Mix-3 (20%)	18.9	21.61	27.81
Mix-4 (30%)	21.66	26.82	30.85
Control Concrete	12.7	22.14	31.65

**Normal curing procedure id followed*

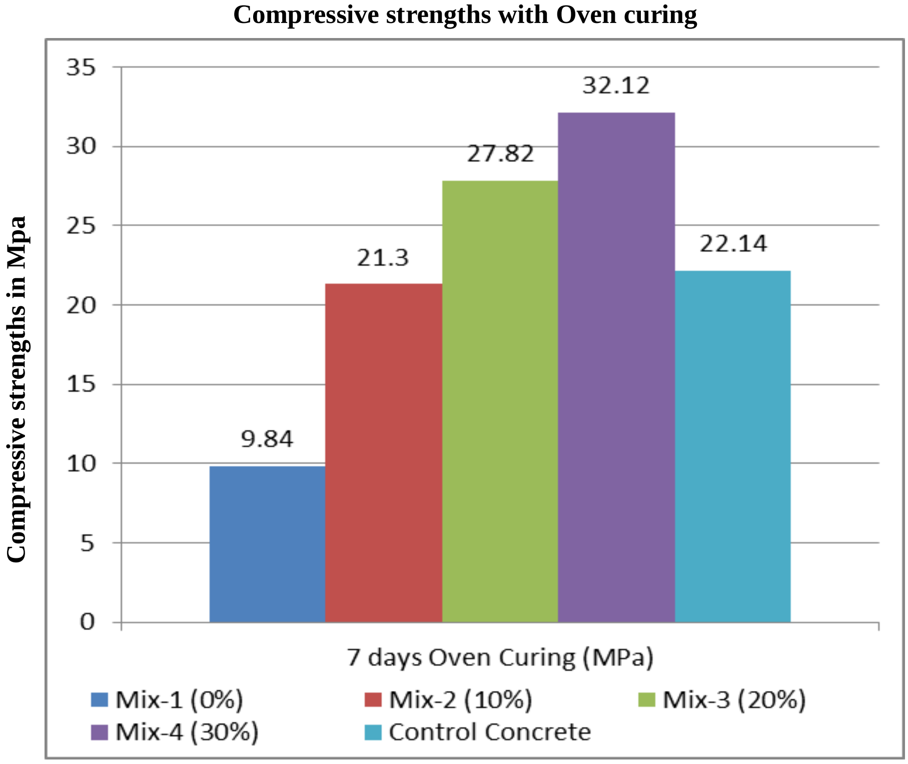
It is observed that at ambient temperature the rate of gain of strength is slow, but it is nearest to target strength at 28 days for combination of AQD and GGBFS geo-polymer concrete, while faster for GGBFS in initial period but gain of strength over age is slow after 7 days at ambient curing. Here Figure 1 and Figure 2 Represent 3 days compressive strength for oven and ambient curing. Figure 3 and Figure 4 represent 7 days compressive strength, Figure 5 and Figure 6 represent graphical comparison strength of oven cured and ambient cured samples 28 days respectively. It is seen from that all results that oven curing gives more strength as compared to ambient curing.



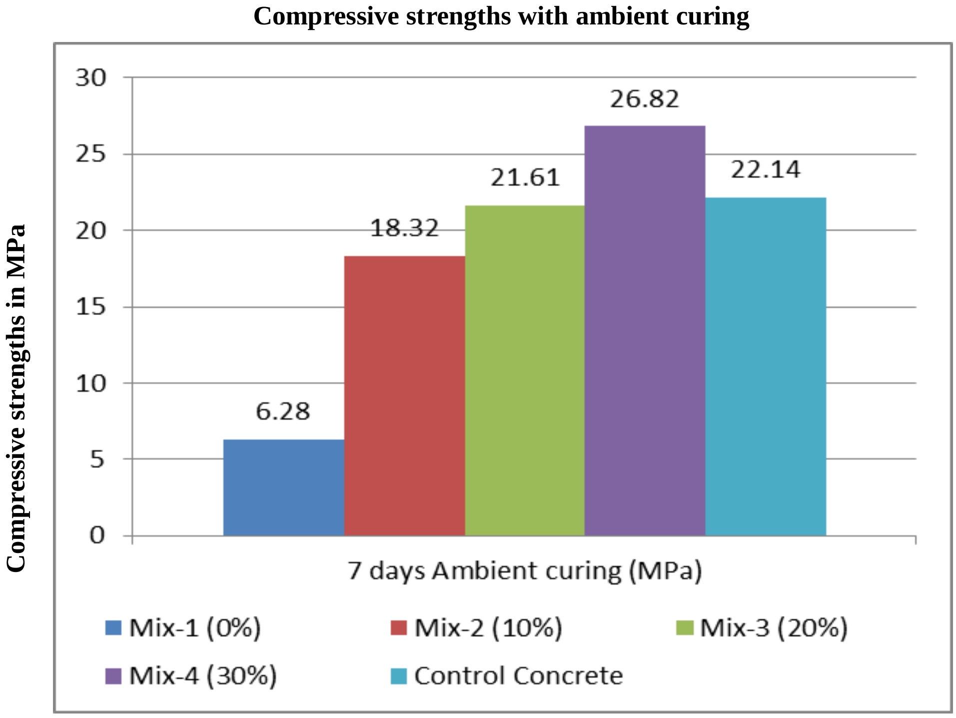
"Figure 1. 3 days Compressive Strength for Oven Curing"



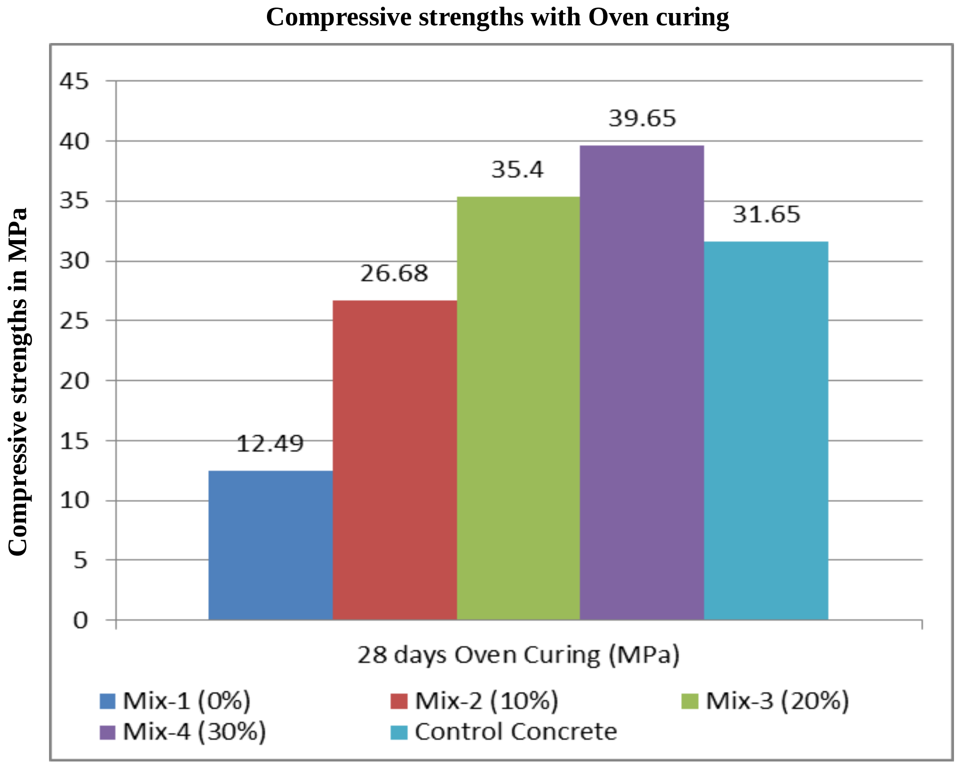
"Figure 2. 3 days Compressive Strength for Ambient Curing"



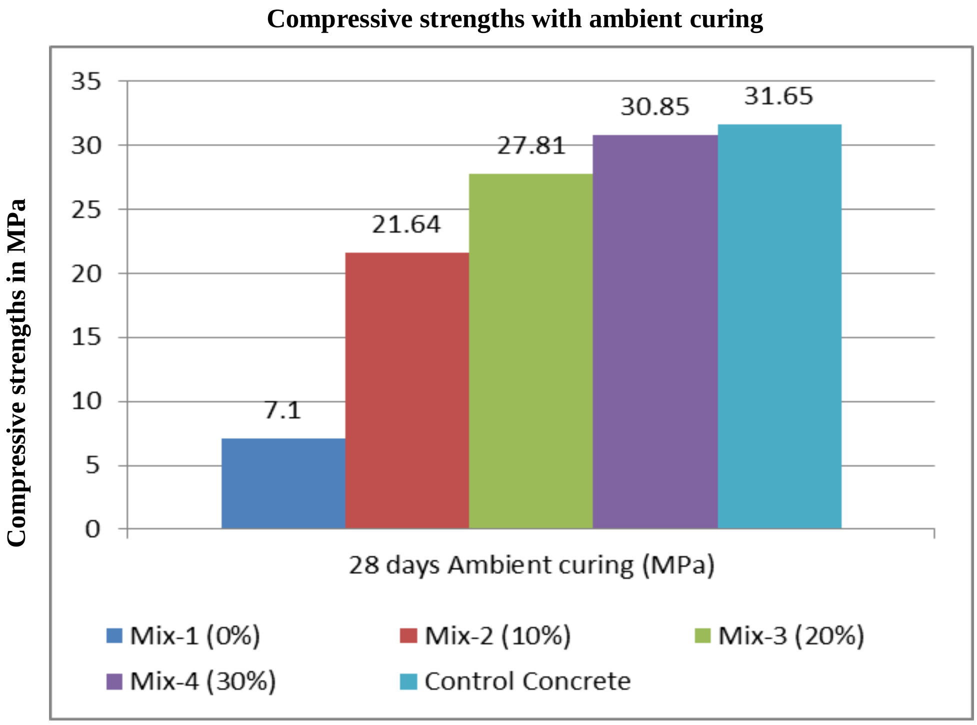
"Figure 3. 7 days Compressive Strength for Oven Curing"



"Figure 4. 7 days Compressive Strength for Ambient Curing"

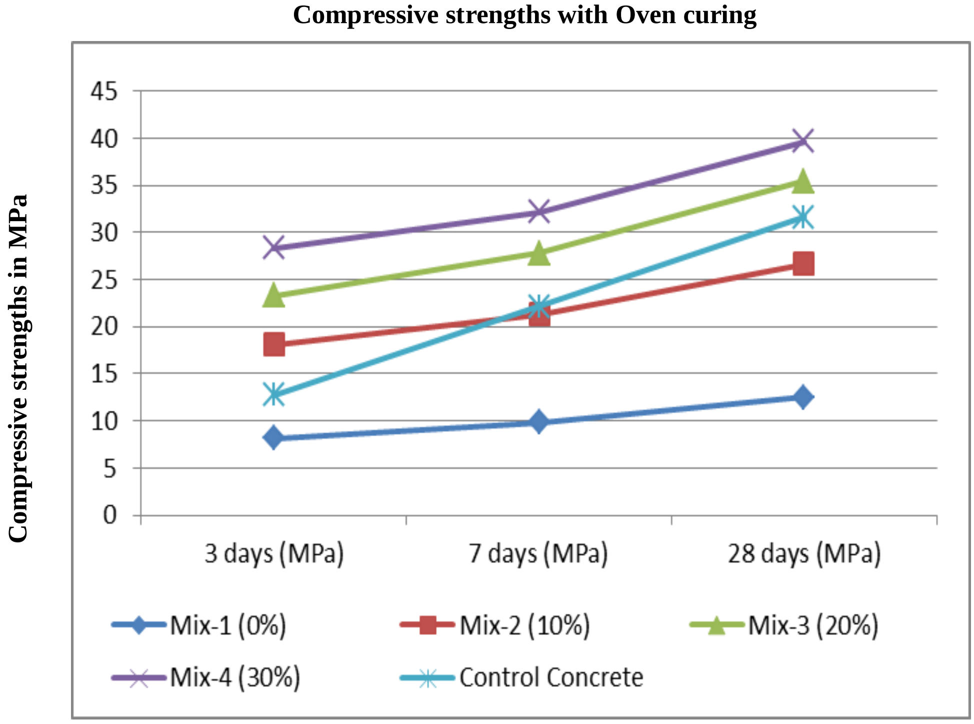


"Figure 5. 28 days Compressive Strength for Oven Curing"

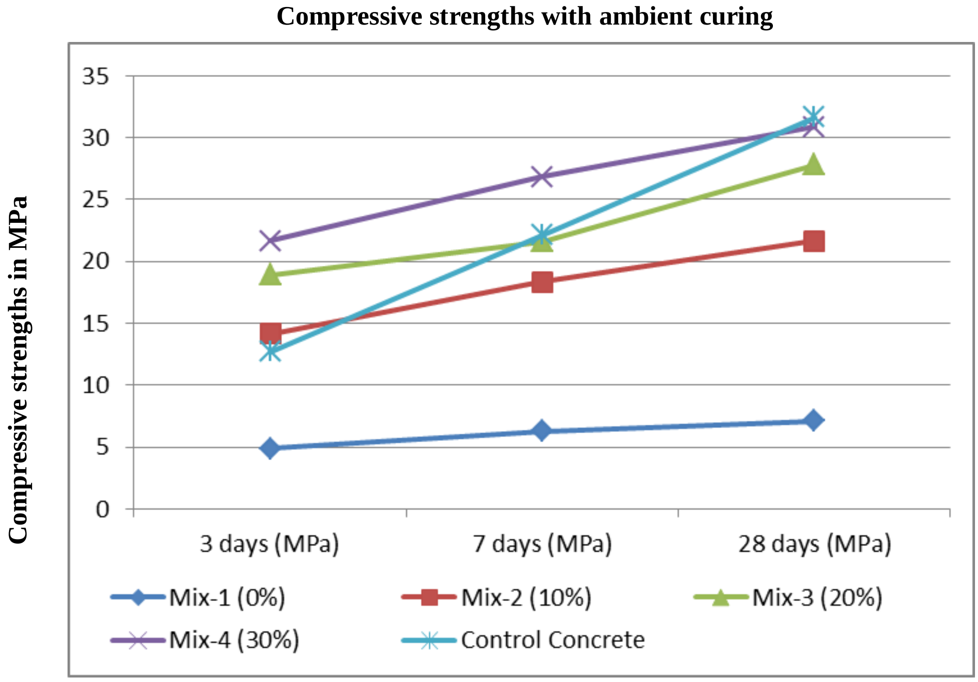


"Figure 6. 28 days Compressive Strength for Ambient Curing"

The summary of the compressive strength of the ambient and oven cured specimensis shown in Figure 7 and Figure 8.



"Figure 7. Compressive Strength in Oven Curing"



"Figure 8. Compressive Strength for Ambient Curing"

IV. Conclusion

The following conclusion can be drawn from the study carried out on that work:

1. Strength of geo-polymer concrete, for Oven Curing is more than ambient cured geo-polymer concrete at 3, 7 & 28 days.
2. By increasing the content of AQD than Compressive Strength decreasing in GGBFS geo-polymer concrete.
3. At 28 days when combination of 70:30 AQD and GGBFS content is used the strength is higher as compare to the same age with control concrete and nearly equal with ambient curing.
4. A higher concentration of GGBFS results in higher Compressive Strength of Geo-polymer concrete.
5. Geo-polymer concrete using various combinations of AQD and GGBFS gives optimum dosage at 70:30 proportion of each of AQD and GGBFS, after that quick setting observed.
6. For that optimum dosage, significant strength can be achieved even at ambient curing.
7. At 28 days Compressive Strength for 70:30 AQD and GGBFS combination content the Oven cured and ambient cured samples yield strength that is nearly equal to 25 MPa indicating that geo-polymer concrete can achieve desired strength at ambient curing.

Thus judicious mixture of GGBFS and AQD can be used to make geo-polymer concrete at ambient temperature for practical field application.

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