EXPERIMENTAL STUDIES OF CURING ON PROPERTIES OF GEOPOLYMER CONCRETE USING INDUSTIAL WASTE

[1]Dr. Bhavin G. Buddhdev, [2]Panchal Zeel Vinodbhai

[1]Assistant Professor, [2] PG Student, Department of Civil & Structural Engineering, Sardar Patel Collage of Engineering, Bakrol, Anand, Gujarat technological University

[1]Applied Mechanics Department,

[1] Vishwakarma Government Engineering College, Chandkheda, Ahmedabad, Gujarat, India

Abstract: Concrete is the world's most adaptable material and reliable concrete material. Next to water, concrete is most used material. Ordinary Portland Cement concrete is the second only to the automobile as major generator of carbon dioxide. In recent years, researchers have focused on finding an alternative to ordinary Portland cement to reduce carbon footprint. Natural material will be scare in future, to fine alternative solution by using such waste and also decrease the scarcity of landfill space. Most critical areas are still undiscovered for production of Geopolymer concrete. Various waste materials which possesses pozzolanic properties are capable of utilized for production of Geopolymer concrete. Apart from that such waste materials can also utilized for replacement of aggregates in Geopolymer concrete. Geopolymer is environment-friendly binder which has gain interest among the research community in last few decades. This type of research work in the area of Geopolymer concrete can drastically change properties of Geopolymer concrete in positive side and ultimately helpful in protection of environment by utilization of waste material in substantial amount. The main objective of this work is to produce the Geopolymer concrete of M25 and M40 grade by using industrial waste with alkaline solution concentration of 8M and 10M. The Geopolymer mix was prepared by using GGBS as binder, alkaline solution as activators. In mix design of M25 and M40 grade, normal sand was also replace up to 10% and 20%. The effect of various curing method were check on compressive strength of GPC and to find most economical and effective method of curing for GPC.

***Index Terms* - Geopolymer concrete, Alkaline solution, Pozzolanic material, Molarity, Curing, Compressive Strength.**

I. INTRODUCTION

Growing emphasis on energy conservation and environmental protection has brought about research of alternative to standard building substance. A few of the goals of these investigations are to lessen greenhouse fuel emissions and decrease the strength required for cloth manufacturing. Presently, portalnd cement is leading cloth for industrial concrete call for international, pleasurable a call for of over 1.5 billion lots annually. The manufacturing is Portland cement is energy-extensively and releases a enormous extent of carbon dioxide to the atmosphere.

Finding a suitable different solution to reduce the environmental humiliation caused by using Portland cement is very important for environmental supportability. The use of geopolymer concrete as an alternative material over Portland cement concrete to reduce the unfavorable effects on the environment is investigated in this paper and also analyses the economic and environmental benefits of geopolymer concrete and address the economic and environmental issues alliance with the production and use of Portland cement.

The geopolymer is synthesized by activating one or more supplementary cementing materials with help of activator solution (AS). Activator solution can be produce using silicates and hydroxides of sodium or potassium. Most regularly used are sodium silicate (SS) and sodium hydroxide (SH). Sodium hydroxide solution (SHS) of known molar application is prepared and mixed with sodium silicate solution (SSS) to form the activator solution (AS).

In this paper, there are two industrial wastes are used, GGBS utilized as a binder material with alkaline solution of sodium hydroxide and sodium silicate. And waste foundry sand is replaced by natural sand up to 20 %.

Experimental programme is carried out to characterize the sources material from industrial waste to prepare geopolymer concrete. Based on characterization of material available mix design for M25 and M 40 grade Geopolymer concrete by using GGBS is prepared. Various curing methods like Ambient curing, Oven curing and Accelerated curing tank method are employed to investigate the effect of different mix variable on the workability and compressive strength of M25 and M40 grade GPC produced from GGBS. Based on the result evaluated from experiments, analysis is carried out to check the effect various curing method on compressive strength of Geopolymer concrete.

II. EXPERIMENTAL WORK

2.1 Materials

2.1.1 Properties of GGBS

Ground granulated blast furnace slag (GGBFS) is one of the most common components in Geopolymer concrete, due to improved mechanical and microstructure properties. However, adding GGBFS cause poor workability due to higher viscosity. The GGBS was collected from Guru Corporation, sarkhej Ahmedabad.

Table 2.1: Properties of GGBS

Sr. No.	Test	Results	Requirements as per IS:12089-1987
1	Manganese oxide (MnO), % by mass	0.36	5.5 Max
2	Magnesium oxide (as MgO), % by mass	8.39	17.0 Max
3	Sulphide sulphur, % by mass	0.22	2.0 Max
4	Calcium oxide (as CaO), by mass	35.01	-
5	Silica (as SiO_2), % by mass	35.73	-
6	Alumina (as Al_2O_3), by mass	12.27	-
7	Iron (as Fe_2O_3), % by mass	0.96	-
8	$\frac{CaO + MgO + 1/3Al_2O_3}{Sio_2}$	1.08	≥ 1.0
9	$\frac{CaO + MgO + Al}{Sio_2 + 2/3\ Al_2O_3}$	1.56	≥ 1.0
10	Insoluble residue, % by mass	0.81	5.0 Max
11	Glass Content, % by mass	86.45	85.0 Max
12	Specific Surface area (Fineness), m^3/kg	489.67	-
13	Loss on ingnition, % by mass	2.25	-
14	Moisture, % by mass	0.65	-
15	Chloride (as Cl), % by mass	0.026	-
16	Acid soluble sodium oxide (as Na_2O), %	0.28	-
17	Soundness (lechatelier Expansion), mm	1.12	-
18	Initial setting time, Minutes	180	-
19	Retention on 45 µ IS Sieve, % by mass	5.64	-

2.1.2 Properties of Foundry Sand

Foundry sand is collected from GIDC Makarpura, vadodara for experimental work and this material is purely a waste material from industry.

Table 2.2 : Properties of Foundry sand

Sr. No.	Metal Oxide	Concentration (%)
1	Acid soluble sodium oxide (as Na_2O), %	2.201
2	Magnesium oxide (as MgO), % by mass	0.879
3	Alumina (as Al_2O_3), by mass	4.766
4	Silica (as SiO_2), % by mass	68.329
5	Phosphorus pentoxide (As P_2O_5), % by mass	0.375
6	Sulfur (as SO_3), % by mass	2.847
7	Potassium oxide (As K_2O), % by mass	0.535
8	Calcium oxide (as CaO), by mass	2.691
9	Titanium oxide (as TiO_2), % by mass	1.371
10	Manganese oxide (MnO), % by mass	0.117
11	Iron (as Fe_2O_3), % by mass	9.042
12	Zink oxide (as ZnO), % by mass	4.518
13	Zirconium dioxide (as ZrO_2), % by mass	0.32
14	Ruthenium oxide (as RuO_2), % by mass	0.135
15	Lead oxide (as PbO), % by mass	0.162

2.1.3 Properties of Coarse and Fine Aggregates

Locally available river sand was used as fine aggregate. The properties of fine aggregate, confirming to IS: 383-2016, are shown in table 2.3. The sieve analysis is conforming to IS: 1963-2016. Natural aggregate of maximum size 20 mm is taken in this study. The physical properties of coarse aggregate are shown in table 2.3. The aggregate was tested as per IS: 2386 (part 1,2,3), 1963 and IS:383-2016. and it was also collected from RMC plant, vadodara.

Table 2.3 : Properties of Coarse and Fine Aggregates

Sr. No.	Particulars	Coarse Aggregates	Fine Aggregates
1.	Gradation	20 mm down	Zone - II
2.	Sp. Gravity	2.88	2.58
3.	Fineness Modulus	6.02	2.83

2.1.4 Alkaline Activators

Sodium Hydroxide: Sodium hydroxide was collected from trading shop at vadodara. Generally the sodium hydroxides are available in solid state by means of pellets and flakes. The cost of the sodium hydroxide is mainly varied according to the purity of the substance. Since geopolymer concrete is homogenous material and its main process to activate the sodium silicate, so it is recommended to use the lowest cost i.e. up to 94% to 96% purity. In this investigation the sodium hydroxide pellets will used.

Sodium Silicate: Sodium silicate is also known as water glass or liquid glass, available in liquid (gel) form. As per the manufacture, silicates were supplied to the detergent company and textile industry as bonding agent. Same sodium silicate is used for the making of geopolymer concrete. The sodium silicate solution having 14.7 % Na_2O, 29.4 % SiO_2, and 55.6 % water by mass use. It was collected from sapana industries vadodara.

2.2 Mix Proportions and Mix Design

Morality Calculation: The solids must be dissolved in water to make a solution with the required concentration. The concentration of Sodium hydroxide solution can vary in different Molar. The mass of NaOH solids in a solution varies depending on the concentration of the solution. For instance, NaOH solution with a concentration of 16 Molar consists of 16 x 40 = 640 grams of NaOH solids per litre of the water, were 40 is the molecular weight of NaOH. Note that the mass of water is the major component in both the alkaline solutions. The mass of NaOH solids was measured as 444 grams per kg of NaOH solution with a Concentration of 16 Molar. Similarly, the mass of NaOH solids per kg of the solution for other concentrations was measured as 10 Molar: 314 grams, 12 Molar: 361 grams, and 14 Molar: 404 grams.

Mix Proportions: Since there are no codal provisions available for the mix design of geopolymer concrete, the density of geopolymer concrete was assume 2400 kg/m^3 and other calculation were made based on the density of concrete as per the design given by lloyd and rangan.

Mix Design: Based on the calculation carried out for mix proportion with the design methodology adopted for various mix proportion of M25 grade and M40 grade of geopolymer concrete are tabulated below.

Table 2.4 : Mix Proportion for M25 8M

Ingredients	Quantity (Kg/m^3) Foundry Sand 0 %	Quantity (Kg/m^3) Foundry Sand 10 %	Quantity (Kg/m^3) Foundry Sand 20 %
Ground Granulated Blast Furnace Slag (GGBS)	350	350	350
Sodium silicate (Na_2SiO_3)	27.56	27.56	27.56
Sodium Hydroxide (NaOH)	16.04	16.04	16.04
Fine Aggregate	684.10	615.69	547.29
Foundry sand	0	68.41	136.82
Coarse Aggregate	1387.28	1387.28	1387.28
Total Water	110	110	110
Extra Water	31.11	31.11	31.11

Table 2.5 : Mix Proportion for M25 10M

Ingredients	Quantity (Kg/m^3) Foundry Sand 0 %	Quantity (Kg/m^3) Foundry Sand 10 %	Quantity (Kg/m^3) Foundry Sand 20 %
Ground Granulated Blast Furnace Slag (GGBS)	350	350	350
Sodium silicate (Na_2SiO_3)	27.56	27.56	27.56
Sodium Hydroxide (NaOH)	19.23	19.23	19.23
Fine Aggregate	682.50	614.26	546.48
Foundry sand	0	68.25	136.50
Coarse Aggregate	1385.69	1385.69	1385.69
Total Water	110	110	110
Extra Water	34.30	34.30	34.30

Table 2.6 : Mix Proportion for M40 8M

Ingredients	Quantity (Kg/m^3) Foundry Sand 0 %	Quantity (Kg/m^3) Foundry Sand 10 %	Quantity (Kg/m^3) Foundry Sand 20 %
Ground Granulated Blast Furnace Slag (GGBS)	510	510	510
Sodium silicate (Na_2SiO_3)	40.16	40.16	40.16
Sodium Hydroxide (NaOH)	23.38	23.38	23.38
Fine Aggregate	620.87	585.79	496.71
Foundry sand	0	62.08	124.17
Coarse Aggregate	1260.58	1260.58	1260.58
Total Water	120	120	120
Extra Water	5.046	5.046	5.046

Table 2.7 : Mix Proportion for M40 10M

Ingredients	Quantity (Kg/m^3) Foundry Sand 0 %	Quantity (Kg/m^3) Foundry Sand 10 %	Quantity (Kg/m^3) Foundry Sand 20 %
Ground Granulated Blast Furnace Slag (GGBS)	510	510	510
Sodium silicate (Na_2SiO_3)	40.16	40.16	40.16
Sodium Hydroxide (NaOH)	28.08	28.08	28.08
Fine Aggregate	619.35	557.42	495.46
Foundry sand	0	61.93	123.86
Coarse Aggregate	1257.46	1257.46	1257.46
Total Water	120	120	120
Extra Water	9.687	9.687	9.687

III. RESULTS AND DISCUSSION

Based on the mix proportion selected, geopolymer concrete is produced to perform experiment work. Each set of cubes are casted and tested for various variation selected for 8M and 10M of concrete grade M25and M40. The compression strength of all variation is tested for various curing method and pattern selected for this work. The 7 day compressive strength and 28 day compressive strength for all those mix are described. In this research work, there are 12 different mix of grade M25 and M40 with molarity of 8M & 10M, using different rest period and partially replacement of foundry sand. For each and every mix 3 cubes are examined and each cube results are given.

3.1 COMPRESSIVE STRENGTH FOR M25 GRADE WITH 8M

Results of 7 and 28 Day compressive strength for design mix of mix 1, mix 2 and mix 3 is shown in figure 3.1 and figure 3.2. The mix 1 is M25 Grade of concrete, 8M with 0% foundry sand. Mix 2 is M25 Grade of concrete, 8M with 10% foundry sand. And Mix 3 is M25 Grade of concrete, 8M with 20% foundry sand (Refer Table: 2.4).

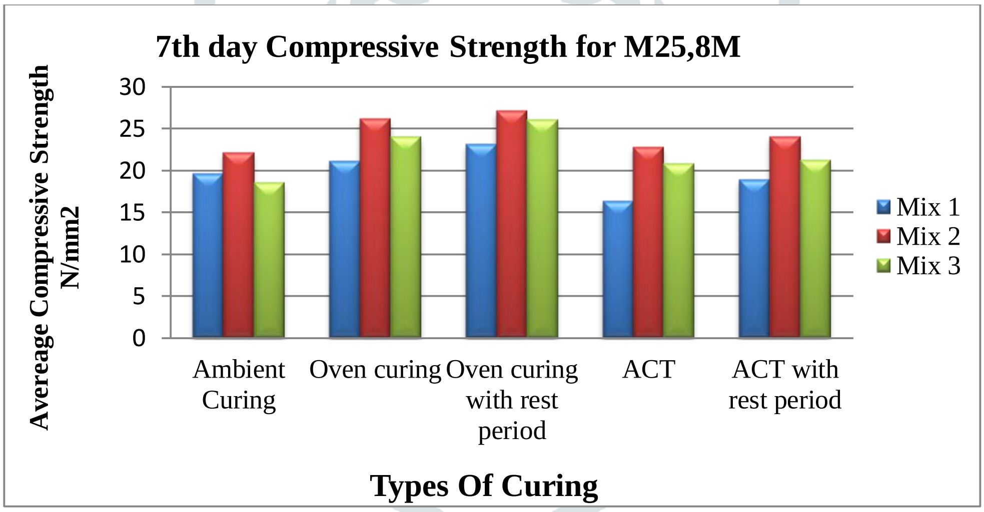

Figure 3.1: Compressive strength of M25, 8M concrete at 7 days

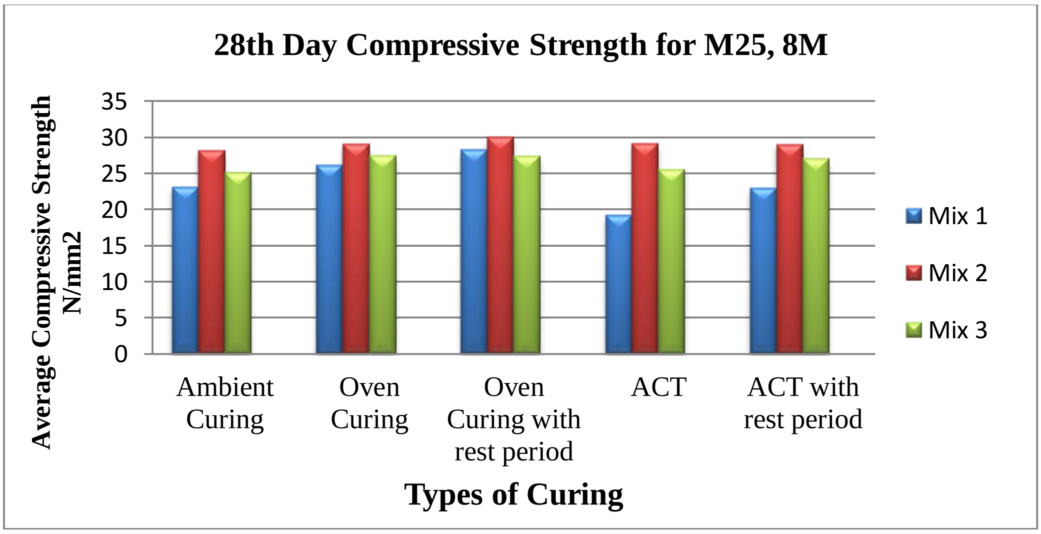

Figure 3.2: Compressive strength of M25, 8M concrete at 28 days

3.2 COMPRESSIVE STRENGTH FOR M25 GRADE WITH 10M

Results of 7 and 28 Day compressive strength for design mix of mix 1, mix 2 and mix 3 is shown in figure 3.3 and figure 3.4. The mix 1 is M25 Grade of concrete, 10M with 0% foundry sand. Mix 2 is M25 Grade of concrete, 10M with 10% foundry sand. And Mix 3 is M25 Grade of concrete, 10M with 20% foundry sand (Refer Table: 2.5).

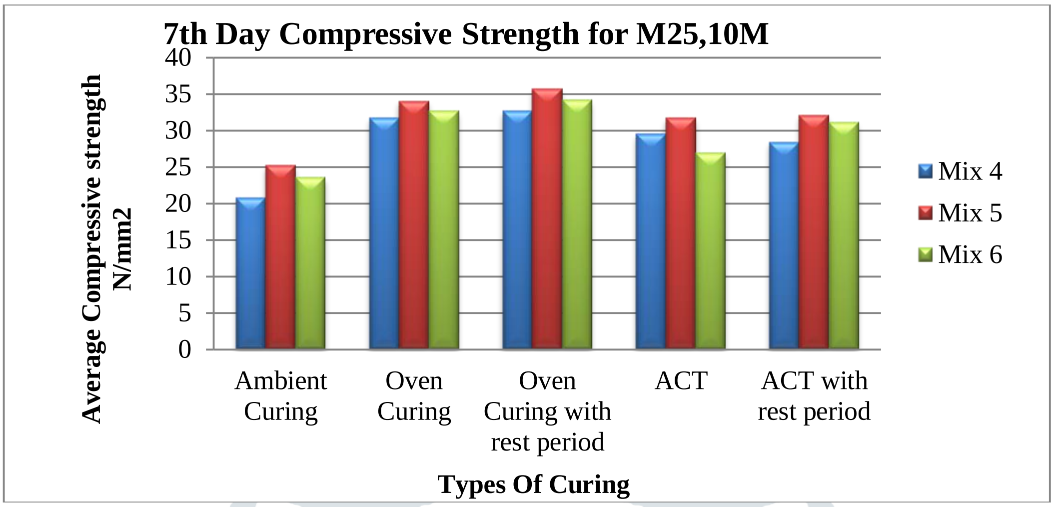

Figure 3.3: Compressive strength of M25, 10M concrete at 7 days

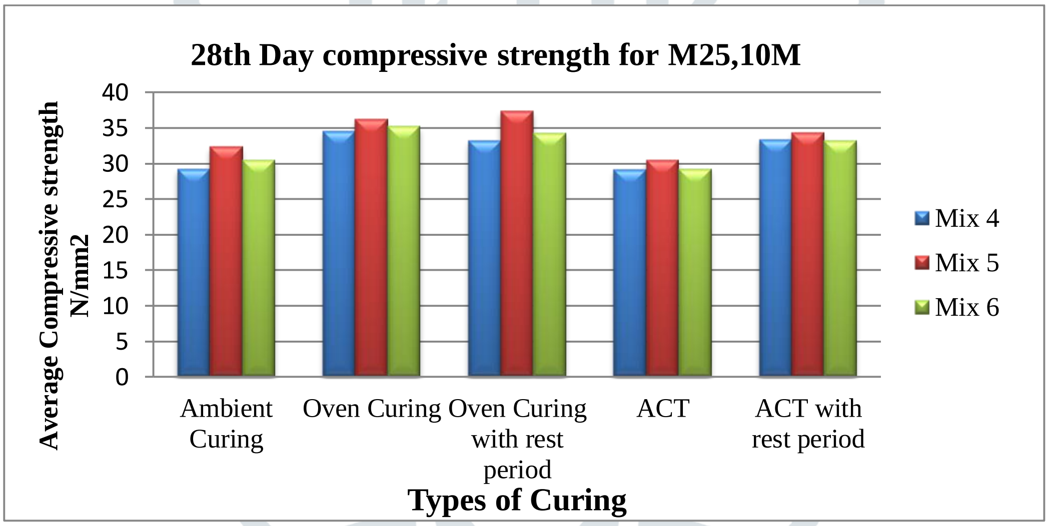

Figure 3.4: Compressive strength of M25, 10M concrete at 28 days

3.3 COMPRESSIVE STRENGTH FOR M40 GRADE WITH 8M

Results of 7 and 28 Day compressive strength for design mix of mix 1, mix 2 and mix 3 is shown in figure 3.5 and figure 3.6. The mix 1 is M40 Grade of concrete, 8M with 0% foundry sand. Mix 2 is M40 Grade of concrete, 8M with 10% foundry sand. And Mix 3 is M40 Grade of concrete, 8M with 20% foundry sand (Refer Table: 2.6).

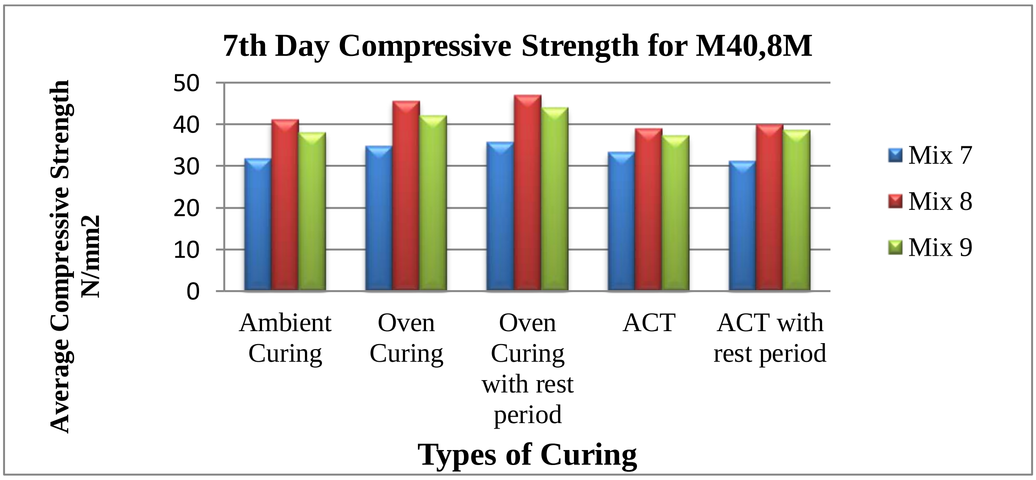

Figure 3.5: Compressive strength of M40, 8M concrete at 7 days

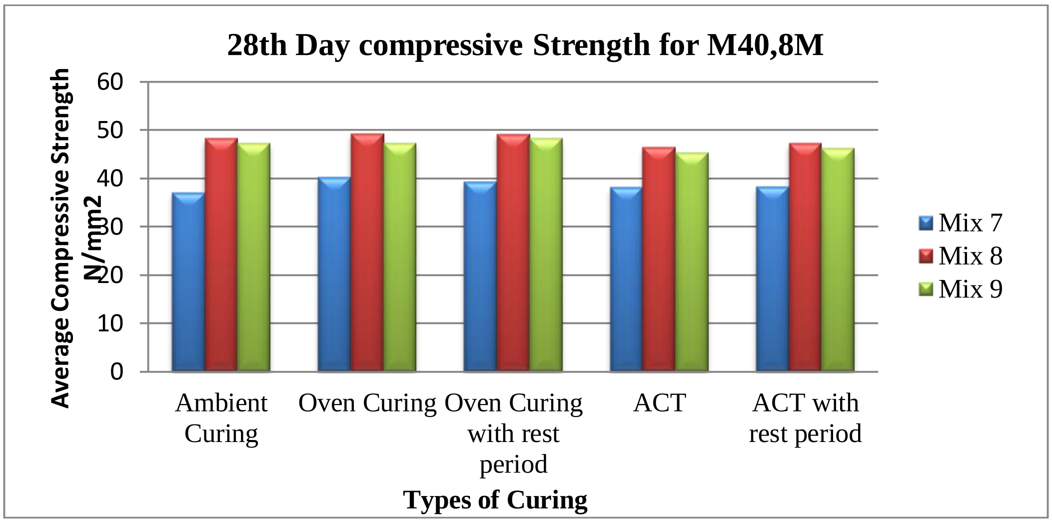

Figure 3.6: Compressive strength of M40, 8M concrete at 28 days

3.4 COMPRESSIVE STRENGTH FOR M40 GRADE WITH 10M

Results of 7 and 28 Day compressive strength for design mix of mix 1, mix 2 and mix 3 is shown in figure 3.7 and figure 3.8. The mix 1 is M40 Grade of concrete, 10M with 0% foundry sand. Mix 2 is M40 Grade of concrete, 10M with 10% foundry sand. And Mix 3 is M40 Grade of concrete, 10M with 20% foundry sand (Refer Table: 2.7).

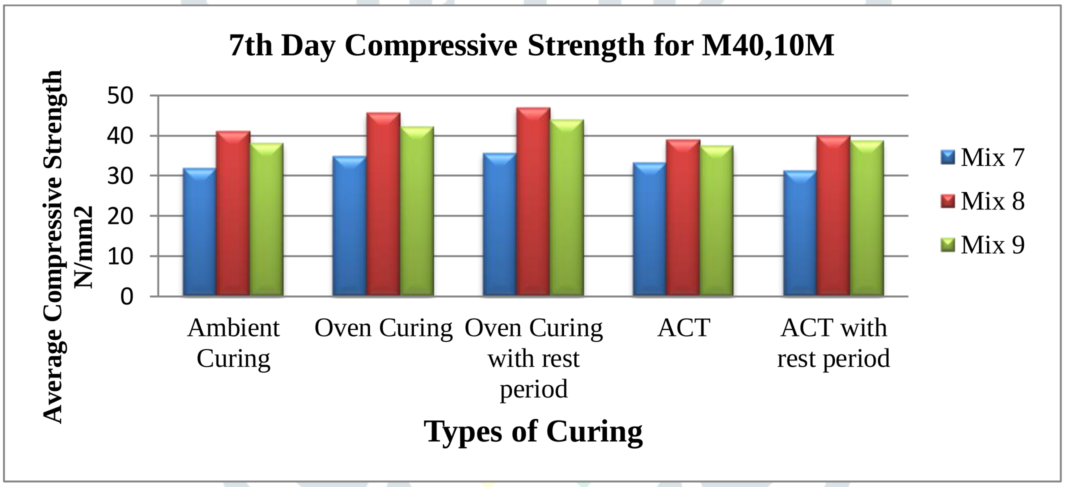

Figure 3.7: Compressive strength of M40, 10M concrete at 7 days

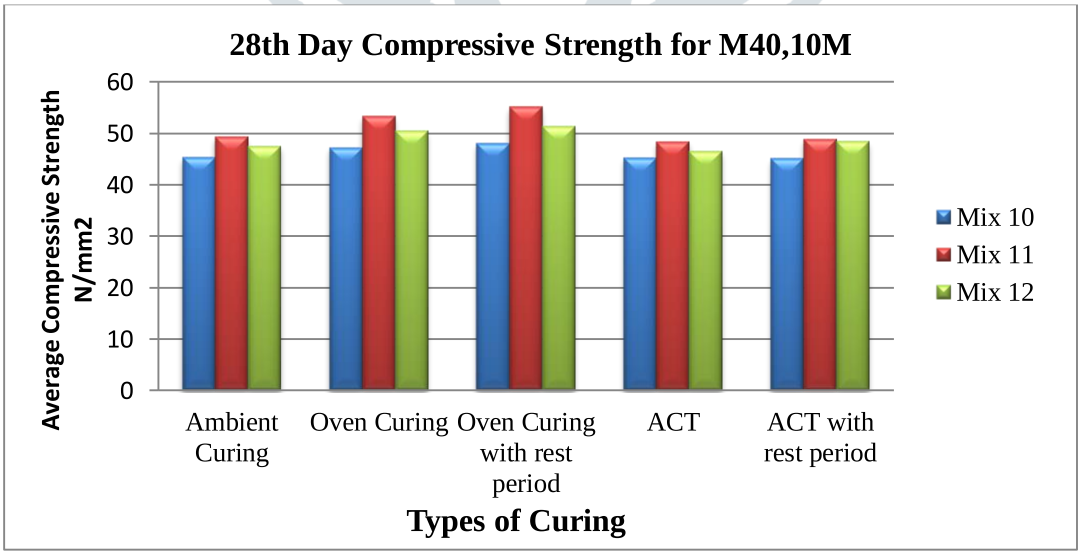

Figure 3.8: Compressive strength of M40, 10M concrete at 28 days

3.5 DISCUSSION:

From the experimental work its show the Compressive Strength is achieved nearest to target mean strength in Ambient Curing at 7 day, for M25 and M40 grade of concrete on both 8M and 10M, and earn more than target mean strength at 28 days for the same curing, same grade of concrete in both molarities. For accelerated Curing, the compressive strength is getting greater than target mean strength at both 7 day and 28 day period of curing, but it is lesser than oven curing and greater than ambient curing. Due to increase temperature, in oven curing compressive strength is getting greater than target mean strength and also is greater than two types of curing: ambient curing and accelerated curing. In all curing method the strength is increase with rest period. 7 and 28 day compressive strength is getting more in M25 Grade of concrete compare to M40 grade of concrete. And also the 7 and 28 day compressive strength is increase with increase the concentration of sodium hydroxide. Using 10% and 20% foundry sand in the place of nature sand the strength in both replacement is getting more than using without replacement of natural sand in concrete, the results of using 10% foundry sand is compare to using 20% foundry sand is more. One of profit thing is that achieved by ambient curing save the water coz of getting nearest compressive strength to target mean strength at 7 day and more than target strength at 28tday, second one is that, using foundry sand we save some percentage of natural sand.

IV. CONCLUSIONS

Based on the experimental work, it is conclude that, user-friendly Geopolymer concrete can be used under similar conditions to those suitable for control concrete. In this work, Geopolymer concrete is made using GGBS, Sodium Silicate & Sodium Hydroxide as a binder. The ratio of GGBS to alkaline solution is 0.35 by mass and ratio of alkaline liquid is 1.0 by mass. Compressive strength of concrete for both grade as well as for both molarity, oven curing with rest period give maximum compressive strength. Compressive strength with rest period gives better strength as compare to no rest period for all types of curing methods consider in this study, however the increase in the strength is very marginal. Compressive strength due to accelerated curing is less as compare to oven curing but more with respect to ambient curing. Compressive strength of mix is increase as the molarity increase and it follows same trends with respect to past research work. Foundry Sand is one of the good materials as an alternative of natural sand. Whereas the foundry sand has some adverse effect on concrete when used in high or full replacement decrease the workability of concrete. In this study 10% replacement of foundry sand give fair result.

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