

**AN EXPERIMENTAL APPROACH TOWARDS ROLE OF GEOPOLYMER CONCRETE
WITH GGBS IN RIGID PAVEMENTS****Sathish M**

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ABSTRACT

In present day construction concrete is overpriced and popular material used where cement is the main source. The world is producing billion tons of concrete in a year. While undergoing cement production process, CO₂ is evolved which is the core cause of Global warming. Current Researchers have did enormous job and created many bountiful ways to alter cement. For composing geopolymer concrete by products of various industries may be used like Fly ash, rice husk. In this inquiry geopolymer concrete is prepared with GGBS. GGBS is a byproduct of steel production industry. In this research geopolymer concrete is prepared with GGBS (Ground Granulated Blast Furnace Slag) and merits and demerits of GGBS are also discussed. Alkaline activator 8M, 10M, 2M & 16M are taken here. The proportion of Activator used is 1:2.5. The cubes prepared for the research was cured in room temperature. Curing is done with ordinary domestic water.

Workability of the geopolymer green concrete was not within the good limit. So, plasticizer is added which enhances the workability. Specimen is tested for compressive strength, flexure strength & split tensile strength. All the tests are performed at the standard period based on literature study and guided for concrete other than GPC. Unit weight of GPC was taken as 2400 KG/M³. There are certain constraints to fully replace GPC with the cement. Engineers are trying to establish complete replacement to protect the environment as it makes a eco-friendly concrete. GGBS is a good replacement of cement and production of CO₂ is reduced considerably. Our study tries to achieve the strength a of m45 grade OP.

Keywords: Geopolymer, Fly ash, rice husk, Ground Granulated Blast Furnace Slag, plasticizer, compressive strength, flexure strength & Split tensile strength test.

INTRODUCTION

In this golden era, the concrete is one of the major and widely used construction material. India consumes tones of ready-mixed concrete every year. Previous study reports conclude on an average

that 3 tons of concrete is used per head. CO₂ is a main cause of Global warming. CO₂ contributes 65% and out of this 7% is from cement manufacturing industry. India, China & USA are generally the major consumers of concrete produced. It was estimated that cement production was raising 2.5% annually and so is the raise of CO₂ emitted in air. Previous studies shows around 1ton of CO₂ is produced in manufacturing of 1ton of cement. On the other hand there were plenty of materials available which are ready to replace cement which helps in reduction of emission of CO₂. Fly ash, slag, rice husk, GGBS are the things which are used for replacement. In this study, the concrete prepared is known as Geopolymer concrete. GPC is considered and developing to achieve full replacement of concrete. Previous studies conducted by the researchers shows that use of GGBS in Geopolymer concrete has improved the strength properties but when added in excess amount may reduce its strength. GGBS is generally produced at the steel manufacturing process. Generally, minerals like limestone and iron ore are put into a kiln for the production of iron. Then heated at a temperature of 16000C. At this heat slag is produced approximately 40% lime (CaO) and 30-40% SiO₂ which is cementitious in nature which hydrated like cement and also chemical resistant. The Molten iron is segregated and slag contains residue which have siliceous and aluminous properties. The molten iron slag when immersed in water produces granulate slag. The cooling should be rapid to obtain granulated Slag. Then it is dried and ground into fine powder to get GGBS. This process of preparation was introduced by Joseph Davidovits in the year 1972 as an alternative of OPC GGBS is white in color and has a specific gravity of 2.6, average particle size of 4.75 mm. This GGBS is an admixture as per IS 456:2000. It contains different ingredients like Aluminum Oxide, Calcium Oxide, Magnesium Oxide, Manganese Oxide, Silica, Sulphur, Iron Oxide. The Alkali – Silicate reaction can be very detrimental to the stability of concrete for this GGBS.

GGBS while replacing the cement, the Alkaline Activator Solution is the source material helps in binding of aggregates. In this study, 75% volume is occupied by Aggregates. Sodium hydroxide and Sodium Silicate solution are used for activating Silicon and Aluminum.

Geopolymer concrete has considerably high strength and can be used for construction of rigid pavement, buildings etc. GGBS have all the properties similar to that of cement. The role of GGBS for rigid pavement is established in this study. It can be one best alternate of OPC concrete. Curing can be executed both in room condition and also in oven to establish the complete behavior at various temperature conditions. Micro cracks found in OPC when exposed to sunlight over a period of time cannot be seen in GGBS.

The demand of OPC based on the consumption is making it expensive and also is harmful to the environment. Numerous studies have been conducted on GPC. But GPC with GGBS for rigid pavements are very little addressed. This research throws light on the suitability of GPC with GGBS for rigid pavements for study the engineering properties of GPC with GGBS. This research also tried to develop a mix without OPC for Rigid Pavements and identify the method for preparation of workable mix.

India is the leading producer of steel. This shows that there are good chances for India to produce GGBS in large quantity. Increase in use of GPC with GGBS will help in reduce the use of OPC and also reduces the pollution that causes. This also helps in achieving the ALL-WEATHER ROAD. The aim of the study is to test the strength of rigid pavements made with GGBS.

The presence of Silicon, Aluminum and polymerization is called geopolymer which was coined by Joseph Davidovits. Geo polymerization includes the chemical reaction between Si-O-Al present in source material. The source material has Si and Al ion react with alkaline activator solution. In 1979 Davidovits made fly ash based geopolymer concrete in 2000 song S. et al. GGBS as source material in 2015 Venkatesan R P and Pazhani 2015 studies about strength and durability. In 2015 Alwis Deva K.J.P and Sakthieswaran N. has conducted study over GGBS and Red mud GGBS is a byproduct formed due to rapid cooling of molten steel and it has similar properties of cement, good thermal insulation property, cheaper and resistant to chemical attack. Slag has the component Al_2O_3 , CaO , MgO and SiO_2 all these material exhibit cementitious property. Presence of Al_2O_3 and CaO will increase the strength and also activation of Si and Al in GGBS 3.5- 5.5% NaOH. Chemical shrinkage and porosity are comparatively much higher in GGBS as that of Portland cement. Past study on alkaline activator binder shown activation of pozzolanic material helping geo polymerization process as it increase the rate of reaction. NaOH and Na_2SiO_3 helps in achieving higher compressive strength. Alkaline solution helps in binding the materials. The preparation of alkaline solution is generally done by mixing sodium hydroxide with water and with sodium silicate solution. In this investigation sodium hydroxide and sodium silicate solution ratio used is 2.5. As already mentioned that NaOH, K_2SiO_3 and Na_2SiO_3 is commonly used as alkaline activator. NaOH has higher degree of resolution as compared to the KOH - Palomo et al. 1999.

Geo polymerization process contains four steps. Isothermal conduction process has been carried out to study the impact of GGBS amount between (5-50%). The reaction at 27oc dissolution ends in precipitation because of dissolution activation of GGBS at 60oc interaction with GGBS. The curing is done both at room temperature and natural sunlight. Various researchers have tried out different curing possibilities out of which steam curing is one important for fly ash binder. Maximum work had been carried out to find out the proper curing method and certain result are obtained between mixtures by varying molarity of sodium hydroxide shows that mix cured in oven posses higher compressive strength as compared with direct sunlight compressive strength ass presented in the figure 1 and 2. In 2019 Ramomohan B, Gopinathan P, Chandrasekhar I., Thus had compared the properties of concrete by using GGBS and fly ash however, it was found that generally GGBS gains the strength more in sunlight.

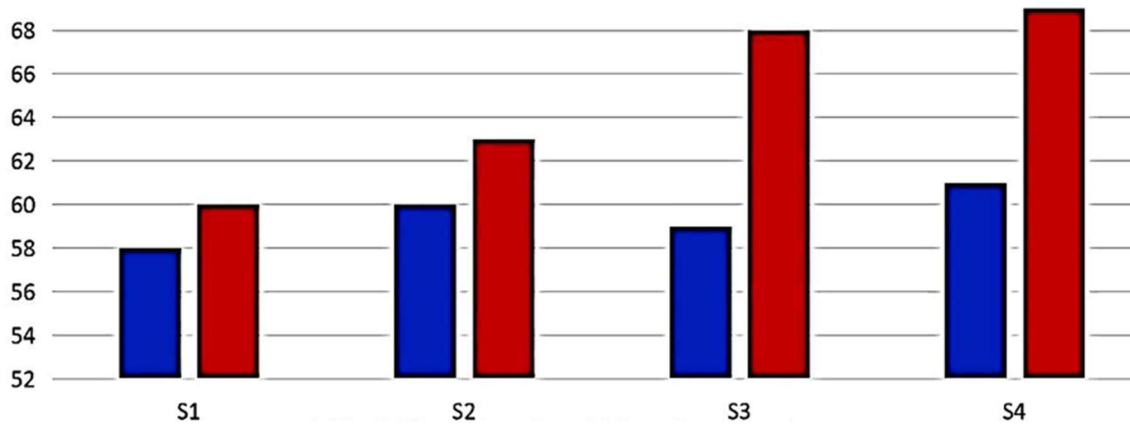


Fig 1: Variation of Compressive Strength at 3 days between Specimen Room Temperature Cured and Direct Sunlight (Blue present sunlight cured specimens and red present oven cured specimen)

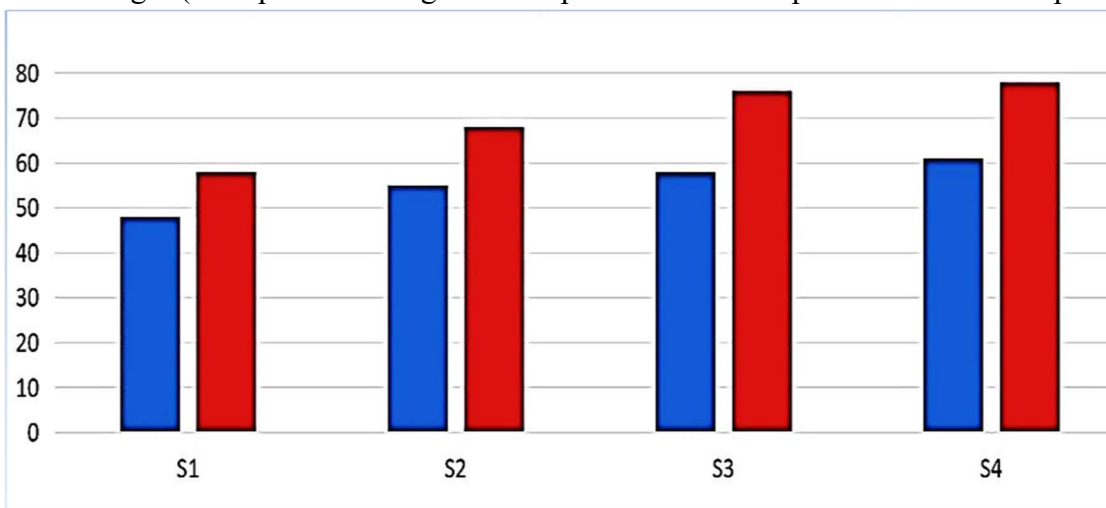


Fig 2: Variation of Compressive Strength at 7 days between Specimen Room Temperature Cured and Direct Sunlight (Blue present sunlight cured specimens and red present oven cured specimen)

Previous studies on engineering properties and behavior of geopolymer concrete shows that compressive strength is one of the main and important property of concrete which is enhanced. In previous period, some studies have been carried out on Geopolymer concrete which is closed. Studied by varying contents. Based on the experiments conducted It was found that increase in GGBS increases the compressive strength. Here a table has been represented showing different mix designs strength attained on various curing periods tested by Ramomohan B, Gopinathan P, Chandrasekhar I.

Table 1: Variations of Compressive Strength

Sample No.	Compressive Strength(N/mm ²)	
	28 days strength of room cured sample	28 days strength of sun dried sample

1	20	24. 31
2	24. 23	27. 74
3	28. 75	32. 25
4	33. 25	38. 12
5	44. 16	47. 89
6	24. 58	24. 58

Some other studies has been carried out on Fly ash based GPC. Mechanical properties have been studied by B.Rajini and A.V. Narasimha. Mainly fly ash and GGBS is used as a Source Material. Alkaline liquid and fly ash Ratio is 0.35. Research have designed M45 Grade of concrete as per IS 10262:2009 and IS 456:2000. NaOH was mixed with water to prepare a solution of concentration of 10 Molar. The sample has 60%water and 40% NaOH. Sodium hydroxide solution taken is 16kg and water is 25 kg. The mass that was denoted by them was 409 kg of geopolymer solid. Complete mass of GGBS with fly ash 470 kg and water to geopolymer ratio 0.17. The complete presentation of material and mixes of cement concrete and geopolymer concrete has been presented as below.

Table 2: Mix Properties of Cement Concrete and Geopolymer Concrete

Materials		Weight(kg/m ³)					
		M 45	FA0-GGBS100	FA25-GGBS75	FA50-GGBS50	FA75-GGBS25	FA100-GGBS0
CA	20mm	606	776	776	776	776	776
	10mm	404	517	517	517	517	517
FA		625	554	554	554	554	554
Cement		533	0	0	0	0	0
Fly ash(classf)		0	0	102.2	204.5	306.7	409
GGBS		0	409	306.7	204.5	102.2	0
SSS		0	102	102	102	102	102
NaOH ₂		0	41(I0M)	41(I0M)	41(I0M)	41(I0M)	41(I0M)
Ex water		0	55	55	55	55	55

Alkaline sol. (FA+GGBS)/ Weight	0	0.35	0.35	0.35	0.35	0.35
Water/Geopolymer solids.	0	0.29	0.29	0.29	0.29	0.29

Table 3: Compressive Strength of Cement Concrete and Geopolymer Concrete

Property	Age	Mix type					
		M45	FA0-GGBS100	FA25-GGBS75	FA50-GGBS50	FA75-GGBS25	FA100-GGBS0
Comp. Str. (MPa)	7	26.12	54.29	51.11	35.30	13.30	10.51
	28	51.39	60.23	58.12	46.32	15.55	12.11
	56	54.23	63.11	59.02	48.33	28.22	18.68
	90	56.34	65.23	62.32	51.78	33.02	22.03

From the above table it can be conclude that concrete with 100% GGBS gives maximum compressive strength. The compressive strength is maximum at all curing periods and the values are lower than that of conventional concrete.

Split tensile strength is one of the most important properties of the concrete. It gives idea about the cracks, shear and anchorage. Various researchers have stated that increasing the percentage of GGBS increases the Tensile strength of the concrete. Study done by B. Rajini and A.V. Narasimha Rao regarding Split tensile strength is presented below in Table 4.

Table 4: Split tensile Strength

Property	Age	Type of mix	
		M45	FA0-GGBS100
Strength (MPa)	7	2.23	2.46
	28	3.44	3.56
	56	3.51	3.82
	90	3.59	4.06

Flexural strength is one of the most important property to be tested. Some other experimental

investigation made by N. Veerendra Babu, B.G. Rahul, Y. Himath Kumar has found the flexural strength as following. The flexural strength is known as bed strength or modulus of rupture. The specimen that was used has Length 500mm, Breadth 100mm, Width 100mm in testing.

Table 5: Molarity and Average Flexural Strength

S.NO.	Molarity	Average Flexural Strength		
		3days	7days	28 days
1	6	4.5	5.1	6.2
2	8	4.2	5.5	6.8
3	10	4.7	5.8	6.8

Study on Alkaline activator ratio also shows us that higher alkaline activator content gives higher strength until a certain limit. Some previous study shows that ratio from 3.3 to 4.0 provides a better amount of results a comparative result for this has been shown in the graph plotted below with molarity from 8M-16M.

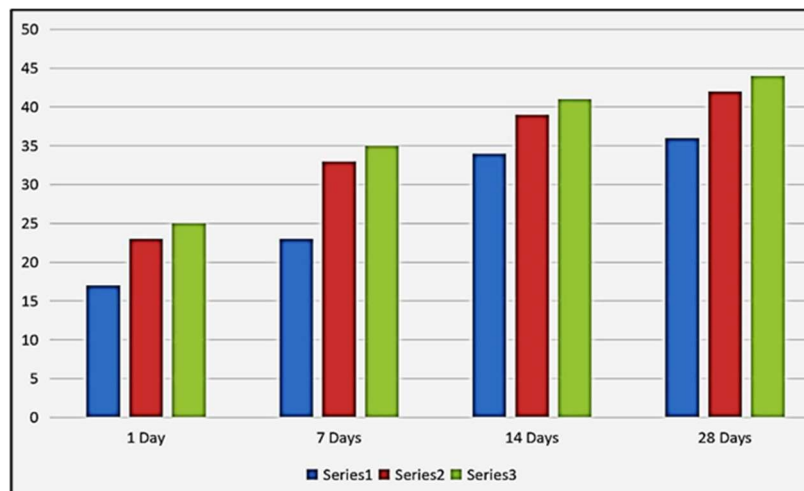


Fig 3: Molarity VS Compressive Strength

Water to geopolymer solid ratio is total mass of water that is to be considered as sum of mass of water in sodium silicate solution, mass of water taken to make Sodium hydroxide. Previous studies have shown that a ratio up to 0.17-0.18 shows moderate results. And if there is increase beyond 0.18 gives negative results.

Sodium silicate and sodium hydroxide ratio were varied in previous studies which had ratio of 1.0 of Na₂SiO₃ & NaOH provides a strength of 70MPa. Research found that a ratio mass 2.5 gives a very high compressive strength. Some other research shows that a ratio of 1.5 gives good result around 48MPa of compressive strength. Apart from this a ratio of 2.5 gives a result of 71MPa of compressive strength. A Research has been carried out in 2017 by Manimaran E and Mohan Kumar

G that on Sodium Hydroxide Concentration and the strength of fly ash based Geopolymer concrete specimen is 95-97% of hot cured concrete. Hot curing may be employed in case of fabrication of Precast Units. An another Research has been carried out in 2018 by Patankar S.V.on effect of temperature and duration Concrete on Compressive strength of fly ash based concrete that the compressive strength of geopolymer concrete increase in the concentration of sodium hydroxide solution for all temperature. If temperature more than 600C is not convenient. A Research has been carried out in 2017 by Manimaran E and Mohan Kumar G that higher concentration of NaOH reduces the slump Value and to make the mix workable add some extra amount of water. The characteristic strength of Geopolymer concrete 3% more than that is easily obtained by lowest molarity 8M Of NaOH both in hot and ambient curing. An another Research has been carried out in 2018 by Patankar S.V studied the effect of various concentrations on the strength of fly ash based concrete on amount of sodium hydroxide solution in terms of Molarity to flyash ratio 0.30, 0.35, 0.40 on workability in terms of flow plastic state. This research shows that compressive strength increases in increases in amount of sodium hydroxide sol in terms of molarity. They recommended 13M solution on the basis of workability and compressive strength. In 2018 Sudhakarreddy K reported that 6% of replacements of cement in Flyash of Geopolymer Concrete Yields the good results in flexure strength of beam. In maximum studies is shown that they have used some other material with GGBS but this work replacing the cement completely.

ANALYSIS AND RESULTS

This test portrays how effectively the prepared mixture works on fresh concrete as per IS: 1199-1959. Tested the slump for different molarities of sodium hydroxide and presented as shown in Table 6. From this table it was concluded that as the molarity of the NaOH increases when the slump value decreases as shown in Figure 4. This means workability of mix decreases when quantity of sodium hydroxide increases. The workability gets decreasing after 10 minutes. In between 10-15 minutes workability was decreasing at a steady rate as compare to first one and at 20 minutes with GPC. A graph Molarity Versus Slump value has been plotted as shown in Figure 5.

Table 6: Molarity and Slump Value

S. No.	Mix no	Molarity	Slump value(mm)
1.	Mix 1	8M	209
2.	Mix 2	10M	182
3.	Mix 3	12M	158
4.	Mix 4	14M	122
5.	Mix 5	16M	92

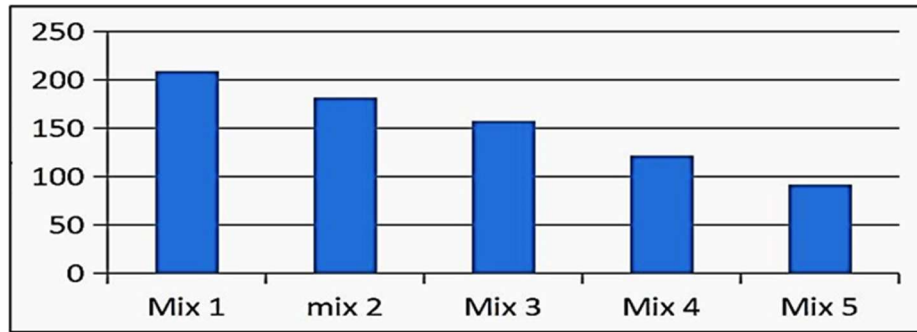


Fig 4: Slump Cone Test Reading

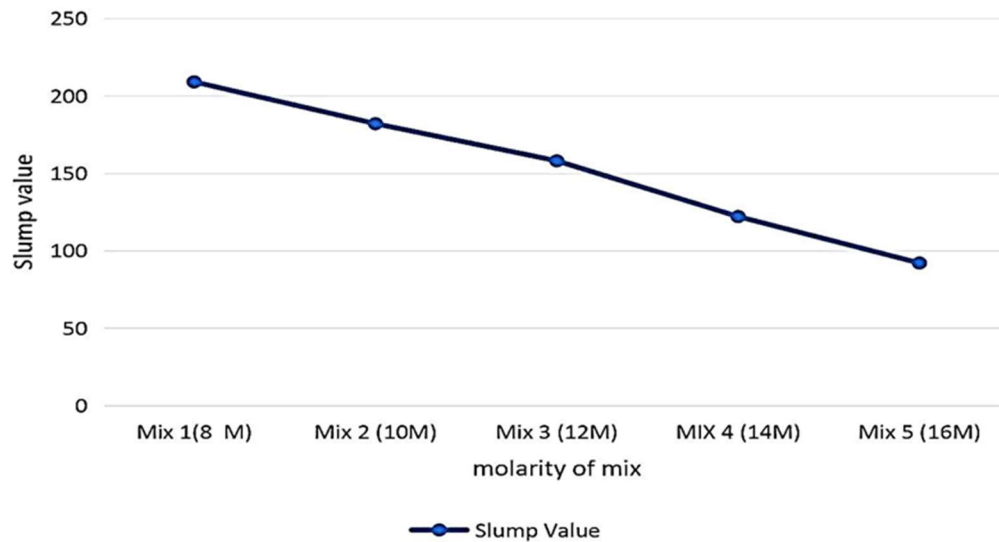


Fig 5: Molarity and Slump Value

Compressive strength has tested the compressive strength of GPC on different molarity. Compressive strength has been tested on different curing ages. It is tested on 3days, 7days and 28days. The average compressive strength is shown below and also plotted below.

Table 7: Compressive Strength of Cement Mix 1

Sr. No.	Age in Days	Cube no.	Molarity	Strength in MPa	Average Strength
1	3Days	1	8M	46.32	47.12
2		2	8M	47.69	
3		3	8M	47.37	
4	7Days	1	8M	55.54	55.65
5		2	8M	56.3	
6		3	8M	55.12	
7	28Days	1	8M	57.82	57.73
8		2	8M	57.39	
9		3	8M	57.41	

Table 8: Compressive Strength of Cement Mix 2

Sr. No.	Age in Days	Cube no.	Molarity	Strength in MPa	Average Strength
1	3Days	1	10M	54.46	56.80
2		2	10M	49.59	
3		3	10M	53.34	
4	7Days	1	10M	57.76	61.79
5		2	10M	58.79	
6		3	10M	59.82	
7	28Days	1	10M	61.32	65.51
8		2	10M	62.85	
9		3	10M	62.37	

Table 9: Compressive Strength of Cement Mix 3

Sr. No.	Age in Days	Cube no.	Molarity	Strength in MPa	Average Strength
1	3Days	1	12M	56.32	52.4
2		2	12M	56.38	
3		3	12M	55.49	
4	7Days	1	12M	61.23	61.48
5		2	12M	61.33	
6		3	12M	61.89	
7	28Days	1	12M	64.39	64.53
8		2	12M	64.50	
9		3	12M	64.72	

Table 10: Compressive Strength of Cement Mix 4

Sr. No.	Age in Days	Cube no.	Molarity	Strength in MPa	Average Strength
1	3Days	1	14M	58.54	58.17
2		2	14M	57.65	

3		3	14M	58.32	
4	7Days	1	14M	62.79	62.48
5		2	14M	62.45	
6		3	14M	62.21	
7	28Days	1	14M	67.36	67.70
8		2	14M	68.58	
9		3	14M	67.17	

Table 11: Compressive Strength of Cement Mix 5

Sr. No.	Age in Days	Cube no.	Molarity	Strength in MPa	Average Strength
1	3Days	1	16M	60.42	61
2		2	16M	61.63	
3		3	16M	60.95	
4	7Days	1	16M	66.37	65.85
5		2	16M	65.72	
6		3	16M	65.48	
7	28Days	1	16M	69.83	69.04
8		2	16M	69.08	
9		3	16M	68.23	

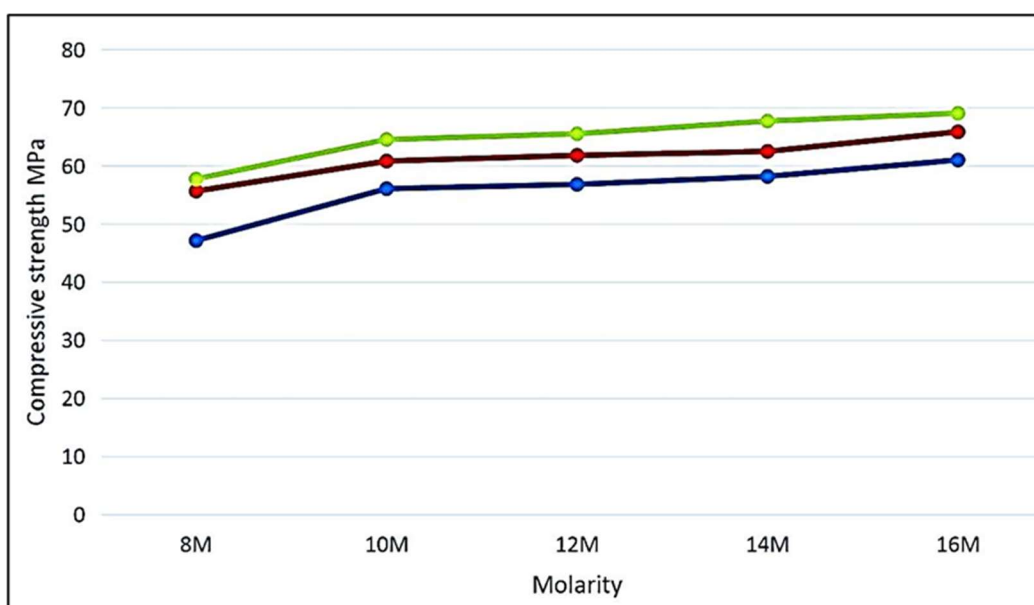


Fig 6: Compressive Strength on Different Molarity

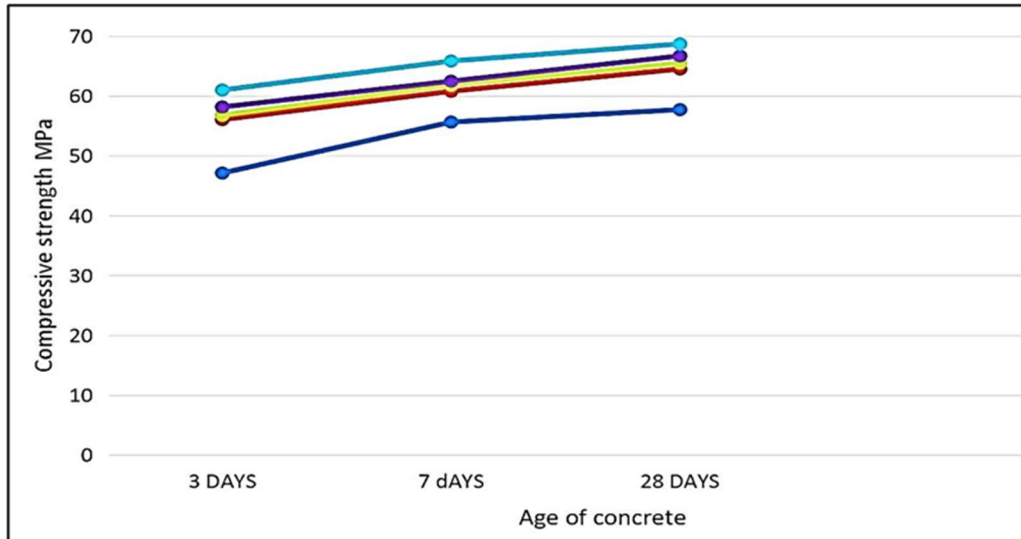


Fig 7: Age of Mix and Compressive Strength

The investigation results for the tensile strength for the GPC. Split tensile strength has been tested on 3days, 7 days and 28 days. The different values of split tensile strength have been plotted below.

Table 12: Split Tensile Strength of Cement Mix 1

Sr. No.	Age in Days	Cube no.	Molarity	Strength in MPa	Average Strength
1	3Days	1	8M	3.20	3.20
2		2	8M	3.18	
3		3	8M	3.21	
4	7Days	1	8M	3.71	3.63
5		2	8M	3.46	
6		3	8M	3.73	
7	28Days	1	8M	3.92	3.94
8		2	8M	3.98	
9		3	8M	3.93	

Table13: Split Tensile Strength of Cement Mix 2

Sr. No.	Age in Days	Cube no.	Molarity	Strength in MPa	Average Strength
1		1	10M	3.72	

2	3Days	2	10M	3.86	3.83
3		3	10M	3.93	
4	7Days	1	10M	4.11	4.16
5		2	10M	4.23	
6		3	10M	4.15	
7	28Days	1	10M	4.42	4.41
8		2	10M	4.38	
9		3	10M	4.41	

Table 14: Split Tensile Strength of Cement Mix 3

Sr. No.	Age in Days	Cube no.	Molarity	Strength in MPa	Average Strength
1	3Days	1	12M	4.49	4.47
2		2	12M	4.58	
3		3	12M	4.36	
4	7Days	1	12M	4.87	4.88
5		2	12M	4.89	
6		3	12M	4.88	
7	28Days	1	12M	5.21	5.28
8		2	12M	5.29	
9		3	12M	5.36	

Table 15: Split Tensile Strength of Cement Mix 4

Sr. No.	Age in Days	Cube no.	Molarity	Strength in MPa	Average Strength
1	3Days	1	14M	4.65	4.61
2		2	14M	4.67	
3		3	14M	4.51	
4	7Days	1	14M	5.03	5.17
5		2	14M	5.32	

6		3	14M	5.18	
7	28Days	1	14M	5.52	5.54
8		2	14M	5.57	
9		3	14M	5.55	

Table 16: Split Tensile Strength of Cement Mix 5

Sr. No.	Age in Days	Cube no.	Molarity	Strength in MPa	Average Strength
1	3Days	1	16M	5.12	5.08
2		2	16M	5.06	
3		3	16M	5.07	
4	7Days	1	16M	5.48	5.59
5		2	16M	5.67	
6		3	16M	5.62	
7	28Days	1	16M	5.88	5.88
8		2	16M	5.87	
9		3	16M	5.89	

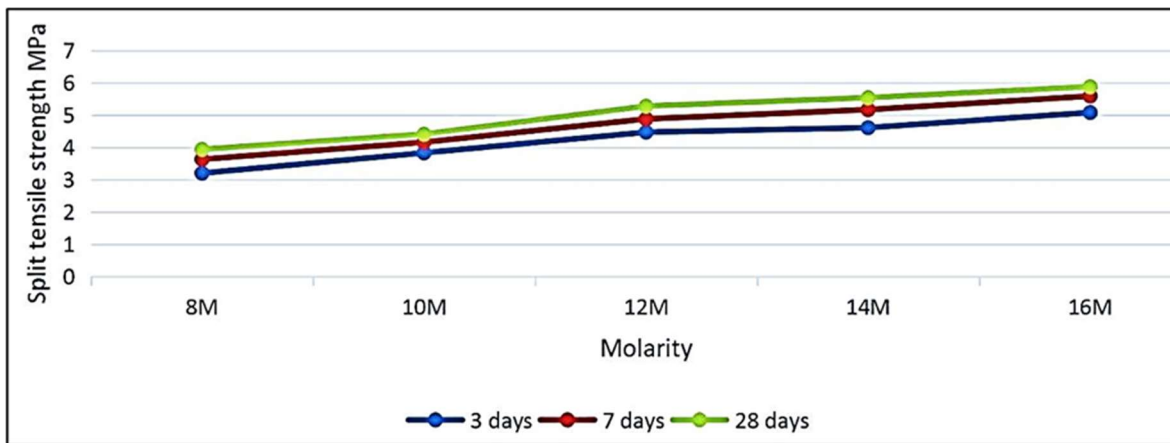


Fig 8: Split Tensile Strength and Molarity

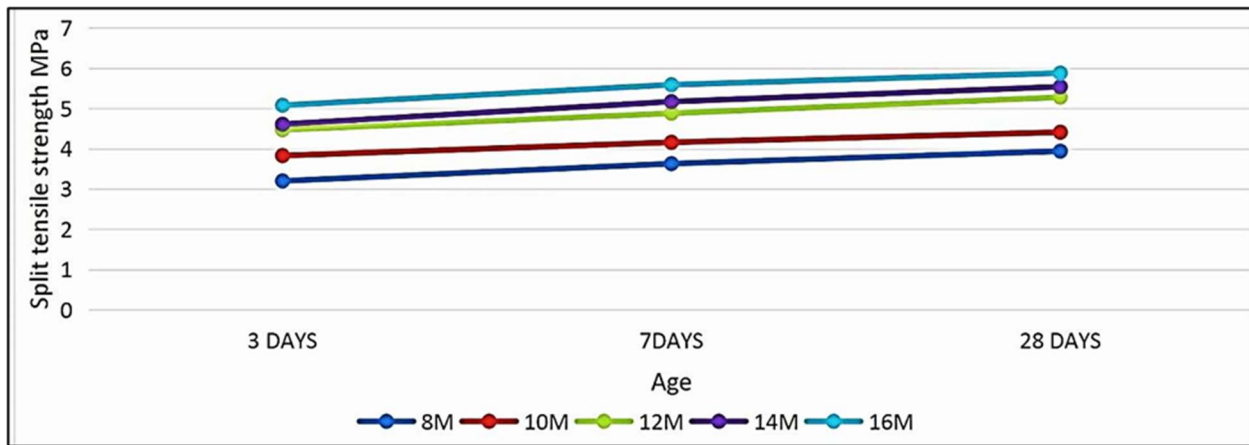


Fig 9: Split Tensile Strength and Age

Table 16: Flexural Strength of Cement Mix 1

Sr. No.	Age in Days	Cube no.	Molarity	Strength in MPa	Average Strength
1	3Days	1	8M	0.63	0.57
2		2	8M	0.61	
3		3	8M	0.55	
4	7Days	1	8M	2.34	2.87
5		2	8M	3.21	
6		3	8M	3.08	
7	28Days	1	8M	3.39	3.33
8		2	8M	3.35	
9		3	8M	3.28	

Table 17: Flexural Strength of Cement Mix 2

Sr. No.	Age in Days	Cube no.	Molarity	Strength in MPa	Average Strength
1	3Days	1	10M	0.95	0.92
2		2	10M	0.94	
3		3	10M	0.89	
4	7Days	1	10M	3.92	3.94
5		2	10M	3.97	
6		3	10M	3.93	

7	28Days	1	10M	4.59	4.57
8		2	10M	4.49	
9		3	10M	4.63	

Table 18: Flexural Strength of Cement Mix 3

Sr. No.	Age in Days	Cube no.	Molarity	Strength in MPa	Average Strength
1	3Days	1	12M	1.12	1.25
2		2	12M	1.41	
3		3	12M	1.23	
4	7Days	1	12M	4.21	4.24
5		2	12M	4.25	
6		3	12M	4.26	
7	28Days	1	12M	4.96	4.93
8		2	12M	4.95	
9		3	12M	4.90	

Table 19: Flexural Strength of Cement Mix 4

Sr. No.	Age in Days	Cube no.	Molarity	Strength in MPa	Average Strength
1	3Days	1	14M	1.59	1.60
2		2	14M	1.62	
3		3	14M	1.61	
4	7Days	1	14M	4.82	4.84
5		2	14M	4.83	
6		3	14M	4.87	
7	28Days	1	14M	5.21	5.23
8		2	14M	5.24	
9		3	14M	5.26	

Table 20: Flexural Strength of Cement Mix 5

Sr. No.	Age in Days	Cube no.	Molarity	Strength in MPa	Average Strength
1	3Days	1	16M	1.76	1.78
2		2	16M	1.80	
3		3	16M	1.79	
4	7Days	1	16M	5.41	5.44
5		2	16M	5.46	
6		3	16M	5.47	
7	28Days	1	16M	5.81	5.82
8		2	16M	5.82	
9		3	16M	5.83	

The graphical variations between flexural strength vs molarity and flexural strength vs age has been shown graphically.

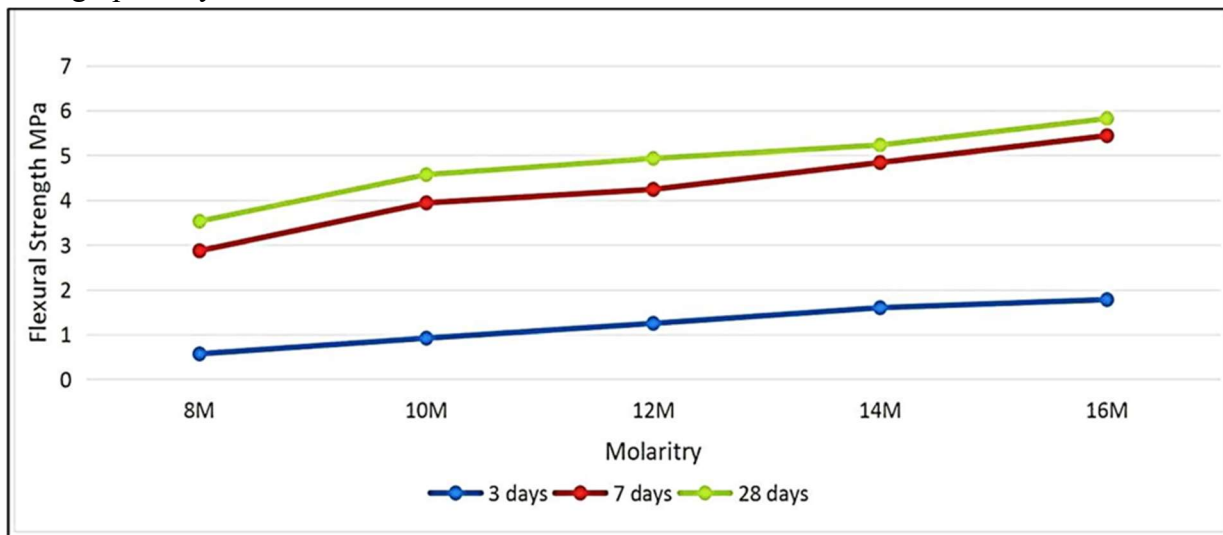


Fig 10: Flexural Strength and Molarity

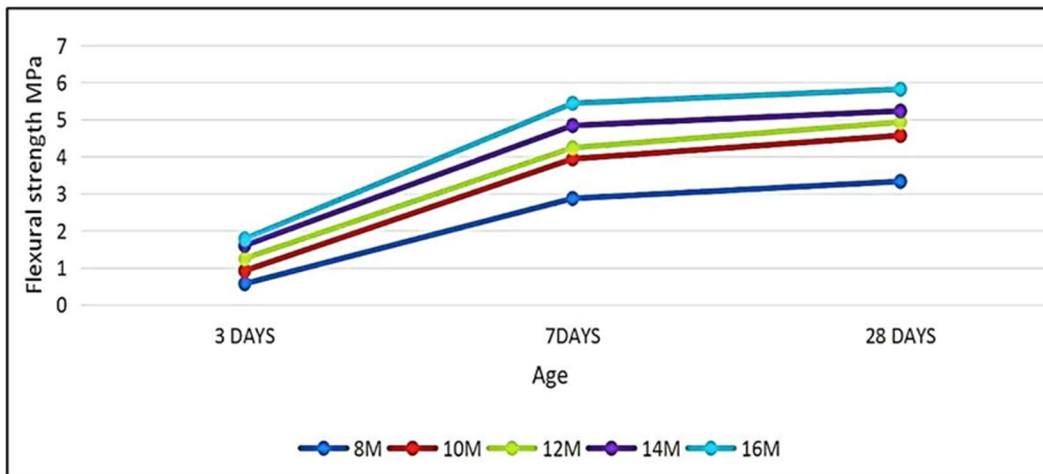


Fig 11: Flexural Strength and Age

This experimental investigation proved that increase the strength of the geopolymer concrete simply by increasing the molarity. Economic analysis GGBS based geopolymer concrete has several advantages over conventional concrete. Research prove the price of the alkaline solution high but overall cost of the Geopolymer concrete is 10% less than conventional concrete. According to it can be said that it will help us to reduce the price in construction and also help in cutting the amount of emission of the CO₂.

CONCLUSION

This report adds up a bit in understanding the geopolymer concrete based on GGBS, higher the amount of the alkaline activator higher will increase the strength considerably. Generally, steam cured concrete attains high compressive strength as compared to sunlight curing. As it is new way of preparing eco friendly concrete and it is new concept to be used in structural members new methods can be here for the concrete mix which must be adopted based on experimental observations. The compressive strength of Geo polymer concrete cube increases up to 16 M. GGBS shows a pozzolanic behavior as that of cement. The increment is molarity resulting in higher compressive strength in the mix design of concrete. Mixture becomes hard after 18 minutes so it is recommended to use as early as possible to achieve maximum results. At the curing stage the strength generally gains strength in first week then slow increment takes place. The influence of replacement of cement by GGBS has been studied based on the experimental work conducted. The Compressive strength in 8M is 81.62% at 3 days of 28 days strength and at 7 days it is 96.39% of 28 day's strength while in 10M, 3 days strength is 86.85 % of 28 days and 7 days strength is 94.32 % also for the 3 days strength of 12M, 14M, 16M are 81.20%, 85.29%, 88.35%. Further the strength of 7 days concrete is 95.27%, 92.28%, 95 % of the 28 days strength the maximum strength in 16M. The split tensile strength in 8M is 81% at 3 days of 28 days strength and at 7 days it is 92% of 28 days strength. In 10M 3 days strength is 86% of 28 days and 7 days strength is 94 % of 28 days strength. Also for the 3 days strength of 12M, 14M, 16M are 84%, 83%, 86%. Further the strength of 7 days concrete is 92%, 93%, 95 % of the 28 days strength. The Flexural strength in 8M is 16% at 3 days of 28 days

strength and at 7 days it is 81% of 28 day's strength. In 10M 3 days strength is 20.13% of 28 days and 7 days strength is 86.21 % of 28 days strength. Also for the 3 days strength of 12M, 14M, 16M are 25.40%, 33%, 32.07%. Further the strength of 7 days concrete is 86.03%, 92%, 93.04% of the 28 days strength respectively. The concrete has good compressive strength but poor flexural strength for 8M and 10M. For making of road pavements minimum flexural strength requirement is 45 Kg/cm². But the strength is very less than this in 8M and 10M. So it is not recommend the concrete to be used for pavements directly. It is required to improve the flexural strength for better use in pavements. It can be used for local streets and parking areas where VDF is very less bur for the 12M-16M research suggest this can be used for pavement construction but some more studies like durability and soundness need to be analyzed.

RECOMMENDATIONS FOR FUTURE RESEARCH

Make few samples of concrete with different percentage of using GGBS with some fly ash and silica content and determine the most suitable percentage of usage to achieve the optimum compressive strength. Determine the durability of concrete with using GGBS. Further investigation can be done by using plasticizers to improve the workability and strength. Also durability investigation can be done to see the long term effect of glass powder replacement test the strength at 90 days kindly go for that. Further steps must adopt some more steps to improve the flexural strength of the concrete to use in pavements. You may use fibers to improve the flexural strength. Some research must be carried out using fibers in the mix to improve the flexural strength of the geopolymer concrete.

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