

Effects of Alkaline Activator Solution on Concrete Mixed with Sugarcane Bagasse Ash and Ground Granulated Blast Furnace Slag

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Abstract

With an advancement in technology and research, various studies have been carried out on traditional concrete mixes and proposes modifications in order to obtain better quality concrete having both mechanical and durability requirements. In this work, both mechanical properties and durability indices of supplementary cementitious material are considered. Agricultural and Industrial wastes like Sugarcane Bagasse Ash (SCBA) and Ground Granulated Blast Furnace Slag (GGBS) are utilized as supplementary cementitious materials. The main objective of the present study is to determine the effect of supplementary cementitious materials, its mechanical properties and durability indices upon alkali activator solution. To develop concrete containing sugarcane bagasse ash and ground granulated blast furnace slag using alkaline activator solution. This study is to determine the optimal replacement of OPC with SCM and compressive strength of different mix ratio concrete.

Key words: *Sugarcane Bagasse Ash (SCBA), Ground Granulated Blast Furnace Slag (GGBS), Concrete, Compressive Strength, Slump cone Test, Curing Period.*

Introduction

The total Portland cement demand in the world is expected to rise 4.5% yearly to 5.2 billion metric tons by the year 2019. As per the estimate of the Indian Bureau of Mines, the total cement grade limestone reserve available to meet the construction industry requirement is 89862 million tones. Based on the growth and consumption pattern, the current available limestone reserves are expected to last only for another 35-40 years. Replacement with supplementary cementitious material in concrete construction will reduce the consumption of cement in concrete and provide durable and sustainable construction. With advancement in technology and research, various studies have been carried out on traditional concrete mixes and proposes modifications in order to obtain better quality concrete having both mechanical and durability requirements. In this work, both mechanical properties and durability indices of supplementary cementitious material are considered. Agricultural and Industrial wastes like Sugarcane Bagasse Ash (SCBA) and Ground Granulated Blast Furnace Slag (GGBS) are utilized as supplementary cementitious materials.

In India, SCBA generation has increased significantly in recent years. Out of 581 sugar mills, 220 mills have co-generation plants and new co-generation plants are under construction. These are the by-products from boilers of sugar industries having high silica component will increase the pozzolanic nature. These are the by-products from boilers of sugar industries. They are having high reactive silica component which will increase the pozzolanic nature of a homogeneous mixture. GGBS is obtained by quenching molten iron slag, by-product from steel manufacturing process. GGBS in concrete to provide protection against both sulphate attack and chloride attack hence more durable. Concrete containing GGBS cement has a higher ultimate strength than concrete made with Portland cement.

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An activator is necessary to hydrate the slag. Solution of Sodium Hydroxide and Sodium Silicates are used as activating reagents. Due to alkali Silica reaction, supplementary cementitious material control expansion by binding alkalis and limiting their availability for reaction. Supplementary cementitious material proposed are rich in Silica and Alumina which are activated by alkaline liquids resulting in a strong binder.

Literature Review

Supplementary cementitious materials having high silica content influence the amount and kind of hydrates formed within the concrete and hence the durability of the concrete. The rate of reaction of supplementary cementitious materials with Portland cement enhanced with increase in pH and temperature. The binders used as supplementary cementitious materials are pozzolanic in nature. Pozzolans are siliceous or aluminous materials, which possess by themselves little or no cementitious properties, but in finely divided form react with calcium hydroxide in the presence of moisture at ordinary temperatures to form compounds possessing cementitious properties. Concrete Strength by Partially Replacing Cement With Sugarcane Bagasse Ash and Fly Ash Mentioned that bagasse ash has been partially replaced in the ratio of 0%, 10%, 15%, 20% and 25% by weight of cement in concrete [1-5]. Fresh concrete tests similar to compaction factor test and slump cone test were undertaken was well as hardened concrete tests like compressive strength test, flexural strength and at the age of 7,14 and 28 days were noted. The results shown that strength of concrete increased as percentage of bagasse ash replacement increased.

Effects of Alkaline Solution on Geopolymer Concrete, on that geopolymer concrete technology has the potential to reduce globally the carbon emission and lead to sustainable development and growth of the concrete industry [6-12]. The objective of this project is to study the various properties of the Geopolymer Concrete and compare it with the OPC concrete. The geopolymer concrete is the mixture of course aggregate, sand, fly ash and alkaline solution of Sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) without water. The compressive, flexural, split tensile strength of Geopolymer concrete were carried out during the project work. Effect of Cement Alkalinity on Pore Solution Chemistry and Chloride-Induced Reinforcement Corrosion in ordinary and sulphate resisting Portland cement concretes. To evaluate the influence of cement alkalinity on the pore solution chemistry, cement paste specimens were prepared and admixed with fixed quantity of sodium chloride and various dosages of alkalinity (in the range of 0.4 to 1.4% Na_2O equivalent). The pore solution was extracted and analyzed to determine the OH^-, Cl^- and SO_4 concentrations [13-16].

Effect of GGBS On strength Characteristics of Geopolymer Concrete at different replacement levels. Sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) solution have been used as alkaline activators [17-18]. In the present investigation, it is proposed to study the mechanical properties viz. compressive strength, split tensile strength of low calcium fly ash and GGBS based geo polymer concrete. The Strength Development Of Geopolymer Concrete Using GGBS. At Ambient Temperature. Geopolymer is an excellent alternative material for cement concrete as it is produced from industrial by-products such as flyash and GGBS replacing 100% of cement in concrete. Alkaline liquids are used for the binding of materials [19]. In this paper, strength development of geopolymer concrete using GGBS along with activators such as sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) has been used. 12 moles of sodium hydroxide solution is prepared before 24 hours of casting GPC.

The optimum ratio of Na_2SiO_3/NaOH was determined by studying the strength development of GPC by varying the percentage of activator ratio such as 2:1, 2.5:1, 3:1, 3.5:1 and 4:1 by keeping

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the cement and w/c constant. Geopolymer Concrete Using GGBFS. A concrete using cement alone as a binder requires high paste volume, which often leads to excessive shrinkage and large evolution of heat of hydration, besides increased cost. With this view we have made an attempt is to replace cement by a mineral admixture, ground granulated blast furnace slag (GGBS) in concrete mixes to overcome these problems. The workability study of concrete with GGBS as a replacement material for cement without the addition of Super plasticizer. Concrete grades of M25 have been taken for the work. The Performance evaluation of SCBA blended cement in concrete and SCBA was used as pozzolanic material in concrete [20]. It was mainly composed of amorphous silica. By conducting an experimental study on the performance of concrete with different replacement levels of SCBA, the variables of investigation included compressive strength, heat of hydration, drying shrinkage and durability performance. The test results demonstrated that the use of SCBA in concrete prominently enhances its performance and compared it with conventional control concrete. Effect Of Mechanical Processing On SCBA Pozzolanicity was intended to understand the effect of using different particle size SCBA on the hydration of cement based paste [21-25]. Various tests were performed during the study to compare the hydration and chemical evaluation of pastes containing SCBA with different fineness and paste with inert (Quartz) and pozzolanic material. The results showed that, with increase in specific surface area and soluble fraction of SCBA, its pozzolanic activity was progressively enhanced due to both portlandite consumption and physical effects.

Methodology

This work is aimed at studying the mechanical properties and durability performances of concrete mixes with supplementary cementitious materials along with alkaline activator solution. In this work the materials proposed to use are Sugar Cane Baggase Ash (SCBA), Ground Granulated Blast Furnace Slag (GGBS), Portland cement, Sodium hydroxide (NaOH) solution. Materials used for making control ordinary Portland cement concrete test specimens are Ordinary Portland cement, Fine aggregate, Coarse aggregate and Water. Following materials are used for making SCM blended concrete test specimens were Sugar cane bagasse ash (SCBA), Ground granulated blast furnace slag (GGBFS), Ordinary Portland cement, Fine aggregate, Coarse aggregate and Alkaline activator solution (AAS).

Mix Design

Conventional mix design procedure is adopting for making SCM blended concrete mixes. In order to analyze the performance criteria of SCM blended concrete , conducting compressive strength test for hardened concrete and workability test for fresh concrete.

Mixing and casting of SCM blended concrete:

Adopting the conventional techniques for making SCM blended concrete. SCBA, GGBFS and OPC mixed in the dry form and it is combining with aggregates which are also in dry form. Sodium hydroxide solution is preparing one day before casting, since when pellets are dissolving in water will generate a lot of heat. AAS is added to the dry mix and using conventional casting and compacting methods SCM blended test specimens are preparing.

Testing of SCM blended concrete

To analyse the binder characteristics, mixtures containing GGBFS and SCBA are prepared with different mix ratios (by mass) such as 50% Cement + 50%GGBFS + 0%SCBA, 50%Cement +

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40% GGBFS+10% SCBA, 50% Cement+30% GGBFS+20% SCBA. Different types of concrete mixes are preparing using this ratio and different molarity activator solution. Specimens are tested after 7days and 28days of curing at both water curing and membrane curing.

Fine Aggregate

The aggregate which pass through 4.75 IS sieve and entirely retained on 75micron IS sieve is called fine aggregate. River sand conforming to Zone II (IS 383-1970 grading requirements) with specific gravity 2.37 is used. The tests are conducted to find the properties of fine aggregate and results are obtained in table 1 and particle size zoning details were given in table 2. Figure 1 depicts particle size distribution curve.

Table 1: Properties of fine Aggregate

S.No	Property	Result
1	Specific Gravity	2/54
2	Loose Bulk Density Compact Bulk Density	1.480 1.650
3	Moisture Content	Nil

Table 2: Sieve analysis of fine aggregate

IS sieve size	Percentage Passing	Percentage passing by weight for grading				Remarks
		Zone I	Zone II	Zone III	Zone IV	
10 mm	0	100	100	100	100	Satisfies Zone II grading require ments
4.75 mm	99.68	90-100	90-100	90-100	95-100	
2.36 mm	99.23	60-95	75-100	85-100	95-100	
1.18 mm	63.54	30-70	55-90	75-100	90-100	
600 micron	36.651	15-34	35-59	60-79	80-100	
300 micron	11.971	5-20	8-30	12-40	15-50	
150 micron	0.39	0-10	0-10	0-10	0-15	

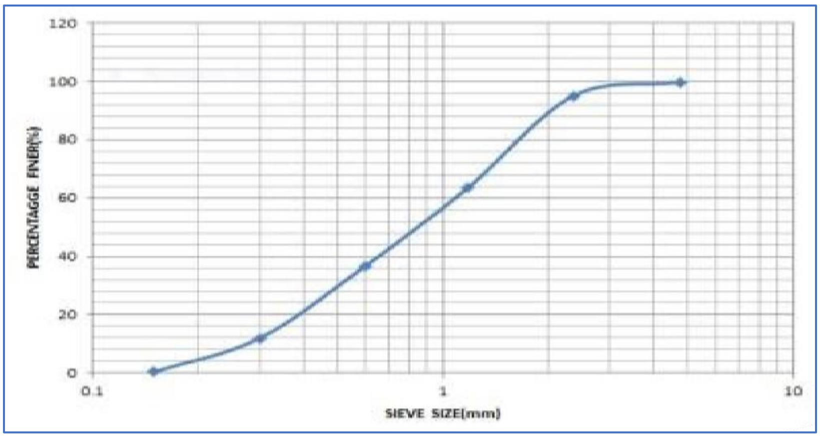

Fig. 1: Particle size distribution curve

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Coarse Aggregates

Coarse aggregate with specific gravity 2.73 satisfying IS 383-1970 grading requirements. Grain size of 20mm below were retained on 12.5mm. Tests were conducted to find the properties of coarse aggregate and the results were obtained in table 3.

Table 3: Properties of coarse aggregate

S. NO	PROPERTY	RESULT
1	Specific gravity	2.73
2	i. Loose Bulk density ii.Compact Bulk density	1.420kg/l 1.540kg/l
3	Water absorption	Nil
4	Fineness modulus	7.195

Supplementary Cementitious Material

Sugarcane bagasse ash is a by-product of sugar factories found after burning sugarcane which itself is found after the extraction of all economical sugar from sugarcane. The disposal of this material is already causing environmental problems around the sugar factories and it is shown in fig 2. The specific gravity of GGBS is 1.2.

Fig. 2: Sugar Cane Baggase Ash

Ground Granulated Blast Furnace Slag (GGBS)

It is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder and it is shown in fig 3. The specific gravity of GGBS is 2.62.

Fig. 3: Ground Granulated Blast Furnace Slag

Alkaline Activator Solution (AAS)

Physical properties of SCBA and GGBFS are found out using different laboratory tests. For casting test specimens AAS used is a combination of sodium silicate solution, sodium hydroxide solution and potable water. AAS is mainly used to activate Si and Al present in SCM and it is shown in Fig 4.

Fig. 4: Preparation of sodium hydroxide solution

Mix Design

Data from the tests as per IS 10262-2009 the mix is designed. The mix ratio obtained was 1:1.69:2.97. Cement used for the test was Portland Cement. The river sand used has a specific gravity of 2.54 and belongs to Zone II. Water cement ratio of 0.5 was chosen. The concrete was mixed by hand mixing and poured in to moulds of size 150 mm x 150 mm x 150 mm with sufficient hand compaction. The cubes were demoulded after 24 hours and cured for 7 and 28 days in water. The percentage variation of binder composition is show in table 5. Slump tests were carried out to check the fresh concrete properties and it is shown in fig 5. The slump is a good measure of workability of the mix. Slump test measures consistency of concrete. It is useful for detecting the variations in the uniformity of the mix of the given proportion. The decrease in the height of the slump concrete is called the slump and is measured to the nearest 5mm. The types of slumps are true, shear and collapse. For concrete with quarry dust the slump value was approximately equal to that of normal concrete.

Fig. 5: Slump test result

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Table 5: Slump Test Binder Composition Results

Binder composition		**Molar Ratio**	**Slump in mm**
SCBA	**GGBFS**		
0%	100%	3M	24
20%	80%	3M	26
40%	60%	3M	36
0%	100%	5M	24
20%	80%	5M	25
40%	60%	5M	25
0%	100%	7M	21
20%	80%	7M	22
40%	60%	7M	21

When the molarity increases, the slump value decreases. The concentration of alkaline solution increases the workability of concrete decreases.

Mixing Method

For the casting of specimen with GGBFS and SCBA are partially replaced with cement, controlled specimen and the test specimen with the optimum values of the given specimens, the hand mixing method is carried out. The SCBA is sieved through 75 micron sieve. Alkaline solution made by dissolving 40 gm of NaOH pillets in 250 ml distilled water and then make the solution to 1 litre.

The mixing is done on an impervious floor. Aggregates, SCBA, GGBFS and fine aggregates are spread on the floor cement is poured on top of it. Mix up to uniformity in colour is obtained. Alkaline solution is sprinkled over the mixture and mixed. Operation is continued till a good homogeneous concrete is obtained and it is shown in Fig 6.

Fig.6: Preparation of concrete cube

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Compressive strength

The results of compressive strength specimens using SCM of various percentages are shown in table 6 and 7 for water and membrane curing. It can be seen that there is a significant change in the compressive strength.

It is clear from the given table and graph that the compressive strength is decreases with increase in molarity of alkaline solution and high strength obtained in saturated curing specimen. The compressive strength of water and membrane curing at 7 and 28 days and graph is shown in Fig 7 to 10.

Table 6: Compressive Strength Result of Water Curing

Binder Composition	Mix proportion	Molar Ratio	Compressive Strength at 7 days (MPa)	Compressive Strength at 28 days (MPa)
50% Cement+ 50%GGBFS+0% SCBA	1:1.52:2.69	3M 5M 7M	12.4 8.4 11.1	20.3 12.8 17.1
50%Cement+40 % GGBFS+10% SCBA	1:1.52:2.69	3M 5M 7M	13.7 9.1 11.8	22.1 15.3 19.5
50%Cement+30 % GGBFS+20% SCBA	1:1.52:2.69	3M 5M 7M	11.6 8.3 9	16.7 12.5 11.4

Table 7: Compressive Strength Results of Membrane Curing

Binder Composition	Mix proportion	Molar Ratio	Compressive Strength at 7 days (MPa)	Compressive Strength at 28 days (MPa)
50% Cement+ 50%GGBFS+0% SCBA	1:1.52:2.69	3M 5M 7M	15.5 11.2 14.4	24.2 17.5 21.7
50%Cement+40 % GGBFS+10% SCBA	1:1.52:2.69	3M 5M 7M	16.4 11.0 14.6	27.2 16 24.1
50%Cement+30 % GGBFS+20% SCBA	1:1.52:2.69	3M 5M 7M	14.2 11 12	20 16.5 17

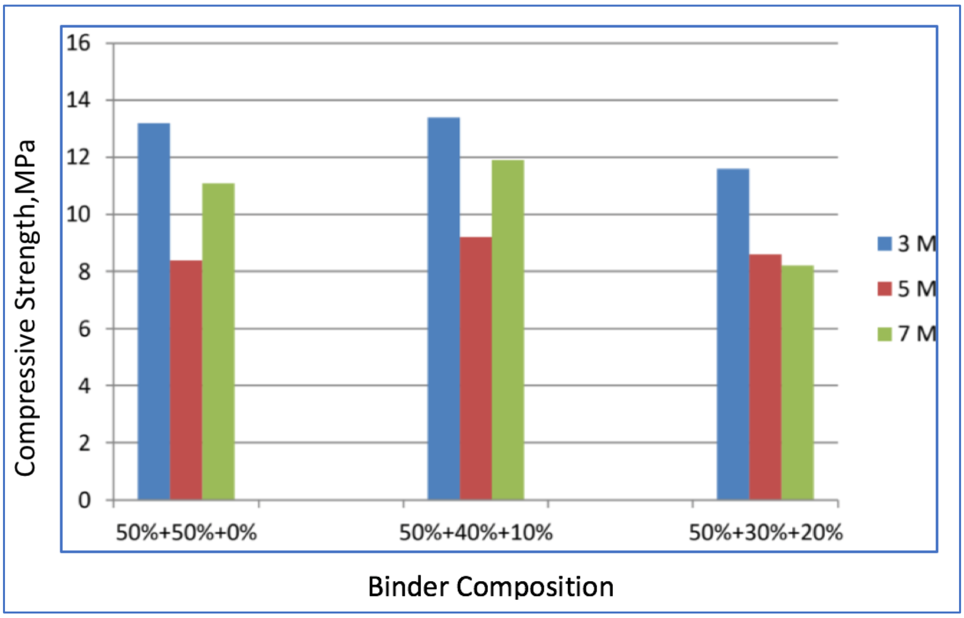

Fig. 7: Compressive Strength in Water Curing for 7 Days

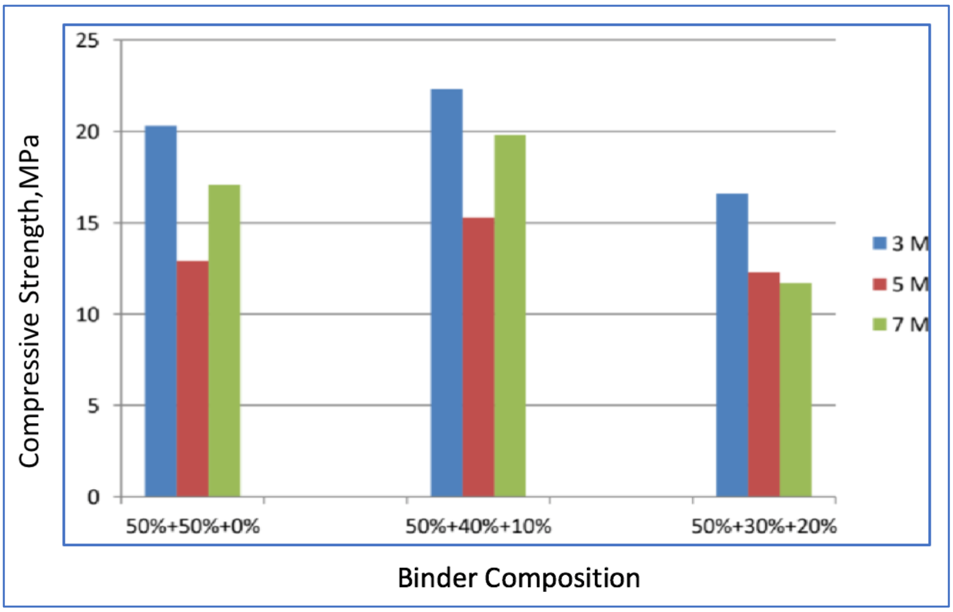

Fig. 8: Compressive Strength in Water Curing for 28 Days

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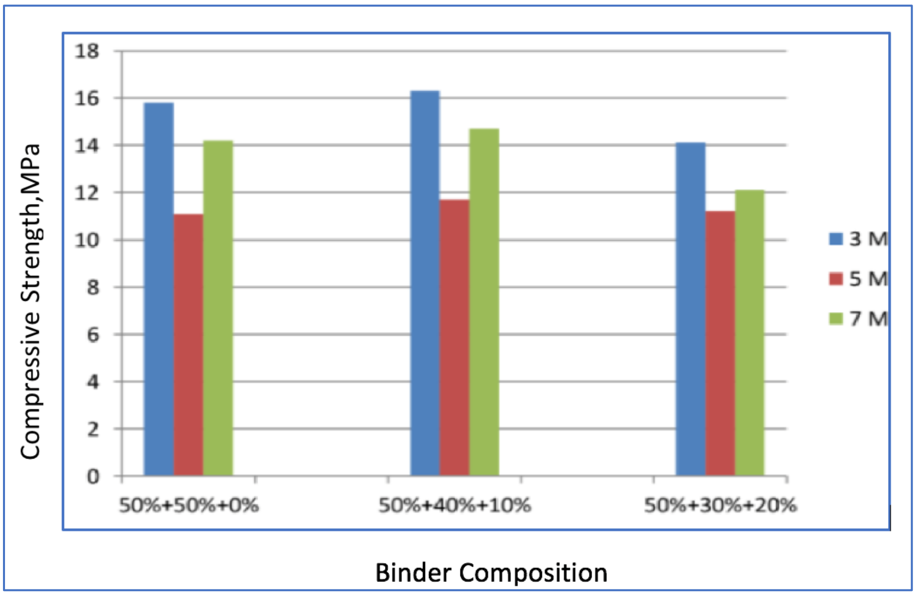

Fig. 9: Compressive Strength in Membrane Curing for 7 Days

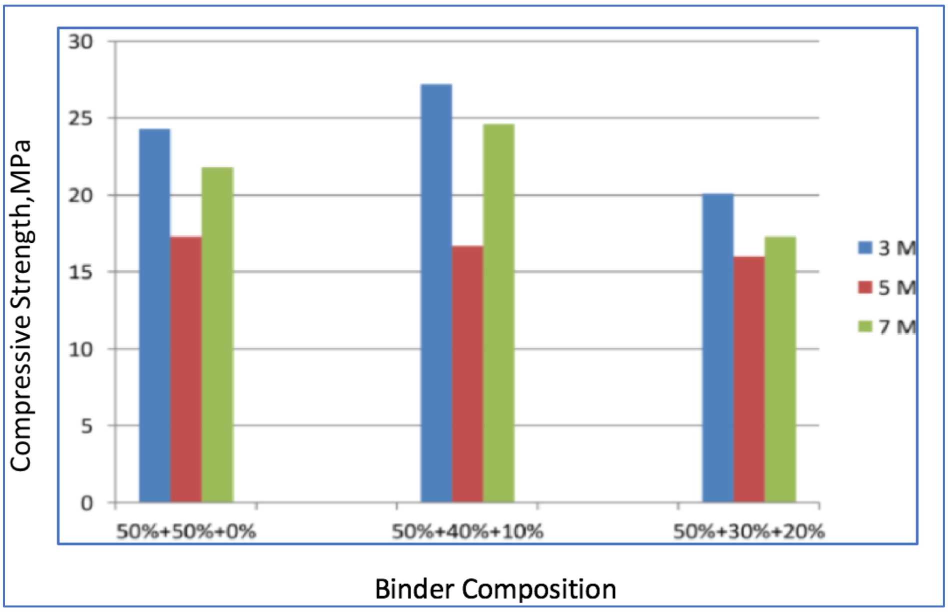

Fig. 10: Compressive Strength in Membrane Curing for 28 Days

Conclusion

This experimental study concludes the analysis of test results for the mechanical properties of concrete mix using sugarcane bagasse ash, ground granulated blast furnace slag blends with Portland cement in alkali activated system. The results obtained for the compressive strength values for this supplementary cementitious material shows higher values which is much higher than that of the value obtained for control specimen. In this project we conducted curing process for the test specimens in two different conditions, water curing and membrane curing.
In this study results reveals that when molarity of alkaline activator solution is increased from 3 to 7 the corresponding compressive strength values for different binder composition get decreasing gradually. For this 3M AAS solution better performance shows for a binder composition of 50%

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Cement, 40% GGBFS & 10% SCBA. The maximum value of compressive strength for the above mentioned binder composition obtained when it is cured under the condition of membrane curing. Hence the project report can be concluded with the analysis that this alternate supplementary cementitious material can be adopted for sustainable concrete construction.

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