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EXPERIMENTAL STUDIES ON EFFECT OF SODIUM SILICATE AND SODIUM HYDROXIDE ON CONCRETE ON REPLACINIG CEMENT BY GGBS AND FLY ASH

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Abstract*— In this present Experimental investigation two types of concrete are prepared and studied in both the types of concrete the cement is completely replaced by GGBS and FLY ASH at (40%,60%,80%,100%) and (60%,40%,20%,100%) respectively. But in type 2 concrete the sodium silicate and sodium hydroxide solution were added at ratio 2.5. The sodium hydroxide used was of molarity 12 (12M) and the LIQUID TO BINDER RATIO was 0.5. Among two types of concrete prepared one being prepared considering economical parameters (type1) and the other being prepared considering strength parameters (type2). Compressive, flexural and split Tensile strength were optimum for the mix proportion where cement was replaced by 100%GGBS and 0% Fly Ash.

INTRODUCTION

The conventional concrete has been in use very widely all over the world since many years. Cement being not so environmental friendly due to the emission of carbon dioxide. Cement concrete is habitually considered as an artificial stone which is prepared by thoroughly mixing of the Portland cement, water, sand, and crushed stone aggregate to create a mouldable mixture. This concrete, during the last century, has developed into the most important building material in the world. But due to the vast increase in constructional activities, the demand for cement has increased. These developments taking place globally have resulted in the increasing of price of cement. This again adding further more burden and ultimately increasing the cost of construction and making the construction work more uneconomical and far from the reach of people with moderate or low income. To achieve proper development rate for any nation especially a developing country like India infrastructure is really predominant factor in determining the rate of growth hence it is our prima facie responsibility to make the constructional ingredients more affordable. We are progressing towards these developmental activities since last two to three decades and there are various other ingredients that are used for creating the concrete replacing the conventional concrete ingredients. Therefore in the modern era of construction with the updates or advancement that are being taking place in our industry we also need to replace the conventional concrete with other ingredients so as to improvise it‟s integral properties and to exhibit certain advantages when compared to old construction practices using conventional concrete. As concrete has it is very own advantages it also comes with certain number of disadvantages so we need to overcome them by carrying out various researches and development for the betterment of entire mankind.

With the new technologies we also need to provide great economy and affordability in construction industry so as to make the modern construction more affordable to all classes of people. This could be achieved only when costly materials like cement etc are replaced by other reasonably priced and more affordable when compared to other conventional and outdated materials. Some of the materials which could be used as a replacement in order to make all the above mentioned points practically possible like GGBS, Fly ash, Rise Husk Ash, Silica Fumes, etc. By adopting this modern technology it provides flexibility to the concrete. Initial setting time could be considerably reduced and hence the casted concrete block could be easily demoulded in a period of less than 24 hours. Water in huge quantities are taken out for the purpose of curing of the concrete which is not a good sign as already there is a lot of scarcity of water in every part of earth, thus we must have to reduce the use of water in construction field as much as possible. This could be possibly achieved by preparing a concrete which could set initially at a faster rate as well as final setting period also should be decreased. This ultimately results in lesser curing period for the setting up of concrete and could bring down the global consumption of water in the construction industry at a considerable rate, which again is a very healthy growth in our industry.

In all the above mentioned points I have considered economy as prime purpose of the project, but this project is not just a investigation of more affordable constructional practices/materials by replacing cement or just giving an alternative to cement to reduce global CO2 emission in huge quantity caused due to cement. Our another important motto is also to prepare a concrete that not only just replaces cement completely but also a concrete which performs better and could

bring out/ provide higher strength parameters when compared to conventional concrete. So for these purposes I have researched and found that by using sodium silicate & sodium hydroxide solutions & adding them partially and completely in different molarity of sodium hydroxide and in different ratios of sodium silicate to sodium hydroxide could satisfactorily provide such results. Hence I have considered preparing two categories of concretes, one fulfilling the economical parameters(Type 1 concrete) and the other fulfilling higher strength parameters(Type 2 concrete). Both type of them being environmental friendly.

I. OBJECTIVES

1. To prepare a concrete that is more economical with better strength parameters.
2. To prepare a concrete that is capable of providing higher strength parameters at lesser time period using admixtures, which increases the cost undoubtedly but such concrete could be taken in to consideration where there is requirement of rapid strength gain.
3. To carry out the work with different ratios of fly ash (FA) as well as slag (GGBS) replacing cement completely.
4. To determine the tensile, flexural and compressive strength of concrete samples of GPC.
5. To reduce environmental impact resulting from CO2 emission and Greenhouse effect caused due to cement by avoiding using of cement completely in every concrete prepared in this investigation.
6. To optimize the mix proportion of GPC.
7. To understand effect of molarity of sodium hydroxide in GPC to obtain the strength.
8. To understand effect of Na2SiO3 to NaOH ratio on strength parameters of concrete.

II. LITERATURE REVIEW

1. V.Hariharan, G.SILAMBARASAN.N & Harishkumar[1]

This investigation is carried out giving more importance on variation of the molarity of the alkaline solution. Here two molarities i.e., 8M&12M are considered, these solutions of different molarity were added separately to the mixes (090%FA+010% GGBS, 080%FA+020% GGBS, 070% GGBS+030%FA & 060%FA+040%GGBS) and were tested at 1,3,7 & 28days for compressive strength and for tensile & flexural strength at 28 days respectively. The optimum mix type was found to be 60%FA+40%GGBS as per all the results obtained. This mix achieved 80.73MPa and 67.07MPa compression strength at 28days with 12M and with 8M respectively. Similarly the tensile strength were recorded as 4.05MPa and 3.8MPa for 12M and 8M respectively at 28days and the flexural strength was recorded as 10.17MPa and 9.83MPa with 12M and 8M respectively at 28days. So the author concludes that with mix proportion 60%FA+40%GGBS it is possible to produce M80 concrete mix. Another outcome of this investigation was that as the raise in the concentration of NaOH was noted the force of the concrete was found to increases.

2. S.P.DANGE, S.R. SURYAWANSHI [2]

This study puts light on the use of GGBS and Fly Ash as the complete substitution for cement in preparing of concrete (Geo-polymer concrete). The alkali based activating solution which was prepared by mixing Na2SiO3 and NaOH at approximate 2.5 ratio in order to give rise to the reaction required to produce heat and add extra binding properties to GGBS and Fly Ash. Here the concrete of different mixes i.e., M40, M60 and M80 were studied. It was recorded 48.9MPa, 72.2MPa and 83.9MPa was the compressive force of the concrete cubes at 028 days for M40, M60 and M80 mixes respectively. Also 3.97MPa, 4.87MPa and 6.72MPa were recorded at 28 days for tensile strength of concrete of mixes M40, M60 and M80 respectively. Finally 2.36MPa, 3.12MPa and 3.96MPa were the results for flexural strength at 28days for mixes M40, M60 and M80 respectively. It was concluded that the GPC gained strength at ambient temperature within 24 hours without water curing.

3. N.MANOJ KUMAR, P.HANITHA[3]

This investigational work has mainly done on comparison of the properties conventional concrete with that of the GPC. Here the cement is completely replaced by GGBS and Fly Ash. The alkali solution is also added for increasing binding properties of GPC. Here M20 concrete is considered for testing. The compressive force at 7,28 and 14 days were 23.3N/mm2, 27.14N/mm2 and 34.36N/mm2. The split tensile strength of GPC at 7,14 and 28days were 3.97N/mm2, 4.18 N/mm2 and 4.33 N/mm2. The flexural strength at 14,28,60 and 90 days were 2.97N/mm2, 4.8N/mm2 5.73 N/mm2 and 6.5 N/mm2. Acid tests for concrete durability check was carried out with HCL and also with H2SO4 separately. The results were positive when compared to conventional concrete. Another test i.e., water absorption test was conducted at 14days,28days and 56days for cylinders and cubes and it was noted that water absorption was 5% less in cylinders and 10% lesser in cubes. At last all the results of the GPC were compared to the conventional concrete and it shows clearly the upper hand of GPC as it had higher strength values for all the tests.

4. Sheikibrahim, Satish, Mohammed Fahad A, Satish Sharma, Karthika, Shanmuganathan.[4]

Here in this investigational study GGBS and Fly Ash were used as complete replacement for cement at different proportions. Like GGBS and Fly Ash were of proportions (GGBS70%+FA30%, GGBS60%+FA40%, GGBS50%+FA50%, GGBS40%+FA60%) and one mix was made of complete cement for comparison. Out of all the above mix proportions the GGBS60%+FA40% gives more optimum results i.e., 32MPa compressive strength at 28day

and 2.5MPa tensile strength at 28days . M40 type of concrete mix is used in this entire experimental work. There was no use of chemical solutions in this study. This study also suggests that by using admixtures to the same mix proportions could produce even better results.

5. Santosh Kumar Karri, G.V.Rama Rao, P.Markandeya Raju[5]

In this work it mainly highlights about replacing cement partially with GGBS at 30%, 40% and 50% then the specimen were tested. The specimen were tested for 28days and 90days and it was concluded that the optimum dosage of GGBS were obtained at 40% of replacement in both grades of concrete used (i.e., M20 and M40). This mix not only gave higher test results on compressive strength test, but also gave maximum results for tensile and flexural strength test. The durability tests were also conducted by curing the specimen in HCL solution and other set of specimen in H2SO4 solution and were tested at 28days and 90 days and found that the mix with 40% replacement outperformed all other mix specimen. also the effect of HCL were comparatively lower and H2SO4 effected the specimen more.

6. Xerses N. Irani, Dr Suresh G. Patil,Rampanth [6]

In this work there are various dimensions that are been discussed and all the test results encourage the use of GPC extensively. The first thing discussed is replacing of cement completely by GGBS and Fly Ash at different proportions. The test results shows that the mix 20%Fly Ash + 80% GGBS gave the maximum compressive strength of 27.3KN/mm2, 46.5KN/mm2 and 67.1KN/mm2 at 1, 3 and 7 days respectively. The variation of molarity of NaOH was done at 8M, 10M and 12M and as per author 10M‟s specimen performed better than other two. Na2SiO3/NaOH ratio was also varied as 1.5, 2 and 2.5, even though every specimen performed well the results of 2.5‟s specimen performed little better than other specimen. L/B ratio i.e., Liquid to Binder ratio was also varied as 0.45,0.50 and 0.55 again here all the specimen were almost identical in its test results and 0.50 performing little better than other two specimen.

III. MATERIALS AND MIX PROPORTIONS

A. MATERIALS

1. Cement: In this present investigation we use OPC (ordinary Portland cement) as a binding material. The test results are tabulated in a below table.

TABLE I
Shows the Preliminary Test Results Of Cement

Particulars of cement	Normal Consistency	Specific gravity	Fineness	Initial Setting	Final Setting
Test outcomes	32%	3.14	4%	44min.	398min.

2. Fine aggregate:

In this present project work fine aggregate used is naturally available river sand which is under zone-II as per IS 383:1970.The preliminary experimental outcomes of FA are as shown in the below table.

TABLE II
Shows The Preliminary Test Of Fine Aggregate.

Particulars of FA	Specific gravity	Water absorption	Fineness modulus	Silt content
Test outcomes	2.65	1.4%	3.02	2.48%

3. Coarse aggregate:

In this present project work crushed angular stone size is about 10mm and 20mm were used. Table below shows the properties of Coarse aggregate.

TABLE III
Shows The Preliminary Test Results Of CA

Particulars of CA	Specific gravity	Water absorption	Fineness modulus
Test outcomes	2.68	0.94%	2.42

4. Ground granulated blast furnace slag:
As the slag is by-product of a manufacturing industry. The GGBS is replaced as a cementious material because it leads in the reducing of carbon dioxide gas emission. As the GGBS is friendly to environment it is used as construction material. It is mainly composed of 30% to 40% of silicon did-oxide ($Si0_2$) and also 40% Cao which is also similar as the chemical composition of cement. It gives a good workability, durability etc to concrete and also acts as a cost effective construction material. Test results are shown in Table IV.

Figure 1: Shows sample of GGBS

TABLE IV
Shows The Test Results Of GGBS Provided By JSW.

Particulars	Specific gravity	Fineness (Kg /m^2)	45 micron (Residue) (%)
Test outcomes	2.66	396	07.60

5. Fly Ash:
Fly ash has been brought from Raichur Thermal Power Plant.

6. Alkaline liquids:
The alkali liquid which is used in the geopolymer mix is a mixture of sodium hydroxide (NaOH) solution & sodium silicate (Na2SiO3) solution. It will activate the Fly Ash.

7. Potable Water: In this experimental work water is used for concrete mixing and curing. water used as clean, clear & free from acid content and portable water used which is referred from IS - 456 2000 are used.

B. MIX DESIGN BY ABSOLUTE VOLUME METHOD

According to IS: 10262-2009 mix design was done for the purpose of concrete casting of various mixes with the help all above preliminary investigation test outcomes. The mix design was done for M40 grade. From the mix design conventional trial mix was prepared and it having mix ratio is 1:1.56:2.98 and the w/c of 0.40

TABLE V
Mix Proportions Of Concrete

Material	Quantity (kg/m^3)	Proportion
Cement	418.96	1
FA	654.151	1.56
CA	1252.475	2.98
Water	187.779	0.44
Chemical admixture	6.284	1.5%

IV. EXPERIMENTAL PROGRAM

A. GENERAL
In this present experimental investigation involves casting of 45 cylinders, 45 cubes and 45 prisms and testing is conducted after curing period of 7, 14 & 28days for type 1 concrete and 1,3 & 7 days for type 2 concrete to assess compressive strength, split-tensile strength & flexural-strength of casted concrete. In this work there are four mix proportions to study the variation of strength and to conclude with optimum percentage of the Fly Ash and GGBS. The below table VI represents the different mix proportion details and their percentage. To determine the durability characteristics of concrete

TABLE VI
Shows type 1 Mix Proportions that Were Involved in this present work

Mix Type	Cement (%)	Fly Ash (%)	GGBS (%)
60% FA + 40% GGBS	00	60	40
40% FA + 60% GGBS	00	40	60
20% FA + 80% GGBS	00	20	80
0% FA + 100% GGBS	00	00	100

TABLE VII
Shows type 2 Mix Proportions that Were Involved in this Present Work

Mix Type (Liquid/Binder = 0.5)	Cement (%)	Fly Ash (%)	GGBS (%)
60% FA + 40% GGBS	00	60	40
40% FA + 60% GGBS	00	40	60
20% FA + 80% GGBS	00	20	80
0% FA + 100% GGBS	00	00	100

B. PROCEDURE FOR CONCRETE CASTING

The standard specimen of the cubes (150mm*150mm*150mm) and the standard cylinders will be (300mm*150mm) and standard prisms will be (150mm*150mm*750mm) will be used in this work to determine the Compressive Strength of the material, Split Tensile Strength of the material as well as Flexural Strength of the material For the each proportion of the fly ash & GGBS replacement will be replaced by cement to the mix & variations.The materials will be weighed as per the mix design. In both the types of concrete the FLY ASH and GGBS are used as complete replacement for cement. The variations will be done for the GGBS and FLY ASH so as to get the high strength.

TYPE 1 CONCRETE

The water-cement ratio or water-binder ratio adopted is 0.40 in type 1 concrete, the materials will be weighed and added as per mix design.The materials are uniformly distributed, the material will be added using trowel. After adding concrete to the mould the materials will be mixed properly by vibrating machine and proper casting will be done by this method. The specimens will be kept for 24 hours after that the moulds will be demoulded so that the samples will be kept in water for curing.The specimens will be kept for curing purpose for normal temperature to get high strength by keeping them for 3,7,28 days respectively. After 3, 7, 28 days test note down the reading & calculate the compressive force , split tensile force & flexural force as per our INDIAN values. All specimens i.e. cylindrical specimens & prisms will be casted same as the cubes.

TYPE 2 CONCRETE

Sodium hydroxide (NaOH) & sodium silicate (Na2SiO3) solution is used to prepare type 2 concrete. The solution will activate the Fly Ash and GGBS by dissolving external most surfaces and also initiate polymerization or chemical process. The NaOH is available in solid pellets, with 97% purity. The NaOH solution is made/obtained from mixing of the solid pellets in water(distilled water).The molarity of sodium hydroxide is kept at 12 (12M) the ratio of NaOH to Na2SiO3 is kept at 2.5.The liquid to binder ratio(Obtained solution to Binder ratio) is kept at 0.5. here binders means various mix proportions of Fly Ash and GGBS. The materials will be weighed and added as per mix design. The materials are uniformly distributed, the material will be added using trowel. After adding concrete to the mould the materials will be mixed properly by vibrating machine and proper casting will be done by this method. The specimens will be kept for 24 hours after that the moulds will be demoulded so that the samples will be kept in water for curing.The specimens will be kept for curing purpose for normal temperature to get high strength by keeping them for 3,7,28 days respectively. After 3, 7, 28 days test note down the reading & calculate the compressive force , split tensile force & flexural force as per our INDIAN values. All specimens i.e. cylindrical specimens & prisms will be casted same as the cubes.

Figure 2: Shows freshly casted specimens

Figure 3: Shows the casted Cured specimens

B. RESULTS AND DISCUSSIONS

1. Slump cone test:

In the fresh state of concrete the test is conducted is slump test for the purpose of checking of the workability of concrete with many trails are conducted. The slump test shows the workability which may increase by rising in proportion partially replaced of GGBS in OPC.

Figure 4: Shows Slump cone test

TABLE VIII Shows Slump cone test Results

Sl.no	Mix type	Slump value in mm
1	Conventional concrete	91
2	60%FA+40%GGBS	70
3	40%FA+60%GGBS	65
4	20%FA+80%GGBS	60
5	0%FA+100%GGBS	55

2. Compaction factor test:

For the determination of fresh concrete workability compaction factor test also conducted.

Figure 5: Shows compaction factor test

TABLE IX Shows Compactaction factor test Results

Sl.no	Mix type	Slump value in mm
1	Conventional concrete	91
2	60%FA+40%GGBS	70
3	40%FA+60%GGBS	65
4	20%FA+80%GGBS	60
5	0%FA+100%GGBS	55

3. Compressive strength:

From the below Graph and table, we can said that there will be a considerable increase in strength of replacement concrete compare to the conventional concrete.

TABLE XI Shows
The Compressive-Strength Results
of **Type 2** Concrete

Mix	Compressive Strength in N/mm^2		
	7 days	**14days**	**28 days**
60% FA + 40% GGBS	18.36	22.22	39.25
40% FA + 60% GGBS	21.33	25.62	42.66
20% FA + 80% GGBS	25.62	29.62	48.88
0% FA + 100% GGBS	29.62	31.85	50.81

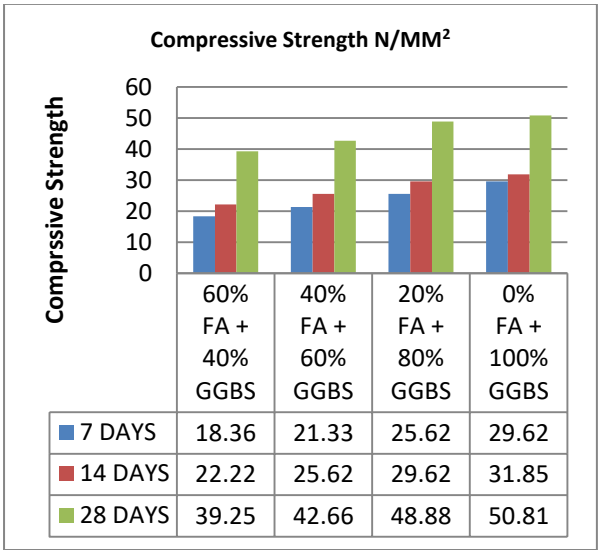


Figure 6: Shows the Compressive-Strength results of type I concrete

TABLE XI Shows
The Compressive-Strength Results
of **Type 2** Concrete

Mix	Compressive Strength in N/mm^2		
	1 day	**3 days**	**7 days**
60% FA + 40% GGBS	22.66	32.58	49.77
40% FA + 60% GGBS	25.77	39.11	54.36
20% FA + 80% GGBS	27.53	44.44	62.22
0% FA + 100% GGBS	29.47	52.14	63.85

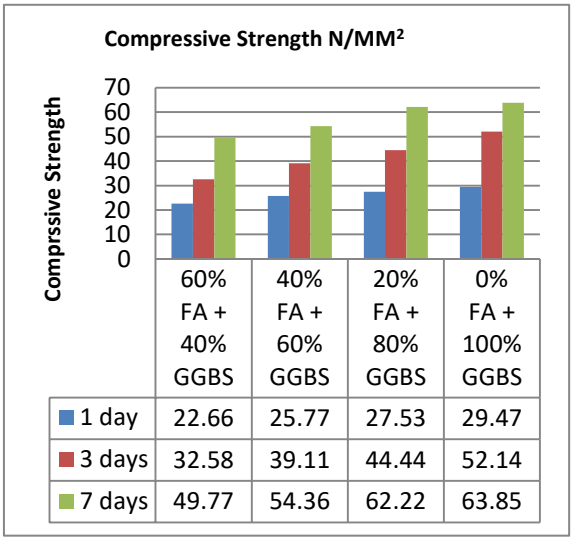


Figure 7: Shows the Compressive-Strength results of type II concrete

4. Split-tensile strength

From the below graph and table we can say that there is a great influence of presence of chemical admixtures, shows the better split tensile strength of concrete compare to other mix.

TABLE XII
Shows The Split-Tensile Strength Results of type 1 concrete

Mix	Split tensile Strength in N/mm^2		
	7 days	**14days**	**28 days**
60% FA + 40% GGBS	2.36	3.06	3.80
40% FA + 60% GGBS	2.56	3.30	4.26
20% FA + 80% GGBS	3.03	3.63	4.53
0% FA + 100% GGBS	3.16	3.73	4.93

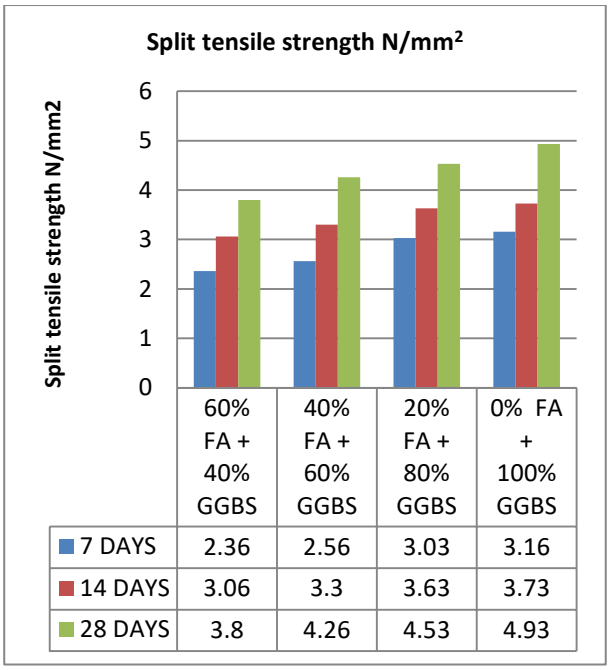
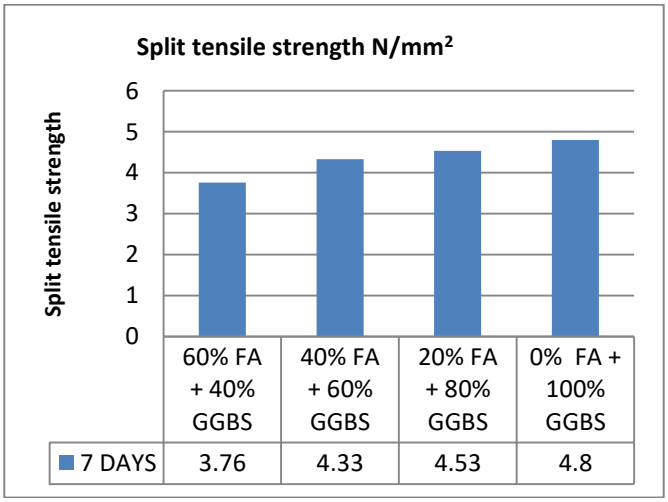


Figure 8: Shows the Split-Tensile Strength results of type I

TABLE XIII
Shows The Split-Tensile Strength Results of type II concrete

Mix	Split tensile Strength in N/mm²
	7 days
60% FA + 40% GGBS	3.76
40% FA + 60% GGBS	4.33
20% FA + 80% GGBS	4.53
0% FA + 100% GGBS	4.80

Figure 9: Shows the Split-Tensile Strength results of type II



5. Flexural Strength

The flexural prism having size is about 700mm×150mm×150mm were casted and tested under two point load testing machine to assess the flexural-strength. The results show that, the integration of chemicals shows the good ductility to flexural force. Shows the extraordinary flexural strength of concrete compare to other mix.

TABLE XIV
Shows The Flexural-Strength Test Results TYPE I concrete

Mix	Flexural Strength in N/mm²		
	7 days	14days	28 days
60% FA + 40% GGBS	3.11	4.93	6.30
40% FA + 60% GGBS	3.66	5.43	6.63
20% FA + 80% GGBS	4.33	5.70	6.93
0% FA + 100% GGBS	4.63	5.93	7.33

TABLE XV
Shows The Flexural-Strength Test Results TYPE II concrete

Mix	Flexural Strength in N/mm^2	
		7 days
60% FA + 40% GGBS		5.93
40% FA + 60% GGBS		6.33
20% FA + 80% GGBS		6.70
0% FA + 100% GGBS		7.13

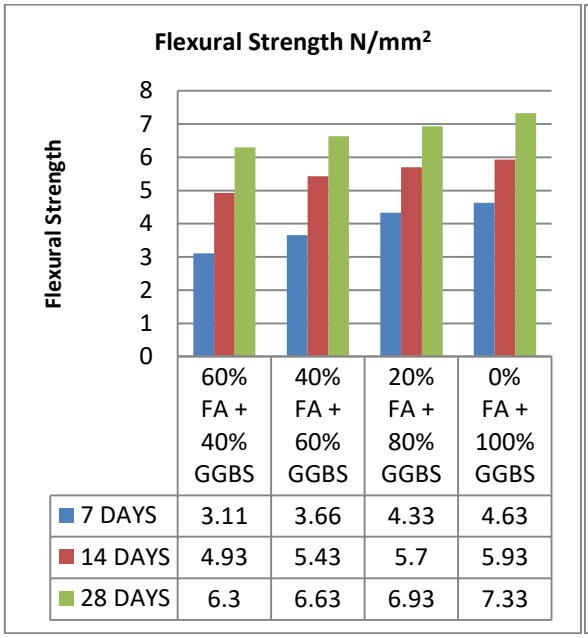


Figure 10: Shows the Flexural Strength results of type I

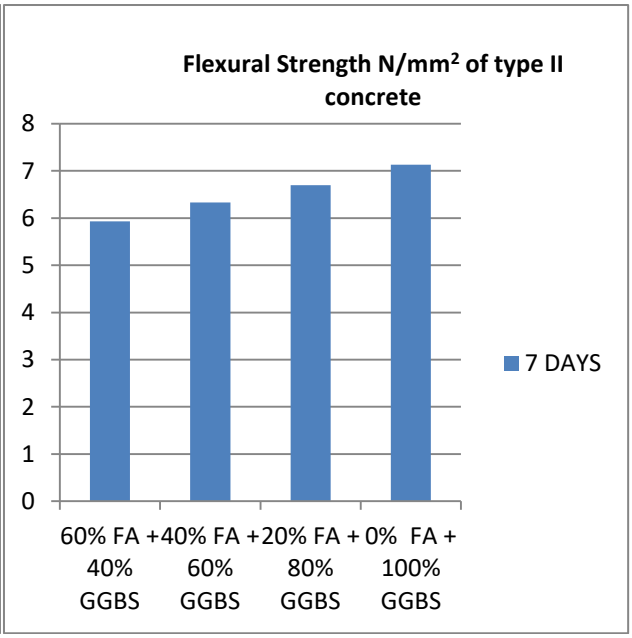


Figure 11: Shows the Flexural Strength results of type II

V.CONCLUSIONS

- The mix type 0%FA+100%GGBS has given overall better test results for all the tests that were performed on both type 1 and type 2 concrete.
- The sodium silicate solution and sodium hydroxide solutions have increased the overall strength parameters of the concrete.
- The sodium hydroxide solution of molarity 12M was used and has affected the strength in a positive way.
- The sodium silicate to sodium hydroxide ratio of 02.5 was used and was found to be very effective on the concrete‟s strength parameters and could be used in concrete.

The investigation was done by adding partial amount of sodium silicate and sodium hydroxide solution as well as adding them completely and I would like to conclude it in two ways as.

- When partially added with water it boosts the reaction at limited magnitude and performs almost similar to conventional concrete in strength gain rate but provides more economical type of concrete with slight better results compared to that of conventional concrete.
- When added completely by replacing it with water (with little quantity of water added for workability purpose i.e., 10%) in the ratio 0.5 [(liquid or Na2SiO3+NaOH sol.) to (binder or GGBS+FA) ratio] it gave the strength greater then that given by above concrete on 28th day at 7th day itself. So this type of concrete mix could be helpful where higher strength is required at lower time period. As the GGBS percentage increases the strength of concrete increases. But, slump decreases

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