A Comparative Study on Strength of Concrete by partial Replacement of Cement with FA and GGBS Using Various Curing Methods

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Abstract- In concrete, the ingredient cement plays a prominent role while getting strength. Numerous pollutants are evolved during the manufacturing process of cement which creates serious environmental hazards. To reduce the cement content in concrete by introducing two mineral admixtures, fly ash(FA) which is a pozzolanic material and ground granulated blast furnace slag(GGBS) is another by-product from industries of iron and steel were used in various curing conditions. A chemical admixture also was used to achieve high workability without increase the water content for M_{30} grade of concrete. These studies will also help in reducing the water which was used for conventional curing up to 28days. The compressive strength tests were conducted and the results were found to be satisfactory.

Keywords: FA, GGBS, Accelerated curing methods.

INTRODUCTION

The consumption of cement has been increasing day-to-day in entire world which emits carbon dioxide in to healthy environment during its chemical process and from fuel burning. Cement is a homogeneous fine material which interlocks the aggregates of fine and coarse when combined with water and gets maximum strength after curing for a specific period of time as per the code. Curing, a practical approach while construction is done which consumes lot of water which is not even recyclable. As per Indian standard code to get the target mean strength, minimum curing time required is 28days for which in laboratory, the test specimens were completely immersed in a curing tank. There are different practices for curing viz., sprinkling of water, membrane curing, steam curing, curing by gunny bags etc. To avoid these reasons, so many researches[1-6] were going on for alternative cementeceous materials, mineral admixtures like silica fume(SF), ground granulated blast furnace slag(GGBS), fly ash(FA) etc.

In present study FA and GGBS[7-10] were used as additives of cement in order to increase the strength, to decrease the pollution, to conserve non renewable sources, to reduce the waste materials in environment etc., keeping in view. FA is a low cost mineral admixture having fineness of 45µm or less, and have a carbon content of less than 4% and GGBS is a solid by-product of iron and steel making industries obtained in lumps form and ground into fine powder of size 20µm which are replaced individually in cement with different proportions of 0%, 10%, 20% and 30%. Curing is important step in the manufacturing process of concrete. To decrease the conventional curing period of 28days in laboratory, accelerated curing methods of warm water curing for a period of not less than 19.5 hours at the temperature of 55± 1^0C and boiling water curing for a period of 3.5 hours ± 5minutes at the temperature of 100^0C were adopted according to the relevant Indian standard code. After a wide literature survey[11-17] the tests for compressive strength were conducted on Compressive Testing Machine(AIMIL) having capacity of 300T for concrete cube specimens after conducting the curing process. From the accelerated curing methods one day compressive strength values are obtained and the 28days compressive strength was calculated by using regression equations which are specified by graphs in the Indian standard code[18] and the regression equations are given as follows:

R_{28}= 12.65+R_a (for warm water curing) ……..…… (i)

R_{28}= 6.09+1.64R_a(for boiling water curing) …….……. (ii)

Where,

R_{28} is the accelerated curing compressive strength of concrete at 28days.

R_a is the accelerated curing compressive strength of concrete at 1day.

EXPERIMENTAL STUDY

The selection of materials plays a very important role in the preparation of concrete. Zuari cement of 43 grade was used which is acts like a binding material in concrete. Aggregates when combined with cement attains good strength. Coarse aggregates of size 20mm and fine aggregates of varying sizes 4.75mm-150microns which are free from deleterious substances are selected. Fly ash of class F [19-21] was used which is evolved from the burning of old, hardened anthracite and bituminous coal, possessing high pozzolanic properties, collected from NTPC, Visakhapatnam. GGBS[21-23] was evolved as quenching molten iron slag in the manufacturing process of iron and steel industries from a blast furnace in water or steam to produce a glassy, granular product which is dried and ground into a fine powder. Super Plasticizer of Conplast SP430 was used to achieve good workability for the selected water cement ratio of 0.45. Bore water free from debris and organic matter was used in mixing of concrete and also in curing process. The materials are selected and test are going to be conducted as per the requirements of Indian standard codes[25-36] and presented in table1. as per the requirement of design mix for M_{30} grade of concrete.

Table 1. Test Data of Ingredients Present in Concrete And Tests on Fresh Concrete

S. No	Name of the experiment	Result	As per Indian standard code
1	Fineness of cement	1.73%	IS:4031(part1)-1996
2	Specific gravity of cement	3.02	IS:2720(part3)-1980
3	Normal consistency	35%	IS:4031(part4)-1988
4	a) Initial setting time	30mins	IS:4031(part5)-1988
	b) Final setting time	360mins	
5	Compressive strength of cement mortar	37.41N/mm^2	IS:4031(part6)-1988

6	Sieve analysis of fine aggregate	Zone 2 and 2.5	IS:383-1970
7	Bulking of sand	4.08%	IS:2386(part3)-1963
8	Specific Gravity of fine aggregate	2.54	IS:2386(part3)-1963
9	Sieve analysis of coarse aggregate	7.58	IS:2386(part3)-1963
10	Specific gravity of coarse aggregate	2.66	IS:2386(part3)-1963
11	Fineness of fly ash	2.6%	IS:4031(part1)-1996
12	Specific gravity of fly ash	2.96	IS:2720(part3)-1980
13	Specific gravity of water	1	IS:456-2000
14	pH of water	6.6	IS:456-2000
15	Specific gravity of super plasticizer	1.22	IS:9103-1999
16	Slump of fresh concrete	75mm	IS:1199 -1959
17	Compaction factor of fresh concrete	0.9	IS:1199 -1959

METHODOLOGY

After the materials were tested, the design of concrete mix was done by using Indian standard code[37] for getting the mix proportion of M_{30} grade of concrete. Using mix proportion values, the fresh concrete was prepared and workability tests were conducted, cube specimens were casted using steel moulds of size 150mmx150x150mm @ 3 per sample. Afterwards, curing was done by various methods i.e., normal water curing method at 28days, warm water and boiling water curing methods of accelerated curing as per relevant codal provisions. Finally, the test for compressive strength were conducted as per code[38] to the specimens and the one day strength of concrete for accelerated curing methods were presented in table 2.

Table 2. Average Compressive Strength of Concrete by Accelerated Curing Methods

S. No.	Method of curing	One day average compressive strength of concrete in N/mm^2							
		0% FA	10% FA	20% FA	30% FA	0% GGBS	10% GGBS	20% GGBS	30% GGBS
1	Warm water curing	18.22	21.41	19.33	16.15	18.22	22.52	20.96	19.56
2	Boiling water curing	20.52	21.63	21.04	17.04	20.52	22.22	21.48	24.74

The compressive strength of concrete at 28days by normal water curing and accelerated curing methods of warm water and boiling water curing values are obtained from the regression equations (i) and (ii) are presented in table 3. The comparative results were shown as figures 1, 2, 3 and 4.

Table 3. Average Compressive Strength of Concrete by Various Curing Methods

S. No.	Method of curing	Average compressive strength of concrete in N/mm^2							
		0% FA	10% FA	20% FA	30% FA	0% GGBS	10% GGBS	20% GGBS	30% GGBS
1	Normal water curing	39.26	43.26	42.96	34.52	39.26	45.19	42.22	44.74
2	Warm water curing	30.87	34.06	31.98	28.80	30.87	35.17	32.80	32.21
3	Boiling water curing	39.74	41.56	40.59	34.03	39.74	39.38	43.02	46.66

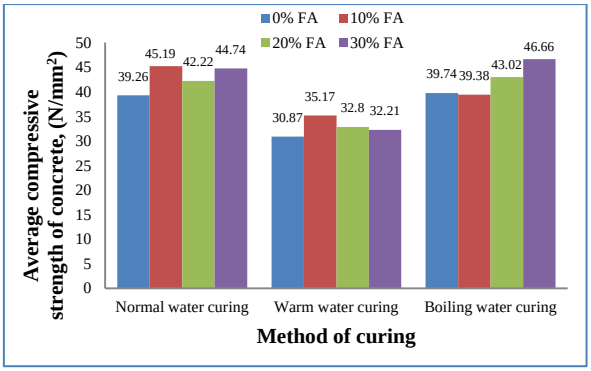

Figure 1. Average Compressive Strength

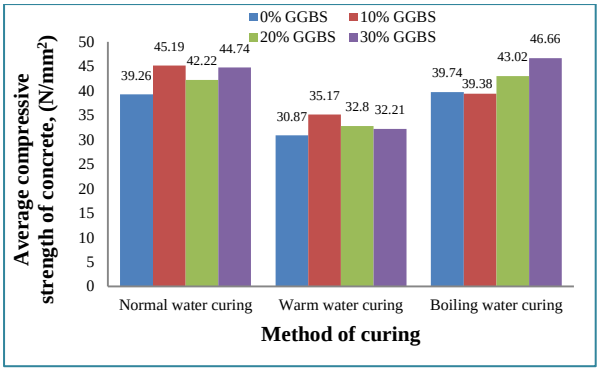

Figure 2. Average Compressive Strength versus Method of Curing for FA Versus Method of curing for GGBS

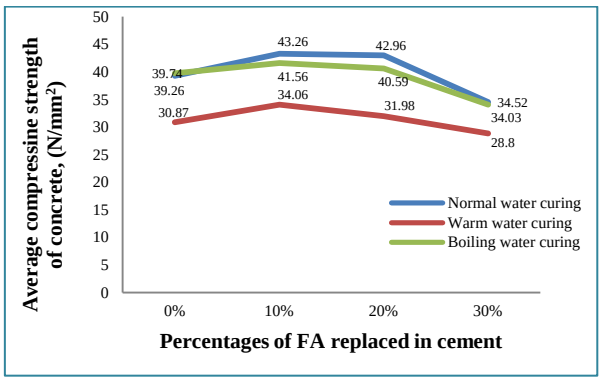

Figure 3. Average Compressive Strength Versus Percentages of FA Replaced

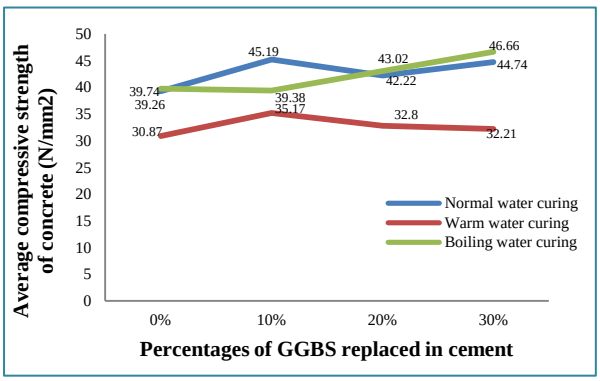

Figure 4. Average Compressive Strength Versus Percentages of GGBS Replaced

RESULTS AND DISCUSSION

Based upon the above experimental results it was seen that the strength values for normal curing are higher than that of target mean strength of concrete i.e., 38.25N/mm^2. From table 3. It was observed that the compressive strength values by warm water curing are less than the normal water curing method. It was due to the fact that in normal water curing the concrete is allowed to set for a period of 24hours and the hydration process takes place. But in warm water curing the concrete is allowed to set for around one hour only and immediately the specimens were transferred to curing tanks along with moulds and incomplete hydration would happens. The average compressive strength values of boiling water curing are more than the results of normal water curing this was the fact that in normal water curing initially C-S-H gel is not formed very well and it didn't attain much strength but in boiling water curing there is a quick formation of C-S-H gel due to high temperature effect and the concrete attains strength quickly when compared with warm water and normal water curing. From the above mentioned values, the compressive strength of concrete was optimum at 10% FA whereas in the case of GGBS it is at 30% replacement. The remaining percentages are also yielding better values near to characteristic compressive strength of concrete. Same trend was observed by the previous scholars [39-42]. Based upon the average compressive strength values, cement replaced with GGBS partially having higher strength when compared with cement replaced with FA partially. GGBS concrete has a higher proportion of the strength enhancing calcium silicate hydrates(C-S-H) than concrete made with FA, also having a reduced content of free lime, which does not contribute to concrete strength.

CONCLUSIONS

From the present studies, it was concluded that by using accelerated curing methods, the compressive strength of the concrete not only increases but also decreases the testing period in laboratories and construction time for pre fabricated members. The results are satisfied according to specified codes. The use of FA decreases the amount of cement in concrete, reduces cost of construction, also solves carbon dioxide emissions and so on in the environment. The use of GGBS protect the reinforced concrete subjected to chloride attack in marine environments, also prevents the occurrence of micro cracking in concrete. Concrete made with GGBS continuously gains strength over time and structure as durable as possible. It was also observed that GGBS is relatively better replaceable material than FA in concrete.

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