Evaluation of Properties of Concrete under Varying Water Curing Duration

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Abstract: ***It is mandatory in construction industry that the curing of concrete structure should be carried out as per the standard guidelines to ensure strength and durability criteria over its service life of the structure. Curing of concrete is an empirical process with an assumption to supplement water to the hydration process of cement and to control the moisture movement from the concrete structure. Keeping in view of this criterion a research project has been undertaken to investigate the variation in mechanical properties of concrete with and without curing. For this investigation concrete of grade M30 were used, two mixes were considered one with ordinary Portland cement (OPC) and another mix with partial replacement of OPC with GGBS as mineral admixture. A series of twenty four cube specimens were cast for each mix in that nine cubes were cured for 28 days curing and nine cubes for partially curing and nine cubes for no curing, and results obtained from the experiment were compared and conclusions were drawn.***

Keywords: Fully curing, Partial curing, No curing, Compressive strength.

1. Introduction

It is mandatory in construction industry that the curing of concrete structure should be carried out as per the standard guidelines to ensure strength and durability criteria over its service life of the structure. Curing of concrete is an empirical process with an assumption to supplement water to the hydration process of cement and to control the moisture movement from the concrete structure. Curing is the process of controlling the rate and extent of moisture loss from concrete during cement hydration. When Portland cement is mixed with water, a chemical reaction called hydration takes place. The extent to which this reaction is completed influences the strength and durability of the concrete. Freshly mixed concrete normally contains more water than is required for hydration of the cement; however, excessive loss of water by evaporation can delay or prevent adequate hydration. The curing period may depend on the properties required of the concrete, the purpose for which it is to be used, and the ambient conditions, i.e., the temperature and relative humidity of the surrounding atmosphere. Curing of concrete must begin as soon as possible after placement & finishing and must continue for a reasonable period of time as per the relevant standards, for the concrete to achieve its desired strength and durability. Curing may be applied in a number of ways and the most appropriate means of curing may be dictated by the site or the construction method. Uniform temperature should also be maintained throughout the concrete depth to avoid thermal shrinkage cracks. Also protective measures to control moisture loss from the concrete surface are essential to prevent plastic shrinkage cracks.

2. Literature Review

D.Gowsika, et al evaluated effectiveness of different curing methods and study the persuade of climate on the strength properties of concrete. Normal concrete was prepared with a water-cement ratio of 0.45. The specimens were cast for testing the compressive strength at 7, 14 and 28 days of curing respectively using seven curing methods namely Ponding, Air Drying, Immersion, Oven curing, calcium chloride (miscellaneous), Membrane curing and Pack (Plastic sheeting) curing to cure the specimens until the day of testing. Test results indicates that water curing (WAC) Immersion , Ponding as well as Membrane curing provide much better results than Plastic Sheeting method of curing. The rate of drying was important when the specimens were subjected to Oven method of curing. The overall finding of this paper suggests that concrete should be cured by water curing to attain a better compressive strength.

Akinwumi, I.I., Gbadamosi, Z.O. have the results of an experimental study on the effects of curing methods and curing ages on the compressive strength development of ordinary Portland cement concrete in a tropical environment. Fifteen (15) concrete cubes each were cured by immersion in potable water, immersion in lime water, covering with wet rug, covering with plastic sheets and air-drying. For each of these curing methods, the average compressive strength of concrete cubes was determined after 3, 7, 14, 28 and 90 days curing periods. The results obtained discourage the use of curing by air-drying method and also suggests limiting the use of the other curing methods to 28-days period. Generally, the highest compressive strength was obtained for concrete cured by immersion in lime water.

T. James, et al. investigated the different curing methods are usually adopted to evaluate the compressive strength of concrete. This study reports the laboratory results of the effect of curing methods on the compressive strength as well as the density of concrete. A total of 72 cubes of mix ratio 1:2:4 were
Investigated after subjecting them to various curing conditions, with the aim of finding which of the curing method is best. The cubes were cured in the laboratory at an average temperature of 28◦C (82.4◦F).

The results obtained showed that the average compressive strength values for 7, 14, 21 and 28 days, vary with curing methods. The results show that ponding had the highest compressive strength and density, followed by wet covering, sprinkling, then uncured for two days, with the totally uncured cubes having the least compressive strength and density as well as highest shrinkage limit. Ponding method of curing was recommended to be the best of all the curing methods.

3. Materials and Methodology

Cement: Ordinary Portland Cement of 43 Grade was used for casting of all the specimens. It is tested as per IS 12269:1987 Recommendation.

Fine Aggregate (FA): Manufactured sand with specific gravity 2.7 and fineness modulus 3.245 confirming to Zone-II is used.

Coarse Aggregate (CA) - Locally available angular crushed aggregates as per IS 383-1970 is used in this experimental work of study. Specific gravity of 2.69 coarse aggregate is determined using the method confirming to Indian Standard 2386.

Water: The purpose of use of water is for both mixing and curing and it shall be clean and free from the any of the detrimental materials such as acidic compounds, alkaline, salt substances, sugar compounds, organic materials or other substances that may be harmful to concrete structure potable water which is used for drinking purpose is in general suitable in mixing and for curing of concrete. It is tested as per IS 10500:2012 Recommendation, details are shown in table.1.

Table 1: Properties of Water

S. No	Characteristics	Water Sample (mg/l)	Permissible Limit (mg/l)
1	pH	7.2	6.5 to 8.5
2	Colour	clear	
3	Taste	Agreeable	-
4	Odour	Unobjectionable	-
5	Total Acidity (as mg/L of CaCO3)	10	-
6	Total Alkalinity (as mg/L of CaCO3)	240	250- 600 mg/L
7	Chlorides	44.99	200-1000 mg/L
8	a. Total Hardness	180	200-600 mg/L
	b. Calcium Hardness	110	-
	c. Magnesium Hardness	70	-
9	a. Total solids	640	-
	b. Total dissolved solids	160	500- 2000 mg/L
	c. Total suspended Solids	480	-
	d. Inorganic solids	520	-
	e. Organic solids(mg/L)	120	-
10	Turbidity	2	10 NTU

Chemical admixture (Superplasticizer) - LaGreen S20 is a low range modified polycarboxylic ether based Superplasticizer for pumpable concrete. The properties of Superplasticizer S20 are tabulated in Table. 2.

Table 2: Properties of Superplasticizer

Type	Polycarboxylic based ethers
Form	Liquid
Colour	Light Brown
Relative Density	1.1 20°C
pH	6.6
Specific gravity	1.1

Ground Granulated Blast Furnace (GGBS): Blast furnace slag is a by-product of iron manufacture. When quenched rapidly with water to a glassy state and fines ground, it develops the property of latest hydraulicity. The proportions of GGBS to be used in concrete depend upon the job requirements, the usual proportions vary from 10 to 50% by weight of cement. GGBS is a cement replacement basis however, if the purpose is to enhance some aspect of concrete durability. Physical Composition of GGBS is shown in Table. 3

Table 3: Physical Composition of GGBS

Parameter	Specifications
Colour	Light grey
Specific gravity	2.85 to 2.95 (2.32)
Specific surface	450 m2/kg

3.1 Methodology

Table 4: Details of test specimens prepared

Designation	Concrete Matrices
CS (M30)	Cement Concrete Specimen
CGS(M30)	Cement + 30%GGBS Concrete Specimen

Mix Design -
Mix Design is one of the process by means of which suitable ingredients in the concrete are selected and in order to determine their relative quantity with object of producing concrete possessing minimum desirable properties like workability in fresh state minimum desirable strength and durability in hardened state. Mix proportion obtained by after mix design is tabulated below.

Table 5: Mix proportion for CS(M30)

Water	Cement	Fine aggregate	Coarse aggregate	Super Plasticizer**
157.6 ltr /m^3	366.511 kg/m^3	778.780 kg/m^3	1232.877 kg/m^3	1.8325 kg/m^3
w/c 0.43	1	2.124	3.363	0.005

Table 6: Mix proportion for CG(M30)

Water	Cement	GGBS	Fine aggregate	Coarse aggregate	Super Plasticizer**
157.6 ltr /m^3	282.214 kg/m^3	120.948 kg/m^3	762.405 kg/m^3	1206.983 kg/m^3	1.4110 kg/m^3
w/c 0.39	1		1.891	2.993	0.005

4. Experimental Programme

Test specimen and testing procedures for compressive strength test, cube specimens of dimensions 150 x 150 x 150 mm were cast. In this study M30 grade of concrete which are often used for buildings and infrastructure construction are considered. The total experimental program consists of the concrete

Figure 1: Compressive strength test

Specimens were subjected under three curing conditions namely fully cured (FC), Partially Cured (PC) and Not-Cured (NC). In FC the specimens were cured for 3 days, 7 days and 28 days, in PC the specimens were cured for 3 days in water and later left for air curing and 7day in water and later left for air curing and in NC the specimen after demoulding on next day were left for air curing. Cubes were tested on compression testing machine as per I.S. 516-1959. In each category three cubes were tested and their average value is reported.

5. Results and Discussion

The hardened concrete test was done as per IS 516:1959. The results of cube for compressive strength at different ages under three curing conditions (Fully cured, Partial cured, Not-cured) are summarized in below table.

Details of Cube specimens, Standard.	Fully Cured, FC			Partially Cured, PC			Not-Cured, NC		
	3 days	7 days	28 days	3 days	7 days	28 days	3 days	7 days	28 days
CS	14.96	22.84	31.85	19.10	24.59	31.85	9.32	11.38	13.32
CGS	13.62	22.21	32.73	18.51	22.96	32.73	9.18	11.40	13.32

The Fig. 2, 3 & 5 shows Cubes Compressive Strength of CS at different ages under three curing conditions (Fully cured, Not-cured & Partial cured). Fig. 4 shows shows the Percentage variation of Cubes Compressive Strength of CS(NC) with respect to CS(FC).

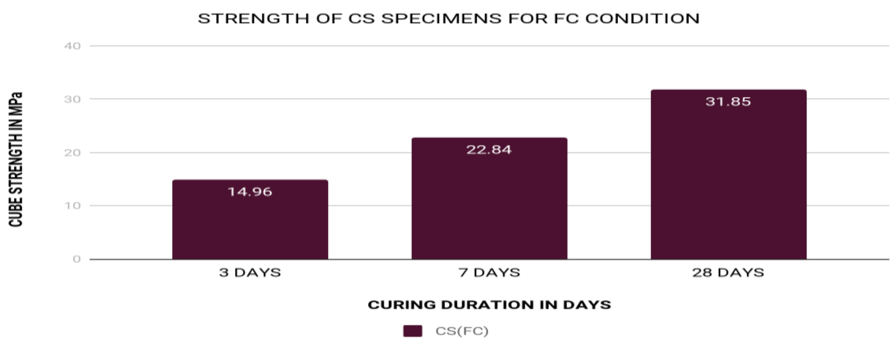

Figure 2: Cube Compressive Strength of CS for FC condition.

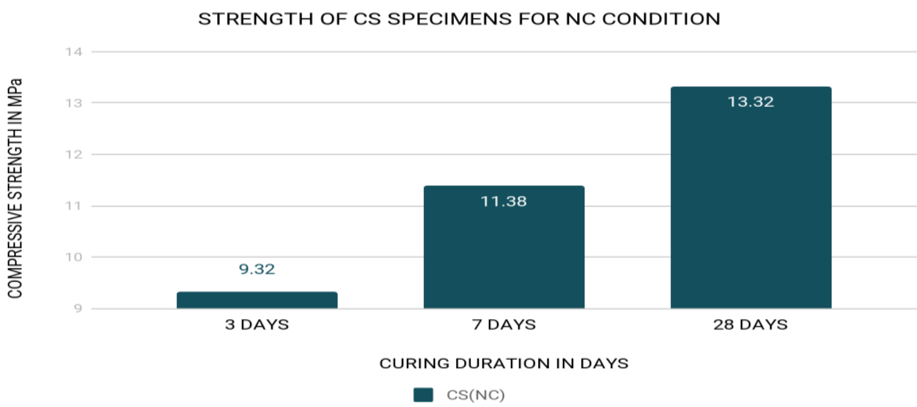

Figure 3: Cube Compressive Strength of CS for NC condition.

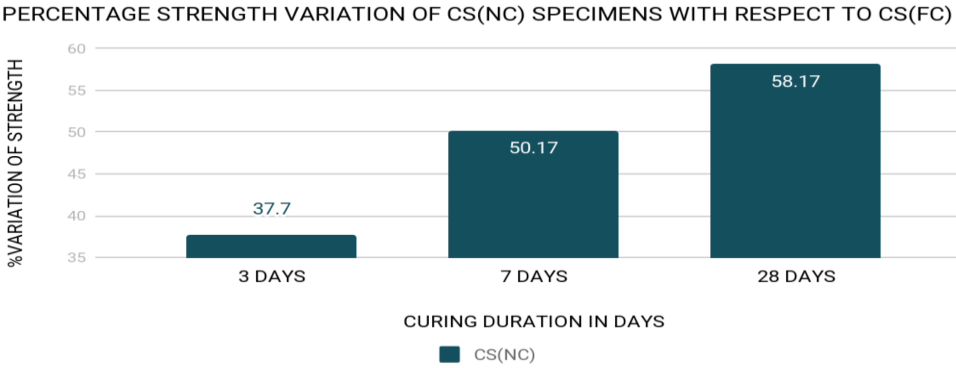

Figure 4: Percentage variation of Cube Compressive Strength of CS(NC) specimens with respect to CS(FC).

The reduced compressive strength under NC conditions specimens is compared with FC condition specimen for CS (M30), the average percentage cube strength reduction for 3 days , 7 days and 28 days is 37.71%, 50.17% and 58.17% respectively.

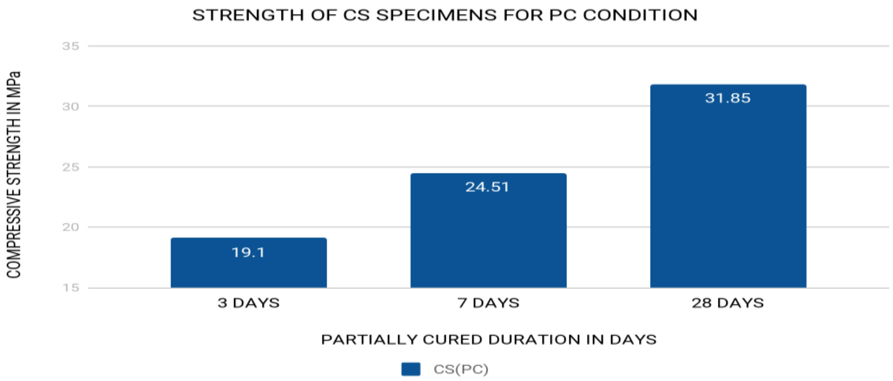

Figure 5: Cube Compressive Strength of CS for PC condition

Fig. 6 shows the Variation of cube compressive strength of CS (PC) specimens with 28 days strength of CS(FC) specimen and Fig. 7 shows Percentage Variation of cube compressive strength of CS(PC) specimens with 28 days strength of CS(FC) specimen.

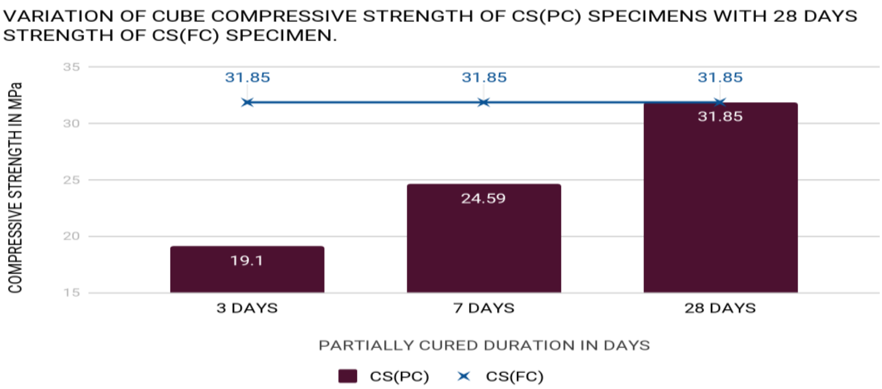

Figure 6: Variation of Cube Compressive Strength of CS(PC) specimens with 28 Days Strength of CS(FC) specimen

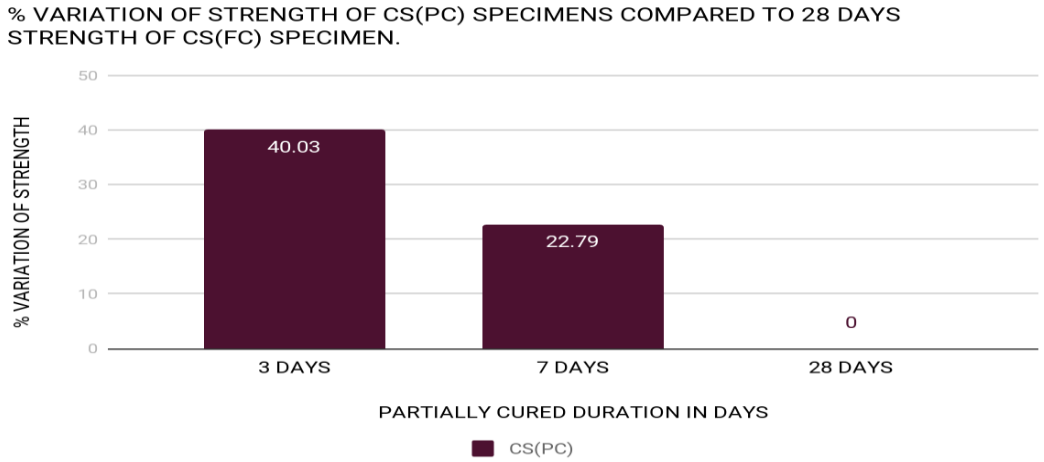

Figure 7: Percentage variation of Cube Compressive Strength of CS(PC) specimens with 28 DAYS strength of CS(FC) specimen

The variation of compressive strength under PC condition specimens is compared with 28 days compressive strength of FC condition specimen for CS (M30), the average percentage cube strength reduction for 3 days , 7 days and 28 days of partially cure is 40.03%, 22.7% and 0% respectively.

The Fig. 8, 9 & 11 shows Cubes Compressive Strength of CGS at different ages under three curing conditions (Fully cured, Not-cured & Partial cured). Fig. 10 shows the Percentage variation of Cubes Compressive Strength of CGS(NC) with respect to CGS(FC).

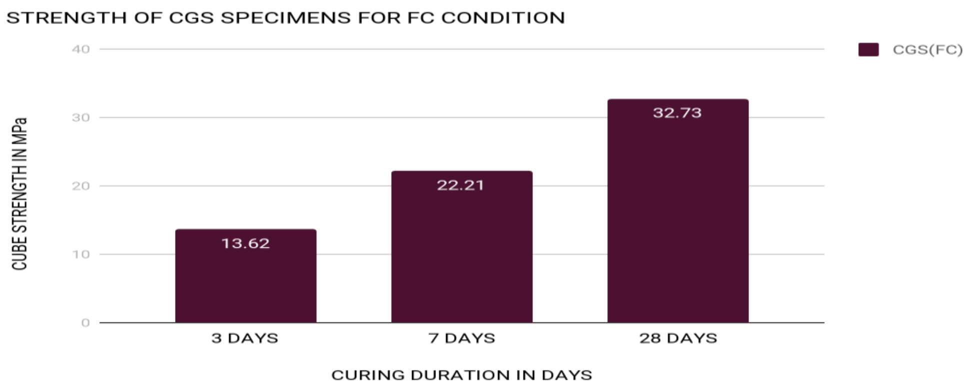

Figure 8: Cube Compressive Strength of CGS for FC condition.

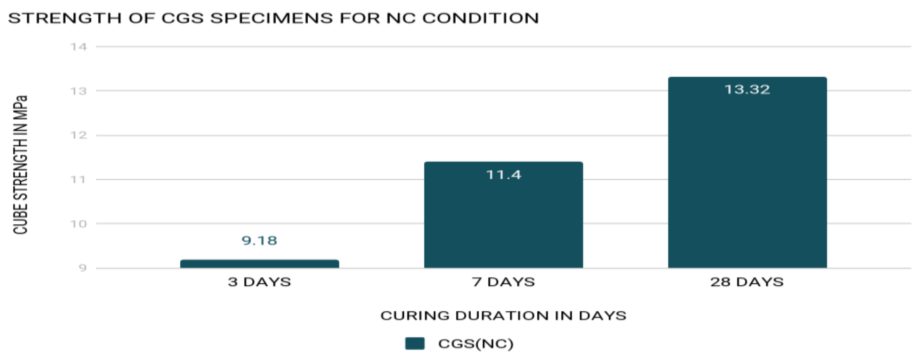

Figure 9: Cube Compressive Strength of CGS for NC condition.

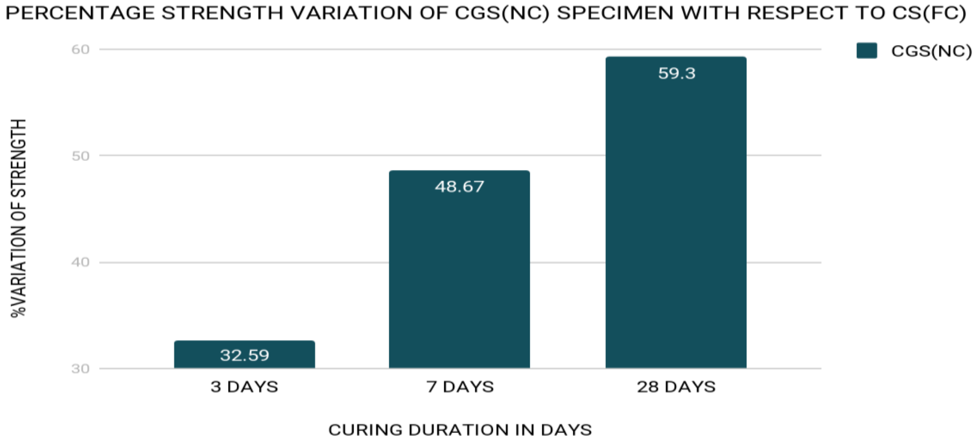

Figure 10: Percentage variation of Cube Compressive Strength of CGS(NC) specimens with respect to CGS(FC).

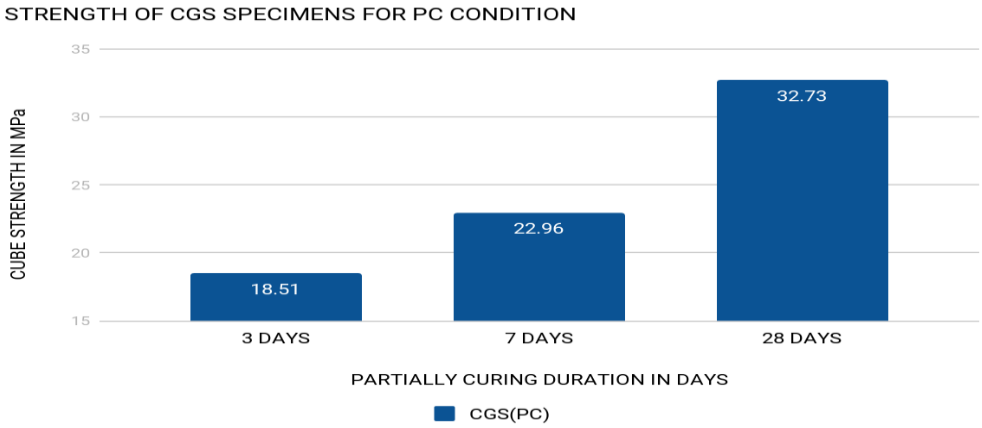

Figure 11: Cube Compressive Strength of CGS for PC condition.

Fig. 12 shows the Variation of cube compressive strength of CGS(PC) specimens with 28 days strength of CGS(FC) specimen and Fig. 13 shows Percentage Variation of cube compressive strength of CGS(PC) specimens with 28 days strength of CGS(FC) specimen.

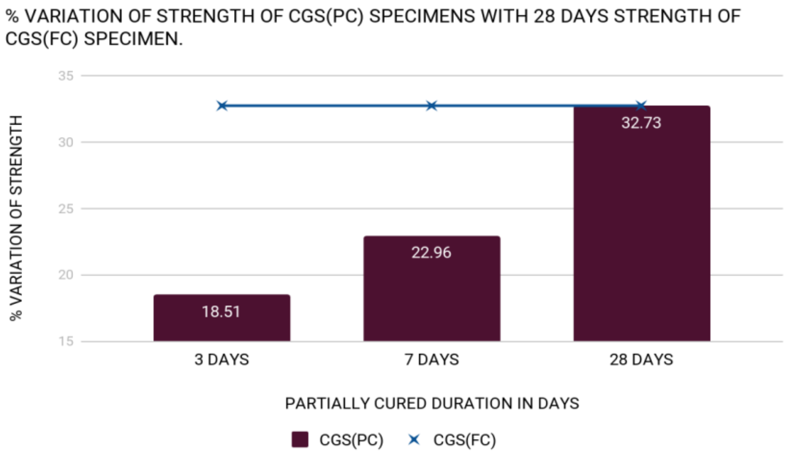

Figure 12: Variation of Cube Compressive Strength of CGS(PC) specimens with 28 days strength of CGS(FC) specimen.

The variation of compressive strength under PC condition specimens is compared with 28 days compressive strength of FC condition specimen for CS (M30), the average percentage cube strength reduction for 3 days , 7 days and 28 days of partially cure is 43.44%, 29.85% and 0% respectively.

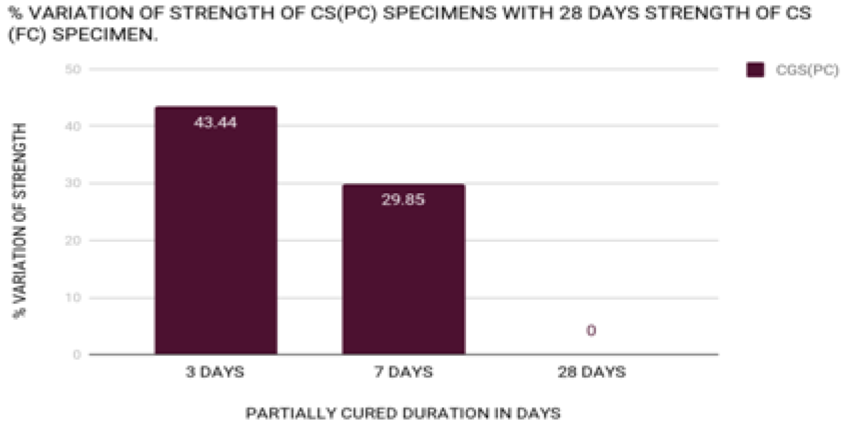

Figure 13: Percentage variation of Cube Compressive Strength of CS(PC) specimens with 28 DAYS strength of CS(FC) specimen

The Fig. 14 shows the Cubes Compressive Strength Curves for CS (PC) and CGS(PC) at various Curing durations.

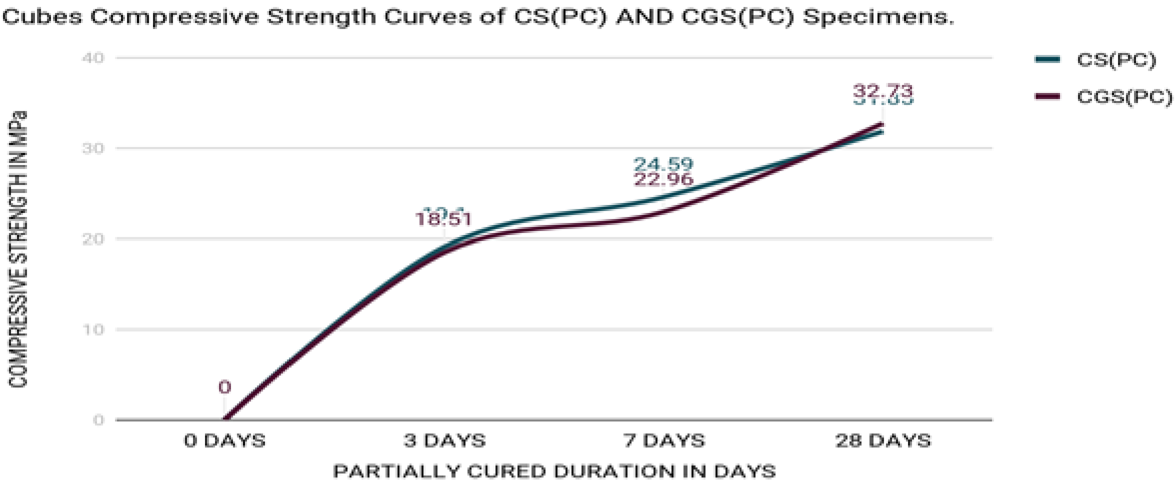

Figure 14: Cubes Compressive Strength Curves of CS (PC) and CGS(PC) specimens

6. Conclusion

Based on the above experimental results it can be concluded that the compressive strength of cube specimens for not cured condition and compressive strength of cube specimens for fully cured condition shows so much variation which is not desirable. It can also be concluded that the there is no much change in the strength due the replacement of GGBS by cement. Even though the compressive strength of cube specimens for partially cured condition compared with 28 days compressive strength of cube specimen for fully cured condition shows less variation than that of not cured condition the desirable strength is not achieved. The cube compressive strength curves helps to estimate the strength of CS and CGS specimens for a known water curing duration, which would be useful in construction field to evaluate actual strength of concrete.

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