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EVALUATION OF MECHANICAL AND DURABILITY PROPERTIES OF PORTLAND SLAG CEMENT WITH PARTIAL REPLACEMENT OF CEMENT BY DIFFERENT MINERAL AND CHEMICAL ADMIXTURES

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ABSTRACT

The construction industry is now slowly becoming aware of the environmental issues and other sustainable development issues for cement and concrete industries. It is looking for the ways and means to develop building products, which will increase the life span and quality. In this regard the merits of using certain industrial by products such as fly ash, ground granulated blast furnace slag, microsilica, and rice husk ash have been well recognized by the construction industry.

Therefore, it should be obvious that certain scale cement replacement with industrial by products is highly advantageous from the stand point of cost, economy, energy efficiency, durability and overall ecological and environmental benefits. In the present investigation an attempt is made to find various properties based on the experimental results, mathematical models were elaborated to predict the strength of mortar cubes with partial replacement of cement by different admixtures with 5% of total powder content by weight. Strength of cubes with Portland Slag Cement (PSC), after 3,7,28 ,90 days and 360 days of curing and also durability tests after 60 days, were analysed to evaluate the effect of addition content, the time of curing and the compressive strength changes.

The investigation revealed that use of waste materials like fly ash, ground granulated blast furnace slag, microsilica and rice husk ash, which are otherwise hazardous to the environment may be used as a partial replacement of cement, which leads to economy and in addition by utilizing the industrial wastes in the useful manner the environment pollution is also reduced to great extent and which leads to sustainable development. Out of all these admixtures used microsilica gives best results when compared to other admixtures used with and without super plasticizer.

KEYWORDS: Compressive Strength, Durability, Fly Ash (FA), Ground Granulated Blast Furnace Slag (GGBS), Micro Silica (MS), Rice Husk Ash (RHA), Superplasticizer

INTRODUCTION

The development of the construction industry in the global level needs more and more quantity of cement for sustainable growth. But, the production of each tonne of cement clinker releases one tonne of carbondioxide, which affects the earth's ecosystem[1].Thus, increasing production of Ordinary Portland Cement (OPC) worldwide is aggravating the problems associated with its production and use. The addition of the pozzolanic materials with OPC, a century old practice, is an alternative practice in the construction industry.

Investigations were undertaken to establish the possibilities of using a much higher amount of flyash content in combination with fluorogypsum, lime sludge and portland cement to enhance the physico-chemical properties of cementitious binder[2]. The experimental results indicated that the addition of FA in concrete improves the durability properties of concrete. One of the greatest drawbacks while using flyash as pozzolanic material in concrete is the early age performance of concrete.

The early age strength development of flyash blended concrete shows poor performance than the ordinary concrete. The development of ternary blends made by a superfine mineral admixture like silica fume (SF) is an alternative possible way to overcome the drawback of binary blends. The SF in the ternary blend improves the early age performance of concrete and the flyash is continuously improving the properties of hardened concrete[3]. According to several researchers, ternary blends are vastly superior to portland cement concrete in terms of durability of structures[4].

The development of ternary blended cement has been the subject of investigation for the past three decades[5]. Some of the developed countries are currently producing the ternary blended cement including a combination of flyash, slag and silica fume[6]. The deterioration of concrete due to sulphuric acid attack is by leaching out of dissolved constituents of hardened concrete leading to loss of strength eventually initiating rapid deterioration.

The rate of chemical attack on concrete is a function of p^H of the aggressive fluid and permeability of concrete (Neville 2003)[7]. The replacement of cement in the binary system using silica fume was suggested as 4%, 8% and 12% of the total powder content by weight. It was analysed by the test results that the compressive strength and the splitting tensile strength were related together and the 0.5 power relationship was found to be inaccurate in all the ternary blended combinations[8].

MATERIALS AND METHODS

Portland slag cement is obtained by mixing blast furnace slag, cement clinker and gypsum and grinding them together to get intimately mixed cement. The quantity of slag varies from 30-70%. The gain of strength of PSC is somewhat slower than OPC. Cement used in the present investigation is Ultratech. The sand used throughout the experimental work was obtained from the river Swarnamukhi near Tirupati, Chittoor district, Andhra Pradesh.

This type of sand was used by the many of researchers as an ingredient in cement mortar which is tested according to IS 650:1966 specifications[9]. The characteristics of water were analyzed according to the standard methods for the examination of water. The different admixtures used are Fly ash (FA), Ground Granulated Blast furnace Slag (GGBS), Microsilica , Rice husk ash (RHA) and super plasticizer conforming to IS 9103:1999[10] Super plasticizer is based on a blend of specially selected organic polymers.

It is instantly dispersed in water. The various tests conducted and the equipment used for the test are given in the Table1.These standard experimental procedures laid down in the standard codes, like IS, ASTM and BS codes were adopted for the determination of normal consistency, Initial and Final setting times, Soundness of Cement, Compressive Strength of cement mortar cubes.

The various durability tests conducted were Acid test, Alkaline test, Sulphate test and Rapid Chloride Permeability Test respectively. The specimens were tested for compressive strength duly following the procedure prescribed in IS 516:1959[11].

For Acid test the various samples prepared are immersed in water which contains 5% of HCL in it by weight of water for 60 days, after a normal curing of 28 days. The compressive strength and loss of weight are determined after the

completion of 90 days. For Alkaline test the various samples prepared are immersed in water which contains 5% of NaOH in it by weight of water for 60 days, after a normal curing of 28 days.

The compressive strength and loss of weight are determined after the completion of 90 days. For Sulphate test the various samples prepared are immersed in water which contains 5% of $MgSO_4$ and 5% of Na_2SO_4 in it by weight of water for 60 days, after a normal curing of 28 days.

The compressive strength and loss of weight are determined after the completion of 90 days. The rapid chloride permeability test for different mortar mixtures was carried out as per ASTMC-1202-97. This test method covers the determination of the electrical conductance of mortar to provide a rapid indication of its resistance to penetration of chloride ions.

Table 1: Details of the Various Experiments and Equipment Used

S.No	Experiment Name	Equipment Used
1.	Initial and final setting times	Vicat's apparatus confirming to IS 5513-1976[12]
2.	Soundness of cement	Le-chatelier apparatus confirming to IS 5514-1969[13]
3.	Compressive strength	100 Tonne universal testing machine
4.	Chloride Permeability	Rapid Chloride Permeability Test Apparatus

RESULTS AND DISCUSSIONS

The results of the present investigation are presented both in tabular and graphical forms. In order to facilitate the analysis, interpretation of the results is carried out at each phase of the experimental work.

This interpretation of the results obtained is based on the current knowledge available in the literature as well as on the nature of results obtained. The significance of the result is assessed with reference to the standards specified by the relevant IS codes.

The averages of both the initial and final setting time of three samples prepared with different cements replacement by 5% of fly ash, ground granulated blast furnace slag, microsilica, rice husk ash and also with chemical admixtures of superplasticizer are compared with ordinary cements.

If the difference is less than 30 minutes, the change is considered to be insignificant and if it is more than 30 minutes, the change is considered to be significant. The average compressive strength of at least three cubes prepared with mineral and chemical admixtures under consideration is compared with that of three cubes prepared with ordinary cements.

If the difference in the strength is less than 10%, it is considered to be insignificant and if it is greater than 10%, it is considered to be significant.

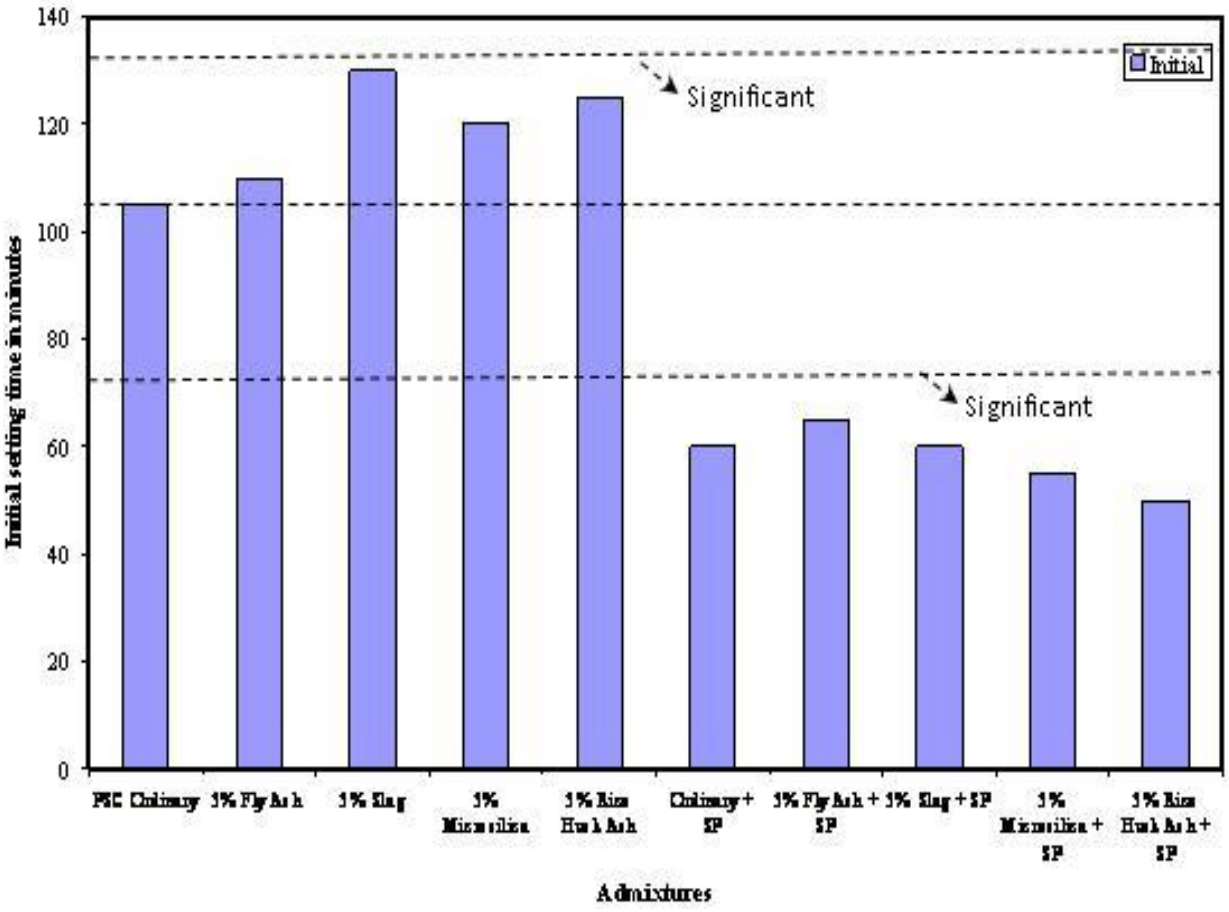
The average soundness test results of three samples prepared with different type of cements replaced with mineral and chemical admixtures under consideration are compared with that of three similar ordinary cements. The unsoundness of the specific sample, made with mineral and chemical admixtures is significant if the result of Le-Chatelier's soundness test is more than 10 mm.

Test results of initial and final setting times, soundness and percentage change in compressive strengths are presented in Table 2 and Figure 1 and Figure 2. Durability tests (Acid Test, Alkaline Test and Sulphate Test) regarding compressive strength of different types of cement mortar cubes with replacement of mineral and chemical admixtures are presented in the Table 3 and Figure 3. Results of Rapid Chloride Permeability Test are presented in Table 4 respectively.

Table 2: Initial and Final Setting Times, Soundness of Cement, Compressive Strength and Percent Change in Compressive Strength of Cement Mortar Cubes at Different Ages Made with 5% Replacement of Mineral Admixtures with and Without Superplasticizer in Portland Slag Cement

S. No	Cement + Admixture	Initial Setting Time (min)	Final Setting Time (min)	Sound-ness (mm)	Compressive Strength MPa					Percent Change in Compressive Strength				
					3day	7day	28day	90day	365 days	3day	7day	28day	90day	365 days
1	PSC	105	195	1.5	22	26.2	36.4	45.8	59	0	0	0	0	0
2	PSC+5% FA	110	210	1.2	23.3	28.5	37.09	45.66	59.11	-5.9	-8.6	-1.9	0.3	-0.2
3	PSC+5% GGBS	130	230	0.6	21.5	32.1	45.13	49.09	54.16	2.5	-23	-24	-7.2	-8.2
4	PSC+5% MS	120	180	0.4	21.7	29.2	37.6	51.47	66.74	1.5	-12	-3.3	-12.4	-13.12
5	PSC+5% RHA	125	205	0.2	24.1	29.7	41.67	45.7	58.94	-9.4	-13	-14.5	0.2	0.1
6	PSC+SP	60	150	0.67	21.8	28.8	35.49	46.94	59.17	0.9	-10	-2.5	1.2	-0.3
7	PSC+5% FA+SP	65	120	1.2	22.4	26.5	33.85	49.00	62.18	-1.9	-1	-7	-9.1	-5.4
8	PSC+5% GGBS+SP	60	125	1.23	23.4	29.9	36.32	45.7	59.47	-6.4	-14	0.2	0.4	-0.8
9	PSC+5% MS+SP	55	120	0.9	23.7	27.4	40.36	50.79	65.01	-7.9	-4.6	-10.9	-14.3	-10.2
10	PSC+5% RHA+SP	50	135	0.9	21.6	26.7	39.74	47.26	59.47	1.9	-1.8	-3.2	1.2	-0.8

Note: PSC –Portland Slag Cement, FA-Fly Ash, GGBS-Ground Granulated Blast Furnace Slag, MS-Microsilica, RHA-Rice Husk Ash, SP- Super Plasticizer



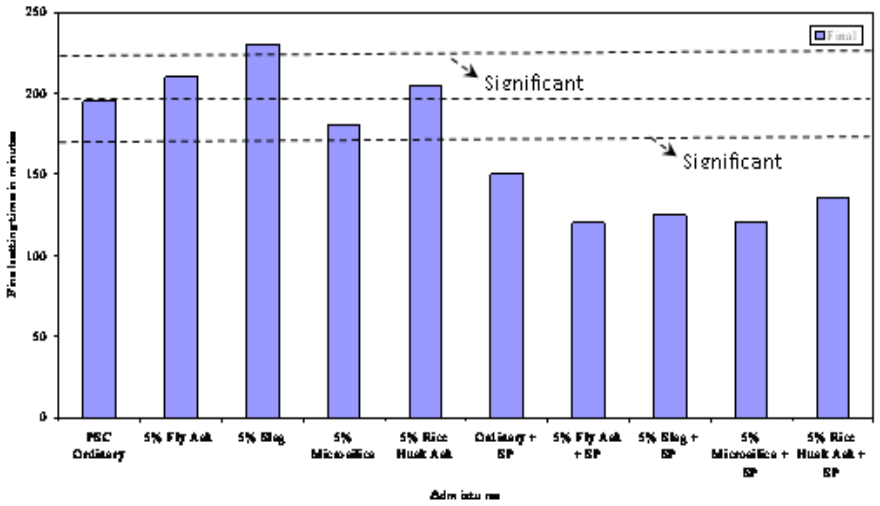


Figure 1: Variation of Initial and Final Setting Times in the Portland Slag Cement with Partial Replacement of Different Admixtures with and without Superplasticizer

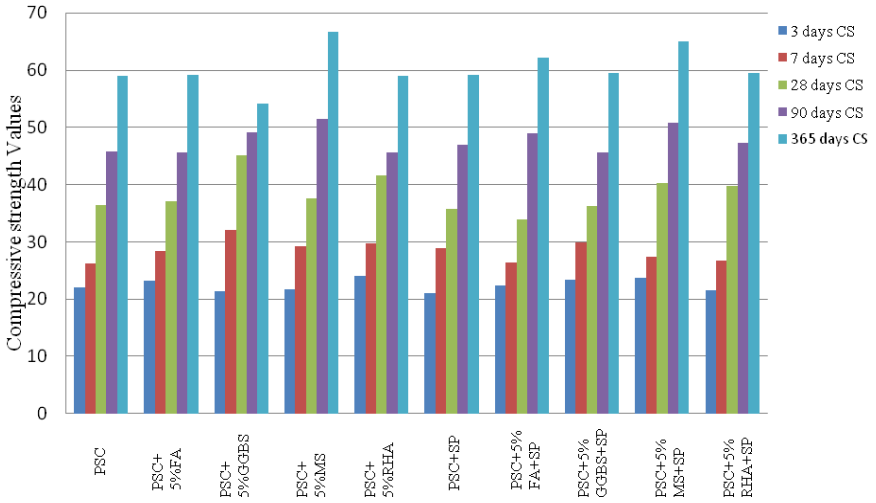


Figure 2: Variation of Compressive Strength of Cement Mortar Cubes at Different Ages made with 5% Replacement of Admixtures with and without Superplasticizer in Portland Slag Cement

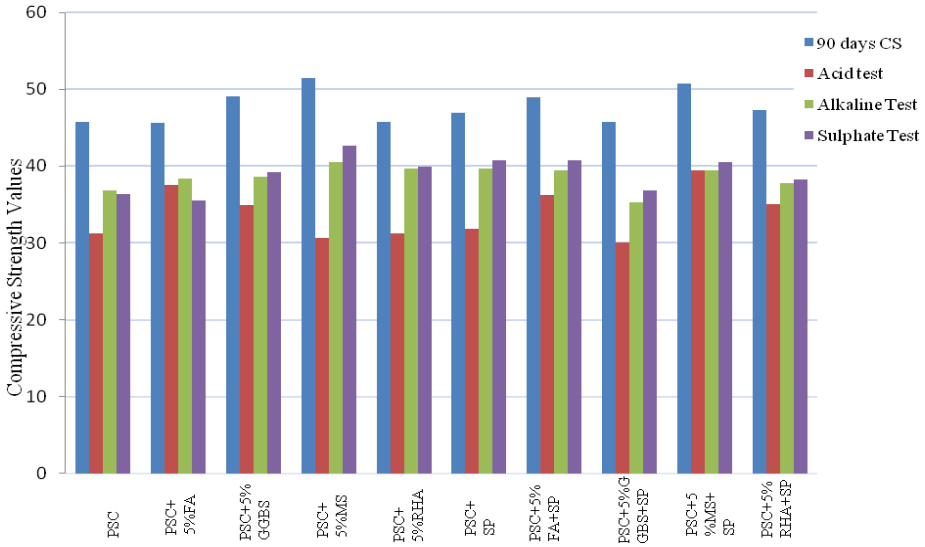


Figure 3: Comparison of Compressive Strength Values at 90 Days and After Acid, Alkaline and Sulphate Test

Table 3: Durability Tests of the Portland Slag Cement made with 5% Replacement of Mineral Admixtures with and without Superplasticizer on the Compressive Strength

S. No.	Cement+ Admixture	Compressive Strength (90days)	Acid Test Mpa	Alkaline Test Mpa	Sulphate Test Mpa	%Loss in Compressive Strength in Acid Test	% Loss in Compressive Strength in Alkaline Test	% Loss in Compressive Strength in Sulphate Test
1	PSC	45.8	31.3	36.8	36.4	31.65	19.65	20.52
2	PSC+5% FA	45.66	37.6	38.4	35.5	17.65	15.9	22.25
3	PSC+5% GGBS	49.09	34.9	38.6	39.2	28.9	21.36	20.14
4	PSC+5% MS	51.47	30.7	40.5	42.7	40.35	21.31	17.03
5	PSC+5% RHA	45.7	31.3	39.7	39.9	31.5	13.13	12.7
6	PSC+SP	46.94	31.8	39.7	40.8	32.25	15.42	13.08
7	PSC+5% A+SP	49	36.2	39.4	40.7	26.12	19.6	16.94
8	PSC+5% GGBS+SP	45.7	30.1	35.3	36.8	34.13	22.75	19.48
9	PSC+5% MS+SP	50.79	39.5	39.4	40.5	22.22	22.42	20.25
10	PSC+5% RHA+SP	47.26	35	37.8	38.2	25.94	20.02	19.18

Table 4: Permeability of Chloride in Portland Slag Cement for every 30 Minutes Interval up to 6hours by using "RCPT Apparatus"

S.No	Cement + Admixture	I_0	I_{30}	I_{60}	I_{90}	I_{120}	I_{150}	I_{180}	I_{210}	I_{240}	I_{270}	I_{300}	I_{330}	I_{360}	ICumulative in mA	Iaverage in Ccoulombs	Penetrability of Chloride
1	PSC	9	9	9	9	10	10	11	11	11	14	14	17	17	2.76	2484	Moderate
2	PSC + 5% FA	10	10	10	11	11	11	12	13	13	13	16	19	19	3.07	2763	Moderate
3	PSC + 5% MS	9	9	11	12	12	13	14	14	14	16	17	17	19	2.98	2682	Moderate
4	PSC + 5% GGBS	5	5	5	8	8	8	9	11	12	12	14	15	17	2.36	2124	Moderate
5	PSC + 5% RHA	8	8	10	12	11	16	18	20	19	21	24	21	24	3.92	3528	Moderate
6	PSC + SP	0	1	1	3	4	4	5	8	9	9	10	10	11	1.39	1251	Low
7	PSC + 5% FA + SP	0	1	3	3	4	4	6	8	8	9	9	10	11	1.41	1269	Low
8	PSC + 5% GGBS + SP	2	2	3	3	4	5	5	6	6	10	11	12	14	1.5	1350	Low
9	PSC + 5% MS + SP	0	1	1	2	2	4	4	6	6	9	10	12	12	1.26	**1134**	**Low**
10	PSC + 5% RHA + SP	8	6	7	7	6	7	6	7	7	7	9	12	12	1.82	1638	Low

Percentage Loss in Weight for Portland Slag Cement

- When the Portland Slag Cement is used to make mortar cubes the percentage weight loss is marginal. The percentage weight loss is 1.43, 0.56 and 0.56 in acid, alkaline and sulphate test performed respectively.
- When the Portland Slag Cement is replaced by 5% fly ash in cement the percentage weight loss is marginal. The weight loss is in the following order sulphate test is greater that of alkaline and acid test.
- When the Portland Slag Cement is replaced by 5% slag in cement the percentage weight loss is 2.06, 1.4 and 1.25 for alkaline, sulphate and acid test respectively.
- When the Portland Slag Cement is replaced by 5% microsilica in cement the percentage weight loss for acid test, alkaline and sulphate test is marginal.
- When the Portland Slag Cement is replaced by 5% rice husk ash in cement the percentage weight loss is in the following order sulphate test is greater than acid and alkaline test.
- When the Portland Slag Cement is replaced by superplasticizer in cement the percentage weight loss is very less.
- When the Portland Slag Cement is replaced by 5% fly ash in cement when addition of superplasticizer the percentage weight loss is 1.3, 1.1 and 1.0 for alkaline, acid and sulphate test.
- When the Portland Slag Cement is replaced by 5% slag in cement with the addition of superplasticizer the percentage weight loss is 1.09, 1.05 and 0.78 in acid, alkaline and sulphate test performed respectively.
- When the Portland Slag Cement is used to make cement mortar by replacing 5% microsilica with the addition of superplasticizer, the percentage weight loss is marginal. The percentage weight loss is 0.7, 0.65 and 0.03 in acid, alkaline and sulphate test performed respectively.
- When the Portland Slag Cement is replaced by 5% rice husk ash with the addition of superplasticizer in cement mortar the percentage weight loss in acid, alkaline and sulphate test is negligible.

From Table 2 and Figure 2 it is clear that the compressive strength is increased from 3 days to 365 days in all the mortar cubes which are prepared by the partial replacement of cement by different mineral and chemical admixtures. But when compared to the other admixtures compressive strength is increased much in the case of mortar cubes prepared with partial replacement of cement by microsilica both with and without superplasticizer.

When the Portland Slag Cement is replaced by 5% microsilica in cement the percentage weight loss for acid, alkaline and sulphate test is marginal. When the Portland Slag Cement is used to make cement mortar by replacing 5% microsilica with the addition of superplasticizer, the percentage weight loss is marginal. The percentage weight loss is 0.7, 0.65 and 0.03 in acid, alkaline and sulphate test performed respectively and these are very less when compared to the other combinations.

According to the results obtained from the Table 4 it is clear that the mortar cubes prepared by the combination of portland slag cement with 5% replacement by microsilica with the addition of the superplasticizer shows much resistance to the permeability of chlorine followed by portland slag cement with superplasticizer alone.

CONCLUSIONS

All the mineral and chemical admixtures which are otherwise hazardous to the environment when they are let-out of the various industries can be used for partial replacement of Portland slag cement through which economy and sustainability can be achieved.

Out of all the admixtures used the combination of Portland slag cement with partial replacement by microsilica with superplasticizer is the best one as it is showing resistance to acid attack, alkaline attack and sulphate attack and showing increase in the compressive strength as the age prolongs up to one year duration also.

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