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Influence of Microsilica on the Properties of Ordinary Portland cement and Portland Slag Cement with and without Super plasticizers

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Abstract— 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. 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 Microsilica admixture with 5% , 10% and 15%of total powder content by weight both with and without the presence of Superplasticizer. Strength of cubes with Ordinary Portland Cement (OPC) and Portland Slag Cement (PSC), after 3,7,28 ,90 days and 365 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 one of such waste materials microsilica which is a waste material obtained from alloy industries can be used for 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.Test results indicate that the use of microsilica has improved the performance of cement in strength as well as in durability aspect.

Key Words — Compressive Strength, Durability, Ordinary Portland cement (OPC), Portland Slag cement (PSC), Microsilica (MS) .

I. INTRODUCTION

Concrete is a widely used construction material for various types of structures die to its structural stability and strength. The usage, behavior as well as the durability of concrete structures, built during the last first half of the century with Ordinary Portland Cement (OPC) and plain round bars of mild steel, the ease of procuring the constituent materials (whatever may be their qualities) of concrete and the knowledge that almost any combination of the constituents leads to a mass of concrete have bred contempt. Strength was stressed without a thought on the durability of structures. As a consequence of the liberties taken, the durability of concrete and concrete structures is on a south ward journey; a journey that seems to have gained momentum on its path to self-destruction [1]. It is known that permeability controls deterioration of concrete in aggressive environments, because the processes of such deterioration as carbonation, chloride attack and sulfates attack are governed by the fluid transportation in concrete. Fillers and pozzolanic materials are introduced to improve the strength and other properties of concrete for necessary conditions [2].

The Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative in the civil construction industry. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor of green house effect and the global warming, hence it is inevitable either to search for another material or partly replace it by some other material [3]. The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact. Substantial energy and cost savings can result when industrial by products are used as a partial replacement of cement. Fly ash, Ground Granulated Blast furnace Slag, Rice Husk ash, High Reactive Met kaolin, Silica fume are some of the pozzolanic materials which can be used in concrete as partial replacement of cement [4]. When pozzolanic materials are incorporated to concrete, the silica present in these materials are act with the calcium hydroxide released during the hydration of cement and forms additional calcium silicate hydrate (C-S-H), which improve durability and the mechanical properties of concrete [5].

Silica fume or micro silica is a byproduct of the smelting process in the silicon and ferrosilicon industry. Micro silica has been recognized as a pozzolanic admixture that is effective in enhancing the mechanical properties to a great extent. By using silica fume along with superplasitcizers, it is relatively easier to obtain compressive strengths of order of 100-150MPa in laboratory. Addition of Micro silica to concrete improves the durability of concrete through reduction in the permeability, refined pore structure, leading to a reduction in the diffusion of harmful ions, reduces calcium hydroxide content which results in a higher resistance to sulfate attack. Improvement in durability will also improve the ability of silica fume concrete in protecting the embedded steel from corrosion

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[6]. Tiwari et al presented a research study carried out to improve the early age compressive strength of Portland slag cement (PSC) with the help of silica fume [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]. 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 [9]. According to several researchers, ternary blends are vastly superior to portland cement concrete in terms of durability of structures [10]. The development of ternary blended cement has been the subject of investigation for the past three decades [11]. Some of the developed countries are currently producing the ternary blended cement including a combination of flyash, slag and silica fume [12].

II. MATERIALS AND METHODS

The Ordinary Portland Cement (OPC) (43 Grade as per IS:8112-1989) [13] was used in the investigation. Portland Slag Cement (PSC) 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 sand used throughout the experimental work was obtained from the river Swarnamukhi near Tirupati, Chittoor district, Andhra Pradesh. The different admixtures used are Microsilica and super plasticizer conforming to IS 9103:1999 [14]. 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. 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 [15]
2.	Soundness of cement	Le-chatelier apparatus confirming to
3.	Compressive strength	100 Tonne universal testing
4.	Chloride Permeability	Rapid Chloride Permeability Test

III. RESULTS AND DISCUSSION

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%, 10% and 15% of microsilica, and also with chemical admixtures of superplasticizer are compared with both the types of 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 for Ordinary Portland cement and Portland Slag Cement are presented in Table 2.Variations of the compressive strengths are presented in Figure 1and Figure 2. Durability tests (Acid Test, Alkaline Test and Sulphate Test) regarding compressive strength of different types of cement mortar cubes with replacement are presented in the Table 3 and Figure 3and Figure 4. Results of Rapid Chloride Permeability Test are presented in Table 4 respectively. Finally the comparison of ordinary Portland cement and Portland slag cement for 10% replacement with microsilica in the presence of superplasticizer are presented in Figure5.

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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 partial replacement of Microsilica(MS) with and without superplasticizer (SP) in OPC and PSC

S.N.	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	OPC	123	218	0.77	23.60	33.90	44.50	48.20	58.02	0	0	0	0	0
2	OPC +5% MS	138	238	1.00	24.49	39.49	52.59	51.86	61.15	-3.80	-16.50	-18.20	-7.60	-5.40
3	OPC +10% MS	113	225	1.05	26.57	38.75	50.12	53.46	64.76	-12.61	-14.31	-12.64	-10.93	-11.63
4	OPC +15% MS	120	210	1.00	24.02	23.82	45.08	49.92	61.18	-1.80	-0.95	-1.32	-3.58	-5.46
5	OPC +SP	120	240	0.58	24.90	35.43	47.60	50.24	61.40	0	0	0	0	0
6	OPC +5% MS +SP	135	235	1.00	26.80	39.72	49.40	53.46	63.32	-7.60	-12.10	-3.80	-6.40	-3.12
7	OPC +10% MS +SP	135	242	0.16	28.24	39.30	53.42	56.60	69.36	-13.41	-10.92	-12.23	-12.67	-12.98
8	OPC +15% MS +SP	140	240	0.57	26.04	37.45	50.44	52.96	66.22	-4.54	-5.56	-5.96	-5.42	-7.85
9	PSC	133	237	0.90	22.50	26.20	36.40	45.80	59.00	0	0	0	0	0
10	PSC +5% MS	120	210	0.40	21.67	29.21	37.60	49.19	63.80	1.50	-11.50	-3.30	-7.40	-8.12
11	PSC +10% MS	127	225	0.80	23.17	28.73	39.37	49.54	64.38	-5.35	-9.66	-8.17	-7.09	-9.12
12	PSC +15% MS	135	210	0.60	22.24	26.38	37.98	48.34	63.38	-1.11	-0.69	-4.32	-5.55	-7.42
13	PSC +SP	145	235	0.67	22.99	28.84	38.85	48.95	60.18	0	0	0	0	0
14	PSC +5% MS +SP	142	215	0.90	24.80	30.16	41.54	53.02	64.51	-7.90	-4.60	-6.90	-8.30	-7.20
15	PSC +10% MS+ SP	130	225	0.50	24.53	31.15	42.30	54.21	65.06	-6.71	+8.04	-8.87	-10.76	-8.12
16	PSC +15% MS +SP	138	220	0.90	23.84	30.62	41.95	52.94	64.45	-3.66	-6.14	-7.96	-8.16	-7.10

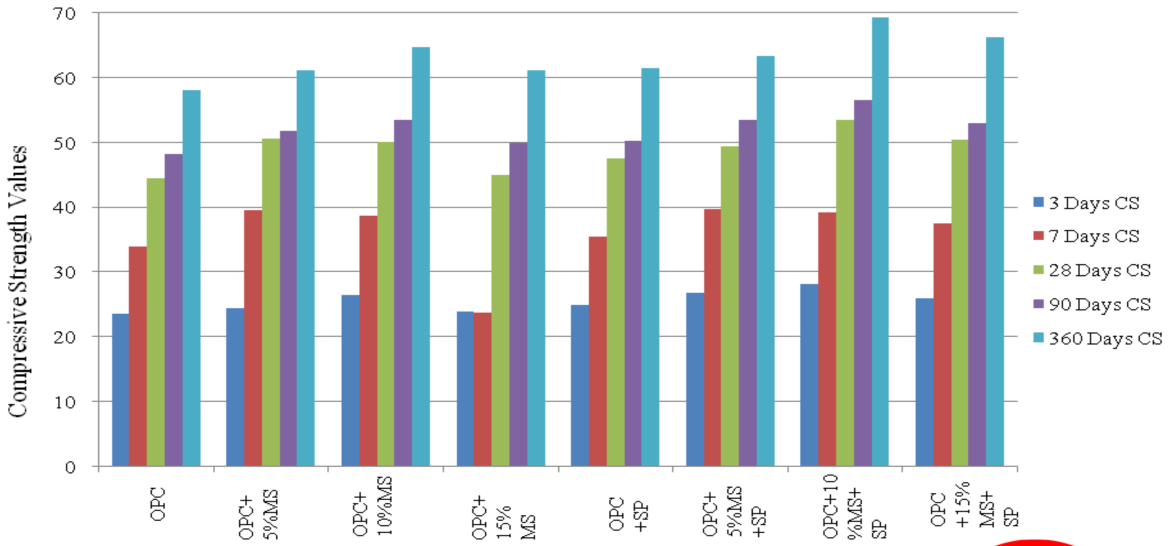

Figure 1 Variation of Compressive Strength of Cement Mortar Cubes at Different Ages made with Partial Replacement of Microsilica with and without Superplasticizer in Ordinary Portland Cement

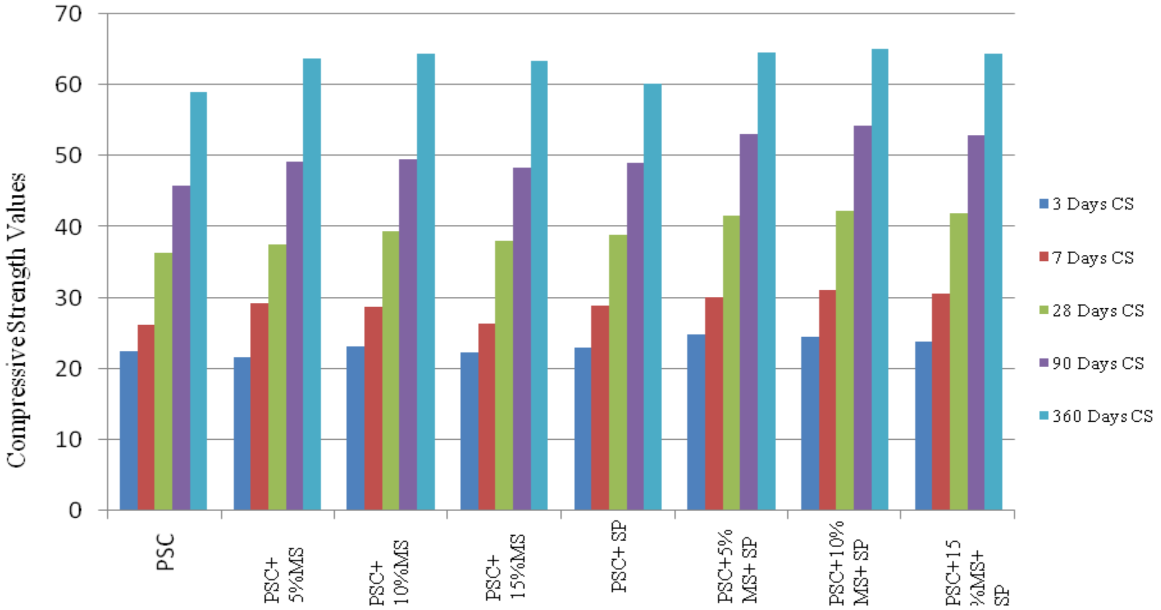

Figure 2 Variation of Compressive Strength of Cement Mortar Cubes at Different Ages made with Partial Replacement of Microsilica with and without Superplasticizer in Portland Slag Cement

Table 3 Durability Tests results of the Mortar Cubes of OPC and PSC made with Partial Replacement of Microsilica with and without Superplasticizer

S.N.	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	OPC	48.20	41.80	41.20	42.90	13.28	14.52	10.99
2	OPC +5% Microsilica	51.86	46.40	45.80	45.70	10.52	11.68	11.88
3	OPC +10% Microsilica	53.46	47.30	46.80	47.05	11.52	12.45	12.00
4	OPC +15% Microsilica	49.92	44.74	43.50	44.47	10.38	12.86	10.92
5	OPC +SP	50.24	44.60	44.10	43.50	11.23	12.22	13.42
6	OPC +5% Microsilica+SP	53.46	47.70	47.20	47.60	10.78	11.70	10.96
7	OPC +10% Microsilica+SP	56.60	49.95	49.50	49.60	11.74	12.54	12.36
8	OPC +15% Microsilica+SP	52.96	47.20	46.88	47.35	1088	11.48	10.59
9	PSC	45.80	39.30	38.80	39.10	14.19	14.28	14.62
10	PSC +5% Microsilica	49.19	43.70	42.50	42.90	11.16	13.60	12.78
11	PSC +10% Microsilica	49.54	43.40	42.90	43.25	12.40	13.40	12.70
12	PSC +15% Microsilica	48.34	42.70	41.92	42.15	11.66	13.28	12.80
13	PSC +SP	48.95	42.80	41.70	42.15	12.56	14.82	13.90
14	PSC +5% Microsilica+SP	53.02	47.05	45.90	46.50	11.25	13.42	12.30
15	PSC +10% Microsilica+SP	54.21	48.10	47.45	47.85	11.27	12.47	11.74
16	PSC +15% Microsilica+SP	52.94	46.95	46.13	46.78	11.32	12.86	11.64

MS:Microsilica , SP: Superplasticizer

Table 4 Permeability of Chloride in OPC and PSC 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}	$I_{Cumulative}$ in mA	$I_{Average}$ in coulombs	Penetrability of Chloride
1	OPC	8	8	8	8	9	9	9	10	10	11	11	12	12	2.30	2070	MODERATE
2	OPC +5% MS	8	10	9	10	12	11	12	13	17	20	19	17	18	3.26	2934	MODERATE
3	OPC +10% MS	0	0	1	2	2	4	6	6	8	10	11	14	16	1.44	1296	LOW
4	OPC +15% MS	0	1	1	1	1	1	2	2	8	8	8	10	10	0.96	864	VERY LOW
5	OPC +SP	8	8	9	9	9	9	10	11	12	12	17	17	19	2.73	2457	MODERATE
6	OPC +5% MS+SP	0	0	0	1	1	5	5	6	6	10	11	11	11	1.23	1107	LOW
7	OPC +10% MS+SP	0	0	0	1	1	2	2	2	4	4	4	6	6	0.58	522	VERY LOW
8	OPC +15% MS+SP	0	0	0	1	1	1	1	1	1	1	2	2	2	0.24	216	VERY LOW
9	PSC	9	9	9	9	10	10	11	11	11	14	14	17	17	2.76	2484	MODERATE
10	PSC +5% MS	9	9	11	12	12	13	14	14	14	16	17	17	19	2.98	2682	MODERATE
11	PSC +10% MS	0	0	1	2	2	4	6	6	8	10	11	14	16	1.44	1296	LOW
12	PSC +15% MS	0	0	0	2	6	6	6	7	7	8	10	10	11	1.35	1215	LOW
13	PSC +SP	0	1	1	3	4	4	5	8	9	9	10	10	11	1.39	1251	LOW
14	PSC +5% MS+SP	0	1	1	2	2	4	4	6	6	9	10	12	12	1.26	1134	LOW
15	PSC +10% MS+SP	0	0	0	0	1	1	2	2	2	2	5	5	5	0.45	405	VERY LOW
16	PSC +15% MS+SP	0	0	0	0	1	1	1	1	1	1	2	6	8	0.36	324	VERY LOW

MS:Microsilica , SP: Superplasticizer

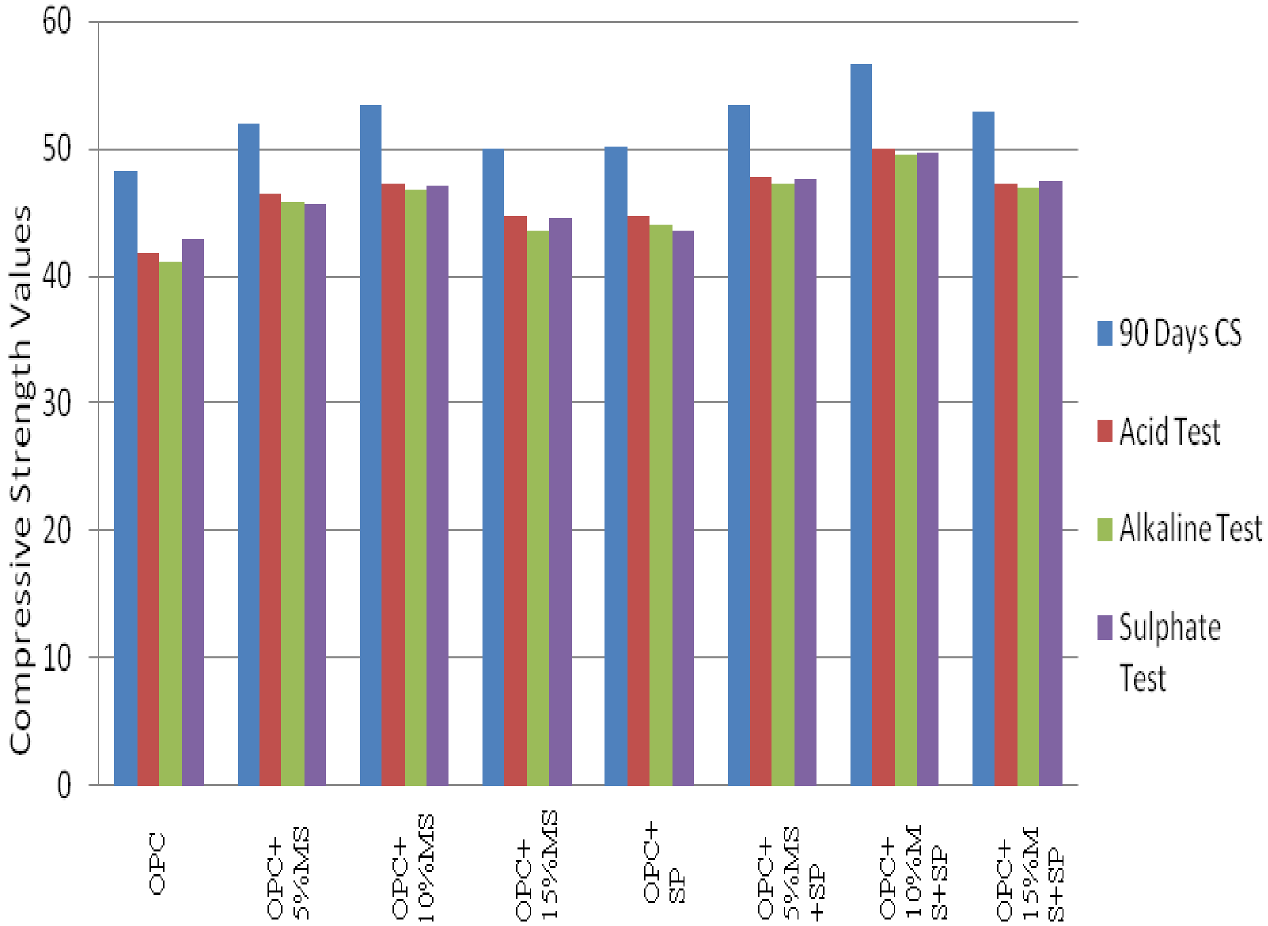

Figure 3 Comparison of Compressive strength Values for Ordinary Portland Cement at 90 Days and After Acid, Alkaline and Sulphate Test

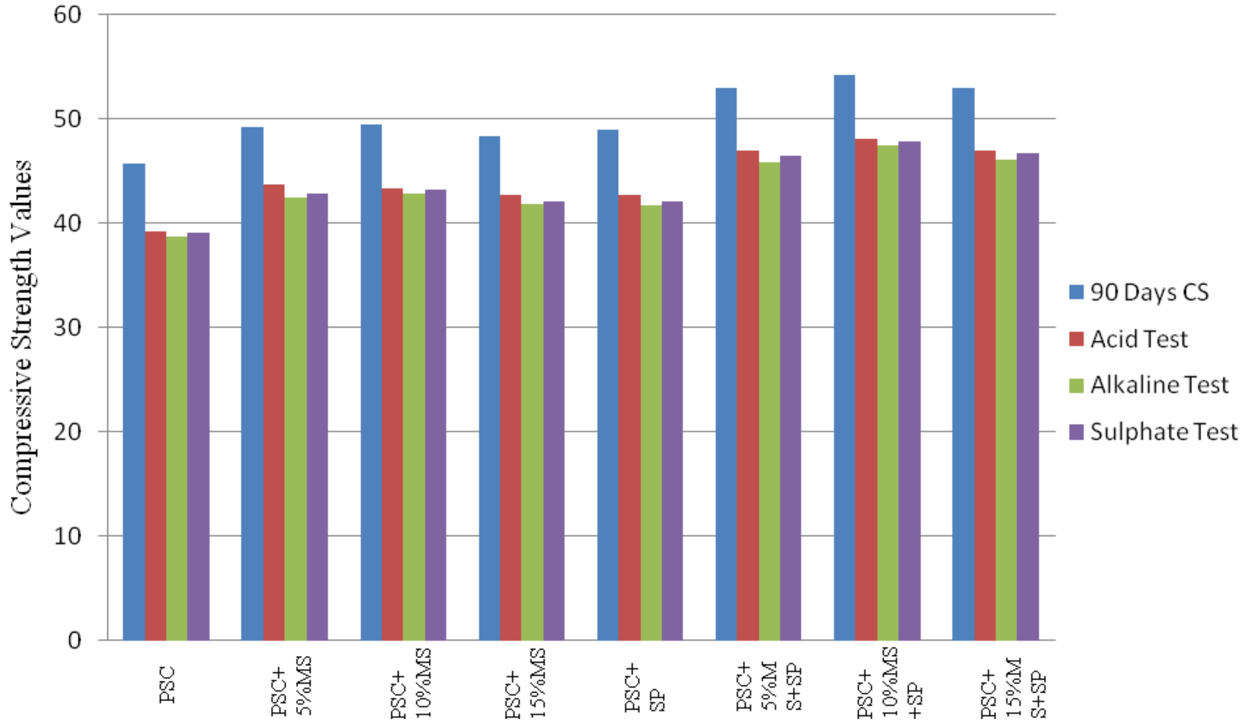

Figure 4 Comparison of Compressive strength Values for Portland Slag Cement at 90 Days and After Acid, Alkaline and Sulphate Test

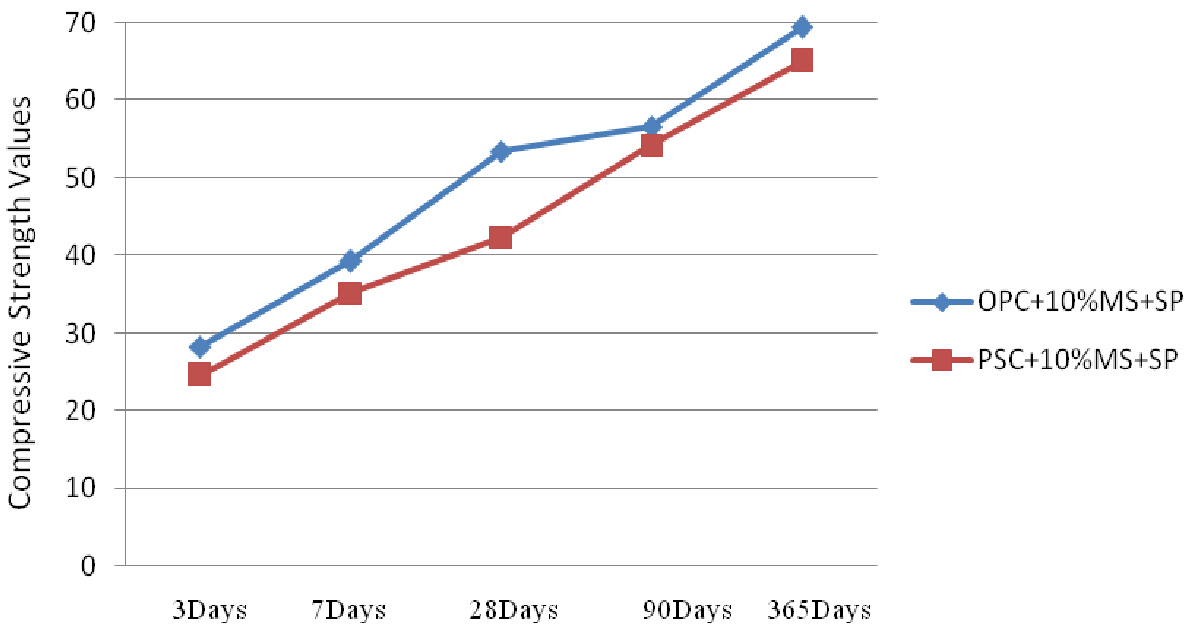

Figure 5 Comparison of Ordinary Portland Cement and Portland Slag Cement for 10% Replacement with Microsilica with Superplasticizer

From Table 2 and Figure1 and Figure 2 it is clear that the compressive strength values for mortar cubes prepared by both the types of cements with partial replacement of cement by microsilica shows an increasing trend in 3 days, 7 days, 28 days, 90 days and 365 days upto 10% and then decline in the strength values to 15% with and without superplasticizer.

It is clearly observed From Table 3 and Figure 3 and Figure 4 that mortar cubes prepared with 10% replacement of cement by microsilica both with and without superplasticizer show much resistance to acid attack, alkaline attack and sulphate attack and also show very less permeability of chlorine also in the case of ordinary portland cement as well as portland slag cement which is shown in Table 4.

IV. CONCLUSION

Out of all the various combinations of both ordinary Portland cement and Portland slag cement with partial replacement by microsilica with superplasticizer and without superplasticizer the best one is OPC+10% Microsilica+Superplasticizer 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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