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Effect of Slightly Acidic Substances in Water on Properties of Natural Admixture Cements

D. Sreehari Rao, I.V.Ramana Reddy,N.Krishna Murthy

Assistant Professor, Department of Civil Engineering, College of Engineering, S. V. University, Tirupati, Andhra Pradesh-517 502, INDIA. Email: rao1777@gmail.com,
Professor, Department of Civil Engineering, College of Engineering, S. V. University, Tirupati, Andhra Pradesh-517 502, INDIA.
Assistant Engineer, Civil Engineering Department, Yogi Vemana University, Cuddapah, Andhra Pradesh

Abstract*— The most aggressive environmental agents that affect the durability of concrete structures are chlorides and sulphates. Admixtures and the water have an important role on application of concrete. The study is aimed at investigating the effect of slightly acidic substances as mixing water on setting times, soundness and compressive strength of admixture cements. This paper therefore presents the result and findings of an experimental research on the influence of slightly acidic substances ($CaCl_2$, $MgCl_2$ and $MgSO_4$) on setting and strength development of admixture cements. In the research PPC plus 10% silica fume was added by weight and cubes were casted with deionised water and deionised water containing slightly acidic substances ($CaCl_2$, $MgCl_2$ and $MgSO_4$). The results shows $MgCl_2$ in deionised water accelerate the initial as well as final setting processes whereas $CaCl_2$ and $MgSO_4$ retard the initial and final setting at all concentrations. $CaCl_2$ and $MgSO_4$ in deionised water increase the compressive strength of mortar cubes significantly in the early days i.e., at 3-day age. In the case of $MgSO_4$ an increase in the compressive strength falls as age prolongs significant decrease in strength has occurred at longer periods like 180-day, 1-year and 2-year with $MgSO_4$. In the present work analysis the hydration characteristics of the admixture cements using the techniques of X-ray diffraction analysis and useful conclusions are obtained regarding the influence of slightly acidic substances.

***Index Terms*— PPC, Silica Fume, Strength Development, X-Ray Diffraction.**

I. INTRODUCTION

The presence of chlorides and sulphates in water changes the properties of concrete in setting times as well as strength. Water is an essential ingredient of concrete as it effectively participates in the chemical reactions with natural admixture cements like natural pozzolana and other supplementary cementitious materials (Silica fume). Pozzolans are commonly used as an addition to Portland cement to increase the long-term strength and other material properties. Concrete is not only material that is risk to physical and chemical process of deterioration associated with water. Therefore, it will be desirable to review, in general, the characteristics of water that make it the principal agent of destruction of material. The I.S.Code 456-2000 also specifies the minimum pH-value as 6.0 and also permissible limits for solids in the water to fit for construction purposes. The code has not specified the limits to the individual components like acidic substances. The use of natural and economical materials seems to be one of the possible solutions for the future. The development of an economical cement concrete with interesting properties in the fresh and hardened state will certainly help and encourage the use of this material in the construction industry. Hence, in the present investigation to find the effects and quality of water on setting and strength properties of admixture cement. The effect of strong acidic substances on setting, hardening and strength development of admixture cement are not known much. Hence, an investigation is carried out on setting time, soundness and strength of admixture cements.

II. MATERIALS AND METHODS

Materials: The details of various materials used in the experimental investigation are presented below.
Cement: The cement used in the present investigation is of 43 grade Pozzolana Portland cement manufactured by ACC Ltd.
Fine aggregate: The fine aggregate used in this investigation is the river sand obtained from Swarnamukhi River near Tirupati, Chittoor district in Andhra Pradesh.
Silica fume: Silica fume used in the present study was obtained from Elkem India Pvt.Ltd., Mumbai.
Water: Deionised water spiked with slightly acidic substances ($CaCl_2$, $MgCl_2$ and $MgSO_4$) with different concentration is used in mixing water.

III. EXPERIMENTAL SYSTEM

The following equipment is used for casting and testing of specimens: (i)Cube moulds, (ii) 200T U.T.M(Universal Testing Machine) for cube compressive strength determination, (iii)Vicat's apparatus including moulds conforming to IS4031 (part-5)-1988 for setting times, (iv) Le-Chatelier's equipment to determine the soundness of cement and (v) cement cubes prepared with water containing $CaCl_2$ in the concentration of 0.5,1 and 2g/L, $MgCl_2$ in the

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concentration of 0.5,1 and 1.5g/L and $MgSO_4$), in the concentration of 0.5,1 and 1.5g/L, in mixing water.

Setting time: Vicat's apparatus confirming IS4031(part-5) 1988 consist of a frame to which a movable rod having an indicator is attached which gives the penetration, weighing 100g and having diameter and length of 10mm and 50mm respectively. Vicat's apparatus included three attachments-square needle for initial setting time, plunger for determining normal consistency and needle with annular collar for final setting time.

Compressive Strength: The test specimens for determination of compressive strength of admixture cement prepared using standard metallic cube moulds adopting IS procedure for the compactions. The cubes were demoulded after 24hours of casting and cured in water having similar quality as used in preparation of mix. The cubes are tested for compressive strength for short term and long term. The compressive strength is computed as the average value of the three samples.

IV. 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 result obtained. The significance of the result is assessed with reference to the standards specified by the relevant I S codes;

1. The averages of both the initial and final setting times of three cement samples prepared with mixing water containing typical chemical or biological component of varying concentrations under consideration is compared with those of the cement specimens prepared with deionised water. If the difference is less than 30 minutes, the change is considered to be negligible or insignificant and if it is more than 30 minutes, the change is considered to be significant.

2. The average compressive strength of at least three cubes prepared with water under consideration is compared with that of three similar cubes prepared with deionised water. 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.

A. Setting Time

1. Calcium Chloride ($CaCl_2$)

The effect of $CaCl_2$ on the initial and final setting times is shown in Fig. 1. Both initial and final setting times accelerate significantly with an increase in calcium chloride concentration in the deionised water. Significant change in initial setting lime is observed at 2.0 g/L, the initial setting time being 31 minutes less than that of the control mix.

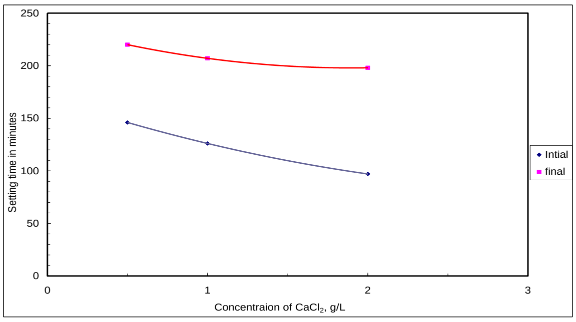

Fig.1 Variation of Setting Times of Admixture Cement (PPC Cement + 10% Silica Fume) Corresponding to Various Concentrations of $Cacl_2$in Deionised Water

But the change in the final setting time becomes significant at relatively low concentrations, i.e, 2 g/L; it is 198 minutes which is 149 minutes less than that of the control mix.

2. Magnesium Chloride ($MgCl_2$)

The effect of $MgCl_2$ on the initial and final setting times is shown in Fig.2. Both initial and final setting times got retarded with an increase in magnesium chloride concentration in deionised water. The retardation for initial and final setting times is significant when the magnesium chloride content exceeds 0.5 g/L. With regard to initial setting time, significant change occurred at relatively higher concentration, i.e., at 1.0 g/L onwards. However, significant change in the final setting time has occurred at relatively lower concentration. At the maximum concentration (1.5 g/L), the initial and final setting times are 52 and 41 minutes more than those of control mix.

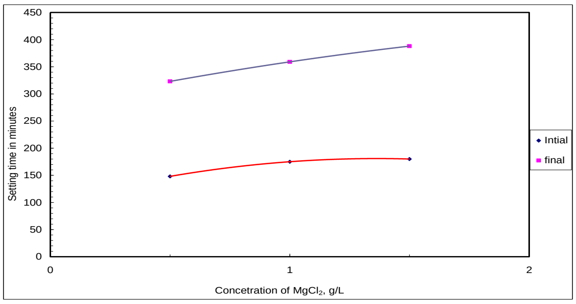

Fig.2. Variation Of Setting Times of Admixture Cement (PPC Cement + 10% Silica Fume) Corresponding to Various Concentrations of $Mgcl_2$ in Deionised Water

3. Magnesium Sulphate ($MgSO_4$)

The effect of magnesium sulphate on the initial and final setting times is presented in Fig 3. Both initial and final setting of cement got accelerated with an increase in the concentration of magnesium sulphate in deionised water. The acceleration in the initial and final setting is significant when the magnesium sulphate content is at 1.5 g/L. The decrease in the initial setting time is, i.e., about 48 minutes at maximum concentration of 1.5 g/L. In the case of final setting time, a drop of nearly 118 minutes is observed when the concentration is 0.5 g/L. And significant decrease in final setting time 133 min is observed when the concentration is 1.5g/L than the control mix.

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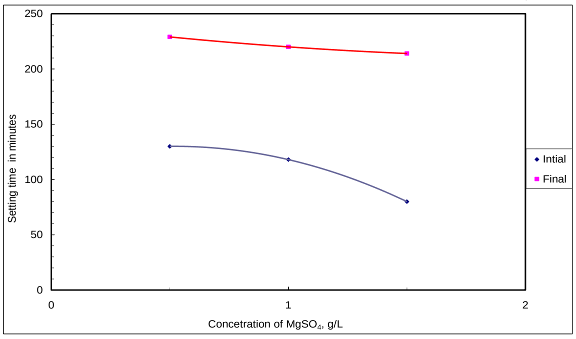

Fig.3. Variation of Setting Times of Admixture Cement Corresponding to Various Concentrations of Mgso$_4$in Deionised Water

B. Compressive Strength

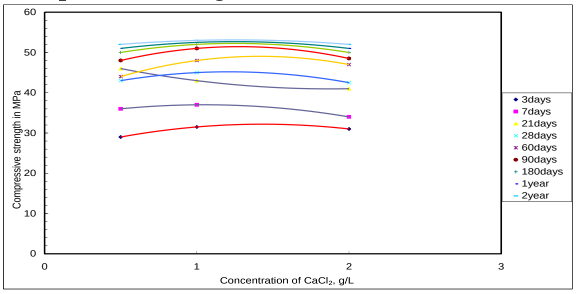

Fig.4. Variation of Compressive Strength of Admixture Cement (PPC Cement + 10% Silica Fume) Mortar Cubes at Different Ages Corresponding To Various Concentrations of Cacl$_2$in Deionised Water

The effect of $CaCl_2$ concentration on the compressive strength of cement mortar is presented in Fig. 4. There is an increase in the compressive strength of the cement mortar cubes prepared with $CaCl_2$ solution is observed at early ages i.e. 3 day samples as the Calcium chloride concentration increases, the decrease in compressive strength observed for longer periods i.e. 180 days, 1 year and 2 year samples up to the maximum concentration studied being 2.0g/L.

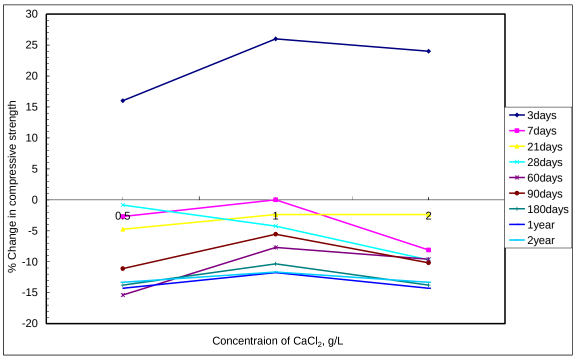

Fig.5. Percentage Variation of Compressive Strength of Admixture Cement (PPC Cement + 10% Silica Fume) Mortar Cubes at Different Ages Corresponding to Various Concentrations of Cacl$_2$in Deionised Water

The percent change in compressive strength of mortar cubes prepared with various concentrations of $CaCl_2$ solution in deionised water is shown in Fig. 5. For 3-day, test cubes, there is an abnormal increase in compressive strength is observed with an increase in concentration of $CaCl_2$ and it is significant when the concentration is at 1.0 g/L. When its concentration is maximum, i.e., 2.0 g/L, the increase in compressive strength is 24% than that of the control mix. However, the decrease in compressive strength for samples of other age is nominal and below significant level and at longer periods (2-year sample), there is a significant decrease in compressive strength (13.33%). Since, there is strength gain only during the shorter periods, it is only an advantage.

The effect of $MgCl_2$ concentration on the compressive strength of cement mortar is presented in Fig. 6. Decrease in compressive strength of the cement mortar cubes prepared with $MgCl_2$ solution is observed as the magnesium chloride concentration increases, the maximum concentration being 1.5 g/L for all age samples.

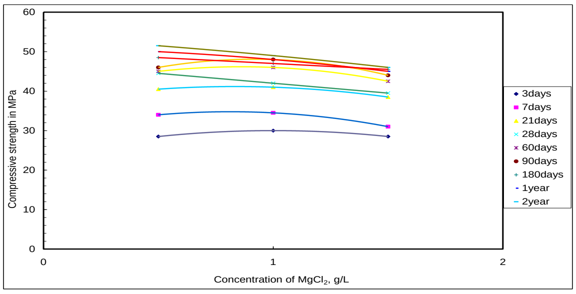

Fig.6. Variation of Compressive Strength of Admixture Cement (PPC Cement + 10% Silica Fume) Mortar Cubes at Different Ages Corresponding To Various Concentrations of Mgcl$_2$in Deionised Water

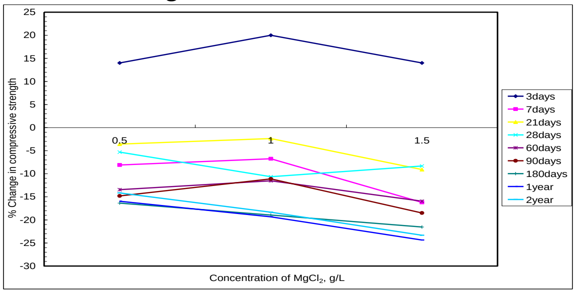

Fig.7. Percentage Variation Of Compressive Strength Of Admixture Cement (PPC Cement + 10% Silica Fume) Mortar Cubes At Different Ages Corresponding To Various Concentrations Of Mgcl$_2$ In Deionised Water

The percent change in the compressive strength of mortar cubes prepared with various concentrations of $MgCl_2$ solution in deionised water is shown in Fig. 7. There is significant decrease in the compressive strength of cement mortar cubes of 7-day, 14-day, 21-day and 28-day and the rate of decrease in compressive strength also gradually increases with the increase in the concentration of the $MgCl_2$. For 3-day sample, significant decrease in strength occurred at 0.5 g/L onwards.

Even though there is decrease in the compressive strength with the increase of concentration of $MgCl_2$ for 60 day, 90-day, 180-day, 1-year and 2-year samples, the change is significant. Thus, in the long run, the influence of $MgCl_2$ in. the water at any concentration (maximum 1.5 g/L) is significant. There is a significant decrease in compressive strength (23.33%), which is evident from the analysis of 2-year sample.

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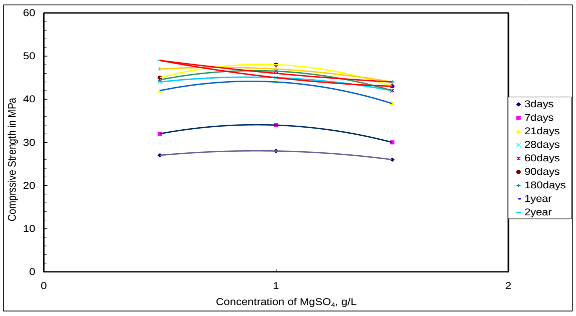


Fig.8. Variation of Compressive Strength of Admixture Cement (PPC Cement + 10% Silica Fume) Mortar Cubes at Different Ages Corresponding To Various Concentrations of Mgso₄in Deionised Water

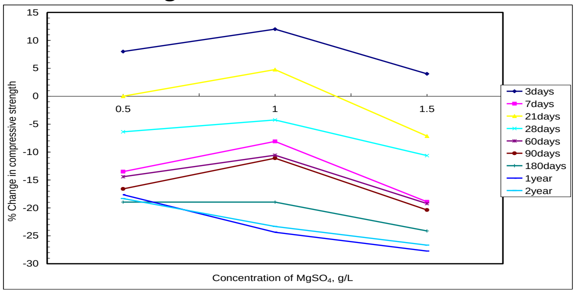
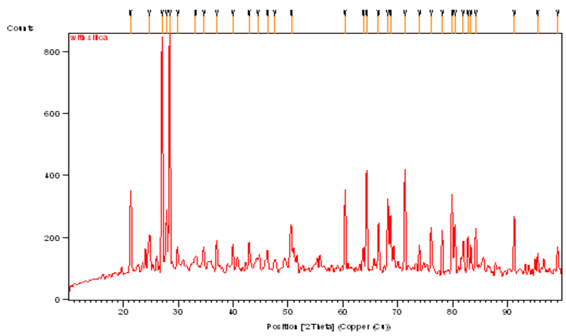


Fig.9. Percentage Variation Of Compressive Strength Of Admixture Cement (PPC Cement + 10% Silica Fume) Mortar Cubes At Different Ages Corresponding To Various Concentrations Of Mgso₄in Deionised Water

The effect of $MgSO_4$ concentration on the compressive strength of cement mortar cubes is presented in Fig 8. The percent change in the compressive strength of mortar cubes prepared with various concentrations of $MgSO_4$ solution in deionised water is shown in Fig. 9. For 3-day sample, increase in compressive strength is observed with an increase in the concentration and it is significant if the concentration is more than 0.5 g/L. When the concentration is 1.0 g/L, the increase in compressive strength is 12% than that of the control mix. A significant but marginal decrease in compressive strength is observed in 7-day sample at the maximum concentration of 1.5 g/L. However, the decrease in compressive strength at other ages, i.e., 14-day, 21-day and 28-day,60-day and 90-day is at significant level. There is decrease in the compressive strength, which is different from other samples in the case of 180-day, 1-year and 2-year samples at all concentrations below significant level and this decrease is 26.67%.

C.X-Ray Diffraction



Peak List

Pos.[°2Th.]	Height[cts]	FWHM [°2Th.]	d-spacing[Å]	Rel.Int.[%]
21.2999	284.22	0.2854	4.1681	34.84
24.6774	108.28	0.4955	3.60474	13.27
27.044	808.37	0.2522	3.29443	99.08
27.8776	207.59	0.2099	3.19779	25.45
28.4259	815.83	0.2414	3.13734	100
29.8629	61.46	0.017	2.98956	7.53
33.171	21.87	1.773	2.69859	2.68
34.6229	69.14	0.3235	2.58867	8.48
36.999	95.41	0.3082	2.42769	11.69
39.9368	86.14	0.2457	2.25562	10.56
42.9052	94.01	0.2153	2.10619	11.52
44.5205	26.66	1.9653	2.03345	3.27
46.209	62.09	0.3433	1.963	7.61
47.5966	1.82	0.0013	1.90896	0.22
50.5851	112.53	0.5774	1.80296	13.79
60.3873	271.37	0.2481	1.53164	33.26
63.6841	71.39	0.2107	1.46006	8.75
64.2899	349.65	0.2524	1.44776	42.86
66.4734	167.42	0.2302	1.4054	20.52
68.16	278.63	0.1668	1.37467	34.15
68.6174	127.28	0.8095	1.36662	15.6
71.3241	356.41	0.2348	1.32126	43.69
73.9238	51.08	0.6812	1.28109	6.26
76.0972	158.41	0.2823	1.24982	19.42
78.0615	135.48	0.2351	1.22321	16.61
79.882	266.63	0.2495	1.19985	32.68
80.4209	154.97	0.2624	1.19316	18.99
81.8855	95.91	0.3066	1.17548	11.76
82.7426	103.41	0.2265	1.16547	12.68

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83.3019	89.55	0.202	1.15906	10.98
84.2383	135.62	0.2587	1.14854	16.62
91.1915	195.95	0.2402	1.07822	24.02
95.4305	30.71	0.952	1.04121	3.76
99.0816	87.25	0.2877	1.0124	10.69

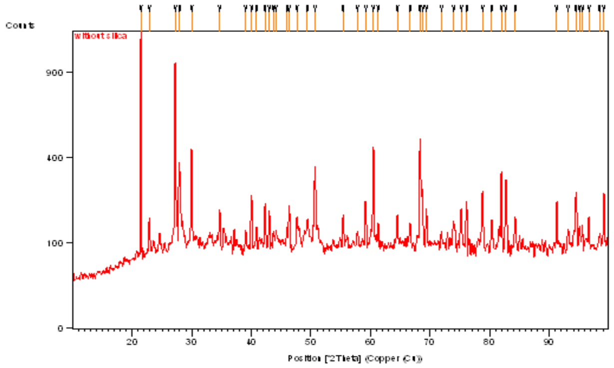

Fig. a. X-Ray Diffraction Pattern of Powdered Admixture Cement (PPC Cement +10% Silica Fume) Mortar Cube Prepared With Deionised Water

Peak List

Pos.[°2Th.]	Height[cts]	FWHM [°2Th.]	d-spacing[Å]	Rel.Int. [%]
21.437	1171.43	0.3008	4.1418	100.00
22.888	86.60	0.1805	3.8824	7.39
27.210	897.90	0.2406	3.2747	76.65
27.914	284.63	0.2406	3.1937	24.30
29.965	345.90	0.3008	2.9796	29.53
34.701	91.95	0.2406	2.583	7.85
39.052	45.30	0.361	2.3047	3.87
40.027	156.15	0.2406	2.2508	13.33
40.831	93.60	0.122	2.2082	7.99
42.307	120.72	0.3008	2.1346	10.31
42.999	92.95	0.1805	2.1018	7.93
43.745	64.71	0.1498	2.0677	5.52
44.137	62.00	0.1389	2.0502	5.29
46.003	89.30	0.1348	1.9713	7.62
46.352	116.21	0.1805	1.9573	9.92
47.667	76.26	0.361	1.9063	6.51
49.402	88.41	0.3519	1.8433	7.55
50.675	254.95	0.2406	1.8	21.76
55.387	84.72	0.2406	1.6575	7.23
57.805	70.69	0.1562	1.5938	6.03
59.194	128.95	0.2406	1.5596	11.01
60.475	358.90	0.2406	1.5296	30.64
61.274	103.90	0.101	1.5116	8.87
64.471	86.67	0.2406	1.4441	7.40
66.641	56.12	0.361	1.4023	4.79
68.282	396.76	0.2406	1.3725	33.87
68.742	241.70	1.6638	1.3645	20.63
69.355	100.93	0.2406	1.3539	8.62
71.922	61.25	0.1721	1.3118	5.23
73.960	57.10	0.4813	1.2806	4.87
75.247	106.14	0.3008	1.2618	9.06
76.135	132.14	0.1805	1.2493	11.28
78.772	171.85	0.2406	1.214	14.67
80.324	75.96	0.3008	1.1944	6.48
81.939	251.31	0.2406	1.1749	21.45
82.719	221.84	0.3008	1.1657	18.94
84.281	85.40	0.2406	1.1481	7.29
91.240	137.60	0.2406	1.0778	11.75
93.175	50.58	0.361	1.0604	4.32
94.473	171.35	0.3008	1.0492	14.63
95.057	91.55	0.1539	1.0443	7.82
95.516	106.10	0.1072	1.0405	9.06
96.651	87.40	0.2406	1.0313	7.46
98.430	77.50	0.1145	1.0173	6.62
99.141	168.76	0.2406	1.012	14.41

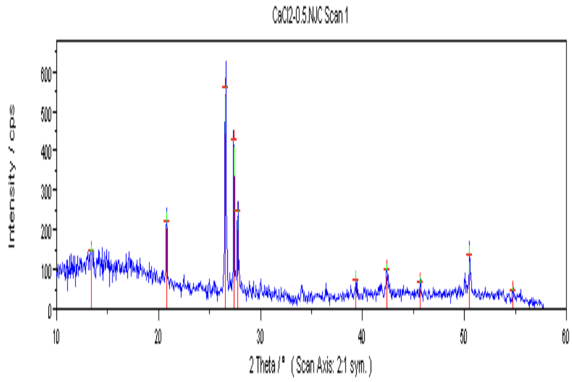

Fig.b X-Ray Diffraction Pattern of Powdered PPC Mortar Cube Prepared With Deionised Water

d_Fit (A1)	Ang-para b	Ang-CO G	Low Limit	Upp. Limit	I-net	I-bgr	FWHM	2-Theta
6.5894	13.4264	13.4170	10.1000	20.6500	146.36	311.70	3.2767	13.4264
4.2677	20.7972	20.8059	20.5500	20.9500	221.30	82.72	0.1723	20.7972

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3.3534	26.5592	26.5710	20.9500	27.2000	558.83	51.22	0.1794	26.5592
3.2530	27.3947	27.3710	27.1000	27.6000	427.30	51.73	0.1527	27.3947
3.2117	27.7547	27.7660	27.5500	29.9500	250.23	51.78	0.1782	27.7547
2.2868	39.3689	39.3545	36.5500	42.2000	71.82	18.26	0.3047	39.3689
2.1298	42.4055	42.3942	41.9500	45.6000	100.01	11.69	0.4913	42.4055
1.9838	45.6968	45.6749	42.6500	49.9500	69.97	8.27	0.2301	45.6968
1.8056	50.5072	50.5054	45.8000	51.5500	136.52	8.44	0.2715	50.5072
1.6741	54.7912	54.7554	54.4000	57.7000	46.15	11.94	0.4373	54.7912

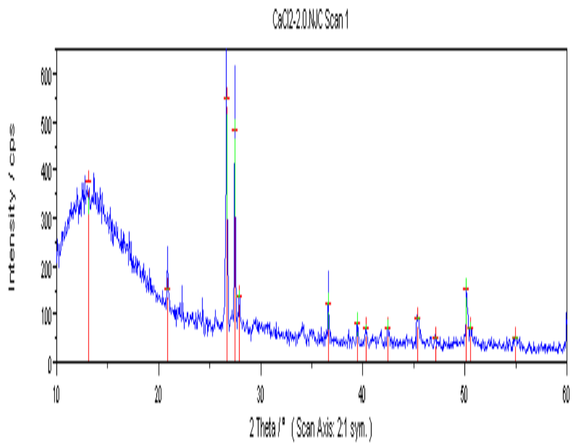

Fig.10. Powder X- Ray Diffraction Pattern for the Admixture Cement (PPC Cement + 10% Silica Fume) Mortar Cubes Prepared With Cacl$_2$ (0.5 G/L and 2.0 G/L) in Deionised Water

The comparison of this powder X- ray diffraction pattern with that of the control mix indicates that the formation of tricalcium silicate (3CaO. SiO2). This is characterized by the presence of d-spacing's 6.461 Å, 3.342 Å and 2.281 Å, these peaks not being present in the pattern for the control mix. The possible chemical reaction upon the hydration of cement with mixing water containing CaCl2 is as follows:

2CaO. SiO2 + CaCl2 + H2O→3CaO. SiO2 + 2HCl

Acceleration of the setting process of cement may be due to the formation of tricalcium silicate from dicalcium silicate in cement mortar. Significant increase in the strength of early day samples may be due to the intrusion of calcium ions into the silicates to generate the tricalcium silicates. In addition to this, considerable increase in compressive strength during the early days and no significant increase in strength later on may be attributed to the chloride ion charge. During early days, the soluble salts of CaCl2 got involved in the hydration process. Thus HCl is formed as a byproduct in this reaction. This acid neutralizes alkalinity of the hydrated cement paste to certain extent and creates a neutral medium. This process leads to the increase in strength at early ages. As the reaction proceeds, the enhanced formation of HCl is responsible for the reduction in strength gain at longer duration.

MgCl2-0.5 Gm

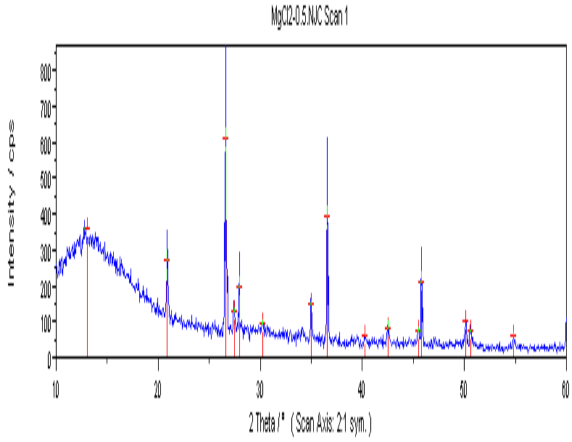

Fig.11. Powder X- Ray Diffraction Pattern for the Cement Mortar Cubes Prepared With Mgcl2 (0.5 G/L) In Deionised Water

d_Fit (A1)	Ang-parab	Ang-COG	Low Limit	Upp. Limit	I-net	I-bgr	FWHM	2-Theta
6.9266	12.7700	13.0527	10.1000	20.7500	358.72	0.00	8.0108	12.7700
4.2394	20.9375	20.8990	20.3500	26.3000	272.29	0.00	0.3127	20.9375
3.3481	26.6020	26.6074	26.3000	26.9500	612.22	0.00	0.1497	26.6020
3.2467	27.4493	27.4489	26.9000	27.8000	132.26	0.00	0.8468	27.4493
3.1902	27.9454	27.9562	27.5500	32.8500	199.11	0.00	0.2196	27.9454
2.9536	30.2353	30.2509	28.8000	34.8000	96.06	0.00	3.7395	30.2353
2.5624	34.9893	34.9773	34.2500	36.4000	149.36	0.00	0.2598	34.9893
2.4538	36.5906	36.5857	36.4000	36.8000	397.49	0.00	0.1702	36.5906
2.2363	40.2970	40.2765	39.6000	42.3500	59.41	0.00	0.7220	40.2970
2.1252	42.5031	42.5090	40.4000	45.4000	83.16	0.00	0.4265	42.5031
1.9921	45.4959	45.4782	42.7000	45.6500	76.93	0.00	0.5884	45.4959
1.9784	45.8293	45.8051	45.5500	46.0500	210.79	0.00	0.2056	45.8293
1.8181	50.1345	50.1516	47.8500	50.4500	101.36	0.00	0.2414	50.1345
1.8021	50.6110	50.6115	50.3000	51.8500	75.72	0.00	0.4345	50.6110
1.6726	54.8445	54.8391	53.8500	56.2000	59.80	0.00	0.3520	54.8445

Powder X- Ray Diffraction pattern for the cement mortar cubes prepared with $MgCl_2$ (0.5 g/L) in deionised water is shown in fig.11. A comparison of this pattern with that of the control mix indicates the formation of brucite (Mg $(OH)_2$) and $CaCl_2$ components. These are characterized by the presence of the sets of d-spacing's (2.453Å, 1.802Å) for Mg $(OH)_2$ and (4.239Å, 3.246Å and 1.818Å) for $CaCl_2$

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Volume 2, Issue 2, August 2012

respectively in this pattern, these peaks not being present in the pattern for the control mix. The possible chemical reaction upon the hydration of cement with mixing water containing $MgCl_2$ is

$$MgCl_2 + Ca(OH)_2 \rightarrow CaCl_2 + Mg(OH)_2$$

$MgCl_2$ solution reacts .with slaked lime to form $CaCl_2$ and Mg $(OH)_2$, The formation of soluble $CaCl_2$ leads to initial strength gain, which is evident in the early day samples. As Mg $(OH)_2$ is insoluble in water, its formation does not increase the porosity and the permeability of the system. Thus the formation of magnesium hydroxide (brucite) leads to slow gain in strength and the loss of strength at longer periods are recouped partially, which is evident in the 2-year sample.

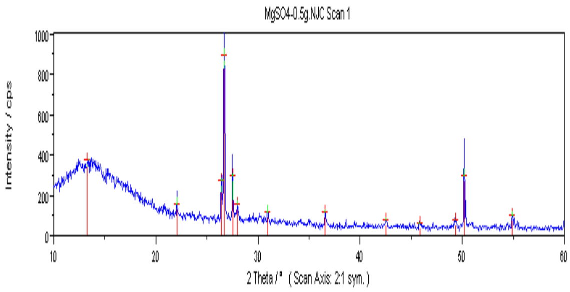

Fig.12. Powder X- Ray Diffraction Pattern for the Admixture Cement (PPC+10% Silica Fume) Mortar Cubes Prepared With Mgso$_4$ (1.5 G/L) In Deionised Water

d_Fit (A1)	Ang-parab	Ang-COG	Low Limit	Upp. Limit	I-net	I-bgr	FWHM	2-Theta
6.3571	13.9194	13.2609	10.1000	21.9500	374.05	0.00	7.7935	13.9194
4.0237	22.0739	22.0507	21.6000	24.5000	153.28	0.00	1.1431	22.0739
3.3680	26.4428	26.4369	24.5000	26.5500	275.49	0.00	0.2536	26.4428
3.3357	26.7029	26.7068	26.5000	26.9500	893.35	0.00	0.1600	26.7029
3.2399	27.5083	27.5076	26.9000	27.8500	299.46	0.00	0.1393	27.5083
3.1841	28.0000	27.9934	27.6500	30.1000	154.89	0.00	0.2990	28.0000
2.8858	30.9629	30.9565	30.3000	34.9000	115.59	0.00	0.5592	30.9629
2.4530	36.6039	36.5746	35.0000	38.5500	117.10	0.00	0.3209	36.6039
2.1233	42.5424	42.5419	39.5500	45.7500	80.37	0.00	0.7321	42.5424
1.9783	45.8308	45.8519	42.7000	47.0500	66.15	0.00	0.9229	45.8308
1.8462	49.3191	49.3188	45.9000	50.0500	79.34	0.00	0.3841	49.3191
1.8154	50.2137	50.2055	50.0500	50.5000	299.19	0.00	0.1064	50.2137
1.6707	54.9118	54.9112	50.4500	59.9000	99.34	0.00	0.3118	54.9118

Powder X-Ray Diffraction pattern shown in Fig. 11. for the admixture cement (PPC+10% Silica fume) mortar cubes prepared with $MgSO_4$ (1.5 g/L) in deionised water. A comparison of this pattern with that for mortar with deionised water indicates the formation of diopside (Ca Mg Si_2O_6) compound, which is evident from the presence of d-spacing's 2.453Å, 2.123Å and 1.815Å in this pattern, which are absent in Fig. a. and Fig.b The possible chemical reaction by the hydration of cement with mixing water containing $MgSO_4$ is

$$3CaO+2SiO_2 + MgSO_4+3H_2O \rightarrow Ca\,Mg\,Si_2O_6 + Ca(OH)_2+ H_2SO_4$$

The probable reason for the acceleration of setting of cement is the formation of diopside. Increase in compressive strength at early age is due to the formation diopside and calcium hydroxide. Decrease in the compressive strength at longer periods is attributed to the reaction of H_2S0_4 with cement constituents. Calcium hydroxide and alumina-bearing phases of hydrated Portland cement are more vulnerable to attack by sulphate ions. The sulphate-bearing water penetrates the hardened cement paste and causes the damage to it in the long run. Sulphate attack can also take the form of a progressive loss of strength and loss of mass due to deterioration in the cohesiveness of the cement hydration products, leading to decrease in the compressive strength at longer periods.

Effect of Slightly Acidic Substances:

The slightly acidic compounds generally present in water are $CaCl_2$, $MgCl_2$ and $MgSO_4$. The effect of each of these compounds at various concentrations in deionised water on the initial and final setting times of cement and the compressive strength of cement mortar cubes has been already discussed in the above sub sections. The behavior of slightly acidic compounds is elucidated in a comprehensive manner as follows. $MgCl_2$ in deionised water accelerate the initial as well as final setting processes whereas $CaCl_2$ and $MgSO_4$ retard the initial and final setting (Fig. 1, 2, and Fig. 3) at all concentrations. $CaCl_2$ and MgSO4 in deionised water increase the compressive strength of mortar cubes significantly in the early days i.e., at 3-day age. In the case of $MgSO_4$ an increase in the compressive strength falls as age prolongs significant decrease in strength has occurred at longer periods like 180-day, 1-year and 2-year with $MgSO_4$. $MgCl_2$ decreases the compressive strength nominally at ages 7-day and 28-day and the decrease in strength becomes significant at longer periods is 23.33%. $MgSO_4$ affect the compressive strength negatively. Among the latter substances, the presence of $MgS0_4$ in mixed water needs more caution since it decreases in strength at longer periods.

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V. CONCLUSION

Based on the results obtained in the present investigation in Chapter 5, the following conclusions can be drawn. Presence of $CaCl_2$ in concentrations more than 1g/L in water accelerates both initial and final setting significantly. Its presence in water does not significantly increase the strength at longer duration with an increase in concentration, the maximum being 2.0 g/L. Presence of $MgCl_2$ in water retards significantly both initial and final setting in concentrations more than 1 g/L. Further, a concentration up to 2g/L results a significant decrease in compressive strength of all age samples up to 2-years including short term and long term. Presence of $MgSO_4$ in water accelerates significantly the initial and final setting in concentrations more than 1 g/. Its presence in water initially increases significantly the compressive strength up to 3days but gradually decreases the compressive strength below significant level on longer duration, the maximum concentration being 1.5 g/L.

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No	d_Fit (A1)	Ang- parab	Ang-COG	Low Limit	Upp. Limit	I-net	I-bgr	FWHM	2-Theta
1	6.4612	13.6942	13.1134	10.0000	20.7500	374.46	0.00	7.3996	13.6942
2	4.2394	20.9375	20.8774	20.7000	25.3500	154.00	0.00	1.5188	20.9375
3	3.3429	26.6450	26.6557	25.3500	27.1000	550.99	0.00	0.1834	26.6450
4	3.2452	27.4621	27.4586	27.2500	27.7500	483.75	0.00	0.1387	27.4621
5	3.1952	27.9007	27.9000	27.6500	29.2500	139.35	0.00	0.5910	27.9007
6	2.4522	36.6156	36.6065	34.2500	39.3500	123.77	0.00	0.1808	36.6156
7	2.2813	39.4684	39.4554	36.7500	40.2000	81.60	0.00	0.3202	39.4684
8	2.2353	40.3156	40.3131	39.6000	42.3500	70.94	0.00	0.4580	40.3156
9	2.1271	42.4637	42.4566	41.8500	45.2000	72.95	0.00	0.3856	42.4637
10	1.9970	45.3774	45.3979	42.5500	47.0000	92.48	0.00	0.5543	45.3774
11	1.9271	47.1215	47.1274	46.7500	50.0000	52.66	0.00	1.4503	47.1215
12	1.8169	50.1701	50.1577	48.6000	51.5000	150.49	0.00	0.3015	50.1701
13	1.8042	50.5476	50.5399	50.4000	54.7500	69.90	0.00	1.9224	50.5476
14	1.6696	54.9500	54.9651	54.4500	59.8500	53.00	0.00	0.7449	54.9500