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PREVENTION OF SALT ATTACK BY USING POZZOLANIC ADMIXTURES

BY

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ABSTRACT

Presence of soluble sulphates in building materials, soil or water has adverse effect on the life of a building structure. Thirty percent (30%) addition of pozzolanic admixtures like furnace slag, rice husk ash, pulverized fly ash, and burnt clay partly replacing ordinary Portland cement, arrests adverse effect of these salts. The study carried out in Building Research Station, Lahore reveals that whereas ordinary Portland cement is comparatively less resistant to sulphate attack and starts loosing compressive strength from the age of one (1) year and onward, the compressive strength obtained from OPC-pozzolanic admixtures (70:30) though low at initial stages, remains un-effected, and continuously increases with age. Addition of Pozzolanas, (30%) as part replacement of ordinary Portland cement, is economical also in Pakistan.

INTRODUCTION

Excess of sodium sulphate present in soils, water and building materials like bricks, concrete and aggregates has adverse effect on strength of the building structure. The salt appears as whitish stains on the surface due to evaporation on drying out of water. It deteriorates concrete, masonry and plastering works etc. Life of structure is reduced. Prevention of efflorescence can be best achieved by selecting suitable materials during construction and by doing subsequent proper maintenance. Prevention of ingress of moisture through walls and roof helps in arresting efflorescence.

Building Research Station, Lahore had been doing research work on various materials which effect structure's life. In this connection a study was carried for five years to find out solution for reducing salt's effect on building materials.

Soluble sulphates present in any of constituents of concrete i.e. aggregate, cement and water etc. interact with Calcium Aluminate which is formed during hydration process of cement forming Calcium-Sulpho Aluminate $\{3CaO\ Al_2O_3\ 2(SO_4)\}$. The compound formed weakens cohesive forces and causes loosening of the bond. Rate of reaction, however, depends on concentration of soluble salts, the higher the concentration, more rapid is the reaction.

EXPERIMENTAL WORK

Experimental studies to observe effect of addition of pozzolanic materials as a part replacement of cement in preventing salt attach was carried out in the Building Research Station, Lahore for five years, For this purpose blast furnace slag (BFA),

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rice husk ash(RHA), pulverized fuel ash (PFA) and burnt clay were selected as pozzolanic materials. The study proceeded in two stages, the first consisted of finding out percentage of pozzolanic materials to be part replaced in the cement and to observe compressive strength of various OPC-pozzolanic blends concrete/mortar cubes at different ages. Mortar cubes were casted of pozzolanic-cement blends using pozzolanas percentage varying from 10% to 35%. Results of compressive strength tested for 7 and 28 days are tabulated in Table-I, indicate 30% of part replacement of OPC with pozzolanic material as optimum useful and appropriate.

TABLE 1.

Description	%age of		Compressive Strength (PSi)	
	OPC	Pozzolana	7 days	28 days
O.P.C - P.F.A.	100	-	2280	2900
	90	10	1900	2450
	85	15	1750	2400
	80	20	1500	2300
	75	25	1450	2200
	70	30	1400	2000
	65	35	1350	1800
O.P.C - R.H.A.	90	10	1800	2400
	85	15	1700	2350
	80	20	1500	2250
	75	25	1450	2200
	70	30	1400	2000
	65	35	1200	1750
O.P.C - B.F.S.	90	10	1550	2600
	85	15	1500	2500
	80	20	1400	2400
	75	25	1400	2300
	70	30	1350	2200
	65	35	1000	1400
OPC - Burnt Clay	90	10	1950	2700
	85	15	1850	2200
	80	20	1500	2150
	75	25	1450	2100
	70	30	1350	2000
	65	35	900	1650
(Determination of %age feasibility of various opc-pozzolanic blends)				

For second stage of the study, OPC-pozzolanic blends (70% OPC-30% pozzolana) were used in the preparation of concrete cubes (4"x4"x4") of 1:2:4 (cement-pozzolana:sand:aggregate) and were tested all in accordance with BS-12:1959. Concrete cubes were also casted in the ratio of 1:2:4 using 100% cement with no pozzolanic material. The second stage study was carried out in two series. In

the Ist. series water for preparing concrete cubes and their curing contained nil sodium sulphate. Water curing was carried out for 28 days and thereafter moist air curing method was adopted. Cubes were tested at 7 and 28 days, 6 months, 1 year to 5 years result are in table-II.

TABLE. 2

	COMPRESSIVE STRENGTH (PSI)				
Age	OPC	OPC-Slag	OPC-R.H.A.	OPC-P.F.A	OPC-Burnt Clay
7 days	1800	1100	1100	1100	1250
28 days	2500	1900	1800	1700	1750
6 months	3100	2600	2200	2400	2400
1 year	3200	2800	2500	2500	2700
2 years	3250	3000	3100	3000	3100
3 years	3200	3500	3600	3700	3600
5 years	3100	3800	3800	4100	3600
(Compresive Strength of opc-pozolana blends (70:30) concrete cubes (1:2:4) prepared and cured in normal media).					

In the second series, the whole process was repeated but using water with 0.1% sodium sulphate for preparation as well as for subsequent 28 days water curing for cubes. The cubes were tested for compressive strength at the age of 7 days, 28 days, 6 months, 1 year and onward to 5 years period. Results are tabulated in Table-III.

TABLE 3.

	COMPRESSIVE STRENGTH (PSI)				
Age	OPC	OPC-Slag	OPC-R.H.A.	OPC-P.F.A	OPC-Burnt Clay
7 days	1800	1000	1000	1000	1000
28 days	2500	1900	1600	1600	1500
6 months	2600	2400	2300	2200	2300
1 year	2400	2600	2500	2300	2700
2 years	2200	3100	2800	2500	2800
3 years	2150	3300	3000	2800	3100
5 years	2000	3500	3200	2900	3100
(Compresive Strength of opc-pozolana blends (70:30) concrete cubes (1:2:4) prepared and cured in saltish media).					

Similar experimental work was carried out by preparing mortar cubes in the ratio of 1:2.75 (cement : sand). In this case also two series were performed. Mortar cubes (2.78" x 2.78" x 2.78") were casted by using OPC-pozzolanic blend (OPC 70% and pozzolanas admixtures 30%) and Ravi sand. Pozzolanas admixtures were same as before i.e., furnace slag, rice husk ash, pulverized fuel ash and burnt clay for

each series of cubes. Water used contained nil of sodium sulphate in the first series and 0.1% sodium sulphate in the second series. Both series included mortar cubes prepared using 100% cement i.e. without addition of pozzolanic materials. Mortar cubes were tested for compressive strength at the same ages i.e. 7 days, 28 days, 6 months, 1 year and upto 5 years. Results of the two mortar cube series are included in Table -IV and Table -V.

TABLE 4.

	COMPRESSIVE STRENGTH (PSI)				
Age	OPC	OPC-Slag	OPC-R.H.A.	OPC-P.F.A	OPC-Burnt Clay
7 days	1900	1300	1200	1000	1200
28 days	2900	2300	1900	1700	1800
6 months	3000	2600	2100	2100	2100
1 year	2900	3100	2600	2600	2900
2 years	2800	3300	3000	2900	3200
3 years	2800	3800	3300	3300	3500
5 years	2800	3900	4000	3700	4100
(Compresive Strength of opc-pozolana blends (70:30) mortar cubes (1:2:4) prepared and cured in normal media).					

TABLE 5.

	COMPRESSIVE STRENGTH (PSI)				
Age	OPC	OPC-Slag	OPC-R.H.A.	OPC-P.F.A	OPC-Burnt Clay
7 days	1800	1000	900	900	900
28 days	2600	2200	1900	1800	2000
6 months	3000	2600	2500	2200	2400
1 year	3000	2800	2700	2500	2700
2 years	2700	3200	2800	2600	2900
3 years	2500	3300	3000	2800	3200
5 years	2200	3600	3300	3100	3300
(Compressive Strength of opc-pozolana blends (70:30) mortar cubes (1:2:4) prepared and cured in saltish media).					

DISCUSSION

The practical work carried out compares compressive strength of concrete cubes casted using ordinary Portland cement as well as those prepared using Portland cement - pozzolanic blends (ratio 70:30). Table-II & Fig.1 show that for concrete samples prepared with ordinary Portland cement, using portable water (without addition of sodium sulphate), the 28 days compressive strength is 25% more than of

those concrete samples prepared using 30% pozzolanic materials (OPC-Slag). The compressive strength of the former continues increasing till the age of 2 years. Simultaneously the OPC-pozzolanic blends concrete cubes show increase in strength. However, after two (2) years period whereas OPC concrete samples declining slightly in compressive strength, the OPC-pozzolanic blends show increase in compressive strength. At five (5) years age, strength, attained by the OPC-pozzolanic blends cubes was atleast 16% more than that of OPC concrete sample.

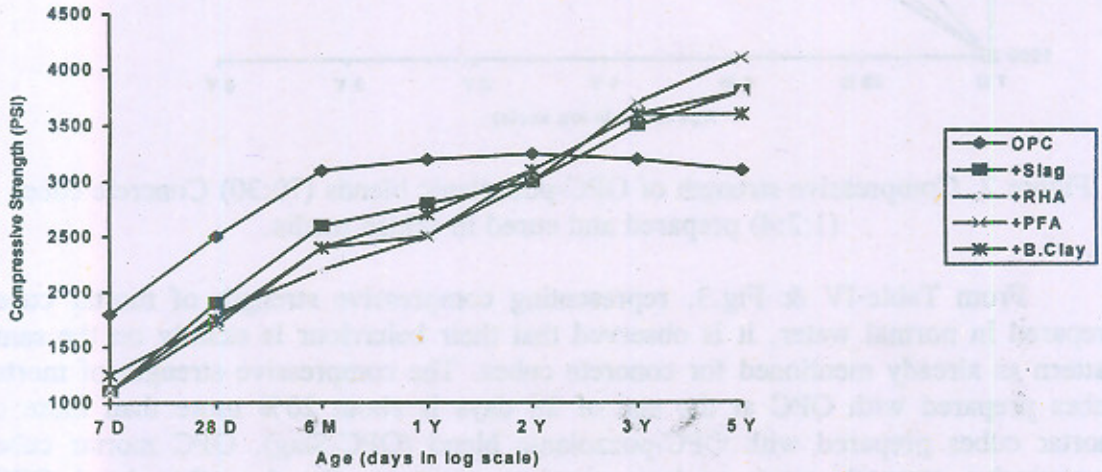

Figure 1. Compressive strength of OPC-pozzolanic blends (70:30) Concrete cubes (1:2:4) prepared and cured in normal media.

Table-3 & Fig.2, which contain results of compressive strength of concrete cubes prepared and cured with water containing 0.1% sodium sulphate, indicate that the 28 days strength of the concrete samples using OPC is 24% to 40% more than those of OPC pozzolanic blends (OPC-Slag). However, the OPC concrete cubes samples started loosing strength after one (1) year age when the strength of both concrete samples i.e. one prepared with OPC and the other with OPC-pozzolanic blends is more or less the same. The OPC-pozzolanic blends concrete samples continue gaining compressive strength even after 1 years. At the end of 5 years percentage loss in compressive strength for the OPC concrete cubes is 20% as against its compressive strength at 28 days. On the other hand OPC-pozzolanic blend (OPC-Slag) gaines about 80% more as compared with its compressive strength at 28 days. Comparing compressive strength of OPC cubes and OPC-pozzolanic blends cubes at the age of 5 years, the strength of the OPC-pozzolanic blends (OPC-Burnt clay) is 55% more than that of OPC concrete samples.

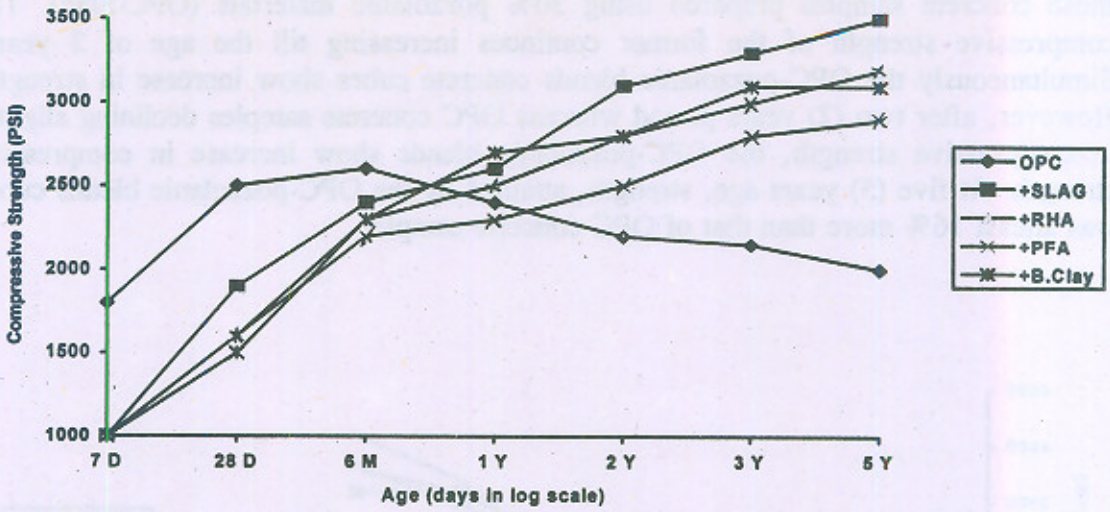

Figure 2. Compressive strength of OPC-pozzolanic blends (70:30) Concrete cubes (1:2:4) prepared and cured in saltish media.

From Table-IV & Fig.3, representing compressive strength of mortar cubes prepared in normal water, it is observed that their behaviour is exactly on the same pattern as already mentioned for concrete cubes. The compressive strength of mortar cubes prepared with OPC at the age of 28 days is about 20% more than those of mortar cubes prepared with OPC-pozzolanic blend (OPC-Slag). OPC mortar cubes compressive strength more or less remaines constant. On the other hand OPC-pozzolanic blends mortar show that though their compressive strength is lower in the early days as compared with that of OPC mortar cubes but the gain in strength continues with the age. At 5 years age the strength of these cubes (OPC-PFA) is about 30% more than that of OPC mortar cubes.

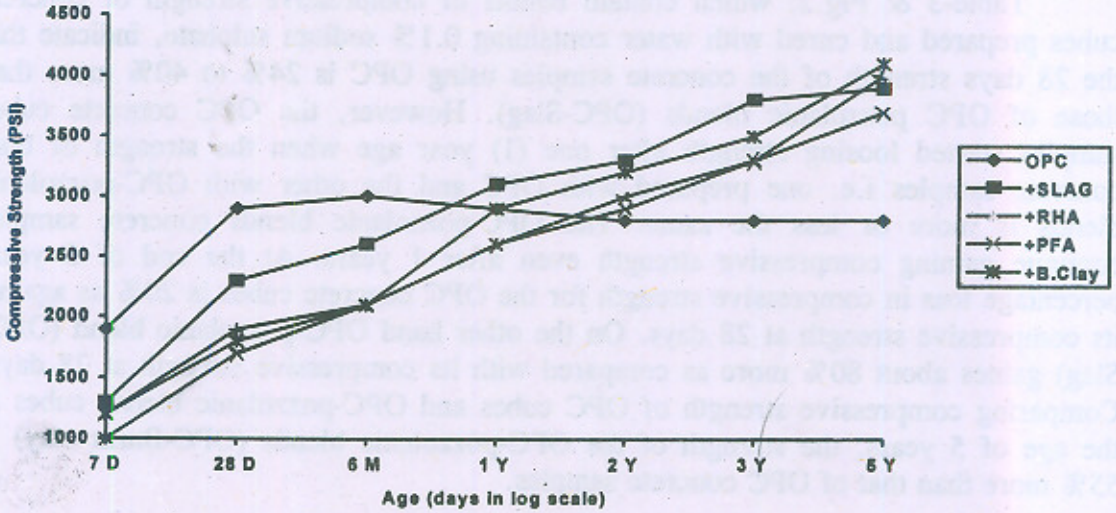

Figure 3. Compressive strength of OPC-pozzolanic blends (70:30) Mortar cubes (1:2.75) prepared and cured in normal media.

On going through Table-V & Fig.4 containing which compressive strength of mortar cubes prepared and cured with saltish media, it is observed that the mortar cubes prepared with OPC have more compressive strength as compared with OPC-pozzolanic admixture samples (OPC-Slag) at the age of 28 days, the strength being about 15% more. The OPC mortar cubes continue gaining strength till the age of 6 months when it is about 4 % more than that of its strength at the age of 28 days. However, after this period the OPC mortar cubes started loosing strength and at the age of 5 years the compressive strength is about 15% less than that of its strength at 28 days. On the other hand OPC-pozzolanic blends mortar cubes show that though they possess low compressive strength at the age of 28 days but with time they continue gaining it. At five years age their strength (OPC-Burnt clay) is about 30% more as compared with corresponding compressive strength of OPC mortar cubes. Further the gain in compressive strength of OPC-pozzolanic admixtures mortar cubes at this age is about 60% more than their 28 days compressive strength.

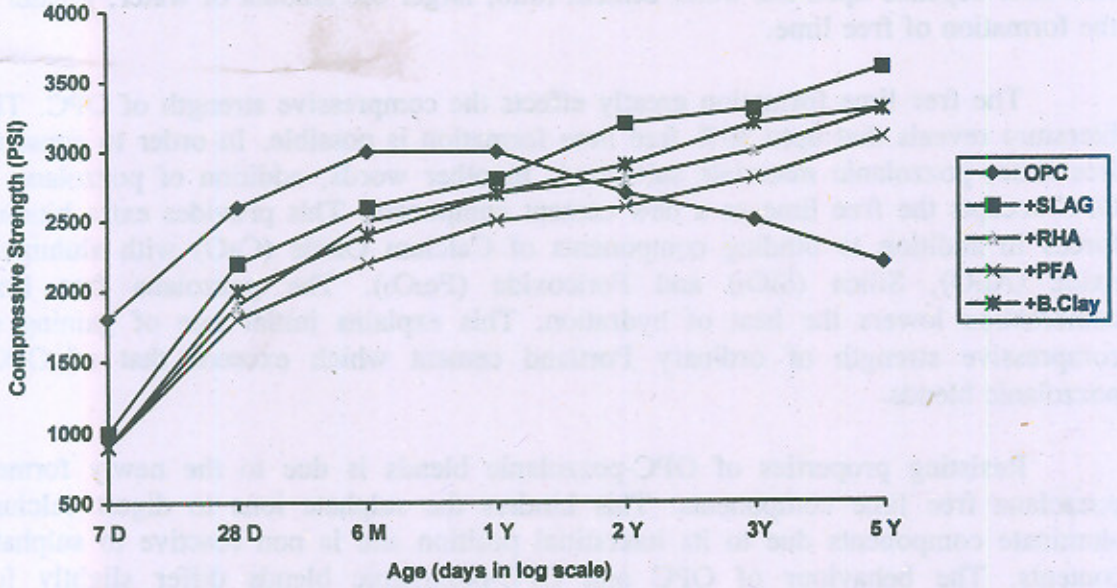

Figure 4. Compressive strength of OPC-pozzolanic blends (70:30) Mortar Cubes (1:2.75) prepared and cured in Saltish media.

The work of above series reflects injurious effect of sulphates on cement concrete/mortars cubes case. Deleterious action is due to the formation of Calcium-Sulpho-Aluminate complex when Sulphate ions reach in the vicinity of ordinary Portland cement structure which contains Calcium-Aluminate, a vital component in cement that imparts binding forces in the hardened cement structure. Figs. 1 to 4 show that the declining tendency for ordinary OPC specimen in either of the media is due to the fact that the gypsum (Calcium Sulphate) added to the clinker to adjust the setting properties of OPC, resides in the OPC structure. On availability of moist conditions, the soluble Sulphate reacts with Calcium-Aluminate resulting in lowering

the compressive strength. In the water containing sodium sulphate ions, such type of reaction starts with multiple intensity owing to greater contents of sulphates available in the media as well as those already present in the cement.

Another important factor encountered is the aspect of slow rate of gaining compressive strength in the initial period by the pozzolanic-OPC blends as compared with that of OPC. This is because the main reactions are hydration and hydrolysis of cement. In hydration process, hydrates of calcium and silicates are formed. The hydrolysis process bifercates water molecules which in turn combine with the Ca-Oxide to form Hydroxides of Calcium, Aluminum and Iron. Hydroxides of Calcium is known as Lime. When water is added into the cement, the reaction starts vigorously, basic function of water is to provide a media of reaction to combine Calcium with Silica (Si_2O_3) Alumina (Al_2O_3) and Iron Oxide (Fe_2O_3) forming Calcium Silicate ($CaSiO_3$), Ca-Aluminate($Ca(Al_2O_3$) and Calcium Ferrets ($Ca(Fe_2O_3$). Calcium Hydroxide ($Ca(OH_2$) formed during the reaction is called free lime. The amount of free lime depends upon the water cement ratio, larger the amount of water, greater is the formation of free lime.

The free lime formation greatly effects the compressive strength of OPC. The literature reveals that upto 30% free lime formation is possible. In order to consume free lime, pozzolanic materials suit good. In other words, addition of pozzolana in OPC accepts the free lime as a new cement component. This provides extra binding forces in addition to binding components of Calcium Oxide (CaO) with aluminum oxide (Al_2O), Silica (SiO_2) and Fericoxide (Fe_2O_3). The pozzolana free lime combination lowers the heat of hydration. This explains initial rate of gaining of compressive strength of ordinary Portland cement which exceeds that of OPC-pozzolanic blends.

Resisting properties of OPC-pozzolanic blends is due to the newly formed pozzolana free lime components. This hinders the sulphate ions to digest calcium aluminate components due to its interstitial position and is non reactive to sulphate contents. The behaviour of OPC and OPC-pozzolanic blends differ slightly for concrete and mortar cubes specimens. The late decline in strength in concrete and early decline in strength in mortar is probably due to the presence and absence of course aggregates respectively.

CONCLUSION

Use of pozzolanic admixtures in ordinary Portland cement (replacing 30% of OPC with pozzolanic admixtures), results in eradicating effect of sodium sulphates on the compressive strength of concrete/mortars. Ordinary Portland cement is less resistant to sulphate attack and starts loosing compressive strength from one year. On the other hand OPC-pozzolanic admixture (ratio 70:30), though show lower initial compressive strength, continues gaining it with time. Furnace slag, Rice Husk Ash, Pulverized Fuel Ash and Burnt Clay perform well as pozzolanic materials and their addition in blend not only successfully resists sulphate attack but is also responsible

for continoues increase in compressive strength with age. Addition of pozzolana to OPC is also economical in cost.

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