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Durability of Portland Slag Cement Mortar Made with Non Potable Water

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Abstract: *This research work reveals that durability of Portland slag cement (PSC) mortar made with non potable water. Fourteen water treatment plants were found out in the Narasaraopet municipality region in Guntur district, Andhra Pradesh, India. All plants are extracting ground water and treating through Reverse Osmosis (RO) process. During water treatment, approximately plants are discharging 1,00,000 L/day from out lets into side drains in Narasaraopet municipality.Physical and chemical analysis was carried out on fourteen plants outlet water and distilled water as per producer described in APHA.In the present work, based on the concentrations of constituent's in outlet water, four typical plants i.e., Narasaraopeta Engineering College (NECWW), Patan Khasim Charitable Trust (PKTWW), Mahmadh Khasim Charitable Trust (MKTWW) and Amara (ARWW) were considered. Test specimens made with four typical plants outlet waters on physical properties i.e., setting times, compressive strength, flexural strength were performed in laboratories and compared same with reference specimens i.e., made with Distilled Water (DW). And also magnesium sulphate effect on test and reference specimens was carried out. No significant change was observed in initial and finial setting time of test specimens made with four plants outlet waters compared to that of reference. Almost, no change was observed in 90 days compressive and flexural strengths in test specimens of four plants outlet waters compared with reference specimens. Compressive strength loss in test and reference specimens due to magnesium sulphate effect was also same. XRD technique was employed to find out main hydrate compounds formed in cement past.*

Keywords: *plant outlet water, PSC, setting time, compressive strength, flexural strength, durability*

1.0 Introduction

Ever since concrete began to be used as a construction material, potable water has been using as the mixing water in concrete due to the chemical composition is well known. The literature search indicates that, not much research work was carried out on the quality of mixing water in concrete and there were no detailed guide lines [1 - 3] for the use of water in concrete. The building code requirements of different countries generally contain broad guidelines on mixing and curing water. Most of the codes consider potable water to be satisfactory for both mixing and curing of concrete and stipulate permissible limits for solids and aggressive chemicals. .However, In recent years, attention has been focused on the potential for various aspects of wastewater reuse, although previous research was performed on the use of wastewater that were produced from the water treatment plants and industries for making concrete and reported that no adverse effects on concrete properties in fresh and hardened state [6-16]. Also [1,17] stated that the compressive strength of the cubes made of water with unknown chemical composition not to be less than 90% of cubes made with potable water. There was a note in BS 3148 – 1980which states that non potable water that results in a strength reduction of up to 20% can be acceptable compared to that of cubes made with potable water, but the mixture proportions should be adjusted appropriately. However, limit of a chemical in mixing water of concrete given by various codes is tabulated in table .1

Therefore, throughout Andhra Pradesh 71 municipalities and 13 municipal corporations were existed. From these municipalities, small to large scale water treatment plants were setup. As a result of water treatment plants, huge volume of ground water is extracting and huge volume of water form plant outlet discharging into side drains. Hence, present work is taken up on the effect of four typical plants outlet waters on properties of PSC and magnesium sulphate effect on PSC mortar.

2. 0 Materials and Methods

2.1 Cement

Portland Slag cement was used. The physical properties of cement are given in Table: 2.

2.2 Sand

The ennor sand was used. Table 3 gives its physical properties. The cement to fine aggregate ratio was maintained at 1:3 by weight in the mortar mixes.

2.3 Water

Distilled water was used in reference specimens and outlet waters from four typical water treatment plants were used in test specimens. The physical and chemical properties of distilled and fourteen plants wastewater are given in Table: 4.

2.4 Sulphate
Magnesium sulphate

Table:1 Tolerable limits of impurities in mixing water of concrete (all values in mg/L, except pH)

Constituent	Tolerable Limit	Reference
pH	3	[18,19]
	>5	[20,21]
	6	[1]
	6-8	[22]
	7-9	[2]
Total solids	50000	[3]
	5000-10000	[23]
	4000	[19]
Suspended solids	2000	[23,24,1]
Dissolved solids	50000	[26]
	2000	[24,1,2]
	<6000	[27]
Organic solids	200	[1]
Inorganic solids	3000	[1]
Total Alkalinity(as $CaCO_3$)	500	[2]
	1000	[28,25]
Sodium Carbonates and Bicarbonates	2000	[20,21,23]
Carbonate	1000	[25]
Bicarbonate	400	[25]
Chlorides for plain concrete	360	[32]
	500	[20,21,24]
	2000	[1]
	4500	[33]
Chlorides for Reinforced concrete	500	[8,1,34]
	1000	[35, 33]

Table 2: Properties of Cement

Property	Result
Specific gravity	3.25
Fineness, m^2/kg	3.3
Initial setting time, minutes	183
Final setting time, minutes	273
Compressive strength ,N/mm^2	
3 days	31.50
7 days	40.59
28 days	58.42
90 days	64.26
Flexural strength ,N/mm^2	
3 days	3.80
7 days	5.48
28 days	6.62

Table 3: Properties of sand

PROPERTIES	RESULTS
Specific gravity	2.645
Bulk density, kN/m^3	15.85
Fineness modulus	2.71
Grading	Percentage
Passing in 2mm sieve	100%
Retained on 2mm sieve	100%
Particles size 2mm to 1 mm	33.33%
Particle size lee than 1 mm to 500µ	33.33%
Particle size lee than 500 µ mm to 90µ	33.33%
Absorption in 24 hours	0.8%
Shape of grains	Sub angular

Table 4: Physical and chemical properties of various plants wastewaters

NAME OF PLANT	PH	ALKALINITY AS $CaCO_3$(mg/L)			ACIDITY AS $CaCO_3$ (mg/L)		SOLID(mg/L)			CHLORIDES (mg/L)	SULPHATES (mg/L)
		OH^-	CO_3^{-2}	HCO_3^-	Mineral acidity	CO_2 acidity	Total solids	Organic solids	Inorganic solids		
DW	7	0	0	0	0	0	0	0	0	0	0
NEC	7.13	0	0	560	0	80.0	502.13	17.13	485	175	22
MKT	6.93	0	0	464	0	81.0	320.93	16.93	304	140	20
PKT	7.16	0	0	545	0	79.0	437.16	17.16	420	160	23.5
AR	7.05	0	0	520	0	82.5	402.05	17.05	385	145	27.8
SMS	6.82	0	0	300.5	0	91.5	219.2	19.2	200	150.34	17
RL	6.01	0	0	410.9	0	92.5	270.2	20.2	250	130.56	16
Varun	6.61	0	0	425.4	0	90.6	227	32.0	195	160.45	08
BST	6.55	0	0	300.23	0	95.9	230	25	205	170.59	05
KC	6.81	0	0	423.25	0	95.2	244	24	220	172.53	11
PRT	6.45	0	0	416.45	0	97.1	281	31	250	144.59	13
VGT	6.64	0	0	413.45	0	96.9	248	28	220	140.58	10.5
MGT	6.35	0	0	400.29	0	98.5	236	20	216	139.49	9.5
VCT	6.35	0	0	355.93	0	54.9	242	20	222	152.93	11.9
RR	6.53	0	0	419.2	0	46.3	171	21.0	150	148.63	12.5

2.5 Methods

Distilled water, plants outlet waters were analysed as per procedure lay down in [36]. The quantity of cement, sand, and mixing water for each specimen were 200 g, 600g, and (P/4 + 3), where P denotes the percentage of water required to produce a paste of standard consistency. Fifteen samples were prepared and tested for initial and final setting time using Vicat's apparatus. Sixty mortar cubes with 50 cm^2cross sectional area and same number of square prisms of 40X40X160mm were cast for compressive and flexural strengths. Tests were performed at 3 days, 7 days, 28 days and 90 days for compressive and flexural strengths. The compacted specimens in moulds were maintained at a controlled temperature of $27^0 \pm 2^0$ and at 90 percent relative humidity for 24 hours by keeping the moulds under gunny bags wetted by the same mixing waters of the specimens. After 24 hours, all specimens were subjected to immersion curing and curing was continued remaining 27 days.

In case of magnesium sulfate attack, After 28 days curing, the reference (DW) and test (NECWW, PKTWW, MKTWW, ARWW) specimens were immersed in 4% concentration of magnesium sulfate solution for six months. The magnesium sulfate solutions were prepared by dissolving magnesium sulfate in deionised water. The concentration of the magnesium sulpahte solution was renewed once in a two months. The above same procedure was adopted for test specimens. The effect of magnesium sulfate on the durability of reference and test specimens was evaluated by measuring the loss in compressive strength. The compressive strength loss in percentage of test specimens was compared with reference specimens.

2.6 Powdered X-Ray Diffraction (XRD)

Powdered XRD technique was used to investigate crystalline compounds in 28 days hydrate cement specimen powder [37]. The reference and test cement specimens (NECWW) were grinded to a fine powder and a flat specimen was prepared on a glass surface using an adhesive for XRD measurement. The diffracted intensities were recorded using monochromatic Copper Kα radiation.

3.0 Results And Discussion

3.1 Initial setting time

Effect of NECWW, PKTWW, MKTWW and ARWW on initial and final setting times of PSC is shown in Fig. 3.1.

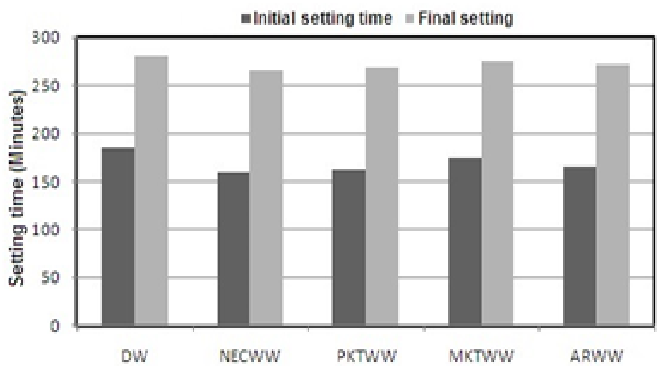

Fig 3.1 Effect of wastewaters on setting times

The effect of NECWW, PKTWW, MKTWW and ARWW on initial setting time of PSC is insignificant when compared to that of DW. Initial setting time of DW, NECWW, PKTWW, MKTWW and ARWW are 183,158,161,174,164 minutes respectively. The initial setting times are retarded by 25,22, 9,and 19 minutes compared to that of DW.

3.2 Final setting time

The effect of NECWW, PKTWW, MKTWW and ARWW on final setting time of PSC is shown in Fig 3.1. Final setting time of DW, NECWW, PKTWW, MKTWW and ARWW are 273,259,263,269and 265 minutes respectively. The final setting times are retarded by 14,10, 4 and 8 minutes when compared to that of DW.

3.3 Compressive strength

Effect of DW, NECWW, PKTWW, MKTWW and ARWW on compressive strength of PPC is shown in Fig 3.2.

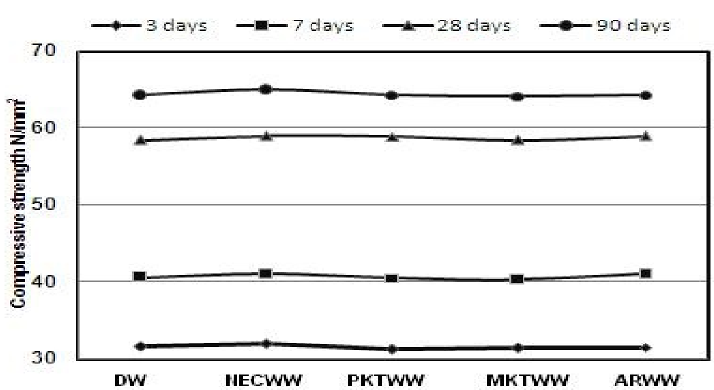

Fig 3.2 Effect of wastewaters on compressive strength

It reveals that the 3 days compressive strength of DW, NECWW, PKTWW, MKTWW and ARWW is 31.50, 31, 31.20, 31.2, 31.1 N/mm^2, for 7 days is 40.3, 40.85, 40.25, 40.1, 40.81 N/mm^2, for 28 days is 57.44, 58.0, 58.0, 58.0, 59.3 N/mm^2, and for 90 days is 64.0, 64.9, 64.20, 64.10, 64.10 N/mm^2 respectively. The change in 3, 7, 28, and 90 days compressive strengths of test specimens made with NECWW, PKTWW, MKTWW and ARWW almost same as that of reference specimens made with DW.

3.3 Flexural Strength

Effect of DW, NECWW, PKTWW, MKTWW and ARWW on flexural strength of PSC for 3 days, 7 days, 28 days and 90 days is shown in Fig 3.3.

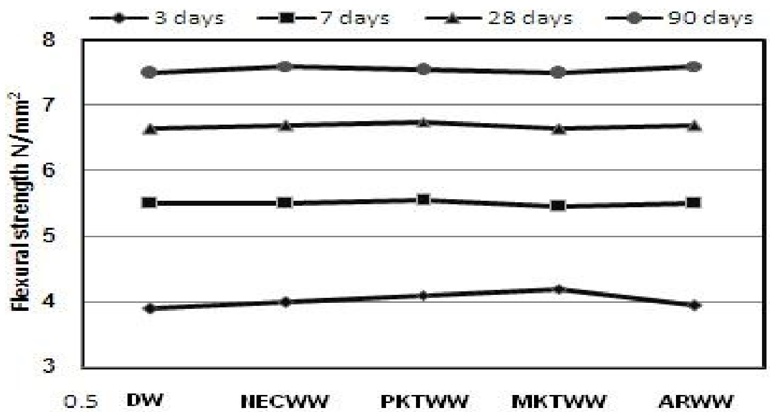

Fig 3.3 Effect of wastewater on flexural strength

It makes kwon that the 3 days flexural strength of DW, NECWW, PKTWW, MKTWW and ARWW is 3.8, 3.9, 4.0, 4.1, 3.90 , for 7 days is 5.4, 5.4, 5.50, 5.42, 5.4, for 28 days is 6.60, 6.5, 6.70, 6.60, 6.60 N/mm^2, for 90 days is 7.4, 7.5, 7.50, 7.45, 7.5 N/mm^2 respectively. The change in 3, 7, 5, 7.60and 90 days flexural strengths of test specimens made with NECWW, PKTWW, MKTWW, ARWW almost same as that of reference specimens made with DW.

3.4 Durability

Reference DW and test specimens NECWW, PKTWW, MKTWW, and ARWW immersed in 4% concentration of Magnesium sulphate solution for duration of 180 days, their compressive strength loss is illustrated in Fig 3.4. In the case of magnesium sulphate attack, magnesium sulphate reacts with calcium hydroxide in cement mortar and produced magnesium hydroxide. And react with calcium silicate hydrate and produced magnesium silicate hydrate. Magnesium silicate hydrate has low binding capacity and non-cementitious material [38]. Fig 3.4 disclosed that as immersed age progressed, compressive strength was decreased. But compressive strength loss in test and reference specimens' was almost same.

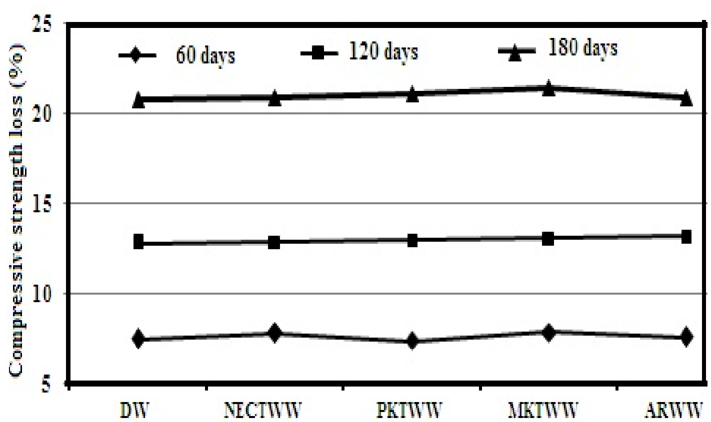

Fig 3.4 Effect of MgSO4 on mortar cubes made with different waters

3.5 XRD Analysis

XRD of reference (DW) and test sample (NECWW) cured for 28 days is shown in Fig. 3.5. It can be seen that both reference and test samples XRD patterns are almost same. The compounds identified in reference sample are C_3S, C_2S, CSH, and CH and in test sample are C_3S, C_2S, CSH, CH,, $CaCO_3$.. Wastewater analysis revealed that among all properties, bicarbonates concentration is more. Due to bicarbonates in test sample the new compound i,e., , $CaCO_3$, is formed, which is responsible for the retardation in setting times.

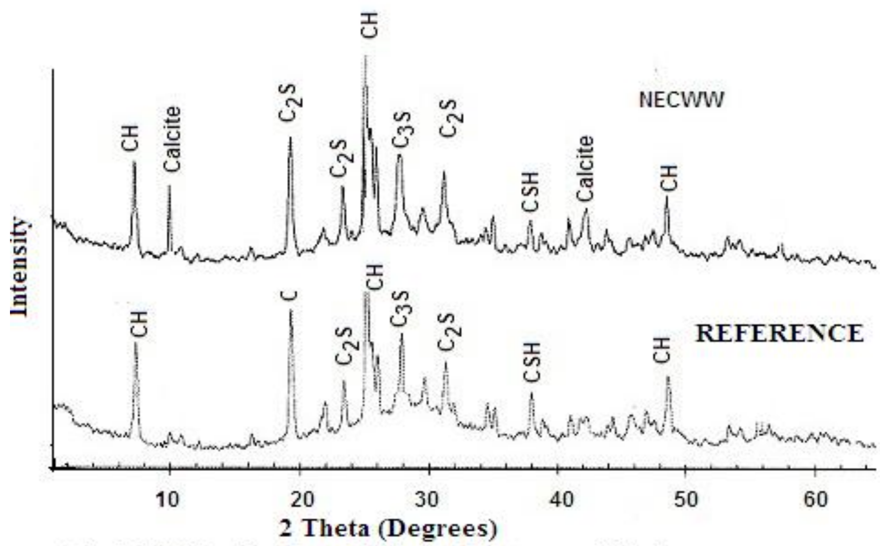

Fig 3.5 XRD of hydrate PSC powder at age of 28 days

CONCLUSION

The following conclusions were drawn on the basis of the results obtained in this paper

- Setting times of test specimens were increased when compared to that of reference specimens but increase in setting times was insignificant
- Compressive and flexural strengths of test and reference specimens were almost same.
- In the XRD analysis, new compound $CaCO_3$ other than regular compounds in hydrate cement was appeared.
- Loss in compressive strength due Magnesium sulphate attack on reference and test specimens was same.
- Out let water of water treatment plants may be recommended to use in cement mortar.

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