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Feasibility of wastewater as mixing water in cement

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Abstract

This paper presents the feasibility of wastewater from small scale water treatment plants located in residential buildings as mixing water in Ordinary Portland Cement (OPC). Fourteen water treatment plants were found out in the Narasaraopet municipality region in Guntur district, Andhra Pradesh, India. Approximately, from each plant, between 3500 and 4000 L/day of potable water is selling to consumers. All plants are extracting ground water and treating through Reverse Osmosis (RO) process. During water treatment, plants are discharging approximately 1,00,000 L/day as wastewater in side drains in Narasaraopet municipality. Physical and chemical analysis was carried out on fourteen plants wastewater and distilled water as per [1]. In the present work, based on the concentrations of constituent's in wastewater, four typical plants i.e., Narasaraopeta Engineering College (NECWW), Patan Khasim Charitable Trust (PKTWW), Mahmadh Khasim Charitable Trust (MKTWW) and Amara (ARWW) were considered. The performance of four plants wastewater on physical properties i.e., setting times, compressive strength, and flexural strength of Ordinary Portland Cement (OPC) were performed in laboratories and compared same with reference specimens i.e., made with Distilled Water (DW) as mixing water. No significant change was observed in initial setting time but significant change was observed in finial setting time. No significant change was observed in 90 days compressive strengths in four plants wastewater compared to that of reference specimens. XRD technique was employed to find out main hydration compounds formed in the process.

Keywords: Wastewater, cement, setting time, compressive strength, flexural strength

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1. 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 has carried out on the quality of mixing water in concrete and there are no detailed guide lines in[2 - 4]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 has been performed on the use of wastewater that are producing from the water treatment plants and industries for making concrete and reported that no adverse effects on concrete properties in fresh and hardened state [5-17].Also in [2,18] 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 is a note in BS 3148 – 1980whichstates 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 India, several unregistered small scale water treatment plants might have setup as a result huge volume of wastewater is generating. Hence, the aim of this work was to study the feasibility of wastewater from small scale water treatment plants located in residential buildings as mixing water in cement.

2. Materials And Methods

2.1. Cement 53- Grade ordinary Portland 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 wastewater from typical four water treatment plants were used in test specimens. The physical and chemical properties of distilled and fourteen plants wastewater are given in Table: 4.

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

Constituent	Tolerable Limit	Reference
pH	3	[19,20]
	>5	[21,22]
	6	[2]
	6-8	[23]
	7-9	[3]
Total solids	50000	[4]
	5000-10000	[24]
	4000	[20]
Suspended solids	2000	[24,25,2]
Dissolved solids	50000	[27]
	2000	[25,2,3]
	<6000	[28]
Organic solids	200	[2]
Total Alkalinity(as $CaCO_3$)	500	[3]
	1000	[29,26]
Sodium Carbonates and Bicarbonates	2000	[21,22,24]
Carbonate	1000	[26]
Bicarbonate	400	[26]
Chlorides for plain concrete	360	[33]
	500	[21,22,25]
	2000	[2]
	4500	[34]
Chlorides for Reinforced concrete	500	[9,2,35]
	1000	[36, 34]

Table 2: Properties of Cement

Property	Result
Specific gravity	3.22
Fineness, m^2/kg	22
Initial setting time, minutes	222
Final setting time, minutes	312
Compressive strength ,N/mm^2	
3 days	33.55
7 days	42.60
28 days	59.44
90 days	62.28
Flexural strength ,N/mm^2	
3 days	4.10
7 days	5.66
28 days	6.45
90 days	6.51

Table 3: Properties of sand

Properties	Results
Specific gravity	2.65
Bulk density, kN/m^3	15.90
Fineness modulus	2.72
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 wastewater

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

2.4 Methods

Distilled water, wastewaters of water treatment plants were analysed as per procedure lay down in [1]. 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 10X2.5X2.5 cm 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.

2.5 Powdered X-Ray Diffraction (XRD)

Powdered XRD technique was used to investigate crystalline compounds in 28 days hydratecement specimen powder [37]. The reference and test cement specimens 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. Results And Discussion

3.1 Initial setting time

Effect of NECWW, PKTWW, MKTWW and ARWW on initial setting time of OPC is shown in

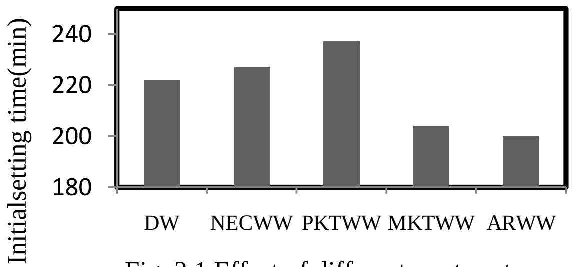

Fig: 3.1 Effect of different wastewaters on initial setting time of OPC

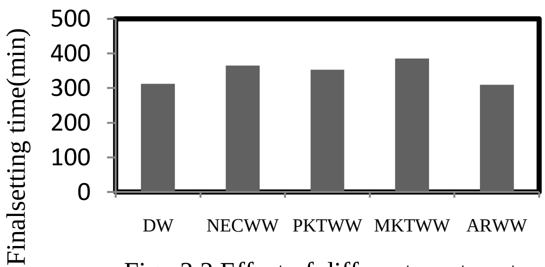

Fig : 3.2 Effect of different wastewater on final setting time of OPC

Fig. 3.1. The effect of NECWW, PKTWW, MKTWW and ARWW on initial setting time of OPC is insignificantly differed compared to that of DW. Initial setting time of DW, NECWW, PKTWW, MKTWW and ARWW are 222,227,237,204,200 minutes respectively. The change in initial setting time is +2,+15,-18,-22 minutes compared to that of DW.

3.2 Final setting time

The effect of NECWW, PKTWW, MKTWW and ARWW on final setting time of OPC is shown in Fig 3.2. Final setting time of DW, NECWW, PKTWW, MKTWW and ARWW are 312,365,353,385and 310 minutes respectively. The difference in final setting time is +53,+41,+73,and -2 minutes.Hence, significant increase in NECWW, PKTWW, MKTWW and insignificant decrease in ARWW can be observed when compared to that of DW.

3.3 Compressive strength of OPC

Effect of DW, NECWW, PKTWW, MKTWW and ARWW on compressive strength of OPC for 3days is shown in Fig 3.3. It reveals that compressive strength of DW, NECWW, PKTWW,

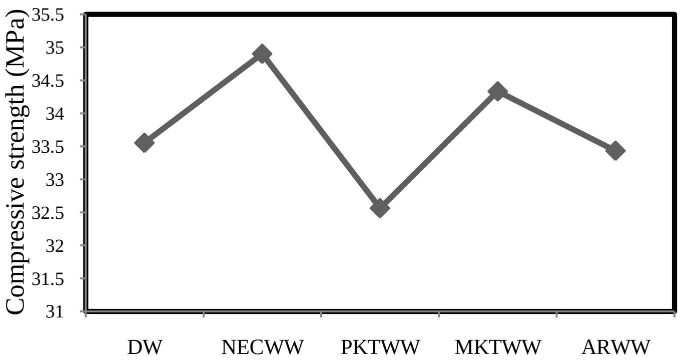

Fig: 3.3 Effect of different wastewaters on 3 days compressive strenght of OPC

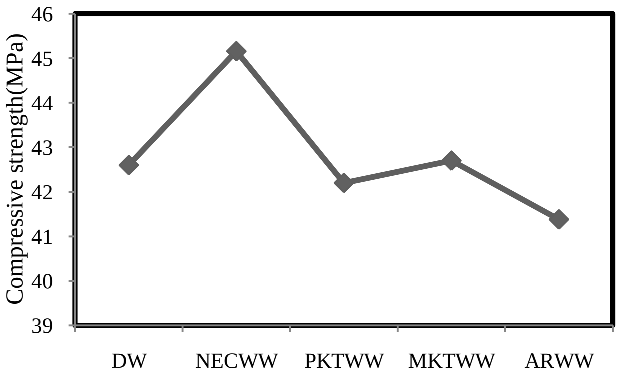

Fig: 3.4Effect of different wastewaters on 7days compressive strenght of OPC

MKTWW and ARWW for 3 days is 33.55, 34.90, 32.56, 34.33, 33.43 N/mm^2 respectively. The change in compressive strength is insignificant when compared to that of DW. The percentage change is (+4.02), (-2.95), (+2.32), (-0.35) respectively compared to that of DW.

Effect of DW, NECWW, PKTWW, MKTWW and ARWW on compressive strength of OPC for 7days is shown in Fig 3.4. It reveals that compressive strength of DW, NECWW, PKTWW, MKTWW and ARWW for 7 days is 42.60, 45.16, 42.2, 42.70, 41.38 N/mm^2 respectively. The change in compressive strength is insignificant when compared to that of DW. The percentage change is (+6.0), (-0.93), (+0.23), (-2.86) respectively compared to that of DW.

Effect of DW, NECWW, PKTWW, MKTWW and ARWW on compressive strength of OPC for 28 days is shown in Fig 3.5. It reveals that compressive strength of DW, NECWW, PKTWW, MKTWW and ARWW for 28 days is 59.44, 56.85, 57.05, 57.32, 56.51 N/mm^2 respectively. The change in compressive strength is insignificant when compared to that of DW. The percentage change is (-4.35), (-1.75), (-3.76), (-4.92) respectively compared to that of DW

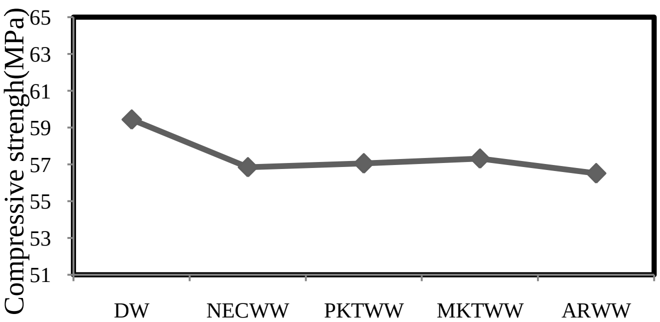

Fig:3.5 Effect of different wastewaters on 28days compressive strength of OPC

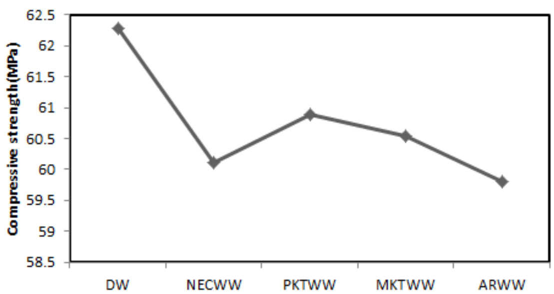

Fig 3.6 Effect of different wastetwaters on 90 days compressive of OPC

Effect of DW, NECWW, PKTWW, MKTWW and ARWW on compressive strength of OPC for 90 days is shown in Fig 3.6. It reveals that compressive strength of DW, NECWW, PKTWW, MKTWW and ARWW for

90 days is 62.28, 60.10, 60.89, 60.54, 59.8 N/mm^2 respectively. The change in compressive strength is insignificant when compared to that of DW. The percentage change is (-3.5), (-2.23), (-2.79), (-3.98) respectively compared to that of DW

However, the percentage change in compressive strength for NECWW for 3days, 7days, 28 days and 90 days is (+4.02), (+6.0), (-4.35), (-3.5) for PKTWW (-2.95), (-0.93),(-4.02), (-2.23) for MKTWW (+2.32), (+0.23), (-3.56), (-2.79) for ARWW (-0.35) ,(-2.86), (-4.92), (-3.98) respectively when compared to that of DW.

3.4 Flexural Strength

Effect of NECWW, PKTWW, MKTWW and ARWW on flexural strength of OPC for 3 days, 7 days, 28 days and 90 days is shown in Fig 3.7 to 3.10.they reveals that flexural strength of DW, NECWW, PKTWW, MKTWW and ARWW for 3 days is 4.10, 4.15, 4.08, 4.12, 4.12 N/mm^{2}for 7 days 5.66, 5.85, 5.65, 5.71, 5.58N/mm^2 for 28 days 6.45, 6.35, 6.46, 6.44, 6.39 N/mm^2 for 90 days 6.61,6.55, 6.51, 6.49, 6.35 N/mm^{2}respectively. The flexural of NECWW, PKTWW, MKTWW and ARWW for 3 days or 7 days or 28 days or 90 days is all most same as that of DW.

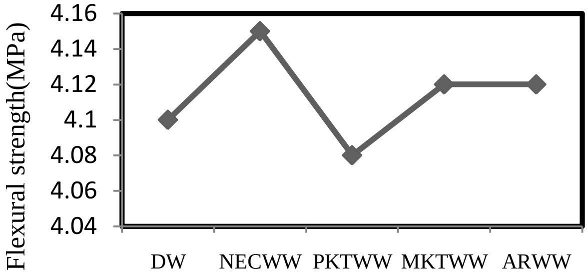

Fig 3.7 Effect of different wastewaters on 3days flexural strength of OPC

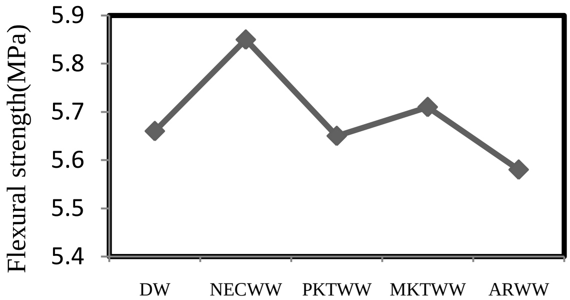

Fig. 3.8 Effect of different wastewaters on 7days flexural strength of OPC

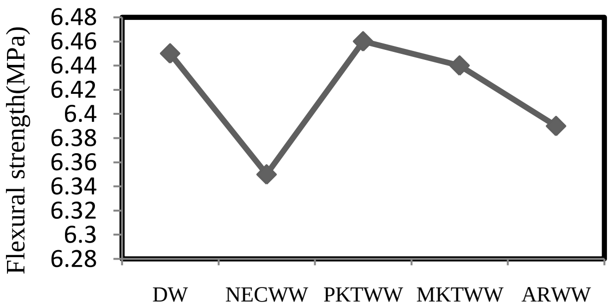

Fig 3.9 Effect of different wastewaters on 28days flexural strength of OPC

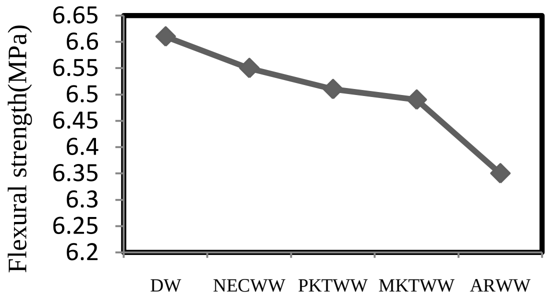

Fig 3.10 Effect of different wastewaters on 90days flexural strength of OPC

XRD Analysis

XRD of reference and test samples cured for 28 days is shown in Fig. 3.10 and 3.11. It can be seen that both reference and test samples XRD pattern is same. The crystalline compounds identified in reference sample are C_3S, C_2S, $Ca(OH)_2$at 18^0, 29.5^0, ($34.2^0$and 47.1^0) and in test sample are C_3S, C_2S, $Ca(OH)_2$, $CaCO_3$, $CaCl_2$at 18^0, 29.5^0, 34.2^0, 47.3^0, 50.9^0. Due to presence of bicarbonates and chlorides in test sample the new compounds i,e., , $CaCO_3$, $CaCl_2$are formed.

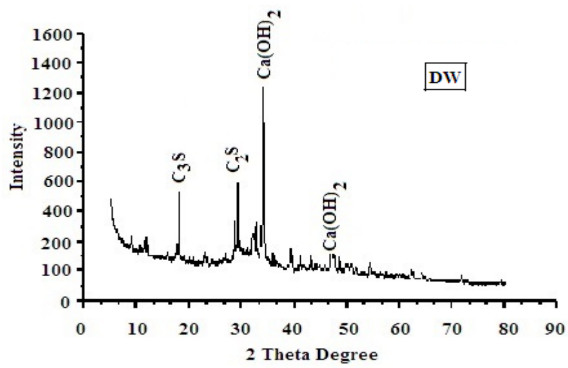

Fig 3.11 XRD for 28 days hydrated refernce sample

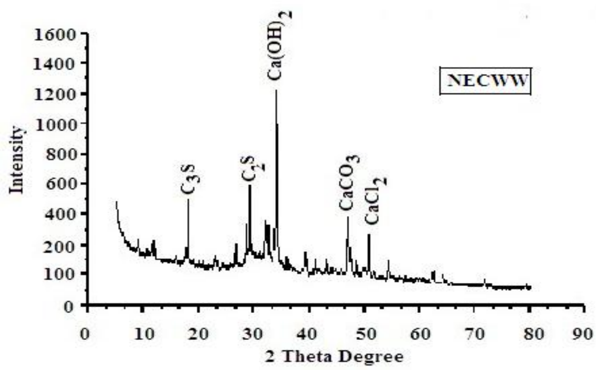

Fig 3.12 XRD for 28 days hydrated of test sample

Conclusions

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

Compressive and flexural strengths of test samples are less than the reference samples but they are well within the limits as per code IS: 456-2000, and BS: 3148-1980.
From four plants wastewaters may be recommended to use in cement mortar.
In the XRD analysis, new compounds other than regular compounds in hydrate cement are $CaCO_3$ and $CaCl_2$.

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