Nature Environment and Pollution Technology © Technoscience Publications	Vol. 6	No.4	pp. 595-600	2007

USE OF TREATED INDUSTRIAL WASTEWATER AS MIXING WATER IN CEMENT WORKS

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ABSTRACT

The feasibility of treated industrial wastewater as mixing water and effect of its constituents on cement mortar was experimentally evaluated. Cement mortar specimens were cast using deionised water (DW), tap water (TW), treated paint industry wastewater (TPIWW), and presence of zinc (Zn), lead (Pb), copper (Cu), cadmium (Cd), nickel (Ni), iron (Fe) and chromium (Cr). The results, when compared with the results of reference specimen made with DW, showed that TPIWW significantly and TW insignificantly increased the setting times and were made indistinguishable strength variations. Compressive and flexural strength increased as the concentration of metals increased, when compared with reference specimens. Therefore, TPIWW is found to be suitable for mixing water in cement mortar with no adverse effects and metal ions are positively interacted with cement mortar.

INTRODUCTION

With the steep increase in population and industrialisation, the availability of potable water is shrinking all over the world including India and it is becoming scarce, expansive and polluted. Further, in country like India, there are many areas, which are perpetually drought prone, where potable water is not available in sufficient quantity even for human consumption, especially in summer months. As per Central Water Commission (CWC), the total wastewater generated from all major industrial sources is 82446 million litres per day. Water demand for industries in the year 2000 was 30 billion cubic metres but it is projected to be as high as 120 billion cubic metres in the year 2025. Hence, the demand for the use of treated wastewater from industry and domestic is bound to increase in future. Efforts towards wastewater reuse have lately gained world wide consideration and attention in both the agricultural and industrial fronts (Metcalf & Eddy 2003).

Water is one of the most vital ingredients of concrete. Water quality has both beneficial and detrimental effects on concrete (Neville 2000). Although considerable work has been done in understanding the role and effects of different ingredient like cement, aggregates, chemical and mineral admixtures in concrete, role of water quality has not received similar attention. Moreover IS: 456-2000, ACI and ASTM have not framed standard recommendation for quality of mixing water in concrete. However, considering the fact that water has a profound impact on the fresh, hardening and hardened properties of concrete, especially its long term durability codal, requirements of water need a close scrutiny.

Heavy metals were shown that delay setting and hardening properties (Barth 1990). Metals in cement matrix positively influence its engineering properties and their long term stability (Arliquie et al. 1983, Zivica 1997).

Even though biologically treated wastewater and reclaimed wastewater are feasible to use in concrete as mixing water without adverse effects (Tay & Yip 1987, Cebeci & Saatci 1989), there is not much information on the specific effect of specifically treated industrial wastewater and major constituents of industrial wastewater such as metals on density, setting times, strengths development, hardening and soundness, hence, an investigation has been carried out in order to evaluate their effects on density, setting times and strengths of cement mortar and soundness under laboratory conditions.

With all these consequences, reuse of treated and partially treated industrial wastewater will have to be practised extensively to conserve precious water resources and to get sustainable development. But a close scrutiny and a guideline document on the use of treated and partially treated wastewater is urgently needed.

MATERIALS AND METHODS

Cement: 43-grade ordinary Portland cement was used. The percentage composition of major compounds of cement is given in Table 1 as per IS: 456-2000.

Sand: The sand used, throughout the work, was obtained from the river Swarnamukhi, Tirupati town, Andhra Pradesh. The properties of sand were analysed as per IS: 456-2000, and presented in Table 1. The cement-to-fine aggregate ratio was maintained at 1:3 in each of the mortar mixes.

Water: The characteristics of deionised water (DW), tap water (TW) and treated paint industry wastewater (TPIWW) are given in Table 2. DW, TW, TEIWW, and metals like Zn, Pb, Cu, Ni, and Cr were used as mixing water.

Deionised water (DW), tap water (TW) and treated paint industry wastewater (TPIWW) were analysed according to the standard methods for the examination of water and wastewater (APHA 1992).

Each metal dissolved in mixing water was made with different known concentrations. The maximum concentration was fixed as high as 20mg/L. Standard consistency, setting times, soundness, specimens cast and testing for compressive and flexural strengths were carried out as per IS: 456-2000.

RESULTS AND DISCUSSION

The effect of different types of mixing water on density, setting times, compressive and flexural strengths and soundness for cement at different age was experimentally evaluated. The interpretation of results is based on the current knowledge as available in the literature as well as on the standards specified as per IS: 456-2000.

Average of initial and final setting times of the three cement samples, prepared from different types of mixing water under consideration, were compared with those of the cement specimens prepared from DW. If the difference in setting times is less than 30 minutes, the change was considered to be insignificant. However, if the difference is more than 30 minutes, then the change was considered to be significant.

An average compressive and flexural strength of at least three test cubes were compared with that of three similar reference cubes and if the difference in the strength is less than 10 percent, it was considered to be insignificant and if greater than 10 percent, it was considered to be significant.

Table 1: Properties of cement and sand.

Oxide Composition	Percent	Properties of sand	Results
CaO	65.49	Specific gravity	2.63
SiO_2	21.67	Bulk density (oven dry)	15.54
Al_2O_3	5.97	Water absorption	1.2%
Fe_2O_3	3.85	Fineness modulus before sieving	2.72
SO_3	1.66	Particle size variation	0.09 to 2.0 mm
MgO	0.78	Loss of weight with conc. HCL	0.124%
K_2O	0.46		
Na_2O	0.12		

Table 2: Characteristics of deionised water (DW), tap water (TW), treated paint industry wastewater (TPIWW), standards as per CPCB and existing characteristics of treated electroplating industry wastewater.

Impurity (mg/L)	Deionised Water (DW)	Tap Water (TW)	TPIWW Standards as per CPCB	Existing concentrations in TPIWW
pH	7.3	8.0	6 – 9	6.3
TSS	-	6	100	150
TDS	15	100	-	-
Alkalinity	10	35	-	-
Acidity	2.0	4.0	-	-
Hardness	2.5	35	-	-
Suphates	0.2	15	-	-
Chlorides	3.0	45	-	-
BOD_5	-	-	50	50
Phenolics, C_6H_5OH	-	-	1.0	4.6
Oil and Grease	-	-	10	10
Zinc (Zn)	-	-	5.0	7.8
Lead (Pb)	-	-	0.1	1.0
Copper (Cu)	-	-	2.0	4.5
Nickel (Ni)	-	-	2.0	5.2
Chromium (Cr)	-	-	2.0	5.6

Units are in mg/L except pH.

Average soundness test results of the three samples were obtained. The unsoundness of the specific test sample of particular mixing water is significant if the results of Le-Chatelier's test was more than 10 mm.

Density: The effect of different types of mixing water on density is given in Table 3. The effect of different types of mixing waters was negligible on density of the cement mortar cubes, when compared against reference cement mortar cubes made with DW.

Setting times: The effect of different types of mixing water on setting times is given in Table 3. Initial and final setting times significantly increased when TPIWW replaced DW in the cement paste. Initial and final setting of cement got retarded as concentration of metals was increased in mixing water, but significant increase was not found even at the maximum concentration of metal at 20mg/L. The results of setting times of different types of mixing water were conformed retarding trend that could be attributed to the presence of metals. The same has been reported by De Angelis et al. (1999), Tashiro (1980) and Bonen & Sarkar (1994).

Table 3: Results of density, soundness, setting times and strengths of cement mortars.

Constituents	Density kg/m³	Soundnes (mm)	Setting times (Minutes) Initial	Final	Compressive strength N/mm² 3 Days	7	28	90	180	365	Flexural strength N/mm² 3 Days	7	28	90	180	365
DW	2290	0.5	112	190	24	33.5	43.0	45.5	46.5	47.5	4.1	4.9	5.9	6.5	6.6	6.7
TW	2285	0.6	130	212	23.5	33.0	42.0	45.0	46.0	47.0	4.0	4.8	5.9	6.5	6.6	6.7
TPIWW	2275	0.98	160	255	18.0	26.5	36.5	42.5	46.0	47.5	3.3	4.1	5.4	6.3	6.5	6.7
Phenolics 4.6 (mg/L)	2280	0.68	135	210	23.5	33.5	43.0	45.0	46.0	47.5	4.0	4.8	5.9	6.3	6.6	6.7
Oil&Grease 10 (mg/L)	2275	0.75	140	235	23.5	33.0	42.0	45.0	46.5	47.0	4.0	4.7	5.8	6.2	6.6	6.7
Zn 7.8 (mg/L)	2285	0.55	120	199	23.5	33	43	46	47	48	3.9	4.7	6.0	6.5	6.6	6.8
Zn 100 (mg/L)	2286	0.68	131	215	22	28.5	37.5	46.5	47.5	48.5	3.6	4.2	5.0	6.2	6.6	6.9
Pb 1.0 (mg/L)	2288	0.78	117	196	23.5	33	44.4	46	47.2	48.2	4.0	4.8	5.8	6.5	6.7	6.9
Pb 100 (mg/L)	2290	0.85	129	206	21.5	30.0	38.0	46.5	48.5	49.0	3.8	4.4	5.2	6.0	6.9	7.2
Cu 4.5 (mg/L)	2287	0.65	120	198	22.8	33.0	43.0	46.0	47.2	48.0	3.8	4.7	5.9	6.5	6.7	6.8
Cu 100 (mg/L)	2288	0.75	130	212	21.5	29.5	37.5	46.5	47.5	48.5	3.6	4.2	5.1	6.0	6.8	7.1
Ni 5.2 (mg/L)	2288	0.61	121	201	22.8	32.6	43.2	45.6	46.5	48.0	3.9	4.5	5.9	6.5	6.7	6.9
Ni 100 (mg/L)	2289	0.78	133	218	20.5	30.5	39.5	46.5	47.5	49	3.6	4.6	5.2	6.0	6.9	7.2
Cr 5.6 (mg/L)	2286	0.58	119	200	22.7	32.8	43.0	45.6	46.5	48.0	3.8	4.6	5.7	6.5	6.6	6.7
Cr 100 (mg/L)	2289	0.73	136	217	21.5	31.5	38.0	46.0	47.5	49.0	3.6	4.6	5.3	6.1	6.8	7.1

Compressive and flexural strengths: The effect of different types of mixing water with different curing ages (3, 7, 28, 90,180 and 365 days) on the compressive and flexural strengths of fifteen different types of mortar cubes is given in Table 3. It shows that cement mortar cubes made with TW have indistinguishable compressive and flexural strengths variation from mortar cubes made with DW. But in cement mortar cubes made with TPIWW, the rate of increase of compressive and flexural strengths were very slower for age up to 180 days curing. After 180 days, compressive and flexural strengths were almost same as that of reference specimen cubes made with DW. Existing concentrations of TPIWW and maximum concentration (20 mg/L) of five metals are given in Table 3, which reveal that mortar cubes made with Zn, Pb, Cu, Ni, and Cr have slower rate of increase of compressive and flexural strengths for age up to 90 days. 90 days later compressive and flexural strengths slightly increased more than that of reference specimen cubes made with DW for existing concentration of metals in TPIWW. It is also clear that compressive and flexural strengths increased by an average of 2% and 5% respectively at maximum concentration of 20 mg/L for age about one year, which were more than that of reference specimen cubes made with DW. In addition to this, as the concentration of metals increased, compressive and flexural strengths also increased.

Hence, strength tests on cement mortar cubes confirm these observations. TPIWW does not affect the compressive and flexural strengths of cement mortar cubes and metals ions also positively interact with cement mortar. Generally, TPIWW has different metals in different concentrations; consequently heavy metal ions could interact with the cement structure during the hydrolysis process of chemisorption, precipitation, surface adsorption, capturing inside the matrix, chemical incorporation or with the combination of mentioned possibilities (Nocun-Wezelik & Malolepszy 1997). So that, cement hydration was delayed and slower strength development of cement mortar was observed (De Angelis et al. 1999, Tashiro 1980, Barth et al. 1990, Arliquie et al. 1983).

Treated wastewater makes slower strength development for age up to 1 year has been reported. An improvement in the compressive strength of concrete made with a reclaimed wastewater over concrete mixed with tap water has been reported (Tay & Yip 1987). In the present research work, one year strength test results imply that the durability of mortar is not adversely affected when TPIWW is used as mixing water and metal ions positively interacted with cement.

Soundness: The effect of different types of mixing waters on soundness is given in Table 3. The actual values of the test results were 0.5 mm, 0.6 mm, 0.98 mm, 0.68 mm, 0.75 mm, 0.68 mm, 0.85 mm, 0.75 mm, 0.78 mm and 0.73 mm for the test samples of DW, TW, TPIWW, and 20mg/L each of Zn, Pb, Cu, Ni and Cr concentrations respectively. All these values are much lesser than the significant value, (10 mm) and hence all the samples made with different types of mixing waters are considered to be sound.

CONCLUSION

The following conclusions of the effect of different types of mixing waters on the properties of cement mortar were drawn from the results and analysis made in this study.

Density was not affected by the different types of mixing waters. Both initial and final setting times were affected by the different types of mixing waters. Setting times were found to be significantly retarded with TPIWW. As the metal concentration increased, setting times were retarded but not significantly.

There were no adverse effects on resulting compressive and flexural strengths, when cement mortar cubes were cured in TPIWW. Cement mortar cubes cured in their corresponding metal mixing water showed slight increase in compressive and flexural strengths with increase in concentration of metals. It can be concluded that heavy metal ions, present in cement matrix, positively influence its engineering properties and long term stability (Risch et al. 1997, Zivica 1997). This study confirms the feasibility of using TPIWW in cement mortar, and metal ions also positively interact with cement mortar.

ACKNOWLEDGMENT

The author (GRB) gratefully thank to Prof. I. V. Ramana Reddy and Prof. H. Sudarsana Rao who provided financial aid under TEQIP, and constant support to carry out this research work successfully.

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