Effect of Sulfates on Cement and Fly Ash Mortar Made With Treated Domestic Wastewater

G Reddy Babu, Pala Gireesh Kumar

Abstract**:** ***Investigative studies were carried out, to evaluate the effects of sulfates on cement and fly ash mortar made with treated domestic wastewater in the laboratory. Treated domestic wastewater (TDWW) from a treatment plant which is in Vishnu Educational Society, Bhimavaram, A.P, India, was used in the present research work. A combination of (70% Portland cement + 30% fly ash) was arrived based on number of trials where the best compressive strength was obtained. This combination was used throughout the research work. 90 days age of reference specimens, cast and cured in Potable water (PW), and 90 days age of test specimens cast and cured in treated domestic wastewater (TDWW) were immersed in sodium sulfate (Na_2SO_4) and magnesium sulfate ($MgSO_4$) solutions. When compered test specimens with reference specimens, Loss of compression strength in test specimens was almost same as that of reference specimens. But $MgSO_4$ was more vulnerable than the Na_2SO_4.***

Keywords: Cement, Fly ash, TDWW, Compression Strength, Durability, sulfates

I. INTRODUCTION

Since long time concrete to be used as a construction material, drinkable water is using as mixing water in concrete. But as of now, no alternative material has been emerged to replace of cement. Apart that usage of concrete has been increasing day by day. At present, rate of consumption of concrete is as same as that of water consumption [1]. Due to increase in population and development in the world, natural resources, at faster rate, are consuming thereby pollution and contamination of environment is increasing. Because of all these consequences, to get sustainable development, industrial by-products which have pozzolana property have partially been replacing cement [2-7]. Considerable research is carried out on reuse of solid industrial waste but reuse of wastewater not gets significant attention. But literature review, on the use of treated wastewater that are producing from various sources for making concrete and reported that not badly affected on properties of concrete or mortar[8-14].Due to increase in pollution, durability of concrete or mortar is most important for structures have effectively perform for their design life in non-friendly environment. All ingredients of concrete or mortar have partially been replacing by various industrial by-products which are having pozzolana properties, or friendly with concrete or mortar. However, if cement or aggregates or water has partially/fully been replaced in concrete or mortar with non-conventional materials, that concrete or mortar durability performance should be evaluated. Therefore, in this investigation, durability performance of mortar made with fly ash cement and treated domestic wastewater was evaluated.

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II. MATERIALS AND METHODS

A. Cement and Fly Ash

OPC (53-Grade), flay ash were used. The oxide compound composition of cement and fly ash are tabulated in Table: 1 The characteristics of fly ash cement (30%Fly ash+70% cement) are given in Table: 2.

B. Sand

Fine aggregate available at Ennor in Tamil Nadu was used throughout the work. The characteristics of fine aggregate are tabulated in table .3. The ration of cement to fine aggregate was 1:3 by weight.

C. Waters

Potable water (PW), and treated domestic wastewater (TDWW) for test specimens were used. The characteristics of Potable water and treated domestic wastewater are tabulated in Table: 4.

Table: 1 Oxides Composition of Cement and fly ash

Properties	OPC	Fly Ash
CaO	61.5	3.71
SiO_2	21.45	56.2
Al_2O_3	4.52	22.4
Fe_2O_3	2.85	6.78
MgO	2.21	1.71
K_2O	1.35	1.65
Na_2O	0.45	0.87
SO_3	2.14	0.65

Table: 2 Characteristics of M4 mix

Property	Result
Compressive strength (PW), MPa	
3 days	27.2.
7 days	32.7
28 days	45.6
90 days	66.9
Compressive strength (TDWW), MPa	
3 days	27.5
7 days	32.9
28 days	45.8
90 days	67.2

Table: 3 Characteristics of Fine Aggregate

Properties	Results
Sp. Gravity	2.66
Density, kN/m^3	16.00
F M	2.72
Grading	Percentage
Passing in 2 mm sieve	100%
retained on 2 mm sieve	100%
Particles 2 mm to 1 mm	33.33%
Particles lee than 1 mm to 500µ	33.33%
Particles less than 500 µ mm to 90µ	33.33%
Water Absorption	0.85%
Grains shape	Sub angular

Table: 4 Properties of Mixing Waters in M4 mix

Properties	Mixing water standards in (I S:456-2000) (mg/L)	Potable water (PW) (mg/L)	Treated Domestic Wastewater (TDWW) (mg/L)
pH	>6	7.2	7.4
Total suspended solids	2000	Nil	Nil
Total organic solids	200	2	8
Total inorganic solids	3000	200	52
Chlorides	500 (RCC)	50	10
Sulfates	400	10	15

D. Methods

Potable water (PW) and treatment domestic wastewater (TDWW) characteristics were found out in laboratory [15]. One hundred ninety two mortar cubes with 50 cm2 cross sectional area were prepared. The prepared cubes in moulds were kept at temperature of 270±20 and 90 percent humidity for 24 hours under wetted gunny bags. After 24 hours, all cubes were submerged in water for curing for remaining 27 days.

For evaluation of cubes durability, 90 days age cubes were kept in Na_2SO_4 and $MgSO_4$ solutions. The cubes cast with PW and TDWW were kept in 1%, 2%, 3%, 4% concentration of Na_2SO_4 and $MgSO_4$ solutions for eight months. These concentrations of sulfates mentioned in ACI 318-99, and prevailed many parts of the world [16]. The concentrations of sulfates were prepared by dissolving in distilled water. The concentration of sulfates solutions was renewed once in four months. The effect of sulfates on the cubes performance in durability cast with PW and TDFWW was estimated by the losing in compressive strength. Compressive strength losing was calculated:

= [R-T]/RX100, T may be T_1, or T_2, or T_3 or T_4

Where R, 90 days age of cubes made with potable water and cured in potable water, is compressive strength of reference cubes. Where T, made with PW or TDWW, is compressive strength of test cubes, kept in sulfate solutions. T_1 is made with PW kept in sodium sulfate solution, T_2 is made with TDWW kept in sodium sulfate solution, T_3 is made with PW kept in $MgSO_4$ solution, T_4 is made with TDWW kept in $MgSO_4$ solution.

III. RESULTS AND DISCUSSION

A. Effect of Na_2SO_4 on T_1 Cubes

Decrease in compressive strength of T_1 specimens made with PW kept in Na_2SO_4 solutions is shown in Fig 3.1. As is evident in Fig 3.1, compressive strength was decreased as age progresses and concentration increased. Decrease in compressive strength, at 2, 4, 6, 8 months, in 4% sodium sulfate solution, was 4.44, 8.98, 10.65, and 13.30% compared to reference cubes R.

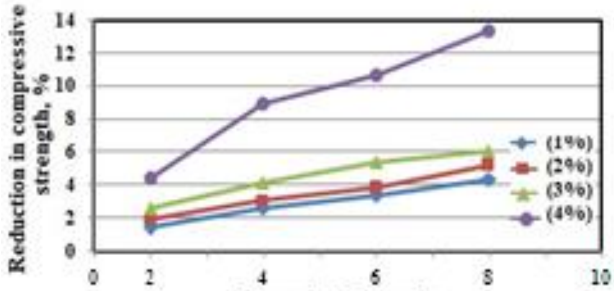

Fig 3.1 Reduction in compressive strength of T_1 specimens immersed in sodium sulfate solution

B. Effect of Na2SO4 on T2 Cubes

Fig 3.2 shows, Decrease in compressive strength of T_2 cubes made with TDWW kept in Na_2SO_4 solutions. Fig 3.2 is evident that compressive strength was reduced as age progresses and concentration increased. Reduction in compressive strength, at 2, 4, 6, 8 months, in 4% sodium sulfate solution, was 4.25, 8.98, 10.24, and 12.50% respectively compared to reference specimens R.

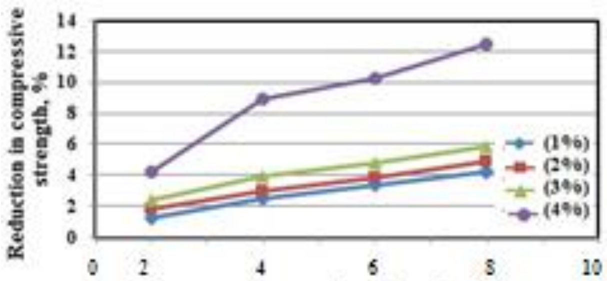

Fig 3.2 Reduction in compressive strength of T_2 specimens immersed in sodium sulfate solution

Mechanism of Na_2SO_4:

Sodium sulfate + Calcium hydroxide → Gypsum

Gypsum + Tetra calcium aluminum hydrate→ Ettringite

Ettringite caused the expansion of cement matrix, leading to instability. Decrease in compressive strength in T_1 specimens made with PW was a little higher compared to T_2 specimens made with TDWW.

C. Effect of MgSO4 on T3 Cubes

Decrease in compressive strength of T_3 cubes made with PW immersed in magnesium sulfate solutions is depicted in Fig 3.3.

As is evident in Fig 3.3, compressive strength of cubes was reduced as age and concentration increased. Reduction in compressive strength, at 2, 4, 6, 8 months, in 4% sodium sulfate solution, was 5.92, 11.45, 14.45, and 17.98% respectively compared to reference specimens R

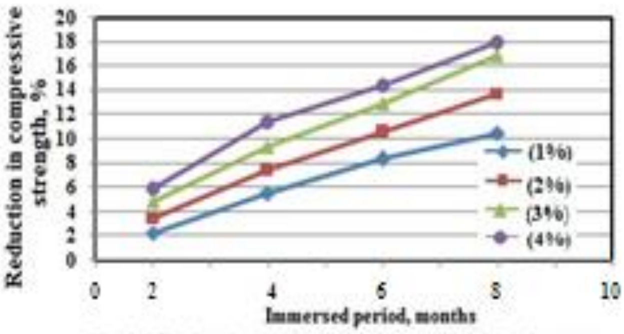

Fig 3.3Reduction in compressive strength of T_3 specimens immersed in magnesium sulfate solution

C.Effect of MgSO4 on T4 Cubes

Fig 3.4 shows, Decrease in compressive strength of T_4 cubes made with TDWW immersed in magnesium sulfate solutions. Fig 3.4 is revealed that compressive strength of cubes was decreased as age and concentration increased. Reduction in compressive strength, at 2, 4, 6, 8 months, in 4% sodium sulfate solution, was 5.89, 10.98, 14.24, and 17.50% respectively compared to reference specimens R.

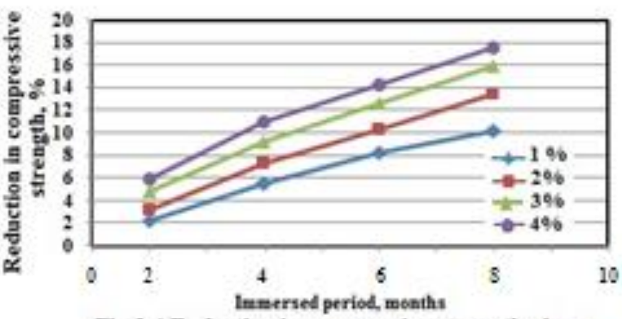

Fig 3.4 Reduction in compressive strength of T_4 specimens immersed in magnesium sulfate solution

Mechanism of $MgSO_4$:

Magnesium sulfate + calcium hydroxide → magnesium hydroxide

Magnesium sulfate + Calcium silicate hydrate → Magnesium silicate hydrate

Magnesium silicate hydrate is lower in binding capacity and non-cementitious material. Decrease in compressive strength in T_3 specimens made with PW is almost synonymous compared to T_4 specimens made with TDWW.

Eventually, result revealed that $MgSO_4$ was more danger than the Na_2SO_4 in same concentration and same age. But in the sulfates solutions, performance of specimens cast with TDWW was almost same compared to specimens cast with PW.

IV. CONCLUSION

Cubes kept in Na_2SO_4 solutions, decrease in compressive was almost same in cubes cast with PW and TDWW. Cubes kept in $MgSO_4$ solutions, decrease in compressive was almost same in cubes cast with PW and TDWW. Decrease in compressive strength of cubes kept in Na_2SO_4 was less than cubes kept in $MgSO_4$ solution. TDWW may recommend for use in cement and fly ash mortar.

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