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Partial Replacement of Cement by ETP Sludge in Building Materials

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Abstract: ***Tirupur is popularly known as the "Banian City" of South India, since it is superior in knitted ready-made garments. According to records of the Tamilnadu state pollution control board (TNPCB), there are 830 industries engaged in textile dyeing processes in Tirupur. Common effluent treatment plants (CETPs) and several individual Effluent Treatment Plants (ETPs) are developed for the treatment of their liquid effluents, and sludge is generated during the treatment process as a result of chemical coagulation, which is becoming a serious disposal issue. Utilization of waste materials and byproducts is a partial solution to environmental and ecological problems. It also has numerous indirect benefits such as reduction in landfill cost, saving in energy, and protecting the environment from possible pollution effects. In this study efforts have been made to use non-biodegradable dyeing Effluent Treatment Plant (ETP) sludge as a partial replacement of cement in concrete and floor tiles. In concrete, a percentage replacement ranging from 0 % to 10% and in tiles replacement ranging from 0% to 20% in the base layer were considered. Compressive strength, Split Tensile strength, Flexural strength for Concrete and water absorption, wet transverse strength, wearing resistance for tiles were carried out and a good strength gain with the addition of admixture was observed.***

Keywords: ETP, CETP, Wet Transverse Strength

1. Introduction

Tirupur is the "knitwear capital" of India. It has emerged with the textile industry in India for the past three decades. There are about 3000 sewing units, 1326 knitting units, 730 dyeing units and other ancillary units. Even though it provides employment to 15,000 people and generates export revenue of around Rs. 15 billion per year, (Jayanth sarathi N et al). They pose very high pollution threat and environmental damage. The textile effluents after primary treatment results in the formation of sludge which is commonly known as Effluent treatment plant (ETP) sludge, which cause negative impacts for human as well for environment.

As per Central pollution control board (2005), in Tamilnadu, hazardous waste of 4 Common Effluent Treatment Plant Sludge (CETPs) disposed of in secured landfill within their premises, of 2 other CETPs is stored on an impervious common place and of the remaining 23 CETPs is stored within CETP's premises. According to the TNPCB (Tamil Nadu Pollution Control Board), 8.8-crore liters of effluents, after primary treatment in effluent treatment plants, are being let out into the Noyyal every day. Sludge which is openly dumped leads to soil and ground water contamination. Land filling and incineration is not a proper method of treatment, since the landfill leaches and cause threat to the residents. A Problem with incineration is that the residual ash and that which escapes with the flue are toxic metals. As per Environmental cell division Coimbatore, there are three methods of managing the sludge, they are (1)Vermi compost,(2)Bio compost and (3) Conversion of textile sludge to building materials. Experimental determination of property of sludge indicates that the use of this sludge as partial replacement of cement is possible up to certain extent. When the sludge is used for construction purpose, leaching will occur, if it is subjected to heavy rainfall.

2. Experimental Program

2.1Materials

Sludge
The textile sludge was obtained from a dyeing industry at Tirupur. The sludge was dried for 24 hours to a temperature of 100^0C in order to remove the moisture content present in it. The dried sludge which passed through 600 micron IS sieve was used for concrete and tiles. Sludge has lower specific gravity and more water absorbing capacity than cement.

Cement
Cement used in the manufacture of concrete is 53 grade ordinary portland cement conforming to IS 12269(1987). For tiles PPC conforming to IS 1489-1(1991) was used.

Fine aggregate
River sand conforming to grading zone-II as per IS 1237:2012 was used as fine aggregate. The maximum grain size as 0.62mm, specific gravity as 2.67 having water absorption of 1.6% was observed.

Coarse aggregate
Coarse aggregate comprised a maximum size of 20 mm having specific gravity of2.75and water absorption as 0.5% was utilized in this study.

Lime stone chips and lime stone powder.
Lime stone chips of size 6mm was used for the formation of mosaic tiles.

2.2 Methodology

The specific gravity (IS: 4031(part 11) – 1980) of the cement and sludge was determined using a density bottle of 50 ml capacity. Chemical properties of the sludge was tested in the Environmental Engineering and chemistry Laboratory. The inorganic soluble salts (expressed in mg/l) were analyzed by making sludge to water in the dilution ratio 1:5 to extract the chemicals present in it. For this, 20 g of dry sludge was added in100 ml distilled water, shaken well and kept for settling for about 30 minutes. Then, the sludge–water suspension was filtered through a Whatman No.1 filter paper and the clear filtrate was subjected to chemical analysis.

Mix Proportions

Concrete

The properties of ETP sludge was studied and the Effluent Treatment Plant (ETP) sludge was added as a partial replacement of cement in concrete with various proportions such as 0%,2%,4%,6%,8% and 10%.Here the water cement ratio is fixed as 0.4.For concrete, cubes of size 150×150×150mm, cylinders of size 150mm diameter and 300mm height and prisms of size100×100×410mm were caste with and without water proofing admixture. Compressive strength, split tensile strength and flexural for concrete were conducted as per IS specifications. Different percentage replacement of sludge in the concrete mix and corresponding weight proportions of cement, fine aggregate, coarse aggregate and sludge is given in Table 1.

Table 1: Mix proportions and constituents weight for concrete

% Replaced	Design mix proportion by weight			Sludge (kg)
	Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	
0%	1	1.032	2.79	0
2%	0.98	1.032	2.79	0.02
4%	0.96	1.032	2.79	0.04
6%	0.94	1.032	2.79	0.06
8%	0.92	1.032	2.79	0.08
10%	0.9	1.032	2.79	0.1
10%+ admixture	0.9	1.032	2.79	0.10+ admixture

Floor Tiles

Mosaic tiles have been made which contains top and base layers. Top layer contains lime stone chips, cement and lime stone powder in the ratio 1:2:1. Base layer consists of cement and sand in the ratio 1:3. In mosaic tiles, cement was replaced by sludge with various percentages of 0%, 5%, 10%,15% and 20% in the base layer. Cement concrete flooring tiles of size 300 × 300 × 25 mm were made as per IS1237-2012 and tested for the water absorption, wet transverse strength and wearing resistance for various percentage of sludge. Different percentage replacement of sludge in the tile mix and corresponding weight proportions of cement, sand and sludge is given in Table 2.

Table 2: Mix Proportions for base layer of mosaic tiles

% Replaced	No. of Samples	Cement (kg)	Sand (kg)	Sludge (kg)
0%	18	1	3	0
5%	18	0.95	3	0.05
10%	18	0.9	3	0.1
15%	18	0.85	3	0.15
20%	18	0.8	3	0.2
20%+admixture	18	0.8	3	0.20+ admixture

3. Results and Discussions

3.1 Concrete

Concrete cubes, cylinders and prisms casted were tested for finding compressive strength, split tensile strength and flexural strength.

3.1.1 Compressive strength

For concrete, 7 and 28 day compressive strength has been tested as per IS 516-1959.Compressive strength observed for 7 days and 28 days curing for different mix proportions are given in Table 3.

Table 3: 7 day and 28 day compressive strength for different mix Proportions

Mix proportions	7 days		28 days	
	Load (t)	Compressive Strength (N/mm^2)	Load (t)	Compressive strength ((N/mm^2)
0%	86.0	37.50	89.25	38.9
2%	80.5	35.09	89.00	38.8
4%	45.0	19.62	62.50	27.25
6%	48.75	21.25	63.00	27.47
8%	43.5	19.09	62.00	27.03
10%	39.5	17.50	60.50	26.38
10%+admixture	85.0	37.06	91.75	40.00

Fig.1 given below shows the compressive strength of concrete cubes for various percentage replacement of cement by sludge.

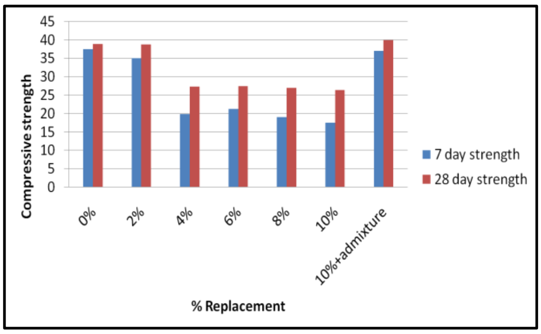

Figure 1: Compressive strength of concrete cubes for various percentage replacement of cement by sludge

It has been found that there is no considerable variation of strength for compression while cement is replaced by sludge with 2 percentage and also it has been found that there is an increase in compressive strength in the presence of admixture.

3.1.2 Split Tensile strength

Split tensile strength was carried out per IS 5816-1970.Splitting tensile strength has been conducted for concrete cylinders, which is an indirect method of finding tension in concrete. Split tensile strength and loads observed for different mix proportions are given in Table 4.

Table 4: 7 day and 28 day Split tensile strength for different mix proportions

Mix proportions	7 days		28 days	
	Load (t)	Split Tensile Strength (N/mm^2)	Load (t)	Split Tensile strength (N/mm2)
0%	18.00	2.49	19.00	2.63
2%	16.75	2.32	20.75	2.87
4%	14.75	2.04	16.00	2.22
6%	15.75	2.18	16.25	2.25
8%	15.00	2.08	15.5	2.18
10%	12.75	1.78	15.00	2.15
10%+ admixture	17.00	2.35	21.25	2.94

Fig. 2 given below shows the Split tensile strength of concrete cylinders for various percentage replacement of cement by sludge.

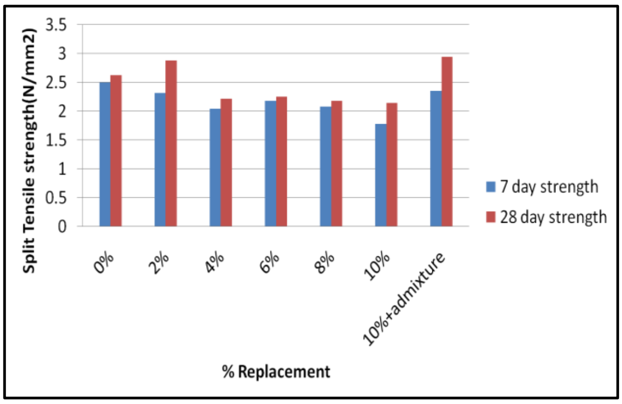

Figure 2: Split tensile strength of concrete for various percentage replacement of cement by sludge

There is a slight increment in split tensile and flexural strength for 2% replacement compared to control specimen and also test results shows that there is an increase in split tension in the presence of admixture.

3.1.3 Flexural strength

Flexural strength was carried out for 7days and 28 days curing as per IS 516-1959. Table. 5 given below shows the flexural strength and loads observed for different mix proportions.

Table 5: 7 day and 28day flexural strength for different mix proportions

Mix proportions	7 days		28 days	
	Load (kg)	Flexural Strength (N/mm^2)	Load (kg)	Flexural Strength (N/mm^2)
0%	1735	5.39	1835	5.59
2%	1700	5.18	1855	5.65
4%	1125	3.43	1510	4.63
6%	1270	3.87	1525	4.64
8%	1115	3.39	1365	4.17
10%	1035	3.15	1350	4.11
0+admixture	1755	6.09	1845	5.61

Fig. 3 given below shows the flexural strength of concrete prisms for various percentage replacement of cement by sludge.

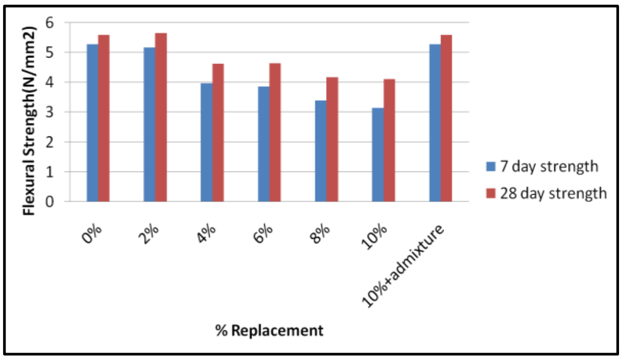

Figure 3: Flexural strength of concrete prisms for various percentage replacement of cement by sludge

Flexural strength for 2% replacement is found to be increased compared to control specimen and also test results shows that there is an increase in flexural strength in the presence of admixture.

3.2Floor tiles

Floor tiles casted with sludge replacing cement in the base layer was tested for water absorption, wet transverse strength and wear resistance.

3.2.1 Test for Water absorption

Water absorption was done as per IS1237-2012.Water absorption observed for 14 days and 28 days curing for different mix proportions are given in Table. 6.

Table 6:14 day and 28 day water absorption for different mix proportions

Mix proportions	Water Absorption (%)	
	14 days	28 days
0%	3.76	3.26
5%	4.72	4.23
10%	5.81	5.12
15%	6.23	5.82
20%	6.62	6.19
20%+admixture	3.48	3.14

Fig. 4given below shows the water absorption of tiles for various percentage replacement of cement by sludge.

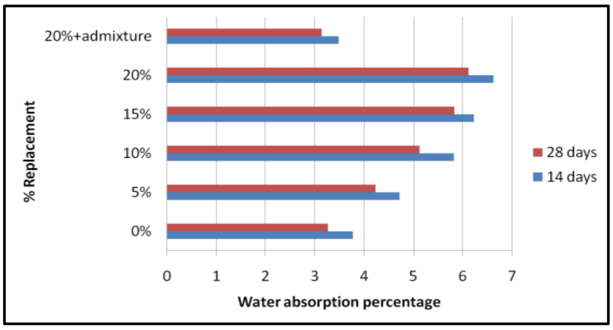

Figure 4: Water absorption of tiles for various percentage replacement of cement by sludge

Tile specimens are satisfying the water absorption criteria as mentioned in IS1237-2012, such that water absorption should not exceed 10% by mass of cement. Even though water absorption is more due to the increased percentages of sludge replacement, it is satisfying with the limits of IS

1237-2012 and it is found to be decreasing in the addition of admixture.

3.2.2 Wet transverse strength

Tile specimens were tested for wet transverse strength for 14 day and 28 day as per is1237-2012.Table.7given below shows the wet transverse strength for 7 days and 28 days curing for different mix proportions.

Table 7: 14 day and 28 day wet Transverse strength for different mix proportions

Mix proportions	14 days		28 days	
	Load (kg)	Wet Transverse Strength (N/mm^2)	Load (kg)	Wet Transverse Strength (N/mm^2)
0%	185.6	3.90	236.00	4.90
5%	174.6	3.68	237.17	4.50
10%	171.6	3.62	187.50	3.96
15%	138.0	2.91	159.17	3.36
20%	132.3	2.79	142.50	2.99
20%+ admixture	192.6	4.06	242.83	5.23

Fig. 5 given below shows the wet transverse strength of mosaic tiles for various percentage replacement of cement by sludge.

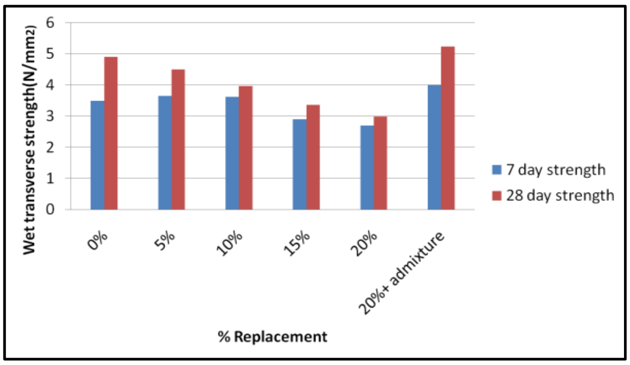

Figure 5: Wet transverse strength of tiles for various percentage replacement of cement by sludge

Tiles up to 15% of sludge comply with the breaking requirements as per IS 1237-2012, which is not less than 3 N/mm^2 and in the presence of admixture there is an increase in strength.

3.2.3 Resistance to wear

As per IS 1237-2012 average wearing resistance should not exceed 3.5mm. Wearing resistance has been checked for top layer as well as base layer, since the sludge has added in the base layer of mosaic tiles. The amount of wear was determined from the difference in thickness readings obtained by measuring thickness using deflectometer dial gauge before and after the abrasion of the specimen. The value obtained was checked with the average loss in thickness of the specimen obtained by formula given in appendix G of BIS (IS-1237-2012).Table.8 shows the wearing resistance of tiles after 28 days curing.

Table 8: Wearing resistance of tiles

% Replaced	Loss in Thickness (Top Layer)	Loss in Thickness (base layer)
0%	0.99 $\pm$ 0.039	1.65 $\pm$ 0.193
5%	0.937+0.065	1.02+0.013
10%	0.921$\pm$ 0.027	2.12 $\pm$ 0.102
15%	0.885 $\pm$0.081	2.16 $\pm$ 0.11
20%	0.995 $\pm$0.054	2.641 $\pm$ 0.077
20%+admixture	0.913$\pm$0.047	1.85 $\pm$ 0.06

Wearing resistance got increased with the addition of water proofing admixture.

4. Conclusion

The study arriving the utilization of the textile dyeing industry effluent treatment plant (ETP) sludge in concrete and mosaic tiles, leads to the following conclusions.

- Addition of sludge as a replacement for cement resulted with decrease in strength of concrete and tile.
- There is a considerable increase in strength for concrete and tiles in the presence of water proofing admixture.
- Concrete in which cement is replaced by sludge can be used for pavement construction.
- For tiles, sludge can be used up to 20% as a partial replacement of cement in the presence of admixture.

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