A study on engineering properties of textile ETP sludge based cement concrete

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Abstract- Textile industry produces waste at a rate of 70-90g/person equivalent/day. Disposal of these huge wastes is creating ecological issues. The literature provides information about the presence of some percentage of silica and calcium content in the textile ETP sludge which can be replaced with cement. The characterization of the textile ETP sludge as a binder was carried out as per the code provisions (IS 1727-1967). The literature may not highlight basic mix design details, hence an attempt has been made to investigate the role of total water content required for producing textile ETP sludge based concrete with a partial replacement for cement and the compatibility of the textile ETP sludge with admixtures was observed. From the present experimental work it is known that textile ETP sludge can be replaced partially for cement in concrete and it is evident that the ETP sludge concrete performs well under compression and tension as like that of conventional concrete.

Keywords - Textile Industry, Water/Binder Ratio, Textile ETP Sludge, optimization

I INTRODUCTION

India has several industrial sectors, among that textile industry is the oldest and has traditional values. There are more than 700 large textile mills mainly concentrated in Ahmadabad, Bombay, Tirpur, Erode, Coimbatore, Kanpur and Delhi. Out of 21076 units in India, Tamilnadu alone has 5285 units [1] whereas Maharashtra has the next highest number of units. Textile industries involves processing or converting of raw materials into finished cloth materials by employing various processes, operation and consumes large quantity of water and produces extremely waste effluents. While treating the waste water released from textile industries huge volume of sludge is generated.

Sludge is an unavoidable byproduct of primary, secondary and advanced wastewater treatment processes. It is typically generated at a rate of 70–90 g/person equivalent per day [2, 3, and 4]. Sludge contains between 1 to 4% weight of solid materials, and the rest is water. Importantly, sludge contains pollutants and unstable pathogen content, therefore leading to potential health and environmental hazards [5, 6]. Compositions of sludge vary considerably depending on the wastewater composition and the treatment processes used [7].

Cement and concrete are manufactured in very large quantities for construction and other industries [8, 9, 10 and 11].The carbon dioxide emitted from the worldwide production of ordinary Portland cement corresponds to approximately 7% of the total greenhouse gas emissions into the atmosphere. Hence there is a demand on by-product which can partially replace cement.

II MATERIALS AND METHODS

A. Textile ETP sludge

The textile ETP sludge used in the present investigation was taken from KSIC Mysore. The collected wet sludge was sun dried. The dried sludge was then grounded to fine powder and sieved in 90µ sieve and the fines passing through the sieve was used in the experimental work. The Physio-chemical characterisation of the textile ETP sludge was done as per IS 1727-1967 and the results are shown in the table.1.

Specific gravity	**1.75**
Specific surface	**3691.5cm^2/g**
colour	**grey**
SiO_2	**3.98%**
Al_2O_3	**0.16%**
CaO	**4.13%**
Fe_2O_3	**6.62%**
Mgo	**0.64%**
Na_2O	**0.50%**
K_2O	**0.51%**
TiO_2	**<0.0003%**
LOI	**82.40%**

Table 1: Physio-chemical Characteristics of textile ETP sludge

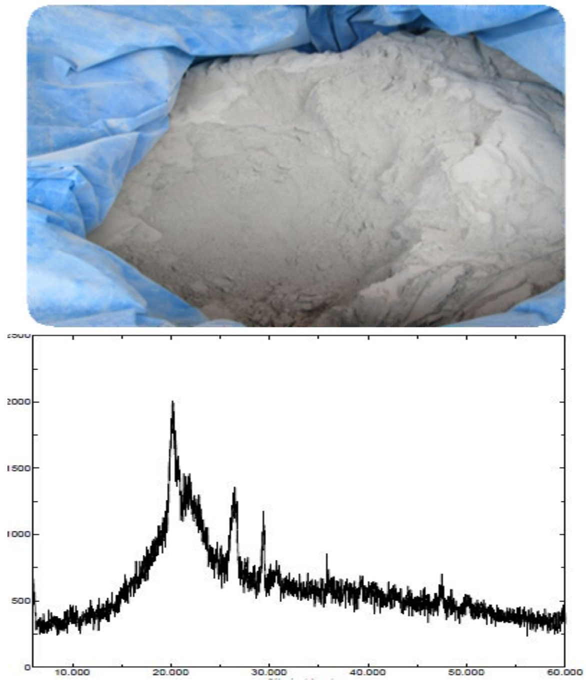


Fig 1: Powdered textile ETP sludge and its XRD analysis

B. Cement

For this experimental investigation OPC 43 grade cement has been used (Coromandal king) and the cement is tested as per IS 4031- 1988.

C. Fine aggregate

For the present experimental work, locally available river sand has considered. The different tests conducted on fine aggregate and the results obtained are tabulated in table 2, the tests are conducted as per IS: 2386(part, 3) 1963(7).

D. Coarse aggregate

In the present investigation 20mm down size aggregates used as coarse aggregates and the physical properties are evaluated as per IS 2386 and the results are tabulated in table 2.

Table 2: Physical properties of fine aggregate and coarse aggregate

Properties	unit	Fine aggregate	Coarse aggregate
Fineness modulus	**-**	**2.82**	**7.45**
Specific gravity	**-**	**2.62**	**2.57**
Water absorption	**%**	**1.20**	**2.6**
Zone	**-**	**Zone II of IS 2386 (Part 3) - 1963 (7)**	**-**

E. Admixtures (Conplast SP430 and Conplast P211)

Conplast SP430 and Conplast P211 are the two different superplasticizers used in this present study which are brown liquids and conforms to IS: 9103:1999 and ASTM C494 respectively.

III. MIX DESIGN FOR TEXTILE ETP SLUDGE BASED CEMENT CONCRETE

A. Mix design for the optimization of water/binder

In this present study three different mixes were carried out i.e. series1 (S1), series2 (S2) and series3 (S3).

- S1 series consists of 5 different mixes (S1M1, S1M2, S1M3, S1M4 and S1M5) which is designed by keeping cement content as constant (320kg/m^3) and varying the water content (140, 160, 180, 200 and 208 liters). Also for each mix, cement is replaced by 5% sludge.
- S2 series consists of 4 different mixes (S2M1, S2M2, S2M3, and S2M4) which is designed by keeping cement content as constant (340kg/m^3) and varying the water content (140, 160, 180 and 200 liters). Also for each mix, cement is replaced by 5% sludge.
- S3 series consists of 4 different mixes (S3M1, S3M2, S3M3, and S3M4) which is designed by keeping cement content as constant (360kg/m^3) and varying the water content (140, 160, 180 and 200 liters). Also for each mix, cement is replaced by 5% sludge.

The above mentioned cement and water quantity are fixed as per IS 10262-2009 codal provision and considering the economy. Table 3 shows the mix proportions for series S1, S2 and S3.

Table 3: Mix proportion (S1, S2 and S3) for 1m^3 of textile ETP sludge

Mix	Cement	Sludge	Water	W/B	FA	CA
	Kg	Kg	Liter	ratio	Kg	Kg
S1M1	304	16	140	0.43	875	1092
S1M2	304	16	160	0.50	852	1063
S1M3	304	16	180	0.56	848	1016
S1M4	304	16	200	0.62	842	970
S1M5	304	16	208	0.65	851	941
S2M1	323	17	140	0.41	828	1122
S2M2	323	17	160	0.47	845	1055
S2M3	323	17	180	0.53	841	1008
S2M4	323	17	200	0.59	835	962
S3M1	342	18	140	0.39	821	1112
S3M2	342	18	160	0.44	837	1044
S3M3	342	18	180	0.50	814	1016
S3M4	342	18	200	0.55	809	969

B. Mixes considered for compatibility study of superplasticizer

Conplast P211 was used at rate of 0.5%, 0.75% and 1% by weight of cement and Conplast SP430 was used at rate of 1%, 1.5% and 2% by weight of cement. Six different mixes were prepared using mix S2M2 and superplasticizers (Conplast P211 and Conplast SP430).

A1: mix S2M2 + 0.5% Conplast P211
A2: mix S2M2 + 0.75% Conplast P211
A3: mix S2M2 + 1% Conplast P211
B1: mix S2M2 + 1% Conplast SP430
B2: mix S2M2 + 1.5% Conplast SP430
B3: mix S2M2 + 2% Conplast SP430

C. Mix design for the optimized mix considering a varying quantity of textile ETP sludge

In order to evaluate the maximum amount replacement of cement with textile ETP sludge, partial replacement of cement with textile ETP sludge was considered (0, 5, 7 and 9%).

Table 4: Mix proportion for C_{ref}, C1, C2 and C3 for 1m^3 concrete

Mix (S2M2)	W/B	Cement	Sludge	Sludge	Water	FA	CA
	ratio	Kg	%	Kg	Liter	Kg	Kg
C_{ref}	0.47	340.00	0	0	160	845	1055
C1	0.47	323.00	5	17.00	160	845	1055
C2	0.47	316.20	7	23.80	160	845	1055
C3	0.47	309.40	9	30.60	160	845	1055

IV. EXPERIMENTAL RESULTS AND DISCUSSION

A. Investigation on water to binder ratio

Present experimental investigation consists of workability test and compressive strength test on series S1, S2 and S3. The tests were carried on concrete with cement replaced by textile ETP sludge. The tests were conducted as per the standard specifications i.e. minimum three specimens of cubes, and the average value is tabulated. The tests results are tabulated in table 6 with appropriate graphical representation.

Table 5: Slump and compression strength of series S1, S2 and S3

Mix	**W/B**	**Slump(mm)**	**Compression Strength(N/mm^2)**		
			3days	**7days**	**28days**
S1M1	**0.43**	**10**	**10.72**	**16.37**	**20.88**
S1M2	**0.50**	**13**	**11.72**	**18.37**	**23.88**
S1M3	**0.56**	**16**	**15.26**	**18.09**	**22.97**
S1M4	**0.62**	**35**	**10.68**	**16.13**	**17.74**
S1M5	**0.65**	**75**	**8.24**	**10.68**	**12.28**
S2M1	**0.41**	**10**	**16.13**	**19.80**	**24.28**
S2M2	**0.47**	**17**	**18.78**	**22.80**	**28.34**
S2M3	**0.53**	**42**	**13.29**	**16.13**	**21.19**
S2M4	**0.59**	**75**	**10.68**	**11.11**	**14.44**
S3M1	**0.39**	**11**	**18.74**	**20.49**	**25.50**
S3M2	**0.44**	**15**	**20.27**	**28.12**	**35.55**
S3M3	**0.50**	**30**	**15.69**	**19.18**	**23.97**
S3M4	**0.55**	**64**	**11.77**	**10.90**	**14.17**

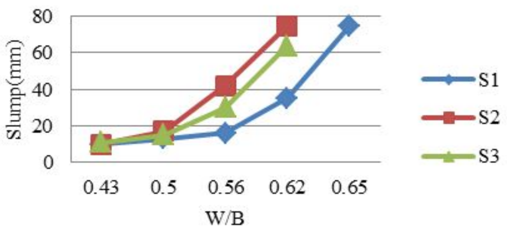


Fig 2: Slump test results of series S1,S2 and S3

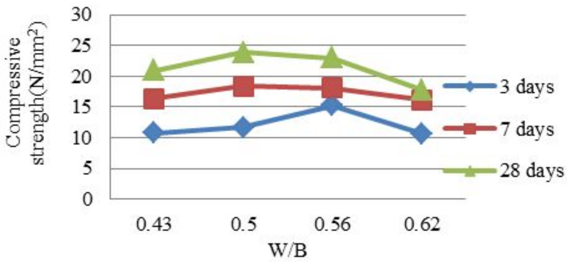


Fig 3: Compression test results of series S1

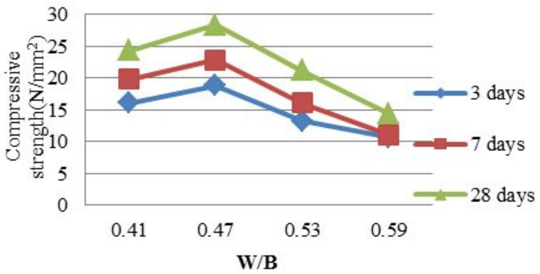


Fig 4: Compression test results of series S2

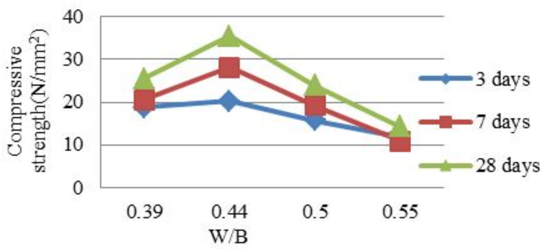


Fig 5: Compression test results of series S3

From the figure 2 it can be observed that with the increase in w/b ratio the slump has been increased in all the three series S1, S2 and S3. It is also observed can be observed the slump has increased in all the three series S1, S2 and S3, it has never crossed 75mm even after maximum water content. This may be due to the presence of textile ETP sludge; this may be due to the fine state of division of the textile ETP sludge. From the figure 3, 4 and 5 it is evident that mix S1M2, S2M2 and S3M2 has achieved higher compressive strengths in the series S1, S2 and S3 respectively. Also it is observed that mix S3M2 has achieved 20.28% and 32.88% more strength than the mixes S2M2 and S1M2. But if we consider the figure (mix S2M2 has a slump value of 17mm and S3M2 has a slump value of 15mm) the slump values of mixes S2M2 and S3M2 are almost same.

B. Optimized mix with a varying quantity of superplasticizer

In this present work slump test has been done to check the workability of the mix. The Compression Strength test was done on cubes for mixes A1, A2, A3, B1,B2 and B3 at 3, 7, and 28 days of curing and results obtained are tabulated below and the suitable graphs are plotted.

Table 6: Compressive strength of Optimized mix with a varying quantity of superplasticizer

Admixture	**Mix**	**Slump**	**Compressive strength**		
			3 days	**7 days**	**28 days**
		mm	**N/mm^2**	**N/mm^2**	**N/mm^2**
-	**S2M2**	**17**	**18.78**	**22.80**	**28.34**
Conplast P211	**A1**	**70**	**9.32**	**10.95**	**13.50**
	A2	**85**	**6.10**	**9.46**	**11.44**
	A3	**110**	**1.76**	**4.68**	**7.33**
Conplast SP430	**B1**	**20**	**6.13**	**13.50**	**26.45**
	B2	**25**	**10.60**	**17.28**	**28.90**
	B3	**30**	**13.80**	**19.00**	**35.00**

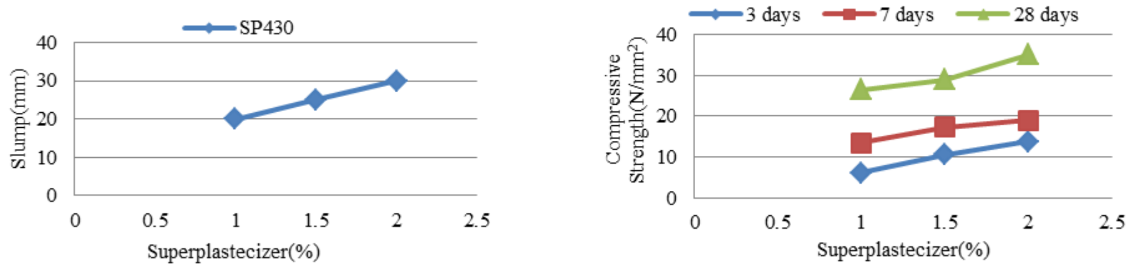


Fig 6: Slump and Compressive strength for a varying percentage of SP (SP430)

From the figure 6 it can be observed that with the increase in the percentage of superplasticizer slump value of mixes B1, B2 and B3 gradually increases and it is 50%, 60% and 66.66% higher than the slump value of the mix S2M2. Also from the figure it is evident that with the increase in the percentage of sludge 3days compressive strength of the mixes B1, B2 and B3 decreases by 76.3%, 45.66% and 25.42% w.r.t the 3days compressive strength of mix S2M2, 7days compressive strength of the mixes B1,B2 and B3 decreases by 40.8%, 24.3% and 16.7% w.r.t. the 7days compressive strength of the mix S2M2 and 28 days compressive strength of the mix B1 decreases by 6.9% w.r.t the 28 days compressive strength of the mix S2M2 and 28 days compressive strength of the mix B2 increases by 1.9% w.r.t the 28 days compressive strength of the mix S2M2 and 28 days compressive strength of the mix B3 increases by 23.5% w.r.t the 28 days compressive strength of the mix S2M2.

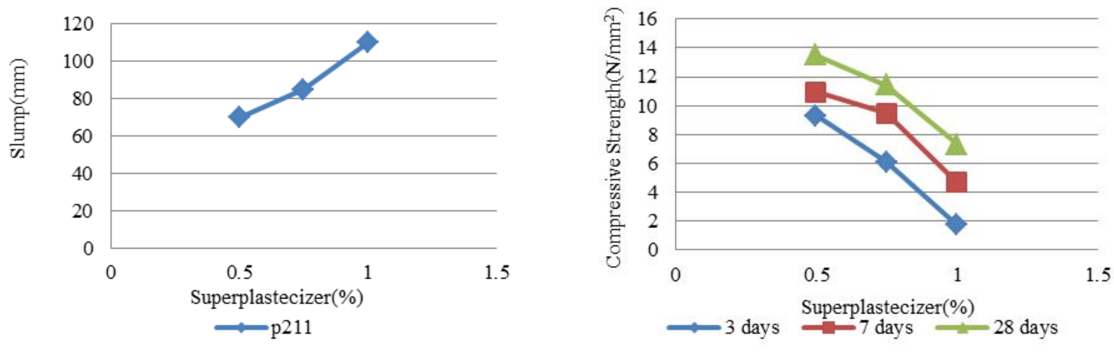


Fig 7: Slump and Compressive strength for a varying percentage of SP (P211)

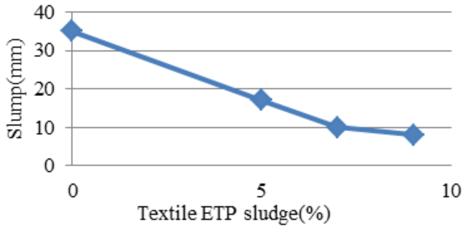
From the figure 7 it can be seen that with the increase in the percentage of superplasticizer slump value of mixes A1, A2 and A3 gradually increases and it is 82.85%, 85.88% and 89.15% higher than the slump value of the mix S2M2. Also from the figure it is evident that with the increase in the percentage of sludge the 3 days, 7days and 28 days compressive strength of the mixes A1, A2 and A3 gradually decreases by 52.36% 59.63% and 74.1% w.r.t the mix S2M2. This enormous decrease in the compressive strength shows that the superplasticizer Conplast P211 is not compatible with the concrete made with textile ETP sludge.

C. Percentile replacement of cement with sludge for the optimized mix S2M2

In this present work slump test has been done to check the workability. The Compression Strength test, split tensile strength test and flexural strength test was done for mixes C_{ref}, C1, C2 and C3 at 3, 7, and 28 days of curing and results obtained are tabulated below and the suitable graphs are plotted.

Table 7: Compressive strength of mixes C_{ref}, C1, C2 and C3

Mix(S2M2)	slump(mm)	Compressive strength(N/mm^2)		
		3 days	7 days	28 days
C_{ref}	35	18.60	25.43	34.33
C1	17	15.83	20.90	28.34
C2	10	9.70	16.56	21.45
C3	8	8.28	15.50	19.69



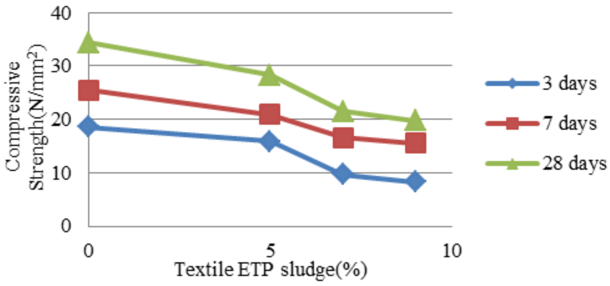


Fig 8: Slump test and Compressive strength of mixes C_{ref}, C1, C2 and C3

From the figure 8 it is clear that with the increase in the percentage of textile ETP sludge the slump value has been decreased from 35mm to 8mm. This may be due to the texture of the textile ETP sludge particles, these particle may entraps certain amount of water used in the mix. It is clearly shows that with the increase in the percentage of sludge, compressive strength of the mixes C1, C2 and C3 has been decreased gradually (17.4%, 37.5% and 42.6%) and also the rate of hydration of mix C1 is almost similar to the rate of hydration in mix C_{ref}.

Table 8: Split tensile strength of mixes Cref, C1, C2 and C3

Mix(S2M2)	Split tensile strength(N/mm^2)		
	3 days	7 days	28 days
C_{ref}	2.30	3.01	3.76
C1	1.16	2.02	2.72
C2	0.98	1.88	2.44
C3	0.91	1.75	2.27

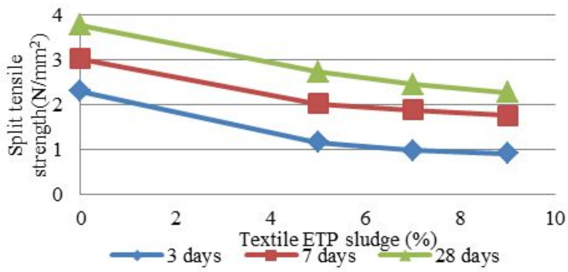


Fig 9: Split tensile test results of mixes C_{ref}, C1, C2, C3

From the figure 9 it is observed that with the increase in the percentage of sludge the 3days tensile strength of the mixes C1, C2 and C3 decreases by 49.5%, 59.38% and 60.4% w.r.t the 3days tensile strength of the mix C_{ref}. The 7days tensile strength of the mixes C1, C2 and C3 decreases by 32.8%, 37.5% and 41.8% w.r.t the 7days tensile strength of the mix C_{ref}. The 28days tensile strength of the mixes C1, C2 and C3 decreases by 27.6%, 35.1% and 39.6% w.r.t the 28days tensile strength of the mix C_{ref}.

Table 9: Modulus of rupture of mixes C_{ref} and C1

Mix(S2M2)	Flexural strength(N/mm^2)		
	3 days	7 days	28 days
C_{ref}	3.41	4.20	6.12
C1	2.34	3.61	5.17

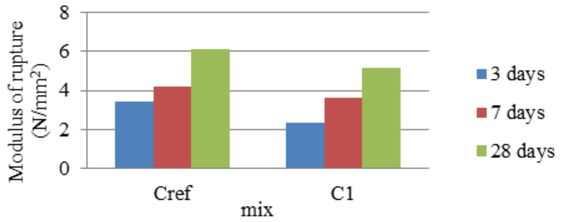


Fig 10: Test results of flexural strength

From the figure 10 it can be observed that the 3, 7 and 28 days modulus of rupture of mix C1 decreases by 31.3, 14.04 and 15.5% with respect to the reference concrete.

Table 10: Water absorption of mixes C_{ref} and C1

Mix(S2M2)	Water absorption (%)
C_{ref}	2.10
C1	2.54

From the table 10 it can be seen that the water absorption of the mix C1 has increased by 20.9% w.r.t. the mix $C_{ref.}$

V. CONCLUSIONS

From the experimental analysis and obtained results, the following conclusions are drawn.

1. Textile ETP sludge fulfills the basic properties of cementatious material, hence can be used as a binder in concrete.
2. ETP sludge based concrete performs and fulfills the basic properties of conventional concrete for the optimized water to binder ratio (0.47) and strength gaining mechanism is not uniform as like conventional concrete at initial period of time but it is as good as conventional concrete after 28 days.
3. As the increase in the percentage of ETP Sludge (5%, 7% and 9%) in concrete the compressive strength and split tensile strength seems to decrease (17.44%, 37.5% and 42.64%, 27.6%, 35.1% and 39.6%) and also weak in flexural strength (15%) and offers a good resistance to the water absorption (20.9%). However the workability of the mix decreases with the increase in the textile ETP sludge content.
4. Superplasticizer Conplast SP430 improves the compressive strength of the concrete made with textile ETP sludge (1.97% up to 23.5%) with respect to the conventional concrete. But it has a very minimum effect on workability. Hence superplasticizer Conplast SP430 is not advisable to use in concrete made with textile ETP sludge.
5. From the experimental results shows it can be concluded that upto 5% of cement can be replaced by textile ETP sludge without any unfavorable effect.

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