Papercrete: A Study of Paper Effluent Treatment Sludge as Partial Replacement for Cement

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Abstract

With increasing industrialization, the industrial by products (wastes) are being accumulated to a large extent, leading to environmental and economic concerns related to their disposal (land filling). Effluent treatment sludge (ETS), a bi-product from paper factory is a compressed partially de-watered product. The use of Effluent treatment sludge (ETS) in cement concrete mix will make it cost effective and environment friendly disposal of the product. Cement is an energy extensive industrial commodity and leads to the emission of a vast amount of greenhouse gases. By reducing the demand of cement, natural reserves of limestone can be preserved, energy can be saved and pollution due to CO2 can be reduced. The feasibility of effluent treatment sludge as a supplementary cementitious material with the physical characteristics of cement is studied. The study on strength characteristics of effluent sludge concrete in with nominal concrete is done and cost of production is evaluated.

Keywords: effluent treatment sludge (ETS), Paper concrete (papercrete), High Strength Concrete (HSC), Effluent treatment Sludge Concrete (ESC), Supplementary Cementitious Material (SCM)

I. INTRODUCTION

In order to make concrete industry sustainable, the use of waste materials in place of natural resources is one of the best approaches. Paper mill sludge is a major economic and environmental problem for the paper and board industry. An enormous quantity of waste paper sludge is generated all around the world. In India, 0.7% of total urban waste generated comprises of paper sludge. UK produces over 1.5 million tons of waste paper sludge annually (Sajad Ahmad, M. Iqbal Malik etal 2013). Paper mill sludge is a major economic and environmental problem for the paper and board industry. The material is a by-product of the de-inking and re-pulping of paper. The main recycling and disposal routes for paper sludge are land-spreading as agricultural fertilizer, incineration in plants at the paper mill, producing paper sludge ash, or disposal to landfill. The scope for landfill spreading is limited and is covered by an industry code of practice. In functional terms, paper sludge consists of cellulose fibers, fillers such as calcium carbonate and china clay and residual chemicals bound up with water. The moisture content is typically up to 40%.

While producing paper the various wastes are comes out from the various processes in paper industries. Due to the cement production greenhouse gases are emitted in the atmosphere. For producing 4 million t of cement, 1 million t greenhouse gases are emitted (R. Srinivasan, K. Sathiya and M. Palanisamy 2010). Also, to reduce the environmental degradation, this sludge has been avoided in mass level disposal in land. To eliminate the ozone layer depletion, production of cement becomes reduced. From the preliminary waste named as Effluent treatment sludge (ETS), due to its low calcium is taken out for our project to replace the cement utilization in concrete. For this, the effluent sludge is used as partial replacement in the concrete as high performance concrete. By utilizing this waste, the strength will be increased and also cost reduction in the concrete is achieved.

This project is concerned with experimental investigation on feasibility, cost, strength of concrete and optimum percentage of the partial replacement by replacing cement via 3%,5%,7%,10% of effluent treatment Sludge. Effluent treatment sludge is a waste product which is only use full to be used as landfill. The studies from journals showed a potential for the waste byproduct as a replacement for the cement. This waste product generated could only be used as landfills. Thus a potential of finding some better use for the byproduct could lead to a large scale reformation on environmental pollution. As paper is produced throughout the world in lots of factories thus by this decreasing the amount of free dumping of a useful waste byproduct.

II. SCOPE AND OBJECTIVE

1) To investigate the feasibility of Effluent sludge as Supplementary Cementitious Materials (SCM)
2) To find the influence of effluent sludge on the strength on concrete made with different cement replacement levels.

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3) Comparison of cost of nominal mix concrete and effluent sludge concrete.

The objective of this project is to find the compressive strength, split tensile strength and workability of concrete with blended effluent sludge cement. The water-to-binder ratio will be taken as 0.45 and four different replacement percentages of effluent sludge (3%, 5%, 7%, 10%) will be tested.

III. METHODOLOGY

A. Feasibility of Sludge:

1) Reason for Feasibility Study:

The feasibility study is done for finding if the ETS is capable of forming into a product with physical characteristics of cement. The feasibility study contains various steps for getting the physical characteristics of cement. The reason regarding the feasibility study is for the product being replaced in for cement and must be within the physical characteristics of cement. The sludge obtained was in bread slice shaped pieces compressed and partially de-watered.

2) Processes Involved in Feasibility Studies

1) The ETS is to be sundried to remove the water content.
2) Sun drying of ETS resulted in as hard and brittle sludge pieces.
3) Thus ETS was to be braised in Los-Angeles abrasion machine to break it into smaller bit so that it could be grinded into powdered form.
4) The ETS was then oven dried for complete water removal.
5) We grinded the ETS to powdered form.
6) To replace cement, we powdered the ETS and sieved it through 90 mm sieve to obtain the ETS in cement consistency.

3) Discussion

The test on feasibility had an expected result. We obtained the ETS in physical characteristics of cement.

B. Component Materials

- Component materials for concrete mixtures were:
- Portland Pozzolona cement (PPC)
- Fine aggregate
- Coarse aggregate
- Effluent sludge
- Water

1) Cement

In this work, Portland Pozzolona Cement of Shankarhas been used. It was procured from a single source and stored as per IS: 4032 – 1977. Care has been taken to ensure that the cement of same company and same grade is used throughout the investigation. The cement thus procured was tested for physical properties in accordance with the IS: 1489-1991(part 1)

The various physical properties of cement were found out and are tabulated in Table.3.1.

2) Coarse and fine Aggregates

The fine aggregate used was locally available m-sand without any organic impurities and conforming to IS: 383 – 1970 [Methods of physical tests for hydraulic cement]. The coarse aggregate chosen for SCC was typically round in shape, well graded and smaller in maximum size than that used for conventional concrete. The size of coarse aggregate used in self-compacting concrete was between 10mm to 16mm.The aggregates were tested for their physical requirements such as gradation, fineness modulus, specific gravity and bulk density in accordance with IS: 2386 – 1963 [Methods of test for aggregate for concrete] and is shown in table 3.2 and table 3.4. The aggregates were surface dried before use.

3) Water

Water used for mixing and curing was potable water, which was free from any amounts of oils, acids, alkalis, sugar, salts and organic materials or other substances that may be deleterious to concrete or steel confirming to IS :3025 – 1964 part22, part 23 and IS : 456 – 2000 [Code of practice for plain and reinforced concrete]. The pH value should not be less than 6. The solids present were within the permissible limits as per clause 5.4 of IS: 456 – 2000.

4) Effluent treatment sludge

Effluent treatment sludge is a product which was introduced for us in Hindustan paper limited factory at thalayolaparambhu. This was the residue from the newly manufactured paper in the factory. Thus from surveys it was found that these were in large amount in the waste dumping yard near the effluent treatment plant. They have various physical and chemical property.

The specific gravity of the sludge = 2
The color before drying grey
The color after drying brown
Water absorption = 7%

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IV. RESULTS

A. *Cube Test Results:*

Samples with 3%, 5%, 7% and 10% replacement of cement with effluent sludge were casted. The cubes were casted as per the procedure specified in IS 516:1959 and IS 456:2000. The strength of 3 samples were tested at 7 and 28 days using compression testing machine. The compressive strength values were compared with that of conventional concrete mix of M25.

Table – 1
Observed results for the cube casted for testing compressive strength

Concrete mixture	*Water/cement ratio*	*Slump (mm)*	*7-day strength*	*28-day strength*
ESC3	*.45*	*65*	*17.11*	*30.55*
ESC5	*.45*	*74*	*18*	*31.77*
ESC7	*.45*	*82*	*20.44*	*33.67*
ESC10	*.45*	*69*	*18.66*	*32.33*
Nominal	*.45*	*60*	*16.44*	*30*

Following the mix design specified in IS: 10262 (1982), samples were casted. The obtained results are shown in fig 1.

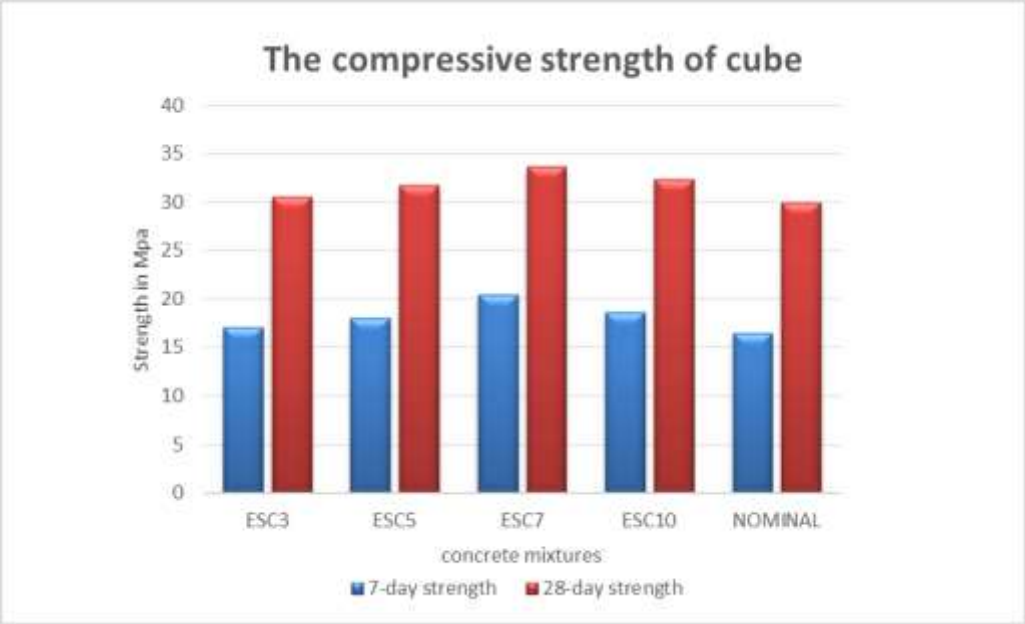

Fig. 1: Compressive Strength of Cubes

The 7 day compressive strength of a standard M25 concrete was obtained as 16.44N/mm^{2}and the 28 day compressive strength was obtained as 3oN/mm^2.From the above results, it is observed that the 7-day strength of 3%, 5%, 7% and 10% is greater than the expected strength of 16.44N/mm^2.The 28 day compressive strength of cube with 10% of cement replacement is only 32.33N/mm^2 which is lesser than 33.67N/mm^2.Therefore,it is observed that the cement can be safely replaced with effluent sludge up to 7%.

B. *Cylinder Test Results:*

1) Compressive strength of cylinder test results

The cylinders were casted as per the design mix specified in IS: 10262 (1982).The obtained results are shown in fig.5

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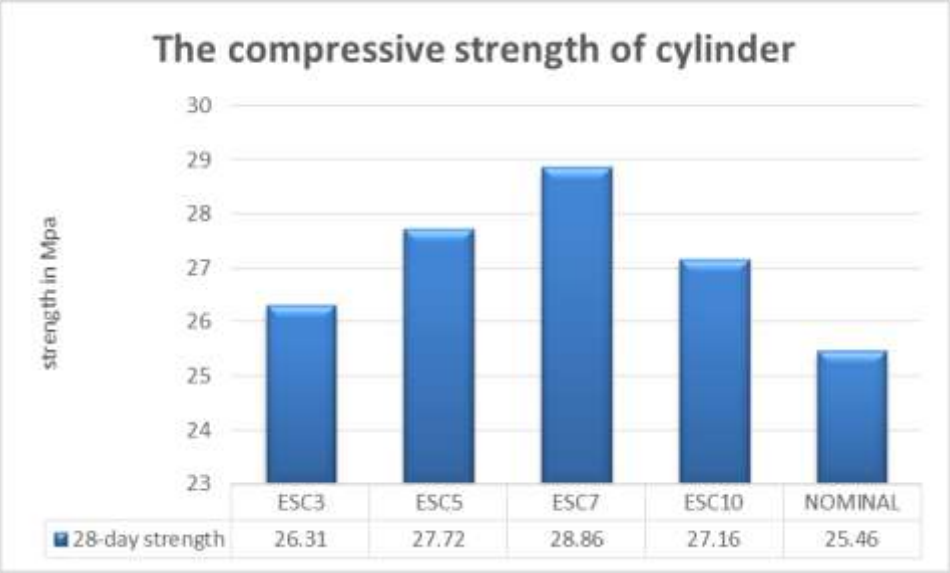

Fig. 2: Compressive Strength of Cylinder

The 28 day compressive strength of cylinder of the nominal sample was obtained as 25.46N/mm^2. Even though the strength has decreased with increase in % of sludge, all the four replacements of cement with effluent sludge are greater than the 28 day compressive strength of nominal sample. The maximum strength was obtained for 7% replacement which is 28.86N/mm^2.

2) Split tensile strength of cylinder test cylinders

The cylinders were casted as per the design mix specified in IS: 10262 (1982).The obtained results are shown in graph

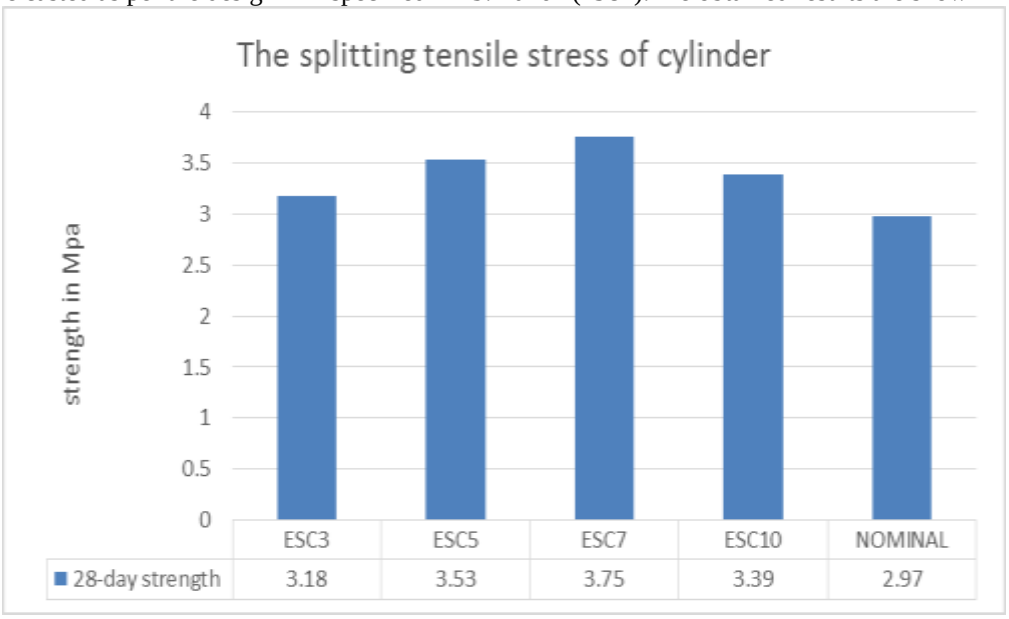

Fig. 3: Split Tensile Strength of Cylinder

The target split tensile strength is given by 0.7 times square root of f_{ck}which is 3.5N/mm^2.Thesplit tensile strength (28 day) of cylinder for the nominal specimen was obtained as 2.97N/mm^2. The cylinders with all percentage replacement of cement with effluent sludge have obtained a greater split tensile strength than 2.97N/mm^2. The maximum strength was obtained for 7% replacement which is 3.75N/mm^2.

V. COST ESTIMATION

The optimum content for the test is 7 % as we obtained the maximum strength from the results as 7% replacement of cement with the ETS. The cost estimations study is a comparative study on the making cost of 1m^3 of nominal cement concrete and 7 % ECS. The cost estimations could vary accordingly with the type of production. The cost estimation rates were an expert's opinion and not according to Kerala municipality values.

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Table – 2
Cost of materials in $1m^3$ concrete in Rupees

Concrete mixture	*Cost of Cement*	*Cost of effluent sludge*	*Cost of Fine Aggregate*	*Cost of Coarse aggregate*	*Cost of 1m3 concrete(Rs)*
Regular	*3406*	*-*	*900*	*1111*	*5917*
7%	*3226*	*8*	*900*	*1111*	*6245*

VI. CONCLUSION

- The feasibility of sludge was positive.
- The effluent treatment sludge as used as a replacement for cement tend to generate better strength on partial replacement
- The strength value of the concrete mix was increased in a small scale but was not as our expectations of HSC.
- We obtained the highest strength value at 7% replacement of the cement with the ETS in concrete.
- Thus we are left with a conclusion that cement can only be partially replaced with ETS.
- Thus higher studies and efficient way of producing the effluent sludge is to be required as compared to our procured hard work of grinding and sieving
- Tests conducted by us have its own limitations.
- Higher studies on these should be done for finding the strength variations at various criterions.
- The cost estimation showed us an approximate manufacturing cost of both the concrete mix.

The effluent treatment sludge produced and used for the manufacture of cement is an efficient replacement in partial form for the cement. But our studies have its own limitations in its bands. Various testing on this component tend to bring a better result and a higher efficiency of producing it is also required. This project is only a study on Feasibility, Strength and Cost on the effluent treatment sludge. The studies showed cement replacements could only be done by partially with this waste material.

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