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Experimental and Analytical Study of Effective Utilization of Lime Sludge and Pulp Black Liquor in Concrete

Asharuddeen Tharammal
M Tech Scholar
AWH Engineering College, Kozhikode

Jisha P
Assistant Professor
AWH Engineering College, Kozhikode

***Abstract*- Effective and economic utilisation of waste products are the problems in the world right now. Civil engineering field can resolve a part of this problem. Concrete is one of the most important used construction materials all over the world. Concrete is the mixture of cement sand and aggregate. The availability of this material is being reduced day by day which results in high cost of construction. In this project, I have used waste material from the TNPL Karur , Tamil Nadu (paper industry) i.e. lime sludge and pulp black liquor as this both material are directly disposed in the water resources or on the land, it creates pollution. We have focused on introducing both this materials PBL and lime sludge. Lime sludge is used as replacement to the cement as it has similar properties as cement. Pulp black liquor is used as an admixture in concrete. Experimentally, the mechanical properties such as compressive strength , split tensile and flexural strength were tested. The optimum replacement was taken to study the flexural and shear behaviour in beams and also for the pull out cubes to check bond performance. The flexural beams , shear beams and the pull out cubes were analysed analytically in ANSYS 16.1 software.**

I. INTRODUCTION

The huge quantity of concrete is consumed by construction industry all over the world. The conventional concrete is produced by using natural sand, cement, coarse aggregate and water. One major challenge facing the civil engineering community is to execute projects in harmony with nature using the concept of sustainable development involving the use of high performance, environment friendly materials produced at reasonable cost. In the context of concrete, which is the predominant building material, it is necessary to identify less expensive substitutes. Paper and pulp industry in India is generating nearly 0.8 million tonne of lime sludge that too only in organized sector. Currently installed capacity for paper manufacture in India is about 4.6 MT out of its 380 paper mills scattered throughout the country. Out of 380 plants 32 plants are in the large scale sector and the rest in medium and small scale sector. Pulp and paper mill generate materials that may be harmful to the air, water and land. Pulp and paper processes generate large volume of wastewater which might adversely affect freshwater or marine ecosystem. Residual wastes from wastewater treatment process may contribute to existing local and regional disposal problems and air emission from pulping processes and power generation facilities may release odour, particulates and other pollutants. Nowadays to improve the characteristics of concrete, addition of admixture to the concrete is widely used**.** Here in this project, we introduce easily available and cost effective admixture pulp black liquor (PBL), a by product from paper industry**.** The continuous discharge of pulp black liquor to the land will cause serious environmental issues. So by adding pulp black liquor to concrete as an admixture, can reduce environmental issues and improve the properties of concrete like workability, compressive strength ,split tensile strength and modulus of rupture. In this project the effect of PBL on concrete with replacing lime sludge to cement is to be studied. Experimentally after finding out the mechanical properties flexural and shear behaviour of the beams were studied and also the bond performance of pull out specimen was studied. After finding the experimentally , it was worked out analytically and the values were matched.

a.Lime Sludge

. 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. Paper mill sludge is a major economic and environmental problem for the paper and board industry. The material is a by-product of the deinking and re-pulping of paper. The main recycling and disposal routes for paper sludge are land-spreading as agricultural fertilizer. Sludge is a semi-solid slurry that can be produced from a range of industrial processes, from water treatment, wastewater treatment or on-site sanitation systems. For example, it can be produced as a settled suspension obtained from conventional drinking water treatment, as sewage sludge from wastewater treatment processes or as fecal sludge from pit latrines and septic tanks. The term is also sometimes used as a generic term for solids separated from suspension in a liquid; this 'soupy' material usually contains significant quantities of 'interstitial' water (between the solid particles).Industrial wastewater treatment plants produce solids that are also referred to as sludge. This can be generated from biological or physical-chemical processes.In the activated sludge process for wastewater treatment, the terms "waste activated sludge" and "return

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activated sludge" are used. Lime sludge is a very fine precipitated CaC03 particles along with unsettled dregs carried over from green liquor clarifier. The average Physico-Chemical properties of Lime Sludge waste is as follows: MC%S5i02% 40-60 2-8 Mineralogy = A1203% Fe203% CaO% MgO% LOI% 0.8-1.2 0.8-1.2 48-53 0.2-3.0 37-42 Calcite, Quartz, Hemihydrate apetite (hydroxyl) Major impurities associated with lime mud (sludge) are Silica and Magnisium. Silica enters mainly via raw materials or through purchased lime and goes to chemical recovery loop. During the causticizing operation Si02 forms Ca Si03 which is geletinous in nature. This geletinous nature hinders the setting property of lime mud (sludge). It has been observed that high percentage of silica in lime mud entraps higher moisture content (4-5). 2 Ca (OH)2 + Si02 + Na2 C03 (Green liquor) -~. NaOH + CaC03 + Ca Si03 (Slow setting lime mud) Particle Size distribution Size range in micron +90 Nil -90 to +50 8 -50 to +30 11 -30 to +10 78 -10 3 Attention is required to use this solid waste either as recycling product to be used for the paper manufacturing process or in some other value added products. Some Paper Industries are already recycling Lime Sludge and converting it to quick lime which can be further reused in paper manufacturing process. Out of 32 large paper mills only 5 mills are having lime reburningcalciner to convert Lime Sludge to quick lime for reuse in the causticizing process. The high temperature process which drives the C02 out of CaC03 to produce CaO is called Calcination. The unit that reburns the lime are called calciners or Lime Kilns. In view of above I the proposed project envisages to convert this solid waste into value added products. One such area is looking into the aspect of reburning of lime sludge to reclaim lime by using appropriate technology which could be economical and cost effective as well as electrical and thermal energy efficient. At the same time it is able to handle different impurities associated with lime sludge which are introduced by using different types of raw materials.

b. Pulp Black Liquor

Admixture is defined as a material, other than cement, water and aggregates that is used as an ingredient of concrete and is added to improve the properties of concrete. These days concrete is being used for wide varieties of purposes to make it suitable in different conditions .In these conditions ordinary concrete may fail to exhibit the required quality performance or durability. In such cases, admixture is used to modify the properties of ordinary concrete so as to make it more suitable for any situation. Due to the increased demand it is necessary to find a low cost admixture. The pulp black liquor is a waste product from paper industry, it has low viscosity and high solubility and it is readily available; due to these factors we are trying to use it as an admixture in concrete. Black liquor is an important liquid fuel in the pulp and paper industry. It consists of the remaining substances after the digestive process where the cellulose fibers have been cooked out from the wood. One of the main ingredients in black liquor is lignin, which is the material in trees that binds wood fibers together and makes them rigid, and which must be removed from wood fibers to create paper. The organic admixtures induce physical effects which modify the bond between particles and can act on the chemical processes of hydration particularly on the nucleation and crystal growth. Accordingly the black liquor constitutes a new and promising admixture.

II METHODOLOGY

- Conduct literature review on use of lime sludge and pulp black liquor in concrete.
- Experimentally find out material properties of various ingredients in concrete such as cement, fine aggregate , coarse aggregate , water , lime sludge and PBL.
- The mix adopted here was M30 mix for the mix proportion 1:1.59:2.33:0.45.
- Replacement of Cement by Lime sludge and addition of PBL in the percentage of water was done.
- Replacement of cement in the percentages of 0%,5%,7.5%,10%,12.5%,15%,20% and 30% for testing compression in cubes
- Addition of PBL was in the percentages of 2%,4% and 6% were fixed for testing compression in cubes .
- Combination of both lime sludge replacement and addition of PBL were done together in the varying proportion repectively of 10 % and 1% , 10% and 2%, 15% and 2% and 15% and 4%.
- The optimum in all the 3 cases i.e., for Lime sludge alone , PBL alone and combination of both were used in preparing cylinders foe split tensile testing , Beams for shear and flexural testing and also pull out cubes for bond performance .
- Shear beams , flexural beams and pull out specimen were analysed using ANSYS 16.1

Table 1: No of specimen to be casted

Sl.no	Specimen	Quantity	Tests to be done
1	Cube	48	Compressive strength test
2	Cylinder	9	Split tensile strength test
3	Prism	9	Modulus of rupture
4	Beams	8(4 shear and 4 flexure)	Shear test and Flexural test
5	Pull out cubes	4	Bond performance pull out test
Total		78	

III. COMPRESSIVE STRENGTH TEST

All Cubes specified in the variables above were tested for compressive strength The optimum was found to be 12.5% of cement where lime sludge was only replaced alone to the concrete , 2% of water where PBL was added alone to the concrete and 15% and 2% in the case of combination.

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Table 2 : Lime Sludge Replacement

Specimen mix (Cube)	Compressive strength (Mpa) 28 days
Conventional	31.11
5%	23.11
7.5%	24.44
10%	23.78
12.5%	36
15%	28.44
20%	23.11
25%	22.66
30%	20.44

Table 3: PBL addition

Specimen mix (Cube)	Compressive strength (Mpa) 28 days
Conventional	31.11
2%	41.33
4%	38.22
6%	35.55

Table 4 : Combination

Specimen mix (Cube)	Compressive strength (Mpa) 28 days
Conventional	31.11
10% & 1%	32
10% & 2%	32.88
15% & 2%	37.77
15% & 4%	31.11

Fig 1 : Compression testing

Fig 3 : Testing Modulus of rupture in prism

IV. SPLIT TENSILE TESTING

The optimum mixes of the compressive strength tests i.e., 12.5% for LS alone , 2% PBL addition and 15% and 2% for combination.

Table 4 Split tensile results

Specimen Designation (Cylinder)	Split tensile (Mpa)
Conventional	2.186
LS optimum	2.82
PBL optimum	3.53
Combination Optimum	3.96

Fig 2. Cylinder Split tensile testing

V. MODULUS OF RUPTURE

The optimum mixes of compressive strength tests were used
here also

Table 5 : Modulus of rupture

Specimen Designation (Prism)	Modulus of Rupture (Mpa)
Conventional	6.667
LS optimum	9.5
PBL optimum	9
Combination Optimum	9.25

VI. FLEXURE AND SHEAR TEST IN RCC BEAMS

- A total of 8 specimen were casted .
- 4 beams for checking shear and 4 beams for checking flexure.
- All the beams were of size 100mm x150mmx750mm with an effective span of 600mm.
- Shear reinforcement consisted of four 8 mm bars of length 650 mm, four 6mm stirrups of dimension 110mmX60mm at 200 mm spacing as per design. Fe 415 was used
- Flexural reinforcement consisted of four 8 mm bars of length 650 mm , four 6mm stirrups of dimension 110 mm X 60 m

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Table 6:First crack load and ultimate load of beams

Beam	Designation	First Crack load (KN)	Mean (KN)	Ultimate Load (KN)	Mean (KN)
Shear Beams	Conventional	34		45	
	L S Optimum	42		50	
	PBL Optimum	63	53.75	73	62
	Combination	76		80	
Flexural Beams	Conventional	38		50	
	L S Optimum	47.5		53	
	PBL Optimum	69	58.125	81.5	67.626
	Combination	78		86	

- The load vs deformation graph was plotted

For beams.

Fig 4: Testing RCC Beams

VII. PULL OUT TEST IN CUBES

- Experiment is Carried out to evaluate the bond stress –slip behavior and pull out strength of reinforced bars embedded in conventional concrete, Lime sludge optimum, PBL optimum and the combination optimum.
- Cubes were of size 150x150x150(mm) and the reinforcing bar embedding the concrete was of size 1 metre and 16 mm dia bar was used
- The specimen were also reinforced with a helix of 6 mm dia plain mild steel at a pitch of 25 mm to prevent splitting failure.
- According to IS 2770 part 1 1961 the tests are done are the results are recorded .
- The bond stress is calculated using the formula

$$\tau_b = \frac{P}{\pi d_b l_b}$$

- where, τ_b, is the bond stress in P is the applied load (N). d_b is the diameter of bar (mm) and l_b is the embedded length of bar (mm).
- The Bond stress vs slip Graph is plotted

Table 7 : Slip and bond stress noted according to IS 2770 Part 1

Sl.no	Specimen Designation	Bond Stress at 0.025mm (MPa)	% increase compared to conventional
1	Conventional	11.18	-
2	L S	11.50	2.86
3	PBL	15.57	39.26
4	Combination	13.90	24.329

Table 7 continued

Sl.no	Bond Stress at 0.25mm (MPa)	% increase compared to conventional	Ultimate Load(KN)	Ultimate Bond stress (MPa)	Mode of failure
1	10.07	-	85	11.27	Pull out
2	10.20	1.29	105	13.90	Pull out
3	13.80	37.04	120	15.91	Pull out
4	13.60	35.05	110	14.58	Pull out

Fig 5: Pull out testing set up

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VIII. ANALYTICAL INVESTIGATION IN BEAMS

- Beams were analysed using ANSYS 16.1
- The load deflection graphs were plotted
- The combination mix had a greater ultimate load in both Flexure and shear beams.

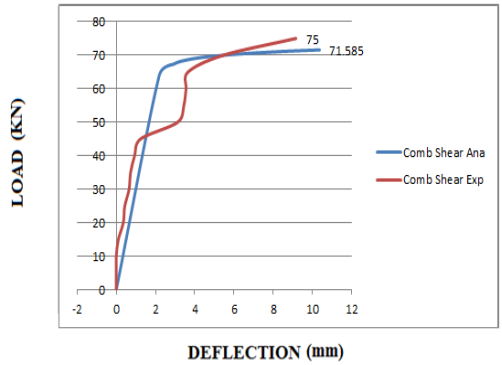

Fig 6 : Load vs. deformation plot of Experimental and analytical together for the optimum shear specimen i.e., Combination mix

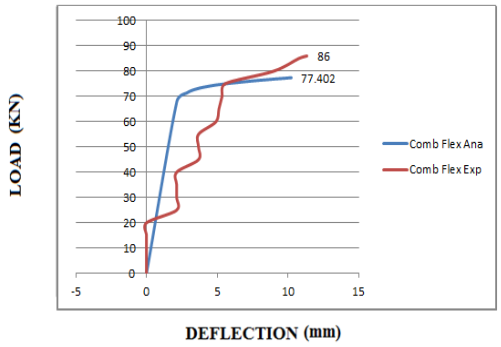

Fig 6 : Load vs. deformation plot of Experimental and analytical together for the optimum flexural specimen i.e., Combination mix

IX. ANALYTICAL INVESTIGATION IN PULL OUT SPECIMEN

- Pull out cubes were also analysed using ANSYS 16.1
- The bond stress vs. slip graph was plotted .
- The optimum specimen was found to be the PBL specimen.

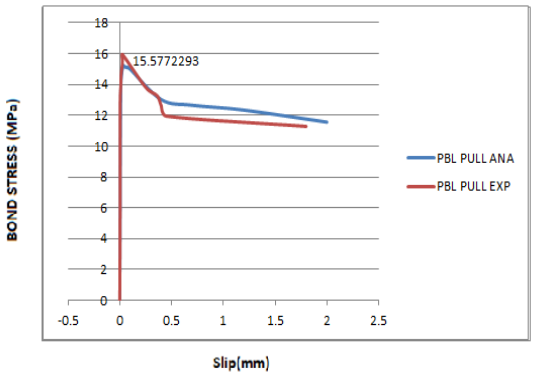

Fig 7 : Bond stress vs. slip plot of Experimental and analytical together for the optimum pull out specimen i.e., PBL mix

X. RESULTS AND DISCUSSIONS

- The experimental and analytical results were compared below
- The experimental results had an increase in percentage than the analytical
- The maximum difference in the Ultimate load of shear and flexural beams was found in the PBL mix that was 12.08 %and 13.15% respectively.
- The least difference in the Ultimate load of shear and flexural specimen was found in Lime sludge mix that was 4.821% and 4.81% respectively.
- The maximum difference for the ultimate bond stress in pull out specimen was found in the conventional mix , 5.587% and the least difference was found in the Lime sludge mix, 0.0020%

Table 8: Comparison of experimental and analytical Results of beam specimen.

Beam	Designation	Ultimate Load (KN)		%increase
		Analytical	Experimental	
Shear Beams	Conventional	42.699	45	5.38
	L S Optimum	47.700	50	4.821
	PBL Optimum	65.128	73	12.08
	Combination	71.585	75	4.77
Flexural Beams	Conventional	44.564	50	12.20
	L S Optimum	50.564	53	4.81
	PBL Optimum	72.624	81.5	13.156
	Combination	77.402	86	11.108

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Table 8: Comparison of experimental and analytical Results of beam specimen

Specimen Designation	Ultimate Bond stress (MPa)		% Change in load compared to FEA
		EXP	
Conventional	10.67892	11.275	5.587
LS	13.92577	13.928	0.0020
PBL	15.22365	15.923	4.564
Combination	13.97671	14.592	4.402

XI. CONCLUSIONS

- Material properties, Compressive Strength ,Split tensile strength and Modulus of rupture were tested respectively on cubes , Cylinders and prisms.
- In Compressive strength PBL Specimen has maximum strength.
- In Split tensile strength and modulus of rupture Combination mix was slight dominant than the PBL,
- The Combination mix dominated in the shear and flexural beams
- In the pull out test PBL mix was slightly dominant than the Combination mix.

REFERENCES

[1] Ganesh R Mahalle (2018), 'Use of lime sludge and pulp black liquor in concrete'.
[2] Y.D. Shermale M.B .Varma (2015), 'Effective use of Paper Sludge (Hypo Sludge) in Concrete.'
[3] S.Sudha(2016) Durability and strength character of concrete using lime sludge and flyash as partial replacement of fine aggregate.
[4] Marimuthu.A et al.(2017). Detailed Investigation on Concrete Using Lime Sludge from Sugar Industry.
[5] Vijay Palet al. (2016)Studyof Effect of Lime Sludge and Silica Fume on Strength of Concrete.
[6] VaishaliSahuet al.(2014)The Use of Fly Ash and Lime Sludge as Partial Replacement of Cement in Mortar.