International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN: 0974-4290
Vol.9, No.01 pp 240-247, 2016

Experimental Investigation on Developing Low Cost Concrete by Partial Replacement of Waste Sludge

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Abstract: In India huge tones of waste materials were generated from industries per annum and also it is estimated as 300 million tones. The toxic waste creates disposal and health hazard problems to environment and humans. Paper industry produces huge ammount of solid waste in the form of sludge. This research work deals with the sludge from paper mill and the recylcing of sludge into useful products. Paper mill sludge takes huge area for dumping the waste on the land in the form of landfill. Some paper mills incinerates the sludge by creating air pollution problems. To reduce and prevent the polltion problem by paper mill sludge, it is used for replacement of bulinding material and make waste as profitable material for construction purpose. Lime sludge from paper mill were used to produce low cost concrete by blending various ratios of cement. Experimental investigation on strength of concrete and optimum percentage of the partial replacement by replacing cement via 10%, 20%, 30%, 40% and 50% of lime sludge were identified.
Keywords: Health hazard, Paper mill sludge, Construction, toxic waste, Cement.

1. Introduction:

Energy plays a vital part in the growth of emergent countries like India. In the background of low accessibility of non-renewable energy resources attached with the necessities of large quantities of energy for Building materials like cement, the significance of using industrial waste cannot be under anticipated. During manufacturing of single tonnes of Ordinary Portland Cement, the same quantity of carbon-di-oxide is released into the ambiance. The carbon-di-oxide emissions act as a silent killer in the atmosphere as a variety of forms[2,6].

Infrastructure acting a vital role in developing countries. India enlarges its infrastructure by constructing a different types of bridges and high rise buildings. For these construction process, a huge amount of cement is needed. Due to this huge demand for cement, depletion of resources like limestone etc, occurs. On the other hand, a huge amount of lime sludge is disposed from the industries. These lime sludge causes the land accumulation problems and environmental problems. Using these lime sludge used as partial replacement of cement, act as a solution for cement replacement and environmental problems[4,5].

Seshasayee Paper and Boards Limited (SPB), an integrated pulp and paper mill, was founded in 1960. SPB is an ISO 9001 and ISO 14001 accredited company. It is located near Erode in Tamil Nadu state, India. It’s capacity has expanded from 20,000 tonnes of paper per annum in the 1960s to over 115,000 tonnes per annum at present. Their products include posters, paper boards, packaging and copier paper. Approximately 20 per cent of SPB products are made for the export market. Annual turnover is about Rs. 3,500 million, and the company employs 1,600 people[3,12,13].

SPB is a pioneer in that it uses bagasse, a residue left after sugar is extracted from sugarcane, for the manufacture of paper. The company has its own sugar mill, Ponni Sugars (Erode) Ltd. The industry produces 400 tonnes of paper everyday which produces 100 tonnes of wet lime sludge gives 40 tonnes of dry sludge on drying. These lime sludge are disposed on land space outside the pallipalayam city. Thus, the lime sludge are disposed as waste in land and it is collected for the research work[10,11].

After recovery of chemicals a huge amount of wet lime sludge is produce per day. It will not able to use for further paper production. Hence these wet lime sludge is disposed from the paper industries. In SPB, which produces 100 tonnes of wet lime sludge per day, the wet lime sludge are disposed on land space outside the pallipalayam city. This sludge consumes a large percentage of local area for each and every year and also causes ground water table to deplete shown in fig 1.

Fig 1 Disposal of lime sludge in seshasayee paper and boards limited

This project aims to compare the strength of concrete with partial replacement of sludge. Thus it may minimize the demand for cement and reduce land disposal problems. The overall objective of the project is to minimize the depletion of limestone by using waste materials in construction thereby reducing the cost of concrete and providing an eco friendly and sustainable environment[8,9].

2. Experimental

2.1 Collection of Sludge

The sludge samples were collected from Seshasayee Paper and Boards Limited (SPB), Pallipalayam, India. The sludge was collected from the plastic bags and kept at open space for 48 hours to remove moisture content present in it. The chemical characteristics of the sludge were analyzed by standard methods. The characteristics of the sludge were studied immediately after collection.

2.2 Chemical tests

The chemical characteristics of the sludge were analyzed to determine the percentage of important ingredients used in cement. The tests done are Moisture Content, Silica, Alumina, Lime and Magnesium

2.3 Tests on Cement and Sludge

Since sludge is being mixed with cement, it should not alter the properties of cement. So basic tests on cement such as consistency test, setting time test, soundness test and specific gravity test were done for cement sample and cement samples mixed with sludge.

Further, tests such as water absorption test and compressive strength test were done on concrete samples with and without sludge for finding any deviation in the strength of the concrete when mixed with sludge.

3. Results and Discussion

3.1 Chemical Tests on Sludge

The basic constituent of the sludge was determined by the chemical tests conducted on the sample. Following are the results obtained, shown in table 1.

Table 1 Sludge properties

Sl.no	Constituents	% Present in sludge
1	Moisture	56.8
2	Calcium oxide (CaO)	46.3
3	Magnesium oxide (MgO)	3.125
4	Silica (SiO_2)	9.0
5	Alumina	3.6

The properties so obtained was compared with the properties of cement, shown in table 2.

Table 2 Comparison of properties of cement and sludge

Sl.no	Constituents	Cement (%)	Sludge (%)	Limits (%)
1	Calcium oxide (CaO)	62	46.3	60-65
2	Magnesium oxide (MgO)	1	3.125	1-3
3	Silica (SiO_2)	22	9.0	16-25
4	Alumina	5	3.6	3-8

The results obtained shows that the sludge lie well within the limits.

3.2 Tests on Cement and Sludge

Normally a minimum of 30 minutes is given for mixing and handling operations. The constituents and fineness of cement is maintained in such a way that the concrete remains in plastic condition for certain minimum time. By partial replacement of cement by sludge, the initial setting time is increase gradually above 30 minutes shown in table 1.

Table 1 Setting time test for cement and sludge

Sl.no	Ingredients	Initial setting time (min)	Final setting time (min)
1	Cement + 0% sludge	31	600
2	Cement + 10% sludge	31	597
3	Cement + 20% sludge	33	594
4	Cement + 30% sludge	34	592
5	Cement + 40% sludge	36	591
6	Cement + 50% sludge	37	590

Once the concrete is placed in the final position, compacted and finished, it should lose its plasticity in the earliest possible time so that it is least vulnerable to damages from external destructive agencies. This time should not be more than 10 hours which is often referred to as final setting time. By partial replacement of cement by sludge, the final setting time is decrease gradually below the limit. The soundness test for cement and sludge is given in the table 2.

Table 2 Soundness test for cement and sludge

Partial replacement of cement(%)	Initial reading (mm)	Final reading (mm)	Expansion (mm)
0	12	13	1
10	12	13	1
20	12	13	1
30	12	13.5	1.5
40	12	14	2
50	12	14	2

The magnesium content is limited to 3% in cement. The exceed amount of magnesium content may cause unsoundness in cement. The sludge contains 3.125% of magnesium. Hence soundness of cement and sludge is necessary to check.

If the expansion is more than 10 mm, the cement is said to be unsound. But the above tested result is within the limit.

3.2 Tests on Concrete

Mix design was done for arriving an M25 concrete and the concrete cubes was tested for its compressive strength is shown in table 3.

Table 3 Mix proportion

Description	Water	Cement	Fine aggregate	Coarse aggregate
By weight (kg)	188.79	419.5	548.35	1163.39
By volume	0.45	1	1.30	2.77

3.3 Water absorption test

Table 4 Water absorption test after 28 days curing

Sl.no	Replacement of cement(%)	Dry weight (kg)	Wet weight (kg)	Moisture content (%)
1	0	8.313	8.401	1.058
2	10	8.397	8.476	0.941
3	20	8.432	8.557	1.48
4	30	8.513	8.627	1.339
5	40	8.577	8.702	1.457
6	50	8.604	8.739	1.569

The percentage of moisture content of the test samples shall not be greater than 5%.For every replacement of cement by sludge the percentage of moisture content is around the value of ordinary Portland cement concrete. Hence it will not cause dampness in the concrete. The water absorption test after 28 days curing is given in the table 4.

3.3 Compressive strength of cubes

The compressive strength of cubes at 14 days shown in table 5.

Table 5 Compressive strength of cubes at 14 days

Sl.no	Replacement of cement %	Ultimate load of specimen (KN)			Average ultimate load (KN)	Ultimate compressive strength (N/mm^2)
		I	II	III		
1	0	370	430	400	400	17.78
2	10	420	390	410	406.67	18.07
3	20	440	470	350	420	18.70
4	30	450	410	430	430	19.11
5	40	380	320	410	370	16.44
6	50	360	250	290	300	13.33

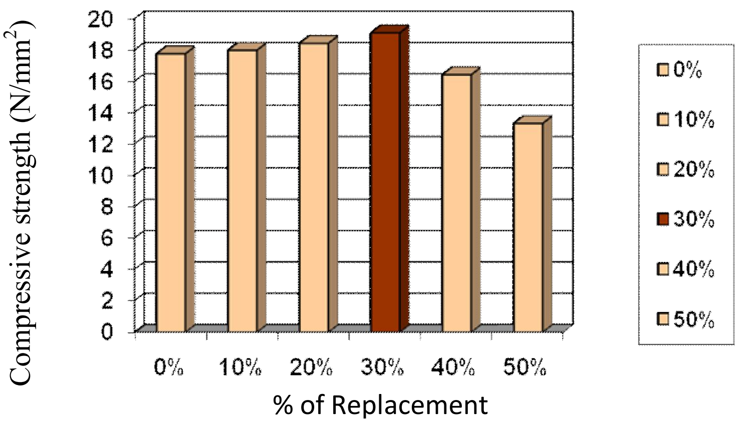

Fig 3 Compressive strength of cubes at 14 days

Table 8 Compressive strength of cubes at 28 days

Sl.no	Replacement of cement %	Ultimate load of specimen (KN)			Average ultimate load (KN)	Ultimate compressive strength (N/mm^2)
		I	II	III		
1	0	620	580	630	610	27.11
2	10	650	610	600	620	27.56
3	20	630	670	620	640	28.44
4	30	660	610	680	650	28.89
5	40	590	640	540	590	26.22
6	50	570	490	620	560	24.89

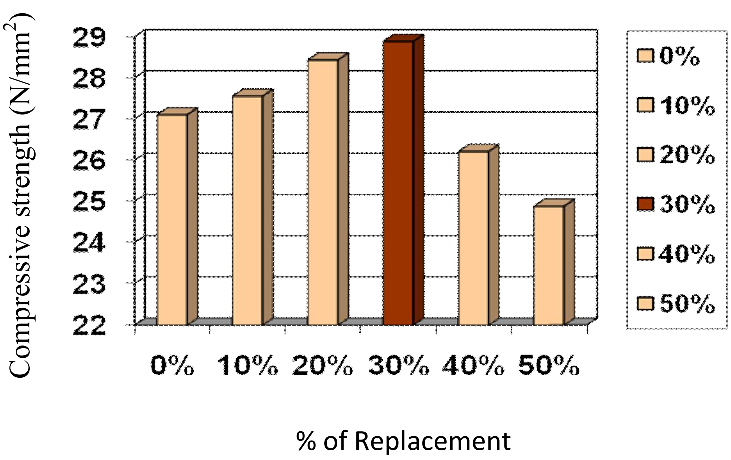

Fig 4 Compressive strength of cubes at 28 days

The compressive strength of concrete cube is gradually increased by increasing the partial replacement of cement by sludge up to 30%. Then start to decrease by increasing the % of replacement.

The 30% replacement of concrete will attain more compressive strength then the ordinary Portland cement concrete[1,7].

3.5 Economic feasibility

Cost analysis is carried out for the optimum proportion of percentage of hypo sludge in concrete.
Cost of one bag of cement = Rs.340.00
Cost of sludge per kg = Rs. 0.50
Cost of sand per m^3 = Rs. 1200.00
Cost of coarse aggregate 20mm size per m^3 = Rs.830.00
(All the rates are include with lead charges)

Table 9 0% Replacement

Description	Quantity (Kg)	Rate (Rs)	Per	Cost of materials (Rs)
Cement	419.530	6.80	Kg	2852.804
Sludge	---	---	---	---
Fine aggregate	548.354	1200.00	m^3	411.2655
Coarse aggregate	1163.388	830.00	m^3	438.9146
				3702.984

Table 10 10% Replacement

Description	Quantity (Kg)	Rate (Rs)	Per	Cost of materials (Rs)
Cement	377.577	6.80	Kg	2567.524
Sludge	41.953	0.50	Kg	20.9765
Fine aggregate	548.354	1200.00	m^3	411.2655
Coarse aggregate	1163.388	830.00	m^3	438.9146
				3438.68

Table 11 20% Replacement

Description	Quantity (Kg)	Rate (Rs)	Per	Cost of materials (Rs)
Cement	335.624	5.400	Kg	2282.24
Sludge	83.906	0.500	Kg	41.953
Fine aggregate	548.354	800.00	m^3	411.266
Coarse aggregate	1163.388	825.00	m^3	438.915
				3174.38

Table 12 30% Replacement

Description	Quantity (Kg)	Rate (Rs)	Per	Cost of materials (Rs)
Cement	293.671	5.400	Kg	1996.96
Sludge	125.859	0.500	Kg	62.9295
Fine aggregate	548.354	800.00	m^3	274.177
Coarse aggregate	1163.388	825.00	m^3	436.271
				2910.07

Table 13 40% Replacement

Description	Quantity (Kg)	Rate (Rs)	Per	Cost of materials (Rs)
Cement	251.718	5.400	Kg	1711.68
Sludge	167.812	0.500	Kg	83.906
Fine aggregate	548.354	800.00	m^3	274.177
Coarse aggregate	1163.388	825.00	m^3	436.271
				2645.77

Table 14 50% Replacement

Description	Quantity (Kg)	Rate (Rs)	Per	Cost of materials (Rs)
Cement	209.765	5.400	Kg	1426.4
Sludge	209.765	0.500	Kg	104.883
Fine aggregate	548.354	800.00	m^3	274.177
Coarse aggregate	1163.388	825.00	m^3	436.271
				2381.46

The compared values of cost show gradual decrement in total cost of per cubic meter of concrete. By increasing the percentage of replacement total cost of concrete will decrease.

The difference in cost of 30% replacement and the normal concrete was Rs.792.914.

Conclusion

The enormous amount of waste produced during the manufacturing of paper in many countries provides challenging opportunities for the use of lime sludge which contain cementitous or pozzolanic properties; they can serve as a partial replacement of cement.

In this study, lime sludge of 10%, 20%, 30%, 40% and 50% by weight of cement was added as a partial replacement and strength, initial and final setting time, water absorption and soundness were evaluated. At 30% of replacement of cement the results obtained are same as that of Ordinary Portland Cement.

By using the paper industrial waste the usage of cement can be reduced. It also avoids many problems such as environmental effects, land accumulation, leachability of chemicals which pollute the water table. It also proves to be economical.

Hence a new construction material is thus found and it can be utilized effectively.

References

1. Code of Practice for Plain and Reinforced Concrete. IS 456-2000, Bureau of Indian Standards, New Delhi.
2. Cyr, M., Coutand, M. and Clastres, P., Technological and environmental behavior of sewage sludge ash (SSA) in cement-based materials, Cement and Concrete Research, 2007, 1278-1289.
3. Donatello, S. and Cheeseman, C., Recycling and recovery routes for incinerated sewage sludge ash (ISSA): A review. Waste Management, 2013, 2328-2340.
4. Enhancing strength and durability of ready-mixed concrete, final report submitted to the US Dept. of Energy for the Project DE-FC07-00ID13867.
5. Kamon, M. and Nontananandh, S., Combining Industrial Wastes with Lime for Soil Stabilization." Journal of Geotechnical Engineering, 1991, 1-17.
6. Methods of Tests for Strength of Concrete. IS 516-1959, Bureau of Indian Standards, New Delhi.
7. Lynn, C., Dhir, R., Ghataora, G., and West, R., Sewage sludge ash characteristics and potential for use in concrete, Construction and Building Materials, 2015, 767-779.
8. Method of Test for Splitting Tensile Strength of Concrete. IS 5816-1999, Bureau of Indian

9. Pan, S., Tseng, D., Lee, C. and Lee, C., Influence of the fineness of sewage sludge ash on the mortar properties, Cement and Concrete Research, 2003, 1749-1754.
10. R. Gracia, R. Vigil de la Villa, I. Vegas, M. Frias, and M.I. Sanchez de Rojas, The pozzolanic properties of paper sludge waste, Construction and Building Materials, 2008, 22(7).
11. T.R. Naik, Concrete with paper industry fibrous residuals: mixture proportioning, ACI Materials Journal, 2005, 102 (4), 237-243.
12. T.R. Naik, Y. Chun, and R.N. Kraus, Use of residual solids from pulp and paper mills for
13. Tay, J., Yip, W. and Show, K., Clay-Blended Sludge as Lightweight Aggregate Concrete Material, Journal of Environmental Engineering, 1991, 834-844.
14. Tenza-Abril, A., Saval, J. and Cuenca, A., Using Sewage-Sludge Ash as Filler in Bituminous Mixes, Journal of Materials in Civil Engineering, 2014.

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