Study on Low Cost Concrete with Paper Industry Waste - Lime Sludge

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Abstract

Paper production generally yields a large quantity of solid waste. Paper fibers can only be recycled a few times before they are too short or weak to produce high - quality paper. This means that broken paper fibers of low quality are separated to become waste sludge. In order to reduce the problems of disposal and pollution resulting from these industrial waste, it is essential to develop profitable building materials. In view of this, investigations were carried out to produce low cost concrete by mixing different ratios of cement with lime sludge. The purpose of this project is to investigate the strength of concrete and the optimum percentage of partial substitution by replacing cement by 10 percent, 20 percent, 30 percent, 40 percent, 50 percent, 60 percent of Lime sludge. Keeping all this view, the aim of investigation is the behavior of concrete while adding waste with different proportions of Lime sludge in concrete by compressive strength test.

Keyword- Concrete, Low Cost, Paper Industry Waste, Compressive Strength, Lime Sludge

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I. INTRODUCTION

Concrete is a composite material made of cement (usually Portland cement) and other cement materials such as slag cement, aggregate (usually a coarse aggregate made of gravel or crushed rocks such as calcareous or granite, plus a fine aggregate such as sand), water and/or chemical admixtures. Concrete is made by mixing: Cement, water, course fine aggregates and admixtures (if required). Concrete is mixed by: cement, water, fine aggregates and admixtures (if necessary). The aim is to traditionally mix these materials to make easy-to - use concrete: transport, placing, compact & finishing so as to obtain strong as well as durable concrete. The properties of hardened concrete affected by the proportional mix of each material (i.e. cement, water and aggregates).

More than 300 million tons of industrial waste is produced annually in India through chemical and agricultural processes. These materials pose disposal problems and health risks. Wastes such as phosphogypsum, fluorogypsum and red buckthorn contain harmful impurities that adversely affect the strength and other properties of building materials. Of the various waste products currently produced, the use of phosphogypsum, flurogypsum, Lime sludge, red mud and mine tailing is of paramount importance in protecting the environment.

All the inks, dyes, coatings, pigments, staples and “stickies” (tape, plastic films, etc.) are also washed off the recycled fibers to join the waste solids. The shiny finish on glossy magazine-type paper is produced using a fine kaolin clay coating, which also becomes solid waste during recycling. This paper mill sludge takes up a large proportion of local landfill space each year. Worse still, some of the waste is discharged as a disposal technique on cropland, raising concerns about trace contaminants building up in the soil or flowing into the lakes and streams. Some companies burn their sludge in incinerators and cause our serious problems with air pollution. In order to reduce the problems of disposal and pollution resulting from these industrial waste, it is essential to develop profitable building materials.

II. EXPERIMENTAL WORK

A. Objective

To investigate the use of Lime Sludge as Supplementary Cementitious Materials (SCM) and the influence of these Lime Sludge on the strength on concretes produced with different levels of cement substitution.

B. Materials

1) Cement

Ordinary Portland Cement (OPC) is the most common cement used. The 53 grade Ordinary Portland Cement compliant with IS: 8112-1989 is used. Many cement tests have been carried out, some of which are specific gravity tests, consistency tests, setting time tests, compressive strengths, etc.

2) Aggregate

Aggregates are the important concrete components. They give concrete body, reduce shrinkage and economic efficiency. Good gradation of aggregates is one of the most important factors for producing workable concrete. Good grading means that the sample contains minimum voids for fractions of aggregates in the required proportion. Samples of the well-graded aggregate with minimum voids require a minimum paste to fill the voids in the aggregate. Minimum paste means less cement quantity and less water, which means more economy, greater strength, less shrinkage and more durability. The aggregate represents approximately 55% of the mortar volume and approximately 85% of the mass concrete volume. Mortar comprises aggregates of size 4.75 mm and concrete contains maximum size up to 150 mm.

3) Coarse Aggregate

Fractions between 80 mm and 4.75 mm are called coarse aggregates. The Coarse aggregates of crushed Basalt rock are used in accordance with IS: 383. The Elongation and Flaccidity Index was kept well below 15 percent.

4) Fine Aggregate

The fractions between 4.75 mm and 150 microns are referred to as fine aggregates. River sand and crushed sand shall be used as a fine aggregate in accordance with the requirements of IS: 383. The river sand is washed and screened to remove damaging materials and particles in excess of size.

Sr. No	Property	Coarse Aggregate	Fine Aggregate
1	Specific Gravity	2.73	2.70
2	Bulk Density (gm/cc)	1.6	1.78
3	Fineness modulus	7.73	2.85
4	Water absorption (%)	0.6%	1.2%

Table 1: Properties of aggregate (fine & coarse)

5) Water

Water is an important ingredient in concrete, because it is part of the chemical reaction with cement. Since it helps to produce cement gel which contribute strength to the concrete, the quantity and quality of the water must be examined very carefully.

6) Lime Sludge

This lime sludge contains low calcium, maximum calcium chloride and minimal silica content. Due to the silica and magnesium properties, lime sludge acts as cement. This silica and magnesium improve the setting of concrete. Figure below shows row lime sludge.

Fig. 1: Lime sludge in powder form

The table 2 below, shows the chemical properties of Lime sludge and the comparison between cement and Lime sludge.

Sr. No.	Ingredients	%Present in Cement	%Present in Lime Sludge
1.	Lime (CaO)	62	43.13
2.	Calcium Sulphate	4	0.565
3.	Silica(SiO2)	22	0.80
4.	Magnesium	1	3.44
5.	Alumina	5	0.671

Table 2: Properties of lime sludge as cement ingredient

C. Calculation of Mix Design (As Per Is 10262:2009)

1) Stipulations of Design

- Required Characteristic compressive strength of concrete in the field after 28 day : M25
- Max. nominal aggregate size : 20 mm (angular)
- Workability of concrete : 0.9 compacting factor

- Degree of quality control : Good
- Exposure type : Mild

2) Test Results of Materials

- Specific gravity of cement : 3.15
- Specific gravity of aggregate

1) Coarse : 2.73
2) Fine: 2.70

- Water absorption for aggregates

1) Coarse: 0.6%
2) Fine: 1.2%

- Free (surface) moisture content for aggregates

1) Coarse: Nil
2) Fine : Nil

- Result of Sieve Analysis is presented in tables below:

IS Sieve Size	*Weight retained (gms)*	*Cumulative weight retained*	*Cumulative % retained*
50 mm	*0*	*0*	*0*
40 mm	*0*	*0*	*0*
25 mm	*0*	*0*	*0*
20 mm	*224*	*224*	*4.48*
12.5 mm	*3612*	*3836*	*76.72*
10 mm	*794*	*4630*	*92.6*
Less than 10mm	*310*	*4940*	*100*
Total	*4940*	*-*	*273.8*

Table 3: Sieve analysis for coarse aggregate

IS Sieve Size	*Weight retained (gms)*	*Cumulative weight retained*	*Cumulative % retained*
10 mm	*0*	*0*	*0*
4.75 mm	*50*	*50*	*2.5*
2.36 mm	*80*	*130*	*6.5*
1.18 mm	*494*	*624*	*31.2*
600 micron	*582*	*1206*	*60.3*
300 micro	*600*	*1806*	*90.3*
150 micron	*84*	*1890*	*94.5*
> than 150 micron	*6*	*1896*	*-*
Total	*1896*	*-*	*285.3*

Table 4: Sieve analysis for fine aggregate

3) Target Mean Strength of Concrete

$$f'_{ck} = f_{ck} + 1.65\ s$$

Where f'_{ck} = Target average compressive strength at 28 days,
f_{ck} = Characteristic compressive strength at 28 days,
s = Standard deviation
Standard deviation, s = 4 N/mm | From Table 1(IS:456-2000)
Therefore target strength = 25 + 1.65 x 4 = 31.6 N/mm^2

4) Water/Cement ratio in Concrete: Maximum water cement ratio = 0.44|From Table 5(IS:456-2000)

5) Selection of Water & Sand Content

For maximum size of aggregate 20mm sand conforming to grading zone II,
Water content / m^3 of concrete = 186 liter.
Sand content as percentage of total aggregate by absolute volume = 35%

6) Calculation of Cement Content

Water cement ratio = 0.44
Cement content = 191.6/.44 = 435.45 kg/m^3
435.45 kg/m^3 > 240 kg/m^3, Hence OK.
Minimum cement content for moderate exposure condition = 240 kg/m^3 | From Table 5 (IS: 456:2000)

7) Proportion of Volume of Coarse Aggregate & Fine Aggregate Content

Mass of fine aggregate content = 585 kg / m^3

Mass of coarse aggregate content= 1184 kg / m^3

8) Mix Calculations

A mix M25 grade was designed as per Indian Standard method and the same was used to prepare the test samples. The design mix proportion is done as shown in the table 6 below for actual quantities (by mass) for one bag of cement.

Water	*Cement*	*Fine aggregate*	*Coarse aggregate*
23.62 liter	*50 kg*	*66.2 kg*	*135.18 kg*
0.47 liter	*1 kg*	*1.324 kg*	*2.71 kg*

III. Methodology

A. Batching of Materials

The measurement of materials for making is known as batching. There are two method of batching.

1) Volume batching.
2) Weight batching.

From which weight batching is opted for the casting of specimen. For important concreting purposes, the weight batching system in batching should always be used, facilitating accuracy, flexibility and simplicity. Various types of batchers are available. The type to be used depends on the nature of the task.

B. Mixing of Materials

Hand mixing concrete ' on the deck' either with an existing concrete slab (which can be removed and then cleaned down) or on a large mixing board. They seem to prefer to mix in a borrowing or bathroom in other countries.

- With a brush clean the surface and hose it down.
- Wisely take measurement of the mixing surface about half the ballast needed into a rough shape.
- Make a crater in the concrete of the heap using a shovel.
- Measure the remainder of the ballast (or gravel and sand) and add a cone shape to the heap.
- Mix all ingredients with a shovel and work around the heap to turn the mixture three or four times to create a evenly colored (grey) mixture.
- Then create another crater in the heap using a shovel & add some water.
- Shovel the ballast to the central crater from the sides of the heap and turn part of the heap into a mixture to distribute the water.
- Repeat to form the heap, to make the crater, add water and turn the heap until the entire mixture is wet.
- As the dry material is absorbed by water, the heap is flattened and the shovel is cut across the top, moving around the heap to mix evenly in the water.
- A good mixture should be smooth and plastic, not wet, runny or dry. As a guide, keep an eye on the ridges as the top of the heap is 'cut'- if cement slurry is between the ridges the mixture OK; if the ridges disappear or cater is fill with a water mix , it is too wet; if it stays dry within ridges, the mix is too dry.

Fig. 2: Hand Mixing of Concrete

C. Placing of Concrete in Mould

Mould specimens as close as possible to the location where they should be stored for the first 24 hours. Place moulds on vibration free rigid surface. If it is not practicable to mould the specimens where they will be stored, move them to the place of storage immediately after being struck off. Place the concrete with a scoop, a blunted trowel or a shovel in the moulds. Choose each scoop or shovel of concrete from the mixing pan to ensure that it is representative of the batch. The concrete may need to be remixed with a shovel in the mixing pan to prevent segregation during the moulding of specimens. Move the scoop or trowel around the top edge of the mould as the concrete is unloaded to ensure a symmetrical distribution of the concrete and to minimize the segregation of the coarse aggregate inside the mould. Further distribute the concrete by using a tamping rod before consolidation begins.

Fig. 3: Placing of Concrete in Mould

Make samples in layer as shown in the test for which they are prepared or as [ASTM C 192-table1]. In the required number of layers of approximately the same volume, place the concrete in the mould. Rod each layer using the number of strokes and the size of the rod specified in table (2) ASTM C 192- 88 with the rounded end of rod. Rod the bottom layer in its depth. Distribute the strokes evenly over the cross- section of the mould and allow the rod to penetrate about 12 mm into the underlying layer for each upper layer when the layer depth is less than 100 mm and approximately (25 mm) when the depth is (100 mm) or more. After each layer is rodded, tap the outside of the mould 10-15 times with the machine to close any holes left by rodding.

D. Vibration

The duration of the vibration required depends on the concrete's workability and the vibrators efficiency. Continue to vibrate only long enough to consolidate the concrete properly. Fill the moulds and vibrate approximately the same layers in the required number. Place all the concrete in the mould for each layer before vibration of the layer begins. Add the final layer so that overfilling is avoided by more than 6 mm. Then finish the surface.

E. Curing of the Specimen

Covering after finishing: to prevent evaporation of water from unhardened concrete, cover the specimens with a non-absorptive, non - reactive plate immediately after finishing. Removal of moulds: after 24 + 8 hours remove the specimens from the moulds. Curing environment: unless specified otherwise, all specimens shall be moist from the time of moulding to the time of testing.

F. Compressive Strength Test

Casting of 150 mm X 150 mm X 150 mm concrete cubes using M25 grade concrete. Specimens with ordinary Portland cement (OPC) and OPC have been replaced with lime sludge from 10 percent, 20 percent, 30 percent, 40 percent, 50 percent and 60 percent. The cubes were vibrated mechanically with a table vibrator during the casting.

Fig. 4: Compression Testing Machine

After 24 hours the specimens were removed from the mould and healed for 7 and 28 days in the water. After curing, the compression strength of the specimens was tested using a calibrated compression testing machine with a capacity of 2000kN.

IV. RESULT & RESULT ANALYSIS

A. Compressive Strength Results

In the current study, replacement of lime sludge with cement by 10%, 20%, 30%, 40%, 50%, 60% to the mix is carried out. The result of compressive strength of each trial mix are tabulated in below table no. 6 for 7 Days & 28 Days respectively.

Partial replacement in% (Lime sludge)	*Number of specimen*	*7 Days*		*28 Days*	
		Ultimate load (kN)	*Average Ultimate Compressive Strength (N/mm²)*	*Ultimate load (kN)*	*Average Ultimate Compressive Strength (N/mm²)*
0	*1*	*570*	*23.700*	*720*	*32.445*
	2	*500*		*740*	
	3	*530*		*-*	
10	*1*	*580*	*24.746*	*750*	*33.482*
	2	*540*		*740*	
	3	*550*		*770*	
20	*1*	*580*	*25.183*	*810*	*35.407*
	2	*550*		*800*	
	3	*570*		*780*	
30	*1*	*520*	*22.963*	*750*	*34.074*
	2	*530*		*760*	
	3	*500*		*790*	
40	*1*	*420*	*20.445*	*620*	*31.852*
	2	*490*		*710*	
	3	*470*		*820*	
50	*1*	*400*	*17.815*	*590*	*27.852*
	2	*390*		*580*	
	3	*370*		*710*	
60	*1*	*330*	*15.407*	*510*	*25.925*
	2	*360*		*640*	
	3	*350*		*600*	

Table 6: Compressive strength of cubes at 7 Days & 28 Days

The maximum compressive strength of concrete is achieved at 20% replacement with lime sludge as shown in the Fig.6 below. So lime sludge can be used as replacement to cement up to 20% for desired maximum compressive strength of concrete.

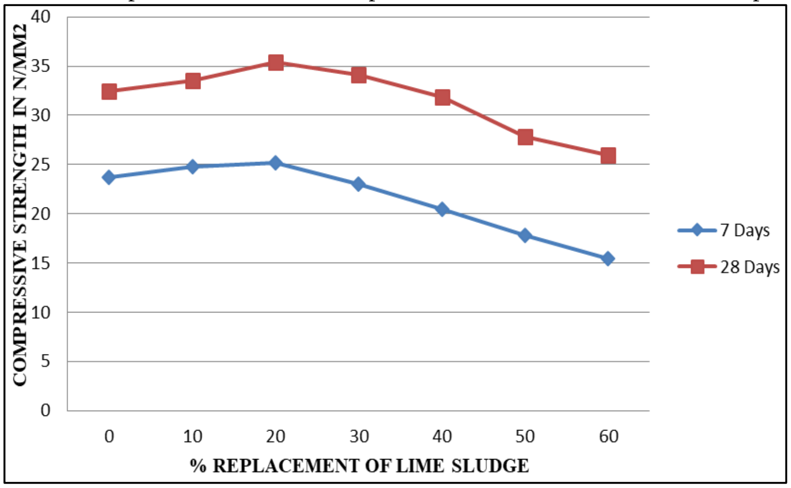

Fig. 5: Comparison of Compressive Strength of Cubes at 7 & 28 Days

B. Economic Feasibility

Cost analysis is carried out for the optimum proportion of percentage of lime sludge with cement per cubic meter of concrete. The cost is compared to the conventional concrete.

1) Cost of Materials

Cement per bag = Rs.300.00
Lime sludge per kg = Rs. 1.00
Sand per m^3 = Rs. 275
Coarse aggregate per m^3 = Rs. 540
(All the rates are including lead charges as per SOR-2013-14)

Replacement of Lime sludge with cement	Material	Quantity Kg/m^3	Cost (Rs.)	Cost of material (Rs.)	Total Cost (Rs.)
0%	Cement	435.45	6.80/kg	2961.06	3453.43
	Lime sludge	-	1.00/kg	-	
	Sand	585	275/m^3	92.37	
	Coarse aggregate	1184	540/ m^3	400.00	
10%	Cement	391.90	6.80/kg	2664.92	3200.83
	Lime sludge	43.54	1.00/kg	43.54	
	Sand	585	275/m^3	92.37	
	Coarse aggregate	1184	540/m^3	400.00	
20%	Cement	391.90	6.80/kg	2664.92	2948.30
	Lime sludge	43.54	1.00/kg	43.54	
	Sand	585	275/m^3	92.37	
	Coarse aggregate	1184	540/m^3	400.00	
30%	Cement	304.81	6.80/kg	2072.71	2695.72
	Lime sludge	130.64	1.00/kg	130.64	
	Sand	585	275/m^3	92.37	
	Coarse aggregate	1184	540/m^3	400.00	
40%	Cement	261.27	6.80/kg	1776.64	2443.19
	Lime sludge	174.18	1.00/kg	174.18	
	Sand	585	275/m^3	92.37	
	Coarse aggregate	1184	540/m^3	400.00	
50%	Cement	217.73	6.80/kg	1480.56	2190.66
	Lime sludge	217.73	1.00/kg	217.73	
	Sand	585	275/m^3	92.37	
	Coarse aggregate	1184	540/m^3	400.00	
60%	Cement	174.18	6.80/kg	1184.42	1893.06
	Lime sludge	261.27	1.00/kg	261.27	
	Sand	585	275/m^3	92.37	
	Coarse aggregate	1184	540/m^3	400.00	

Table 7: Cost of material per cubic meter of normal concrete

The table no. 7 above reflects the comparative cost values up to 60% replacement of lime sludge with cement and cost difference for normal concrete to 20% partially replaced lime sludge concrete is Rs. 505.13 per m^3 of concrete. There is gradual decrement in total cost of per cubic meter concrete is observed.

V. Conclusion

Based on limited experimental investigation concerning the compressive strength of concrete, the following observations were made regarding partially replaced lime sludge with cement.

1) Compressive strength of the concrete increases when the percentage of replacement is increased up to 20% and decreases when replacement is increases beyond 20%.
2) In present study, it was observed that the cost difference between normal concrete & 20% partially replaced lime sludge concrete by 20 percent, is about Rs 505.13 per cubic meter of concrete.
3) This material can be used as economic alternative to the conventional concrete as after 28 days, we get sufficient strength. This material can be used for government projects to provide temporary shelter for those affected by the tsunami, E.Q. etc..
4) Using lime sludge in concrete can save the disposal costs of waste from the paper industry and produce greener construction concrete.
5) The dangerous effects of industrial paper waste on the environment can be reduced. Also the amount of cement production can be reduced to some extent.

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