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Utilization Of Paper Industry Residue For Producing Supplementary Cementation Material In Concrete - Based On Experimental Investigation

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Abstract

Every year almost 300 tons of industrial waste is produced from chemical and agricultural industries. A huge amount of solid waste is generated in paper industry. Recycling of paper fibres can only be done few times before they lose their capacity to generate high quality paper. Therefore, there is a need to investigate about the usage of this waste to produce profitable building materials. Phosphogypsum, flurogypsum, lime sludge, hypo sludge, red mud, and mine tailing pose critical threat to environment. Therefore, generating building materials from these elements would be beneficial for building constructions and it would help to overcome the environmental problems caused by the disposal of this industrial waste. This manuscript deals with production of concrete by utilising cement and different proportions of lime sludge. The aim of this manuscript is to know the concrete compressive strength, acid and sulphate resistivity by replacing cement with 0 %, 10%, 20%, 30%, 40%, and 50% lime sludge.

Keywords: Paper fibres, Industrial waste, building materials, compressive strength, acid and sulphate resistivity

Introduction

The importance of recycling industrial waste cannot be overstated, especially given the limited availability of non-renewable energy supplies and the high energy demands of building materials such as cement. The quest for a less expensive alternative to Ordinary Portland Cement (OPC) is necessary.

The quantity of sludge produced by a recycled paper mill is mostly determined by the type of raw material utilized and the end product produced [10]. There is less number of small paper mills and nearly large mills are about 28 in India. Paper consumption in India is about 3.2 kg per capita and against Asia it is 18 kg and world average of 47.7 kg. Per capita consumption of newsprint is 0.6 kg per capita as compared to Asian average of 1.9 kg and world average of 6 kg [9].

Lime sludge constitutes less content of calcium, maximum amount of calcium chloride and minimum content of silica. Due to this composition lime sludge behaves like cement. The addition of silica and magnesium to the concrete improves its curing time. The main aim of this manuscript is to investigate the usage of lime sludge as a Supplementary Cementitious Material (SCM) and its impact on concrete strength and durability. The major goals are to promote low-cost housing for people, identify the appropriate strength of partial concrete replacement, minimize maximum cement consumption, reduce maximum environmental degradation caused by cement, and protect the ozone layer from greenhouse gas emissions [2]

Need for Lime Sludge Utilisation

Numerous wastes emerge from the various processes of paper industries while producing paper. For our investigation lime sludge is utilised due to its less calcium content to replace cement. Cement production leads to emission of greenhouse gases into atmosphere. Environmental degradation is avoided by restricting mass level dumping of sludge on land.

Reduced cement production will be required to prevent ozone layer depletion. Lime sludge can be utilised as a partial substitute in high-performance concrete to achieve this goal. It is possible to increase the strength of concrete while lowering the cost of manufacture by utilising this waste.

Fıgure .1:Solid waste from Paper Industry

Materials and Methods

The materials for replacing sludge and regular concrete are listed below.

Sludge replaced concrete

a) Lime Sludge: The experimental material was lime sludge, an inorganic and non-combustible waste obtained from Mysore Paper Mills (MPM), Bhadravathi, Karnataka.

b) Aggregate:20 mm sized coarse aggregates and 4.75 mm down sized Fine aggregates were used.

c)Water: Potable drinking water was used.

d)Cement: The experimental work was carried out with 53 grade OPC.

Normal Concrete

a) Cement: Ordinary Portland cement ACC Birla Super 53 grade was used for the experimental work.

b) Water: Potable drinking water was used.

c)Aggregates:20mm sized coarse aggregates and 4.75mm down sized fine aggregates were used.

Specimen Preparation

For Strength Studies

Six cubical moulds of size 150mm x 150mm x 150mm utilised to make sludge replacement specimens, and the same was done for normal concrete.

For Durability Studies

Six cubical moulds of size 150mm x 150mm x 150mm were used to prepare specimen of Sludge Replaced Concrete and the same was for normal concrete.

Mixing for Normal Concrete (NC)

For about three minutes, cement and aggregates were dry mixed in a 60 kg capacity laboratory concrete mixer. After that, water was added and the mixture was blended for roughly two minutes. The aggregates and cement, which make up conventional concrete, were dry mixed in the pan mixer for around three minutes. After that, the liquid part of the mixture, namely water, was added to the solids. Wet mixing was continued for two minutes more.

Mixing for Sludge replaced concrete(SRC)

For about three minutes, cement, lime sludge, and aggregates were dry mixed in a 60 kg capacity laboratory concrete mixer. Then, for around two minutes, water was added to mix everything together. In the pan mixer, the solid elements of typical concrete, namely aggregates and cement, were dry mixed for roughly three minutes. After that, the liquid portion of the mixture, namely water, was added to the solids. For another two minutes, the wet mixing was continued.

Casting

For Sludge replaced and Normal concrete

The freshly produced lime sludge-based low-cost concrete had a bright colour and a gleaming finish. Usually, the blends were well-behaved.After mixing, the fresh concrete was poured in three layers into typical cube moulds. A vibrator was used to compact each layer.

Curing

For sludge replaced and normal concrete

All sludge replaced and normal concrete specimens were moved to the curing tank for 28 days before being kept at ambient temperature for an hour before to testing.

Strength Studies

Compressive Strength Test on NC and SRC specimens

After being removed from the curing tank after 28 days, the SRC and NC specimens were tested week by week. IS:456-2000 was used to evaluate compressive strength. Individually, the specimens were surface cleaned and weighed, and their values were recorded. The specimen was then placed in the compression testing machine (CTM) and the load was applied. Before the specimen failed, cracks were visible, and the needle indicating the load application began to fall back. The specimen had failed at this point.

Figure.3: Specimen after testing, as the load is applied the specimen shows cracks before it fails.

Figure .2: Specimen without load being applied.

Durability Studies

Acid Resistance Test on NC and SRC specimens

Acid resistance in concrete is not complete. Depending on the type and concentration of acid, most acid solutions will degrade Portland cement either slowly or quickly. Ca $(OH)_2$ is the most sensitive portion of the cement hydrate, however the C-S-H gel can also be damaged. Compared to calcareous aggregates, siliceous aggregates are more robust. Liquids having a pH of less than 6.5 can damage concrete [4]. However, only when the pH falls below 5.5 does the attack become severe. The attack is especially severe when the pH falls below 4.5. As the attack progresses, all of the cement compounds, as well as any carbonate aggregate material, are eventually broken down and leached away. Calcium sulphate is attacked by sulphuric acid.

Sulphate Resistance Test on NC and SRC specimens

At the age of 28 days of curing, the sulphate resistance test can be performed on 150 cm cubes.

For six weeks, the cube specimens are weighed and immersed in water diluted with 5% Magnesium

Sulphate by weight. Every two days, the cubes were alternated between being wet and being dry. The specimens were then taken out of the sulphate water mixture every week, and the cube surfaces were cleaned. The specimen's weight and compressive strength were then determined, and the average percentage loss of weight and compressive strength was estimated.

Results and Discussions

Compressive Strength Test on NC and SRC specimens

Table. 1: Compressive strength for different percentage of sludge replacement.Specimens having 10% of sludge replacement shows high compressive strength.

Percentage of Sludge Replacement	No of Specimens	Compressive Strength (N/mm^2)
0%	3	35.55
10%	3	48.88

20%	3	37.77
30%	3	36.00
40%	3	20.44
50%	3	12.46

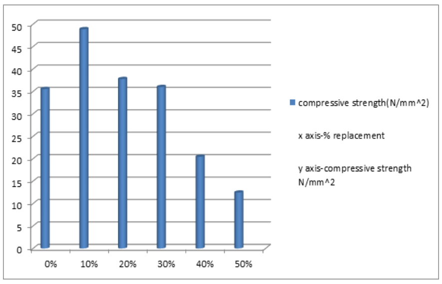


Figure .4: Graphical representation of Compressive strength for different percentage of sludge replacement at 28 days. Specimens having 10% of sludge replacement shows optimum compressive strength.

Figure 5: Graphical representation of Compressive Strength of NC and SRC.Maximum compressive strength is shown by NC.

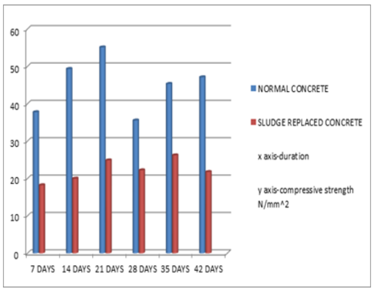


Figure 6: Graphical representation of Percentage Compressive strength loss.NC shows decreasing

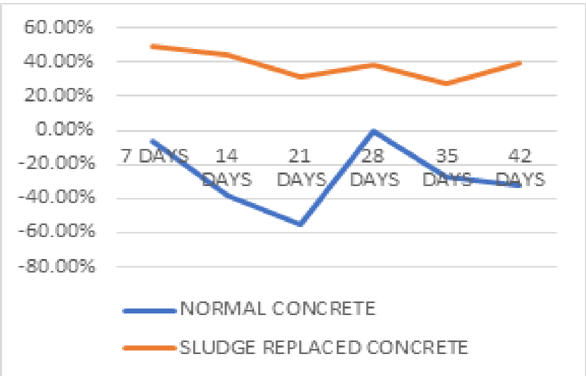


Figure 7: Graphical representation of Percentage weight loss for NC and SRC.SRC shows maximum weight loss for 21 days of curing.NC shows gradual increasing trend initially and decreasing trend till 28 days.

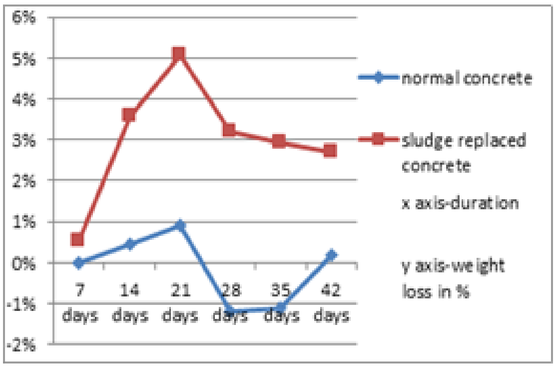


Table.2: Acid Resistance Test for Normal concrete. After 21 days, concrete exhibits maximum compressive strength

Time Period	**Compressive Strength(N/mm^2)**
7 days	37.77
14 days	49.33
21 days	55.11
28 days	35.55
35 days	45.33
42 days	47.11

Acid Resistance Test on NC and SRC specimens

After 35 days curing, concrete shows maximum compressive strength.

Table.3: Acid Resistance Test for Sludge replaced concrete

Time Period	Compressive Strength(N/mm^2)
7 days	18.22
14 days	20.00
21 days	24.88
28 days	22.22
35 days	26.22
42 days	21.77

Table.4: Percentage Compressive Strength Loss. Normal concrete shows compressive strength loss when compared to SRC

Duration	Normal Concrete	Sludge replaced concrete
7	-6.24%	49.38%
14	-38.76%	44.44%
21	-55.02%	30.88%
28	0%	38.27%
35	-27.51%	27.16%
42	-32.50%	39.52%

Table.5: Weight loss of cubes trend of compressive strength till 21 days and increasing trend upto 28 days and decreases SRC shows gradual decrease and increase.

Initial (from water curing)-8.53 Normal Concrete	**Initial (from water curing)-8.29 Low cost concrete**
8.530	8.245
8.490	7.990
8.450	7.870
8.635	8.025
8.625	8.045
8.515	8.065

Time period	**Compressive Strength(N/mm^2)**
7 days	58.22
14 days	48.88
21 days	52.44
28 days	48.88
35 days	53.33
42 days	52.44

Time Period	**Compressive Strength (N/mm^2)**
7 days	25.77
14 days	27.55
21 days	32.44
28 days	26.66
35 days	28.88
42 days	33.33

Figure.9: Graphical representation of Compressive Strength of NC and SRC.NC exhibits optimum compressive strength when compared to SRC

Table.8: Sulphate Resistance Test on Sludge Replaced Concrete.21 days of curing gives maximum compressive strength to concrete

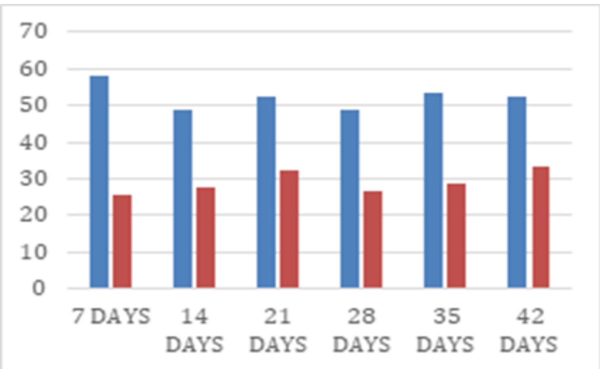
Table.6: Percentage Weight Loss of Cubes.SRC exhibits more weight loss when compared to NC

Normal Concrete	Sludge replaced concrete
0%	0.54%
0.46%	3.60%
0.93%	5.06
-1.17%	3.19%
-1.11%	2.95%
0.17%	2.71%

Sulphate Resistance Test on NC and SRC specimens

Table.7: Sulphate Resistance Test on Normal Concrete after 7 days curing concrete shows high compressive strength

Table.9: Percentage Compressive Strength Loss.NC shows compressive strength loss.



Duration	Normal concrete	Sludge Replaced
7 days	-63.79%	28.00%
14 days	-37.50%	23.47%
21 days	-47.55%	9.88%
28 days	-37.50%	25.90%
35 days	-50.00%	19.70%
42 days	-47.50%	7.4%

Conclusions

In compared to normal concrete, lime sludge replaced it, according to the research. To create low-cost concrete, lime sludge is used as a substitute for Portland cement. The design mix proportions of M20 grade are included and illustrated for both sludge replacement and normal concrete. Durability properties of both concrete were estimated by performing acid resistance test, sulphate resistance test.

When compressive strength test was performed at 28 days, sludge-replaced concrete with 10% and 20% sludge provides 27.27 percent and 5.9 percent more strength than regular concrete, respectively. As a result, the sludge-replaced concrete gains strength quickly. However, after 28 days, concrete with 30% sludge restored has the same strength as regular concrete. When 40% or 50% of the concrete is replaced with sludge, the strength of the structure suffers greatly. When acid resistance test was performed, initially, there was a minor gain in compressive strength for NC, but a considerable drop in compressive strength for SRC. The percent weight loss graph shows that the values of normal concrete vary in a hostile manner, whereas the values of sludge replaced concrete vary in a naive manner. When Sulphate Resistance Test was performed, there was an initial rise in compressive strength for NC and a decrease in compressive strength for SRC. For each, there was a slow increase and drop. The values of both NC and SRC vary in a hostile manner, as can be seen in the percent weight loss graph.

According to this manuscript, we can conclude that, the compressive strength of NC is the same as the compressive strength of 30% sludge replacement concrete. The amount of cement used in the production of concrete is lowered, resulting in lower cement costs. Maximum compressive strength is achieved, when we replace 10% of cement with lime sludge Wastes are harmful to the environment, and the amount of cement that can be utilised is restricted. Because it achieves similar results to conventional concrete, sludge-replaced concrete can be used in structures where compressive strength is a significant requirement. This project opens up the possibility of a better and more versatile cementitious material.

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