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Investigation of Waste Paper Cellulosic Fibers Utilization into Cement Based Building Materials

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Abstract

Phosphogypsum, fluorogypsum, lime sludge, hypo sludge and red mud include poisonous elements that degrade the strength and qualities of building materials, posing disposal issues as well as health risks. This manuscript is about an experimental study on concrete strength, durability, and the best proportion of partial substitution of cement with 0%, 10%, 20%, 30%, 40%, and 50% lime sludge and also presents to create low-cost concrete in another term call it as Economical Concrete (E-Concrete), lime sludge is used as a substitute for Portland cement. Paper production generates a significant amount of solid waste. Separation of low-quality paper fibers, dyes, and kaolin coating, which gives magazines a shiny appearance, produces waste sludge. Every year, this paper mill muck takes up a significant amount of local landfill space. In order to lessen disposal and environmental issues, investigations were undertaken to produce low-cost concrete by blending different ratios of cement with lime sludge.

Keywords: Low-Cost Concrete, Lime Sludge, Cement, Water Cement Ratio, paper mill muck, solid waste

Introduction

Energy plays a crucial role in the growth of developing countries like India. An equal quantity of carbon dioxide is discharged into the atmosphere when 1 ton of Ordinary Portland Cement (OPC) is manufactured. The quest for a less expensive alternative to OPC is necessary. Y.D. Shermale, M.B. Varma conducted an investigation on 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. The lime sludge has a low calcium content, a high calcium chloride content, and a low silica content. Because of its silica and magnesium content, lime sludge behaves like cement. The addition of silica and magnesium to the concrete improves its curing time. This silica and magnesium help the concrete's settling. The goal of this study is to look into the use of lime sludge as a Supplementary Cementitious Material (SCM) and its influence on the strength and durability of concrete. G.L Abhishek work on the main scope is to promote low-cost housing for people, determine the optimal strength of partial concrete replacement, reduce the maximum demand for cement, reduce the maximum environmental degradation caused by cement, and protect the ozone layer from greenhouse emissions. Cherian Varkey, Jefin P John, Neema V.N, Namitha Joshy work on the mechanical properties of the concrete specimens were evaluated for up to 28 days using compression, splitting tensile, and flexural tests.

Need for Lime Sludge Utilization

Numerous wastes emerge from the paper industry's various processes when creating paper. Due to its low calcium content, the preparatory waste known as lime sludge is chosen for our proposal to replace cement in concrete. Greenhouse gases are released into the atmosphere as a result of cement manufacture. They emit 1 million tons of greenhouse emissions for every 4 million tons of cement they produce. This sludge has also been avoided in mass level land disposal to limit environmental degradation. Reduced cement production is required to prevent ozone layer depletion. Lime sludge can be utilized as a partial substitute in high-performance concrete in this case. By repurposing this waste, the strength of concrete can be improved while also lowering the cost of manufacture.

Jayraj et al. conducted an experimental examination on the strength of concrete and the optimum percentage of partial replacement by designing a mix M20 grade according to Indian Standard Method and using it to manufacture test samples in 2013. The optimum compressive stress attained by using paper waste was at 30 percent replacement in the test. The cost comparisons show a continual decrease in the total cost of concrete per cubic metre. This material can be utilised for economic feasibility when the government implements initiatives for temporary shelters for persons affected by natural disasters.

Materials and Methods

Materials for sludge replaced and normal concrete

Lime Sludge

The experimental material was lime sludge, an inorganic and non-combustible waste supplied from Mysore Paper Mills (MPM), Bhadravathi, Karnataka shown in the figure 1.

Figure 1: Waste from paper mills

Aggregates

The coarse aggregates were 20 mm in size, and the fine aggregates were 4.75 mm in size for both normal and sludge replaced concrete.

Water

Potable drinking water is used for both normal and sludge replaced concrete.

Cement

The trial work was carried out with ordinary Portland cement of the ACC Birla Super 53 grade for both normal and sludge replaced concrete.

Methodology

Six 150mm x 150mm x 150mm cubical moulds were used to make sludge-replacement concrete and normal concrete specimens.

Sludge replaced concrete

For roughly 3 minutes, cement, lime sludge, and aggregates were dry mixed in a 60 kg capacity laboratory concrete mixer. Then, for around 2 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 continued.

Normal concrete

For roughly 3 minutes, cement and aggregates were dry mixed in a laboratory concrete mixer with a capacity of 60 kg. Then, for around 2 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 continued.

Casting

The freshly lime sludge-based low-cost concrete had a light shade and a sparkling finish. Usually, the mixture was well-behaved.

After mixing, the fresh concrete was poured in three layers into typical cube moulds. A vibrator was used to condense each layer.

Curing

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

Strength Studies

Compressive Strength

After being removed from the curing tank for 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 CTM and the load was applied and comressive strength values are given int the table 1 with figure 2.

Figure 2: Specimen before testing

Figure 3: Specimen after testing

Durability Studies

Acid Resistance Test

Liquids having a pH of less than 6.5 can damage concrete. 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. Corrosion can occur if acids or salt solutions access the reinforcing steel through fractures or porosity in the concrete, causing cracking.

The acid resistance test can be performed on a 100 mm cube specimen that has been cured for 28 days. For 6 weeks, the cube specimens are weighed in water diluted with 2N 10% hydrochloric acid by weight. Every two days, the cubes were alternated between drying and wetting. The specimens were then removed from the corrosive water and the cubes' surfaces were cleaned once a week. After that, the specimens' weight and compressive strength are determined, and the average Percentage loss of weight and compressive strength is calculated as shown in the table 2 and table 3 for Normal Concrete and Sludge replaced concrete as shown in figure 5.

Sea Water Test

It is critical to use rich concrete with a low water cement ratio and use the proper type of cement with low C3A content to improve the durability of concrete in sea water. The rich concrete with low w/c ratio primarily makes the concrete impenetrable to the attack of sea water, and the concrete's small capillary pores do not hold water, causing expansion either by freezing or by salt crystallization. Other ideal procedures for strengthening durability against sea water include providing appropriate cover, using pozzolanic material, good compaction, and well-made building joints, among others.

The sea water resistance test can be performed on 150 mm cube specimens that have been curing for 28 days. Weighted cube specimens are immersed in sea water for six weeks. Every two days, the cubes were alternated between drying and wetting. The specimens were then removed from the salt water every week and the cubes' surfaces were cleaned. After that, the specimens' weight and compressive strength are determined, and the average Percentage loss of weight and compressive strength is calculated.

Sulphate Resistance Test

The sulphate resistance test can be performed on 150 cm cubes that have been curing for 28 days. For 6 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 wetting and drying. The specimens were then removed from the sulphate water mixture once a week and the cubes' surfaces were cleaned. The specimens' weight and compressive strength were then determined, and the average percent weight loss and compressive strength were calculated as shown in the table 7 and table 8 for Normal Concrete and Sludge replaced concrete.

Results and Discussions

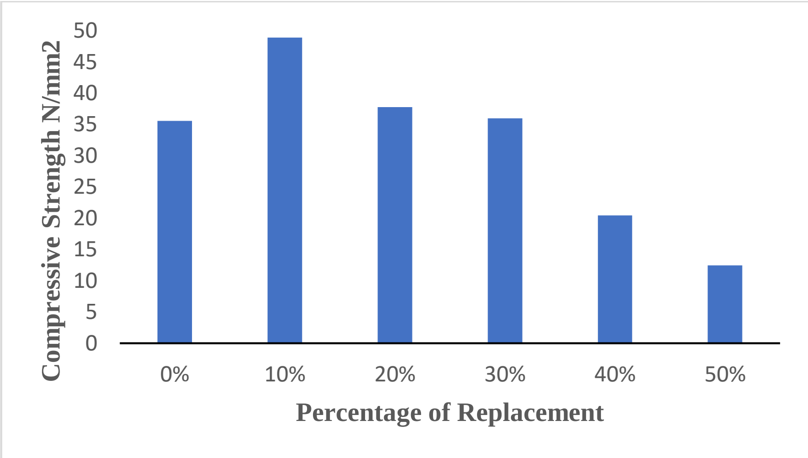
Compressive Strength

Table 1: Compressive Strength

Percentage of sludge replacement	No. of specimen	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: Compressive strength for different % of replacement at 28 days



Acid Resistance Test

Figure 5: Compressive strength of NC and SRC

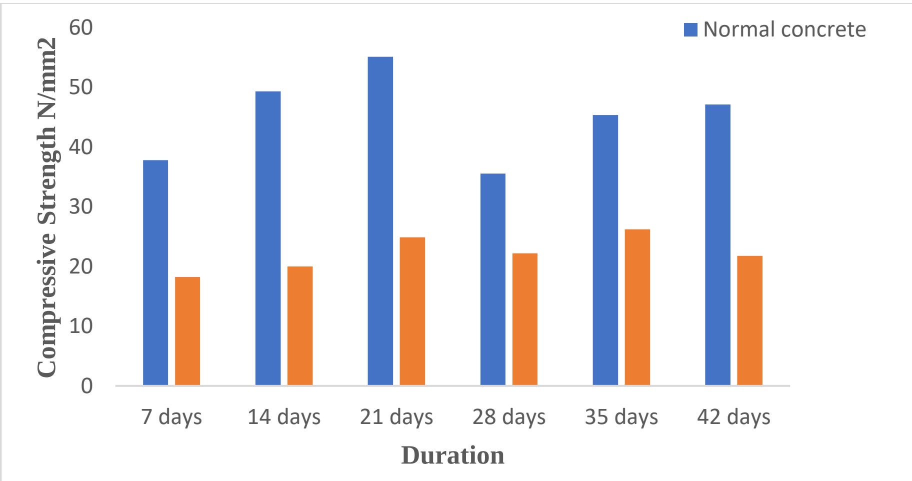


Table 2: Acid Resistance Test for Normal concrete

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

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

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

Figure 6: Compressive Strength for NC and SPC

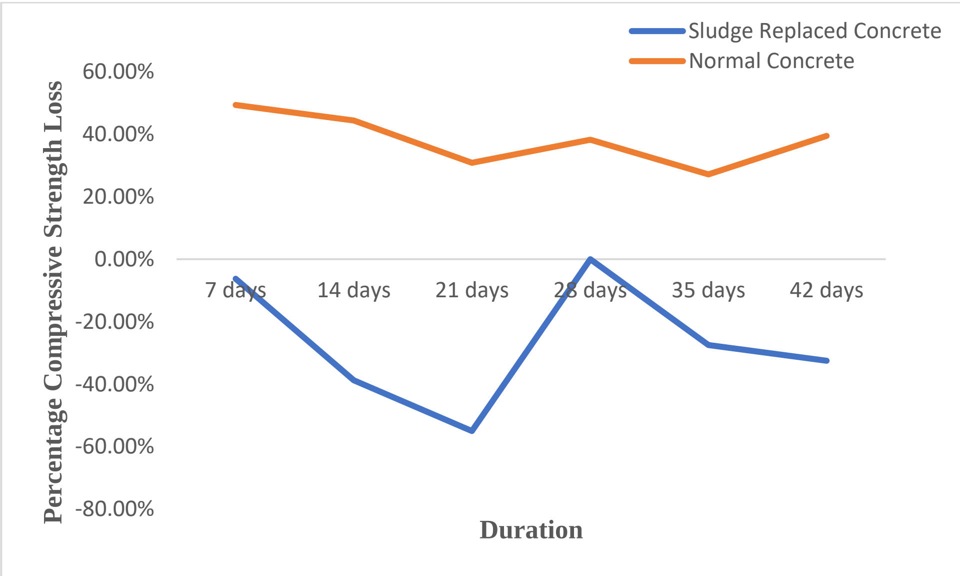


Table 5: Weight Loss of Cubes

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

Table 6: Percentage Weight Loss of Cubes

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%

Figure 7: Percentage weight loss for NC and SRC

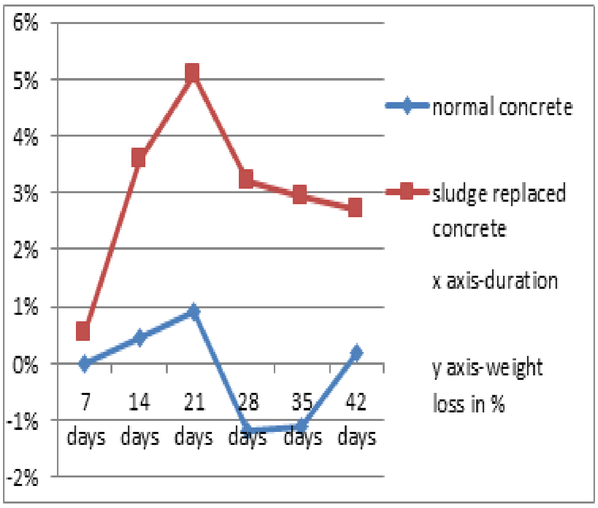
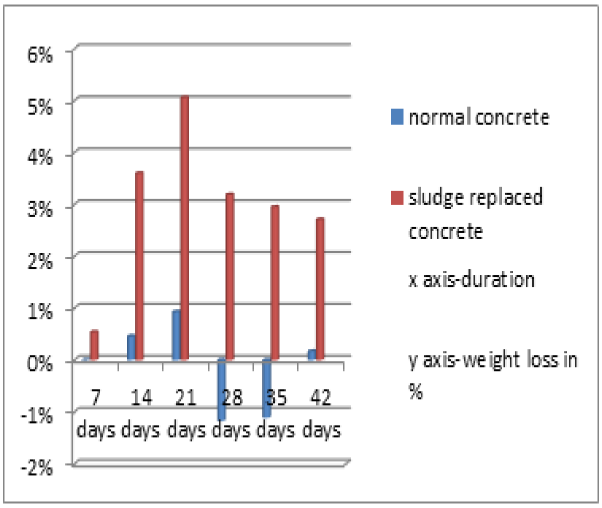


Figure 8: Percentage weight loss for NC and SRC



Sulphate Resistance Test

Table 7: Sulphate Resistance Test on Normal Concrete

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

Table 8: Sulphate Resistance Test on Sludge Replaced Concrete

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: Compressive Strength of NC and SRC

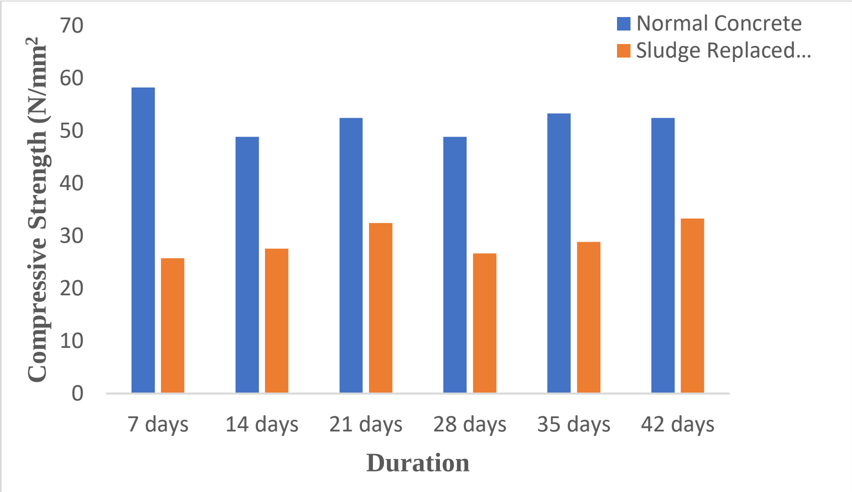


Figure 10: Compressive Strength Loss for NC and SRC

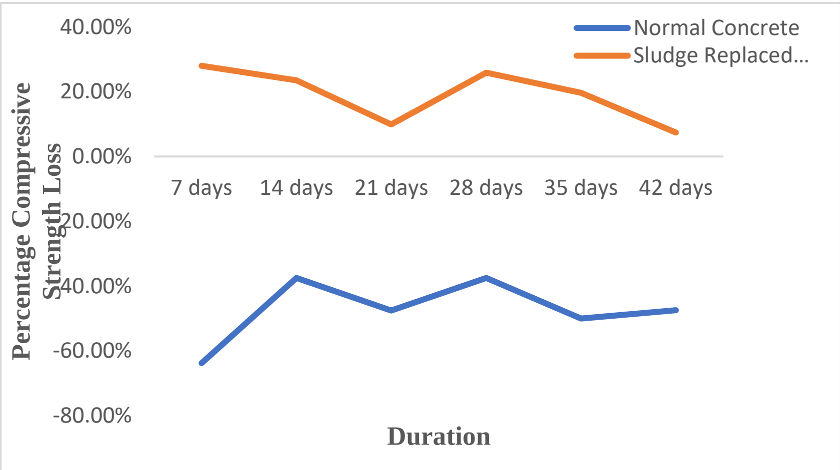


Table 9: Percentage Compressive Strength Loss

Duration	Normal Concrete	Sludge Replaced Concrete
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%

Table 10: Weight Loss of Cubes

Initial (from water curing)-8.520 (Normal Concrete)	Initial (from water curing)-8.250 (low-cost concrete)
8.460	8.120
8.425	8.300
8.565	8.165

8.450	8.150
8.445	8.185
8.400	8.070

Table 11: % Weight Loss of Cubes

Normal concrete	Low-cost concrete
0.70%	1.57%
1.11%	-0.60%
-0.52%	1.03%
0.82%	1.21%
0.88%	0.78%
1.40%	2.18%

Figure 11: Percentage weight loss of NC and SRC

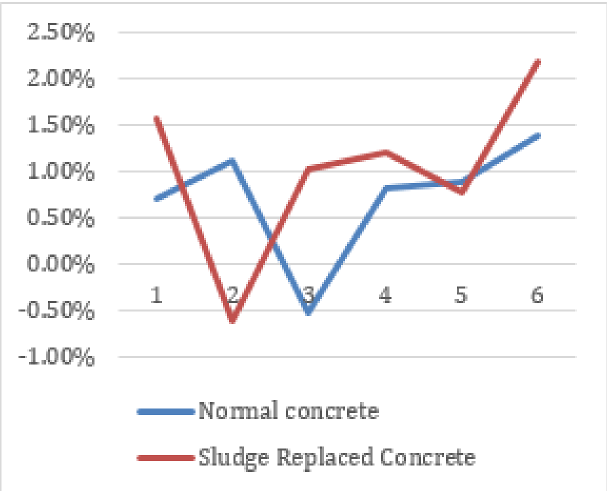
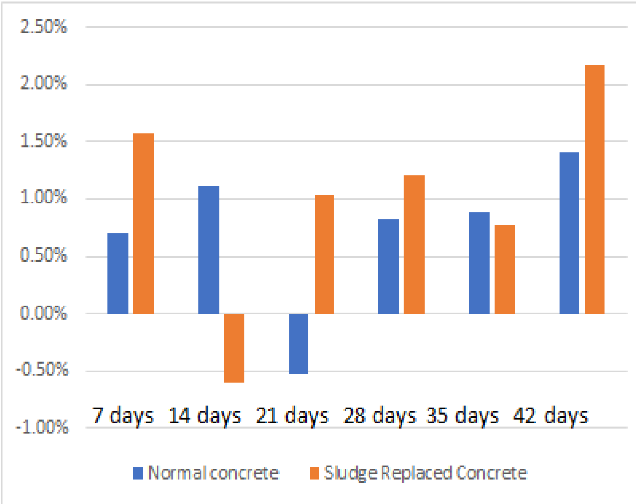


Figure 12: Percentage weight loss of NC and SRC



Sea Water Resistance Test

Table 12: Sea Water Resistance Test of Normal Concrete

Time Period	Compressive Strength (N/mm^2)
7 Days	46.66
14 Days	57.77
21 Days	44.00
28 Days	53.33
35 Days	36.88
42 Days	48.88

Table 13: Sea Water Resistance Test of sludge replaced concrete

Time Period	Compressive Strength (N/mm^2)
7 Days	26.66
14 Days	25.33
21 Days	27.55

28 Days	28.88
35 Days	31.11
42 Days	25.33

Figure 12 compressive strength of NC and SRC

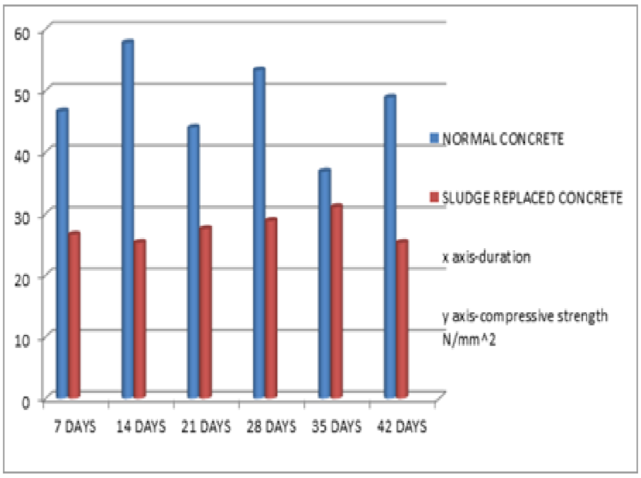


Figure 13: Compressive Strength of NC and SRC

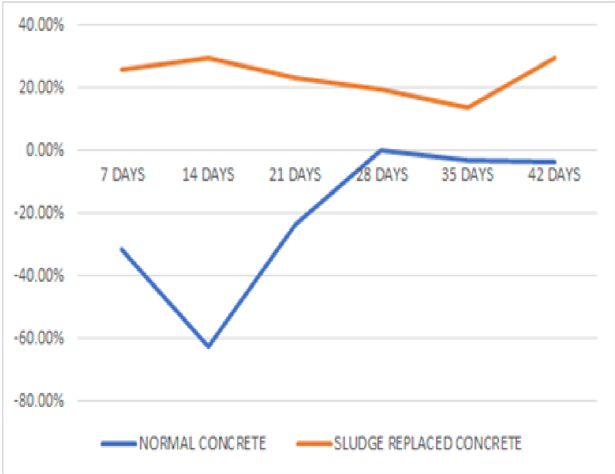


Table 14: Percentage Compressive Strength Loss

Duration	Normal Concrete	Sludge Replaced Concrete
7 Days	-31.25%	25.94%
14 Days	-62.50%	29.63%
21 Days	-23.75%	23.47%
28 Days	14 DAYS	19.70%
35 Days	-3.07%	13.58%
42 Days	-3.75%	29.63%

Table 15: Weight Loss of Cubes

Initial (from water curing)- 8.500 (Normal concrete)	Initial (from water curing)- 8.230 (sludge replaced concrete)
8.430	8.150
8.400	8.060
8.770	8.330
8.555	8.125
8.300	8.190
8.555	8.310

Table 16: Percentage Weight Loss of Cubes

Normal concrete	Sludge replaced concrete
0.82%	0.97%
1.17%	2.06%
-3.17%	-1.12%
-0.64%	1.27%

2.35%	0.48%
-0.64%	1.20%

Figure 14: Percentage weight loss of NC and SRC

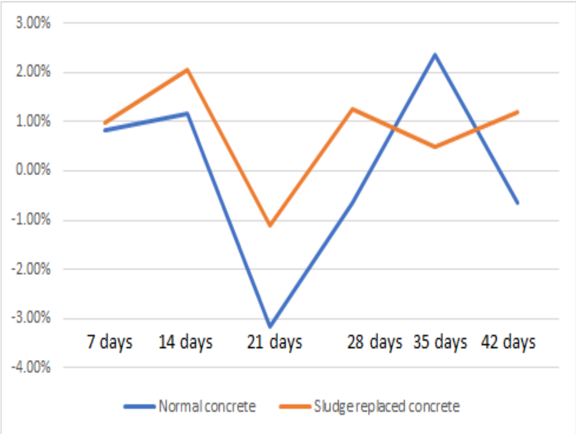
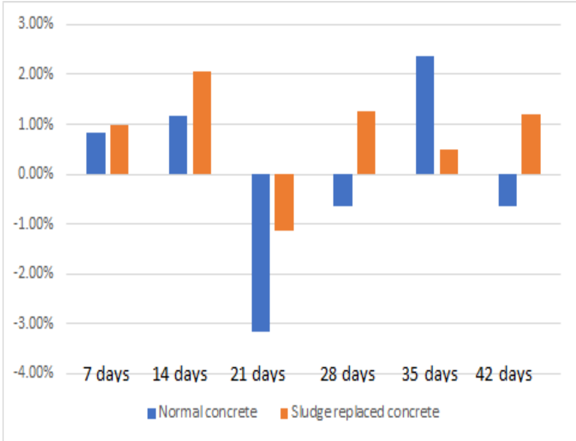


Figure 15: Percentage weight loss of NC and SRC



Conclusions

At 28 days, sludge-replaced concrete with 10% and 20% sludge produces 27.27 percent and 5.9 percent higher strength than conventional concrete, respectively. As a result, the sludge-replaced concrete achieves early strength. However, in 28 days, 30% sludge-replaced concrete had the same strength as regular concrete. The strength of 40 percent and 50 percent sludge-replaced concrete deteriorates dramatically. For Acid Resistance Test the normal concrete showed a minor gain in compressive strength, whereas SRC showed a significant loss. 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. For Sulphate Resistance Test the normal concrete showed an increase in compressive strength at first, while SRC showed a loss. For each, there was a slow increase and collapse. The values of both NC and SRC vary in a hostile manner, as can be seen in the percent weight loss graph. For Sea Water Resistance Test the compressive strength of NC increased, while the compressive strength of SRC decreased, albeit not by a significant amount. The values of both NC and SRC vary in a hostile manner, as can be seen in the percent weight loss graph. From this we can conclude that, the maximum compressive strength is achieved by replacing 10% of the cement with lime sludge. Wastes have a negative impact on the environment, and the maximum amount of cement that may be used is limited. Sludge-replaced concrete can be utilised in structures where compressive strength is a primary consideration, as it produces similar results to regular concrete. The compressive strength of ordinary concrete is the same as that of 30 percent lime sludge-replaced concrete.

References

Cherian Varkey, Jefin P John, Neema V.N, Namitha Joshy. (2016), 'Study on Utilization of Waste Paper Sludge by Partial Replacement of Cement in Concrete', IRJET, Vol. 3 Issue 5, ISSN 2395-0072.

G.L Abhishek (2017) “Experimental Study on Behaviour of Paper Sludge Concrete” a Journal of multidisciplinary science and technology, Vol. 8, Page 73-78, ISSN: 0976-3104.

IS 10262:1981 “IS Method of Mix Design”, Bureau of Indian Standards, New Delhi.

IS 516:1959 “Methods of Tests for Strength of Concrete”, Bureau of Indian Standards, New Delhi.

IS 456:2000 “Code of Practice for Plain and Reinforced Concrete”, Bureau of Indian Standards, New Delhi.

Jayraj Vinodsinh Solanki, Jayeshkumar Pitroda, “Investigation of Low Cost Concrete Using Industrial Waste as Supplementary Cementitious Materials”, International Journal of Engineering Science and Innovative Technology (IJESIT), Volume 2, Issue 1, ISSN: 2319-5967, pp.81-88, January 2013.

NevilleA.M and BrooksJ.J,”Concrete Technology”, ELBS with Longman, Essex CM20 2JE, England, 1994.

Srinivasan.R and Palanisamy .M et al, “Experimental Investigation In Developing Low Cost Concrete From Paper Industry Waste”, Tamilnadu college of engineering, Karumatham patti, Coimbotore, (private communication).

Y.D. Shermale and M.B .Varma, “Effective use of Paper Sludge in Concrete” IJSRD - International Journal for Scientific Research & Development| Vol. 3, Issue 08, 2015 | ISSN (online): 2321-0613.