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Experimental Investigation On Properties Of Concrete Using Lime Sludge As Partial Replacement

Prashant Sunagar[1*] , Hemavathy S [2] , Nagashree B[3] , Mouneesh Jayakumar [4] , Sumalatha J [5]

[1,3 ,4& 5] Department of Civil Engineering, M S Ramaiah Institute of Technology, Bangalore, India

[2]Department of Mechanical Engineering, M S Ramaiah Institute of Technology, Bangalore, India

Abstract

Paper industry produces an enormous amount of solid waste.The paper fibres can be recycled only for certain number of times to produce high quality paper.Hence, it is of prime concern to develop methods to use this waste to produce affordable building materials.Lime sludge can be used as a supplementary cementation material in concrete composition,which is tested as an alternative to standard concrete.This manuscript deals about generating low-cost concrete by combining various ratios of lime sludge with cement and to eliminate disposal and pollution problems caused by lime sludge.Various tests were undertaken to assess the mechanical parameters, like, concrete compressive strength, sea water resistivity and sulphate resistivity by replacing cement with 0 %, 10%, 20%, 30%, 40%, and 50% lime sludge.

Keywords: Solid waste, paper fibres,Affordable building materials,concrete composition, compressive strength,sea water resistivity, sulphate resistivity

Introduction

We require around 1 tonne of resources from earth, such as lime stone, to produce 1 tonne of Ordinary Portland Cement (OPC). Furthermore, an equivalent amount of carbon dioxide is released into the atmosphere during the manufacture of 1 tonne of Ordinary Portland Cement. Emissions of carbon dioxide, is harmful to ecosystem. In this context, finding a less expensive alternative to OPC is essential (8).

Composition of lime sludge includes less amount of calcium, maximum amount of calcium chloride and minimum silica concentration.The major reason for lime sludge to behave as cement is due to silica and magnesium constituents.These two elements improve the setting of concrete(8).

The amount of sludge produced varies in each mill. The amount of sludge produced by a recycled paper mill is mostly determined by the type of furnish utilised and the final product produced. Paper mill sludge can be utilised as a partial replacement for cement in the production of fresh concrete for low-cost housing projects (9).

Fingure .1: Solid waste from Paper Industry

Materials Utilised for the Experiments

For determining the various properties of replaced sludge and normal concrete the following materials are utilised.

Sludge replaced concrete (SRC)

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

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

Water: Potable drinking water was used.

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

Normal Concrete (NC)

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

Water: Potable drinking water was used.

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

Preparation of Specimen

Cubical moulds of size 150mm x 150mm x 150mm, total six in number was used to make specimens for sludge replaced and same was done for normal concrete, in order to study the strength properties.

Six 150mm x 150mm x 150mm cubical moulds were utilised to make sludge-replaced concrete specimens, and the same was done for normal concrete,for the tests in order to determine the durability properties.

Mixing

a) Procedure for mixing of 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 was continued.

b) Procedure for mixing sludge replaced concrete

In a 60 kg capacity laboratory concrete mixer, cement, lime sludge, and aggregates were dry mixed for roughly 3 minutes. After that, water was added and the mixture was blended for roughly 2 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.

Casting for SRC and NC

Freshly prepared lime sludge based low cost concrete had shiny appearance and was light in colour.Unusually the composition was cohesive.The fresh concrete was casted into standard cube moulds in three layers,after mixing.Each layer was compacted using vibrator.

Curing for SRC and NC

The freshly lime sludge based low cost concrete was light in colour and shiny in appearance. The mixtures were usually cohesive. After mixing, the fresh concrete was casted into standard cube moulds, in three layers. Each layer was compacted using vibrator.

Strength Studies

Compressive Strength on SRC and NC

Concrete is designed to withstand compressive loads; the determination of compressive strength has attracted a lot of attention among the various concrete strengths. To determine the compressive strength, 100mm or 150mm cubes are employed. The specimens are casted, cured, and tested according to industry standards. Varying specimens give different compressive strengths for the same concrete mix.

Procedure for the test

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 compression testing machine (CTM) and the load was applied. Before the specimen collapsed, cracks were visible, and the needle indicating the load application began to fall back. The specimen had failed at this point.

Figure.2: Specimen before testing .Specimen that is taken out after curing for 28 days is surface cleaned and weighed for ested under compression testing machine.

Figure.3: Specimen after testing.Cracks were visible before specimen collapsed

Durability Studies

Concrete's durability refers to its ability to withstand weathering, chemical attack, abrasion, or any other deterioration process.

A durable concrete is one that works well in the workplace under the conditions it is expected to be exposed to during service.

Materials and mix proportions should be chosen and applied in such a way that implanted metal is protected against corrosion.

Factors that influence durability

1. Environment

2. Cover the steel that has been embedded.

3. The type and grade of the materials that make up the components.

4. The concrete's cement content and water/cement ratio.

5. The member's shape and size.

Water - Cement Ratio (w/c)

The durability of concrete is influenced mainly by water-cement ratio.This ratio should always be of low value,in case of high value it results in high permeability which causes change in volume of concrete leading to cracks and failure of the structure.

Sea Water Resistance Test on SRC and NC

Concrete deterioration in sea water is frequently characterised by loss or erosion of constituent from material without any expansion.When concrete is exposed to sea water, it experiences a number of reactions at the same time.

It is essential to use rich concrete with a low w/c 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 impervious 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 crystallisation. Other ideal procedures for strengthening durability against sea water include providing appropriate cover, using pozzolanic material, good compaction, and well-made building joints. For greater durability, high-pressure steam-cured prefabricated concrete pieces should be used whenever possible.

Procedure for sea water resistance test on SRC and NC

The sea water resistance test can be performed on 150 mm cube specimens that have been cured for 28 days. The cube specimens are weighed 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 cube surfaces were cleaned. After that, the specimen's weight and compressive strength are determined, and the average percentage loss of weight and compressive strength is calculated.

Sulphate Resistance Test on SRC and NC

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 wetting and drying. 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 Discussion

Compressive strength of SRC and NCSpecimens

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 ofSpecimens	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

Fıgure 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

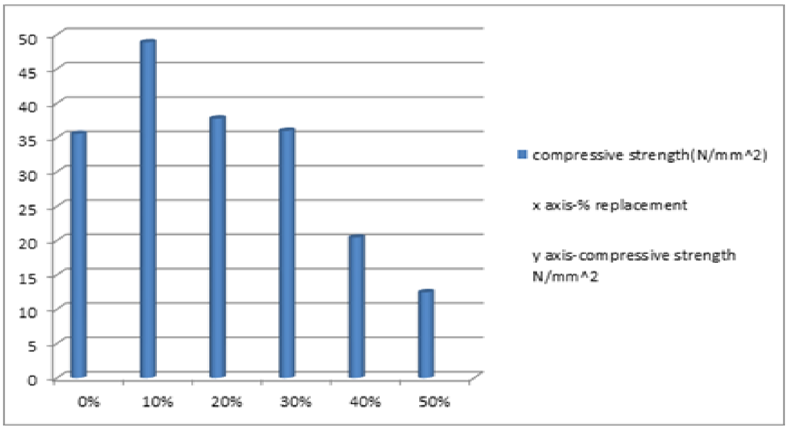
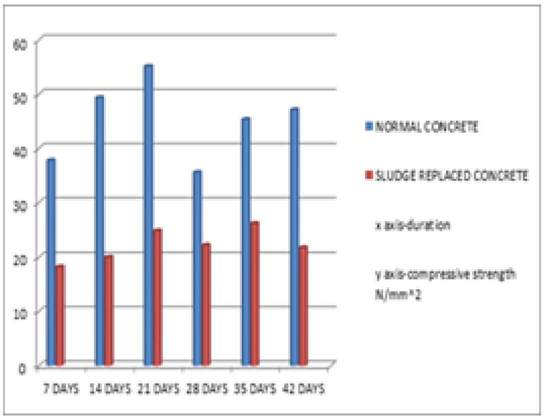


Figure.5: Graphical representation of Compressive Strength of NC and SRC. Maximum compressive strength is shown by NC.



Sea Water Resistance of SRC and NC

Sea Water Resistance test on NC

Table.2: Tabular representation of results of sea water resistance test on NC. At 14 days of curing NC shows highest compressive strength.

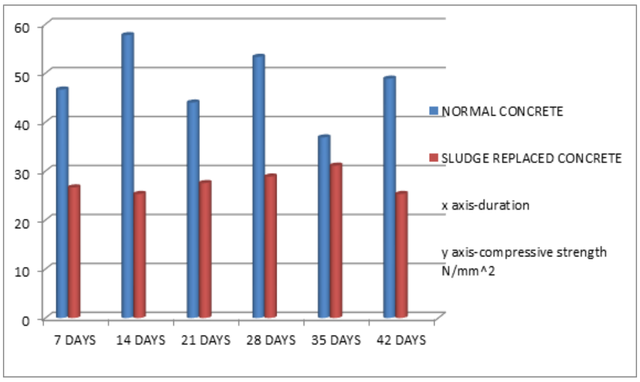
Time period	Compressive Strength(N/mm^2)
7 days	46.66
14 days	57.77
21 days	44.00
28 days	53.33
35 days	36.88
42 days	48.88

Sea Water Resistance test on SRC

Figure 3: Tabular representation of results of sea water resistance test on SRC. At 35 days of curing NC shows highest compressive strength.

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.6: Pictorial representation of Compressive strength of NC and SRC.At 35 days of curing both NC and SRC specimens will show nearly same compressive strength.

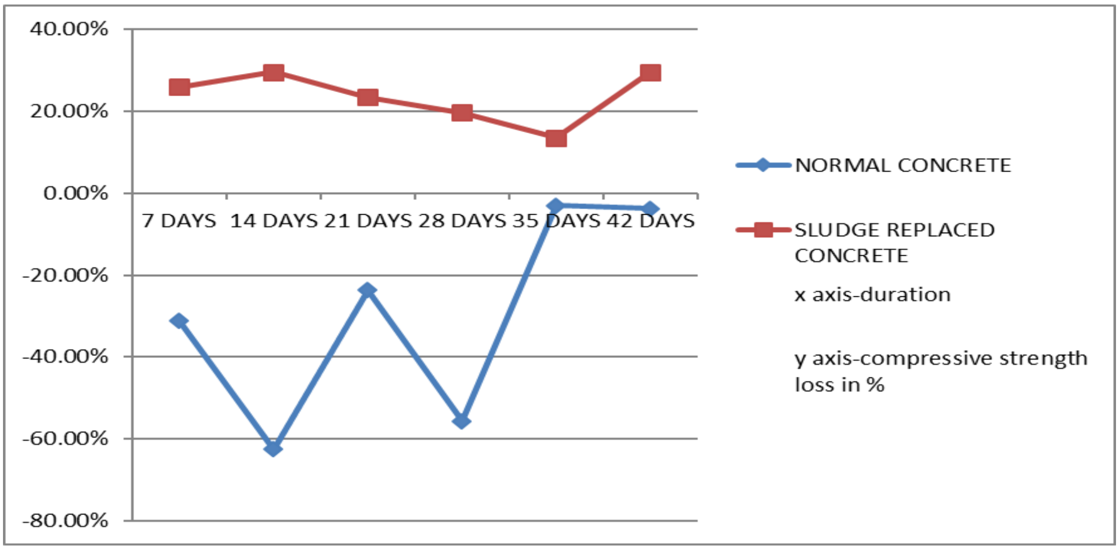


Sea water resistance test on SRC and NC (Percentage compressive strength loss)

Table.4: Tabular data of percentage compressive strength loss of SRC and NC in sea water resistance test

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%

Figure 7: Pictorial representation of SRC and NC specimen's compressive strength



Sea water resistance of SRC and NC (weight loss of cubes)

NC shows decreasing and increasing strength upto 35 days and remains same. SRC shows slight increase initially and then decreases till 35 days and then increases.

Table.5: Tabular representation of results of sea water resistance test on SRC and NC for determining weight loss in cubes. Maximum weight loss is 8.770 for NC and 8.330 for SRC.

Initial (from water curing) -8.500 (NC)	Initial (from water curing)- 8.230 (SRC)
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.6: Tabular representation of results of sea water resistance test on SRC and NC for determining percentage of weight loss in 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 .8:Pictorial view of percentage weight loss of NC and SRC during sea water resistance test.NC shows more weight loss for sea water impact than SRC

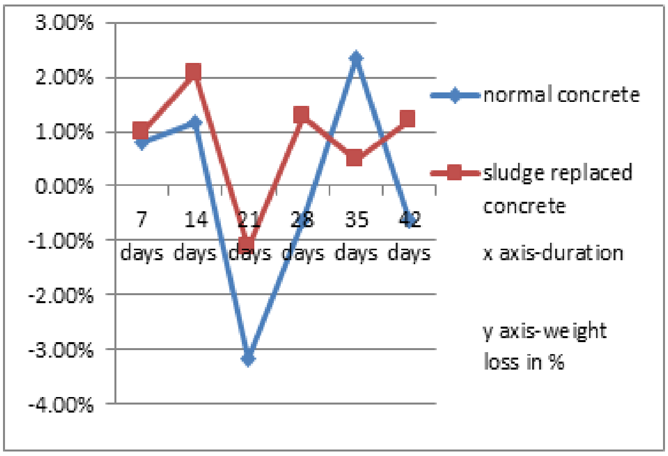
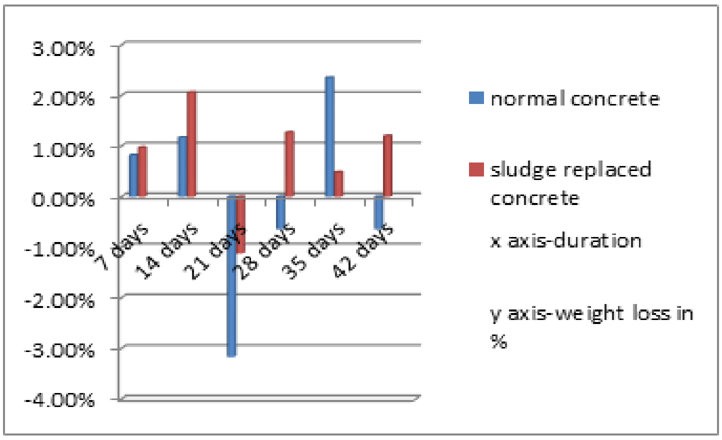


Figure .9:Graphical representation of percentage weight loss of NC and SRC after carrying out sea water resistance test.NC shows more weight loss for sea water impact than SRC.



Sulphate resistance test on NC and SRC

Table.7: Tabular representation of Sulphate Resistance Test on NC.After 7 days curing concrete shows high compressive strength

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

Figure.10:Graphical representation of Compressive Strength of NC and SRC.NC exhibits optimum compressive strength when compared to SRC

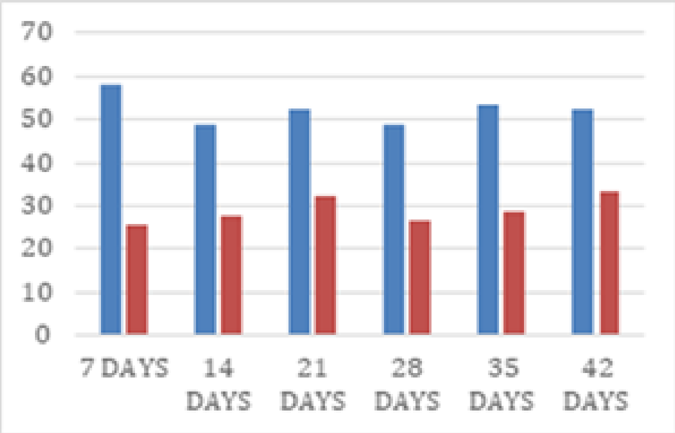


Figure.11:Graphical representation of Compressive Strength Loss for NC and SRC.SRC shows decreasing trend and again increases and then decreases.NC increases upto a point and then shows decrease and increase trend.

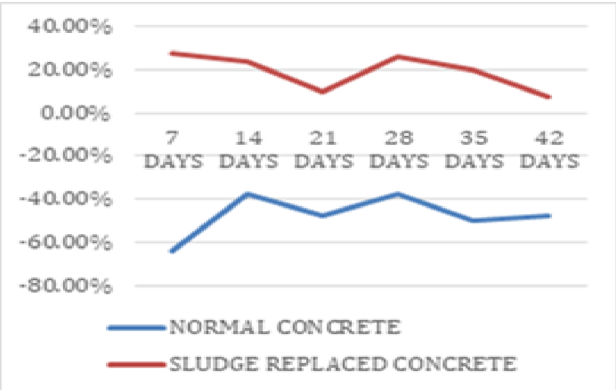


Table.8: Tabular representation of results of Sulphate Resistance Test on Sludge Replaced Concrete.21 days of curing gives maximum compressive strength to concrete

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

Table.9: Tabular representation of data result of percentage Compressive Strength loss. NC shows maximum compressive strength loss than SRC.

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%

Figure 12: Graphical representation of percentage weight loss of NC and SRC after carrying out sulphate resistance test.NC and SRC both show almost same trend of percentage weight loss

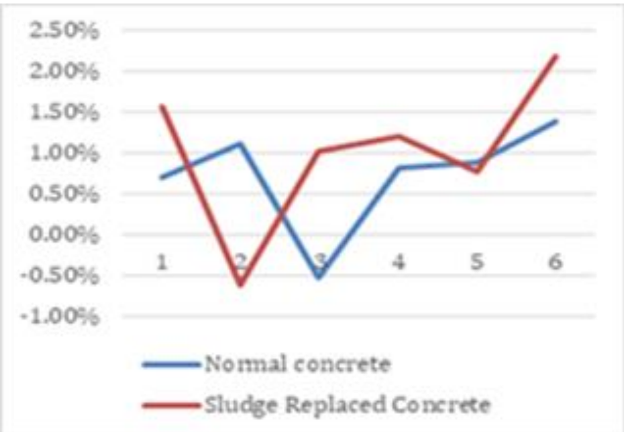


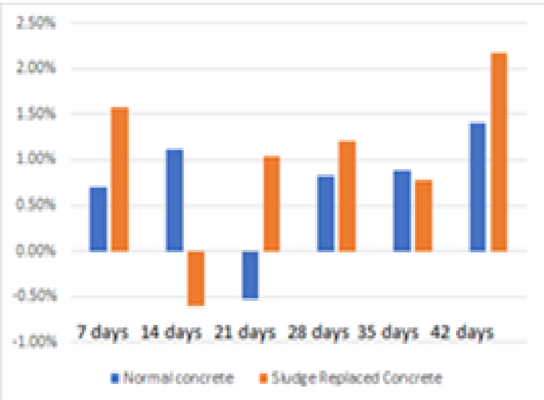
Table.10: Tabular representation of results of sulphate water resistance test on SRC and NC for determining weight loss in cubes. Maximum weight loss is 8.565 for NC and 8.300 for SRC.

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: Tabular representation of results of sulphate water resistance test on SRC and NC for determining perccentage weight loss in cubes due to impact of sulphate.

Normal Concrete	Sludge replaced 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 .13: Graphical representation of Percentage weight loss of NC and SRC after sulphate resistance test.



Conclusion

This manuscript gives the detailed view of the experiments performed on NC and SRC specimens to determine and assess the comparison between them regarding their compressive strength, sea water resistance and sulphate resistance. This is helpful to produce low cost concrete having similar or more effective properties than the normal concrete.At 28 days, sludge-replaced concrete with 10% and 20%

sludge produces 27.27 percent and 5.9 percent higher compressive 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.Sea water resistance test showed that compressive strength of NC increased, while the compressive strength of SRC decreased, although not by a significant amount. The values of both NC and SRC vary in a hostile manner, as can it be seen in the percentage weight loss graph. Sulphate resistance test showed that 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 collapse. The values of both NC and SRC vary in a hostile manner, as can be seen in the percentage weight loss graph.As per this manuscript, the compressive strength of NC is the same as the compressive strength of 30 percent sludge replacement concrete. Cement prices are reduced as the amount of cement required in concrete manufacturing is reduced. When 10% of the cement is replaced with lime sludge, the maximum compressive strength is obtained. The ecology is harmed by waste, this can be minimised by using SRC. The amount of cement that may be used is limited. Sludge-replaced concrete can be utilised in structures where compressive strength is important since it provides similar results to conventional concrete. This experimental investigation opens the door to a more versatile and superior cementitious material.

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