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Development of sustainable concrete by using paper industry waste

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ABSTRACT
To develop a sustainable concrete using new supplementary cementitious material (SCM) like Lime sludge which is produced in paper industry while producing paper. It was replaced partially with Ordinary Portland cement (OPC). The properties of concrete investigated include compressive strength, split tensile strength, flexural strength and sorptivity keeping optimum percentage of Lime sludge supposedly supplementary cementitious material (SCM). Also compared the cost of sludge based concrete with conventional concrete. In this work, M25 grade was developed and test results indicate that the use of Lime sludge with cement in the concrete has improved the performance of concrete on mechanical properties and cost economical.

1.1 Introduction

While the developed, industrialized countries are called upon to reduce pollution of the environment and their share of the usage of the world's resources, including energy, the developing countries need to avoid the mistakes of the past. This problem is particularly acute, since cement production as well as fly ash generation in developing countries are expected to increase significantly in the next few decades. There is an increasing demand for concrete worldwide, estimated to double within the next 30 years. This demand can be met without a corresponding increase in greenhouse gases by using supplementary cementitious materials to replace a maximum amount of the cement in concrete; we can reduce energy and resource consumption, reduce CO_2 emissions, and reduce the negative environmental impact. There is a further environmental benefit in that most commonly used supplementary cementitious materials (SCM) such as Lime sludge, fly ash, silica fume etc. are some different kind of waste products and end up in landfills. Paper making generally produces a large amount of solid waste. It means that the broken, low- quality paper fibers are separated out to become waste sludge. This paper mill sludge consumes a large percentage of local landfill space every year and also contributes to serious air pollution problems. It is most essential to develop profitable building materials from them. This report concisely explains the technical and environmental benefits of supplementary cementitious materials use, as well as the limitations, applications and specifications

1.1 Lime sludge

Energy plays a crucial role in the growth of developing countries like India. In the context of low availability of non-renewable energy resources coupled with the requirements of large quantities of energy for building materials like cement, the importance of using industrial waste is very important. While producing paper various wastes are comes out from the various processes in paper industries. The preliminary waste from paper industry is named as Lime sludge.

The Lime sludge contains, low calcium, maximum calcium chloride and minimum amount of silica. Lime sludge behaves like cement because of silica and magnesium properties. This silica improves the setting of the concrete. The raw Lime sludge disposal is shown in fig 1.1.For this, the Lime sludge is used as supplementary cementitious material for partial replacement in the concrete as high performance. By utilizing this waste the strength will be increased and also cost reduction in the concrete is achieved.

Fig 1.1. Raw Lime sludge disposal.

1.2 Properties of Lime sludge

The sludge which used in present investigation is brought from ITC (BPL) Bhadrachalam paper industry Private limited Bhadrachalam, Telangana state, India.

Table 1.1. Comparison between Cement and Lime sludge

Sl .No	Constituents	Cement (in %)	Lime sludge (%)
1	Lime(Ca O)	62	46.2
2	Silica(SiO_2)	22	09
3	Alumina	05	3.6
4	Magnesium	01	3.33
5	Calcium sulphate	04	4.05

Jayeshkumar Pitroda et all [1] (2013), in their research cement has been replaced by waste paper sludge accordingly in the range of 0% (without Lime sludge), 10%, 20%, 30% & 40% by weight for M-25 and M-40 mix.

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Concrete mixtures were produced, tested and compared in terms of strength with the conventional concrete. These tests were carried out to evaluate the mechanical properties like compressive strength up to 28 days and split strength for 56 days were taken. As a result, the compressive increased up to 10% addition of Lime sludge and further increased in Lime sludge reduces the strengths gradually. This research work is concerned with experimental investigation on strength of concrete and optimum percentage of the partial replacement by replacing cement via 10%, 20%, 30%, and 40% of Lime sludge. Keeping all this view, the aim of investigation is the find out the behavior of concrete like mechanical and durability properties by adding sludge in different proportions in concrete mix. From the literature it was noticed that the work on utilization of Lime sludge in concrete is scarce and hence there is a gap in this area.

1.3 Objective of the Study

1. To utilize Lime sludge as Supplementary Cementitious Materials (SCM)
2. Influence of Lime sludge on the mechanical properties of concrete.
3. Cost effective
4. Eco friendly
5. To find out the better properties of sludge by using less cement content in the mix

2. Materials and Methods

2.1 Materials used

The different materials used in this investigation are-

2.1.1 Cement- ordinary portland cement (OPC) 53 grade cement confirming to IS:12269 was used in this investigation. Few tests like slump test for workability, initial setting time (30 min) , Specific gravity (3.15) and fineness of cement were caluculated

2.1.2 Fine Aggregate- River sand confirmng to IS 383 , Zone 2 sand has been used in this experimental program .Specific gravity of fine aggregate is 2.62 .

2.1.3 Coarse Aggregate- Machine crushed granite confirming IS 383 and IS 2386 , has been used in this experimental program .Specific gravity of coarse aggregate is 2.82.

2.1.4 Water- Water with pH value 6.5 – 8 was used in this investigation.

2.1.5 Lime sludge- While producing paper various wastes are comes out from the various processes in paper industries. The preliminary waste from paper industry is named as Lime sludge. The Lime sludge contains, low calcium, maximum calcium chloride and minimum amount of silica. Lime sludge behaves like cement because of silica and magnesium properties. This silica improves the setting of the concrete.

2.1.6 - Admixture (conplast SP430) –To improve the workability, admixture is used 0.5% of cement weight.

3. Experimental Investigation

In this research work an attempt is made to produce sustainable concrete using Lime sludge. The percentage of Lime sludge is taken as 10%, 20% &30% replaced with OPC and found out mechanical properties. In this case ordinary Portland cement content is taken as 250kg/m3 to find the better properties of sludge In order to improve the workability of concrete chemical admixture (CONPLAST SP430) is added. The mix proportion is presented in Table.2

In the laboratory, all the required materials are mixed in rotary mixing machine with addition of Water for 3-5 minutes specimens casted. The concrete is poured into the moulds.

Make sure top surface is well finished and the sizes of the specimens like cube moulds (150mm x 150mm x 150mm), cylindrical moulds (150mm x300 mm) and prism moulds (500 mm x 100 mm x 100 mm). The casted specimens are demoulded after 24 hours and are kept in different curing regimes. The specimens cured in water for 7 days and 28 days.

4. Discussions on Results

4.1 Effect of Lime sludge on compressive strength of concrete-

It is very much evident from the figure 4.1 that there is a steep increase in compressive strength in Lime sludge concrete. Lime sludge was replaced in Ordinary portland cement from 0 to 50% and found out 30% is optimum

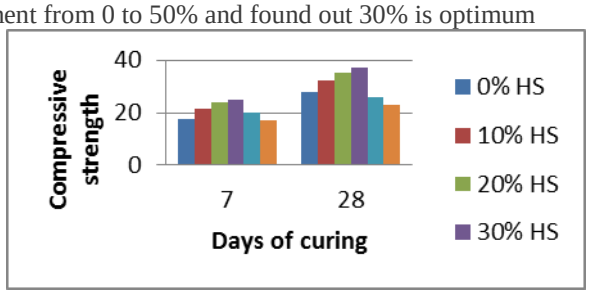
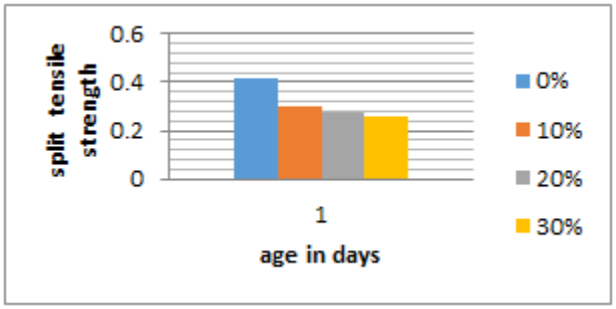


Fig 4.1. Comparison for compression strength

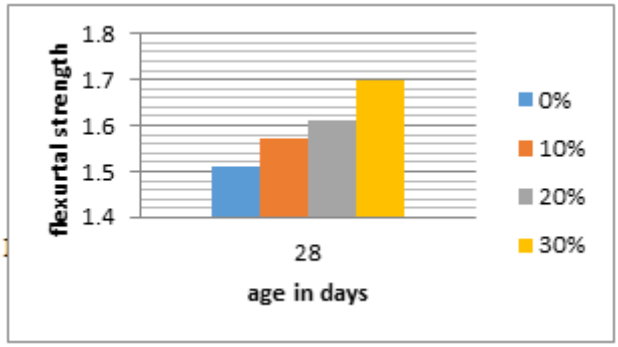
4.2 Effect of Lime sludge on split tensile strength of concrete-

From the fig 4.2 it was shown that split tensile strength of Lime sludge concrete for various replacements conducted on 150 x 300mm height cylinder by loading on it and test results noted that because of using less cement content of 250kg/m^3, there is decrease in split tensile strength with increase in age.



4.3 Effect of Lime sludge on Flexural Strength of concrete-

The flexural strength of Lime sludge concrete with various replacements are shown in fig 4.3. Test results indicate there is increase in flexural strength up to 30% and then decrease due to less cement content.



4.4 Sorptivity

In the present investigation sorptivity tests were conducted on cube specimens i.e. with w/c 0.5 on 150*150*150mm Cube moulds. The weight recorded at the end of different intervals is noted down and sorptivity is calculated. The results are showed in fig 4.4.

A general observation made from the figure is that sorptivity decreases with addition of Lime sludge and it is better than normal concrete.

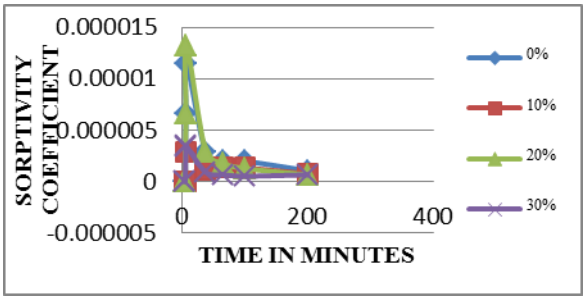


Fig 4.10 Sorptivity of the cubes immersed up to 10mm in water

5 Cost Analysis

Cost analysis is carried out for 30% replaced Lime sludge in concrete and compared to conventional concrete.

Cost of materials (approx. cost as per 2016)

Cost of cement per ton = Rs.5000.00

Cost of sand per ton = Rs.800.00

Cost of Lime sludge per ton = Rs.400.00

Cost of coarse aggregate per ton = Rs.450.00

Cost of admixture per liter = Rs.100.00

Cost analysis of conventional concrete materials are shown in Table 3 & Table 4

The cost of conventional concrete is Rs. 2662

The cost of Lime sludge concrete /m^3 @ 30 % replacement of Lime sludge is Rs.2314

The compared values of cost show gradual decrement in total cost of per cubic meter concrete.

The above table shows cost values up to 30% replacement and the difference in cost from conventional concrete to 30% replaced concrete was Rs. 348/-

Table 3. Cost analysis of 30% conventional sludge concrete.

S no	Description	Qty kg/m3	Cost approx... (INR)	Total cost
1	Cement	250	5000/ton	1250
2	Lime sludge		400/ton	
3	Fine aggregate	711	800/ton	550
4	Coarse aggregate	1420	450/ton	650
5	Admixture	2.12	100/liter	212
			Total	2662

Table 4. Cost analysis of 30% replaced sludge concrete.

S no	Description	Qty kg/m3	Cost approx... (INR)	Total cost
1	Cement	175	500/ton	875
2	Lime sludge	75	400/ton	27
3	Fine aggregate	711	800/ton	550
4	Coarse aggregate	1420	450/ton	650
5	Admixture	2.12	100/liter	212
			Total	2314

5. Conclusions

1. The replacement with 30% gives more compressive strength and reduces beyond addition compared to normal concrete.
2. There is steep increase in flexural strength with 30% replacement
3. The coefficient of sorptivity is better than normal concrete with 30% replacements
4. Less cement content (250 kg/m3) is used to find out better properties of sludge.
5. Hence, it can be concluded that Lime sludge concrete is good enough to satisfy the requirements for compressive strength, flexural strength and sorptivity
6. It was noticed that Lime sludge concrete is economical and eco friendly

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