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Lime as a Partial Replacement of Cement in Concrete Mix

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Abstract: ***This is an experimental and theoretical study to determine the benefits of using lime as a replacement of cement in concrete mix. M20 grade of concrete is taken in work keeping a constant slump of 60 mm. The compressive strength of concrete cubes are made and tested after 7, 14 and 28 days at room temperature. From the test result it is found that the concrete gives maximum compressive strength when 30% of lime is replaced with cement. Apart from that, other information including chemical reactions which takes place while mixing and other properties of lime are discussed in this paper.***
Keywords: Cement, Concrete, lime powder, compressive Strength, Replacement, Concrete mix.

I. INTRODUCTION

A. Reasons For Choosing Lime Over Cement In Concrete

Lime concrete as compared to cement concrete, makes a better base for load bearing walls, columns, or laying below floors as it has higher degree of flexibility than cement concrete. Due to lesser porosity, it has more waterproofing properties comparing to cement concrete which prevents subsoil dampness in walls and floors. Apart from that, making lime concrete is easier and cheaper while providing a durable substance that resists weathering and tear and wear.

B. Properties Of Lime Powder

Relatively, lime (calcium hydroxide) is insoluble in water, by a solubility rate of 5.5 x10^{-6} Ksp, that is big enough that its solutions are alkaline according to the following reactions:

$$Ca(OH)_2 \rightarrow Ca^{2+} + 2OH^-$$

At room temperature, $Ca(OH)_2$ also known as portlandite dissolves in water to produce an basic solution having pH of about 12.4. $Ca(OH)_2$ solutions can be harsh to human body. At large pH, its solubility decreases quickly. The aqueous solution of lime is known as limewater and it is an intermediate strength base that reacts with acids and can react with several metals like aluminum in pursuit of saving other metals from corrosion like iron and steel by reaction on their surface. In presence of CO_2, limewater turns milky by forming calcium carbonate, this process is known as carbonation:

$$Ca(OH)_2 + CO_2 \rightarrow CaO + H_2O$$

While burning at 512°C, water's partial pressure in equilibrium with $Ca(OH)_2$ reaches 101KPa (normal atmospheric pressure), and it gets converted in calcium oxide and water:

$$Ca(OH)_2 \rightarrow CaO + H_2O$$

Fig. Calcium Hydroxide

C. Lime As The First Cement

From the ancient times, lime is used to make mortars and plasters in structures. Basically lime is made through burning of limestone. Chemically, by burning Calcite ($CaCO_3$), CO_2 is removed and it gets converted into calcium oxide (CaO) also known as Lime. Lime is drastically caustic and it can melt human bones.

When treated with water, lime slowly transforms into a mineral named Portlanite in the reaction given below:

$$CaO + H_2O \rightarrow Ca(OH)_2$$

When lime is mixed in a satisfactory amount of water which makes it fluid, called as Slaked Lime. Then for weeks, slaked lime continuously hardens. Now, it must be mixed with sand and other ingredients in order to make a slaked lime cement, which will be used as to mortar between stones or bricks in structures. Then for the time after hardening, the slaked lime cement will react with CO_2 in the atmosphere to form calcite again which can be reused as artificial lime.

D. Lime makes a comfortable livelihood

Open textured material such as lime plasters aid in stabilizing the internal humidity of the building by absorbing and releasing moisture. This makes a healthy comfortable environment and decreases surface condensation and mould growth.

E. Ecological Benefits Of Lime

1) Lime has less latent heat than cement.
2) Lime absorbs CO_2 in the settling process
3) Lime can be produce on a small scale
4) Lime can be reused as Artificial Lime
5) A very low proportion of lime stabilizes clay soil.

II. LITERATURE REVIEW

(N. Suneel, G. Sree, M. Thirupathamma, D. Sasikala and R. Lakshami, 2017) described the properties and factor of lime which enhances its waterproofing, flexibility, eco- friendly properties when used as a binding material in construction projects. The author also did experimental investigations which show the increase in concrete's physical properties when lime is partially replaced with cement.

(Anne Nichols and John Nichols, 2012) described the decrease in strength of concrete on the basis of experimental investigations when lime is used as a partial replacement for cement in concrete mix. But when the water content is increased, the increase in the strength is seen without any significant reduction in the workability as measured by slump.

(Namagg and Attadero, 2009) explained the project to study the large volume of lime in concrete. Authors used lime for replacement (partially) in cement and fine aggregates. They showed that concrete having 25% to 35% of lime gave the most satisfactory results for its compressive strength.

This was seen due to the pozzolanic effect of lime.

(Hwang, Naguchi and Tomosawa, 2004) based on their experimental investigations about the compressive strength difference of concrete containing lime, the authors confirmed that the pores in concretes are reduced by adding lime in replacement of sand.

(Siddique, 2003) did an experimental study to determine the mechanical properties of concrete mixes when fine aggregate (Sand) was replaced (partially) by class F lime. I was done in five percentages (10%, 20%, 30%, 40% and 50%) of class F lime by weight. The author concluded that the compressive strength of lime concrete mixes with 10% to 50% compressive strength of concrete samples kept on increasing with increased lime percentage. This increase was seen due to pozzolanic effect of lime. Not just compressive strength but the tensile strength was also increased with increase in lime percentage.

(A.V.S Sivaram) described the changes of pH and Ca concentration. Commonly cementitious materials are alkaline, having high pH and high Ca^{++} ions. Apart from that, demineralized pure water has low pH and low Ca^{+} ions compared to cementitious substances. Therefore, when cementitious materials are introduced with water, Ca^{+} ions and pH value increases in water.

III. EXPERIMENTAL INVESTIGATION

In this paper, we have made an attempt to study the change in physical properties of concrete when lime is partially replaced as cement. The property of concrete and the tests conducted are discussed in this module.

The mixing was done in the laboratory, a M20 concrete was made having a mix ration of 1:1.5:3 the property considered in the study is compressive strength, for which the compression test is done.

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A. Compressive Strength Test

Concrete has high compressive strength, but it is low on tensile strength. Different concrete mix gives different strengths, by following the IS 10262:1982. This IS gives the design strength values and characteristics for various grades of concrete. The strength is tested by the compressive strength of the sample using which, the concrete cubes of 150mm x 150mm x 150mm are made and then the cubes are placed in water for curing. The compressive strength is tested after 7 days, 14 days and 28 days according to IS 516:1939 for ordinary and partially replaced samples.

Fig. Compression testing machine

IV. RESULT

Following are the results of the compressive strengths of all the concrete cubes of all the mixes which are replaced with lime with various percentages. The compressive strengths are determined after 7 days, 14 days and 28 days after curing them for these days. The following table shows the results of compression test:

TABLE. Compression strengths of all the samples

Sample no.	%age of lime	7 days (N/mm^2)	14 days(N/mm^2)	28 days(N/mm^2)
Sample 1	0	14.4	16.33	21.8
Sample 2	10	13.3	14.67	21.82
Sample 3	20	14.324	17.37	22.63
Sample 4	30	16.14	16.94	24.86

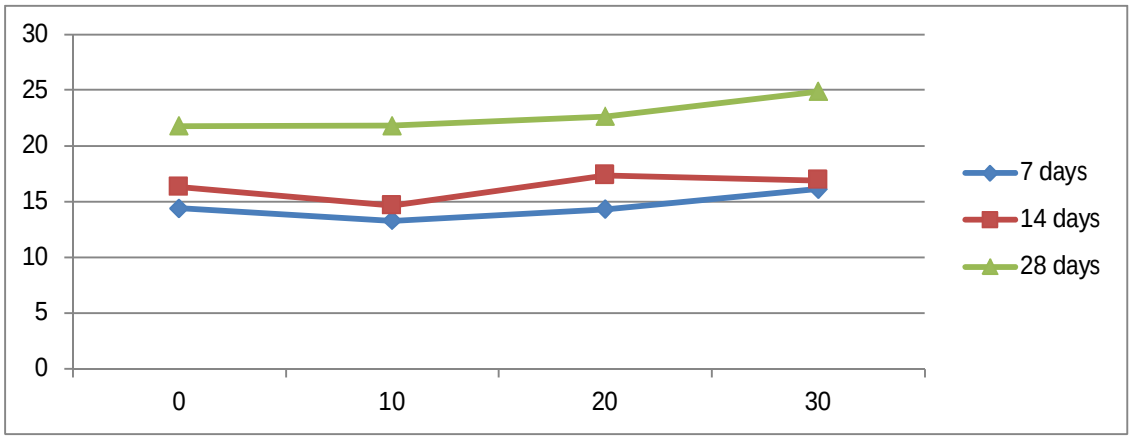

Fig. Graph showing compressive strength at various days of curing vs percentage of lime replaced

From the graph, we can see that the compressive strength of the concrete mixes gradually increases with the increase in percentages of lime replacements up to 30% of cement in concrete samples.

According to the tables and graphs, the concrete mix prepared by replacing the 30% of cement by the lime has the maximum compressive strength. If in any construction project, there is a need of more strength using the same concrete mixtures, 30% of cement can be replaced by lime in order to increase the strength.

Since, we cannot judge the exact percentage at which the compressive strength is largest through the graph. But we can say that the highest strength can be seen between 20% to 30%. But here we adopt that the concrete mix with 30% lime gives the high compressive strength than the conventional concrete mix.

Further increment in strength can be seen if we increase the lime percentage further but it will also increase the cost factor, which will eventually become an uneconomical decision.

V. CONCLUSION

Replacement of 30% lime gives the maximum compressive strength.

The concrete mix is more workable when 30% cement is replaced by lime as the slump values are high as compared to conventional concrete mix.

At last, we can say that the 30% replacement of cement with lime in a concrete mix will give the best result with nearly 20% higher compressive strength.

Now, considering all the environmental factors and problems like green house effects, increment in carbon dioxide content in air, global warming, shortage of river sand etc., we must say that Industries must start using lime at full extent as alternative of construction materials (especially cement) as it will reduce the impact on environment by absorbing CO_2 from the atmosphere.

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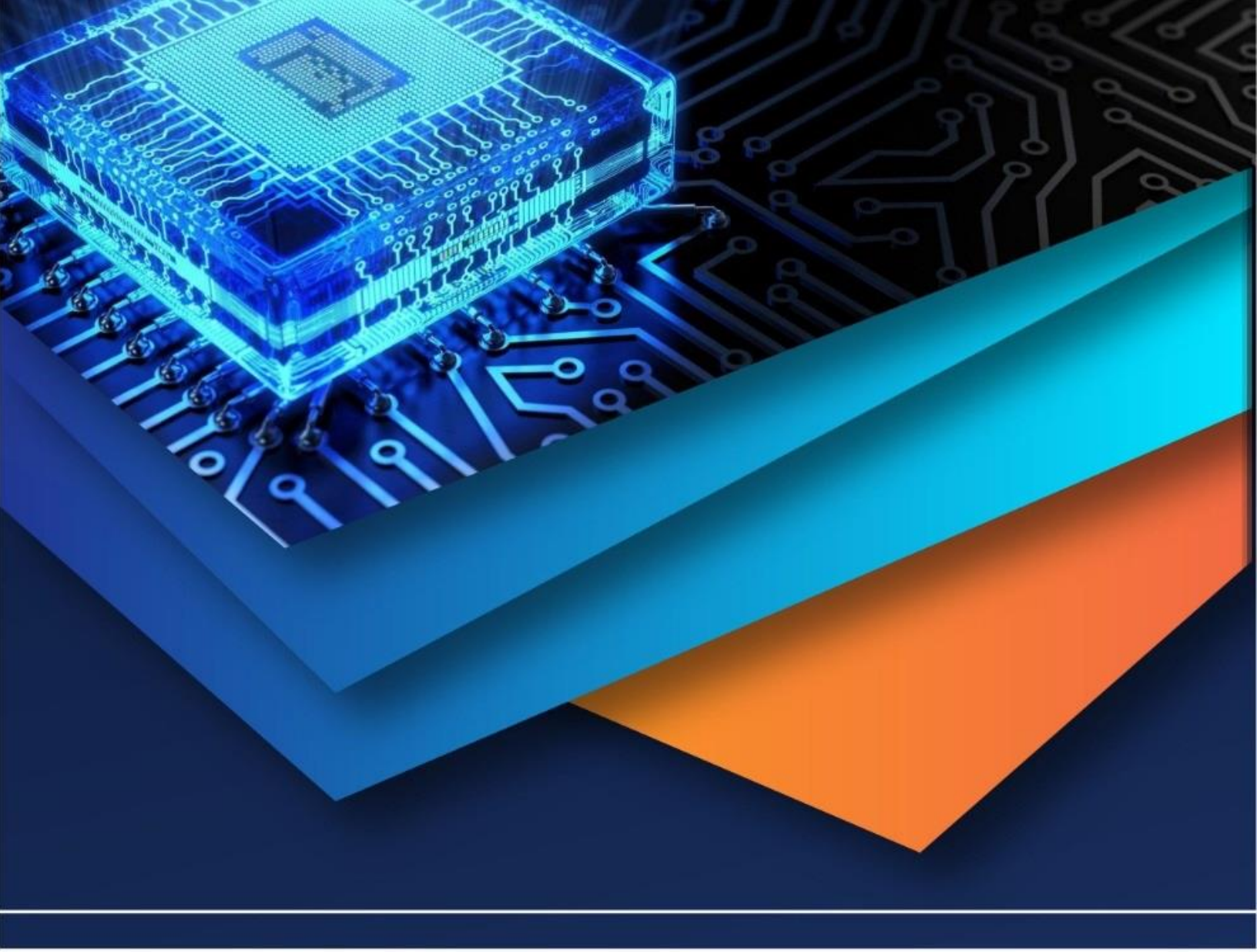

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