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REGRESSION ANALYSIS OF MICROBIAL CONCRETE ON CALCINED CLAY BASED CONCRETE

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Abstract

Due to concrete's widespread use, natural resources including such river sand and gravel have been over-exploited. Simultaneously, expanding businesses and a growing population have resulted in a rise in garbage creation. Several of these waste products might be recycled into cementitious materials. Calcined clay, a type of waste material, was studied to see how it affected the qualities of Microbial concrete in this study. Calcined clay's effect on Bacterial concrete's mechanical qualities has been researched by numerous researchers. Consequently, no consensus has yet been established, and outcomes have been published that are quite conflicting. The compression strength, concrete tensile strength and workability of such Microbial concretes are investigated in this study, and prediction results of Split tensile strength are found. Calcined clay was utilized as a partial replacement for cement, with substitution levels ranging between 0percent to 25percent in 5-percent increments. The bacteria "Bacillus subtilis" two concentrations 105 cfu/ml and 106 cfu/ml was used in this experiment. Bacillus subtilis, a standard experimental bacterium capable of producing calcite precipitates on an appropriate medium supplemented with a calcium supply, may create calcite precipitates. Microbial Concrete specimens were cast with two different cell densities, as well as a control specimen. The values of R2 have been determined by regression analysis for "Compressive Strength and Tensile Strength" and "Compressive Strength and Predicted Tensile Strength" of bacterial concrete.

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1. Introduction

Concrete is the most commonly utilized construction substance in the world, next only to water. Natural resources such as natural sand and gravels have been over-exploited as a result of fast urbanization and industrialization, posing sustainability concerns [1], [2]. Because of the increased use of concrete as a result of industrialization and urbanization, river sand is being over from the riverbank. Cement/Concrete is perhaps the most commonly utilized construction substance on earth. For compressive loading, concrete has a high massive amount capability, but it is brittle under tension. To be able to create buildings, steel reinforcing rods are inserted in the material. When the concrete fractures in tension, the reinforcement bars take up the load [3]-[5].

In order to create Microbial Concrete, bacteria must be embedded in the concrete that is capable of precipitating calcite on a continuous basis. Microbiologically generated calcite condensation is the term used to describe this occurrence. Because of the broad variety of research and engineering consequences of calcium carbonate condensation, which is a common occurrence among bacteria, it has been extensively researched [6], [7]. In the laboratory, calcite production is accomplished by Bacillus subtilis, a model bacterium that can generate calcite crystals on an appropriate medium that has been supplied with calcium. In order to produce CaCO3 condensation, a suitable soil bacterium, Bacillus subtilis, was employed. Based on the fundamental concepts of urease hydrolysis, which produces ammonia and carbon dioxide, as well as the following rise in pH caused by the ammonia released into the environment, resulting to a buildup of insoluble CaCO3, this application has been developed and tested. Positive circumstances do not exist in a physical form, but must be produced in order to be effective. This will be the subject of a significant portion of the study [8], [9].

In this research, calcined clay is mixed in concrete with two concentrations of Bacillus bacteria by taking them in different proportions. The novelty of this work is that different proportions (0%, 25%) of calcined clay have been tested for mixing with bacteria in concrete. The question then becomes, how might the perfect conditions be created for the bacteria to not only survive in concrete but also flourish and produce the amount of calcite needed to repair cracks in the concrete that are required? Moreover, the microorganisms must be maintained in a certain percentage in a specific medium before they are mixed with the concrete components to ensure that they are not killed. In this case, improvement is required, which entails experimental investigation.

2. Materials and Experimental Methodology

A. Calcined Clay

Energy consuming cement manufacturing necessitates the employment of several operating units to transform raw materials into finished products, resulting in pollution of the surrounding environment. As a result, the continual release of CO2 into the atmosphere has a negative effect on the environment. Calcined clay has the potential to be a useful tool in the effort to reduce the carbon footprint of the environment [10]-[12]. In the current research, calcined clay was utilized as pozzolans to decrease the amount of cement required for construction while simultaneously improving the mechanical characteristics and achieving a long-lasting feature of the concrete mix. Table 1 shows the chemical constituents of cement and calcined clay, respectively.

Table 1. Chemical Properties of calcined clay and cement.

Content	CaO	SiO_2	Al_2O_3	MgO	Fe_2O_3	K_2O	Na_2O_3	LOI
Cement	44.29	27.29	8.45	1.12	4.80	0.07	0.19	2.70
Calcined Clay	0.59	49.12	32.98	0.80	1.78	0.15	0.19	15.03

B. Bacillus subtilis Bacteria

The pure bacterial culture was obtained from a soil sample taken from the "Sewage Treatment Plants, GLA University, Mathura" and is being cultured on nutrient agar plates on a continuous basis. On nutrient medium, it produces aberrant white dry colonies that are uneven in shape. In order to develop the culture, a single morphology of the culture is injected into nutrient bacterial broth [13], [14] of twenty-five milliliters in a hundred milliliter volumetric flask and the growth conditions are sustained at 37 degrees Celsius and 125 revolutions per minute in an orbital shaker. Specifically, peptone (5 grams/litter), sodium chloride (also 5 grams/litter), and beef extract (3 grams/litter) are the medium components needed for development of a culture.

Stock cultures of B. subtilis were grown on nutrient agar plates to preserve their viability. The colony was spread onto culture plates using an inoculating loop/rod, and the slants were then incubated at 370C for 30 minutes [15], [16]. After two to three days of development, slant cultures were harvested and stored under refrigeration (40°C) [17], [18] until they were needed for another application. Every 90 days, sub culturing was done to provide a consistent product. The presence of contamination from other microorganisms was tested on a regular basis by spreading on nutrient agar slants.

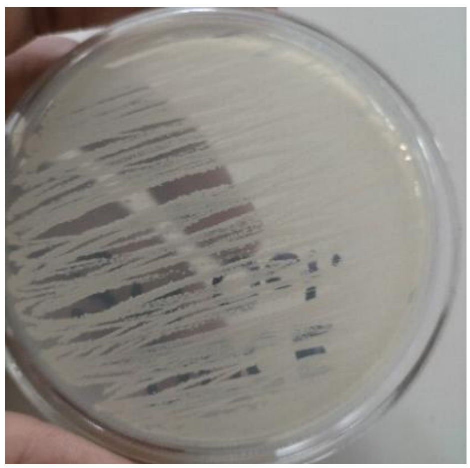

Figure 1. Growth of Bacteria.

3. Mix Proportion

A single reference mix, consisting only of cement, was produced, and the other ten mixes, consisting various percentages of calcined clay in lieu of cement and two bacterial concentrations, were prepared as well. Each mix included various percentages of calcined clay ranging from 0 to 25 percent by weight of cement, with an equal incremental rise of 5 percent in each mix. There were also two distinct concentrations of bacteria (105 cfu/ml and 106 cfu/ml) in each mix. All of the components were mixed in the dry condition, and the weight percent (w/c) of all of the mixes was maintained at “0.4”.

Table 2. Bacterial Concrete design mix.

Mix Id	Cell Concentration Cells/ml	Cement Kg/m3	Calcined clay Kg/m3	Fine Aggregate Kg/m3	Coarse Aggregate Kg/m3	Water Kg/m3
BS0C0	-	400	-	961	1438	159
BS7C5	BS105	380	20	961	1438	159
BS7C10	BS105	360	40	961	1438	159
BS7C15	BS105	340	60	961	1438	159
BS7C20	BS105	320	80	961	1438	159
BS7C25	BS105	300	100	961	1438	159
BS8C5	BS106	380	20	961	1438	159
BS8C10	BS106	360	40	961	1438	159
BS8C15	BS106	340	60	961	1438	159
BS8C20	BS106	320	80	961	1438	159
BS8C25	BS106	300	100	961	1438	159

4. Result and Discussion

A. Compressive Strength

The compressive strength was measured in accordance with Indian Standard 516:1959 [19]. For each mix, three cubic specimens of 150 mm in size were examined, and the average strength of the three specimens was used to determine the compressive strength of that specific mix. A total of 162 cubes were cast, nine for each percentage replacement of calcined clay (0%, 5%, 10%, 20%, and 25%), and the strength of the cubes was evaluated at curing periods of seven, twenty-eighth, and fifty-six days, respectively.

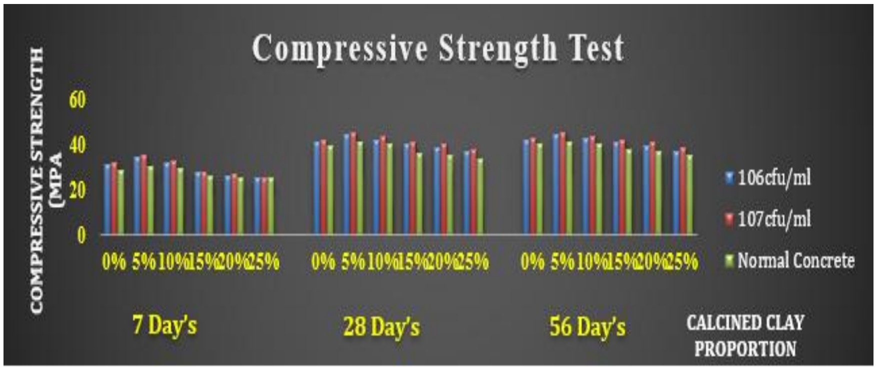

Figure 2. Compressive Strength test result of Bacterial Concrete.

B. Split-Tensile Strength Test

The test was conducted on cylindrical samples with dimensions of 150 mm $\times$ 300mm in accordance with Indian Standard 5816:1999 [20]. Five replacement levels (0%, 5%, 10%, 20%, and 25%) were cast and evaluated at different curing ages: seven, twenty-eighth, and fifty-six days of curing period.

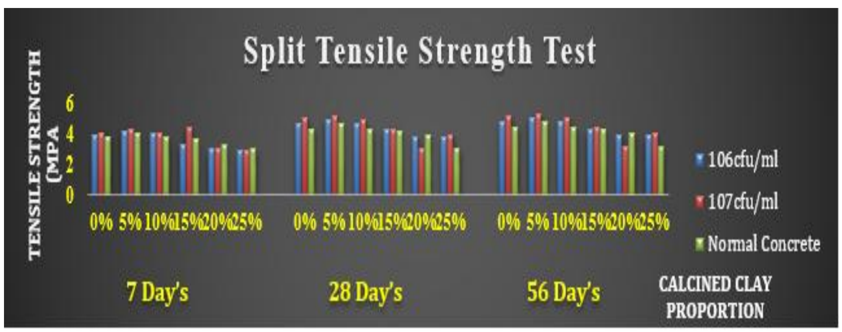

Figure 3. Predicted Split Tensile Strength test result of Bacterial Concrete.

When the results of the tests were analyzed using linear regression [21], the relationship between both the compression strength of microbial concrete and split tensile strength of microbial concrete was discovered, and it is represented by the formula (A).

$$F_{\text{tensile}} = 0.23F_{\text{compressive}}{}^{0.73} \text{ (A)}$$

Here "Fsplit" denotes the split-tensile strength of concrete (in MPa) at *t* days and "Fcompressive" denotes the compressive strength of concrete (in MPa) at the same time. According to equation (A), the split tensile strength was calculated by plotting against the observed values, as well as the correlation between the two was high, with an R2 of 0.9995 as can be seen in Figure 6 and Figure 5 shows a relation between 'casted cylinder and cubes' split tensile and compressive strength linear regression [22-25].

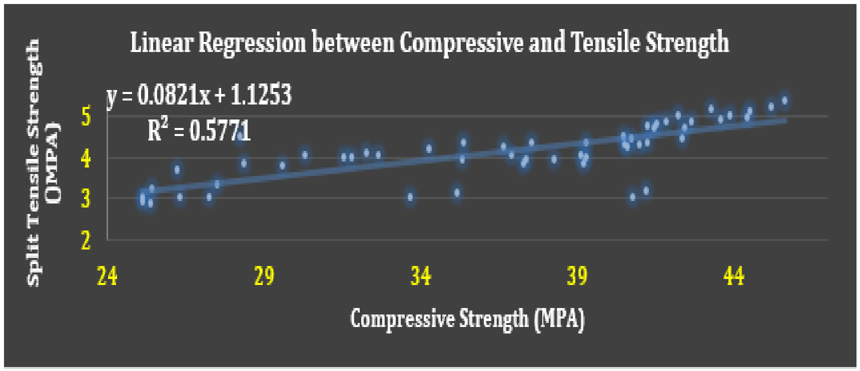

Figure 4. Linear regression between compressive and tensile strength.

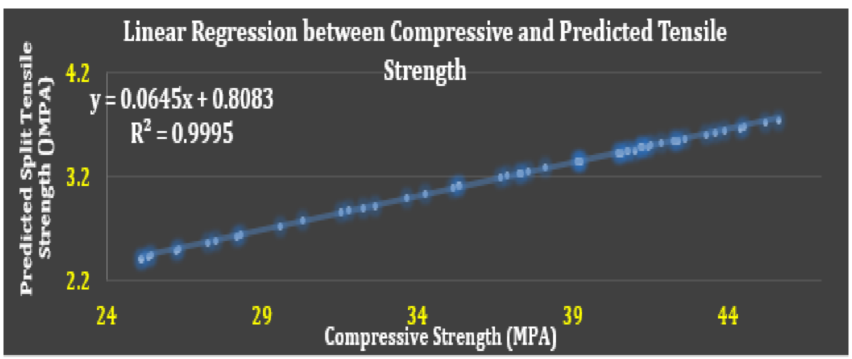

Figure 5. Linear Regression between compressive and Predicted tensile strength.

5. Conclusion

Bacillus subtilis may be generated in the laboratory, and it has been shown to be both time-saving and cost. The application of B. subtilis microorganisms to cement concrete helps to enhance the hydrated structure of the concrete mix. When the concentration of bacteria 105 and 106 cells per ml is added to cement concrete, the compressive strength of concrete increases, and the compression strength of bacterial concrete is also increased as compared to ordinary concrete, with an increase in the interval of curing days, Therefore, in terms of compressive strength, bacterial concrete proves to be better than ordinary concrete. When B. subtilis bacteria are added to the cement concrete, the compression strength of the concrete is enhanced. When B. subtilis bacteria are added to normal concrete grade, overall compression strength is increased at consecutive day periods, as opposed to the traditional concrete. A substantial improvement in split tensile strength was seen when bacteria from B. subtilis were added to conventional concrete, as compared to normal concrete alone. In this study, a multiple-regression shrinkage prediction model was developed, which took into account the percentage of calcined soil in the mix as well as the concentration of bacteria in the mix. The model was found to be reasonably accurate in predicting the split tensile strength of concrete mixtures. According to the results of the suggested model, a significant correlation/regression (R2) between both the compressive and forecasted readings of split tensile strength was found, suggesting that it was successful in predicting the tensile strength of concrete including partial replacement of calcined clay in cement.

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