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Mechanical Properties of Bacterial Concrete by Partial Replacement of Cement by Nano Silica in Different Grades of Concrete

Kodavati Divya Bharathi[1], Dhondy Rupesh Kumar[2], Polapali Saikiran[3] and Belli Karthik[3]

Civil Engineering Department,University College of Engineering, Osmania University, Hyderabad, Telangana, India

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ABSTRACT

Concrete with nano-silica also has a higher strength compared with normal concrete. In the current study, an examination of the mechanical characteristics of bacterial concrete containing nano-silica is conducted. The impact of concrete was examined in this study employing *Bacillus subtilis* for self-Healing Microbial Type Culture Collection (MTCC) Strain no.121, Among the bacteria concentrations of 10^4, 10^5, and 10^6 cells/ml, a concentration of 10^5 cells/ml gives more strength, so further investigation is done using 10^5 cells/ml cell concentration for different percentages of nano-silica is examined. Firstly, Bacterial cell concentration is optimised. Each of the 40 sets of cubes (150 mm x 150 mm x 150 mm), cylinders (150 mm diameter and 300 mm height), and prisms (100 mm x 100 mm x 500 mm) are cast and tested at 28 days and 90 days as part of further research to determine the mechanical properties of bacterial concrete with different percentage of nano silica with and without bacteria. It has been noted that adding nano-silica to concrete increases its strength from 0% to 1.5% before being decreased to 2%. concrete splintering occurs due to a number of causes, including mechanical compression and low tensile strength, shrinkage, freeze-thaw reaction, and others. External loads can cause high tensile strains. For any combined nano-silica percentage when compared to regular concrete, bacterial concrete is stronger.

Key words: *Bacterial Concrete, Nano silica, Compressive strength, Flexural strength, Split tensile strength.*

Introduction

The most often utilized building material is concrete, yet concrete cracks are problematic. Shrinkage, the freeze-thaw response, mechanical compression, and insufficient tensile strength are only a few of the causes of cracks in concrete.External loads can cause high tensile strains. Without prompt and effective treatment, cracks have a tendency to enlarge and eventually necessitate expensive repair.These deformations include expansive responses, such as reinforcing corrosion, analkali-silicaa reaction, or sulfate, as well as imposed deformations (induced by temperature gradients, restricted shrinkage, and differential settlement). Without immediate and suitable treatment,cracks frequently worsen and eventually need pricey repair. These flaws also reduce the durability of concrete since they make it simple for liquids and gases containing potentially dangerous compounds to be transported. The concrete may be affected (direct degradation) if microcracks spread and reach the reinforcement, but the reinforcement may also corrode if exposed to water., oxygen, and possibly carbon dioxide and chlorides (indirect

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([1]Research Scholar, [2]Professorr, [3]Master Student, [3]Master Student) degradation).So, micro fractures are a sign of impending structural failure. As a result, a unique method has been created that encourages calcium carbonate (calcite) precipitation by exploiting specific microbial metabolic activities. It is well recognised to have a number of restrictions despite its adaptability in building.

Bacteria are single-celled, prokaryotic microorganisms. Different sizes and forms of bacteria exist. Soil, acidic hot springs, radioactive waste, water, deep inside the Earth's crust, organic materials, and the live bodies of plants and animals are just a few places where bacteria can be found thriving. Bacteria are often cultured on solid or liquid substrates in the laboratory. Agar plates are a common solid growth medium a technique for obtaining pure colonies of a certain bacterial strain.When growth measurements or substantial amounts of cells are necessary, growth media are liquid. While it can be challenging to isolate a single bacterium from a liquid medium, growth in stirred liquid media occurs as an even cell suspension, making the culture of bacteria easier to transfer and divide. Specific organisms can be identified with the aid of media selection (medium with particular nutrients added, depleted, or with antibiotics added). Three phases of bacterial growth are present. The cells of a population of bacteria must adjust whenIt starts off in an environment rich in nutrients that encourages growth.

The kinds of bacteria that live in concrete, how they affect public infrastructure's longevity, and the trigger the chemical reaction in the bacteria, what happens to the particular types of specialised bacteria when exposed to the catalyst, and how they cooperate to not only prevent cracks from forming but also to strengthen the overall structure they are incorporated into, are all important topics to be covered. The crack that has formed is filled in, the concrete's structure is strengthened, and the bacteria adhere tothe edges of the crack to seal the damaged location after going through a chemical reaction when exposed to food and air.

Objectives

The primary investigation of strength research on standard grade and common grade concrete is the purpose of the current experimental research, with and without the inclusion of bacteria from the Bacillus Subtilis Strain No. 121 together with nano silica. i) To choose the ideal bacterial cell concentration for the mortar mix's compressive strength. ii) To investigate bacterial concrete's compressive strength. iii) To investigate bacterial concrete's split tensile strength. iv) To investigate bacterial concrete's flexural strength.

Methodology

Materials Used

Cement

Concrete depends heavily on cement. Concrete, the most adaptable building material, is created by binding sand and rocks together with cement, an adhesive. In order to produce clinker, which is then blended s with crushed gypsum and other additives and pulverized to a fine powder (a few microns) to create cement, a combination of calcium, silicon, aluminum, iron, and other components is combined in a thermochemical reaction. The selection criterion is cement's capacity to produce a superior microstructure in concrete. The amount of tricalcium aluminate (C3A), tricalcium silicate (C3S), and dicalcium silicate, as well as the fineness, heat of hydration, alkali content, and compressive strength of the cement at different ages, are all factors to consider (C2S), among other things, are some of the factors that need to be taken into account when choosing the cement.

Granular Aggregate

As coarse material, crushed angular granite from a nearby quarry is used. The cleaned coarse aggregate is chosen and put to the test for a number of characteristics, including bulk modulus, fineness modulus, and specific gravity. According to IS: 2386-1963, the physical features are put to the test.

Sand

In the current experiment, the locally accessible river sand is utilised as fine aggregate. According to IS: 2386-1963, the chosen and tested cleaned fine aggregatefor a number of characteristics, including specific gravity, fineness modulus, bulk modulus, etc.

Water

Fresh potable water that complies with IS: 3025 - 1964 part 22, part 23, and IS: 456 - 2000 is used for mixing and curing.

Nano Silica

When the Ca(OH)2 crystals are adsorbeed by nano-SiO_2, the interfacial transition zone of aggregates and the binding paste matrix become denser and shrinking in size and quantity. The binding paste's matrix becomes denser, enhancing the concrete's long-term strength and durability. The nano-SiO_2 particles cover the spaces in the C-S-H gel structure and serve as a nucleus to tightly link with the C-S-H gel particles. In addition to acting as a filler to enhance the microstructure of mortar and cement, nanoscale SiO_2 also acts as a catalyst for pozzolanic processes. The used nano silica has a specific gravity of 1.22. Cementitious materials play a huge role in the building sector, but despite their wide range of uses, their complexity must not be obscured.

Table 1. Shows detailed description of physical properties of Nano silica.

S. No	Characteristics	Values obtained
1	Parameter	Cem Syn XTX
2	Active nano content	30%
3	pH (20 ^{0}C)	9-10
4	Specific gravity	1.20-1.22
5	Particle size	5-40nm

They feature multi-scale internal structures and are, in fact, composite materials that have developed over time Amorphous nanostructured hydration is more specifically the cement paste product known as C-S-H (calcium silicate hydrate) gel that is embedded in a porous substance made of calcium hydroxide (portlandite), aluminate, and unhydrated cement (clinker). This gel is the primary hydration product of cement paste due to its remarkable mechanical qualities as well as the fact that it makes up between 50 and 70 percent of the total volume.

Bacteria

Bacillus subtilis strain No. 121, a laboratory-cultured bacterium, is used. The sample of "*Bacillus subtilis*," a soil bacterium, was cultured by providing the microbes with the right food, they evolved to meet the needs of research at Professor Jayashankar Telangana State Agricultural University.

Culture of Bacteria

The pure culture was continuously maintained on nutritional agar slants. On nutrient agar, it grows in uneven, dry, white colonies. Whenever necessary, A single colony of the culture is injected into 25 cc of nutrient broth in a conical flask measuring 100 ml, with the growth conditions kept at 37 °C and the flask being shaken at a speed of 125 rpm. Peptone (5 g/l), sodium chloride (5 g/l), and yeast extract (3 g/l) are the three components of the medium that must be present for the growth of the culture.

Maintenance of stock culture

On nutritional agar slants, stock cultures of *Bacillus subtilis* were kept alive. With an inoculating loop, the culture was streaked on 37°C agar slants, and the slants were then incubated at 370°C. Slant cultures were stored under refrigeration (40 °C) for a future usage after two to three days of growth. Every 90 days, subculturing was done. On nutrient agar plates, streaking was used to screen for contamination from other microorganisms.

Results and Discussion

The strength of the cement mortar's compressive force is increased by the inclusion of *Bacillus subtilis*

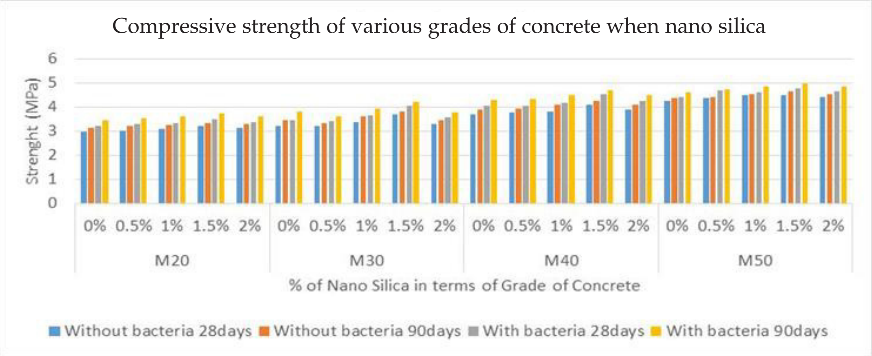


Fig. 1. Shows Compressive strength of various grades of concrete when nano silica replaced with and without bacteria for 28 days and 90 days.

Table 2. Compressive strength of various concrete grades when nano silica is replaced, both with and without Bacteria.

Concrete Grade	% of Nano Silica Replacement	Strength of Concrete without Bacteria (Mpa)		Strength of Concrete with Bacteria (Mpa)	
		28 days	90 days	28 days	90 days
M20	0	29.55	31.02	33.53	35.2
	0.5	30.25	31.76	34.32	36.03
	1	31.26	32.82	35.47	37.24
	1.5	32.28	33.89	36.63	38.46
	2	31.96	33.56	36.26	38.07
M30	0	39.55	41.6	45.49	47.855
	0.5	40.82	42.94	46.95	49.39
	1	41.05	43.18	47.21	49.66
	1.5	42.65	44.86	49.05	51.6
	2	40.22	42.31	46.26	48.66
M40	0	49.58	52.15	57.88	60.94
	0.5	50.22	52.88	58.63	61.73
	1	51.52	54.25	60.15	63.33
	1.5	53.46	56.29	62.41	65.71
	2	52.3	55.07	61.06	64.29
M50	0	58.69	61.91	69.26	73.06
	0.5	59.45	62.71	70.16	74.01
	1	61.62	65	72.72	76.71
	1.5	63.23	66.7	74.62	78.72
	2	61.92	65.32	73.07	77.08

Table 3. Split Tensile strength of various concrete grades when nano silica is replaced, both with and without Bacteria.

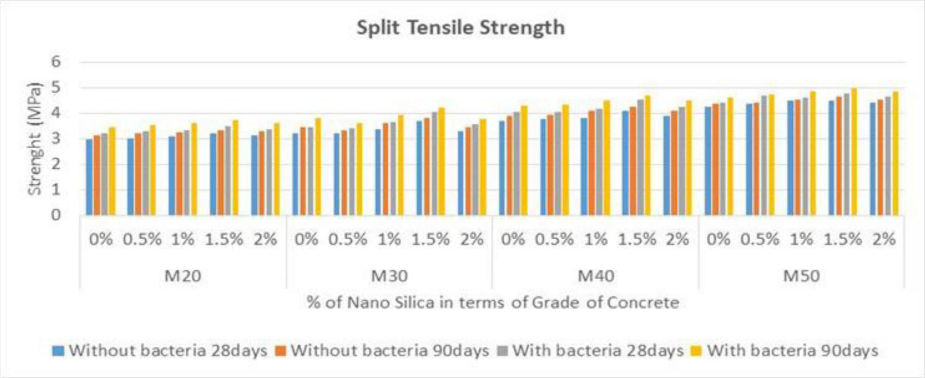
Concrete grade	% of Nano silica replacement	Strength of Concrete without Bacteria (Mpa)		Strength of Concrete with Bacteria (Mpa)	
		28 days	90 days	28 days	90 days
M20	0	2.98	3.15	3.37	3.42
	0.5	3.02	3.2	3.44	3.49
	1	3.1	3.27	3.51	3.56
	1.5	3.2	3.33	3.65	3.71
	2	3.15	3.28	3.53	3.58
M30	0	3.2	3.45	3.57	3.62
	0.5	3.2	3.35	3.63	3.68
	1	3.38	3.6	3.83	3.89
	1.5	3.7	3.8	4.25	4.31
	2	3.3	3.46	3.76	3.81
M40	0	3.7	3.9	4.23	4.29
	0.5	3.79	3.95	4.25	4.31
	1	3.8	4.1	4.37	4.43
	1.5	4.1	4.25	4.75	4.82
	2	3.9	4.09	4.45	4.51
M50	0	4.24	4.36	4.63	4.69
	0.5	4.36	4.43	4.84	4.81
	1	4.49	4.54	4.9	4.97
	1.5	4.51	4.66	5.23	5.31
	2	4.43	4.54	4.89	4.96

Microbial Type Culture Collection (MTCC) strain 121. Cement mortar reaches its maximal compressive strength at a specific cell concentration, 10^5 cells/ml.

Bacillus subtilis strain 121 is added to cement mortar to increase its hydrated structure. *Bacillus subtilis* strain no. 121 bacteria with 10^5 cells/ml cell Density are employed for further research, such as that on the mechanical qualities of concrete, because they increase the compressive strength of cement mortar.

Various grades of Compressive Strength (M20, M30 M40 and M50) of concrete was studied using bacteria and partial replacement of nano-silica are increased by a maximum of 13.47%, 15.00%, 16.74%, and 18.01%, respectively, at 28 days in comparision to conventional concrete.

By using bacteria with partial replacement of nano-silica in concrete, the flexural strength of various grades (M20, M30, M40, and M50) is increased by a maximum of 12.61%, 14.79%, 15.30%, and 15.41% at 28 days in comparisions to conventional concrete.The use of bacteria and partial replacement of nano-silica in concrete increases the split tensile strength of various grades M20, M30, M40, and M50 by up to 14.06%, 14.86%, 15.85%, and



Fig, 2. Shows Split Tensile strength of various grades of concrete when nano silica replaced with and without bacteria for 28 days and 90 days.

Table 4. Flexural strength of various concrete grades when nano silica is replaced, both without and with Bacteria.

Concrete Grade	% of Nano Silica Replacement	Strength of Concrete without Bacteria (Mpa)		Strength of Concrete with Bacteria (Mpa)	
		28 days	90 days	28 days	90 days
M20	0	3.88	3.92	4.28	4.34
	0.5	4.01	4.29	4.55	4.62
	1	4.32	4.51	4.75	4.82
	1.5	4.52	4.72	5.09	5.16
	2	4.46	4.62	4.87	4.94
M30	0	4.2	4.3	4.81	4.87
	0.5	4.29	4.48	4.83	4.89
	1	4.5	4.75	5.17	5.24
	1.5	4.8	4.94	5.51	5.63
	2	4.3	4.7	5.03	5.1
M40	0	4.4	4.6	5.03	5.1
	0.5	4.52	4.69	5.08	5.15
	1	4.65	4.8	5.36	5.44
	1.5	4.9	5.3	5.65	5.73
	2	4.5	4.8	5.13	5.2
M50	0	4.6	4.9	5.42	5.5
	0.5	4.92	5.09	5.5	5.57
	1	5.15	5.31	5.62	5.75
	1.5	5.32	5.62	6.14	6.22
	2	5.29	5.43	5.81	5.94

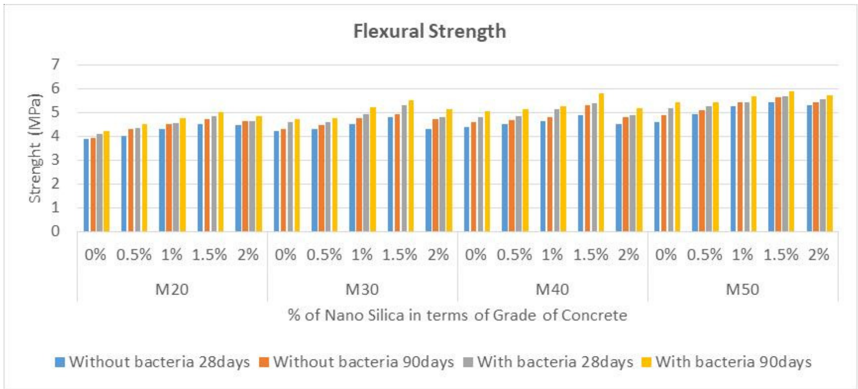


Fig. 3. Flexural strength of various grades of concrete when nano silica replaced with and without bacteria for 28 days and 90 days.

15.96%, in comparision to conventional concrete, Irrespective of type of concrete and grade of concrete, it is clear that the strength of concrete is increased by the addition of nano silica from 0% to 1.5% and then reduced for 2% of nano silica, because for any pozzolanic admixture, In order to achieve maximum strength, OPC must employ the ideal replacement proportion.

For any percentage of nano silica, Compared to regular concrete, bacterial concrete is stronger, because its nano silica particles are still more active in the chemical reaction compared to other active admixtures.A natural bio mineralization process called microbiologically-induced calcite precipitation (MICP) involves bacteria produces calcium carbonate ($CaCO_3$), which heals cracks and improves concrete strength and durability.

Conclusion

The hydrated structure of cement mortar is improved by the inclusion of the microorganisms *Bacillus subtilis* (MTCC-121). Cement mortar's compressive strength optimum 10^5 cells/ml conceration of bacteria. Consequently, with a bacteria with 10^5 cells/ml further studies were processed. The bacterial concrete has showed more strength improved as compared to conventional concrete at 1.5% of nano silica in different grades of concrete.

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