"A STUDY ON STRENGTH AND DURABILITY PROPERTIES OF BACILLUS SUBTILIS BACTERIAL CONCRETE"

Kavya KP[1], Mr. Adanagouda[2]

[1]PG student, Department civil engineering RYM engineering college ballari, karnataka, India.
[2] Assistant professor Department of civil engineering RYM Engineering collage, ballari, karnataka, India

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Abstract - *The activity life span of concrete sharply decreases with the formation of cracks on its surface which leads to corrosion of concrete. This leads to the failure of the structure, to remediate this type of failure due to cracks and fissures an approach of using biomineralization in concrete has evolved in recent years in this method the performance of concrete, the calcite precipitating spore-forming bacteria is introduced into the concrete. When water enters through the cracks, it reacts with bacteria and forms precipitates of calcium carbonate as a byproduct which fills the cracks and makes cracks free of concrete. This type of concrete prepared with bacteria is called bacterial concrete.*

In this Research paper, the experimental investigation has been carried out to evaluate the impacts of Bacillus subtilis bacteria on concrete properties. The experiment has been carried out using 2x108 cells/ml bacterial concentration in concrete mix and a grade of M30 concrete is prepared with different bacterial percentages of 10%, 20%, and 30%. A different test on both normal concrete and a bacterial concrete has been carried out and the specimen was left for 7days and 28days of curing to test the various strength and compare the results respectively

Key Words: Bacillus Subtilis, biomineralization.

1. INTRODUCTION

After hardening, a bacterial response in the concrete causes self-healing concrete, also known as bacterial concrete, to fill up structural defects. Various types of bacteria and their mechanisms of action are explored. A new level of building has been reached thanks to the usage of current technologies. Good, long-lasting concrete building may be achieved using a variety of techniques, methods, and materials. In spite of human errors, mishandling, and inexperienced workers. In order for a structure to last its intended lifespan, it must be efficient. There are several issues that develop after the building, including weathering, fractures and leaks. Before and after the construction, a number of corrective treatments are used to address these issues.

1.1 Chemical process of self-healing or bacterial concrete

Bacteria function as a catalyst when water comes into touch with the concrete's unhydrated calcium, resulting in the formation of calcium hydroxide. Carbon dioxide combines with calcium hydroxide to generate limestone and water in the atmosphere. The process can't stop because of the additional water molecule.

After that, the limestone hardens and fills in the crevices left by the liquid. To meet the criteria of sustainable development, careful consideration of the materials used in construction is critical. Concrete is one of the most prevalent building materials. It has a significant environmental impact because of the amount of energy required to produce it. Objects made of concrete may be affected by external forces. Consequently, fissures form in the substance. Using an ecologically friendly and efficient method of alternative crack removal in the damaged material is necessary in order to achieve its durability and to comply with the assumptions of sustainable building. To ensure that concrete constructions last as long as possible, bacterial self-healing concrete decreases the expenses of damage identification and maintenance. In certain cases, the durability of bacteria-infused concrete may be increased. In spite of this, it is not yet used on a large basis. Industrial application is not possible because to the prohibitive cost of the substrates. Bacterial concrete may be a viable solution to the problem of sustainability in the construction industry.

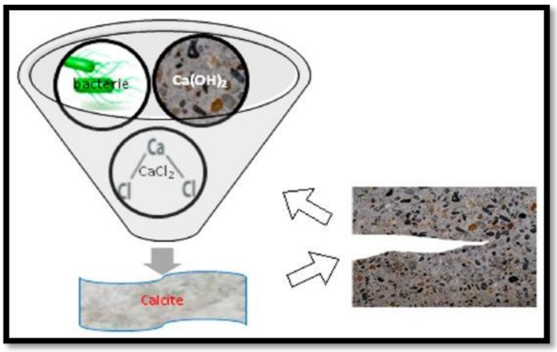

Plate 1.2: Process involved in Bacterial concrete

Concrete may be damaged by even a little fracture on the surface of the material, which results in a serious structural collapse. Corrosion of reinforcing steel happens when water penetrates through fractures in concrete. As a consequence, the structure's lifespan is shortened. Bio concrete is favoured for its superior properties.

2. Aim and Objectives

1.To investigate the influence of varied bacterial concentrations on compressive strength, tensile strength, flexural strength, and impact strength.

2. Immersing microbiological concrete in HCL solution is a way to test its resistance to deterioration over time.

3. METHODOLOGY

- There have been some basic tests done on cement, fine aggregate, and coarse aggregate.
- Conventional and bacterial concrete moulds were tested for a variety of properties, including compressive tests, split tensile tests, flexural and impact tests.
- Replacement of Bacillus Subtilis Bacteria is to be conducted at levels of 0%, 10%, 20% & 30%.
- 1% of Superplasticizer has been added during the mixing of concrete.
- For durability test concrete moulds have been immersed in a HCL for 30 days.
- This experiment used an IS 10262-2009-based mix design for the bacterial concrete.

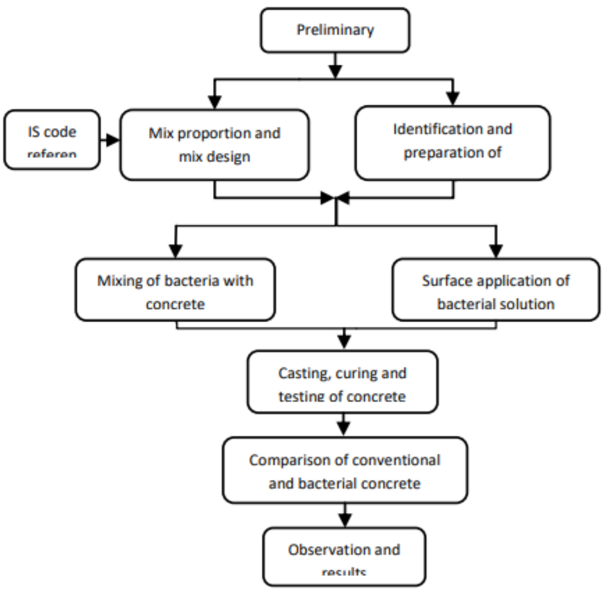

Fig 1: Methodology followed during the test

4. MATERIALS-AND-EXPERIMENTAL DETAILS

4.1 BASIC MATERIALS USED ARE

1. Fine Aggregate
2. Cement
3. Coarse Aggregate
4. Super Plasticizers
5. Water
6. Bacillus substilis
6. HCL

PHYSICAL PROPERTIES	RESULTS
Fineness	2946 cm^2/g
Normal Consistency	31%
Initial Setting Time	55 Min
Final Setting Time	192 Min
Specific Gravity	3.15
Compressive Strength at 7Days	38.01 N/mm2
Compressive Strength at 28Days	46.12 N/mm2

Table 1: Physical properties of cement

SL No	IS Sieves	Mass retained In 'Grams'	Percentage of Mass retained	Cumulative percentage Of Mass Retained	Cumulative Percentage of passing
1	4.47	0.031	3.1	0.031	96.9
2	2.36	0.04	4	0.071	92.9
3	1.18	0.240	24	0.311	68.9
4	600 µ	0.334	33.4	0.645	35.5
5	300 µ	0.265	26.5	0.91	9
6	150 µ	0.089	8.9	0.999	0.1
7	P 75	0.0081	0.81	1.000	-

Table 2: Particle size distribution of Fine Aggregate

SL No	IS Sieves	Mass retained In 'Grams'	Percentage of Mass retained	Cumulative percentage Of Mass Retained	Cumulative Percentage of passing
1	20 MM	1069	21.38	21.38	78.62
2	10 MM	3771	75.42	96.8	3.2
3	4.75 MM	154	3.08	99.88	0.12
4	2.36 MM	0	0	0	0
5	1.18 MM	0	0	0	0
6	600 u	0	0	0	0
7	300 u	0	0	0	0
8	150 u	0	0	0	0
9	pass	06	0.12	100	0

Table 3: Particle size distribution of Coarse Aggregate

PROPERTIES	VALUES
Specific Gravity	2.7%
Grading analysis	2.18%
Impact Test	9.89%
Crushing Test	24.79%
Flakiness Index	13.58%
Elongation Index	13.58%
BULK DENSITY	**VALUES**
Loose	14.2 kn/m³
Compacted	15.7 kn/m³
Water Absorption: 4.75mm Retained 20 mm Passing	 0.88% 0.99%

Table 4: Properties of Aggregates

Appearance	Brown Liquid
Specific Gravity	1.18
Chloride Content	Nil
Air Entrainment	<2%

Table 5: Properties of Super Plasticizers

5. RESULTS AND DISCUSSIONS

5.1 Tests on Fresh Concrete

5.1.1 Slump Test

Tensile strength are evaluated using checking which defines the most severe step of flexural responsibility that maybe a sample absorbs prior to actually breaking. Between the platens of a stress test specimen, a progressively applied burden packs the test specimen, which is typically in the form of a shape, crystal, or chamber.

Concrete Mixes	Slump Range (mm)
Columns, Retaining Walls	75 – 150mm
Be am sand Slab	50 – 100mm
CC Pavements	20 – 30mm
Decks of Bridges	30 – 75mm
Huge Mass Construction	25 – 50 mm

Table 6: Recommended Slump of Concrete

- For the 0.40 water cement ratio, it is True slump (80mm)

5.2 Tests on Hardened Concrete

5.2.1 Compressive Strength Test

Adding of B Subtilis Bacteria in concrete mix	7 Days Compressive Strength in N/mm²
0%	24.00
10%	25.48
20%	29.00
30%	23.62

Table 7: 7 days Compressive Strength

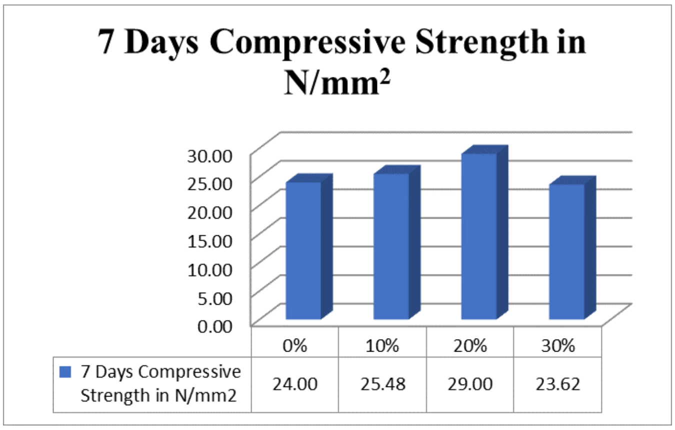

Fig 2: 7 days Compressive Strength

Observation

• Tables 5.7 provide the results of the compressive strength tests.& Compressive strength for different % of bacteria for 7days graph is drawn and the remarks are as follows,

• As can be observed from the previous seven days of compressive strength, Bacillus Subtilis has a compressive strength of 29 N/mm2, which is greater than remaining.

• At 20% bacterial solution, the hydration products seem to be saturated, indicating that the compressive strength of the concrete has grown as the proportion of bacterial concrete.
• Increases in bacterial solution concentration have little effect on strength, and as a result, the concentration drops.

• For 20% of bacterial concrete, the compressive strength rises after 7 days. In other words, the 7days compressive strength of M30 grade concrete with 20% bacterial concrete is 29 N/mm2, as shown in Table -5.5 below.1.To investigate the influence of varied bacterial concentrations on compressive strength, tensile strength, flexural strength, and impact strength.

Adding of B Subtilis Bacteria in concrete mix	28 Days Compressive Strength in N/mm²
0%	39.00
10%	40.14
20%	42.60
30%	38.92

Table 8: 28 Days Compressive Strength

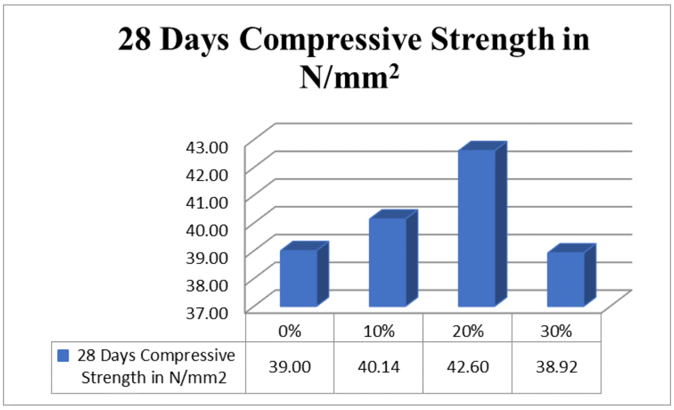

Fig 3: 28 Days Compressive Strength

Observation

• Tables 5.7 provide the results of the compressive strength tests. & Compressive strength for different % of bacteria for 28days graph is drawn and the remarks are as follows

• From the above 28 days compressive strength it is clear that at 20% of Bacillus Subtilis the compressive strength was seen to be 42.60 N/mm2 which is comparatively higher than the reaming.

• For 20% of bacterial concrete, the compressive strength rises after 28 days. This results in a compression strength of 42.60 N/mm2 for M30 grade concrete after 28 days of exposure to a 20% bacterial concrete solution (Table -5.6).

5.2.2 Split Tensile Strength

Adding of B Subtilis Bacteria in concrete mix	28 Days Split Tensile Strength in N/mm²
0%	4.3
10%	4.6
20%	5.8
30%	5.5

Table 9 : 28 days Split Tensile Strength Test

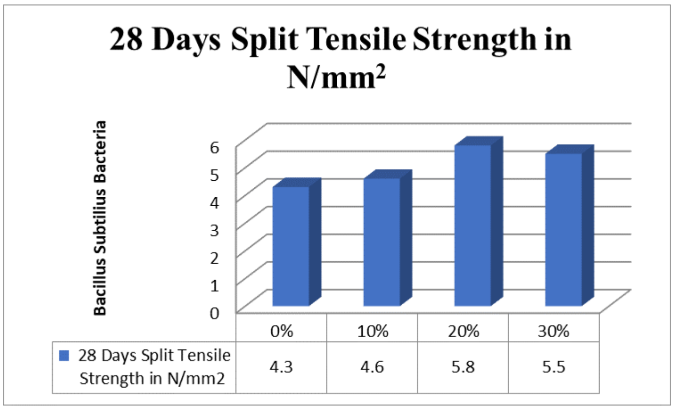

Fig 4: 28 days Split Tensile Strength Test

Observation

•For 28 days, the results of split tensile strength tests were compiled in tables 5.7 and split tensile strength. graph is drawn and the remarks are as follows,

•From the above 28 days Split Tensile strength i
t is clear that at 20% of Bacillus Subtilis is seen to be 5.8 N/mm2 which is comparatively higher than the reaming.

•It is observed that 10% , 30% of bacterial concrete values are low when compared to the 20% of bacterial concrete that is due to higher water concentration where the bacteria fails to fill the voids and hence the strength is decreased.

• After 28 days, bacterial concrete's split tensile strength drops by 10% and 30%, respectively. Because of this, the 28days split tensile strength of M30 grade concrete for 20% bacterial concrete was 5.8 N/mm2.

5.2.3 Flexural Strength

Adding of B Subtilis Bacteria in concrete mix	28 Days Flexural Strength in N/mm²
0%	4.0
10%	4.4
20%	6.0
30%	5.8

Table 10: 28 Days Flexural Strength Test

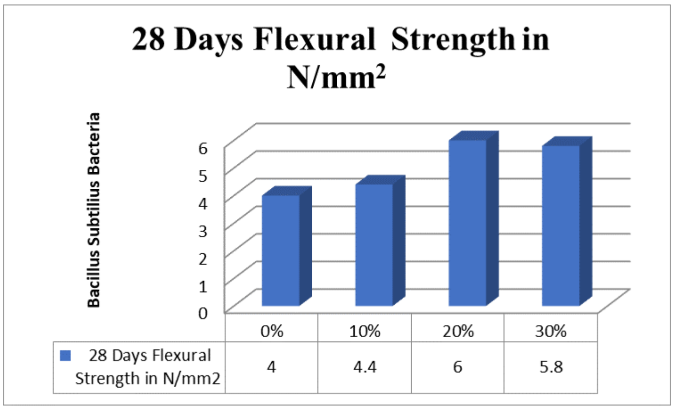

Fig 5: 28 Days Flexural Strength Test

Observation

• Flexural strength test outcomes are tabulated in tables 5.7 & flexural strength for different % of bacteria for 28 days graph is drawn and the remarks are as follows,

• The flexural strength at 20% of Bacillus Subtilis was found to be 6.0 N/mm2, which is greater than the remaining, as can be observed from the above 28 days of Flexural strength.

• The flexural strength of bacterial concrete decreases by 10% after 28 days. That's 6 N/mm2 in flexural strength for 20% bacterial concrete in M30 after 28 days, as shown in Table -5.10.

5.2.4 Durability Test

Adding of B Subtilis Bacteria in concrete mix	30 Days HCL Residuals Compressive Strength in N/mm²
0%	35.49
10%	36.8
20%	40.18
30%	34.42

Table 11: HCL Residuals Compressive Strength Test at 30 days

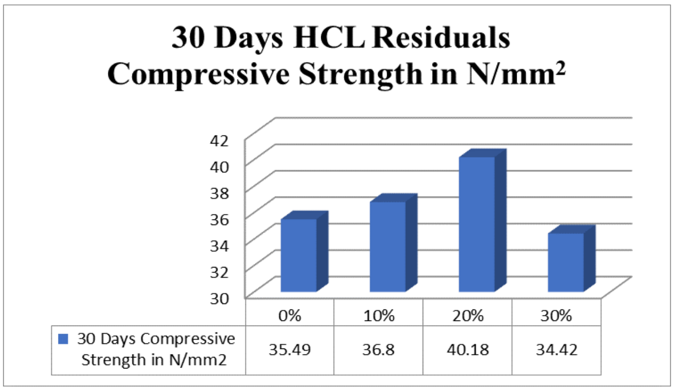

Fig 6: HCL Residuals Compressive Strength Test at 30 days

Observation

• Compressive strength test outcomes are tabulated in tables 5.7 & compressive strength for different % of bacteria for 30 days graph is drawn and the remarks are as follows

• From the above 30 days compressive strength it is clear that at 20% of Bacillus Subtilis the compressive strength was seen to be 40.18 N/mm2which is comparatively higher than the remaining.

• Compressive strength increases from 0% to 20% when bacterial concrete is used, but it decreases at 30% because the hydration process is saturated at 20% bacterial solution, and so any more bacterial solution does not contribute to strength, resulting in a decrease in compressive strength.

• After 30 days, bacterial concrete loses 30% of its compressive strength. Table -5.12 shows that the compressive strength of M30 grade concrete at the end of 30 days for 20% bacterial concrete is 40.18 N/mm²

5.4.5 Impact Test

Adding of B Subtilis Bacteria	No of blows for 28 Days Strength of Impact test	
	N1=Initial crack	N2 = Final crack
0%	171	180
10%	213	228
20%	220	281
30%	190	201

Table 12: 28 Days Compressive Strength

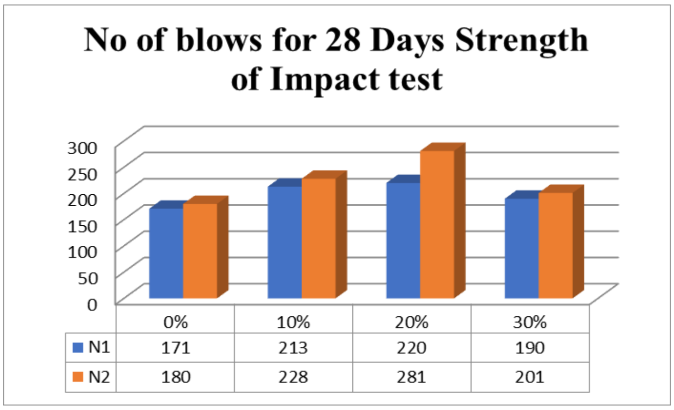

Fig 7: No of blows for 28 Days Strength of Impact test

Observation

• Impact strength test outcomes are tabulated in tables 5.10 & Impact strength for different percentage of bacteria for 28 days graph is drawn and the remarks are as follows,

• From the above 28 days Impact strength it is clear that in 20% of Baciliu Subtilis the resistive strength was seen to be 281 blows which is comparatively higher than the remaining.

• Due to mineral precipitation, holes and pores are shut up and the concrete's strength is clearly boosted as a result.

• Furthermore, as we raise the proportion of bacteria in compressive strength, split tensile and flexural strength tests, we see that the strength increases as well until the moulds have been hydrated.

6. CONCLUSIONS

The following are the findings that may be drawn after the completion of the tests and examination of the data about the strength and durability of concrete.

1. Use of Bacillus Subtilis in concrete improves its compressive strength, split tensile strength, Flexural Strength, Impact Strength and Durability.

2. 20 percent of B Subtilis yielded a compressive strength of 29 at 7 days and 42.60 at 28 days compared to normal concrete, which is 20.83 percent and 9.23 percent greater.

3. In comparison to normal concrete, B Subtilis' split tensile strength at 28 days was found to be 89% greater for 20% of the B Subtilis sample.

4. At 28 days, the Flexural strength of B Subtilis was found to be 6 for 20% greater than normal concrete, an increase of 87%.

5. The Durability strength at 30 days, the compressive strength was seen to be 40.18 for 20% of B Subtiliis which is 13.21% higher than the conventional concrete. Compressive strength at 30 days was found to be 40.18 for 20% B Subtiliis, which is 13.21 percent greater than ordinary concrete.

6. When the impact strength of B Subtilis reached 20%, the strength was found to be much higher.

7. The use of B Subtiliis in the concrete arrests the cracks and there by improves the strength of the concrete.

8. Using B Subtilis in a concrete mix increases the concrete's tensile strength, as seen by the preceding findings, at 20% mixing of B Subtilis Compressive strength, impact strength, durability property is seen to be enhanced and at 30% it is observed that strength has decreased, hence it clear that at 20% use of B Subtilis enhance the strength and durability.

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BIOGRAPHIES

Kavya K P
P.G. Scholar
Department of Civil Engineering.,
RYM ENGINEERING COLLEGE
BALLARI, Karnataka, India.

Mr Adanagouda
Assistant Professor.
Department of Civil Engineering.,
RYM ENGINEERING COLLEGE
BALLARI, Karnataka, India.