Library Progress International
Vol.44 No. 3, Jul-Dec 2024: P. 15010-15017

Print version ISSN 0970 1052
Online version ISSN 2320 317X

Original Article

Available online at www.bpasjournals.com

Experimental Investigation On Self Healing Concrete With Calcium Lactate And Pseudomonas Fluorescens Bacteria

G. Bhasker[1], Dr. C. Venkata Siva Rama Prasad[2], Dr P. Kishore Kumar Reddy[3]

[1]MTech Student, Department of Civil Engineering, Malla Reddy Engineering College, Secunderabad-500100, Telangana, India.
[2]Associate Professor, Department of Civil Engineering, Malla Reddy Engineering College, Secunderabad-500100, Telangana, India.
[3]Associate Professor, Department of Civil Engineering, Malla Reddy Engineering College, Secunderabad-500100, Telangana, India.

How to cite this article: G. Bhasker, C. Venkata Siva Rama Prasad, P. Kishore Kumar Reddy (2024) Experimental Investigation On Self Healing Concrete With Calcium Lactate And Pseudomonas Fluorescens Bacteria. *Library Progress International,* 44(3), 15010-15017.

Abstract
Bacterial concrete has lately appeared as a new option for healing cracks in constructions such as pavements, reinforced concrete (RCC) buildings, bridges, pipes, and canal linings. Commonly occurring cracks in concrete allow chemicals and water to seep in, weakening the structure and harming the reinforcement when exposed to these and other pollutants. It might be expensive to repair these cracks because they usually need regular upkeep and specialist treatments. Henk Jonkers developed bacterial concrete as a solution to this problem, allowing concrete structures to have their fissures repaired.According to his research, some bacteria can be employed to seal existing fissures. The usage of calcium lactate and the bacteria Pseudomonas fluorescens to stop concrete cracking is investigated in this experimental investigation.The key to the bacteria's selection is its capacity to endure in an alkaline environment. Pseudomonas fluorescens and calcium lactate were added to M40 grade concrete in the investigation at weight percentages of 5%, 10%, and 15%. A link between compressive strength and flexural strength is given as the empirical formula.

***Keywords**:* Pseudomonas fluorescens, microbial concrete, compressive strength, tensile splitting strength, and bending strength.

1. Introduction

Cement concrete is becoming more and more important in construction projects in the current period of global i nfrastructure development.However, for further durability, steel reinforcement, or rebar, is needed because of its brittle n ature and propensity to shatter.The tensile strength of reinforced concrete is still less than that of its compressive strength, despite having a higher resistance to stress.Even while the structural integrity may not be immediately jeopardized, these cracks expose the steel reinforcement to the elements, which increases the risk of corrosion and rising maintenance expe nses.As a result, concrete frequently needs extensive maintenance.Conventional concrete is rigid and can only withstand strains of 0-1% before failing.

Self-healing concrete aims to address these limitations by automatically repairing cracks, thereby extending the lifespan of concrete structures. A promising advancement in this field is microbial concrete, a type of self-healing concrete. It incorporates bacteria, specifically Pseudomonas fluorescens, calcium lactate, and nutrient broth to sustain the microorganisms once activated. These bacteria consume the nutrients to heal the cracks. This study will delve into the mechanisms behind microbial self-healing concrete, exploring the various components involved and how they work both independently and in conjunction. Additionally, the study will discuss the practical applications of this self-healing method in existing structures and its real-world implementation.

1.1 The Self-Healing Mechanism

Studying the bacteria that live in concrete, how they prolong the life of structural elements, and how they break down chemicals in the concrete are the main goals of research into the selfhealing mechanism of concrete.The study delv es into the ways in which particular microorganisms respond to environmental stimuli, cooperating to both reinforce and mending fissures before they widen.The bacteria go through a series of reactions that solidify within the crack once they are activated by exposure to environmental elements like air and nutrition. This reinforces the concrete and seals the fract ure edges.By doing this, the structure's lifespan is increased and the cracks are repaired.This technique can be used to me nd cracks in a comparatively short amount of time.

Concrete buildings are currently made to withstand crack widths of up to 2 mm since tiny fissures are not thought to pose an immediate risk to the stability or strength of the building.Because of the natural qualities of the concrete, these small f issures frequently mend themselves.Small cracks can still allow water to seep in, though, particularly in subterranean buil dings where the erratic nature of crack formation makes repairs more difficult.Pseudomonas fluorescens bacteria is used i n the selfhealing technique outlined here to fill in fractures before they enlarge and become more troublesome fissures.Th e term "biocalcification" refers to this multistage process.Modern methods for examining the deposition of minerals like s par on the surface and inside fissures include scanning electron microscopy (SEM) and X-ray diffraction (XRD).

The microorganisms that are used in concrete should be able to prevent cracks over an extended period of time—ideally for the lifetime of the building.The reagent function of the bacteria in bacterial fracture repair involves the conver sion of precursor chemicals into filler components.These recently created materials, which function as bio-cement to effectively seal newly formed fissures, include mineral precipitates based on calcium carbonate.

Some bacteria are inherently resistant to assimilating into the matrix of concrete.These are members of a particular class of alkaliresistant, sporeforming bacteria.While dormant cells may withstand extreme circumstances, such as chemical an d mechanical stressors, and can persist for more than 50 years in a dry state, living spores have the ability to proliferate. However, the spores usually only live for one to two months after being added to the concrete mix.The bacteria become d ormant after they are implanted in the concrete matrix because of continuous interactions with the cement that diminish t he pore sizes within the material.The bacteria's functions are reactivated when exposed to air again, which enables them t o fill concrete gaps with limestone.By consuming oxygen, this process keeps steel from corroding and prolongs the life o f reinforced concrete structures.

1.1 *1.2 Research Significance*

While the strength characteristics of self-healing concrete have been extensively studied, there is limited research on the specific use of Pseudomonas fluorescens bacteria. This study introduces Pseudomonas fluorescens bacteria and calcium lactate as key components in self-healing concrete. It also proposes an empirical relationship between flexural and compressive strength, offering new insights into the potential of bacterial concrete made with this unique combination.

1.2 2.Materials and Testing Methods

1.3 *2.1 Cement*

Ordinary Portland Cement (OPC) grade 53 was used in this experiment.
The physical properties of the cement were investigated in accordance with IS 4031-1996 guidelines. These particular OPC properties are listed in the table below (not shown here). Grade 53 was selected because to its potency and suitability for the research.

1.4 Table 1. Physical properties of Portland cement (53 grade)

S. No.	Test Characteristic	Result	conformity with IS 12269-1987 requirements[14]
1	Fineness (a) Sieve test (b) Blaine	 3% 285m²/kg	Not more than 10% Min 225 m²/kg
2	Typical Uniformity	32.0%	-
3	Specific Gravity	3.02	-

4	first-time setting	97minutes	Not less than 30 minutes
5	last-time setting	285minutes	Not more than 600 minutes
6	Compressive strength (a) 3days (b) 7days (c) 28days	 38N/mm² 40 N/mm² 55N/mm²	 28 N/mm²(Min) 38 N/mm²(Min) 55 N/mm²(Min)
7	Suitability (Le-Chatlier Experiment)	3mm	Not more than 10mm

2.2 *Fine Aggregate*

The particle size distribution curve for the fine aggregate is shown in Figure 1 below.
The fine aggregate has a specific gravity of 2.68.

2.3 Coarse Aggregate

The characteristics of the coarse aggregate are shown in the figure (not shown here), along with t he particle size distribution curve.

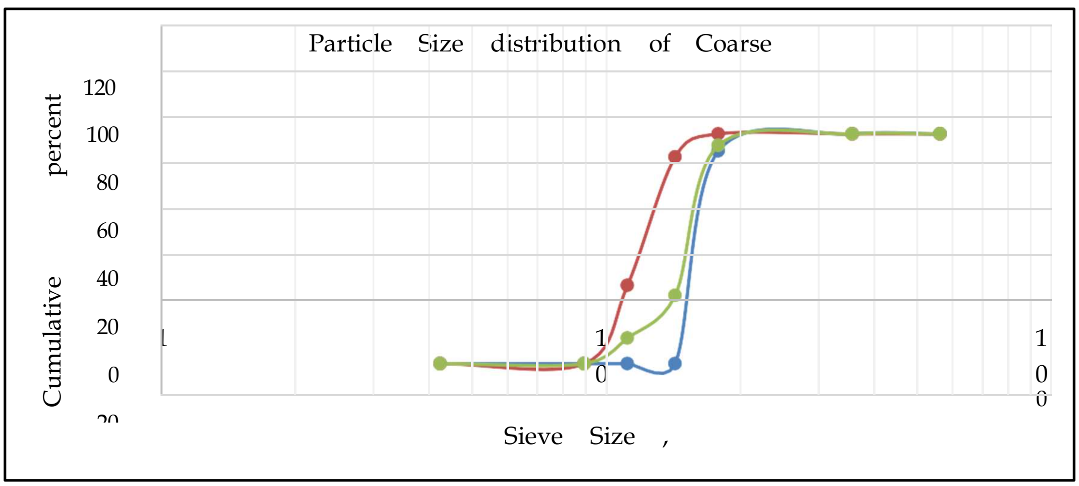

Figure 1 shows the coarse aggregate's particle size distribution curve.

2.4 *Water*

1.5 For all of the mixes, readily available potable drinking water was utilized.

2.5 *Microorganisms*

Pseudomonas fluorescens, the microbe utilized in the experiment, was grown in the lab of DVS Bio Life P vt Ltd.

2.6 Culture of Bacteria

1.6 The bacterial culture was kept alive on nutrient agar slants after being taken out of DVS Bio Life Pvt Ltd.
One colony was incubated at 37°C with 125 rpm shaking in a flask containing nutrient broth. Peptone (5 g/L), NaCl (5 g/L), and yeast extract (3 g/L) made up the growing media.

2.7 Calcium lactate

1.7 The experiment involved the use of Pseudomonas fluorescens in conjunction with calcium lactat e (C6H10CaO6).

2.8 Compressive strength

1.8 Following IS: 5161959 standards, 15 cm x 15 cm x 15 cm cubes were evaluated for compressive st rength at 7, 14, 28, 60, and 90 days after curing.

2.9 Tensile strength

1.9 As per IS: 5816
1999 standards, a cylinder with a diameter of 150 mm and a length of 300 mm was utilized for the s plit tensile strength test.

2.10 Flexural strength

1.10 In compliance with IS: 516-
1959 guidelines, the 100 mm x 100 mm x 500 mm beams were utilized for the flexural strength test.

2.11 Mix Design

The proportions of the mix for concrete of M40 grade were determined by referring to IS: 10262-2009 specifications. The ratios for the different concrete combinations are shown in Table 2.

Table 2. Mix ratios for concrete of M40 grade

Mixture No	SHCR00	SHCR05	SHCR10	SHCR15	SHCM 00	SHCM 05	SHCM 10	SHCM 15
Cement(kg/m³)	395	395	395	396	396	396	395	395
River Sand(kg/m³)	638	639	639	639	--	--	--	--
M-Sand(kg/m³)	--	--	--	--	638	639	639	639
Coarse Particle Count (kg/m3)	1270	1270	1272	1272	1272	1272	1272	1272

w/c ratio	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Admixture (kg/m³) (ECMAS)	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Bacterial Cells (cfu/ml)	--	10^6	10^6	10^6	--	10^6	10^6	10^6
Percent of bacterial solution	00	10	15	10	00	10	15	10

3. Results and Discussions

3.1 Compressive Strength and Curing Age of Bacterial Concrete

Figure 2 illustrates how curing age affects the compressive strength of M40 grade bacterial concrete.
Compaction strength gets better with increasing curing age.
Due to the effects of Pseudomonas fluorescens and calcium lactate, strength noticeably increases after 28 days and contin ues to do so for 60 and 90 days.
From 0% to 10%, the compressive strength climbed, but at 15%, it decreased because of hydration product saturation.

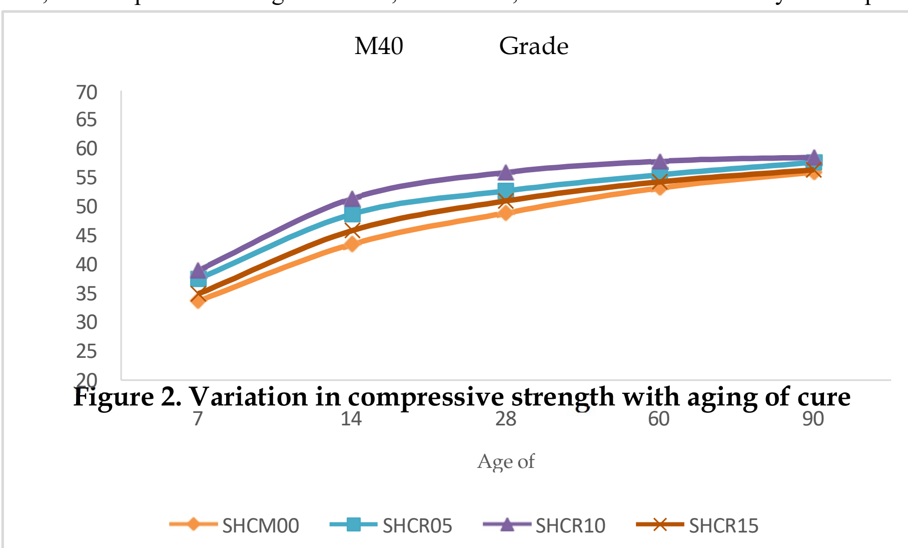

Figure 2. Variation in compressive strength with aging of cure

3.2 Split Tensile Strength and Curing Age of Bacterial Concrete

The split tensile strength of M40 microbiological concrete over time is shown in Figure 3.
Split tensile strength rose with curing age, especially at 60 and 90 days, just like compressive strengt h did.
The strength increased from 0% to 10% as the bacterial percentage rose, but rising above 10% resulte d in a decrease in strength.

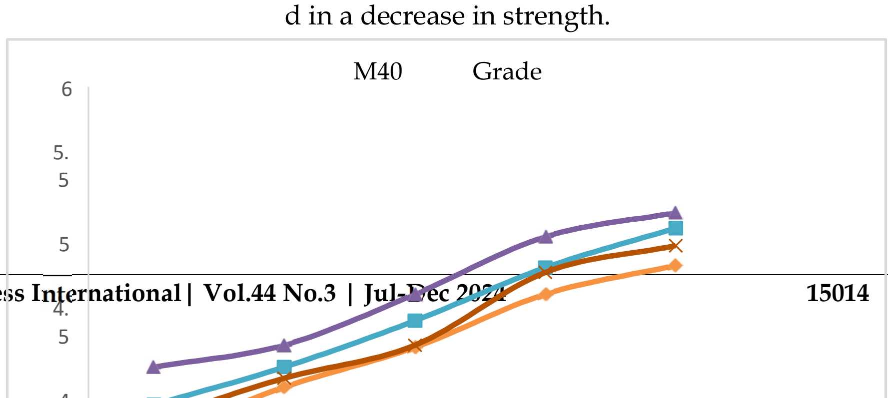

Figure.3 Variation in split tensile strength with aging of cure

3.3 Flexural Strength and Curing Age of Bacterial Concrete

Flexural strength increased with curing age, as demonstrated in Figure 4, particularly at 60 and 90 days.

Flexural strength increased up to 10% bacterial concentration but declined at 15% because of product saturation, same like the other strength metrics.

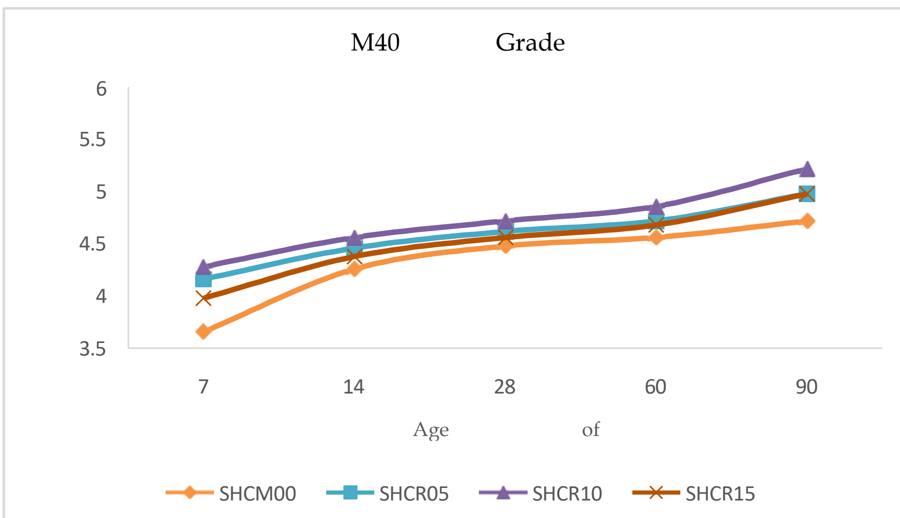

Figure.4 Variation in flexural strength with aging of cure

3.4The empirical relationship between the bacterial concrete's flexural and compressive strengths is proposed as follows:

The Indian Code IS 456-2000, the American Code ACI-318-2002, and other standards offer empirical connections between compressive and flexural strength. Since the investigation was unable to determine a clear correlation between these strengths in bacterial concrete, a new correlation was created, as Figure 5 illustrates.

The link between compressive and flexural strength at various bacterial percentages was ascertained using the experimental data.

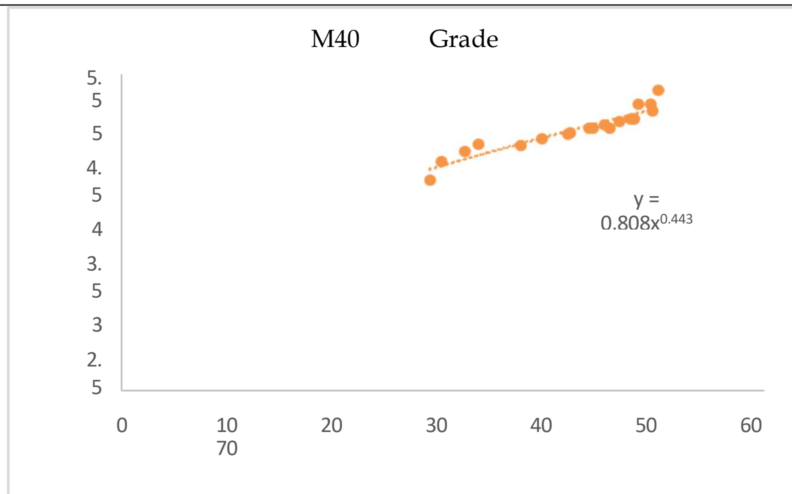

Figure.5 Empirical relationship between flexural and compressive strengths

4.Conclusions The investigation produced the following findings:

1. Because calcium carbonate crystal precipitated within the gel matrix, M40 grade bacterial concrete with a 10 % bacterial solution attained maximum compressive, flexural, and split tensile strength.
2. The 10% bacterial concrete outperformed the control mix in terms of compressive strength after 28 days.
3. At all ages, the presence of bacteria increased split tensile strength.
4. A 10% bacterial solution produced the best strength gain, and the empirical relationship between compressi ve and flexural strength is as follows: ft=0.808fck0.443ft = 0.808 fck^{0.443}ft=0.808fck0.443

References: Zwaag, S. (Ed.). (2008). Self-healing materials: an alternative approach to 20 centuries of materials science (Vol. 30). Springer Science+ Business Media BV.Jonkers, H. M., &Schlangen, E. (2007, April). Crack repair by concrete-immobilized bacteria. In Proceedings of the first international conference on self healing materials (pp. 18-20).Joseph, C., Jefferson, A. D., &Cantoni, M. B. (2007, April). Issues relating to the autonomic healing of cementitious materials. In First international conference on self-healing materials (pp. 1-8).Kessler, M. R., Sottos, N. R., & White, S. R. (2003). Self-healing structural composite materials. Composites Part A: applied science and manufacturing, 34(8), 743-753.Santhosh, K. R., Ramakrishnan, V., Duke, E. F., & Bang, S. S. (2000). SEM Investigation of Microbial Calcite Precipitation in Cement. In PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON CEMENT MICROSCOPY (Vol. 22, pp. 293-305). INTERNATIONAL CEMENT MICROSCOPY ASSOCIATION.Ramakrishnan, V., Ramesh, K. P., & Bang, S. S. (2001, April). Bacterial concrete. In Smart Materials (Vol. 4234, pp. 168-177). International Society for Optics and PhotonicsWang, J., Van Tittelboom, K., De Belie, N., &Verstraete, W. (2012). Use of silica gel or polyurethane immobilized bacteria for self-healing concrete. Construction and building materials, 26(1), 532-540.Li, V. C., & Herbert, E. (2012). Robust self-healing concrete for sustainable infrastructure. Journal of Advanced Concrete Technology, 10(6), 207-218.Jonkers, H. M., Thijssen, A., Muyzer, G., Copuroglu, O., &Schlangen, E. (2010). Application of bacteria as self-healing agent for the development of sustainable concrete. Ecological engineering, 36(2), 230-235.Reddy, S., Satya, K. A., Rao, M. V., &Azmatunnisa, M. (2012). A biological approach to enhance strength and durability in concrete structures. International Journal of Advances in Engineering & Technology, ISSN, 2231-1963.Jonkers, H. M. (2011). Bacteria-based self-healing concrete. Heron, 56 (1/2).

Schlangen, H. E. J. G., Jonkers, H. M., Qian, S., & Garcia, A. (2010). Recent advances on self healing of concrete. In FraMCos-7: Proceedings of the 7th International Conference on Fracture Mechanics of Concrete and Concrete Structures, Jeju Island, Korea, 23-28 May 2010.

IS: 4031-1996. Methods of physical tests for hydraulic cement, Bureau of Indian standards, New Delhi, India.

IS: 12269-1987. Specification for 53 grade ordinary Portland cement. Bureau of Indian standards, New Delhi, India.

IS:516-1959. Indian standard code of practice- methods of test for strength of concrete, Bureau of Indian standards, New Delhi, India.

IS:5816-1999. Splitting tensile strength of concrete – method of test. Bureau of Indian standards, New Delhi, India.

IS: 10262-2009. Concrete mix proportioning-Guidelines. Bureau of Indian standards, New Delhi, India

IS: 456- 2000. Plain and reinforced concrete code of practice (fourth revision). Bureau of Indian standards, New Delhi, India.

ACI Committee 318 (2002) Building Code Requirements for Reinforced Concrete and Commentary, ACI, MI.

NZS – 3101-2006. Concrete structures standard. New Zealand.

EC- 02Designers, Handbook to Euro-code 2 Part1.1 Design of Concrete Structures. Thomas Telford Services Ltd., London.

The Canadian code of practice (CSA**)**. Design of Concrete Structures. CSA A 23.3:1994, Technical Committee, Canadian Standards Association, Rexdale, Ontario.