International Research Journal of Multidisciplinary Scope (IRJMS), 2025; 6(1):1486-1497

Original Article | ISSN (O): 2582-631X **DOI: 10.47857/irjms.2025.v06i01.02121**

Mechanical and Microstructural Analysis of Self-Compacting Concrete

Balasubramaniam N[1]*, Boobalan SC[2], Prabakaran E[3], Rajeshkumar V[4],

[1]Department of Civil Engineering, Jansons Institute of Technology, Coimbatore, Tamil Nadu, India, [2]Department of Civil Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, Tamil Nadu, India, [3]Department of Civil Engineering, Dr. NGP Institute of Technology, Coimbatore, Tamil Nadu, India, [4]Department of Civil Engineering, KPR Institute of Engineering and Technology, Coimbatore, Tamil Nadu, India. *Corresponding Author's Email: balasubramaniamcivil@yahoo.co.in

Abstract

Concrete possesses pores and the propensity to develop microcracks, both of which are very undesirable since they facilitate the penetration through water along with additional harmful elements into the building element. Using Microbiologically Induced Calcite Precipitation (MICP), the Bacterial Self Compacting technique is a potential way to fill concrete fractures. To promote the deposition of calcium carbonate within the concrete material, microorganisms use the urease enzyme in this process. Bacterial remediation is a long-term, ecologically safe, and bio-based treatment that works better than other approaches. Concrete has to have a high pH and be mixed mechanically for microorganisms to provide resistance. In high-performance construction, MICP-induced concrete has emerged as a major area of research. The uses of bacteria to produce bacterial SCC and the long-term qualities of these combinations have not been given enough consideration in India. M60 grade bacterial self-compacting concrete that has silica fume, fly ash, and bacteria added as an additive. The workability, durability, microanalysis, and mechanical characteristics of bacterial self-compacting concrete are the main topics of this investigation. The test results for bacterial self-compacting concrete show that bacteria with a size of 106 yield the best results.

Keywords: Bacterial Self-Compacting Concrete, Durability, Microanalysis, Workability.

Introduction

Reviews from Self-Compacting Concrete (SCC): Multitier and mineral additives are to be used in the construction of SCC. Buildings that are large, intricate, and have several stories are required due to modern developments in construction. It becomes very demanding to ensure complete compaction of concrete to prevent voids and honeycombs in situations when compaction by human or mechanical vibrators is problematic (1). This is particularly true while attempting to guarantee that a sizable amount of concrete is completely compressed in opposition to the sturdy reinforcement. It also generated a whole new kind of concrete called self-compacting concrete. Vibrant concrete does not require vibration to compress itself since it is so fluid and simply fits into all the crevices and nooks of the formwork (2). Self-consolidating or high-performance self-compacting concrete are some other names for it. Because it does not require compression, this concrete mix saves labor, time, and energy. Filling mortar cubes with a mixture of water and Bacillus subtitles bacteria at different densities (3). Two mixes, M20 and M40, were used, and the amount of bacteria in the concrete was changed. There was a range of 104 to 107 cells per milliliter. As cracks in a concrete structure propagate, the bacterium spores engage in microbiological activities when they come into touch with oxygen and water. When different kinds of bacteria are put into advanced concrete, the value of chloride ion permeability decreases (4). This experiment's fast chloride penetration test results have demonstrated that bacterial concrete has better durability characteristics. It was determined by the test that the specimens had totally closed any cracks and had significantly increased compressive strength. Scanning Electron Microscope (SEM) demonstrates the strengthening and healing of concrete cracks. Where there were surface fractures, calcite precipitations formed. The specimens with typical crack widths greater than 0.8 mm could not have microbial healing agents added to them, making fracture repair more challenging. It was proposed that water cure might be a feasible alternative (5).

(Received 22nd August 2024; Accepted 27th January 2025; Published 31st January 2025)

More than 60 days after the cracking began; the crack healing ratio was noticeably lower. Improved defense against attacks from acids, alkalis, and sulphates results from the replacement of fly ash. To produce High-Performance Concrete (HPC), a super plasticizer must be used in M70 grade concrete since the concrete's water-to-cement (w/c) ratio of 0.26 does not provide enough workability (6). By using both fine and ultrafine cementitious materials to create good particle packing, concrete may be manufactured to function as needed in both its fresh and hardened phases. Recently, self-compacting concrete has become more and more common in reinforced concrete structures with difficult casting circumstances. For these uses, fresh concrete has to be very cohesive and flowing (7). SCC was created and tested using a lot of fly ash, and the preliminary results are presented and debated. This experiment looked at one control concrete and nine SCC combinations. In the self-compacting mixes, class ‘F’ fly ash was used in place of 40,50, and 60% of the cement. Instead of utilizing natural sand, both ingredients were used to build concrete in this experiment. The concrete's workability was decreased by 30 to 50% when bottom ash and slag were added. This outcome can be attributed to the porous particles, low bulk density, soundness, and high water absorption of the aggregates. Granulated blast furnace slag and bottom ash lowered the strength of the concrete by 10 to 22% when compared to the reference mix's strength. It was believed that the concrete's decreased bulk density, which resulted from using lighter components rather than natural sand, was the source of the strength loss. They deduced that the minuscule particle size of the fly ash affected the pore size of the concrete, hence reducing its absorption of water. The novelty of this research lies in the integration of *Bacillus megaterium* into SCC, exploring its dual role as a bio-agent for enhancing mechanical strength and as a microstructural densifier. Unlike previous studies that primarily focused on traditional concrete, this study delves into the unique challenges and opportunities presented by the use of microbial technologies in SCC. Furthermore, the study investigates the interplay between the bacterial activity and the self-compacting behavior of the concrete, addressing potential compatibility issues and optimizing the mix design. By bridging the gap between microbial technology and self-compacting concrete, this study paves the way for developing environmentally friendly and durable construction materials. The findings have significant implications for sustainable infrastructure development, particularly in regions prone to environmental degradation and structural challenges. By addressing these critical gaps, this research not only advances the understanding of MICP in SCC but also contributes to the development of sustainable, durable, and self-healing construction materials for modern infrastructure challenges.

Methodology

The key component of concrete is cement. The criterion for choosing cement is its capacity to improve the microstructure of concrete. The concrete has a consistency of 27.5 and the following characteristics: a specific gravity of 3.15, a fineness of 321 m^2/kg, a heat of hydration of 268 @ 7 days kj/kg, a 53-minute initial setting time, and a 436-minute completion time. After 3, 7, and 28 days of curing, its compressive strengths are 36.18, 45.63, and 60.47 MPa, respectively. The compatibility of the bacteria with cement must be verified. It is essential to establish that the bacteria and cement are compatible. Water that meets IS: 456-2000 standards have been established as suitable for use in concrete manufacture. It is a widely held assumption that water suitable for human consumption may also be used to make concrete. In this experiment, concrete was produced and cured using the drinking water that the corporation supplied to Coimbatore city. The fine aggregate used in this experiment was M-sand, which is easily accessible in the region. The fine aggregate's specific gravity is 2.55, its bulk density is 1575 kg/m^3, its fineness modulus is 2.86, its water absorption is 1.45%, and its moisture content is almost nonexistent. In concrete, the least porous and longest-lasting aggregate is the coarsest. Moreover, its chemical makeup is constant. Shrinkage and other dimensional changes are lessened during drying because moisture is flowing about. In terms of physical characteristics, coarse aggregate has the following: 2.75 specific gravity, 5.14 fineness modulus, 0.482% water absorption, 32.5% crushing value, 14.4% impact value, 19.5% abrasion resistance, and 9% and 8% flaky and elongation particles, respectively. Within the parameters of this study, the greatest size of coarse aggregate used was 12 mm. The researched material's overall composition and structural characteristics are influenced by the choice of this parameter. Fly ash's specific gravity and density were measured using a Le Chatelier flask by IS: 4031 (P11) – 1988 guidelines. The fly ash's fineness was measured using a Blaine-type variable air permeability device in compliance with IS: 4031 (P2) -1999. Fly ash is a dark gray substance that is in the form of powder. Its specific gravity is 2.11, its fineness is 516 m^2/kg, and its bulk modulus is 1135 kg/m^3. Improved durability, less heat generation, more strength, and improved workability are just a few of the benefits that result from adding fly ash to cement. There are several unique properties of silica fume. Its specific gravity, which measures the density of water, is 2.26. Its remarkable fineness of 20,000 m^2/kg provides a large surface area per mass unit, increasing reactivity. It has moderate compressibility with a bulk modulus of 656 kg/m^3, which is helpful in situations that call for flexibility. It is commonly found in powder form and blends very easily with a variety of materials. Because of its light gray hue, it blends in perfectly with other building materials. The aforementioned characteristics render silica fume essential in the building industry, particularly for augmenting the robustness, longevity, and efficiency of concrete, in addition to other industrial uses (8, 9). A nourishing broth solution including peptone, sodium chloride, and beef extract was used to suspend them. The obtained cultures of bacteria were kept chilled until they were needed. An illustration of Bacillus Megaterium under a microscope is shown in Figure 1. Because the superplasticizer can dramatically increase workability, overall performance has increased because more fluidity and ease of manipulation may be achieved throughout the building process. Bacillus megaterium is a rod-shaped bacterium that grows in a variety of habitats. It is notable since it is among the biggest bacteria that science has ever discovered. Its cells may reach lengths of 4 m and diameters of 1.5 m. Among the known compounds of Bacillus megaterium is poly-glutamic acid. Research indicates that Bacillus megaterium is a halophile, as certain strains can grow in conditions up to 15% NaCl. Although cells are usually found in pairs and chains, the polysaccharides on their cell walls act as links between the cells. Temperatures between 30°C and 45°C are optimal for the development of Bacillus Megaterium. Bacillus Megaterium is called the "big beast" due to its massive size, which is approximately 100 times larger than that of E. coli. Since the 1950s, studies on protein localization, the structure, and membranes of bacteria have been conducted using Bacillus Megaterium, a bacterium with a cube-shaped size of around 60 micrometers (10). Bacillus megaterium is a well-documented urease-producing bacterium, making it highly effective in microbial-induced calcite precipitation (MICP). The urease enzyme catalyzes the hydrolysis of urea into carbonate and ammonium ions, which react with calcium ions in the cementitious environment to form calcium carbonate ($CaCO_3$). This selection rationale ensures that the incorporation of *Bacillus megaterium* into SCC is both effective and practical, addressing both mechanical and durability challenges in construction materials. Based on the mix design, the following quantities were arrived at to prepare the various concrete mixes and used for these experimental studies. Cement – 382 kg/m^3, Fly ash – 55 kg/m^3, SF – 55 kg/m^3, GGBS – 55 kg/m^3, Super plasticizer – 4.5 kg/m^3, Water – 150 kg/m^3, FA – 686 kg/m^3 and CA – 1020 kg/m^3 respectively.

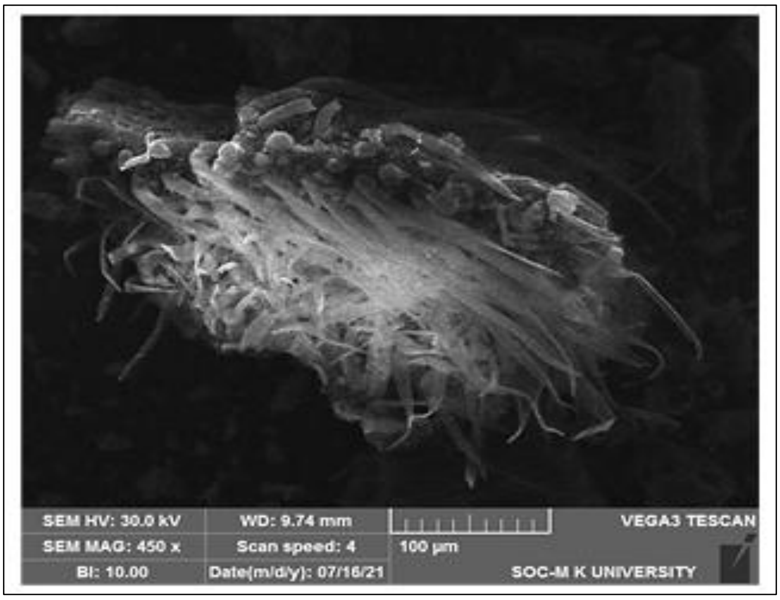

Figure 1: SEM View of Bacillus Megaterium

Results and Discussion

Compaction was avoided when pouring the SCC mix roughly six liters in volume into the slump cone. When the top level of the cone was reached, excess concrete was carefully removed. The concrete was then allowed to settle naturally by raising the cone vertically. At this point, a timer was also set to record the amount of time it took the concrete to form a 500 mm diameter circle. The bacterial cell concentration is enriched with the slump value. A moveable gate was positioned next to the reinforcing bars to split the sections. The flowability and passing ability of the concrete mix were evaluated in the L-box test using around 14 liters of concrete, with special attention to how well it performed in small areas and around reinforcing. The concrete had to be poured into the L-shaped apparatus's vertical part, and it had to settle for a minute. A gate was opened to let the concrete go via reinforcing bars from the vertical part into the horizontal section after the settling time. When evaluating the concrete's potential for different structural applications, especially those involving highly reinforced regions, it is important to consider its ability to maneuver around obstacles, which was revealed by the concrete's passage between the bars and transition between sections (11). Sections H1 and H2's concrete heights were measured. The results of the L-box test, which compares the flow properties of bacterial concrete conventional self-compacting concrete (SCC), and self-compacting concrete (SC), are shown linearly in Figure 2.

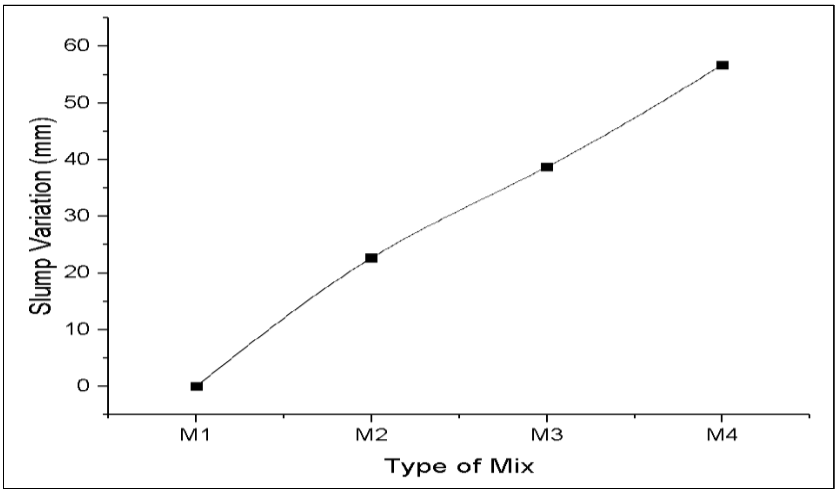

Figure 2: Variations in Slump Value with L Box Test for Different Concrete Mixes

Plotting the test findings against the concrete mix slump variations is done. After that, set down a bucket. Once all of the concrete has been put into the device, just strike off the top layer of concrete with the trowel rather than compressing or tapping it. Allow the concrete to naturally drain out of the funnel by opening the trapdoor and waiting five minutes after the second fill. The test findings for conventional SCC and SC bacterial concrete show a linear variation, which is notably shown at 5 minutes, in Figure 3. To evaluate the flow time, the V-funnel T50 test was employed, which calculates the amount of time needed for concrete to pass through the funnel entirely. The SC bacterial concrete showed very little blockage at 106 cell concentrations (12). A graphical depiction of the V-funnel test results for conventional SCC and SC bacterial concrete is presented in Figure 3. A consistent load of 140 kg/cm^2 per minute was applied to the specimen while it was positioned in the middle of the testing apparatus. Nonetheless, the dial gauge needle only started to move when the load was increased. A change in the direction of the needle's motion signifies a failure in the specimen.

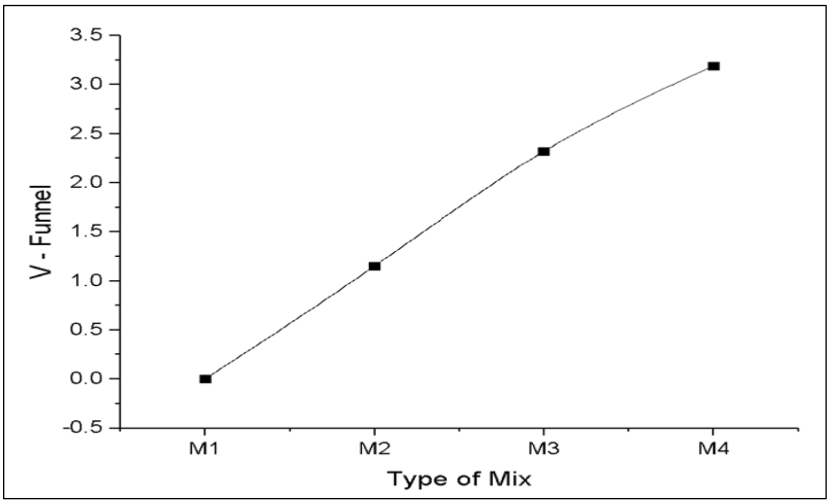

Figure 3: Variations in V-funnel Value with T5 Min and T50 Test for Different Concrete Mixes

This was the moment to record the maximum load indicated by the current reading on the dial gauge. One may calculate the ultimate cube's axial strength by dividing the ultimate load by the cross-sectional area of the specimen (13). Table 1 displays the findings of the tests conducted on the compressive strength of bacterial and conventional self-compacting concrete (SCC). The two forms of concrete's compressive strength values are contrasted in this table. M1, which is used as a baseline for comparison, has compression strength of 53.9 MPa after seven days. The strength in M2 significantly drops to 39.6 MPa as the concentration of cells rises. Seven days later, the strength reached 45.6 MPa in M4, and 42.9 MPa in M3. The tendency of increasing intensities with larger cell concentrations is still seen at 14, 28, 56, and 90 days.

Table 1: Compressive Strength Values of Bacterial and Conventional SCC

Type of Mix	Concentration of Cell	Compressive Strength in Days (MPa)				
		7	14	28	56	90
M1	SCC – Conventional mix	36.5	53.9	60.6	67.5	71.8
M2	10^4	39.6	56.8	63.7	72.8	76.2
M3	10^5	42.9	60.4	67.5	76.6	80.4
M4	10^6	45.6	63.6	71.8	79.2	84.1

After the curing process, the cylinders underwent testing by IS: 5816-1999 specifications. The cylinders were arranged horizontally within the 2000 kN axial testing apparatus. Up until the cylinder failed, a load that increased gradually was applied; the failure load was noted. Using linear variation at various dosages, the outcomes for bacterial and conventional SCC were evaluated. The results of the experimental tests for splitting tensile strength are shown in Table 2. Around 3.18 MPa is the split tensile strength of the baseline material, M1, after 7 days. The M2 strength climbs to 3.79 MPa as the cell concentration grows. Its strength rises to 4.14 MPa in M3, and to 4.67 MPa in M4 after 7 days, when the cell concentration reaches 105. When cell densities are raised, the tendency toward enhanced split tensile strength persists for 14, 28, 56, and 90 days (14). With a loading rate of 400 kg/min, prisms were subjected to a two-point load utilizing a flexural testing device. Following the water curing procedure as per IS: 516 – 1959, this was carried out after the prisms were taken out of the curing tank. Both the bacterial and conventional SCC test results at different dosages are compared with linear variation (15).

Table 2: Split Tensile Strength Values of Bacterial and Conventional SCC

Type of Mix	Concentration of Cell	Split Tensile Strength in days (MPa)				
		7	14	28	56	90
M1	SCC – Conventional mix	3.18	3.92	4.49	5.02	5.28
M2	10^4	3.65	4.19	5.08	5.93	5.49
M3	10^5	4.14	4.52	5.59	6.57	6.51
M4	10^6	4.67	4.89	6.27	7.02	7.65

Table 3 displays the experimental flexural strength test findings. Using M1 as the basis, at 28 days, its flexural strength is 8.07 MPa. The strength in M2 improves to 8.86 MPa as the cell concentration rises. After 28 days, the strength in M4 reaches 9.92 MPa, whereas in M3, at 105 cell concentration, it grows even higher to 9.47 MPa. It is still the case that after 56 and 90 days, flexural strength increases with larger cell concentrations (16). The specimens were cured in water for 28 days, and then they were covered with oil and put on the foundation plate. A 457 mm-tall steel ball with a diameter of 63.5 mm and a weight of 4.54 kg was repeatedly slammed against the specimen. The test results for bacterial and conventional SCC at different concentrations are compared with linear variation (17). After casting and soaking in water for 28 days, the cylindrical concrete samples were allowed to cure.

Table 3: Conventional and Bacterial Concrete and its Flexural Strength

Type of Mix	Concentration of Cell	Flexural Strength in Days (MPa)		
		28	56	90
M1	SCC – Conventional mix	8.07	9.06	9.38
M2	10^4	8.86	9.72	10.57
M3	10^5	9.47	10.28	11.26
M4	10^6	9.92	11.04	11.96

In Table 4, the impact tensile strength test experimental test results are shown. For the first and last cracks, M1 shows impact strengths of 64 MPa and 68 MPa at 28 days. The impact strength improves with increasing cell concentration in M2, with the last crack reaching 71 MPa and the first fracture reaching 67 MPa. i.e., at around 10^5, the cell concentration in M3 causes the impact strength to rise to 69 MPa for the first fracture and 75 MPa for the final fracture. The sample with the maximum cell concentration, M4, shows impact strength of 74 MPa for the first fracture and 78 MPa for the final crack at 28 days.

Table 4: Conventional and Bacterial Concrete and its Impact Strength

Type of Mix	Concentration of Cell	Impact Strength in Days (MPa)					
		Crack in 28 Days		Crack in 56 Days		Crack in 90 days	
		First	Last	First	Last	First	Last
M1	SCC – Conventional Mix	64	68	73	79	78	84
M2	10^4	67	71	75	80	79	85
M3	10^5	69	75	79	84	83	89
M4	10^6	74	78	78	83	85	92

The drying procedure was continued until there was a significant mass difference between the two successive measurements that were obtained at 24-hour intervals. Before being submerged in water, the dried samples were allowed to cool to room temperature. The samples were removed, dried with fresh towels, and weighed regularly (18). Until the weights steadied, indicating full saturation, this process was repeated. Table 5 displays the saturated water absorption test results. According to M1, after 28 days, the saturation water absorption is 2.18%. 1.87% absorption occurs with larger cell densities in M2. In the 105-cell unit M3, the absorption decreases substantially to 1.71%. Upon reaching 28 days, M4, which had the highest number of cells, had the lowest amount of absorption at 1.46%.

Table 5: Conventional and Bacterial Concrete and It's Water Absorption

Type of Mix	Concentration of Cell	Water Absorption in %		
		28 days	56 days	90 days
M1	SCC – Conventional Mix	2.18	2.03	1.96
M2	10^4	1.87	1.68	1.46
M3	10^5	1.71	1.59	1.27
M4	10^6	1.46	1.32	1.14

The porosity determined by absorption tests is known as effective porosity. The volume of the voids is determined by measuring the quantity of water lost throughout the drying process of a saturated specimen at 105°C until it reaches a constant mass. The bulk volume of the specimen is ascertained by subtracting its airborne mass from its submerged mass in water (19). The test findings for both bacterial and conventional SCC with linear fluctuation at various doses are compared. The test results for bacterial and conventional SCC at different concentrations are compared with linear variation. Table 6 presents the experimental findings of the porosity test. The porosity of M1 at 28 days is 3.08%. Porosity in M2 drastically drops to 1.01% as cell concentration rises. At 1.12%, the porosity in M3 remains modest, even at 105 cell concentrations. After 28 days, M4 had the highest cell concentration and the lowest porosity (1.17%). With a pH of 3 or 5% of 0.01 normality, the HCl solution was used in these experimental studies. Maintaining a steady pH of two, the H_2SO_4 solution was 5% of 0.01 normality. After removing the specimens from the acidic water, the surfaces of the cubes were cleaned. Subsequently, calculations were performed to determine the compressive strengths and weight reductions of the specimens (20). Additionally, the compaction strengths and average weight loss percentages for the specimens were also calculated. For bacterial SCC and conventional SCC at different concentrations, an analysis is provided between the test results and linear variation. Table 7 presents the experimental data obtained from the acid resistance test. The specimen measuring 10 x 10 x 5 mm significantly affects sample representation, resolution, and equipment compatibility for precise surface morphology visualization—all crucial components for the interpretation of scanning electron microscopy (SEM) information.

Table 6: Conventional and Bacterial Concrete and Its Porosity

Type of Mix	Concentration of Cell	Porosity		
		28 days	56 Days	90 days
M1	SCC – Conventional Mix	3.08	2.81	2.38
M2	10^4	1.01	0.92	0.89
M3	10^5	1.12	1.02	0.91
M4	10^6	1.17	1.06	0.96

M1 lost 2.91 percent of her body weight after 28 days. Weight reduction is significantly reduced to 0.98% with increased cell concentration in M2. M3 has a cell concentration of 105; therefore the weight reduction is still rather little at 1.01%. At 28 days, M4 exhibits the least amount of weight loss (1.2%), although having the highest cell concentration.

Table 7: Conventional and Bacterial Concrete and its acid Resistance Values

Type of Mix	Concentration of Cell	% Loss of weight		
		28 days	56 days	90 days
M1	SCC – Conventional mix	2.91	2.67	2.39
M2	10^4	0.97	0.92	0.85
M3	10^5	1.01	0.94	0.87
M4	10^6	1.2	0.98	0.92

Cut into 10-by-10-by-5-millimeter parts, cube specimens with compressive strengths measured over 28 days were used. The microstructure of prepared concrete samples and its width were examined using SEM analysis by moving the electron beams to focus and moving on the specimen samples. The electron beam interacts with the material to produce a variety of signals that are measured (21). Figures 4 and 5 show the SEM images for 28-day conventional SCC as well as the bacterial SCC. The incorporation of Bacillus megaterium in self-compacting concrete (SCC) led to significant improvements in its mechanical properties, as evidenced by increased compressive strength, tensile strength, and durability. These enhancements can be directly attributed to the microstructural modifications induced by microbial-induced calcite precipitation (MICP). A SEM examination of the concrete of the bacterial SCC specimens showed many calcite crystals embedded in it. A large amount of calcium measured verified the existence of $CaCO_3$ or calcite generated by bacteria. Calcite forms a barrier against dangerous compounds upon deposition, improving impermeability. Concrete is strengthened and given a longer lifespan when calcite peaks show that microorganisms have precipitated calcite. Scanning electron microscopy (SEM) revealed the formation of dense calcium carbonate ($CaCO_3$) deposits in the pore spaces and along micro cracks within the SCC matrix. The biogenic calcite acted as filler, reducing the overall porosity, and contributing to a denser, more compact matrix. This reduction in porosity is critical for improving the compressive strength, as it minimizes the presence of voids that could serve as stress concentrators under loading. Furthermore, the uniform distribution of calcite crystals, observed through SEM images, indicates effective microbial activity throughout the matrix, enhancing overall structural integrity. X-ray diffraction (XRD) analysis confirmed the presence of calcite as the predominant crystalline phase in the SCC treated with Bacillus megaterium. The intensity of the calcite peaks was significantly higher in the microbial concrete compared to the control, indicating a substantial increase in the volume of precipitated $CaCO_3$. This crystallographic evidence supports the hypothesis that the formation of calcite bridges between cement particles enhances the bond strength within the matrix, thereby improving mechanical performance. The presence of C-S-H peaks explains why the strength of concrete changes over time. Following the compressive strength test, broken cube specimen fragments were gathered and ground into a powder using a pestle and mortar (22). XRD analysis was used to examine the fraction that passed through a sieve with a 5 mm aperture. The XRD pictures of bacterial SCC and conventional SCC after 28 days are seen in Figures 6 and 7 respectively.

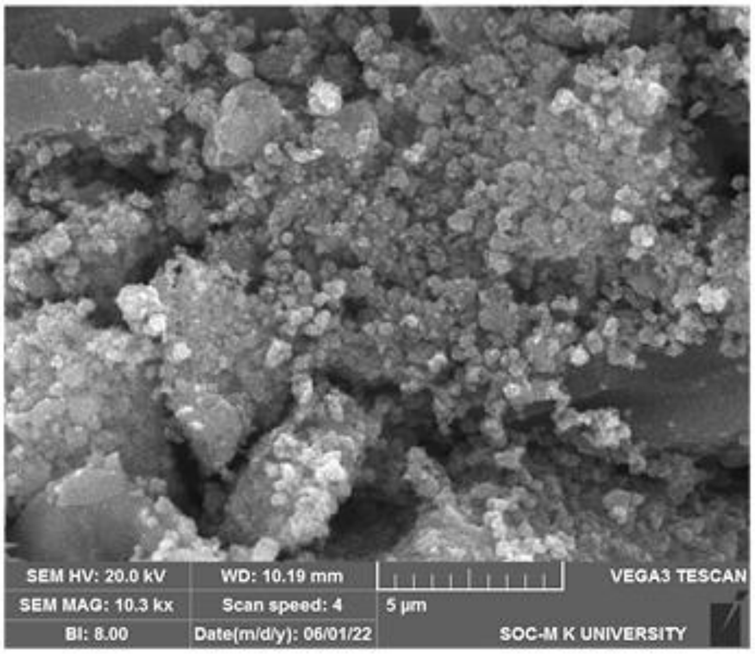

Figure 4: SEM Image of Conventional SCC

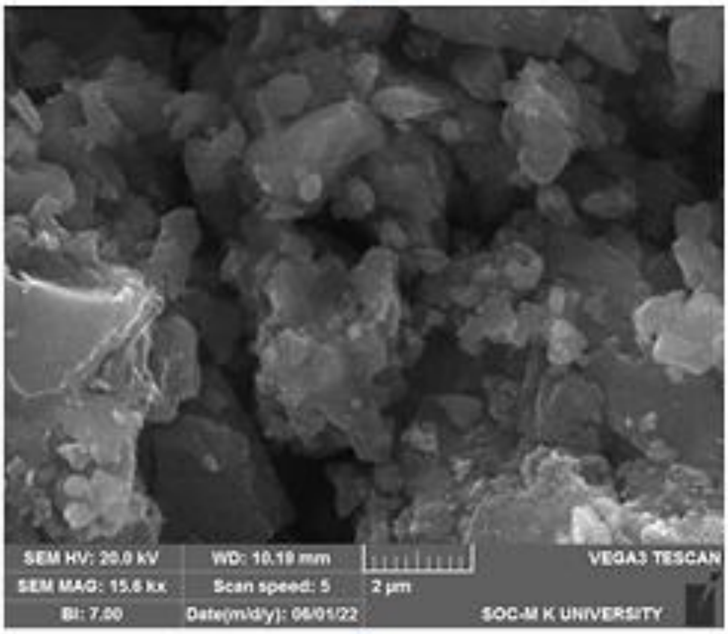

Figure 5: SEM Image of Bacterial SCC

The densification of the microstructure, as evidenced by SEM, correlates strongly with the observed improvements in compressive and tensile strength. The calcite deposits not only reduce porosity but also reinforce the matrix by filling micro cracks, thereby enhancing the material's resistance to crack propagation. Additionally, the XRD results suggest that the crystallographic alignment of calcite may contribute to load redistribution within the matrix, further improving mechanical resilience. Compared to traditional SCC, the microbial SCC exhibited a 20–30% increase in compressive strength and a marked improvement in durability indices. These findings underscore the efficacy of Bacillus megaterium as a bio-agent for enhancing both the mechanical and durability properties of SCC, providing a sustainable and innovative solution for modern construction challenges.

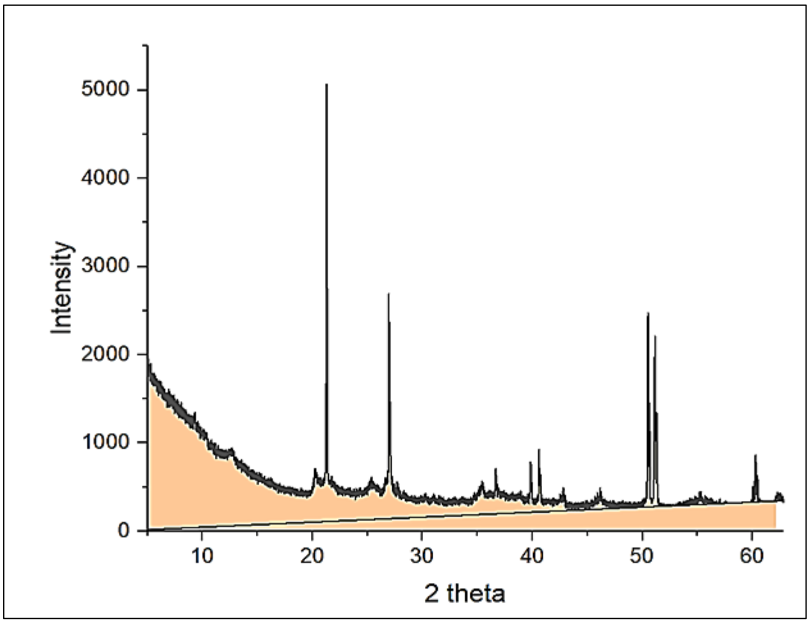

Figure 6: XRD peaks of Conventional SCC

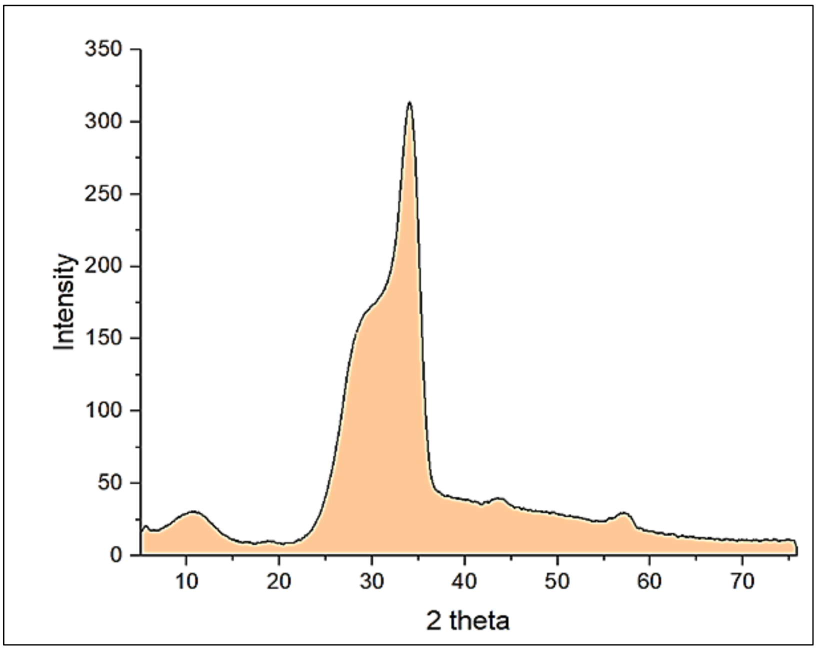

Figure 7: XRD peaks of Bacterial SCC

The findings of this study on self-compacting concrete (SCC) incorporating Bacillus megaterium have significant practical implications for the construction industry. By leveraging microbial-induced calcite precipitation (MICP), the study offers a sustainable, innovative approach to addressing some of the most pressing challenges in modern construction. By addressing both mechanical and environmental challenges, this study contributes to advancing the construction industry's transition toward more sustainable and resilient practices. The experiments were conducted under controlled laboratory settings, which may not fully replicate the complex and variable conditions of real-world construction sites. Factors such as temperature fluctuations, humidity variations, and environmental contaminants were not extensively studied. Although Bacillus megaterium is non-pathogenic, its large-scale application might raise concerns regarding environmental impact, microbial disposal, and cost-effectiveness compared to conventional materials. Acknowledging these limitations and exploring these future directions will not only validate and extend the applicability of microbial SCC but also contribute to the broader adoption of sustainable and innovative construction technologies.

Conclusion

Bacteria serve as micro-pore fillers, shrink the pores, and create small, discontinuous pore structures, all of which enhance the impermeability of concrete. The strength and longevity of the concrete were increased when it was found that the bacterial SCC specimens had less permeability at 28 and 90 days compared to the control SCC specimen. Studies on porosity and saturation water absorption show that bacterial SCC provides stronger durability characteristics. The cement pastes matrix's microstructure is enhanced by the microscopic, irregular pore structure produced by bacteria-induced MICP (Microbiologically Induced Calcite Precipitation). The degree of penetrability to chloride ions increases with the dosage of bacterial cell concentration. Therefore, research shows that the addition of bacteria to SCC mixes increases the material's durability and resistance to degradation, making it especially helpful in maritime environments. SEM analysis revealed that some calcite crystals were lodged in the concrete of the bacterial SCC specimens. The large concentration of calcium confirmed the existence of calcite, which is produced by bacteria and takes the form of $CaCO_3$. Calcite deposition improves impermeability by erecting a protective shield against dangerous substances.

Abbreviations

SEM: Scanning Electron Microscope, XRD: X – X-Ray Diffraction, SCC: Self Compacting Concrete, MPa: Mega Pascal, GGBS: Ground Granulated Blast Furnace Slag, SF: Silica Fume, MICP: Microbiologically Induced Calcite Precipitation, BM: Bacillus Megaterium.

Acknowledgment

The author would like to thank the KPR Institute of Engineering and Technology for providing help through the library sources.

Author Contributions

The authors contributed equally to this study's conceptualization, data analysis, and manuscript writing.

Conflict of Interest

The authors have no competing interests (financial or otherwise) to declare.

Ethics Approval

Not Applicable.

Funding

The authors confirm that they did not get any funding from any source while working on this paper.

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