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Effect of Sporosarcina Pasteurii on Rheological and Strength Properties of Bio-Self Compacting Concrete

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Abstract:- The study was conducted to evaluate the rheological and strength properties of bio-self compacting concrete. The materials used are cement, fine and coarse aggregates, bacteria (*Sporosarcina pasteurii*), and superplasticizer. Preliminary tests were conducted on the materials to ascertain its conformity to standard, and a full factorial design of experiment was adopted. The bacteria nutrient was varied at a ratio 1:3 of the bacteria content (i.e. 75% nutrient and 25% bacteria) at 10^5 cell/ml *Sporosarcina pasteurii* which was added to the fresh concrete at 5-25ml dosage by weight of water at 5ml increment, while the superplasticizer was added into the fresh concrete at 0.2-1.0% at 0.2 % increment by weight of cement which translated to 234 concrete samples. The rheological tests conducted were slump, V-funnel, L-box, and J-ring test, while the concrete strength tests conducted were compressive, flexural, and split tensile strength. Results from the experiment showed that workability of most of the bio-self compacting concrete is very high compared to the control concrete, and are within the range specified by codes, and the 28 days compressive strength of concrete produced by adding 20 – 25 % bacteria and 0.4-0.8% superplasticizer had 28 days compressive strength equal or greater than the control concrete. Also, the 28 days flexural strength of control concrete is significantly higher than flexural strength of all the bio self-compacting concrete, while the split tensile strength of bio self-compacting concrete produced by adding 25% bacteria and 0.4 – 0.8% superplasticizer is higher than the control concrete.

Keywords:- *Bacteria Concrete; Compressive Strength; Flexural Strength; Rheology; Split Tensile Strength.*

I. INTRODUCTION

➢ *Background of Study*

Due to its workability, self-compacting concrete (SCC) is considered a technological breakthrough in the construction industry. Even in the presence of congested reinforcement, SCC can flow under its own weight and completely fill the formwork without vibrating [1]. Similar to conventional vibrated concrete, SCC is composed of cement, aggregates, water, and chemical and mineral admixtures. The reduction of coarse aggregate content and the increase in powder quantities give SCC its passing ability and segregation resistance. The high fluidity of the concrete mix is attributed to the superplasticisers (high range water reducers), whereas the powder and viscosity modifying agents improve stability and cohesiveness by decreasing bleeding and segregation of the mixture [1].

In the current study, the self-compaction of concrete was accomplished through the application of superplasticizers, which are High Range Water Reducers (HRWR), a novel class of enhanced plasticizers. They allow for a 30% water reduction without compromising workability, in contrast to other plasticizers that can only reduce water by 15% [2]. Super-plasticizers are used to make concrete more fluid without adding too much water. By using steric and/or electrostatic forces to oppose the cement particles' attractive forces, these molecules physically separate the particles [3]. The concrete is therefore simpler to place. Without changing the water-to-cement (w/c) ratio, which determines the strength and durability of concrete, they can be used to improve workability [3]. "Superplasticizers are classified into four (4) groups which are the Sulphonated Melanine-formaldehyde condensates (SMF), Sulphonated Naphthaleneformaldehyde condensates (SNF), Modified Lignosulphonates (MLS) and others which include the new generation of superplasticizers such as Acrylic polymer based (AP), Copolymer of carboxylic acrylic acid with acrylic ester (CAE), Crossed linked acrylic polymer (CLAP), Polycarboxylate ester (PCE), Multicarboxylatethers (MCE) and any combination of the above [3]. For the purpose of this study, Polycarboxylate ester (PCE) Superplasticizer is been adopted due to its many advantages over lignosulfonate based, melamine based and naphthalene-based superplasticizers, such as dispersing cement particles, and retaining concrete slump without prolonging its setting times at low dosages [4]. Thus, it is being more and more widely used in high performance concrete [5, 6].

On the other hand, over time, the use of superplasticizers in self-compacting concrete may cause the hardened concrete to shrink and crack [7], which decreases concrete's durability because superplasticizers have a high capacity to dissolve water, which leads to excessive bleeding and aggregate segregation, uneven material distribution, and eventually, cracked hardened concrete. One strategy to reduce the shrinkage and cracking problems with self-compacting concrete is to use an internal curing agent made of various materials [7], such as bacteria's which have self-healing capabilities of concrete.

Over the last decade, the application of bacteria in the construction industry has become a topic of research worldwide, with a focus on Microbial Induced Calcite Precipitation (MICP), which has been researched and used in the field of civil engineering for surface protection of natural stone, soil improvement, crack remediation, and strength and durability improvement, the use of bacteria in the construction industry has gained international attention over the past ten years. Calcite precipitating bacteria are used in concrete technology (MICP) to repair micro and even macrocracks in the material while also enhancing other concrete properties. MICP has been used successfully by researchers in enhancing concrete properties such as compressive strength [8], concrete durability [9] remediation of cracks [10], water absorption [11], surface consolidation [12], and Rebar corrosion inhibition [13] amongst other applications. This widespread success recorded in the use of MICP in concrete has opened up a new possibility for its use in SCC.

Sporosarcina pasteurii (S. pasteurii), hitherto referred to as *Bacillus Pasteurii* in older classifications, is an aerobic, mesophilic, rod-shaped (0.5–1.2 µm in width and 1.3–4.0 µm in length), gram-positive bacterium that is the most dominant microorganism used in MICP [14]. Endospores are non-reproductive structures produced by bacteria, and *S. pasteurii* has the ability to form them. Alternatively, the bacterium can reduce itself to a dormant state. Oftentimes, malnutrition is the primary driver of endospore development. Until the environment improves and the endospore can revive itself, endospores allow the bacterium to remain dormant for extended periods of time in the absence of nutrition, surviving ultraviolet (UV) radiation, desiccation, high temperatures, freezing temperatures, and chemical disinfectants [14]. This feature increases *S. pasteurii's* resistance to environmental stressors and allows it to have its metabolic system enabled or disabled in accordance with engineering specifications. This bacterium thrives in an alkaline pH range of 9 to 10, as it is an alkaliphile [15]; however, it can survive in moderately harsh circumstances up to a pH of 11.2 [16], making it also a suitable admixture component for building construction applications".

Research has indicated that the most commonly used species for bacteria-based crack healing is the genus "Bacillus [17-19]. This genus is characterized by spore-forming bacteria that have compact, round shapes, thick cell walls, and are usually between 0.8 and 1 µm in size [17], could survive about 50 years [20, 21], for hundreds of years [22], possesses the capacity to tolerate extreme environmental factors such as chemicals, high mechanical stresses, and UV radiation. According to other research, bacillus species spores can hibernate for up to 200 years in hostile environments [23]. These dormant bacterial spores readily absorb moisture from the air and cause the cell to germinate, grow, and form calcite, sealing the cracks in situ. When cracks occur, the capsules rupture and release the healing agents [20, 21, 24, 25]. The capsules burst and release the healing agents when cracks appear. These dormant bacterial spores readily absorb moisture from the atmosphere, which causes the cell to proliferate, grow, and form calcite, sealing the cracks in place [26, 27]. Next, the bacteria that are present prepare themselves to survive in the alkaline environment.

Rheology plays a crucial role in the performance of self-compacting concrete (SCC) [28-30]. The study of material flow and deformation is known as rheology [31, 32], and in the case of SCC, it determines its workability and flowability [32]. Rheological characteristics of SCC play a major role in determining its unique properties, which include its capacity to fill complex forms and flow without the need for external compaction [32]. Moreover, concrete's resistance to shrinkage, cracking, and segregation can be increased by good SCC rheological qualities, which will ultimately result in a longer service life and better structural performance [33-35].

Concrete is prone to cracking, which shortens its lifespan and necessitates costly repairs. For a variety of reasons, including formwork movement, plastic settlement, weathering, drying shrinkage, and thermal stress, among others, cracks can appear in both the plastic and hardened stages. Although it is not possible to stop cracks from happening, there are a number of methods for fixing them. But some of these techniques, like using chemicals and polymers, have been shown to be hazardous to the environment and human health, and they only offer short-term fixes. As an alternative, microbial self-healing concrete has proven to be a viable strategy because of its good bonding power and compatibility with concrete. Concrete that can mend structural flaws by filling it with bacteria that trigger a biological reaction that seals the crack is known as self-healing concrete or bacterial concrete [36].

Additionally, a number of factors, including the type and concentration of bacteria as well as the application technique, influence the strength properties of concrete [24], and number of days of incubation [19]. A study done by Iheanyichukwu, et al. [37] stated that by using 10^5 cell/ml concentrations of bacterial species *Sporosarcina pasteurii* species show better compressive strength of concrete followed by *Bacillus aerius*. Kumarappan and Sudharsanp [18], concluded that the compressive strength of bio-brick is about 10 Mpa, which is 19% higher than conventional brick and 3 times lighter in weight than conventional brick after 28 curing days of experiment. However, authors like Stanaszek-Tomal [38] stated that adding more bacteria to concrete lowers its quality because there is more nutritional competition between the bacteria as their density rises, which results in a 10% decrease in compressive strength when compared to regular concrete [22]. Stanaszek-Tomal [38] concluded that 10^5 cell/ml bacteria concentration with 28 curing days shows better compressive strength. A similar study done by Magil, et al. [25] also showed that 10^5 cell/ml concentration of bacteria for 7, 14, and 28 curing days results in 14.89, 16.42, and 19.26 Mpa compressive strength respectively, which is higher than conventional concrete, having a compressive strength of 10.03, 11.38, and 12.49 Mpa. Therefore, from the aforementioned, the rheological and strength properties of bio-self compacting concrete was determined using *Sporosarcina pasteurii"* at 10^5 cells/ml and various dosages of PCE superplasticizer.

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II. MATERIALS AND METHODS

A. Materials

➢ *Cement*

Cement used in this study was obtained from a dealer in Zaria-Kaduna State, Nigeria and used for the experiment.

➢ *Water*

Water obtained from Civil Engineering Laboratory of ABU (Ahmadu Bello University) Zaria was used to prepare the concrete.

➢ *Fine Aggregate*

The fine aggregate used was also obtained from an open market in Zaria, Kaduna State, Nigeria. It was sieved sieve to remove silts are coarse aggregates before been used.

➢ *Coarse Aggregates*

Coarse aggregate was also sourced from a local dealer within the research area (Zaria, Kaduna State).

➢ *Bacteria*

Calcite precipitating bacteria Bacillus Pasteurii was obtained and cultured at the department of Bio-chemistry, Ahmadu Bello University, Zaria, while meat extract was used as the nutrient.

➢ *Super Plasticizer*

Hydroplast – 300 High Performance Water Reducing (PCE) Super-plasticizer was used in this study. The superpasticizer was in liquid form and it meets the requirement of ASTM-C494 [39] type F standard specification for chemical admixtures for concrete.

B. Methods

➢ *Preliminary Tests on Cement*

- *Consistency of Cement*

This test was done in line with BS-EN-196-3 [40], at the laboratory of Ahmadu Bello University Zaria.

- *Setting Time of Cement*

The test was done in accordance with BS-EN-196-3 [40].

- *Soundness of Cement*

The test was carried out in line with BS-EN-196-3 [40].

- *Specific Gravity of Cement*

This test was done in accordance with BS-EN-196-3 [40].

➢ *Preliminary Tests on Aggregate*

- *Sieve Analysis of Fine and Coarse Aggregates*

Fine and coarse aggregate sieve analysis was carried out using relevant sieve sizes in accordance with BS-882:2 [41].

- *Water Absorption Tests of Aggregates*

Water absorption test was done in line with BS-812:2 [42].

- *Specific Gravity of Aggregates*

Coarse and fine aggregates tests for specific gravity was done in line with BS-812:2 [42].

- *Bulk Density of Aggregate*

Coarse and fine aggregates bulk density teas was done in line with BS-812:2 [42].

- *Aggregate Impact Value Test*

Aggregate impact value test was done in line with BS-812-110 [43].

- *Aggregate Crushing Value*

The test was done in line with BS-812-110 [43].

C. Methods

➢ *Design of Experiment (DoE)*

Design Expert v13 was used to design the experiment of bio self-compacting concrete by adopting the full factorial, which includes every factor in the DoE. There are three factors in the DoE (i.e. bacteria content, plasticizer content and curing days). However, the bacteria content have five levels (5, 10, 15, 20, and 25 ml), the plasticizer content also have five levels (0.2, 0.4, 0.6, 0.8, and 1.0 %), and the concrete was cured for three days (7, 14, and 28). Hence, this translates to 75 runs (i.e. 5 x 5 x 3 = 75). Also, each of the experiments were cast in triplicates, which makes the overall DOE 225 concrete samples plus 9 control sample, making it a total of 234 samples cast, as shown in Table 1.

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Table 1: Bio Self-Compacting Concrete DOE

	Factors				**Response**						
Experiment	**Bacteria (ml)**	**Plasticizer (%)**	**Days**	**N**	**Compressive strength**	**Flexural strength**	**Tensile strength**	**Slump**	**V-funnel**	**L-box**	**J-ring**
Control	0	0	7-28	9	-	-	-	-	-	-	
B5:P0.2	5	0.2	7-28	9	-	-	-	-	-	-	
B5:P0.4	5	0.4	7-28	9	-	-	-	-	-	-	
B5:P0.6	5	0.6	7-28	9	-	-	-	-	-	-	
B5:P0.8	5	0.8	7-28	9	-	-	-	-	-	-	
B5:P1.0	5	1.0	7-28	9	-	-	-	-	-	-	
B10:P0.2	10	0.2	7-28	9	-	-	-	-	-	-	
B10:P0.4	10	0.4	7-28	9	-	-	-	-	-	-	
B10:P0.6	10	0.6	7-28	9	-	-	-	-	-	-	
B10:P0.8	10	0.8	7-28	9	-	-	-	-	-	-	
B10:P1.0	10	1.0	7-28	9	-	-	-	-	-	-	
B15:P0.2	15	0.2	7-28	9	-	-	-	-	-	-	
B15:P0.4	15	0.4	7-28	9	-	-	-	-	-	-	
B15:P0.6	15	0.6	7-28	9	-	-	-	-	-	-	
B15:P0.8	15	0.8	7-28	9	-	-	-	-	-	-	
B15:P1.0	15	1.0	7-28	9	-	-	-	-	-	-	
B20:P0.2	20	0.2	7-28	9	-	-	-	-	-	-	
B20:P0.4	20	0.4	7-28	9	-	-	-	-	-	-	
B20:P0.6	20	0.6	7-28	9	-	-	-	-	-	-	
B20:P0.8	20	0.8	7-28	9	-	-	-	-	-	-	
B20:P1.0	20	1.0	7-28	9	-	-	-	-	-	-	
B25:P0.2	25	0.2	7-28	9	-	-	-	-	-	-	
B25:P0.4	25	0.4	7-28	9	-	-	-	-	-	-	
B25:P0.6	25	0.6	7-28	9	-	-	-	-	-	-	
B25:P0.8	25	0.8	7-28	9	-	-	-	-	-	-	
B25:P1.0	25	1.0	7-28	9	-	-	-	-	-	-	
Total				**234**							

B = Bacteria (ml); and P = Superplasticizer (%)

➢ *Sample Preparation*

The Bio self-compacting concrete was prepared such that the Bacillus pasturei (10^5 cell/ml) was introduced to the fresh concrete at 5-25 ml dosage by weight of water (5 ml increment), and the Superplasticizer was introduced into the fresh concrete at 0.2-1.0 % (0.2 % increment) by weight of cement. However, the bacteria nutrient was varied at a ratio 1:3 of the bacteria content (i.e. at 5 ml bacteria, nutrient was 75% and bacteria was 25 %).

D. Tests on Fresh Concrete

➢ *Slump Test*

Slump test was done in line with BS-EN-12350;2 [44].

➢ *V-Funnel Test*

The V-funnel test was done in line with BS-EN-12350;2 [44] and EFNARC [45].

➢ *L-Box Test*

This test determines the flow-rate, filling ability, passing ability and blocking ability of SCC between steel bars in congested steel arrangements and was done in accordance with BS-EN-12350;2 [44].

➢ *J-Ring Test*

The test determines the passing ability of SCC. For blockage prevention, the height difference should not exceed 10 mm [45]. This is in line with BS-EN-12350;2 [44].

E. Tests on Hardened Concrete

➢ *Compressive Strength Test*

The hardened concrete was determined after 7, 14, 28, and 56 days curing days using the compressive testing machine line with BS-EN-12390-3 [47].

➢ *Flexural Strength Test*

A three point bending flexural strength test was done in line with ASTM-C78 (2009).

➢ *Split Tensile Test*

The test was conducted in line with ASTM-C496 [49] standard test method.

III. RESULTS

A. Preliminary Test Result of Materials

Tests were conducted on the materials used to determine its conformity to standard codes, as presented in Table 2.0.

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Table 2: Preliminary Tests Result of Cement and Aggregates

Description of Test	Results	Standard	Code
Cement			
Consistency (%)	31.0	26-33%	BS-EN-196-3 [40]
Initial setting time (mins)	142	≥45	BS-EN-196-3 [40]
Final setting time (mins)	201	≤ 600	BS-EN-196-3 [40]
Soundness (mm)	1.0	≤ 10mm	BS-EN-196-3 [40]
Specific gravity	3.15	3.1 – 3.16	BS-EN-196-3 [40]
Fine Aggregates			
Specific Gravity	2.50	2.5 – 2.8	BS-812:2 [42]
Bulk density	1360	<1520	BS-812:2 [42]
Coarse Aggregate			
Specific gravity	2.60	2.5 – 2.8	BS-812:2 [42]
Bulk density	1455	<1520	BS-812:2 [42]
Aggregate Crushing Value	27.11	25 – 30%	BS-812-110 [43]
Aggregate Impact Value	28.28	25 – 30%	BS-812-110 [43]

The results showed that the cement used is adequate for concrete production since the consistency (31%), initial setting time (142 minutes), final setting time (201 minutes), soundness (1mm), and specific gravity (3.15) all satisfied standard code requirements. Also, the fine aggregate is adequate for concrete production as the specific gravity (2.50), and bulk density (1360kg/m^3) are within the requirement of BS-812:2 [42]. Finally, the coarse aggregate used have a specific gravity, bulk density, aggregate crushing value, and aggregate impact values of 2.60, 1455kg/m^3, 27.11%, and 28.28% which all satisfied the requirement of BS-812:2 [42], and BS-812-110 [43], confirming its adequacy for concrete production.

➤ *Gradation of Fine Aggregate*

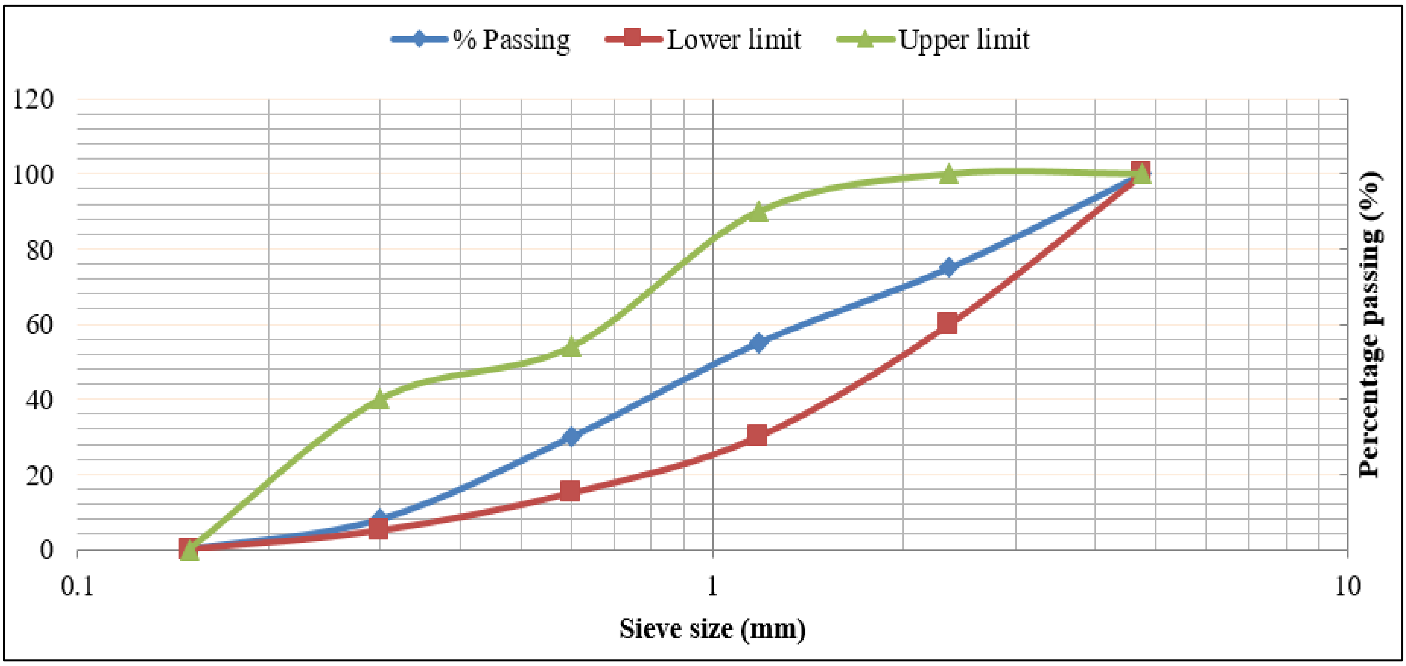

Fig 1: Particle Size Analysis for Fine Aggregate

Figure 1 showed that the aggregate (fine) falls within Zone II classification of fine aggregates to be used in concrete production as specified by ASTM-C33 [50]. Zone II fine aggregate is suitable for concrete production [51-53], hence, the aggregate (fine) is good for use in producing concrete.

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➢ *Gradation of Coarse Aggregate*

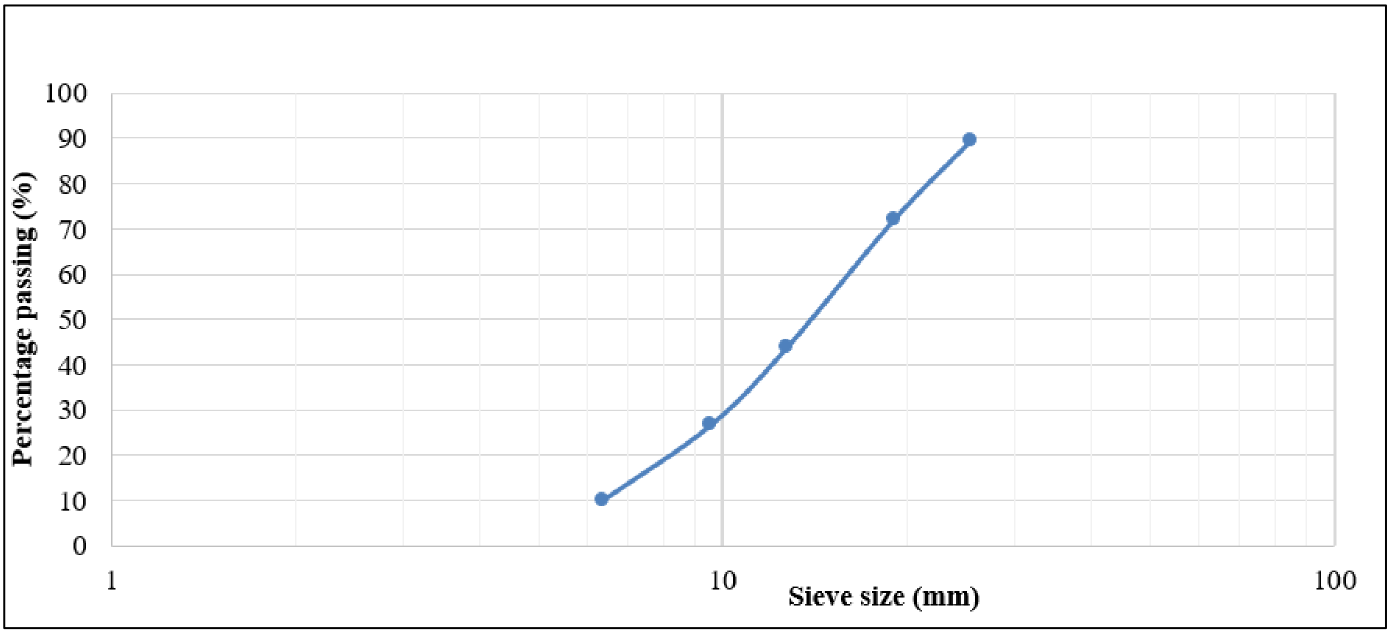

Fig 2: Particle Size Distribution Curve of Coarse Aggregate

Figure 2 showed that the aggregate (coarse) used was uniformly graded and has a maximum size of 25.4mm. Hence, the coarse aggregate used in this study is adequate for concrete production.

B. Workability of Bio-self Compacting Concrete

➢ *Slump Test*

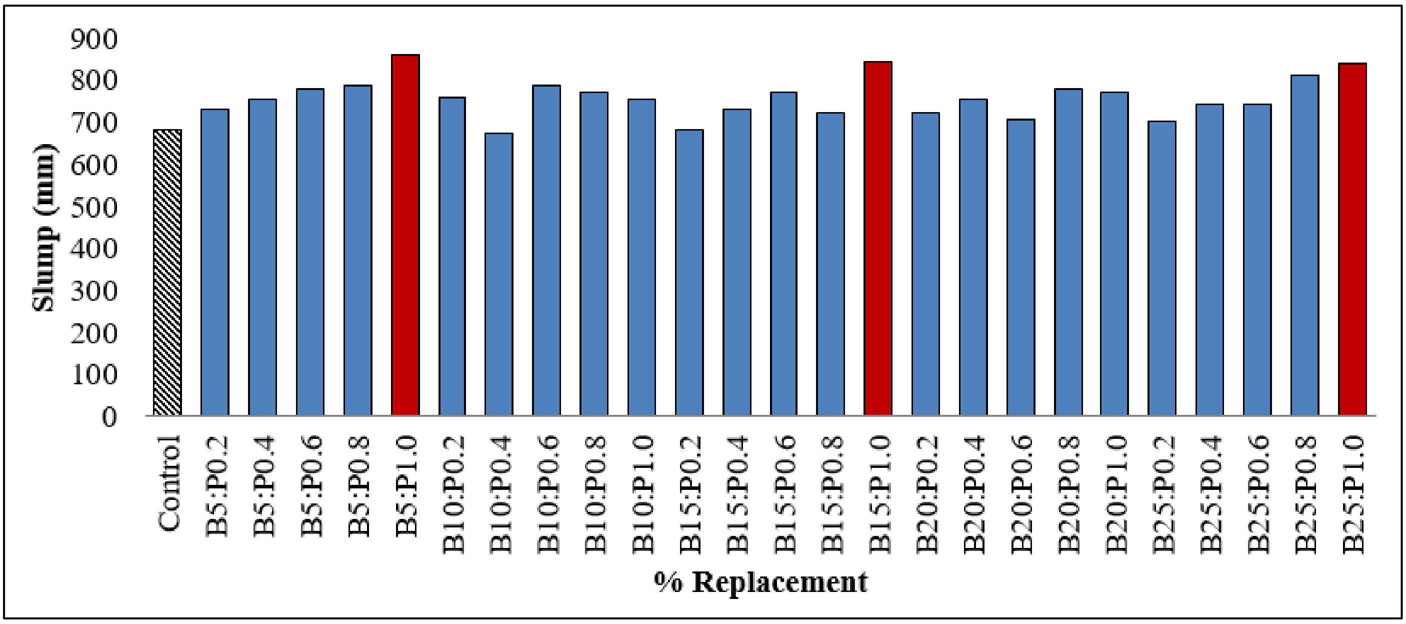

Fig 3: Slump of Bio Self-Compacting Concrete

The result from Figure 3 showed that the self-compacting concrete had higher slumps than the control concrete, and the slump values of the control concrete and some bio self-compacting concrete ranges from 650 – 800 mm which satisfies the requirements of BS-EN-12350;2 [44] and EFNARC [54]. However, fresh concretes produced with B5:1.0, B15: 1.0, B25:0.8, and B25:1.0 had slump values higher than 800 mm as specified by EFNARC [54], which can be attributed to the superplasticizer in the mix, and is an indication that such mixes, although highly workable, can result in the segregation and bleeding of the concrete mixture, leading to a decrease in the overall strength and durability performance of the concrete.

➢ *V-Funnel Test*

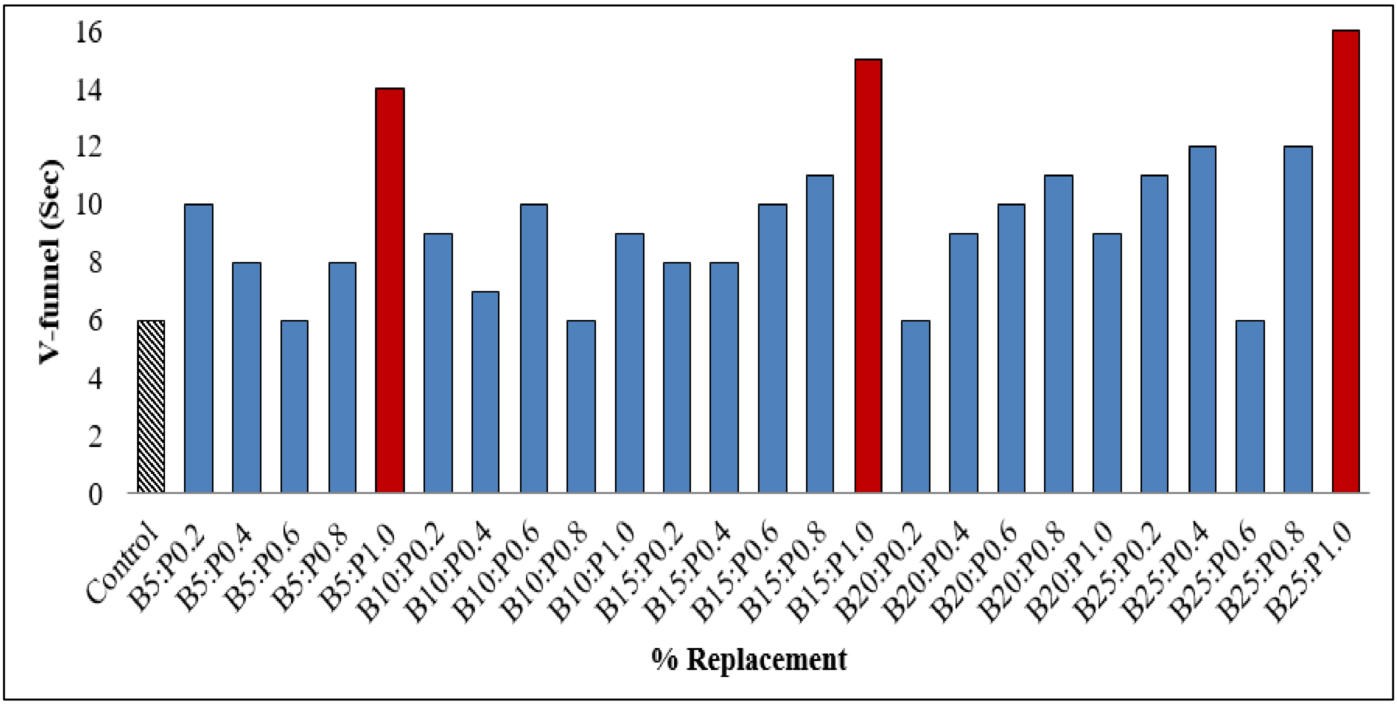

Fig 4: V-Funnel of Bio Self-Compacting Concrete

The V-funnel result from Figure 4 showed that with the exception of B5:1.0, B15: 1.0, and B25:1.0 mix, all the bio-self compacting concrete including the control have values within 6 – 12 seconds as specified by EFNARC [54]. This implies that majority of the bio-self compacting concrete have good flowability and resistance to segregation [54]

➢ *L-Box Test*

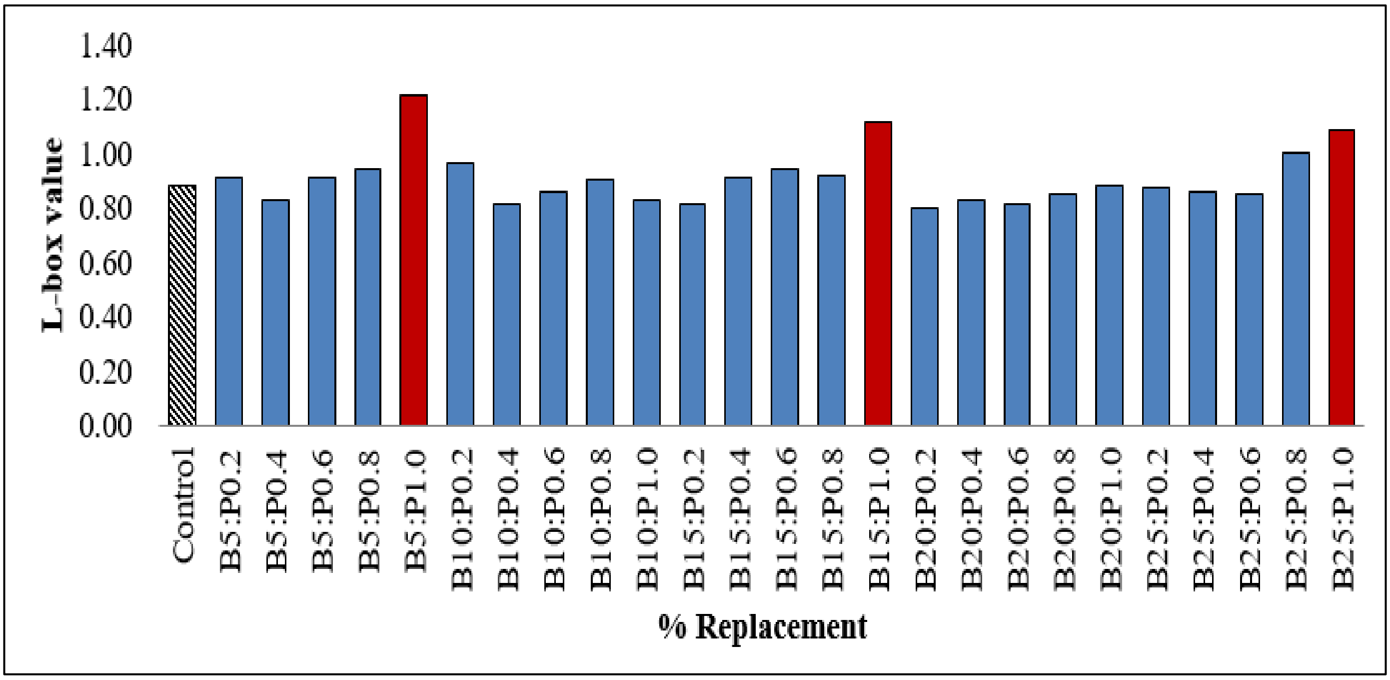

Fig 5: L-box of Bio Self-Compacting Concrete

The result of the L-box test from Figure 5 also showed that all the bio-self compacting concrete including the control concrete have values within 0.8 – 1.0 (h_2/h_1) as specified by EFNARC [54], with the exception of B5:1.0, B15: 1.0, and B25:1.0 concrete mix. This implies that majority of the bio-self compacting concrete exhibits good filling ability, passing ability and blocking ability of SCC between steel bars in congested steel arrangements.

➢ *J-Ring Test*

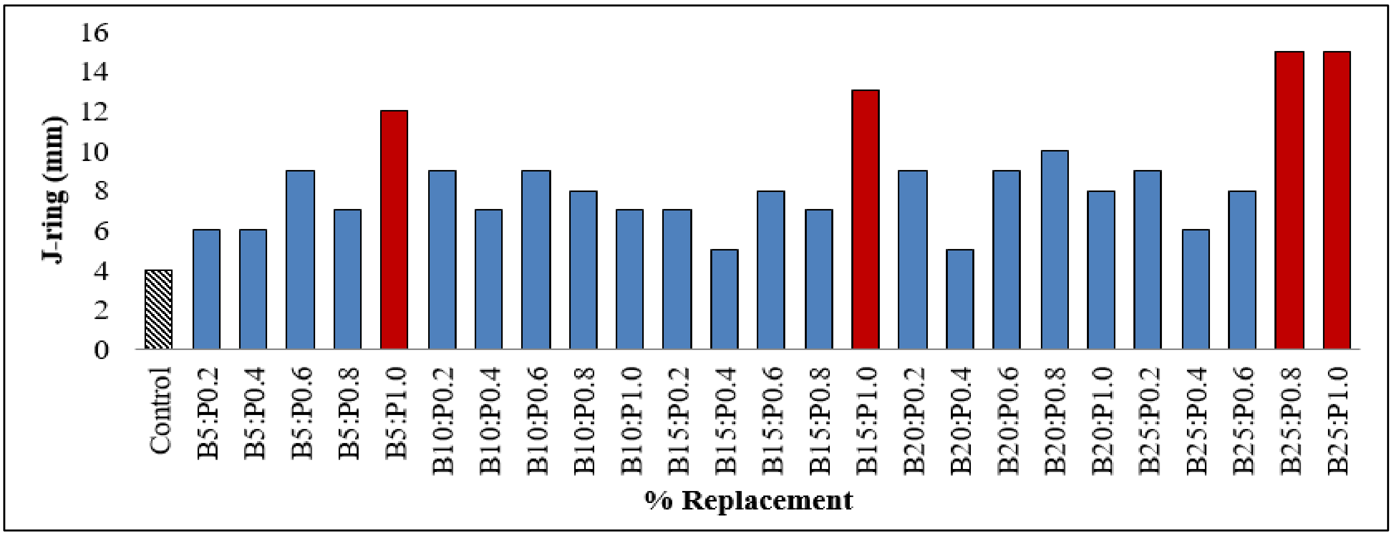

Fig 6: J-Ring of Bio Self-Compacting Concrete

The result of the J-ring test in Figure 6 also showed that all the bio-self compacting concrete including the control concrete have values within 0 – 10 mm as specified by EFNARC [54] and BS-EN-12350;2 [44], with the exception of B5:1.0, B15: 1.0, B25:0.8, and B25:1.0 concrete mix, which can be attributed to the high superplasticizer dosage of 1.0 % in each of the mixes.

C. Compressive Strength of Bio Self-Compacting Concrete

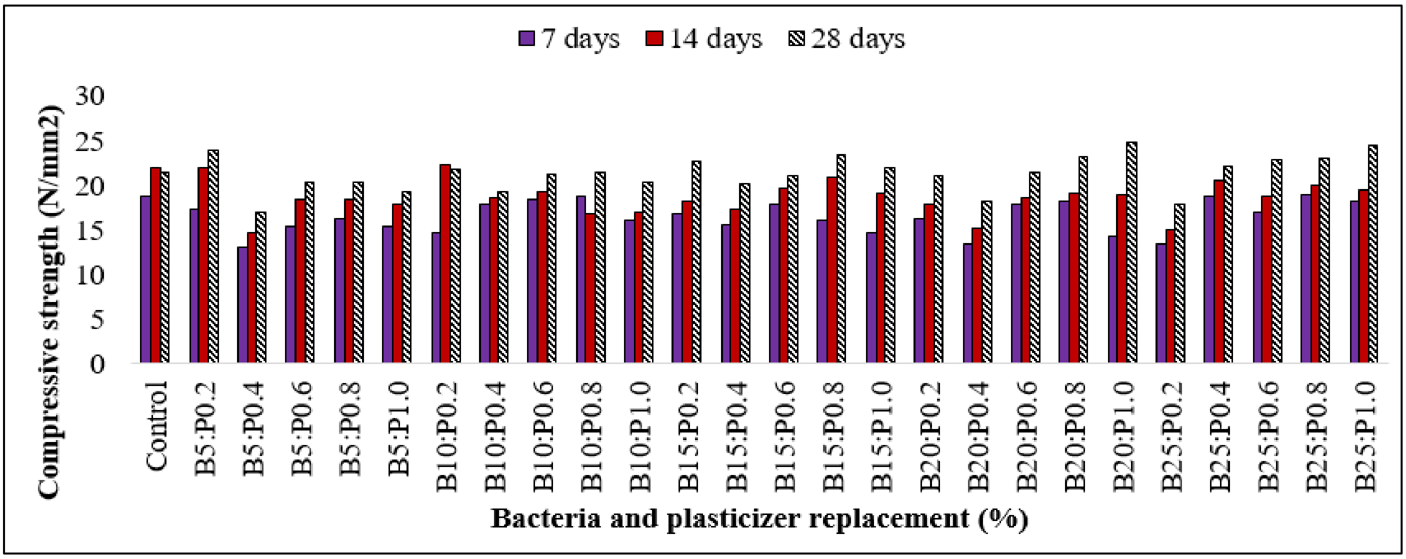

Fig 7: Compressive Strength at 7, 14, and 28 Days

The result from Figure 7 shows that the compressive strength trend of concrete produced by incorporating bacteria and superplasticizer at various percentages follows an irregular pattern. However, the twenty-eight days' compressive strength of concrete showed that the design concrete (control) has a compressive strength of 21.48N/mm^2, which is lower than most of the experimental concrete (bio self-compacting concrete). The outcome from these findings showed that majority of the maximum compressive strength of the experimental concrete occurred when concrete is produced with 20% bacteria and 0.6 – 0.8% superplasticizer; and 25% bacteria with 0.4 – 0.8% superplasticizer.

This high 28 days bio self-compacting concrete can be attributed to the bacteria feasting on the nutrient within the mix thereby releasing calcium carbonate as a byproduct which forms solid minerals that bind together the particles in the mixture, effectively enhancing its overall strength over time. In addition, this natural process continues even after the concrete has been poured, allowing it to self-heal cracks that may occur over time. The outcome of the findings from this study is in accordance with that of [55-57].

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D. Flexural Strength of Bio Self-Compacting Concrete

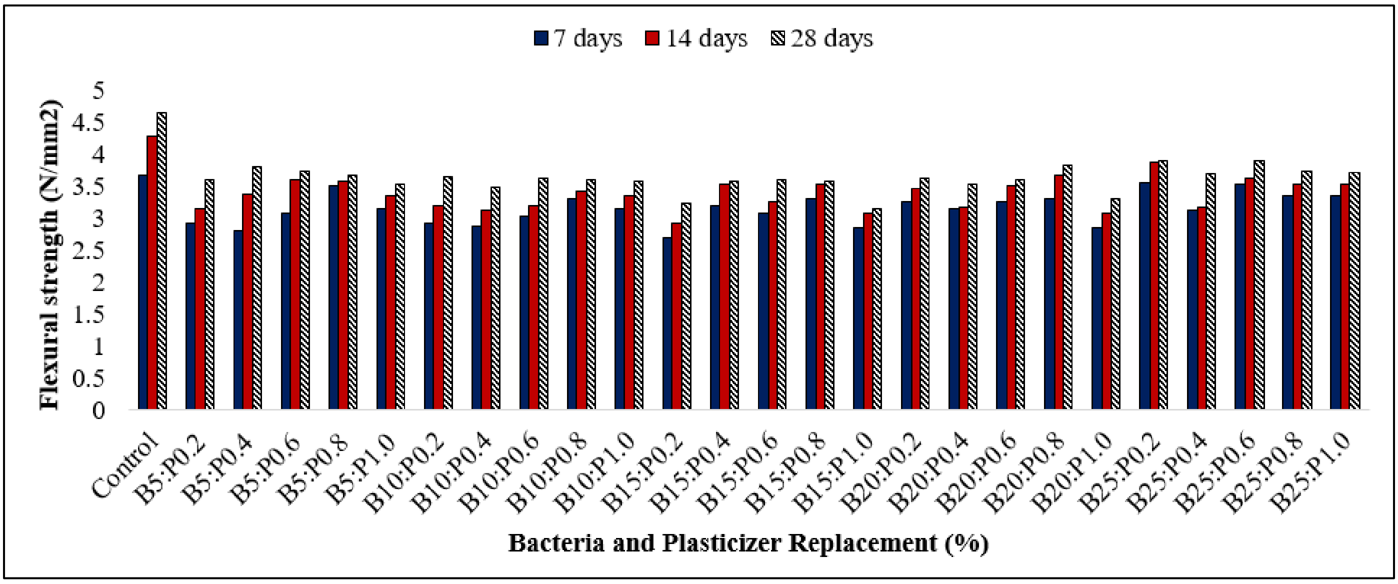

Fig 8: Flexural Strength of Concrete at 7, 14, and 28 Days

The result from Figure 8 shows that the flexural strength trend of concrete produced by incorporating bacteria and superplasticizer at various percentages also follows an irregular pattern. However, the design concrete (control) has a compressive strength of 3.68N/mm^2, 4.28N/mm^2, and 4.65N/mm^2, at 7, 14, and 28 days respectively, which are all higher than the flexural strength of the experimental concrete (bacteria and plasticizer concrete). The outcome of the findings from this study showed that although, bio-self compacting concrete may exhibit good compressive strength, it tends to have low flexural strength due to likely occurrence of crack or fail under tension or bending forces rather which is attributed to the size and distribution of crystal formations within the bacteria mix that tends to be irregularly shaped and discontinuous throughout the material, leading to weaker points along the concrete's surface that cannot withstand significant bending forces.

E. Split Tensile Strength of Bio Self-Compacting Concrete

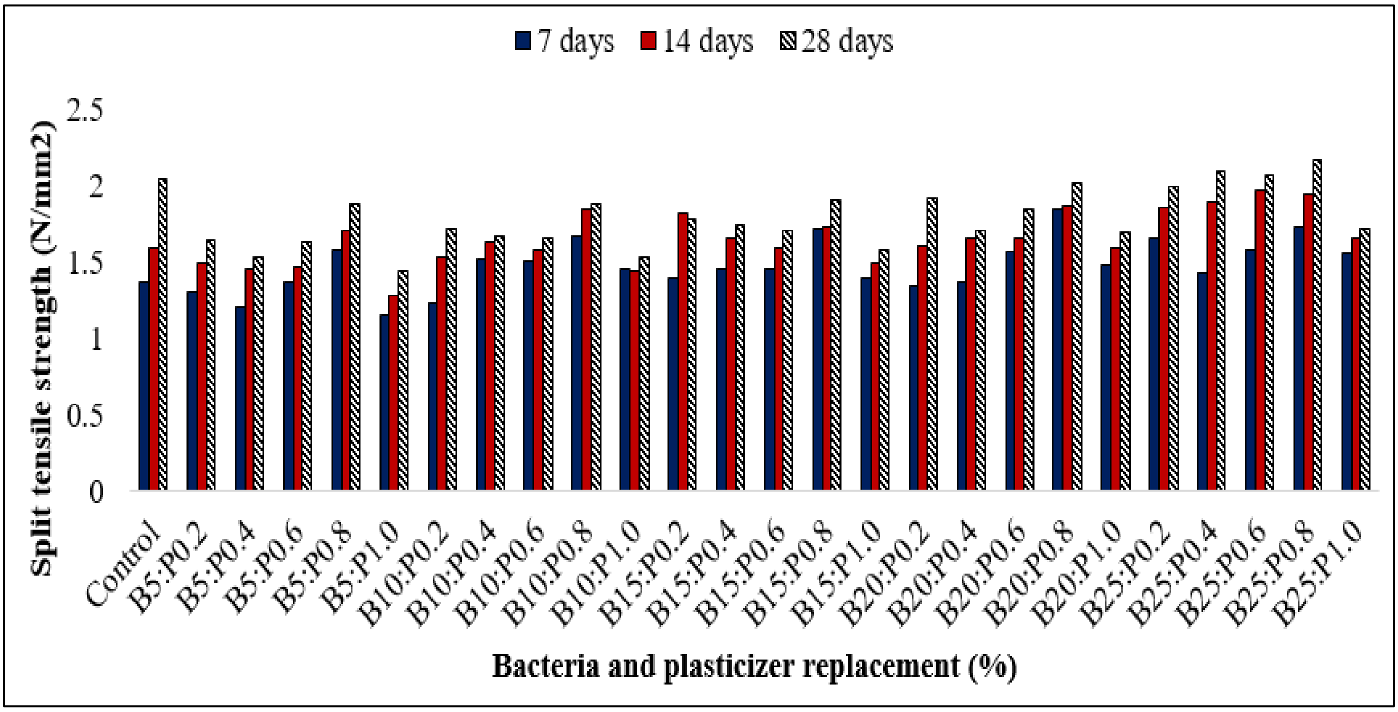

Fig 9: Split Tensile Strength of Concrete at 7, 14, and 28 Days

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The result from Figure 9 shows that the trend in split tensile strength of concrete produced by incorporating bacteria and superplasticizer at various percentages follows an irregular pattern. However, the design concrete (control) has a split tensile strength of 1.37N/mm^2, 1.59N/mm^2, and 1.64N/mm^2, at 7, 14, and 28 days respectively which is higher than the split tensile strength of some of the experimental concrete (bacteria and plasticizer concrete). Also, from Figure 4, the 28 days' compressive strength of concrete produced by incorporating bacteria and superplasticizer at various percentages also followed an irregular pattern. However, the design concrete (control) has a split tensile strength of 2.04N/mm^2, and the optimum experimental concrete (bacteria and plasticizer concrete) with 28 days' split tensile strength equal or greater than the design concrete (control) are concrete produced by adding 25% bacteria and 0.4% superplasticizer (2.09N/mm^2), 25% bacteria and 0.6% superplasticizer (2.07N/mm^2), and 25% bacteria and 0.8% plasticizer (2.17N/mm^2).

The low split tensile strength of the bio-self compacting concrete can be attributed to uneven distribution of the bacteria throughout the concrete mixture, resulting in lack of necessary bonding strength required for resisting splitting forces. It can also be attributed to the superplasticizer in the mix which tends to increases the water content in the concrete, and in turn weakens its overall structure. As a result, the concrete becomes more prone to cracking under tension or bending forces, hence leading to low split tensile strength.

IV. CONCLUSION

At the end of the study, it was concluded that the workability (slump, V-funnel, L-box, and J-ring) of all the bio-self compacting concrete is very high compared to the control concrete, and is within the range specified by codes, with exception of B5:1.0, B15: 1.0, B25:0.8, and B25:1.0 mixes which was slightly above the code requirement. Also, the bio self-compacting concrete produced by adding 20% bacteria and 0.6-0.8% superplasticizer; and 25% bacteria with 0.4-0.8% superplasticizer had 28 days compressive strength equal or greater than the control concrete which has a compressive strength of 21.48N/mm^2, while the 28 days flexural strength of control concrete is significantly higher than flexural strength of all the bio self-compacting concrete, and the split tensile strength of bio self-compacting concrete produced by adding 25% bacteria and 0.4% superplasticizer, 25% bacteria and 0.6% superplasticizer, and 25% bacteria and 0.8% plasticizer is higher than the control concrete.

V. CONFLICTS OF INTEREST STATEMENT

With respect to the subject matter or materials discussed in this manuscript, the authors whose names and initials are listed thereof, certify that they have no affiliation(s) with or involvement in any entity that has any financial interest (such as honoraria, educational grants, speaker's bureau participation, membership, employment, consultancies, stock ownership, or other equity interest, and expert testimony or patent-licensing arrangements) or non-financial interest (such as personal or professional relationships, affiliations, knowledge, or beliefs) with regards to this study.

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