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Determination of the Strength Characteristics of *Sporosarcinal - Pasteurii* Concrete

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ABSTRACT

The strength characteristics of Sporosarcinal Pasteurii concrete (S. Pasteurii concrete) was investigated. To achieve this aim, the suitability of the materials used for concrete specimens were tested before the compressive, tensile and flexural strength of the S. Pasteurii concrete was investigated. Bacteria concentration of 0, 0.5, 2, 4 and 6OD was mix with the concrete. The water cement ratio adapted was 0.5. For the compressive strength, three cubes of size 150 x 150 x150mm was crushed for each curing day of 1, 3, 7,14, 28 and 56 days. The average compressive strength was obtained as the compressive strength of the concrete at each curing age. For the split tensile strength, three cylindrical specimen of size 100mm x 200mm was used at each day to obtain the strength at 7, 14, 21 and 28 days. The average tensile strength was obtained and for the flexural strength, three beam samples of 100 x 100 x 450mm was used at each curing day of 7, 14, 21 and 28days to obtain the average flexural strength. All the properties of the materials used for the concrete production met the standard requirement of the relevant code of practice. The compressive, tensile and flexural strength of S. Pasteurii concrete was improved in comparison with the control concrete. The percentage increase of the compressive strength at 28days are 17.76%, 19.72%, 25% and 4.04% for 0.5OD, 2OD, 4OD and 6OD respectively. The highest tensile strength was increased by 16.24% and obtained when 0.5OD bacteria concentration was used and cured for 14days. The flexural strength of S. Pasteurii concrete was improved by 44.44%, 8.89%,47.40% and 8.52% for 0.5OD, 2OD,4OD and 6OD respectively at 28 day of curing.

Key Word: Concrete, Compressive Strength, Flexural Strength, Sporosarcinal Pasteurii, Tensile strength.

1.0 INTRODUCTION

1.1 General

Concrete is the most commonly used construction material worldwide but there are certain issues that affects its durability and the environment. Issues such as; cracks and the emission of CO_2 have led to a rising need for the production of sustainable concrete for environmental development [1]. Microbial induced calcite precipitation (MICP) is one of the many alternatives use for the production of a sustainable concrete worldwide [1-4]. MICP has attracted attention in many disciplines of civil engineering due to the fact that it is a phenomenon by which microorganism produces some amount of solid precipitation with the aid of chemical environment which can penetrate into a network of microscale pores thereby causing a long-range clogging. This result to gain of strength and superior mechanical properties of the medium [5-6]. The MICP Micro-organism that will be used for this research is *Sporosarcina pasteurii* (*S. Pasteurii*). *S. Pasteurii* is mostly available in the soil and it is known with the ability to resist harsh environmental condition and to precipitate calcium carbonate through microbial induced calcium precipitation [7-8]. *S. Pasteurii* which was formerly named bacillus pasteurii originates from the bacilli family of bacteria. It facilitates nucleation of nano scale crystals of calcium carbonate on it cell surface and it growth via ureolysis [9]. According to [3] the important factors for MICP using *S. Pasteurii* are the bacteria cell concentration, urea concentration and calcium ion concentration.

S. pasteurii-concrete is a concrete in which *S. Pasteurii* is induced into the concrete mixture for maximum efficiency and it is also known for itself healing properties. The use of this microorganism for the production of MICP has been carried out by many researchers [10-15] to produce concrete and thereby proved to be safe, durable, economical and sustainable. This type of concrete was developed as a result of the quest to eliminate cracks in concrete structure. According to [7], the compressive strength of *S. Pasteurii*-concrete cubes is higher than the normal concrete cubes with the range of 5.2% to 30.2% depending on the growth medium used for the MICP. The research conducted on *S. Pasteurii* concrete were carried out using different approaches compared to this study. [16] developed a self-healing concrete with bacteria immobilized in porous expanded perlite particles. [17] observed that newly formed cracks were healed by the presence of bacteria in the concrete mix of 10%, 20% and 30% and also 5% and 10% dosage of fly ash and silica fume respectively replacing cement in the bacterial solution of 10^3, 10^5 and 10^7 cells/ml. [18] considered *sporosarcina pasteurii* media as an admixture to achieve the early compresive strenght of a concrete. But this research focuses on the effect of *S.pasteurii* on the compressive, tensile and flexural strenght of concrete using thirty percent replacement of water with *S.Pasteurii* solution at varying concentration of 0, 0.5, 2, 4,and 6OD of the bateria.
Concrete structures are extremely vulnerable to micro cracking which allows water, gases and other potential harmful liquids to penetrate and degrade the concrete thereby reducing the performance of the structure in terms of strength and durability. Though cracks may not endanger the concrete strength in early age but the formation may be a serious risk to the durability of the structure [19]. When the micro cracks propagate further deep, not only the concrete itself will be damaged, it can also lead to corrosion of the reinforcement steel in the concrete structures. To remediate cracks in concrete structures sealants are either injected or sprayed in the cracks. These sealants comprise of epoxy resins, chlorinated rubbers, waxes, polyurethane, acrylics and siloxane. Although sealant has been used for healing cracks, they have various limitations which hinders their usage. The limitations of sealers include: poor weather resistance, moisture sensitivity, low heat resistance, unsustainability, poor bonding with concrete etc. [14]. Most importantly these methods are not environmentally friendly and are very expensive. Repairs can be particularly time consuming and expensive because it is often very difficult to gain access to the structure to make repairs, especially if they are underground or at a great height. To overcome this disadvantage, there is need for continuous maintenance in the form of micro crack repairs. The idea of introducing *S-Pasteurii* into concrete enhances self-healing mechanism in concrete which is developed to circumvent the above stated disadvantages through bio-mineralization. Every repair method follows the procedure of detection, monitoring and repair of cracks but in the self-healing method the procedure of detection, monitoring and repair is autogenous throughout the structure's life-cycle thus reducing the repair maintenance significantly. Also, the production of cement is a major source of carbon dioxide (CO_2) which is a major cause of global warming. The United Nation proclaimed that the concrete industries are responsible for 9% of carbon dioxide emission which is a contributing factor to the climate change.

The reform of concrete using *S. pasteurii* concrete will repair cracks in the concrete through its self-healing process. This occur when the bacterial spores come in contact with water as it penetrates into the cracks, they become active and precipitate calcium carbonate in form of crystals. The amount of calcium carbonate crystals increases until the cracks are closed completely [20]. This reduces the energy and materials required for inspection and maintenance [1]. It also consumed carbon dioxide from the air to form calcium carbonated and water thereby reducing the emission of carbon dioxide and making the concrete eco- friendly. It also reduces hydration product thereby reduces the production of carbon dioxide.

The aim of this study is to determine the strength characteristics of *S. Pasteurii* concrete. The objectives of this study include: determination of the preliminary properties of the concrete materials used, determination of the strength characteristic of the conventional and the *S. Pasteurii*- Concrete at different concentration of 0, 0.5, 2, 4 and 6OD for 1, 3, 7, 14, 21, 28, and 56 days.

This research is limited to the investigation of the effect of *S. pasteurii* bacterial on the compressive, tensile and flexural strength of concrete. To achieve this, thirty percent of the water used for the concrete production was replaced with *S. Pasteurii* solution at varying concentration of 0, 0.5, 2, 4, and 6OD. The water cement ratio adopted was 0.5 and the concrete mix was 1:1.5:3.

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2.0 MATERIALS AND METHODS

2.1 Materials

The materials used for this research are: ordinary Portland cement, fine aggregates, coarse aggregates, water, micro-organism (*Sporosarcina pasteurii*) and cementation reagents. Dangote Ordinary Portland Cement was used for this research. A mix ratio of 1:1.5:3 was adopted to meet the recommendation for minimum concrete strength. The fine aggregates (river sand) that was used was obtained from Ahmadu Bello University (ABU) dam samaru Zaria, Kaduna State. The coarse aggregates (crushed stones) used for this study was obtained from a quarry site opposite Nigeria College of Aviation technology along sokoto road Zaria, Kaduna. The water used was obtained from the concrete laboratory of the department of Civil engineering ABU Zaria. It satisfied the requirements of [21]

The microorganism used in this research work was *S. Pasteurii* which is classified according to [22]. It was a rod-shaped Gram-positive bacterium with diameter 2 – 3μm and about 0.5 – 1.2μm wide and 1.3 - 4μm long. The *S. Pasteurii* microorganism was obtained from the department of micro biology laboratory Ahmadu Bello University Zaria.

2.2 Methods

The determination of the physical and chemical properties of materials were done in accordance with the relevant standard.

2.2.1. Physical properties of cement

2.2.1.1 Fineness Test of Cement
The fineness test of cement was carried out according to [23]
2.2.1.2 Specific Gravity of Cement

The specific gravity test was carried out to determine the specific gravity of cement according to [24]
2.2.1.3 Consistency test of cement.
The consistency of the cement was carried out based on [23]
2.2.1.4 Soundness test of cement
Soundness test was conducted based on [23]
2.2.1.5 Initial and final setting time
The initial and final setting time of the cement was determined in accordance with [23]

2.2.2. Physical Properties of Aggregate (Fine and Coarse Aggregate)
Samples of fine and coarse aggregate were subjected to various laboratory test in other to access their physical properties. Below are the tests conducted on both fine and coarse aggregates.
2.2.2.1 Particle size Distribution on coarse aggregate were determined in accordance with [24].
2.2.2.2 Specific Gravity
Specific gravity test was conducted on both fine and coarse aggregate based on [24].
2.2.2.3 Aggregate Impact Value
This was determined for the coarse aggregate based on [24].
2.2.2.4 Aggregate Crushing Value
The aggregate crushing Value was also determined for the coarse aggregate in accordance to [25].

2.2.3 Workability of Fresh Concrete
Slump test was conducted on the fresh concrete based on [26]
2.2.4 Determination of the Strength Properties of *S. Pasteurii* concrete
The compressive, flexural and split tensile strength properties of the hardened *S. pasteurii* concrete at various concentration of 0, 0.5, 2, 4 and 6OD was determined. For the compressive strength, three cubes of size 150 x 150 x150mm was crushed for each curing day of 1, 3, 7,14, 28 and 56 days. The average compressive strength was obtained as the compressive strength of the concrete at any of the curing age. For the split tensile strength, three cylindrical specimen of size 100mm x 200mm was used at each day to obtain the strength at 7, 14, 21 and 28 days.

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The average tensile strength was obtained. For the flexural strength, three beam samples of 100 x 100 x 450mm was used at each curing day of 7, 14, 21 and 28days to obtain the average flexural strength.

3.0 RESULT AND DISCUSSION

3.1. Physical Properties of Cement

The results of the physical properties of cement are presented in Table 3.1. from the table below, all the values obtained falls within acceptable limit as indicated in the table. This implies that the cement is suitable for the production of concrete.

Table 3.1 Physical Properties of Cement

Properties of Cement	Result	Limit	Standard Code
Fineness	3.6%	≤ 10%	(BS EN196-3: 2016)
Specific gravity	3.16	3.1 -3.16	(BS EN196-3: 2016)
Consistency	29%	26% ≤ consistency ≤ 33%	(BS EN196-3: 2016)
Soundness	4.6mm	≤ 10mm	(BS EN196-3: 2016)
Initial setting time	133mins	≥ 45mins	(BS EN196-3: 2016)
Final setting time	196mins	≤ 600mins	(BSEN196-3: 2016)

3.1.3 Physical Properties of Fine and Coarse Aggregate

The physical properties of fine and coarse aggregates such as: specific gravity, aggregate impact value, aggregate crushing value and bulk density are presented in Table 3.2. it was observed that all the values obtained falls within the acceptable limits as specified by listed code of practice presented in the table. This implies that the materials are suitable for the production of concrete.

Table 3.2: Physical properties of fine and coarse aggregates

Properties	Fine Aggregate	Coarse Aggregate	Limits	Standard code
Specific gravity(g/m^3)	2.5	2.6	2.5 – 3.0	BS 812: 1995.
Silt content (%)	4	-	< 6	BS 812: 1995.
Aggregate impact value (%)	-	21.22	≤ 45	BS 812: 1995.
Aggregate crushing value (%)	-	22.89	≤ 45	BS 812: 1995.
Bulk density (Kg/m^3)	1600	1900	1500 -2000	BS 812: 1995.

3.1.3 Particle Size Distribution of Fine and Coarse Aggregate

The results of particle size distribution test of fine and coarse aggregate are presented in figure 3.1and figure 3.2 respectively. Figure 3.1 shows that the fine aggregate was classified as zone 1 in accordance with [24]. The fine aggregate has a silt content of 4 and specific gravity of 2.5 which made it suitable for concrete production. Figure 3.2 shows that the coarse aggregate was well- graded with nominal size of 20mm. The coarse aggregate was suitable for concrete production.

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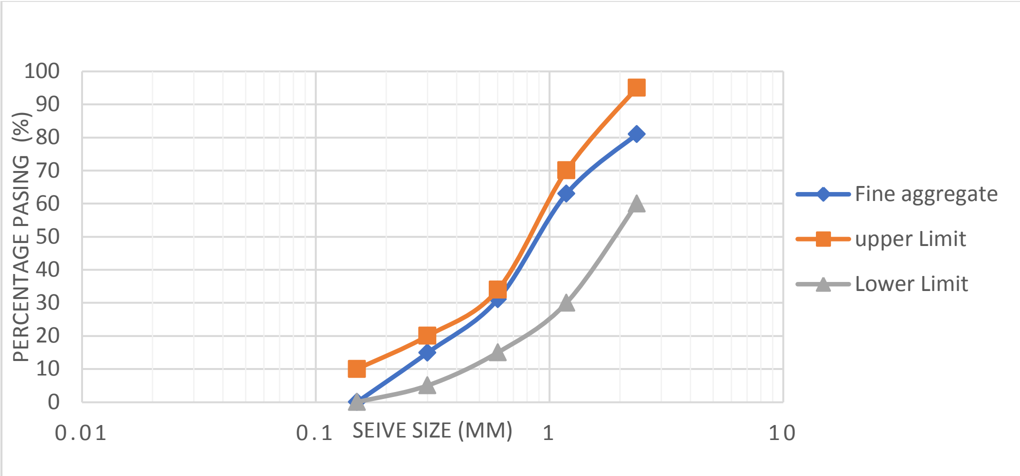

Figure 3.1: Particle size Distribution of fine aggregates

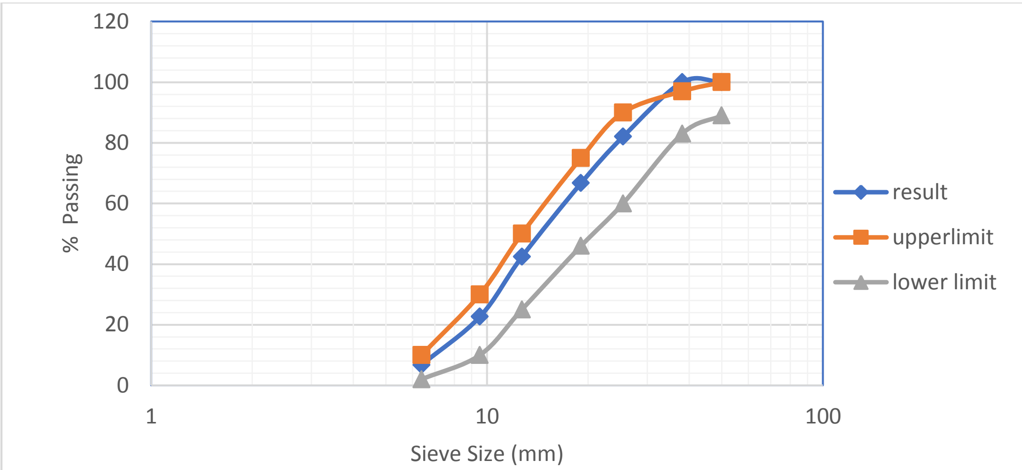

Fig 3.2: Particle size Distribution of Coarse Aggregates

3.1.4 Slump of fresh *S. Pasteurii* concretes

The relationship between slump and the bacterial concentration in the *S-pasteurii* concrete is presented in Figure 3.3. An undulating curve trend was observed between 0OD and 4OD. There was an increase in the slump at 0.5OD with 28.57% but at 2OD there was a drop in slump by 37.8%. However, increment in slump was observed when the concrete mixture was mixed with 4OD and 6D bacteria concentration by 42.86% and 10% respectively. This contradicts the finding of [4]. It could be that as the bacteria concentration further increase the slump value might decrease. The maximum slump was obtained when 0.5OD bacterial concentration was used.

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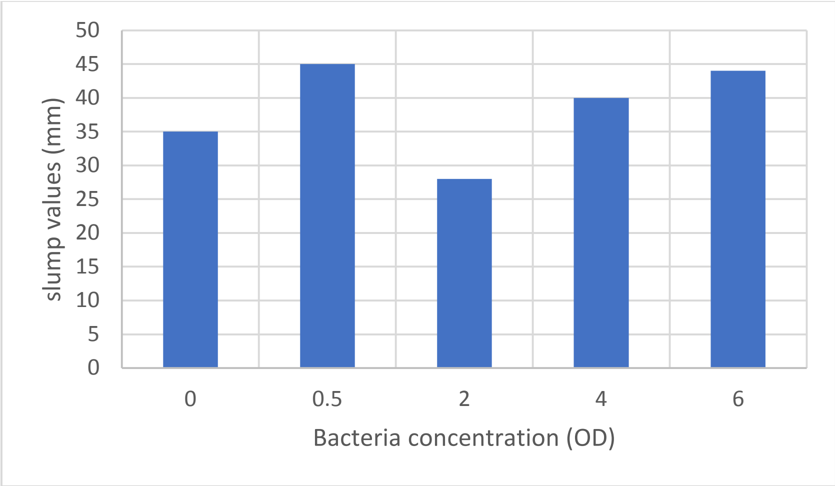

Figure 3.3 Relationship between Slump and Bacteria concentration.

3.1.5 Compressive Strength of *S-Pasteurii* Concrete

The results of the compressive strength of *S. Pasteurii* concrete are presented in Table 3.1 and Figure 3.5. It was observed that there was an improvement in the compressive strength of *S. Pasteurii* concrete with the various bacteria concentration and the compressive strength of *S. Pasteurii* concrete increases with curing age. The percentage increase of the compressive strength at 28days are 17.76%, 19.72%, 25% and 4.04% for 0.5OD, 2OD, 4OD and 6OD respectively. At 56day the compressive strength was increased by 11.10%, 40.17%, 46.32% and 3.69% for 0.5OD, 2OD, 4OD and 6OD respectively. The percentage increase is within the range of 4.04% and 25% at 28days while at 56days the increase range is 3.69% and 46.32%. bacteria concentration of 4OD has the highest compressive strength at 28 and 56days. The reason for the improved compressive strength is as a result of the microbiological induced calcite precipitation which clogged the pores of the concrete as stated by [7, 11,27]

Table 3.1 Compressive Strength of *S. Pasteurii* Concrete

Curing Age (Days)	Compressive Strength of *S. Pasteurii* Concrete(N/mm^2)				
	0OD	0.5OD	2OD	4OD	6OD
1	11.81	20.74	18.08	18.97	11.85
3	15.11	21.93	20.29	21.04	19.56
7	16.15	24	21.19	24	21.78
14	22.37	24.15	23.26	26.67	23.7
21	21.04	24.44	28.15	25.85	23.41
28	22.52	26.52	26.96	28.15	23.41
56	23.25	25.83	32.59	34.02	24.11

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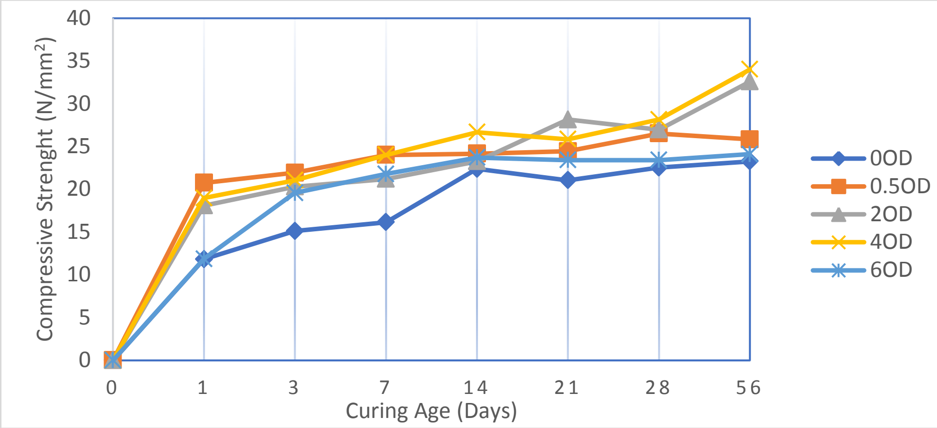

Figure 3.5 Relationship between Compressive Strength and Curing Age of *S. Pasteurii* Concrete

3.1.6 Tensile Strength of *S. Pasteurii* Concrete

The results of the tensile strength of the *S. Pasteurii* concrete were presented in Table 3.2 and Figure 3.6. From Table 3.2, it was observed that the tensile strength increased with the curing ager for each bacteria concentration. The highest tensile strength was obtained when 0.5OD was used and cured for 14days. From Figure 3.6, it was observed that the tensile strength increased with increase in the bacteria concentration. This is as a result of the increase in calcium carbonate precipitation by *S. Pasteurii* in the concrete. [7, 11, 27] The highest tensile strength was increased by 16.24% and obtained when 0.5OD bacteria concentration was used and cured for 14days.

Table 3.2 Tensile Strength of *S. Pasteurii* Concrete

Curing Age (Days)	Compressive Strength of *S. Pasteurii* Concrete(N/mm^2)				
	0OD	0.5OD	2OD	4OD	6OD
3	1.72	2.09	1.98	2.37	1.88
7	1.65	2.66	2.62	3.01	2.04
14	2.02	3.55	3.13	2.39	2.6
28	3.14	3.38	3.41	2.62	3.14

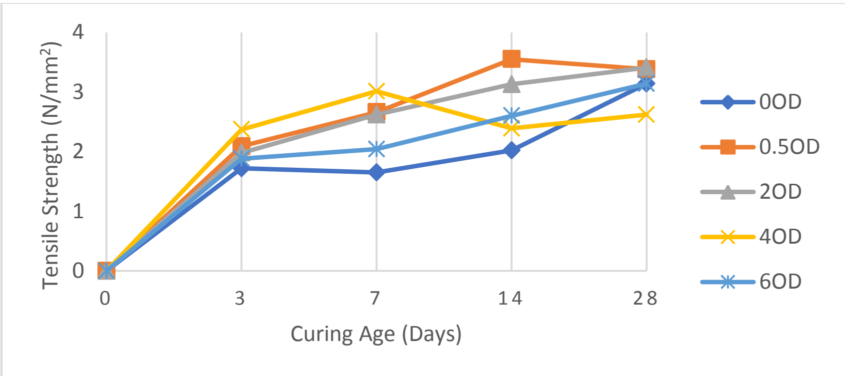

Figure 3.6 Relationship between Tensile strength and Curing Age of *S. Pasteurii* Concrete

3.1.7 Flexural strength of *S. Pasteurii* Concrete.

The results of the flexural strength test were presented in Table 3.3 and Figure 3.7. From Figure 3.7 it was observed that the flexural strength increased with the inclusion of *S. Pasteurii* in the concrete compared to the control concrete. At 28days of curing the flexural strength obtained was 2.7N/mm^2, 3.9N/mm^2, 2.94N/mm^2, 3.98N/mm^2 and 2.93N/mm^2 for control, 0.5OD, 2OD, 4OD and 6OD respectively. The flexural strength of *S. Pasteurii* concrete was improved by 44.44%, 8.89%,47.40% and 8.52% for 0.5OD, 2OD,4OD and 6OD respectively. The highest average flexural strength

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was obtained when 0.5OD of bacteria concentration was used. The precipitation of calcium carbonate in the concrete is responsible for the improvement in the flexural strength of the *S. Pasteurii* concrete. the improvement of the flexural strength may be as a result of microbiological induced calcite precipitation [7, 11,27].

Table 3.3 Flexural Strength of *S. Pasteurii* Concrete

Curing Age (Days)	Flexural strength of *S. Pasteurii* Concrete (N/mm^2)				
	0OD	0.5OD	2OD	4OD	6OD
3	1.35	3.6	2.1	2.7	2.7
7	2.18	3.53	2.1	3.15	2.85
14	2.7	3.98	3.68	3	2.7
28	2.7	3.9	2.94	3.98	2.93

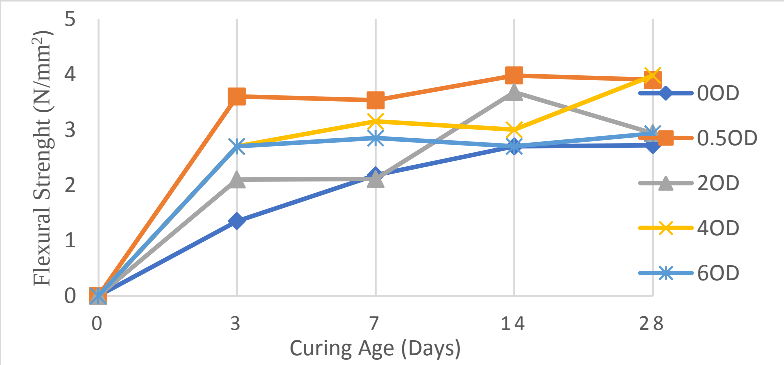

Figure 3.7. Relationship between Flexural Strength and Curing Age

4.0 CONCLUSION AND RECOMMENDATION

4.1 Conclusion

Based on the results presented, the following conclusion were made:

i. All the properties of the materials used for the concrete production met the required standard of the relevant codes of practice.

ii. The compressive, tensile and flexural strength of *S. Pasteurii* concrete was improved when compared with the control concrete.

ii. The maximum tensile and flexural strength was obtained at 14days of curing, when 0.5OD was used to mix the fresh concrete. The percentage increment of the tensile and flexural strength at the 14day of curing when 0.5OD was used are 3.55N/mm^2 and 3.98N/mm^2 respectively.

4.2 Recommendation

The quantity of cementation reagent should be increased as the bacterial concentration increases to ascertain the performance of *S. Pasteurii* concrete.

REFERENCES

1. Jonker, H.M., Thijssen A., Muyzer, G., Copuroghu, O., & Schlangen, E. (2010). Application of Bacteria as self-healing Agent for the Development of Sustainable Concrete. *Journal of Ecological Engineering* p230-235

2. Bhaduri, S., & Montemagno, C., (2018) *Sporosarcina Pasteurii* can clog and strengthen a porous medium mimic. PLOS ONE 13(11) https://doi.org/10.1371/journal.

DOI: 10.31695/IJASRE.2024.6.4

3. Hamed, A., Bujang, B., Afshin, A., Mohsen, Z., & Satoru, K. (2018). Electrokinetic Properties of Pasteurii and aquimarina Bacteria. Environmental Geotechnics

4. Chen, Y., Wang, S., Tong, X., & Kang, X. (2022): Crystal Transformation and Self- Assembly Theory of Microbially Induced Calcium Carbonate Precipitation, *Apply Microbiology Biotechnol*, 106 (9- 10): 3555 – 3569. Doi 10.1007/S00253-022-11938-7

5. Fortin, D., Ferris F.G., & Beveridge, T.J, (1997). Surface – Mediated Mineral Development by Bacteria. *Review mineral* 35: 161 -180

6. Hamphicharnchai, P., Mayteeworakoon, S., Kitikhun, S., Chunhametha, S., Likihitrattanapisa, S., Eurwillaichitri L., & Ingriswang, S., (2022): High level of Calcium Carbonate Precipitation achieved by Mixed Culture Containing Ueolytic and Nonureolytic bacterial strain, Lett *Apply Microbiology*, 75(4): 888-898. Doi 10.111/lam.13748.

7. Yoosathaporn S., & Pathom (2016). A cost-effective Cultivation Medium for Bio-calcification of Bacillus Pasteurii KCTC 3558 and its Effect on Cement Cubes Properties. *Microbiology Research* Volumes 186-187, pages 132-138.

8. Cuppuccino, J. & Sherman, N., (2014) A Microbiology laboratory manual, tenth edition

9. Ghosh, T., Bhaduri, S., Montemagno, C., & Kumar, A. (2019). *Sporosarcina Pasteurii* Can forNanoscale Calcium Carbonate Crystals on Cell Surface. *PLOSE ONE*

10. Ahmed, S., & Saba, T. (2017). Behavior of Bio-Concrete Thick Slab under repeated loading *ARPN Journal of Engineering and Applied Sciences* Vol.12.

11. Aregawi, S., Goshu, A., Alemu, B., Woldaregay, D., Abdulkadir, N., & Mesfin, Y. (2018) Investigation of the Compressive Strength of Portland Cement Mixtures by Application of Bacteria – *Sporosarcina Pasteurii*. *Integrated Solutions for Infrastructure Development*

12. Williams, S., Kirisits M., & Ferron, R., (2016). Optimization of growth medium for *Sporosarcinal Pateurii* in Bio-Based Cement Paste to Mitigate Delay in Hydration Kinetics. *Journal of Industrial Microbiology and Biotechnology*

13. Lapierre, F., Schmid, J., & Ederer, B., (2020). Revealing Nutritional Requirements of MICP- Relevant *Sporosarcinal Pasteurii* DSM33 for Growth Improvement in Chemically Defined and Complex Media. *Scientific Reports*

14. Ma, L., Pang, A., Luo Y., Lu, X., & Lin, F., (2020). Beneficial Factors for Bio- mineralization by Ureolytic bacterium *Sporosarcina Pateurii*. *Microbe Cell fact*.

15. Chuo, S., Mohammed, S., Setapor, H., Ahmed, A., Jawaid, M., Wani, W., Yaqoob, A., & Nasir, M., (2020). Insight into the Current Trends in the Utilization of Bacteria for Microbially Induced Calcium Carbonate Precipitation. *Materials*

16. Zhang, J., Liu, Y., Feng, T., Zhou, M., Zhao, L., Zhou, A., & Li, Z. (2017). Immobilizing Bacteria in Expanded Perlite for the Crack Self-Healing in Concrete.” *Construction and Building Materials,* 148, 610-617.

17. Chahal, N., Siddique, R., & Rajor, A., (2012) Influence of Bacteria on the Compressive Strength, water Absorption and Rapid Chloride Permeability of Fly Ash Concrete. *Construction and Building Materials*,28(1); p 351-356

18. Chidara, R., Nagulagama, R, & Yadav, S., (2014). Achievement of Early compressive Strength in Concrete Using *Sporosarcina Pasteurii* Bacteria as an Admixture, *Advances in Civil Engineering Article* ID 435948

19. Achal, V., Mukhaerjee A., & Reddy, M., (2011). Microbial concrete: Way to enhance the durability of building structures. *Journal of Materials in Civil engineering.* 23(6) P. 730 – 734.

DOI: 10.31695/IJASRE.2024.6.4

20. Wang, J.Y., De Belie, N., & Verstraete, W. (2016). Diatomaceous Earth as a Protective Vehicle for Bacteria Applied for Self – Healing Concrete. *Journal of Industrial Microbiology* 39(4) pages 567 – 577.

21. BS EN 1008. (2002). Mixing Water for Concrete. British Standard Institute 389, Chiswick High Road, London, W44AL

22. American Type Culture Collection as ATCC 11859

23. BS EN 196, part 3, Methods of Testing Cement: Determination of Setting Time and Soundness London: British Standard Institution, 2016

24. BS 812, Part 2 (1995): Method of Determination of Physical Properties of Aggregates. *British Standard Institution, London*

25. BS EN 1008. (2002). Mixing Water for Concrete. British Standard Institute 389, Chiswick High Road, London, W44AL

26. BS 1881-102 (1983). Testing concrete; part 106, Methods for Determination of Compressive Strength of Concrete. *British Standard Institute 389, Chiswick High Road, London, W44AL*

27. Vijeth, N., & Radhakrishna (2013) A Study on Effect of Bacteria on Cement Composites. *International Journal of Research in Engineering and Technology* ISSN: 2319-1163

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DOI: 10.31695/IJASRE.2024.6.4