International Journal of Scientific Research in Engineering & Technology
Volume4, Issue2 (March-April 2024), PP: 133-137.
https://www.doi.org/10.59256/ijsreat.20240402021
www.ijsreat.com ISSN No: 2583-1240

Enhancement on mechanical parameters of concrete by Application of bacillus megaterium bacteria

Dr. Ajay Kumar Garg[1], Sandeep Goyal[2], Anju Jangade[3], Twinkle Sahu[4], Shivani Rathiya[5], Sevant Kumar[6], Himanshu Chandraker[7]
[1]*Head of Civil Department, Civil Department, Government Engineering College, Raipur, Chhattisgarh, India.*
[2,3]*Assistant Professor, Civil Department, Government Engineering College, Raipur, Chhattisgarh, India.*
[4,5,6,7] *Civil Department, Government Engineering College Raipur, Chhattisgarh, India.*

To Cite this Article: *Dr. Ajay Kumar Garg1, Sandeep Goyal[2], Anju Jangade[3], Twinkle Sahu[4], Shivani Rathiya[5], Sevant Kumar[6], Himanshu Chandraker[7], "Enhancement on mechanical parameters of concrete by Application of bacillus megaterium bacteria", International Journal of Scientific Research in Engineering & Technology Volume 04, Issue 02, March-April 2024, PP: 133-137.*

Abstract: *This paper presents experimental results of self-healing process of concrete and effects on mechanical properties of concrete. Essentially, the self-repair of concrete occurs when cracks close due to the rehydration of unhydrated or inadequately hydrated cement particles within damaged areas. Bacterial concrete facilitates crack healing by converting calcium lactate to calcium carbonate through microbiological processes, leading to the cessation of crack propagation. Bacillus genus demonstrates impressive efficacy in diverse conditions for concrete reinforcement. Concrete vulnerabilities to attacks are inherent and cannot be entirely prevented. Water infiltration through these cracks initiates corrosion, significantly reducing the lifespan of concrete. Hence, there was a pressing need to develop and activate biomaterials for a self-repairing technique that could effectively address cracks and fissures in concrete. Bio-concrete emerges as a promising solution for enhancing concrete durability. This approach is highly desirable as it promotes eco-friendly crack remediation, employing Bacillus megaterium to induce artificial crack healing in cement concrete. Specimens were cast and subjected to mechanical strength and water absorption tests after 7 and 28 days of curing. Results show a notable improvement in compressive and flexural strengths by 12.91% and 9.02% respectively, compared to standard M25 grade concrete mix, after 28 days of curing. Additionally, bacterial concrete exhibits lower water absorption values than standard concrete mix, attributed to crack filling via calcite precipitation facilitated by Bacillus megaterium bacteria.Consequently, Bacillus megaterium, belonging to the Bacillus family, proves to be an effective agent for enhancing mechanical strength by reducing voids in concrete.*

Key Word: *Bacillus Megaterium, compressive strength, bio-concrete, water permeability, activated biomaterial, flexural strength, water absorption.*

I.INTRODUCTION

Self-healing concrete is capable of detecting the formation of cracks and responding autonomously to mend itself without the need for human intervention. Self-healing concrete is a product that biologically produce limestone to heal the cracks that appear on the surface of concrete structures. Concrete is a building material that is used globally (approximately 6 million m3/year are manufactured) because of its first-rate properties and easy availability. However, it is a critical material as it easily cracks due to multiple reasons such as autogenous shrinkage, mechanical compressive forces and tensile forces. Micro-cracks do not remarkably affect the strength of concrete but cause to more fluid penetration such as water and other chemical solutions resulting in cement matrix depletion and consequently corrosion of reinforced embedded steel bars. Presence of cracks not only reduce the mechanical strength and durability of a material but also affect the structure safety and security [1]. Self-healing concrete is usually defined because the ability of concrete to repair its small cracks autonomously without any human intervention. The concept of self-healing concrete was taken from the process by organisms like trees or animals. Damaged skin of trees and animals can be repaired autonomously. Redressing cracks in concrete structure is very important and significant for its service durability and structural safety and security.The most keyword of this text is self-healing concrete. Other similar keywords are self-healing, autonomous healing concrete, bio inspired, biological concrete, and calcite precipitation. Recently, developing self-healing concrete technology has become a significant objective for researchers in biotechnology and applied science [2].

Mr. Sk Alisha, Mr. P. Rohit, Mr. K.S.N. Sachine, Mr. V.Rajesh Babu (2023)[3] studied that self-healing concrete has excellent properties compared to traditional concrete. Because of several helpful properties the self-healing concrete square measures usually employed in many sorts of infrastructure. Attacks on concrete are evasable and a concrete specific weakness. Through these cracks, Water and Salt escapes easily. It initiates corrosion and shortens the life of the concrete. Therefore, there was a need to develop and facilitate biomaterial self-healing processes that can repair cracks occur in concrete. The mechanism of crack healing in bacterial concrete is believed to be through the metabolic conversion of salts to carbonates, which ultimately seal cracks. The optimal level of Megaterium B is often assumed to be 10^6 cells/ml. When properly cured, cracks heal within 30 days.

Nidhi Nain. R. Surabhi, Yathish N.V., V. Krishnamurty T. Deepa, Seema Tharannum., (2019)[4] studied Bacillus megaterium microbial spores, nutrients were assembled. The results show that Bacillus megaterium can use glucose and calcium lactate as precursors, and this new repair system greatly improves the efficiency of self-repair.Calcium lactate, the precursor, has higher repair performance than glucose, and greatly improves water resistance and ion resistance after repair. The average healing depth exceeded 4000 mm. At the same time, the detrimental effect of cement on hydration was less than that of glucose.

Jun feng, Bingcheng chen, Weiwei Sun, Yang Wang.,(2021)[5] Study of Dif ferent cracks in specimens with the self-healing agent after different healing stages in 07 and 28 days. The cracking of concrete tends to occur in different age. Test used for microbial self-healing ,Preparation of cement paste spec imens, creation of artificial cracks, microbial self-healing agent preparation, healing incubation conditions, self-healing effect characterization methods. The precipitations formed at the cracks surface were calcite.However, the capacity of concrete crack self-healing depended on many factors. The crack was more and more difficult to be repaired with the increase of average crack width and the repair ability of microbial repair agent was limited for specimens with crack width up to 0.8 mm. Water curing was shown to be the best way for bacteria-based self-healing concrete [6].

II.MATERIAL AND METHODS

Materials:

1. Cement-Ordinary Portland Cement 43 grade is used as per IS: 4031-1988 [7] and tested for various properties and found to be confirmed to the various specifications of IS 12269-1987 [8] with a specific gravity of 3.10.

2. Fine aggregates-Locally available M-sand passing through 4.75 micro sieves is used as fine aggregate. IS 2720 [9] is referred to obtain Specific Gravity. Fine aggregate acts as a filler in concrete to fill in the matrix and give a compacted structure bound by
Cement. The specific gravity is found to be 2.60[10].

3. Coarse aggregates-A locally available aggregate of 20 mm downsize is used. IS 2386-1963 [11] is referred to determine the Specific Gravity. The coarse aggregate occupies most of the volume in concrete, it also adds on to the strength and resistance to abrasion. The specific gravity is found to be 2.80[12].

4. Water-The quantity of water for the experiment is calculated as per mix design. Whereas, 100 ml of water is replaced with 100 ml of bacterial solution for every 1000 ml of water [13].

5. Bacteria- Bacillus Megaterium is an extremely large bacterium at about 60 micrometers which is often used to study protein localization, structures and membranes. It is a rod like, gram-positive, mainly aerobic, spore forming bacterium found in widely diverse habitats.It has a cell length upto 100 micron and a diameter of 0.1micron, which is quite large. The concentration of Bacillus Megaterium is 10 B CFU pergm is used [14].

Calcium Lactate, Nutrient Broth, Conical flask, Magnetic stirrer, Spetula, Aluminium Foil, Weighing Machine, BOD Incubator, Distilled water also used along bacteria.

Methodology:

1. Ordinary Portland cement of 43 grade was used and tested for various properties as per IS: 8112- 2013[15]. Soundness and specific gravity of cement were determined as 2mm and 3.15 respectively [16]. Initial & final setting times of cement were determined to be 33 minutes and 600 minutes respectively. Sand was used as fine aggregate which lies in Zone2 [17]. Moisture content and specific gravity of fine aggregate were 1.4% and 2.52 respectively. Locally available coarse aggregates with maximum nominal size of 20mm and 10mm were taken in this study. Fineness modulus of coarse aggregate of 20mm and 10mm are 3.251 and 2.276 respectively [18]. Bacillus megaterium bacteria of Bacillus family were used. The bacteria have been obtained in powder state from ANSEL BIOTECH, Gujarat. Bacillus megaterium bacteria provide calcite precipitation in the void of concrete specimens during and after healing that helps in making the structure more compact and durable. Fineness of cement obtained is 8%. Water absorption and moisture content of coarse aggregate obtained to be 1.81%.and 0% respectively [19].

2. Prepared of bacteria used-First take the conical flask of 250ml. Then take 100ml of distilled water in each. Add with 2.8 gm of nutrient broth and 1gm of bacterial powder in each specimens. Shaking it for 10 min. cover the top with cotton and aluminium foil. Incubate the above two specimens in BOD INCUBATOR overnight. Temperature-37°C of incubator is required [20].

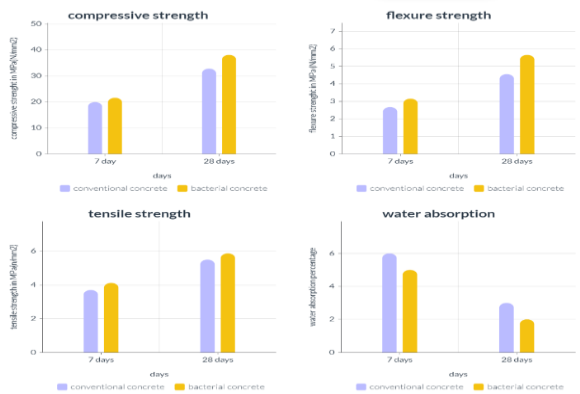
3. Mix Preparation- Concrete mix of grade M30 has been prepared by using OPC 43 grade cement, locally available course aggregates of 20 mm (60%) and 10 mm (40%) maximum nominal sizes, natural sand of zoneIII, bacillus megaterium bacteria in liquid form having density 108 cell/ml and Polycarboxylic ether based superplasticizer are prepared using of cement, fine aggregate and coarse aggregate [21]. Fine aggregate and coarse aggregate were first mixed in pan mixer with small quantity water for around two minutes in order to minimize dust due to mixing of aggregate in pan mixer. After that the required quantity of cement has been added and the mixing is continued for next two minutes. Then the remaining water along with the bacterial solution were added in pan mixer and mixed for three minutes. The mix is then casted into the desired moulds. [22]

4. Casting of Specimens- The casting of specimens has been done in accordance with IS-1199-1959[23]. After proper mixing, the concrete has been poured into the moulds in three layers. Each layer has been tamped 25 times. The moulds were then compacted to remove the air voids using vibrating table. After compaction these moulds are kept intact for 24 hours. The de-moulding of specimens was done after 24 hours and all the specimens were then cured in water till the time of testing. A total of 6 cube specimens of size150mm x150mm x 150 mm, 6 cylinder of height 200mm and diameter 100mm and 6 beams of size 100mm x100mm x500mm were cast for standard and bacterial concrete. The specimens so cast have been tested for the strength in tension, compression and flexural and also for water absorption at desired age of curing. Standard precautions were taken during the preparation of specimens and the moulds were tightened properly so that there was no chance of slurry leakage [24].

5. Testing-The cured specimens were tested for strength in compression as per IS 516: 1959[25]. The testing was done while the surface of the concrete specimen was in dry condition using UTM. The load was applied at the rate of 2kN/mm2/min and the loads at failure were recorded for all the specimens. Cylindrical specimens of diameter 150mm and height300 mm were cast for the test of split tensile strength which was carried out using the same digital compression testing machine accordance with IS 5816: 1999[26] at 7 and 28 days. The loads at which the test beams failed were recorded and then used to determine the flexural strength. The representative strength, in all the testing, has been considered by taking the average of the strength of three specimens measured at 7 and 28 days of curing. To find out the absorption capacity of concrete specimen under FSAET 2020 IOP Conf. Series: Materials Science and Engineering 1116 (2021) 012168 IOP Publishing doi:10.1088/1757-899X/1116/1/012168 4 environment condition, water absorption test was conducted in accordance with [27]. The specimens were cast and cured in the same manner as that for compressive strength test. After 7 and 28 days of curing, the cured specimens were taken out from water tank and were dried in oven at 105oC for a period of 24 hours. After drying, the weights (W1) of the specimens were recorded using a digital weighing machine. The specimens were then again kept in curing pond for next 24 hours for the purpose of absorbing water. After 24 hours of water absorption the specimens were taken out and their weights (W2) were recorded again. The water absorption capacities of the specimens were calculated using equation (1). The representative water absorption values correspond to the average of the water absorption values of the three specimens [28].

III.RESULT

Specimens were cast for the compressive, flexural strength test, tensile strength test and water absorption test. The testing has been carried out as per the Indian standard codes i.e. IS: 516-1959[29] and IS 5816: 1999[30]. The testing has been done for bacterial culture mix concrete as per Indian standard testing methods. In this experimental investigation, the effect of bacillus megaterium bacteria on the strength and water absorption properties of concrete specimens has been studied. The testing for specimens was performed at 7 and 28 days of curing. Test results have shown increase in compressive, flexure and tensile strength and decrease in water absorption by significant value.



IV.DISCUSSION

After introducing bacteria along with the nutrient, a sample from specimen after 7 days of curing, is tested for bacterial viability using a simple plate count test. Bacterial colonies after an overnight of incubation proved that bacteria were capable of withstanding the harsh alkaline environment in the interior of concrete. Hence, the bacteria survived in the cement mixture and multiplied in early stages and produced Calcium carbonate as well adequately. The Calcium carbonate deposition plugs the pores and certain micro cracks in the concrete. It was also observed that once the pores are plugged, the flow of nutrients and oxygen to bacteria cells stopped, gradually cells died or form into endospores and acts as organic fibre, thus increasing compressive strength. This study concludes that bacteria from genus Bacillus is not only proved to be efficient in crack healing ability but also plays a great role to increase the strength. The work was done previously on the self-healing concrete is reviewed to understand the influence of different bacteria on the mechanical properties of concrete. Based on the literature survey, the results showed that, the mechanical properties improved as the cracks were filled with calcium carbonate. As of now, the self-healing of concrete is studied much in the laboratory. The further focus should be aimed at reducing the healing time and improving the efficiency of materials used in the self-healing concrete. When compared with conventional repair methods, self- healing of concrete can heal the micro-cracks present inside the specimen. Self-healing of concrete can be used in marine and subterranean concrete because of its healing ability.Thepresence of calcium ions is necessary, for the precipitation of CaCO3. Based on the work done previously, the water absorption, permeability, reduces when compared to conventional concrete. The life span of the structure will be increased due to the utilization of calcite precipitation by the bacteria. Self-healing of concrete can also be done by the addition of admixtures, fibres, and polymers, which are capable in the healing of the cracks The surface pores can also be reduced by the utilization of the bacteria in the concrete matrix. The presence of fewer surface pores increases the strength of the concrete. Calcium carbonate precipitation and crack healing efficiency also depends on the curing conditions. Self-healing of concrete is an eco-friendly and sustainable concrete.

V.CONCLUSION

In this paper investigations have been carried out to study the effect of bacillus megaterium bacterial solution on the mechanical properties and water absorption of cement concrete. Based on the laboratory investigation, following conclusion can be drawn from this investigation: 1. the incorporation of self-healing agents can positively impact the compressive strength of concrete by promoting healing mechanisms and reducing the detrimental effects of cracks. Bacillus megaterium bacteria were found capable of filling the pores. [31]. Strength in compression of the concrete gets increased by 8.43% and 16.11% at 7 and 28 days respectively as compared to standard cement concrete. 2. By promoting self-healing mechanisms and reducing the permeability of the concrete matrix, nanomaterials contributed to lower water absorption rates and improved durability, incorporating nanomaterial-based self-healing agents can effectively enhance the water absorption resistance of concrete. The water absorption of bacillus megaterium bacterial concrete has reduced due to the filling of the voids by bacteria [32]. The water absorption in this study has reduced by 5.53% and 7.67% as compared to standard concrete at 7 and 28 days respectively. 3. By promoting self-healing mechanisms, such as crack sealing and restoration of material integrity, the presence of microcapsules contributed to improved resistance to bending stresses 4.Tensile strength is significantly increased in bacterial concrete providing greater resistance.Therefore the bacillus megaterium bacteria can be effectively utilized to improve the strength and durability properties of the concrete.

REFERENCES

1. *Bacteria based self-healing concrete– A review Kunamineni Vijay, Meena Murmu, Shirish V. Deo Department of Civil Engineering, National Institute of Technology, Raipur, India*
2. *Application potential of Bacillus megaterium encapsulated by low alkaline sulphoaluminate cement in self-healing concrete Yilin Su a,b,c, Tianwen Zheng a,b,c, Chunxiang Qian a,b,c, a School of Materials Science and Engineering, Southeast University, Nanjing 211189, China b Research Center of Green Building and Construction Materials, Southeast University, Nanjing 211189, China c Jiangsu Key Laboratory for Construction Materials, Southeast Univer sity, Nanjing 211189, China*
3. *Influence of bacteria in self-healing of concrete- a review P.V. Yatish Reddy a, B. Ramesh a, L. Prem Kumar b aDepartment of Civil Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, (SIMATS), Chennai 602 105, India bDepartment of Microbiology, Saveetha Medical College, Saveetha Institute of Medical and Technical Sciences, (SIMA)*
4. *Influence of Bacillus megaterium on crack healing and mechanical properties of concrete Rishab Attri, Abhilash Shukla, Vinayak Sharma, Ayush Thakur 3rd International Conference on Innovative Technologies for Clean and Sustainable Development: ITCSD 2020 3, 139-155, 2021*
5. *Microbial induced calcium carbonate precipitation study using Bacillus sub tilis with application to self-healing concrete preparation and characterization Author links open overlay panelJun Feng a, Bingcheng Chen b, Weiwei Sun b, Yang Wang c a National Key Laboratory of Transient Physics, Nanjing University of Science and Technology, Nanjing 210094, China b Department of Civil Engineering, Nanjing University of Science and Technology, Nan jing 210094, China c School of Environmental and Biological Engineering, Nanjing University of Science and Technology, Nanjing 210094, China*
6. *Application of Bacillus Subtilis Bacteria for Improving Properties and Healing of Cracks in Concrete C. Neeladharan1, J. Sharpudin2, V. Loganath3, B. Jagan4, C. Chinnarasu5, K.R. Vijaykaran6 Assistant Professor, Department of Civil Engineering, C. Abdul Hakeem College of Engineering and Technology, 32 Vellore, Tamil Nadu, India 1,2 UG Student, Department of Civil Engineering, C. Abdul Hakeem College of Engineering and Technology, Vellore, Tamil Nadu, India.*
7. *Self-Healing Concrete Using Bacteria Mr. Sk. Alisha, Mr. P. Rohit, Mr. K.S.N. Sachin, Mr. V.Rajesh Babu Civil Engineering Department, Vishnu institute of technology,Andhra Pradesh, India*
8. *Self-Healing Concrete Using Bacteria Mr. Sk. Alisha, Mr. P. Rohit, Mr. K.S.N. Sachin, Mr. V.Rajesh Babu*
9. *Yilin Su, Tianwen Zheng and Chunxiang Qian published a paper on Applica tion potential of Bacillus megaterium encapsulated by low alkaline sulphoalu minate cement in self-healing concrete*
10. *Mian Luo, Chun-xiang Qian, Rui-yang Li published a paper on Factors af fecting crack repairing capacity of bacteria-based self-healing concrete. 3. Hassan Amer Algaifi, Suhaimi Abu Bakar, Rayed Alyousef , Abdul Rahman Mohd Sam, M.H. Wan Ibrahim, Shahiron Shahidan, Mohammed Ibrahim, Ba batunde Abiodun Salami published a paper on Bio-inspired self-healing of concrete cracks using new Bacillus pseudomycoides species.*
11. *Priya S Nair, Rajesh Gupta, Vinay Agrawal published a paper on Self-healing concrete: A promising innovation for sustainability- a review*
12. *Crack healing in concrete using various bio influenced self-healing techniques Wasim, Muhammad Basit Ehsan National University of Sciences and Tech nology (NUST), Islamabad, Pakistan.*
13. *IS 5 6:2 4, "Method of Tests for Strength of Concrete," IS 516 - 1959 (Reaffirmed 2004), p. New Delhi,India, 2004.*
14. *Nataliya Hearn (1998) "self-healing, autogenous healing and continued hydration: what is the difference?" Materials and structure Oct. (1998), PP 563-567*
15. *S. S. Rautray, B. N. Mohanty, and M. R. Das, "Performance of self-compacting geopolymer concrete using Bacillus Licheniformis," in Materials Today: Proceedings, 2019.*
16. *N. Gupta, A. Gupta, K. K. Saxena, A. Shukla, and S. K. Goyal, "Mechanical and durability properties of geopolymer concrete composite at varying superplasticizer dosage," Mater. Today Proc., 2020.*
17. *Samir A. Al-Mashhadi, Ghalib M. Habeeb and Abbas Kadhim Mushchil, Control of Shrinkage Cracking In End Restrained Reinforced Concrete Walls. International Journal of Civil Engineering and Technology, 5(1), 2014, pp.89– 110.*

18. *Salmabanu Luhar, Suthar Gourav, A Review paper on self-healing concrete, Journal of Civil Engineering Research, S.5(3), 2015, pp 53-58.*
19. *V. Suleman Ahamed and Dr. S. Siddiraju, Study of Strength of Concrete with Palm Oil Fuel Ash as Cement Replacement. International Journal of Civil Engineering and Technology, 7(3), 2016, pp.337–341.*
20. *A. Gupta, N. Gupta, K. Saxena, and S. Goyal, "Investigation of the mechanical strength of stone dust and ceramic waste based composite," Mater. Today Proc., no. xxxx, 2020*
21. *N. Gupta, A. Gupta, K. K. Saxena, A. Shukla, and S. K. Goyal, "Mechanical and durability properties of geopolymer concrete composite at varying superplasticizer dosage," Mater. Today Proc., 2020.*
22. *J.Y. Wang (2014) "self-healing concrete by use of microencapsulated bacterial spores" cement and concretes research 56(2014) 139-152 ELSEVIER*
23. *M. Roig-Flores, S. Moscato, P. Serna and L. Ferra, Self-healing capability of concrete with crystalline admixtures in different environments, Construction and Building Materials, S.86, 2015, pp 1-11.*
24. *Salmabanu Luhar (2015) "A review paper on self-healing concrete" journal of civil engineering research 2015 ,5(3): 53-58*
25. *U. U. Jadhav, M. Lahoti, Z. Chen, J. Qiu, B. Cao, and E. H. Yang, "Viability of bacterial spores and crack healing in bacteria-containing geopolymer," Constr. Build. Mater. 2018.*
26. *Wiktor V & H.M. Jonkers, Application of bacteria-based repair system to damaged concrete structures. 2nd International workshop on structural life management of underground structures, 2012.*
27. *Rakesh Chidara, Rahul Nagulgama, Smitha Yadav, ''Achievement of early compressive strength in concrete using Sporosarcina pasteurii Bacteria as an Admixture" Hindawi publication corporation advances in civil engineering volume 2014, Article ID 435948*
28. *] W. De Muynck, D. Debrouwer, N. De Belie, W. Verstraete, Bacterial carbonate precipitation improves the durability of cementitious materials, Cem. Concr. Res. 56 (2008) 1005–1014.*
29. *] Jiaguang Zhang, Yuanzhen Liu, Tao Feng, Mengjun Zhou, Lin Zhao, Aijuan Zhou, Zhu Li, Immobilizing bacteria in expanded perlite for the crack self-healing in concrete, Constr. Build. Mater. 148 (2017) 610–617*
30. *] S. Krishnapriya, D.L. Venkatesh Babu, G. Arulraj, Isolation and identification of bacteria to improve the strength of concrete, Microbiol. Res. 174 (2015) 48–55.*
31. *F. Pacheo-Torgal, J.A. Labrincha, Biotech cementitious materials: some aspects of an innovative approach for concrete with enhanced durability, Constr. Build. Mater. 40 (2013) 1136–1141*
32. *Rakesh Chidara, Rahul Nagulgama, Smitha Yadav, ''Achievement of early compressive strength in concrete using Sporosarcina pasteurii Bacteria as an Admixture" Hindawi publication corporation advances in civil engineering volume 2014, Article ID 435948.*
33. *] Ramin Andalib, Muhd Zaimi, Abd Majid, Mohd Warid Hussin, Mohanadoss Ponraj, Ali Keyvanfar, Jahangir Mirza, Han-Seung Lee, Optimum concentration of Bacillus megaterium for strengthening structural concrete, Constr. Build. Mater. 118 (2016) 180–193.*