International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 12 | Dec-2017 www.irjet.net p-ISSN: 2395-0072

Critical literature review on improvement of concrete properties by bacterial solution

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Abstract - *There are a lot of bacteria existing on our world and from that same are healthful and important bacteria are available used for improvement of the mechanical properties of concrete in the building construction and Mentaniance material. Now a day, it is establish that bacterial solution by precipitation of calcium carbonate when it contact with water that resulting healing of cracks in concrete it improves the all properties of concrete. Bacterial solution based concrete is a most important material, which can effectively healing the cracks in concrete. This method is extremely attractive since the mineral precipitation induced as a result of microbial activities is free from pollution and it's natural. The use of crack healing concept in normal concrete leads to potential design of latest material called Bio Concrete. Hence, this paper cover the summary of same critical literature reviews on the previous found that related to self healing concrete and also review the result of these bacterial solutions on the concrete properties.*

Key Words: Bacterial solution, Bio concrete, Improvement, Properties of concrete

1. INTRODUCTION

Concrete which forms a main constituent in the construction engineering as it is easily available, cheap and suitable to cast. But it has a disadvantage such as micro crack, less in stiffness and less ductility. Also, failures like corrosion can result in structural failures with possibly serious long-term operational consequences so, it cracks under sustained loading and due to aggressive environmental agents, which ultimately reduce the life of the structure which is built using these materials. This method of harm happens initial lifespan of the construction structure and during its lifetime. When this type of problems is happening, the quality of concrete is decreases from that strength is one and which results in the decay of structure artificial materials are used for decrease the harms. But, they are not well-matched, expensive, decrease visual appearance and compatible, costly, reduce the aesthetic appearance and need continuous care. Therefore, bacterial species that precipitate calcium carbonate has been projected as a crack remediation and environmental-friendly substitute material hence improving the behavior of construction structure.

Current study has overview that biotechnology can really be a supportive device to reduce micro cracks in concrete structures by using bacillus species of bacterial in concrete. This latest category of concrete, that is set to fix itself, shows a powerful enormous improvement in community infrastructure's service-life, there by considerably reducing the maintenance costs and lowering CO2 emissions. Several investigations are made of bacterial concrete in last few years. This paper cover the review of concrete based on bacterial solution are discussed.

2. CRITICAL REVIEW ON CONCRETE BASED ON BACTERIAL SOLUTION

Following are several critical literature reviews of paper that are published on different national and international journal on bacterial based concrete. This all reviews are on bio concrete and enhancement the properties of normal concrete and behavior of the bacterial based concrete.

E. Madhavi et al. (2016) has published a paper on utilized that fly ash and GGBS materials and to decrease this kind of thermal power waste in the environment, the Ground Granulated Blast Slag and fly ash replacing cement contain bacteria of 10^6 bacillus pasteurii in M40 mix. The fly ash and Ground Granulated Blast Slag used in the amounts of 10% of cement. From this research, the results are much better as compare to that of the convention concrete [1].

S. Sanjay, S. Neha, and R. Jasvir (2016),This paper was presented the experimental investigation on bacterial concrete to increase the strength of bio concrete and to inform the process involved in the bacterial concrete. To know the calcite crystals formed in bacterial concrete analysis of microstructure has been done that is used for the potential to recovery the cracks in bacterial concrete and also to inform the biological reaction in concrete. As a result, has been got because of good adaptability of nutrient broth medium of bio concrete at 28 days attained better strength when compared to urea medium.

N. Amudhavalli, K. Keerthana and A. Ranjani (2015), this paper has presented the overview of bacterial concrete, bacteria the state of art results in all projects show that material designed as self-healing agents. Some of the bacteria is drawbacks not directly functional in construction structure like houses and offices because of health concerns this bacteria like B. Pasteuri, B. megaterium, B. subtilis. Lastly, they achieve that bacterium that have used in concrete in better way because of their advantages than other bacteria that are B. Sphaericus and Eschericheria Coli [3].

K. Pappupreethi, A. Rajisha and P. Magudeaswaran (2017), this paper has been presented that using bacterial in concrete to enhancing the properties of bacterial concrete when it compared to normal concrete such as compressive and flexural strength and within the same time to decrease the water absorption, permeability and reinforcement corrosion. This paper enhanced the knowledge about bacterial concrete by defining the type, merit, and demerit and how it's used as repair material and also used different admixtures such fly ash, silica fume in bacterial concrete due to this condition bio concrete achieved improved durability and strength [4].

N. Ganesh and Dr. S. Siddiraju, this paper have been informed using calcium lactate and bacteria to repair the cracks. The percentages of bacteria selected for the study are 3.5% and 5% with mass of cement. The cement replacing with 10% and 5 % of calcium lactate was used in concrete. in this experiment B. pasteurii bacterial species is used with different concentrations of bacterial for an M40 concrete grade. Several tests are done in this investigation such as elastic modulus, flexural strength, and compressive strength. The cubes of dimensions of 10x10x10 cm were used for the compressive strength test. It was found that40.53 MPa and 19.8 MPa for 28 and 7 days by using calcium lactate for normal concrete of compressive strength tests respectively and from this they observed reducing of compressive strength due to calcium lactate and also 10% is optimum dosage of calcium lactate. By the introducing of bacteria in concrete they found enhancing of the properties of concrete and of concrete which is better than conventional concrete. Finally, they concluded that effective self-healing agent produced by using 5% of bacteria and 3.5% of calcium lactate. [5].

G. Mohit and P. Krishna Chaitanya, this paper has presented that, experimental investigation on bacterial concrete by B. pasteurii bacterial species and also compare the results with the normal concrete within this cement is replacing by 30% of GGBS and fly ash in M25 concrete grade. Different tests have been conducted in this investigation tests like X- Ray diffraction test, compressive strength, flexural strength, slump flow test and split tensile strength for several sample of 40ml, 50ml, and 60ml bacterial concentrations for each sample. The compressive strength improved by 30% in bio concrete and bacterial concrete with fly ash by 15% and GGBS by 20%. It was found that bio concrete of 40ml and 50ml bacterial solution is attains extreme flexural strength and split tensile strength but it's not true for 60ml bacterial solution after 14 days when they did flexural tensile strength. Also, the optimum dosage of bacterial solution used in concrete is 50ml it's the point of maximum improvement of mechanical properties of bacterial concrete. Generally, more CaCO3 is produce in concrete because of bacteria species which has enhancing durability of structure due to reducing of voids by 10%. [6].

B. Chithra P Bai and V. Shibi, this paper was presented, bacterial concrete with various bacterial solution of 10^3ml, 10^5ml and 10^7ml and they have been used B. Subtilis bacteria species in this experiment and also bio concrete is formed by 10%,20%, and 30% fly ash replacing cement by its mass. The Ultrasonic Pulse Velocity, split tensile, Flexural and compressive strength tests have been doing after 28 and 56 days for M30 grade .All mechanical properties of bio concrete enhancing at 10% fly ash replacing cement and by 10^5ml bacterial solution achieved maximum values for all test they conducted. Finally, The precipitation of $CaCO_3$ due to bacteria in the concrete by bio technology concept that improves mechanical properties of fly ash concrete [7].

A. Thakur, A. Phogat, K. Singh (2016), This paper has presented the overview of several paper in the current years on the use of bio concrete for improving in the mechanical properties, durability and permeation features of normal concrete. They have been studies the analysis on bio concrete by XRD and SEM tests and also several types of bacteria's, their isolation process, several methods used in the adding of bacterial species in concrete and their belongings on water absorption and compressive strength. Finally, they concluded the bacterial type such as B. cereus and S. pasteurii extreme rise in the compressive strength and the maximum reduce in water absorption for 28 days curing period of specimen respectively. The bacterial like bacillus sphaericus, B. pasteurii, and Bacillus flexus are not harm the human body and also, they have the potential to precipitate calcite but some other bacterial species is dangerous for human health [8].

N. Kannan, Ravindranatha, Likhit M. L, this paper has presented a comparison of bio concrete and normal concrete regarding to flexural and compressive strength tests using beams and cubes moulds with B. pasteurii. The concrete cubes and beams were prepared by adding a calculated quantity of bacterial solution and they were tested for 7 and 28 day compressive and flexural strengths. Finally found that there was a high rise of remedial of cracks and strength exposed to loading the concrete sample. The properties of concrete effectively improving due to bacterial species by attaining a very high early strength rise and also found that the structure produced by the bio concrete is resistive to seepage and more compact due to the bacterial produce calcium carbonate in the concrete[9].

C M Meera and V Dr. Subha, this paper has been discussed about the bio concrete using B. subtilis JC_3on the durability and mechanical properties of concrete and in this experiment, they used15 * 15 * 15 cm size cubes moulds and 20* 10 *10 cm cylinders with the concrete grade of M20. The cubes and cylinder are used for test compressive and split tensile strength respectively for several bacterial solutions at 7 and 28 days. It was found that the split tensile and compressive strength increase by 62% and 42% respectively for 10^5 ml solutions of bacteria at 28 days and also other tests are done like water absorption, chloride, durability acid and assessment. Finally, they concluded loss in mass during acid exposure by the introducing of bacterial in concrete and that improving the acid attack factor of concrete. The

bacterial concrete lesser rise in mass than normal concrete and the bio concrete is less porous because of production of $CaCO_3$by bacteria in concrete and due to chloride exposure and the using of bacterial in the concrete reduce the mass loss that increases compressive strength [10].

K. Chintalapudi, R Mohan Rao.P (2016),this paper has been presented the bio technology that gains the satisfactory outcomes in remedying the micro cracks in concrete and informed that micro- cracks sealed by process of hydration in continuous situation. For better outcomes in strength and durability the improvement of pore structure and optimum bacterial solutions were did. They concluded that by the introducing of bacteria in concrete achieved reduction of permeability, keeping pH under favorable situations rise durability and compressive strength and also the potential to seal and heal the micro-cracks in concrete was found. The compressive strength observed for 91 days given satisfying results than compared to 28-day compressive strength observed for a bacterial concentration of 10^5 cells/ml. B. pasteurii used in concrete that improve the durability and cut down the water absorption in concrete structure. The bacterial solutions are the ability used as admixtures in concrete helps in enhancing the mechanical performance of concrete [11].

M ShVekariya1, Prof. J. Pitroda (2013), this paper was presented that the microorganisms used in concrete to enhance the all properties of concrete by the biological mechanisms. Bio concrete have eco- friendly, self-healing and rise in durability of several construction material this gives good technology than other normal technologies. Study of several researchers has enhanced our understanding of the possibilities and limitations of biotechnological applications on building materials. Decreasing in permeability, improving of compressive strength, corrosion of reinforcement, water absorption has been observed in several stone and cementations material. Cementation by this method is very simple and suitable for usage. Finally, they concluded that more work is regarding to economical and practical viewpoint to enhance the possibility of biotechnology with high- quality structures. [12].

R. Sri Bhavana, P. Polu Raju, S S Asadi (2014), in this study has been presented; a biological repair technique was used in which bacteria of 105cells/ml were mixed with concrete to seal the micro-cracks. The tests they did on this experiment are like Flexural, split tensile and compressive strength by B. subtilis type of bacteria for 3, 7 and 28 days. In addition to above technique fly ash was partially added in the place of cement. The cement is replacing by 10% and 30% fly ash in concrete mix tests were did generally found that cement when replacing by 10% fly ash attained maximum strength with and without bacteria than normal concrete [13].

V.Krishnan et al. (2001) this paper has been informed that MICP it's the mechanism used for healing crack and fissure by using biotechnology and they use B. pasteruii. They observed that because of the production of calcite is in the natural way the MICP is cost effective. Durability, stiffness and strength of concrete is enhancing by the use of bacterial solution in concrete. They use XRD and SEM analysis to measure the amount of precipitation of calcite and pictured. Finally, they observed that the several chemical attacks and the shrinkage enhance because of introducing of bacteria in various medium of concrete [14].

N. Chahal and R.Siddique (2008) this study has been presented that with use of Sporosarcina pasteurii which would make it, self-healing. They observed that newly formed cracks healed by the presence of bacteria. In the concrete mix 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. They did tests on the water absorption and porosity, chloride permeability and compressive strength by using up to age 91 days. They concluded that by the presence of S. pasteruii increase compressive strength, cut downs the permeability and porosity of silica fume and fly ash concrete [15].

P. Ingle, M. Shrestha, R. Potdar (2017) this paper has presented the bio concrete with and without risk husk and also permeability compressive strength tests they are did by introducing of B. pasteruii. They use 2%, 4% and 6% rise husk replacing cement and used several bacterial solutions like 10^3, 10^5 and 10^7cells/ml I production of concrete. Finally, they concluded that compressive strength rise, permeability and porosity of rice husk concrete is decrease by the introduction of B. pasteruii and also enhances durability [16].

Prof. M. Manjunath, A. A. Kalaje, Santosh A. Kadapure, (2014), This paper was presented the observation they are did the tests on the mechanical properties of concrete, chloride permeability and water absorption and also fly ash replacing cement by 10% and 20% with bacterial solutions of 10^3,10^5,10^7 using B. sphaericus at age of 28 days. Generally, they concluded that mechanical properties are improved by the presence of bacteria and decrease water absorption and permeability. The better results gains at bacterial solution of 10^5cells/ml [17].

Kunal. R. Patil, B. Waghere, B. K. Ahire, et al (2016), This research has been informed that an experiment on bio concrete with the several type of bacteria B. pasteruii and bacillus sharicus to enhancing durability and strength of concrete with the mechanism of MICP at age of 7,28 days. They found that when bacteria are added to the concrete its gives less compressive strength than nutrient broth solution by bacillus sphaericus and B. pasteruii [18].

H. Ling, C. Qian, This paper has been presented the effects of bacterial on self- healing cracks by chloride tests. Besides the method of electro-migration was used to accelerate the transmission of chloride. They observed that bacteria can heal the crack by itself that really delay the chloride

transmission in cracks and take defensive effects for RC. This study also shows good application values of microbial self-healing technique used in the practical construction and provides a new approach to reinforce the durability of structure [19].

R. Siddique, K. Singh, M. Singh, et al.They have been published paper, They cover on this paper bio concrete of 5%, 10%, 15% and 20% rise husk is replacing cement with bacterial solution of 105 cells/ml and type bacterial used is B. aerius. They did tests are for specimen up to 56 days. They found that better compressive strength is attained for rise Rusk concrete at 10% replacement and higher strength is gain for rise husk concrete with bacteria than without bacterial and also porosity, water absorption and permeability are decrease due to bacteria. Generally, they put that improved the life span of structure due to rise Rusk and bacterial present in concrete [20].

N. Balam, M. Eftekhar, D. Mostofinejad this paper has been presented bacterial based LWAC with 10^6 cells/ml bacterial solution of S. pasteruii bacteria and they did tests on rapid chloride and water permeability, water absorption and compressive strength. They found that water absorption and chloride permeability cut downs by 10% and 20% respectively and also compressive strength rise by 20% in the experimental specimens relative to the similar properties in the control ones. Furthermore, LWAC specimens with bacteria is porosity is low and denser than concrete mix with bacterial only [21].

R. Siddique, A. Jameel, M. Singh, et al they have been informed that affect of bacterial in the concrete with 5%, 10% and 15% silica fume that replacing cement by 10^5 cells/ml of bacterial solution. They observed that 10-12 percent rise in compressive strength at 28 days and also found that all properties of bacterial concrete is better than concrete without bacterial. Reduce the chloride permeability, water absorption and porosity in bio concrete [22].

Siddique, V. Nandaa, E. Kadri et al. they have been found that bio concrete with the 10%, 20% and 30% of CBFD replacing cement in bacterial concrete with 10^5 cells/ml bacterial solution and they did tests on the behavior of concrete at 56 and 28 days. Finally, they observed that cut downs of water absorption and the same compressive strength with normal concrete at 28 days by 10% CBRD cement replacing. [23].
VSrinivasa Reddy, S Sushma, M Seshagiri Rao, this paper was presented is an attempt to define the experimental investigations conducted, it was found that use of bacteria not only improves the properties characteristics of concrete but also recovers the strength lost due to damage. They concluded that at 10^5/ml cell concentration of bacterial solution extreme compressive strength would be achieved. Precipitation of these crystals inside the gel matrix may raise the durability of concrete significantly. Furthermore, they observed that when cost of production reduces carbon footprint also reduced compared to normal concrete [24].

S. Krishnapriyaa, D. Babub, G. Arulrajc,have been published a paper and found that significant rise in strength and cracks healing in concrete sample cast B. megaterium B. licheniformis and bacillus megaterium MTCC 1684. They observed that because of presence of bacterial in the concrete strength and other properties of concrete rise and also production of calcite in concrete healing a crack [25].
Pei, S.Wang, M. Yang, has published a paper and observed that, Furthermore, compressive strength and porosity rise and cut downs respectively because of cell wall of bacterial at 28 days and also because of the producing calcium carbonate in the concrete by the cell wall of bacterial voids are filled and all behavior of concrete achieved good performance [26].

3. Major Findings from the Literature Review

After completion of literature reviews, following are the numerous findings of the reviews as follows:

1. Combination of numerous types of bacteria like E. Coli, B. subtilis, S. pasteurii, and bacillus Sphaericus etc., in the concrete, caused in the enrichment of compressive strength based on the kind of bacteria, the grade of cement and other ingredients. [4,6,5,7,9,8,10,11,15, 16, 17,18,20,21,24,25]

2. Because of calcium carbonate precipitation durability and corrosion linked behavior of the concrete was improved, which can do bacteria like bacillus sphaericusin, sporosarcina pasteurii, bacillus Subtilis etc. [4,6,7,8,3,9,10,11,14,18,19]

3. At 10^5 ml/ cell bacterial solution achieved maximum compressive strength, durability and other linked behavior of bio concrete. Cell concentration of the bacteria in the water, which was introduced to the concrete. [6,7,10, 11, 13, 16, 17,20,23,24]

4. The overall behavior of the concrete improved and also some properties like microstructure, strength and density with all bacteria of bacillus group. [1,3,2,6,5,7,9, 10, 12,8,4,11,26]

5. The b. subtilis, JC3, etc introducing in concrete that decrease the water absorption of concrete [4,6,7,8,10,11,21,23]

6. The self-healing concrete are also used with other industrial waste material such as fly ash, silica fume, Rise husk and etc [16,20,22,23]

4. CONCLUSION

From the previous research paper study and above critical literature reviews following conclusions can be made

1. Properties of concrete such as compressive strength of concrete was improved in all curing period of

concrete using different type of bacterial specially bacillus type.

2. All mechanical behavior of concrete was enhanced at concentration of 106 and 107 per ml. of water into the concrete.

3. The maximum enhancement of mechanical properties of concrete at concentration of 105 per ml. of water.

4. Durability of concrete was improved as contrast to normal concrete by incorporating bacillus type of bacteria into concrete.

5. Overall performance of concrete made with use of bacteria was enhanced and it will lead to better construction practices in near future.

6. Bio concrete is new construction material that improves overall properties of concrete and environmental friendly material.

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