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Analysis of the Impact of Bacterial-Based Building Material as an Advanced Innovative Approach to Sustainable Building Construction in South East Nigeria

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ABSTRACT
The bacteria used as admixture to building materials are acid producing bacteria. These types of bacteria can be in dormant cell and be viable for decades under dry conditions. These bacteria act as a catalyst for automatic building maintenance. The responses of thirty-four builders randomly selected from south-eastern zone of Nigeria were used to elicit information on the positive and negative impacts of bacteria-based building materials towards the achievement of sustainable buildings in Nigeria. The data collected were analyzed using means, while t-test statistic was used to test the hypothesis. The finding of the study shows that the positive and negative impacts of bacteria-based building materials have significant influence in the realization of sustainable buildings. Therefore, bacteria-based building material is an innovative technique towards the achievement of sustainable buildings in Nigeria. Contractors and clients should be sensitized by relevant professional bodies on the positive impact of this building material. Stakeholders in Nigeria construction industry should collaborate with expects in other countries to abate the negative impact of this material in Nigeria building industry.
Keywords: *Bacteria, preparation of bacteria-based building material, mechanism of bacteria-based building material, impacts of bacteria-based building material.*

INTRODUCTION

According to Prabhu (2016), bacteria producing the enzyme urease are used in bio-cement technology. Prabhu maintained that scientists have reported the use of bacteria proteus, klebsiella, and bacillus for bacteria-based building material. Certain bacteria can utilize urea present in the material by the production of enzyme urease. This enzyme hydrolyzes urea to ammonia and carbon dioxide. Ammonia increases the pH of the surrounding and carbon dioxide combines with calcium ions resulting in formation of calcium carbonate in the form of calcite. Jonkers (2010) highlighted that, the bacteria spores that have a life of about fifty years, when inserted directly into the concrete mix, undergo a drastic decrease in life expectancy. Wiktor (2011) maintained that, the immobilization of bacteria in porous clay aggregate before the conglomerate mixing can greatly extend their life. The principle mechanism of bacterial crack healing is that the bacteria themselves act largely as a catalyst, and transform a precursor compound to a suitable filter material. For effective self-healing, both bacteria and a bio-cement precursor compound should be integrated in the material matrix. However, the presence of the matrix-embedded bacteria and precursor compounds should not negatively affect other wanted concrete characteristic. Bacteria that can resist concrete matrix incorporation exist in nature and these appear related to a specialized group of alikali-resistant spore-forming bacteria (Jonkers, 2011). Interesting feature of these bacteria is that they are able to form spores, which are specialized spherical thick-walled cells homologous to plant seeds. These spores are viable and can withstand mechanical and chemical stresses and remain in dry state viable for

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periods over 50 years. Cement and water have a pH value of up to 13 when mixed together, usually a hostile environment for life (most organisms die in an environment with a pH value of 10 or above). Microbes that thrive in alkaline environment which can be found in natural environment such a alkali lakes in Russia, carbonate-rich soils in desert areas of spain, and soda lakes in Egypt (Jonkers, 2011). Jonkers maintained that, samples of endolithic bacteria (bacteria that can live inside stones) were collected along with bacteria found in sediments in the lakes. Strains of the bacteria genus bacillus were found to thrive in this high alkaline environment. Different types of bacteria were incorporated into a small block of concrete. Each concrete block would be left for two months to set hard. Then the blocks would be pulverized and the remains tested to see whether the bacteria had survived. The group of bacteria that were able to survive was the ones that produced spores comparable to plant seeds. Such spores have extremely thick cell walls that enable them to remain intact for up to 200 years while waiting for better environment to germinate. They would become activated when the concrete starts to crack, food is available (calcium lactate), and water seeps into the structure. This process lowers the pH of the highly alkaline concrete to values in the range (pH 10 to 11.5) where the bacterial spores become activated.

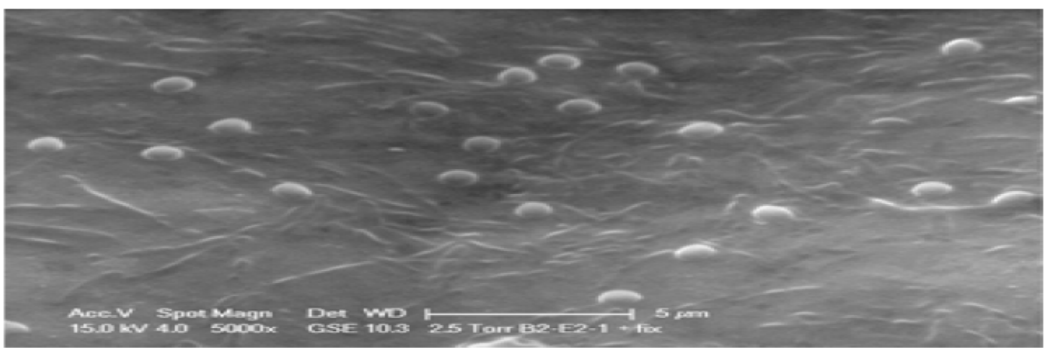

Figure 1. ESEM Photomicrograph (5000x Magnification) of Alkali-Resistant Spore Forming Bacterium (Bacillus Strain B2-E2-1). Visible are active vegetative bacteria (rods) and spores (spheres), showing that spore diameter sizes are in the order of one micrometer.
Source: Bacteria-based concrete (Jonkers, 2011).

MECHANISM OF BACTERIAL-BASED BUILDING MATERIAL

Self-repair concrete is a result of biological reaction of non-reacted limestone and a calcium based nutrient with the help of bacteria to heal the cracks appeared on the building. Special types of bacteria known as bacillus are used along with calcium nutrient known as calcium lactate. While preparation of concrete, this products are added in the wet concrete when the mixing is done. These bacteria's can be in dormant stage for around 200 years. When the cracks appear in the concrete, the water seeps in the cracks. The spores of the bacteria germinate and starts feeding on the calcium lactate consuming oxygen. The solution calcium lactate is converted into insoluble limestone. The insoluble limestone starts to harden, thus, filling the crack automatically without any external aide.

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As the oxygen is consumed by the bacteria to convert calcium into limestone, it helps in the prevention of corrosion of steel due to cracks. This improves the durability of steel reinforced concrete construction.

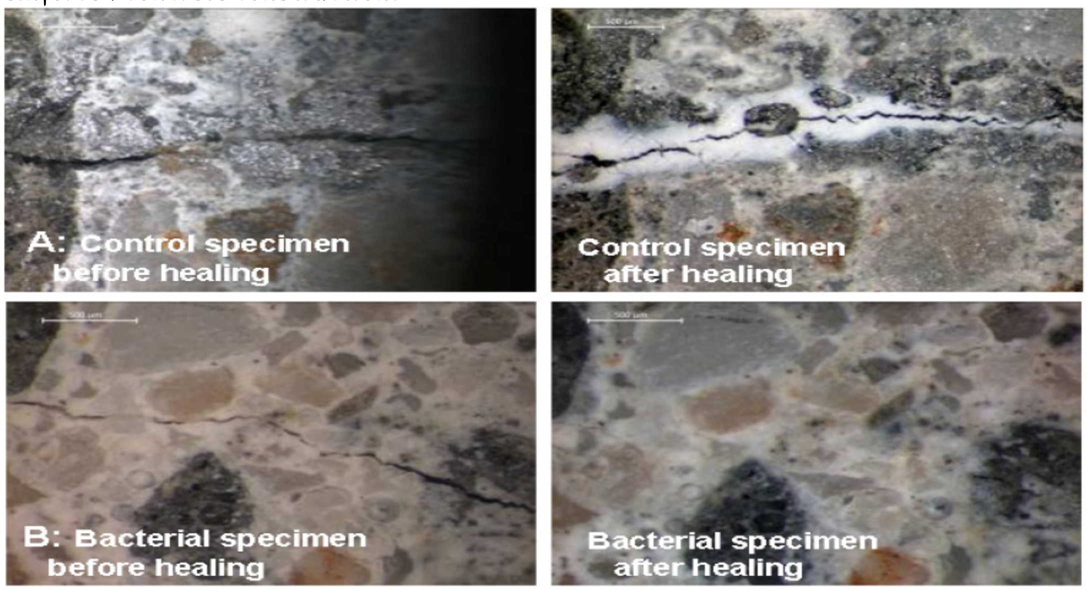

Figure 2. Light Microscopic Images (40 times Magnification) of Pre-cracked Control (A) and Bacterial (B) Concrete Specimen before (left) and after (Right) Healing (2 Weeks Submersion in Water). Mineral precipitation occurred predominantly near the crack rim in control but inside the crack in bacterial specimens. Efficient crack healing occurred in all six bacterial and two out of six control specimens.
Source: Bacteria-based self-healing concrete (Jonkers, 2011).

PREPARATION OF BACTERIAL-BASED BUILDING MATERIAL

Bacterial Concrete can be Prepared in two Ways:
By Direct Application
By Encapsulation in Lightweight Concrete

In direct application method, bacterial spores and calcium lactate is added into concrete directly when mixing of concrete is done. The use of this bacteria and calcium lactate doesn't change the normal properties of concrete. The bacteria are exposed to climatic changes. When water comes in contact with this bacteria, they germinate and feed on calcium lactate and produces limestone, sealing up cracks. By encapsulation method, the bacteria and its food are placed inside treated clay pallets and concrete is prepared. About 6% of the clay pallets are added for making bacterial concrete. Encapsulated method is commonly used, even though it's costlier than direct application.

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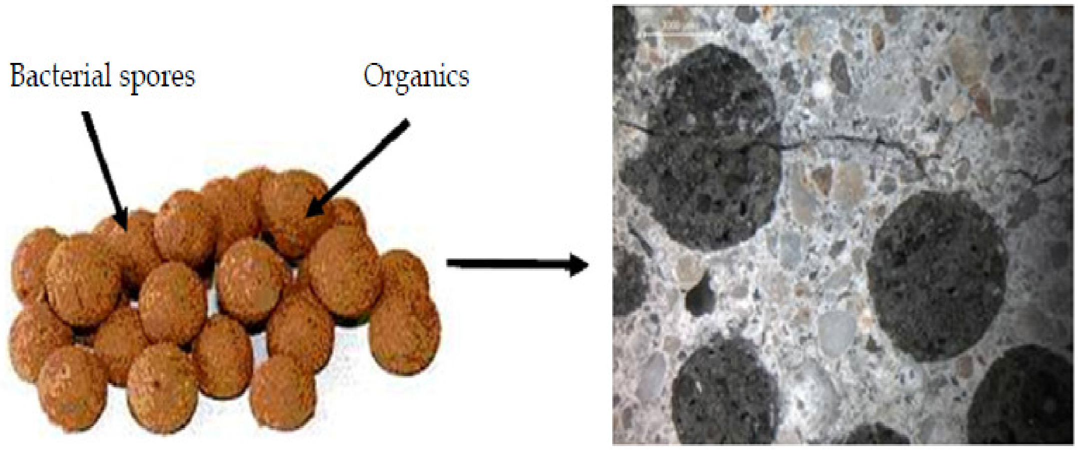

Figure 3. Self-healing Admixture Composed of Expanded Clay Particles (left) Loaded with Bacterial Spores and Organic Bio-Mineral Precursor Compound (Calcium Lactate). When embedded in the concrete matrix (right) the loaded expanded clay particles represent internal reservoirs containing the two-component healing agent consisting of bacterial spores and a suitable bio-mineral precursor compound.
Source: Bacteria-based self-healing concrete (Jonkers, 2011).

Chemical Process of Bacterial-Based Building Material

When water comes in contact with the unhydrated calcium in the concrete, calcium hydroxide is produced by the help of bacteria, which acts as a catalyst. This calcium hydroxide reacts with atmospheric carbon dioxide and forms limestone and water. This extra water molecule keeps the reaction going. The limestone then hardens itself and seals the cracks in the concrete.

Advantages and Disadvantages OF Bacterial Concrete

Advantages

Self-repairing of cracks without any external aide. Significant increase in compressive strength and flexural strength when compared to normal concrete. Resistance towards freeze-thaw attacks. Reduction in permeability of concrete. Reduces the corrosion of steel due to the cracks formation and improves the durability of steel reinforced concrete. Bacillus bacteria are harmless to human life and hence, it can be used effectively.

Disadvantages

Cost of bacterial concrete is durable than conventional concrete. Growth of bacteria is not good in any atmosphere and media. The clay pellets holding the self-healing agent comprise 20% of the volume of the concrete. This may become a shear zone or fault zone in the concrete. Design of mix concrete with bacteria here is not available in any code of practice. Investigation of calcite precipitate is costly.

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RESEARCH QUESTION

What are the impacts of bacterial-based concrete in the achievement of sustainable buildings?

HYPOTHESIS

H_o: the positive and negative impacts of bacterial-based concrete have no significant influence in the achievement of sustainable buildings.

METHODOLOGY

The study was a survey research. The researcher narrowed the research work to concrete. The responses of thirty-four builders randomly selected from south-eastern zone of Nigeria were used to elicit information on the positive and negative impacts bacteria-based concrete towards the achievement of sustainable building in Nigeria. The data collected were analyzed using means, while t-test statistic was used to test the hypothesis. The decision was that any mean from 2.50 and above was regarded as Agree/High influence while those with less than 2.50 were regarded as Disagree.

Table 1: Mean Analysis of Respondents' Responses on Positive Impacts of Bacteria-Based Concrete

S/N Item Statement	X	SD	Remark
Repairing of cracks without any external aide.	3.14	1.91	Agree
Significant increase in compressive strength and flexural strength when compared to normal concrete.	2.88	1.08	Agree
Resistance towards freeze-thaw attacks.	3.63	1.59	Agree
Reduction in permeability of concrete.	3.09	1.44	Agree
Reduces the corrosion of steel due to the cracks formation and improves the durability of steel reinforced concrete.	3.66	1.32	Agree
Bacillus bacteria are harmless to human life and can be used effectively.	3.57	0.88	Agree

Source: Field Survey (2019).

Table 2: Mean Analysis of Respondents' Responses on Negative Impacts of Bacteria-Based Concrete

S/N Item Statement	X	SD	Remark
Cost of bacterial concrete is durable than conventional concrete.	2.89	0.92	Agree
Growth of bacteria is not good in any atmosphere.	3.01	1.15	Agree
The clay pellets holding the self-healing agent comprise 20% of concrete volume. This may become a shear zone or fault zone in the concrete.	2.73	0.86	Agree
Design of mix concrete with bacteria here is not available in any code of practice.	2.65	1.27	Agree
Investigation of calcite precipitate is costly.	3.21	1.43	Agree
Not readily available.	3.58	0.11	Agree

Source: Field Survey (2019).

Table 3: T-test of the Analyses of the Positive and Negative Impacts of Bacterial-Based Concrete have no Significant Influence in the Achievement of Sustainable Buildings.

Variables	Impact	N	X	SD	Df	t-cal	t-crit	Remark
Positive	impact	35	2.87	0.98	2	2.21	1.98	Reject H_o
Negative	impact	35	2.64	1.10	68.70			

DECISION

From table 1 and 2, the respondents' responses in all the items have mean points above the cut-off point of 2.00. These however indicate that bacteria-based concrete have a high influence in the achievement of sustainable buildings. In table 3, the value of the t_{CAL} of 2.21 is greater than the t_{CRI} value of 1.96. Hence, the H_O is rejected. This shows that the positive and negative impact of bacteria-based concrete have significant influence in the realization of sustainable concrete.

CONCLUSION

Bacterial-based concrete is a product that will biologically produce limestone to heal cracks that appear on the surface of concrete structures making it sustainable. Specially selected types of the bacteria genus bacillus, along with a calcium-based nutrient known as calcium lactate, nitrogen and phosphorus, are added to the ingredients of the concrete when it is being mixed. Currently, the cost of this new technology is still considered prohibitive, as it is twice the cost of regular concrete manufacture. But, bio-concrete reduces cost of maintenance on a building. Additionally, bio-concrete is an effective technique towards the production and achievement of sustainable buildings in modern construction.

RECOMMENDATIONS

Contractors and clients should be sensitized by relevant professional bodies on the positive impact of bacteria-based concrete. Stakeholders in Nigeria construction industry should collaborate with expects in other countries to abate the negative impact of bacteria-based concrete in Nigeria building industry. Buildings types that requires compulsorily bio-concrete (bacteria-based) should be clearly classified by expects.

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