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Bioconcrete Use in the World

Bianca Aparecida Fernandes Veloso[1], Clésio de Oliveira Mariz[2], Aniel da Costa Lima[3], Bruno da Cruz Pádua[4], Thiago Bomjardim Porto[5]
[1,2]Bacharel Engenharia Civil, Centro Federal de Educação Tecnológica de Minas Gerais, Campus Curvelo
[3,4,5]Professor Efetivo, Centro Federal de Educação Tecnológica de Minas Gerais, Campus Curvelo
([1]biancaveloso@outlook.com, [2]clesiomariz@hotmail.com, [3]aniel@cefetmg.br, [4]brunopadua@cefetmg.br, [5]thiago.porto@cefetmg.br)

Abstract-The construction industry is one of the activities that cause the greatest impact on the environment and society in recent years has been increasingly concerned about sustainability and methods that do not lead to environmental degradation or pollution. The use of bacteria in concrete is an idea that has gained a lot of strength in recent years. Its working process is similar to biomineralization that occurs in nature. The use of bacteria in concrete and mortar allows the filling of cracks and the regeneration of structures, as well as an increase in the strength of concrete.

Keywords- *Concrete, Bioregeneration, Bacterium*

I. INTRODUCTION

Society is in a constant process of evolution, as a consequence the types of constructions, the construction methods and the materials used change. Today a theme that is under constant discussion in construction is sustainability, seeking ways to build with less waste, extending the life of the building and generating less maintenance waste are increasingly in focus.

Concrete is a material that is intensely employed in construction. It is characterized by being a plastic material that can adapt to a predetermined shape and that when dry presents resistance similar to natural rocks [1]. Due to its characteristics the consumption of concrete has become increasingly intense, with various purposes being used in homes, buildings, special works of art, highways, among other enterprises.

Concrete has several advantages, but depending on the environment, the way it is produced, the characteristics of the materials used and other external factors, it can present cracks, pathologies and in severe situations can compromise the structure and prevent its use. In an attempt to improve its characteristics, new studies, materials and techniques have been employed in concrete in all parts of the world.

The use of bacteria in concrete to prevent cracking processes, future pathologies, reduce maintenance costs and ensure a longer service life has been studied worldwide. Microbiologist Henk Jonkers was primarily responsible for the study conducted by the University of Delft in the Netherlands in recent years [2]. The initial idea is to promote the regeneration of concrete in a natural way similar to what happens in nature and in the human body.

Despite being a new technology, some enterprises have already employed or intend to employ this new technology in their constructions, in order to promote a longer service life and avoid maintenance costs.

II. BIOLOGICAL CONCRETE WORKING PRINCIPLE

The principle of operation of biological concrete is through the action of bacteria that when finding the right medium can feed and excrete calcium carbonate (CaCO3), this process occurs through biomineralization [3]. Biomineralization occurs naturally, living beings have the ability to produce minerals that promotes the hardening or stiffening of existing structures (tissues). In biocalcification, calcium carbonate ($CaCO_3$) precipitation occurs by the union between calcium cations (Ca^{2+}) and carbonate ions (CO_3^{2-}), according to equation 1.

$$Ca2+ + CO32- \rightarrow CaCO3\ (s) \quad (1)$$

Microbial Induced Carbonate Precipitation (MICP) carbonate production occurs through the accumulation in calcium extracellular medium that is not used by microorganisms [4]. Bacteria to be used in concrete must be resistant to extreme environments, such as volcano craters, and be able to precipitate calcium carbonate by having a food source in their surroundings; The bacteria that best exhibit these characteristics and can be used are: Bacillus pseudofirmus, Bacilluscohnii, Escherichia coli, Bacillus pasteurii, Bacillus balodurans, Bacillus subtilis e Bacillus sphaericus [5].

Figure 1 shows a representative scheme of how calcium carbonate precipitation occurs from the urea. This process occurs when calcium ions in the solution are attracted to the bacterial cell wall due to its negative charge. After the addition of urea to the bacteria, carbon dioxide and ammonia are released [3].

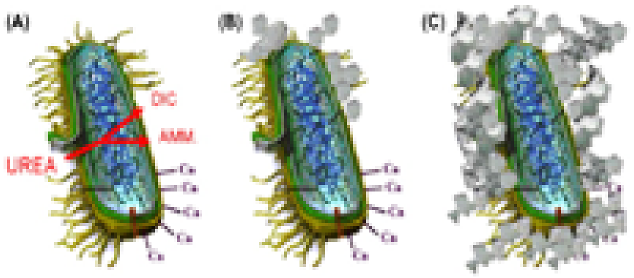

Figure 1. Representative scheme of how calcium carbonate precipitation occurs. Source: PELEGRINELLO, 2017

For calcium carbonate production to occur, the bacteria chosen for use in concrete must have some source of calcium at their disposal, such as calcium lactate. The process of mixing the bacteria in the concrete can be by encapsulating the bacteria and their food source in an expanded clay capsule that is added to the concrete mix, the other way to mix is to place the bacteria directly and your food directly (concomitantly) during concrete production. In both cases the bacteria were latent until cracking occurs in the concrete and upon contact with water the bacteria will feed and substrate present in the medium and will release calcium carbonate.

Some environmental factors, such as temperature, pH, the concentration of inorganic carbon present in the dissolved medium and the presence of nucleation sites can interfere with the calcium carbonate production generated by the bacteria. The temperature range they can perform is between 20 and 37 degrees Celsius, but the ideal temperature is 35 degrees and the pH should be in the basic range between 8.7 and 9.5 this is very beneficial as concrete is a alkaline mixture [6].

A limiting factor for the use of biological concrete is the thickness of the crack, since the extent to which the bacteria act on the crack is unlimited, but the crack thickness should not exceed 8 mm, as values above this thickness may compromise the integrity of the concrete [7]. According to [8] the Crack Formation Limit State (ELS-F) states that the maximum cracking that can be achieved without compromising the structure is 0.4 mm according to Table 1, so bacteria can meet thicknesses greater than those established by the Brazilian standard.

TABLE I. DURABILITY REQUIREMENTS RELATED TO CRACKING AND REINFORCEMENT PRESTRESSING, ACCORDING TO THE ENVIRONMENTAL AGGRESSIVENESS CLASSES (ADAPTED). SOURCE:ABNT, 2014.

Structural Concrete Type	Environmental Aggressiveness Class (CAA) and prestressing type	Crack Requirements	Combination of actions in service to be used
Simple Concrete	CAA I a CAA IV	Não há	--
Reinforced Concrete	CAA I	ELS - W wk ≤ 0,4 mm	Frequent combination
	CAA II e CAA III	ELS - W wk ≤ 0,3 mm	
	CAA IV	ELS - W wk ≤ 0,2 mm	
Precast Concrete Level 1 (partial prestressing)	CAA I pretension or CAA III and IV posttraction	ELS - W wk ≤ 0,2 mm	Frequent combination
Prestressed Concrete Level 2 (limited prestressing)	CAA II pretension or CAA III and IV posttraction	Check both conditions below	
			Frequent combination
		ELS - D[1]*	Almost permanent combination
Prestressed Concrete Level 3 (complete prestressing)	CAA III and IV pretension	Check both conditions below	
		ELS-F	Rare combination
		ELS - D[1]*	Frequent combination
[1]* At the designer's discretion, the ELS-D may be replaced by the ELS-DP with a_p = 25mm			
1 The definitions of ELS-W, ELS-F and ELS-D are in 3.2.			
2 For environmental aggression classes CAA-III and IV non-adherent chords are required to have special protection in the region of their anchorages.			

III. PLACES YOU ALREADY USED IN THE WORLD

Studies on the use of bioconcrete are recent, but point to the benefits of avoiding cracking and cracking in buildings as well as avoiding expansion joints.

Some major and relatively large works are already using biological concrete, such as a 60-story building in Osaka Prefecture, Japan, and a bridge built in 2006 over Interstate 94 in Michigan, USA [9].

This building is about 300 meters high and is considered a high altitude work for Japan, as it is a country that suffers from frequent earthquakes and as a consequence its constructions may present cracks and cracks from the movement. The bridge built on Interstate 94 in Michigan, USA, eliminated the use of traditional expansion joints [9] and avoided the concern of frequent maintenance on the structure.

To verify the actual results in the biological concrete, a residence was built (Figure 2) which is periodically inspected [7]. Thus, it is possible to evaluate the possible consequences of the insertion of bacteria in the concrete.

Figure 2. Residence built with biological concrete. Source: PET ENG. CIVIL UFSC,2016. http://pet.ecv.ufsc.br/2016/10/bioconcreto-o-concreto-que-ganhou-vida/

IV. Cost

The benefits of using biological concrete are significant in terms of saving time and money in maintaining bridges, buildings, water supply systems, and avoiding the disruption and disruption of daily activities to perform structural repairs. However, bioconcrete is a new technology and as such has a high cost both because it is being implemented by companies operating in the field of construction, and because it demands a higher cost because it is a smaller scale of production until its full diffusion in the world market [2].

Today the use of biological concrete generates a cost about 3 times higher than conventional concrete and depending on the size of the project can directly affect the budget of the work. But when taking stock and checking the long-term savings generated by maintenance and repairs that require skilled labor and skilled projects, it becomes apparent that it is economically viable to use biological concrete [10].

V. Conclusion

The emergence of cracks and pathologies in concrete is very common in everyone. And the search for new technologies is crucial to avoid these problems.

The use of bacteria that produce calcium carbonate mixed with concrete appears as a possibility to solve cracks and ensure a longer service life, avoiding frequent maintenance and repairs in buildings.

Therefore, the use and dissemination of this new technology in the construction market is essential to ensure that it remains in the market and can increasingly encourage new discoveries and technologies to be researched and used in construction.

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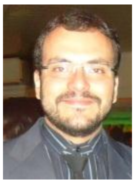
Bianca Aparecida Fernandes Veloso, Graduated in high school and technical from the Federal Center for Technological Education of Minas Gerais, Curvelo Unit, in the Environment course; She is currently a Civil Engineering intern at the Minas Gerais Sanitation Company – COPASA

Clésio de Oliveira Mariz, Graduated in Mathematics from the Federal University of Juiz de Fora (2013). Has experience in Mathematics, focusing on Mathematics. Currently graduating in Civil Engineering at CEFET MG

Aniel da Costa Lima, Master in Environmental Engineering and Bachelor of Chemistry - Industrial Chemical Qualification from the Federal University of Ouro Preto. Professor of the General Training Department of CEFET-MG Campus X - Curvelo. Has experience in Chemistry, focusing on Environmental Chemistry in the analysis of organic micro pollutants in water and air. Has expertise in instrumental analysis such as atomic absorption spectrophotometry, flame and UV-Vis spectrophotometry, liquid chromatography coupled to mass spectrometry and gas chromatography coupled to mass spectrometry, method validation and environmental legislation. Participates in a research group on uncertainty analysis and system reliability.

Bruno da Cruz Pádua, Graduated in Biological Sciences in the modalities of Bachelor and Bachelor degree from the Federal University of Ouro Preto (UFOP) and master and doctorate in the area of Structural and Physiological Biochemistry by the Postgraduate Program in Biological Sciences also by UFOP. He is currently an effective professor and researcher at the Federal Center for Technological Education of Minas Gerais (CEFET), Curvelo campus, where he teaches the General Biology course for the Environment, Building and Electrotechnical courses and develops research related to Biochemical and Physiological Action. Cerrado plants. In addition, he served as Deputy Chief and Head of the General Training Department, Extension and Community Development Coordinator and Research Coordinator. Currently, in addition to biology classes, he serves as Deputy Director of Campus Curvelo.



Thiago Bomjardim Porto, Graduated in Civil Engineering from the School of Engineering of UFMG (2008) and Master in Civil Engineering, with emphasis in Structures, in this same institution (2010). PhD in Civil Engineering, with emphasis in Geotechnics from UFOP (2015). He currently teaches at CEFET-MG, teaching the following subjects: Soil Mechanics I, Soil Mechanics and Foundations (MSF), Reinforced Concrete I, Reinforced Concrete II and Special Topics in Structures: Bridges and Viaducts. He has been a collaborating professor in the Graduate Program at NUGEO / UFOP since 2016, working with teaching (Foundations Structures and Containment and Foundations Pathology) and research (masters and doctorate orientations and co-orientations). Has experience in Earthworks, Tailings and Barren Mining, Soil-Structure Interaction (ISE), Containment Geotechnics and Foundation Engineering, Special Artworks (Bridges, Viaducts and Walkways), Experimental Soil Mechanics, Theoretical Soils and their applications (monitoring anchored containment structures). In the private sector, he worked for over a decade in the development of natural slope and mining stability projects, foundations and containment projects, especially industrial (mining, oil / gas and steel), residential, commercial and infrastructure projects general.

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