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The Use of Biochemically Modified Silicate in the Mechanisms of Pathological Manifestations Increasing the Life of Reinforced Concrete Structures

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Abstract: This article aims to analyze and present the various uses and protections of biochemically modified silicate in increasing the lifetime of reinforced concrete structures in severely aggressive conditions. The biochemically modified silicate is associated with the free calcium of concrete. Every time it comes into contact with moisture, the gel reacts chemically resulting in the formation of a C-S-H gel inside the concrete. By expanding, the gel seals empty pores and capillaries inside the structure, protecting it and acting on the mechanism of several pathological manifestations that requires the free calcium of the concrete to occur. By incorporating into the reinforced concrete structure, biochemically modified silicate provides definitive (self-healing) regenerative properties to the structure. Whenever it comes into contact with moisture the chemical reaction within the concrete causes the C-S-H gel to form and expand as the structure needs. Its reaction follows the porosity and cracking of the structure, filling the necessary voids for protection of the concrete structure, and acting on one of the main factors generating pathological manifestations in the structure, the free calcium. The increase in the lifetime of the structure, its protection against the main pathological manifestations in concrete structures and the sustainability that this system has provided for more than 40 years in the world market for reinforced concrete structures are pillars of the contribution of the development of good technique in Brazilian engineering.

Key words: biochemically modified silicate, concrete protection, degradation mechanisms, pathological manifestations

1. Introduction

Reinforced concrete structures are widely used as key pillars in the development of the economy and society as a whole, from residential, commercial, industrial to infrastructure projects. Its application is well accepted due to its excellent cost-benefit, where its useful life is a determining factor for success. Thus, it is essential that the behavior of the structure occurs in a way that meets the minimum life of the project and consequently the economic and financial viability of the enterprise.

In order to meet the expectation of an adequate design life, it is necessary to take into account what type of structure is to be designated and what aggressiveness it will be subjected to.

The moment of concreting the structure is crucial. Special care should be taken with the densification of the concrete and the concrete must heal correctly. However, in the process of performing the procedures correctly, the newly concrete structure, can present itself irregularly and since concrete structures are mainly in environments of severe aggressiveness, the weaknesses and deficiencies of the structure will be revealed in a short time, regardless of the quality of the project and the materials used [1]

In order to maintain the durability of concrete structures, one must analyze both the external factors, environment in which the structure is inserted, as well as internal factors, its chemical composition. The mechanisms of action of the main external aggressors

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will be analyzed, but in the microstructure of reinforced concrete there are three factors that are fundamental and greatly influence the process of its degradation: the porosity of the concrete, the free calcium present in the structure after hydration of cement, and water from the environment. These three actors are responsible for the appearance of the vast majority of pathological manifestations in concrete structures, influencing and reducing their useful life, considerably increasing their maintenance cost, and directly affecting the financial planning of the cost-benefit related to the useful life of the enterprise. Therefore, it is essential to protect the structure of reinforced concrete in order to achieve an increasing service life. Depending on environmental conditions and the place where the reinforced concrete structure is inserted, there is a greater or lesser need for protection of the structure, because the aggressiveness in the concrete varies according to the environment in which it is inserted.

There are several techniques that allow to protect the structures from external aggressiveness. Most protections are associated with the outer part of the concrete structure with the use of barriers, usually through membranes or protective layers, such as polyurethane membrane, epoxy, increased cover of the structure, among others. However, there are also internal protections, used within the concrete structure, such as the use of zinc inserts for cathodic protection, and silicate-based materials that react with concrete, among others.

All these protections used in concrete structures come from tests and studies related to concrete structures where the protection capacity and service life of each solution must be carefully analysed. Depending on, for example, its useful life, there is a need to reapply this protection, which does not only interfere in the cost of the material and labor employed in the process, but, especially in cases of industrial areas, there is the need to paralyse the production process in order to be able to protect the structure again, causing multimillion-dollar losses. Gjorv (2015) [1] Reports have shown that more and more owners of concrete structures have realized that small additional costs related to design and execution greatly impact the durability and life of the structures, becoming an excellent investment.

This concern with the economic viability related to the lifetime of the structures is not recent. According to MCBEE (1983), in its report to the U.S. Department of the Interior, the chemical attack of sulfate in reinforced concrete in the United States annually brings multimillion-dollar losses to industrial plants of metallurgia, fertilizers, and chemicals due to the loss of productivity caused by maintenance and repairs from the attack of sulfates on reinforced concrete structures.

This work seeks to present some of the main mechanisms of degradation of reinforced concrete structures, such as chloride attack and sulfate attack, how the biochemically modified silicate solution completely incorporates itself into the concrete structure and its chemical composition and is capable of providing several protective benefits to the structure in which it has been applied.

2. Degradation Mechanisms

The pathological manifestations of reinforced concrete structures are nothing more than the final result of the entire physical-chemical process related to the environment in which the concrete structure is inserted. Therefore it is essential to carry out the pathology, that is, to study the reasons why the structure reacts with the environment in which it is inserted. It is essential to understand the mechanisms of degradation of reinforced concrete structures because this is the origin of the whole process. Therefore, the degradation mechanisms related to the attack of relacionados, a carbonation, chloride attack, and the attack of sulfates will be presented.

2.1 Carbonation

Carbonation is one of the main factors, if not the main deleterious factor, to the reduction of PH in the structure. When delving inside the concrete, the carbonation front reaches the depth of the reinforcement, ending the external protection. When PH is close to 9, the concrete allows the start of the process of depassivation of steel and consequently its corrosion process.

Its chemical reaction is expressed in Eq. (1), where carbon dioxide reacts with water, forming carbonic acid, which by reacting with calcium hydroxide from the cement paste forms calcium carbonate and water, providing more water to react with carbon dioxide, allowing asism that the carbonation front deepens more and more in the structure reducing its PH until it reaches the depth of the steel, thus allowing the start of the corrosive process.

$$CO_2 + H_2O \rightarrow \underset{\text{Carbonic Acid}}{H_2CO_3} + Ca\,(OH)_2 \rightarrow \underset{\text{Calcium Carbonate}}{CaCO_3} + H_2O \quad (1)$$

2.2 The Chloride Ion Attack

Chloride ion attack will only happen after the depassivation of the layer of steel, which in turn is protected by the high value of PH that the concrete structure provides. If the PH remains between 12.3 to 13.5 [2], which are the values that the concrete assumes without any aggressiveness, the oxidation of steel will not occur. However, there are several aggressive agents in concrete structures, including chloride, whose chemical reaction of chlorine ion with water, forms hydrochloric acid, expressed in Eq. (2), which has the ability to reduce the PH of concrete.

$$Cl^- + H_2O \rightarrow \underset{\text{Hidrochloric acid}}{HCl} + O_2 \qquad (2)$$

After the beginning of the corrosion of the steel, with oxidation, the steel expands, generating internal stresses that can cause cracks and the disintegration of the concrete, further accelerating the corrosive process. Seeking to protect the lifetime of concrete structures inserted in aggressiveness with chloride attack, several technical solutions are used, among them: increased reinforcement cover, use of membranes adhered to the external face of the concrete structure, additions used in the mixture of cement mass, additions applied later to concreting, in addition to protections capable of absorbing the loads generated depressing the corrosion process of the reinforcement, such as the application of an external electrical potential for chlorine ion extraction, developing a migration mechanism [3].

Helene (2003) [4] presents the importance of diffusion of chloride ions on external faces of reinforced concrete structural components exposed to the aggressiveness of chloride ion attack relating the thickness of the reinforced concrete cover, the age of the structure, and its resistance to compression. The greater the compressive strength of the structure, the greater its density, with lower porosity and void index, hindering the penetration and locomotion of aggressive agents inside the reinforced concrete structure, providing greater protection. Thus, in order to project a certain lifetime of reinforced concrete structures, it is extremely relevant to analyze the impact on the financial cost of the enterprise between changing the thickness of the reinforcement cover or changing the strength of the concrete in order to achieve the life of the project.

The reduction of the PH of the concrete structure provides the appropriate environment for the penetration of more chlorine ions that will act in the corrosive process of the reinforcements, according to the Eq. (3) [2].

$$Fe^{++} + 2Cl^- \rightarrow FeCl_2$$
$$FeCl_2 + 2H_2O \rightarrow Fe(OH)_2 + 2HCl \qquad (3)$$

Chloride ion attack on reinforced concrete structures is one of the main deleterious agents and annually generates costs of hundreds of millions of reais to carry out the necessary structural recoveries. Main causes are the lack of monitoring and maintenance to concrete structures. Not performing preventive maintenance and leaving chloride ions to carry out corrective interventions costs are about 5 times more than if preventive maintenance were carried out [5].

2.3 Sulfate Attack

The deletery action of sulfate attack on concrete structures can also be considered one of the main deteriorating agents of these structures, which can be found in natural waters, soil, sea, industrial effluents, sewage, among others [6].

Sulfate ion attack (SO_4^{2-}) occurs in concrete structures both saturated by diffusion and dry by absorption. Sulfate ions (SO_4^{2-}) when reacting with calcium, potassium, sodium, and magnesium in concrete, soil or present in water form sulfates. The different types of sulfates deteriorate the concrete, however its aggressiveness and mechanisms depend on the type of sulfate being analyzed. According to CESÁRIO (2015) [7], the sulfate associated with water penetrates through the pores of the hardened cement paste, reacting with the cement hydration compounds, forming compounds such as ettringite ($Ca_6Al_2(OH)_{12}*(SO_4)_3*26H_2O$) and gypsum ($CaSO_4*2H_2O$). These two compounds have the characteristic of occupying a larger volume than the original compound, this causes internal stresses in the concrete that ends up cracking, thus allowing a greater amount of sulfates to penetrate the structure, in addition to other aggressive agents such as water, chlorides ions (Cl^-) and carbon dioxide (CO_2).

According to Coutinho (2001) [8], the attack of sulfates on concrete requires calcium hydroxide and water to be able to react with the tricalcium aluminate or with the aluminum oxide of the aggregate to result in hydrated calcium ettringite, gispista and sulfoaluminate, forming a compound with final volume 2.5 times greater than the initial volume, causing internal stresses, irregular cracking of the concrete, further accelerating the deterioration of the structure.

Centurione (2003), is emphatic when stating that:

“There is unanimity in accepting that the increase in the slag or pozzolan content leads to an increase in the resistance to sulfates in concrete.

This increased resistance is mainly attributed to:

a) combination of slag or pozzolan, with calcium hydroxide, forming C-S-H and leaving less $Ca(OH)_2$ free;

b) refinement of the pore structure, making ionic diffusibility difficult;

c) modification of the system’s chemistry, with the formation of monosulfoaluminate instead of ettringite, and consequently with insignificant expansion.

Understanding that the attack of sulfates from sewage is an extremely important factor to be analyzed, its mechanism will be presented in item 2.3.1

2.3.1 Attack by Sulfates in the Sewer

The attack of sulfates (SO_4^{-2}) generated by the sanitary sewage has severe aggressiveness to the integrity of reinforced concrete structures. Its importance is quite relevant, since most cities have a basic sanitation system and the impact of this aggressiveness on effluent treatment facilities and especially in pipes that interconnect the system. If they fail, it can impact on the lives of thousands of people, generating direct and indirect costs of the order of millions of reais.

The life of a water supply system or rainwater or sewage collection system should be taken with extreme importance and care, because the cost of its implementation is quite high, time consuming and ends up directly interfering in the road flow of cities with excavations and other interventions, thus altering people’s travel habits for a considerable time. All these indirect costs should be taken into account when choosing the technical solution that should be used to protect the concrete structure, because the longer the useful life of the chosen solution, the lower the cost felt by the population. In some cases, the indirect costs generated in society and in the economy by such an intervention may be even greater than the cost of implementing the work itself. What will be said if this intervention is related to any system failure, generating corrective maintenance.

According to Von Sperling (2005) [9], the PH of the sanitary sewage is in the range of 6.7 to 8.0, which causes the reduction of the PH of the concrete structure, allowing the attack of other chemical elements to the reinforcements. In addition to acting in the reduction of the PH of the concrete, the reaction of sulfuric acid formed with calcium hydroxide of cement paste, form gipsita (4), which reacting with tricalcium aluminate and water forms ethyringite (5) [10]. The molecular gypsum and ethringite formed, have a volume that is much larger than its original volume, from 124% to 700% of its initial volume [10, 11], thus generating internal tensile stresses that cause cracking and deplatement of concrete, accelerating the deleteheric action of sulfuric acid on the concrete structure and allowing acidic agents to deteriorate the reinforcements.

$$\begin{matrix} SO_4^{-2} \\ + \\ \text{reducing bacteria} \end{matrix} \rightarrow \begin{matrix} S^{-2} \\ + \\ H_2O \end{matrix} \rightarrow \begin{matrix} H_2S \\ + \\ 2O_2 \end{matrix} \rightarrow \begin{matrix} H_2SO_4 \\ + \\ Ca\,(OH)_2 \end{matrix} \rightarrow CaSO_4 \cdot 2H_2O \ \text{(gypsum)} \qquad (4)$$

$$3CaSO_4 \cdot 2H_2O + 4\ CaO \cdot Al_2O_3 \cdot 13H_2O + 14\ H_2O \rightarrow (CaO)_3Al_2O_3 \cdot (CaSO_4)_3 \cdot 32H_2O \quad \text{(ethringite)} \qquad (5)$$

It is essential to understand the mechanism of action of the sanitary sewage in its deletery action in reinforced concrete, because only understanding how it works and what causes the sulfate attack is it possible to define the best technical solution and interfere in increasing its useful life, thus benefiting the whole society.

3. Material and Method

3.1 Biochemically Modified Silicate Characteristics

The biochemically modified silicate has a chemical reaction with the free calcium present in the cement paste and this reaction produces the C-S-H gel. It is important to keep the concrete righteous and keep the PH of the concrete high, keeping the passivation of the reinforcements. The analysis with greater depth of this chemical reaction of this material with the free calcium of concrete is extremely important, because as previously presented in the deleterious mechanisms of reinforced concrete, calcium hydroxium is a decisive factor in the chemical reaction of carbonation and sulfate attack. According to the technical data sheet provided by the manufacturer, this biochemically modified silicate penetrates up to 20 mm inside the concrete and reacts with the free calcium of the concrete structure, forming the C-S-H gel that buffers the empty and capillary pores present within the physical structure of the concrete, waterproofing it. The reaction of the C-S-H gel formation is a continuous reaction that occurs whenever moisture comes into contact with the compound formed by biochemically modified silicate and free calcium, not allowing calcium hydroxide to be available in higher concentrations, within up to 20 mm depth, to react with other chemical compounds deleterious to the reinforced concrete structure.

The biochemically modified silicate is a liquid that must be sprayed into the structure of cured reinforced concrete, which, according to the manufacturer, provides long-term waterproofing and durability of concrete structures, which we will check in item 4 (materials and methods). Other information obtained from the manufacturer is that: biochemically modified silicate has a PH equal to 11.7, is nontoxic, odorless, is environmentally friendly, does not generate waste, does not alter water potability, increases the concrete's strength to axial compression and abrasion and resists the aggression of chemicals with PH greater than 3.5.

This material has been used for more than 40 years in the world market protecting and increasing the service life and waterproofing various types of concrete structures, so it is of fundamental importance to perform tests and analyze some behaviors and results of this material applied to reinforced concrete structures.

3.2 Procedures

All tests and procedures were performed by IPT-SP, as presented below:

The materials used in this work are presented below.

- Drinking water supplied by Sabesp;
- Portland cement compound CPII F 32;
- Kid aggregate: natural river sand;
- Large aggregate: crushed stone (gravel 1 and gravel 2);

In this work, two concretes were molded: reference concrete and concrete for application of biochemically modified silicate. The trace of the concrete used was 1:2,44:2,14:1,43:0,6 (cement, sand, gravel 1, gravel 2, water), which is recommended by the NBR 12171 standard — Adhesion applicable in waterproofing system composed of waterproofing cement and polymers — Test method [12].

3.3 Methods

3.3.1 Tests

Axial compressive strength: NBR 5739 - Concrete - Cylindrical specimen compression test [12].

Chloride ion penetration resistance: ASTM C1202 — Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration [13].

3.3.2 Curing Conditions and Application of Biochemically Modified Silicate

The specimens were cured in a humid chamber with 100% humidity and room temperature of approximately 22°C.

The sampling steps for the tests are as follows.

Step 1: Cure for 28 days;

Step 2: Drying for 34 days;

Step 3: Surface application of biochemically modified silicate with a consumption of 200 mL/m² (shown in Fig. 1);

Step 4: Hydration of the specimens, which was performed after drying the biochemically modified silicate (approximately 3 hours);

Step 5: Application of accelerator agent based on calcium hydroxide, which was performed by spray 24 hours after hydration of the specimens;

Step 6: Healing the specimens for 28 days. The

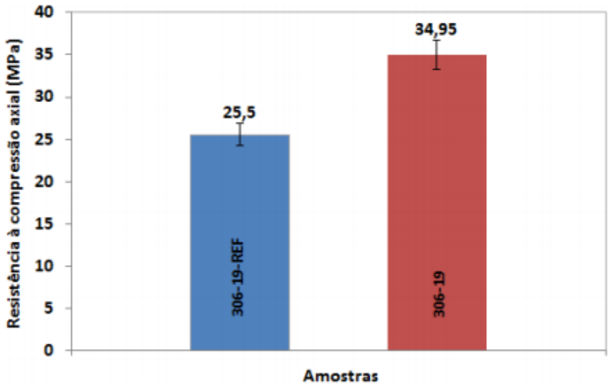

Fig. 1 Axial compressive strength.

reference specimens (without application of biochemically modified silicate) were tested at the same age as the samples with the application of biochemically modified silicate;

The sample nomenclature of the reference concrete is 306-19 REF (unprotected) and the sample nomenclature where biochemically modified silicate was applied is 306-19 (protected).

4. Results and Discussions

4.1 Results

4.1.1 Properties of Concrete in Fresh State

Table 1 presents the following properties of concrete in the fresh state: abatement, specific mass and embedded air content).

4.1.2 Properties of concrete in hardened state

(1) Axial Compressive Strength

The axial compression test was performed according to NBR 5739-Concrete-Cylindrical specimen compression test [12], with the results presented in Table 2.

Fig. 1 shows the average of the results obtained in the axial compression assay, where an average increase of 37% (approximately 10 MPa) in the

Table 1 Properties of concrete in the fresh state.

Properties	Results
Slump (NBR NM 67) (ABNT, 1998)	15 mm
Specific mass (NBR 9833) (ABNT, 2008)	2,200 kg/m³
Built-in air content	1.40%

Table 2 Axial compressive strength.

Axial compressive strength Sample	CP's	Axial compression resistance (MPa)
306-19-REF	1	26.33
	2	23.58
	3	26.73
306-19	4	33.56
	5	36.11
	6	35.17

resistance of the test body to axial compression can be concluded. Thus, a test body that has an average compressive strength of 25.5 Mpa, after approximately one month of application of biochemically modified silicate had as a mean result the compression of 34.95 MPa, practically a behavior of a 35 MPa test body.

(2) Resistance to Chloride Ion Penetration

The chloride ion penetration resistance test according to ASTM C1202 - Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration. ASTM (2018) [13], was carried out in order to present the behavior of biochemically modified silicate incorporated into the concrete aiming at the protection of reinforced concrete structures inseriated in environments with high chloride concentration.

Table 3 shows the resistance to penetration of chloride ions (Cl^-) in concrete, in the reference test body and in the test body with application of biochemically modified silicate, expressed in passing loads (Coulombs).

Table 4 presents the limits of passing load in Coulombs, indicated in ASTM C1202 [13], according to the degree of aggressiveness in which they are inserted, for the classification of concrete for penetrability to chloride ions.

Table 3 Test results, in passing electrical load (Coulombs).

Identification of samples	Results, in Coulombs (C)		
	Test A	Test B	Average
306-19-REF	6292	6307	6300
306-19	3502	2305	2904

Table 4 Classification of concrete for penetrability to chloride ions.

Passerby load in Coulombs (C)	Classification of concrete for penetrability to chloride ions (according to ASTM C 1202:2018)
> 4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Too low
< 100	Despicable

4. Discussions

The results obtained through the axial compression test are quite relevant, because an increase of almost 10 MPa, or 37%, in the resistance of the test body to axial compression with the application of biochemically modified silicate is fundamental for several applications, especially in relation to the reinforced concrete structure that did not reach the resistance to design compression. Instead of performing a deeper intervention in the structure to achieve a certain resistance, this solution could be an alternative to be considered. It is logical that further studies and studies on the action of this material with concrete should be carried out, but this result is already an indication that this can be a very viable solution to increase the compressive strength of some concrete structures, rather than having to perform a treatment with a much more aggressive or more costly intervention to acquire the necessary design resistance.

When talking about severe aggressiveness in reinforced concrete structures, several authors understand that the first factor to be analyzed in relation to the durability of concrete structures is compressive strength, because this is the first parameter indicative of how the physical composition of concrete is formed, the higher the porosity, void index, cracks and microcracks present in the concrete structure, the lower its compressive strength will tend to be. Therefore, authors such as Moreira (2001) [4], present that it is of fundamental importance to analyze the compression resistance of reinforced concrete structures inserted in environments of severe aggressiveness, are the primary factor for any study linked to chemical attack in concrete structures. Depending on the attack, it can compromise up to 60% of the capacity of reference specimens.

Therefore, the performance of axial compressive strength caused by biochemically modified silicate is relevant regarding the protection it can provide to environments of severe aggressiveness, and further studies should be carried out regarding its performance in specimens with different resistances to axial compression and how this material alters permeability, water absorption, void index, and specific mass, as they are also factors that have a direct influence on the propagation of the aggressiveness front where the concrete reinforced structure is inserted.

The calcium hydroxide present in the cement paste is one of the main factors that allow the environment with severe aggressiveness to come into contact with concrete, acting directly or indirectly to allow the external environment to degrade the structure of reinforced concrete. Some studies have already been conducted and have shown that materials that react with calcium hydroxide and make calcium unavailable for new reactions, provide an improvement in the internal structure of concrete because the reduction or removal of free calcium hydroxide end up preventing or drastically reducing aggressive attack on the reinforced concrete structure. Neville (1997) [2], shows that the use of pozzolans ends up fixing calcium hydroxide from cement paste, which is present in most acid attack chemical reactions to concrete structures, as previously presented. Therefore, the biochemically modified silicate, when associated with calcium free concrete and moisture, forming the C-S-H gel within the internal structure of the concrete, drastically reduces the availability of calcium hydroxide free of cement paste, not allowing it to react with external aggressiveness.

In Lafin (2015) [14] it is possible to verify the case study of the application of biochemically modified silicate in a sewage treatment plant and the option for its use occurred not only in its work of waterproofing the reinforced concrete structure, but also by the protection provided by its protection against sulfate attack.

Another very important factor to be analyzed and studied related to biochemically modified silicate is that because it has a high PH equal to 11.7, it provides the necessary environment to protect and further alkalize the structure of reinforced concrete, maintaining the passivity of the reinforcements, consequently increasing its useful life, and reducing the need for maintenance, thus improving the cost-benefit of the enterprise.

Regarding chloride attack on reinforced concrete, the result obtained in Table 4 shows that there is a significant reduction in the penetration of passing loads in the concrete structure of approximately 46%, that is, according to ASTM C1202 [13], which classifies concrete for penetrability to chloride ions. Structure that is inserted in an environment of high aggressiveness, where the passing load in Coulombs is greater than 4,000, when using the protection of biochemically modified silicate, could be designed considering a moderate aggressiveness, where the passing load in Coulombs is greater than 2,000 and less than 4,000 Clombous. Thus, it can influence the cover or strength of the reinforced concrete structure design. Again, further studies should be carried out to better understand the behavior of this silicate-based solution, but results in case studies and tests carried out in works in Brazil and outside Brazil present long-term protective benefits and performances evident to reinforced concrete structures, improving their performance and increasing useful life.

5. Conclusion

The use of biochemically modified silicate in the specimens analyzed proved to be very effective in relation to the improvements in its performance and protections caused in the structure of reinforced rectus. For example, the 37% increase in axial compressive strength and its diffusion capacity of 46% of chloride ions, even reducing the class of aggressiveness of the environment, from high to moderate, conform and the classification of ASTM C1202 [13].

Because it is a liquid material and can be used in the most diverse ages of concrete structures and its chemical reaction with concrete is based on the association with calcium hydroxide and C-S-H gel formation, that expands according to contact with water, this solution can be used in the most diverse reinforced concrete structures, both for waterproofing and for the long-term protection of them, reducing the need for maintenance interventions, improving the performance in use of these structures, thus bringing a better cost-benefit to the enterprise.

Further and comparative studies of other materials related to aggressiveness and performance should be carried out, such as: chloride attack, sulfate attack, alkali-aggregate reaction, urea attack, carbonation, leaching, water penetration, among others. And this solution analyzed presents several characteristics that are worth being studied in greater depth, because it is a solution of simple application, great performance and service life in service according to the life of the structure. It can certainly solve and assist the protection of the most diverse structures, especially those that are subjected to environments of severe aggressiveness.

It can be concluded, through the results presented, that by incorporating the microstructure of concrete, biochemically modified silicate has particularities that allow us to understand and verify that there is a significant improvement in the internal composition of the reinforced concrete structure, in the behavior of the structure as a whole, directly influencing the increase of its useful life, reducing the need and periodicity of maintainability of the structure. Thus saving the despendium of millions of reais in direct and indirect costs of public initiative, private and society itself, related to interventions for the recovery of structures, generating direct impact on their use, on reducing productivity, directly influencing the quality of life of society.

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