Modern Environmental Science and Engineering (ISSN 2333-2581)
September 2021, Volume 7, No. 9, pp. 898-904
Doi: 10.15341/mese(2333-2581)/09.07.2021/004
Academic Star Publishing Company, 2021
www.academicstar.us

Use of Biochemically Modified Silicate at the Waterproofing System Case Study of A Residential Enterprise in Belo Horizonte

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Abstract: This paper aims to present a case study of waterproofing a multipurpose slab of a residential enterprise located in Belo Horizonte, approximately 2,250 m², including swimming pools, wet deck, gardens, tennis court, sports court, leisure areas, and areas of common use. Using the waterproofing system with a biochemically modified silicate will increase the waterproofing life to a higher level, according to NBR 15,575, providing sustainability to the environment, less time in isolation of the treated area, the benefits gained, the internal conditions of the concrete structure, and the ease of maintenance of the structure if necessary. The biochemically modified silicate associates with the free calcium of the concrete and whenever it comes in contact with moisture, it reacts chemically resulting in the formation of a CSH gel inside the concrete, which by expanding seals empty and capillary pores within the structure, protecting and waterproofing the structure. Thus providing definitive regenerative properties (self-healing), because its chemical reaction within the concrete causes the formed CSH gel to expand as the structure needs, by forming a gel. Its reaction follows the characteristics of porosity and cracking of the structure, filling the voids needed to protect the concrete structure. The increase in service life, the great improvement in maintainability and the sustainability that this system provides for over 40 years in reinforced concrete structures should be presented seeking the development of good technique in Brazilian engineering.

Key words: waterproofing system, biochemicaly modified silicate, concrete protection, mechanism of degradation, pathological manifestation

1. Introduction

Competitiveness in the construction industry, mainly related to the construction of residential and commercial enterprises, is increasingly fierce, so the need for cost reduction and productivity are key factors to improve the cost-benefit ratio of the enterprise. However, the option for one waterproofing system over another cannot be based exclusively on the financial character, because each system has its recommended application sites, different productivity and each system has its recommended lifetime.

In order to establish and guide designers in the elaboration of projects more appropriate to the useful life of each construction system used in buildings, the Brazilian Association of Technical Standards (ABNT) has developed a regulation seeking to establish useful life limits for the various construction systems [1]. Thus, the projects must comply with the technical guidelines presented in this regulation, seeking to make the construction systems have the durability compatible with the pre-established design life (VUP).

Therefore, the waterproofing system of the building structures should be defined on the basis of their lifetime and the area in which it will be used. The definition of waterproofing according to NBR 9575 (2010) [2], is the set of operations and techniques, which protect the constructions against the deletery

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action of fluorides, vapors and moisture. The definition of watertightness according to NBR 9575 (2010) [2], is the ability of an element to prevent the penetration or passage of fluorides through itself.

When it comes to waterproofing in reinforced concrete structures, three are the factors of the concrete microstructure that directly influence its process and degradation: the porosity of the concrete, the free calcium present in the structure after the hydration of cement, and water from the environment. These three factors are directly responsible for some deleterious effects on concrete structures, such as: efflorescence, carbonation and corrosion of reinforcements.

Therefore, in order to prevent the deleterious effects of water on reinforced concrete structures are usually used membranes above the concrete structure for their protection. The vast majority of waterproofing systems that use membrane, require, in addition to the waterproofing layer (membrane), regularization so that waterproofing can be applied above it, the separating layer and a structure on the separator layer to protect the membrane, called mechanical protection. However, there are other waterproofing materials, which are part of some waterproofing systems that are added to the concrete, and can be added at the time of concreting the structure, such as with the addition of crystallizers or other materials that are added after curing the concrete, such as using biochemically modified silicate, which will be studied in this case study.

2. Theoretical Foundation

The need for protection of reinforced concrete structures is fundamental when thinking about the useful life of the structure and the environment in which it is inserted. Queruz (2007) [3] states that water is one of the main degradation agents directly or indirectly of reinforced concrete structures.

Another factor that should be taken very much into account in the structure of reinforced concrete is its porosity. When analyzing the durability of the structure, several authors understand that the axial compression test is a primary factor to be analyzed and that through this test it is possible to better understand how the physical composition of the concrete is formed. The higher the axial compressive strength value, the lower it will tend to be its porosity and void index. Moreira (2001) [4], presents that the analysis of axial compression resistance is fundamental, because this is a primary factor for any study linked to chemical attack in concrete structures, because depending on the type of attack, it can compromise up to 60% of the capacity of the reference specimens. Helene (2003) [5] presents the importance of the study of the resistance of compression, the thickness of the concrete comb of the reinforcement, and the age of the structure. This information is important to analyze because the exposure to an aggressive environment provides a good basis for understanding how the structure is behaving, if the structure is existing, or how it should behave if the structure is recent or is being built.

Therefore, the previous study of which material to use for each desired solution and the behavior provided for the second structure projected are fundamental aspects and indications that allow analyzing the performance of the waterproofing system used over time, thus determining its lifetime and the interventions necessary over this time to perform and meet what had been designed.

3. Material and Methods

3.1 Biochemically Modified Silicate Characteristics

The main characteristic of biochemically modified silicate is to chemically react with the free calcium present in the cement paste, produces ingoing the C-S-H gel, fundamental to keep the concrete sane and because it has a PH equal to 11.7. The biochemically modified silicate helps in the maintenance of the PH of the high concrete, thus maintaining the favorable conditions for the maintenance of the passivation of the reinforcements. According to information and tests provided by the manufacturer, biochemically modified silicate penetrates up to 20 mm inside the concrete and along the passive cracks and cracks that may already exist or may occur. When reacting with calcium free from cement paste, forms the C-S-H gel that buffers the empty pores and capillaries present within the physical structure of the concrete waterproofing it. In addition to waterproofing the sturge on, this material removes calcium up to 20 mm from its surface and prevents aggressive agents of the environment from reacting with the calcium hydroxide present in the cement paste and initiating the deleterious process of the reinforced concrete structure. Reactions such as leaching and carbonation require calcium to occur and once calcium is not available or has little calcium available, these reactions do not occur or occur with a very mild incidence.

The C-S-H gel formation reaction occurs whenever the structure where the biochemically modified silicate was applied comes into contact with moisture. The chemical reaction does not wear out over time and thus, there is continuous protection. By expanding, the formation of the C-S-H gel buffers empty and capillary pores of the internal structure of the reinforced concrete, waterproofing it and protecting it against various aggressiveness present in the environment. Thus providing definitive regenerative properties (active self-healing), since the formation of the C-S-H gel remains active when coming into contact with moisture, it allows to monitor the work performed by the reinforced concrete structure, sealing pores, voids, capillaries, existing passive cracks of up to 2.0 mm and, after the application, passive cracks of up to 0.4 mm. The information obtained from the manufacturer allows us to say that it really is a system of protection and waterproofing of active concrete, that is, it has a certain ability to monitor the movements of the structure and form the C-S-H gel as long as the structure allows it, thus providing a long-term waterproofing.

Other relevant characteristics of biochemically modified silicate are that this liquid must be sprayed in the structure of cured reinforced concrete, this material is nontoxic, odorless, is environmentally correct, does not generate residues, does not alter the potability of water and increases the strength of the concrete by 37% to axial compression tests (compared to a reference proof body of 25Mpa) and abrasion.

3.2 Implementation Methodology

The waterproofing system analyzed in this case study is composed of biochemically modified silicate and point treatments are performed with polyurethane membrane.

The waterproofing system using biochemically modified silicate requires the use of polyurethane to complement watertightness in non-concrete structures, such as masonry, blocks, pipes. The biochemically modified silicate can only be used in a structure of reinforced concrete, where it reacts with free calcium and when it comes into contact with moisture to form the C-S-H gel that expands within the empty and capillary pores of the structure, according to the internal physical composition of the concrete structure, because the expansion of the C-S-H gel depends on the pores, voids and capillaries within the concrete structure to have space to expand.

Thus, the proposed case study will be presented in a residential development located in Belo Horizonte, MG, with an area of approximately 2,250 m². Monitoring the application of the waterproofing system using biochemically modified silicate and polyurethane membrane as a complement to the system has been held for more than three years, in all areas of the common use floor of the residential development, covering areas such as: pool, uncovered pools, wet deck, gardens, tennis court, playground, sports court, leisure areas, common areas, and roof slabs, all areas were on the third floor of the development, as shown in Fig. 1.

The following is the application methodology contemplating all the stages of the waterproofing system, which were carried out in the case study analyzed and which are in accordance with the technical information provided by the manufacturer.

Fig. 1 Aerial photo of the residential development delivered.

3.2.1 Surface Preparation

A blower was used to perform the surface cleaning of all dust and sediments in the structure, in order to better expose and verify the existing cracks and cracks and identify all the interferences present and that do not belong to the surface of the reinforced concrete structure, such as: nail tips, woods, exposed rebars, mortar, or other material adhered to the concrete structure. In cases where some layer or film adhered to the surface of the concrete was identified, it was removed by polishing and subsequent hydroblasting by removing the material or dirt adhered to the surface, leaving the concrete free of contaminant materials and prepared for the application of biochemically modified silicate.

3.2.2 Application of biochemically modified silicate

The application of biochemically modified silicate can only be realized after the reinforced concrete structure in which it will be applied is completely dry. Therefore, it was necessary to wait because the structure is humid due to the hydroblasting performed in the previous stage.

The biochemically modified silicate was applied by spraying on the surface of the reinforced concrete structure and an airless machine was used for its application. In the application of this material in the structure, an average consumption of 5 m²/l was used, which is the consumption determined by the manufacturer so that the amount of material used has the best performance incorporating into the structure.

3.2.3 First Hydration

After the end of the application of biochemically modified silicate, it was waited 4 hours, to start the hydration process, where water was applied abundantly at a minimum amount of 3 times the volume of the biochemically modified silicate applied. The manufacturer informs that the time when biochemically modified silicate penetrates the reinforced concrete structure can vary between 2 to 6 hours, depending on weather conditions. The indication to start hydration is that the surface of the structure is dry or touch, at which time the process of the first hydration should begin.

3.2.4 Second Hydration

24 hours after the first hydration, a second hydration was performed, applying water abundantly to a minimum amount of 3 times the volume used in the application of biochemically modified silicate.

3.2.5 Third Hydration

After 24 hours trans runs of the second hydration, the third hydration was performed, applying water abundantly a minimum amount of 3 times the volume of the biochemically modified silicate applied, in the place where the treatment is being carried out。

3.2.6 Application of Polyurethane Membrane

After the hydration of the biochemically modified silicate and the complete drying of the structure, the punctual treatments were performed with the polyurethane membrane, which is a biocomponent material and its consumption used was 2 kg/m², according to the manufacturer's guidelines.

The point treatments performed with polyurethane membrane were in all changes of plans and constructive details, including walls, half-canes, pillars, drains, drains, etc..

The application of the polyurethane membrane followed the following steps:

- First stage: Application of the first end of the polyurethane membrane.
- Second stage: Between 6 and 24 hours, after the first hand, the second round was performed with the polyurethane membrane and nesting of the polyester fabric.
- Third stage: Between six and twenty-four hours, after the second hand, the thirdhand of the polyurethane membrane was performed in order to completely cover the polyester screen seated on the secondhand.
- Fourth stage: Between six and twenty-four hours, after the third hand, it was verified that the entire application of the polyurethane membrane is without bubbles or voids and whether the polyester fabric is fully covered by the polyurethane membrane. In cases where this did not occur, a new polyurethane membrane hand was used to regularize the application and fully cover the polyester screen.

The height of use of the polyurethane membrane in all vertical planes of concrete interface with other material, as for example in the masonry closing the periphery of the enterprise, cannot be less than 20 cm high [2].

3.2.7 Watertightness Test

After the completion of the waterproofing, the 72-hour watertightness test was performed, which is what the manufacturer and NBR 9575 (2010) [2] recommend as a minimum watertight test period, however, the manufacturer recommends leaving the area in charge with water, as long as possible, if possible a week of watertightness testing. This is because the longer the time of contact of the water with biochemically modified silicate, the greater the stimulus in its reaction and incorporation with the concrete structure, accelerating its characteristics and its performance with the protection and waterproofing of the reinforced concrete structure.

In cases where the watertightness test follows the 72 hours, the manufacturer informs that the final result of the incorporation of biochemically modified silicate will be the same as performing a watertightness test of one week, however the complete result of the incorporation of this material in the reinforced concrete structure will take longer, because the result of this chemical reaction is accelerated the longer the time of contact with water.

4. Results and Discussions

The waterproofing reaction of biochemically modified silicate incorporated into the reinforced concrete structure through the formation of the C-S-H gel, combines the need for waterproofing of the structure with its protection, through benefits such as reduction in cracking, increased resistance to axial compression, preventing efflorescence and carbonation due to the removal of free calcium present up to 20mm depth of the concrete surface.

In addition to these protections, biochemically modified silicate has a PH of 11.7 that maintains the concrete with a certain alkalinity, as well as protecting the concrete structure from the main deleterious agents present in the environment.

The use of polyurethane membrane in the waterproofing system studied has a complementary role in the interfaces that occur next to the structure of reinforced concrete that are not concrete, such as the junction between the closing masonry of the enterprise with the slab, passing pipes, drains, where the interface between the pipe and the concrete structure must be waterproofed. For all these interfaces, this waterproofing system uses a polyurethane membrane to ensure water tightness between the different materials that have an interface with the concrete structure.

Usually the vast majority of waterproofing systems are executed at the end of the work, however one of the characteristics of this waterproofing system is power and preferably should be applied as soon as possible after curing the concrete, because in this way, its incorporation into the structure will allow increased compressive strength, reduction in cracking, mitigation of possible leaching and carbonations in the concrete structure, among others.

Another advantage for the use of this waterproofing system is that when applying it immediately after the concrete is cured, the waterproofing stage in the construction schedule is anticipated and the protective characteristics of the silicate biochemically modified by the course of the rest of the work, which can last for a few months or even years until the project is delivered to the owner. During this entire period before the delivery of the project, the waterproofing is tested, mitigating any need for maintenance after the delivery of the enterprise.

When a waterproofing system is used that requires mechanical protection and a leak occurs, there is usually a difficulty in identifying the origin of the problem, since the percolating water below the waterproofing comes into another point. Another relevant factor when this occurs is the need for the removal of mechanical protection, generating waste, which should be disposed of appropriately, besides generating major inconvenience to the owners, as this will influence the use of the spaces of the enterprise that cannot be used while maintenance is being performed. Often, some owners end up having to park their vehicles in other locations to clear the area where the intervention will take place.

In the case of the system presented, where the structure becomes apparent, any maintenance is extremely simple, virtually without waste generation and any leakage that occurs has an identification of its location and maintenance much simpler than waterproofing with membrane and mechanical protection.

This system is widely used in the world market, protecting and waterproofing concrete structures for more than 40 years, and can be applied in various structures of reinforced concrete, apparent or with coating. In the case of an apparent structure, this system allows the work of the structure that may happen to be monitored visually. In the case of the structure being covered with the concrete cover, it is not possible to verify the work of the reinforced concrete structure, only when it works in such a way that the efforts are transferred to the waterproofing membrane and later to the mechanical protection. It will be possible to visually identify the cracks at the top of the structure and cracks that are occurring in the reinforced concrete structure and being transferred to the top of the exposed floor.

5. Conclusions

According to information from the manufacturer, in Brazil, the biochemically modified silicate has protected and waterproofed more than one million square meters, has over 20 years of operation in the country. In the case study in question there was no return or need for maintenance in this project to date.

There is a strong need on the part of designers in the country for waterproofing solutions that have a long-term lifespan, because according to NBR 15,575 (2013) [1], waterproofing of indoor areas, swimming pool, outdoor areas with floors, garage areas, ramps, among other areas, requires a project that includes a minimum lifetime of 20 years, ideal lifetime of 25 years and maximum lifetime of 30 years. That said, few waterproofing systems can meet this lifetime, and the use of the waterproofing system with the application of biochemically modified silicate in the reinforced concrete structure is present meeting this need, because, since this solution is incorporated into the concrete and its chemical reaction of C-S-H gel formation does not wear out over time, the service life of the C-S-H gel becomes the life of the structure itself, obeying the useful life required in NBR 15.575.

Therefore, this case study recommends that other studies related to the performance of biochemically modified silicate in waterproofing and protection of reinforced concrete structures occur, because at first, this solution brings several benefits to residential and commercial enterprises, solving a problem that is constant in civil construction, the deleterious effect of water and aggressive agents of the environment on reinforced concrete structures.

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