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How can concrete be improved through processes that are bio-friendly to the environment and that enhance its construction qualities?

¿Cómo mejorar el concreto mediante procesos bioamigables al medio ambiente y que repotencien sus cualidades en construcción?

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Since the beginning of civilizations, man's need to improve his living conditions has led to constant development. A basic problem is the need to protect our life from the problems that it can offer us, not only the changes of nature but also the need to protect ourselves from others. From this arises the idea of generating structures capable of overcoming this need. Consequently, the first cements appeared, which were capable of resisting and joining these first structures. The cement must go according to the development of the humanity, one of the new innovations is the cement based on microorganisms, that not only is friendly to the environment, but its efficiency is such that it has the capacity to seal fissures. Bio-concrete is capable of regenerating the cracks that sooner or later appear in the concrete due to solar action, humidity, temperature differences, etc.

Keywords: Bio-concrete, concrete, micro-organisms, seaweed

Desde comienzos de las civilizaciones, la necesidad del hombre por mejorar su condición de vida nos ha llevado a un constante desarrollo. Un problema básico es la necesidad de proteger nuestra vida frente los problemas que nos pueda ofrecer, no solo los cambios de la naturaleza si no también la necesidad de protegernos de otros. De ahí surge la idea de generar estructuras capaces de sobrepasar esta necesidad. En consecuencia aparecen los primeros cementos, que eran capaces de resistir y unir estas primeras estructuras. El cemento debe ir acorde al desarrollo de la humanidad, una de las nuevas innovaciones es el cemento a base de microorganismos, que no solo es amigable al medio ambiente, sino que su eficiencia es tal que tiene la capacidad de sellar fisuras. El Bio-concreto es capaz de regenerar las grietas que, tarde o temprano aparecen en el concreto por la acción solar, humedad, diferencias de temperatura, etc.

Palabras clave: Algas marinas, bio-concreto, hormigón, microrganismos

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Introduction

Since the beginning of civilizations and through time, the importance of cement in great housing and infrastructure works has been evident. These have belonged to the most relevant moments in the history of man that are built with this material, which more than a discovery has become a true engine of development for humanity. According to some investigations, the oldest known findings about the use of cementitious mixtures "*date back to 7000 and 6000 B.C. when in the regions of Israel and the former Yugoslavia respectively, traces of the first concrete floors were found from calcined limestone. Later, around the year 2500 B.C., mixtures of calcined limestone and gypsum were used to glue together the large stone blocks that were used to build the pyramids of Giza in Egypt...*" (Jahren & Sui, 2017; Osorio, 2017). From there we see the first intentions of human beings to improve their creations, and they idealized a plan that consisted of a material based on porous volcanic rocks for the elaboration of concrete and thus improve its qualities when putting it into practice. It is known that these ideas of concrete have been important since ancient times.

But the advances did not stop there, but rather throughout history a way has been sought to improve this material, which is so vital when it comes to construction, and it is sought to respond better and better to the new problems of the last century. As for the compressive strength of concrete, it is known to range from 2500 psi (17 mpa) for residential concrete, to 4000 psi (28 mpa) for commercial structures (Mirza & Lacroix, 2002; Mostafazadeh & Abolmaali, 2016). At the moment of making a mix, these resistance test studies are made to know if the mix is complying with the minimum requirements of the specific resistance in some already established parameters.

Today, concrete is one of the most resistant mixtures, and it is formed by the union of sand, water and cement. Cement is a conglomerant formed from a mixture of calcined limestone and clay, and later ground, which has the property of hardening on contact with water (Wikipedia, 2017). The resulting product of the grinding of these rocks is called clinker and becomes cement when a small amount of gypsum is added so that it acquires the property of setting when water is added and hardens later. Although there are different types of cement that are implemented in the construction industry and among these are the portland cement, masonry or mortar, mixed cement or the cement implemented for the elaboration of oil wells, and they can vary in their use or their qualities it is known that they still seek to improve their qualities at the time of their use.

Although its final quality depends in a very important way both on a deep knowledge of the material and on the professional quality of the engineer, concrete in general is unknown in many of its seven major aspects: nature, materials, properties, selection, and maintenance of the structural elements (Mehta & Monteiro, 2014). The possibilities for the use of concrete in production are increasing, and it can now be used for a wide variety of purposes. The only limitation to its multiple applications may be the engineer's lack of knowledge of all the aspects already indicated; as well as the relative importance of them according to the use that is intended to be given to the material.

Building application

Literally *live* concrete

Since 2009, a material has been implemented that improves thermal comfort in buildings and reduces CO_2 (carbon dioxide) emissions into the atmosphere. According to the virtual journal www.upc.edu a biological concrete is being developed to build with lichens, mosses and other microorganisms.

One of the qualities of this innovative idea according to Mundo magazine is that this revolutionary concrete has the property of repairing itself, no doubt an incredible quality for a material that is exposed to different factors that can alter its structure and can cause the failure of such an object.

In the last decade a biological material for construction has been developed based on lichens, mosses and other microorganisms that allow reducing the CO_2 emissions to the atmosphere and that has the quality to seal fissures in the concrete, and to increase the durability of the cement along the time.

This type of microorganism helps to seal, in an environmentally friendly way, the micro fissures present in the structure that are not detected by the naked eye. At the Dolft Technical University in the Netherlands, a type of inconcrete was developed that is literally a living material that can regenerate and wear away from buildings.

Another study carried out by the National University of Colombia encouraged workers to test walls by insulating them for a time in a saline solution. As a result, they found two layers that generate calcium carbonate, something never before recorded, and in turn a bacteria that helps improve the durability and strength of the cement.

The objective of this discussion is to publicize new, more effective, and more environmentally friendly ways of building using a chemically modified cement to improve in all its aspects. One of the advances is the implementation of algae and microorganisms to the concrete, which has been called biological concrete. This is a new material that promotes biological growth on its surface, specifically certain families of micro algae, fungi, lichens and mosses.

This concrete is made from two cement-based materials. The first is conventional carbonated concrete, based on Portland cement, and the second is a magnesium phosphate cement, a fast-setting hydraulic binder (Fig. 1).

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Figure 1. Multilayer concrete developed by the Universitat Politècnica de Catalunya (Staff, 2017).

To obtain this new material it has been necessary not only to modify the pH of the mixture, but also to modify other parameters relating to porosity and surface roughness to favour the bio-receptivity of the material.

The new green concrete achieves the direct growth of organisms by being a multilayer element formed by the following layers (Manso & Aguado, 2016):

1. The structural layer, in charge of resisting actions on the structure.

2. A waterproofing layer located above the previous one, which serves as protection against the passage of water towards the structural layer to prevent it from deteriorating.

3. A biological layer, which will allow colonization and has the capacity to capture and store rainwater, this layer facilitates the development of biological organisms.

4. A layer of coating, discontinuous that will make the function of reverse waterproofing, allowing the entry of rainwater and preventing its loss leading to the output of water where you want to obtain biological growth.

The challenge of living inside the concrete

The new material has many environmental advantages. Thanks to the biological coating it will absorb and consequently reduce CO_2 from the atmosphere, purify the air around it and contribute to the maintenance of biodiversity. It has the capacity to capture solar radiation and will be able to regulate the thermal conductivity inside buildings. And the most obvious advantage will be an ornamental alternative that will allow to decorate the façade of the buildings or the surface of the constructions with different finishes and chromatic shades.

To reduce the CO_2 emissions generated by cement manufacture, research has been carried out recently. One of these investigations is being carried out in the city of Bogotá (Colombia) by the company Argos (Argos, 2017). These investigations are based on the fact that micro algae are perhaps 100 or 200 times more efficient than trees in capturing CO_2.

One of the ways in which the design is intended is that the algae on the bio-reactive facade grow faster under direct sunlight, thus providing more internal shade in summer. In this way, the bio-reactors not only produce biomass that can later be harvested, but also capture solar thermal energy, two sources of energy that can be used to power the building.

But as mentioned above this material has too many qualities and one of these is to be sealed, but how do they do this? With the isolation of microorganisms that form calcite (calcium carbonate crystals) the production of a material that provides greater durability to the cement is studied.

These types of microorganisms help to seal the micro-fissures present in the internal structure of the bio-cement in an environmentally friendly way, since small spaces may remain in the mixture.

To do this, Sandra Milena Montaño Salazar, a biology student at the National University of Colombia in Bogotá, collected samples from walls and platforms of different buildings at the university campus, and in the Microbiology Laboratory she immersed them in saline solution, and subjected them to a process of agitation at 10 degrees centigrade for 15 days (Montaño, Lizarazo, & Brandão, 2018). With this experiment he managed to isolate the material for the respective release of the microorganisms. Later, he sowed them in culture platelets, thus generating calcite precipitation and allowing, in turn, to know which are the microorganisms that produce it. As a result, two strains were found to generate calcium carbonate, something that had not been recorded in the scientific literature. In addition, a bacterium was found that helps improve the durability and strength of cement.

Algae and its applications with constructive purposes

Algae as insulating material for construction

Since the beginning of humanity, microorganisms and algae already existed. The most important and diverse number of living beings in the biosphere is represented by microorganisms, which include some metazoan animals, protozoans, numerous algae, fungi, bacteria and viruses (Fig. 2).

These microorganisms possess unique characteristics that distinguish them from others. Thanks to these characteristics, their study is facilitated. These microorganisms are also distinguished by their relatively short life cycle and their large populations. One quality is their adaptability and reproductive capacity. They tend to form dense populations according to the environmental conditions in which they are found.

Electricity, gas and petroleum are more expensive than ever and therefore intelligent energy management has never

Figure 2. Algae treatment plant (Argos, 2017).

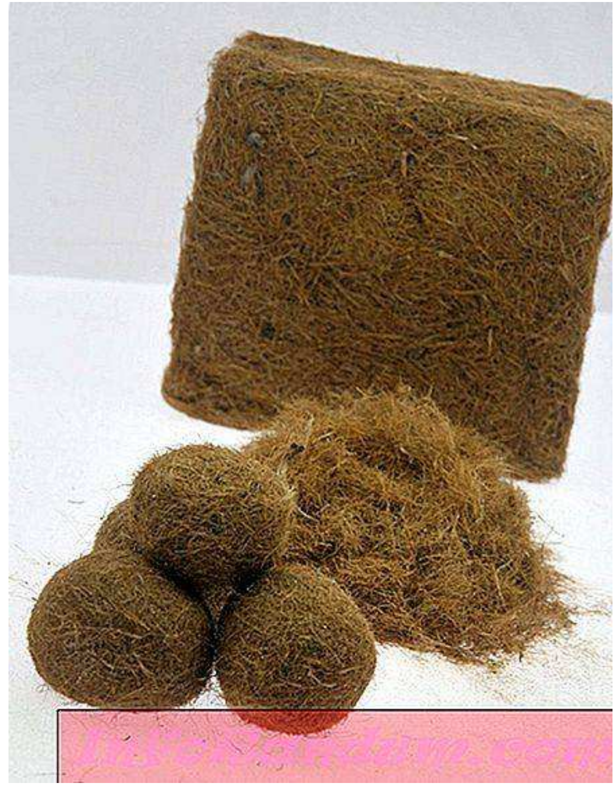

Figure 3. Stuffed seaweed (Coxworth, 2017).

been more important than it is today. Given this situation, it is worth asking what the practical implications of energy efficiency are, what the environmental and economic benefits are, and whether drastic limitations leading to a reduction in consumption can be accepted.

Buildings use 40% of the energy consumed in Europe, and generate a third of the greenhouse gas emissions. Smart buildings will be needed to reduce the carbon footprint of society and increase its energy efficiency. Many new building proposals include energy-efficient cooling technologies such as solar heating systems, combined heat and power generation, heat pumps and thermal energy storage. All these innovations already exist on the market. But there is another option available and cost-effective: insulation using environmentally friendly means.

For many coastal residents, stranded seaweed is nothing more than an inconvenience. But what do these plants have to do with buildings and their heating? German researchers have discovered that this natural material can act as building insulation and together with a team of industrial partners have succeeded in turning it into a viable insulation material (Fig. 3).

The beaches of the Mediterranean are filled during autumn, winter and spring with small balls of algae from the plant Posidonia oceanica. Although this abundant and renewable natural material is considered a waste product and usually ends up in landfill, it could be too valuable to simply discard. Algae have a number of interesting characteristics for construction, such as being practically fireproof and resistant to mould. They can be used as insulation material without the addition of exogenous chemicals in the spaces between the roof beams and the inside of the walls and they buffer the environmental conditions by absorbing and expelling water vapour without losing their insulating properties. In addition, their low percentage of salt, between 0.5 and 2 points, allows them to be used without causing decomposition problems.

However, the process of converting these algae into a building material is not easy because the sand that impregnates them must first be removed, they tend to adhere to almost any object, even each other, and they tend to clump together during processing and when they are spread into the spaces to be insulated. The Fraunhofer Institute for Chemical Technology (ICT), in collaboration with other industrial partners, has found new methods to convert Posidonia residues into a viable insulating material (Fig. 4). The project partners set out to create an insulating material that could be attached or sprayed on to its target space without too many complications.

Shaking the Posidonia balls is the ideal way to achieve the longest possible fibers without sand, explained Dr. Gudrun Grübe of the Fraunhofer ICT (Industrial, 2017). The meticulous separation of the algae masses achieved by Dr. Grübe and her team guarantees an ideal way of obtaining

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Figure 4. Fraunhofer Institute for Building Physics (Scheithauser, 2017).

fibres. After cleaning them from sand, they reach the crusher via a conveyor belt, which deposits fibres of between 1.5 and 2 centimetres in bags.

The Fraunhofer Institute for Building Physics (IBP) in Holzkirchen (Germany) found that the insulation material obtained is capable of storing a considerable amount of energy (2,502 joules per kilogram kelvin (J/kgK)), 20% more than wood or wood products. This characteristic allows it to keep buildings cool during hot periods by protecting them from heat during the daylight hours. The results of an analysis confirmed the high insulating capacity of Posidonia fibres. It can be used in construction at a density high enough so that it does not sink under its own weight. The required density was determined at the MPA NRW Materials Testing Institute in Dórtmund, Dr. Grübe explained. The suitability of this material from a health point of view was also investigated. The results provided by the Eco-Institute in Cologne revealed that it does not contain any toxic or residual materials and is therefore particularly suitable for allergy sufferers.

Environment

In 2008, Argos, a leader in the cement and concrete production sector, began to develop research projects in biotechnology to minimize the environmental effects of its operations. The following year it opens the Research and Development Center within the university campus. In 2010, EAFIT begins with Argos Adaptatio, a pioneering research project aimed at generating at the University the scientific capacity to grow micro algae, which was the foundation of the SP1 project (Restrepo, 2017).

This biotechnological research in its initial stage seeks to characterize, by 2014, the conditions in which CO_2 capture is maximized, within the range provided by the cement industry. Specifically, it seeks to evaluate the response of micro-algae to gas mixtures from sulphur and nitrogen oxidation, found in the stacks of the cement production process.

Argos believes that innovation is the fundamental pillar for achieving sustainable and environmentally friendly growth. With this research, the company intends to consolidate the bases for the development of a technology that will allow the mitigation of the emission of polluting gases and replicate this good practice to any type of industrial activity that generates CO_2, says Camilo Restrepo Restrepo, Vice President of Innovation at Argos.

Importance of micro algae

About 75 percent of the oxygen that is breathed is produced by micro-algae, of which there are about 40,000 species. These are characterized by their speed of growth and their capacity to capture CO_2, 10 times faster than a normal plant.

These microorganisms are a source of nutrients of great importance for the rest of living beings, they are the food base of the pyramid, they provide oils that can be used as chemical precursors, biofuels or as food (omega 3 oil, etc.). Some species produce colourings and even hydrocarbons and alcohols.

This project, framed in sustainability, is aligned with Argos and EAFIT policies, where science is shared, visible and responsible (Fig. 5).

Figure 5. SP1 Research of EAFIT University and Argos Company (Restrepo, 2017).

Tests of concrete with microorganisms

The idea sounds as appealing as science fiction: buildings that close their own cracks as if they were living beings healing their wounds. For the Dutch scientist Henk Jonkers, this project that sounds fantastic is, let's say, a fairly concrete reality.

At the Technical University of Delft in the Netherlands, they have developed bio-concrete, a material that is literally alive and can regenerate the wear and tear of buildings. Our concrete is going to revolutionize the way we build, because we are inspired by nature, Jonkers said when he was nominated for the European Inventor Award in 2015 (Fig. 6).

Figure 6. Earthquakes in Latin America. Another cause for bio-concrete research (Mundo, 2017).

But more than inspired by nature, bio-concrete is composed of it. The extraordinary properties of this material are due to tiny beings: bacteria.

Hard to kill

To prepare bio-concrete, traditional concrete is mixed with strains of Bacillus Pseudofirmus bacteria that in their natural state can live even in such hostile environments as active volcano craters. The amazing thing about these bacteria is that they form spores and can survive for more than 200 years in the building, Jonkers explains. Calcium lactate is added to that mixture, which is what the bacteria eat, and the bio-concrete is ready (Fig. 7).

Figure 7. Pseudomonas Aeruginosa (Mine, 2017).

This is how one of the smallest beings on the planet can be a fundamental part of the most imposing constructions that man can design. In only three weeks, when cracks are formed in buildings made of this material, the bacteria that inhabit it are exposed to the elements, mainly water.

The humidity that penetrates the cracks awakens the microorganisms that begin to feed on calcium lactate and as a final product of their digestion they secrete limestone. This material seals the cracks in the bio-concrete in as little as three weeks.

Bio-concrete in Latin America

Bio-concrete is a new material that helps to filter water. In the Design Week of America, the prototype of a house called Rainhouse was presented, causing a great impact. In this house, rainwater is channeled through a series of stainless steel pipes, where barrier filters remove the largest impurities, to a bio-concrete tank, installed on top of the house. This tank acts as a natural limestone cave, which automatically adjusts the pH of the water to an optimal level. The tank has a special silver-based coating, which ensures that it stays clean, and a series of filters that complete the work of purifying the water to make it drinkable, without the use of chemicals (Fig. 8).

Figure 8. Examples of bio-concrete use (Verde, 2017).

As part of the evaluations of bio-concrete, Henk Jonkers reported that this material has been used to build irrigation canals in Ecuador, a highly seismic country. Although it can be more expensive than traditional concrete, the economic benefit is soon evident because it saves on maintenance costs, the scientist told the English daily The Guardian. But even old buildings crisscrossed by cracks, the kind that abound in Latin America and which risk collapsing even with the slightest tremor, could have hope.

The Technical University of Delft has a spray on the market, made on the basis of the same principle, which can be applied directly to small cracks. Although the idea of a building being repaired is only fascinating, bio-concrete still has to pass the toughest test: the market.

This project is going to revolutionize the way we build, because it is inspired by nature. Known by the name of bio-concrete or organic concrete, this material can regenerate and heal itself, by the wear and tear of the buildings, caused by any telluric movement or some blow to the structure.

The Technological University of Delf is working on this experimental cement that is mixed with a bacterium, which

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helps to repair the cracks in the cement. The experts conducting this experiment are: Eric Schlangen, and micro biologist Henk Jonkers, who indicate that bioconcrete does not directly cause the loss of strength of structures.

The extraordinary properties of this material are due to tiny beings or bacteria, which in their natural state can live even in such hostile environments as active volcano craters. Calcium lactate, which is what the bacteria eat, is added to the mixture between the concrete and the batteries in order to have the organic concrete ready. The amazing thing about these bacteria is that they can survive for over 200 years in the building (Fig. 9).

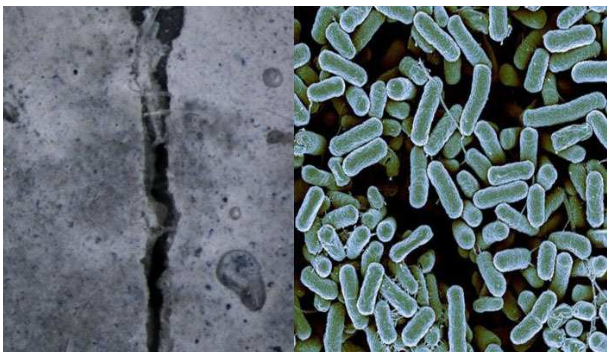

Figure 9. Bioconcrete or organic concrete (Verde, 2017).

Although concrete is the most widely used building material in the world, it has one flaw: it can easily break when under stress. If these cracks become too large, they will lead to corrosion of the steel reinforcement, which not only results in an unattractive appearance, but also jeopardizes the mechanical qualities of the structure. That is why engineers often use more than the necessary amount of steel reinforcement inside a concrete structure to prevent cracks from becoming too large. This extra steel has no structural use and is an expensive solution as steel prices are high. Another way to deal with cracks is to repair them, but this can be extremely difficult in underground or liquid retaining structures. The solution would be self-healing concrete, which is exactly what TU Delft researchers are working on.

By embedding calcite precipitating bacteria into the concrete mix, it is possible to create concrete that has self-healing capabilities. As the pH value of concrete is very high, only so-called alkali bacteria are able to survive. They have mixed several of these bacteria in a cement paste and after one month they found the spores of three particular bacteria.

In theory, the use of bacterial concrete can lead to substantial savings, especially in steel-reinforced concrete. It will also mean that durability problems can be addressed more economically when designing concrete structures. Bacterial concrete is ideal for the construction of underground hazardous waste retainers, as no human being would have to go near it to repair any cracks that occur. However, for residential buildings it seems that traditional crack repair will remain the most economically attractive solution for now.

Research is currently focused on creating the right conditions for bacteria to produce as much calcite as possible and on optimizing the distribution of food for bacteria. They are also studying the self-healing capacity of bacterial concrete and how this is affected by the various deterioration mechanisms involved, such as sulphate attacks or temperature fluctuations. All research is carried out in TU Delft's Microlab, where equipment is available for fracture testing as well as numerical tools for information on structures and fracture models.

The Self Healing Concrete project is part of the TU Delfts research program on Self-Correcting Materials at the Delft Materials Center (DCMat). They also work in collaboration with the Biotechnology section of the School of Applied Sciences and the South Dakota School of Mines in the United States.

Bacterial bio-concrete, as it has become known to the media, incorporates bacillus bacteria into the basic concrete mix developed by the Dutch university, producing spores that can survive for up to five decades without food or oxygen, Jonkers told The New Scientist in 2010, when the research had succeeded in its first experiments a year earlier.

How does it work? To carry out the repair, the bacillus bacteria are stored inside the concrete in capsules made of biodegradable plastic, which open when they come into contact with water, once the mixture has solidified. The bacteria are stored in calcium lactate and produce limestone, the material that repairs concrete.

The team of researchers is currently working on testing the different capacities of bacteria to respond to sulphate attacks or wide thermal oscillations. They also seek to reduce their production costs to become an accessible alternative to the current offer, since their potential for commercial exploitation is wide: from residential buildings to the construction of underground containers for hazardous waste, since people would not have to go near them to repair the cracks produced, according to the TU Delft's MicroLab.

Applications

In the application of microorganisms in the construction industry, different biotechnological products and biotechnologies for civil engineering have been created, based on a new science that we could call construction biotechnology, as we have already observed throughout the article. The application of microorganisms, algae and other biological material is one of the alternatives, if not the best in the application to improve and enhance the main material in civil works as it provides us with an environmental balance and a better adaptation to environmental conditions (Figs. 10, 11 and 12).

Figure 10. Concrete slab with freshly formed cracks (Alvarez, 2017).

Figure 11. Crack in the concrete, 28 days after the action of the bacteria (Alvarez, 2017).

Figure 12. Crack in the concrete, 56 days after the action of the bacteria (Alvarez, 2017).

One of the solutions proposed during the course of the project is the effectiveness that concrete has with these additives that add a quality, as important as having the ability to seal the cracks, this is shown in the BBC magazine article the idea sounds as attractive as science fiction: buildings that close their own cracks as if they were a living being healing their wounds. For the Dutch scientist Henk Jonkers, this project that sounds fantastic is, let's say, a fairly concrete reality. At the Technical University of Delft in the Netherlands, they have developed bio-concrete, a material that is literally alive and can regenerate the wear and tear of buildings.

But the most extraordinary thing is that these bacteria form spores and can survive for over 200 years in the building. Just thinking about this quality we are amazed at the great benefit micro algae provide but how this method works. When cracks are formed in buildings built with this material, the bacteria that inhabit it are exposed to the elements, mainly water. The humidity that penetrates the cracks awakens the microorganisms that begin to feed on calcium lactate and as a final product of their digestion they secrete limestone. Bio-concrete can save billions of pesos in the maintenance of structures as varied as buildings, bridges or dams. Not to mention that the maximum sealing capacity is 8 millimeters wide regardless of length. This is just one of the many benefits that the implementation of this material for concrete brings (Fig. 13).

Figure 13. Cracked wall already repaired (Alvarez, 2017).

Undoubtedly, this quality will be very useful when building on irregular surfaces or unstable soils with a high degree of humidity or soils containing a high proportion of water, since these soils are more prone to cracking due to the sinking of the earth; but thanks to this material this will no longer be a problem in the future.

Another of the qualities of this material, if not the most important, is its ability to reduce CO_2 emissions (carbon dioxide). This quality of the material is so important not only for the material but for the ecosystem itself, since the area of the constructions produces 5% of the world's pollution. In Colombia, the Argos cement company has been carrying out studies on this problem.

Together with researchers from the EAFIT University, Argos has been carrying out one of the most promising research projects in the country since 2010, with the aim of consolidating the bases for a sustainable technology that allows a rational mitigation of the emission of gases that cause the greenhouse effect. Currently, research is advancing in the search for the most effective species in CO_2 capture, so that in the near future these findings can be projected to any type of industrial activity generating emissions, thus contributing to the development of more sustainable industries through science and innovation. The goal for 2018 is to implement the technology in one of

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Argos' nine cement plants in Colombia and achieve a 20% reduction in CO_2 emissions (equivalent to 140,000 t of CO_2) generated in the production process of 700,000 t of cement (November 2013). Recently, several researches have been released regarding the implementation of microorganisms in the construction industry due to their high effectiveness in absorbing CO_2 through algae, since they help to reduce CO_2 emissions. It is known that some of them have the quality of being 100 or 200 times more effective than trees in terms of their main function of transforming CO_2. Without doubt it will be a great help to the environment (Fig. 14).

Figure 14. Microalgae plant (Argos, 2017).

The new material has many environmental advantages, thanks to the biological coating it will absorb, and consequently reduce CO_2 from the atmosphere, purifying the air around it, as well as contributing to the maintenance of biodiversity. It has the capacity to capture solar radiation and will be able to regulate the thermal conductivity inside the buildings; and the most obvious one will be an ornamental alternative that will allow to decorate the facade of the buildings or the surface of the constructions with different finishes and chromatic shades.

Undoubtedly this material shows us a new way not only for the constructions and other applications but a new form of sustainable development, in other investigations they have given the name of biological ormigon the material is thought to be used as vertical garden in buildings not only of new construction but to rehabilitate the already existing ones, or used in other constructions in Mediterranean climates. Last year it won the Beyond Building Barcelona-Construmat prize for an innovative project in its sixteenth edition (29 June 2016). This material not only helps the environment but also opens up new designs for buildings, creating self-sustainable models.

This material not only brings us new and better working conditions but also goes hand in hand with the environment, without a doubt this could be a solution to the new trends with each and every one of the qualities already mentioned. We could say that the microorganisms, algae and others are one of the exits to face future problems not only in the construction but in the fight against the deterioration of the earth in our time.

Conclusions

There are currently hundreds of methods in the world literature for determining the composition of conventional concrete mixtures. The choice of one or another depends on several factors, basically the type of concrete required and the experience or customs of the place. However, the evolution of the market towards the production of concrete in an industrialized way has caused that the prefabrication plants have developed their own methodology, mainly to be more competitive and to obtain the maximum saving in the cement consumption.

The objective of the dosage is to find the best combination of ingredients that responds, in each case, to the three main phases of the life of a concrete, that is, the laying, the contractual age and, from this, the useful life. This translates into requirements for workability, strength and durability, respectively.

In this sense, the analysis of the structure of bio-concrete, the influence that its component phases (aggregates, transition zone and hardened cement paste) have on the most significant properties in practice, can only increase its importance. Of particular interest is the influence of the porous structure of the cement paste on the permeability (durability) and strength of the concrete.

It is important to keep in mind that optimization of total costs (economic, environmental) is one of the essential purposes in any process. In this sense, it has been shown that cement represents around three quarters of the cost of the materials used to manufacture one cubic metre of normal concrete without chemical additives, so reducing this cost, without compromising workability, strength and durability, means major economic benefits and a reduction in the consumption of oil in cement manufacture.

It is interesting to note that, as the water/cement ratio decreases, the paste content must be increased to obtain the same workability. The type of aggregate used also influences the amount of slurry, so that the more rounded particles require a smaller volume of slurry as the workability of the mix increases.

On the other hand, several authors (Abrams, for example) point out that it is only the quality of the hardened cement paste that controls the strength of comparable concretes.

There is no doubt that the water/cement ratio is the most influential factor in the strength of a fully compacted concrete; however, the use of microorganisms, cement and aggregates, as well as the maximum size of these, play a significant role in the strength of concrete.

The conglomerant used in dams is made up of Portland clinker and natural fly ash or pozzolan, this reduction in cement content being beneficial from a thermal and economic point of view. Depending on the percentage of additions, they can be classified as type II or type IV cements (pozzolanic cement).

To carry out the repair, the bacillus bacteria are stored inside the concrete in capsules made of biodegradable plastic, which open when they come into contact with water, once the mixture has solidified.

Concrete is extremely alkaline and healing bacteria must wait inactive for years before being activated by water.

Jonkers chose calcium lactate, placed the bacteria and calcium lactate in capsules made of biodegradable plastic, and added the capsules to the wet concrete mix.

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