BIOMIMETICS ECO MATERIALS, AN EFFICIENT WAY TO SUSTAINABILITY

ECOMATERIAIS BIOMIMÉTICOS, UM CAMINHO EFICIENTE PARA A SUSTENTABILIDADE

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Palavras Chave
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ABSTRACT

This paper aims to demonstrate how Biomimicry collaborates in the creation of new eco-efficient and innovative materials through the analysis of some examples, such as the hydrophobic and self-cleaning materials based on the Lotus plant, giving rise to paints and coatings that do not They do not wet or get dirty; Hydrodynamic materials based on the skin of the shark that gave rise to tissues that diminish the friction and increase the performance of swimming athletes; Adhesive materials based on the gecko gowns, which allow super adhering surfaces of carpet fastening without the need for glues; Water abstraction materials based Namibian beetle, that enable products such as Warka Water to store water from atmospheric air in regions of scarcity; And finally, self-cleaning and de-polluting materials based on the photosynthesis of the leaves, which allow the coating of constructive modules on facades capable of helping to decontaminate high-flow pathways of cars. This approach highlights the use of nature as a source of inspiration for the creation of these new materials and demonstrates the great potential for their application in Design and Architecture projects, evidenced in these examples that are in great harmony with the sustainability scenario.

RESUMO

Este artigo tem o intuito de demonstrar como a Biomimética colabora na criação de novos materiais eco-eficientes e inovadores através da análise de alguns exemplos, tais como: os materiais hidrofóbicos e autolimpantes baseados na planta Lótus, dando origem a tintas e revestimentos que não se molham nem se sujam; materiais hidrodinâmicos baseados na pele do tubarão que deram origem a tecidos que diminuem o atrito e aumentam o desempenho de atletas de natação; materiais aderentes baseados nas batas da lagartixa, que possibilitam superfícies super aderentes de fixação de carpete sem necessidade de colas; materiais para captação de água baseados no besouro da Namíbia, que possibilitam produtos como o Warka Water capaz de armazenar água do ar atmosférico em regiões de escassez; e por fim, materiais despoluentes e autolimpantes baseado na fotossíntese das folhas, que permitem o revestimento de módulos construtivos em fachadas capaz de ajudar a despoluir vias de grande fluxo de passagem de carros. Tal enfoque coloca em evidência a utilização da natureza como fonte de inspiração para criação destes novos materiais e demonstra o grande potencial de aplicação destes em projetos de Design e Arquitetura, evidenciados nestes exemplos que estão em grande consonância com o cenário de sustentabilidade.

1. INTRODUCTION

Throughout the history of Humanity, it is possible to verify the application of biological solutions in different periods, and in many areas such as science, technology, architecture, art, design, engineering, medicine, as well as material engineering, among other areas. This inspiration in nature has generated a growing number of inventions that have made possible many innovations and resources over time.

To get an idea of the learning potential with this multitude of organisms in nature, Benyus (1997) recalls that it is enough to observe the incredible feats of: bioluminescent algae, which combine substances to supply their organic lanterns; Fish, and frogs of Arctic regions that freeze and re-emerge into life without ice damage to their organs; Brown bears that hibernate in whole winters without being poisoned with their own urea; Polar bears that protect themselves from the cold through a layer of transparent hairs that function like the glazing of a greenhouse; Bees, turtles and birds that move without maps; Whales and penguins that plunge to the bottom of the waters without diving equipment; Dragonflies that exceed the maneuverability of the best helicopters; Ants that can carry the equivalent of hundreds of pounds; Hummingbirds that cross the Gulf of Mexico with the equivalent of 3ml of fuel, etc.

Although all this knowledge has existed throughout the evolution of life on Earth, only a small portion of this has been seized, and a great part of it is still unknown and neglected to be unleashed. Through a focused look at nature's solutions, there are a variety of good examples of eco-efficiency, through organisms that build without much waste of materials and energy, and which still coexist in harmony with the biosphere. To Evidence of this new way of perceiving nature is quite different from the idea of exploration to which man is generally associated.

Therefore, observing how nature operates in the creation of its species, be they plants, animals or minerals, it is possible to transpose this same method in the development of products, systems, constructions and even services, because the "criteria" observed in living beings, can serve as a basis for the development of more efficient solutions. (BENYUS, 1997)

Some recent research on the universe of Biomimetics has generated knowledge and new materials that are based on analogies with the natural world and are being applied to innovative products, as will be shown in the example of Lotusan ink, FastSkin fabric, Prossolve370e constructional modules, in the TacTiles adhesive modules, in the water capture screen of the Warka project.

2. BIOMIMICRY AND ECO MATERIALS

A great enthusiast and disseminator of these strategies today is the biologist and American researcher Janine Benyus, who for almost 20 years have sought to spread the principles of Biomimicry, defined by her as a new science that studies the models, principles and processes of Nature and imitate or inspire them to solve human problems. (BENYUS, 1997)

Although using Nature as a reference for creations is not something new, just remember the inventions of Leonardo da Vinci, the Art Noveau movement, or even the architectural inspirations of Gaudí. Throughout history, many are the cases of inspiration in nature, since the beginning, man has always observed and learned from it. But during this process of "evolution" of knowledge, technological development and financial systems, this learning became more and more distant reality and gave way to a more devastating action, the exploration, and this has triggered a series of other problems that interfere not only in the well-being of man, but in that of the whole ecosystem, which is included and dependent on it.

Manzini and Vezzoli (2002) point to environmental education as a pillar of sustainable development, as it contributes to integrate humanity into the environment and awakens in individuals and organized social groups the desire to participate in the construction of their citizenship.

The good news is that recently, many voices have joined in this cause of rescuing this conscious look for the genius of life, seeking parsimony in the use of resources and being inspired by nature for its innovations. As Benyus (1997) would say, it is the rediscovery and liberation of a forgotten source that gives rise to new hopes about problems that were previously considered insoluble.

This context has many relationships with the production of eco materials, as seen in the investigations developed by the School of Architecture of Barcelona of the International University of Catalunia, which has produced a series of researches focused on the issue of eco materials under the tutelage of the architect Ignasi Perez Arnal. In his book: "Eco Productos, en la arquitectura y el deseo" he outlines the 10 items that allow a good framing of the problem of eco materials: (ARNAL, SAUER et al., 2008)

- **CO^2 Absorbent Material:** The choice of a material that actively participates in solving one of the most complicated current problems. Global warming mitigation is the best choice that construction can make to the environment.

- **Sustainable Material:** Using raw materials that nature offers us inexhaustible means not conditioning the future of the planet's reserves.
- **Recyclable Materials:** The destination of a recyclable material found in the reuse does not end up in the landfill.
- **Recycled Material:** It avoids the contamination and the energy consumption necessary for the new manufacture of the same material, consequently reduces the amount of waste.
- **Compositional Purity:** The rawer materials are used in the same product, the more complicated its separation and recycling becomes.
- **Embedded energy:** In addition to the initial energy costs (extraction, transportation, manufacturing ...), it is important to understand the energy dependence of the material throughout its life cycle (thermal inertia; maintenance, ruptures and wear; possibility of being recycled or reused).
- **Degree of Industrialization:** Just very small scale projects justify the use of a handcrafted material that requires a lot of labor and the intensive use of resources at work (water and energy). In all other projects, it is necessary to use industrial materials where there is a controlled consumption of resources and energy.
- **Healthy materials:** Avoid the use of products that could affect the health of the manufacturer, the user and the worker in the recycling process. Particularly in the case of toxic or carcinogenic particles.
- **Maintenance requirements:** Low maintenance materials promote user comfort and reduce the use of paints, lubricants and varnishes.
- **Ecologically certified materials:** Few materials are certified to ensure a good use of resources, and those that have it deserve a privileged treatment.

3. BIOMIMICRY IN THE GENERATION OF NEW MATERIALS AND THEIR EXAMPLES OF SUSTAINABLE DESIGN

Soares (2016) highlights the most recurrent types of analogy with the natural world used in the process of Biomimicry, where the easiest to understand is the Morphological Analogy, defined by Bonsiepe (1982) as the experimental search of elaborated models of the translation of structural characteristics and formal to transpose into projects. Thus, this type of analogy seeks to study and analyze why the natural form, the interrelations of its geometry, observing and understanding its textures, shape characteristics, parts and components, details of some part at the macro or microscopic level, as well as for its structural forms.

In this sense, Versos (2010) provides a good example of Morphological Analogy with the Shinkansen-Bullet Train developed by engineer Eiji Nakatsu (Figure 1). The project has as reference the shape of the elongated beak of the Martim-Fisherman bird, which facilitates the diving without splashing water in search of his meal. In order to solve one of the great problems of the bullet train, which was the vibration and the noise, the engineer sought inspiration in the shape of this bird's beak, resulting in a significant improvement with gain of 10% faster, consuming 15% less energy, and reducing the air pressure by 30% compared to the previous model.

Figure 1: SHINKANSEN (Japan), the world's fastest high-speed bullet train, redesigned based on the beak of a Martin-Fisherman bird.

Source: Soares, 2016

Functional Analogy, however, seeks to study the functioning of the natural physical and mechanical system; Tries to understand which functions play both in the whole, and in its parts and components, in which the functional attributes, specific (non-morphological) qualities that can mimic the natural structure analyzed, are evidenced, since natural organisms have developed complex and highly adaptable, one can identify these functional aptitudes and apply them to artificial artifacts. While morphological analogies are limited, functionally they can be multiple. (SOARES, 2016)

So, much research has been generated through partnerships with biology departments to acquire information specific to the natural world, an example is the work of Liua & Jiang (2011), which presents in Table 1 the functions of some living organisms that can guide the generation of ideas for the solution of design problems by analogy in design.

The great advantage of Functional Analogy is that the identification of these functions allows the application of the strategy found in more than one type of artifact, generating more solutions of the same study. Some examples of biomimetic eco materials and their respective references to the natural world will be presented below.

Table 1: Table of natural organisms and their respective functions.

BIOLOGICAL MATERIAL	FUNCTIONS	AUTHORS
BUTTERFLY WING	Super-hydrophobicity Directional adhesion Structural color Chemical self-cleaning.	Y.M.Zheng, X.F. Gao, L. Jiang (2007) O. Sato, S. Kubo, Z.Z.Gu, Acc. Chem (2009)
NACRE	Mechanical properties, Structural color	X.F. Gao, X. Yan, X. Yao, L. Xu, K. Zhang, J. H. Zhang, B. Yang, L. Jiang (2007) G. Mayer (2005)
CIGARETTE WING	Anti-reflection Super-hydrophobicity	T.L. Sun, L. Feng, X.F. Gao, L. Jiang (2005)
SPIDER SILK	Mechanical properties of shrinkage Adhesiveness Elasticity	Y.M.Zheng, H. Bai, Z.B. Huang, X.L. Tian, F.Q. Nie, Y. Zhao, J. Zhai, L. Jiang (2010) N. Becker, E. Oroudjev, S. Mutz, J.P. Cleveland, P.K. Hansma, C.Y. Hayashi, D.E. Makarov, H.G. Hansma (2003) B.O. Swanson, T.A. Blackledge, C.Y. Hayash (2007)
THE LEG OF THE PASSOLARGO IN WATER	Durable Sturdy Super-hydrophobicity	X.F. Gao, L. Jiang (2004)
ROSE PETAL	Super-hydrophobicity, Structural color, High adhesion	L. feng, Y.A. Zhang, J.M. Xi, Y.Zhu, N. Wang, F. Xia, L. Jiang (2008) L. Feng, Y.A. Zhang, M.Z. Li, Y.M. Zheng, W.Z. Shen, L. Jiang (2010) B. Bhushan, E.K. Her (2010)

Source: Soares, 2016

3.1 Hydrophobic and self-cleaning eco materials

In the study of the Lotus plant, the researcher Barthlott identified the functions of water repellency and self-cleaning of their surfaces. This happens due to the angle formed by its micro and waxy nanostructures, which prevent contact with the water, causing it to roll and form drops that collect the dirt along the way. Through this, it has been found that nanoscale rough surfaces are more hydrophobic than smoother surfaces. In the Lotus leaf, the actual contact area is only 2-3% of the surface of the drops.

This functional analogy generated some materials, applied commercially in products such as Lotusan ink (Figure 2) and also through sprays (BASF Lotus Spray) for the textile, wood and glass industries, simulating the same effect of the plant. In paint, when creating micro ridges, it repels water, self-cleaning and resisting stains for decades. Thus, despite the replication of these microstructures, the generated artifacts do not refer to the shape of the leaves themselves, but to the identified function of hydrophobia and self-cleaning. (VERSOS, 2010)

Figure 2: LOTUSAN (Germany), water-repellent and stain resistant ink, inspired by the microstructures of lotus leaves.

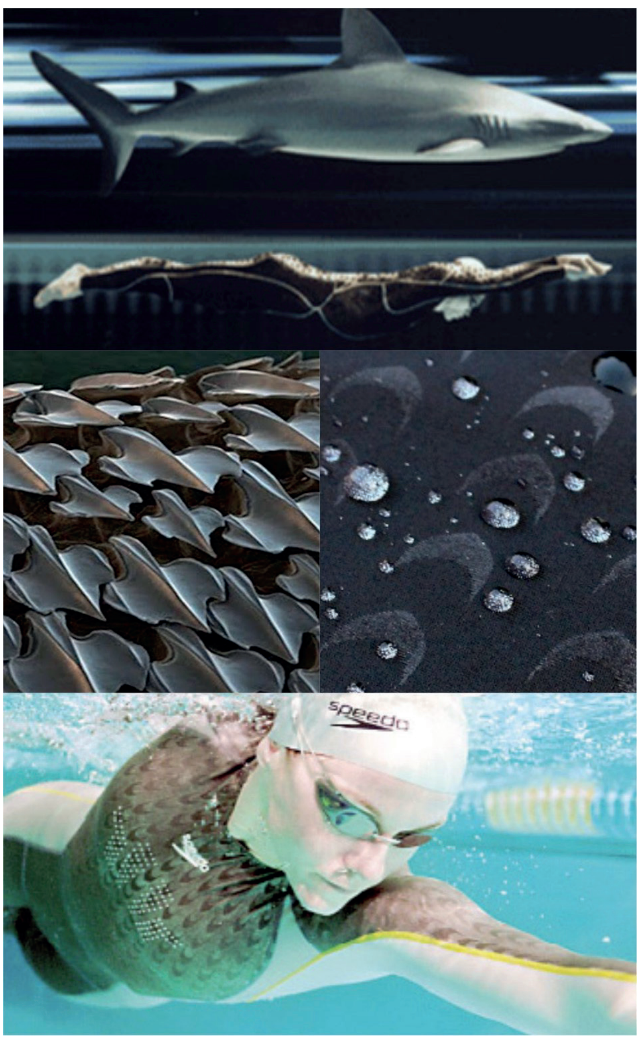
Source: Soares, 2016

3.2 Hydrodynamic eco materials

Another example of eco material came from shark skin scales research, responsible for the performance of their agility in the water. According to experts, water slides through the micro grooves of the animal's skin reducing friction. The result of this study gave rise to a fabric called Fastskin (from the company Speedo), now used in swimming apparel of the Olympic champions (Figure 3). The texture of these garments is based on the "denticles" of the shark's skin. This format the advantages of passive resistance reduction by about 4% and also of muscle vibration, increasing the speed and performance of athletes. (VERSOS, 2010)

In sharks, these micro-scales also prevent small crustaceans and algae from being attached, an inspiration for synthetic coatings that can be applied to ship hulls in order to reduce friction, saving energy and also this biological inconvenience that causes maintenance, which proves Once again that the functional analogy can generate application in several artifacts and is not limited only in the form of the investigated animal, but in the function that has been identified and that one wishes to replicate.

Figure 3: FASTSKIN (Speedo), swimsuit for swimming competition that mimics the hydrodynamic efficiency function of the shark skin, resulting in reduced friction and consequent speed increase.



Source: Soares, 2016

3.3 Adhesive eco materials

Another example of a biomimetic eco material is the paw of the gecko. An intriguing feature of this animal is its effortless walking on walls and ceilings. This is due to the extraordinary adhesion function found in the hairs of their paws, caused by the intermolecular force found in the micro and nanopoles that bind the molecules of these to the molecules of the surface on which they rest, allowing them to stick even on smooth surfaces such as glass. (Figure 4)

From this study, the company Interface created the TacTiles, an adhesive material that is used in a carpet installation system that uses these glue-free adhesive connectors to attach instead of gluing to the floor. Other applications are used as stickers for smartphones, allowing adhesion on glass and car panels, for example.

Figure 4: TacTiles, adhesive material resulting from the study of the adhesion function of the paw of the gecko.

Source: SOARES, 2016

3.4 Eco materias for abstraction of water

Another example, this time, inspired by the beetle of the desert or Namibiam beetle, an insect investigated by Andrew Parker (2001), University of Oxford, UK. The insect captures the water from the air through the pores of its shell, when the humid air passes through its protrusions and microscopic grooves, condense and are channeled towards its mouth, an adaptive feature that allows the survival of the same in the desert. This functional analogy is being transferred to various materials and artifact solutions, one of which is produced by QinetiQ in the United Kingdom where it developed a plastic film to collect water, mimicking the beetle shell, useful for capturing water in areas rich in mist. (FORNIÉS, 2012)

A similar application of this same study was developed by the Italian architects Arturo Vittori and Andreas Vogler of the studio Architecture and Vision, called Warka Water. It is an incredible tower made of natural materials designed to collect moisture from the air by condensation and thus deposit the water in a container, capable of capturing about 100 liters of water per day (Figure 5). As air always contains a certain amount of water, regardless of the ambient temperature and the humidity condition, the design makes it possible to produce almost anywhere.

The project website indicates that there are many biomimetic inspirations, such as the Namibian beetle already commented on, the leaves of the lotus flower, the spider web threads and the integrated system of collecting haze in cacti. All this has been translated into specific materials and coatings that can improve dew condensation and water flow as well as improve the storage capacity of the mesh. Another cited biological reference that influenced the external design of the product, improving the air flow, were the termite hives.

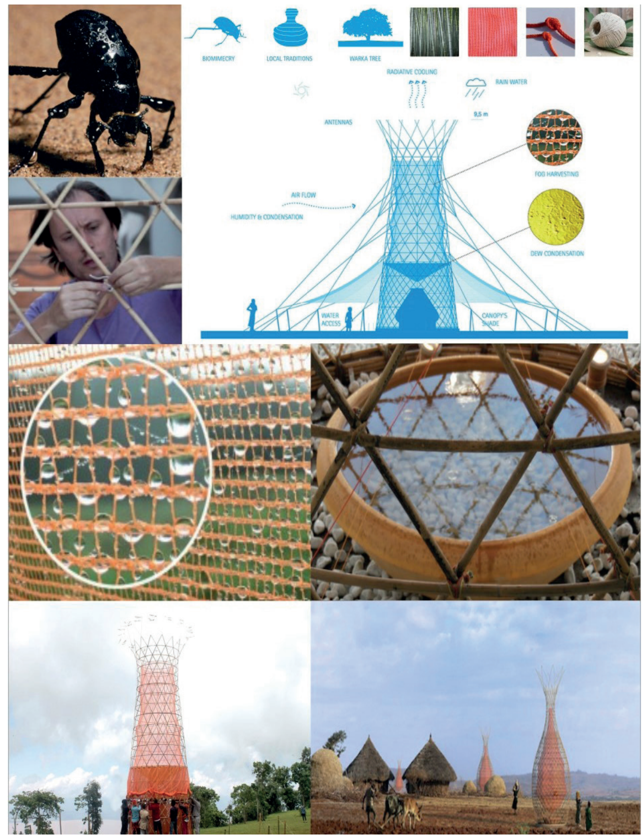
Its structure is mainly based on bamboo, natural fiber strings and an inner lining that is a mesh made from recycled plastic with beetle technology to pick up the dew droplets that flow into a basin inside the tower. The bamboo braid provides lightness, strength and stability and is joined with metal and hemp pins.

At the upper extremities are small mirrors that keep the birds away and do not contaminate the water. The whole structure is modular, composed of 5 parts, measures about 10 meters and weighs 60 kilos. It can be built from scratch by 10 people in 10 days or, if only the assembly with the pieces ready, in up to 2h by 10 people, without the need of scaffolding and with their own hands. It costs on average $ 1000.

In addition to the more obvious benefits, the project incorporates local culture and vernacular architecture through traditional Ethiopian weaving techniques in the product. In addition to improving the living conditions of these people, it was also designed to create shade, a social space that generates public meetings of education and social interaction among community residents, an analogy also to the native tree of the region, symbolically much (The fig tree) which in the local African language is called Warka.

The project was first presented at the Venice Architecture Biennale in 2012 and is targeted at rural populations in developing countries where the infrastructure to provide access to safe drinking water is very precarious.

Figure 5: Warka Water Project for water collection based on the Namibian beetle.



Source: Soares, 2016

3.5 De-polluting and self-cleaning materials

This last example presents the modular architectural system for facades Prosolve370e, which can effectively reduce air pollution in cities. The system consists of modules that are coated with a super-thin layer of titanium dioxide (TiO^2), a pollution-fighting technology that is activated by sunlight, a material known as pigment because of its self-cleansing and germicidal qualities. Small amounts of UV light and natural moisture to effectively reduce air pollutants in harmless amounts of carbon dioxide and water, breaking down and neutralizing the nitrogen oxides and volatile organic compounds in the environment. It can be used for various purposes, including clothing. (SOARES, 2016)

In architecture, the german office Elegant Embellishments used the Prossolve370e on the facade of a new hospital in 2013, called Manuel Gea Gonzales Specialty Tower, in Mexico City. The facade has an area of

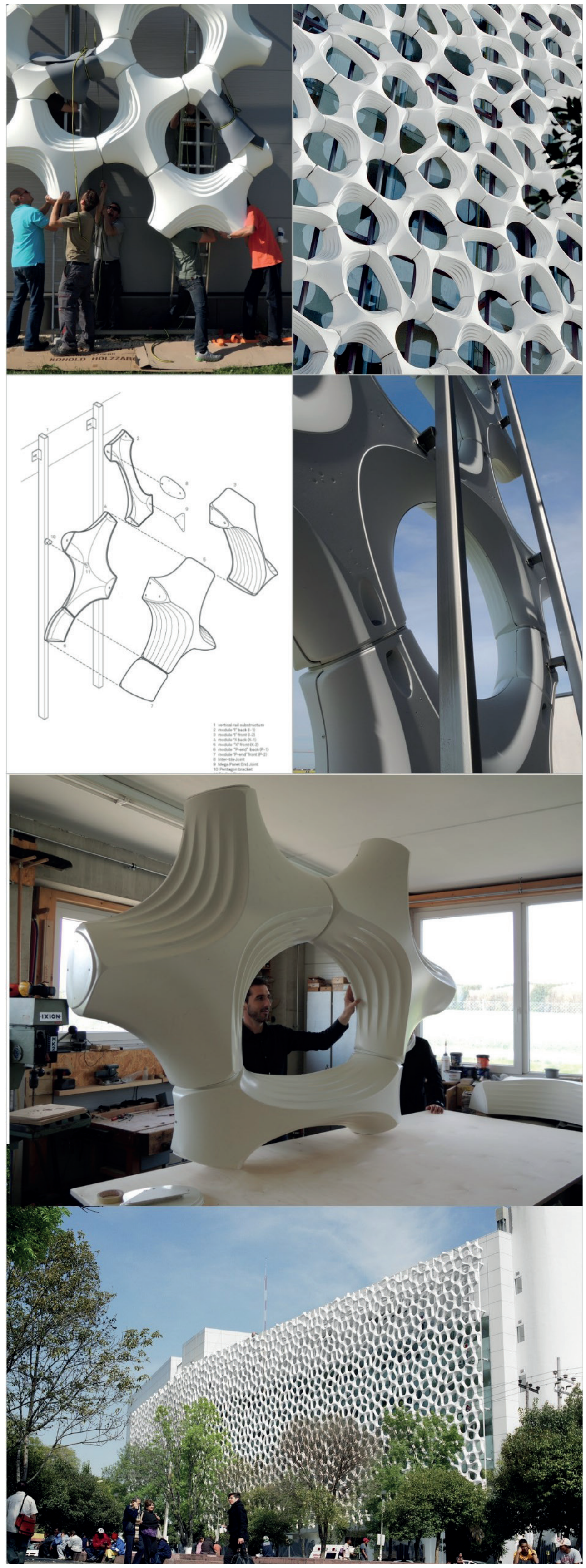
2500m² with 100m in length and is helping to reduce an estimated pollution of 1000 cars per day. (Figure 6)

The reference in the cellular pattern is clear on its configuration, although the company informs that it shapes refer to the pattern of organic growth inspired by fractals in nature. The fact is that these organic forms are not only aesthetically attractive, they are translated into an efficiency gain because their undulations maximize the surface area of the active coating to diffuse light, air turbulence and pollution, ie, they maximize the coating technology since surface complexity helps in capturing omnidirectional light where it is dense or scarce. (SOARES, 2016)

The system is composed of only two replicate modules and their parts can be adapted to the needs of the project (sizes and formats). For the hospital, these parts were produced in a thermoforming fabric in Ulm/Germany, where a 1: 1 scale prototype provided a pre-set-up time prior to assembly. The material used was thermoformed ABS plastic, joined with standard steel fasteners. Structural engineering was done by Buro Happold New York and the project's technical consultant is the professor of physics at Duke University, Joshua Socolar. (SOARES, 2016)

The modularity of the system allows complex architectural forms to be more accessible, since it facilitates the fabrication and assembly. As decoration, they have potential for indoor or outdoor use; Regeneration of aged or modernist facades; Being well indicated for parking lots, hospitals, buildings in general and especially places where there is great flow of car and pollution. Outside this hospital, the project has already expanded to several other countries, due to its great potential for use and innovation. (SOARES, 2016)

Figure 6: Prosolve370e modular system applied to the facade of the Manuel Gea Gonzales Hospital by the company Elegant Embellishments.



Source: SOARES, 2016

4. CONCLUSION

The issue of ecomaterias goes beyond recycling and reuse. In the examples shown, has identified new materials based on the strategies of Nature that always promote an efficiency of resources and energy for their creations. In this way, biomimetics aims to collaborate so that more sustainable materials are produced in order to be applied in the creation of products more efficient for human activities while not damaging the ecosystem.

To achieve this goal there are no quick answers or instant solutions. The reformulation of the linear production process into a circular model is achieved by the joining together of numerous and diversified efforts and it is therefore important to disseminate new paths such as those proposed by biomimicry to realize that in the midst of the current complexity there is a range of possibilities and potential solutions for materials within this biomimetic context.

Analyzes of hydrophobic and self-cleaning materials based on the Lotus plant, which gave rise to paints and coatings that do not get wet or dirty; The hydrodynamic materials based on the shark's skin, which gave rise to tissues that decrease friction and increase the performance of swimming athletes; Adhesive materials based on the gecko gowns, which allow super adhering surfaces of carpet fastening without the need for glues; Water abstraction materials based Namibian beetle, that enable products such as Warka Water to store water from atmospheric air in regions of scarcity; And finally, self-cleaning and de-polluting materials based on the photosynthesis of the leaves, which allow the coating of constructive modules on facades capable of helping to decontaminate high-flow pathways of cars, are just some of the beautiful examples that take up the hopes in a world with intelligent and eco-efficient materials that contribute to the fact that the Design can promote the resolution of problems in the world.

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