

CLADDING INNOVATIONS: COMPOSITE MATERIAL TECHNOLOGIES AS ENVIRONMENTALLY FRIENDLY, RESPONSIVE AND LIGHTWEIGHT SOLUTIONS

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Abstract

The use of contemporary composite materials as a technological solution for façade systems has been increased and improved during the last few years. This because those innovative materials can assure high performances and environmentally friendly solutions. New generations of acrylic surfaces, laminates and aggregates panels are brought into trade everyday and more and more performant compositions are continuously tested.

Moreover, a specific attention on recycled materials is being paid in order to reduce energy building consumption and foster sustainable and avant-garde technologies. Consulting a material library like for example Material ConneXion, we can find thousands of different composites having a big variety of physical and aesthetical properties and made with infinite sorts of components (from carbon particles to bovine fibers!) and processes.

Unfortunately, only a small amount of these innovative materials are already used on the building construction field. Composite materials like artificial stones, solid surfaces (i.e. Corian Dupont), laminates (i.e. Alucobond) and other less known elements are nowadays commonly adopted for ventilated façade solutions and help projects reaching high levels of building sustainability certifications like LEED (Leadership in Energy & Environmental Design) or KlimaHaus. The purpose of the following article is to analyze the thermic and physical benefits the application of composite materials on the building envelope generates in the sense of environmental design prescriptions.

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Keywords: Composite materials, innovative façades, renewable cladding components.

Introduction

In the last two decades the area of advanced materials and technologies have developed rapidly. New researches on nanomaterials, biomaterials and smart composites imitating natural nano-structures and processes are experimented everyday within the cutting-edge technologies adopted mainly by aerospace and chemical engineer. In the architectural field, and especially in the sector of building cladding, only a small amount of such advanced technologies have settled. As an alternative to traditional components and techniques, architects and civil engineers are nowadays using advanced composites materials. Composite technologies are actually nothing new. Artificial composite materials have been used as building and cladding system solutions since long ago.

With the connotation “composite” we refer to every material constituted by two or more different components (usually a matrix and a reinforcement that can be both either natural or synthetic), whose physical and mechanical properties have a superior grade quality than the sum of the single raw materials’ ones. We distinguish three main groups of matrices: composites materials can be metal-matrix composites (MMC), polymeric-matrix composites (PMC) and ceramic-matrix composites (CMC), while reinforcements can be almost any kind of material: from natural particles to high-tech fibers or even high-performance nano-components.

One of the first man-made composite wall construction method we know is that of sun-dried adobe blocks elevation, which have been used since 9000 years ago in the construction of the Neolithic

city of Çatalhöyük, in Anatolia. Those bricks were made up of a mixture of clay, mud and a reinforcement of straw or dung. A similar ancient procedure for raising walls is the rammed earth technique (or pisé), which consists on the compression of a mixture of earth, sand, clay, lime and gravel onto an inner wooden frame or mold, in order to create entire walls or single bricks. This method is still used in today's architecture. An example of a recent building cladding designed with such technology, in which a rigid insulation panel is embedded in order to lower energy consumption, is the Nk'Mip Desert Culture Centre, built last year in Osovoos, Canada and designed by HBBH Architects. Its exterior walls are made of several longitudinal and irregular stripes having thirty different hues of colour (from light yellow to red) that blend with the desert environment and imitate the sinuous contours of the surrounding valley dunes. In this project the purpose of improving energy efficiency and of lowering energy consumption during transportation and dismantling, is therefore joined to a great respect for natural and cultural aspects. Moreover, natural ventilation, joined to an embedded 100mm insulation panel within the wall, help reducing air-forced system consumption by 50%.

Composites

Composite products can be reinforced by fibers (continuous or discontinuous) or particles and, as we know, the most common composites are metal, ceramic or polymeric matrix based. Prevailing composites materials adopted by architects are concrete (that is one of the eldest aggregates, since it was first manufactured from the Romans) and its main derivatives: GFRC (Glass Fiber Reinforced Concrete) and GFRP (Glass Fiber Reinforced Polymer), both reinforced by high performant fibers. Such materials, when used on the construction field, are a testimony to the fact that particles or fibers reinforcement are essential in helping designers and architects obtaining high performance solutions that meet products aesthetic quality (in order of colours, finishes, effects) and physical and sustainable requirements. A glass fibers addiction to a traditional matrix like concrete, for example, can reduce the compound's weight by 30% and eliminate micro-porosity while helping architects obtaining the designed effect in terms of superficial appearance.

In the field of PMC not only glass but many other different kinds of fibers or particles (carbon, aramide, animal or wooden based) can be incorporated either into thermosetting or thermoplastic resins in order to give the compound the same stiffness and strength of hard materials like metals. Thanks to their fundamental characteristic of blending together the different raw materials properties and behaviours, composites can also be included in the branch of reconstituted materials, which uses waste products acting synergistically with synthetic phases.

A compound based on natural raw materials and used as a second skin component for nowadays buildings is engineered stone, also known as artificial marble or quartz stone, that is a composite made of fine particles of quartz, marble or granite (derivative from production scraps) and blended with a small percentage (5 - 9%) of thermosetting polyester resin. This artificial stone distinguishes itself from natural stone for the capability of regulating its aesthetic and physical characteristics, which allows construction designers to treat the envelope as if it were an homogeneous surface, even if it's made of a multitude of "marmette"(tiles usually 30x30 cm or 60x60 cm size). Such material can be cut into very thin slabs (from 12 to 33mm) and its main characteristics are insulation, transparence and lightweight, all features that can be planned upon production. An example of artificial marble ventilated façade is Quarella S.p.A. headquarter in Verona. Quarella S.p.A. is one of the most important engineered stone manufacturer in Italy. The building is covered with a marble based reconstituted stone having a soft green vein which lightens the massive surface and makes it being in harmony with the blue sky of Verona. Thus such design solution joined the purpose of applying and exhibiting outside the material they produce inside, as if it were an open-

air showroom with that of acting in an environmentally friendly way, from both sustainable and adaptive perspectives, thanks to the natural ventilation and the mimic connotation of the envelope.



Fig.1. Quarella S.P.A. Headquarter, Verona, 2014 [Anna Martini]

Talking about thermoplastic resins, an example of artificial composites made of raw materials drowned in resin are Solid Surfaces like Dupont Corian® or LG Hi-Macs®. In such compounds a Poly Methyl Methacrylate PMMA resin (usually 70%) is used as a matrix and the reinforcing phase is made of bauxite derivative micro particles (Aluminium Hydroxides). Thanks to its thermoformable, flexible, ultra-resistant and non-porous properties, these solid surfaces can be molded into infinite shapes and assure high performances at the same time. These panels can reach a 9mm thickness and are joined together by an apposite Dupont thermoplastic glue in order to create a perfectly homogeneous and non-porous surface. An example for cladding solutions made of LG HI-MACS® surfaces is the Southern façade of BENETEAU Headquarter in Givrand, France, designed by PAD Architectes. The façade is covered with a perforated random mesh-like second skin that resembles the firm's logo and, as stated by the architect: *“gives the impression that the façade is moving, like a wave coming to cover and protect the building”*. With this acrylic homogeneous cladding the architect's aim of integrating the building to the surrounding environment and allowing a natural illumination to the huge glass gallery, while giving a fresh look to the surface, was perfectly reached.

High performances

During the last years more advanced composite materials and technologies, deriving from other scientific research fields (especially that of aerospace engineering, automotive industry, etc.), have been used as double-skin façade system components in order to assure natural ventilation and reduce energy consumption.

These new generation composite materials have higher chemical qualities than that of traditional ones. They can guarantee excellent physical and mechanical characteristics in order of: lightness, fire resistance, high performance, impermeability, stiffness, ultimate tensile strength, etc. Moreover, such innovative dry materials and construction technologies proved to be more valid than the traditional ones towards energy consumption reduction during production and dismantling of construction sites, that is a very important and fundamental aspect in the sense of ecology.

Laminates, that are products made of several interwoven layers, pressed, glued or stuck together, are one of the biggest and most common category in composites classification. Almost every raw or recycled material can be employed in the production of this kind of compounds. Thus there can be layered products made of metal, wood, plastics, glass, gypsum, etc. and they usually have an insulation core made up of polyethylene, rock-wool or of any other type of natural or synthetic lining or foam offered by the market.



Fig.2. Eureka Tower: view from The Shrine, Melbourne, NSW, Australia, 2011 [Anna Martini]

A well-known laminate composite in trade is Alucobond® from the firm 3A Composites, a lightweight but tough panel consisting of two aluminum cover sheets and an insulating plastic core that is extremely impact-resistant, waterproof and easy to install. Thus assuring a light, high performant and easily transportable cladding system. A similar product is the Alpolic® panel, produced by Mitsubishi, which is composed of a non-combustible mineral filled core sandwiched between two layers of 0.5mm thick recycled aluminum and that can be molded in different shapes and finished-off with any kind of colour and topcoat.

Its principal feature is lightweight: compared to a 3mm Aluminum sheet, which weight is 8.1 Kg/m², it is very light (a 3mm Alpolic®/fr is 6.0 Kg/m²). Moreover, Alpolic®/fr is 100% recyclable and energy saving, while maintaining the equivalent strength of solid metals. This product has been used as a ventilated cladding system for the surface of the higher landmark that has been built in Melbourne in the later years, the Eureka Tower, a 91 stories skyscraper which stands out against the Australian metropolis' skyline. This representative building is a 300 meters high tower covered with an alternation of dark blue stratified window panes and white Alpolic® panels. As most of contemporary Australian city buildings, this tower gives special attention to sustainability and eco-friendly appliances: besides water recycling, a light and eco-friendly double skin system has been designed in order to minimize heat transfer, and an openable pressure sensitive window system has been planned, in order to facilitate natural ventilation and reduce energy consumption both in summer and in winter time.

Regarding high performances, the most innovative, lightweight and eco-friendly composite components in trade, obviously apart from nanotechnologies, are smart and memory form products. As disclosed before, such innovative materials are usually coming from the aerospace engineering research field, where a need of natural source energy exchange and lightweight but, at the same time, highly resistance (either at temperatures or at impact) features are requested. Shape memory alloys or phase changing materials are the most common smart technologies used in architecture and design. An emblematic example of this technological transfer from the aerospace field to the cladding building technology sector can be found in the Homeostatic Façade, a prototypical surface designed by Decker & Yeadon architects. As suggested by its name, such façade system follows the natural principle of homeostasis, that is an automatic response and self-regulation which characterizes most of flora and fauna attitudes (for example a human homeostasis system is blood thermoregulation). Its components, called "muscles", are made of a flexible polymer covered on both sides by a dielectric silver layer. When the sunlight hits their exposed surface, dielectrics make the elastomer bending or twisting and combine to bring about a self-controlled shading system that works without electrical energy in response to temperature increases and light variations. These muscles are inserted in a double glazed system and, when opening and closing, help controlling solar heat gain through the façade. Such system can also be regulated by users through an electric input from the inside.

Another smart façade project, unfortunately realized only as a prototype, is Lotus 7.0, one of the most relevant works of Studio Roosegaarde, a dutch design firm whose aim is that of letting a physical space becoming "*immaterial in a poetic morphing of physical space and human interaction*" (Dan Roosegaarde, 2010). The project consists on a wall made out of smart layered mylar foils, lights and custom electronics connected to movement proximity sensors that make the whole process starting when visitors are passing by. In the meanwhile the spectator is approaching Lotus 7.0, sensors trigger a lighting input to the lamps, which in turn give out heat, causing a shape changing to the foils. Those hundreds of foils are made of a shape memory alloy (SMA), a material that permits them to unfold in response to a temperature increase and to change back to their initial state when the external solicitation is gone by. "*No movement, no heat – the "lotuses" will close again, slowly sealing the "transparent voids between private and public,"*" as Roosegaarde wrote on his website.

As seen from the description of those two installations and from the reference hereunder, lots of prototypes based on smart, adaptive, innovative and self-control cladding technologies have been developed during last year but their application is still very sporadic, due to high costs.

Conclusions

“Architecture represents a vast opportunity for the application of new materials. Many architects are fascinated by the idea of using new technologies and materials in construction. However, few end up doing so for a variety of reasons such as difficulty with building codes, resistance from construction crews, and union demands which lengthen the building process. Many situations require shortcut solutions, so architects revert to standard methods and methods to get projects going. Design innovation is surely a useful tool, but when technology is incorporated in the form of new materials and processes, the results are always noticeable” (Beylerian, Dent, 2005.)

When talking about architecture, the integration of innovative composite material solutions inside, outside or above the external envelope helps reducing energy consumption in buildings by continuously regulating heat and light transfer and assisting HVAC systems. Most of the architectural projects that reproduce natural composition and adaptivity have been designed to combine an innovative and charming building skin with the necessity of reducing electricity consumption inside the building and greenhouse gas emission outside the building.

Comparing LCA (Life Cycle Assessment) studies analyzing different types of materials and, taking cognizance of the above-mentioned examples, not only the technological cladding structure design aspect is fundamental in the sense of environmental and ecological respect, but also the kind of material applied is very important from a sustainable point of view. The use of a reconstituted and/or recyclable material, a resin based conglomerate or a laminate can assure assembling, transportation and disposal handiness in building constructions, allowing a reduction of energy consumption and pollution derived from the heavy machinery production and carriage. These innovative technologies, indeed, can obtain the same (or even superior) mechanical and physical properties of the traditional ones, while having a very thinner gauge and being therefore easily carted, trucked and installed.

Moreover, being, in the most of cases, products built of dividable and reusable parts or constituted by a mix of raw materials that can be crushed together and later reconstituted, they help reducing waste production from the construction site after demolition and saving energy (and money) for the disposal. This is maybe the most important aspect to consider when using such innovative technological solutions. In the last twenty years several prototypical façades and artworks mimicking natural phenomena and structures have been developed: projects based on the concept of embedded reinforcement (as it is for bones), or on energy exchange (as it is with photosynthesis, electromagnetism, homeostasis or pupillary light reflex) are proposed to better the human life and, most of all, to improve energy efficiency and lower the building energy consumption. Using high performance composite materials, these new cladding technologies are able to control several factors such as heat, light, humidity, etc. and to act as a membrane from the exterior to the interior (or vice-versa) surfaces of the installation. In order to reach such accomplishment, they are mainly using innovative materials and/or technologies coming from external branches of scientific research such as chemistry, computer science, aerospace engineering, etc.

Architecture is nowadays asked to achieve a low carbon footprint, a positive impact on the built environment and significant savings in operating costs both during construction and during dismantling. It has to be environmental responsive, intelligent, reconfigurable and interactive, or, in other words, to be adaptive. Development on the use of composite, nature-emulating materials and technologies is probably the best way to satisfy such requests.

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