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Chameleon Building

M Mandaglio[1,*]

[1]Department of Architecture and Territory, Mediterranea University of Reggio Calabria, Salita Melissari 1, 89124, Italy

*mariateresa.mandaglio@unirc.it

Abstract. The research lines that are outlined for the next few years identify the most promising innovation territory for the development of resilient envelopes in materials and construction systems. In the last two decades, this research lines has fuelled the development and then the entry on the market of different materials supported by a growing demand for resilience and characterized by the adoption of different approaches: from the design of the same material to the modification of some of its characteristics, obtained by technological transfer both within the same building sector, both from other sectors already tested, from the "eco-active" ones to obtain self-cleaning surfaces, up to PCM Phase Change Material, TIM Transparent Insulation Material, Aerogel, ETFE Ethylene, a polymer made of a translucent and resilient plastic film an air cushion that inflates and deflates according to weather conditions. To this, adds the strong contribution of SMART systems that produce sensitive and responsive envelopes that define its new resilient character. Another approach inherent in the adaptive requisite of buildings is that following the dictates of Biomimetic, it directs studies towards the realization of iridescent facades in the material-functional and language responses, to the different solicitations deriving from the contexts.

Assuming nature as a model, measurement we study materials and components that react to environmental stimuli in an organic and passive way. These highly adaptive strategies could substantially contribute to the realization of resilient envelopes. The use of innovative materials and systems would therefore in a certain sense "tune" the building to the climate, in fact with the right sensors and controls the building is able to respond to weather conditions in real time.

1. Introduction

If we want the envelope as "skin" of building, which protects the interior from the elements but at the same time it uses the power in a functional way, then we can think about the creation of a protected space controllable. In this case the external environmental conditions become a resource and not a force to be struggled against while the envelope is a "reactive skin" that improves internal wellbeing and evokes many possibilities for change [1].

The external envelope is the "first line" of the interaction between the building construction and environmental agents: the research trajectories that are outlined for the next few years identify the most promising innovation territory for the development of materials, construction systems and resilient envelopes.

Inspired by strategies of dynamic response to external stresses taken by living organisms and natural systems - based on reactivity, adaptivity and self-repair ability of individual parts, which thus contribute to determining the behavior of the complex system - innovation invests primarily materials and building components, incorporating individual services, whose contribution have to be integrated into the operation of the building, to become effective [2].

In the last two decades, this research line has fueled the development and then the entry on the market of different “eco-active” materials, from the range of functionalizing coatings that exploit photo catalysis to obtain self-cleaning surfaces, up to PCM, Phase Change Material, which provide thermal capacity not by exploiting inertial mass, but thanks to their phase change, allowing cyclically alternating absorption and release of thermal energy in relation to the variation of the temperature to which they are exposed. In the same direction, even the diffusion of devices for the capture of solar energy has made “large” areas of the building envelope “active”, with an indirect effect of increasing its resilience.

These pioneering applications are in some ways the precursors of the scenarios that open up thanks to the development of nanotechnologies and the extensive use of solutions inspired by the strategies of the living, or “biomimetic”.

The integral reproduction in the artificial systems of the metabolic behaviors of natural organisms, the adaptivity and reactivity, conveyed by a material to the more complex systems that incorporate it, are emblematic of a productive innovation that offers to the applications in the architectural field new resilient capacities, which they are conferred thanks to the reproduction of devices inspired by biological systems, or developed in order to reduce the impact of waste, recycling waste products, or conveyed by the use of innovative, nanomodified, unconventional materials.

Not only. In fact, in response to the increasing number of manifestations of perturbative climate events, manufacturers of building components are developing solutions that, instead of opposing, allow the event to “give vent” to its effects in a non-destructive way and indeed, if possible, exploit them. This is the case with the increasing diffusion of draining pavements, which offer the double advantage of preventing flooding and allowing water to filter and be disposed of in the subsoil. Constant improvement work has led to the application of these products not only in the driveway area (e.g. car parks, transit areas, etc.) but also in the paving of public spaces.

The development of materials capable of repairing themselves in the event of damage is also very promising, the result of innovations that the research and experimentation activities at the peak feed effectively. In this context, the work done at Delft Technical University in the development of self-repairing cements for water tanks is significant. The protagonist of the process of self- destruction phenomenon is a bacterium, able to produce calcite in the presence of water [3].

From the application to the tanks, to the most widespread use in situations of risk (for example hydrogeological) the step could be short and the effects of very significant flow.

In the area of product innovation, therefore, different trajectories are emerging, fed by a growing “demand for resilience” and characterized by the often combined adoption of different approaches: from the project of the same material and its performances to the modification of some of its characteristics, obtained by technological transfer from other industrial sectors, both within the same building sector, from areas already tested to other fields of application.

For this reason, productive innovation can aim to be complementary to the quality of the architectural project as an end in itself, thus contributing to integrate the levels of environmental and social resilience of a single architecture, as well as of a complex urban system.

In this perspective, we have to consider not only the whole process in all its phases, including the disposal of the work, but also to foresee its interactions with the situations that will occur in the local and global context with which it interacts.

In the concluding part of the text The Architecture of the Well-Tempered Environment, Bahnam has its roots in an innovative vision of the building envelope conceived not only as the “architectural business card”, but as a complex system- filter selective polyvalent ”which, in addition to separating the two areas, it is able to control and modulate the interactions and material exchanges and intangible between inside and outside, by reacting in a manner flexible to the variability of environmental conditions, minimizing the heat losses in the winter period and limiting the increase in temperature in the summer, with the consequent improvement of living comfort and quality of life of the user [4].

The development of technologies, systems and components for the building envelope able to fulfil these multiple functions has been the field of action of the research carried out, starting from the '70s, by the German architect Thomas Herzog. These experiments led to the development of high-level building envelope systems energetic efficiency consisting of a “appropriately structured and integrated set of materials, components and systems”, in many cases extremely innovative, able to transform, enhance, reduce and modulate the thermal, acoustic and light signals coming from outside.

A building envelope can, in fact, be considered energetically efficient if it constitutes a “dynamic interface”, in continuous and active interaction with external climatic factors, and is able to activate “in a planned and optimal way, and based on specific conditions, the metabolic exchange of matter and energy necessary to respond to changes of environmental stimuli and to the needs of the occupants” [5] .

The development of an envelope system “climatically active” have to therefore be based on a knowledge specific and depth of external climatic factors, the parameters that define the level of internal environmental comfort and energy performance of materials and building components that they constitute the envelope itself.

2. Necessity and problems identified

Over the last few years, in relation to climate change, the growth of the attention of professionals regarding environmental issues and the evolution of legislation on energy saving and consumption of resources, has led many operators in the “environmental energy and construction” sector, to identify precisely in the building envelope an essential element for the project for the purpose of reducing energy consumption and limiting its environmental impact throughout the life cycle. Just in light of these considerations, the interest in a project of virtuous architecture and linked to issues of intelligent interaction with the environment has led to conceive the envelope as a dynamic epidermal layer that changes and changes according to the seasons and fits to the different weather conditions and users' requests. An envelope, therefore, capable of “adapting to different needs”. The concept of dynamism and interactivity/adaptability of the envelope with the integration of intelligent materials, capable of containing the energy consumption of the envelopes, leads to the creation of a prototype capable of being used as a serial component for advanced envelopes and aimed at achieving high energy performance [6] . Therefore, it is not only necessary to produce the necessary knowledge to encourage the activation of processes linked to product innovation, identifying new performance requirements linked to energy efficiency, but above all to realize the technological transfer from the scientific sector to the productive sector involved for the drafting of the prototype, creating a synergy between the various subjects involved.

Technological innovation in the industrial field has an increasingly important role and represents a necessity to which companies have to know how to respond also to be competitive on the market, especially in this moment of crisis. Since the beginning of the 20th century, the synergic relationship between architectural design and industry has represented a key element towards technological innovation in the product/building design sector. The result of this synergy manifests itself through the experimentation of technologies and materials in the construction field with the creation of specific joint-ventures between the research world, for the design aspects, and the industrial world, for the realization and commissioning prototype work.

The need for this study starts from the analysis of the evolution of the architectural envelope performance from passive to active, investigating the technological innovation processes that have allowed to develop the etymological and performance passage from the concept of closure to the facade and finally to that of dynamic and intelligent envelope [7].

The study intends to insert itself, in fact, in the varied field of research conducted over the last decade on the energy performance of the architectural envelope, understood as the totality of the parts that define an internal environment (characterized by stable “climatic/environmental” conditions) external environment (variable by nature). In recent years, the envelope system has been the subject of many basic and applied researches that have contributed to its evolution, through the experimentation of new components and materials characterized by high performance and performance. The increasing attention to the problem of reducing energy consumption and environmental well-being has generated a multiplication of the technical and functional elements that make up the envelope, which transforms from static closure into dynamic stratification, in which each layer contributes to satisfying different aspects of climatic, acoustic, energetic type, etc....

The complexity of these technological systems makes it very difficult to assess their energy behavior correctly, given the sum of the different performances of the components they are made of and dependent on the climatic conditions of the geographical area in which they are made;

The need therefore arises to analyses the energetic behavior of buildings, according to the geographical areas and the climatic conditions in which they operate, in order to establish rules so that the technological systems of envelope are not simply exported from a locality to the other, depending on their aesthetic - architectural characteristics, but adapted in relation to the geographical area of reference by evaluating the energy performance.

3. Operational goals of the study and methodology

Part of the technological innovation linked to the energetic performances of the contemporary envelope is due to the realization and adoption of new transparent materials subdivided by characteristics in: passive (prismatic panels, LCP, FISH profiles, OKASOLAR profiles, etc.), active (chromogenic glasses, electrochromic glasses, holographic glasses, etc.) and high performance (aerogel, TIM, ETFE. PTFE). In many contemporary buildings, the envelope is made with façade systems that allow the accumulation of incident solar energy and transform it into heat to implement the winter energy needs of the building, in others the envelope becomes a real active element of energy production, thanks to the integration of technological systems related to renewable energy sources (photovoltaic and solar thermal).The opaque and transparent vertical closures are developed as complex technological components capable of interacting with the surrounding environmental conditions, able to reduce the energy needs of the building.

To meet these needs there is a growing need to develop innovative building envelopes with high energy performance, whose performance evaluation is undeniably linked to the dynamic variables related to the external environmental conditions with which they relate.

The study will be developed by adopting a methodological model of deductive, systemic and scalar type that will allow to structure the work of investigation for consequential in-depth moments: passing from the definition of the macro-theme, defined by the themes linked to the dynamic and energyefficient building envelope , to those relating to the identification of the characteristics of smart façade systems, to finally reach the development and subsequent realization of an innovative component, capable of implementing plant integration in a functional stratification of elements distributed in relation to the characteristics of the site, in relation to the analysis that will be conducted through simulations and experiments with standardized protocols.

4. The intelligent structures

An intelligent structure can be defined as such if it is able to monitor the physical operating environment, collect and interpret the information and then respond to the appropriateness of the same in an appropriate manner. To perform these tasks, the structure have to be equipped with a sensor system, a data acquisition and processing system and an implementation system. See Figure 1.

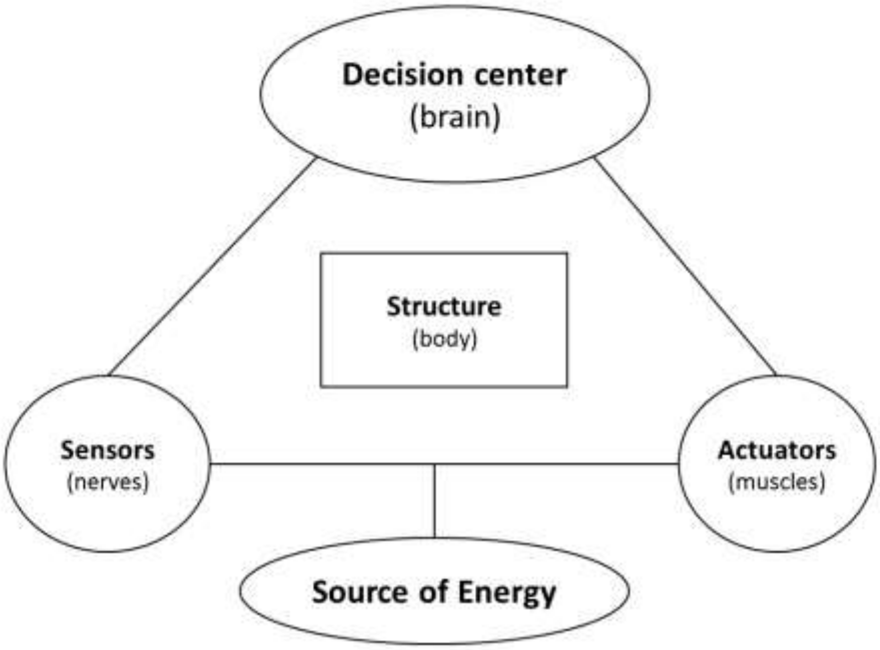

Figure 1. Scheme of a biological system.

In recent decades, the design of the external surfaces of buildings has acquired a strategic role by opening up to the experimentation of increasingly innovative technologies, applying intelligent systems that make the façades dynamic and allow them to interact with the most diverse environmental parameters.

Various professionals have tried to design kinetic elements of the building envelope, for example by positioning sensors that perceive the climatic variations and which, according to the external temperature, send commands to operate moving elements. So they take shape of facades that change appearance, that move and that we could call “kinetic”. These are mechanical and electronic devices that allow the movement of some parts of the structure without this obviously affecting the stability of the building; an idea that may seem futuristic, but which is an expression of technological progress applied to architecture.

A kinetic facade could be generically considered as a transformable object adaptable to different spatial and climatic conditions and is usually designed in such a way that parts of it can move and perform functions that would be impossible for a static structure. They are facades that adapt to the context and interact with it, absorbing its inputs through the action of natural or artificial agents. An example is the dynamic solar shading, with the function of containing and controlling energy consumption or glare [8].

An adaptive envelope can be described as a locking system that has the ability to change its own properties and control different flexibly parameters. These changes are produced to respond to a change in external weather conditions or internal measures to improve environmental well-being indoor. The change in the performance of an envelope it can be obtained in several different ways: through chemical changes in the materials that compose it, with the movement of elements or introducing air flows.

Dynamic façades represent the future of building. These will allow the user to independently control the movements of his house façade. It sounds like science fiction, but it's all real. Users will be able to adjust the indoor climate of the rooms as they please, as well as to establish on what tones to create their place of study, life and work, all with a simple click [9].

Among the most common materials used for the creation of such facades is certainly the aluminium combined with internal engines, which allow the desired shape and size changes. This material is one of the first examples of dynamic façades located in Australia (composed of 112 aluminium panels that combine the same number of engines that act as a filter against heat and repair for the winter cold). See Figure 2.

Figure 2. Australia Dynamic Facade. Source: http:// comefare.fixool.com/facciate-inamiche/

Another very interesting example of a dynamic facade is that found at Abu Dabhi. The facade consists of triangular panels that work like a curtain. In this building each triangle is made of glass fiber and programmed to respond to the movement of the sun, to regulate the excessive heat and the torrid weather conditions of the Arab city. In the evening the triangles are closed. This mechanism provides for the possible reduction of over 50% of the internal heat of buildings. Precisely for this reason, the building will not require a continuous conditioning system and will allow its inhabitants to have a considerable energy saving. See Figure 3.

Figure 3. Abu Dabhi Dynamic Facade. Source: https:// www.archdaily.com/89270/kiefer-technic-showroom-ernst-giselbrecht-partner/kiefertechnic_4

Another noteworthy example is the pavilion built for the 2012 Expo from Denmark. The goal was to reproduce the movement of the sea waves. In this case, 180 lamellas made of glass fiber reinforced polymers were used. The movements were coordinating from a central computer that allowed the realization of the sinuous movement, in addition to the exchange of light between the internal environments and the dissipation of heat. Another very famous example is that of the Centercity Gallery created by UNStudio in 2010. In this case everything was focused on the creation of a strong optical illusion. The dynamic façade is formed by two layers arranged on a vertical aluminium grid with a severe alternation between the straight limbs and the angled parts. This system has created a deep layer of lights and shadows of the system that allow you to have an absolutely unique and exceptional effect. In short, it seems that the most used element for the realization of the dynamic facades is aluminium, which is very valid both for its resistance and for its economy, excellent characteristics for the creation of facades. See Figure 4.

Figure 4. CenterCity South Corea Gallery Dynamic Facade. Source: https://www.archdaily.com/125125/galleria-centercity-unstudio

The MediaTic building, located in the heart of Barcelona e designed by the Spanish architect Enric Ruiz -Geli, is a perfect example of the technical and formal union that this kind of works requires.

The external envelope of the Media-Tic building is characterized by a counterfaçade in Efte (Ethylene tetra fluorine- ethylene), which, being able to be injected by air and nitrogen, becomes inflatable or deflated according to those that the external environmental stresses are: this in order to obtain a building behaviour that guarantees adequate indoor comfort levels together with precise requirements of sustainability. The vertical closures in question come kept swollen in cold periods to exploit the thermal resistance of the air, and deflated in the rest of the year, when the high territorial temperatures of Catalonia have to be governed to ensure both adequate internal thermo-hygrometric comfort and a containment of expenditure Energy.

Efte is a polymer source material that only it has recently started to be used in construction, and which, in the project in question, covers the most of the closures: of the large lenticular “cushions” in Efte, connected to a pneumatic blowing system to his time controlled by some probes that regulate the behaviour depending on environmental stresses external (temperature, air humidity and pressure atmospheric), swell and deflate if necessary during the year. See Figure 5.

Figure 5. Mediatic Barcelona Dynamic Facade. Source: https:// www.teknoring.com/news/progettazione/facciate-dinamiche-linvolucro-in-efte-del-media-tic-di-barcellona/

Another example is given by the facade of the Institute du Monde Arabe in Paris by Jean Nouvel composed of square steel diaphragms that open and close at each change of hour, changing the aspect according to the light. Between the panels is housed a system of grids that filter the light flow inside by means of photoelectric cells. Visiting it one gets the impression of entering the frame of a camera, as Nouvel himself points out: “The sequence of passages between different volumes and lighting levels, depending on the different trajectories inside it, can be seen as a series of angles and openings of a photographic lens”. Jean Nouvel creates a façade that not only continuously changes, but that manages to blend the rational forms of the West with the geometric patterns typical of Arab buildings. See Figure 6.

Figure 6. Institut du Monde Arabe Paris Dynamic Facade. Source: https://www.parigi.it/it/institut-du-monde-arabe.php

The American artist Ned Khan realizes kinetic facades using two-dimensional components made of plastic or glass or stainless steel that seem to be shaped by the wind and which produce bright optical effects by reflection of the sun's rays. The parking facade of Brisbane Airport, Australia, is covered with small square aluminium panels locked in two points on the upper side and left free in the lower part, a solution that allows them to move at every gust of wind. Passing through the panels, the wind waves the elements that move each one autonomously: the global effect is a façade that moves according to unpredictable patterns. By combining art and technology, one can obtain a work that not only produces an effect for the benefit of those who see it, but also has a function for the entire building: the panels protect the building from sunlight and promote its natural ventilation.

Among the numerous examples you can mention there is also the envelope of Kinetower. The project of Kinetura (Xaveer Claerhout & Barbara Van Biervliet), designed in 2008, represents a synthesis between the concepts of adaptability, sustainability and use of innovative materials. The envelope involves the use of a memory skin of shape that, divided into blades in correspondence of the windows, is able to open and close by adjusting the incoming light. Particularly interesting they are the corner solutions where the blades (similar to the fingers of two hands) seem to diverge and then converge between them. Current research in the field of shielding is focusing on increasing integration of materials capable of capturing and transforming (photovoltaic) energy or reacting automatically according to external environmental conditions, using very little energy (homeostatic shieldin). See Figure 7.

Figure 7. Kinetower Dynamic Facade. Source: http://www.evolo.us/kinetower-is-a-metamorphic-skyscraper-kinetura/

This dynamism of the parts can even affect not only the external shell, but the entire structure that gives rise to surprising results such as those observed in the "Casa Accordion". Undoubtedly it is a particular construction, since it changes shape according to the seasons, expanding and shortening. It is located in Sweden, in the forests of Glaskogen and was designed by the architects and owners Maartje Lammers and Boris Zeisser of 24H Architecture.

The project starts from the desire to transform a shed into a summer vacation retreat that has resulted in the construction of a building with a fully mobile part that adapts to different weather conditions. In winter it retracts and in summer it expands. The expandable body consists of the living room, the rest is equipped with bedroom, bathroom and kitchen. Made of wood and glass to fully integrate with the natural landscape of the forest, it is powered by solar panels on the roof and is equipped with a pulley that, with a system of ropes and pulleys along two steel rails, allows the structure to "stretch out"". Surely a curious object that demonstrates how architecture, thanks to new technologies, can be adapted to the most different purposes and situations, respecting the environments it occupies. See Figure 8.

Figure 8. Accordion House Sweden. Source: https://contemporarygreenbuilding.wordpress.com/2014/06/29/casa-fisarmonica-in-svezia-ledificio-che-si-modifica-con-le-stagioni/

5. Conclusions

It has become more and more real the idea of adapting the architecture to different weather conditions also trying to build the moving parts that make a living structure.

We are moving towards an era of "Mobile Intelligence". Intelligence is described in the Encyclopaedia

Britain as "the ability to adapt effectively to the environment, both by implementing a change in itself themselves that changing the environment or finding a new one". Miniaturization and production of materials equipped with special properties, the integration of sensitivity properties, of the information and intelligence in the individual materials are factors that allow these same materials to interact, communicate and be perceived [10].

Associating the term "kinetic" may seem absurd (the house has always given the idea of "fixity"), but certainly refers to a new way of conceiving architecture. The new building control and management tools, in fact, if on the one hand they can make buildings similar to machines, on the other they bring us back to a less stable size of the building. Now the houses can actually move remaining in their place.

The kinetics introduced in the architecture certainly offers a great possibility to different high tech solutions. An intelligent, accurate and adjustable control of the relationship between external and internal environment can offer unthinkable results, reaching buildings that can be defined "alive".

All this represents an opportunity for integrated research and experimentation of activities and skills aimed at controlling the overall quality of the building and the context of reference through the development and application of technologies and materials resilient to changes and variability of the climate.

Work in progress.

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