Metadata of the chapter that will be visualized in SpringerLink

Book Title	New Metropolitan Perspectives
Series Title	
Chapter Title	Integrated, Adaptive and Smart Envelope for Near Zero Energy Buildings
Copyright Year	2021
Copyright HolderName	Springer Nature Switzerland AG

Corresponding Author	Family Name	**Milardi**
	Particle	
	Given Name	**Martino**
	Prefix	
	Suffix	
	Role	
	Division	Architecture and Territory Department
	Organization	Mediterranea University of Reggio Calabria
	Address	Via dell’Università 25, 89124, Reggio Calabria, Italy
	Email	mmilardi@unirc.it

Abstract

The current scenario on the energy efficiency of buildings has now sanctioned the strategic role of the envelopes for the achievement of the objectives of controlling consumption and offering high levels of quality of life within the confined spaces, but with undeniable connections and relationships with the outdoor environment in general. Attention focuses on the building envelope, on the high number of performances to be satisfied, on its role as moderator of the flows in and out of the building system, which makes it the decisive element in terms of energy efficient operation, greenhouse gas emissions and living comfort levels. It therefore appears necessary ensure full fulfillment of these objectives starting from the design phase.

The use of the term envelope referred to architecture is quite recent and was born as an evolution of the concept closure which identified the vertical and horizontal external infill panels as distinct units.

Keywords: Smart envelope - Biomimetics envelope - Sustainable project

Integrated, Adaptive and Smart Envelope for Near Zero Energy Buildings

Martino Milardi(✉)

Architecture and Territory Department,
Mediterranea University of Reggio Calabria, Via dell'Università 25,
89124 Reggio Calabria, Italy
mmilardi@unirc.it

Abstract. The current scenario on the energy efficiency of buildings has now sanctioned the strategic role of the envelopes for the achievement of the objectives of controlling consumption and offering high levels of quality of life within the confined spaces, but with undeniable connections and relationships with the outdoor environment in general. Attention focuses on the building envelope, on the high number of performances to be satisfied, on its role as moderator of the flows in and out of the building system, which makes it the decisive element in terms of energy efficient operation, greenhouse gas emissions and living comfort levels. It therefore appears necessary ensure full fulfillment of these objectives starting from the design phase.

The use of the term envelope referred to architecture is quite recent and was born as an evolution of the concept closure which identified the vertical and horizontal external infill panels as distinct units.

Keywords: Smart envelope · Biomimetics envelope · Sustainable project

1 Background

In contemporary construction, the building envelope, which indicates the entire external closure system of the building, "has been released of its historical role as a defensive barrier from climatic agents and has been configured as skin, something that breathes and that regulates, in the broadest sense of the word, the dynamics of communication with the outside with a view to a building organism that, like an animated being, experiences exchanges, direct or figurative, with its own context".

The current concept of the building envelope originates from the work of Reyner Banham who already in 1969 introduced the concept of "well-tempered environment" and recognized the shell a fundamental role in determining this condition [1].

Analyzing the history of architecture identifies three main "control models environmental", each of which can be associated with a type of building envelope with specifications features. The first model is conservative and is characterized by a type of environmental control that uses large building walls with few openings to reduce heat loss in cold climates and at the same time, to mitigate the heating effects due to direct solar radiation in hot climates (or periods). The second model, defined as selective, is particularly suitable for hot and humid climates and is characterized by general

C. Bevilacqua et al. (Eds.): NMP 2020, SIST 178, pp. 1–7, 2021.
https://doi.org/10.1007/978-3-030-48279-4_202

principles similar to the previous one, but "uses the structure not only to preserve the desired environmental conditions, but to allow these conditions to enter from the outside". The third model, that regenerative, characterizes the typical buildings of the American construction tradition without "massive" walls in which the environmental control is totally entrusted to the systems, precisely defined as "regenerative installations" while the envelope is intended only as a barrier capable of limiting the interactions between the interior and external.

In the concluding part of the text The Architecture of the Well-Tempered Environment, Banham lays down roots for an innovative vision of the building envelope conceived no longer just as the "business card of architecture", but as a "complex multi-purpose selective filter system" which, in addition to separating two areas, is capable of control and modulate the interactions and the material and immaterial exchanges between inside and outside, reacting in flexible way to the variability of environmental conditions, minimizing heat losses over the period winter and limiting the temperature rise in the summer, with the consequent improvement of the home comfort and user quality of life [2].

The envelope therefore acquires new specificities and new performances dictated by the need to have one osmotic membrane, gradual and capable of varying its behavior with varying stresses: transforms into a selective mediation element, capable of controlling, activating or deactivating a series of variable signals according to the project objectives (filter, isolate, accumulate or transform energy).

The environmental behavior of the envelope is inseparable from the building-system-external environment system.

The passive envelope indicates a technological system capable of exploiting the natural energy available on site in combination with architectural components and, therefore, maximizes direct solar gain because it is equipped with extended glass surfaces on the walls exposed to solar radiation, provides buffer spaces for protection from cold and greenhouses to take advantage of solar energy in the winter, promotes natural ventilation and uses the outside air to cool the building structures at night.

The building envelope becomes active when it not only supports, but integrates the system systems (those for the collection and transformation of solar energy and for the artificial ventilation of indoor environments) such as, ad for example, the enclosures equipped with air or water solar collectors, the enclosures equipped with photovoltaic panels, the enclosures equipped with ventilated windows (when they function as an air preheating coil in the period winter before sending it to the air handling unit, or from heat recovery units).

The hybrid envelope (in which building and plant technologies become complementary to each other and the envelope becomes part of an integrated building-plant system, full of regulation and control devices) is together passive and active, but also multipurpose, because it is capable of performing functions that in the past were entrusted to technological devices of different nature, and dynamic, because they are able to modify its physical-technical performance over time, in relation to the climatic circumstances and the needs of the occupants.

Today the current trends that characterize the building envelope system lead to give other definitions:

- Integrated envelope: born from the integration of the facade and the summer and winter air conditioning systems. It can consist of steel uprights and crosspieces in which hot or cold fluid fed by the thermal power plant, according to the seasons. The heat is supplied with this type of plant mainly by radiation, therefore the classic radiant panel conditions are achieved, with the difference that the radiant surface is actually constituted by the facade of the building itself.
- Hyper-insulated envelope: exploits the stratified structure/coating technologies that have the possibility of calibrate the stratifications and respond promptly to the requirements foreseen in the design phase. From the thermal point of view, in a light and hyper-insulated envelope there is a decrease in the passage of heat: more the building is insulated the higher the thermal resistance that opposes the passage of heat. The envelope has an adiabatic behavior. The key points of the hyper-insulated envelope are therefore the improvement of the thermal resistance of the opaque and transparent parts, an almost airtight seal perfect.
- Ventilated envelope: it can be considered as a matte closure with dynamic insulation, in fact through the variable flow of air inside at a certain temperature, it is able to vary "Dynamically" its thermal behavior. The airflow, depending on the speed, of its state thermal and that of the surfaces it contains, the ratio between the volume of the duct and the surfaces of heat exchange can in fact release or remove heat from the wall. This behavior can be done vary according to the objectives that are proposed and in relation to the boundary conditions.
- Double envelope: belongs to the category of dynamic insulation closing systems. This system, born in the Nordic countries, to be truly effective it has to take into account the climatic specificity of the site. These envelopes can be classified using the origin of the ventilation air, the type of ventilation, or the destination of the ventilation air: double passive envelope: the cavity is naturally ventilated, double active envelope: the cavity is mechanically ventilated, double interactive envelope: they are present both ventilation modes. Parameters such as the position of the double glass are very important in order to guarantee comfort in the rooms. The introduction of a screen inside the cavity has effects on the energy aspect positive (decreases the equivalent transmittance of the envelope), however, increasing the heat exchange radiative, causes an increase in the internal surface temperature, compared to the configuration without screen. Another factor that have to be taken into account is the height of the cavity: an increase in height causes a deterioration in performance, both from an energy and comfort point of view.
- Integrated envelope with energy production plants: a good integration presupposes that the systems are designed simultaneously with the conception of the building organization. Especially photovoltaic is experiencing an exponential evolution in the last period, thanks to its versatility.
- Multimedia interactive envelope: it is a system obtained thanks to the rear projection of images onto various transparent supports.

Glass allows the appearance of good quality images on transparency, while ensuring visibility from the inside out, also allowing the view and the passage of light through the windows. Skin of the building for this type of envelope consists of vertical panels of coupled translucent material, on which the images are projected, mounted on these metal supports.

2 Evaluation Areas and Criteria Related to the Problem

The development of technologies, systems and components for the building envelope capable of fulfilling these many functions constituted the field of action of the research conducted, starting from the 70s, in many areas of architecture, engineering, technical physics etc. developing strategies and techniques whose results are today at the basis of the most significant and reliable innovations. These experiments led to the development of energy efficient building envelope systems consisting of an “appropriately structured and complex integrated materials, components and systems” in many cases extremely innovative, capable of transforming, enhance, reduce and modulate thermal, acoustic and light signals from outside [3–6].

A building envelope can, in fact, be considered energy efficient if it constitutes “an interface dynamic”, in continuous and active interaction with external climatic factors, and is able to activate “in a programmed and optimal way, and according to specific conditions, that metabolic exchange of matter and energy necessary to respond to changes in environmental stimuli and to the needs of the occupants” [7].

Therefore, the development of a “climatically active” envelope system have to be based on specific knowledge and in-depth analysis of external climatic factors, parameters that define the level of internal and environmental comfort the energy performance of the materials and building components that make up the envelope itself. Of consequently, given the interaction with the other components and “design parameters” of the building, commissioning point of a building envelope system that is effectively efficient requires a coordinated contribution of different specialized skills able to manage the complexity of the numerous factors that influence its energy behavior.

The character of adaptivity therefore acquires further and “dense” meanings relating to passive response services, active and intelligent facade systems of the latest generation or in experimental development.

The basis for this new need is a direct consequence of the energy-intensive nature of buildings and applications in response to the European Directives that configure the large umbrella of energy efficiency objectives. These objectives guide the construction sector towards the creation of an interactive building capable of creating one significant turning point in the current scenario that qualifies international construction. In this sense, it is important to underline that the most consolidated literature and reliable reports on trends by 2050, highlight how much the role of the building envelope is strategic for the purposes of these objectives and for the resilient responses of the systems involved. It is indeed known, as today the innovative building practice requires a high number of new performances to be guaranteed and which they can be “collected” in technical strategies aimed at the objectives of a resilient building, such as to make it, in summary: active, integrated, energy efficient and adaptive.

In addition, the state of the art identifies the creation of an adaptive envelope as a strategic “tool” able to implement plant integrations through deferred functional stratifications in relation to the context geomorphological and climatic location. Added to this is the strong contribution of SMART systems that, in addition to performance monitoring, make “sensitive and responsive” enclosures for sensors and actuators that define its new resilient character. Another approach inherent in the adaptive requirement of buildings is what following the dictates of Biomimetic, directs the studies towards the realization of iridescent facades in the material-functional and language responses, to the various requests deriving from contexts. Taking "nature as a model, measure and mentor" we study materials and components that react to stimuli environmentally and passively [8].

The envelope has slowly evolved from a predominantly protective barrier element into a complex filter system selective and versatile, able, on the one hand, to optimize the interactions between the internal environment and the macro-environment external (and the other way around) to the changing of the different climatic-environmental conditions during the course of the day of the year, even during the life of the building body and/or the man who lives there; on the other, to respond more and more often in an "intelligent" sense to the same psychological, sociological and cultural changes of the way of live relationships with these micro and macro environmental factors by users of "enveloped" architecture.

The shape and function of the envelope have undergone a substantial evolution over time both in the use of materials and in the performance of its components. We pass from the concept of wrapping as an energetically passive element the concept of envelope as a dynamic and interactive element of the complex energy system that regulates the operation of the building and characterizes its image. The technological evolution of energy performance of the architectural envelope is recordable and perceptible through the dematerialization of the surfaces that constitute and the automation of its compositional elements.

Technological innovation in the industrial sector has an increasingly important role and represents a necessity to which companies have also to be able to respond in order to be competitive on the market, especially at the moment of crisis. The synergistic relationship between architectural design and industry is manifested through the testing of technologies and materials in the construction field with the creation of specific joint ventures between the world of research, for the design aspects, and the industrial world, for the realization and commissioning prototype work.

All this starts from the analysis of the evolution of the performance of the architectural envelope from passive to active, investigating the technological innovation processes that have allowed us to develop the etymological passage e performance from the concept of closure to that of facade and finally to that of dynamic and intelligent envelope. 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 is transformed from static closure in dynamic stratification, in which each layer contributes to satisfying different aspects of climatic, acoustic, energy, etc.

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

The testing of dynamic and intelligent wrapping systems is currently linked to independent cases of architectural realization, through a model of direct experimentation of technologies, with the consequent risks for users and clients.

The need arises to analyze the energy behavior of buildings, according to geographic areas and of the climatic conditions in which they operate, in order to establish rules for the technological systems they are not simply exported from one location to another, according to their characteristics aesthetic-architectural, but adapted in relation to the geographical area of reference by assessing their performance energy.

From the scenario described so far it is possible to identify relationships with the following areas of evaluation of the Ithaca protocol: B.1.3 Total primary energy; B.1.X Thermal energy useful for heating B.1.Y Thermal energy useful for cooling; B.3.2 Total contribution of energy from renewable sources B.4.7 Materials from sources renewables; B.6 Enclosure performance and passive systems; B.6.3 Average thermal transmittance of the building envelope; B.6.4 Control of solar radiation; C.6.8 Heat island effect; D.2.5 Ventilation and air quality; D.3.2 Operating temperature in summer; D.4.1 Natural lighting; E.3.6 Home automation systems; E.3.7 Integration of building automation systems in the building organization; E.6.1 Maintaining the performance of the enclosure building.

3 Developments and Perspectives

This synthetic panorama highlights how much, in particular, the envelope, invested by the universe of signals that they qualify the external environment, react with specific reactivity, natural or dependent on regulations plant. The envelope therefore represents the physical element of mediation between the external and internal environment and can transform, enhance, reduce, modulate the thermal, acoustic, light physical signals from outside, thus becoming a signal generator in which the environmental quality depends on graduation and control.

From this interpretation, the design potentials in the development of new systems are evident envelope oriented towards environmental quality and sustainable development objectives.

In fact, the building is increasingly required to be able to guarantee high levels of living comfort at the same time contribute to reducing GHG emissions through significant energy savings. In this sense, there is no doubt that the envelope as a system and, above all, the parameter of "differentiation" in relation to the context environment/climate are playing an increasingly important role.

In the face of this, and despite having more technical-material options, there is a strong homogeneity of the wrapping packages, as well as their location in relation to the different orientations of the prospectuses.

This would result in lowering the energy load of buildings on the one hand while consuming less on the other producing energy through the exploitation of energy capacities during the year.

In recent years, the issue of climate and environmental changes, the increasingly stringent savings regulations energy and resources, have led many operators in the construction sector to identify the envelope building as the strategic element for reducing consumption and the impacts of the construction industry throughout the life cycle of processes and products. In this sense, interest in an architectural project linked to intelligent interaction criteria with the environment led to conceiving the envelope as an "epidermal layer dynamic that changes and adapts" according to the different conditions of the climatic-environmental context and to the different ones user needs.

The concept of dynamism and interactivity/adaptivity of the envelope with the system integration or better than intelligent materials, capable of controlling the energy consumption performance of buildings, leads to creation of prototypes capable of being translated into serial components for advanced envelopes capable of providing high environmental performances. It is about not only producing knowledge and methodologies necessary to encourage the activation of processes related to innovation but above all to concretize the technological transfer from the scientific sector to the production sector involved for the drafting of solutions and prototypes, creating a useful synergy to the subjects involved.

References

1. Banham, R.: The Architecture of the Well-Tempered Environment. Architectural Press, London (1969)
2. Banham, R.: The Architecture of the Well-Tempered Environment. University of Chicago Press, Chicago (1984)
3. Daniels, K.: Low Tech – Light Tech – High Tech. Building in the Information age. Birkhauser Publishers, Berlin DE (2001)
4. Milardi, M.: Integration strategies for smart-energy functioning of the building envelope. In: Proceedings in 41st IAHS World Congress, Sustainability and Innovation for the Future, 13–16th September 2016 Albufeira, Portugal, ITeCons Instituto de Investigacao e Desenvolviment, Coimbra PRT (2016)
5. Croce, S., Poli, T.: Trasparency. Facciate in vetro tra architettura e sperimentazione. Ed. il Sole 24 Ore, Milano (2013)
6. Milardi, M.: Adaptive models for the energy efficiency of building envelopes. J. Technol. Innov. Renew. Energy **6**, 108–117 (2018)
7. Harrison, H.: Intelligence Quotient: Smart Tips for Smart Buildings. DEGW Architecture Today (46) EMAP Publishing Ltd. Company, London (1994)
8. Benyus, J.: Biomimicry: Innovation Inspired by Nature Paperback. William Morrow Paperbacks, NYC, 17 September (2002)

MARKED PROOF

Please correct and return this set

Please use the proof correction marks shown below for all alterations and corrections. If you wish to return your proof by fax you should ensure that all amendments are written clearly in dark ink and are made well within the page margins.

Instruction to printer	*Textual mark*	*Marginal mark*
Leave unchanged	• • • under matter to remain	Ⓘ
Insert in text the matter indicated in the margin	⋏	New matter followed by ⋏ or ⋏ⓧ2
Delete	/ through single character, rule or underline or ├──┤ through all characters to be deleted	∂/ or ∂/ⓧ2
Substitute character or substitute part of one or more word(s)	/ through letter or ├──┤ through characters	new character / or new characters /
Change to italics	— under matter to be changed	⌴
Change to capitals	≡ under matter to be changed	≡
Change to small capitals	= under matter to be changed	=
Change to bold type	~ under matter to be changed	~
Change to bold italic	≂ under matter to be changed	≂
Change to lower case	Encircle matter to be changed	≢
Change italic to upright type	(As above)	⊹
Change bold to non-bold type	(As above)	⊹
Insert 'superior' character	/ through character or ⋏ where required	Y or ⋏ under character e.g. Y or ⋏
Insert 'inferior' character	(As above)	⋏ over character e.g. ⋏
Insert full stop	(As above)	⊙
Insert comma	(As above)	,
Insert single quotation marks	(As above)	Y or ⋏ and/or Y or ⋏
Insert double quotation marks	(As above)	Y or ⋏ and/or Y or ⋏
Insert hyphen	(As above)	├=┤
Start new paragraph	⌐	⌐
No new paragraph	↩	↩
Transpose	⊔⊓	⊔⊓
Close up	linking ⁐ characters	⁐
Insert or substitute space between characters or words	/ through character or ⋏ where required	Y
Reduce space between characters or words	| between characters or words affected	⊤