VARIABLE PROPERTIES ENVELOPES
Evoluzione e sperimentazione negli involucri selettivi e a configurazioni dinamiche
Evolution and experimentation on selective and dynamic configurations envelopes

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Introduction

Bioclimatic quality, adaptivity, selectivity, dynamism as key requirements of the contemporary architectural envelope

For slightly more than a century, as the world population has grown 7 times larger, while per capita energy needs have risen 70 times, our approach to "managing" energy resources has led to seven pressing problems:

- A staggering increase in harmful emissions in the air and the atmosphere;
- Increased pollution of water and soil;
- Growing scarcity of primary food resources;
- Impoverishment of fresh-water resources;
- Depletion of "non-renewable" energy resources (petroleum, methane, coal etc.);
- Rise in global warming and climate change;
- Onslaught against the five major natural systems: the perennial glaciers, the permafrost, deserts, forests and oceans.

A great deal of the responsibility can be placed on the planning, construction and management (and decommissioning) of buildings. A stark reminder is the fact that in Europe, the construction sector alone absorbs 40% of final energy consumption.

And so the topics of eco-sustainability and energy efficiency constitute paradigms of quality in construction that cannot be ignored, with their overriding importance due to the challenge of defending the environment and its resources. To this end, a key ethical principle worthy of universal affirmation is the need for improved integration within the ecosystem, and with natural biological cycles, of the entire life cycle of artificial structures. Looking at the past, it quickly becomes apparent that there is nothing terribly innovative about this outlook, seeing that vernacular, pre-technological architecture provides valid examples of eco-compatible designs meant to control the indoor climate and make use of local resources, guided by the Greek concept of téchne, which expressed a refined technical knowledge intimately joined to skilled craftsmanship.

It was after the first energy crisis, in 1973, marked the demise of the naïve faith in the omnipotence of technology and the striving to build in a uniform manner no matter what the context, that a new transformational way of thinking began to take shape, closely tied to the specific characteristics of a given site, and to the use of traditional local construction techniques, in combination with "soft" technology: in other words, a technology based on non-destructive initiatives, employing natural materials and light construction systems respectful of the environment and supportive of a regenerative approach to its biological processes. Among the innovative methodological contributions of the 70's-80's, V. Olgyay's evaluations of thermo-hygrometric comfort were of particular note, as was Thomas Herzog's work on bioclimatic construction design.

Today it is unacceptable for buildings to be constructed without any consideration for the local climate or surroundings; criteria of energy consumption and eco-compatibility must be an integral part of the process right from the initial stages in the conceptualisation of a construc-

Nella pagina a fianco:
Torre Civica dell'Ecoquartiere di Monterotondo Scalo, Roma. Dettaglio della facciata sud. Conseguita nel 2019 la certificazione LEED PLATINUM. Progetto dello Studio Arch-in-Progress, con consulenza di Alessandra Battisti e Fabrizio Tucci per gli aspetti tecnologico-ambientali e bioclimatico-energetici.

ted organism, guiding project decisions on architecture, types of structures and construction techniques.
There can be no ignoring the demands posed by the need for environmental sustainability, as part of a rediscovered relationship between tradition and innovation, nature and technology, all of which has given rise, and for some time now, to a new, revolutionary approach to the processes of territorial planning, urban design and architecture.
The primary objective of environmental design, or better yet “environmentally aware” design, is to build a living environment able to satisfy the changing demands of human wellbeing while adapting itself to the various conditions of the external environment through eco-compatible systems, drawing primarily on resources available in the local area and that lend themselves, whenever possible, to eventually being returned to their natural biological cycles.
The complexity of the topic makes a modicum of general training an irremovable prerequisite to developing an adequate awareness of what this entails within the construction process. The first step is definitely the attainment of the relevant knowledge.
Standards of eco-compatibility in architecture can be summarised in three main classes:
- safeguarding of the environment (healthiness of the air, soil, subsoil and water resources, defence of greenery and of historical-cultural resources), in the spirit of the German and Scandinavian theoretical outlooks on nature (ranging from the experimentation of the Finnish architect Reima Pietila to the Green Building Approach initiatives of recent years);
- eco-compatible use of material resources (use of renewable, recyclable raw materials), water resources (the collection, recovery and reutilisation of rain water and grey water) and resources related to energy and climate, through both active and passive systems (from the “Prairie Style Houses” of Frank Lloyd Wright to the bioclimatic buildings of T. Herzog, as well as the eco-quarters and solar cities built in recent years in Europe and the rest of the world);
- the wellbeing and comfort of the users of the architecture, and especially their thermo-hygrometric, acoustic, visual and perceptive-sensorial wellbeing, together with the quality of the air etc. (from the studies of Alvar Aalto, master of the modern, to the experiments and explorations of the Dane architect Jan Gehl).

The overall strategy of “eco-sustainable” design of retrofitting initiatives (ranging from the territorial context to the building organism, along with its technical-construction aspects) is essentially based on two complementary approaches: the lowering of the demand for energy, plus self-production of clean energy from renewable sources, such as photovoltaic power, solar energy, wind power and geothermal energy.
The first of these objectives involves introducing the multiple prerequisites of eco-compatibility into planning through specific “passive” design strategies or “bioclimatic” criteria (for heating in winter, cooling in summer and natural illumination) and technologies, including the rediscovery of construction techniques from centuries past (as shown to us by the studies of Rudofsky or the Egyptian architect Hassan Fathy).
Today, the various guidelines for the development of eco-sustainable design can be identified in a number of strategies entailing cultural, methodological and operational considerations: from “neo-traditional” strategies (use of local resources and reformulation of traditional con-

struction systems) to strategies of “advanced technology/lightness” (minimisation of resources and of their energy content); from “active” strategies for producing renewable energy (“Zero consumption” buildings, the “Plusenergiehaus”) to “passive/envelope” strategies designed to maximise the energy performance of building envelopes, an area of experimentation pursued primarily in the countries of northern Europe, culminating, in the 90’s, in the establishment of the Passivhaus construction standard.
In modern architecture, the process of “dematerialisation”, together with the thinning of architectural envelopes (which has led, in certain cases, to the spread of architectural organisms that are widely approved, but have little to do with the climate, culture or materials of the local context), have been accompanied by a gradual increase in demands for wellbeing and comfort, with an attendant rise in the levels of performance expected from building envelopes.
In effect, the transfer of “light” envelope models, when not properly reinterpreted, has led to more than a few problems, especially in temperate zones, where wellbeing is frequently related to the need to defend against excessive quantities of solar radiation and overheating in summer.
A climate such as that of Mediterranean area, in which a variety of different meteorological conditions occur during the year, with noteworthy day/night shifts in temperature, calls for an architectural method able to adapt to changes in climate. What is needed are envelope designs that can contain energy dispersion in winter, while, at the same time, attenuating the summer thermal loads produced by solar radiation, thus guaranteeing ambient comfort all year round.
Of equal importance to effective planning for winter conditions is the proper design of passive cooling, with priority on the problem of energy consumption in summer; for all intents and purposes, the objective to pursue is that of near-zero-energy buildings.
One of the main problems of modern constructions is that they have lost the ability to react to the demands posed by the outdoor climate, giving rise, during the last century, to an increasing reliance on machine-driven climate control and to buildings that devour energy.
Buildings risk completely losing their capacity to naturally adjust to changes in outdoor conditions (fluctuations in temperature, relative humidity, light, wind, solar radiation …).
The aim is to address problems tied to energy efficiency through research aimed at developing architectural envelope systems that, in a way similar to the human body, interact continuously with the outside environment, guaranteeing the lowest possible level of energy consumption, plus the greatest possible ambient comfort.
The envelope of the future must succeed in being a highly dynamic system, offering features of technology, configuration and performance that vary in accordance with the microclimatic conditions found outdoors and the demands of the users.

Adaptability and dynamism of architectural envelopes

An attentive analysis of the current state of innovative architectural envelope design, in terms of technology, types of models and performance, points to a number of important issues that have an effect on approaches to research and experimentation.
The first factor to be considered is the seemingly “unstoppable” (as Kenneth Frampton sees it) process of dematerialisation and the ‘thin-

ning' of architectural envelopes underway for a number of decades, driven by two main causes. First, the supposed benefits in terms of appearance provided by light construction casings, for the most part transparent or semi-transparent, in the opinion of clients and/or designers. Such envelopes are also assumed to increase the ability to control and limit construction costs, thanks to the significantly reduced assembly and installation times, the lower amount of materials used and the overall simplification of the worksite phases. Another factor is the higher performance levels expected from modern architectural envelopes, far above the basic performance an envelope had to provide half a century ago. The third issue is the limited extent to which users can control the configurations and behaviour of such envelopes. Only a short time ago, mobile façade components - windows, screens, shutters - made possible complete control of envelopes, whereas today it is nearly impossible, if not totally so, to adjust the more technologically complex building façades, and thus the micro-environmental factors inside. Quite often this occurs when there is no “intelligent” building management system, with levels of internal comfort entrusted entirely to mechanical systems that, all too frequently, are energy intensive, inefficient and powered by non-renewable energy.

In the case of certain factors, such as thermal insulation, there is no denying the paradox that they cannot be modified in response to variations in outside conditions a season or a given day. It would help to be able to reduce thermal transmission in winter and increase the capacity for dispersion of heat in the summer, but users cannot be expected to remove or to apply layers of insulation on the façade. Still, direct intervention by man on building coverings can definitely be both beneficial and necessary, in order to arrive at a correct, fully informed management of conditions of comfort and energy consumption.

This last consideration raises the question of changes in configuration, both dimensions and shape, of modern architectural envelopes, whose increasingly complex performance features can be understood in light of certain key factors that have significantly affected social, cultural and technological change in recent years.

First, there is the building-climate-energy relationship, along with the problem of the manageability of the dynamic interactions required of envelopes in response to changes in climatic conditions and needs for energy and comfort. Certain aspects of human health undermined inside of buildings can be attributed to shortcomings in envelopes (the Sick Building Syndrome is a condition widely recognised by the scientific community), and then there is the ever increasing speed with which the functions and activities that buildings are called on to provide keep changing.

The Envelope/Climate/Energy relationship

According to Walter Kroner, an international expert on artificial façades, one of the chief problems of modern times is the extent to which buildings and their users have become addicted to artificial climates.

The loss of the ability to react to ongoing fluctuations in outside conditions, plus the insistence on maintaining standardised conditions of comfort, whether day or night, summer or winter, has resulted, in the space of only a few decades, in an increasingly massive reliance on mechanical regulation, leading to higher energy consumption (and frequent blackouts in summer), a trend that, despite the regulatory measures promulgated and the world summits held, continues to rise.

There is the risk that the capacity of our buildings to adjust naturally, and "passively", to ongoing fluctuations in temperature, relative humidity, conditions of daylight, winds and external microclimatic conditions in general will be lost forever.
In one of James Marston Fitch's many seminal writings on bioclimatic design, he holds that the façades of a building with various orientations, in the interests of optimising its climate and energy-related performance, should not have the same characteristic in terms of the type of façade, technology and required performance levels. Instead, an innovative effort of research and experimentation should be carried out for each one, so as to make the most of its potential for interaction with external factors of climate and energy.
It has been clear for some time now that one of the ills of our age is how, for decades, the tendency has been to render the coverings of buildings increasingly sealed off and less dynamic, less able to react with external climatic conditions, such as ventilation and natural lighting. This approach has spawned factors that, over time, have proven pathogenic (bacterial flora and other harmful side effects of mechanical systems) to the health and lives of the users of the buildings. Along with the subject of physical illnesses tied to poor planning of building envelopes, a no less important concern is psychological dissatisfaction, which can result, for example, in a sharp drop in the productivity of workers, when they are unable to regulate the environmental conditions of their work space, not even by means of building management system.
Another paradox, in the case of envelopes with a high level of transparency and openness towards the exterior, can arise from excessive albedo and visual glare, or excessive overheating in summer and cooling in winter. This leads to a practice of self-protection by the individual users, in the form of improvised screens and systematic dependence on climate control and artificial lighting. Apart from the user's dissatisfaction and discomfort, a further drawback is a significant increase in energy consumption.
In reality, it should be common knowledge by now that, even for economic motives alone, any improvement in architectural envelopes which enhances their capacity to dynamically interface with external factors tied to energy or the environment is destined to lead to significant savings for the building operator: direct savings on energy expenses, but also indirect savings for society (lower healthcare expenses), for the environment and due to worker productivity.

The building skin, evolution of performance requirements

The array of performance requirements that building envelopes have been expected to meet from the nineteen-nineties onward has become increasingly elaborate and complex, in response to the ever evolving needs of man and the environment, all within a framework of growing regulatory demands and requests for wellbeing and comfort on the part of users.
As Thomas Herzog has pointed out, any building, regardless of the functional category it belongs to, generates fluid-dynamic turbulence, reflects and absorbs light, transforms solar radiation into thermal energy, casts shadows and transmits sound waves. It is not, therefore, a static object, but rather a balanced set of flows undergoing constant variation. Such a perspective restores the leading role of the architectural envelope as a key connecting element between the building,

the climate and energy: the home moulds, reflects, filters, absorbs, stores, transforms and distributes flows of energy, utilising natural climatic factors to do so. Architecture has no choice but to move forward, in terms of its bioclimatic and energy-related performance, even though the field of energy and microclimatic flows produced by the building lacks any visibility whatsoever during the design phase. In recent years, this has brought about a new need, starting from the initial conception of the building (and extending up to its construction and operation), for simulation of air-flow patterns, heat distribution, conditions of natural lighting and the diffusion of sound.

The concept of building-envelope performance no longer refers to a “static” condition of the building’s covering, but rather to the procedures and characteristics of its behaviour during its ongoing interaction with constantly changing external and internal conditions. In recent years, this outlook has led to the introduction of series of innovative, “advanced” performance standards that, over the last decade of experimentation, have given rise to a framework which, though still a work in progress, groups the 22 most important regulatory requirements for modern architectural envelopes into three main categories:

- control and passive use of bioclimatic factors for energy-related and bioclimatic purposes;
- use and integration of systems for the production of renewable energy;
- control and reduction of pollution and, more generally, of environmental loads.

In the first category, the primary reference is to factors and processes that include:

- direct passive thermal gain in winter from the greenhouse effect of solar radiation;
- passive thermal gain from heat accumulation by masses, plus indirect restitution of the heat from solar radiation;
- natural lighting to increase visual comfort indoors and reduce the energy needed for electric power;
- ventilation to increase passive cooling in summer;
- solar shading to lower the air temperature for the purpose of summer cooling.

In the second category, a key role in the envelope/environment interaction is played by the use of renewable sources of energy (solar radiation, wind power, aerothermal, hydrothermal, hydraulic and hydroelectric energy, plus biomass energy).

In the third category, finally, the concept of envelopes brings into focus a number of different strategies, with the most important being: increasing the durability of their materials and components, while also increasing their dematerialisation, in order to reduce the environmental load; ensuring that materials are bio-ecological, and that any waste is reusable and recyclable; controlling the entire life cycle of the individual elements, and the system as a whole.

Technological evolution of research on architectural envelopes

The most recent scientific developments in research and experimentation on the chemical-physical properties of materials, and in the fields electrostatics, microelectronics, micromechanics, nanotechnology, optics, holography, fluid dynamics and computer science have opened up the possibility of completely new scenarios for the design of “dynamic” architectural envelopes capable of interacting with the

external microclimate. The progress made with this research in recent years has led to the creation of brand-new categories of construction products referred to as variable property materials, or VPM, which are specifically conceived of, and designed for, increasing the capacity for dynamic interaction with environmental, climatic and energy-related factors.
The 10 most important and promising categories of these new envelope components are:
- dynamic, high-capacity, transparent insulation materials developed for application in architecture roughly twenty years ago, though they continue to be the subject of ongoing experimentation and research on their dynamic applicability to massive opaque or semi-opaque envelopes;
- materials based on a dynamic gel capable of turning opaque when heat rises;
- variable conductance insulation, or VCI, on which new experimentation has been carried out following the research done by Thomas Potter in the 80's, and which could increase the thermal exchange governed by a building's external surface area by 30% to 90%;
- translucent aerogel components, the lightest category of artificial materials in the world, with an incredibly low level of thermal transmission;
- paints that are "chromatically variable", depending on the incident solar radiation, the absorbed heat and the envelopÉs surface temperature;
- "dielectric" types of glass that, depending on the material, are capable of producing ionic or electronic polarisations, or those involving orientation or space charge;
- "variable transmittance glass", or VTG, and "variable convection diodes", or VCD;
- photochromic, thermochromic and electrochromic components from the field of "chromogenic materials", capable of interacting with the thermal manifestations of environmental factors, such as sunshine and ventilation, changing their chemical-physical state in real time from a transparent to an opaque configuration, or one with a chromatic characterisation;
- "dynamic prismatic" glass with what is known as "angular selectivity", designed to orient the rays of the sun to produce redirection or penetration into interiors or, on the contrary, reflect the radiation outside, depending on the conditions that hold;
- "phase change materials" or PCM, capable of modifying their chemical-physical state from solid to liquid, to aeriform or plasmatic, depending on the quantity of heat absorbed, which becomes "latent heat" in hot periods and "transferred heat" in cold periods.

Moving from the component dimension to that of an entire wall or roofing system capable of reacting dynamically to eternal variations, mention should be made of the experimentation still underway on:
- "dynamic Trombe walls", or classic passive solar walls with the added capacity to interact in real time with changes in the factors of the external climate and environment during the year;
- "dynamically integrated" solar or ventilation skylights and chimneys, roofing systems that move, allowing them to "follow" or "correspond to" external environmental conditions;
- "dynamic" water walls that interact with water for bioclimatic purpos-

es and thermal regulation, their functions varying in accordance with the season or the time of day;
- integrated envelopes with micro-motors, activated both by user commands and building management systems, capable of receiving data and information on external environmental conditions through sensors and computer networks;

Based on these innovative components and systems for dynamic interaction with the outside environment, three main technical procedures can be identified for including them in the day-to-day functioning of the envelope:
- façade or roof components that do not need to move, but whose materials are capable of changing their properties, in response to variations in external environmental and microclimatic conditions;
- variations in the composition and configuration of the façade or roofing elements through the sliding or retraction of mobile components inside or outside of the building envelope;
- changes in the positions of the different façade or roof elements, through rotation around a vertical or horizontal axis.

Just as our body, guided by the brain, can procure external supports for the climate-regulating action of the skin, prompting us to put on clothes or remove them, so too can an architectural envelope change its outside “clothing” by means of additional mobile, dynamic elements, based on the changing demands of the seasons. The envelope of the future should be a highly dynamic system, with characteristics of technology, configuration and performance that vary in accordance with the external microclimatic conditions and the users’ needs.

Typological evolution of research on architectural envelopes

Research over the last three decades on evolving changes in the “types” of architectural envelopes has focused on two main “typological” categories: multi-layer casings that are primarily opaque or semi-opaque, and lightweight ones that are primarily transparent, semi-transparent and translucent.

In the case of an opaque or semi-opaque wall, the envelope can be broken down into functional parts (layers) designed to establish the relationship with the outside and the interior, while providing the performance characteristics of a light buffer and, most importantly, making possible control of the many different climatic factors. Each functional layer is of strategic importance when it comes to allowing the constructed system to achieve an adequate level of “energy efficiency”, plus overall “eco-efficiency”.

The layers that support the envelope in satisfying the performance features requested (as defined under the UNI 8979 standard) can serve a single function or combine two. Either way, they fall under one of three main categories:
- support layers, to distribute hanging loads and provide mechanical resistance, with all the other layers attached to them;
- connecting layers, or the sum total of the technical elements that serve to attach the external coating on the support layer;
- external coating layers, which have the function of protecting the wall as a whole, serving as the element of reference for the performance features of finishing and appearance.

Other types of functional layers can be added to the above, depending on what type of wall is being constructed:

- a thermal insulation layer whose function is to provide the wall with its overall capacity for thermal transmission at the required level;
- a sealed layer that keeps out water and the elements, to ensure the required level of waterproofing;
- a sealed layer that keeps out air and wind, providing an adequate barrier against the passage of air and against wind pressure;
- a sealed layer that keeps out vapour, preventing it from penetrating and, most importantly, from accumulating in the walls;
- a layer for the diffusion of vapour, to prevent internal pressure overloads in walls, due to the evaporation of water found inside them;
- a layer sealed against fire, providing the wall with the proper fire resistance, as per the pertinent regulations;
- a thermal accumulation later, to govern the overall thermal inertia of the wall, adjusting it to the necessary levels;
- a ventilation layer, providing air movement, primarily upward, so as to contribute to the hygrometric control of the wall;
- a regularisation layer, designed to eliminate irregularities that could hinder adhesion between the various layers;
- an internal coating layer.

The most recent developments in experimental research have, as their guiding principle, a conception of the envelope as a system of parts that interact with one another. Under this approach, opaque and transparent envelopes can be subdivided in an even more specialised fashion, with the opaque envelopes being identifiable as:
- “multilayer” envelopes equipped with increasingly refined systems of thermal insulation, which have progressed from the “box” model of wall with a cavity to a wall with a “cloak” of insulation that ensures that the thermal mass remains in the inner portion of the wall;
- multi-layer “dynamic performance” envelopes, innovative systems with an elevated capacity for thermal absorption and insulation, based on innovative properties of translucent nanotechnology or phase changing, designed to be applied on massive wall supports;
- “opaque ventilated” envelopes, in which the external coating layer remains detached from the cloak insulation, hanging from the back wall support while its junctures provide the wall cavity with ventilation;
- “solar air” envelopes, featuring a sequence consisting of a wall with a variable thickness and no insulation, an air cavity and external glazing for passive generation of direct heat through indirect convection by radiation (Trombe-Michelle walls), or made of these same elements, combined with a layer of insulation in the cavity and connected by passive conduits installed in the false ceilings of the indoor environments (Barra-Costantini envelope).

The topic of transparency, semi-transparency and translucence is more complex, addressing even wider-ranging fields of research that consider various factors of thermal control, lighting and ventilation, visual wellbeing, control of the sun, plus the resulting idiomatic possibilities. The four main categories of transparent/translucent envelopes, currently the subject, in both conceptual and technological-operational terms, of an in-depth exploration of their functional and semantic possibilities, include:
- “high-performance” envelopes, and most notably the category of “low emission” glass, or aerogel, the world’s lightest material;
- “angular selectivity” envelopes capable of guaranteeing control of

incoming radiation from a thermal standpoint, along with optimal redirection of the sun's rays for lighting;
- "chromogenic" envelopes capable of interacting with external climatic factors by changing their chemical-physical characteristics, as well as their opacity and colour;
- double envelopes "with special glass" that is ventilated and screened, capable of providing specific performance features, such as high levels of acoustic insulation or control of its own potential overheating in summer.

The two macro-categories of envelopes - multilayer opaque and semi-opaque, on the one hand, and light transparent, semi-transparent and translucent, on the other - which contain, between the two of them, the main technological innovations in envelopes with respect to energy efficiency and bio-climatic effectiveness, are reinterpreting the principal categories cited above, in light of the renewed framework of performance requirements, further elaborating them into a series of ten main innovative types of architectural envelopes:
- a multilayer "ventilated" envelope, opaque or semi-opaque, with an outer lining detached from the wall support, and from the cloak insulation, and with junctures that are always open, to provide ventilation;
- a multilayer "energetic ventilated" envelope, similar to the preceding type, but with the addition, on the outer lining, of active solar-power systems, and with the possibility of regulating the openings of the ventilation junctures;
- a multilayer "solar air" envelope that features, moving from its interior to its exterior, a wall support, a thermal absorption layer, a ventilated chamber, and a glazed layer generating a greenhouse effect for passive heating of the air and the wall, with the wall becoming a radiating plate;
- a multilayer envelope with translucent "energetic" insulation, similar to the preceding model, but with the addition of external components for solar screening and photovoltaic capture;
- a multilayer "translucent insulation" envelope with external elements capable of optimising the passive solar contribution. The most widely known version of this envelope is made with TIM, transparent insulation material, applied to the underlying wall support, whose surface is given a dark treatment, making it capable of both capturing solar radiation and ensuring thermal insulation;
- a multilayer "phase change" envelope with PCM - phase change material - components capable of interacting with changes in thermal conditions, modifying its chemical-physical state while making use, during these mutations, of the principle of latent heat;
- a light, continuous "curtain wall" envelope with transparent, translucent, semi-opaque or opaque elements hung from the outside of the floor slabs in an array of perfect continuity, so as to provide the thermal insulation required for all the performance features;
- a light "double", non-ventilated envelope with transparent, translucent, semi-opaque and opaque elements hung on the outside, in a perfectly continuous array, and with the double layer of light panels designed to improve the performance features, starting with the insulation;
- a light, continuous "energetic" envelope, similar to the "continuous" envelope, with the addition of active solar power systems to the layers of panels;

- a light, ventilated, “high performance” translucent envelope with a configuration similar to the preceding model, but very different in terms of its performance features, in that, on its outer layer, it utilises “chromogenic”, “special” glass, components, with the further addition of systems of mobile screening in the intermediate layer of the ventilated chamber, in order to improve overall performance and, in particular, the amount of sunshine in winter and ventilation in summer;
- a light, “high performance” envelope that employs “chromoge nic” glass, providing “translucent insulation” and “angular selectivity”, with the ability to passively interact with changes in external lighting conditions, modifying the opacity or transparency of the component, its translucence, and redirecting incoming luminous radiation, based on the seasons and the incident temperature;
- a light, “energetic”, ventilated envelope, transparent or semi-transparent, with a double layer of light, hung panels, of which the outer one is open to ventilation and integrated with active solar power systems.

2. Valutazione critica della sperimentazione internazionale: 80 casi di studio

2.1 Impostazione delle informazioni, degli aspetti e dei caratteri ricercati e rilevati nei casi di studio

Dopo aver condotto nel capitolo precedente una ricerca sulla sperimentazione internazionale, selezionando circa 80 casi studio nel mondo di involucri dinamici con componenti a proprietà variabili, nel presente capitolo sono riportati gli esiti di analisi e valutazioni critiche condotte su ogni singolo caso studio.Tali analisi e considerazioni critiche hanno prodotto 82 schede, articolate in diverse sezioni in cui per ciascun caso studio, reale, prototipo o modello virtuale, sono riportate le informazioni di seguito descritte.

Ciascuna scheda presenta una prima parte identificativa e descrittiva (che coincide con la prima pagina) del caso studio considerato, in cui vengono richiamati i codici di classificazione presenti nella matrice-quadro di insieme redatta nel capitolo precedente. In breve, i codici presenti nella scheda fanno riferimento alle seguenti tre macro-categorie.

- V1_ VARIABLE PROPERTY MATERIALS
  V1.1_ Variable conductance insulation “VCI”
  V1.2_ Variable trasmittance glass “VTG”
  V1.3_ Smart gel
  V1.4_ Phase Change Materials PCM
  V1.5_ Leghe a memoria di forma
  V1.6_ Termo bi-metalli/ Membrane polireattive
  V1.7_ Elastomero dielettrico
  V1.8_ Materiali igromorfici
  V1.9_ Polimeri elettro-attivi
  V1.10_ Materiali piezoelettrici
  V1.11_ Materiali cellulari

- V2_ COMPONENTI D’INVOLUCRO CON VARIABILITà DI FORMA/CONFIGURAZIONE
  V2.1_ Schermo solare
  V2.2_ Chiusura verticale trasparente a densità variabile

  V2.3_ Chiusura verticale opaca a densità variabile
  V2.4_ Involucro multistrato con scorrimento/sovrapposizione degli strati funzionali

- V3_ SISTEMI DI INVOLUCRO INTELLIGENTI, DINAMICI, ADATTIVI
  V3.1_ Pelle dinamica con generatori di energia elettromagnetici
  V3.2_ Facciata in micro-turbine (nano-fabbricazione/microrganismi)
  V3.3_ Facciate intelligenti adattive (isolamenti VIP, TIM, produzione energie rinnovabili, assorbimento CO2)

Sempre nella prima parte della scheda vengono poi descritte le caratteristiche principali del sistema legate alla dinamicità.

- VARIABLE PROPERTY. Si individua la caratteristica del sistema che varia dinamicamente conferendo un comportamento variabile all'involucro architettonico. In particolare le proprietà variabili considerate sono: Trasmittanza termica, Trasmittanza luminosa, Trasmissione sonora, Capacità/massa termica, Ventilazione, Capacità di eliminare sostanze inquinanti.

- SYSTEM MECHANISM. Si descrive il tipo di meccanismo che attiva la "variabilità" della caratteristica considerata e dunque la specifica dinamicità dell'involucro architettonico. In particolare tale dinamicità dell'involucro può essere attivata attraverso un meccanismo passivo, in risposta agli stimoli ambientali esterni quali temperatura, umidità, luce solare, suono, concentrazione di anidride carbonica, o attraverso un meccanismo attivo che a sua volta può necessitare di un'attivazione manuale gestita direttamente dall'utente, meccanizzata o automatizzata.

- BENEFITS. Si descrive dunque il contributo dell'involucro dinamico alla strategia energetica bioclimatica dell'edificio e i conseguenti benefici in termini di comfort ambientale interno. Le principali strategie considerate sono:
  Controllo solare (riduzione guadagni termici, graduazione daylight, riduzione abbagliamento)
  Graduazione isolamento termico
  Graduazione ventilazione naturale
  Raffrescamento passivo (storage termico per massa, PCM,…)
  Riscaldamento passivo (storage termico per massa, PCM, produzione di energia termica da radiazione solare,…)
  Graduazione dei fattori acustici
  Controllo del livello igrometrico dell'aria
  Controllo della qualità dell'aria e dell'inquinamento
  Integrazione energie rinnovabili (produzione energia termica, produzione energia elettrica)

Viene dunque data una breve descrizione del sistema, accompagnata da una serie di immagini, che mette in evidenza le caratteristiche principali dei materiali, dei componenti e il sistema e modalità di funzionamento dell'involucro nelle diverse condizioni operative.
La scheda continua poi con una seconda parte analitica e valutativa in cui sono date informazioni dettagliate sulle caratteristiche del sistema e sono riportate, anche sotto forma di schema logico, valutazioni qualitative sulle performance e sulle criticità del sistema stesso.
In particolare la seconda parte della scheda è strutturata nel modo seguente.

- *Analisi delle caratteristiche del sistema alla macro scala*
  In tale sezione viene specificata la scala del componente analizzato che potrà identificarsi progressivamente come una unità tecnologica, un sistema tecnologico o un involucro architettonico.

  Si individua l'elemento di fabbrica oggetto di applicazione del sistema dunque partizione interna, chiusura verticale esterna, copertura, rivestimento, schermatura solare.

Si danno infine informazioni sullo stato di avanzamento della sperimentazione considerata: caso studio reale costruito, prototipo, stato di progetto, modello virtuale su cui sono state condotte delle simulazioni.

- *Performance, applicazioni, criticità*
  In questa sezione si approfondiscono le performance energetiche ambientali e di sostenibilità per valutare qualitativamente il contributo del sistema al comportamento bioclimatico energetico dell'interno edificio in cui viene applicato.

In dettaglio vengono identificate le performance energetiche ambientali cui contribuisce il sistema: riscaldamento passivo, raffrescamento passivo, controllo solare, comfort termoigrometrico, produzione di energia rinnovabile.

Vengono valutati alcuni principali parametri di sostenibilità ambientale a cui risponde il sistema considerando il comfort indoor e outdoor, la produzione energetica da fonti rinnovabili e la ottimizzazione dei guadagni termici estivi e invernali.

Vengono infine riportate delle considerazioni qualitative circa le criticità legate al sistema che possono essere legate alle varie fasi quali la gestione del processo produttivo, la messa in opera, il consumo di risorse durante l'intero ciclo di vita, la gestione in uso e la manutenzione.

La scheda si conclude con i riferimenti bibliografici e sitografici.

2.2 Elaborazione delle analisi e valutazioni critiche di componenti e sistemi a proprietà variabili per involucri dinamici nella sperimentazione internazionale: 80 casi di studio

Seguono le schede che, coerentemente con quanto illustrato nel par.2.1, riportano, oltre che i principali caratteri di ogni sistema analizzato, una sintetica descrizione e alcune immagini di riferimento, anche e soprattutto una analisi delle caratteristiche e una valutazione delle performance offerte, della concreta applicabilità e delle tipologie di criticità presentate dal sistema stesso.

V1_ VARIABLE PROPERTY MATERIALS

V1.1_3 Variable conductance insulation "VCI"
Application of Dynamic insulation in a residential building, Balerno project, city of Edinburgh, UK, 2005

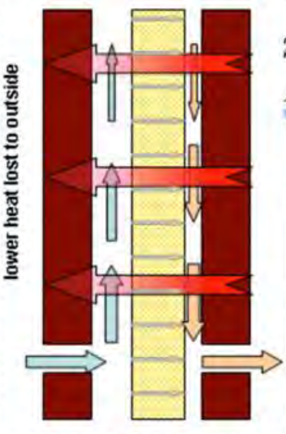
CARATTERISTICHE DEL SISTEMA

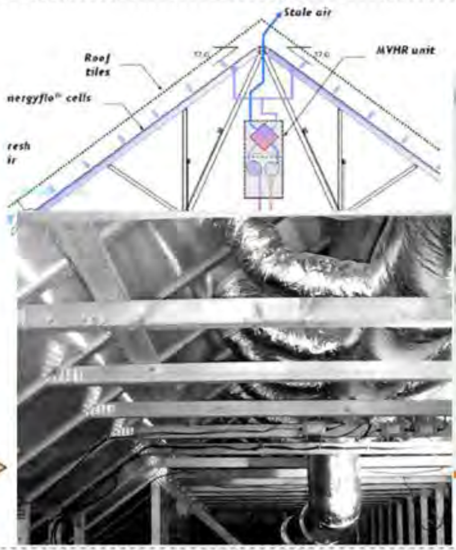
VARIABLE PROPERTY: trasmittanza termica
SYSTEM MECHANISM: passivo (ventilazione)
BENEFITS: graduazione isolamento termico, controllo livello igrometrico dell'aria

DESCRIZIONE

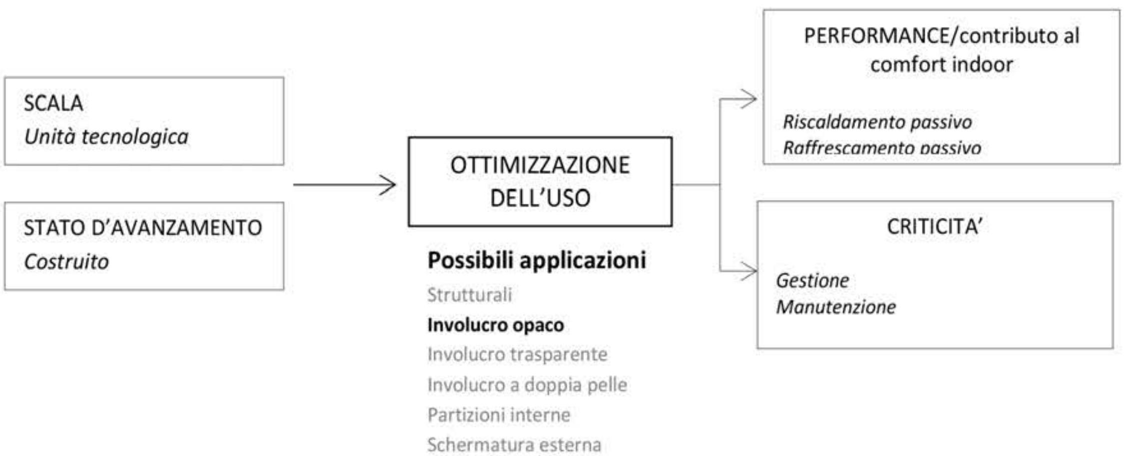
Il progetto Balerno è una casa indipendente 4 camere da letto, che presenta un tetto traspirante con isolamento dinamico collegato al sistema di trattamento aria e al sistema di ventilazione meccanica con recupero del calore (MVHR).

IMMAGINI





ANALISI DELLE CARATTERISTICHE: macro scala	***PERFORMANCE, APPLICAZIONI, CRITICITA'***
Scala	**Performance energetica-ambientale**
Unità tecnologica ■	Riscaldamento passivo ■
Sistema tecnologico □	Raffrescamento passivo ■
Involucro architettonico □	Controllo solare □
	Comfort termoigrometrico □
	Energie rinnovabili □
Applicazione	
Partizione interna □	
Partizione esterna	**Sostenibilità ambientale**
Chiusura verticale ■	Comfort indoor ■
Copertura □	Comfort outdoor □
Rivestimento □	Produzione energetica □
Schermatura esterna □	Ottimizzazione guadagni termici ■
	Criticità
Stato avanzamento	Gestione processo produttivo □
Costruito ■	Messa in opera □
Prototipo □	Consumo di risorse □
Progetto □	Gestione ■
Modello virtuale □	Manutenzione ■



Riferimenti Bibliografici e Sitografia | *References and Sitography*

Brown, A.R., Imbabi, M., Peacock, A., The Balerno Project, Conference Paper WREC X, July 2008, Glasgow (UK).
http://documents.mx/documents/energyflo-datasheet.html

V1_ VARIABLE PROPERTY MATERIALS

V1.2_7 Variable trasmittance glass "VTG", electrochromic glazing "EG" Managing Variable Transmittance Windowpanes by Model-Based Autonomous Control, Massachusetts Institute of Technology, Cambridge

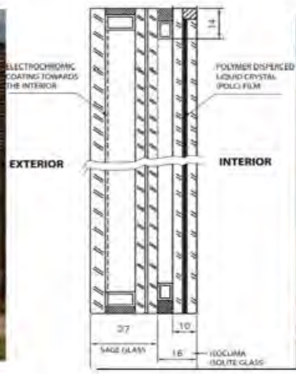
CARATTERISTICHE DEL SISTEMA

VARIABLE PROPERTY: trasmittanza luminosa
SYSTEM MECHANISM: attivo (automatizzato con BMS- Building Management System)
BENEFITS: controllo solare (riduzione guadagni interni, riduzione abbagliamento e controllo daylight)

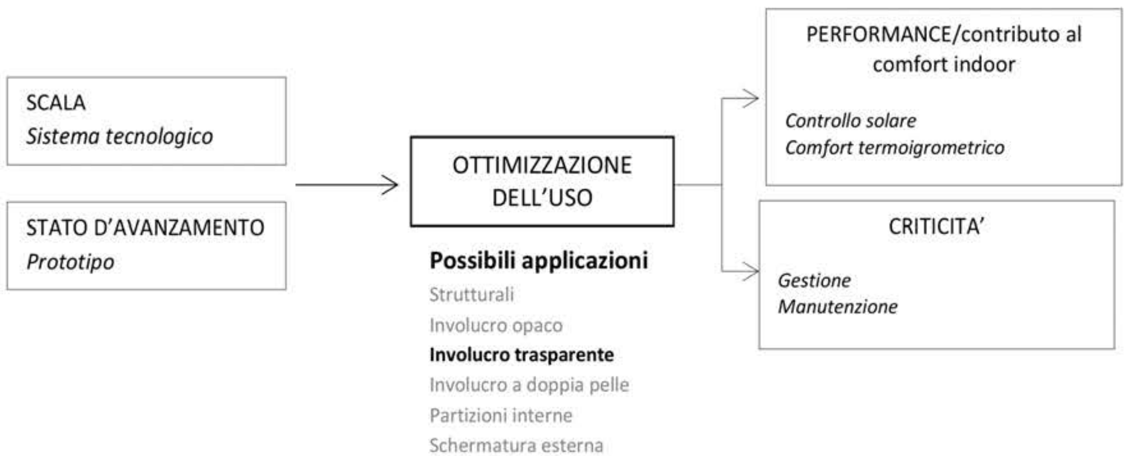
DESCRIZIONE

La ricerca indaga l'integrazione nell'edificio tra i materiali a trasmittanza variabile e "intelligenza artificiale" come metodo di controllo e di gestione dell'edificio. La gestione dei materiali di trasmittanza variabile della facciata attraverso un sistema di controllo autonomo computerizzato di alto livello consente l'ottimizzazione delle prestazioni dell'edificio in base ai dati in tempo reale attraverso sensori (che rilevano temperatura, flusso d'aria, radiazione solare) e in base alla pianificazione degli occupanti (vista e privacy interne). E' stato studiato un prototipo di casa a Trento in cui nella facciata sud sono state inseriti pannelli di finestre "programmabili" con VTG.

IMMAGINI



ANALISI DELLE CARATTERISTICHE: macro scala	***PERFORMANCE, APPLICAZIONI, CRITICITA'***
Scala	**Performance energetica-ambientale**
Unità tecnologica........................ □	Riscaldamento passivo.............. □
Sistema tecnologico..................... ■	Raffrescamento passivo............ □
Involucro architettonico.............. □	Controllo solare.......................... ■
	Comfort termoigrometrico........ ■
	Energie rinnovabili..................... □
Applicazione	
Partizione interna........................ □	
Partizione esterna	**Sostenibilità ambientale**
Chiusura verticale.................. ■	Comfort indoor................................ ■
Copertura............................... □	Comfort outdoor.............................. □
Rivestimento................................ □	Produzione energetica.................. □
Schermatura esterna .... □	Ottimizzazione guadagni termici.... ■
	Criticità
Stato avanzamento	Gestione processo produttivo............. □
Costruito.. □	Messa in opera.................................... □
Prototipo.. ■	Consumo di risorse.............................. □
Progetto.. □	Gestione.. ■
Modello virtuale.......................... □	Manutenzione.. ■



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Kotsopoulos, S.D., Casalegno, F., Ono M. and Graybill, W. (2013), Managing Variable Transmittance Windowpanes by Model-Based Autonomous Control, in Journal of Civil Engineering and Architecture, ISSN 1934-7359, USA, May 2013, Volume 7, No. 5 (Serial No. 66), pp. 507-523.

V1_ VARIABLE PROPERTY MATERIALS

V1.4_19 PHASE CHANGE MATERIALS
"AIF" advanced integrated façade, Glass and Facade Technology Research Group, Engineering Department, University of Cambridge, UK

CARATTERISTICHE DEL SISTEMA

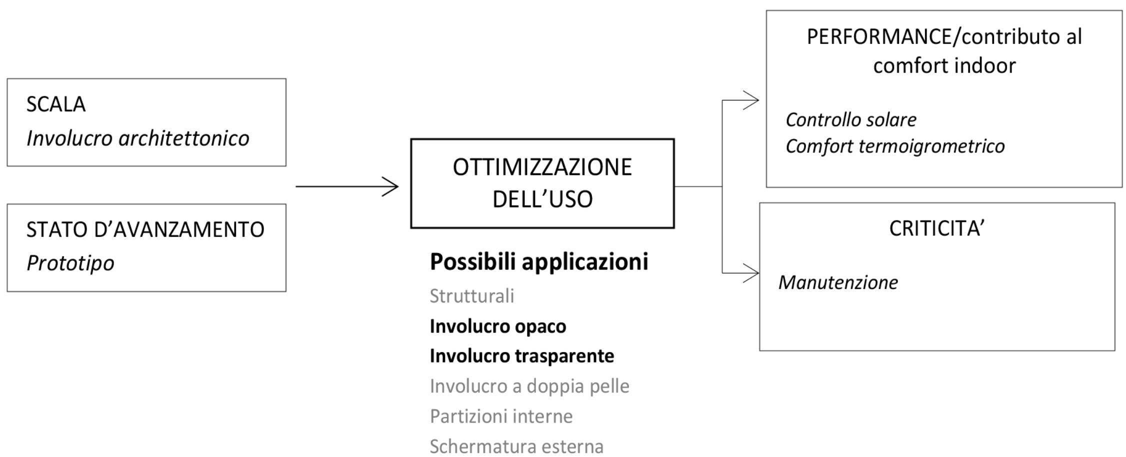
VARIABLE PROPERTY: capacità/massa termica
SYSTEM MECHANISM: passivo (temperatura)
BENEFITS: Controllo solare (riduzione guadagni termici, graduazione daylight, riduzione abbagliamento), integrazione energie rinnovabili (produzione energia elettrica), riscaldamento e raffrescamento passivo (storage termico per massa PCM)

DESCRIZIONE

Sistema di facciata ACTRESS (ACTive, RESponsive and Solar envelope), costituito da una parte opaca e una parte trasparente (Transparent Sub- Module (TSM) and an Opaque Sub-Module (OSM)) che integra al suo interno diversi componenti e materiali dinamici (PCM, VIP, AEROGEL) che interagiscono tra loro per massimizzare le prestazioni energetiche e il confort ambientale interno. La parte opaca si comporta come una facciata ventilata (OVF), con ventilazione forzata, inoltre la superficie ha incorporati dispositivi fotovoltaici per la conversione dell'energia solare diretta. Uno strato VIP altamente isolante è posto dietro la cavità, in abbinamento ad un pannello PCM (rivolto verso l'ambiente interno), per immagazzinare l'energia termica e moderare il microclima interno. Il modulo trasparente è simile ad una facciata convenzionale: esso è costituito da un'unità vetrata tripla con rivestimento basso emissivo e AEROGEL all'interno. Schermature solari altamente riflettenti sono posizionate nella cavità esterna del vetro, per controllare la trasmissione solare e della luce.

IMMAGINI

ANALISI DELLE CARATTERISTICHE: macro scala	***PERFORMANCE, APPLICAZIONI, CRITICITA'***
Scala	**Performance energetica-ambientale**
Unità tecnologica……………………. ☐	Riscaldamento passivo………….. ☐
Sistema tecnologico………………… ☐	Raffrescamento passivo……….. ☐
Involucro architettonico…………. ■	Controllo solare……………………. ■
	Comfort termoigrometrico…….. ■
	Energie rinnovabili………………. ☐
Applicazione	
Partizione interna…………………… ☐	
Partizione esterna	**Sostenibilità ambientale**
Chiusura verticale…………….. ■	Comfort indoor………………………….. ■
Copertura……………………….. ☐	Comfort outdoor………………………… ☐
Rivestimento…………………………. ☐	Produzione energetica………………. ☐
Schermatura esterna ……………… ☐	Ottimizzazione guadagni termici…. ■
	Criticità
Stato avanzamento	Gestione processo produttivo………… ☐
Costruito……………………………….. ☐	Messa in opera…………………………….. ☐
Prototipo……………………………….. ■	Consumo di risorse……………………….. ☐
Progetto………………………………… ☐	Gestione…………………………………………. ☐
Modello virtuale…………………….. ☐	Manutenzione………………………………… ■



Riferimenti Bibliografici e Sitografia | *References and Sitography*

Favoino, F. (2015), Assessing the performance of an advanced integrated facade by means of simulation: The ACTRESS facade case study, in Journal of Facade Design and Engineering 3 (2015) 105–127.

V1_ VARIABLE PROPERTY MATERIALS

V1.5_23 LEGHE A MEMORIA DI FORMA
Smart materials systems, research, Insrael Institute of Technology

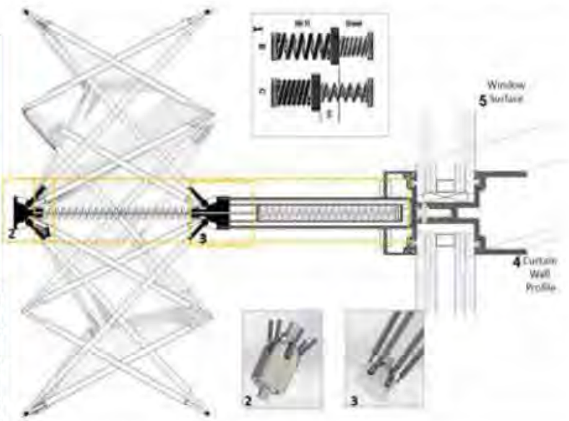
CARATTERISTICHE DEL SISTEMA

VARIABLE PROPERTY: trasmittanza luminosa
SYSTEM MECHANISM: passivo (temperatura)/attivo
BENEFITS: Controllo solare (riduzione guadagni termici, graduazione daylight, riduzione abbagliamento)

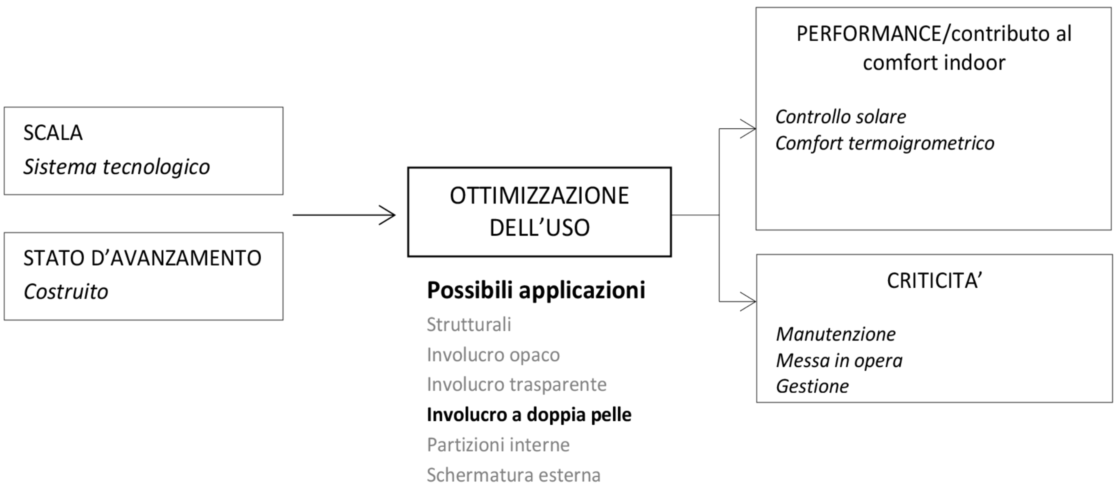
DESCRIZIONE

Caso studio: facciata costituita da elementi schermanti reattivi costituiti da materiali (leghe o polimeri) a memoria di forma utilizzati come sensori ed attuatori di movimento che permettono correlazione diretta tra la temperatura e il livello di radiazione solare e il livello di ombreggiamento richiesto. Il massimo risultato può essere raggiunto combinando il sistema passivo (dovuto alla reattività del materiale) con un sistema di controllo attivo della schermatura per le situazioni intermedie.

IMMAGINI



ANALISI DELLE CARATTERISTICHE: macro scala	***PERFORMANCE, APPLICAZIONI, CRITICITA'***
Scala	**Performance energetica-ambientale**
Unità tecnologica……………………. ☐	Riscaldamento passivo…………. ☐
Sistema tecnologico………………… ■	Raffrescamento passivo……….. ☐
Involucro architettonico………….. ☐	Controllo solare……………………. ■
	Comfort termoigrometrico…….. ■
	Energie rinnovabili……………….. ☐
Applicazione	
Partizione interna……………………. ☐	
Partizione esterna	**Sostenibilità ambientale**
Chiusura verticale……………. ☐	Comfort indoor………………………….. ■
Copertura……………………….. ☐	Comfort outdoor………………………. ☐
Rivestimento…………………………. ☐	Produzione energetica……………… ☐
Schermatura esterna ……………… ■	Ottimizzazione guadagni termici…. ■
	Criticità
Stato avanzamento	Gestione processo produttivo…………. ☐
Costruito………………………………. ■	Messa in opera………………………………. ■
Prototipo………………………………. ☐	Consumo di risorse…………………………. ☐
Progetto………………………………… ☐	Gestione…………………………………………. ■
Modello virtuale……………………. ☐	Manutenzione………………………………… ■



Riferimenti Bibliografici e Sitografia | *References and Sitography*

Lazarovich, N., Capeluto,G., Silverstein, M.S. (2017), Smart material systems for high performance building envelopes in Luible, A., Overend, M., Aelenei, L., Knaack, U., Perino M., Wellershoff, F., "Adaptive facade network – Europe", TU Delft Open for the COST Action 1403 adaptive facade network.

V1_ VARIABLE PROPERTY MATERIALS

V1.5_26 LEGHE A MEMORIA DI FORMA
Prototype dynamic facade, Decker Yeadon firm in New York, Smart screen version B, Decker Yeadon firm in New York

CARATTERISTICHE DEL SISTEMA

VARIABLE PROPERTY: trasmittanza luminosa
SYSTEM MECHANISM: passivo (temperatura)
BENEFITS: Controllo solare (riduzione guadagni termici, graduazione daylight, riduzione abbagliamento)

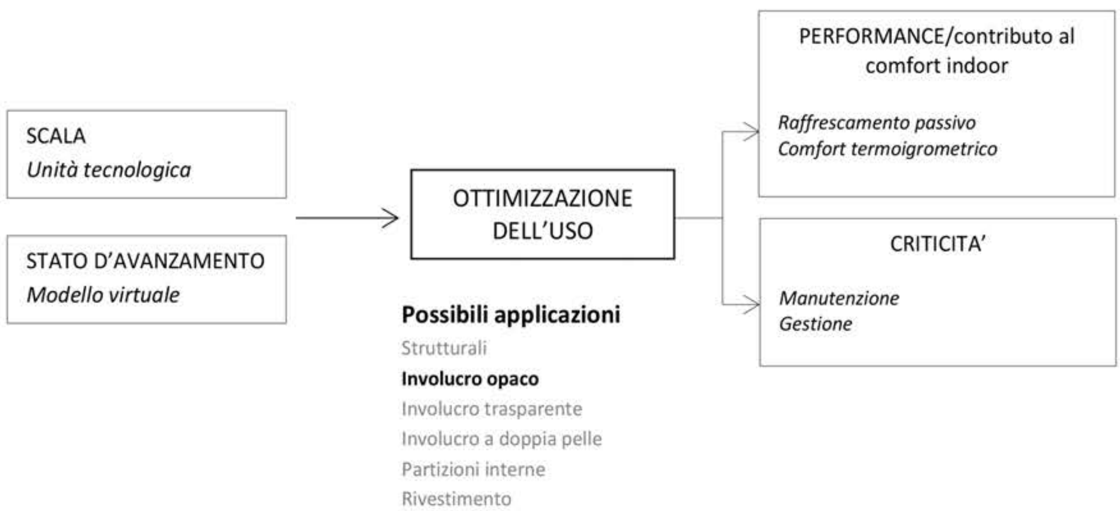
DESCRIZIONE

Sistema intelligente di ombreggiatura per facciate, basato sull'uso di materiali termo responsivi a memoria che possono espandersi e contrarsi regolando il passaggio della luce attraverso la vetrata.

IMMAGINI



ANALISI DELLE CARATTERISTICHE: macro scala	***PERFORMANCE, APPLICAZIONI, CRITICITA'***
Scala	**Performance energetica-ambientale**
Unità tecnologica.......................... ■	Riscaldamento passivo.............. □
Sistema tecnologico...................... □	Raffrescamento passivo............. ■
Involucro architettonico.............. □	Controllo solare.......................... □
	Comfort termoigrometrico........ ■
	Energie rinnovabili..................... □
Applicazione	
Partizione interna......................... □	
Partizione esterna	**Sostenibilità ambientale**
Chiusura verticale................. ■	Comfort indoor................................ ■
Copertura................................ □	Comfort outdoor.............................. □
Rivestimento................................. □	Produzione energetica.................... □
Schermatura esterna .... □	Ottimizzazione guadagni termici.... ■
	Criticità
Stato avanzamento	Gestione processo produttivo............. □
Costruito.. □	Messa in opera.................................... □
Prototipo.. □	Consumo di risorse.............................. □
Progetto... □	Gestione.. ■
Modello virtuale........................... ■	Manutenzione....................................... ■



Riferimenti Bibliografici e Sitografia | *References and Sitography*

http://challenge-old.bfi-internal.org/application_summary/1144

V1_ VARIABLE PROPERTY MATERIALS

V1.6_33 TERMO BI-METALLI
Bloom, material and application gallery, Los Angeles, CA, Doris Kim Sung (principal investigator), DO|SU Studio

CARATTERISTICHE DEL SISTEMA

VARIABLE PROPERTY: ventilazione
SYSTEM MECHANISM: passivo (temperatura)
BENEFITS: graduazione ventilazione naturale

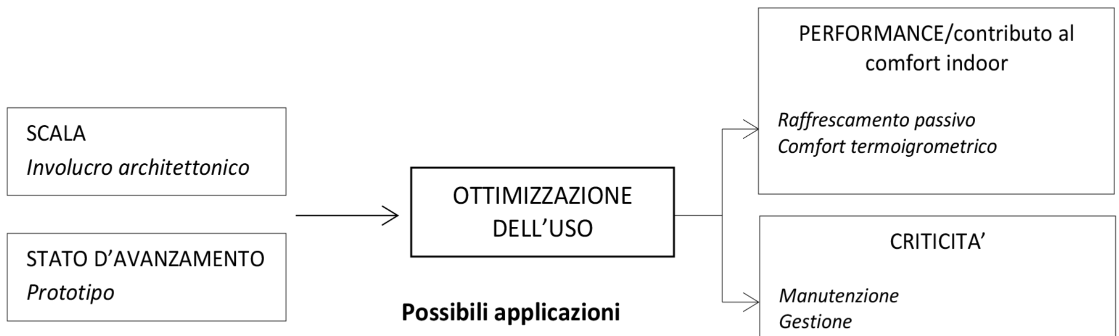
DESCRIZIONE

Una installazione temporanea, costituita da thermobimetal un materiale che in realtà è un laminato di due metalli diversi, ciascuno con il proprio coefficiente di dilatazione termica. La superficie sensibile è costituita principalmente da 14.000 piastrelle thermobimetal intelligenti, in cui non ci sono due pezzi uguali. Ogni singolo pezzo si "arriccia" automaticamente di una quantità specificata quando la temperatura ambiente esterna supera 70F o quando il sole penetra la superficie. Ciò significa che ogni piastrella reagisce in modo diverso alla luce del sole, quindi alla temperatura, in espansione e in contrazione, provocando tensione tra le due superfici, e in definitiva, un effetto di "arricciatura". Così, quando la superficie diventa calda, i sottili pannelli si contraggono per consentire a più aria di passare attraverso lo spazio sottostante, quando la superficie si raffredda, gli elementi si chiudono di nuovo.

IMMAGINI



ANALISI DELLE CARATTERISTICHE: macro scala	***PERFORMANCE, APPLICAZIONI, CRITICITA'***
Scala	**Performance energetica-ambientale**
Unità tecnologica……………………. ☐	Riscaldamento passivo………….. ☐
Sistema tecnologico…………………. ☐	Raffrescamento passivo………… ■
Involucro architettonico…………… ■	Controllo solare…………………….. ☐
	Comfort termoigrometrico…….. ■
	Energie rinnovabili……………….. ☐
Applicazione	
Partizione interna……………………. ☐	
Partizione esterna	**Sostenibilità ambientale**
Chiusura verticale…………….. ☐	Comfort indoor………………………….. ■
Copertura……………………….. ☐	Comfort outdoor……………………….. ☐
Rivestimento………………………….. ■	Produzione energetica……………….. ☐
Schermatura esterna ……………… ☐	Ottimizzazione guadagni termici…. ■
	Criticità
Stato avanzamento	Gestione processo produttivo…………. ☐
Costruito……………………………….. ☐	Messa in opera……………………………… ☐
Prototipo……………………………….. ■	Consumo di risorse………………………. ☐
Progetto……………………………….. ☐	Gestione…………………………………………. ■
Modello virtuale…………………….. ☐	Manutenzione………………………………… ■



Possibili applicazioni
Strutturali
Involucro opaco
Involucro trasparente
Involucro a doppia pelle
Partizioni interne
Rivestimento

Riferimenti Bibliografici e Sitografia | *References and Sitography*

http://dosu-arch.com/armoured.html

V2_ COMPONENTI DI INVOLUCRO CON VARIABILITA' DI FORMA/CONFIGURAZIONE

V2.1_52 SCHERMATURE SOLARI
Blight, Vincent Gerkens, Belgium

CARATTERISTICHE DEL SISTEMA

VARIABLE PROPERTY: trasmittanza luminosa

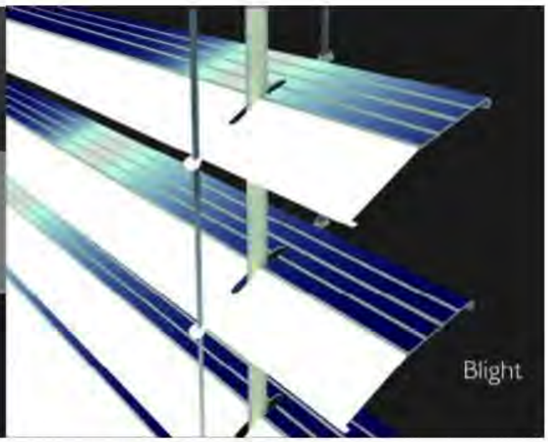
SYSTEM MECHANISM: attivo (automatizzato) sun traking mechanism

BENEFITS: Controllo solare (riduzione guadagni termici, graduazione daylight, riduzione abbagliamento), integrazione energie rinnovabili (produzione energia elettrica)

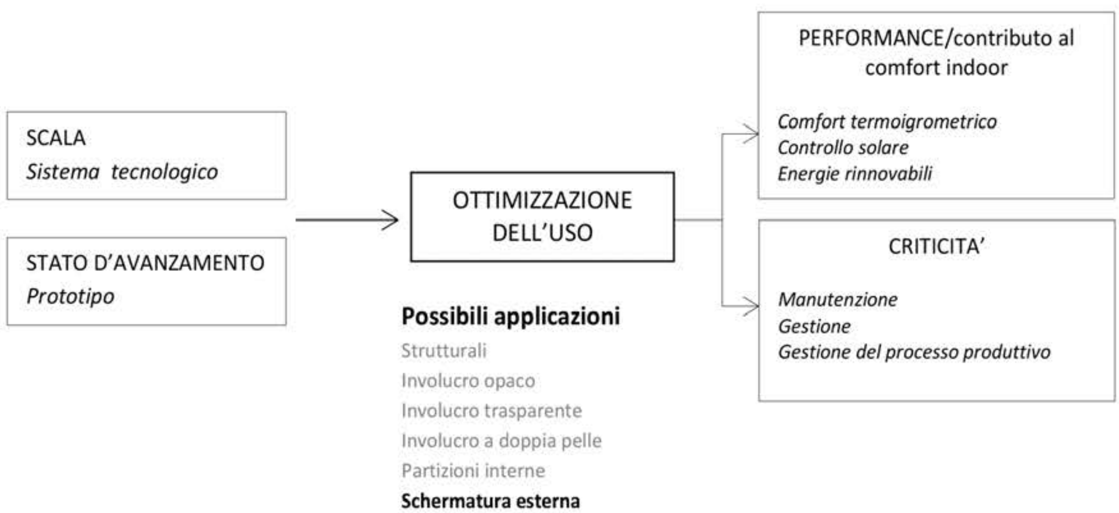
DESCRIZIONE

Il sistema è concepito come un sistema di schermatura costituito da lamelle che con lame rotanti seguono il percorso del sole durante il giorno in modo da catturare il massimo dell'energia e convertirla attraverso celle fotovoltaiche. L'elettricità è immagazzinata in una batteria, e ri-emessa durante la notte attraverso lamine elettroluminescenti usate per illuminare l'interno.

IMMAGINI



ANALISI DELLE CARATTERISTICHE: macro scala	***PERFORMANCE, APPLICAZIONI, CRITICITA'***
Scala	**Performance energetica-ambientale**
Unità tecnologica........................... □	Riscaldamento passivo.............. □
Sistema tecnologico...................... ■	Raffrescamento passivo............ □
Involucro architettonico.............. □	Controllo solare......................... ■
	Comfort termoigrometrico........ ■
	Energie rinnovabili.................... ■
Applicazione	
Partizione interna........................ □	
Partizione esterna	**Sostenibilità ambientale**
Chiusura verticale................. □	Comfort indoor.............................. ■
Copertura.............................. □	Comfort outdoor............................ □
Rivestimento................................ □	Produzione energetica.................. ■
Schermatura esterna .... ■	Ottimizzazione guadagni termici.... ■
	Criticità
Stato avanzamento	Gestione processo produttivo............. ■
Costruito.. □	Messa in opera.................................... □
Prototipo.. ■	Consumo di risorse.............................. □
Progetto.. □	Gestione.. ■
Modello virtuale.......................... □	Manutenzione....................................... ■



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V2_ COMPONENTI DI INVOLUCRO CON VARIABILITA' DI FORMA/CONFIGURAZIONE

V2.1_61 SCHERMATURE SOLARI
Building the CJ R&D Center Kinetic Façade, South Corea, Seul, Yazdani Studio

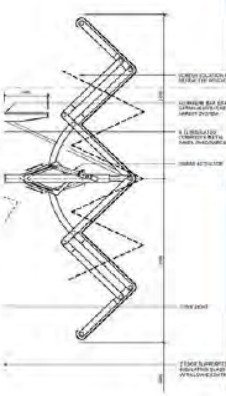
CARATTERISTICHE DEL SISTEMA

VARIABLE PROPERTY: trasmittanza luminosa
SYSTEM MECHANISM: attivo (automatizzato)
BENEFITS: Controllo solare (riduzione guadagni termici, graduazione daylight, riduzione abbagliamento)

DESCRIZIONE

La facciata reattiva ha lo scopo di controllare la quantità di luce diretta del sole che entra all'interno attraverso dispositivi di ombreggiatura cinetici aggiuntivi. Il sistema di ombreggiatura a fisarmonica avvolge tutte e tre le torri e fornisce una protezione dal riverbero solare. Il sistema ottimizza il controllo solare con un meccanismo a scomparsa progettato su misura in base al semplice meccanismo ombrello. Nastri di acciaio perforati sono installati su attuatori a forbice che possono essere in grado di aprire o chiudere automaticamente per garantire una corretta illuminazione naturale riducendo il surriscaldamento.

IMMAGINI



ANALISI DELLE CARATTERISTICHE: macro scala	PERFORMANCE, APPLICAZIONI, CRITICITA'
Scala	**Performance energetica-ambientale**
Unità tecnologica ☐	Riscaldamento passivo ☐
Sistema tecnologico ■	Raffrescamento passivo ☐
Involucro architettonico ☐	Controllo solare ■
	Comfort termoigrometrico ■
	Energie rinnovabili ☐
Applicazione	
Partizione interna ☐	
Partizione esterna	**Sostenibilità ambientale**
Chiusura verticale ☐	Comfort indoor ■
Copertura ☐	Comfort outdoor ☐
Rivestimento ☐	Produzione energetica ☐
Schermatura esterna ■	Ottimizzazione guadagni termici ■
	Criticità
Stato avanzamento	Gestione processo produttivo ☐
Costruito ■	Messa in opera ☐
Prototipo ☐	Consumo di risorse ☐
Progetto ☐	Gestione ■
Modello virtuale ☐	Manutenzione ■

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V2_ COMPONENTI DI INVOLUCRO CON VARIABILITA' DI FORMA/CONFIGURAZIONE

V2.1_65 SCHERMATURE SOLARI
SOMA Architecture, "One Ocean" pavilion in South Korea for the EXPO 2012

CARATTERISTICHE DEL SISTEMA

VARIABLE PROPERTY: trasmittanza luminosa

SYSTEM MECHANISM: attivo (bus-sistema computerizzato con sensori)

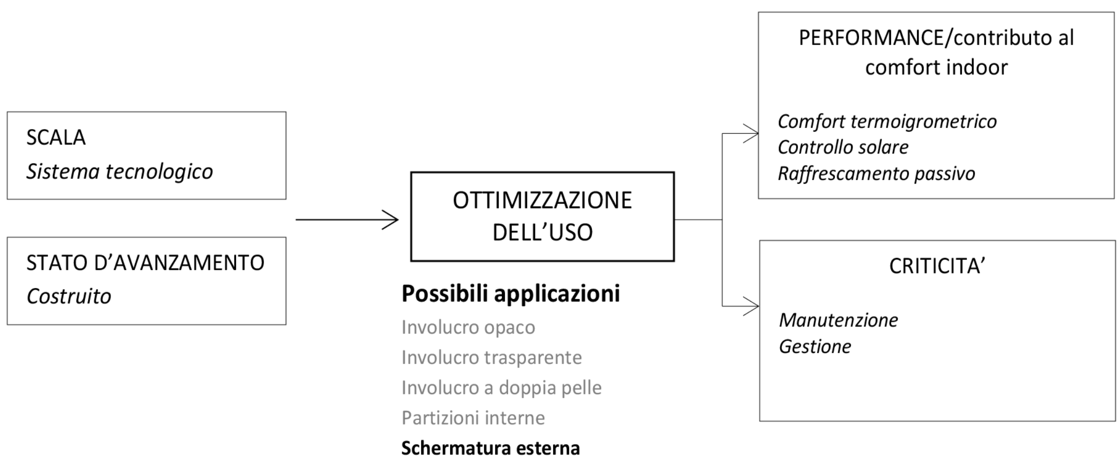
BENEFITS: Controllo solare (riduzione guadagni termici, graduazione daylight, riduzione abbagliamento), graduazione ventilazione

DESCRIZIONE

La facciata cinetica è composto da 108 lamelle di vetroresina che si aprono e chiudono. Le lamelle sono realizzate in polimeri rinforzati in fibra di vetro (FRP), che combinano alta resistenza alla trazione, con bassa rigidità alla flessione, permettendo grandi deformazioni elastiche reversibili. Le lamelle sono movimentate da attuatori sia sul bordo superiore ed inferiore della lama in FRP, che inducono forze di compressione per creare la deformazione elastica. Gli attuatori riducono la distanza tra i due cuscinetti e in questo modo inducono una flessione che si traduce in una rotazione laterale della lamella. L'attuatore delle lamelle è un mandrino a vite azionato da un servomotore. Un bus-sistema computerizzato permette la sincronizzazione degli attuatori. Ogni attuatore è sincronizzato, sensori controllano continuamente lo stato delle lamelle e trasmettono i dati ad un server tramite un bus di sistema. Ogni lamella può essere indirizzato individualmente all'interno di una logica specifica di movimento per mostrare diverse coreografie e modalità di funzionamento. Le prestazioni del materiale delle lamelle biomimetiche produce un effetto interrelato di geometria, movimento e luce. Più lunga è la singola lamella - più ampio l'angolo di apertura - più grande è la zona colpita dalla luce.

IMMAGINI

ANALISI DELLE CARATTERISTICHE: macro scala	***PERFORMANCE, APPLICAZIONI, CRITICITA'***
Scala	**Performance energetica-ambientale**
Unità tecnologica………………………□	Riscaldamento passivo…………..□
Sistema tecnologico…………………■	Raffrescamento passivo…….…..■
Involucro architettonico………….□	Controllo solare……………………..■
	Comfort termoigrometrico……..■
	Energie rinnovabili……………......□
Applicazione	
Partizione interna……………………□	
Partizione esterna	**Sostenibilità ambientale**
Chiusura verticale……………..….□	Comfort indoor…………..………………■
Copertura………………………..…..□	Comfort outdoor……………….……….□
Rivestimento……………………….…..□	Produzione energetica…………….…..□
Schermatura esterna ………..…….■	Ottimizzazione guadagni termici….■
	Criticità
Stato avanzamento	Gestione processo produttivo…………□
Costruito…………………..…………….■	Messa in opera……………………..…………□
Prototipo………………………………….□	Consumo di risorse………..……………….□
Progetto………………………………….□	Gestione…………………………………….….■
Modello virtuale…………………….□	Manutenzione……………………………..…■



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