

Typologies of Intelligent Facades in Efficient Buildings

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Abstract: The production of efficient building models promotes the search for intelligent technologies, capable of making the building sufficient, from an energy point of view, to improve the comfort and well-being of the occupants, while respecting the environment and the planet. So they need new building processes that increase market demand, enhancing the use of alternative sources in which construction becomes the focus of productivity. The objectives are those of energy self-sufficient buildings, with passive use of the roofs, in which the different materials and systems optimize the efficiency and effectiveness of the energy and technological systems, with an innovative constructive integrated design approach, for the new, for the redevelopment and recovery of the building, also according to European regulations including UNI EN 13830: 2015 and other worldwide ones. The criteria are distinguished according to the needs of the occupants, for the use of energy self-sufficient environments, security, with air quality, living comfort, cost reduction and increased productivity of the real estate sector. The methodologies point to a new conscious and shared model for the use of innovative construction technologies, with BIM (Building Information Modeling) design and MEP (Mechanical, Electrical and Plumbing) systems, which aim at digitization with pre-planning and intelligent management in construction, and smart BMS (Building Management Systems) systems in the BA (Building Automation). So they use typologies of intelligent facades in efficient buildings, *unitized curtain walling system, structural glass facades, suspended curtain-walls*, etc., with double and triple *skin glazed systems*, LED glass, with solar screens, etc. Therefore, high performance in passive systems, for natural lighting and ventilation, etc. is distinguished in envelopes in operation the solar incidence and solar carving techniques. The challenge is the well-being of the occupants in the use of innovative technologies for types of intelligent facades, in passive and efficient, low-carbon enclosures that interact with the user and the context, with a view to the durability of the systems, energy saving and some materials.

Key words: Facade systems, intelligent construction technologies, clean energy, sustainability.

1. Introduction

The new construction technologies, adopted in sustainable and intelligent passive enclosures, aim at new building processes, through prefabricated and integrated design based on parametric BIM modeling and for MEP systems. The objectives of improving the use of renewable resources with passive devices of intelligent facades of efficient envelopes, increase sustainable construction that is constantly evolving, through integrated building/plant projects, which follow restrictive technical regulations in respect of the user, the environment and the planet. In particular, we follow lines of European standards such as UNI

EN 13830: 2015, UNI EN 17213: 2020 [1] and worldwide standards, for the reduction of CO₂, with sustainable construction and typologies of performance facades that improve comfort and efficiency with environmental, economic and social sustainability objectives. So we aim at intelligent and self-sufficient construction, from an energy point of view, with passive envelopes through digitization with pre-fabrication, on site and off site of production. In fact, the configuration of the efficient envelopes is highlighted by a conscious and shared building model of a new building process, in which the architectural and technological designs integrate, with an innovative design, systems and components of intelligent facades.

They are aimed at the efficiency of the envelope and energy systems, which entail the comfort and well-being of users, new dynamic environments,

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enhanced by natural light from types of continuous facades, windows that represent the skin of the building that interacts with the inside and the outside environment. Sensor systems, for monitoring and controlling internal temperatures, interface with envelopes closure systems, and vertical openings and relative blinds. Among the types of intelligent facades, there are the *curtain wall unitized system*, *structural facades*, etc., open joint, thermal break, *suspended curtain walls*, integrated curtain walls with LED glass, etc. These are integrated in the casing with intelligent energy systems with smart BMS management that interact, for monitoring, and control with the user, via PC and smartphone applications, for the reduction of CO₂, energy saving and optimization of thermal gain with improvement of the systems for commercial buildings, tertiary, offices, mixed with residential, etc., towards Net_Zeb.

2. Facades in System Design

Among the innovative *curtain wall unitised system* facades, the Center Building, by Rogers Stirk Harbor + Partners, on the LSE campus, London in 2019, for the redevelopment of the LSE University (London School of Economics) is highlighted [2]. The facades of the glass, aluminum and steel enclosure, with prefabricated elements, meet natural ventilation requirements, of approximately 60% with embodied carbon saving (Fig. 1). The design of the facades develops, on the east west axes, with exposure that follows solar radiation and a system of aluminum blackouts, to avoid summer overheating. It is a sustainable design, with software technologies BIM and Mep, for implants, distinct with excellent Breem certification. The AGC glass curtain wall, Glassiled Uni [3], is a unique combination of light and transparency, energy saving, with integration of monochromatic or RGB LED glass, which illuminates the facade uniformly [4]. This type of facade highlights high insulating and thermo-hygrometric factors, with lighting and acoustic performance,



Fig. 1 Center building, Rogers Stirk Harbour + Partners, in LSE campus, London UK, 2019 (perspective on Houghton Street, Houghton Block. Mep design. Installation of aluminum curtain wall unitized system, with aluminum rain screen cladding, frameless glass balustrades).

Source: photo by the author Consiglia Mocerino.

high technical properties, tested by sophisticated photorealistic rendering simulations. They are intelligent and efficient, low energy consumptions with high visibility performance, which optically increase the interior spaces, improving the environmental quality of the inhabitants and the architectural performance.

In the type of *curtain wall*, the self-supporting prefabricated system, *stick system*, anchored to the load-bearing structure, has high performance also in relation to climatic and environmental data. It transmits stresses of its own weight (permanent load), shielding loads, relative automation devices, etc. to the primary structure. Horizontal loads are the action of the wind, with higher depression, in the edges, in an 8:5 ratio, usually, with the pressure load, accidental loads of people, impacts, snow, scaffolding and seismic shock. Another type of aluminum *curtain wall unitized system* is the Q-Air modular glass system, high performance, of the European project Horizon

Table 1 Q-QIR H2020 system: increase in energy efficiency compared to double and triple glazing systems.

Glass curtain wall	Ucw \geq	g	LT
Q-Air 6 rooms (QATT6)	0,30 W/m ² K	0,09 – 0,19	0,10 – 0,33
Q-Air 5 rooms (QATT5)	0,43 W/m ² K	0,10 – 0,27	0,11 – 0,40
Q-Air 3 rooms (QATT3)	0,62 W/m ² K	0,12 – 0,34	0,14 – 0,56
Double glazing	\approx 1,5 W/m ² K	0,1 – 0,6	0,1 – 0,75
Triple glazing	\approx 1,0 W/m ² K	0,1 – 0,5	0,1 – 0,65

Ucw: thermal transmittance; g: solar heat gain (values go SHGC); LT: light transmittance.
Table formed by the author Consiglia Mocerino. Source: Ref. [5].

2020 [6] which has an energy saving reduction capacity of 15-35 kWh/m², with double and triple glass typologies (Table 1). Since the telluric stresses usually determine a rigid translation of the anchor, depending on the inter-plane deformation, causing the lateral inclination in the metal warping of the vertical uprights, with breakage or expulsion of the glass components, checks are carried out in the laboratory for the behavior of the facade, with dynamic simulations, according to criteria of the EN 13830: 2015 standard, Curtain Walling with relative testing.

2.1 Efficient Typologies

In curtain walls with prefabricated independent cells, the *unitised systems*, lower deformations occur, under the action of seismic stresses, resulting in a horizontal translation. Modular systems are configured in two-dimensional, three-dimensional cells, etc., where efficiency is the result of technology, design and materials. In fact, in the example, the efficient building, *Solar Carve Tower*, 63 m high, and 187 m², intended for offices and residences, on the High Line, 40 Tenth Avenue, certified by Leed Gold, of 2019, in Manhattan has a dynamic facade, prefabricated off site (*Unitized Curtain Walling System*), produced by Focchi and Arup structures, mounted on site. The cell system is made up of a highly performing *Double Glazed Units* (DGU) framed module in aluminum and low-iron glass, consisting of five components, including a rhomboid central panel, enclosed on the sides, by four triangular shapes.

The module is installed perpendicular on the soffits and extrados of concret floor, forming the dynamic articulation of a complex facade, with characteristics of lightness and durability, based on principles of sustainability and energy saving (Fig. 2). It has a converging shape of the central rhombus, inwards, limiting solar overheating. In fact, the facade has two particular angles on two fronts, for solar incidence, according to the “solar carving” technique [7], guaranteeing light and air, from the South and West (Fig. 3).

Usually, cell systems are particular façade systems aimed at creating large thermal break frames, a principle based on the insertion, in an internal chamber of the profile, of a material with low thermal conductivity, which interrupts the thermal continuity,

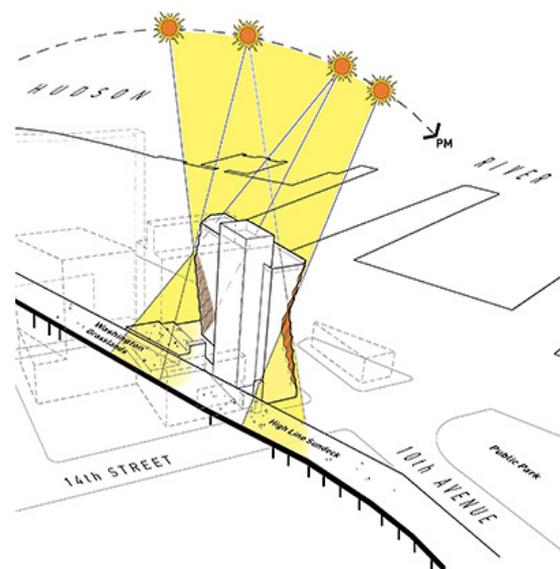


Fig. 2 40 Tenth Avenue, Solar Carve, Gang architects Studio, NY. Solar incidence on double skin facades.
Source: Ref. [8].



Fig. 3 40 Tenth Avenue, Solar Carve, Gang architects Studio, NY, 2019. Double glass and aluminum cell facade. *Unitized Curtain Walling System.*

Source: Ref. [8].

for example of aluminum, having a high conductivity. Among the materials, with high thermal performance, recently used, is nylon reinforced with polyester, as an alternative to PVC products, neoprene rubbers, etc., polyurethane that deforms with respect to the different deformations of the external facade, compared to the internal one of the aluminum, caused by temperature changes.

Between the uprights of the structural curtain wall, which must guarantee air and water tightness, the thermal expansion joints are equipped with anti-friction shoes and EPDM (Ethylene-Propylene Elastomer) gaskets, DIN 7863. These have an external plug, stack joint, of the same material, equally applied between vertical and horizontal pressers (60 mm in size), for the continuity of sealing between gaskets, both static and dynamic, and pressers (infill). The central gaskets (open joint or pressure compensation) form a pressure equalization chamber, through their

rearward installation, with respect to the external surface, while in the profiles, special channels for ventilation and for the outflow of rainwater constitute drainage to the outside.

In the type of *suspended curtain-walls*, the visible anchors are balanced by a series of plastic gaskets which are in contact with the glass plates, assembled together, by means of silicone and anchored to the supporting structure, (of usually in tubular steel) with point fixing.

This is achieved through connections of rotules, with ball-joint and insulated from the glass, through bushings or washers in aluminum, or in nylon, for expansion, and as a hinge function between tempered glass (sometimes with thickness, minimum of 10 mm, drilled for the passage of the bolts) and metal structure. They transfer the loads to the secondary structure, made up of the so-called “spiders” or metal spiders, with stainless steel crosses.

The rotules are attached to the cruises, which have the function of absorbing the dynamic thrusts of the glass plates. This type of facade is configured, also in the continuity of the casing, in spherical, pyramidal, etc. covers (Fig. 4) with the use of double-glazing, equipped with aluminum bushings for the passage of the steel bolt of the rotules. The joints are completed, externally to the facade, by metal studs, to guarantee the sealing performance, small horizontal protrusions, called little hands, which support the weight of the infill, are distinguished in the texture of the structural glazing facade, in whose load-bearing structure, of metal warping, both glazed and opaque infill panels are applied. A silicone sealant, which constitutes a highly adhesive elastic bond, transmits to the supporting frame structure, the loads of the glass plates.

In these systems, the construction principle of the glass closures is the open or pressure compensated joint, a technological solution that guarantees a high resistance to atmospheric agents, and drainage of the water, through drain holes, according to the balance of pressure, which is created inside the profile.

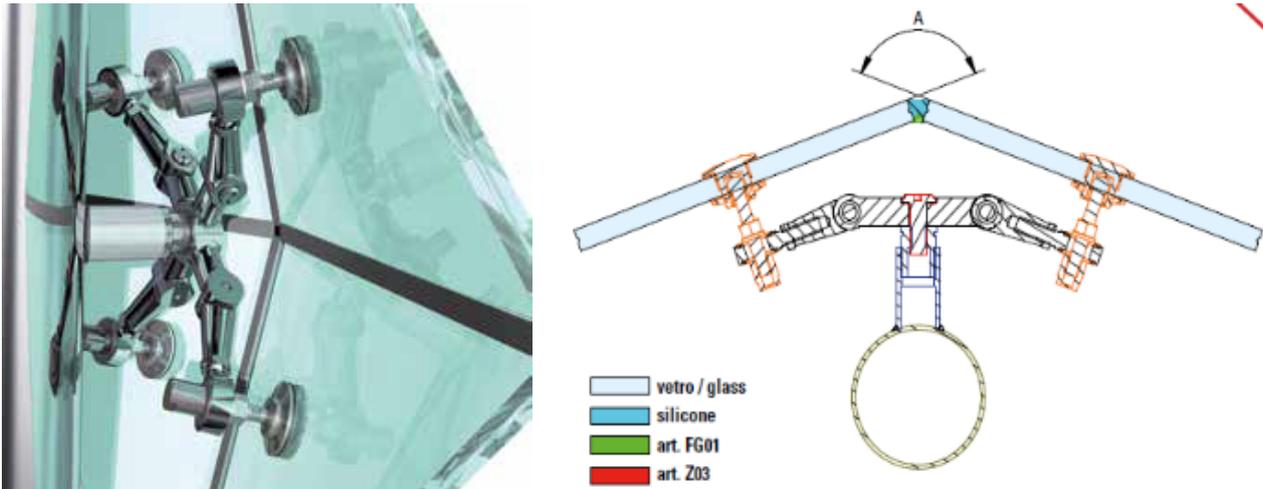


Fig. 4 Suspended curtain-walls. Detail: 4-point stainless steel cruise, with glass of maximum 400 kg. Source . Ref. [9].

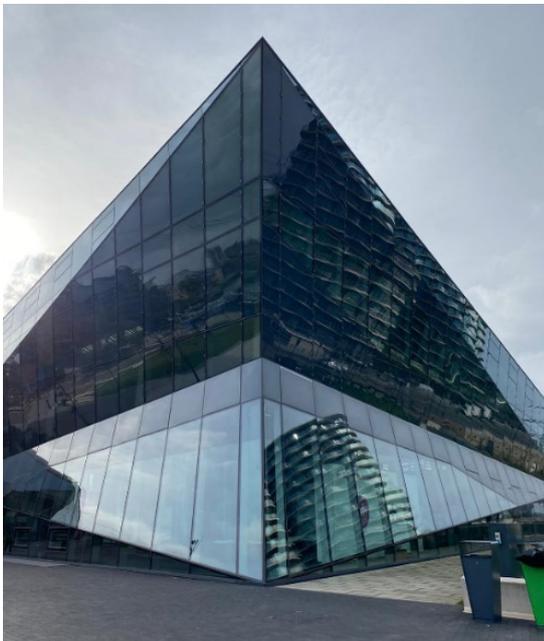


Fig. 5 The Crystal, Wilkinson Eyre architects, London, UK. Smart building. Structural curtain glass. No external slatted shades for angular facades, which leads the building to self shading.

Source: photo by the author Consiglia Mocerino.

Among the high performance of these types of intelligent facade construction [10], with requirements for lightness, dynamism and durability of the materials, those in double or triple skin in glass, or multiple-skin windows, intended mainly for offices, the service sector, etc., are the most energy efficient, reducing heat loss by 20-30%, with a 10-20%

improvement in comfort in the summer. They are used to reduce, also the thermo-acoustic and dynamic stresses, such as the strong thermal excursions, the wind pressure, the rain load, snow, etc., and to reduce the particularly severe thermal and acoustic stresses. These *intelligent structural glass facades* are highly performing and intended to reduce demand and save energy, with the function of a thermodynamic filter,



Fig. 6 The Crystal, Wilkinson Eyre architects, London, UK. Detail façade: six types of insulated glass panels suitable for different spaces.

Source: photo by the author Consiglia Mocerino.

with internal microclimatic control and calibration of the building (as per internal solar screens, with digital control of sensors, etc.) and consequent reduction of artificial lighting. The architectural design of the envelope, of a BA (Building Automation) building, with inclined structural facades (Figs. 5 and 6), in the shape of a diamond, integrates with the technological systems, through the different angles that creating shaded areas, reduce solar overheating and increase daylight in office interiors. The facets create shaded areas with translucent glass upwards, while at the bottom they gain them through the fringed shape. So, six types of facade glass are clear, translucent and opaque, suitable for natural lighting in the various spaces, with installation of types of clear glass, for the exhibition hall, while for the offices the clear glasses filter with greater intensity, the light in the interior. For the north and south facades, clear glass is used, respectively, for more natural light, but with less thermal gain, and mixed translucent and opaque glass to reduce the glare of light [11].

They also increase natural light [12], integrated, usually, with HVAC (Heating, Ventilation and Air Conditioning) systems with smart BMS, intended for the thermo-hygrometric treatment of indoor air. The high performance of these types of facades is highlighted, above all, by the increase, in winter, of the heat of hot air, conveyed into the ventilated cavity of an accumulation of solar thermal energy and renewable source.

In fact, the air is conveyed between the glass facades, placed at a distance, according to project requirements, of about 20-25 cm, while for the redevelopments, from 50-80 cm, and with reduction, in summer, of the summer load, with air expelled outside the cavity. In the latter, the air is conveyed naturally or mechanically from the inside or outside of the building, through fixed or adjustable air vents, closed in winter, creating a thermal insulation filter, buffer zones, for the greenhouse effect, and open in

summer, creating natural ventilation for the chimney effect.

Thanks to the latter, the surplus (about 25% of direct solar radiation) of the heat in the cavity is expelled outside, through upward movements of the air, since it is compensated by the absorption of the glass walls, by the action of shielding interposed solar and metal devices of the cavity. In the latter, the air can also be operated mechanically from air conditioning systems, with a closed system, with additional types that are distinguished in forced ventilation and natural ventilation.

The elimination of thermal bridges also contributes to lower heat loss. Furthermore, among these multilayer systems of ventilated glass facades, with high performance, we highlight the ventilated walls (so called for the chimney effect) with multiple-skin closures, on a cantilevered, cantilevered supporting system of uprights and crosspieces in extruded aluminum, anchored through steel brackets, to the bearing structure of the building.

The *multi-skin glass closure*, installed on the framed structure, is separated from the latter, by a cavity whose dimensions are a function of the thermofluidodynamic calculations of the façade, which facilitates the evaporation of surface condensates, attenuates thermal loads, through natural ventilation of air vents, installed at the bottom and top of the same facade [13].

The efficient technologies of these intelligent glass facades improve living comfort, with the advantage of reducing heat loss, ensuring the functionality of the insulating layer, and act as thermal-acoustic, hygrometric insulation, with high results in energy efficiency and values architectural.

For fire protection in multi-skin glazed and *ventilated facades*, the application of anti-combustible insulators with the integration of dividing elements for each floor, which confines any smoke from the spread of flames that may occur in the cavities, is fundamental.

3. Conclusions

The innovative intelligent construction technologies, for intelligent facades of efficient building envelopes, highlight a new architectural performance, aimed at reducing energy needs and improving the habitat. For this purpose, a new sustainable envelope design is highlighted that integrates energy technologies, based on parametric design with BIM MEP, for energy self-management, with natural and forced ventilation systems. Therefore, the optimization of internal environments with integrated passive systems is promoted, from an intelligent design to technological and energy systems of the building envelope, for energy saving and management with smart BMS systems mainly for the thermohygro-metric treatment of air in the rooms. In this trend, digitalisation in the building process tends to a new performance of a passive and sustainable prefabricated building, with sophisticated intelligent systems that highlight an innovative technological, design with energy efficiency in the construction, both for the new and for the redevelopments in innovative building models [14]. Therefore, the objectives of an energy self-sufficient building, with passive use of the envelope with solar carving techniques, etc., are mainly based on efficient methodologies with the application of innovative typologies of sustainable and efficient envelope facade. This mainly highlights intelligent facades such as the *Unitized Curtain Walling System*, with requirements for lightness, dynamism and durability, together with the innovative *suspended curtain-walls*, *structural curtain walls*, *ventilated curtain walls*, etc. To these are integrated the materials in glass, aluminum, LED glass, brick, nylon, nylon reinforced with polyester, as an alternative to PVC products, neoprene rubbers, and polyurethane, etc. creating complex and efficient, energy-saving facades, with CO₂ reduction, reduction of costs and materials. So the challenge is in the use of innovative technologies in intelligent typologies for building envelopes, with low carbon, for living comfort, safety,

environmental protection and energy efficiency.

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