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The Glass envelope and Transparency in Contemporary Architectural Design

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Abstract
Transparency is a modern invention because the technology of glass - according to a positivist reading - has permitted a new concept of design. Historic architecture, being unable to have transparency, never dealt with this issue, and always affirmed itself as an instant object, as a volume-mass, as a presence ontologically lasting through time: variations concern the quality of volumetric conformation, the way of relating to space, from the Platonic absolute of Greek and Roman or Neoclacissic temples, to the empirical way of Romanesque or the post-empirical way of Baroque. But in every case, we are always speaking of the affirmation of the presence of a presence. Historically, transparency was never visual, but was introduced for symbolic, poetic or narrative reasons with the penetration of light and air, from the oculus of the Pantheon which opens the dome of the temple of all the gods to the sky, to Romanesque rose - windows, a metaphor of the setting sun. Contemporary architecture is increasingly characterized by a massive presence of transparent enclosures. The report highlights the relationship of some architectural-formal choices to the principles of environmental eco-compatibility and looks at the different characteristics and performances. In relation to these aspects, glass has become the promise of modern society. Clear and pure, it represents cleanliness and transparency and symbolizes the disappearance of the massive and dark walls of the pre-industrial world. When combined with glass, light and transparence represent aspects of a healthy society, in which the political processes are visible and accessible to all, and whose citizens can be seen live through department store windows and television screens. Glass has become the symbol of open and transparent civilization and, by that, the namesake of democracy. However, it is anything but transparent and, taken closer, the crystalline symbolism associated with it a little (too) quickly is even an illusion, a fundamental error, heavy with consequences.

Keywords: architecture, design, energy, glass, transparency

Glass: a sustainable building material

The impact of energy and carbon embedded from glass and the durability of glass as a building material, including its reuse and recycling, are discussed in the following paragraphs. The intrinsic energy of a building is the energy consumed by all materials and processes associated with building construction, from the extraction and processing of natural resources to the manufacture, transport and delivery of products (Sattary and Thorpe, 2012). Similarly, a building's embedded carbon is the total carbon associated with all materials and processes used in the building's total life cycle. Strategies for reducing total embedded carbon in buildings are of great importance. This can be achieved by:

- reduction of the quantity of materials used and minimization of waste,

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- reduction of the use of mole of materials and methods of production with high energy requirements, and
- inclusion of sound environmental management and methods for updating the reuse and recycling of materials.

Energy and carbon embedded in common building materials

Intrinsic energy/carbon of buildings has been somewhat neglected in government regulations the current regulation focuses mainly on the reduction of operational energy/carbon. Sturgis and Robert (2010) estimate that embedded carbon can account for up to 45% of a building's total carbon impact over its life cycle. While an intrinsic/carbon energy analysis is required to assess the total impact of a given building, a reliable study of intrinsic/carbon energy is not trivial. Transport, for example, can affect intrinsic energy - a material made and used in London has an intrinsic energy impact different from the same material transported by road to Edinburgh. Recycled materials are sometimes used to make new products, and these products usually have a reduced carbon impact. It is also difficult to take into account the energy required to maintain, repair and renovate a building throughout its life cycle. Despite the difficulty in performing an accurate analysis of the energy/carbon impact incorporated materials building a given building throughout the life cycle, some methods have been listed in the literature. One method is the "Carbon and Energy Inventory Database of the University of Bath" (Hammond and Jones 2006), and this inventory provides an open-access database on the energy/carbon impact of more than 400 materials (Hammond and Jones 2008). This database has been used by various researchers and developers of carbon footprint calculators, including the carbon calculator of the British Environment Agency for Construction (Hammond and Jones, 2008).

Energy / carbon embedded glass

Table 3.1 shows a comparison between the energy/carbon values of glass and two frequently used building materials, concrete and steel.

Material	Embedded energy MJ/kg	Embedded carbon MJ/kg
Float glass	15	0.232
Tempered glass	23.54	0.346
Reinforced concrete	1.39	0.057
Steel (bar et rod)	24.6	0.466

Table 3.1 - Embedded energy and carbon values of glass, concrete and steel (Hammond and Jones, 2006)

Although the exact intrinsic energy/carbon impact of building materials depends on the application, the values given in Table 3.1 can be used to study the relative impact of glass on concrete and steel. Float glass has a built-in energy / carbon of 15 / 0.232 MJ / kg which is lower than that of steel (24.6 / 0.466 MJ / kg), but higher than reinforced concrete (1.39 / 0.057 MJ / kg)

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(Table 3.1). Much of the intrinsic energy/carbon of glass is attributed to the process of producing temperature. Due to the secondary heating process used in tempered glass, it has a greater energy / carbon incorporated (23.5 / 0.346 MJ / kg) than floating glass. It should be noted that, although concrete has relatively low built-in energy per unit mass, its overall impact is greater than that of glass due to the large volumes of concrete used in the construction industry. concrete is the most widely used construction material in the world with an estimated annual consumption of more than 12 billion m3 (~ 25 gigatonnes) of concrete (Gursel et al., 2014) and ~ 200 billion kg of steel (World Steel, 2010)). On the other hand, the mass/volume of glass required to build buildings is less than that required for an equivalent concrete element. In addition, glass is more durable than steel and concrete, and the use of glass also has also has the potential to reduce the operational / carbon energy impact of buildings. For example, glass is a more durable construction material than concrete and steel, despite the fact that the embedded energy of glass is greater than that of concrete on the basis of unit mass.

Reducing the impact of glass energy/carbon

Buildings that are efficient in terms of the quantity of materials used are also efficient in terms of energy and carbon. The quantity of materials needed for construction can be optimized by improving the overall efficiency of designs, for example, better specification of design guidelines, optimal structural designs, avoiding over-engineering, designing for future use by including adaptability and flexibility, etc. It is also important to reduce waste of materials, for example by using off-site know-how and construction. Another important way to reduce the impact of embedded energy/carbon is to recycle and reuse materials.

Glass recycling

Although glass bottles are generally recycled, glass plates used in buildings are not recycled. This is mainly due to the difficulty in removing coatings and other materials (e.g. adhesives, metals, glass produced by other manufacturers, etc.) mixed with glass waste. The low energy savings that can be achieved from recycling is another reason for the lack of recycling of glass. Table 3.2 provides the potential energy savings that can be achieved by recycling glass and some other materials, aluminum, plastic and cardboard (Sattary and Thorpe 2012).

Material	Energy required for production from virgin material : MJ/kg	Energy saving using recycled materials: MJ/kg
Float glass	15	5
Aluminum	250	95
Plastic	98	88
Paper	26.5	24

Table 3.2 - Potential energy savings from recycling glass, aluminum, plastic and cardboard (Sattary and Thorpe, 2012)

Recycling glass only saves up to 5% of the energy required in the original production using raw materials (Table 3.2). This is a very low energy saving per compared to the one that can be achieved

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by recycling aluminum and plastic, where the potential energy savings are 95% and 88% respectively. During the recycling of the glass, the old clean glass crushed into small pieces of glass and mixed with the raw materials (silica, lime, soda, etc.). The mixture is then heated and annealed in the same way as the production from pure raw materials. Due to the high energy required for this process, the energy savings from recycling are limited to 5%. Although recycling glass waste is not particularly attractive, glass waste can be reused in many ways.

Reuse of glass

In developed continents, more than 1.2 million tons of waste are generated each year through the demolition and renovation of buildings in which glass waste represents only about 0.6% (Glass for Europe, 2015b). Glass manufacturers generally do not recycle most of the glass waste, and therefore reuse of the material is important. Since glass is a hard and relatively inert material, it naturally lends itself to be used as an aggregate in concrete. Because of the different colors and the brightness when the sunlight falls on the glass, the concrete with the aggregates of the glass have an excellent aesthetic (see Fig.1). However, the glass aggregate in concrete has a problematic durability due to the alkali-silica reaction. Research has shown, however, that the alkali-silica reaction may not occur if the glass waste is finely crushed, typically less than 75-100 µm in size (Corinaldesi et al. 2005).

Fig.1: Use of glass in concrete

Another successful application of glass waste is its use as an alternative aggregate in asphalt materials in road construction, where the term glass asphalt is used (Khatib, 2009). The amount of glass bitumen replacement in conventional aggregates is up to 50%, but more generally about 10% is used (Khatib, 2009).

Glass waste, after being crushed to a size specified by the end-user, can also be used as glass beads for reflective paint, as a pipe cushion for French systems and rain showers, and as an abrasive (as sandy) (Khatib, 2009). Other useful applications of fine glass waste are ashtrays, filter media for swimming pools, sand traps on golf courses, aquarium sand, etc. (City and County of Honolulu, 2005). Glass waste reuse is greener than recycling, and the availability of many reuse applications means almost all glass waste is reusable.

Use of Glass in Passive Low Energy Buildings

To date, a significant share of total electricity/gas production is consumed by buildings, particularly in developed countries. For example, about 40% of the total primary energy in the United States is consumed by buildings (United States, 2009). There is an imperative need for energy efficiency in buildings. Energy efficiency is one of the main attributes of an ecological building. In recent years, we have seen a radical overhaul of the approach to building design; the reduction of energy demand for lighting, ventilation, cooling/heating, etc., is foreseen.

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Recent developments in energy saving technologies are mainly twofold: (1) active technologies, such as heat pumps coupled with air/groundwater heat sources, solar thermal collectors, renewable energy sources such as solar photovoltaic panels and wind, etc., and (2) passive technologies, which include insulation, efficient use of daylight and solar inputs, heat recovery from ventilation air and/or wastewater, etc. (Sartori and Hestnes, 2007).

The use of active technologies such as renewable energy sources is expensive, and solutions can also increase the built-in carbon of buildings. On the other hand, passive building design-based technology (for example, passive houses), in which design exploits passive technologies to reduce energy demand, can significantly reduce total energy needs without increasing carbon or total construction cost. Passive home systems outperform conventional buildings in terms of quality of life and energy efficiency through heat recovery, good thermal insulation and overall optimization of building performance (Sartori and Hestnes, 2007). Some renewable energy sources can also be used in these buildings to generate low energy demand and, therefore, have a zero-sum total energy. The development of passive house buildings is a win-win situation due to potential reductions in energy demand and carbon footprint.

Recent innovative advances in glass products show that glass has become the most essential building material in energy-efficient buildings, passive houses. As described above, proper use of glass can reduce heat losses but also allows a solar gain useful for heating the building. Using solar glass properly while maintaining daylight transmission can eliminate the need for artificial air conditioning systems.

In a well-designed passive house, the interior temperature can be maintained between 20°C and 26°C and the relative humidity inside between 30% and 60%, ensuring the comfort of the building in all seasons. Passive house construction is now happening all over the world; significant energy savings and high levels of occupant satisfaction are verified. In the next chapter, we will examine the sustainability aspects of buildings through the exploitation and control of natural resources through glass.

Lightweight façade systems

Light glass weighs tons

Glass is lighter than aluminum, but as it is fragile, it must be quite thick, which is a considerable weight for large surfaces or double or triple glazing. Even small-format lenses can have a weight that can cause unexpected costs, for example because common double-flapping windows require thicker frames with stronger fittings. The installation of glass facade elements requires considerable logistics since, due to their weight and size, they must be transported by crane to their location between the scaffolding and the large work, then adjusted to several people at the same time, before fixing and sealing them. "Suspended façades or curtain walls" means those non-bearing glazing at the head of the slabs; this term reminds us of the lightness of enveloping fabrics rather than a cumbersome, heavy and brittle material. This new contradiction, linked to the use of glass, represents a permanent challenge for architects and obliges them to find a solution that reconciles the structure of the building and glass. In his project for Banco de Bilbao in Madrid, *Francisco Javier Saenz de Oiza* tries to give the facade the textile aspect, flexible, mobile of a suspended fabric. It wraps the imposing concrete structure with a rounded glass skin at the corners and belts of the maintenance bridges, and closes this curtain by a slightly asymmetrical "seam" over the entire

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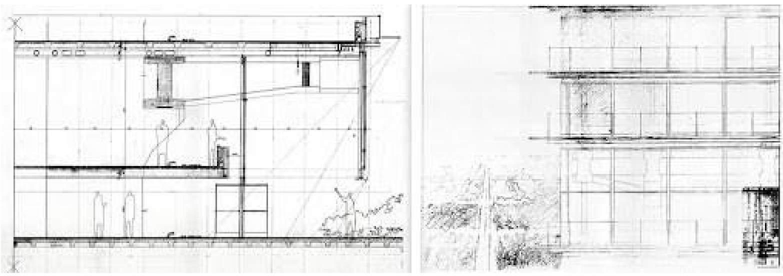
height of the tower. Closed by a kind of zipper, the lower part, suspended, of this garment overhangs the indented entrance and ends with a grooved metal profile. To increase the "hem" effect, the facade clothing goes down and the high-waisted visitors instinctively lower their heads to avoid bumping into it. But perhaps they are just unconsciously feeling the weight hanging over their heads.



(a-b)

c d e

Figure 2 a,b,c,d,e : Francisco Javier Sàenz de Oiza, Banco de Bilbao, Madrid , 1981
Source: http://extranet.ensan.fr - https://esacademic.com - http://www.festivalarchitettura.it

Carrying glass: the sum of all the contradictions?

Making something look lighter than it actually can be a fantastic challenge for an architect. Weight denial is indeed one of the drivers of the evolution of architecture. What better way to respond to this aspiration than with “transparent” glass?

Since the bearing elements of wood and metal can only be reduced to a certain extent, it is understandable that we want to achieve a complete "optical" disappearance by means of carrying glass. There has been a steady boom in this field, which has been booming since the 1980s; even if the practical applications have not managed to become fully established. The technique of glued exterior glazing. (Structural Glazing) replaced the window frames and profiles, and glass stiffeners placed perpendicularly to the surface ensure contouring while leaving the space open. Pillars and glass-bearing walls abolish all horizontal boundaries, while staircases, floors and glass roofs open the vertical space.

However, we do not release the glass from its contradictions, even if they do not strengthen. The glass building does reflect the sum of all its oppositions. To conclude with an expression of the dream of crystal-clear architecture, we say that the glass building remains a “natural fantasy”.

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The materialization of light systems

The term "envelope" identifies the physical boundary of the building in relation to the external environment and at the same time defines the cultural assumptions on which the project is based. Usually, if this term is used with the adjective "light", it is used to indicate the area of current technological developments associated with innovative systems. After the first conscious use of fully glazed walls in the first decades of the 1900s, the widest diffusion of transparent systems for the case can be dated to the 1950s. The large buildings with mostly glazed surface date from this period. The Seagram Building of *Mies van der Rohe* in New York and the Pirelli skyscraper of *Giò Ponti* in Milan were born between 1955 and 1959. From the beginning of the 1960s, the introduction of the Float glass production process expanded the possibility of using glass and mechanical coupling systems were developed which, from there, will be continuously developed, until the 1980s, what appears the systems with punctual fixation of plates.

a b c

Figs.3 a,b,c : Detail of punctual hanging of glass plates of the most diffuse systems

In parallel with the technological development of systems, after the 70s, with the diffusion of environmental awareness and the resulting regulatory impositions, research aims to improve energy efficiency. The last two decades have seen the development of “dual skin” systems (whose history refers to projects and stops that began in the first half of the last century), which seek a new interpretation of contemporary trends towards the exploitation of natural energies. The office building "Briarcliff House" of 1984, located close to the Farnborough airport, is connotated by a double facade that completely envelops the structure and uses the protection function. Since the 1990s, the use of transparent envelope systems has become even more widespread, and aspects related to the need for better control of system performance have also strongly influenced the shape of the architecture when the designer has to adapt the building in the expected comfort conditions.

The office building "Briarcliff House" of 1984, located close to an airport (Farnborough Airport), is connotated by a double facade that completely envelops the structure and uses the protection function. Since the 1990s, the use of transparent envelope systems has become even more widespread, and aspects related to the need for better control of system performance have also strongly influenced the shape of the architecture when the designer has to adapt the building in the expected comfort conditions.

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a b

Figs.4 a,b : Briarcliff House, 1984 , Farnborough, Hampshire, United Kingdom. Source: https://www.alrimo.co.uk

Formal issues of sustainability and comfort

Cultural influences, performance opportunities, production and management methods have liberated the project from the limitations imposed by the use of traditional building elements and allow the maximum exploitation of the technological knowledge used in production sectors other than construction. This broadens the scope for intervention both in the case of new constructions and in situations of re-use of existing buildings and generates a series of formal consequences on the building itself.

In particular, the components of radiation control and operation are crucial for the physiognomy of the architecture. These components provide performance ranging from solar technologies for the production of electrical or thermal energy to leaning greenhouses and all solar radiation protection systems. In particular, radiation control, which is often a source of problems in the management of the internal microclimate, finds a solution in the construction of external structures. In buildings with transparent facades, both the functional aspects and the image communicated depend on the sensitivity to environmental problems that has stimulated the search for innovative solutions at the technological level.

"In the Roche pharmaceutical research building of Herzog & De Meuron, the different positions of the screens change the image of the envelope according to the season and the different hours of the day. "

However, the creativity of increasingly original architectural solutions does not always correspond to an efficient result for certain performances. Glass-wrapped buildings often meet the formal need for transparency, but the indoor climate they generate is characterized by poor comfort and the amount of energy needed to achieve acceptable conditions is very high. The first critical aspect stems from the custom of using the same facade system for the different sides of the building. This, if it responds to the need to generate formal uniformity and ease of construction, causes an imbalance because the climate situation is different according to the different exposures.

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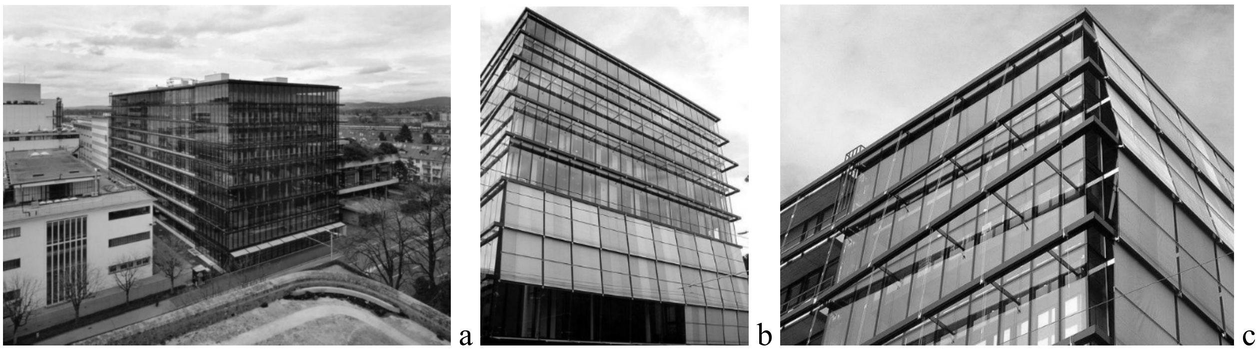

Figs 5 a,b,c : Herzog & De Meuron - Roche pharmaceutical research building, Basel 2000. Source: https://www.pinterest.com

Facades facing north will never be able to use the effect of direct solar radiation in certain climates and will hardly provide the same insulation as a traditional opaque wall (if one does not use glazing with an inert gas chamber with insulation function, argon, krypton, xenon and with the use of low-emissivity coatings that allow to obtain values of thermal transmission even less than $1W/m^2k$). controllable only with the use of expensive mechanical conditioning systems, both from an environmental and purely economic point of view. Moreover, the use of vertical walls almost completely devoid of thermal mass makes the control of the internal microenvironment sensitive to changing conditions and therefore requires rebalancing actions, even in this case rebalancing with the use of mechanical environmental control systems. An additional complexity comes from the diffusion of the "dual skin" system. Double-sheeted buildings, created to exploit the natural potential of cold climates, do not always adapt to use in our latitudes, characterized by long periods at high temperatures. The functional complexity characteristics of these systems therefore require ad hoc designs, chosen according to the climate of the site, both for the purely technical aspects and for the aspects related to the management of the building which becomes in fact a "machine" and as such, it must be understood.

Innovation, technology and transparency

"The materials and techniques have changed, the organizational conditions governing the design and construction processes have changed, the reference forms have changed; But there is a common denominator between the first greenhouses built by *Joseph Paxton* and the greenhouses of the City of Science and Industry developed by *Peter Rice*: an original contamination between technique and design." (Campioli, 1998, p. 116).

Never in recent years has transparency characterized and underpinned contemporary architectural research, while

reinforcing the link between technical innovation and expressive intentionality. The transparency that characterizes many of today's building envelopes is often the subject of linguistic, formal and even technical experimentation: innovative envelopes that, on the one hand, allow light to become the main element in the shape of space, transforming the perception of the internal environment; on the other hand, they give transparency a metaphorical value, not exclusively linked to its original meaning (Perricciolí, 1998).

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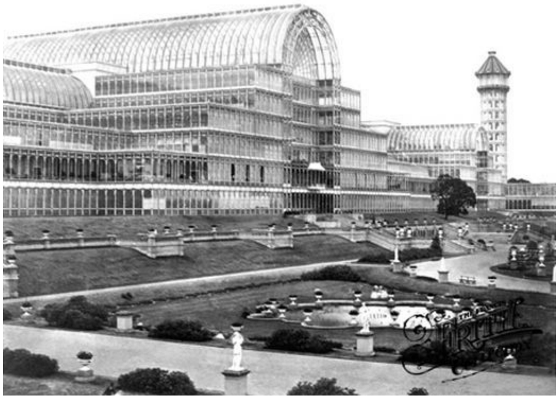
In this perspective, transparency is closely linked to the term "technology" and" innovation", which intersect, generating interesting research tracks.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Figs. 6 : Joseph paxton and the cristal palace, 1851. Source: https://pinterest.fr
Figs. 7 : Cité des Sciences et de l'Industrie Paris (19 ème), 1986) Source: https://structurae.net.fr

We are looking at some of them, by decreasing transparency not only in relation to the passage of light, as traditionally understood, but also in relation to other factors such as materiality, energy and lightness. This interpretative approach allows to address topics concerning new materials, technology transfer, custom production, with reference to the paradigm of transparency. In the most traditional sense, transparency is compared to the ability to let light filter, in a ratio between empty and full that favors the first over the second.

Starting from the first, which characterizes it much more, one can easily say that the preferred material for the realization of transparency has always been glass.

This material has long been a compulsory choice with unquestionable advantages, but also with some limitations due to its characteristics of hardness and fragility. Features that today are partly overcome thanks to tempered and laminated glass, much more robust to the constraints of compression and traction.

Research on this material is very advanced in the perspective of changing its characteristics to enrich it with optical, dynamic or plastic properties.

As for dynamism, it can be implemented with devices with filter function varying according to the stress characteristics to which the surfaces are subjected: they are dichroic, chromogenic or liquid crystal materials. The building for the *Scottsdale Museum of Contemporary Art* in Carpenter is emblematic with the "screen wall" created through tempered glass with dichroic properties.

Finally, with regard to the plastic possibilities of glass, they can reach very high levels not exempted, among other things, from a certain formalism, like the concave and convex diamonds for the Prada Store of Tokyo by Herzog and De Meuron. In this project, the glass was folded with a production technology that involves the use of a high-temperature fluid that ‘fold’ the glass slowly with its own weight. The cells were manufactured one by one with a technology closer to the artisanal methods than to the industrial production.

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a b c

Figs. 8 a,b,c : Scottsdale Museum of Contemporary Art, Carpenter , Arizona, 2014. Source: https://en.wikipedia.org

This first variation of transparency, which "sees glass as a privileged material", is closely linked to the notion of material coherence.

In reality, alternatives in terms of material properties allow today multiple combinations of the materials, allowing the creation of products "tailor-made", with solutions with high level of performance. To achieve transparency, it is often desirable to have characteristics such as ductility, lightness or translucency.

On this side, plastics such as coatings, typical of tense structures, have made their way and conquer an important place in the experimentation on the envelope. They come from advanced technology sectors and are then “transferred” to architecture, often after simplification.

The energy report is the second way in which we can analyze certain lines of evolution. In this sense, innovation for transparency seems to be evolving along two distinct but interdependent axes: on the one hand, experimentation in search of the best relationship between the light component and infrared solar radiation.

On the first side, glass producers have approached a ratio that is about 2% (that is to say, percent of the visible part passes fifty percent of the heat), which is considered the almost physical limit of this material, not wanting to overly penalize the light transmission. Some examples are solar-controlled insulating glazing with selective thermal insulation.

On the other hand, research is being carried out on the double skins, from external sun protection systems, to intercept the incident radiation before it affects the envelope, to the dynamic double envelopes that manage the heat by exploiting the ventilation through an air chamber. The types are numerous and vary depending on the ventilation mode of the cavity, the size of the cavity, the positioning of the screens. Many of the expected benefits depend strictly on the climate and urban context in which a double envelope is achieved.

So far, while the argument about transparency has been made in relation to the "empty" part, it is also important to study the relationship with the solid part, that is, with the structure that supports the transparent part. In this area, there is often the exposure of transparency through the exaltation of the technique, made possible by the advances in production techniques that now allow the customization of products, by mass customization, i.e. tailor-made production. In this context, the industry gains very high degrees of freedom because of the ability to vary products through digital ordering machines, without having a serious impact on the final costs of the product. Mass customization is well suited to systems and materials related to industrial production systems such as metals.

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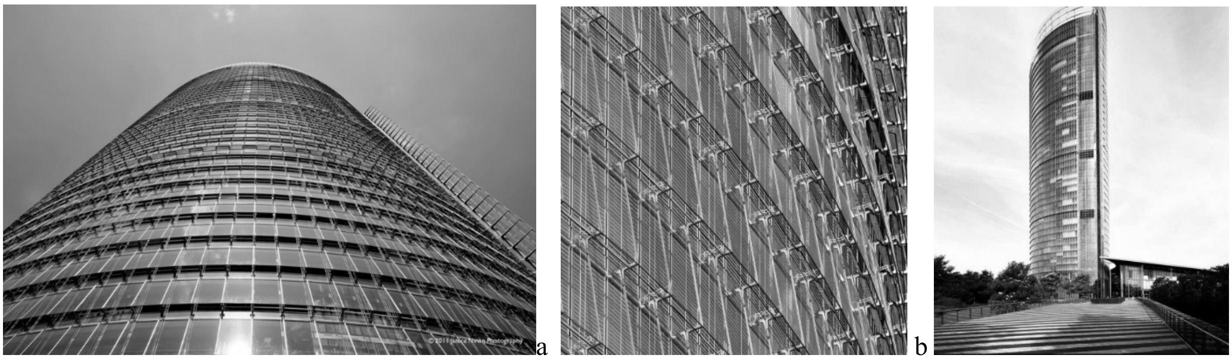
An interesting and instructive case is the *Murphy and Jahn* Tower in Bonn, whose front posts are made of steel. In this project, which consists of a double envelope with a "dimmed" facade, the amounts of the south facade were made with the extrusion of steel profiles.

In this case, innovation in production techniques achieves a level of transparency by introducing consolidated technology, such as extrusion, for steel; unlike aluminum, allowing a better relation between resistance and surface. On another front, it's interesting to note that a decisive boost to transparency was given by the precision of the scientific-mathematical calculation applied to the dimensioning of buildings, which reduced this matter to the fullness mentioned above, strings,

buffered with glass panels optimized the construction of a sail, curved, light and transparent. It is a question of considering transparency in relation to lightness, an interpretative category that is often associated with it.

The image of transparency

An architectural work can be considered from different points of view, including the one assessing its aesthetic dimension. From this point of view, the transparent envelope of contemporary buildings takes on a hermeneutic value, that is, an interpretation of reality that brings out the deepest essence.



a b c

Figs. 9 a,b,c : Post Tower, Werner Gensmantel, Murphy et Jahn , Bonn Source: http://gensmantel.net

The forms of the collective imagination of the last century are more and more influenced by the representation of reality.

reproduced through media that project images on two-dimensional screens. The form of architecture after the last decades of the 20th century seems to feel this influence, thus bringing the transparency of the glass envelopes to assume new meanings in relation to its current appearance.


a

b

c

Figs.10 a,b,c:. L’Hotel Industriel 1990, Berlier ,Paris. Source: https://audience.cerma.archi.fr

Contemporary glass envelopes, now far from the formal purity of rationalist orthodoxy, which represented “sincerity” through the metaphor of transparency, use glass to describe the complexity of the present.

The current curtain walls most often express enigmativity; the transparency of the past, which allowed us to perceive the contents of the building, has been replaced by the reflection of the outside and is only rarely a conscious expression of the historical ways of architecture.

The tendency, moreover, to choose "light" envelope systems made with the increasingly widespread use of glass surfaces (the term "light" must be understood as the visual and non-physical lightness of systems made of metal and glass) is justified by the levels of performance provided by these components.

In fact, it is now possible to build buildings from "dynamic" performance. The technological “skin” can be attributed the ability to adapt to external variations to take advantage of thermal variations and reach the maximum in terms of exploitation of natural energies.

Another feature of transparent systems for the envelope is the nature of the materials and processes used to make them. In fact, they belong to the field of industrial production and their use in construction includes methods of dry assembly of components and the possibility of more control.

Dry mounting of systems also makes it easier to insert new components during the building's useful life to update performance and allow for easy maintenance. At the time of disposal (disassembly), it allows the recovery of the components up to the single material element; this allows easy recycling of the whole. The envelope can thus be designed and constructed according to a logic consistent with environmental needs and the building can become an instrument for energy production and conservation.

Dominique Perrault, designed (Figs.10) the Berlier industrial hotel in Paris in 1990 with the aim of "giving a new architectural image to the industry". The facades of the Hotel Industriale Berlier are all identical composed of a transparent wall-curtain from top to bottom equipped with double-glazing, slightly tinted and lined; a transparent building where the glass shows the cables and the various technical pipes, as well as the industrial activities that take place inside. Inside, a structure of metal sunshades is constructed above and below which also pass the heating and air conditioning ducts with pulsed air. The sunshades consist of horizontal 0.4 meter wide bands made of perforated galvanized sheet and placed every 0.3 meter.

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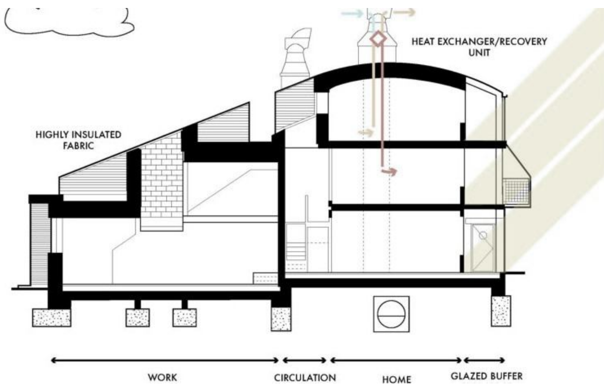
Transparency performance and architectural design process
Methodological Approach

In order to properly respond to the complexity that distinguishes the construction of the transparent envelope system and to obtain the benefits arising from the exploitation of natural resources, it is necessary to implement the method of design and control of the construction so that the complex envelope of the building functions as a homogeneous whole. This method must prefigure all the characteristics that the system will have to provide. This can only be done by specifying functional expectations in terms of performance and organizing the design process according to verifiable procedures, the following list provides a summary.

- identification of objectives, deadlines and verification with the client;
- formulation of performance-type documentation to which the choices of the systems used should be referred;
- defining and assigning responsibilities to the various actors in the process;
- study of the physical and environmental characteristics of the site in bioclimatic terms;
- structuring the design-production process in a workplan with feedback control;
- identification and integration of management methods in all phases of the project, starting from the initial adjustment.
- update sequences: design / project / production control / realization / work /assembly / management, in relation to the needs of specific objectives.

Project planning must also be integrated by a monitoring and information program that must involve all the actors involved in the process from the initial planning phases.


a



b

Figs.11 a,b: "BedZed" Bill Dunster, Great Britain: diagram of the internal flows of one of the buildings of the site. Source: https://hidden-london.com

The conclusions of this brief excursus can be summarized by considering that the current phase of development of systems, marked by a continuous evolution of techniques and equipment, must be accompanied by a logic that goes beyond the use of the surface of the glass with the only criterion of transparency used in aesthetic / symbolic terms but, returning to the origins, in ethical terms of sincerity that becomes, in practice, coherence and respect for the environment. The vertical and horizontal elements anchored to the structure of the building, the light facades - or

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curtain facades - have many advantages: lightness, aesthetics, transparency, functionality, durability, comfort, performance, implementation by prefabrication reducing construction time, use of various finished materials, etc. In addition, they can be used for all types of buildings (housing, offices, etc.).

The contribution of new technologies to transparency

The double skin facade

The double façade has been defined as "a simple traditional facade lined inside or outside by a second façade essentially glazed. Each of these facades is commonly called skin" (Renckens, 1996) Various terms are used to describe these façades: 'active facade', 'passive facade', 'double skin facade', 'climatic facade'.

The dual-skin facade is designed to regulate the heat of the building. It protects him from weather constraints. Compared to direct sunlight, it avoids summer overheating and limits the use of air conditioning. It also allows to bring a pleasant temperature and humidity of the air. This double facade can be likened to a protective screen, an envelope around the building.
In their research for the British Department of Transport and Environment Michael Wigginton and Battel McCarthy describe the role of the double skin facade in energy consumption. The study shows that 'double-skinned buildings are able to reduce energy consumption by 65% and C02 emissions by 50% compared to single skin' (Wigginton and McCarthy, 2000).

a b

Figs 12 a,b: The building of 'Düsseldorf city gate', Germany, 1999 Architect: Petzinka, exterior view (a), cavity view (b) (Source :H.Poirazis 2004)

The building 'Düsseldorf city gate' in Germany (Fig.12), for example, is a transparent building with a double façade on the south facing façade. The nature of the two skins is made of glass. The double facade allows Assi to increase the acoustic insulation.The building marks for its first year of commissioning a significant reduction in energy consumption (Poirazis, 2004).

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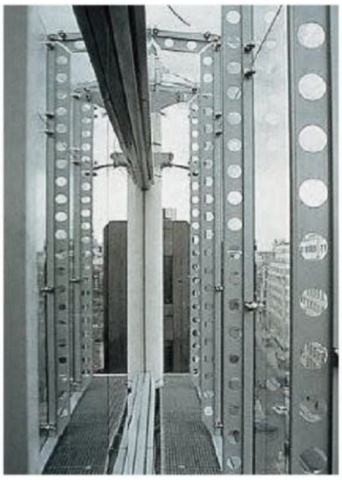
The Helicon Pavement building in London (Fig.13), built in 2001, is another example of a transparent building with a double glass skin on the south side. It helps to reduce heating consumption in the building. In the cold season, the temperature of the interior glazing will be higher, allowing the occupants to avoid feeling the cold surface of the glazing and to dispense with the installation of heating bodies.


a


b

Figs.13 a,b: Le 'Helicon' Finsbury Pavement, London 2001(UK) architecte Sheppard Robson, vue sur l'extérieur (a), vue de la cavité (b). Source: V. Yellamraju, 2004)

The transparent component: typologies of innovative elements

The glass disappears?

By nature invisible, the glass itself is struck by the tendency to erase. How far can the physical reduction of thin glass walls go? What is the minimum thickness of an envelope? How thin can you make the glass and reduce its refractive index before it disappears? Plastic films seem to be about to dethrone the glass and leave us in this (almost) dematerialized state that we have always dreamed of, it seems. Plastic films and membrane cushions are already widely used in greenhouses, where a ratio between light and heat penetration is permitted (and desired), less demanding than in residential and office buildings. Products made with special gas-filled films will no doubt soon take over some functions performed today by glass products. After erasing the walls, the glass itself will erase.

Chromogenic glasses (photochromic, thermochromic, electro chromic, liquid crystals) (Fig. 14).

Their main characteristic is the ability to modify the optical properties (light and solar transmission) following the variation (always reversible) of an electric field (liquid and electrochromic crystals), the incident luminous intensity (photochromic crystals) or the temperature (thermochromic crystals). Photochromic and thermochromic lenses are therefore self-adjusting devices according to the surrounding conditions, whereas electrochromic and liquid crystal lenses, activated electrically, require adjustment by the user.

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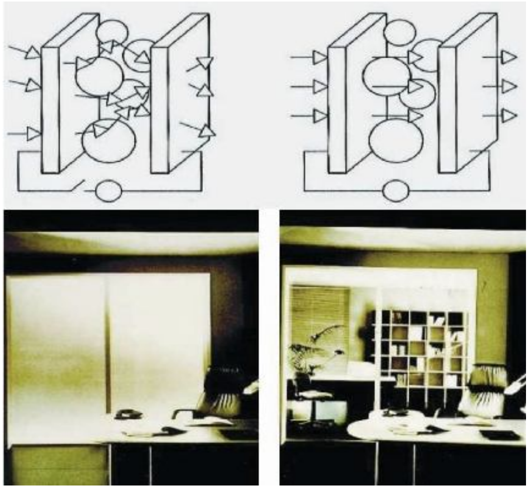

Fig. 14. Application of liquid crystal glasses: under active electric field conditions, the view to the outside is altered.

Holographic optical element (HOE) films (Fig.15).

They are passive optical components, integrated into the glass sheets, capable of diffracting the sunrays transmitted in a predetermined direction, defined from the characteristic solar paths of the zone considered. Behavior in the face of incident solar radiation is selective: it is diffracted differently depending on the wavelength or the angle at which it affects the film. Spectral selectivity networks have the characteristic of reflecting infrared radiation (in a way completely similar to reflective glass), and at the same time transmitting most of the light radiation, thus determining high levels of natural lighting and reduced thermal loads inside the building. Angular selectivity networks, on the other hand, are able to vary the amount of solar, hourly or seasonal gains, reducing the solar transmission in hot season (minimum incidence angles) and keeping it high in cold season (maximum incidence angles).

Fig. 15. Glass transparent envelope with holographic film

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Prismatic panels (Fig.16).

Made of a thin grid of transparent prisms made of acrylic material with a saw-tooth finish, they are made with different inclinations of the teeth, which correspond to different angles of refraction of the incident light and are often partially covered with a reflective silver film, with a very high light reflection. The action is two-fold: protection of direct sunlight, reflected outwards, and transparency to the diffused natural light from the celestial vault (especially zenithal zones), refracted and redirected towards the ceiling and thus, for secondary reflection, towards the part of the room farthest from the windows The prismatic panels, while being transparent, distort the image seen through.

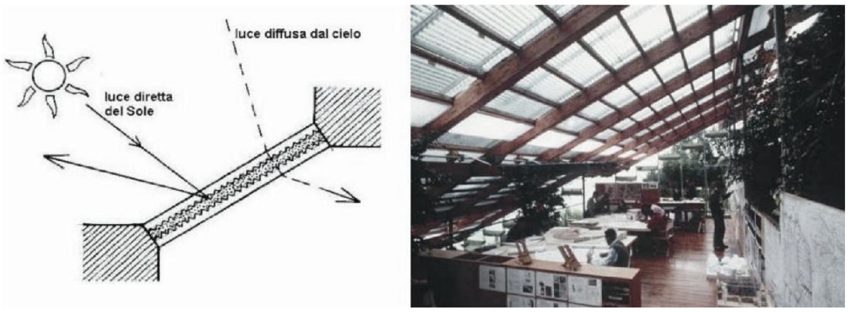

Fig. 16. Working principle and applications of prismatic panels (Renzo Piano workshop Building in Genoa-Italy).

Laser cut panels (Fig.17).

It is a natural light redirection system consisting of thin panels of transparent acrylic material in which incisions are made with a laser beam. The efficiency of the system to transmit (by refraction) sunlight is very high. If the panels are mounted vertically (with horizontal incisions), the incident sun light with angles greater than 30° is almost entirely reflected outward, while below 20° it is refracted to the ceiling and thus to the part of the environment. further away from the windows. This helps to reduce the amount of solar radiation transmitted in the environment during summer, while maximizing the amount transmitted in winter.

Even for panels mounted horizontally (in the form of horizontal blades or Venetian blinds), the fraction of sunlight reflected outward is high. They allow the view outward (distortion is minimal), but their optimal position is above the eye level to avoid possible reflections.

Fig. 17. Application of laser cut panels to South State School environments in Brisbane - Australia

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Conclusion

The search for innovative technologies for transparency is increasingly leading to a dematerialization of construction, which, as we have seen in some of the examples cited, is not always and not only linked to the evolution of glass, but is indeed very often determined by innovation in the increasingly sophisticated technical assembly systems that condition the achievement of transparency. This tendency to dematerialization consists in the progressive reduction of the intensity of the use of energy and materials in the production of a system or component. we are talking about structural lightening, slab thinning, replacing heavy materials with light alloys and composites.

In conclusion, in contemporary architecture, technology tends to be expressed in the measured display of structural forces, in the lightness, variety and sophistication of performance obtained both on an ancient material such as glass and on new materials (Nardi, 2003).

The problem that we have today, in addressing the question of transparency in architecture, I believe, is to be linked to what it really represented in the development of architectural forms, that is to say, as a tremendous stimulus to the experimentation and consequent formation of new attitudes of design.

We need to look for techniques that can optimize the material/transparency/energy relationship in new ways of designing and using space. Without this premise, the real reason for even the most innovative transparency research is lost.

References

AGHEMO, C.; PELLEGRINO, A. e LO VERSO, V. 2002. *Scale models under an artificial sky as tool for daylighting design: possible applications*. In: Atti Della Cie Light & Lighting 2002 International.

AGULHON, M. et al. 1998. *La ville de l'âge industrielle; le cycle haussmannien*, Paris.

BENJAMIN, W. 2000. *Œuvres III*. Paris, Éditions Gallimard.

BOUDON, P.2003. *Sur l'espace architectural, Marseille*, Éditions Paranthèses.

CAMPIOLI, A. 1998, *Oltre il vetro*. In Transparenti leggerezze, M. Perriccioli (ed.), Rinascita, Ascoli Piceno.

COHEN, J.-L. 2012. *L'architecture au futur depuis 1889*. Phaidon, Paris.

CONAN, M. 1990. *Concevoir un projet d'architecture*. L'Harmattan, Paris.

CORINALDESI. V. and MORICONI, G. 2004. *Durable fiber reinforced self-compacting concrete*.
Cement and Concrete Research 34(2): p.249-254.

DE FÉLICE, P. 2001. *L'effet de serre:Un changement climatique annoncé*. L'Harmttan, Paris.

DEREK, P. *Daylighting Natural Light in Architecture*. Architectural Press First published 2004.

FRAMPTON, K. 2006. *L'architecture moderne. Une histoire critique.* Thames and Hudson, Paris.

GIEDION, S. 1981. *The Eternal Present: The Beginnings of Architecture*. Princeton, Princeton University Press.

GIEDION, S. 2004. *Espace, temps, architecture*. Éditions Denoël, Paris.

GROPIUS, W. 1985. *Architecture et société*. Éditions du Linteau, Paris.

HAMMOND G. and CRAIG J. 2008. *Embodied energy and carbon in construction materials*, in "Energy", University of Bath, p.87-98.

KHATIB J.M. 2009. *Sustainability of Construction Materials*. Elsevier, London.

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Esempi di Architettura
ISSN 2035-7982

LE CORBUSIER. 1926. *« Les cinq points d'une nouvelle architecture »*. Dans CONRADS, Ulrich (1996). Programmes et manifestes de l'architecture du XXe siècle, Paris: Éditions de la Villette.
LIEBARD A. & DE HERDE A. 2005. *Traité d'architecture et d'urbanisme bioclimatique*. Ed: Obser'ER. Paris.
LO VERSO, V.R.M. 2002. *La simulazione dell'illuminazione naturale mediante cieli artificiali*. Genova. Tesi di Dottorato. Facoltà di Ingegneria, Università degli studi di Genova, 236 p. March 2007, Pages 249-257.
MAZRIA, E. 1981. *Le guide de l'énergie solaire passive*. Parenthèses, Paris.
MIES VAN DER ROHE, L. 1923. *«Thèse de travail»*. Dans CONRADS, Ulrich (1996). Programmes et manifestes de l'architecture du XXe siècle, Paris : Éditions de la Villette.
PARMENTIER, A. 2012. *Atténuation des îlots de chaleur en milieu urbain*. Édité par Académiques, Paris.
PETEK, A.G., MARYMAN, H., OSTERTAG, C. *A life-cycle approach to environmental, mechanical, and durability properties of "green"concrete mixes with rice husk ash*. Department of Civil and Environmental Engineering, University of California, Berkeley, CA 94720, USA.
RENCKENS, J. 1996. *Gevels & Architectuur façades in glas en aluminium*. TU Delft
SARTORI, I. and HESTNES, A. 2007. *Energy use in the life cycle of conventional and low-energy*, Energy and Buildings, Volume 39, Issue 3, March, 249-257.
SATTARY, S. and THORPE, D. 2012. *Optimizing embodied energy of building construction through bioclimatic principles.* In: 28th Annual Association of Researchers in Construction Management Conference (ARCOM 2012), 3-5 Sep 2012, Edinburgh, United Kingdom.
SCHEERBART, P. 2013. *L'architecture de verre*, Éditions Circé, Strasbourg.
SCHEERBART, P. and PAYOT, D. 1995. *L'architecture de verre ; précédé de : La société « barbare » de Paul Scheerbart par Daniel Payot*. 1ère éd. 1914. Strasbourg: Circé.
SCHITTICH, C. 2003. *Il vetro come concetto.* In "Nuova Finestra" 5/2003, Reed Business Information, Milano.
ZEVI, B. 1981. *Le langage moderne de l'architecture*. Dunod., Coll. Espace & architecture, Paris.
ZIMMERMAN, C. 2014. *Photographic Architecture in the Twentieh Century*, Minneapolis: University of Minnesota Press.
ZUCKER, P. 1959. *Town and Square: From the Agora to the Village Green*, Columbia University Press, New York.
ZIMMERMAN,C. 2006.*Mies van der Rohe :1886-1969, la structure de l'espace*. Taschen, Paris.