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North, South, East and West: The Environmental Approach to Transparent Design

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Architecture has always been interested in transparency but this characteristic has strong implications for energy performance. For many years architecture has neglected this factor but today, in a time when society has developed an awareness of the carbon footprint, architecture must restructure its approach and process. Transparency is still possible but its implications must be taken into consideration from the very beginning of the process: when façades are designed with respect solar exposure and the advantages of internal natural ventilation, transparency becomes sustainable in terms of energy balance in addition to contributing to architectural expression.

Keywords: Glass, Environment, Natural Ventilation, Integrated Design

1. Introductions

The German expressionist avant-garde focused their attention on transparency as a political issue believing that a transparent architecture permeated by light could also have social implications. On the other hand, the expressionist architects showed how transparency is related to technology, and, in particular, the Glass Pavillion of Bruno Taut highlights the limits of the technology of the time.

In the Eighties and in the early Nineties the High-Tech movement, thanks to its strong interest and advances in technology, was able to dematerialise the façade and remove the usual frames by substituting them with glass fins or wind cable trusses. The envelopes of iconic buildings of that period, the Willis Faber and Dumas of Norman Foster, the Project 117 of Future Systems, are sealed enclosures, rather than permeable skins, thus requiring the use of mechanical plants to control the internal conditions.

In the Eighties, the innovative development of double facades was a first attempt to reduce air-conditioning and has opened a new discourse. In parallel, transparent envelopes are not limited to prestigious buildings but have begun to characterise many typologies of common building.

In this continuous development toward the immaterial building, we are now facing a new generation of buildings where transparency is sustainable thanks to a thorough approach which relates the facade to the external environment and, in particular, to sun exposure.

2. New strategies in the design of transparent facade

RFR has designed transparent buildings from the very beginning of its activity starting with the Bioclimatic Green Houses of La Villette. Continuing from that experience, each successive project is a step in a new direction which contributes to an ongoing evolution. The projects developed in the last ten years also show some new trends. They go beyond the usual structural use of glass and the dematerialisation of the surface. They go beyond the maximalisation of transparency in pursuit of the realisation of facades which are not an event in themselves, but contribute to the global functioning of the building. The project here presented traces this recent evolution, particularly with reference to environmental and energy considerations which are today becoming a primary design parameter in our society which has a growing consciousness of the importance of reducing the carbon footprint.

2.1. Avignon TGV Station

The Avignon TGV Station (arch. AREP/Duthilleul, 1998-2001) has been designed with reference to a particular Avignon site and its environment which is characterised by a strong sun in the summer and the Mistral that blows from the Rhone Valley. One result of this is that the building is 450 meters long, as is the train itself, in order to protect the passengers from the wind while waiting the train. The south facade is opaque, in order to prevent direct sunlight from penetrating the space, and a transparent north facade allows direct views of the sky over the trains while the passengers are waiting.

A CFD study proved that the shape of the building was effective in sheltering the train platform. A simulation of the slow air movement proved that the air flow was consistent with the need to ventilate the inner space for extracting heat. Since the building is slightly curved and the North facade is sloping, an illumination study was developed to be sure that the inner space was efficiently protected and that the glass frit was effective in shading the critical areas.

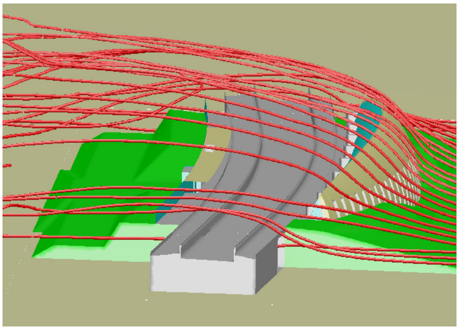



Figure 1: Interior space of the Avignon TGV Station. - Figure 2: Wind analysis.

With respect to the glazing technology, for reasons of geometry it was not possible to decompose the surface using only flat glass. Instead of using curved glass, the skin is composed of cold bent (elastically bent) double glazing units. The sealant joint of the double glazing unit was proven to be sensitive to the combination of the bending stress and stress due to the variation in temperature and volume of the chamber. To avoid over-stress the units were specifically developed as “pressure equalised double glazing units,” one of the first application of this new technology.

2.2. Nile House and Danube House

A further step ahead is represented by the design of the atriums of Nile House, Danube House (2000-2005) and Amazon Court in Prague (arch. Kohn Pedersen Fox, 2005-2009). The first two buildings are characterised by South-facing facades and a transparent roof. The atrium acts as buffer zone: it is neither heated nor air-conditioned and its function is to reduce the heat exchanges between the office (facing the atriums) and the exterior spaces with a volume of an intermediate temperature. The atrium is naturally ventilated, and, during the summer months, openings at the perimeter of the roof extract hot air. Additional fans augment the natural ventilation at peak time.

Starting from this principle, other parameters came into play such as functional organisation, structure and shading strategy. The atrium assures the circulation through the building. The stairs and lift are on the south façade, and the walkway along the facade gives access to the wings of the building, while providing a view over the historical city centre. From the technical point of view, these walkways act as horizontal wind trusses and they also have the additional function of brise-soleil thanks to their horizontal depth.

The same concept applies to the roof structure. Efficient, slender, but high beams shade the internal façade, reducing the glare in the offices but allowing an unobstructed view of the sky from the bottom of the atrium.

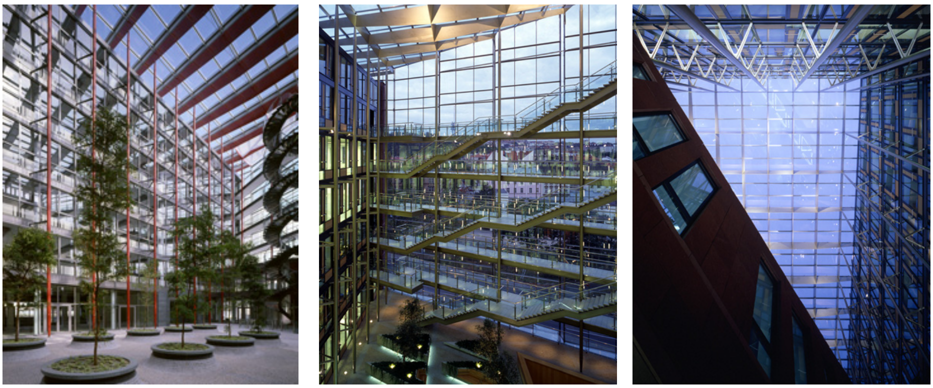


Figure 3: Nile House. - Figure 3 and 4: Danube House.

This project shows how an integrated design which deals simultaneously with the several design parameters can lead to new solutions coherent with the energy-saving considerations while creating a pleasant public space.

2.3. Elm park Development

More sophisticated is the design of the double facades of the Elm Park Development in Dublin (arch. Bucholz Mc Evoy, 2001-2008). Contrary to many standard cases of the projects of the Nineties, the double facade here is not an added element to the building, it is conceived in conjunction with the opposite façade, and its role goes beyond the function of extracting hot air since it also activates cross-ventilation. Moreover, the cross-ventilation has a daytime and a night-time regime: during the day the double facade sucks away hot air, while, during the night, the fresh air flush cools the ceiling before being extracted by the facade.

In order to take maximum advantage of the thermal mass, the concrete slabs are exposed without any false ceiling. Such a solution maximises the heat exchange between the air and the slab, reducing the slab temperature so that during the day its lowered temperature compensates the increase in temperature due to the working activity.

Completely new is the fact that the efficacy of the double facade is reinforced by the extraction effect created by the wind acting on the façade's openings at the roof level. This strategy has been developed on the basis of Dublin weather analysis and is made possible by the coincidence of hot days with windy days. CFD was used in order to prove that the roof openings are in negative pressure areas.

Moreover, given that the building is composed of five parallel blocks, there was a risk of a masking effect of one building on the adjacent one. CFD analysis was used to analyse the interaction between the buildings and has demonstrated that the air flow was not compromised by the sequence of blocks.

The architectural logic merges with the technical considerations, and both the outer aspect and the inner spaces are the expression of this thorough design process. Last but not least is the integration with the surrounding landscape, thanks to the use of wood structures that smooth the transition between the natural and the artificial [1].

Figure 5,6 and 7: Double façade of the Elm Park Development..

2.4. Strasbourg

The Strasbourg TGV Station extension (arch. AREP/Duthilleul, 2003-2008) is the consequent evolution of the Avignon TGV station, but, in this case, the facade is facing South, instead of North, and the inner space is still naturally ventilated. This radical change is the result of many factors coming together, such as the new glasses now available, improved calculation possibilities, and, most importantly, a new technical and architectural consciousness that reflect the know-how accumulated in these last years.

The zone of overlap between the new shell and the roof of the existing building is used for extracting hot air, while the main entrance and the two side doors are used as air intake. Moreover, as with a “puit canadien”, the enclosed hall is directly connected to underground tramway station so that the incoming air is at lower temperature, thus reinforcing the cooling effect due to the natural ventilation.

The glass is printed with a variable frit pattern up to 75% coverage on the upper parts of the shell in order to reduce the solar gain within the space. A Southwall XIR film reflects part of the non visible energy spectrum and a low-e coating on the interior side in order to minimise thermal radiations in the inner space

Figure 8 and 9: Strasbourg TGV Station.

Water nebulisation, at ground level, helps to control the temperature by taking advantage of the evaporation effect, which retrieves energy from the air. In addition, a series fans move the air, increasing the feeling of comfort which depends not only on the absolute temperature but on the psychological aspects of perception and on the exchange of heat between the air and the skin of occupants of the space.

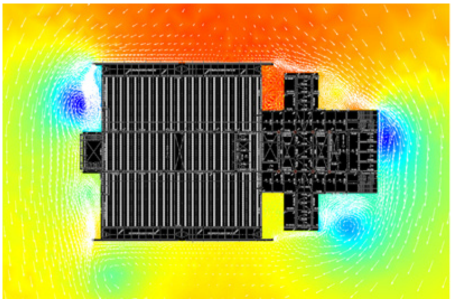
Further, the curved glass panels are not hot bent but cold bent using the innovative technique of cold bending the glass on a jig before its lamination in the autoclave [2 and 3].

This building shows that the dream of total transparency is now possible thanks to a wise design that merge together all the technical, environmental and architectural variables.

2.5. Banca Intesa-San Paolo Tower

The visual aspect of the Renzo Piano San Paolo-Intesa Tower (Turin, 2007-2012) is marked by two double facades facing West and East. The external skin is a transparent screen composed by an interrupted series of louvers which extends well above the roof of the tower. In spite of its appearance, this double facade has a specific function and interacts with the building in a new way, addressing the particular requirements of the bank's activities, which prohibit having both transversal ventilation and night cooling, as is the case with Elm Park.

The double facades, during the winter, act as a buffer zone mitigating the energy loss. During the summer, openings located every four floors, evacuate the heat accumulated in the chamber. The most relevant function is at night time, and, in this case, the strategy is to circulate the air inside the perforated slab instead flashing it. Consequently, the louvers, corresponding to every floor, are opened to let the air enter into the slab and go through the entire width of the building to be extracted on the opposite facade. The air cools the concrete slab and activates their thermal mass by reducing the temperature of the internal space during the day, as in the case of Elm Park. The air is drawn by the difference of pressure between the West and East façade, generated by the wind acting on the building.



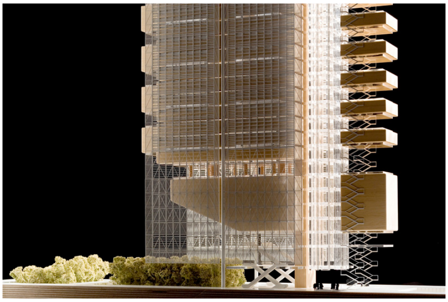


Figure 10: Wind pressure chart. - Figure 11: Study Model

The pressure differentials have been validated thanks, firstly, to CFD simulation as well as to a vast regime of wind tunnel tests using various physical models (a 1:200 model for the pressure acting on the façade and a 1:50 model used for determining the pressure inside the double facade cavity). With respect to the design of the slab, the loss of pressure within the duct was determined using a 1:1 mock-up test.

These data have been post-processed on the basis of the meteorological chart in order to evaluate the behaviour on the overall year. The openings of the facade and those of the slabs are controlled by computer system connected to several sensors used for collecting the primary environmental data, such as internal and external temperatures, wind speed and direction, etc.

The South facade corresponds to a different logic. The external stairs are enveloped by a glass screen composed of louvers, in order to transform the vertical space into a winter garden. Every landing becomes a pleasant space to rest in the winter, when it is protected by the wind, and in the summer, when the breeze blows through the open louvers.

The exterior aspect of the tower is founded on an architectural concept, but the exposure of the facades drives the expression of the building and illustrates its relationship with the environment.

3. Conclusion

The crystal skyscrapers of the economic boom of the 80's, with their four identical elevations, have mutated into organic buildings. The lessons learned in these years dictate that each elevation is now specifically designed as a transparent skin perfectly adapted to the sun's orientation and well integrated into the environmental design of the entire building. The scientific approach, the developemment of new "ad hoc" technical solutions, such the cooling slab of the Intesa San Paolo Tower, and the new design strategies, are the tools for pursuing more and more efficient and sustainable buildings.

These technical advances, the new know-how, and a burgeoning design culture which is sensitive to the environment and energy use, have nowadays reversed the perception of glass facades. In the eighteenth century, a glass envelope was nothing more than a greenhouse to cultivate tropical plants in the hostile English climate. Today, a south-oriented, transparent, and naturally ventilated envelope creates a comfortable environment for human activities even during the hottest summer days.

4. Acknowledgements

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