Viewing Sustainable Buildings through Integrative Façade Engineering

By Andrew Xiao Junzhao

For decades, driven by consumer's demand, designers have been infatuated with seamless transparent building envelope. Since façade systems used in the building envelope induce a significant impact on energy efficiency, the occupants' interaction with the surrounding environment, and the indoor environmental quality performance of a building, it is increasingly and inevitably vital to examine the performance of the building envelope with regards to selection of materials, technologies, detailing and installation. Each of these intrinsic elements shall possess characteristics congruent to pragmatic maintenance, economical operational cost and satisfactory occupants' comfort.


Andrew Xiao Junzhao, Principal ESD Consultant of Meinhardt Group

Whilst it is notable that the best glazing available in the market will not match the thermal conductivity value of an insulated opaque wall, and general consensus that heavily glazed buildings consume more energy than buildings with moderate glazing-to-wall ratio, there is still a demand for transparent facades for a variety of reasons such as day lighting, connection to the outdoors, corporate image, thinner envelope for more lettable gross floor area. This has led to rigorous and controversial debates where some may argue that the use of sun-shading devices is not a resolution for an unavoidable sustainability catastrophe. Instead, it is merely mitigating the problem as a result of overusing transparent façade, and substantially increase the embodied energy of the envelope. Perhaps instead of employing sun-shades, designers should compromise on the physical aesthetics by optimizing the window to wall ratio, and select materials with reduced embodied energy. But will consumers be receptive towards architectural designs adopted in the earlier centuries where bulky building blocks are commonly used, and windows are tiny and recessed? Instead of progression, should the industry adopt retrospective design concepts? With the advent of new technologies, it is incumbent on the designers to evolve continuously, challenge dogma and revolutionise the built environment with readily available materials and software that may facilitate or enhance the design process.

At the commencement of the initial concept design stage, building physics modeling is of great relevance to quantify the building's ecological performance through series of iterative analysis. The results assist designers to minimize environmental impact over the life cycle of the building. Given that, as a crude approximation, the first cost of an air-conditioning system is approximately USD 1,000 per cooling tonnage. Every additional cooling tonnage as a result of an inefficient performing façade will attribute to larger air-conditioning system with increased capital investment, larger plant room leading to lower rentable area, and increased operation and maintenance cost.

The objective of sun path analysis, solar incidence analysis, and daylight analysis is to investigate the amount of heat and daylight entering the building's interior air-conditioned spaces. Extensive daylight penetration will lead to undesirable glares, heat and thermal discomfort. Similarly, extensive whole building energy modeling can be used to accurately predict the energy consumption based on proposed design specifications, be it façade specification, lighting and receptacle loads, occupancy density and et cetera. Through an iterative process, this tool can be used to determine the optimal combination of façade design, HVAC systems and lighting strategy for any particular building.

With the results of these studies, we begin to investigate the available technologies for transparent building façade. Some advanced building envelope systems and materials that are increasingly being considered for improved performance include:

- Double-skin façade,
- Low-emissivity double or triple glaze system,
- "Cool" paints and coatings,
- Smart glazing and responsive systems, and
- Phase change materials (PCM).

Even tough double-skin façade system have increasingly been thought, in the last two decades, to be an expression of contemporary design and advance ecological façade concept in temperate region, it might not necessary be applicable in hot climatic regions such as Middle East. An article authored by Dr. Karl Gertis affirmed that the air temperature within the cavity would approach 40-50^{0}C with an ambient temperature of 30^{0}C. Gertis further explained that substantial cooling could not be achieved unless the air change rate within the cavity approached 20. This would be hypothetically impossible with natural ventilation and reasonable ventilation air gaps. With increased opening thought to promote air movement within the cavity, the acoustical performance would compromise.
At Meinhardt Façade Technology, a computational fluid dynamic (CFD) analysis on Abu Dhabi National Oil Company (ADNOC) HQ double skin façade revealed similar results. With an external temperature of 45^{0}C, the cavity temperature approached high of 81^{0}C at critical air flow of 0.2 m/s. Our study confirmed that low resistance air flow is critical to prevent the built-up of greenhouse effect and the presumption of stack ventilation through cavity was inadequate and ineffective.

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Automatic sun shading devices, either coated with heat absorbing phase change materials or even metal surfaces with higher surface reflectance index to minimise heat exposure upon the second glazing skin can be installed within the cavity. Perforated metal catwalks may also be installed for maintenance accessibility and serve as horizontal shading devices, further improving the shading coefficient of the facades.

Examples of smart and responsive glazing systems are photochromic and electrochromic glass. The former system automatically adjusts the opacity to respond to ambient lighting condition, thus optimizing the use of artificial lighting indoor and eliminate glare discomfort on occupants.
The latter system consists of liquid crystal film installed between glazing panes. Variation to the electrical field influences the crystals to align or misalign to provide clear or frosted vision.

With comprehension of the respective benefits and trade-offs, the onus is on the designers and clients to analyze the life-cycle cost and environmental impact prior to implementation. A simple set of good design practices includes positioning staircase or mechanical rooms at the east and west façades, sensibly reducing window-to-wall ratio for east and west facades, and introducing shading devices for south façades for projects in the northern hemisphere and vice versa, to reduce peak cooling load. Strategies are not universal but instead they are project specific due to geographical and climatic difference, often requiring detailed analysis to be iterated. Hence it is imperative for clients to understand the importance of building physics modeling and the requirement of high performance façade systems as the first initiative towards the creation of an ecological sustainable building. ■

(The Author, Andrew Xiao Junzhao is the Principal ESD Consultant of Meinhardt Group)