HOT CLIMATE DOUBLE FAÇADES:

Avoiding Solar Gain

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A FOCUS ON SOLAR AVOIDANCE

The initial seminal publication on the topic by Eberhard Oesterle in 2001, "Double-Skin Façades: Integrated Planning"[1] has been followed by hundreds of independent research projects and papers that attempt to establish firm cases either "for" or "against" double façade systems. The results seem not to have been gathered into a definitive or conclusive text, meaning that "the jury is still out". In the 10+ years that have passed following my initial research into double façade systems, "Understanding the General Principles of the Double Skin Façade System", given at the National Building Envelope Council (of Canada) Conference in 2003, the construction of double façade envelope systems has continued to increase and *persist* in spite of the lack of conclusive hard data to prove the energy benefits. This may be due in part to an architectural infatuation with tectonics and appearance, a desire to believe in the technological/environmental benefits of the system and an appreciation of many practical benefits that may not be readily quantifiable but are nonetheless easily understood.

Early double façade buildings, such as Occidental Chemical in Niagara Falls, NY, opposite, tended to be constructed in temperate climates that required solutions that could balance the environmental issues presented by heating *and* cooling. Double façades are now being applied to a wider range of climates that present greater extremes in heating and cooling conditions as well as humidity. Where early double façade applications tended to use a very comprehensive approach to mitigating the effects of these opposed climate issues on the building, applications in extreme climates seem to have skewed the solutions to address the most pressing issues. In the case of hot climates this will be seen to be solar avoidance as this climate type is absolutely dominated by this condition. This focus on solar avoidance is able to suggest very clear, more easily quantified, environmental benefits to justify the use of a double façade solution.

OVERCOMING CONTINUING OBSTACLES

Although there continue to be many obstacles to the implementation of double façades in buildings, the ability of a hot climate scenario allows for a focused approach that is able to better address these issues and make very effective use of the double façade for the primary concern of solar avoidance through shading.

Hard Data

There is little published data pertaining to the ongoing operating energy benefits of double façade construction. Even in cases where energy data may be published, much of this provides a generalized or overall energy use value and fails to provide specific credit for the system or systems that were responsible for improving performance. As many double façade buildings also make use of numerous other aggressive methods to achieve reductions in energy use intensity such as geothermal systems, daylighting with sensors, and efficient mechanical and electrical systems, the particular benefits of a double façade system may be difficult to extract. There are synergistic benefits, for instance, of the use of shading systems within the double façade cavity that are not easily segregated if the opposite benefits of passive solar gains are also being sought. A hot climate scenario will look to avoid passive solar gains, and so the benefits of the shading provided by the double façade system to reduce cooling

loads are more easily identified when making a comparison with a base case curtain wall system using interior blinds that would be the construction norm for most commercial buildings in these regions.
The relative newness of double façade projects will require ongoing monitoring to provide performance data that can be averaged over a number of years in order to normalize for varied and unusual weather patterns. Hot climate scenarios tend towards more climate consistency in this regard, experiencing less dramatic extremes, although there continues to be benefits sought from access to ongoing performance data.

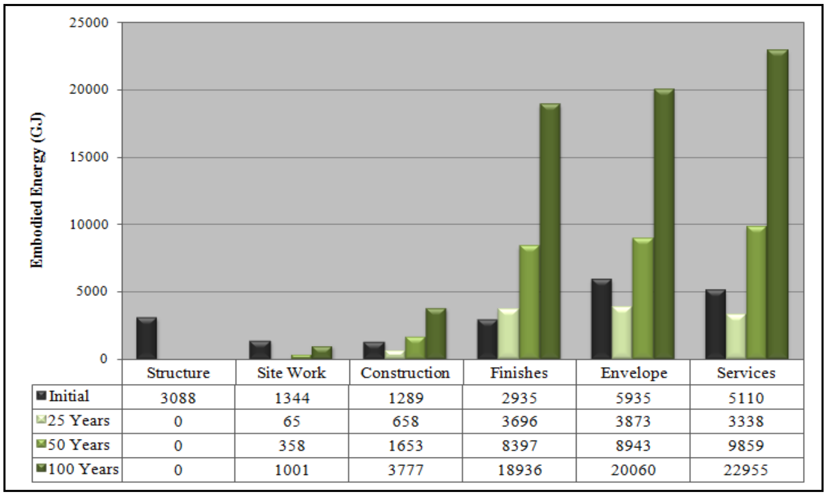
Access to such performance data is at best difficult. Given the private nature of the ownership of buildings in the subject area of this paper, the United Arab Emirates and Qatar, it is highly unlikely that detailed performance data is ever to become available.

Embodied Energy and Construction Costs

In the area of new construction, double façade systems continue to be limited to applications that have access to higher budgets. Although there is considerably more practical experience now in terms of the design, fabrication and erection of double façade systems, this has not brought their capital costs in line with more standard curtain wall as there will always be "more material" in a double façade system which equates to higher material and installation costs. This doubling of the façade necessarily results in higher embodied energy in the envelope system.
The argument can still be made that the potential benefits of the reduction in operating energy provided by the system should outweigh the additional carbon costs of the system itself, over time. However as operating energy is eventually reduced to meet Carbon Neutral targets, the embodied energy of cladding systems such as double façades will come under closer scrutiny, particularly in terms of their increased use of material such as aluminum as it has one of the highest embodied energy costs of all common building materials. The Donnelly Center for Cellular and Biomolecular Research in Toronto, Canada uses a custom twin face double façade system for its south elevation (opposite). This increased the capital and carbon costs of the project.

This is where durable construction and an excellent maintenance plan will come to bear. One of the justifications for the use of high embodied energy materials such as aluminum is their durability and long life. The design, detailing and material selection of the components of the system need to prioritize durability and maintenance in order to answer to issues regarding embodied energy.

Double façade systems, particularly those that employ shading systems in the cavity, are more difficult to clean and maintain. If the building owner does not adhere to a strict maintenance plan, the degradation of the various components of the double façade system can result in an unnecessary increase in embodied energy as a direct result of the need to replace and retrofit.



	Structure	Site Work	Construction	Finishes	Envelope	Services
■ Initial	3088	1344	1289	2935	5935	5110
■ 25 Years	0	65	658	3696	3873	3338
■ 50 Years	0	358	1653	8397	8943	9859
■ 100 Years	0	1001	3777	18936	20060	22955

Figure 1: Initial Embodied Energy vs. Recurring Embodied Energy of a Typical Canadian Office Building Constructed from Wood. Although the image refers to a wood structure, the costs associated with renewal of the building envelope are quite clear. In this instance a standard curtain wall has been modeled. The energy costs for a double façade would exacerbate this data. 2

Figure 1 illustrates the case for the potential embodied energy costs to repair and upgrade a more common curtain wall over time. The associated costs for a double façade would be much higher. If the use of a double façade is able to reduce the extent of the mechanical systems required to heat and cool the building, then there is potential for a subsequent reduction in the capital and ongoing energy costs associated with the services of the building, which from the above graph exceed the energy costs associated with the renewal of the envelope. In hot climate scenarios the focus on solar avoidance has been translated into projected reduction in cooling loads. As the effects of shading can be fairly precisely predicted in a climate where the solar conditions are consistent and predictable, there tends to be confidence in reducing the cooling plant, which if carefully considered should provide a positive long term impact on the scope of the renewal of these systems.

Where the embodied energy of double façades leads to higher overall embodied energy costs in new construction, when it comes to the adaptive reuse of existing buildings double façades can provide for a reduction in embodied energy and associated construction costs by allowing for the salvage and reuse of an existing building. The aesthetics of the system are capable of transforming an outdated piece of architecture into a state of the art project, both visually and environmentally. There has been a surge of renovation to existing high rise buildings and in order to preserve the value in the existing construction a double façade is an efficient way to preserve the embodied value of the existing structure (and partial envelopes in some cases) while allowing for a significant energy upgrade to the building. These applications are particularly prevalent in urban centers where much of the high-rise commercial building stock was constructed during the 1960s and 1970s. The curtain wall, precast concrete and glazing systems of these structures have already reached their 50 year point which is the standard expected life for these systems. From the perspective of energy performance, façade construction of these decades predated global concerns for energy efficiency and most are significantly underperforming and will benefit from replacement.

Although most of the high rise construction in countries such as the UAE, Saudi Arabia and Qatar is significantly less than 30 years old, (Marina Bay in Dubai pictured opposite) the envelope systems of these buildings were not necessarily designed to be high performing as there had been an assumption of energy abundance in this region. Most have little or no external shading and use standard curtain wall construction. Double façade systems that create an external shading envelope hold promise for envelope upgrades to increase energy performance while maintaining the building structure.

Software Limitations

Although many research investigations have ensued to establish hard data to prove the energy savings in double façade applications, the number of applications greatly exceeds the data available. Much of our belief in the energy saving potential of double façade systems lies in our faith in simulated data. This is difficult to generate as the majority of thermal simulation software has no capacity to handle double façade systems as they vary greatly in their detailing as a function of the specific system chosen, combined with climate, exposure and orientation. Many of the buildings that employ double façades are highly complex, which of itself proves challenging for effective energy simulation. Modified double façades that focus on a particular environmental benefit such as solar shading are more easily assessed for a benefit in cooling load reductions as the modeling parameters can be limited in scope.

Maintenance and Cleaning

Double façade systems have added costs for maintenance and cleaning. Standard cleaning stages for high-rise construction can no longer be used. The difficulty of access varies with the particular type of double façade application. Façade systems that are ventilated to the exterior will require greater cleaning frequency due to the deposit of particulates on the interior surfaces of the components. This is problematic as the ventilated façade type has the highest benefit when seeking to include natural ventilation strategies in commercial buildings of mid to high-rise heights. Double façades are either cleaned from within the air corridor or must be accessed from within the building where the dimension of the air corridor is insufficient. The Donnelly Center, opposite, provides access to the vented cavity from an atrium adjacent to the offices to reduce interruption.

Of particular concern to building owners is the direction of the opening of the access pane. A study by Henk de Bleeker of the Permasteelisa Group that was published at the Shanghai Congress of the CTBUH in 2012[3] cited issues with inward opening access windows as a major concern for building owners. Problems associated with this type of façade included the disruption involved in moving furniture to access the windows for cleaning as well as the presence of cleaning staff in offices where sensitive material may be present. Permasteelisa has responded with the creation of a Closed Cavity Façade system. The sealing of the cavity answers issues of cleaning of the façade interiors by precluding a natural ventilation strategy. This may be valuable in Supertall buildings but less attractive for lower rise buildings seeking a more balanced, natural solution. A sealed system would more closely compare to a triple glazed sealed curtain wall system and without the influence of cavity ventilation, would be easier to simulate, as well as maintain. In extremely hot and humid climates it is likely that many building types will not wish to use natural ventilation at any time of the year as would be provided with a more difficult to clean twin face system. Closed Cavity Façade systems could see increasing use in these types of applications.

Systems that allow for the maintenance of the internal spaces of the façade from within the façade provide a means to avoid cleaning personnel entering the occupied spaces. However these systems give over more potential usable or leasable floor area to the envelope system when comparing the net effect of a 1 to 1.5 meter "air corridor" to the more modest 150mm air space used in some of the slimmer prefabricated systems. High profile or "iconic" buildings that are presently using double façades in hot regions have not been deterred by the additional area required for sizeable cleaning access corridors.

Hot climates present different issues for cleaning. In the UAE in particular we see high levels of humidity, which can result in condensation on the exterior of the façade. The blowing sand and dust becomes firmly deposited on the damp façade. This is very clear in the construction stage photo of Capital Gate in Abu Dhabi, opposite. As the region has a shortage of fresh or desalinated water, cleaning is expensive and difficult if abrasion of the façade is to be avoided. The cleaning frequency needs to increase in order to manage the deposits and prevent build-up. Double façade systems exacerbate this problem by creating more surfaces to clean. Some innovative techniques to address cleaning will be shown within the application section of this article.

PRACTICAL REASONS FOR THE PERSISTANCE OF DOUBLE FAÇADES

Double façade systems are continuing to be used for reasons that are practical and easily understood. The purely economic benefits of these practical reasons may be far less clear than the benefits provided by a reduction in operating energy, however the benefits may be more tangible as they have physical or visual consequences to the occupants and users. These practical reasons seem to be consistent throughout climate types, including hot climates.

As many buildings are being constructed in noisy urban environments a double façade system has been effective in **controlling noise**. The extra layer provided by the buffer, twin face or extract-air systems has been effective in improving the acoustic performance of the envelope. The office building, opposite, by Petzinka, Pink Architects in Berlin, Germany is using the double façade for acoustic improvement.

Many sustainable buildings are looking to **natural ventilation to improve occupant comfort** as well as diminish the cost of operating energy in shoulder seasons where temperatures as not as extreme. Twin face systems can provide natural ventilation through strategies that offset the path of the flow of air thereby avoiding the effects of wind gusts that would result from direct openings in the envelope. This offset can also mitigate issues of pollutants in the air if the system is fitted with closable dampers for use during peak traffic hours or weather events. The offset path will also reduce the transfer of urban noise into the interior spaces.

Natural ventilation is not presently being used in many high-rise commercial buildings in extremely hot climates as a full dependence on mechanical cooling has been firmly established along with its comfort expectations. That said, the inclusion of some operable windows in new high-rise commercial buildings in developing countries is quite usual when compared to North American buildings. Many of these hot climate locations do have many months of the year where natural ventilation would be beneficial and double façade systems could be seen an effective solution in the future.

Double façade systems provide **protection to solar shading devices** which would otherwise be exposed to snow, ice, wind and rain. This allows ultimate flexibility in the design and deployment of operable louvers and shading systems as these can be environmentally protected which can serve to reduce the cleaning requirements, wear and tear on mechanical components, thereby assisting with issues of durability and longevity. The Helicon Building in London, opposite, was one of the first extract-air systems. Its louvers are protected within the cavity. It is to be noted that hot climate applications have tended not to position operable louvers in unsealed air corridors due to issues with the accumulation of dust and fine sand that results in cleaning issues. Interior blinds continue to be chosen to assist in shading and glare control and provide occupant control.

”Specializations” of the general double façade types of buffer, twin face and extract-air that reflect very specific climate-focused considerations have evolved and can be seen in recent hot climate projects located in the Persian Gulf area. In some instances this may have resulted in a hybrid approach to the façade or in others a simplification of a more complex, traditional approach that has been more normally been required to address the opposing issues of heating *and* cooling. In extremely hot climates the design strategy has focused on the strength of a double façade approach to achieve heat or solar avoidance. In some hot climate hybrid double façades the shading system has become *the* outer layer of the double façade system, thereby eliminating the more usual extra curtain wall layer. This new typology is emerging as a specific hot climate double façade type.

HOT CLIMATE DOUBLE FAÇADES

Heat avoidance is of primary concern in hot climates as a means to reduce energy use and provide comfort to occupants. The office building in Dubai, opposite, uses horizontal shading to cut down on solar gain. Abu Dhabi, for instance, is situated at 24.43° north of the equator. The projection requirements for south façade shading are minimal when compared to the requirements for latitudes further north. It is possible to achieve good shading protection for the façade by simply using the grated cleaning and maintenance platform that is normally provided in wide air corridor double façades, without requiring additional louver shades in the cavity as is more common in northern locations. The east and west façades of tower type buildings in particular pose a greater problem as they cannot be served by simpler horizontal systems that are efficient for south facing glazing with high sun angles (if we consider buildings north of the equator).

This is of particular concern for iconic towers as they tend to be situated on more isolated sites which increases their solar exposure. Standard commercial towers in cities like Dubai tend to be built on smaller sites and clustered more closely thereby providing shading to each other, using a traditional hot climate clustering response. Although double façades of the more usual buffer, twin face and extract-air types continue to be built in these regions, unique double façades have been developed that focus solely on the provision of shading as the primary means of heat avoidance. This is usually coupled with relatively high performing glazing in curtain wall skins to further limit heat transfer and solar gain. Many of these shading systems are derived from the tradition of the Islamic *mashrabiya* which is a wooden lattice screen that is used to allow for some air circulation while blocking significant solar radiation and providing visual privacy. This vernacular based precedent for a second layer can be seen to be naturally extended to create a new type of double façade system.

The tradition of the *mashrabiya* screen is very long. It is acceptable in this climate to have direct views to the outside obscured by these screens. This is important to understand when evaluating the success of double façade systems that use a variation of this system. They cannot be viewed in Western, cold climate terms where a fixed reduction to view is unlikely to be tolerated. Culturally the screen is well accepted in this region.

Figure 2: Two modern interpretations of the Islamic mashrabiya. Left, The Souk and right, Masdar City, both projects located in Abu Dhabi, UAE and both from the offices of Foster + Partners.

Hot climate double façades can be loosely divided into two types:

1. Those that employ a shading screen (mashrabiya) as the exterior face coupled with a high performance curtain wall system as the interior layer of the façade, in which

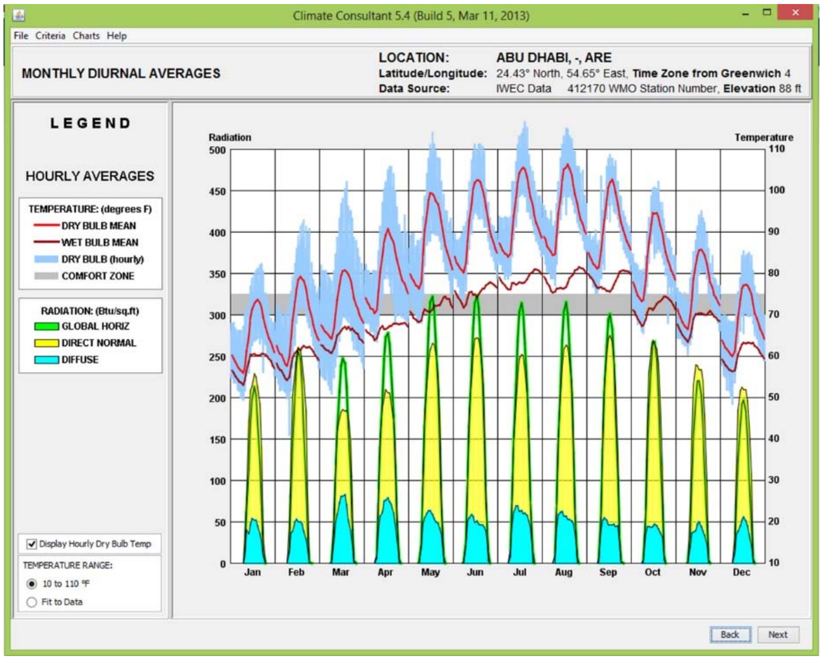
- A second layer of glass is not used to provide the outer layer.
- The layers tend to be separated by a wide air corridor to provide access for cleaning.
- The exterior shading layer is either fixed or responsive.
- The shading layer must be very durable to withstand exposure to the elements as well as cleaning.

2. Those that use a more traditional approach (buffer, twin-face or extract-air) where the exterior layer is glazed and where

- The air corridor is usually wide enough to allow cleaning access without interfering in the interior spaces.
- The air corridor is used to buffer the temperature extremes.
- The air corridor may or may not form part of the cooling system.
- The shading devices are not normally positioned in this cavity if it is not sealed.

Where the cavity or air corridor is not sealed and outside air would be permitted to enter the corridor, this would allow airborne sand particulates to accumulate and would result in cleaning issues. The open nature of the new screen type exterior layer that is situated between one and 1.5 meters from the primary curtain wall facilitates easier access for internal cleaning, which will be required as the open nature of the screen will allow significantly more deposits to occur.

The absence of shading devices in the air corridor differentiates the hot climate double façade type from temperate or cold climate scenarios where the shading devices are purposefully positioned in the cavity as a means to protect them. As previously mentioned, the latitude in the UAE works well to limit the dimension of south facing horizontal shades which can allow for fairly effective south shading in wide air corridor types by the simple use of the grated cleaning platform that is usually located at each floor level.



Climate Consultant 5.4 (Build 5, Mar 11, 2013)

MONTHLY DIURNAL AVERAGES

LOCATION: ABU DHABI, -, ARE
Latitude/Longitude: 24.43° North, 54.65° East, Time Zone from Greenwich 4
Data Source: IWEC Data 412170 WMO Station Number, Elevation 88 ft

☑ Display Hourly Dry Bulb Temp

TEMPERATURE RANGE:
● 10 to 110 °F
○ Fit to Data

Figure 3: The climate profile of Abu Dhabi as captured from Climate Consultant 5.4.[4] *The climate sees high levels of solar radiation and the majority of temperatures sitting above the comfort zone (in grey). This data would be used to determine the approach as predominantly cooling dominated.*

Following are some examples of innovative applications of double façade systems in hot climate locations, predominantly in the Persian Gulf area and unapologetically, without numerical data to back up their performance as none is available and is unlikely given the nature of the private ownership of the buildings. The projects are recent and the building owners are not inclined to publish performance data.

The climate of the United Arab Emirates and Qatar where these projects are located is unusual and extreme for a desert climate in that it is also extremely humid, although the appearance and impression if you have not visited would presume that it is arid due to the lack of vegetation and fresh bodies of water that are normally present in hot-humid climates. The high humidity combined with extreme levels of sand particulates due to the windy desert conditions make condensation an issue, where highly chilled glazing surfaces that result from high levels of air conditioning come into contact with outside temperatures in the range of 45^{o}C with humidity in the range of 80%. If the U-values of the glazing units is high the dewpoint can be reached on the outer surface. This causes blowing sand to adhere to the buildings. As fresh water is not to be found and the desalination of sea water is the primary source of water, the cleaning and maintenance of buildings is of great concern and cost.

Doha Tower, Qatar | Ateliers Jean Nouvel

The Doha Tower uses a double façade that employs a fixed screen element as the outer layer of the system.

Figure 4: A view of the variations in the density of the screen pattern on the Doha Tower. The variation in density to achieve different screening results is achieved by the simple layering of the prefabricated components. Photos courtesy Ateliers Jean Nouvel and CSCEC.

The exterior skin of the Doha Tower is composed of four "butterfly" aluminum elements of different scales to evoke the geometric complexity of the Islamic *mashrabiya* while serving as protection from the sun. The pattern varies according to the orientation and respective needs for solar protection: 25% towards the north, 40% towards the south, 60% on the east and west. The variation in opacity of the aluminum screen addresses the variation in solar avoidance required on the façade orientations.[5]

Due to the round shape of the tower, some shading is required on the "north" façade as it will receive sunlight in the early morning and late afternoon hours. Where this oblique solar radiation may not be significant in more temperate climates, it does significantly impact the cooling load in Qatar as the humid climate traps the daytime heat and does not allow a significant drop in the nighttime temperatures.

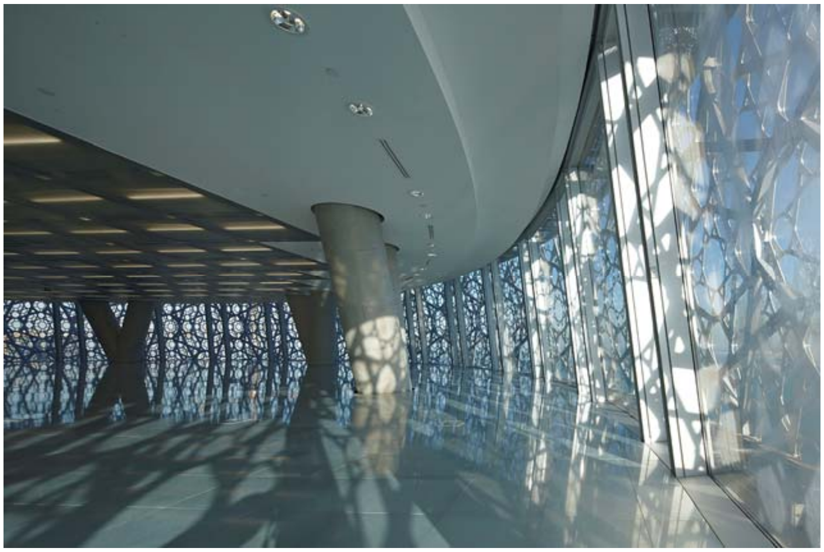


Figure 5: A view of the interior of one of the office floors showing the effect of the geometric screening on the interior. Not all direct sunlight is blocked in order to preserve significant views from the tower. Photo courtesy Ateliers Jean Nouvel and CSCEC.

The internal layer is a slightly reflective glass skin that completes the solar protection. Lastly, a system of interior, user controlled roller-blinds is provided to permit the occupants personal control of their environment. The façade system is projected to reduce cooling loads by 20%. As can be seen from the interior image, Figure 5, significant sunlight reaches the interior. Some of the heat gain is controlled by the glazing selection.

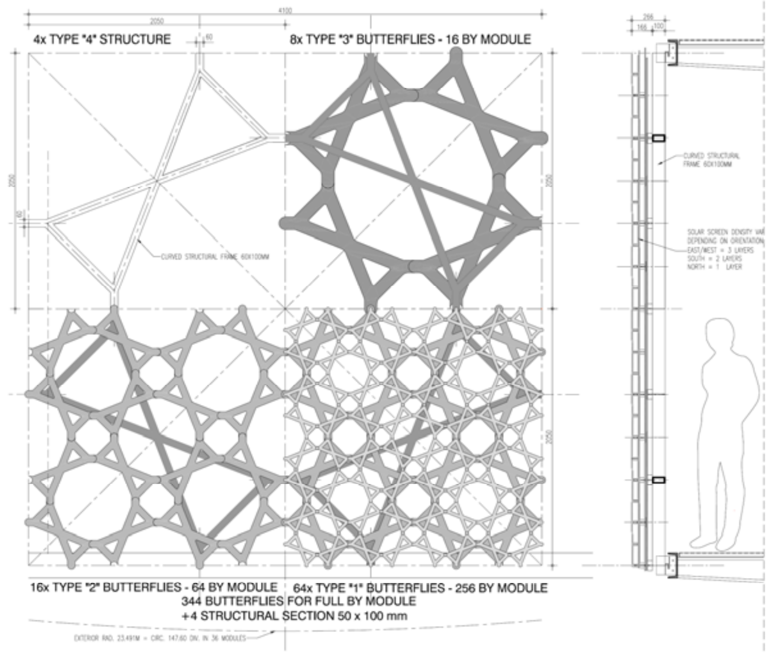


Figure 6: A detail of the layers of the screen. A diamond mesh grate is used on the corridor floor to provide access for cleaning as well as providing some additional horizontal shading. Tower lighting is also housed in this zone. Image courtesy Ateliers Jean Nouvel.

O-14, Dubai, UAE | RUR Architecture

The O-14 Tower in Business Bay, Dubai, UAE designed by RUR Architecture (Reiser + Umemoto) with engineering by Ysrael A. Seinuk uses a double façade system to simultaneously provide an exterior structural diagrid-like support system and shading. The Business Bay location has the tower situated adjacent to a body of water which increases the exposure of the tower to the sun and limits shading from adjacent buildings. The 22-story tall commercial tower sits atop a 2-storey podium. With O-14 the designers wanted to turn the office tower typology inside out by reversing the position of the structure and skin.

In this instance the exterior screen component is a fixed load bearing reinforced concrete wall with a pattern of perforations that range in size, lighten the self-weight of the wall and facilitate reduced solar radiation. The concrete exoskeleton acts as a second skin where the mass and limited openings allow the interior skin to be fully glazed from floor to ceiling. This provides occupants with the impression of an all glass building without the excessive heat gain of an all glass façade. The interior curtain wall has fixed glazing and excludes natural ventilation.

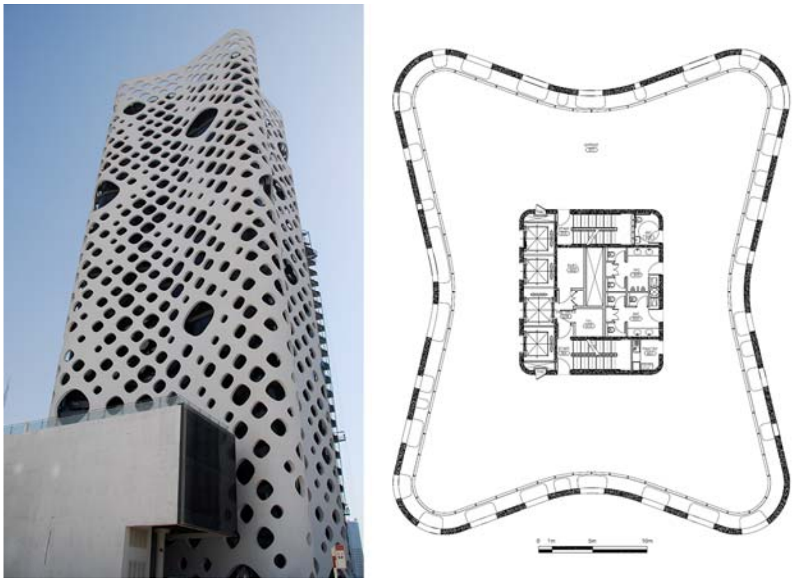


Figure 7: The exterior of O-14, left, illustrating the nature of its perforated diagrid exoskeleton. A typical floor plan of the tower, right, showing the space between the perforated exterior façade and the fully glazed interior layer.

The exterior system provides shading to all façades to preclude solar gain from oblique and low angles as well as provide a consistent appearance to this iconic tower. This solution will have the benefit of lower maintenance costs due to its simplicity, fixed components and choice of materials. The concrete exoskeleton will require cleaning from the eventual accumulation of windborne sand. The interior continuous glass skin will not pose significant maintenance issues.

Figure 8: A view of an office interior showing the continuous nature of the floor to ceiling glazing that creates the inner layer of the double façade.

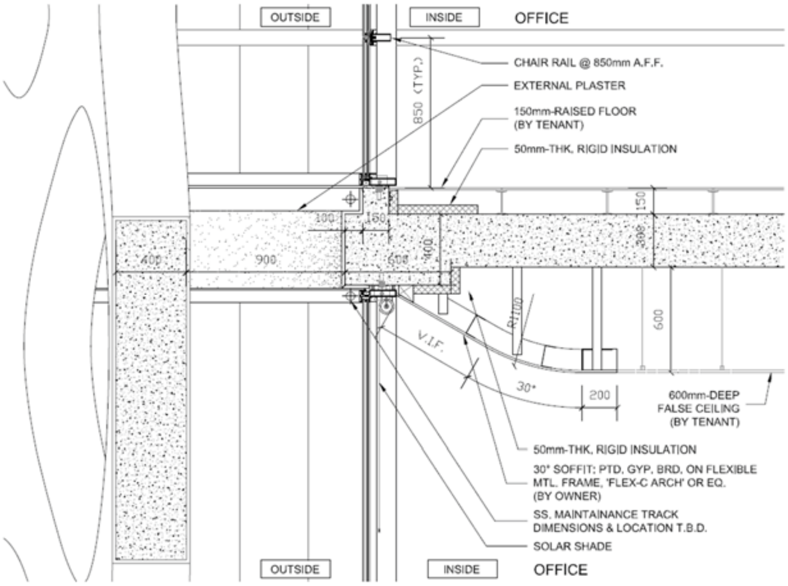


Figure 9: A detail showing the junction of the floor condition and the space between the two façade layers. The space between is approximately 1 meter at this point. This varies slightly throughout the height of the building due to minor undulations in the exterior façade.

According to RUR the one-meter gap between the main enclosure and exterior shell creates a chimney effect, a phenomenon whereby hot air has room to rise and effectively cools the surface of the glass windows behind the perforated shell. This passive solar technique is a natural component of the cooling system for O-14, reducing energy consumption and costs by more than 30%.[6]

Al Bahar Towers, Abu Dhabi | Aedas Architects with Arup

The Al Bahar Towers use a double façade system that wraps around approximately three-quarters of the building. The exterior layer would be classed as a responsive façade as it is programmed to open and close according to the daily path of the sun. The north façade of the building has been designed without shading as overheating due to direct solar gain is less of an issue for this orientation and the views to the city have been preserved. As these towers house a UAE bank, a traditional Islamic motif was used to provide the basis of this innovative and visually interesting external automated shading system. The dynamic façade was conceived as a contemporary interpretation of the traditional Islamic *mashrabiya* which is a vernacular form of wooden lattice screen used as a device for achieving privacy while reducing glare and solar gain. The *mashrabiya* at Al Bahar Towers is comprised of a series of semi-transparent umbrella-like components that open and close in response to the sun's path. Each of the two towers includes over 1,000 individual shading devices that are controlled via the building management system to create an intelligent second façade.[7]

According to Aedas each unit is comprised of a series of stretched PTFE (polytetrafluoroethylene) panels and is driven by a linear actuator that will progressively open and close once per day in response to a pre-programmed sequence that has been calculated to prevent direct sunlight from striking the façade and to limit direct solar gain to a maximum of 400 watts per linear meter. The entire installation is protected by a variety of sensors that will open the units in the event of overcast conditions or high winds. The benefits of this system include: reduced glare, improved daylight penetration, less reliance on artificial lighting, and over 50% reduction in solar gain, which results in a projected reduction of CO_2 emissions by 1,750 tonnes per year.

Figure 10: A view of one of the panels during construction showing three "umbrellas" in a fully open position. Once commissioned the action of the opening and closing will be consistent and follow the path of the sun allowing for a more open view during non-solar times.

The façade system will be cleaned via suspended access between the layers which have been set approximately 2 meters apart. This will be labor intensive as the nature of the PTFE screen and its protective Teflon coating system will not allow for power washing. A gentler method is required that will include brushing and wiping of the screens with a damp cloth to remove the build-up of particulates.

Figure 11: A view up through the double façade during construction. The transparency of the PTFE panels can be seen.

Figure 12: When the mashrabiya is in its fully closed position, the majority of the harsh desert sunlight is prevented from striking the glazed façade thereby reducing the cooling load on the building. Although the mashrabiya may appear very solid in this view, it is created from a PTFE screen material to allow some light to the interior.

There are internal sky gardens along the southern façade of the building that sit between the curtain wall of the office space and the *mashrabiya*. These also help to alleviate the effects of solar exposure and serve as an amenity to users, who utilize the spaces for meetings or breaks and during the months where the temperatures are not as extreme.

During the competition stage of this project Aedas and Arup developed customized applications to simulate the movement of the façade in response to the sun’s path as proof of concept and went on to support the detailed design development by undertaking a variety of additional simulations.

Cleveland Clinic, Abu Dhabi | HDR Architecture

The double façade system used on the Cleveland Clinic in Abu Dhabi differs from others in the region in that it is not designed to focus on the provision of shading and uses a variation of a buffer and extract-air double façade system. The facility has been designed to LEED^{TM} Gold principles and the designers feel that this particular double façade application to be the first ever used in a hospital.

The double façade cavity is open from the bottom to the top and creates a stack or ”lung” effect, allowing the building to ”breathe.” The process works by placing the mechanical floor at the bottom of the hospital tower, exhausting cool air previously used within the hospital from the bottom of the tower to the stack between the double curtain wall which warms and rises by chimney effect through to the roof. This exhaust creates a protective buffer between outside air and the interior of the building. The air inside the building is cooled in a tripartite approach using sea water, heat reclamation, and used cool air exhausted through the 1.5 meter wide air corridor space.

The shading system in this case is not positioned in the cavity but rather on the interior for easy occupant control. The double façade system is uniform on all orientations of the hospital to provide buffering of the extreme temperatures to all façades. The double façade system is expected to reduce the cooling costs of the patient tower building by approximately 33% due to a reduction in the cooling loads.[8]

The cleaning and maintenance of the air corridor will take place from within the corridor as the 1.5 meter width will accommodate this activity. Access from within patient rooms would not have been an option for cleaning access if a narrower air corridor would have been employed.

Figure 13: The Cleveland Clinic under construction in 2012. A hollow structural steel diagrid is used to support the exterior layer of the modified buffer system. The steel diagrid system was prefabricated in uniform modules allowing for a fairly rapid site assembly to take place.

Figure 14: The installation of the layers of the double façade. The interior layer is a fairly standard sealed rectilinear curtain wall system. The tubular steel diagrid that supports the exterior layer of glazing is supported by arms that are connected back to the building structure. Grated walkways span between the arms to provide access to the cavity for cleaning and flow through ventilation to support the stack effect. The exterior diamond shaped glazing layer is connected to a cable system that is used to further subdivide the larger structural diamonds.

Capital Gate, Abu Dhabi | RMJM Architects and Engineers

The designers of Capital Gate, the 18° backward leaning tower located in Abu Dhabi, had a significant sustainable agenda for the project. The offset of the floors to achieve the backward lean creates two distinct types of spaces and exposures which have resulted in the use of two types of double façade systems. The lower office floors are protected by a large metal mesh canopy called "the splash" which starts at the entry level as a sun shade over the car drop-off area and climbs the façade, terminating at the projecting pool level provided at the 19th floor. The mesh is supported on an Architecturally Exposed Structural Steel Frame and is 90% open. The mesh allows for air circulation while blocking approximately 30% of the solar radiation from striking the curtain wall of the office spaces.[9] This is a variation of the hot climate double façade system that uses a fixed shading screen in lieu of a glass layer for the exterior element of the double façade system. The application at Capital Gate is innovative in that the screen transforms from a shading system for the office floors to become a shading canopy for the passenger drop-off area.

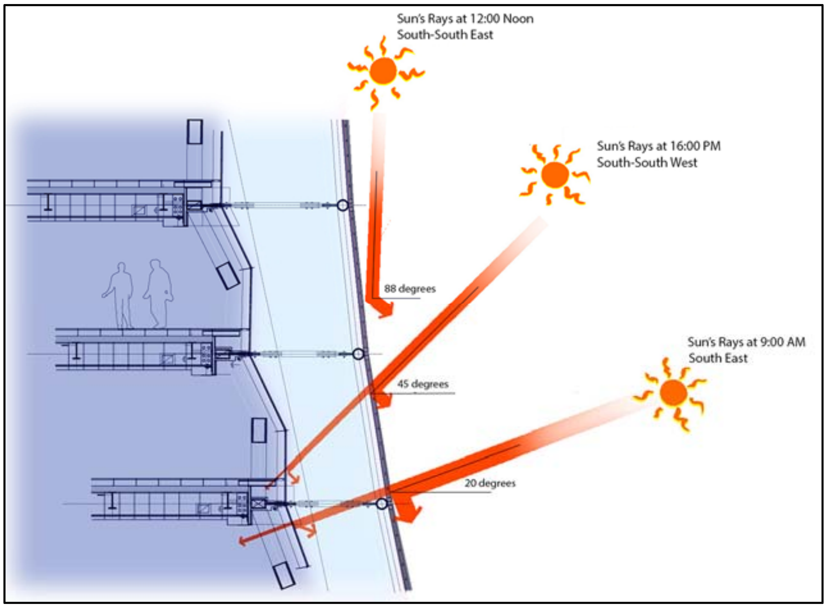


Figure 14: The exterior shading skin on the lower, office portion of the tower is designed to prevent solar radiation from the south east and south west directions. Credit Jeff Schofield, ADNEC.

The hotel rooms located at the 19th floor and above use a more typical double façade system. A diamond shaped prefabricated curtain wall system is attached to the structural steel diagrid of the tower and forms the outside layer. The interior layer uses a less expensive rectilinear glazing system. This is a modified double façade system which recycles interior air from the guest rooms into the façade cavity. Here it creates an insulating buffer between the cool interior and the extremely hot exterior.

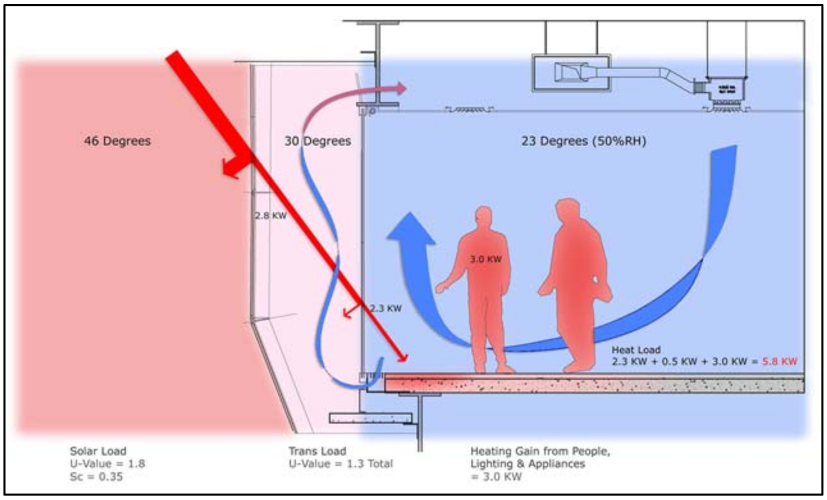


Figure 15: The double façade system for the hotel levels uses an air corridor that is wide enough to allow access for cleaning. Credits Jeff Schofield, ADNEC.

The air is filtered, reconditioned and reused in the rooms rather than replaced with outside air. There are operable glazing units on the exterior of the double façade wall to allow fresh air intake at those times of year when it is feasible. No operable units are installed in the glazing layer of the guest rooms. It would be difficult to control user input by transient guests that would not understand or appreciate the operation of the system.

Façade maintenance strategies were well considered for Capital Gate. A good understanding of the tendency for the build-up of sand and grit on the building, which would be exacerbated by its backwards lean and highly exposed location were understood. Cleaning is managed through the use of *abseiling*, a method of suspending the maintenance crew from ropes to access the building for cleaning.

Figure 16: Abseilers clean between the curtain wall and metal "splash" (credit Jeff Schofield, ADNEC) and maintain the exterior of the double façade skin.

Hooks are attached to the façade to allow the workers to clip themselves close where the geometry would create a distance from their normal vertical drop position. The method of cleaning by *abseiling* works well with the odd geometries of the building which negate the use of more standard stages for window washing. It is also a more commonly accepted practice in the UAE.

IN SUMMARY

The examples provided show a very clear adaptation of the double façade envelope system to address the avoidance of solar radiation in the hot climate of the Gulf Region. Two primary types of façade systems have been developed to respond to the climate: one that has exchanged the outer glazing layer for a ventilated *mashrabiya-like* screen element and one that maintains the glazed characteristics of the typology and concentrates on creating a buffer to slow heat loss. In the latter type the operable shading devices have been moved to the building interior to provide occupant control and remove them from potential degradation due to airborne dust and sand.

The instances of the new variation of the double façade that has substituted the *mashrabiya* layer for the exterior glazed layer seem to be more widespread. There are numerous examples beyond those mentioned in this article where the extensive use of a lattice-like shading layer is used. The cultural tradition and acceptance of the screen has reinforced its modernized use in this emergent double façade typology. In this climate where the solar condition is extreme and persists throughout the year, the singular focus on shading is supported.

Although no performance data is currently available to substantiate the projected savings to the cooling loads of the projects, the adapted *mashrabiya* system, as it is based on the known benefits of a vernacular type in the region, affords confidence in its performance as a credible shading system. The full benefits and performance of the modified buffer system will likely not be known.

Notes:

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