**Burj Dubai, the shining building**

SunGuard in the façade of the tallest building in the world

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**Project:** Burj Khalifa (Burj Dubai), Dubai (United Arab Emirates)  
**Architects:** Skidmore, Owings and Merrill ([www.som.com](http://www.som.com))  
(contact: Peter Weismantle - SOM Chicago)  
**Structural engineers:** William F. Baker, SOM Partner in Charge of Structural and Civil Engineering, Chicago, IL  
D. Stanton Korista, SOM Director of Structural Engineering, Chicago, IL  
Lawrence C. Novak, SOM Associate Partner, Chicago, IL  
**Contractor:** Samsung C&T, Besix + Arabtec  
**Developer:** Emaar Properties  
**Construction started:** January 2004. (First IGU installed August 2007)  
**Construction ended:** 2010. (October 2009 Façade)  
**Glass processor:** White Aluminum (Abu Dhabi)  
**Cladding company:** Far East Aluminium and Arab Aluminium

<table>
<thead>
<tr>
<th>Site area</th>
<th>104,210 m²</th>
<th><strong>Project area:</strong></th>
<th>454,249 m²</th>
<th><strong>Building height:</strong></th>
<th>828 m</th>
<th><strong>Floors:</strong></th>
<th>160</th>
<th><strong>Cost:</strong></th>
<th>1,5 billion US Dolar</th>
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“Burj Khalifa, formerly Burj Dubai, at the center of a large-scale development, is the tallest building in the world. The design combines cultural influences with cutting-edge technology to achieve a high-performance building. Its massing is manipulated in the vertical dimension to minimize the impact of wind on the tower’s movement.”

**Project Awards**

- 2010 • Arab Investment Summit • Arab Achievement Award 2010: Best Architecture Project  
- 2010 • Chicago Athenaeum • International Architecture Award  
- 2010 • Cityscape Awards for Real Estate in the Middle East and North Africa • Best Mixed Use Built Development  
- 2010 • CTBUH • Best Tall Building Middle East & Asia  
- 2010 • Structural Engineers Association of Illinois • Excellence in Structural Engineering: Most Innovative Structure

**The structural system**

The height of the multi-use skyscraper exceed the current record holder of 509 m tall Taipei 101. The 280,000 m² reinforced concrete multi-use tower is used for retail, a Giorgio Armani hotel, residential, and office.

Designers purposely shaped the structural concrete Burj Dubai —“Y” shape in plan— to reduce the wind forces on the tower, as well as to keep the structure simple and foster constructability. The structural system can be described a “buttressed” core. Each wing, with its own high performance concrete core and perimeter columns, buttresses the others via a six-sided central core, or hexagonal hub. The result is a tower that is extremely stiff torsionally. SOM applied a rigorous geometry to the tower that aligned all the common central core and column elements to form a building.

Each tier of the building steps back in a spiral stepping pattern up the building. The setbacks are organized with the Tower’s grid.

The setbacks are organized such that the tower’s width to change at each setback. The advantage of the stepping and shaping is to “confuse the wind.” The wind vortexes never get organized because at each new tier the wind encounters a different building shape.
Sustainability

The tower was designed following the most important guidelines for sustainable design:

- The building is provided with a low-emissivity glass with enhanced thermal insulation against high ambient temperatures of Dubai.
- Cooler air temperatures, reduced air density, and reduced relative humidity at the top of the building allow for “sky-sourced” sustainability innovations. When ventilation air is withdrawn at the top of the building, it requires less energy for air conditioning, ventilation, and dehumidification.
- Burj Khalifa has one of the largest condensate recovery systems in the world. Diverting and reusing water from air conditioning condensate discharge reduces the need for municipal potable water. Estimated annual savings are equal in volume to 14 olympic sized swimming pools.
- Conduction of electric power using higher voltage reduces energy losses and increases energy efficiency when compared to low voltage energy distribution.
- Individual electric energy monitoring systems enable ongoing energy optimization of the tower’s systems over its lifetime. This will result in a reduction of Burj Khalifa’s energy related environmental impact.
- Burj Khalifa’s building management system (BMS) provides the tower with low operational costs, a more efficient use of building resources and services, good control of internal comfort conditions, effective monitoring and targeting of energy consumption.
- Burj Khalifa was designed to passively control these forces, reducing the need for mechanical means of pressurization while saving energy.

Learning from the design and construction processes of Burj Khalifa, SOM is currently applying similar technologies to new projects. For example, the new DMC Tower in Seoul will make use of the naturally occurring wind stack effect. By generating a percentage of the building’s power demand using wind turbines, the design will reduce municipal energy use to a fraction of a supertall building’s typical consumption.

Interview with the responsible for this project by Guardian.

Guardian: Francesco Tritta
Phillip Higgins
Sanjeev Krishnan
Earnest Thompson
Bruce Milley
Chris Dolan

1. Which is the glass surface in this building?

With about 26,000 glass panels, 150,000 m² is the total amount of glass installed in the facade, 100,000 m² of them in the bassament.

Proportion of the laminated glass is not high comparing with the whole glass façade, with about 5,300 m² laminated glass installed in the area below 0.7 m for outfalling security regulation.

- 5000 m² Lami 44.2 + Coating ClimaGuard (2x4 mm floatglass with 0,76 mm PVB layer)
- 300 m² Lami 55.2 + Coating ClimaGuard (2x5 mm floatglass with 0,76 mm PVB layer)
- The biggest size was 3200 mm x 1800 mm

Heat strengthened glass was mainly used, unlike tempered glass that is mainly used in Europe. One of the main reason is to avoid the risk of spontaneous breakage due to nickel sulfide inclusions that can occur on tempered glass easier than in heat strengthened glass.

Heat strengthened glass presents a better optical quality than tempered glass regarding distortions. This is mainly due to the cooling process which is different compared to tempered glass (it runs slower).
2. Project started in 2004. Can you tell us when first meetings or contacts between architect and Guardian took place to define the product?

2002 Guardian US got the first contact with SOM architects. Since that first approach, local UAE sales managers from Guardian and later Guardian Europe got involved. The complex and global nature of the design and construction started six years ago, when the project for the Burj Khalifa was announced and meetings were held in Chicago, Germany and Switzerland. The first requests about the glass started in 2003 and different calculations were carried in the following years:

- Technical values of the IGU
- Glass thickness calculations based on a windload of 3.0 kN/m² which corresponds to a windspeed of 250 km/h
- Temperature and movement calculations for IGU including temperature differences between ground floor and top (production of IGU and installation) and also between the different seasons.

Guardian plants in Germany and Luxembourg produced the coated glass for the Burj Khalifa. Guardian is also supplying the glass for the Burj Residence project, six towers that surround the Burj Khalifa. The Burj Residence will use Guardian SunGuard HP Green 63, produced at Guardian’s Rayong, Thailand float glass plant and coated at Guardian’s Bascharage, Luxembourg float glass plant.

3. In which phase of the project was the product definitively defined?

Beginning of 2005 decision was made that Guardian glass will be used. First IGU was installed in August 2007. The good optical appearance is mainly due to good heat treatment of the glass but also the segmented position of the glass elements, even so a high reflected glass.

4. Which were the first ideas for the glass?

Wish of the architect was to have a matt, silver reflective colour to outside without disturbing the inside. No body tinted glass or ceramic frit was accepted.

5. Were there any conditions in the project that limit the decision about the glass?

The main condition was a solar factor around 15-17 with shading coefficient of 0.18.

6. Which were the local law requirements? Were there aesthetic limitations?

There was no particular local requirement from the aesthetic issue. This is the tallest tower of the world with the most local potential people.

7. Are the country legal requirements similar to European ones? Which safety requirements were considered?

Yes. Outfalling security requirement is based on the North American standard. Over a height of 0.7 m, no security glass is needed. This is also the reason of using mainly heat strengthened glass.

Generally speaking, most buildings in the Middle East are supplied with fully tempered glass for both the outboard and inboard lites. That is a long standing approach and it is very difficult to change. The only use of heat strengthened glass is when an international architect specifies it for a building. Typically this would be for a large monumental project. Annealed glass is not considered in any case.

8. Was the high performance glass a legal requirement? Or just the owner requirement to save energy cost? Or did Guardian convince them for that?

The owner imposed via HVCA team the shading coefficient of 0.18.
9. How is the influence of the different periods (spring, summer...) in the glass decision? With which two sentences would you define the local climate zone where the tower was built?

The main issue was the temperature difference between production and installation. As an example, IGU was produced in January in Abu Dhabi at temperature of 26 °C and installed in August at 48 °C. This including solar intensity of 900 W/m² (in Europe 750 W/m² maximum for vertical facade). Temperature difference outside (48 °C) inside (set up to 22 °C) was also considered. The calculations of stress and deflection of the glass unit have made a certain decision of the different glass thicknesses.

10. Was ClimaGuard (Guardian low emissivity glass) a must since the beginning?

Yes. In the Middle East low U-value is requested on regular basis years ago. This is to keep the heat out of the building during the night time (indirect heat outside still present with high temperature).

Most people don't realize how popular Low E glass is in the Middle East and why it should be used. Generally, people think of the use of Low E glass in cold weather climates and the reason for this has been well documented. The concept of blocking and reflecting indirect heat at night time and daytime, is something that many people wouldn't consider.

The surrounding area of a building (other buildings, desert, mountains) absorbs the intense heat all day long and it continues to radiate this heat throughout the night. Low E glass helps to reflect that long wave radiation and minimize the transmission of it. Muscat, Oman is an interesting example. This city is positioned throughout several small mountains which radiate a lot of the heat that has been retained from the daytime hours. This effect makes night time temperatures and humidity in the city of Muscat hotter than other areas.

The other advantage of Low E glass in the Middle East is that it helps reduce condensation on the exterior glass throughout the hotter summer months. It is common to see windows covered in condensation every day throughout the summer.

11. Which movements of the tower were considered to define the margins and gaps? Are the glasses standing those movements? Or the structure behind the glass?

The glass resists the movements as the frame is considered to move and hold the glass with some space in the frame (there is no direct contact between glass and frame). Regarding the exact movements of the structure, Guardian was not involved in this matter.

12. How is the influence of the position of the panes in their definition?

The glass is positioned vertical in the frame and segmented around the tower. This is to avoid the distortions due to the heat treatment of the glass. In completely flat facade the high reflective glass would show more distortions.
13. Which is the influence of the glass thicknesses in the energy efficiency of the glass? How is the tower divided in terms of glass thicknesses? Why?

The choice of the glass thickness is a choice of stress and deflection calculations depending on the sizes, temperature differences and windload. For the whole tower typical wall types were defined with different glass dimensions. Mainly a bigger size with smaller sizes around.

14. Which wind load was calculated for the whole tower? (According to the information, the estimated wind load was 3 kN/m2, so 250 km/h).

Yes. That was the data provided by the curtain wall consultant.

15. Why heat strengthend glass instead of tempered glass? Which is the difference between the American or Asiatic rules an the European one regarding this subject (NiS inclusions)?

Heat strengthened was used based on the North American standard. Over a height of 0,7 m no security glass is needed, so laminated or tempered was not compulsory. On the other side HS glass is not so exposed to NiS inclusions as tempered glass. So that was an additional point to consider, since heat-strengthened glass has a much lower potential incidence of spontaneous breakage than tempered glass.

Heat-strengthened (HS) glass has been subjected to a heating and cooling cycle and is generally twice as strong as annealed glass of the same thickness and configuration. HS has a greater resistance to thermal loads than annealed glass and, when broken, the fragments are typically larger than those of fully tempered glass and initially may remain in the glazing opening. Heat-strengthened glass is not a safety glass product as defined by the various code organizations but safety glass was not required for much of the project. HS glass is intended for general glazing, where additional strength is desired to withstand wind load and thermal stress but does not require the strength of fully tempered glass.

HS glass is typically used for applications that do not specifically require a safety glass product and additional glass strength is required due to thermal stress.

16. Tempered and heat strengthend glass stand different temperatures while the fabrication process. Which are the advantages of one regards the other?

Tempered glass resists a ΔT of 200 °C, HS glass around 100 °C ΔT. HS glass is heated in the same way as tempered glass. Difference is in the cooling where HS glass takes longer with less cooling pressure produced. This can have an impact on the optical distortions, being HS Glass slightly better regarding optical distortions.

17. How influence the air cavity in the glass performance?

In Burj Dubai it seems that air cavity goes from 12 to 18 mm.

Only the U-value will change, from 1,4 to 1,7 W/m²K. All the other light and energy values remaining the same and are not influenced by the spacer dimension.

18. Which other glasses were considered within the process? Why were they not selected?

Local producer Emirates Glass was the strongest competitor, but Guardian relation with SOM (many projects in USA and Europe, mainly in London) and the appearance of the glass were key for the selection.
19. Which was the final composition of the glass?

<table>
<thead>
<tr>
<th></th>
<th>Outerpane</th>
<th>10 mm HS SunGuard Solar Silver 20</th>
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<tbody>
<tr>
<td></td>
<td>Spacer</td>
<td>12 mm to 18 mm air</td>
</tr>
<tr>
<td></td>
<td>Innerpane</td>
<td>4 to 10 mm HS ClimaGuard (depending on static and temperature calculations)</td>
</tr>
</tbody>
</table>

Silver 20 is similar to coatings produced by many other companies. For this project, the architects collected more than 20 different options, yet selected Sunguard Silver 20 based on performance and aesthetic value. The general consideration was that the Sunguard Silver 20 had a more crisp silver reflection than others.

Standing at the foot of the finished project today and looking upward from podium to spiral one can only agree with their reason for accepting this beautiful product.

The supply of this glass needed to meet an extremely stringent process specification standard to ensure that the glass was supplied without tempering distortion and coating defect to both the inner and outer panels. Quality inspection of the glass at all stages of the processing and installation ensured that our UAE processor, White Aluminium, supplied only the very best finished product.

The most challenging aspect of the glazing on Burj Khalifa was the aesthetic appearance of the glass. Guardian's SunGuard Silver 20 overruled all other manufacturers products because of the "mat silver appearance". The other challenge was the processing quality in regards to flatness of the glass and strain patterns (anisotropy) that gets induced on glass during heat strengthening. Minimizing the said patterns that the human eye would not detect was put in place with the help of Guardian's tech team at the glass processor and it needed a very highly controlled QC inspection on all units that was glazed on the landmark skyscraper. The outcome of all these challenges satisfied the world-renowned project team (contractor, architect and project management co.) and the client.

* Guardian has 27 float plants around the world including one in the UAE, located in the Emirate of Ras Al Khaimah.

* IGU: insulating glass unit.