The Next Generation of Super Tall Towers

A Case Study: Entisar Tower

Keywords:
Building Enclosure
Performance
User Experience
Transparency

Figure 1. Entisar Tower in Dubai UAE, one hundred and twenty-one stories, five hundred and twenty-five meters ©AE7

Abstract

Entisar is a super tall tower located in Dubai, United Arab Emirates. Currently under construction, the completion date is scheduled for 2020. When finished, Entisar will be the second tallest tower in the city measuring 525 meters. It is a mixed-use complex comprised of residential, hospitality, and retail located along Sheikh Zayed Road in the Dubai World Trade District. This paper will examine the development of the building envelope in relation to the project design principles, programmatic uses, functionality and thermal performance. As a central focus, the paper will underscore the importance and responsibility of developing an enclosure system to satisfy the human comfort, needs, and experience for inhabitants residing 500 meters above sea level.

The paper will follow two tracks: one examines the organization of the tower and the other examines the guiding principles that informed the design and development of the enclosure system(s). The tower is conceived as a vertical organization of individual communities each served by public amenities that differentiate the tower into discreet zones. Each community, defined by the amenity floors that serve it, are expressed through the articulation of the building envelope that adapts to satisfy the functional and performance requirements of each.

The design principle that guides the development of the overall enclosure system is to enhance the experience of high-rise living for the tower inhabitants. This design principle touches every aspect of the enclosure system and at times was at odds with thermal performance requirements and energy goals. The design of the enclosure system was the resolution of these diametrically opposite demands. The design implements several means to satisfy these requirements including glass coatings, IGU inserts, unique interlayer laminations as well as unitized unit sizes. This paper will retrace the challenges of enhancing occupant experience while satisfying performance requirements of the enclosure system.

Introduction

Entisar Tower, when completed in 2020, will be the second tallest tower in Dubai, United Arab Emirates measuring five hundred and twenty-five meters. It is a one hundred and twenty-one story mixed-use development that includes retail at the base, hospitality in the lower half and residential above. It is located in the prestigious Dubai Financial District on the only freehold residential plot along Sheikh Zayed road. A freehold residential plot grants for the ownership of units instead of renting, which is typically the case for Dubai properties. This lends the property significant value contributing to the height of the tower, which is only limited, by the conical aviation envelope of five hundred and thirty-five meters originating from the Dubai International Airport. The plot size is typical for the district measuring only sixty by sixty meters. Taking into account the plot setbacks results in a fifty-three by fifty-meter footprint lending the tower its high slenderness ratio of one to ten. This represents a new trend in super tall tower design that is driven to maximize real estate value of standard urban lot sizes.

Tower Organization

From its inception, Entisar Tower was based on the idea of a vertical organization of communities, providing various residential types combined with a diversity of services and amenities catered to the needs of the residents. This model stems from garden type developments that are typical in the region. These developments are comprised of diverse communities based on a variety of housing types that include garden style apartments, single-family townhouses and midrise apartments each of which appeal to various demographic groups ranging from single professionals, to couples to young families. Each individual community is served by an array of amenities that include recreational, leisure and communal activities. Services that complete these developments consist of a central retail and professional services hub that include cafes, grocery stores, health care and similar services. Entisar takes this model as a basis and reorganizes it into a vertical format to create communities for vertical living.

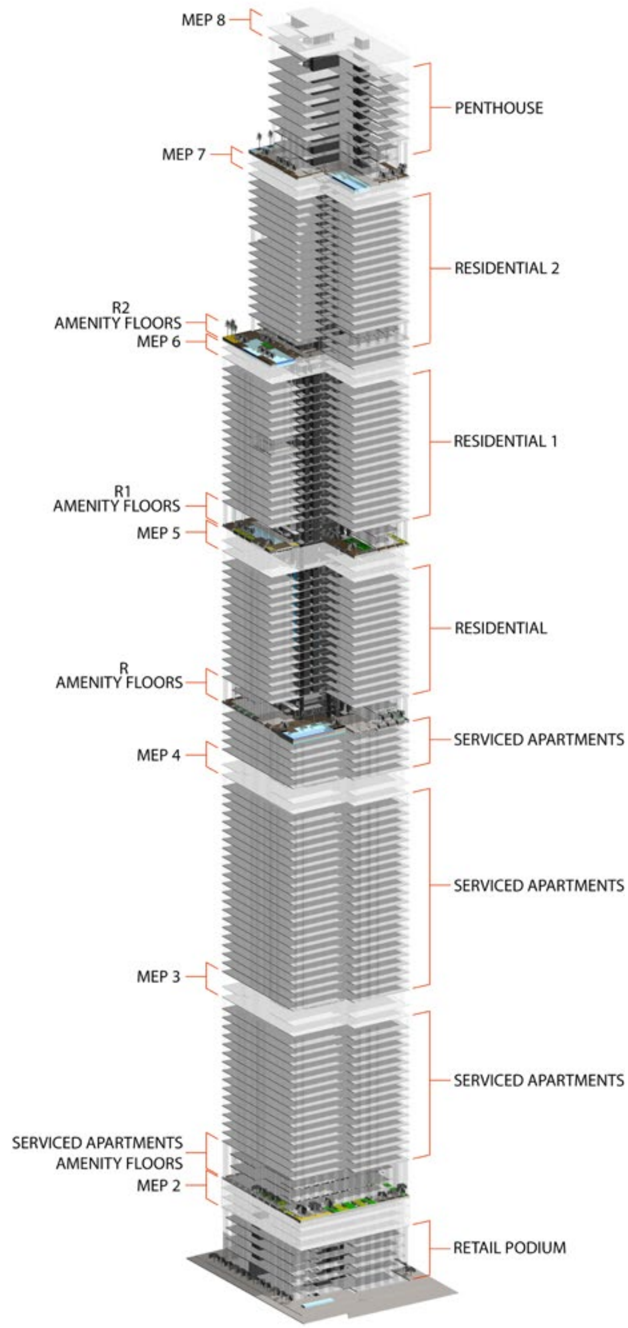

Figure 2. Vertical organization of Entisar Tower; vertically organized communities

Entisar is divided vertically into six components: (1) Podium; (2) Serviced Apartments; (3) Residential (R); (4) Residential One (R1); (5) Residential Two (R2); and (6) Penthouses. Except for the podium, each of these components creates a self-sufficient community with the retail podium providing services to the tower as a whole. As in the garden community model, Entisar offers different residential types to attract a diverse residential population. The five residential and hospitality components create six distinct communities each served by its own set of amenity floors. The amenity floors are located at the base of each community and constitute outdoor gardens and pools, cafes, juice bars, gyms, spas, community rooms, yoga, daycare, libraries and other leisure, recreational and communal activities. The formal articulation of Entisar tower clearly expresses the organization of these individual communities subdividing the tower into a composition of neighborhood zones.

To distinguish communities from one another, both from the exterior and within, unit types and the unit mix layout per floorplate vary between communities. The unit mix layout per floorplate within a single community remains consistent but these layouts differ between communities. This creates a tower with non-repetitive floors, which is quite unique for a super tall tower. In total Entisar has thirty-four unique floor plates, which is greater than one quarter of its total floors. The three residential blocks, R, R1, and R2 each have their own unit mix floor arrangement and unit types. R2 has its own unique floor plate, which is recessed within the perimeter of R and R1. The non-repetitive unit layouts between communities are expressed on the skin to distinguish their individuality. To introduce a smaller granularity three sky-villas are incorporated within the overall residential component of the tower. Sky-villas are two story villas with their own garden space that are typical of the region. These are inserted into the tower and clearly expressed in the residential fabric of the skin.

Building Enclosure Types

Entisar has four unique building enclosure types: base building, amenity, podium, and mechanical. For each type there is a further gradient of permutations that account for the mediation of specific conditions. The four skin types correspond to the organization and functions of the building as described above. The base building represents the greatest percentage of the four types and occurs at the residential units. This is a modular system that consists of two different module types and four different panel types within the smallest module size. The organization of the modules and panel types respond to the living conditions within each unit ranging from public to private functions. The amenity skin type occurs, as its name suggests, at the amenity floors. This skin is developed as a counterpoint to the base building skin and responds to public and communal activities. The podium is a solid glazed block that expresses the retail contents within. The mechanical skin type is actually a sophisticated screen that conceals a continuous plenum space that lines each mechanical floor.

Base Building Facade Type

The base building skin was developed from the standpoint of user experience, to emphasize the view from inside out. With this as a starting point, there were a number of factors that led to the final articulation of the curtainwall. To maximize visibility, the use of highly transparent glass with minimal reflectivity to remove or minimize any intermediary between the user and their surroundings was suggested. However, highly transparent glass performs poorly with respect to energy and thermal performance. To compensate, panel types were introduced with much higher thermal and energy performance, leading to the organization and modulation of different panel types.

Figure 3. Chicago Style Window: Central fixed vision panel flanked by smaller operable panels. Reliance Building, Chicago, Burnham and Root.

Due to several factors, the column grid of the tower is not uniform and has a range of approximately four to six meters center to center between columns. This made one uniform module or even the combination of two to three distinct modules unmanageable because the spacing of the columns would always run out of synch with the mullions. The design took the non-uniform spacing between columns as an advantage and considered the reinterpretation of the Chicago Window as a potential solution. The Chicago Window, typified by the Reliance Building in Chicago by Burnham and Root, 1889-95, is characterized by a central bay fixed window flanked by two smaller operable windows. This model was used as an organizational technique for the modulation of the base building curtain wall for Entisar. In Entisar's case, the large central bay window varies from 2.4 to 3.0 meters in width in relation to the varying spacing between columns. On either side of the central bay window, smaller panel modules are placed measuring seven hundred and fifty millimeters wide to make up the space between the bay window and the columns. The smaller panels are not always symmetrical, sometimes they consists of two on one side and one or neither on the other pending bay sizing and functional needs for the room. The asymmetrical design was deliberate to create an exterior texture that differentiates the larger residential blocks, R, R1 and R2 from one another.

The smaller seven hundred and fifty millimeter wide modules come in four different types: vision fixed, vision operable, micro-louver and spandrel. It was important that the residents do not live in a hermetically sealed tower, therefore the majority of rooms have access to an operable window with a top pivot mechanism. Each residential unit includes several operable windows providing the occupants with fresh air. This again is in keeping with the design principal of the project by providing the user an unencumbered relationship to their surroundings. The glazing type and coatings of all modular units is alike to maintain consistency in appearance, color and reflectivity from the exterior and interior.

The micro-louvre module type contains a highly reflective metallic louvered insert running vertically within the air space of the IGU. This insert reflects the solar rays back to the exterior drastically reducing the solar heat gain coefficient from 0.35 for a non-treated unit to 0.12. The louvers are designed related to their solar orientation on the building. There are three different angles measured perpendicular to the glass ranging from 30, 45 and 60 degrees. The spacing between louver blades varies pending their angle to the glass. Consistent gaps between blades provide for sight lines through the unit. On the interior, one does not notice these inserts at first, as it creates a bit of a filtered view. The metallic surface of the blades reflect the surroundings to ensure that one gets a doubling effect instead of a subtractive effect typical of ceramic frit coatings.

The spandrel unit provides zero solar heat gain coefficient and improved 'U' value. The panel consists of an IGU and an insulated back pan. The micro louver continues in the IGU of the spandrel panel to maintain a consistency with adjacent micro louver panels. The design intent was to avoid the typical striped effect between vision and spandrel of most towers by creating a gradient moving from transparent vision panels to the intermediate vision / louvered panels to the opaque spandrel louvered panels and back.

A second effect that the louvers create is to animate the tower' s skin through the reflectivity of the sun. Spandrel panels on most towers appear lifeless because they are just an opaque panel.

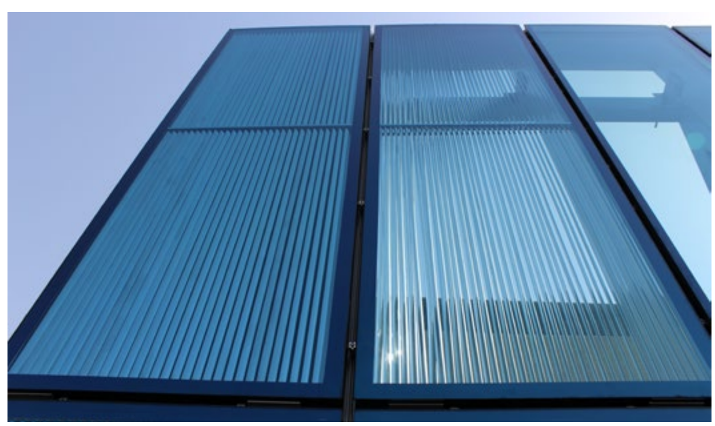

Figure 4. Base Building Curtainwall Modulation: Bay window vision panel flanked by two 750mm vision panels adjacent to vision with micro louver and spandrel.

The louvered inserts activate these panels by providing a shimmering effect. The varying angles of the blades mapped onto the building skin means different portions of the tower will reflect the sun at different times of the day. This subtle design feature helps articulate the tower to break down and humanize the scale by animating the skin.

The arrangement of the four different module types was based on two different requirements: accommodating the functionality of the room and providing for a net averaged thermal performance of the curtain wall. As mentioned above it was desired to provide fresh air for the occupants therefore the majority of the rooms have operable window units. The other modular units were placed pending privacy, thermal or exterior requirements. The target value for the solar heat gain coefficient for the residential curtain wall was 0.23. For the tower, this was an averaged value achieved by the combination of lesser and higher performing modular units. The values per unit varied as defined in Figure 5 below. The vision glass by itself had a solar heat gain coefficient of 0.32, visible light transmittance of greater than 50% and an interior and exterior reflectance of less than 15%. The glazing assembled in an IGU achieved a 1.4W/m^2K U-value or better. Adding the micro louver insert reduced the SHGC of the neutral vision panel from 0.32 to 0.12 nearly reducing the SHGC value by a multiple of three. The spandrel panel has an SHGC of zero and an improved U-value of 0.57W/m^2K including the back pan and integral insulation compared to the vision panel of 1.4 W/m^2K. With these three panel types, one underperforming the targeted 0.23 SHGC value and the other two outperforming this value, a distribution pattern was developed that achieved a 0.23 SHGC average value. Spandrel panels are consistently located over columns but additional spandrel panels were sometimes required to reduce the SHGC. The vision panels with the micro louver inserts made up the balance. All operable window units employed vision glazing without micro-louvers in order to achieve the SHGC average value of 0.23. Often times, this determined if a room would receive an operable unit or louvered vision panel. This iterative process finally concluded with a HAP test simulation that assigns specific performance values to every glazed unit.

Amenity Floor Facade Type

The envelope for the amenity floors was developed as a counterpoint to the base building skin enclosing the residential units. The perimeter building envelope of the amenity floors is recessed within the boundary of the residential floors. This recess provides a natural break between the tower components or communities. Per the design goals and performance requirements of the serviced apartments and residential floors, the base building curtain wall was developed into a patterned skin consisting of different unit module types. In contrast, the amenity floor façade was developed without patterning, a completely transparent skin. This transparency was related to the public functions and activities hosted within offering the occupants a completely uninterrupted view of the city. This fit within the design intent considering the amenity floors as a public piazza that is open and free bounded by the residential blocks of the city, this is the same expression but in a vertical organization.

Glazing					Performance requirements				
System	Glass type and appearance	Outer Lite	Air Space	Inner Lite	Shading Coefficient	U-Value w/ m^2K	Internal reflectance	External reflectance	Light Transmission
Tower Glazing typical curtain wall (FT-01, FT-03, FT-07)	IGU Vision Neutral appearance	8+8 mm H.S. clear laminated with H.P coat on surface 4	air filled	6mm H.S. clear	≤0.32	≤1.4 W/ m^2K	<15%	<15%	≥50%
	IGU Spandrel Neutral appearance (color matched to vision)	8 mm H.S. clear with H.P. coat on surface 2	air filled	6mm H.S. clear	-	≤1.4 W/ m^2K	-	<15%	≥50%
	IGU Vision with sun louvers	8+8 mm H.S. clear laminated with H.P. coat on surface 4	air filled and Integral "Chrome" sun louvers	6mm H.S. clear	≤0.12	≤1.4 W/ m^2K	<15%	<15%	≥50%
	IGU Spandrel with sun louvers Neutral appearance	8 mm H.S. clear with H.P. coat on surface 2	air filled and Integral "Chrome" sun louvers	6mm H.S. clear	-	≤1.4 W/ m^2K	-	<15%	≥50%

Figure 5. Glazing Types and performance values

To achieve this the criteria for the amenity floors was relaxed. By Dubai Municipality (DM)code, the first two levels of a tower are considered showroom space, which lends to the programming of these spaces for retail. This showroom classification reduces the thermal performance requirements of the curtain wall allowing merchants to display their goods by an uninterrupted glazed curtain wall. To achieve the showroom classification the logic presented to the Dubai Municipality proposed the tower was not a single tower but in fact six individual towers stacked on top of one another. Each individual tower comprised a community served by a set of amenity floors or showroom space at its base. The municipality agreed and granted showroom classification for each of the amenity floors. DM regulations for showroom spaces set the SHGC at 0.35 with a U-value of 1.9W/m²K. The SHGC of the transparent glass in the residential units is 0.32 and assembled in the IGU provided a 1.9W/m²K which meant this glass could be used uninterrupted around the perimeter of the amenity floors; no spandrel panels, no louver inserts, no pattern. To accentuate an uninterrupted feeling on the interior, custom exterior mullions were developed that tapper as they project from the curtainwall creating a diminishing affect. Often times, entirely glazed curtainwalls use glass fins to maintain transparency but the glass fins cut into the interior space creating modular chambers. This was to be avoided; it was desired to create a continuous glass skin that occupants could walk along enjoying panoramic views of the city. The mullion spacing took the same cue developed for the residential units; a larger central unit flanked by smaller units on either side. The width limit for most post fabricating glass manufacturers is two and a half meters. This width accommodates tempering, laminating and the application of low emissivity coatings. The width of the central units for the amenity floors is two and a half meters and they run floor-to-floor, five meters in height. They are centered between the columns with smaller flanking units on either side. Typically, the curtainwall is recessed within the columns so there is another mullion centered on the column providing for a completely glazed wall.

Figure 6. Entisar Tower Podium and Main Entrance. Seventy-Eight foot high double glass skin suspended from mechanical floor

Podium Facade Type

The idea of showroom classification was taken to an extreme for the third façade type, the podium skin. Several considerations led to the design of the podium. The first being the programmatic use of retail space which requires the clear expression of goods within. The second is the proportion of the podium in relation to the overall scale of the tower. The third is the scale suitable to Sheik Zayed Road comprised of sixteen lanes of fast moving traffic. The fourth factor was a play on traditional podiums, which are solid, perceived as strong to support the tower. The design goal was to invert this relationship and create a glass block upon which the tower sits striking an air of lightness for the overall tower.

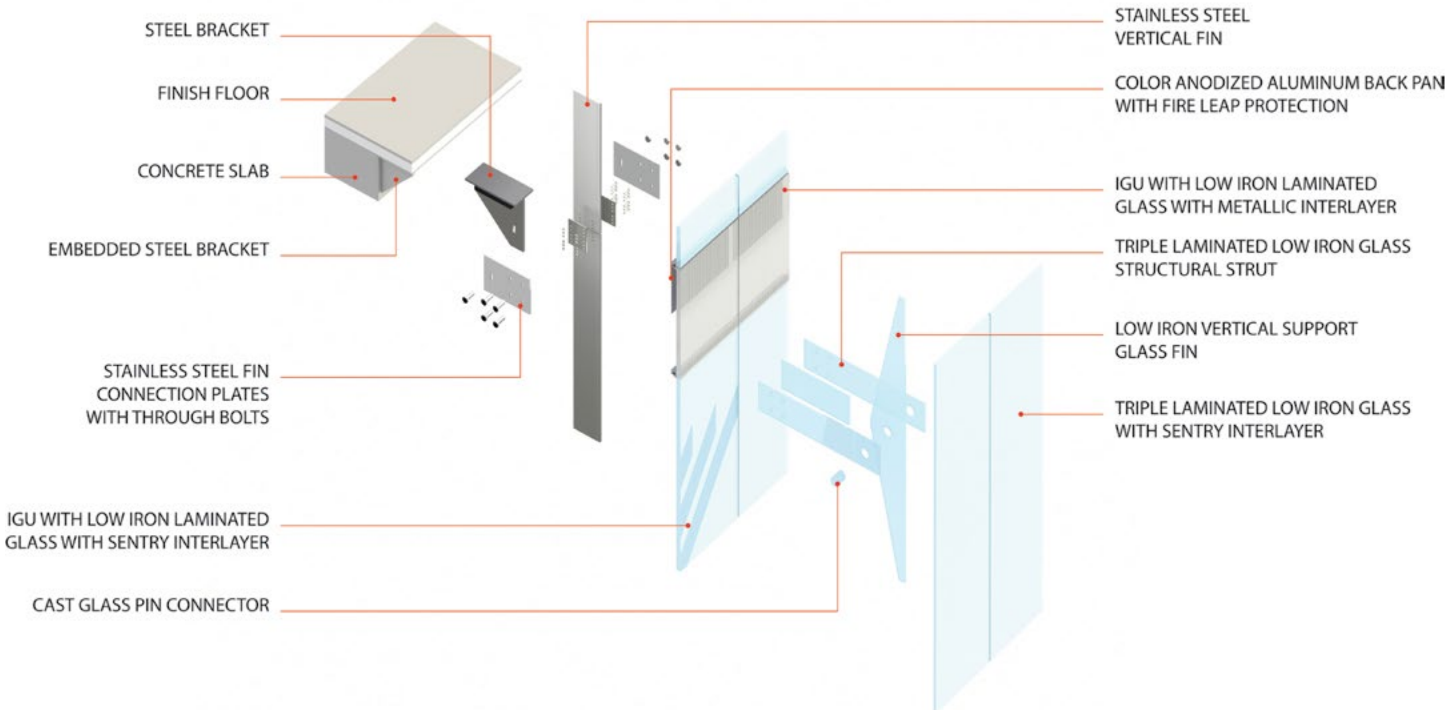

Figure 7: Entisar Tower Podium double glass skin module exploded axon of components.

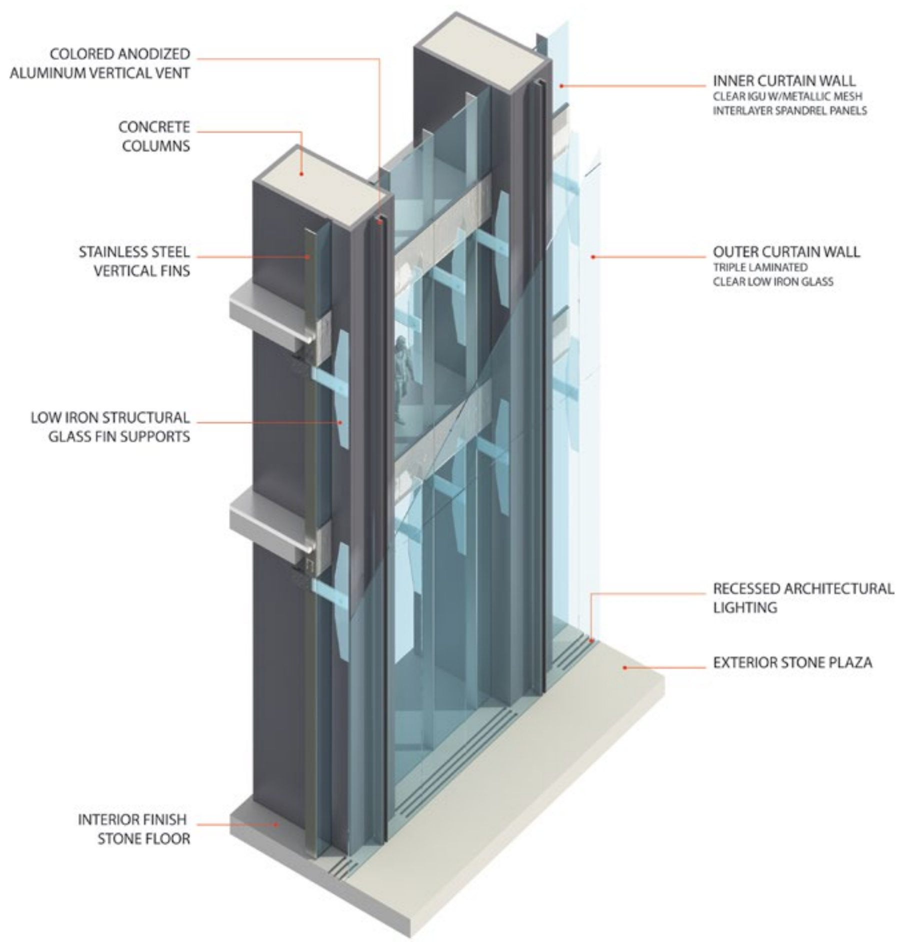

Figure 8: Entisar Tower Podium double glass skin module cut-a-way.

The solution was a retail base with a double glazed skin. The outer glazed skin completely envelopes the base of the tower rising to an uninterrupted height of twenty-four meters. This entire glazed skin is hung from the underside of the fifth floor through a unique suspension system. This suspension system consists of stainless steel hanger-plates inboard of the interior glazed skin. The hangers follow the same mullion spacing rules of the amenity floors not exceeding a two and a half meter spacing centered between columns. Glass struts in the form of triple laminate glass plates are connected to the stainless steel hanger plates. The glass struts in turn connect to a triangular glass bracket attached to the outer triple laminate glazed skin by means of a single cast glass pin. The outer glass skin and supports are completely glazed no steel struts, pins or clips. There are continuous vertical vents centered on the face of each column that relief the air within the double skin. The interior glass skin follows the formula of the amenity floor framing but without the exterior mullions.

The double glass skin deemphasizes the pancaking and related scalar effect of consecutive floorplates. The floorplates are held back to the interior skin allowing for an uninterrupted exterior skin. In the cavity between the two a reflective metallic screen is suspended. When lit from below the screen accentuates the verticality of the uninterrupted skin, creating a shimmering lantern affect at the base of the tower.

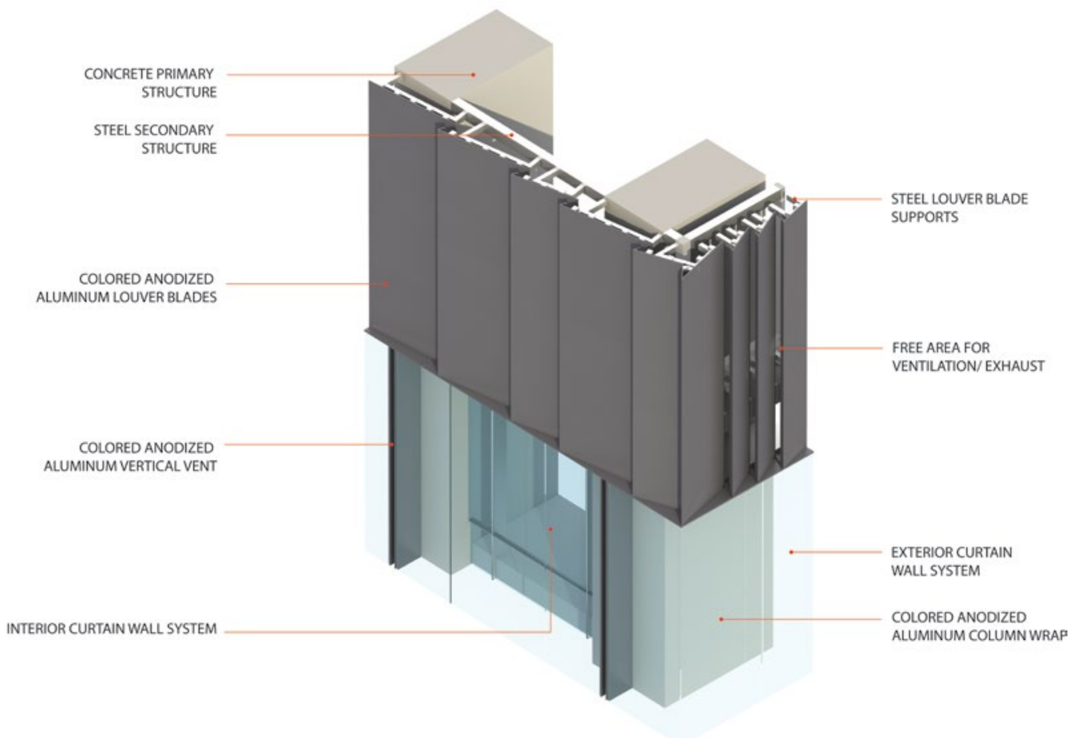

Figure 9: Entisar Tower Mechanical Floor Façade type, Louvers enclosing continuous plenum space.

Mechanical Floor Facade Type

The mechanical floors represent the last façade type of the four and complete the building envelope for Entisar Tower. The mechanical floors occur approximately every ninety meters due to pressure restrictions of the chilled water cooling system. They are double height spaces consisting of a floor and mezzanine measuring twelve meters in height. To work with the organization of the tower they typically occur at the underside of each set of amenity floors and feed services down to the residential block below. Consequently, the stacking that occurs is a residential block sitting on top an amenity block sitting on top of a mechanical block. This is a consistent organization and reading of the tower. The discreet relationship of these pieces was emphasized to break down the scale of the tower and underscore the unique functionality of each piece.

Although these floors are not conditioned, they do have a weather and airtight enclosure that prevents air infiltration that can contribute to stack effect. The perimeter building enclosure for the mechanical floors is in fact a double skin. The inner layer consists of an airtight masonry assembly and the outer layer is an aluminum louvered skin enclosing a continuous plenum. Intake and/or exhaust ductwork terminates at the masonry wall with adequately sized mechanical louvers. The plenum is divided into chambers based on the free air area requirements related to each individual system and distance requirements between intake and exhaust. The exterior louvered skin is modulated into a number of varying panel widths. The louvers run vertically and in plan have a chevron shape. There are six different louver blade widths ranging from five hundred to two thousand five hundred millimeters wide and projecting out three hundred millimeters. The short edge or return side of the louver blade has a two hundred millimeter wide slot. This width multiplied by the twelve meter height of the louver provides the free area for the each louver blade; just over two square meters per blade. The quantity and width of exterior louvers change in relation to the demands of the inner plenum chamber free air requirements. Plenum chambers that demand a greater percentage of free area receive a greater number of exterior louvers that are typically small in width and vice versa for chambers with lower demands. On the exterior, this creates a variable modulated rhythm that serves to break down the uniform mass and animate the surface. LED light fixtures are located within the slot and shine out using the adjacent louver blade as a reflector, which creates a rhythmically modulated glowing effect at night.

Conclusion

Entisar will be the second tallest tower in Dubai once completed in 2020. It stands as a counterpoint to the tallest tower in Dubai, Burj Khalifa, in its slenderness ratio, the transparency of it skin and its elevated amenity floors and garden spaces to enhance living. Entisar tower was designed from the inside out placing the importance on the resident and their experience of high-rise living removing barriers between the occupant and their surroundings. Entisar stands unique amongst super tall towers in that it is not just a series of repetitive floor plates but it is a composition of individual neighborhoods organized in a vertical community. Entisar is an example of urban living in the twenty-first century. It takes density as its cue and offers leisure and recreational activities combined with services to enhance the quality of life for its residents. Entisar Tower represents the next generation of skyscraper design increasing height, density, and slenderness ratio but offering all the comforts of home.

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Credits:

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Glazing Consultation: PPG Industries Inc., Annissa Flickinger, Overseas Architectural Manager

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