Facade Design for Super High-Rise Building in Subtropic Region in China

Super high-rise building will always be iconic elements at any location. Accompanied by the growth of building technology and urbanization, tall and supertall buildings have emerged rapidly in the past two decades.

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As a major energy consumer, the high-rise building does not ordinarily conjure images of sustainable design. But a new generation of tall buildings could incorporate new developments in technology and design to produce responsive, energy-efficient buildings.

A high-rise building, can be understood in terms of systems and subsystems in which Environmental systems of Indoor Air Quality, Comfort, and Serviceability can be related to subsystems of Structure, Transportation, Mechanical, and building envelope. In sustainable tall buildings the interdependence of these systems and subsystems becomes immediately apparent where the design and construction of one subsystem impacts other subsystems.

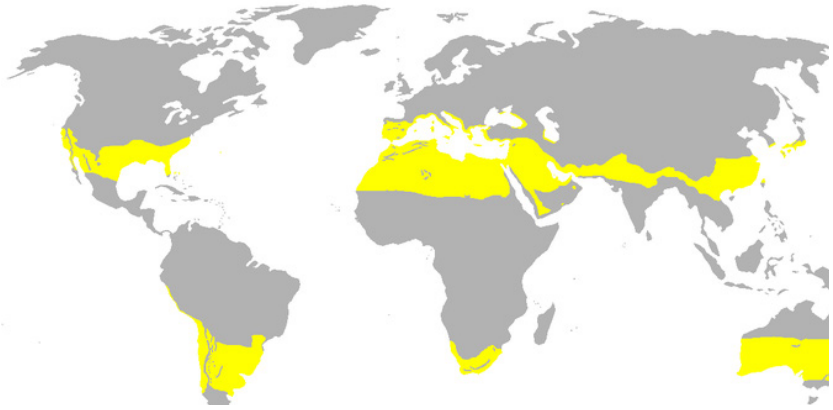
In current practice, building envelope is being designed as a separation between exterior and interior environments, to provide an enclosure for comfortable indoor environment. In China, beyond aesthetics, façade systems are addressing the unique needs of Chinese climate and geography. The majority of southeast China falls into the humid subtropical climate category, experiencing hot humid summer and mild winter.

This paper is to identify the appropriate sustainable façade type for high-rise building in southeast China, and four case studies will be used to demonstrate the variety façade type.

EAST CHINA CLIMATE CHALLENGE

In East Asia, Subtropical climate zone is found the southeastern quarter of mainland China, the northern half of Taiwan, northern Vietnam, narrow areas along the coast of South Korea and Japan. Cities on the equator-ward boundary of this zone include Hong Kong, Shanghai, Nanjing, Shenzhen, Guangdong.

The East China climate is sometimes decided by the typhoon from the seas



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and the ocean current. Different from the other China regions' climate, East China climate are affected all years around by two factors—the monsoon from the continent, the ocean current and the typhoons from the both seas. Controlling by the monsoons from the continent and sea and the typhoons from the both seas, the features of East China climate include hot and rainy in the summer, cold and dry in the winter, the rainfall appears in the summer especially in the August and September. Due to the temperament climate condition most high-rise building consume major amount of energy in cooling and heating all year round.

The design challenges brought from the climate condition as well as urban condition are:

- High temperature and extensive solar radiation in the summer
- Heavy rainfall during summer
- Strong wind during winter
- High humidity in summer and winter
- Air pollution
- Urban heat island effect
- Noise

BUILDING EFFICIENCY REQUIREMENT IN CHINA AND FAÇADE DESIGN TREND

In this paper the super high-rise building is defined as a building more than 30 stories tall. (100meter).

For high-rise office buildings the façade is the largest surface area of the building perimeter where direct heat exchange between the outside and inside environment takes place and therefore can contribute significantly to achieve more sustainable buildings. In China, due to stringent energy and environmental targets set by governments and higher comfort requirements (thermal, daylight, acoustics, outside view) required by clients and tenants, traditional façades in high-rise office buildings face difficulties to comply. New generation of high-performance façade will not only play the key role in energy efficiency, also will help to solve other built environmental issues.

BUILDING EFFICIENCY REQUIREMENT IN CHINA AND FAÇADE DESIGN TREND

Performance is essential to modern tall buildings in China. Official data shows that in 2008, building energy consumption accounted for 27.5% of China's total energy consumption (Zhu Neng 2009). Last year China published its energy conservation "white book" as part of the 12th five-year plan, in which the central government set goals for different regions. For Beijing and

Shanghai, the energy consumption is planned to be reduced by 17% and 18% respectively, which will result in a cumulated energy saving of 32.01% and 34.4% compared to energy consumption in 2005.

China also published the document –GB50189: 2005: Design Standard for Energy Efficiency of Public Buildings. Compared to the current European energy conservation regulations, such as the UK Building Regulation, Approved Document Part L 2010- L2A, GB51089 sets much more stringent requirements. For Beijing climate, GB 51089 requires that, for an individual elevation, when the window-wall ratio is between 50% to 70%, the U-value of the curtain wall vision area shall be no higher than 2.0 W/m2K and the U-value of the opaque area shall be no higher than 0.6 W/m2K. This is equivalent to a U-value 1.3 –1.58 W/m2K for a curtain wall overall with 50–70% window-wall ratio respectively, while according to UK Building Regulation Part L the compliance value is 2.2 W/m2K for curtain walls.

Increasingly stringent regulations imposed in recent years mandate the adoption of high performance façades in new construction and encourage the substitution of existing-low performance envelops in older high-rise buildings.

The results are now evident both in terms of environmental performance and architectural impacts. Single-glazed, fully transparent façades that were common in the first 20 years of the "curtain wall" era, have evolved into the complex double-skin, multi-layered façades of current buildings, which characterize the visual image of many skyscrapers. Though such examples represent an important opportunity for architects and engineers, higher performances can be attained with the adoption of high- performing materials applied on simpler envelope systems.

Innovative and iconic high rise buildings all over the world combine latest integrated design know-how, energy-efficient building envelopes and up-to-date construction technology to create an optimized, multi- functional, recognizable and unique appearance.

NEW FAÇADE TYPE

Double Skin Façade

The double-skin façade is ventilated with outside air and allows the ventilation of outside air through operable windows. The double-skin façade is conversely characterized by an openable double glazed inner windowpane and a closed single windowpane on the outside. The cavity space between the glass structures is connected to the outdoor air to induce natural ventilation. The solar-and daylight controls is also situated in the air cavity. The double-skin façade is of a bigger size than the climate façade. In practice the depth of air cavity varies between 200 and 1000mm. An air cavity depth smaller than 200mm significantly reduces the air change rate in the room behind a double-skin façade.

Climate Façade

The climate facade is characterized by a closed double glass layer in the outer structure an operable single glass layer in the inner structure with a cavity space varying from 60 to 200mm. The cavity space between the glass structures is ventilated by means of exhausting air through the space with air drawn from the room on the innerside. Solar and daylight control facilities are located in the cavity space. The climate façade withstands maximum outdoor climate influences and offers a solution to reduce the problem of heat loss in

winter and heat load in the summer, particularly in high-rise building, which have a relatively large and preferably clear glass façade area.

Closed Cavity Façade

The closed cavity façade provides all the advantages of a naturally-ventilated double skin façade without the need for opening elements, deep façade cavities for effective ventilation or the risk of interstitial condensation. It consists of an internal double (or triple) glazed unit and external single glazing with an intermediated blind system.

In order to prevent condensation within the cavity, controlled low volume/low pressure dry air is introduced into the cavity. The flow rate is an engineered balanced design that ensures condensation risk is eliminated by using the minimum level of energy for the dry air system. The system doesn't require the tedious cleaning and maintenance work within the cavity caused by heavy pollution or dust. Therefore it has great advantage in major city in China where pollution and air quality is a main concern.

APPLICATION IN PROJECT

Siemens Center Shanghai- Double Skin Façade

The Siemens Campus in Shanghai consists of four buildings (Phase 1) with a 13-floor high rise main entrance building being the gateway to the four building compound. The innovative skin is a major feature to lower the total energy consumption of the building by more than 1/3 compared with others.

With a double-skin type of facades, there is an insulated layer (primary façade) at the inside, with operable windows for natural ventilation, a permanently ventilated cavity where an external sun shading device is located, and an outside mono-plane. The "additional" plane, forming the second skin, meets a set of important requirements:

- Protection of motorized external sunshade blinds from wind, dirt and debris; putting the sunshade outside the insulated envelope is the key to low cooling energy, and keeping them clean is the key to efficient use of daylight direction devices;
- Reduction of outside noise level to enhance natural ventilation through operable panels without being disturbed by traffic noise;
- Reduction of wind effects, providing protection from wind draft through natural ventilation openings especially in open-plan offices. The very large, 2.8 x 4.0 meter size façade units were preassembled completely in the factory, with operable louvers, motorized blinds, and glass and glazing which were lifted up on site without the need for any external scaffolding. Therefore, installation speed was very high and installation quality was very good.

Pearl Tower, Guangzhou –Climate Façade

It is a 71 story, 310meter tall office tower with associated conference facilities, a total gross area of approximately 2.2 million square feet.

The exterior enclosure for the tower is an internally ventilated climate façade system consisting of a double glazed insulated glaze unit with integral spandrel panel in a 3.0 x 3.9 meter unitized panel. Tow hinged 1.5 x 2.8 meter single glazed leaves are fixed to the back face of the mullion to create a 200mm cavity with a small gap at the base. Within the cavity is a motorized perforated

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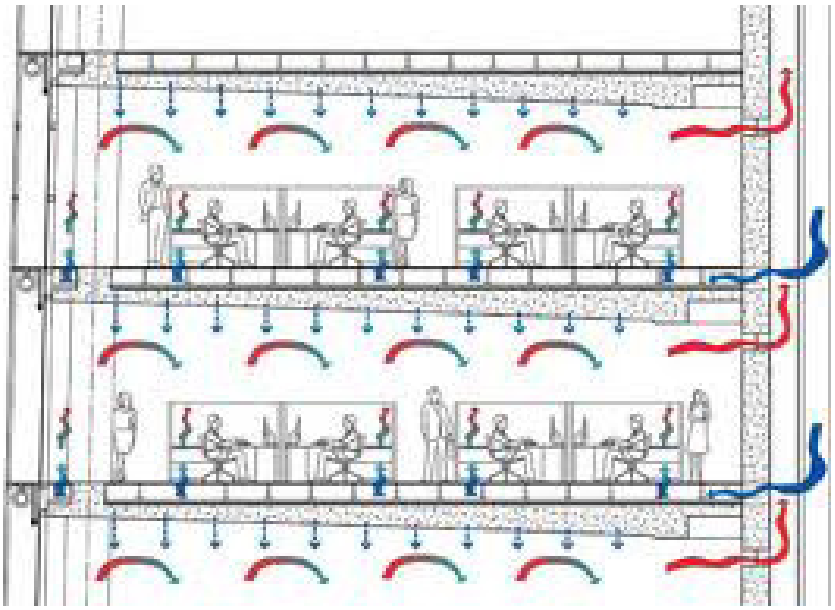
silver venetian blind. The blind will always be fully extended within the cavity, however it has 3 modes of operation: open, closed to 45 degrees or fully closed depending on the angle of the sun. The blind position is determined by a photocell that tracks sun position and is connected to the building management system which activates the blind position to ensure occupancy comfort from both solar gains and glare. Exterior glazing will be insulated, tempered glass with a low-E coating, the inner layer will be operable clear glass panel and each panel can be opened for maintenance. The wall will be internally mechanically ventilated every floor. The cavity acts as a natural chimney using the cooler air from the occupied office areas to enter the cavity via a gap at floor level whilst acting as pressure relief valve to allow more fresh (make up) air to enter the occupied areas. The trapped hot air in the cavity is then extracted through the ceiling void and is used either as pre-heat or pre-cool depending upon outside air temperatures.

By maintain a low temperature on the inside layer of glass, closest to the occupants, the mean radiant temperature will be decreased, thus reducing the "operative" temperature of the space. This lower operative temperature will create an environment of improved thermal comfort at the perimeter zones and should directly improve the flexibility and usability of the area closest to the exterior glazing.

Wuhan Tower – Closed Cavity Façade
Wuhan tower is a 125 story, 636 meters tall mix-used building with hotel, residential and office function.

The closed cavity façade can provide high thermal performances, dramatically lowering heating and cooling demands. In addition, users get the maximum from the usable space, due to the optimized thickness of the external wall, coupled with the fact that the internal glass cannot be opened, resulting in a very small loss of usable area.

Figure 2: Siemens Center.



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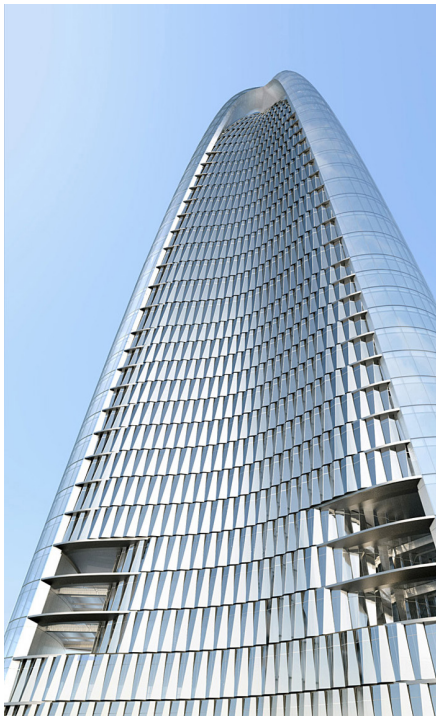

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1 Peking Road– Triple Skin Façade

1 Peking Road(Kowloon) was in 2003. The building design strongly emphasizes the green building approach. In the top of the roof there are BIPV integrated. The façade layout recognizes the different orientations of the building and there is a call for action to natural daylight in the offices.

One of the aims of the development was to provide all users of the building with a direct and intimate relationship with a direct and intimate relationship with the surroundings via a transparent external building envelope. Although this required clear glass to be specified, the designers were able to offer an environmentally sensitive cladding system. The tower features a triple-glazed active wall system; combing three layers of low emissivity clear glass with a ventilated cavity that results in high light transmission yet a low overall thermal transfer value (OTTV). Venetian blinds are housed in a 200mm air gap in the glazing system and are operated by a computerized system. When sunlight sensors detect a need for shade, the blinds automatically descend to cut glare and heat gain in the interiors. Sensors also control the blinds' blade angles and power for their operation comes from an array of photovoltaic panels located at the rooftop. The south elevation features innovative arrangements to reduce solar gain yet allow increased light transmission at the same time.

CONCLUSION

As a major global economy, China recognizes that the improved standards of living and competition have lead to a greater energy demand. Energy demands though are increasing at a greater rate than sustainable supply and greater energy efficiency technologies in buildings are being applied. Mixed-use super high-rise buildings entail a more complex spatial logic than had been developed for commercial office buildings and present challenges to provide thermal comfort while being energy efficient. Particularly, most dense urban areas in China are located in subtropical regions that provide a unique set of climate conditions that need to be addressed at early stages of designing and planning. Future advanced façade design research is needed in order to understand sustainable design in a more comprehensive way and apply its principles to tall buildings

Figure 3: Pearl Tower, Guangzhou –Climate Façade.

Figure 4: Wuhan Tower.

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in subtropics region. The performance of existing high-rise buildings that have been designed with sustainable facade needs to be evaluated. Better integration models need to be developed. More sophisticated computer modeling programs need to be developed to simulate changing environmental conditions that impact the design and performances of tall buildings and to facilitate an integrated approach to planning and design of tall buildings.

Figure 5: 1 Peking Road- Triple Skin Façade.