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Mediating Scale, Performance and Iconicity: A 21st Century Supertall Tower for Guiyang

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A series of challenging site constraints prompted an innovative structural solution for the Guizhou Culture Plaza Tower (GCP), through which a new performance-based expression was created for Guiyang's skyline. A design solution that values performance, iconicity, and the public realm with equal weight was a result of an integrated and collaborative process. By leveraging technology, the GCP Tower is an example of an emerging new design language that is reshaping supertall tower design; an integrated workflow that is based on solving performance-based criteria as its primary focus.

Guiyang – A City in Flux

Located in China's lush and mountainous Guizhou province, Guiyang is a city that is experiencing explosive growth. Currently ranked as a second-tier city by Chinese national standards (Explore and Compare China, 2015), Guiyang's economic and development potential make it a premier provincial capital, booming with intra-China ecotourism amidst good air quality and a rich ecological, cultural, and historic setting (Air Quality Index China, 2015). It has a population of approximately four million people, a figure which is projected to double within the next 15 years, as a result of the economic shift from rural to commercial. To meet the projected demand, rapid growth, and development is occurring across the metropolitan landscape, a place characterized by the imposing presence of mountains and giant limestone karsts. The constantly changing ground-plane impacts the scale and morphology of new development and creates challenging conditions for new construction. In contrast to this topographic condition, a handful of key environmental conditions make Guiyang an ideal location for building vertically: mild weather, favorable soil conditions, diffuse-light conditions, low wind patterns and great air quality.

A Tower for Guiyang's Future

The Guizhou Culture Plaza Tower's site is located at the intersection of Guiyang's cultural and commercial axis, a strategic position where it can anchor and catalyze future development. The tower will be the tallest in Guiyang and is bordered to the West by the central retail area of the GCP Master Plan, and to the East by the Nanming River and the Shixi River. The site is planned as a node in the larger network of Transportation Oriented Development that will link regional and local transportation networks. The larger vision for the historic city center includes renewing key transportation arteries and leveraging existing city assets to increase both land value and public wellness. The Guizhou Culture Plaza Master Plan calls for a total area of 1.4 million m^2 and includes the GCP Tower (mixed-use, office, and hotel), a performing arts center, two SOHO (live-work prototypes) towers, a retail mall, and several residential towers. One of the primary goals of this project is to create a rich network of open space along the Nanming River, renewing the existing river walk and interconnecting the existing assets with the new development. To achieve this, an emphasis was placed on enriching the public realm with high-quality open space that activates the ground plane and creates meaningful relationships with the city's existing assets.

Programmatically, the project brief called for the following mix of uses in a single, 521 meter-tall tower: 60% office, 37% hotel, and 3% observation deck (height until the last occupied floor: 450 m).

Favorable Conditions for Supertall Design

There are several natural factors which make Guiyang an optimal location for a supertall tower, including the following:

1. Guiyang has a temperate climate (China National Tourism Office, 2015), generally lacking direct sunlight. Most days are brightly lit with neutral, diffused light. These solar conditions also remove the need for intensive solar shading strategies, and negates the potential use of solar power collection technology.
2. The wind speeds are relatively calm throughout the year, with average speeds around 2.4 m/s (China Weather Institute, 2015). This precludes the integration of wind-harvesting technologies, but also reduces the potential impact of high lateral forces.
3. Good air quality favors Guiyang throughout most of the calendar year. Averages range between "moderate" to "satisfactory" (China National Tourism Office,

Opposite: Site plan of the Guizhou Culture Plaza development in central Guiyang. Source: Zhongtian Urban Development Group Co., Ltd

Top: View of the Nanming River, Zhucheng Square, and the GCP Tower. Source: Zhongtian Urban Development Group Co., Ltd

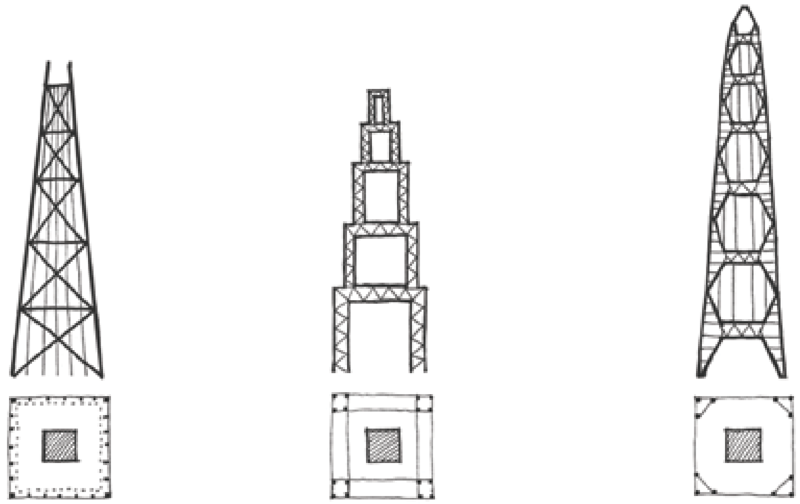
Project Data:
Guizhou Culture Plaza Tower

Location: Guiyang, China
Height:
Architectural: 521 meters (1,709 feet)
To Tip: 521 meters (1,709 feet)
Occupied: 447 meters (1,467 feet0

Floors Above Ground: 109
Area: 1,470,000 m^2 (15,822,948 ft^2)
Use: Hotel / Office

Proposed: 2010

Owner/Developer: Zhongtian Urban Development Group Co., Ltd
Architect: Skidmore, Owings & Merrill LLP (design); CAPOL (architect of record)
Structural Engineer: Skidmore, Owings & Merrill LLP (design); Architectural Design and Research Institute of South China University of Technology (engineer of record)
Other Consultants: FAST Fire Safety Performance Evaluation (fire); Guiyang Architectural Survey Design Ltd. (geotechnical); MVA Transportation, Planning & Management Consultants (traffic); Arup (vertical transportation)



Major Performance Attributes	Diagonal Braced Tube	Super Frame	Articulated Super Frame
Gravity	+	-	+
Lateral	+	+/-	+
Ductility	-	+	+
Overturning Moment	+	+	+

2015). During the swing season and summer months, natural ventilation potential increases which diminishes the load on environmental systems and increases the potential for localized comfort control.

4. The soil conditions have proven to be optimal for the structural foundation requirements of supertall tower design. With favorable soil conditions, the challenging aspect of placing deep foundations within a site that is bordered by two rivers is lessened.

Together, these create an open field for the implementation of new structural innovations. This experimentation has as a primary objective to further the evolution of mixed-use supertall design and achieve greater design efficiency.

Design Concept

The concept for the GCP Tower captures the most efficient performance attributes of two legacy structural systems, the tapered diagonal braced tube also used for the John Hancock, and the stepped superframe system conceptualized by Fazlur Khan (Khan, 2004). The diagonal braced tube system is adjusted to absorb higher seismic energy, while the superframe system is streamlined to eliminate transfers, resulting in the "Articulated Superframe system," a 21st Century structural system for superior performance to extreme environmental loads.

The tower's Articulated Superframe structural system is a direct response to the challenging constraints of the site. By orienting the tower diagonally on the site, the four corners of the plan leverage the stability of the tower in an efficient manner to resist the wind and seismic forces. The four-corner superframe columns are separated by 65 m, resulting in a minimized aspect ratio of 1:8.

The tower's floor plan tapers along the building height, from 65 m x 65 m at ground level to 45 m x 45 m at the roof. The gravity system typically consists of composite floor framing, and is comprised of composite truss deck supported on steel beams, which span from the steel perimeter columns to the reinforced concrete core. Typical gravity steel beam spacing is 3 meters on center. This lightweight efficient system minimizes the building mass, thereby reducing the overall seismic demands on the lateral load resisting components and the gravity demands on the vertical gravity components.

The primary structural system consists of a conventional ductile reinforced concrete core and perimeter articulated superframe system. The superframe system is symmetric on both axes of the building, and is interconnected with the superframe girder on a 16-story module.

The superframe girder also acts as a mechanism used to further optimize both building gravity and lateral load distribution. Each superframe girder distributes the gravity loads from the perimeter 16-story column segment to the corner lattice superframe system. By effectively managing the distribution of gravity loads to the outside corners of the superframe, the system provides maximum resistance to overturning and eliminates tension loads induced by wind and seismic lateral forces. Additionally, by creating a 16-story module, these perimeter steel columns can maintain

“The concept for the GCP Tower captures the most efficient performance attributes of two legacy structural systems, the tapered diagonal braced tube used for Chicago’s John Hancock, and the stepped superframe system conceptualized by Fazlur Khan.“

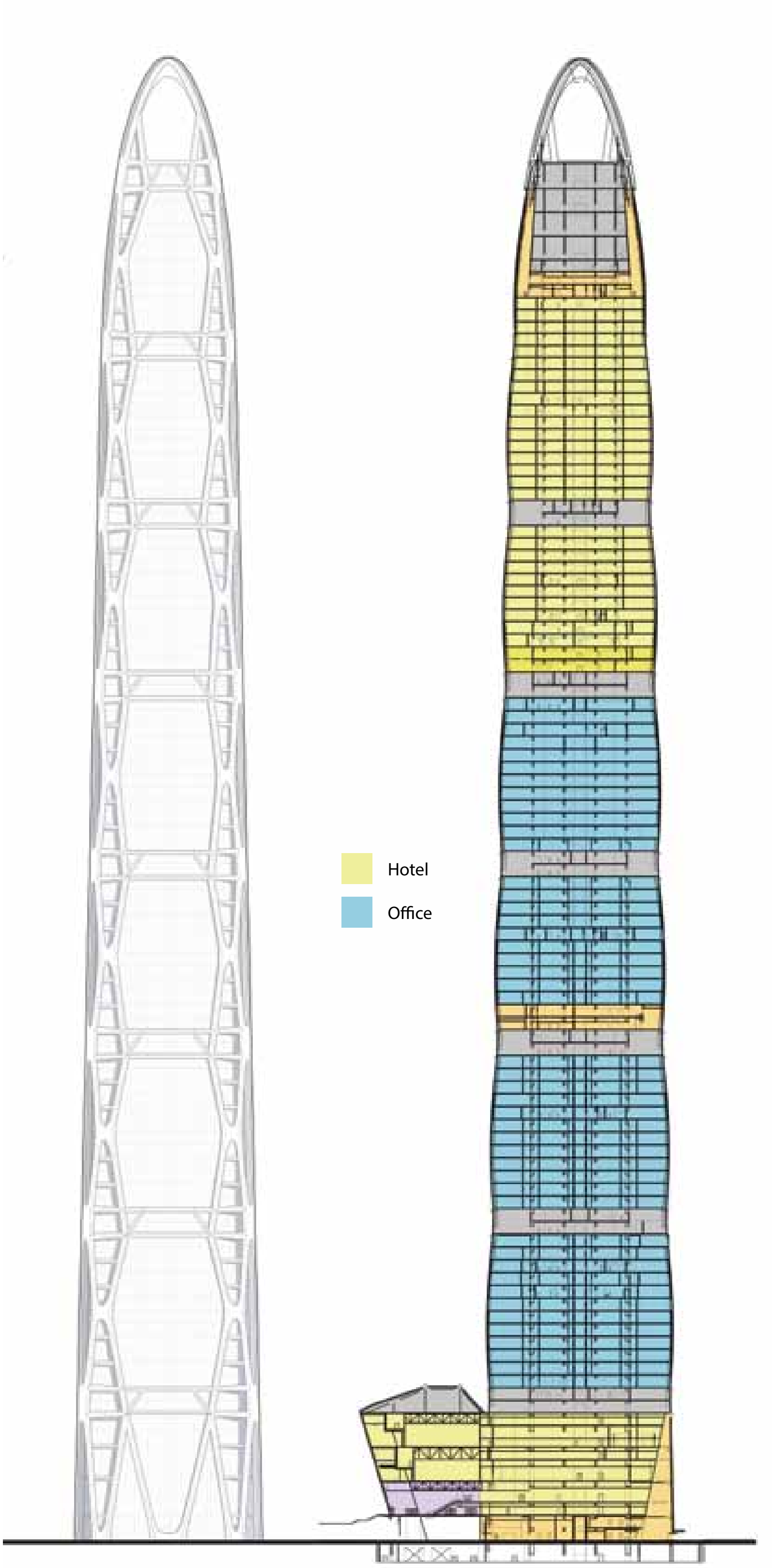
Opposite: Comparison of different types of structural frames. Source: Zhongtian Urban Development Group Co., Ltd

Right: The tower is composed of 16-story modules which incorporate separate programs. Source: Zhongtian Urban Development Group Co., Ltd

the same size up the building, thereby limiting their impact, and maximizing the occupied floor plate areas, and generating a repetitive construction module.

The tower employs a dual lateral load resisting system, which consists of a conventional ductile reinforced concrete core and a perimeter ductile articulated superframe system. The superframe system concentrates material at the corners in the form of a “lattice” while at the same time providing an “open” corner. The “open” effect in the corners of the tower was utilized to efficiently disrupt the wind vortices on the tower, thus reducing the overall lateral loads. This results in an optimal and sustainable use of materials.

The superframe system articulated around the perimeter plays an important role in dissipating energy from lateral seismic events through ductile moment frame action, and the interior reinforced concrete core provides shear action, which dissipates energy through the link beams. Load sharing and interconnectivity between the interior core and the superframe is ensured by moment frame beams at the corners



Bottom: East–West axial alignment from Zhucheng Square to the GCP Tower. Source: Zhongtian Urban Development Group Co., Ltd

Opposite Top: The base of the tower connects the private and public realms. Source: Zhongtian Urban Development Group Co., Ltd

Opposite Bottom: View of the lobby-wall screen, which helps filter circulation and is a primary way-finding device. Source: Zhongtian Urban Development Group Co., Ltd

of the building on each floor plate and through thickened slabs at the top and bottom levels of each superframe girder, which act as virtual outriggers. This provides additional stiffness to the lateral load resisting system and ensures proper load sharing between the two systems.

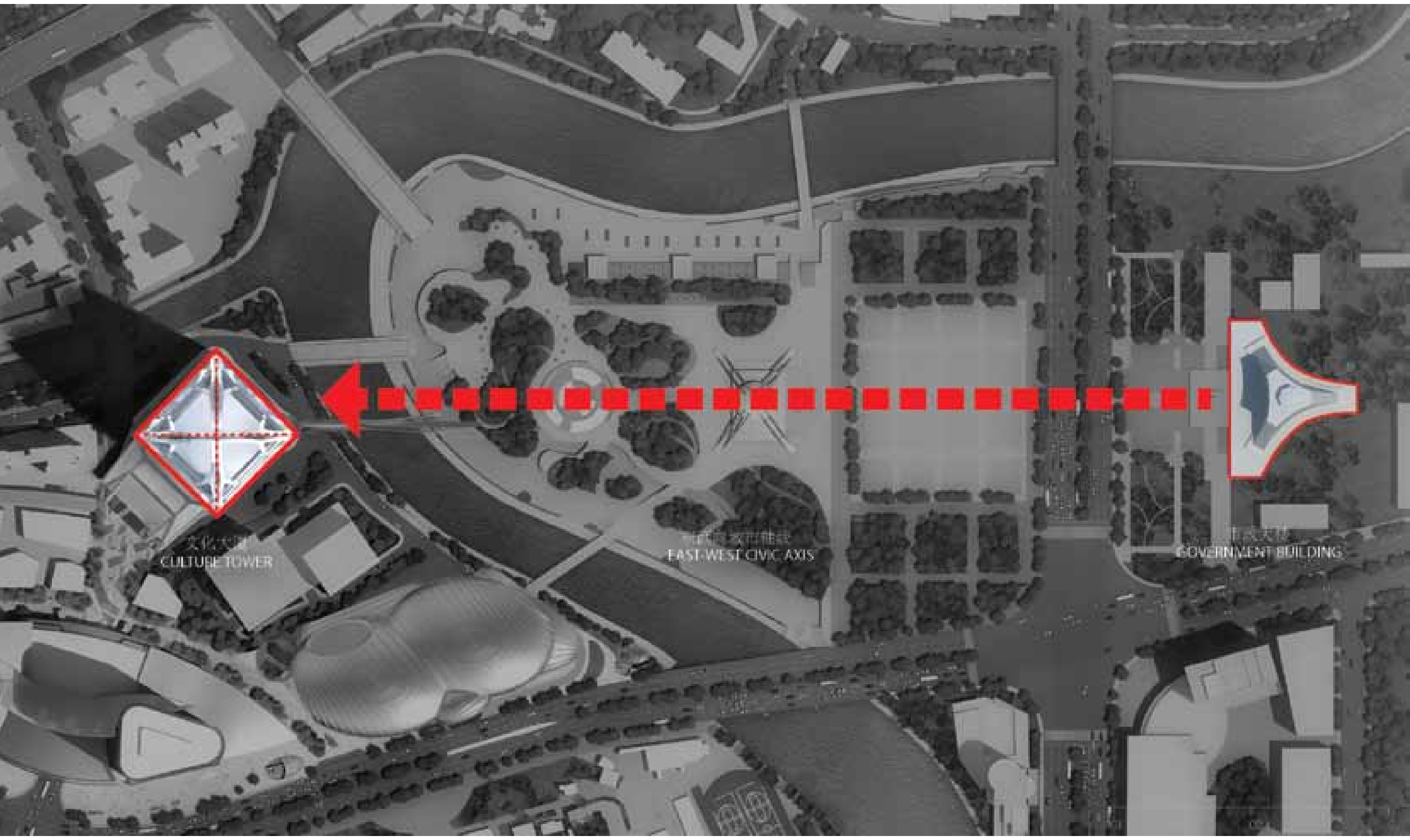
The clarity in structural form reflects the path of loading and distribution of forces in the overall frame, resulting in a distinctive architectural expression. The geometric rhythm of the articulated superframe is further integrated into the architectural vision by revealing the lattice superframe columns, opening up the corners to minimize wind loading, and developing areas of refuge in strengthened zones within the superframe itself.

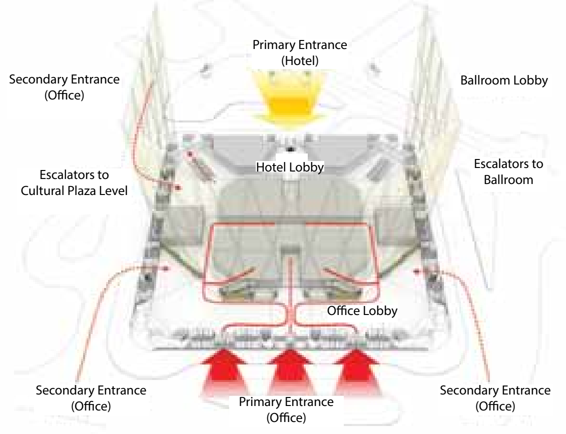
Symbolic Axial Alignment

Directly opposite the GCP Tower site lies Zhucheng Square, an important public asset and heavily programmed open space. The square itself is a multi-level hybrid of retail space and civic plaza, which has at its heart a series of monuments that sit on an east-west axis aligned with the city's main government building. One of the primary goals for siting the tower was to align with the civic axis of Zhucheng Square. The base of the tower was rotated by 45 degrees to further heighten this alignment and to meet the vehicular circulation needs at grade. Also, the perception of depth from a Zhucheng Square vantage point is dramatized by the perspective, which is "forced" by the different lighting quality on each façade (shaded façade on the north side versus the lit façade on the south side). Given the prominent and open quality of Zhucheng Square, this effect on a viewer's perspective would be noticeable from many different parts of central Guiyang.

Activating the Ground Plane

Aside from the symbolic relationship to Zhucheng Square, the GCP Tower also creates physical links that engage the public realm at the larger scale of the city. One of the primary links is the Guiyang Bridge, which effectively links Zhucheng Square to the new retail area west of the tower. This pedestrian connection transverses the lobby spaces at the nine-meter level and activates multiple podium floors with public access. The public realm is engaged through the eastern link of the Guiyang Bridge and the





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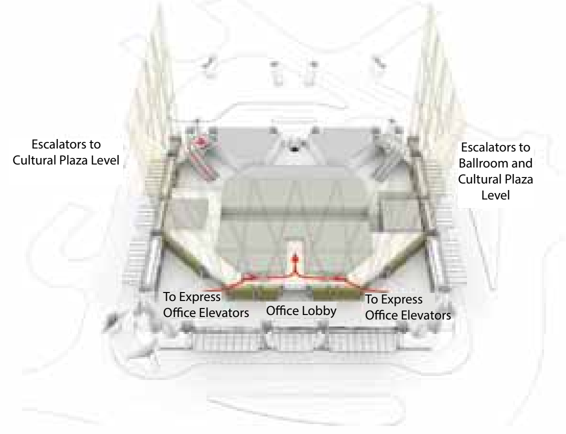

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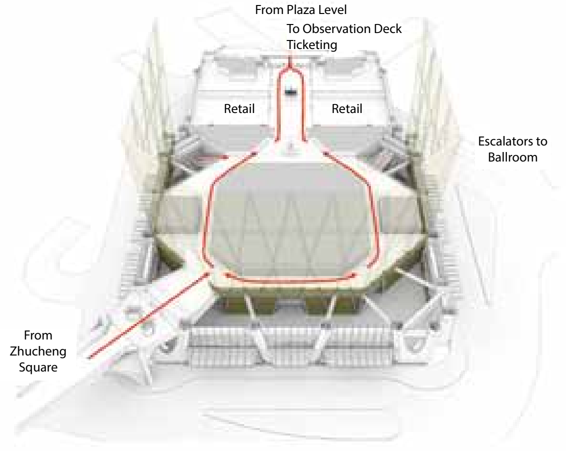

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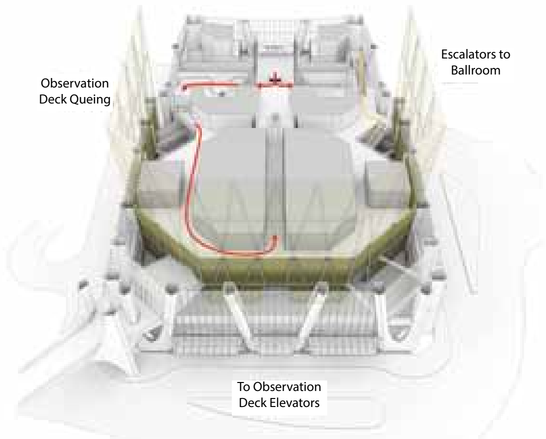


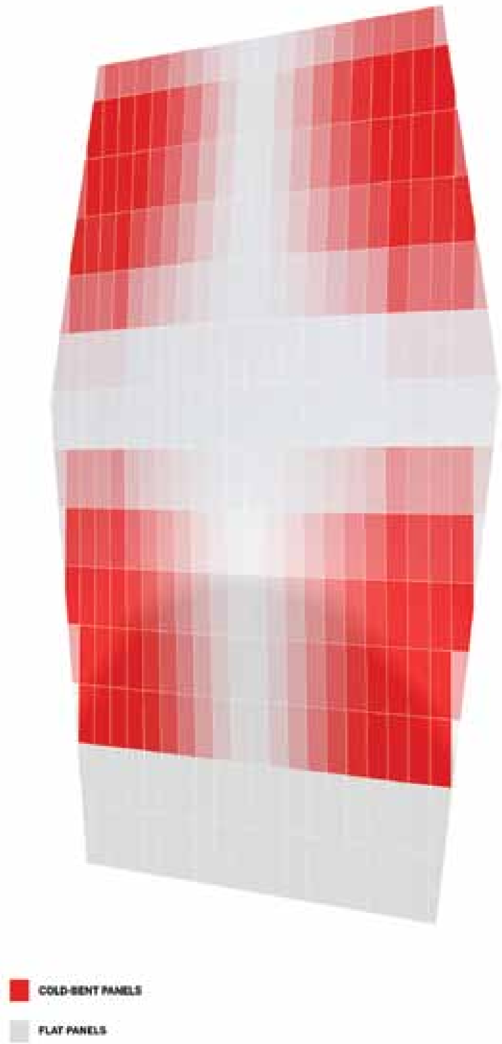
LEVEL 4

western connection to the new retail area of the Guizhou Culture Plaza development. The GCP Tower's podium negotiates the public and private realms it filters the circulation of the various (private) user groups from the three ground-floor lobbies, and organizes the public user groups at the elevated nine-meter public level (retail users, observation deck users, and pedestrian traffic).

Around the perimeter of the tower base, an array of smaller vegetated open spaces interweaves the drop-off areas to the Guiyang Riverwalk. Through these simple moves, the tower engages with the network of open space in Guiyang's city center, and creates a seamless, uninterrupted pedestrian experience around and through the GCP Tower.

An Integrated Design and Technical Approach

The current nature of large-scale construction projects requires an accelerated form of communication, and detailed coordination between multiple parties. With the collaborative platform developed for the GCP Tower,

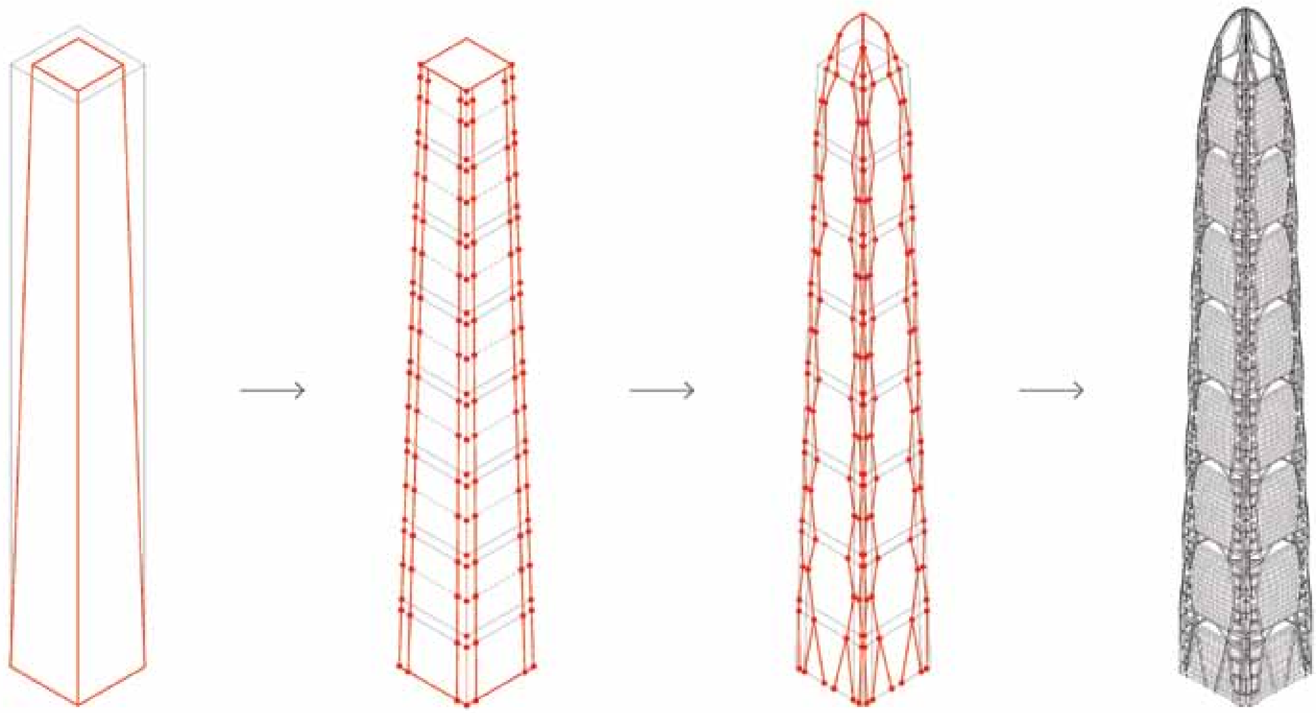


Left: Curvature of the tower's mid-section, with the cold-bent panels highlighted. Source: Zhongtian Urban Development Group Co., Ltd

Bottom: An integrated design process with a platform for rapid information-sharing. Source: Zhongtian Urban Development Group Co., Ltd

the coordination across design and construction disciplines began at a very early stage in the process.

The GCP Tower's 16-level structural module is designed to meet interdisciplinary criteria: program-based area targets, mechanical optimization, environmental optimization, and vertical transportation population constraints. This process of optimization created an interdependency within the conceptual design process. A live link between a central REVIT model and Grasshopper data (the Rhinoceros 3D plug-in and data platform) was created to track the optimization of this 16-level structural module. The data from Grasshopper was transferred to REVIT. Within REVIT the geometry was created natively



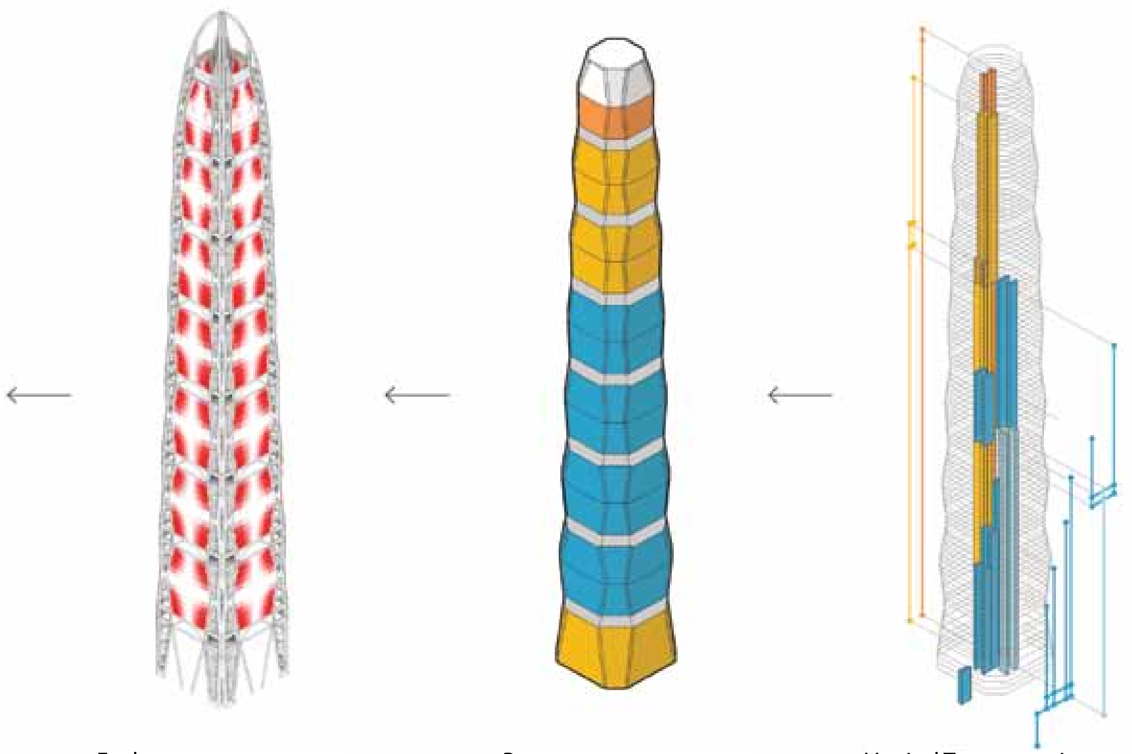
through a custom plug-in, which was developed through the REVIT API. This live link allowed both the structural and MEP teams to visualize the architectural concept model, and created the potential for rapid reconfiguration based on live data.

The process of curtain wall panelization also takes advantage of the REVIT API link by enabling the exterior enclosure team to rapidly populate the REVIT model with new panels. The optimization of the curtain wall required meeting manufacturer-based criteria for cold-bent glass for each of the mid-sections of the structural module. Within the threshold of 42 to 45 mm of deviation, panels were simplified to lower construction cost and complexity. Geometric "fitness" tests were performed to find the balance between creating unique panels and maintaining an expressed curvature. The 1.5-meter lease span gain proved valuable for the interior leasable areas, especially for the hotel; the top of the tower tapers significantly, and any additional space helps the room modules meet the target areas.

This integrated workflow also facilitated multiple iterations of the building form; the tapering of the tower was calibrated to optimize lease spans, and to achieve an overall tower efficiency that was ideal for both the office and hotel. To achieve the program targets, which were lease spans ranging from 10 meters to 13 meters, the taper of the tower was calibrated within the Grasshopper definition. The resulting data was fed into the structural team's ETABS model and the central documentation REVIT model. The 'Building Form' is therefore the result of an optimization process: programmatic, structural and environmental criteria are evaluated with equal weight. After an exhaustive series of iterative negotiations, the point of convergence between the multiple disciplines represents the final optimized solution.

Optimization 1: Tower Vertical Module, Taper, and Lease Spans

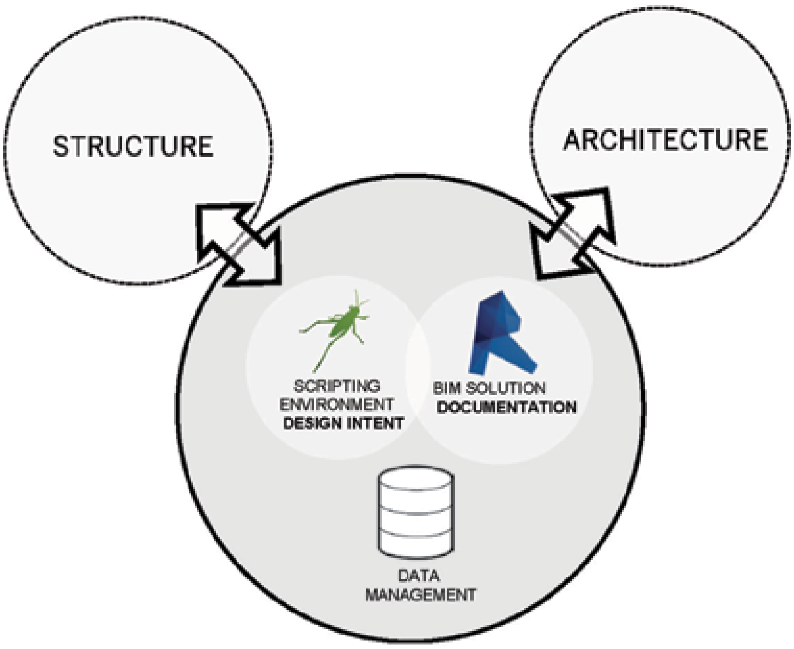
During the earlier phases of a project, it is often difficult to define the final program areas. Hotel operators usually have specific program requirements, which may evolve during the later stages of the design process. For the GCP Tower design, it was particularly challenging to design the

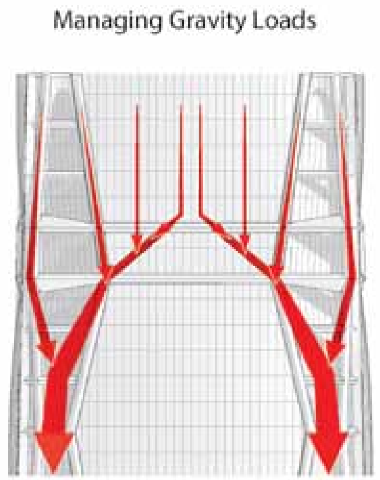


Enclosure
Cold form panels

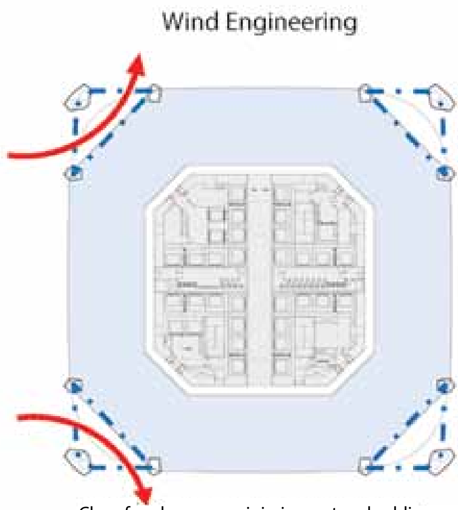
Program
Program organization

Vertical Transportation
Elevatoring





Gravity loads traced through the surface



Chamfered corners minimize vortex shedding

16-level structural module in a way that it could account for an evolving hotel program. An iterative approach to the tapering of the tower was used to strike a balance between ideal lease spans and the division of program areas within the vertical module. The modular segmentation of the tower also aligns with the vertical transportation strategy; both sky-lobbies (hotel and office) sit above the horizontal, stiffened mega-girder levels, and coincide with the modular division of program.

Optimization 2: Managing Gravity Loads

Gravity loads are distributed to the outer corners of the floor plate to help prevent overturning under lateral loads, and to create more column-free space within the office and hotel lease spans. With the structural model linked to the enclosure, architectural, and MEP model, the members could be resized dynamically. Although this detailed level of BIM coordination is commonplace during the later stages of design, it seldom takes place during the conceptual design stages of a project.

Optimization 3: Wind Engineering

The building's form minimizes vortex shedding by effectively confusing the wind via chamfered corners, building taper and the open tower crown. Additionally, the tower's variable mass decreases acceleration from wind forces. The calibration of the corners was studied in conjunction with preliminary CFT modeling to better understand the implications of having the structure exposed, as an "open corner."

Optimization 4: Enclosure

As many other aspects of the GCP Tower change, the enclosure model continually references the latest structural model. And within the enclosure model, a secondary form of a surface optimization takes place to lessen the number of unique and cold-bent panels. At the center of each module, an extrusion of 1.5 meters increases the lease span for both office and hotel. This enhances the overall tower efficiency by increasing the rentable floor area.

Optimization 5: Environmental Optimization

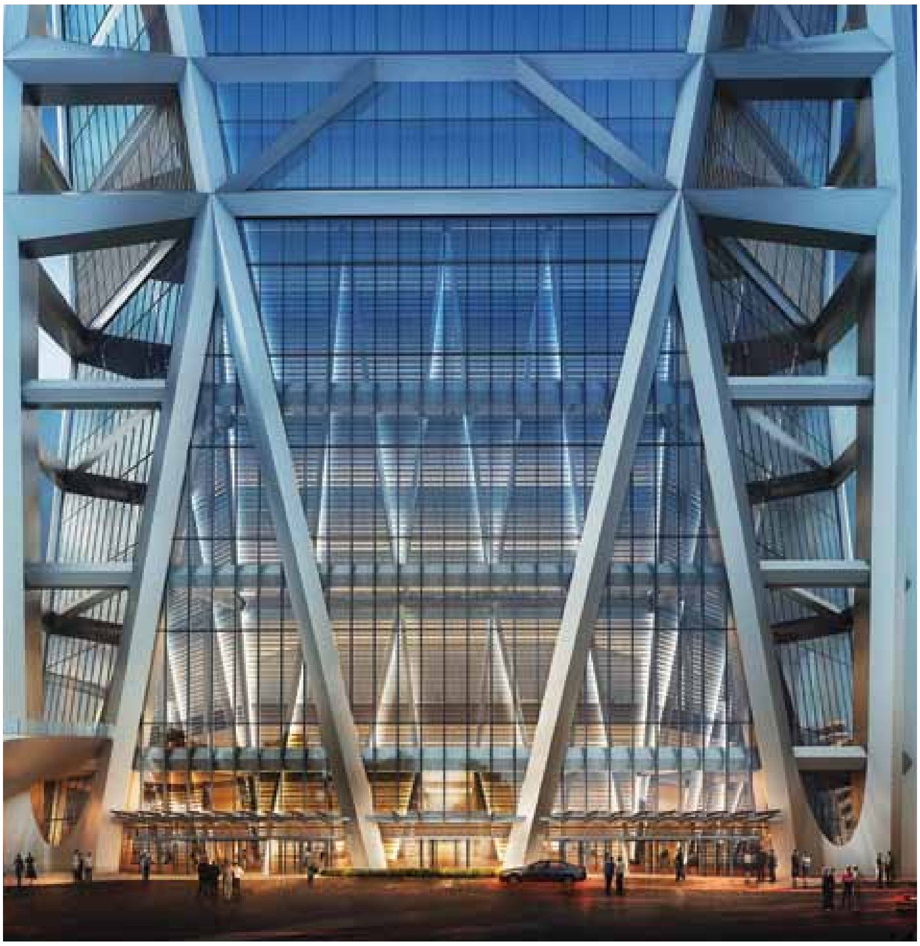
Between each 16-level vertical module, a stiffened mega-girder level hosts the mechanical equipment areas. Most of the

Opposite Top: Grasshopper to REVIT integration. Source: Zhongtian Urban Development Group Co., Ltd

Opposite Bottom: Optimizing the structural frame for gravity loads and mitigating the effect of wind loads with the expressed, open corner. Source: Zhongtian Urban Development Group Co., Ltd

Bottom: View of the GCP Tower's mid-section with an open, expressed corner. Source: Zhongtian Urban Development Group Co., Ltd

"The need for high-capacity mixed-use developments is also causing architectural homogeneity within such cities. Given the complexities of supertall design, it is often dangerously easy to apply a proven solution to similar design problems in unrelated contexts."



air intakes and exhausts are built into these levels, and thus become part of the exterior expression of the tower. Additionally, natural air ventilation was integrated into the spandrel detail of every level to promote localized comfort control for both office and hotel areas.

Towards An Emerging Design Language

The speed of design innovation often fails to keep up with the rapid economic development of cities across China. The need for high-capacity mixed-use developments is also causing architectural homogeneity within such cities. Given the complexities of supertall design, it is often dangerously easy to apply a proven solution to similar design problems in unrelated contexts.

Opposite Top: Rendering of the tower entry. Source: Zhongtian Urban Development Group Co., Ltd

Opposite Bottom: The morphology of the landscape of Guizhou (left) compared with a rendering of GCP Tower in its urban context. Source: Zhongtian Urban Development Group Co., Ltd

Guiyang is a city within an incredibly unique landscape, but its skyline does not yet contain any remarkable iconic expressions. The GCP Tower was designed to be the synthetic expression of an iterative design process which met all of the necessary performance criteria; it is within this expression that one can find a design language that is iconic and resonates with the morphology of the landscape. The tower should not only stand as a marker for new development, but it should also become simultaneously engaged with the historic context and the mountainous topography. The iconic quality of the tower emerges from an integrated design process that values performance over everything else. (Abalos & Herreros, 2003) Given the scale of investment and technical complexities of supertall design, the primary responsibility of the design team was to value performance-based criteria over the ambition of creating an iconic expression. "Iconicity" for a growing city is important because it can cultivate a positive image of the city and attract investment. But producing such an expression from a response to performance-based needs is a fresh take on the idea of developing an iconic supertall.

The uniqueness of the design solution is also based on certain site and programmatic constraints. It is through the parameters of performance, program, and site that the idea for a new form of "regionalism" emerges (Powell, 1985). This process aspires to generate architectural design language specifically calibrated for this particular site, program, and within this particular economic climate.

Through this process, the GCP Tower represents a uniquely crafted design solution that becomes—by default—indigenous to Guiyang. It relates to its context via the resolution of pedestrian walkways and open space, and also to existing city assets by engaging civic structures on its axis. It meets the program's needs by fulfilling space allocations and partitioning the program via a vertical module. Finally, it creates an enduring symbol that blends the historic and natural setting with the future aspirations of the city.

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