buildings

INNOVATIVE PROJECTS

Looping, Leaning Tube in Beijing Is an Antidote to the Skyscraper

Inclined towers joined at base and top reinvent the tube

07/16/2008

By Janice L. Tuchman

+ click to enlarge

Overhang links activities of the TV station and administration.

China Central Television's multipurpose station and headquarters is part of a new generation of cutting-edge structures whose innovative architecture comes to life with the help of advanced modeling and measuring tools. The looping first-of-its-kind structure on the east side of Beijing's central business district has a dramatic overhang suspended 36 stories in the air and a diagonally braced continuous-tube frame expressing the forces of its structural system onthe facade. Engineers precisely predicted preset positions for the inclined steel, and the contractor, using more than 600 monitoring stations, made sure the structure moved into the correct final position. Foundation work included a record-setting, 40,000-cu-meter continuous concrete pour.

Multimedia:

Video:
Antidote to the Skyscraper

The owner, the country's major television broadcaster, is a subministry of the central government that reports official views on the news. Programming, however, is a mix of comedy, drama and soaps, and popularity with viewers is important for advertising revenue. CCTV leaders wanted a new headquarters that its audience would talk about. It held an international design competition for the project in 2002 that was won by Rem Koolhaas's practice, the Office of Metropolitan Architecture (OMA), based in Rotterdam, the Netherlands. OMA worked closely with London-based Arup for a range of engineering services and in alliance with East China Architecture and Design Institute (ECADI), which became the local design institute of record for both architecture and engineering.

Reengaging City Space

+ click to enlarge

At that time in Beijing, there was "a vision that everything would be replaced by a forest of skyscrapers," says Ole Scheeren, OMA's partner in charge of the project and head of OMA's Beijing office. But OMA saw skyscrapers declining from their original role as a catalyst of urban development to more of a commercial tool to maximize profits. As Scheeren puts it, the "race for height" has become pointless as one building taller than the last is announced before the preceding is complete. He finds a "visual deafness" to such buildings that look the same from any direction. Instead, OMA wanted to reengage city space in a different way that would "proclaim" the organization of the building's inner workings. Their alternative here was a loop of interconnected activities in which the "linear principle of hierarchy is dissolved in a circuit of equal parts without beginning or end, without top or bottom," said Scheeren.

Iwan Baan

Density of the diagonals varies with the stresses on the buildings.

The CCTV headquarters combines administration and offices, news and broadcasting, program production and services in a continuous loop of interconnected activities. The idea, according to the architect, is to break down silos within the broad-based organization and spark creativity, collaboration and efficiency among producers, administrators, technicians and the creative team. The need to stack 32 studios of many different sizes—some up to 2,000 sq m—also influenced the evolution of the building's shape. With this structure, "They didn't interfere. We didn't have to make compromises," said Scheeren.

+ click to enlarge

Iwan Baan

Smaller Television Cultural Center will add hotel, restaurants, conference rooms.

Rising 234 m with 52 levels, the CCTV building provides 473,000 sq m of space. By comparison, the Burj Dubai, rising more than 800 m in the Arab emirate, will have a gross floor area of 475,000 sq m. CCTV has a nine-story base building on one side. Two leaning towers, which slope 6° on both X and Y axes, are connected by the base at the bottom and by a 13-story "overhang" pointed in the opposite direction—and suspended 36 stories in the air. Scheeren calls the overhang an "urban plateau" that lifts space off the ground but also makes it accessible to the public. The base and towers define a public plaza at the bottom that has four levels below grade.

Although most of the building is for employees only, the public will have access to a circuit that will bring them glimpses of different elements of broadcasting, from the arrival of actors and celebrities to production studio tours. The public loop includes an observation area in the overhang offering views across Beijing as well as straight down onto the plaza through circular "windows" in the floor.

The site includes a media park and a second sculptural building, called the Television Cultural Center, which has additional public facilities such as a hotel, theater, restaurants,ballroom and conference rooms. A third building, circular in plan, houses mechanical, electrical and energy services for both high-rises and connects to them through tunnels.

Continuous Tube

See page 4 below.

+ click to enlarge

Arup

The need to stack 32 studios, some up to 2,000 sq m in size, influenced the evolution of the building's shape.

Arup determined early that the best way to deliver this architectural form was to use the entire facade of the structure as a continuous structural tube. It would deal with the majority of gravity forces and also wind and seismic forces. A regular grid of columns and edge beams with diagonals brace the tube system. Arup used a four-story diamond as the module to "mesh the surface" of the tube and analyzed it with gravitational and horizontal forces.

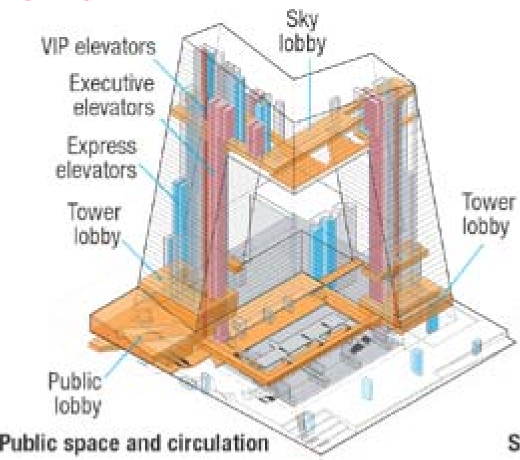
“It showed a rainbow of stresses from the worst areas to the lightest,” says Rory McGowan, director of Arup’s Beijing office. “We could have had a regular structure and then adjusted the member sizes to deal with the forces, but the range of forces was so enormous that we decided to keep the diagonal elements a constant size but then double or quadruple the density of the mesh where needed while halving or quartering the density where possible. The pattern flows around the corners and that’s not contrived.”

Scheeren (left) and McGowan connected program and structure.

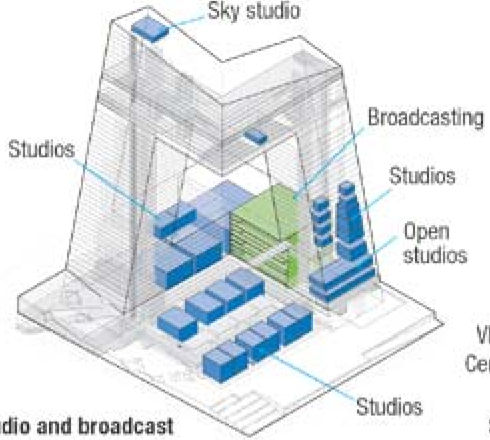
Scheeren adds, “There was an intuitive coherence that the building assumed structurally and programmatically because the whole issue was a sense of continuity. The idea of connecting the program in an equal way without any one section dominating was the starting point of the architecture.”

Both the core, which encloses elevators, stairs and mechanical risers, and a system of columns run vertically and help support the floor system. Since column lines cannot run directly from bottom to top of the sloping towers, two-story-deep trusses transfer loads midway up the building. The floors that temporarily cantilever from the leaning towers to create the overhang are enclosed by the external diagrid, supporting a transfer deck in the lower two floors to carry the columns above.The building will have 79 elevators, including 16 double-deck units.

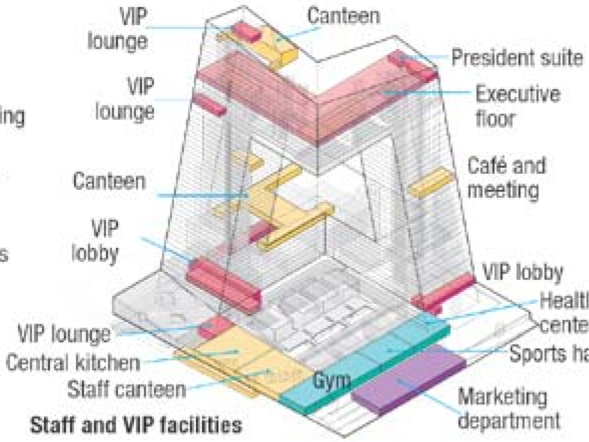
McGowan and Scheeren counter the idea that structural pyrotechnics or an unreasonable amount of resources were required to bring the CCTV structure...



Public space and circulation



Studio and broadcast



Staff and VIP facilities

buildings

INNOVATIVE PROJECTS

Looping, Leaning Tube in Beijing Is an Antidote to the Skyscraper

Inclined towers joined at base and top reinvent the tube

07/16/2008

By Janice L. Tuchman

...to reality. “The moment that something looks unusual or daring, there is an immediate suspicion that it must be outrageous,” Scheeren says. CCTV uses about 250 kilograms of steel per sq m, the same tonnage as a much taller but simpler new building nearby and half as much as another building in the area that handles earthquake loads with a heavy truss system. The Chinese seismic code generally stipulates a “heavy kind of engineering,” McGowan explains, but CCTV went through a special performance-based process because of its innovative design.

Record-Setting Pour

Overhang will offer views out and down through “windows” in the floor.

Construction started in 2005 by main contractor China State Construction Engineering Corp. with dewatering and installation of almost 1,300 piles. The mat foundation is integrated with the piling system, acting as homogeneous pile caps that counteract the overturning forces generated by the leaning towers and the overhang. The 133,000-cu-m mat foundation was divided into sections with pour strips to accommodate creep and shrinkage. The largest, a record-setting 40,000 cu m and almost 11 meters thick, was placed in December in a continuous pour that took 50 hours. The previous record for a continuous pour was a 17,010-cu-m mat for the foundation of the MesseTurm in Frankfurt, Germany, built in 1988.

The record pour used three concrete batch plants, 160 concrete trucks, 20 concrete pumps, 200 vibrators, 40,000 sq m of insulation blankets, six tower cranes and 400-person crews working 12-hour shifts. Concrete was pumped down into the mat through fixed hard pipe extending from each stationary pump, and with a flexible line from the boom truck. The pipes were insulated to reduce the chance of freezing.


Iwan Baan
Foundation mat included a record 40,000-cu-m continuous pour that took 50 hours.

To control the heat of hydration, the contractor used three layers of insulation blankets. Sensors were attached to rebar throughout the depth of the foundation and linked to a computer network that monitored the temperature. Core temperature and surface temperature werekept within 25°C. Pulverized fuel ash was used to create a ball-bearing effect to fill voids, improve flowability and prevent blockages in the pipelines, and an antifreeze agent was added to deal with Beijing's cold winter weather.

The pours were "incredibly successful and went according to plan," says David Howell, project manager for Turner International, a construction consultant to China State. The actual surface temperature was measured to be an average of 30°C, well within design tolerances. "The mass-concrete approach simplified the construction schedule compared to layering concrete and having to work out construction joints. The success was in the planning and testing," Howell adds.

Monitoring Movement


Iwan Baan
Adjustable bracing was used to allow fine-tuning as the transfer trusses were linked.

Craig Gibbons, an Arup director who worked on the project from Hong Kong in the design phase, says it was recognized early on that a process had to evolve that would not be too prescriptive about how the contractor would build the towers. "Overprescriptiveness would equal increased cost," he says. "But a lot of attention was given to movement, measurement of movement and tolerances of the erected structure—from the foundation slab to reference floors at intervals up the building." This was a key part of the prescriptive requirements.

One issue, Gibbons notes, was the potential for daily movement of one tower relative to the other as the gap became shorter and shorter as the overhang was about to be bridged. As the sun moved across the sky there was the potential for one tower, with its overhang, to move relative to the adjacent tower. The contractor was required to monitor these movements as the day of linkage approached to pre-prepare for the timing of the connection of the overhang. It was clear the optimum time for this to limit movement was at dawn, when both towers were at the same ambient temperature, with minimum differential movement between them.


Michael Goodman / ENR

Erecting steel on the inclines first involved calculating the anticipated deflection of the steel and then developing a construction sequence that preset members to counter the anticipated deflections and thus achieve the correct final design position. "It was essential to make sure that the physical construction was behaving like the model," says Howell. The process involved GPS-guided tools and more than 600 survey points. The foundation slab had 70 monitoring points, and each reference level had 30 basic monitoring points.

Connecting the overhang required a special survey method, Howell adds. A sensor was welded onto one tower and extended to the other, making it possible to find the relative shifts between the two towers.Structural stresses were monitored by attaching sensors to members.

Howell compares constructing the overhang to building a bridge. The transfer structure was launched off the towers segmentally, similar to launching the cantilever section of a bridge deck. Adjustable bracing was used to allow for fine-tuning as work progressed. The transfer truss floors on levels 37, 38 and 39 were erected and linked before any additional superstructure or loads were placed on them. Engineers stepped up monitoring for two weeks before the connection.

Crews calmed jitters about working in the overhang at an onsite shrine (Top). Measuring temperature and wind speed were key to monitoring process (above).

The first connection, last September, was a “soft link using seven pin connections that allowed the two inclined towers to move independently of each other,” Howell reports. Actual stresses could then be verified against anticipated stresses, and loads due to temperature variations and winds could be accommodated before connections were welded. “It came together extremely well,” Howell says.

HOWELL

The facade, which had to deal with all directions of movement and all the different loading conditions, was another technical challenge. Architecturally, it “reflects and projects the structural system as the outer image of the building,” says Scheeren. The support system for the glass curtainwall is attached to the structure at the nodes of the diamond-patterned bracing—the point of the structure that moves the least. The steel-mullion system for the glass creates a second layer of steel parallel to the structural steel diagrid but separated by about 150 millimeters to 200 mm. In each diamond, the top two members are structural pieces; transoms hang below them. “That allowed us to make everything tighter and smaller,” says Scheeren, who worked with New York City-based curtainwall consultant Front. The large diamonds are made up of multiple pieces of glass assembled with mullions and transoms, but “structurally it acts as one tight unit and the movements are concentrated along those points.”

The facade will be substantially complete when millions of people pour into Beijing for the Olympics in August. CCTV’s final completion is now slated for December 2009. Scheeren says the “enormous will and commitment” of China to bring this project to reality was unlike any situation he had experienced.

“In a risk-averse environment, we determine everything to be a risk instead of something you can achieve,” he adds. “Chinese officials came up with a structural approval process so that it could be responsibly done. They took pride in making it possible.”