

CCTV Headquarters, Beijing, China:

Building the structure

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1. Architect's illustration of the completed building.

Erecting two massive leaning Towers, and connecting them with a 9-13 storey Overhang suspended 36 storeys in the air, presented the structural engineers and contractors with unprecedented design and construction challenges.

This is the third *Arup Journal* article about the CCTV (China Central Television) building in Beijing; it covers the construction of this unique project. The previous two articles dealt with the structural¹ and services engineering² design.

Introduction

China Central Television (CCTV) had been expanding greatly, in competition with major international television and news service providers, and early in 2002 it organised an international design competition for a new headquarters. This was won by the team of OMA (Office for Metropolitan Architecture) and Arup. The team subsequently allied with the East China Design Institute (ECADI) to act as the essential local design institute for both architecture and engineering. The first *Arup Journal* article¹ outlined the design collaboration process.

The unusual brief, in television terms, was for all the functions of production, management, and administration to be contained on the chosen site in the new Beijing Central Business District, but not necessarily in one building.

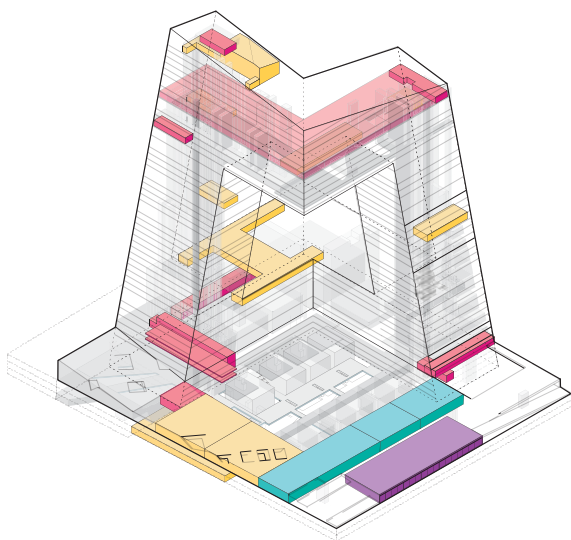
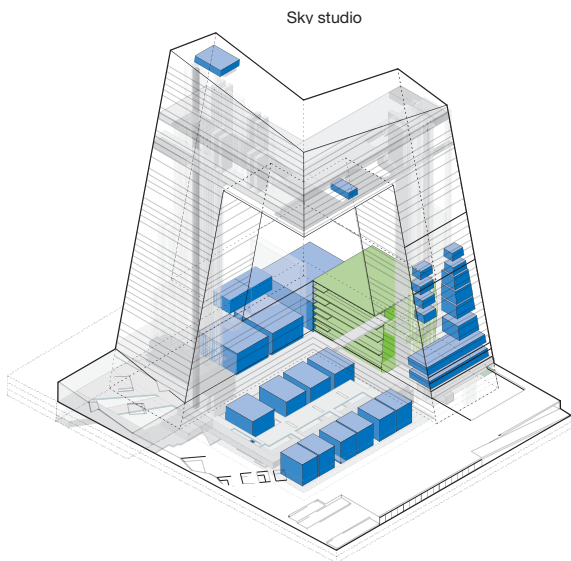
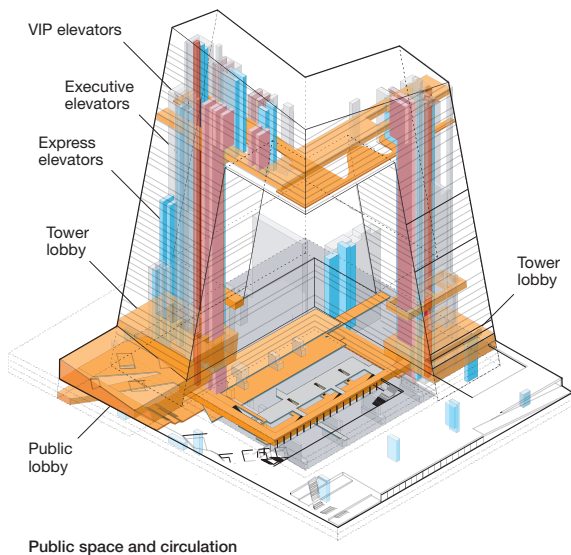
In its architectural response, however, OMA decided that by doing just this, it should be possible to break down the “ghettoes” that tend to form in a complex and compartmentalised process like making television programmes, and create a building whose layout in three dimensions would force all those involved to mix and produce a better end-product more economically and efficiently (Fig 1).

The winning design for the 473 000m², 234m tall CCTV building thus combines administration and offices, news and broadcasting, programme production, and services – the entire process of Chinese television – in a single loop of interconnected activities (Fig 2) around the four elements of the building: the nine-storey “Base”, the two leaning Towers that slope at 6° in two directions, and the 9-13 storey “Overhang”, suspended 36 storeys in the air. The public facilities are in a second building, the Television Cultural Centre (TVCC), and both are linked to a third service building that houses major plant as well as security.

The whole development will provide 599 000m² gross floor area and covers 187 000m², including a landscaped media park with external features.

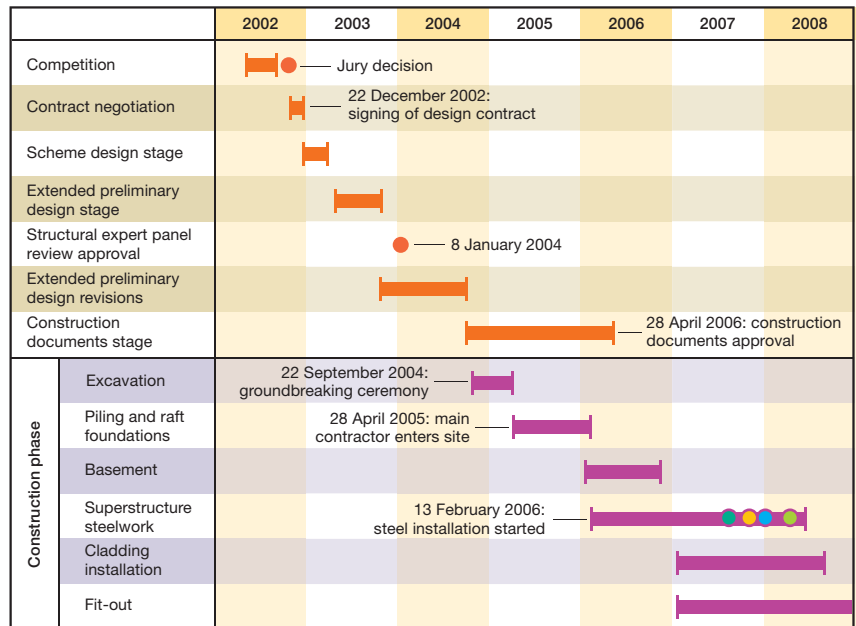
Construction Documents phase

In August 2004, after receiving approval for the structural design from the Chinese Ministry of Construction, Arup handed over the extended preliminary design (EPD) documents to ECADI, which then began to produce the Construction Documents (CDs). Arup, however, maintained an extensive involvement on completion of the EPD design phase, including production of tender documentation for the main structure and interaction with the tenderers for the works, as well as being part of the tender review process. Together with the architects OMA, Arup also had a continuous site presence during construction, working with the contractor in implementing the design (Fig 3).



Staff and VIP facilities

2. Functions and layout within the CCTV building.



● 1 August 2007: construction of Overhang starts ● 8 December 2007: connection of Overhang
 ● 26 December 2007: Overhang connection ceremony ● 27 March 2008: topping-out ceremony

3. CCTV timeline.

As previously described¹, the building's shape and form meant that it fell outside the prescriptive codes for buildings in China. In consequence, a rigorous series of meetings was required with an assembled expert panel comprising 12 professors from around China, appointed by the Ministry of Construction. Dialogue with these experts influenced the approach to the design and determined the extent of analysis required to justify the seismic performance of the building.

As part of the expert panel approval process¹, several suggestions were made that Arup and ECADI subsequently addressed during the CD phase. These included a requirement for three physical tests to be carried out, in order to verify the analytical calculations:

- Joint test ("butterfly plate"): Beijing's Tsinghua University tested a 1:5 scale model of the column-brace joint to confirm its performance under cyclical loading, in particular the requirement that failure takes place by yielding of the element rather than at the connection.
- Composite column: Tongji University in Shanghai carried out destructive tests on 1:5 scale models of the project's non-standard steel reinforced columns. These tests resulted from concerns that the high structural steel ratio might lead to reduced ductility.
- Shaking table test model: A 7m tall 1:35 scale model of the entire building was constructed to test the structural performance under several seismic events including a severe design earthquake (known as Level 3 - average return period of 1 in 2475 years). The tests were undertaken by the China Academy of Building Research (CABR) in Beijing, using the largest shaking table outside America or Japan (Fig 4 overleaf).

This large-scale shaking table test was of particular interest. In China it is the norm for buildings that fall outside the code to be thus studied, and the CCTV model was the largest and most complex tested to date. The nature of the testing required the primary structural elements to be made from copper (to replicate as much as possible in a scale sense the ductility of steel). The model also included concrete floors (approximately 8mm thick) to represent the 150mm thick composite floor slabs.

Interestingly, in a scaled model test the duration of the earthquake is also scaled, so that the severe design earthquake event lasted less than four seconds when applied to the model.

In all cases, the physical tests correlated closely with the analysis. It is arguable that computer analysis is now more accurate than a physical shaking table test, which is still the standard practice in China. Due to the amount of scaling required, the accuracy of such models and tests may be significantly less than the proven accuracy of the analytical software used to design the building. Nonetheless, a shaking table test helps to corroborate the computer model and provides a demonstration that the design has safely accounted for seismic issues.

Tender, excavation, and foundations

As noted already, Arup had a major role in the tender process for appointing the main contractor, including the production of the steelwork drawings and specifications. One key document was the Particular Technical Specification, which placed several requirements on the contractor that were specific to the design of CCTV.

Some of the specific issues identified in the Particular Specification included:

- weight audits – ie onus on the contractor to convey the weight added to the building at stages during the construction
- specific monitoring of the Tower deformation (married to the construction weight assessment)
- specific monitoring of deformations (including dishing) of the foundations
- presetting of the structure
- monitoring of daily variation in the difference between the position of connection points as the Overhang construction advanced prior to linking
- the requirement to connect when the relative movement between the connection points of the Overhang were manageable (suggesting connection when the two Towers were at an even temperature, ie at dawn)
- a means of showing that the extent of connection was commensurate with the daily movement measurement, so as to prevent the connection ripping apart once it had been firmly made
- a requirement for post-installing certain key structural elements.

In addition to regular gravity and lateral forces acting on the structure, there are significant additional construction stage forces due to the fact that the building comprises two separate leaning Towers with cantilevers up until the point at which they are joined to become one structure. The additional bending and overturning stresses that get “locked” into the Towers and foundations prior to joining depend on the amount of structure and façade completed at the time of connection.

In essence, the greater the construction load applied to the building prior to connecting the two Towers, the more this would manifest itself as increased locked-in base moments in the Towers.



4. Shaking table model.



5. Three alternative methods of constructing the Overhang.

After the connection was made, any added weight would result in a thrust between the two Towers via the Overhang. The final stresses in the building were therefore very much linked to the construction sequence. The Particular Specification defined an upper and lower bound range of permissible locked-in stress, allowing the contractor some flexibility in choosing his final construction sequence.

Another interesting feature of the process was the proposals put forward by different tenderers to meet the Particular Specification requirements and the particularly challenging aspects of the Overhang construction. One of the three shortlisted tenderers proposed a temporary tower the full 162m height to the underside of the Overhang, providing a working platform to build the Overhang connection in situ. The second tenderer opted to build a partial cantilever from the Towers and then construct the lower part of the Overhang at ground level and strand jack the assembly into position. The third tenderer proposed to construct incremental cantilevers from each Tower until the two met and connected at the centre of the Overhang (Fig 5). This latter approach was as described in Arup's documentation, though any construction approach was deemed acceptable provided it could satisfy the locked-in stress limits defined in the Particular Specification.

The Particular Technical Specification approach has become a leading example of best practice for high-rise construction within Arup.

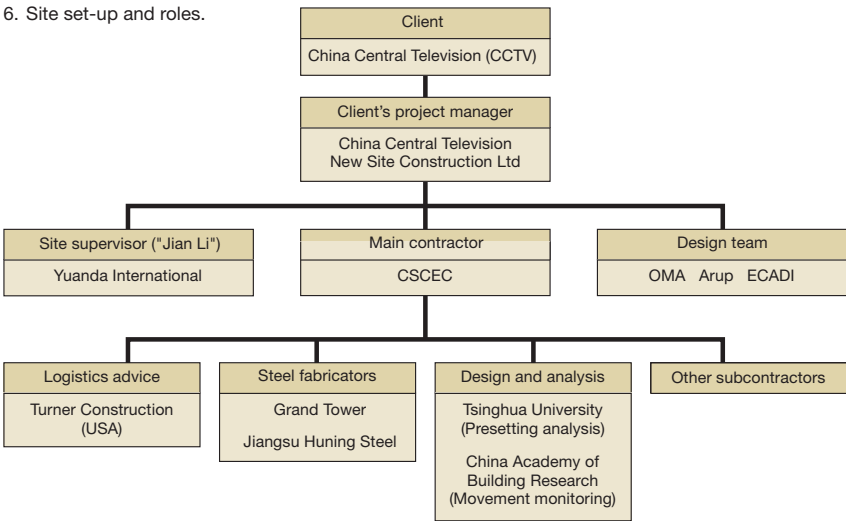
China State Construction Engineering Corporation (CSCEC) was awarded the main contract in April 2005. CSCEC tendered on this third approach.

Construction team

CSCEC, a state-owned enterprise under the administration of the central government, was established in 1982 and is China's largest construction and engineering group. CSCEC now enjoys an international reputation, having completed an increasing number of projects abroad including the Middle East, South America and Africa. The steelwork fabricators were Grand Tower, part of the Bao Steel group based in Shanghai (China's largest steel manufacturer), and Jiangsu Huning Steel, based in Jixing, Jiangsu Province.

Other members of the team were Turner Construction (USA), providing support to CSCEC on construction logistics, China Academy of Building Research (CABR), one of the major design institutes in Beijing, and Tsinghua University, which carried out the presetting analysis and is one of China's foremost universities. The independent site supervisor was Yuanda International, established in 1995 (Fig 6).

6. Site set-up and roles.



Excavation and foundations

The ground-breaking ceremony took place on 22 September 2004, and the excavation of 870 000m³ of earth began the following month under an advance contract. Strict construction regulations in Beijing meant that spoil could only be removed at night: nonetheless, up to 12 000m³ of soil was removed each day, the entire excavation taking 190 days. Dewatering wells were also installed, since the groundwater level was above the maximum excavation depth of 27.4m below existing ground level.

7. Cutting down piles by hand.



8. Preparation of foundation raft.



9. Delivery of column baseplate, April 2006.

The two Towers are supported on separate piled raft foundations with up to 370 reinforced concrete bored piles beneath each, typically 33m long and up to 1.2m in diameter. In total, 1242 piles were installed during the spring and summer of 2005. In common with many other Beijing projects, the piles were shaft- and toe-grouted (in accordance with an alternative design by CABR). The top 2m of the piles were then topped off by hand rather than with machinery (Fig 7) - one of the few occasions when sheer numbers of workers had to be mobilised to carry out the work: such unskilled, labour-intensive tasks were few on this project.

The Tower rafts were constructed over Christmas 2005 (Fig 8). The 7m thick reinforced concrete slabs each contain up to 39 000m³ of concrete and 5000 tonnes of reinforcement. Each raft was constructed in a single continuous pour lasting up to 54 hours. At one stage, 720m³ of concrete was being delivered every hour, using a relay of 160 concrete trucks from three suppliers. Chilled water pipes were embedded inside the pour and temperatures were monitored for more than two weeks to ensure that the concrete did not experience too high a temperature gradient during curing. The two rafts, poured within days of each other, were the largest single continuous concrete pours ever undertaken by China's building industry. In total, 133 343m³ of concrete went into the foundations of the Towers and podium.

The seismic analysis indicated that some columns and their foundation piles could experience tension during a severe design earthquake. Some of the perimeter columns and their baseplates were therefore embedded 6m into the rafts to enhance their anchorage (Fig 11). Certain piles were also designed for tension.

Steelwork construction

The first column element was placed on 13 February 2006 (Fig 12). In total, 41 882 steel elements with a combined weight of 125 000 tonnes, including connections, were erected over the next 26 months, at a peak rate of 8000 tonnes per month.

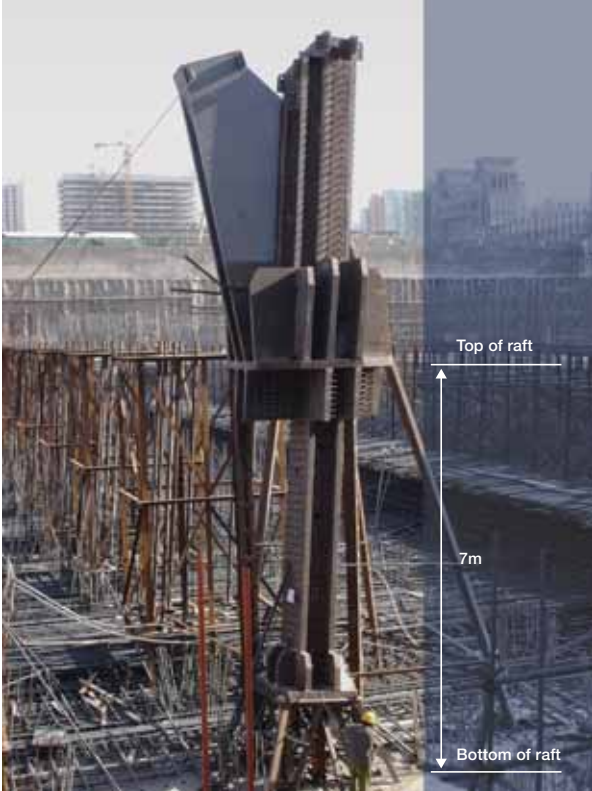
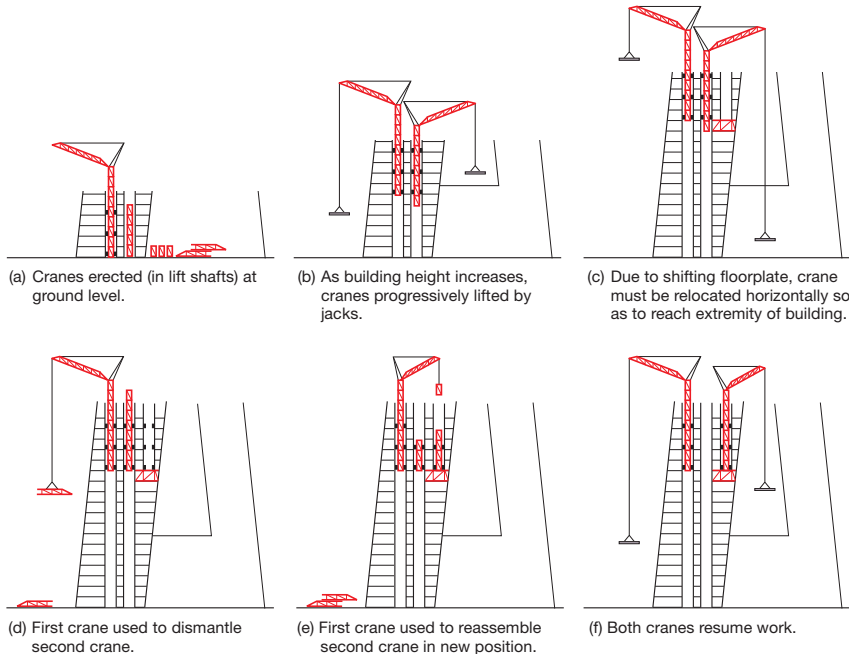
During the design it was thought that some high-grade steel elements would need to be imported, but in the end all the steel came from China, reflecting the rapid advances of the country’s steelwork industry. Steel sections were fabricated at the yards of Grand Tower in Shanghai and Huning in Jiangsu, and then delivered to site by road (Fig 9), with a size limit of either the tower crane capacity (80 tonnes at a distance of 12m) or the maximum physical dimensions that could be transported (18m length). Inspections generally took place prior to shipping, with further checks prior to installation. Only minor fabrication work was carried out on site.

The size of the site enabled many elements to be stored after delivery (Fig 13), although heavier ones were kept on the backs of trailers until they could be craned directly into position. Due to the many different elements, each was individually coded to identify its location and orientation.

The elements were lifted into place by two tower cranes working inside each Tower. These were *Favco M1280D* cranes imported from Australia – the largest ever used in China’s building industry - plus a smaller *M600D* crane. Even so, care was needed when locating the temporary ground-level working platforms to which the elements were delivered for craning, to ensure that all parts of the sloping Towers stayed within the cranes’ operating radius as their height progressively increased.

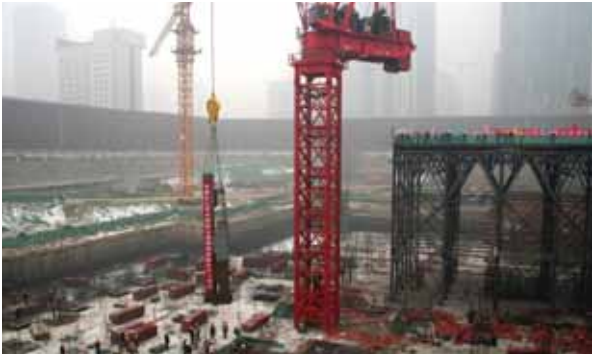
Each crane not only had to be raised up to 14 times during construction, but also slewed sideways up to four times when it reached the upper levels, to maintain position relative to the edges of the progressively shifting floorplate (Fig 10).

10. Crane slewing process.



11. Column embedded in raft.

12. Installation of first column.



13. Prefabricated elements stored on site.



14. Craning in action.

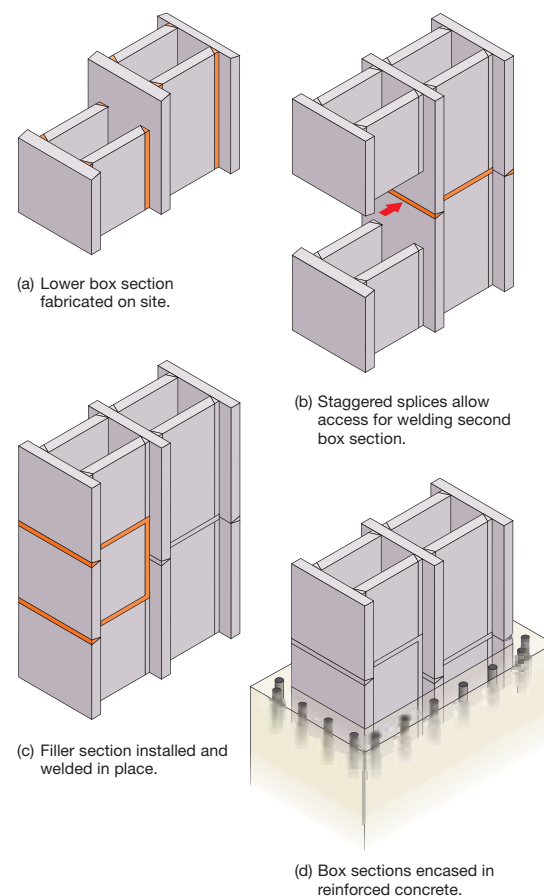


Due to the 6° slope of the Towers, the perimeter elements needed to be adjusted to approximately the correct installation angle after being lifted a short distance off the ground, using a chain block. This simplified the erection process at height.

The vertical core structure was generally erected three storeys ahead of the perimeter frame. This meant that the perimeter columns could be initially bolted in place and braced to the core columns with temporary stays, then released from the tower crane before final surveying and positioning. The welders could then start the full-penetration butt welds required at every connection: a time-consuming task requiring shift work to achieve a continuous 24-hour process.

The maximum plate thickness of the columns is 110mm and the volume of weld sometimes reaches as much as 15% of the total connection weight. At the extreme case, a few connection plates near the base of the Tower required a 15m long site splice of 100mm thick plate, each taking a week to complete. The plate thickness of some elements exceeded the maximum assumed in design, which had been determined by likely steel availability. Onerous material specifications were laid out for thick sections to ensure satisfactory performance.

The welders had to be specially qualified for each particular welding process. Before the start of a given weld, the welder's qualification, the electrodes, scaffolding safety, the preheating temperature, and the method would all be checked. Procedures were laid down for monitoring preheating temperatures, the interpass temperature,



17. Weld process for complex section.

Life on site

An average of 1200 workers were on site at any one time, rising to 3500 at peak of construction. They ranged from unskilled migrant labourers to experienced welders and top-level management. CCTV actually employed far fewer labourers than other large projects in the city, since the building contains a limited amount of conventional reinforced concrete construction (by contrast almost 50 000 were employed on Beijing Airport's new terminal). The men, and a few women, usually worked 8-10 hour days. In 2007, construction workers in Beijing could typically earn up to £120 per month - a considerable sum by rural income standards - with workers sending much of this home to support their families. Accommodation and food were usually provided by the contractor. Most lived in dormitories on the outskirts of Beijing, provided by the contractor, although some actually lived on the site.

The workers hail from all parts of China, and generally return home for two weeks once a year during the Spring Festival (Chinese New Year). The site meeting minutes recorded some unusual working concerns: for example, productivity being



15.

affected by homesickness in the lead-up to the Spring Festival, or by workers suddenly returning to farms in the surrounding provinces during the wheat harvest season between May and June.

Mealtimes are possibly the most important part of the day, with the site almost coming to a standstill at lunchtime, except for the non-stop sparks from welders. During summer evenings, outdoor film screenings were arranged for workers in public squares near the site.

16. Welding in process.



and any post-heating treatment. Non-destructive testing 24 hours after completion was carried out by the contractor, site supervision company, and third parties employed by the client.

Though, following standard Chinese practice, all quality control was carried out by the independent site supervisor, Arup maintained a site presence to observe progress and provide a liaison with the architect and client, due to the project's complexity.

Some of the most complex sections required careful thought to achieve a full weld, with staggered splices used in some cases to reduce concentrations of weld stresses where possible (Fig 17).

The geometrical complexity made construction slower than for other steel-framed buildings. Although the rate of erection increased as the contractor became more familiar with the process, CCTV has no "typical floors". Nevertheless, up to six storeys per month was achieved for the relatively uniform levels at Tower mid-height.

Concreting the composite columns and floor slabs took place several storeys behind steel erection, off the critical path.

18. Basic concept of presetting for a sloping Tower.



(a) Tower deflects under its own weight.



(b) Preset upwards and backwards.



(c) Resultant: no deflection under self-weight.

Movements and presets

Arup's calculations included a "construction time history" analysis to take account of the effects of the predicted construction method and sequence on the completed building's deflections and built-in forces. This indicated that the corner of the Overhang would move downwards by approximately 300mm under the building's dead weight. For there to be no overall downward deflection under this load case, the whole structure needed to be preset upwards and backwards to compensate (Fig 18), and the contractor continuously monitored construction to ensure that the actual movements corresponded to analysis assumptions and predictions.

The presetting process was further complicated by the fact that when completed, almost all the columns have different stresses, depending on the ratio of gravity to seismic loads, unlike in a conventional building where all perimeter elements will be similarly stressed. As a result, different presets were required on different sides of the Towers, the exact values also depending on the final construction sequence. In practical terms, this meant fabricating the columns longer on one side of each Tower, so that they would eventually shorten to the correct geometry under load.

Presetting was in two stages: at the fabrication yard, based on the results of the analytical modelling, and then at installation, if required, to suit the actual building deformation as monitored during the course of construction. Progress of floor plate concreting was also controlled to suit the assumptions made in the presetting estimation.

The contractor commissioned CABR to carry out the movement monitoring, while Tsinghua University performed the building movement prediction and presetting analysis as required by the Arup specification. This required a more detailed time history analysis of the final construction sequence, dividing the process into 53 assumed stages based on estimated progress for the perimeter tube, core, slab concreting, façade, services, and interior fit-out. This was compared with the results of the movement monitoring, and checks and adjustments were made as necessary.

The studies found that the movements during Overhang construction would be far more significant than those at the earlier stages caused by the Towers' lean only. Due to the large number of variables needed for the presetting calculation (variable axial stiffness, final construction sequence, foundation settlement, thermal movements, etc), the main focus of the analysis was on the critical Overhang construction stage. By the time Overhang erection commenced, there was already much movement data from the Tower construction that could be used to calibrate the analysis.



20. Large "butterfly" plate.

Overhang construction

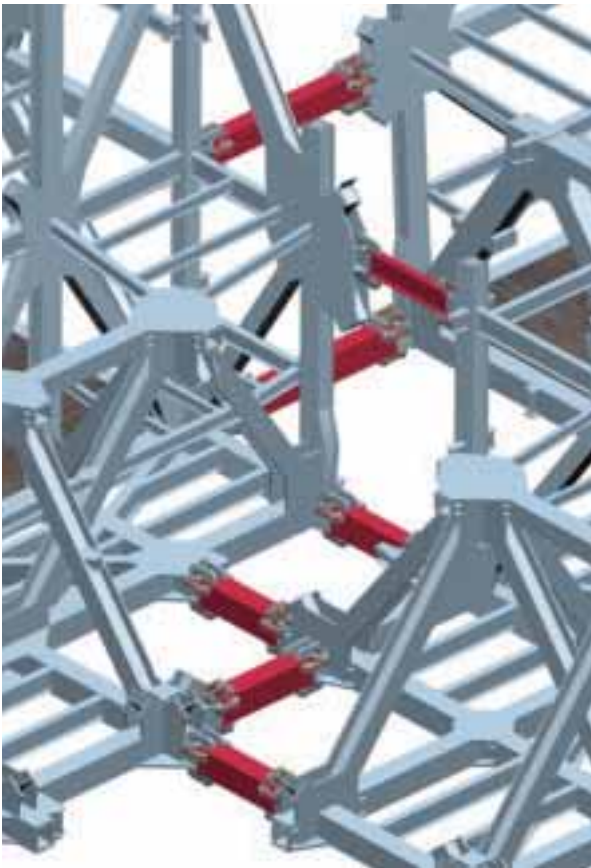
Construction of the Overhang began after the steelwork for the two Towers was completed to roof level. Tower 2 Overhang began first, in August 2007, and the structure was cantilevered out piece-by-piece from each Tower over the course of the next five months (Fig 22). This was the most critical construction stage, not only in terms of temporary stability but also because its presence and the way it was built would change the behaviour of those parts of the Tower already constructed. The forces from the two halves of the partly constructed Overhang would be concentrated in the Towers until such time as the two halves were linked and the building became a single continuous form, when the loads would start being shared between all of the permanent structure.

The bottom two levels of the Overhang contain 15 transfer trusses that support the internal columns and transfer their loads into the external tube. In the corner of the Overhang, these trusses are two-way, resulting in some complex 3-D nodes with up to 13 connecting elements, weighing approximately 33 tonnes each.

Fabrication accuracy was therefore crucial for this part of the structure, with erection being carried out piece-by-piece 160m above ground level. Trial assembly of these trusses at the fabrication yard prior to delivery was essential to ensure that minimal adjustment would be needed at height.



19. CCTV under construction at times presented almost surreal vistas from surrounding streets.



21. The seven initial connection elements.

22. The Overhang before connection.



23. Installation of first connection element.



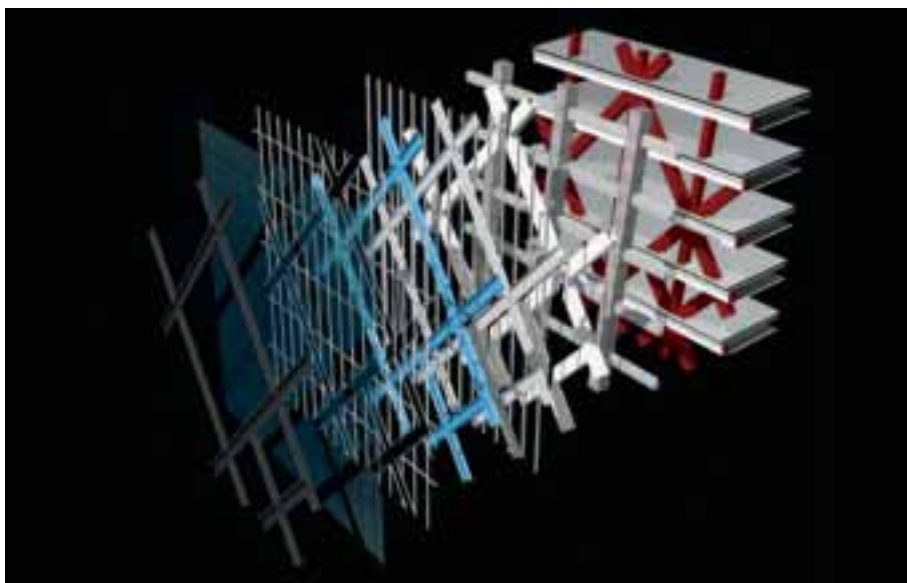
24. The completed Overhang structure, showing the three 3m diameter circles punched in the deck to create glazed viewing platforms for the public viewing gallery.

Prior to connection, the two Towers would move independently of each other due to environmental conditions, in particular wind and thermal expansion and contraction. As soon as they were joined, therefore, the elements at the link would have to be able to resist the stresses caused by these movements. As a result, the connection strategy required a delay joint that could allow a sufficient number of elements to be loosely connected between the Towers, then locked off quickly to allow them all to carry these forces safely before any relative movement took place. Arup specified that this should take place early in the morning on a windless day, when the two Towers would be at a uniform temperature and the movements at a minimum.

In the lead-up to connection, Arup's specification required one week of monitoring of global and relative movements so that the correct dimensions of the linking elements could be predicted. The relative movements of the Towers during the day were found to be around $\pm 10\text{mm}$. The contractor made the final measurements of the gap exactly 24 hours beforehand (ie at identical ambient conditions) so that final adjustments could be made to the length of the linking elements while they were still on the ground prior to installation.

The contractor chose to connect seven link elements at the inside corner of the Overhang during this initial connection phase (Fig 21). These were lifted into place – to less than 10mm tolerance – and temporarily fixed with pins in the space of a few minutes at 9.00am on 8 December 2007, before the Towers started to move relative to each other (Fig 23). The pins allowed them to carry the thermal loads while the joints were fully welded over the following 48 hours.

The specification originally called for the connection to take place while ambient temperatures were between $12\text{--}28^\circ\text{C}$ (ie close to the standard room temperature assumed in analysis). Since the connection took place during winter, the temperature at the time was around 0°C , so further analysis of the structure was carried out by the design team to check the impact of the increased design thermal range.



25. Façade build-up.

Once the initial connection was made, the remainder of the Overhang steelwork was progressively installed. With the building now acting as one entity, the Overhang was propping and stabilising the two Towers, and continued to attract locked-in stresses as further weight was applied. In addition to the primary steelwork elements, a continuous steel plate deck up to 20mm thick was laid down on the lowest floors of the Overhang to resist the high in-plane forces that were part of this propping action. The steel plate is not, in fact, fully continuous – three 3m diameter circles were punched into the deck to provide glass viewing platforms for the public gallery at the Overhang's bottom level (Fig 24).

The concrete floor slabs were only added once the entire primary structure had been completed, so as to reduce the loads during the partially-constructed stage. Again, the construction stage analysis needed to take account of this sequencing.

A topping-out ceremony on 27 March 2008, on a specially-constructed platform at the corner of the Overhang, marked the completion of the steelwork installation.

Post-installation of key elements

Arup's early analysis showed that the corner columns on the inside faces of the Towers would attract a huge amount of dead load from the Overhang, and thus have little spare capacity for resisting seismic loads. Increasing the column sizes was rejected since they would become stiffer and hence attract even higher loads. Instead, the corner column and brace elements directly below the Overhang were left out until the end of construction, forcing the dead loads to travel via the diagonals down adjacent columns and enabling the full capacity of the corner elements to be available for wind and seismic loads in the as-built condition.

Key elements at the intersection of the Towers and podium were also post-fixed for similar reasons. In addition, this process enabled the architectural size of the elements to be controlled, while giving the contractor additional flexibility to deal with construction movements.

Delay joints were introduced between the Towers and the Base to allow for differential settlement between the two structures' foundations. It should be noted that over half the predicted settlements were expected to take place after the Towers were constructed to their full height, due to the disproportionate effect of the Overhang on the forces in certain columns. These were fully closed after completion of the main structure. Further late-cast strips were also provided at several locations around the basement to control shrinkage.

Follow-on trades

Installing the façade began once the structure had reached mid-height, so the façade design needed to take account of significant movements subsequent to installation. This sequencing also created tricky interfacing problems due to the need to share tower crane use with the steel erection, and cope with protecting workers – and completed cladding – from work taking place above.

The lean of the Towers meant that workers on the re-entrant sides of the Tower would be protected from falling objects above (albeit with additional installation hurdles to overcome), while extra care would be needed to protect those on the other faces which were subject to higher risk.

Services installation also began while the structure was in progress. This fast-track process was in marked contrast to many other projects in the city, in which façade and MEP installation would sometimes only start once the structure had been completed.

26. Construction progress at March 2008.





27. The façade design includes large diagonal “diagrid” elements that span between each primary floor, mirroring the structural braces.

Novel construction solutions for a novel building

The challenge of constructing a vast, cranked, leaning building made the contractor devise some other intriguing solutions.

Cutting down piles

The wide availability of unskilled labour in China means that many operations are carried out in a very different manner from the West. On CCTV, for example, piles were cut down by hand, with hammer and chisel, to expose the reinforcement (Fig 7).

While this avoided workers suffering from Vibration White Finger, a condition that often affects those working with vibrating machinery like drills, this was still a very time-consuming process, and other methods were developed to speed things up. Once the outer part of the pile had been broken back, a notch was cut into the central part, and cables were tightened around the remainder of the section.

Then, with the help of a *Tirfor* winch, the mass-concrete pile top could simply be snapped off.

Façade installation

The façade design includes large diagonal “diagrid” elements that span between each primary floor, mirroring the structural braces (Fig 27). These heavy pieces had to be lifted with the tower cranes, but on the re-entrant faces, the slope of the Towers meant that it was impossible to get them close enough to the edge of the floor to fix them in position. The contractor came up with an ingenious system of supporting the element off a counterbalanced “mini-crane”, hanging on the end of the main crane cable. This allowed a team inside the Tower to manoeuvre the piece laterally into position.

The other faces also involved challenges. The glazing panels were lifted up individually by rope, but on the outer faces of the Towers, men were needed on the ground to pull the rope sideways to keep the panels away from the Tower as they were lifted, to prevent damage to glazing already installed.

Surveying

Not one of the 121 columns in either Tower’s perimeter frame is vertical, and many of the pieces in the Base and Overhang are aligned in completely different directions. To ensure every element was positioned correctly, the contractor continuously monitored the control points throughout the building, reaching 670 in number at the most critical stage around January 2008 after the linking of the two Towers. Monitoring included vertical movements of Tower circumference at particular floors, corner column movements at the Overhang soffit, internal levelling, stress, raft settlement, and Overhang movement.

Reinforcement bars

Spare reinforcement is used for almost everything on a Chinese construction site - handrails for temporary staircases (and sometimes the staircases themselves); impromptu hammers and other tools; drain covers. Very few offcuts go to waste. Meanwhile, almost all reinforcement used in the permanent works is coupled rather than lapped - material costs are still the main driver in China.

Recycling

As is standard in China, virtually nothing from the site demolition or new building went to waste. Every brick, nail, pipe, and piece of timber and reinforcement was meticulously extracted and collected by a team of workers, before being used again on site or sent away for reuse or recycling.



28. The TVCC building, to the left of the CCTV headquarters, April 2008.

TVCC and the Service Building

The other buildings on site, TVCC (Fig 28) and the Service Building, were built simultaneously. Construction of the Service Building began in April 2006, and it was handed over in June 2008.

The Service Building was actually the critical path item, as it had to be complete and fully commissioned in advance of CCTV and TVCC. Service tunnels running between the three buildings introduced a significant element of civil engineering works to the site.

The contract for TVCC was given to a separate contractor, Beijing Urban Construction Group. Work began in March 2005, and the structure was complete by September 2007. TVCC and the Service Building will be described in detail in a future issue of *The Arup Journal*.

Conclusion

The structure of the CCTV building was completed in May 2008, with the façade due to be finished by the start of the Beijing Olympic Games. Within weeks of structural completion, China was struck by its most violent earthquake of recent years. Although the epicentre was nearly 1000 miles from Beijing, the tremor was felt on site. Like other structures in seismic regions, CCTV is designed to resist a certain level of earthquake during construction, and no damage was reported. However, this served as a timely reminder of the importance of the building's rigorous seismic design and approvals process.

That the contractor could construct such a vast and complex building with few delays was a credit to the design team and to CSCEC, in particular the attention paid to devising a feasible construction sequence from an early stage, and the careful thought about the buildability of the primary structural elements and connections.

Chris Carroll is a Director of Arup in the Buildings London 7 group. He led the structural design of the CCTV headquarters.

Dr Craig Gibbons is a Director of Arup in the Gulf group, and is Country Leader for the United Arab Emirates. He was the Project Manager for the CCTV headquarters.

Dr Goman Ho is a Director of Arup in the Beijing office. He led the structural team in the Beijing office for the CCTV headquarters.

Michael Kwok is a Director of Arup and leads the Shanghai office. He was the Project Director for the CCTV headquarters.

Richard Lawson is an Associate of Arup in the Buildings London 7 group. He was a structural engineer for the CCTV headquarters.

Alexis Lee is a Director of Arup in the Hong Kong B group. He was the acting project manager for the CCTV headquarters.

Ronald Li is a senior engineer in Arup's Vietnam group. He was the Resident Engineer for the CCTV headquarters.

Andrew Luong is an Associate of Arup in the Hong Kong B group. He was a structural engineer for the CCTV headquarters.

Rory McGowan is a Director of Arup China, Beijing office. He was leader of the competition and design team for the CCTV headquarters.

Chas Pope is an Associate of Arup in the Beijing office. He was a structural engineer for the CCTV headquarters.

Credits

Client: China Central Television **Architect:** OMA Stedebouw BV, Ole Scheeren and Rem Koolhaas
Structural, MEP, geotechnical, fire, and security consultant: Arup - Abdel Ahmed, Cecil Balmond, Carolina Bartram, Chris Carroll, Wayne Chan, Mark Choi, Dean Clabrough, Paul Cross, Roy Denoon, Omar Diallo, Mimmy Dino, Xiaonian Duan, Gary Ge, Craig Gibbons, Sam Hatch, Colin Ho, Goman Ho, Jonathan Kerry, Michael Kwok, Richard Lawson, Alexis Lee, Jing-Yu Li, Ronald Li, Zhao-Fan Li, Peng Liu, Man-Kit Luk, Andrew Luong, John McArthur, Rory McGowan, Hamish Neville, Jack Pappin, Steve Peet, Dan Pook, Chas Pope, Andrew Smith, Stuart Smith, Alex To, Felix Tong, Paul Tonkin, Ben Urlick, Bai-Qian Wan, Yang Wang, Yi-Hua Wang, Will Whitby, Robin Wilkinson, Michelle Wong, Stella Wong, Eric Wu, Lucy Xu, Angela Yeung, Terence Yip, George Zhao (geotechnical, structural) **Main contractor:** China State Construction Engineering Corporation
Steelwork contractors: Grand Tower; Jiangsu Huning Steel **Construction logistics:** Turner Construction
Building movement monitor: China Academy of Building Research **Presetting analyst:** Tsinghua University
Independent site supervisor: Yuanda International
Illustrations: 1, 2, 25 OMA; 3, 6, 10, 17 Nigel Whale; 4, 12, 14, 16, 19, 23, 27, 29 Chas Pope; 5, 8, 18 Arup; 7, 9, 11, 13, 15, 20 Rory McGowan; 21 CSCEC; 22, 24, 26, 28 ©Arup/Frank P Palmer.

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29. The scale of the completed structure is emphasised by the quantity of site works that were still in progress around its base in August 2008.