The shocking events of 9/11 challenged both industry and consumer perceptions of how safe tall buildings are. Since then, building owners, occupiers and developers have increasingly called for building designs that are not only taller than ever before, but more robust as well. The following three case studies demonstrate Arup's response to the new demands of this changing market.

Words: Chris Webb

Tall orders

Ever since the word 'skyscraper' entered into architectural vocabulary in the late 19th century, architects and engineers have strived to push the boundaries of structural possibility. Now, those boundaries are not only concerned with height but also with form itself – an area in which Arup leads the way.

Tall buildings are not, of course, all the same. First, they may differ in function, as Craig Gibbons, a director in Arup's Hong Kong office, explains. "A client's new headquarters may be there to make a special statement – an iconic structure. The primary design driver for a mixed-use building, such as one that includes apartments, offices and a hotel, will more likely be that of useable floor space – though the client may equally want it to be a landmark."

A statement, a landmark, lots of floor space: these are all important in tall buildings, where the need to accommodate many occupants in comfort is paramount. Nowhere is this more apparent than in Hong Kong, where population densities may be as high as 45 000km^2, space comes at a premium and plot ratios are high. The equation is simple: small footprint and high occupancy equals tall building.

Tall buildings may also differ considerably in their layout, a factor that can have serious implications on their viability, and consequently, their cost. By using the latest technology in 3-D and 4-D modelling and always considering the latest in materials and construction systems, Arup teams are always able to work within the parameters of any given project.

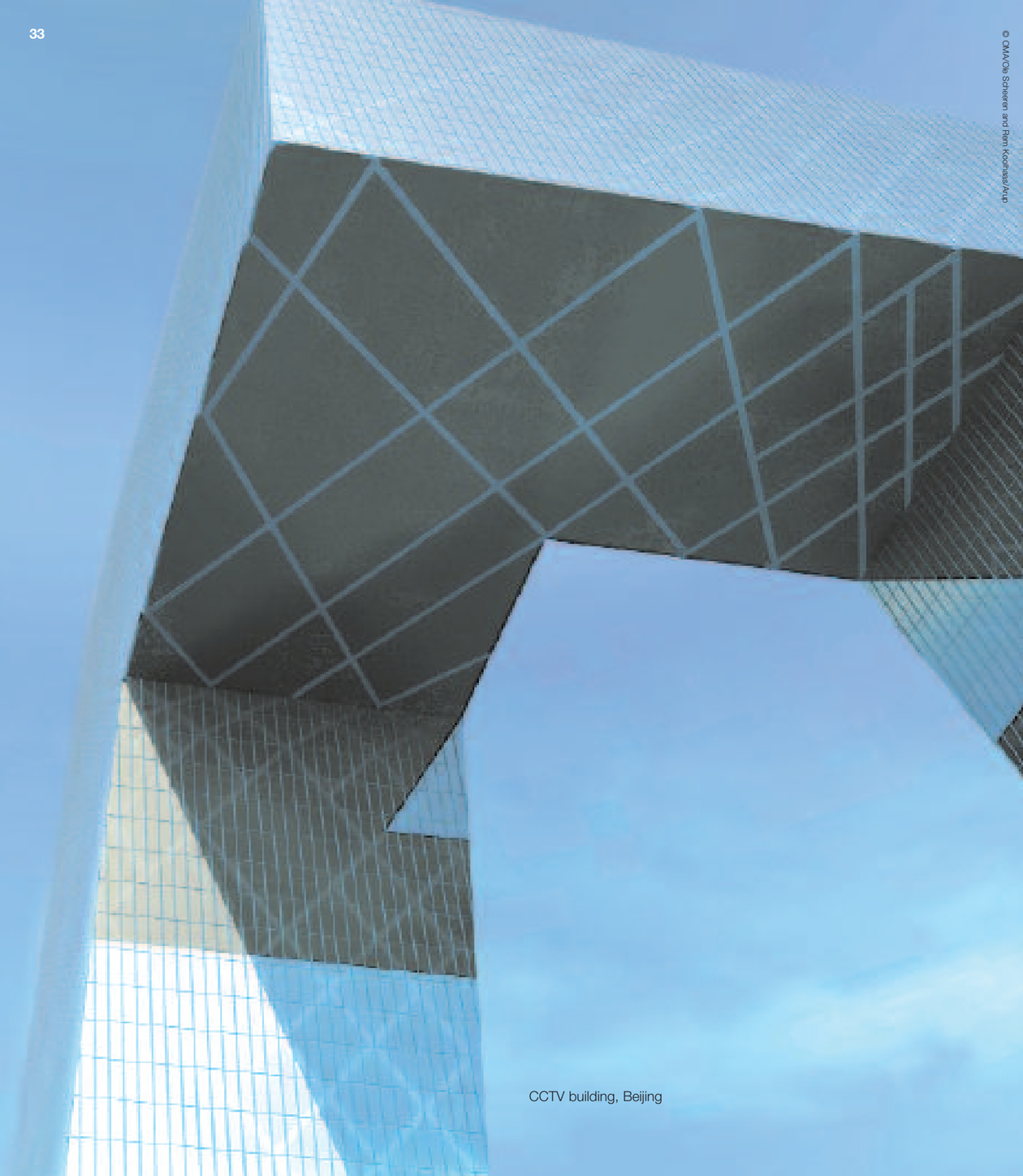
The result of this approach is a better understanding of not only the static and dynamic issues, but also the social and environmental problems a particular building presents. There are also considerations relating to building form. No longer must a client be constrained by simple building forms. Buildings can instead respond to their function.

When disaster struck in America on September 11 2001, the viability of tall buildings came under siege and across the world the security in everyone's living and working environments came under unprecedented review. Nevertheless, tall buildings are also planned for construction in some of the most environmentally hostile regions on earth, where typhoon winds (Hong Kong), or unpredictable seismic activity (Beijing) present additional challenges. Such locations require special consideration and customised solutions. In the race to build higher and higher, the need for buildings to continue to do their job in extreme circumstances is pushing at the boundaries of engineering, requiring more and more from design and materials.

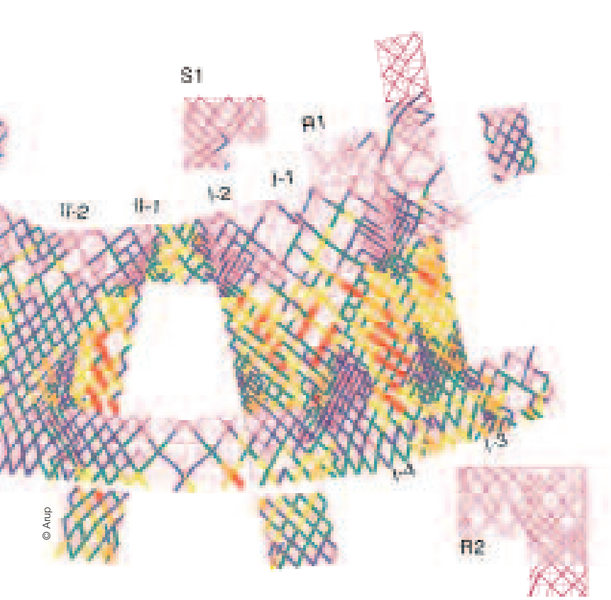
Arup's response to the World Trade Center disaster was swift, establishing an Extreme Events Mitigation Task Force charged with evaluating the risks of disasters similar to those that have taken place in recent years, analysing the technical challenges they represent and developing design solutions to address them. With typical zeal, and chaired by the late Tony Fitzpatrick, then chairman of Arup's Americas region, the task force mobilised the might of the firm's in-house research and development capabilities and specialist teams on tall buildings, fire, materials, structural analysis and other disciplines to see what lessons could be learnt from the World Trade Centre disaster.

Under the direction of a single project director, the task force continues to play a critical role in the operation of facilities when unplanned or unanticipated events occur. Arup makes full use of its multidisciplinary fire, risk, security, information technology, telecommunications and systems skills to amass a rapid understanding of the threats and risks faced by the client. Based on this, the task force assesses reasonable risks and develops additional mitigating measures to address exceptional scenarios, where appropriate. Client requirements and cost-effectiveness are also taken into account in the overall design solution.

Despite the catastrophic events and subsequent uncertainty surrounding the future of tall buildings in relation to safety, the industry has continued to grow to be as mighty as the buildings themselves. In fact, there are more tall buildings on drawing boards now than ever before, making this one battle in which technology has triumphed over terrorism.



CCTV building, Beijing



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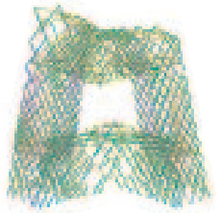


The CCTV project involved close collaboration between the architect and the engineer. Fold-out analytical models of the building were developed to convey the stresses in the diagonal braces and develop the precise configuration of the expressed form of the structure better.

CCTV building, Beijing

Chinese Central Television (CCTV), the Chinese state-run media company, has ambitious plans to compete on the world stage of broadcasting, transmitting in time for the Beijing Olympics in 2008. This expression of national pride extends to its new US$600M headquarters in Beijing's central business district. The commission to design the building was won by Ole Schreeren and Rem Koolhaas from Rotterdam-based Office for Metropolitan Architecture (OMA), with Arup. The Arup team, working closely with OMA and East China Architecture & Design Institute (ECADI), a Shanghai-based local design institute, delivered the design through seamless global collaboration, crossing time zones, cultures, cost centres and even the SARS outbreak.

Early on, the Arup team determined the only way to deliver the desired architectural form of the building was to make the two towers rise at an angle of six degrees, to be joined at the top by a 9–13 storey 'overhang' that is suspended 36 storeys high, all of which combine to form a continuous tube. The building will achieve its landmark status because of its form, as opposed to other buildings designed to achieve landmark status through their height alone.

The CCTV building is a unique, and structurally unprecedented, 450 000m², 234m-high cranked and leaning form consisting of a nine-storey base on a rectangular footprint.

Going up

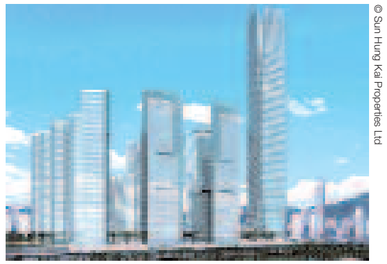
Though the idea of building an incredibly tall building or structure may seem appealing at first, it can often be the most practical elements that put a stop to a project – like lifts, for example.

Tall buildings present Arup's vertical transportation team with vitally important opportunities to make a considerable difference to the viability of a project. Recent designs for a 100-floor tower included a required lift provision that would occupy almost 90% of the floor space in certain parts of the building. By using double deck shuttles and multiple sky-lobbies, this was reduced from 13 000m² to 8 000m². The value of this saved space in London would amount to approximately £50 million.

The team is constantly reviewing and questioning common practice to find areas where innovation can make a real difference to clients' businesses, either by improving the financial return or the business process itself.

Solutions can include anything from reducing the capital cost of the lift installation to reviewing lifting options where the net lettable space occupied can be reduced.

This approach often requires Arup to work well outside of normal parameters for a lift engineer, integrating solutions with other specialist considerations such as fire, security and acoustics. Consequently, the team works closely with lift manufacturers, often reviewing new products before they have even been released. It gives Arup the opportunities to discuss any potential challenges facing clients and to offer guidance on how manufacturers can adapt their products to better suit these demands.



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International Commerce Centre, Hong Kong, China

Hong Kong's tallest building, the International Commerce Centre (ICC) is the centrepiece of the MTR Kowloon Station development. The total building stands 484m high and consists of 118 floors, housing hundreds of grade A offices and a world-class hotel. When complete, ICC will become Hong Kong's tallest building and the third tallest in the world.

The main structural skeleton of the ICC is formed from a high-strength concrete inner core wall, steel and prestressed concrete outrigger structures and eight mega columns on the perimeter. In partnership with architects KPF/Wong & Ouyang, Arup is providing civil/structural and geotechnical design for the Kowloon Station development, scheduled for completion in 2010.

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Situated on opposite sides of Hong Kong's Victoria Harbour, Two International Finance Centre and International Commerce Centre will form a new gateway to the city.

2IFC Hong Kong

Winner of the prestigious Zhan Tien Yau award for engineering excellence in China, Two International Finance Centre (2IFC) is one of the most prestigious buildings to be constructed in Hong Kong in recent years. At the time of the 9/11 attacks in New York, the 2IFC building had been constructed up to the 30th floor. Perhaps not surprisingly, 2IFC was subjected to intense re-analysis and verification to assess the safety of the design and potential implications for re-design. The studies and their findings revealed that the design was inherently sound, requiring no changes, and provided direct feedback to world practice on the design of tall buildings post 9/11. Dynamic robustness concepts have taken an elevated importance on the world stage following 2IFC studies – specifically, the need for codified ductility requirements at floor plate connections to avoid disproportionate collapse. Towering at 420m and 88 storeys, 2IFC is one of the tallest buildings in East Asia, and just a part of the multi-phase US$3 billion IFC Development. In all, it provides a total floor area of 180 000m² of grade A office accommodation.

Arup also had to address special design requirements in order to provide for rapid construction of the building. These included several construction-led principles including the building of a 61.5m diameter temporary cofferdam to allow an early start to the raft foundation and the surrounding basement to be constructed from the top down, saving around eight months in the construction programme.

CCTV
Developers
Chinese Central Television
Architects
OMA/Ole Scheeren & Rem Koolhaas
Local Design Institute
ECADI

ICC
Client/Project manager
Sun Hung Kai Properties Ltd
Building services engineer
J Roger Preston Ltd
Architect
Wong & Ouyang (HK) Ltd
Concept architect
Kohn Pedersen Fox Associates

2IFC
Developers
Central Waterfront Properties
Architects
Cesar Pelli Associates
with Rocco Design Ltd

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