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Issue 5 2018

FIRST

Tai Kwun - Centre for Heritage and Arts, Hong Kong

ARUP

Welcome

Digital technology and data are rapidly reshaping the world around us and the traditional architecture, engineering and construction industry is trying to catch up quickly with this evolution. As the digital leader, Arup is helping our clients to solve their biggest challenges and transform how people engage with the built environment through technology.

In this issue you will read about some of our latest digital innovations that have helped streamline the design process and deliver better outcomes for our clients. These include the sophisticated parametric design that has optimised the structural system of Beijing's tallest building; a web-based platform to increase data analytics capability for building performance simulation; a new modelling approach to quantify the urban heat island effect that enables early involvement of planners and architects; and innovative applications of mobile laser scanning to collect high quality data for design.

We believe that, by building genuine digital capability in-house and sharing expertise across industries, we will unlock the full potential of digital. This is the idea behind the Digital Den, a space in the Hong Kong office for our staff to share ideas, experience emerging technology and explore the possibilities that digital offers. In this issue, you will read the varied talks and events taking place at the Den and you are most welcome to visit us at the Den – it's now holding an exhibition where you can glimpse into the latest digital applications both from Arup and our collaborators from different sectors.

The advancement of technology enables us to achieve what was previously seemed impossible. From the Tai Kwun - Centre for Heritage and Arts in Hong Kong to the V&A Grain Silo Complex in Cape Town, our solutions are bringing a new life into historical buildings and engineering a future for the past. In Japan, we have helped to rebuild the city hall for resilience and sustainability, providing a catalyst for the downtown area.

Also in this issue you will read our latest foresight reports and stories of KO Yeung and Berny Ng, who have led many technical breakthroughs for ambitious systems and structures in Hong Kong.

We hope you enjoy this issue and find it valuable. If you have any thoughts, questions or comments, we'd love to hear from you at **ea.arupuniversity@arup.com**.

FIRST is a publication produced by East Asia Arup University (AU) for our clients and partners, exploring design, innovation and technical solutions for the built environment. It takes its name from the unique model of AU: Foresight, Innovation, Research, Sharing, and Training.

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Tai Kwun - Centre for Heritage and Arts, Hong Kong

From police station to cultural hub: Transforming a Hong Kong landmark

Client:
A partnership between The Hong Kong Jockey Club and the Hong Kong SAR Government

Arup's scope of services:
Structural engineering, civil engineering, geotechnical engineering, façade design, lighting design, fire engineering, materials science and security consultancy

Tai Kwun - Centre for Heritage and Arts is Hong Kong's largest ever historic building revitalisation project, transforming the city's former Central Police Station compound, with its 170 years of history, into a new arts and cultural centre. After more than a decade in transformation, the centre is now open to the public.

Tai Kwun, or Big Station, is the colloquial name of the once closed compound. The name has been adopted as a reminder of the historical importance of the site. Standing in sharp contrast to the surrounding commercial towers, Tai Kwun today provides a rare 'courtyard' in the middle of one of the densest cities in the world where the public can enjoy scenery, tranquillity and the city's heritage.

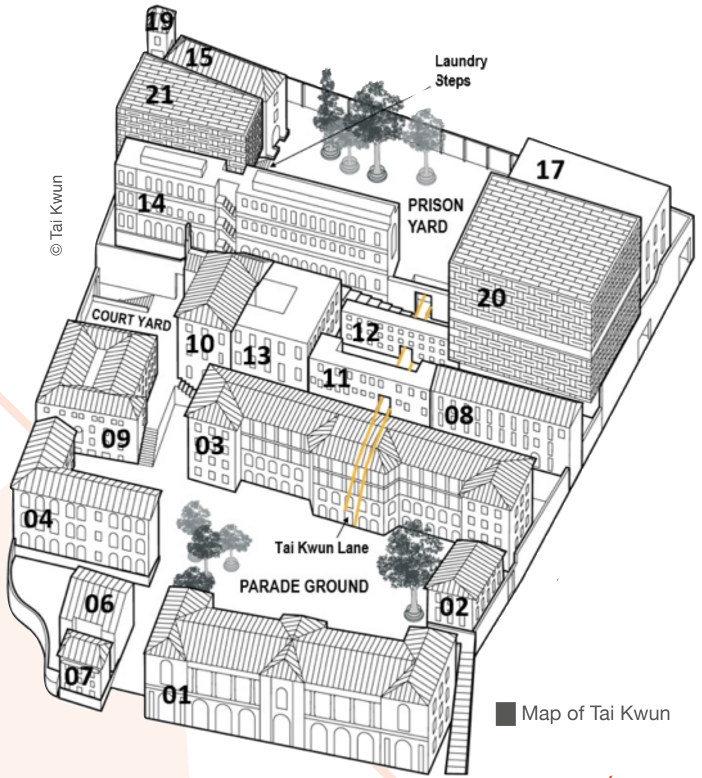
Arup has been involved in the project since 2007, providing multidisciplinary engineering services covering structural, civil and geotechnical engineering as well as façade, lighting, fire, materials and security consultancy.

Led by The Hong Kong Jockey Club in partnership with the Hong Kong Government, the project covers conservation of 16 historic buildings on a site comprising three declared monuments (former Central Police Station, Central Magistracy and Victoria Prison) and the addition of two iconic buildings and one footbridge designed by Swiss architects Herzog & de Meuron.

Through seamless collaboration between Arup's Hong Kong and London offices and specialist conservation architect Purcell, and with support from local approval authorities, these unique historic buildings have been successfully retained, repaired and strengthened for adaptive reuse. Overall stability of these buildings has been enhanced with minimal and reversible structural interventions wherever possible – setting a benchmark for future revitalisation projects in Hong Kong.

The Parade Ground and the Prison Yard have been retained, providing much-needed public open space (over 30,000 ft²) at the heart of Central

© Tai Kwun



Map of Tai Kwun

01	Police Headquarters Block	11	A Hall
02	Armoury	12	B Hall
03	Barrack Block	13	C Hall
04	Married Inspectors' Quarters	14	D Hall
06	Married Sergeants' Quarters	15	E Hall
07	Single Inspectors' Quarters	17	F Hall
08	Ablutions Block	19	Bauhinia House
09	Central Magistracy	20	JC Contemporary
10	Superintendent's House	21	JC Cube

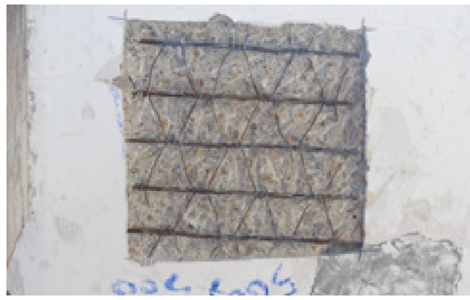
Adaptive reuse of heritage fabric

One of the biggest challenges of the Tai Kwun project was how to retain the existing historic fabric for adaptive reuse. There were no record drawings nor construction information about the century-old buildings. Moreover, all buildings were found to be in different structural forms and conditions, and composed of different materials.

Arup's team of structural engineers and material specialists in Hong Kong conducted a three-month structural survey work when the project started in 2009 to investigate the form, condition and strength of the existing structural elements, including historical brickwork, timber, concrete and steel. Structural plans were reproduced and material samples were taken for testing. Furthermore, a team of experts in the Arup London office provided invaluable advice on the properties and treatment of historic materials such as bricks, timber and cast iron.

A balanced design and construction approach was adopted such that both regulations and conservation of historic fabric could be satisfied. By applying engineering principles, results from detailed site investigations and in-situ performance testing, Arup was able to retain many historic elements such as timber floors and cantilever granite staircases for adaptive reuse.

One example comes in the existing floor slabs. During investigation works the Arup team discovered an unusual type of reinforcement inside the concrete floor slabs taking the form of two or three 5mm diameter wires twisted into bundles. At the material testing laboratory, samples of these twisted wire reinforcement were demonstrated to have similar tensile strength to modern reinforcing bars. Using a 'first principles' engineering approach combined with statistical analysis of the test data and appropriate design factors, Arup proved the technical viability of reusing the existing slabs with twisted wire reinforcement to the authorities and avoided extensive recasting of floor slabs in both the Police Headquarters Block and the Central Magistracy.



Existing concrete slabs with twisted wire reinforcement

Conservation with sympathetic structural enhancement

As most of the existing buildings were built by local builders following the limited codes and regulations that were in place at the time of construction, the engineered approach to the assessment of existing buildings has inevitably led to some requirements for structural enhancement.

Due to the wide range of existing building forms and materials the Arup Hong Kong structural team took a case-by-case approach in collaboration with Arup London's Advanced Technology and Research team.

One of the prison buildings, D Hall, was a significant surviving portion of an original radial prison built between 1858 and 1862. The ground floor in the west wing of the hall featured an elegant space featuring a brick vaulted ceiling and arched colonnade. However, assessment of the arched brick piers showed that they were of limited capacity. In order to avoid internal framing which would ruin the vaulted ceilings, Arup designed plated steel arches which fit snugly underneath the brick arches to enhance the overall capacity of the perimeter walls.

Brick arches in D Hall are structurally enhanced by steel arches

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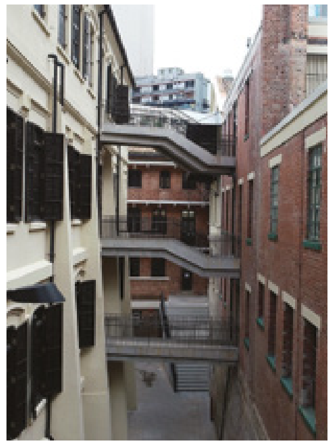


Spaces are connected by elegant walkways and footbridges to enhance connectivity within the revitalised compound

New openings were carved on existing buildings to create Tai Kwun Lane which connects various platforms from the Parade Ground to the Prison Yard

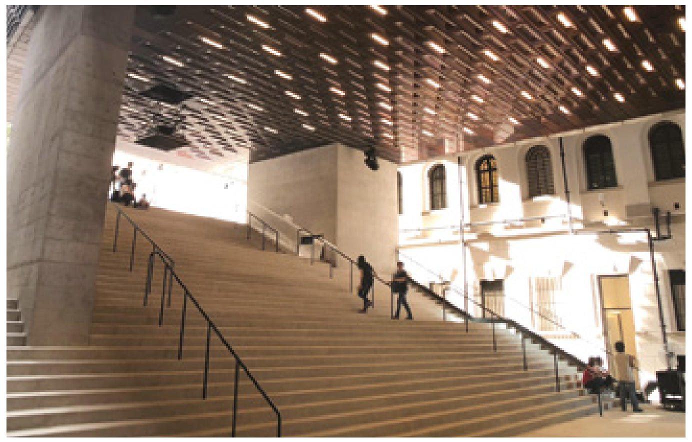
Subtle strengthening work was applied to the staircase balustrades to meet current building codes without affecting the authenticity of the staircase

Elegant footbridges and walkways were designed and new openings were also formed in the revetment walls and buildings to enhance pedestrian access and connect the once segregated zones within the compound.

New buildings with bespoke façade

Two new buildings, JC Contemporary and JC Cube, were added to house contemporary art gallery and performance spaces, respectively. Both new blocks cantilever beyond their base and 'float' above historic revetment walls to create new spaces below, including a covered semi-outdoor performance space under the JC Cube.

The form of the new buildings has been realised using a system of reinforced concrete core, cantilever steel trusses and perimeter steel trusses around the 'boxes'. A sculpture-like reinforced concrete spiral staircase with needle gun finishes connects the galleries inside the JC Contemporary and forms a strong visual element that draws visitors up from the entrance.



The new JC Cube building floats above the Laundry Steps, providing a casual open space for performances underneath the auditorium

At the JC Contemporary, a sculpture-like reinforced concrete spiral staircase connects the two galleries inside the building

Arup's façade team worked for over two years on the research and development of a bespoke façade system around the two new buildings. Each building is cladded by over 4,000 cast aluminium bricks made from 100% recycled alloy wheels. The shape and dimensions of the aluminium bricks echo the granite blocks of the existing revetment walls surrounding the site, setting up a dialogue between old and new.

The bricks interlocked to form the façade and spanned between vertical members of the perimeter trusses. Mock-ups were tested for wind loading and approved by the authorities.

The façades of JC Contemporary and JC Cube feature interlocking aluminium bricks that echo the granite blocks on the existing revetment walls

Post-pressurised shaft-grouted friction steel H-piles

Innovative foundation solutions

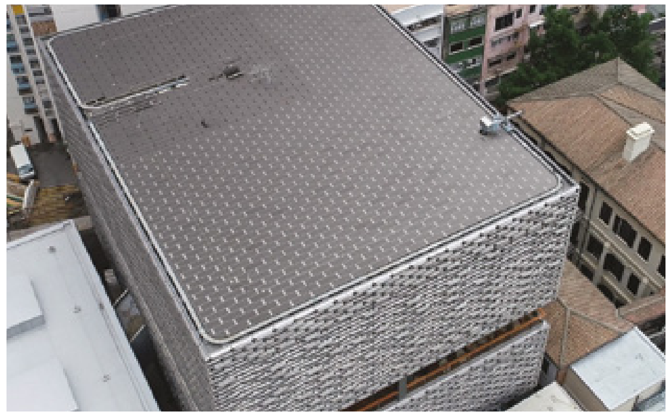
At the site, bedrock was only encountered at a depth of 80m or deeper, which posed challenges for the end-bearing piles. In view of the very deep rockhead level and the proximity to the existing heritage buildings, Arup introduced an innovative piling system using post pressurised shaft-grouted steel H-piles in pre-bored holes for the foundation of the two new buildings. This type of piling system was non-percussive and steel casing was provided for the boring work, therefore keeping to a minimum any vibration or disturbance to the existing historic buildings on shallow footings nearby.

The post pressurised grout in the pile shaft enhanced the ultimate skin friction between the pile and the surrounding completely decomposed granite stratum, and thus making the foundation possible in a site with deep bedrock.

The adjacent F Hall, a two-storey steel frame with brick piers and shallow pad footings, was underpinned by shaft-grouted friction mini-piles. A bored pile wall system with grout curtain worked in conjunction with four layers of steel struts (some with pre-loading) to ensure no damage was done to the existing historic buildings and retaining walls during the 12m deep excavation for the new basement of the JC Contemporary.

The art of lighting

Arup's lighting design for Tai Kwun is intrinsically integrated with the architecture and finishes to help weave together the various forms and spaces. For the two new blocks, Arup's lighting design makes full use of the aluminium bricks to express the texture of the façade while providing functional light to these areas. On the roof of JC Contemporary, the aluminium façade takes on a further functional form, morphing into a solar shading grid designed specifically for the site to protect the top-floor gallery from direct sunlight.



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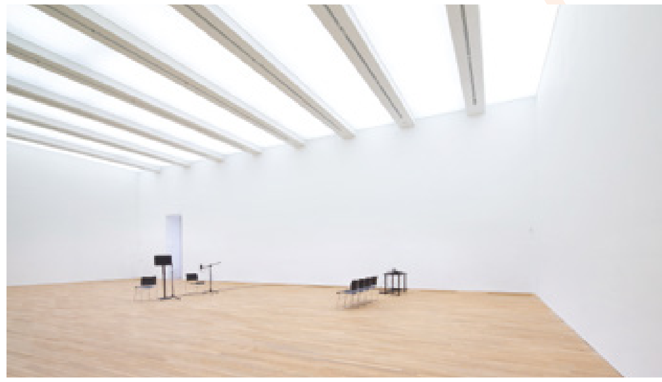
The aluminium grille at the roof of JC Contemporary was specially designed to perform as a solar shading device

JC Cube houses an 8m high multi-purpose auditorium space, over which is an accessible technical grid. Consistent with the overall theme of integrating the lighting and filtering light through the architectural fabric, the house lighting for this space is located above the grid, shining through to give a soft, general light to the space below. The glowing 'halos' of light created on the grid are then referenced by spherical cast-glass LED pendant lighting in the adjacent auditorium lobby, visually connecting these spaces together.

The lighting scheme for the public routes and spaces was designed to have minimal impact on the surrounding heritage façades while lifting these areas at night. It uses simple, low-impact, tightly controlled façade-mounted floodlights to light the paths and to give a warm embrace of light to the two main outdoor spaces: The Prison Yard and The Parade Ground.

Night view of the Police Headquarters Block and footbridge

Inside the gallery space, the ceiling is characterised by a stretched diffuse membrane to filter the incoming daylight and create a serene ambient light for the exhibitions within, keeping daylight levels to a controlled range and addressing art conservation concerns. At night, electric lighting above the membrane takes over, maintaining the ceiling glow in place of daylight.



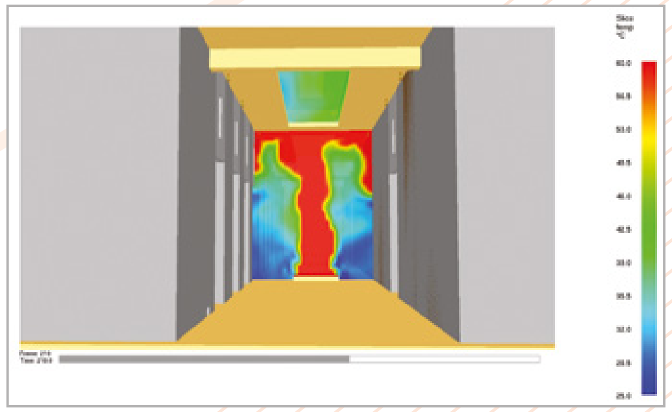
Diffused natural lighting, electric lighting or blackout by roller blinds could be provided in the gallery spaces

Managing fire safety

Arup's fire engineers have successfully preserved the historical elements without compromising the safety of the buildings.

In the Police Headquarters Block and the Central Magistracy, it was not feasible to modify the existing escape staircases to fulfil the prescriptive requirements in terms of staircase and exit widths. Arup proposed a number of enhancements including provision of smoke detection. Based on the new occupant loads and enhancements, evacuation analysis was conducted to compare the evacuation time under a code-compliant design and the proposed design. Results demonstrated that occupants can leave the building quicker under the proposed design because of the early fire detection warning and good fire safety management. As a result, the original fabric of the historic staircases has been retained.

In B Hall and E Hall, former prison halls of the Victoria Prison, connections between floors were provided by internal circulation staircases. Prescriptive code requirements would result in fixed barriers at least 450mm-long suspended from the underside of the ceiling around the stair voids to ensure formation of a hot smoke layer for active sprinkler protection adjacent to the openings. Due to conservation considerations, neither fixed smoke barriers nor automatic smoke curtains were desirable. To overcome this constraint, fast-response sprinkler heads were proposed and computational fluid dynamics (CFD) modelling was conducted to estimate the activation time of these sprinkler heads.



CFD result in terms of smoke temperature when a fire occurs in E Hall

Through perseverance for over a decade Arup engineers have helped to transform and revitalise the colonial-era Central Police Station compound into a vibrant cultural hub. Arup is honoured to have the opportunity to work on this unique once-in-170 years project and helped preserve its invaluable heritage for public enjoyment and future generations to treasure.

Since its opening in May 2018 Tai Kwun has been well received by professionals and the general public. It is a shining example of Hong Kong's heritage conservation work, and has set a benchmark for future revitalisation works in Hong Kong.

Watch the video telling the stories behind

Beijing's new airport: fire safety design and structural optimisation

Client:
Beijing Institute of Architectural Design Co Ltd

Arup's scope of services:
Fire engineering, structural design peer review and optimisation services

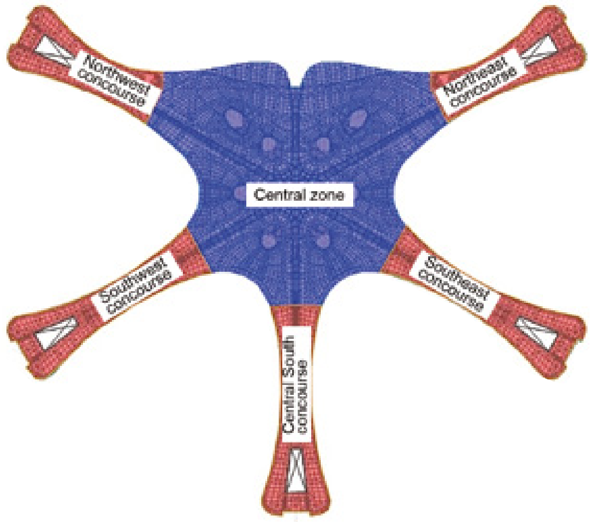
Shaped like a phoenix with a head to tail distance of 1.2km, Beijing's Daxing International Airport is going to be a new iconic building in the Chinese capital. The new airport terminal building has a total GFA of over 700,000m² and is set to become the biggest airport terminal in the world with the largest passenger capacity.

It is also designed to be a super transportation hub for Beijing – beneath the terminal building there will be three underground railway stations with a total area of 200,000m². The stations will accommodate five railway lines and will allow easy transfer for passengers to various means of transportation.

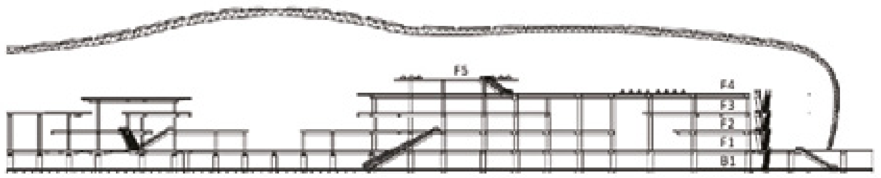
A single vast fire compartment

While the flowing, interconnected form of the terminal building creates a stunning piece of architecture, it poses huge design challenges in terms of fire safety. This is further complicated by the transportation hub located underneath the airport. The total area of the connected public space reaches 540,000m², including spaces from Levels F1 to F5 in the Central zone, and the train stations and platforms on Level B1 in the basement. These interconnected spaces need to be treated as a single massive fire compartment. Therefore, Arup's fire engineers took a performance-based design approach and adopted a series of fire protection strategies.

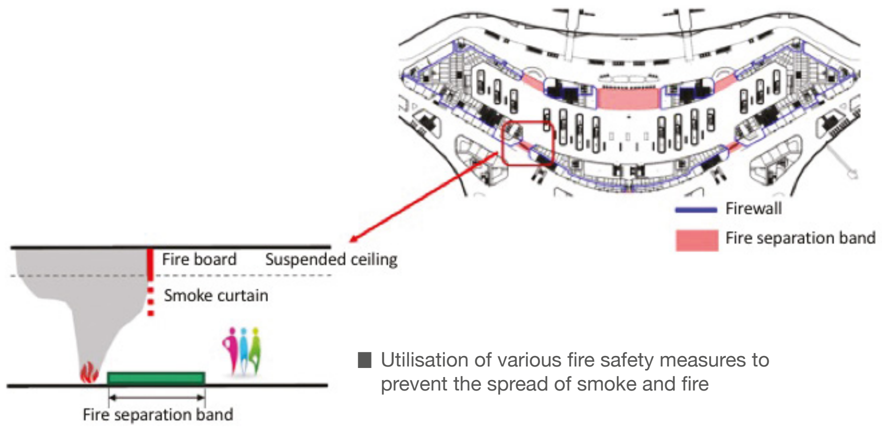
The public space is divided into 30 fire control zones (ranging from 2,000m² to 48,000m² in area) according to their functions. The conventional solution is to put a solid wall between adjacent control zones and to determine fire safety issues separately for each zone. However, solid barriers will impact the flowing form of the building design, affect passenger circulation during normal operations and hinder egress during fire emergency. Therefore, Arup proposed to use various flexible measures including smoke curtains, fire shutters and fire separation bands to prevent the spread of fire and smoke from one fire control zone to another. The fire control zones were investigated case-by-case to identify the fire protection measures most suitable for each zone. This is the first time the concept of 'fire control zones' was introduced in an airport design.



The terminal consists of six zones: the Central zone (main lobby area of the airport terminal) and five concourse wings



The Central zone of the terminal, including the large atrium and interconnected floors, is treated as a single fire compartment



Utilisation of various fire safety measures to prevent the spread of smoke and fire

To more effectively contain a fire, should one occur, high risk areas are fully contained with fire resistant construction. Each unit is limited to a maximum area of 2,000m² and will be equipped with 2-hour fire-rated walls and 1.5-hour fire-rated floor to restrict the spread of flames.

Arup also took advantage of the large atrium in the Central zone to control the smoke by buoyancy and dilution. Passive vents were provided in the ceilings in some areas so that when the smoke on the lower floors rises to the atrium above it will be sufficiently diluted and a tenable environment can be maintained. To ensure the effectiveness of this strategy Fire Dynamics Simulator (FDS) analysis was performed to examine the occurrence of fire at all possible locations.

A smart egress strategy

Emergency egress presents another major design challenge due to the vast size of the terminal building and the large number of occupants. The escape distance to outside is over 200m for most parts of the Central zone, whereas in a standard building this escape distance should be within 75m.

Twenty-nine egress stairs were provided in the Central zone to shorten the travel distance on various floors and help divert passenger flow to prevent bottlenecks. However, the egress stairs in the central area lead to the baggage handling rooms on Level F1 where the connected carousels may trap people, potentially leading to a serious risk of people running into a fire. If these stairs are removed from the design fewer egress paths will be available on each floor and occupants will need to walk a longer distance. Alternatively, in a code-compliant design the egress stairs will need to discharge to outside via a protected corridor which would interrupt the baggage handling system and other building services.

The blue egress stairs will land in the inner area or the baggage handling spaces on Level F1, causing fire safety concerns

To solve these problems Arup proposed a smart egress strategy for the public space in the Central zone. This innovative solution provides different egress routes based on the fire location. For example, if the fire occurs on Level F1, smart signage will direct occupants on other floors in the building towards egress stairs along the building perimeter or leading outside and avoiding the central egress stairs. When the fire occurs on a level other than F1, then all egress stairs will be used to ensure rapid evacuation. This strategy can achieve fire safety while maintaining the integrity of the baggage handling system.

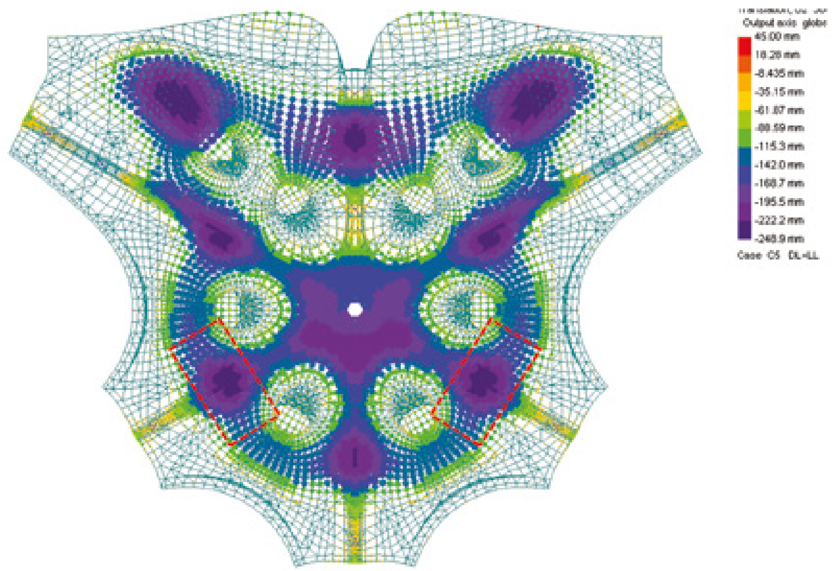
The smart egress system will direct people to the safest egress route based on the fire location

The roof of the Central zone is a continuously flowing dynamic shape supported by giant C-shaped columns which connect seamlessly with the roof curvature

Optimising the roof structure

Arup carried out peer review and value engineering for the roof of the terminal building, a large-span and complex hyperboloid steel grid structure covering over 350,000m² and containing more than 170,000 steel members.

From project commission to report submission, Arup had to complete the design analysis and optimisation within three months in order to meet the tendering schedule. This tight time scale imposed huge challenges on the structural team. But with the help of Arup's in-house inter-operability tools, the roof structure analysis models were set up within a week in various structural analysis software for all the necessary design reviews and still leaving sufficient time for the team to explore different optimisation options.



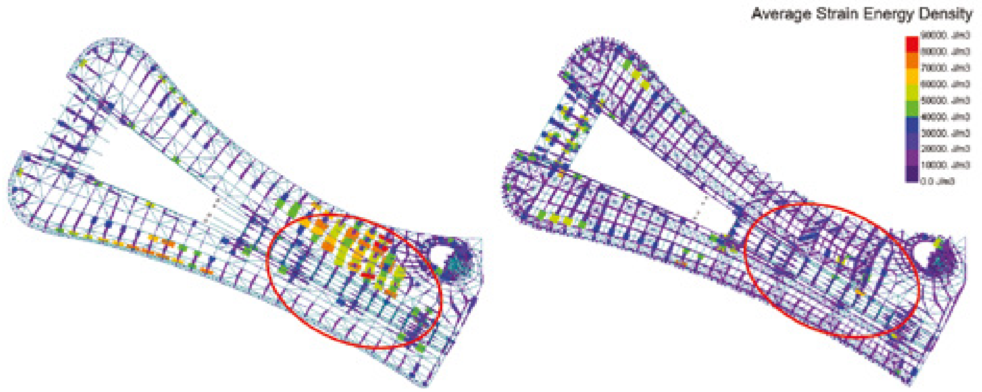
Example of analysis for the Central zone deformation of the roof under dead and live loads

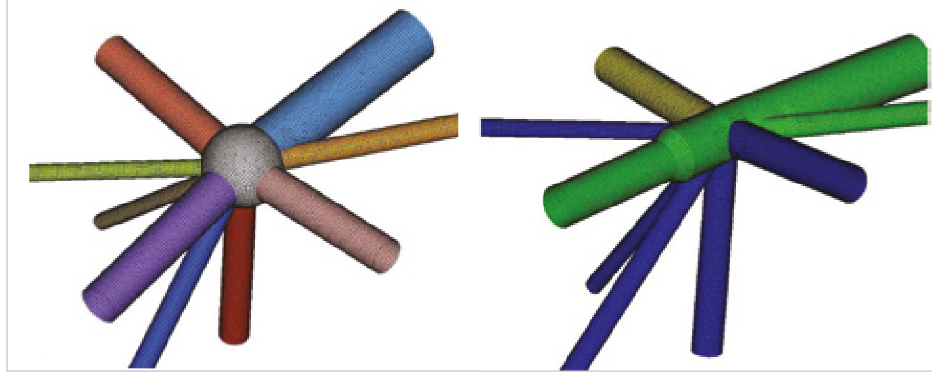
The roof of the Central zone spans 457m from north to south and 504m from east to west and is supported by giant C-shaped columns, rigid support-tubes and steel tube columns. The C-shaped columns are the most critical elements in the terminal as the span between them can reach 180m. The five concourse wings share similar structural layouts – the upper part consists of a steel truss roof and supporting posts while the lower part is a reinforced concrete structure. These structural components and the interaction between steel and concrete were studied.

The structural design of the terminal was mainly governed by the material strength and slenderness ratio of the steel elements. In the review process, Arup engineers studied the structural configuration, loading, vertical support system reactions and the structural deflection and displacement. A total of 420 load combinations were considered and 38 different cross section sizes were employed in the superstructure.

The analysis revealed that around 1% of the steel members had exceeded design limits and should be strengthened. Apart from the cantilevers near the C-shape columns which had reached the deflection-span limit, deflection in other regions ranged from 1/2000 to 1/600, far from the 1/250 limit in the design criteria. In addition, over 90% of the steel members had a stress ratio less than 0.5. Hence there was room for design optimisation.

Strain energy density in the original scheme (left) at the Northwest wing was concentrated in a number of structural elements. By adjusting the member sizes and improving the member stiffness the strain energy density in the optimised scheme (right) was redistributed thus reducing the overall steel weight and deformation





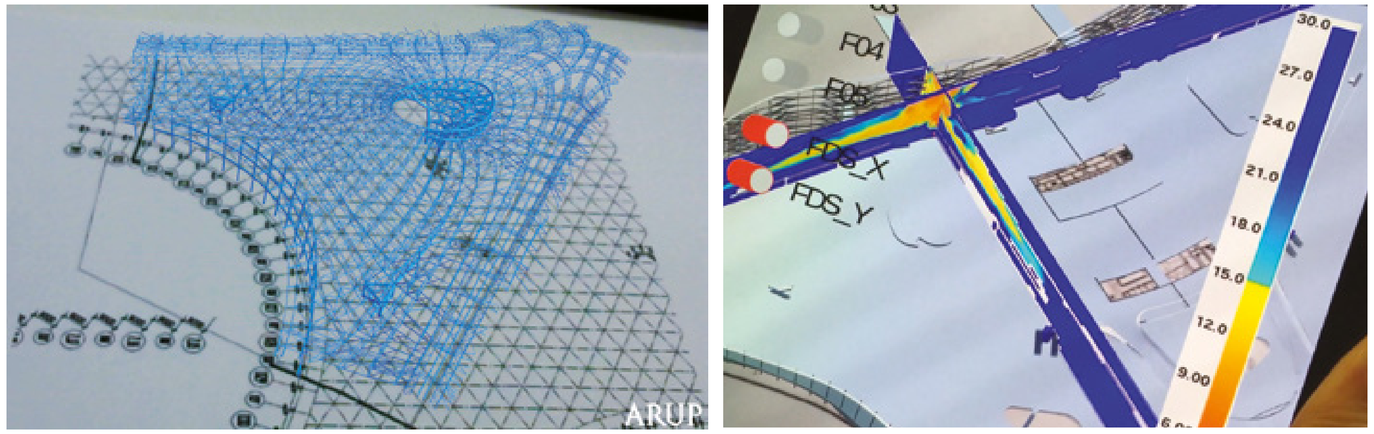
A large quantity of spherical joints (both welded and cast steel types) were used in the original scheme. Based on finite element analysis results of their bearing capacity, Arup recommended that some of the spherical joints (left) be replaced by tubular joints (right) to reduce the self-weight of the long-span structure, save on steel tonnage and also improve the aesthetics of the terminal building

With extensive experience in long-span steel structures and structural design optimisation, Arup proposed various optimisation strategies for the different zones of the terminal to improve the roof truss patterns and reduce unnecessary structural depth and member sizing.

Although the design of the steel roof had already been reviewed by several local design institutes prior to the peer review, Arup's comprehensive optimisation strategies helped the project to achieve further reduction in steel tonnage, resulting in significant cost saving and reduction in carbon emission. The whole service was completed in three months, meeting the timeline and perfectly matching the period for steelwork tendering.

With the completion of the terminal and the satellite hall south of the terminal building, Beijing's new airport can reach a maximum capacity of 120 million passengers per year. Arup's input helped realise the flamboyant design of this multi-modal transport centre. The structural analysis not only helped to ensure the safety of the airport terminal structure but also optimised its design, leading to huge savings in steel tonnage. The performance-based design of Arup's fire engineering team successfully gained fire approval, making this terminal building one of the largest and longest fire compartments in mainland China. By realising the integration of the transportation hub and the terminal building – instead of placing them at separate locations – Arup's solution will help to save over 1.5 million hours for nearly 30 million passengers every year.

The terminal's interior construction work is scheduled to be completed in 2018 and the opening ceremony will be held in 2019 as part of the celebration for the 70th Anniversary of the founding of the PRC.



Arup's in-house developed visualisation app ArupREAL helped to demonstrate the analytical data and simulation results: (left) roof steel member arrangement, (right) fire and smoke evolution

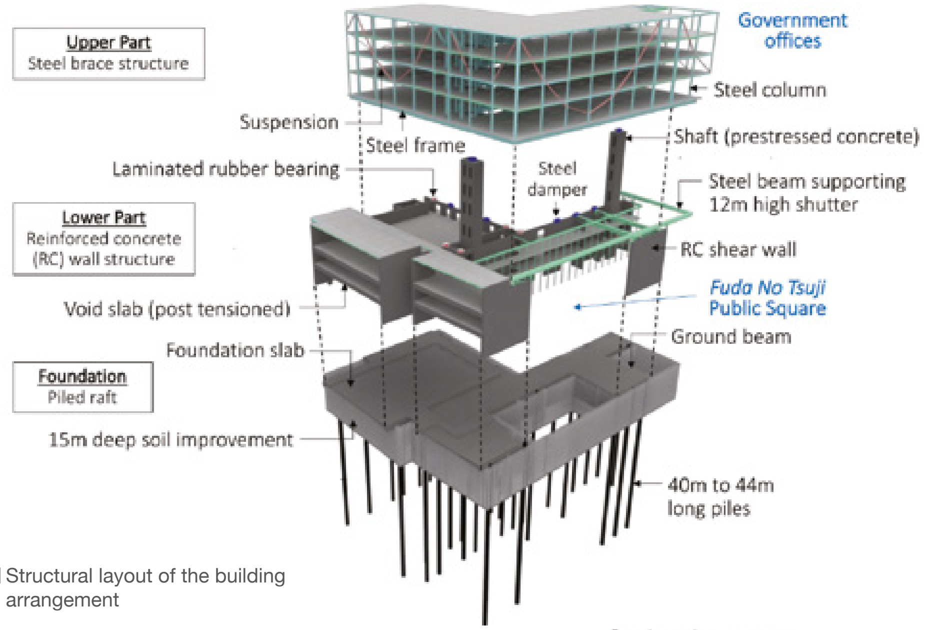
Shibata City Hall:
a catalyst for city renewal

Client:
aat+ makoto yokomizo, architects Inc.

Arup's scope of services:
Structural engineering, mechanical engineering, electrical engineering, public health engineering, façade design and lighting design

The new Shibata City Hall is acting as a catalyst to revitalise the downtown area of this historic castle town in Chubu, Japan. Built to replace the old city hall damaged by major earthquakes in 2004 and 2007, it brings together all the government functions under one roof and, at the same time, provides a gathering place for the public.

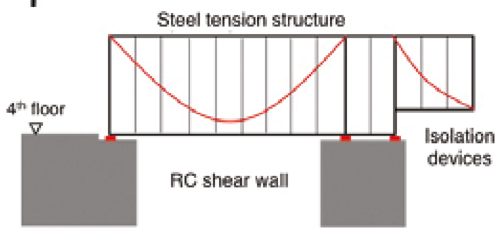
The new city hall consists of a light upper part with a soft grey double skin glass façade that 'floats' over the building and houses government functions; the heavy lower part, which is open to the general public, fits in with the neighbourhood and comprises the *Fuda No Tsuji* public square. The focus of the design was to adapt the large building volume (14,000m^3) to the small scale of the surrounding town and lay out the multi-purpose space to create an exciting venue while also allowing flexibility for the long-span office space.



■ Structural layout of the building arrangement

Making the 'cloud' float

The government floors sit on top of the semi-indoor public square where a large column-free space with high headroom is needed. To realise the long-span space a suspension bridge approach was adopted for the upper floors so that the steel brace structure can float over the building like a 'cloud'. Flat bars (300mm wide by 40-90mm thick) are used as suspension hangers and arranged in a curve between the main columns (maximum span 38m) of the outer frame. The on-site measured deformation of the frame was 25mm, matching the predicted value from the structural analysis. In this way we have realised a multi-purpose space that can be used both inside and outside.



■ Hangers (red) are arranged in a curve to form the 'suspension bridge' above the isolation devices

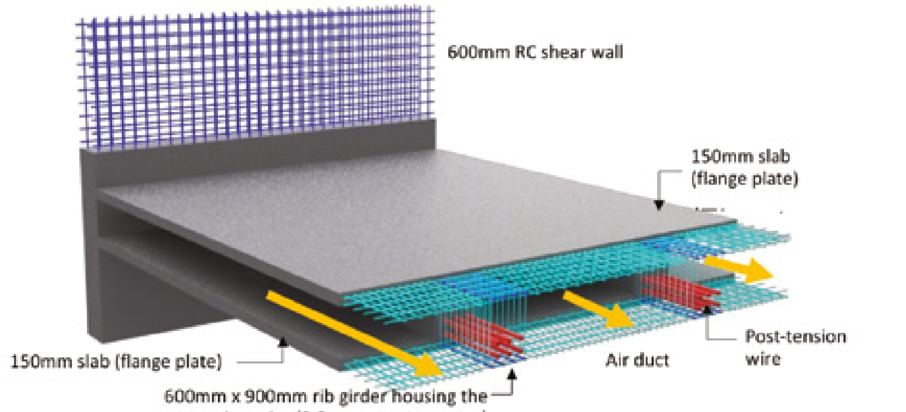
Ensuring safety

Seismic performance is a key building design factor and the biggest challenge for the project team was to minimise earthquake vibration impact on the government floors so that they can remain operational even after major disasters. This was achieved by installing isolation devices between the government floors and the lower part of the building to attenuate the transmission of ground motion. The isolation devices – 10 laminated rubber bearings and eight steel dampers – sit on top of the 3/F structural walls, within a 400mm gap. The weight of the upper part of the building above the isolation devices acts as a mass damper to increase seismic resistance.

Compared to a conventional design, where an independent 'isolation layer' is reserved for the isolation devices, this is the most economical solution due to the minimum structural frame size requirement. It also provides an easy access for inspection and maintenance and makes the most effective use of the limited architectural space.

A concrete shear wall structure forms the lower part of the building to resist lateral loads. Large 25m-span void slabs implemented at the 2/F and 3/F form a moment frame with a shear wall and the voids between the rib girders operate as air ducts. As the void slabs are just 900mm thick concrete cracking has been controlled by post tensioning.

The building is supported by a piled raft foundation with 40m to 44m long piles. Due to poor soil condition, and to avoid large horizontal and vertical displacement caused by liquefaction and settlement of the surrounding ground during an earthquake, deep ground improvement work (15m) was carried out.



■ The 900mm thick 25m-span void slab

Design for sustainability

Based on a comprehensive comparative study considering initial cost, life cycle cost and environmental performance a co-generation system was adopted as the air conditioning heat source. Waste heat from the generator is used to power absorption chillers and pre-heat domestic water. Since the co-generation system is used in both normal and emergency conditions, both peak power and cost are significantly reduced.

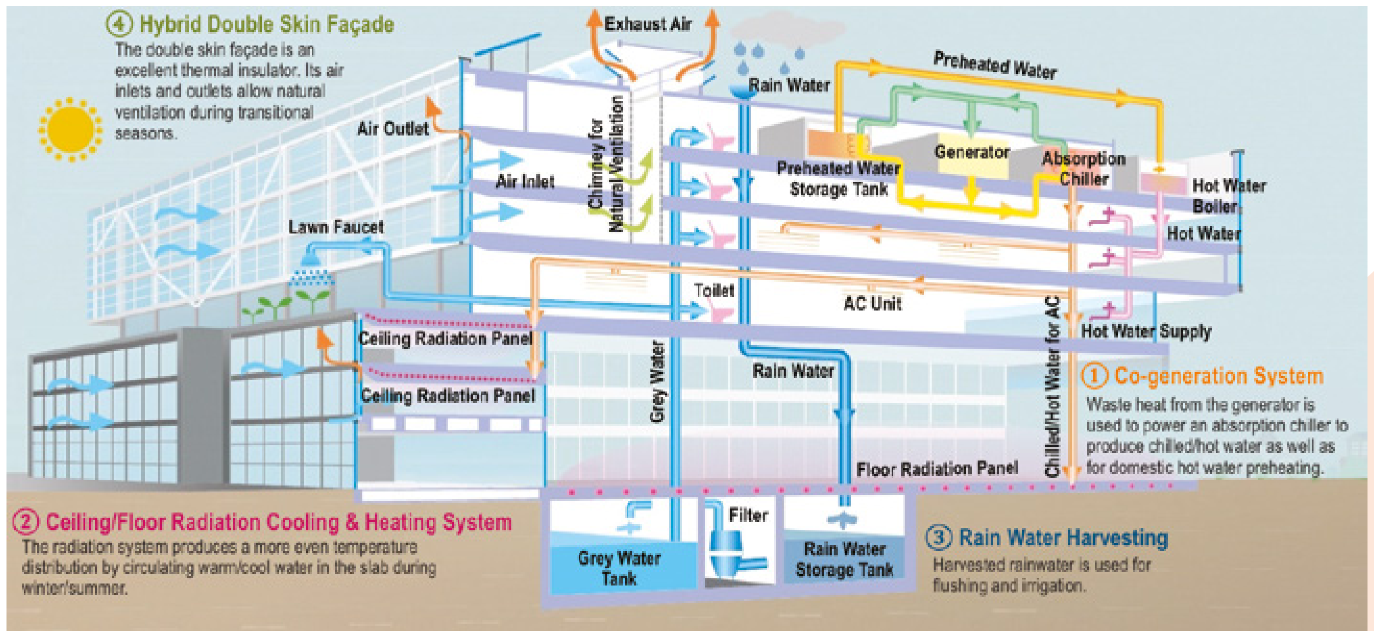
A ceiling radiation cooling and heating system was implemented for offices facing south to conserve energy and enhance thermal comfort. Water pipes connecting to the absorption chiller are installed in the ceiling slabs to form radiation panels; cool water is circulated in summer and warm water in winter to cool down or heat up the rooms. To maximise the radiation panel efficiency air circulation fans are installed to capture cooling/heating capacity leaking above the ceiling. Special design consideration was also given to control water condensation.

Moreover, a floor radiation system was adopted in the public square. And rain water is harvested for flushing and irrigation while also acting as runoff control to reduce the flood risk to the neighbourhood.

The Shibata City Hall also boasts a number of passive design features. The ceramic façade features several patterns to diffuse natural light to accentuate the workspace and save power. The hybrid double skin façade acts as a heat shield or heat insulation depending on the season; with its air inlet and outlet at the façade and a ventilation chimney at the back of the building, the façade system allows natural ventilation. A test after building completion shows that the room temperature is only 2-4 degrees higher than the outside temperature in the intermediate season, in line with the simulation results during the design phase.

The Shibata City Hall has welcomed thousands of visitors since opening in 2017. Arup's solution has successfully helped to create a city hall that is not just an administrative building for the local government but also a community space for citizens to relax and enjoy themselves.

■ Major sustainability features



China Zun: robust structural system enhanced by parametric design

Client:
CITIC HEYE Investment Company

Arup's scope of services:
Structural engineering, geotechnical engineering, fire engineering and security consultancy

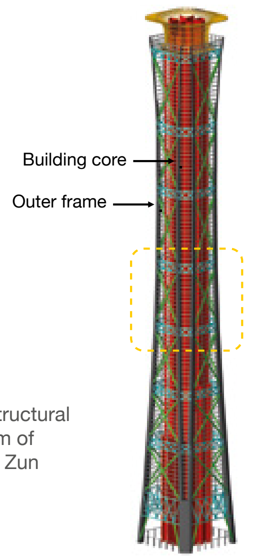
Located in the heart of Beijing's central business district, the China Zun tower is the tallest building in the capital city. The mixed-use development includes a 7-storey basement and a 108-storey, 500m plus tall mega tower providing 350,000m² GFA above ground. The name of the building comes from the 'zun', an ancient Chinese ritual vessel with a characteristic slim waist which inspired the building design.

© Fu Xing Architectural Photography

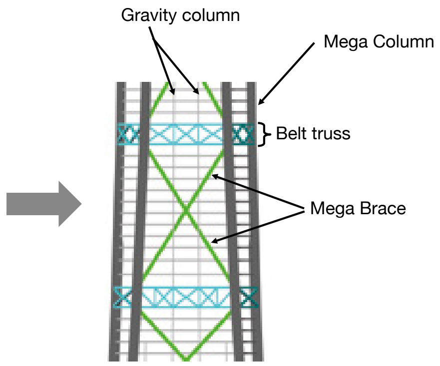
Most super high-rise buildings feature their smallest dimensions at the top to reduce the wind load and seismic mass. On the contrary, China Zun's floor plan reduces from 78m in width at the bottom to 54m at its 'waist', which then enlarges again to 70m at the top to maximise the floor area at higher levels to bring more value to the client. However, this unique building shape exacerbates the challenge of building such a tall tower in a high seismic zone.

Making the 'zun' stand

Arup engineered a highly efficient tube-in-tube structural system composed of a central reinforced concrete core and perimeter steel braced frame to meet seismic resistance requirements. The perimeter steelwork consists of mega braces, transfer belt trusses (which form part of the overall lateral stability system and visually divide the height of the building into zones), mega columns (which run the full height of the building) and gravity columns (which support gravity loads only).



The structural system of China Zun



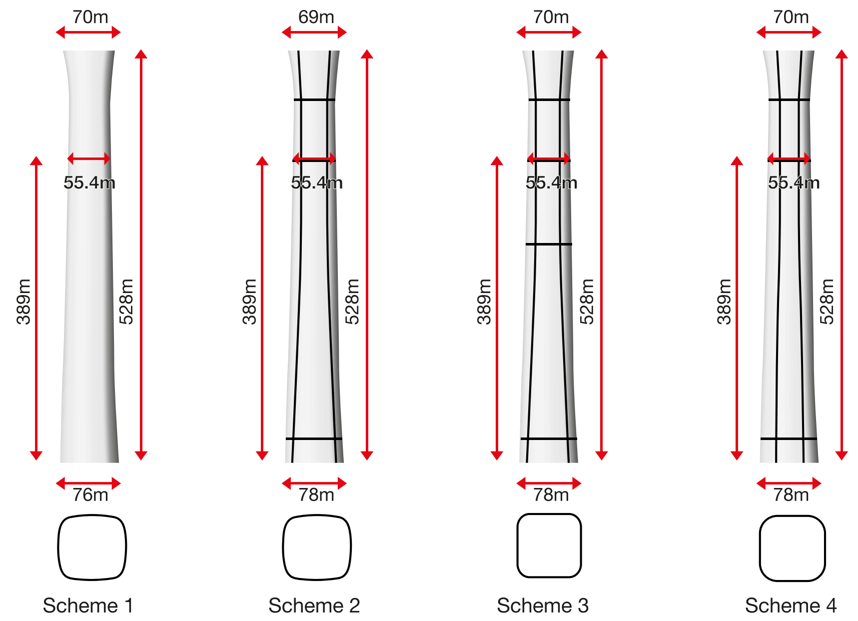
The first layer of mega brace and belt truss

© Zhou Ruogu Architecture Photography

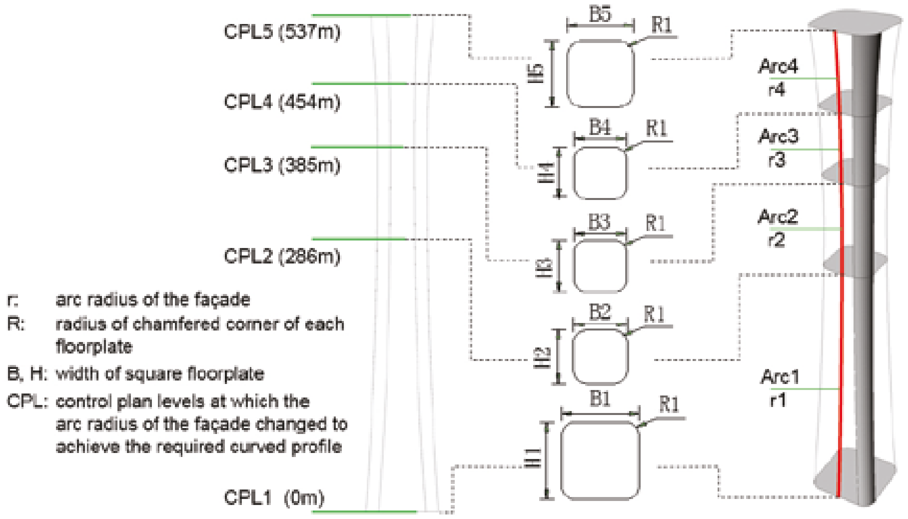
Optimising the form

The geometry of the mega frame and the building's curved façades required complex and lengthy structural analysis. They were carefully studied with the architect using an advanced parametric structural design approach and BIM technology.

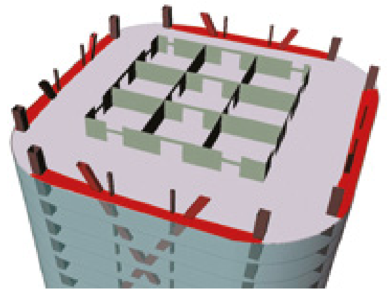
Parametric modelling allows the use of very few key parameters to define an entire structural system. Therefore the effect of different architectural variables could be analysed quickly and accurately, with the complex structural model automatically regenerated for each design iteration. As a result, more than 800 design options for China Zun were studied in record time to perfect the geometry of the building's curved façade.



Four of the different architectural options investigated using parametric modelling, with variations in arc fillet radius and floor dimensions at the top, base and the 'waist'



The form of the tower was optimised by varying several critical parameters which control the architectural functions as well as the structural performance



Multiple geometries were studied to minimise the area between the façade and the mega columns (highlighted in red) on each floor

Parametric modelling was also applied to optimise the design of the mega columns. This included investigating multiple solutions to minimise the distance between the mega columns and the façade on each floor to increase usable floor area. By keeping this distance as small as possible, the engineers managed to increase the total usable floor area by 7,800m² while achieving acceptable structural performance.

Seismic loads

Due to its exceptional height, China Zun is a code-exceeding structure and a hybrid empirical and performance-based methodology was adopted for its seismic design.

Elasto-plastic analysis was carried out using LS-DYNA to evaluate the building's behavior under severe earthquake. The overall performance of the tower was evaluated by the elasto-plastic storey drift, shear-weight ratio, top storey drift, bottom shear time-history curve, plastic time-history development and plastic zone. Plastic deformation in structural members and the lateral drafts all satisfied the required code limit.

Dynamic time history analysis results indicated that the perimeter structure carries 40-50% of the relevant storey shear forces at different floors caused by an earthquake, and about 67% of the total overturning moment. Capacity requirement to the concrete core is hence reduced except at the floors at the 'waist' of the tower, because of the dual effect of a smaller thus weaker perimeter structure and the negative shear force caused by inwards tilting of the perimeter columns. As a result, steel diagonals were added to the core wall at the waist floors to form an embedded steel skeleton together with steel stanchions. The strengthening was justified by elasto-plastic nonlinear analysis to be appropriate, and will not attract more seismic forces and create new weak areas.

A 1:40 physical shaking table test was carried out at the China Academy of Building Research to test the structural performance under time history records corresponding to different levels of earthquakes. The major results were consistent with the elasto-plastic analysis and verified the structural safety of the tower.

The China Zun tower marks a new height record in high seismic zones and presents the maturity of design and construction of composite structure in tall buildings. Arup has helped realise the architect's vision for this elegant curved-shape building with a safe, cost-effective and sustainable structural solution.

China Zun was fully topped out in the autumn of 2017 and is expected to be completed in the 4th quarter of 2018.


© Tessa Brunette

V&A Grain Silo: rebirth of an industrial heritage

Client:
Victoria and Alfred (V&A) Waterfront Holdings Pty Ltd

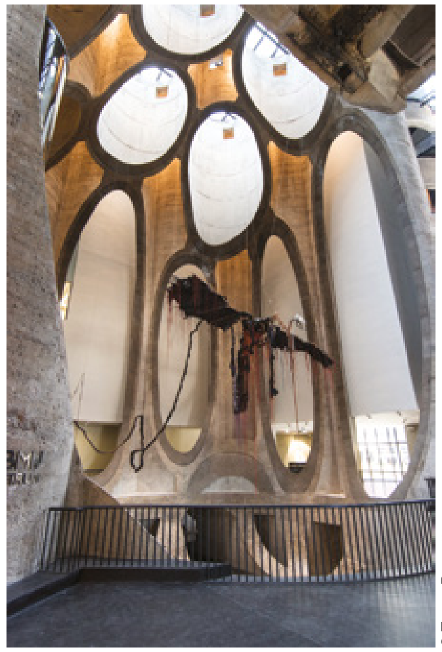
Arup's scope of services:
Façade engineering, mechanical and public health engineering.
Multidisciplinary engineering up to scheme design (notably including structural engineering) as well as targeted wind, security and lighting studies

Built in the 1920s, the V&A Grain Silo was once used to store grain for export from South Africa. It was decommissioned in the 1990s and subsequently fell into a state of disrepair in a forgotten corner of the prestigious V&A Waterfront in Cape Town. As part of the plan to rejuvenate this precinct, the grain silo was ingeniously transformed into a luxury hotel and the largest museum of contemporary African art in the world.

Structural concept and scheme design

The original building consisted of a 57m tall grain elevator tower and a storage annex consisting of 42 tightly-packed concrete silos each measuring 5m diameter by 30m tall. The architect Heatherwick Studio devised an innovative idea to carve out huge sections of the building's tubular interior to create a massive volume to house the museum, and this bold architectural vision was realised with the help of Arup's structural concept and scheme design.

As the matrix of 42 silo tubes was being carved into in order to create the atrium to the west and multi-storey gallery spaces to the east, the silo walls need to be structurally integral in order to be held in their original form.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Carved silo tubes and the grain-shaped atrium cutout

Therefore, a thick reinforced concrete sleeve was cast inside each of the tubes, essentially creating an entirely new building structure in and around the old structure and able to hold the old one in place. This stable composite structure allowed the silo cylinders to be extensively carved out without any rebuilding being required. To honour the building's history the shape of the atrium cutout is an exact replica of a piece of grain, which was 3D scanned and inserted into the 3D model, but on a much larger scale.

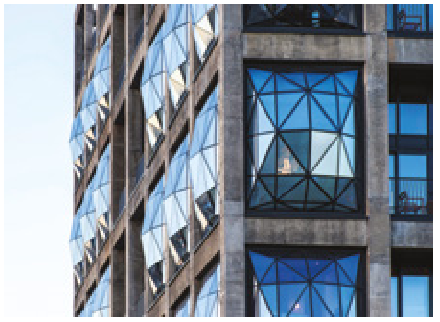
The steel structure of the multi-storey grain elevator tower was generally in good condition but new cores were provided for stability as the original perimeter concrete wall panels were removed at top and bottom levels. Three primary columns were cut away at lower levels, as part of the atrium cut out at the interface with the adjacent tubular silos annex. The column loads were transferred through major reinforced concrete corbels into the new cores. Original filler joint floors were strengthened with a reinforced topping slab and new reinforced concrete slab floors were added within the lower silos.


© Tessa Brunette

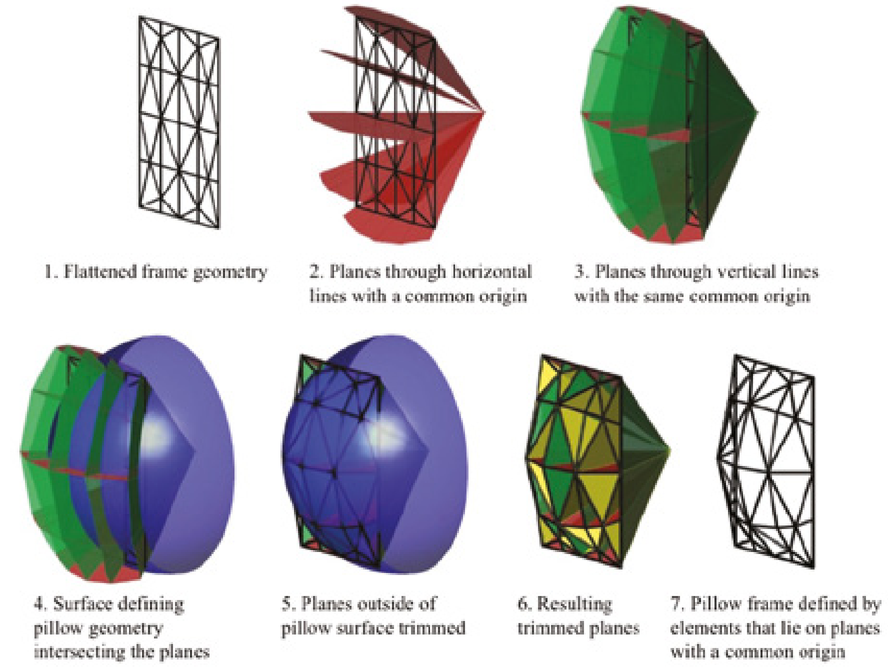
Carved silo tubes above the atrium are fitted with skylights and form part of the rooftop sculpture garden

Façades

The greatest change to the building's external structure is the iconic glazed 'pillow' panels that are inserted into the existing geometry of the grain elevator tower's upper floors and on top of the silo bins. A total of 98 pillowed glass windows have been incorporated, each containing 56 triangular glass panels. Arup's façade team developed these pillowed windows with the architect, following their concept of convex 'lantern' lights, and the two teams collaborated closely to deliver the technically challenging design intent in a pragmatic and buildable manner. The first step was to define the number of facets in each pillow and the conceptual detailing. Arup then set up a Rhino parametric model fed with a Grasshopper script. The model locked in the necessary structural constraints while leaving the architect free to explore the aesthetic resolution in order to give the desired form to the window. The parametric model also allowed specific geometry to be developed for each of the five different overall window sizes, following the same pattern and constraints, and construction drawings of the framing and glazing panels could be quickly generated from the parameter file to assess the viability of each solution. This ensured that the complex design intent was achieved efficiently, providing a sound basis for procurement and reducing costs and programme risks within the architectural design intent.



New pillowed windows are inserted on top of the grain elevator tower (above) and the silo bins (below)



Visual description of the defining parameters in the model

Each large pillowed window (up to 5074mm × 5022mm in size) was prefabricated and glazed as a single unit in factory and then transported to the site. Due to the weight and size of the panels, fixing them onto the building presented a challenge. After several tests on site showed that the existing concrete was too weak to be fixed to, the decision was made to strip it back around each column (encasing large steel members) and install new concrete around the retained steel elements. This allowed the pillows to be fixed directly to the new concrete.

Mechanical and public health engineering

Arup also provided international best practice design to deliver precise environmental control to the museum. Emphasis was placed on energy efficient design to reduce power consumption and the buildings demand on municipal infrastructure.

High-performance double-glazed solar control glass was selected to reduce solar gain as much as possible within the design intent. Compared with a conventional flat façade, the faceted façade form maximises views and gives access to natural light while reducing peak energy loads due to the multiple reflection angles. In combination with the glazing, this resulted in the mechanical system being designed for a lower peak condition and the plant size accordingly reduced, leading to lower running costs and energy use.

The retained external façade of the silo bins has been insulated and re-sleeved with new concrete to create a thermally massive structure, protecting the spaces and the art work from the external environment.

This remarkable feat of engineering has reinvented the valuable industrial heritage complex into a unique centrepiece for the V&A Waterfront. The spectacular cathedral-like atrium of the Grain Silo expresses the exciting geometries of the cut cylinders. The delicate pillowed windows create a crystalline counterpoint to the robust existing concrete frame and act as lanterns to the harbour and city.

Fewer lecture halls, buildings with AI and holistic 'learn-life' services: a new Arup report identifies key trends that will allow universities and colleges to provide more flexible learning experiences and reduce running costs.

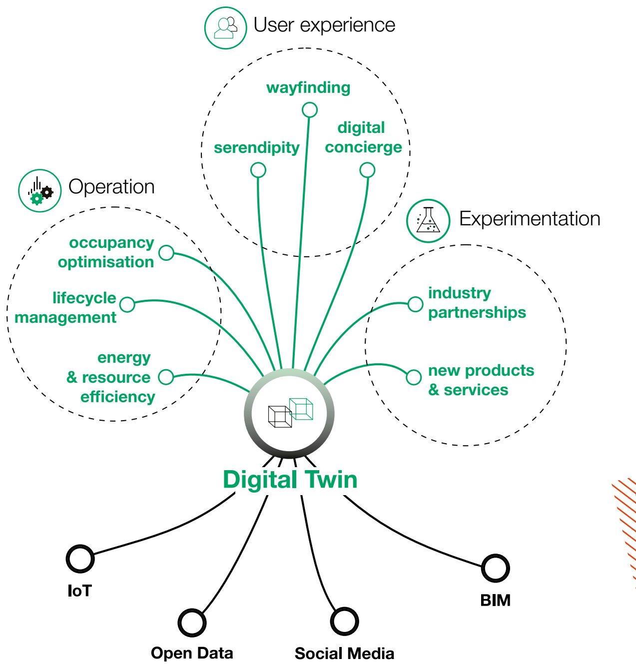
Campus of the Future

The 'Campus of the Future' report calls for a rethink of the design and operation of higher education facilities to prepare for a new era of learning.

Digital learning, automation and the expectations of an increasingly diverse student body are affecting how, what and where we learn. With more varied learning methods than ever before, the requirement for campus buildings are being redefined. And in the face of shifting financial resources, the campus of the future will need to navigate constantly changing international and local contexts, whilst reducing environmental impact and fulfilling commercial opportunities.

The report highlights various approaches that higher education leaders, designers, developers and facility managers should consider to maximise opportunities to become more adaptable and resilient in the face of changes. These include:

- Blurring the 'learn-life' boundaries – The boundaries between everyday life and learning are continuously blurring. This trend, combined with the increased autonomy of students to choose where and how they want to research or study, is leading to a need for a holistic work-life experience on campus. As students and staff spend a large proportion of their day within the campus, facilities should be provided to integrate the campus with the broader fabric of touchpoints of student and staff life. Interior and exterior spaces should be designed with human wellbeing at their core.
- Buildings that are flexible by design – There is a rising demand for spaces that can be transformed on a regular basis, to adapt to the ever-changing curricula and the individual requirements of students, departments and industry partners. Advanced technologies such as digital fabrication and 3D printing can make it easier to design structures that can be constructed, deconstructed and then reconstructed. Design strategies should also consider the entire life cycle of buildings and look to create adaptable layers that can be easily separated, moved and modified.
- Making waste work – Universities can be ideal environments to turn waste into resource. For example, by-products such as heat from laboratories can be used by other facilities while solutions such as blue roofs can help harvest rainwater. As decreasing public expenditure impacts many facilities, these design strategies will be essential to reduce resource consumption and future-proof the financial performance of a campus.
- Using data to maximise facilities – A campus-wide Internet of Things network, supported by AI and machine learning algorithms, can gather a diverse range of real-time data, allowing operators and facilities managers to learn usage patterns over time and implement strategies to increase efficiency in campus resource management. This can allow higher education institutions to maximise resource consumption by making their facilities available to private or public organisations, using a model similar to WeWork.



Data harvested from multiple sources enhances campus performance

- Being a catalyst for innovation – Academic institutions can play a key role in facilitating the creation and diffusion of knowledge. Proximity to the local business community can help foster regional innovation and provide employment and learning opportunities for students. To enable both cross-departmental and external collaboration, buildings should be open and inviting with multi-functional and adaptable spaces for co-working.

Case study: The Why Factory

This think tank and research institute in the Netherlands is housed in a striking, 3-storey structure containing meeting rooms, lecture halls and research facilities, while stairs and seating on top of the structure allow the atrium to become an auditorium. Furniture is designed to be highly flexible and the large glass façade showcases the vibrant activities in the centre to the broader community.

© Rob't Hart. Image courtesy of MVRDV

Complementing the research are three imaginative scenarios realised in collaboration with students from MA Narrative Environments at Central Saint Martins, University of the Arts London. These scenarios give a glimpse of the future; visualising and narrating higher education spaces and services of tomorrow.

The 'Campus of the Future' report and other Foresight tools and publications are available at **https://www.driversofchange.com**.

Download the report

Shenzhen Bao'an International Airport Terminal 3

© Kalson Ho

Future of Air Travel: The Future Ready Airport

Arup is leading the way in analysing the future of the Aviation industry. Working closely with our clients and leading industry experts we are identifying the key issues facing our clients, both today and in the future, creating programmes to deliver innovation and resilience for the challenges of future business development.

Our Future of Air Travel (FoAT) programme provides a platform for bringing to life current thinking, identifying new ideas and driving innovation. We achieve this through a series of forums that bring together visionaries from across the aviation industry and beyond: operators, planners, developers, engineers, economists and technologists. These forums are aimed at building a more detailed understanding of the drivers shaping the future of air travel across socio-cultural, technological, economic, environmental and political domains.

Our inaugural forum in San Francisco in February 2015 focused on the travel experience and how technologies will converge to affect the 'Future of Airports' over the next 30 years. A second forum, titled 'Future of Air Travel' and held jointly by Arup and the Intel Corporation in Istanbul in December 2015, focused on a shorter horizon (the next 10-15 years) and took a deeper look at key experience drivers such as passenger screening, the checked bag and the role of Big Data to make predictions about the entire end-to-end travel experience.

Our latest forum focused on the 'Future Ready Airport'. Working with GVK Airports Innovation Lab, the session held in Bangalore in February 2017 examined the needs of a specific airport over the 1 to 5-year horizon and identified initiatives that challenge today's terminal format and cost model.

Four key themes were explored and a series of implementable pilot programmes were identified to focus the airport design and operations on becoming future ready:

- Delivering a zero-queue terminal: The pilot projects will identify opportunities, using current or emerging technologies, to streamline the flow of passengers and their bags, thereby reducing stress and delay, and will reimagine the entire airport as a service-oriented enterprise to improve passenger experience.
- Re-imagining retail, entertainment and dining: This theme focuses on the need to engage the passengers and create solutions that are experiential. The pilots will create brand experience showrooms in the terminal area and extend the omni-channel retail concept into a real-time connectivity solution.
- Designing the future terminal – one space, multiple uses: The goal is to create dynamic terminals that can expand to meet peak demand in a simple and seamless way with the help of digital technology. The pilot programmes will explore opportunities to consolidate processes and allow infrastructure functionality changes in response to passenger flows as well as the feasibility of a baggage reclaim on-demand concept.
- Cost efficiency: The focus is to explore opportunities of shared services among stakeholders using cost effective digital solutions. An investment evaluation framework will also be developed to measure the overall value of the various pilot projects being proposed so that all stakeholders will buy-in to the results.

Through these pilot projects, airport management, along with their key stakeholders, can manage risk and gain the best understanding of the potential benefits of an innovative solution before making major investments into the existing infrastructure and changes in data management policy.

© Marcel Lam Photography

Hong Kong International Airport Terminal 2

Download the report

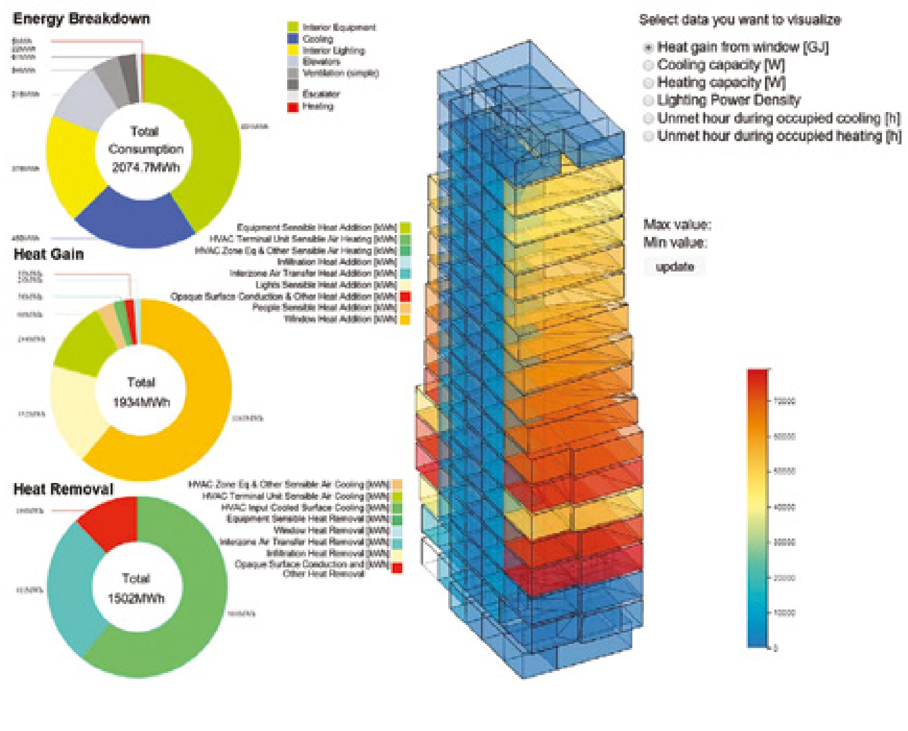
Drawing on our digital and aviation expertise, Arup has customised the Future of Air Travel and Aviation methodology to deliver workshop events for clients across the globe. These will target the specific needs and questions clients have based on their preferred timeline, addressing strategy, collaboration, creative thinking, design innovation and leadership through forward thinking.

For more information about our FoAT programme and how we can deliver a targeted workshop for you, please email **FOAT@arup.com**.

Managing building performance data: a web-based platform

Building performance simulations generate vast quantities of data, which require manual, time-consuming post-processing and are prone to human error. Furthermore, the data is often not fully utilised in the design process, due to the sheer quantity, so building physics engineers often only look at limited parameters such as energy consumption and energy demand pattern and they may miss some other important details. It is also not easy to locate relevant simulation results from similar projects for design reference.

In order to better use the data resources, a research team in Arup's Hong Kong office has developed a web-based platform to increase data analytics capability and extract better values from building performance simulations. This tool automates the post-processing workflow to improve the efficiency, consistency and accuracy of energy simulation, capitalising on Arup's building energy modelling experience through a centralised knowledge database.



Interactive visualisation example showing the heat balance and solar heat gain from windows

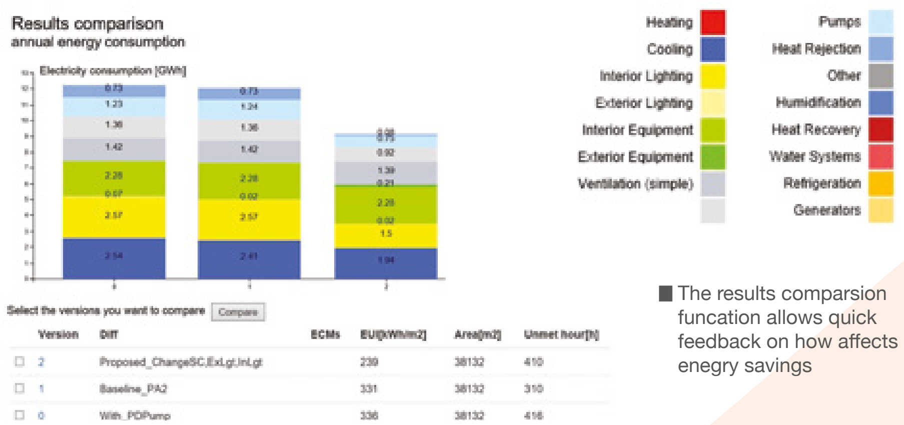
Key features

In the conventional workflow, simulation results are extracted and plotted in graphs manually, consuming significant amounts of time and adding pressure to the already tight project schedule. With the new platform the user only needs to upload the EnergyPlus simulation results file and input the project metadata such as the building's functional programme and location. Once the data file is uploaded, the server will import it into the database and automatically prepare comprehensive visual graphics and diagrams.

The visualisation interface of the tool can map important parameters such as energy use intensity and solar heat gain onto 3D geometry. Since an energy simulation model is usually composed of several hundred zones and it is almost impossible to check the data for each zone, the visualisation can help users to quickly understand and validate the data and compare simulation results.

The building performance simulation results stored in the database can be searched by project name, building type, building location and green building certificate (such as LEED and BEAM Plus). This function allows users to readily extract relevant building performance data for comparison, thereby increasing data reusability and enabling learning from previous experience.

As the building energy model is often changed numerous times within one project, making it difficult to track the changes, a version log function is provided in the platform to enable easy data management. The results in each version can then be quickly compared to understand the energy saving from each energy conservation measure (ECM).



The results comparsion funcation allows quick feedback on how affects energy savings

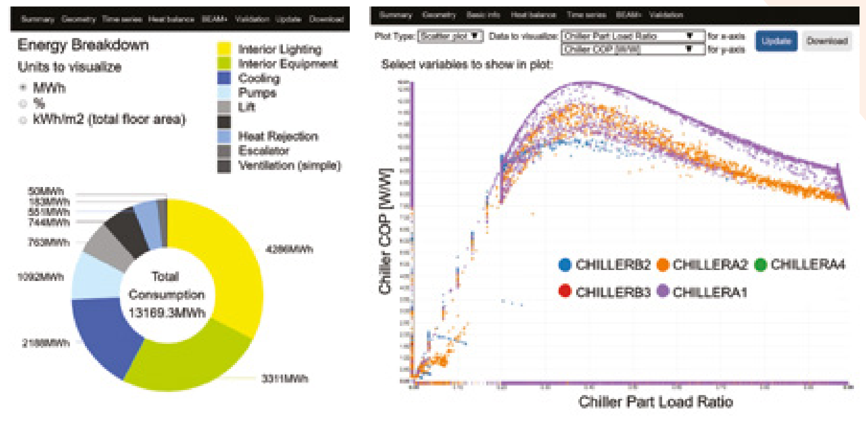
Simulation results can also be easily shared within the project team through a URL address and the data can be downloaded as a CSV file for further analysis. Additionally, users can view the simulation results visualisation in Jupyter Notebook (an open-source web application) and tailor the script to optimise the representation of the results to suit each project's own characteristics. Once a new visualisation is proven to be useful in multiple projects the script can be merged into the post-processing platform, thereby extending its visualisation capability.

Furthermore, energy simulation results from Honeybee (a Grasshopper plugin for environmental analysis) can be uploaded to this platform using a custom Grasshopper component. This enables architects and MEP engineers who are not familiar with energy modelling to run simulations easily and explore different design options to achieve better energy savings.

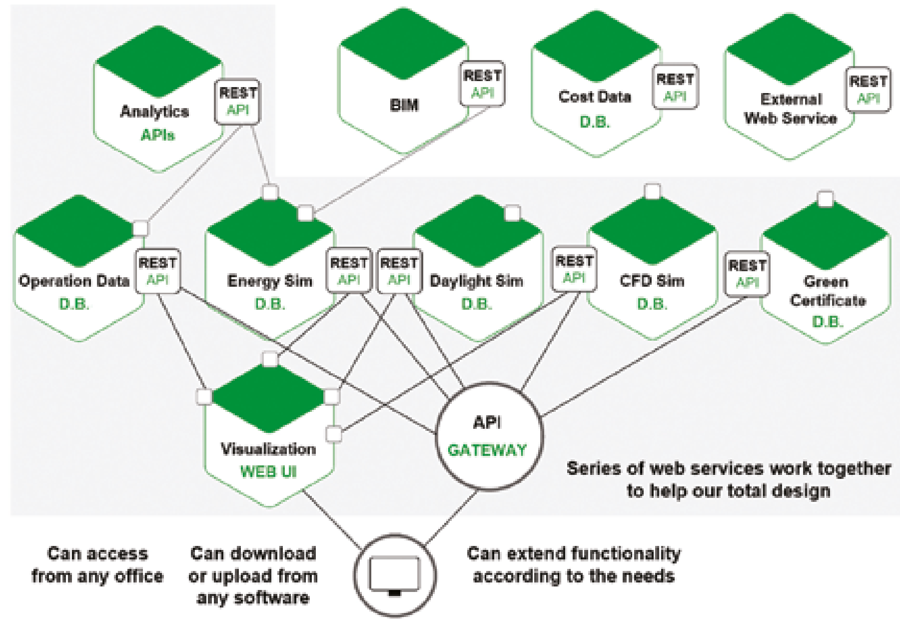
Value of this platform

The automation of the post-processing and visualisation of the results has significantly accelerated the workflow process giving Arup designers more time to explore different building performance design possibilities to reach the best solution. With the easy-to-understand graphical interface, building performance can also be communicated more efficiently with project stakeholders so that the quantitative data from simulations can actively contribute to design decisions.

And the centralised database is also a knowledge platform aggregating all the energy simulation results from previous Arup projects. It is, therefore, useful for providing insights and benchmarking at early design stages, allowing Arup consultants to provide design recommendations based on the project nature and location without going through the whole simulation process.



Clear visualisation from different aspects allows the stakeholders to utilise the data for better decision making



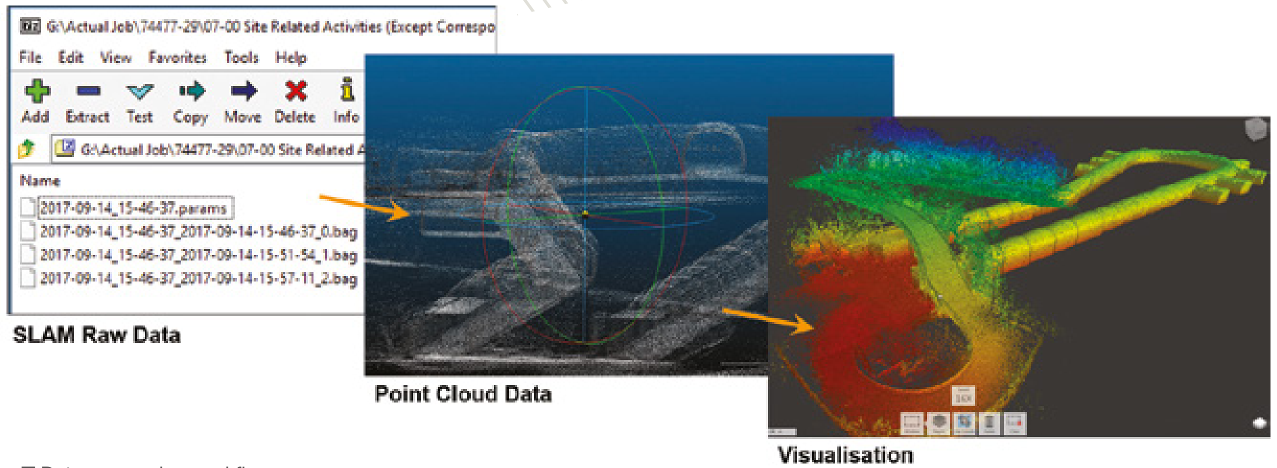
Microservice image by which users can access any kind of building performance data stored into a dedicated database through browser

The building performance data can also be utilised for facility management. In many cases, the actual operation is different from the design condition which could lead to less energy savings than expected. This platform will enable long-term management of energy model data and allows Arup to help clients to find effective ECM combining actual operation data and energy simulation data.

Future development plan

This is just the beginning of developing data analytics capability in the building physics domain using this web platform. As simulation results currently are often saved locally in specific formats, comprehensive analysis is difficult. The research team is exploring opportunities to create microservice architecture to include platforms for BMS data, HVAC system database, daylight and CFD simulations to achieve a total design in a data-driven way.

Mobile laser scanning: collecting quality data fast



■ Data processing workflow

Site inspection and data collection is traditionally a time consuming and manually intensive process that requires an engineer to spend considerable amounts of time inspecting, measuring, recording and photographing the key areas of interest within a site. If not well planned or conducted by inexperienced parties, this can lead to inaccurate data or crucial information being missed.

To enhance the speed, accuracy and quality of the information collected, Arup has been exploring the use of mobile laser scanning (MLS) devices. The use of digital tools enables rapid collection of highly accurate point cloud data of site conditions, with the interlinked video footage collected at the same time as the scan data providing an opportunity to ‘revisit’ the site and double check key information.

Owing to its versatility and mobility, a handheld scanner was selected for this research. The device makes use of Simultaneous Localisation and Mapping (SLAM) technology, which can concurrently map and navigate utilising information from sensors to compute a best estimate of the device’s location and a map of the environment around it. Each scan is conducted in a closed loop (either O-shape or 8-shape) so that the start and finish environments are accurately matched.

A typical site scan can be completed in 20 to 25 minutes, with the collected raw data processed directly within the proprietary software provided by the scanner manufacturer to generate a 3D point cloud model. These point clouds are then further processed and analysed using other open source software, including the merger of datasets from adjacent scan areas to generate combined models for large sites as well as the extraction of site measurements, plans and sections. The point cloud dataset can even be directly exported to a BIM environment to allow visualisation of the processed scan data, the generation of meshes and objects and the direct integration of the scan data with other design information.

A number of site trials of the MLS device were carried out for different geotechnical applications. One of these included the inspection of a 330m long looping tunnel that was previously used for temporary explosives storage during the construction of a nearby railway line. Before this facility could be upgraded for other permanent after-uses, a detailed condition survey was required to check the tunnel alignment, geometry and rock mass condition and to provide data for design works. Using the handheld scanner, the Arup geotechnics team collected detailed data and records of the site condition and generated a detailed 3D model of the site. This included information on the existing ground surface, excavation profile and the various fixtures and fittings within the tunnel. All of this was achieved following a short 20-minute scan and despite a complete lack of lighting within the tunnel.

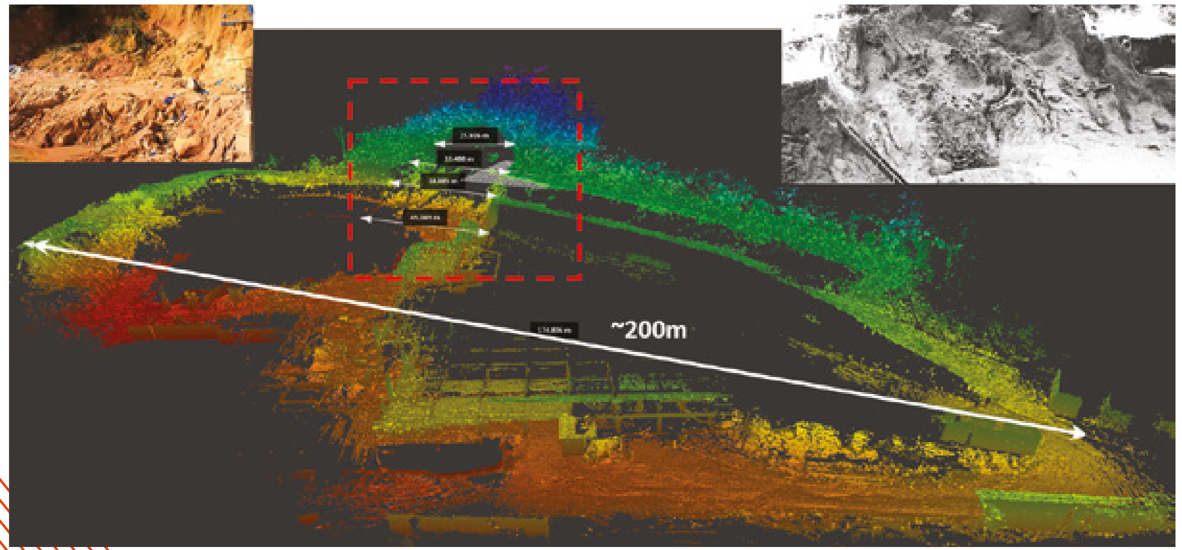
Another example comes from a major landslide within an active construction site in Malaysia, where Arup was called in to investigate the cause of the failure. However, due to the dangerous condition of the landslide scar no access was permitted within the scar itself. Using the laser scanner, which has a range up to approximately 30m, a scan was successfully completed by walking around the margins of the landslide scar. The data from this facilitated detailed measurement of features within the scar as well as the estimation of landslide volume. The highly-detailed 3D model generated from the scan data also provided key data on the profile of the landslide scar, which formed an essential part of the back analysis for the slope failure. Such data formed an invaluable and crucial part of Arup’s investigation works.

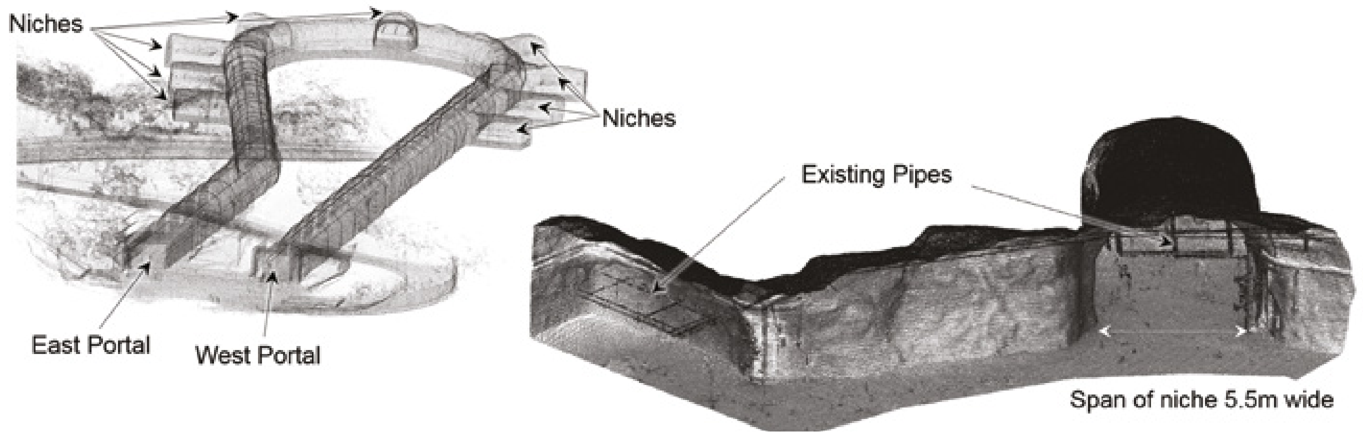
The range of the MLS device means that it is suitable for any site survey where the features to be measured are within 30m of the operator. In addition to site condition surveying and inspections of slopes, landslides, tunnels and construction sites, laser scanning can also be used for active construction monitoring and the generation of detailed as-constructed records in BIM compatible formats, providing a highly effective tool for monitoring both construction rates and quantity of works completed.

Furthermore, the MLS device is particularly useful for scanning features such as buildings and plant rooms, especially for cases where detailed records do not exist or are outdated. The scan data can be readily transformed into building elevations and sections, floor plans and BIM models showing the layout of installations and pipe works.

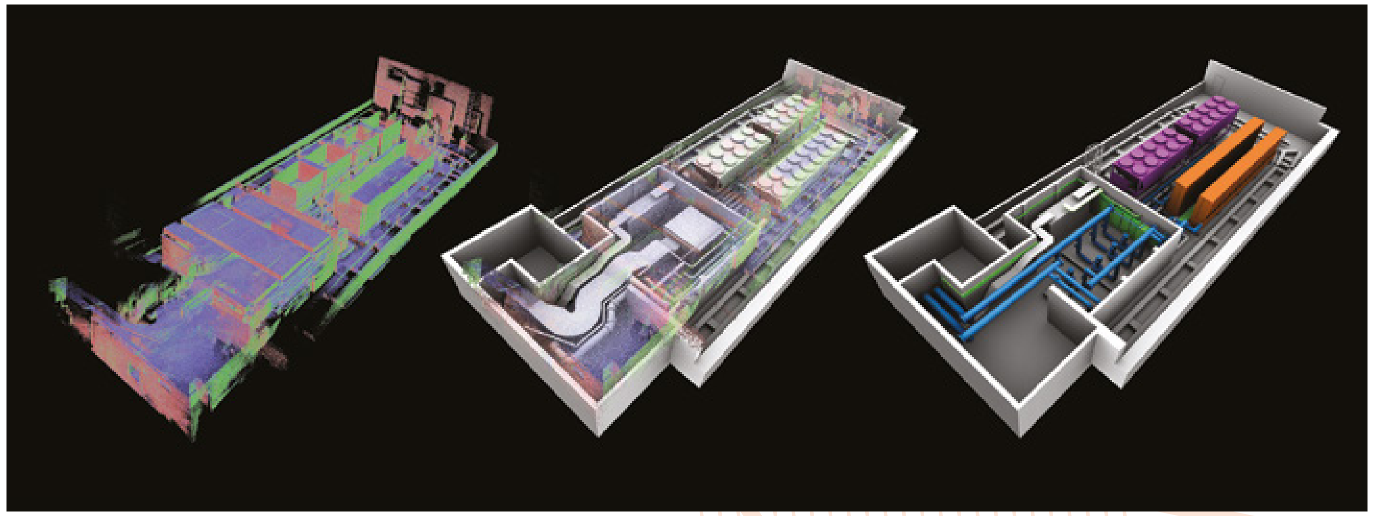
With further development, MLS can be applied to other engineering disciplines and the 3D point cloud data obtained integrated with different models in a BIM environment, facilitating seamless and efficient analysis and design workflows.

■ General view and 3D model of the landside



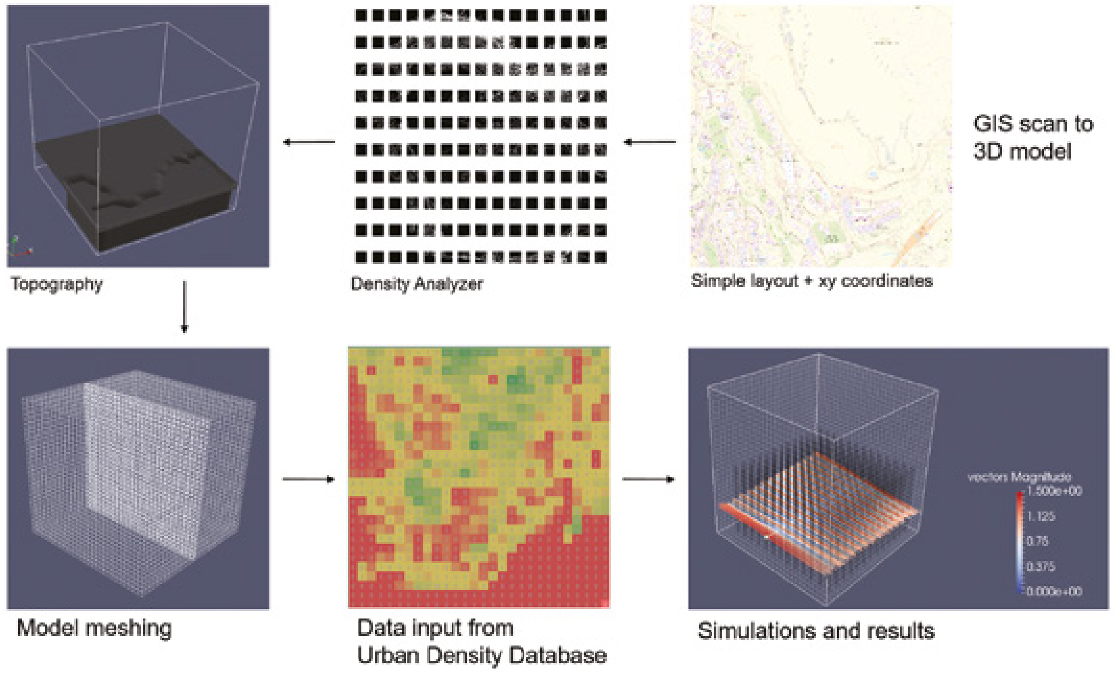


■ 3D point cloud model of the explosives magazine tunnels



■ BIM model of a chiller plant was generated from point cloud data, allowing MEP engineers to easily identify spatial constraints.

Quantifying urban heat island effect: a simplified approach



■ Workflow of the UHI model

Urbanisation has a significant impact on the climate of a city and one of the most well-known consequences is the urban heat island (UHI) effect which develops when urban cooling rates are slower than rural ones. UHI is especially significant in metropolitan cities like Hong Kong and a research study by the Hong Kong Polytechnic University (PolyU) showed that the UHI effect in Hong Kong can reach up to 12°C. While the impact of UHI can be reduced through various measures such as building layout, provision of greenery and the use of albedo materials to reflect solar radiation, these measures need to be planned and implemented during the early urban planning stages. An efficient and quantitative method is, therefore, required to model the UHI effects.

However, as yet there is no commonly accepted methodology in Hong Kong for this purpose. Computational fluid dynamics (CFD) is often used to study the microclimate in a small area but rarely used to study the UHI phenomenon on a city-scale as it will require detailed input data, intensive computational power and a long simulation time.

To meet this need, Arup carried out a research study to develop a simplified approach to quantify the UHI effect. The new approach reduces the requirement on input details and modelling complexity and shortens the analysis process from three months to one week.

The research was carried out in collaboration with PolyU and the Hong Kong Housing Authority and the research was co-funded by Arup and the Innovation and Technology Fund of the Hong Kong government.

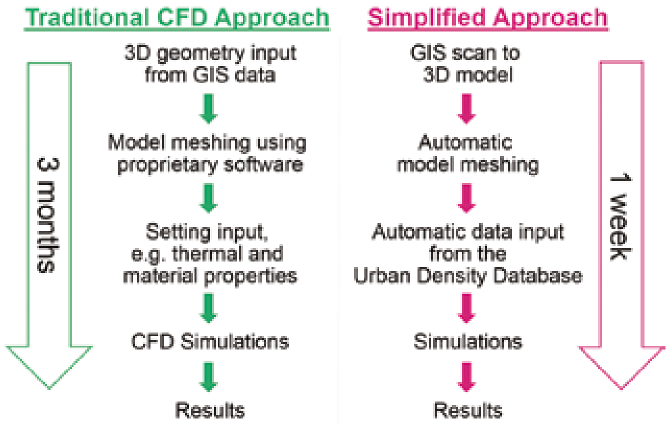
Methodology

In the traditional CFD approach a detailed physical domain is needed to simulate the fluid flow and heat transfer; this requires a very fine model grid for computing the mean velocity and temperature. The new UHI modelling approach adopts the volume averaging method, so that larger grid sizes can be used, thus reducing the simulation time and the level of input data. Instead of developing all the 3D geometry, the geometrical information is simply represented by porosity (%) and permeability (%) per unit control volume while other urban features are represented by area weighted percentage (%) per control volume.

An Urban Density Database is created using GIS data storing the local urban characteristics of Hong Kong, including the buildings area, roads area and greenery area as well as the average buildings and terrain heights. A computational code developed on Python is used to extract GIS data from digital topographic maps, digital orthophotos and 3D spatial data into urban density parameters. The entire area of Hong Kong is divided into 10m × 10m grids and a pixel analysis is carried out to calculate the percentage of different types of areas (e.g. roads, water bodies) per grid.

Building heights and terrain height are obtained using Rhino and Grasshopper to place a set of control points in 10m separation and the XYZ coordinated points are extracted and stored in the database. Simulations are then carried out using an advanced mathematical model.

■ Study area in Tsim Sha Tsui and the measurement locations



■ Workflow comparsion between traditional CFD approach and simplified aapproach

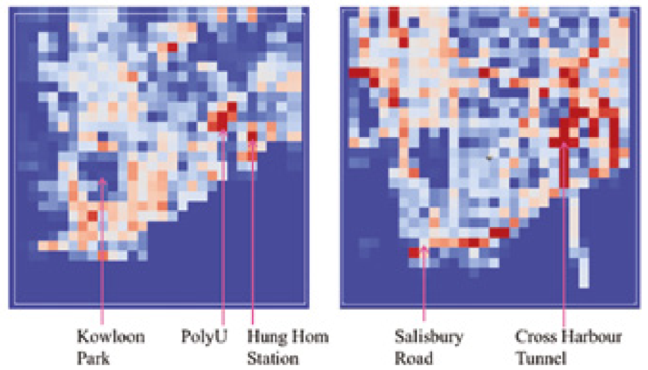
Model validation

The research also involved environmental measurements carried out at various locations in Hong Kong such as housing estates and parks. Environmental parameters (including ground level air temperature and wind speed) and urban parameters (including building height and green areas) were measured to monitor the urban heat transfer. This was the first major UHI measurement in Hong Kong.

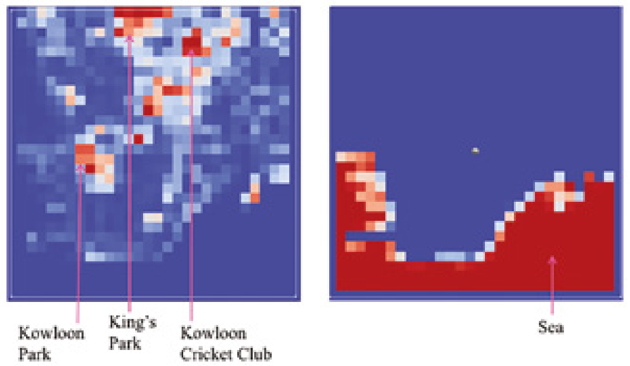
One of the case studies to validate the UHI model was carried out in the Tsim Sha Tsui area in Hong Kong. The study area was 2640m × 2640m and a computational grid of 80m x 80m was used in the model. Environmental measurements were made at three locations and were then used as parameters in the UHI simulations. Results indicated that the simulated air temperatures followed the trend of the field measured air temperatures for all three locations.

Value to Arup

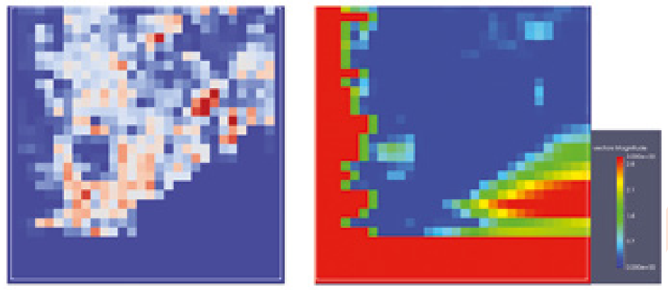
This research demonstrates a new approach to predict the UHI effects. This flexible and easy-to-use tool can assist planners and architects in carrying out UHI assessment at the early stage of the urban planning process so that strategies to mitigate the impact of UHI can be incorporated to achieve a more sustainable urban design. As the concept of UHI study has already been implemented in Hong Kong's BEAM Plus Neighbourhood Version 1.0 (launched in 2016) and BEAM Plus New Buildings Version 2.0 (launching in 2018), this new tool will further increase Arup's capability and competitiveness in the city sustainability market.



■ Building density in the model (left) and road density in the model (right)



■ Greenery density in the model (left) and sea area in the model (right)



■ Example of results: building density (left) and simulated wind speed (right) at 20mPD

Regular talks at the Digital Den

Arup staff riding on a virtual train at the digital exhibition

Digital Den: a space for digital growth

The ever-changing digital built environment presents new opportunities to enhance the way we live and work. At the same time, it presents unprecedented challenges for all stakeholders.

To embrace the opportunities that digital offers and develop new capabilities that keep Arup relevant, both commercially and creatively, the Digital Den has been set up at Arup's Hong Kong office to promote digital development in the East Asia Region. Networking events and talks are held regularly for people to share ideas, experience emerging technology and explore possibilities for digital services offerings. External speakers are also invited to share their insights, for example the CTO of SmarTone Mobile Communications discussed the roadmap for 5G deployment and its potential implications on smart city development while a venture capitalist and early investor in Alibaba shared the stories behind the company's rise and what Arup can learn from Alibaba's experience to drive digital transformation.

The Den is now holding an exhibition on digital technologies till the end of November 2018 to showcase Arup's capabilities. Topics include:

- Virtual train: a virtual reality 'walk through' which provides a realistic train travel experience and can help examine station and rolling stock design.
- 3D printed structural nodes: a design method for sophisticated, customised structural elements using 'additive manufacturing' (AM) techniques.
- Machine learning applications in engineering: a tool using neural networks algorithms to identify room functions based on room layouts.

Also on display are applications developed by some of Arup's collaborators, such as the cable robot for building envelope by O-Matic and the collision-tolerant drone for indoor inspection designed by Flyability and operated by DroneSurvey.

The exhibition is open to Arup staff as well as members of the industry. Check with your Arup contact or email **ea.arupuniversity@arup.com** to book a visit.

Panel discussion at the book launch event on 30 January 2018

Arup's stories behind the storeys

In densely populated Asian countries high-rises are, essentially, mini-cities that require a systematic approach to ensure that they are commercially viable, operationally efficient and socially engaging. Also, the rapid growth of urban population means that this vertical urbanism will continue to play an integral role in our urban landscapes.

As one of the global leaders in tall building design, Arup has presented the book *'Arup's Tall Buildings in Asia, Stories Behind the Storeys'* to celebrate our success and share our experience with the world. The book exhibits the multidisciplinary design and engineering skills aligned from our wide range of expertise in delivering varied and complex high-rises and also points out the latest development trends in the field to inspire more ideas in tall building design.

Twenty detailed case studies from mainland China, Singapore, Hong Kong, Vietnam and Japan illustrate our 'Total Design' approach well, a true partnership between client, architect and our engineers from a wide range of disciplines. It is this collective thinking and exchange of ideas that enables us to achieve better designs and foster innovation to overcome the various design constraints and challenges met in realising these ambitious structures.

While the projects featured in the book may not be the tallest buildings, they have all been selected for their significant engineering insights and values. For example,

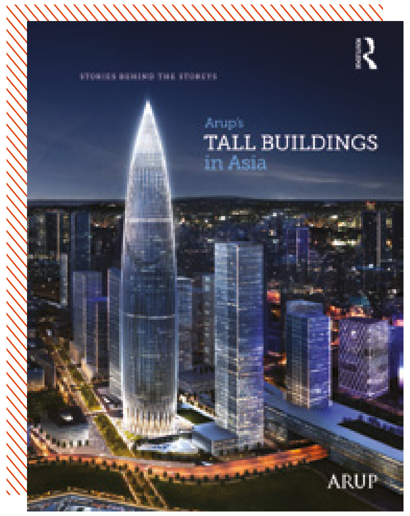
- Raffles City Chongqing and the application of our innovative hybrid outrigger system which has been patented in China
- CCTV Headquarters in Beijing and the challenges encountered in the construction of its highly unusual 'three-dimensional cranked loop' shape

Other case studies include Tianjin's Goldin Finance 117 Tower, Ho Chi Minh City's Vincom Landmark 81 and Tokyo's Nicolas G Hayek Center. These examples offer a peek into how the ingenious combination of engineering architecture and construction technology can realise sophisticated structures.

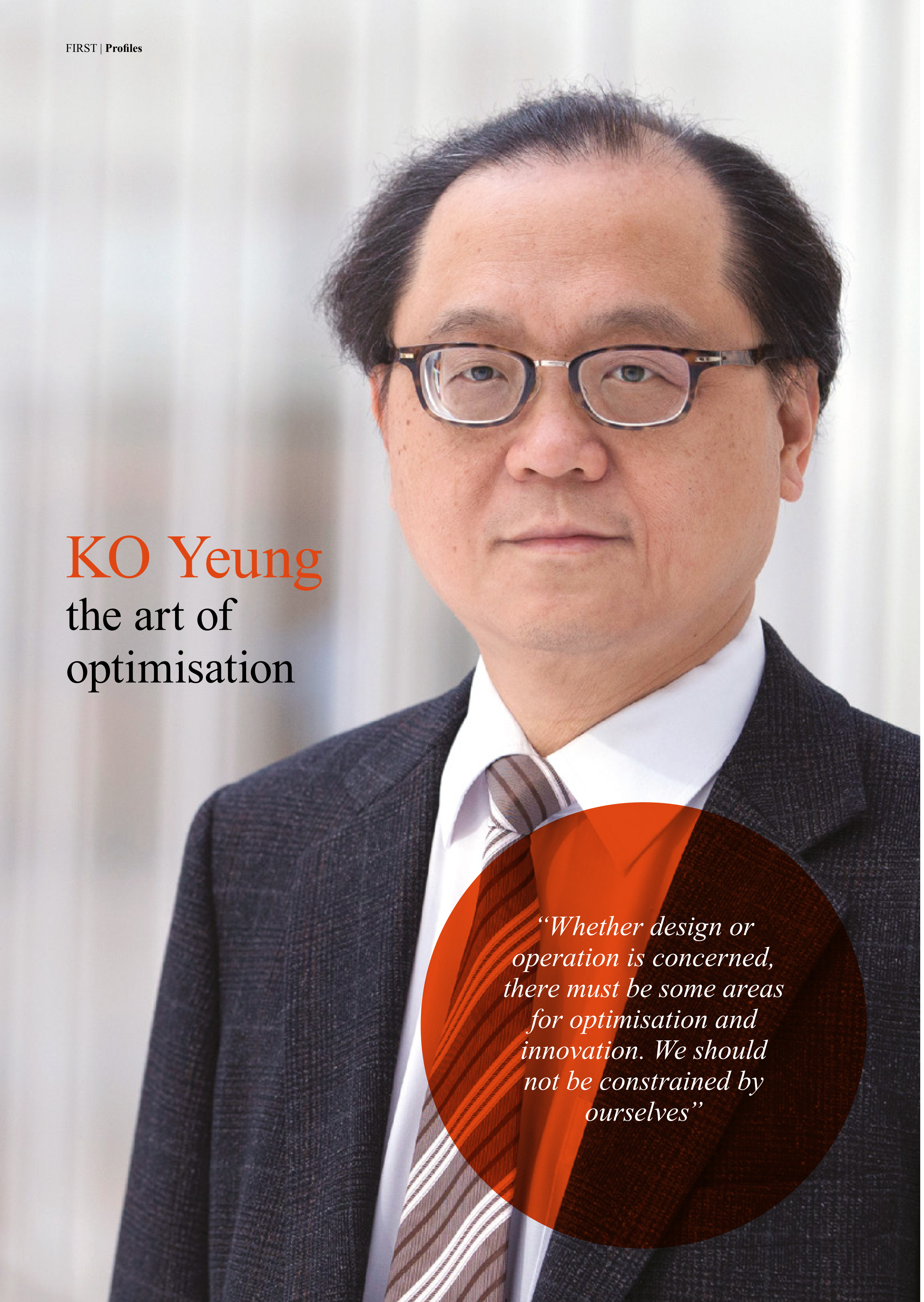
This book is a compelling statement of how Arup continues to shape a better world with a strong commitment to innovation and technical prowess. By sharing our design stories we hope to invite an exchange of ideas across the global building community and to make sure the sky really is the limit when it comes to tall building design.

Dr Goman Ho signing for guests

The publication of the book was led by Dr Goman Ho, Arup Fellow and global tall buildings leader, and coordinated by the East Asia Arup University team.



Purchase the book



KO Yeung
the art of optimisation

"Whether design or operation is concerned, there must be some areas for optimisation and innovation. We should not be constrained by ourselves"

KO Yeung stepped down as Arup's East Asia Region COO in March 2017 after 10 years on the role. Here we talk with KO on his three decades of fruitful career and his views on the future.

Everyone close to KO may note that one of his most frequently used words is 'optimisation'. From optimising the cost, time and quality of a project to optimising the mix of skills in the firm. When asked about his career transition from a MEP engineer to a COO, he also says: "It's the natural choice when optimising the performance of the team and hence the region." But before all that, he enjoyed the pure pleasure of applying new ideas to projects in a team with the perfect combination of heart and experience.

On design

KO joined Arup's Hong Kong MEP team in 1981. From the Hong Kong Jockey Club Shatin Clubhouse to the InnoCentre, the team introduced numerous fresh approaches to enhance building performance while meeting local requirements. Many of them are widely used today in the local market including free cooling, ice-storage cooling and the energy optimisation system.

"It is a common perception that MEP design has little room for creativity due to a range of constraints such as space availability and the client's budget, but we should not bind ourselves," says KO, "Think big and beyond, and surely you will find some gap to fill."

KO's proudest projects


© Neil Duncan

The Hong Kong Jockey Club Shatin Clubhouse
A number of innovative solutions were put forward including free cooling, heat pumps and ozone pools

China Sun Oil Blending Plant, Shenzhen
Working closely with the local design institute and local contractors to complete the fast track project within 10 months


© John Nye

The Hong Kong Jockey Club Happy Valley redevelopment
Pioneering use of ice-storage cooling for the project and comfort cooling for kitchens

InnoCentre, Hong Kong
With optimum building design, time and costs, the project obtained an Energy Efficiency Award and the Hong Kong Institution of Architect Award for its total engineering design integral with the architecture

KO believes that an optimum MEP solution should not only be practical and cost-effective, but also well integrated into the overall project and ‘friendly’ and efficient throughout the project life cycle – from installation and commissioning to operation and maintenance.

His best technical solution so far? KO selected the implementation of the district cooling system at Kai Tak. The study, which looked into the first major district cooling plant in Hong Kong, covered not only MEP and civil engineering but also energy modelling, cost modelling, thermal storage, environmental impact and the associated legislative framework. The plant came into operation after 10 years of the study.

“It sets out a model for this kind of plant in Hong Kong – it saves a lot of energy and plant space in buildings, reduces time for installation and provides a more reliable central cooling system,” says KO with great pride. Since then, this design approach has been adopted in many new districts in Hong Kong and new towns in other Asian cities.

Kai Tak district cooling system

San Miguel Brewery in Hong Kong

On business

KO also applied the ‘think bigger, think beyond’ concept to develop the MEP business. Arup’s MEP discipline gradually established itself in the Hong Kong market with several high profile commercial buildings. “As we grew into the 90s, we realised that we had to look beyond buildings and develop MEP+, by integrating MEP systems with other systems such as fire, information technology and communications and the related specialist skills such as building physics and project management”, reflects KO. “We focused on industrial facilities which were in huge demand and where we were able to best integrate these skills.”

The team successfully secured some major industrial projects including two San Miguel Brewery plants in Hong Kong and the IBM manufacturing facility in Shenzhen.

To KO, the process of optimisation is like climbing a mountain. Inevitably, you will reach a local peak and then you have to look for the next summit – to innovate by identifying new solutions or venturing into new places or new areas of work. “Only in this way can we attain new heights by developing capacity and refreshing our portfolio,” he says.

In the mid-90s, the MEP team saw the need to diversify into the infrastructure sector with a focus on railway projects. They started to build up their track record in Singapore and Thailand and then came back to the Hong Kong market to pursue various packages of the mega West Rail project. Fortunately, they got four packages at the same time which laid a solid foundation for the team to ride out the impact of the Asian financial crisis.

In the early 2000s, Beijing’s urban transformation leading up to the Olympics presented tremendous opportunities for the MEP team to expand into the mainland. “We supported various world-class architects to deliver urban icons such as the Bird’s Nest, Water Cube, CCTV headquarters and Beijing Capital International Airport Terminal 3, which put us at the leading role of the regional MEP league table,” he says.

On management

KO gradually took up more management roles and became COO of East Asia in 2007 and says: “It was not originally planned but came as a result of knowing my strengths and finding a fit.”

Looking back, two experiences sharpened his business acumen and commercial skills – attending a part-time Master degree course on construction management in the mid-80s and joining the firm’s Global Financial Executive (currently Commercial Executive) in the mid-90s. “The former broadened my basic knowledge in project management, construction laws, contract strategy and construction economics while the latter gave me a better understanding of the financial and commercial aspects of the entire firm.”

KO’s decade as COO was full of turbulence and uncertainty, especially the financial tsunami of 2008 and China’s slowdown in the mid-2010s. “We had to identify both hard and soft spots within our operation across the region, proactively project the business trend, take prompt preventive measures to optimise our performance and sustain our business together,” he recalls.

Like an MEP system made up of various components, an organisation is a complex system of people, process, technology and their relationships; the key is to make them work seamlessly together. “To get the best outcome means to overcome the constraints and bridge the gaps imposed by imperfection of our process and human behaviour – that is, by mutual trust and respect among all of us,” he summarises.

To KO, his greatest job satisfaction comes from understanding Arup people in different parts of the world, influencing them and enabling them to work together to shape and share the success.

Receiving 35-year long service award in 2016

On future

Looking into the future, KO believes that digital tools will continue to lead the evolution of MEP engineering. 3D and BIM tools for visualisation and coordination help eliminate clashes and significantly reduce time for installation. In the future, they will permeate all phases of projects from outline and conceptual design throughout to installation, as-fitted, commissioning and operation and maintenance with total coordination solutions.

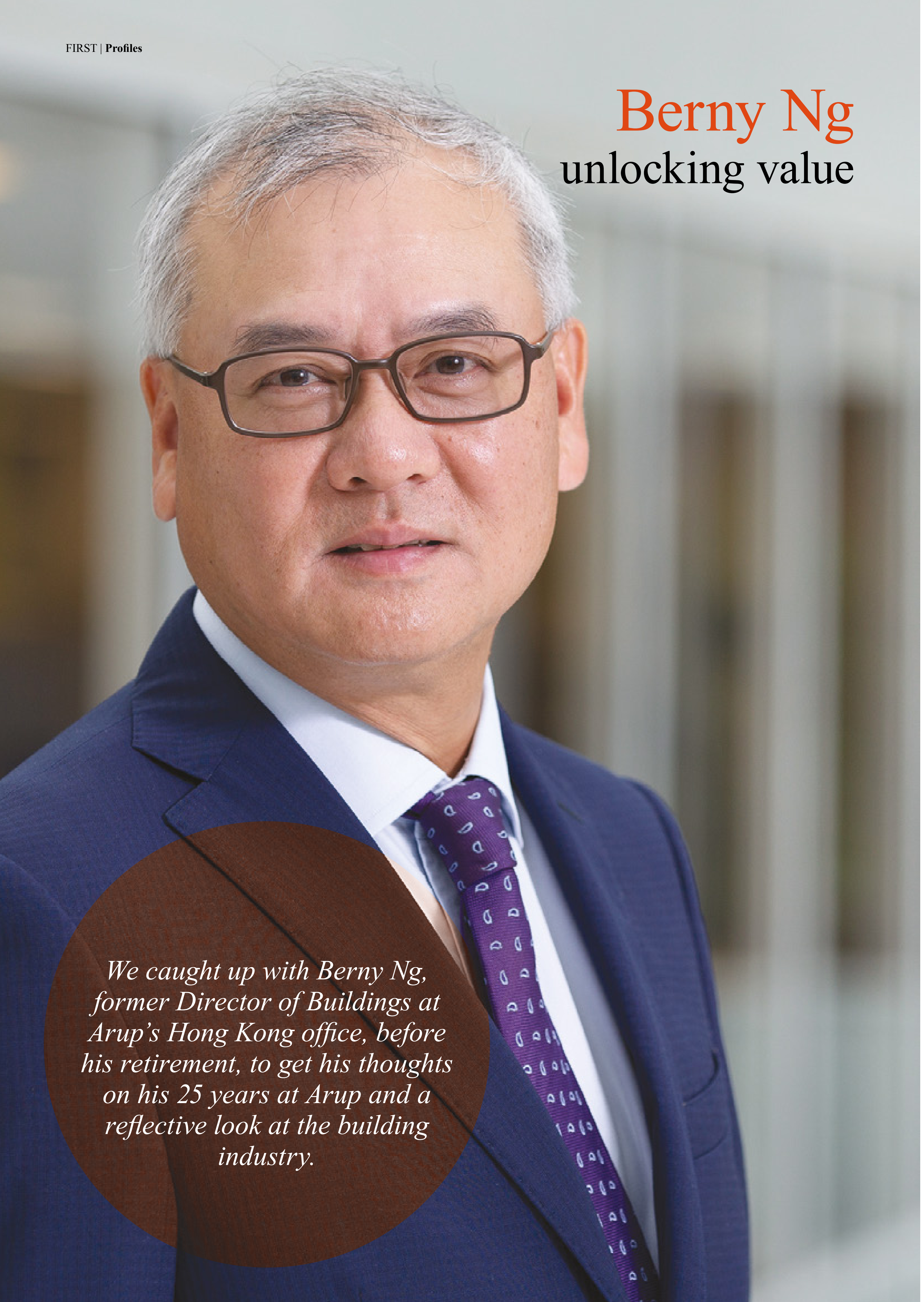
“The key areas for improvement and innovation will happen in sustainability, time and space optimisation and effective installation methods,” he predicts.

To find the best solution, he suggests that designers and engineers should first understand the project objectives and constraints and then, with these in mind, ask “what works best”– to optimise – and “what is the best possible” – to innovate – and then focus on the most viable options for detailed analysis to establish the most cost-effective recommendation to achieve the objectives of our clients and projects.

As for the technical vs managerial dilemma for young engineers, KO urges them to acquire basic competence in both areas first and understand their own strengths, interest, potential and career goals. “As a people business that offers quality design, we need both highly capable technical and commercial leaders, but we need a proper balance,” he points out.

Once the direction is set, he encourages people to focus on continuous, steady improvement for long-term growth – a process of self optimisation. These include enhancing basic skills in focused areas, collaborating through the Arup University, developing commercial skills, increasing exposure and making themselves known for their specialism both internally and externally.

“Don’t forget to seize opportunities to work in different countries and experience the Arup culture, philosophy and synergy for working together,” he reminds us.



Berny Ng
unlocking value

We caught up with Berny Ng, former Director of Buildings at Arup's Hong Kong office, before his retirement, to get his thoughts on his 25 years at Arup and a reflective look at the building industry.

A handshake of support and gratitude with LM Lui (right), former East Asia Region Chairman, at Berny's retirement party

"It was 1 April 1993, a special day for both myself and Arup in Hong Kong," recalls Berny, who still remembers clearly the day he joined Arup.

"On that day, the number of Hong Kong office staff exceeded 400. Another special occasion on the same day was that three locally recruited staff were promoted to directors: LM Lui, KO Yeung and KK Kwan. All later became top leaders of the region," says Berny, walking down memory lane.

25 years on, Arup has more than 2,000 staff in Hong Kong. On the threshold of retirement, Berny feels extremely lucky that he has witnessed the rapid development of the local consulting industry which he described as "incredible".

A start that started everything

Berny joined another UK consulting firm's Hong Kong office in 1981 after graduating from the University of Manitoba, Canada. Later, he emigrated to Canada and worked in Toronto until the recession in the early 1990s. Then he looked for opportunities back in Hong Kong and joined Arup through a referral from an ex-Arupian.

But his story with Arup started much earlier. When in Canada he worked on The Ballet Opera House in Toronto conceived by renowned architect Moshe Safdie. Featuring a half-shell-half-pyramid roof, the design posed great challenges for his team and the legendary structural engineer Peter Rice in Arup was called on for expert advice.

Berny notes that what attracted him to Arup was much more than the engineering ingenuity. "One person who has held me here for decades is our founder Sir Ove Arup, though I have never met him," he says. Ove's vision of shaping a better world perfectly shows that the value of engineering is much more than nuts and bolts.

"Ove's greatness was enhanced by his embrace of the staff ownership structure, he created Arup and simply handed it over, leaving it to run by itself with his philosophy and values passed on from generation to generation. This is hard to imagine in the Chinese culture where family business dominates," he says.

Shaping solutions around clients' needs

Berny has led a wide range of building projects across the region, from complicated topside developments to vast malls and adaptive reuse of historic spaces. Among all these, he views The Palazzo, a residential development in Hong Kong above the existing Ho Tung Lau Maintenance Centre as his best design solution, both technically and commercially.

The development site decked over the existing railway facilities while part of the railway live track, with overhead live cable, remained in operation. Arup successfully converted the steel structural deck into a deck of in-situ concrete and precast concrete and obtained the authority's approval, saving significant cost for the client while ensuring public safety.

Due to limited construction space, Arup innovatively used high-strength mini-piles for the foundation scheme

A glimpse into Berny's diverse project portfolio

Hung Hom Station renovation and extension, Hong Kong
Berny's first project at Arup included a new concourse designed by Foster and Partners and demolition and protection of a complicated network of walkways on track while maintaining its operation.

Tseung Kwan O Hospital, Hong Kong
A design and build project with Arup acting as the contractor's designer; the first Hong Kong government project that required seismic detailing

© Zhou Ruogu Architecture Photography

Riverside 66, Tianjin
The mega shopping complex is a standalone 380m long structure which features high atriums, a unique curved roof with highly complicated geometry and oddly-shaped floor plates in close vicinity with a number of historical buildings. The project started Arup's collaboration with Hang Lung Properties in their ambitious expansion across mainland China.

The Palazzo, Hong Kong
A 10-tower residential development above the existing Ho Tung Lau Maintenance Centre. A number of innovative solutions were developed to realise this challenging project above an operating railway.

© Marcel Lam Photography

Tai Kwun - Centre for Heritage and Arts, Hong Kong
The city's largest heritage conservation project which turned the historic Central Police Station compound into a vibrant cultural hub.

The podium of the Palazzo was built above existing railway facilities with overhead lines that had to remain in daily operations.

in areas very close to the railway track. The structural capacity of these mini-piles is approximately twice that of typical mini-piles normally built in Hong Kong. More importantly, Arup accompanied the client, KCRC, from the very beginning throughout all the changes and challenges.

"The project is a powerful illustration of how engineers can convert professional know-how to real values beyond calculations," Berny says. He believes that the value creation starts with a genuine interest to understand the client's needs and help them to resolve problems with Arup's domain expertise. This thinking helps Arup build positive relationships with clients and supports its own ambitions.

His belief is perfectly illustrated in Arup's 10+ years fruitful collaboration with Hang Lung Properties. From Tianjin to Dalian and Shenyang, in the Hong Kong developer's market penetration into Northern China, Arup has been there continuously helping them to solve their unique problems, from the super long to the super tall, and bringing in new structural ideas. "This repeat business is a clear sign of the client's recognition," says Berny, eyes beaming with pride.

At the opening ceremony of Shenyang Palace 66, Hang Lung's first completed shopping mall in Northern China with Arup's engineering input.

A project of pressure and pride

When asked about his proudest achievement, Berny picked Victoria Dockside, the redevelopment of New World Centre located on the Victoria Harbour waterfront in Tsim Sha Tsui in Hong Kong. This 274,000m^2 mega-scale project comprises a 280m tall mixed-use tower, a 17-storey hotel tower, an 8-storey retail podium and a 4-level basement.

Berny claims the project as the one most special to him, both technically and emotionally. The most complex and challenging part was the demolition and reconstruction of the 250m × 100m 4-level basement due to numerous site constraints, with part of the existing basement structure that housed the plant rooms of the still operating Inter-Continental Hotel to be retained. After a costing exercise, Arup proposed to reuse the existing structure to laterally support the new basement construction. Ten years in the making, the first phase of the project celebrated its opening in April 2018.

© Zhou Ruogu Architecture Photography

Victoria Dockside nearing completion

Evolving with changing challenges

Looking into the future, Berny points out the implications of digital technology are yet to be settled. He notes that these tools make Arup's design more accurate and cost-effective but sometimes it also takes away safety factors. "So engineers must advise clients on the bottom line taking into account the risk factors. This needs engineering judgement, not just calculation and analysis," he says.

Technology enables engineers to understand more precisely the structural behaviour and gives them more information to make engineering judgement on the design work and solutions. "On the other hand, the more you know, the more responsibility you have to take," he points out.

With much of his career dedicated to retail development, Berny also looks into the trends of future malls. He believes that with increasing land scarcity and urban population growth, Hong Kong's model may go for vertical multi-storey malls as part of mixed-use high-rise buildings with a small footprint where people can shop, dine and work all within walking distance.

He opines that structural engineers will face formidable challenges if Hong Kong introduces statutory seismic design standards for buildings. Hong Kong is located in a low-to-moderate seismicity zone and buildings here are traditionally designed without seismic resistance provisions. Due to urban density, the city is full of mixed-use high-rise buildings with transfer structures to fulfill multi-functional demands but such structural forms are generally vulnerable to seismic action.

"If Hong Kong introduces seismic codes, it will put numerous constraints on structural design and we have to evolve in response. Multi-storey, multi-functional buildings are our strengths, but they are also challenging in terms of seismic requirements. Structural engineers have to think ahead and help developers solve these problems," he advises.