WINNERS AND COMMENDATIONS

50th StructuralAwards2017

The Institution of Structural Engineers

AWARDS SPECIAL

50th StructuralAwards2017 Contents

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Judges

Judging process

The judging panel comprises some of the most experienced and respected professionals in the structural engineering industry. Their collective knowledge spans a variety of specialties within the field, including academia, architecture, construction, sustainability, innovation and research.

This year the judging process was extended to three stages:
1) Firstly, a panel of eminent judges independently reviewed all entries and awarded points.
2) Secondly, the highest-scoring entries were evaluated by a 'sitting judging panel' to establish the shortlist.
3) Lastly, the final invited judging panel met to decide category winners. The final panel was composed only of those judges who did not have a potential conflict of interest with any shortlisted projects.

Chairman of the judging panel

Professor David A. Nethercot
For 12 years, David was Head of the Department of Civil and Environmental Engineering at Imperial College London. He is a past member of the Council of the Royal Academy of Engineering and received an OBE for services to Structural Engineering in 2006. David is Past President of the International Association for Bridge and Structural Engineering, a Past President of the Institution of Structural Engineers and recipient of the Gold Medal Award 2009. David is a foreign member of the National Academies of Engineering of Australia and the USA.

Judging panel

Dr Michael Cook
Michael is a Partner and former Chairman of BuroHappold, and Professor of Creative Design in the Department of Civil Engineering at Imperial College London. He was a Vice-President of the Institution of Structural Engineers 2015/6 and is a Fellow of the Royal Academy of Engineering.

Kayin Dawoodi
Kayin is a Lead Structural Engineer at Sweco in Sweden and a Founding Trustee of Bridges to Prosperity's UK Charitable Trust. Kayin was the winner of the Institution's 2014 Young Structural Engineering Professional Award.

Tanya de Hoog
Tanya is a founding director of Thornton Tomasetti's London office. She has worked on a diverse range of projects that focus on engineering creativity and innovation with an intent to foster good design.

Ian Firth
Ian is a world-leading expert in bridge design and construction. he is currently a Director of COWI (formerly Flint & Neill) and is the current President of the Institution of Structural Engineers.

Tristram Hope
Tristram is the founder and Chairman of independent consultancy THiSolutions Ltd. He is also the Royal Academy of Engineering Visiting Professor in Engineering Design and Sustainability for the School of Civil Engineering at the University of Leeds.

Professor Tim Ibell
Tim was President of the Institution of Structural Engineers in 2015, and is a Fellow of the Royal Academy of Engineering. He was recently appointed to the Sir Kirby Laing Professorship of Civil Engineering at the University of Cambridge.

Robert Jackson
Robert graduated from the University of British Columbia with a Bachelor's Degree of Applied Science in Civil Engineering. He is the recent recipient of two awards from the Institution of Structural Engineers, including the Young Structural Engineering Professional Award 2016.

Martin Knight
Martin is one of the leading UK architects specialising in the design of bridges and transport infrastructure. He founded international bridge designers Knight Architects in 2006 following nine years at Wilkinson Eyre Architects.

Toby Maclean
In early 2005, Toby established structural engineering consultancy TALL. In September 2016, TALL merged with Canadian structural engineering firm Entuitive and Toby continues to take a lead role in the UK.

Andrew Minson
Andrew is Executive Director at MPA responsible for The Concrete Centre and British Precast. He is currently chair of the Design Practice, Risk and Structural Safety Committee of the Institution of Structural Engineers.

Simon Pitchers
Simon has over 40 years of construction industry experience. He is Director of Craddys, consulting structural engineers, and Arc Bauen, construction managers, and a Member of the Institution of Structural Engineers Trustee Board, Council and Editorial Advisory Group.

Sam Price
Sam founded Price & Myers with Robert Myers in 1978. His many award-winning new buildings and alterations include a number of the colleges at Oxford and Cambridge. He has lectured at Cambridge, Glasgow, Trieste, Bergen, Hong Kong, and Vancouver.

Julia Ratcliffe
Julia is a Director of Expedition Engineering. She has collaborated with leading architects and designers on buildings ranging from towers and performing arts centres to private residences. In 2015 she was appointed a Design Council Cabe Built Environment Expert.

Tara Reale
Tara works with Mott MacDonald in London and holds a PhD in bridge management from Trinity College Dublin, where she was involved in European-wide research projects.

Roger Ridsdill Smith
Roger Ridsdill Smith is the Head of the Structural Engineering team at Foster + Partners. He is a Fellow of the Institution of Structural Engineers and won the Royal Academy of Engineering Silver Medal in 2010.

Peter Terrell
Peter is founder and President of Terrell Group Consulting Engineers. After early years with Ove Arup, Peter set up as sole practitioner in 1982 in Paris, building a practice that is today recognised as one of the leading structural engineering consultancies in France.

Grant Tolley
Grant is Chief Engineer of Temporary Works, Balfour Beatty Major Projects, and Founding Director of the Temporary Works Forum (TWf).

Excellence in structural engineering

Professor David A. Nethercot
OBE, FREng, FTSE, NAE
Emeritus Professor of Civil Engineering, Imperial College London, UK; and Chair of the Structural Awards Judging Panel

‘Excellence in structural engineering’ is the cornerstone of our Institution. But for the first 40 years of our existence, we did little to celebrate this internally and to broadcast it externally. Then came the Structural Awards. First introduced by the Council as the ‘Institution Special Award’ to be conferred on the Severn Bridge (Figure 1) as part of a lunch to mark our 60th anniversary in the presence of the Duke of Edinburgh, the scheme now attracts annually over 100 entries from across the globe. This year marks 50 years since that first Award.

With some 5000 different structures having been submitted for consideration, the scheme has obviously seen a very varied cross-section, ranging from high-profile international projects to domestic-scale improvements. A particularly welcome feature of the past 10 years has been the growth in the number of high-quality ‘Small Projects’ submitted. This year’s entries see this category (actually two categories as there are now two levels of ‘Small Projects’) being especially competitive. Of course, the suspicion is that such projects have always been around but that, until comparatively recently, those responsible did not see fit to submit them.

Some prize-winning entries are, of course, timeless, their qualities being such that they would have impressed any of the judging panels charged with debating the merits of any particular year’s submissions. What makes projects such as the Severn Bridge, Sydney Opera House (Figure 2) and the London Eye such clear winners is, of course, not difficult to see. Innovative, responding to major and newly identified challenges and beautifully done, such projects make for easy judging. Sometimes, of course, the judges will be presented with several highly deserving projects in the same year, thus making their task more difficult but adding strength to the scheme’s reputation. And sometimes it is the deceptively simple solution, embodying that old engineering principle that ‘The best solution is the simplest that does the job’, which really impresses the judges.

> “ITS MOST IMPORTANT FEATURE WILL REMAIN AS THE COLLECTIVE SKILL, IMAGINATION AND INGENUITY OF OUR MEMBERS”

CONSISTENT EXCELLENCE

Looking back over the 50 years of the Structural Awards, the obvious highlight is the consistently excellent quality of the structural engineering being conducted by our members. As the scheme has evolved – more opportunity and better focus through the introduction of categories; streamlined submissions that have moved from A1 posters to an electronic portfolio of drawings, photos and text; recognition that ‘sustainability’ is an integral part of projects, not a special additional feature – the judges have been confronted by larger numbers and more clearly presented examples of this. And they have come from an increasingly diverse group of countries. Who can forget seeing the reconstruction of the Iron Market from Haiti (Figure 3), the Mariinsky Theatre staircases from Russia or the ‘Glass Lantern’ Apple Store (Figure 4) from Turkey – not obvious places in which to find structural excellence created by our members.

Support for the scheme has also grown, with entries being submitted by a far more diverse set of organisations than was the case in the early years. This is partly due to the encouragement given to ‘Small Projects’ and ‘Small Practices’ and partly due to changed methods of working that permit relatively small organisations to develop niche skills. As an illustration, it is now the norm to receive several entries of

Figure 1
Severn Bridge – inaugural winner of Special Award

NICHOLAS MUTTON (CC BY-SA 2.0)

Figure 2
Sydney Opera House – winner of Special Award in 1973

Figure 3
Iron Market, Haiti – winner of Award for Sustainability in 2012

Figure 3
Apple Zorlu Glass Lantern, Istanbul – winner of Supreme Award in 2014

ROY ZIPSTEIN

staircases and 'sculptures' that constitute significant and ingenious structures in their own right. While the 'traditional' structural arrangements utilising steel and concrete continue to feature prominently, the ever-more-ambitious use of materials such as timber and glass that have not always been associated with significant structures has been very noticeable of late. Temporary or demonstration structures – we always receive an entry for London's annual Serpentine Pavilion – are another growing feature.

Although not strictly a highlight in the sense of the projects that have featured in the scheme, the Awards dinner and the sense of anticipation engendered by the earlier publication of the shortlisted entries demonstrate how the Structural Awards now enjoy far greater prominence. The dinner for some 400 guests is always sold out – as, incidentally, was the original lunch that also accommodated 400, although that was far from the case in the immediately following years – and provides a splendid opportunity to 'show off' what we do, to discuss the featured projects and to be a little smug about what a good service our members provide. Given all the efforts that have gone into the work that actually makes the submissions possible, those present deserve a little recognition, reward and relaxation.

LOOKING AHEAD

But what of the future? Will the Structural Awards be around 50 years from now and, if so, what might they look like? My answer to the first question is a resounding 'Yes'. An institution such as ours should celebrate the successes of its members, it should convey to colleagues, clients and the wider public the excellence and value of what we do and it should recognise that a very visible and well-run set of awards assists all our members.

Answering the second question is more tricky. Looking back over 50 years, there has been far more change in the way in which the scheme has been run than in the nature of the projects submitted. Of course, developments in technology – especially computing – have made it easier to do certain things. Improved materials and our ability to utilise them, coupled with improved understanding of how structures behave, have made the previously impossible or very difficult relatively straightforward. The shifting economic balance between materials and labour, site activities and transportation, as well as between environmental concerns and costs, has influenced the balance between the various constraints to which all projects are subject.

We hear of the 'new technologies' of Building Information Modelling (BIM), artificial intelligence (AI), robots, 3D printing, etc. And are constantly being told that they will revolutionise our industry. Yet the first three of these have been around (in the sense of known about and available to those wishing to avail themselves of the technology) for at least a quarter of a century, but only now seem to be gaining more traction. Greater use of digital technology, prefabrication and the facility to adapt structures over time are also gaining prominence, but are hardly new ideas.

So, will those submitting, judging, being shortlisted and receiving awards and enjoying the presentations 50 years from now be experiencing something radically different from today. Somehow, I doubt it. Inevitably there will be differences in the sorts of structures, the techniques used to design and to produce them, and in the way in which the Structural Awards scheme is run. But its most important feature will remain as the collective skill, imagination and ingenuity of our members.

ANSWERS TO THE QUIZ

1) Liverpool (Paddy's Wigwam is the local nickname for the Metropolitan Cathedral); **2)** Paul Robeson; **3)** Moonraker; **4)** Penteli Mountain, Greece; **5)** Toronto Blue Jays (baseball team); **6)** World Student Games; **7)** Immersed tube method; **8)** 600m; **9)** 65m; **10)** Akashi Kaikyo Bridge (Japan); **11)** Shanghai World Financial Center at 492m (the Shanghai Tower at 632m is the current tallest); **12)** 1%; **13)** Buttressed core.

Sponsored by The Telegraph

SUPREME AWARD FOR STRUCTURAL ENGINEERING EXCELLENCE

For the finest example of excellence in structural engineering design selected by the judges from the winners of the 12 principal award categories.

Winner: British Airways i360 (Brighton, UK) | Jacobs

Pod during operations

PROJECT TEAM

Client: Brighton i360 Ltd
Principal contractor: Hollandia Infra b.v. (Rotterdam)
Main contractor (tower and cladding): Nardo Hoogendijk
Architect: Marks Barfield Architects
Structural/civil/mechanical/electrical engineer and project manager: Jacobs UK Ltd
Pod, drive system and control system: Pomagalski SAS ('Poma'), France
Foundations substructure and beach building: J T Mackley & Co Ltd

IN BRIEF...

►The British Airways i360 is 162m tall and only 3.9m in diameter. It has a slenderness ratio of 41 to 1 and holds the Guinness World Record for the most slender tower in the world. Visitors can see as far as the Isle of Wight (50 miles).

►The tower was fully fabricated in Rotterdam and transported directly by barge across the North Sea to the beach site – no road transport was used at either end.

►It was built from 17 individual steel tubes ('cans'). Each can weighs between 50 and 100t and was fully fitted out in Rotterdam with all the internal and external equipment.

►Wind-induced dynamic movements are limited by 'sloshing liquid dampers'. The water in the dampers comes from Australia!

►The i360 created a vibrant new tourist attraction in a somewhat run-down area of Brighton beach, replacing the root end of the derelict West Pier (a Grade 1 listed structure). It carried over 100 000 passengers in the first four weeks of operation and created over 160 new jobs.

JUDGES' COMMENTS

With a height of 162m and a diameter of 3.9m, the i360 is the world's tallest moving observation platform. Constructed from 17 cans, each weighing between 50 and 100t, the tower was erected using an ingenious top-down method in a 10-week period. It arrived by boat – rather like the Mulberry harbours for the Normandy landings – to be sited on a concrete foundation that sits, in turn, on the chalky rock below.

Can 2 being placed onto Can 1

Because of its extreme slenderness and thus its high flexibility, it is, potentially, highly susceptible to dynamic movement caused by gusting winds. Careful dynamic analysis identified the potentially critical modes of vibration. Through a combination of purpose-designed perforated cladding that minimises vortex shedding and sloshing dampers that counter oscillation, it is able to operate in wind speeds of up to 30m/sec.

This unique structure posed numerous challenges: its slenderness required both detailed consideration of dynamic response and special measures to control this; as an observation platform in a highly visible site, it has to appear clean and attractive; as an attraction moving up to 200 people in its viewing pod through 138m vertically, it had to house all the mechanical and electrical equipment and to provide access for inspection and maintenance; and it had to be erected on a beach in 10 weeks in front of the summer crowds.

"AN ILLUSTRATION OF THE ART AND SCIENCE OF THE STRUCTURAL ENGINEER WORKING TO PRODUCE A RESULT THAT DELIGHTS AT ALL LEVELS"

As an illustration of the art and science of the structural engineer working to produce a result that delights at all levels, the i360 is a fine statement and the submission that, in the opinion of the judges, is the best example of structural engineering excellence.

First jacking operation

British Airways i360 in operation


Multi-material modelling, analysis and design software
Available to rent or buy for a lot less than you might think
SCIA ENGINEER
• BIM / Revit compatible
• Design codes for concrete, steel, timber, aluminium, composite and cold formed steel in one model
• Footfall, dynamics, stability and non-linear analysis
• 3D wind load generator
• UK field support team
• Co-developed and supported by CADS
CADS
Blavatnik School of Government, Oxford
Pell Frischmann. RIBA National Award 2016
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01202 603031

Sponsored by CADS

AWARD FOR LONG SPAN STRUCTURES

Awarded for structural engineering excellence in buildings (not bridges) incorporating particularly long spans, relative to the proportions of the structure.

Winner: San Mamés Football Stadium Cable Roof Extension (Bilbao, Spain) | IDOM

Stadium in use following completion of roof extension

PROJECT TEAM

Client: Athletic Club
Principal contractor: INBISA and PFEIFER
Architect: ACXT-IDOM (IDOM Group)
Project manager: IDOM
Cladding supplier: Vector Foiltec
Wind tunnel testing consultants: BMT Fluid Mechanics

IN BRIEF...

►The cable-net roof extension increases the span of the original cantilevered roof by between 13 and 23m, so that the total roof spans become 60–75m.

►The assembly of the main structure was completed in just two months during the summer off-season, meaning there was no disruption to matches.

►While the roof extension structure is made entirely of steel, the cladding is based on translucent ETFE cushions which contribute to energy efficiency by helping to minimise the shading effect on the turf.

►The roof extension has not only considerably improved spectator comfort on rainy days, but has also improved the stadium atmosphere by maximising the acoustics during matches.

JUDGES' COMMENTS

The new ETFE-clad roof extension to the San Mamés Football Stadium in Bilbao is a virtuoso performance in the art of balancing tension and compression. The client body, Athletic Club, saw a need to improve spectator comfort on rainy days

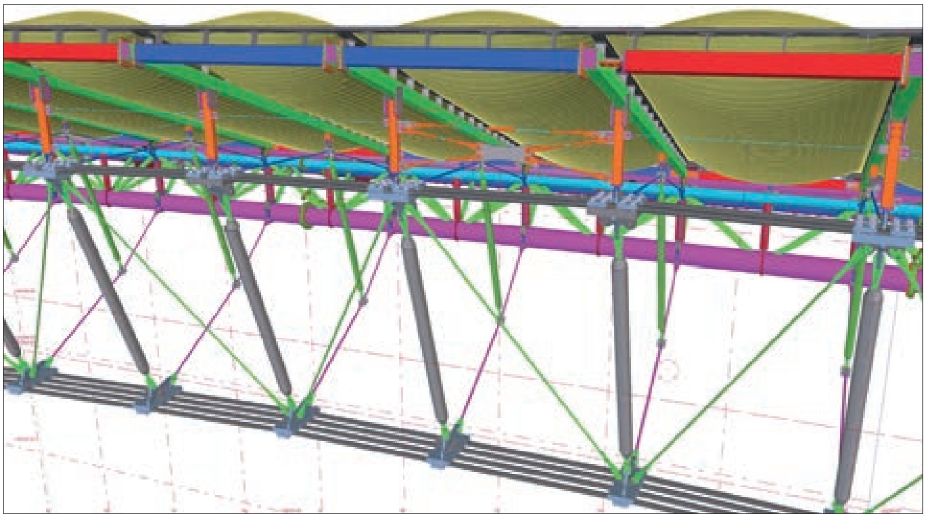
"THE NEW ETFE-CLAD ROOF EXTENSION ... IS A VIRTUOSO PERFORMANCE IN THE ART OF BALANCING TENSION AND COMPRESSION"

and this has been achieved by adding a new lightweight, translucent 4700m^2 oculus of ETFE-clad roofing within the existing stadium roof opening. The new structure extends the cantilever span of the original roof by between 13 and 23m, resulting in maximum projections of 75m.

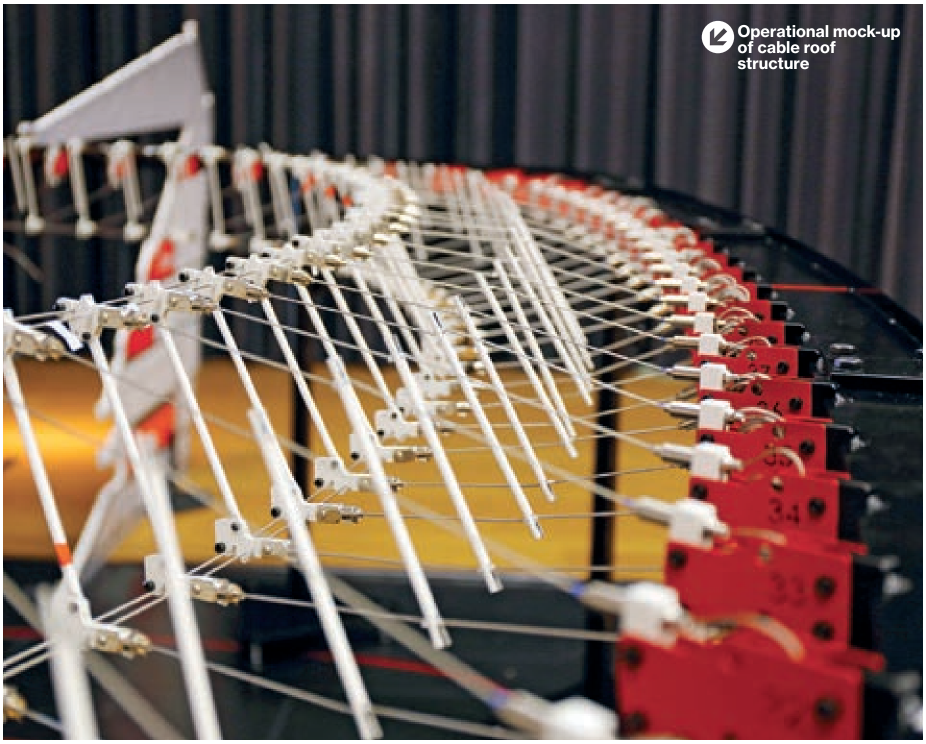
The structure designed to do this was an oval cable net arrangement, comprising an external structural steel prismatic truss compression ring linked by radial cables to a two-layer internal cable tension ring. The total weight of the roof extension structure, including the cable system and reinforcement of the existing cantilevered roof, is around 680t.

The entire arrangement of compression structure and cable net was assembled, lifted into position and tensioned in a period of just two months during the stadium's summer closure period, allowing the whole roof extension project to be completed without loss of a single hour of playing time.

The engineering design relied heavily on 3D modelling and interactive computer analysis of the new and existing structures. This was supported by wind tunnel model testing, computerised fluid dynamics modelling and wind-driven rain simulation, as well as the use of a 1:30 scale operational mock-up of the roof to simulate and assess the actual processes of lifting and tensioning the new structure.



Modelling of structural joints



Operational mock-up of cable roof structure

Assembly and raising of cable net

Sponsored by Mapei

AWARD FOR VEHICLE BRIDGES

Awarded for excellence in the design of bridges carrying highways and/or railways.

Winner: Destructor Bridge (Bath, UK) | COWI (formerly Flint & Neill)

Completed bridge showing concealed lighting within handrails and timber benches

PROJECT TEAM

Client: Crest Nicholson Ltd with Bath & North East Somerset Council
Principal contractor: Britannia Construction
Architect: Knight Architects
Steelwork fabricator: Cordioli
Launching contractor: ALE

IN BRIEF...

►Destructor Bridge is a 48m long tied arch bridge with a single eccentric arch on one side supporting a composite deck formed by two longitudinal box girders and transverse steel cross girders.

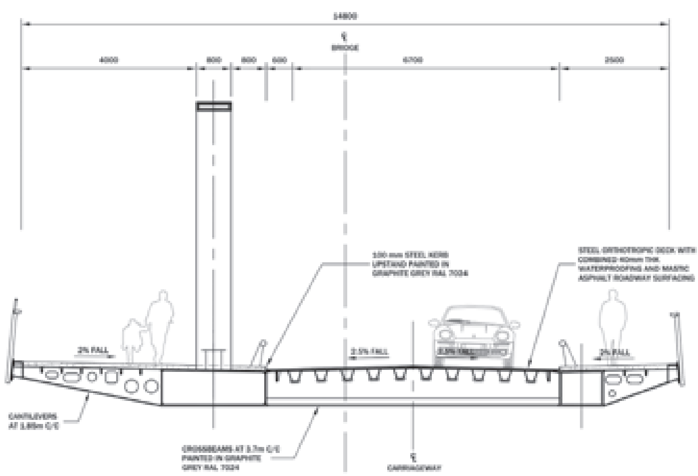
►The arch uses flat plates as hangers, rather than cables or rods to provide additional lateral stiffness to stabilise the arch. These fix to a wide and shallow steel torsion box under the deck, which also acts as a tie between the ends of the arch to avoid horizontal loads on the abutment.

►A smaller longitudinal box girder is placed under the opposite carriageway edge, and the deck crossbeams support a lightweight steel orthotropic deck. Cantilevers outside the main girders support the footways.

►The bridge was assembled as a complete

"THE OVERALL RESULT IS THE PARTICULARLY CLEAN AND PLEASINGLY SIMPLE APPEARANCE THAT CAN RESULT ONLY FROM EXPERTLY CONSIDERED ENGINEERING"

Cross-section of bridge



Construction of arch

unit on the south side of the river, then launched across the river in a single operation by a pair of self-propelled multi-axle transporters (SPMTs).

►It provides a vital link in unlocking the huge potential of a new riverside development of over 2000 homes.

JUDGES' COMMENTS

Despite its name (an inheritance from the previous bridge on the site which is near the 'Destructor' waste incinerator), the Destructor Bridge is an extremely elegant piece of engineering and a fitting and respectful addition to the site not far from the 1836 Grade II listed Victoria suspension bridge, designed by James Dredge.

The road, pedestrian and cycle bridge, supported mainly by an arch placed eccentrically to the deck but assisted by a pair of box girders in the deck, achieves a span of 48m with a clear and succinct structural diagram that is the hallmark of so many accomplished designs.

The arch has a surprising and bold slender aspect, just 200mm deep and 800mm wide, and the deck hangers, themselves just 40mm thick and generously spaced at 3.7m centres, contribute to the arch stability while maintaining visual openness.

Similarly, the parapets, so often an ill-considered blight on bridges, follow through the carefully detailed design, along with benches neatly slotted between the hangers. The overall result is the particularly clean and pleasingly simple appearance that can result only from expertly considered engineering.

The clarity of the both the engineering design and the bridge itself is a testament to the skill of the engineers in producing a bridge of delightful simplicity and technical accomplishment.

Launching of bridge using SPMTs

Mapei Figures

more than
50,000
Tons of CO_2 offset

more than
161,000
Professionals from the sector involved in Mapei training courses

73
Plants in 5 continents, in 33 different countries

80 years
1937-2017

Sponsors of the Vehicle Bridges Awards

2.4
Billion Euros estimated consolidated turnover in 2016

more than
25,000
Tons of products shipped every day

more than
66,000
Clients around the world

more than
5,000
Products for the building industry

18
Main research centres in 13 countries

more than
80
Mapei subsidiaries around the world

3,000,000
Tons of CO_2 saved thanks to Mapei additives for cement grinding

more than
1,000
New formulates every year

more than
9,000
Employees, with 12% working in R&D

Sponsored by The Structural Engineer

AWARD FOR PEDESTRIAN BRIDGES

Awarded for excellence in the design of pedestrian and/or cycle bridges, or other lightweight bridge structures.

Winner: New Mobile Walkway of Geneva's Jet D'Eau (Geneva, Switzerland) | INGENI SA

Walkway in elevated position

PROJECT TEAM

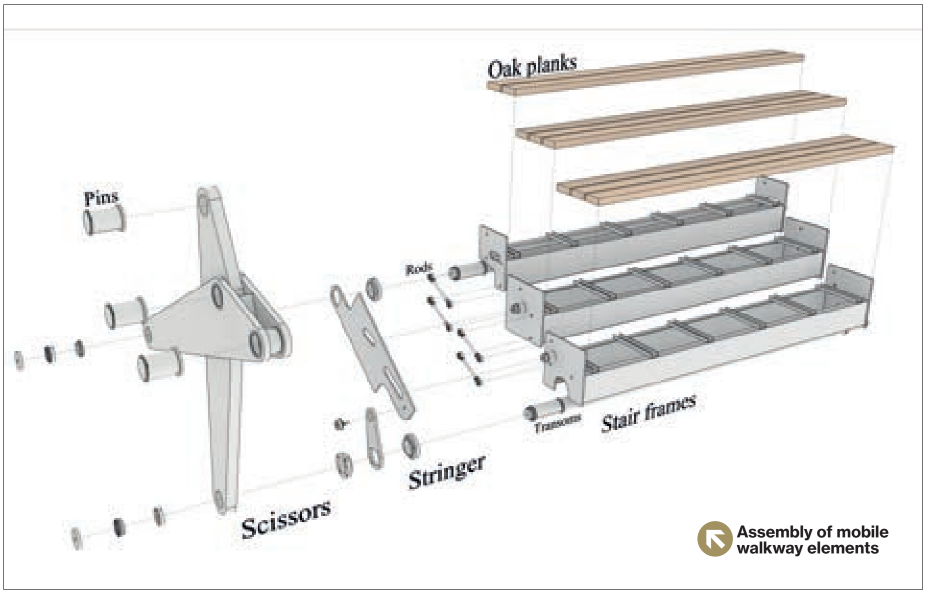
Client: HAU Geneva
Principal contractor: Stephan SA
Architect: MIDarchitecture sarl
Other contractors: Implénia SA and JPF Ducret

IN BRIEF...

- The walkway spans over 12m, transforming into a 10-step staircase over 2m high to allow boats to pass underneath without interrupting pedestrian access.
- The bearing structure for the decking is a scissor mechanism with a single axis of movement. Eight pistons at the ends can be used to separate the supports by sliding them on a rail, automatically opening all the scissor mechanisms and lifting the walkway.
- A total capacity of 80t is needed in the pistons to push up the 15t of structure, including 30 pairs of scissors made of duplex stainless steel.
- Horizontal stability is provided by embedding cross-members in the load-bearing scissor mechanisms at either end of the walkway. The cross-members are 13cm diameter steel cylinders on which the deck rests.
- The walkway was pre-assembled in a workshop in order to carry out a series of tests before installation.

JUDGES' COMMENTS

The new mobile walkway of Geneva's Jet d'Eau is a unique piece of structural



Assembly of mobile walkway elements

Walkway transforms from flat state to elevated bridge with steps

> “THE JUDGES WERE IMPRESSED BY THE ELEGANT DETAILING AND CONCEPT OF THIS MOVING STRUCTURE”

engineering. The bridge spans over 12m and is capable of transforming from a low flat deck to a 2m high series of stairs, allowing boats to pass underneath. The bridge is a part of a new pedestrian walkway expansion that provides better access to the iconic Geneva water fountain at the end of the existing stone pier.

The bridge is supported at two points on either end, like a cantilever bridge. Ingenious 1.2m high stainless steel scissor mechanisms allow the bridge to be raised and lowered. They are made of 20–60mm duplex 1.4462 stainless steel plates, and are driven upwards by horizontal pistons at each end. Next to the pistons are tracks, allowing for the horizontal movement that takes place when the bridge is raised or lowered. When the walkway is raised, the deck turns into a stairway thanks to a series of conrods and ball joints at each step.

The deck is approx. 4m in width, and is made from solid oak sourced exclusively from the forests of Geneva. The bearing structure for the oak decking includes precast concrete beams and metallic pipes, all intentionally hidden to give the impression that the decking is floating on water.

The judges were impressed by the elegant detailing and concept of this moving structure. It is truly a novel accessibility solution that is a testament to creative structural engineering.

Sponsored by Trimble

AWARD FOR SMALL PROJECTS (UNDER £1M)

Awarded for excellence in the structural design of projects with a construction cost of less than £1M, including art structures and sculptures.

Winner: The Pump House (London, UK) | Webb Yates

View from mezzanine showing cast iron roof truss nodes

PROJECT TEAM

Client: Private
Principal contractor: Clean Lines Construction
Architect: Fabric Space

IN BRIEF...

►The structure of the mezzanine is entirely formed with 1.2 × 0.7m cast iron plates that interlock to form both the floor and balustrade.

►The pieces were sand cast using ductile iron, with the pattern modelled in Rhino and CNC cut from timber. A single mould was used to cast all the panels, reducing manufacturing time and cost.

►The form represents the flow of load and stress through the pieces and is optimised for weight and strength while maintaining a very thin depth.

►All the complexity and detail was carefully built into the cast forms, with connections only bolts in shear.

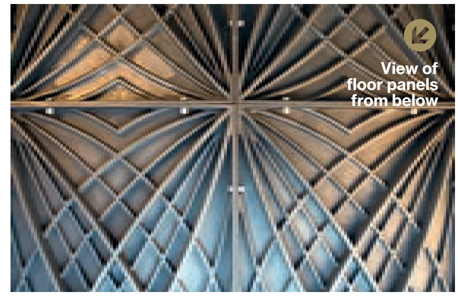
JUDGES' COMMENTS

The Pump House was constructed in 1903 by the London Hydraulic Power Company, a company set up by an Act of Parliament in 1883 to install a hydraulic power network in London. The building is predominantly masonry, while the trusses of the existing roof are plain bar with cast iron nodes. Externally, the cast iron setting tanks can be seen and the panelling is reminiscent of water towers across the UK.

The renovation of the internal space of this tall historic workshop included the addition of a 6.3 × 2.3m mezzanine floor which fits tightly between the existing floor and the lowest point of the trusses, meaning the structure and build-up had to be aggressively minimised.

By using cast iron floor panels and eliminating all finishes above and below the mezzanine floor, the structure itself formed a decorative soffit below and a hardwearing floor above. The panels are cast with a monolithic stiffened underside and a solid

Completed mezzanine structure showing patterned balustrade



View of floor panels from below

continuous top face, and then bolted together to form a continuous floor slab. With only a shear connection required, simple bolted connections could be used between panels. By forming the edge of one side of each panel at a 45° angle, the handrail sections could be fixed directly to the floor panels.

Cast iron has many advantages over steel. It is a cheaper raw material and can be formed into endlessly complicated shapes by casting. Collaboration with a local foundry and contractor identified that using as much repetition as possible was key, as creating the casting moulds is the most significant cost.

The same mould was used for the floor plate and handrail plate.

Ductile cast iron, a graphite-rich variation, was used to reduce brittle fracture and improve impact resistance. With repetition being a requirement, a panelised floor system was developed that works in a similar way to traditional stone landings, supported off the surrounding walls with shear connections on two or three sides. Therefore, bending moments did not have to be transferred across the connections and each panel had a similar stress distribution under uniform load.

Commendation: Armadillo Vault (Venice, Italy) | Block Research Group and ODB Engineering

PROJECT TEAM

Client: Venice Biennale
Principal contractor: The Escobedo Group
Architect: Block Research Group

JUDGES' COMMENTS

The Armadillo is a doubly curved, unreinforced, compression-only, cut-stone funicular vault, constructed from 399 limestone blocks. Computational form finding, structural analysis and digital fabrication were all interwoven to create a structure inspired by traditional masonry craftsmanship and analysis methods. It stands as an example of the use of modern methods to design an elegant form with stone, a material traditionally used for its compressive strength.

Vault *in situ* at Venice Architecture Biennale

The static equilibrium vault weight is 24t, where the thickness of stone varies from 8–12cm at the supports to 5cm at its peak. With a height of 4.4m and spans of over 15m, the structure has a span-to-thickness ratio less than half that of an eggshell. The double-curvature shape gives a geometrically stiff structure that allows for the reduction of the overall weight.

A discrete-element analysis was performed with loading cases involving self-weight, line loads, concentrated loads and constant horizontal seismic acceleration loads. For the analysis, the horizontal acceleration was increased until collapse, where the vault achieved at least 0.325g of loading. Plated steel supports were designed to transmit the vertical reaction forces (36–74kN) to the ground over as large an area as possible, to minimise contact pressures on the historic floor.

A steel tie system connected the three perimeter supports to resist the horizontal thrusts (25–32kN). The vault pushes outwards and, as the main ties that emanate from the triangle were not braced, the torsional stiffness of the vault was used to provide torsional stability.

Computational methods were required to control the cutting of the stones. A circular saw blade with tolerances in the range of 0.4–0.8mm was preferred to milling tools. As no mortar was used at the interfaces between blocks, accurate cutting was critical. The extrados (outer) surface was kept flat, to avoid having to turn over the stone and precisely reposition it. Instead, the intrados (inner surface) provided curvature to the vault through parallel cuts, creating fins that were broken off with a hammer.

Sponsored by Randstad

AWARD FOR SMALL PROJECTS (OF BETWEEN £1–3M)

Awarded for excellence in the structural design of projects with a construction cost of between one and three million pounds, including art structures and sculptures.

Winner: Adele 25 Stage (multiple locations) | OPS Structures Ltd


Adele 25 stage in use at concert

PROJECT TEAM

Client: Star Events Ltd and Remedy Touring LLC
Principal contractor: Star Events Ltd
Architect: Star Events Ltd

IN BRIEF...

►OPS developed an efficient and understatedly elegant structural solution, with sustainable legacy use at its heart, for a new stage concept for pop star Adele's 25 album tour.

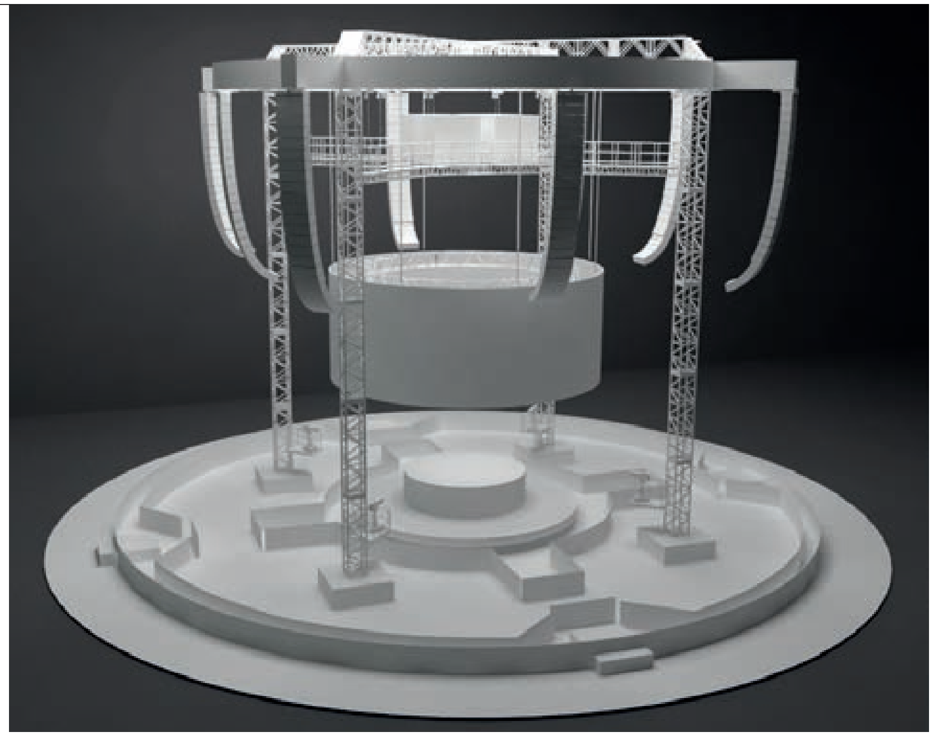
►The design focused on minimising working at height, ensuring unobstructed views that negated traditional bracing, and facilitating containerised transportation, as well as compliance with multiple codes across continents.

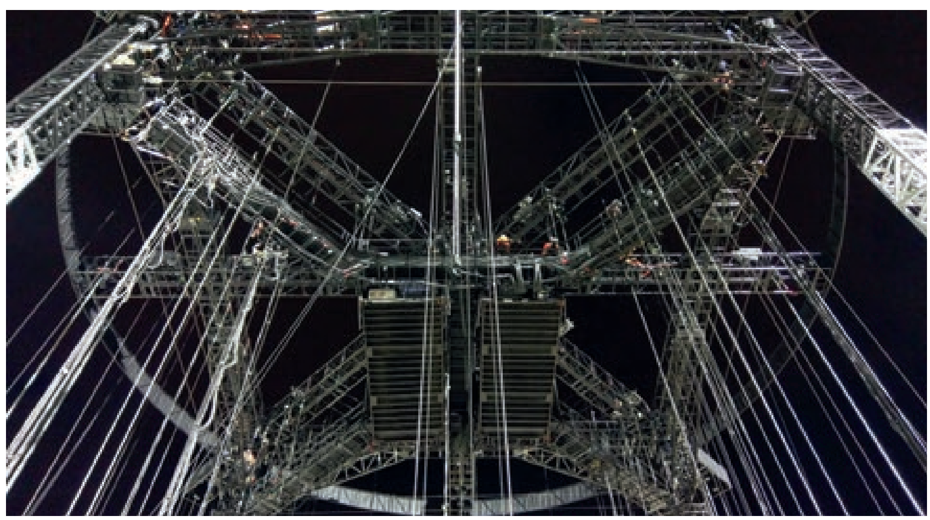
►The stage structure occupied a footprint of 22.5 × 22.5m, reaching an unbraced elevation of 26m. The components were packed in 11 shipping containers for transportation across the world.

►The project used hot rolled steel tubes fabricated into reusable CHS and RHS trusses in grades S355 and Q345 respectively. All trusses were designed to be compatible with the client's existing systems, thereby ensuring a legacy use after the tour.

►When assembled, over 85t of equipment was suspended above the stage, with over 20t of loudspeakers cantilevering out from the perimeter.

Stage structure



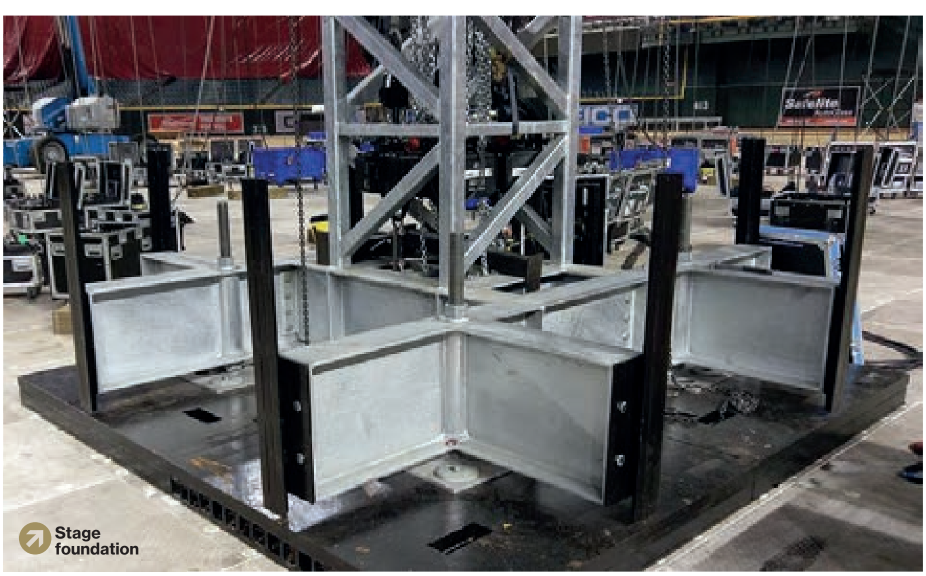


“THE CAREFUL DETAILING AND EXECUTION REFLECTS THE STRENGTH OF THIS SUBMISSION”

JUDGES’ COMMENTS

Four slender trussed columns stand 25m tall above the main stage supporting a halo of steelwork and performance equipment for the Adele 25 Australasian Tour. At first glance, the structure appears simple in form as a two-way portal frame; however, it reflects a myriad of design considerations, constraints and time pressures all resolved into an apparently straightforward structure. It is this elegant and thorough resolution and the innovation evident in the final detailing that makes this project a significant piece of engineering.

The design considered the functional requirements of the ‘in the round’ stage location and necessary viewing requirements from all angles. It responded with an elevated, unbraced, steel trussed structure that minimised interference during the concert. This combination of tall and unbraced with significant load at height is unusual, and the careful detailing and execution reflects the strength of this submission.



Stage foundation

The integrated design addressed practical considerations such as transportation between venues and the safe and rapid construction of this temporary structure. The elevated steel grillage was erected at ground level and then hoisted up and locked into place to minimise working at height. The installation process was completed in 24 hours and deconstruction in 12 hours.

The flexibility in its design allows the stage to be used in different countries, taking account of change in environments and multiple design code requirements. An adaptable base system was developed to avoid the need for ground anchors and allow for variable foundation and support conditions.

Sponsored by Warners Midlands

AWARD FOR TALL OR SLENDER STRUCTURES

Awarded for structural engineering excellence in projects where height or slenderness presents a particular structural challenge in the design and construction.

Winner: British Airways i360 (Brighton, UK) | Jacobs

Pod during operations

PROJECT TEAM

Client: Brighton i360 Ltd
Principal contractor: Hollandia Infra b.v. (Rotterdam)
Main contractor (tower and cladding): Nardo Hoogendijk
Architect: Marks Barfield Architects
Structural/civil/mechanical/electrical engineer and project manager: Jacobs UK Ltd
Pod, drive system and control system: Pomagalski SAS ('Poma'), France
Foundations substructure and beach building: J T Mackley & Co Ltd

IN BRIEF...

►The British Airways i360 is 162m tall and only 3.9m in diameter. It has a slenderness ratio of 41 to 1 and holds the Guinness World Record for the most slender tower in the world. Visitors can see as far as the Isle of Wight (50 miles).

►The tower was fully fabricated in Rotterdam and transported directly by barge across the North Sea to the beach site – no road transport was used at either end.

►It was built from 17 individual steel tubes ('cans'). Each can weighs between 50 and 100t and was fully fitted out in Rotterdam with all the internal and external equipment.

►Wind-induced dynamic movements are limited by 'sloshing liquid dampers'. The water in the dampers comes from Australia!

►The i360 created a vibrant new tourist attraction in a somewhat run-down area of Brighton beach, replacing the root end of the derelict West Pier (a Grade 1 listed structure). It carried over 100 000 passengers in the first four weeks of operation and created over 160 new jobs.

JUDGES' COMMENTS

The British Airways i360 holds the Guinness World Record for the most slender tower in the world. Soaring 162m above Brighton, it has a diameter of only 3.9m, leading to a slenderness ratio of 41:1! It carries 200 passengers at a time in a circular glass viewing pod up to a maximum viewing height


British Airways i360 in operation

First jacking operation

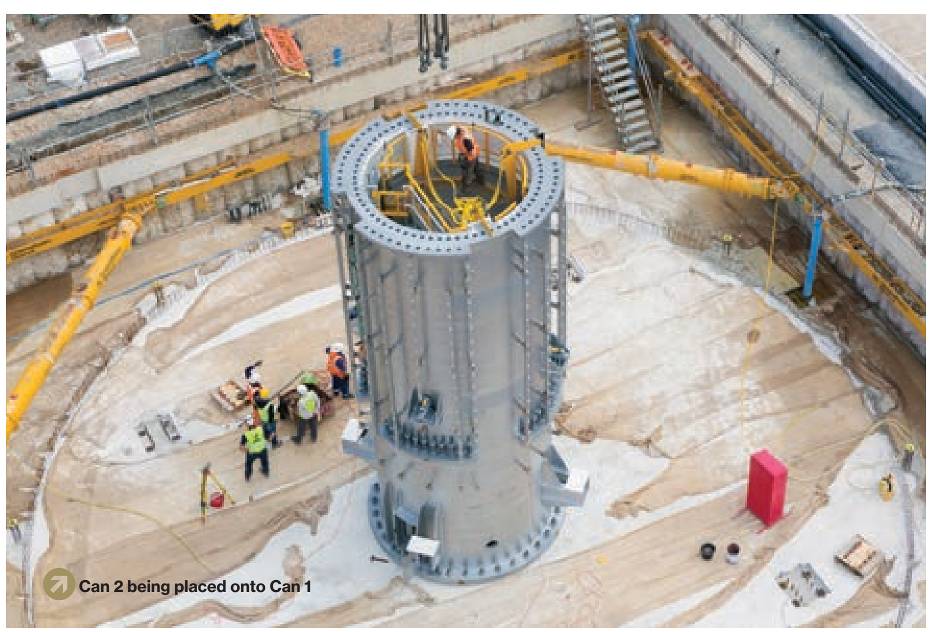
> “THE BRITISH AIRWAYS i360 HOLDS THE GUINNESS WORLD RECORD FOR THE MOST SLENDER TOWER IN THE WORLD”

of 138m, which also makes the i360 the world’s tallest moving observation tower.

The steel tower is clad in perforated aluminium Expamet sheet, which successfully interrupts the regular shedding of alternate-side vortices.

To assist the dynamic characteristics of the flexible tower still further, 78 sloshing liquid dampers are tuned to the first, second and third mode frequencies, and are located at the top of the tower (for the first and second modes) and at the peak deflected shape points (for the second and third modes). These innovations were essential, given that the lowest natural frequency of the tower (first mode) is less than 0.2Hz!

Another innovation lies in the manner in which the tower was constructed. It comprises 17 ‘cans’, each weighing between 50 and 100t, which were jacked up one by one in a top-down method of construction using a jacking frame. This avoided the use of unfeasibly large cranes, and ensured that all construction occurred safely at ground level. And you’ll be happy to know that over 60% of the energy used to lift the pod each time was recovered on its descent. A remarkable feat of engineering.


Can 2 being placed onto Can 1

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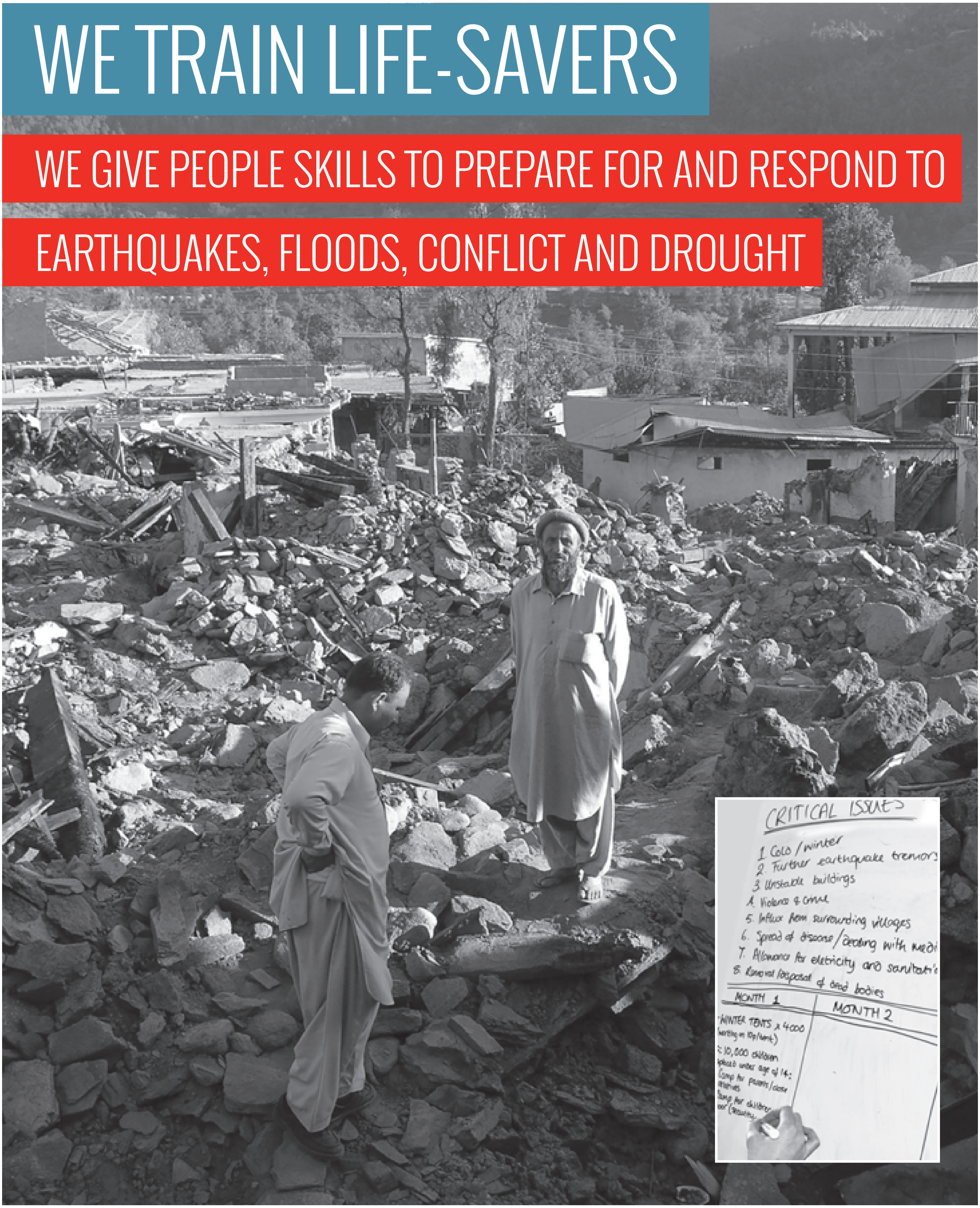

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AWARD FOR STRUCTURES IN EXTREME CONDITIONS

Awarded for excellence in the design of structures subject to extreme actions, including marine and offshore structures and those in seismic zones, or involving unusually complex interactions with the ground and/or particularly challenging foundations.

Winner: MeyGen Phase 1A Tidal Turbine Support Structure (Inner Sound, Pentland Firth, Scotland) | Robert Bird Group

Turbine and supporting tripod awaiting installation

PROJECT TEAM

Client: MeyGen Ltd
Principal contractor: MeyGen Ltd
Offshore installation contractor: James Fisher Marine Services
Turbine suppliers: Atlantis Resources Corporation and Andritz Hydro Hammerfest
Turbine support structures fabricator: Global Energy Group
Ballast fabrication: JGC
Cable supply and installation: JDR

IN BRIEF...

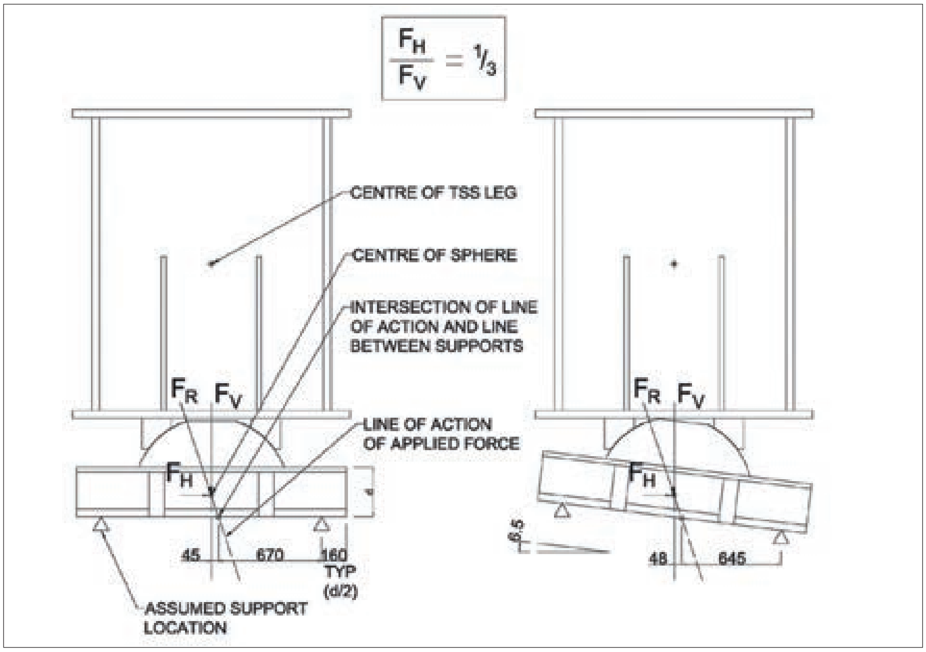
►In Phase 1A of the MeyGen project, four turbines have been installed off the north coast of Scotland, together supplying 6MW rated capacity to the grid. This is the first stage of the planned 398MW MeyGen tidal turbine farm, and the first project of its kind in the world.

►Sitting in 30–50m of exposed fast-flowing turbulent waters, the steel tripod gravity foundations have been designed from first principles to enable year-round turbine operation over a 25-year life with no maintenance.

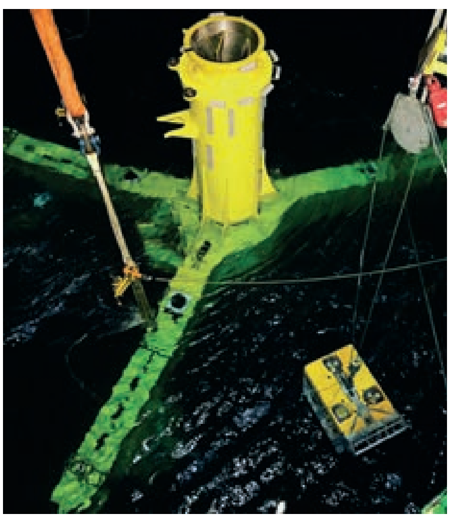
►Each of the four turbine support structure (TSS) tripods is approx. 20 × 25m in plan, with the overall assembled device approx. 23m from seabed to tip of the rotor blades.

►Each TSS is constructed of 158t of fabricated steel plate, partially infilled with grout to improve on-bottom stability in the temporary case. 1200t of steel ballast in the form of six 200t blocks was installed on each TSS to provide stability.

►The turbine is designed to yaw about the pylon to align its rotor blades with the tidal flow.



Design of articulated feet



"THE JUDGES WERE PARTICULARLY IMPRESSED BY THE STRUCTURAL ELEGANCE ACHIEVED IN THESE PROTOTYPE TRIPOD TIDAL TURBINES"

Transportation and installation of turbines

JUDGES' COMMENTS

The judges were particularly impressed by the structural elegance achieved in these prototype tripod tidal turbines, which enabled this future tidal farm and the technology to be developed further.

Sitting in up to 50m depth of fast-flowing turbulent sea, which is critical for the tidal power generation nature of the project, with waves of around 15m, clearly presents uniquely extreme design conditions. The requirement for a maintenance-free structural solution lasting 25 years necessitated close collaboration between all disciplines. In addition, the more 'typical' challenges of strength, 40-minute construction windows, variable seabed surfaces, multi-axial fatigue and ever-changing yaw orientation also needed to be tackled, highlighting a need to fundamentally understand the site and first principles of the loading conditions.

To have solved these challenges without fixed foundations highlights the care and passion applied to the structural design. A minimalist, low-profile, non-obstructive gravity foundation with a single extended structural support in the direction of the prevailing current was devised with articulated support bearings. While satisfying and even minimising the loads efficiently, the solution also minimises the use of material, fabrication costs and physical impact on the seabed.

It is evident to the judges that the engineers involved worked hard to develop this world-first successful test from concept through to full-scale prototype; producing a structure to be proud of.

Sponsored by Conrad Consulting

AWARD FOR STRUCTURAL HERITAGE

Awarded for excellence in structural design where important heritage characteristics of the original structure are maintained through appropriate restoration, conservation, extension or refurbishment.

Winner: Rejuvenation of the heritage Makatote rail viaduct (North Island, New Zealand) | Opus International Consultants

Makatote viaduct following refurbishment

PROJECT TEAM

Client: KiwiRail
Principal contractor: TBS Farnsworth
Heritage architect: Heritage New Zealand
Project management and contract administration: 41 South
Environmental engineer, planner and coating specialist: Opus International Consultants
Independent coating inspector: Pacific Corrosion Consultants

IN BRIEF...

► Makatote is one of the tallest railway viaducts in New Zealand and holds significant heritage value due to its elegance and the technology used at the time of its construction *circa* 1908.

► The viaduct had begun to suffer from ongoing deterioration of the coating, which was over 50 years old, resulting in corrosion which subsequently led to section losses of steel elements.

► With an additional desire to upgrade the viaduct to the future load requirements of KiwiRail, it was refurbished and strengthened to extend its life for another 50 years.

JUDGES' COMMENTS

This magnificent early-20th century viaduct, whose main constituents are five riveted steel trestle piers up to 79m in height, supporting 35m long riveted steel trusses, was both corroded due to erosion of the 50-year-old paintwork, and incapable of justification for carrying increased loading from future rolling stock.

After preparing the business case for refurbishment and strengthening, the engineers worked in partnership with the chosen contractor to arrive at a solution that would allow continuous use of the bridge during construction.


Tie strengthening with tension rods anchored at nodes

The judges were singularly impressed with the elegance of the structural solutions, combining replacement of diagonal lacings between channel sections on compression members with steel plates, retaining the overall original member sizes, and adding


Bottom chord strengthening with tension rods

tension rods to the bottom chords, hidden within the original structural plates and anchored to the struts at the nodes.

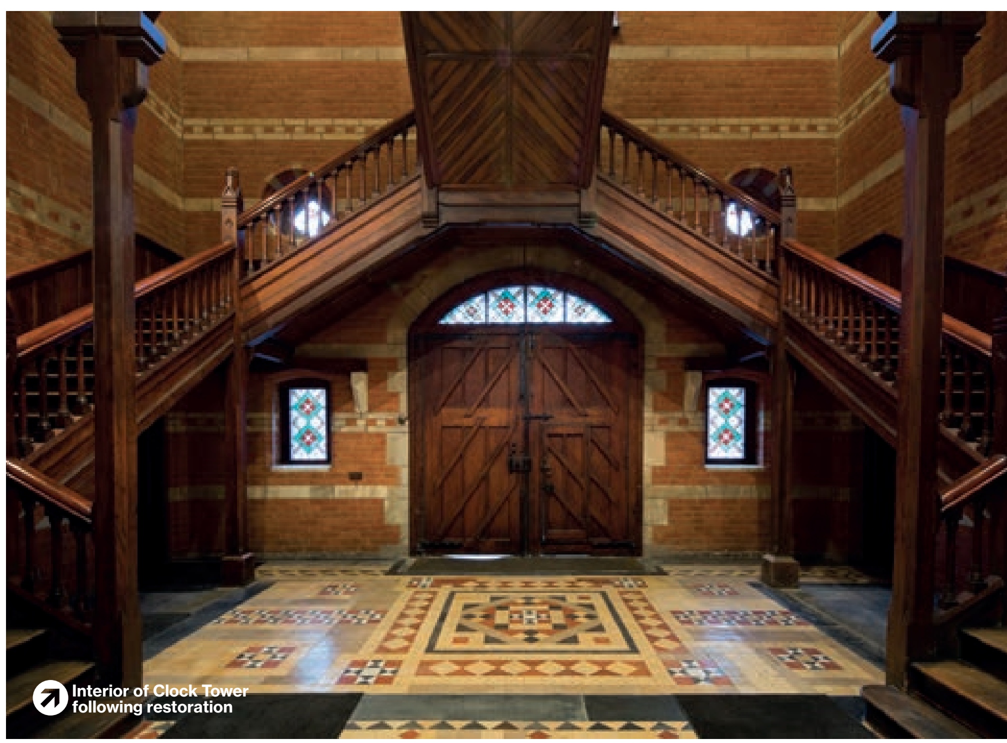
Replacement of rivets with HSFG bolts on the original structural members as an intermediate measure, due to the time-consuming operation of rivet removal, is one example of the intelligent organisation and sequence of strengthening procedures, particularly of compression members, which allowed continuous operation of the railway throughout the works without ever compromising safety.

In terms of engineering excellence, value and sustainability, the engineering team has excelled in all three, and has allowed an iconic structure to continue in service for at least the next 50 years.

Commendation: Arts Centre of Christchurch, Block C (Christchurch, New Zealand) | Holmes Consulting

PROJECT TEAM

Client: Arts Centre of Christchurch Trust Board
Principal contractor:
Fletcher Construction Company
Architect: Warren & Mahoney
Project manager:
Fletcher Construction Limited


Interior of Clock Tower following restoration

JUDGES' COMMENTS

Engineering excellence in heritage structures is often about what you don't see, rather than what you do. The refurbishment and strengthening of the Christchurch Arts Centre following the devastating earthquake of 2011 is a case in point. The engineers were faced with the task of restoring to its former glory a badly damaged but magnificent Neo-Gothic building, giving it a robustness that would prevent such damage in the future, and making the associated structural works all but invisible.

They achieved this in an exemplary fashion, carefully cataloguing thousands of structural elements, painstakingly removing both wall and roof structures, before inserting reinforced concrete and timber components respectively, then replacing the original finishes within the same volumes. Reinforced concrete beams at eaves level were inserted within the original geometry, and serve to tie the roof and shear wall structures together to form a more robust seismic resistant ensemble.

The heterogeneous nature of the structural materials, added to the uneven damage from the earthquake, meant that reinforcement solutions were diverse and included glass-fibre polymer overlays, stainless steel pins and vertical drill and grouted post-tensioned bars between header beam and foundations.

The result is an all-but-invisible intervention that prolongs the life of this important building for the foreseeable future.

Sponsored by Energi People

AWARD FOR STRUCTURAL TRANSFORMATION

Awarded for projects demonstrating structural engineering excellence in the transformation, extension, renovation or rehabilitation of an existing building or structure.

Winner: Design Museum (London, UK) | Arup

Completed Design Museum with view of roof from below

PROJECT TEAM

Client: Chelsfield Partners LLP
Principal contractor: MACE
Architect (interior design and fit-out): John Pawson Ltd
Architect (shell and core): OMA
Architect (shell and core): Allies & Morrison
Landscape architect: West 8
Structural, MEP, facade, acoustic and fire engineering: Arup
Fit-out contractor: Willmott Dixon
Building services engineer: Chapman BDSP

IN BRIEF...

► The roof of the Grade II* listed Commonwealth Institute exhibition building consists of a central post-tensioned concrete hyperbolic paraboloid shell, typically only 75mm thick.

► Arup provided a radical engineering solution to redevelop the 1960s building as a new home for the Design Museum, strengthening and then retaining the 2000t (55 × 55m) roof and primary structure by temporarily suspending it 20m above ground, supported entirely by temporary works.

► This enabled the replacement of the existing facade and internal structure, and a significant new basement covering the entire building plan to be created.

► The original building used a mixture of *in situ* and precast reinforced concrete, with many elements post-tensioned to reduce their size. The new concrete used for the strengthening was typically a high-strength C67 mix in order to reduce the sizes of the new elements. Post-tensioning was also incorporated into many of the elements.

► The original joints in the precast rafters had been infilled with high-alumina cement which had fully converted to its weaker form of approx. ⅓ of the original strength (~20N/mm^2). New very-high-strength mortar (>100N/mm^2) was used to repair these joints.


Propping of roof during construction works

JUDGES' COMMENTS

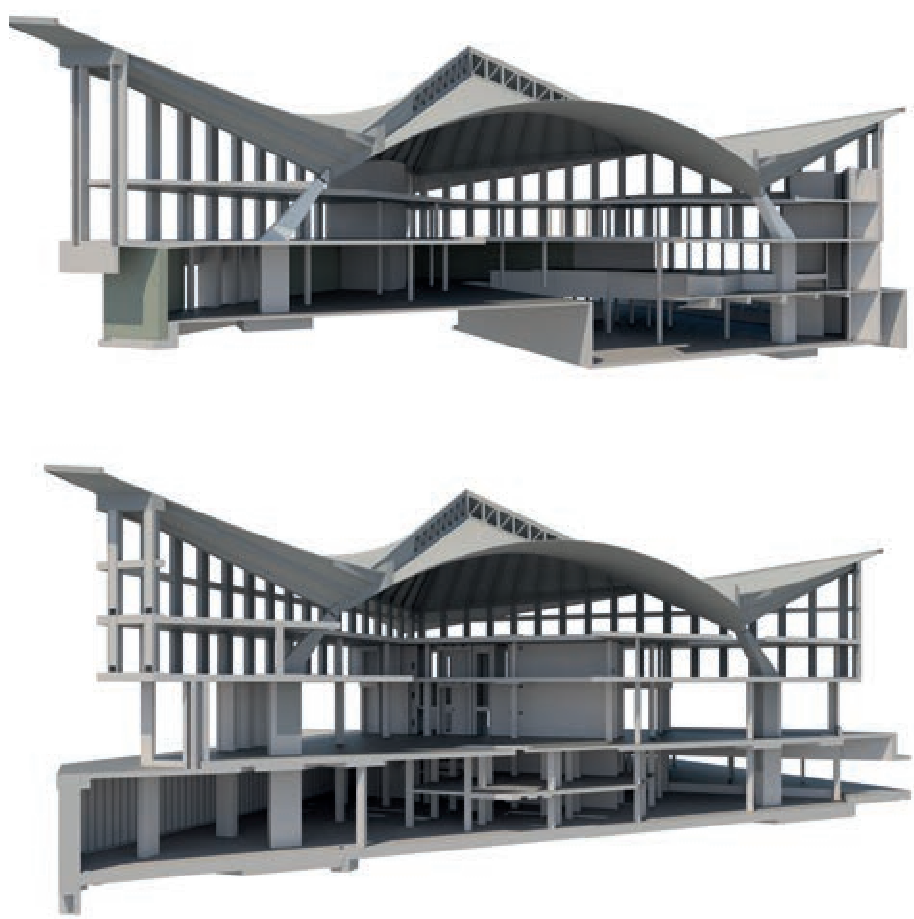
Used frequently in the 1960s and 70s, hyperbolic paraboloid roofs are smoothly curving in shape, but are formed from a series of straight pieces.

The copper-covered hyperbolic paraboloid roof of the Grade II* listed Commonwealth Institute exhibition building, originally constructed in 1962, weighs 2000t and measures some 55 × 55m – the same area as 15 tennis courts. It was strengthened and then supported on temporary supports, in its original position some 20m above ground. Then its walls and floors were demolished. Below the temporarily supported roof, new basement and floor structures were constructed, ultimately being built up to provide permanent support for the roof. The roof is very thin, so damage to it could have been caused if movements in the temporary supports had exceeded a tiny ±5mm.

Particularly impressive is the way in which the risks associated with supporting such a large fragile roof so high in the air were dealt with, by initial painstaking investigation, the design of the strengthening, and an analysis that checked what might happen under various scenarios – e.g. the supports moving after initially being set up.

This audacious transformation of a listed building has created a fitting new home for the Design Museum and has delighted hundreds of thousands of visitors since its opening in November 2016.

Models of existing (top) and proposed structure (bottom)



Sponsored by Tarmac

AWARD FOR CONSTRUCTION INNOVATION

Awarded for projects demonstrating structural engineering excellence in the innovative use of construction materials or processes.

Winner: TallWood House at Brock Commons (Vancouver, Canada) | Fast + Epp

NATURALLY WOOD

Building approaching completion showing 17 timber storeys

PROJECT TEAM

Client: UBC Properties Trust
Principal contractor: Urban One Builders
Architect: Acton Ostry Architects
Infrastructure and development: University of British Columbia
Tall wood advisers: Architekten Hermann Kaufmann
Wood structure erection: Seagate Structures
Timber supplier: Structurlam Products LP
Fire science and building code: GHL Consultants Ltd
Virtual design modelling: CadMakers Inc.

IN BRIEF...

►At 53m tall, the 18-storey TallWood House is the tallest contemporary mass timber building in the world. It has a footprint of 15 × 56m and a total building area of 15 115m^2.

►Over 2000m^3 of timber was used in the building's construction. Floor panels are five-ply cross-laminated timber (CLT) panels, while columns are glued laminated or parallel-strand laminated timber. Concrete cores provide lateral stability, and a concrete transfer slab is located at level two.

►The building is essentially a 'kit of parts' that was installed quickly and easily with minimal labour on site. Two 900m^2 floors were erected each week, enabling the timber superstructure to be erected in just over nine weeks. A comprehensive 3D model was produced for fabrication and construction sequencing purposes.

JUDGES' COMMENTS

The client's challenge to deliver a mass timber building to compete with traditional concrete-framed solutions for this student residential tower led to a series of innovations through the design and construction. The judges were unanimous in their admiration for the fresh approach that was taken across design and detailing to develop an economic new hybrid

SEAGATE STRUCTURES

Kit-of-parts approach allowed rapid erection of superstructure

> "THE JUDGES WERE UNANIMOUS IN THEIR ADMIRATION FOR THE FRESH APPROACH THAT WAS TAKEN"

system for high-rise structures. This sets a new precedent for what can be economically achieved in predominantly timber structures.

The engineers worked with the CLT supply chain to demonstrate sufficient two-way spanning action in the floor panels to remove the need for supporting beams: with each panel supported directly onto timber columns at their corners. A steel spigot detail was developed to transmit column axial forces and support the panels. The engineers carried out a finite-element analysis of the laminated timber panels and full-scale physical testing to demonstrate punching capacity in excess of the standard code guidance.

The use of concrete cores for economy, combined with the timber columns, required a detailed analysis and adjustments to predict and mitigate against the relative differential shortening due to strain, shrinkage and creep. Monitoring has been carried out to understand the behaviour of the frame in use.

Commendation: ElevArch (UK) | Freyssinet and BHA

PROJECT TEAM

Client: Network Rail and Rail Safety and Standards Board
Principal contractor: Freyssinet BHA
Architect: BHA and Freyssinet

Lift in progress

JUDGES' COMMENTS

The judges were impressed by the potential of this idea that can solve significant logistical problems associated with increased height requirements on rail lines. The carefully developed system and sequencing provides continuous restraint and supports the masonry arch through a series of jacks and vertical slip bearings inserted in key locations cored into the masonry bridge.

The lifting operation was carried out after wire-saw cutting the arch – with the 50t capacity jacks computer-controlled from a central unit to an accuracy of 0.1mm to ensure a synchronous lift. Monitoring was carried out throughout the lift to verify the arch behaviour.

The final bridge position was 435mm higher than original – permitting limited reprofiling of the approach ramps and supports reinstated by flooding joints with concrete.

The judges recognised this inventive system could only be realised with the engineers' deep knowledge of masonry behaviour and lifting processes and has the potential to extend the life of many bridges while dramatically reducing costs and disruption to rail services during electrification works.

Sponsored by Griffiths & Armour

AWARD FOR CONSTRUCTION INTEGRATION

Awarded for projects demonstrating excellence in the interaction between the structural design and the construction scheme where this represents a significant feature of the structural solution.

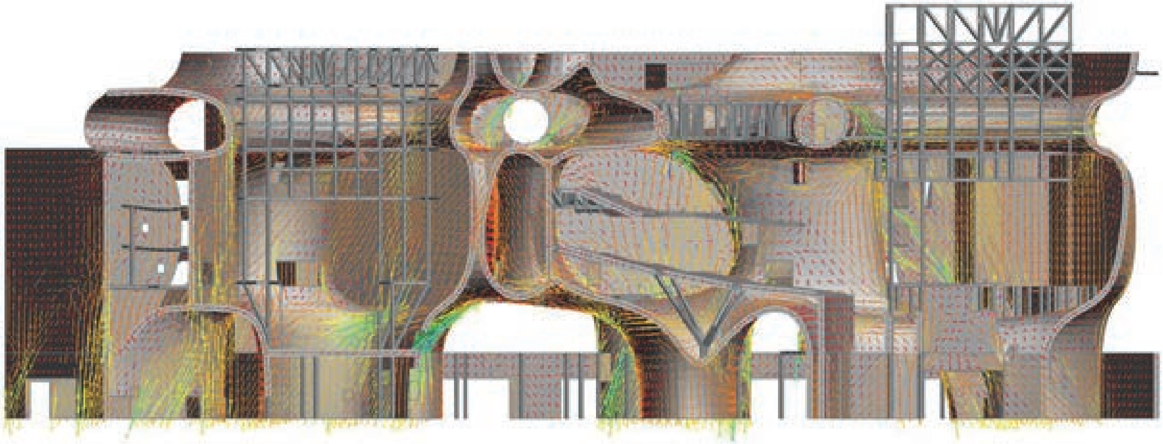
Winner: National Taichung Theater (Taichung, Taiwan) | Arup

PROJECT TEAM

Client: Taichung City Government
Principal contractor: Lee Ming Construction Co.
Architect: Toyo Ito & Associates

IN BRIEF...

►The National Taichung Theater is a performing art centre consisting of an opera house and ancillary performance spaces.
►The primary structure is a doubly curved concrete shell plate, with concrete facades, cores around lift shafts and stair cases, and plug walls separating the auditoriums from the foyer.
►As the structure was outside the scope of any building code, early-stage investigation was carried out using a variety of software packages to undertake reinforcement optimisation and perform seismic analysis.
►The key element for construction was the truss wall, which was used as an interface to set out the reinforcement and element thickness. Mock-ups confirmed that construction could be carried out without formwork, while also demonstrating that the surface thickness could easily be varied.
►The construction method adopted allowed the wall to be fabricated simply off site and assembled into units with most of the reinforcement added. Overlapping bars and a fine layer of mesh on each side were added on site, with the concrete then poured between this mesh.



Section through auditorium and stage area showing principle stresses

Truss wall units arriving on site

JUDGES' COMMENTS

The National Taichung Theater houses an opera house with 2009 seats, a playhouse with 800 seats and a small theatre space with 160 seats. Its construction has transformed Taichung through the creation of a cultural hub in the city.

The main structure is a free-form doubly curved reinforced concrete shell made as a single flowing surface. A new construction method was developed that is integral to the engineering design. It allows complex forms to be constructed off site and then brought together on site without the need for traditional formwork. The collaborating design team developed a single geometric model shared by all, to ensure coordination.

The site being severely seismic, the engineering design of such a complex form pushed the boundaries of a code approach. A numerical approach was pursued that allowed the engineers to include non-linear effects within the steel and concrete – something more commonly used for nuclear power stations. Such an approach allowed the engineers to tune the thickness of the concrete across the whole building and to control mass by tuning up the reinforcement.

Construction mock-ups were used to help develop construction techniques that relied on precast sections being formed off site and installed on site with *in situ* concrete poured within the units.

This is a tour de force of engineering, using advanced analytical techniques to deliver a building that that will undoubtedly inspire people who experience its complex and unexpected form in pursuit of culture.

"THIS IS A TOUR DE FORCE OF ENGINEERING … A BUILDING THAT WILL UNDOUBTEDLY INSPIRE PEOPLE"

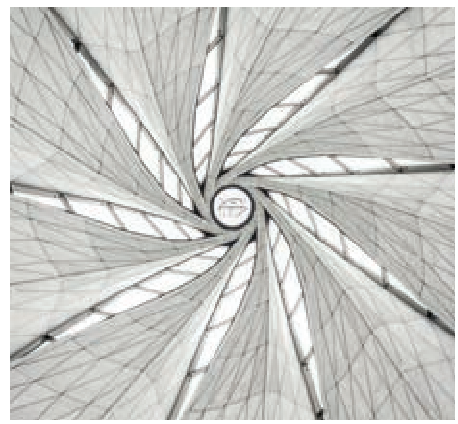
Southern elevation of completed building

Sponsored by Oasys

AWARD FOR STRUCTURAL ARTISTRY

Awarded for projects in which what could otherwise have been an adequate and worthy solution has been transformed by the vision and skill of the structural engineer into something exceptional.

Winner: Bahá'í Temple of South America (Santiago, Chile) | Simpson Gumpertz & Heger, Patricio Bertholet M., Halcrow and Josef Gartner GmbH



DANIELA GALDAMES GARCIA

Petal structure of Bahá'í Temple

Roof viewed from inside

PROJECT TEAM

Client: National Spiritual Assembly of the Bahá'ís of Chile
Principal contractor: Gartner Steel and Glass
Architect: Hariri Pontarini Architects

IN BRIEF...

►The temple consists of nine wing-shaped, translucent 'petals' of free-formed tubular steel space trusses clad with cast glass on the exterior and marble on the interior.

►It stands more than 30m tall and has an area of approx. 1200m².

►The temple was constructed in a high-seismic zone with unique materials and structural systems developed for the project.

JUDGES' COMMENTS

Located on a hillside against the Andes mountains in Santiago, Chile, the Bahá'í Temple of South America welcomes visitors from around the world for prayer and community activities. The project is the result of an international competition with 135 entries, won by architects HPA. The temple consists of nine wing-shaped 'petals' – steel space frame trusses – which combine to form the temple enclosure. The temple is in a seismic region. As a result, the structural design employed performance-based design methods, and the entire structure rests on bearings that protect it from the shaking due to the earthquakes.

In keeping with the architect's design intention for the petals to allow light to enter the internal space, the frames are clad in translucent marble on the inside, and cast glass on the outside. The cast glass was a new product developed by the project artists, and engineers Simpson Gumpertz and Heger carried out laboratory testing in order to determine the properties of the material. The geometry of both the structure and the cladding is complex and has no repetition – a result achieved by the team's extensive use of digital design and fabrication tools.

The temple is an example of the ingenuity of a structural design team in responding to the challenges set by the architectural vision for the project. The engineering team have shown creativity in their approach to the concept, technical excellence in the analysis and design process, and subtlety in their detailing and execution of a complex structure in a seismic zone.

Commendation: BMW sculpture for the 2016 Goodwood Festival of Speed (Goodwood, West Sussex, UK) | Stuart Holdsworth, Hooman Baghi, Bruno Postle

BMW sculpture *in situ*

PROJECT TEAM

Client: BMW AG
Principal contractor: Littlehampton Welding

JUDGES' COMMENTS

The new sculpture for the Goodwood Festival of Speed comprises three curved triangular sections, each of which supports a car at its tip. The sections are constructed from rolled steel, and the geometry has been conceived so that all the section sides are developable surfaces that can be fabricated from flat sheets which are rolled into curves to achieve the final form. The steel sheets were laser cut and welded together into the triangular section, which provides all the required strength and stiffness for the structure.

The sculpture is a fusion of art and engineering, and shows an understanding of structural design and manufacturing technology, along with the practical knowledge of efficient construction.

Commendation: Apple Kunming Pavilion (Kunming, Yunnan, China) | Eckersley O'Callaghan

PROJECT TEAM

Client: Apple Inc
Principal contractor: Frener & Reifer
Architect: Integrated Design Associates Ltd
Fabrication and structural design of CFRP roof: Premier Composite Technologies LLC
Structural design of reinforced concrete support structure: Prime Consulting Engineers Ltd
Fabrication and structural design of acrylic skylight: Reynolds Polymer Technologies Inc

Pavilion at night

HUFTON + CROW

JUDGES' COMMENTS

The glass pavilion is located in Shuncheng Mall Plaza in the Yunnan province in China. The structure provides an entrance to the store from all sides of the plaza, with a glass stair leading down into the basement showroom. The pavilion is formed by eight glass panels, each 5.4m high, which support a carbon fibre-reinforced polymer roof 20.9m in diameter, into which a circular acrylic skylight is inserted. The space between the glass columns is completed by a combination of 16 swing doors and eight pivot doors.

The structure is an elegant application of glass technology. The technical complexity of combining the different materials in a seismic region has been controlled and detailed to produce a result that gives an impression of lightness and permeability.

Sponsored by J&D Pierce Ltd

AWARD FOR OUTSTANDING VALUE

For projects where the structural engineering solution has resulted in significant savings for the client, or has delivered best value in some other way, based on the evidence provided, as determined and selected by the judges from all the entries.

Winner: ElevArch (UK) | Freyssinet and BHA

Bridge lift operation in progress

PROJECT TEAM

Client: Network Rail and Rail Safety and Standards Board
Principal contractor: Freyssinet BHA
Architect: BHA and Freyssinet

IN BRIEF...

►ElevArch was conceived as a sustainable solution for jacking rail masonry arch structures, avoiding unnecessary demolition and reconstruction for electrification schemes.

►The unique system has completed phase 1 of a Future Railway/Rail Safety and Standards Board competition in the UK; phase 2 will involve a full-scale demonstration of the technology.

►The method involves structural and geotechnical investigation; design of a lift system; excavation behind each abutment down to just below the arch springing point; forming a vertical cut line through the wing walls and counterfort and inserting slip bearings; coring and installing pot ram jacks within the abutment; then lifting the arch.

►Following the lift, the gap is grouted and jacks removed; the brickwork facing is made good and any voids injected with grout; the excavation is backfilled and the road surface and parapets are re-profiled to suit the new bridge height.

> "ELEVARCH IS A BRILLIANT AND INNOVATIVE SCHEME FOR RAISING THE ORIGINAL BRIDGE TO THE REQUIRED NEW LEVEL"

Jacked-up section showing slip bearings and close-up of jack

JUDGES' COMMENTS

One of the challenges of electrification of our railways is the height under many old bridges. There are about 500 masonry arch bridges in the UK that are too low to allow the electrification of the railway that runs under them. There are countless others throughout the world. Demolition and rebuilding is one way of increasing the headroom, as is lowering of the tracks. Both are costly in terms of direct financial costs and indirect financial costs from track closures.

ElevArch is a brilliant and innovative scheme for raising the original bridge to the required new level. The masonry is cut through at the springing of the arch to separate it from the abutments, and the bridge is then jacked up to provide the necessary clearance. The scheme was developed by Freyssinet, who are experts in the jacking of heavy structures, and Bill Harvey, who is an expert on masonry arches. This is a highly cost-effective solution to the problem of increasing the clearance under masonry bridges.

The ElevArch technique is not expected to completely replace bridge reconstruction or track lowering completely, but rather create a third option when the situation is appropriate. The value to the rail network providers is considerable given the number of sites where it can be applied. In addition to financial advantages, it offers value to client and society in the form of avoiding demolition of attractive listed structures.

"THE VALUE TO THE RAIL NETWORK PROVIDERS IS CONSIDERABLE GIVEN THE NUMBER OF SITES WHERE IT CAN BE APPLIED"

50t jacks are computer-controlled from central unit to within 0.1mm of each other

Sponsored by Beale & Company

AWARD FOR SUSTAINABILITY

For projects demonstrating outstanding commitment to sustainability and respect for the environment in the structural design, selected by the judges from all the entries.

Winner: The Enterprise Centre (Norwich, UK) | BDP

Interior of Enterprise Centre showing extensive use of timber

Modular construction was used for thatch panels

PROJECT TEAM

Client: University of East Anglia – Adapt Low Carbon Group
Principal contractor: Morgan Sindall
Architect: Architype Architects

IN BRIEF...

►The Enterprise Centre is a ground-breaking timber-framed project showcasing low-carbon sustainable building in a design that achieves Passivhaus and BREEAM 'Outstanding' standards.

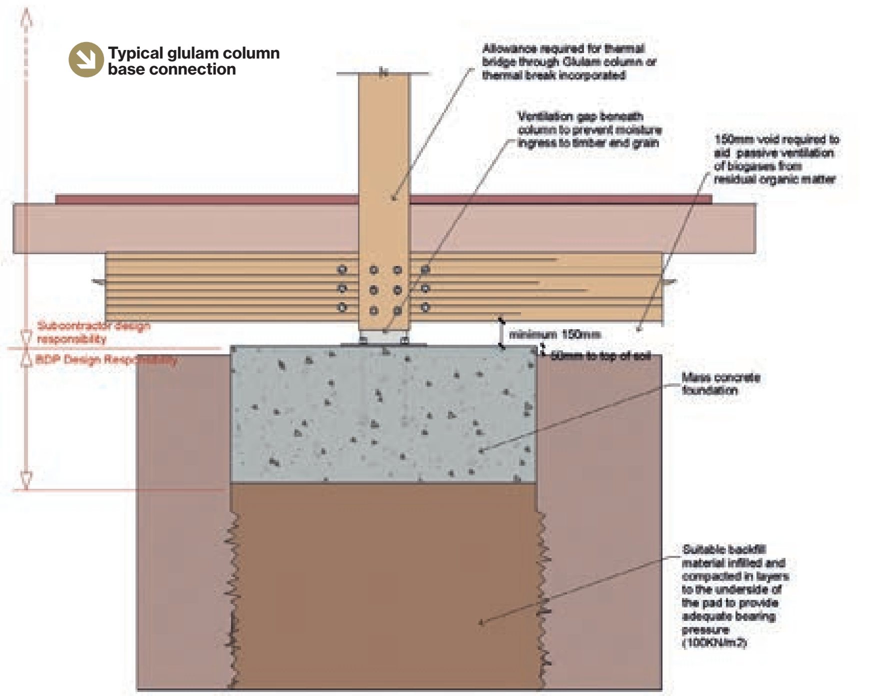
►The team prioritised structural materials that could be sourced locally and, through research and testing, demonstrated that local Thetford Forest timber could be produced to the required classification and grade.

►A target of using 50–70% local timber in the project was adopted. To overcome the risk-averse nature of the local timber industry, BDP devised a very straightforward timber frame with standard structural members and very simple, yet elegant connections.

►A unique modular thatch cladding system was also developed for the building, allowing local thatchers to prefabricate panels indoors during the wintertime and install them in the summer.

JUDGES' COMMENTS

The Enterprise Centre in Norwich is the latest addition to the University of East Anglia campus. The project was won by a contractor-led team of Morgan Sindall,



Typical glulam column base connection

> "THE BUILDING IS A CELEBRATION OF TIMBER; ALMOST EVERY INTERNAL SURFACE IS WOOD"

architects Architype, and BDP engineers. The brief called for an innovative, low-carbon, sustainable building, and the team decided to make as much of the building as possible from wood, and to source as much as possible locally.

The main frame of glued laminated (glulam) beams and columns had to be imported from Scandinavia, but all the rest of the wood was sourced from Thetford Forest. This is not an area that is used to producing structural timber and the engineers had to work with the supplier to select suitable wood, in this case stress-graded Corsican pine.

The engineers kept the basic design simple, with simple and elegant connections, much of them visible in the finished building. The building is a celebration of timber; almost every internal surface is wood. Externally, some of the walls are covered with thatch, bound into 'cassettes' and hung in strips between the windows – a truly innovative design.

Great effort was made to track the origin of all the materials used in the construction to make sure that as much as possible came from no further than 30 miles from the site. This is a super-sustainable building, built to Passivhaus and BREEAM 'Outstanding' standards. And the timber structure is a crucial part, thanks to the determination of the engineers to encourage and exploit local resources.

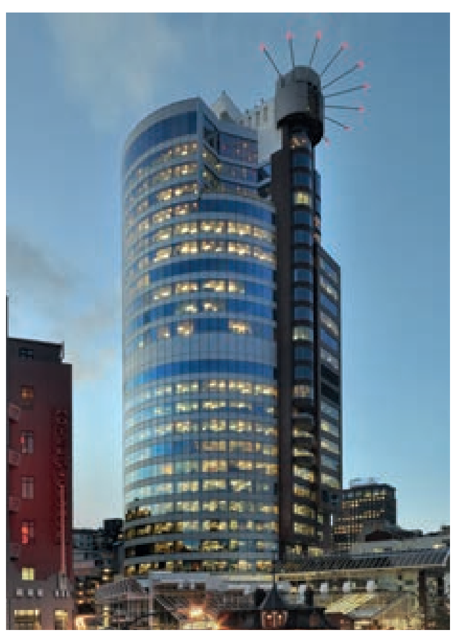
Commendation: Seismic strengthening of the Majestic Centre (Wellington, New Zealand) | Holmes Consulting

PROJECT TEAM

Client: Kiwi Property Group
Principal contractor: Fletcher Construction
Architect: Opus Architecture
Project manager: Building Intelligence Group

JUDGES' COMMENTS

The Majestic Centre in Wellington, New Zealand is a 30-storey tower built in 1991. Following the Christchurch earthquake in 2010, the seismic capacity of the building was assessed and it was found to have only 40% of the strength required by the codes. One option would have been to demolish and rebuild, which would have meant rehousing 2700 tenants, and would have used an enormous amount of energy in plant and materials. It was decided instead to strengthen the tower to make it fully compliant with the code. Various problems included the arrangement at Level 5 where alternate perimeter columns stop on a large edge-beam that was found to have insufficient strength.



Majestic Centre following strengthening programme

An extremely complex series of operations followed, while the tower was still nearly fully occupied. The lift shafts were strapped with horizontal and vertical steel flats; the Level 5 edge-beam was increased in depth with reinforced concrete and torsionally stiffened with large steel brackets under the floor slab; the floors were strapped to the cores with steel flats and prestressing cables; the foundations were strengthened with a new one-storey-deep post-tensioned concrete slab to tie together the pad footings of the lift shafts and the piled foundations of the perimeter columns.

This was an extraordinarily difficult operation that avoided demolition and rebuilding and kept most of the building occupied. It was a truly sustainable solution to this very difficult problem.

Structural Awards quiz

How well do you know the past winners of the Structural Awards? Test your knowledge in our short quiz (answers can be found on page 29).

1) **The building known locally as 'Paddy's Wigwam', joint first winner of the Structural Special Award in 1968, can be found where?**
Manchester
Glasgow
Liverpool
Dublin

2) **Thirteen years before it won the Structural Special Award, who was the first person to perform at the Sydney Opera House in 1960 when singing to the construction workers as they ate their lunch?**
Joan Sutherland
Luciano Pavarotti
Maria Callas
Paul Robeson

3) **The Pompidou Centre in Paris, winner of the 1977 Structural Special Award, featured in which James Bond film?**
The Spy Who Loved Me
Moonraker
For Your Eyes Only
Octopussy

4) **The white marble used for the Bahá'í House of Worship in New Delhi, winner of the 1987 Structural Special Award, comes from where?**
Carrara, Italy
Vermont, USA
Dubai
Penteli Mountain, Greece

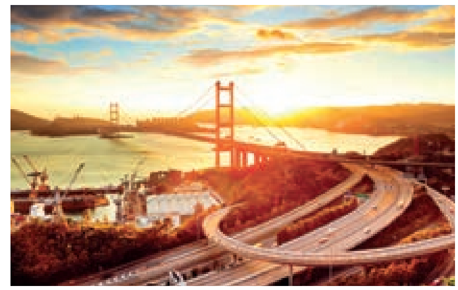
5) **The Skydome in Toronto (now the Rogers Centre), winner of the 1989 Structural Special Award, is home to which Canadian sports team?**
Toronto Argonauts
Toronto Maple Leafs
Toronto Blue Jays
Toronto FC

6) **The Don Valley Stadium in Sheffield, winner of the Structural Special Award in 1991, hosted which athletics event that year?**
World Student Games
European Athletics Championship
Commonwealth Games
Athletics World Championship

7) **The Conwy Tunnel, winner of the 1992 Structural Special Award, is the first and only use to date of which tunnelling method in the UK?**
New Austrian Tunnelling Method (NATM)
Box-jacking
Cut-and-cover
Immersed tube

8) **The length of the 1993 Structural Special Award-winning Orwell Bridge in Suffolk grows and shrinks by how much due to thermal expansion?**
60cm
1cm
5cm
20cm

9) **Blackpool's Big One (formerly the Pepsi Max Big One) rollercoaster, winner of the 1994 Structural Special Award, has a top speed of 119km/h (74mph). How high above the ground is its highest point?**
55m
65m
45m
35m



10) **At the time of its opening in 1997, when it won the Structural Special Award, Hong Kong's Tsing Ma Bridge was the second longest (by main span) suspension bridge in the world. Which is currently the longest?**
Xihoumen Bridge (China)
Akashi Kaikyō Bridge (Japan)
Great Belt Bridge (Denmark)
Osman Gazi Bridge (Turkey)

11) **The Jin Mao Tower (421m) in Shanghai, winner of the Structural Special Award in 2000, was the tallest building in China from 1999 until 2007 when it was surpassed by which building?**
International Commerce Center, Hong Kong
Shanghai Tower
The Pinnacle, Guangzhou
Shanghai World Financial Center

12) **ETFE (ethylene-tetrofluoroethylene), used for the National Aquatics Center (Water Cube) at the Beijing Olympic Games, which won the 2008 Award for Sports Structures, weighs what percentage of an equivalent sized glass panel?**
1%
10%
25%
33%

13) **What structural system is used for the Burj Khalifa skyscraper in Dubai, winner of the 2010 Award for Commercial or Retail Structures and currently the tallest building in the world?**
Mega core
Buttressed core
Trussed tube
Tube-in-tube