Eckersley O'Callaghan

Advanced Engineering,
Materials & Technologies Group

Integrating advanced engineering, materials and technologies to create unparalleled innovation

Eckersley O'Callaghan

Advanced Engineering, Materials & Technologies Group

About us

Founded in 2004, Eckersley O'Callaghan collaborates with visionary clients across the world on state-of-the-art projects, pushing the boundaries of what is possible.

Our iconic work with innovative and complex materials has received some of the highest accolades in the industry, and we are synonymous with pioneering new advances in design and engineering.

Glass Wippe GlassTec 2018
Messe Dusseldorf
Sedak
Glass seesaw constructed entirely from transparent components, including its bearing mechanism, utilising transparent structural silicone in a way never attempted before

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We have developed an international reputation for boldness and bravery, pushing boundaries across every material, form, scale, and use

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eocengineers.com

As we have grown and evolved as a practice, so too has our culture and design process. This, in turn, has inspired and emboldened us to take on ever more ambitious technical challenges.

Of course, every ground-breaking project we complete is both exciting and rewarding. However, we believe that our people, tools and design processes tell a far more interesting story, with the intrinsic properties of different complex materials perfectly intertwined with how we think and develop our engineering designs.

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1 **Transparency is key**
Informal discussions allow our engineers to share and build on new ideas

2 **Apple Piazza Liberty Milan, Italy Foster + Partners**
A curtain of water, created by a series of jets running over 8m tall glass panels, provides both a focal point for the amphitheatre and a striking entrance to the store beneath

3 **Professor James O'Callaghan lecturing at TU Delft**
Integrating research and development into our core culture with university partnerships is vital

Working intensively with any material produces a close working relationship with a designer, engineer or fabricator – one that allows them to really get to know its intricacies and associated challenges.

Glass, for example, is often viewed as a simple material. However, its transparency belies its complexity and without the relevant technical expertise on hand, it is extremely challenging to truly understand, question and communicate this unique material's capabilities to clients and collaborators.

This is particularly true when it comes to more innovative structural design, where greater justification of its technical viability and environmental performance is required by local authorities.

1 **Apple Marunouchi**
Tokyo, Japan
Foster + Partners
8m tall glass facade that resists high seismic loads and movements up to 85mm

2 **Finite Element Analysis (FEA) stress analysis**
Understanding and measuring seismic loads and tolerances through in-depth analysis

3 **Seele Autoclave**
Pushing glass fabrication technology to discover new possibilities

4 **Apple Causeway Bay**
Hong Kong
Bohlin Cywinski Jackson | Woods Bagot
This project features glass panels that were 15m tall, the largest ever fabricated and required additional justification to the Hong Kong Building Authorities

5 **Dilworth Park**
Philadelphia, US
Kieran Timberlake
These entrances to the city's transport network are among the largest constructions of laminated structural glass ever erected

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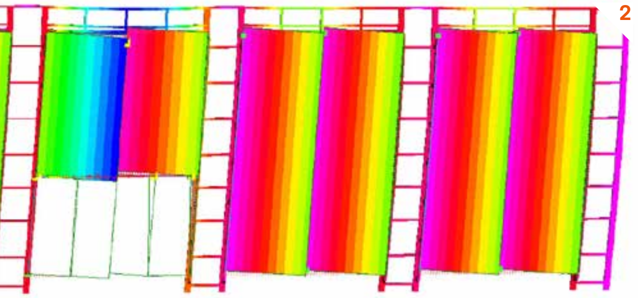

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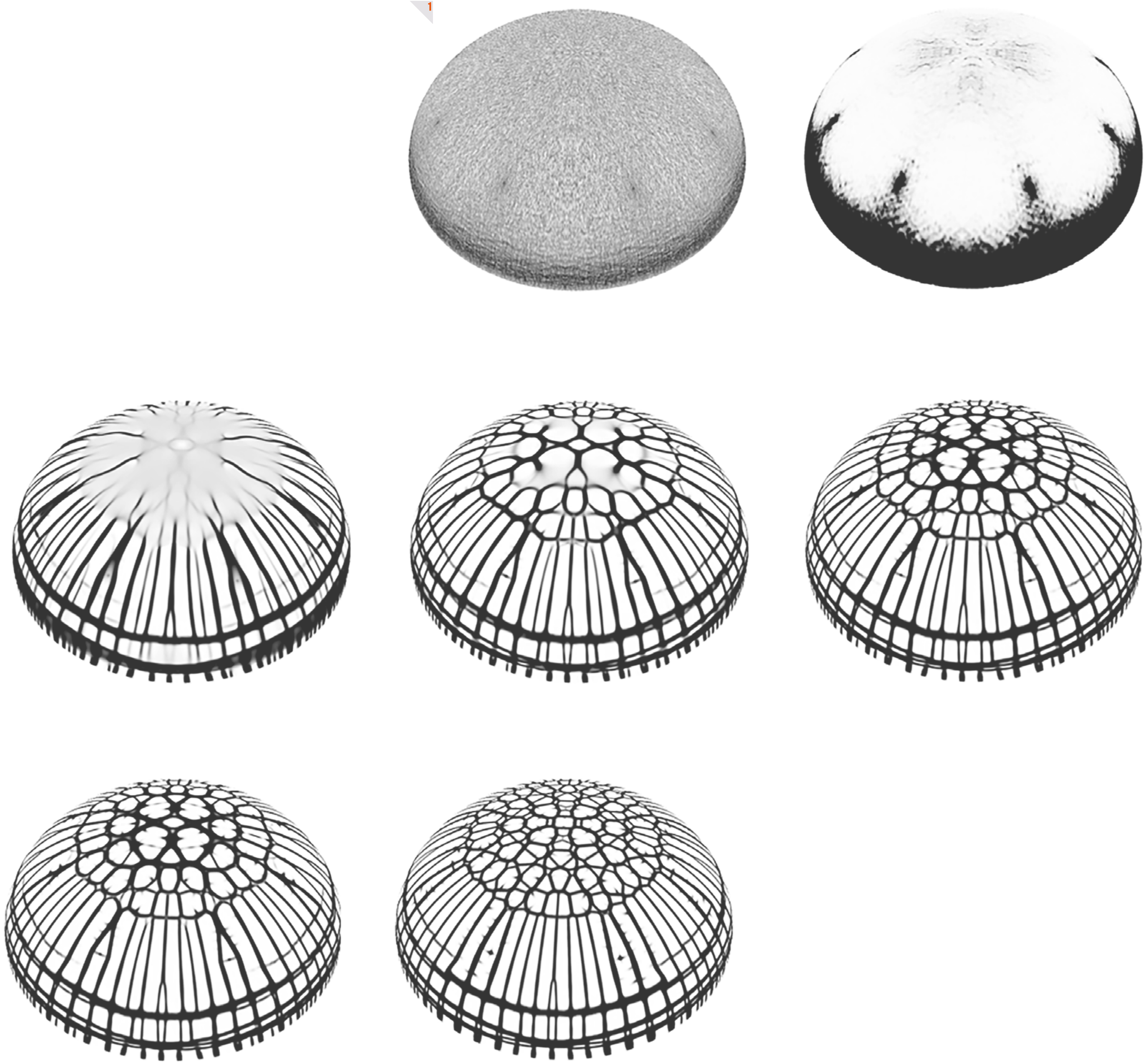

Investment in research and development combined with continuous learning from past projects is at the core of our culture at Eckersley O'Callaghan.

Thanks to our leadership position within the industry, we are working with key decision makers to create a growing awareness of, and active contribution towards, ever more sustainable design and technology.

In short, we are using the latest advances to push the sustainability agenda to create a real and lasting impact that supports the future of our planetary health.

1 **Topology optimisation**
In-depth design analysis allows for more sustainable designs that maximise performance and minimise material volume/weight

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1 **Bharat Vandana Park**
Delhi, India
Arcop Associates | rat[LAB]Studio
Analysis of a one-of-a-kind footbridge connected to nine diagrid steel pylons

2 **Panel clustering**
Finding common shapes within limited tolerances of large-scale complex structure

3 **Beam length colour gradient**
Assessing geometry and regularity patterns

4 **Adjacent angles colour gradient**
Assessing kink angles

5 **Tropicalia**
Côte d'Opale, France
Coldefy & Associés Architectes Urbanistes
Applying technical expertise to design the world's largest new biodome

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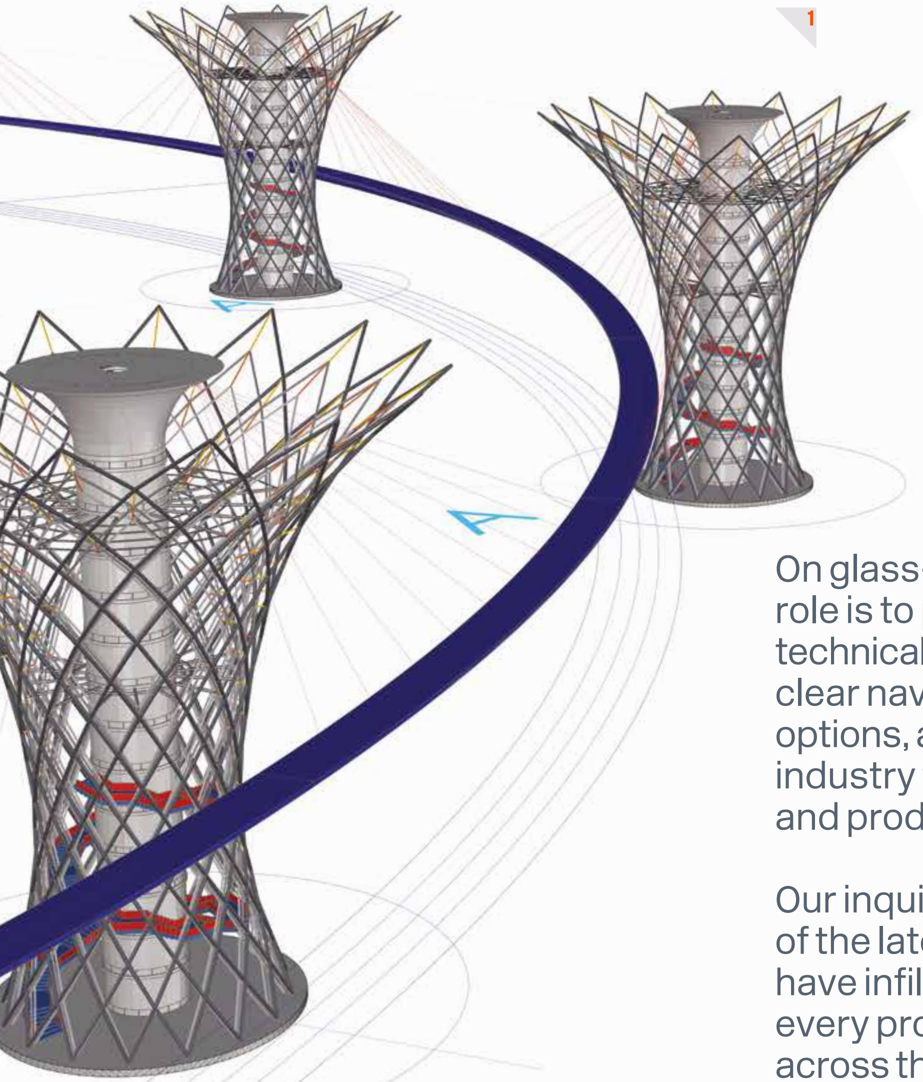

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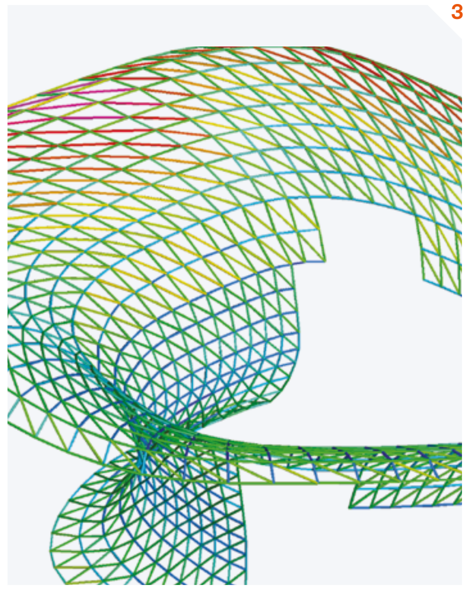

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On glass-centric projects, our role is to provide the specialist technical expertise for performance, clear navigation of the possible options, and ability to challenge the industry to develop new solutions and products.

Our inquisitive culture and use of the latest digital design tools have infiltrated their way into every project we do, extending across the business and deployed on our non-glass projects too, so that we can shape the future of many more ground-breaking and pioneering projects.

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Our Glass History

For almost 20 years, Eckersley O'Callaghan has been at the cutting edge of glass design and looking back across our history, it is clear why we have the skill and confidence to make innovative leaps into the future of complex design projects.

Our own story runs in parallel with some of the most significant advances in glass technology many through our long term collaboration with Apple, which has shaped, developed, and refined our approach and culture.

Here are just a few of the seminal moments that we are proud to have played a pivotal role in.

2004 **Apple Soho**
New York, US
Bohlin Cywinski Jackson
Laminated glass fittings to stair treads - a unique and eye-catching design feature developed with glass fabricators, Sedak, and patented by Apple.

2005 **Apple 5th Avenue Mark I**
New York, US
Bohlin Cywinski Jackson
This bold, iconic glass entrance structure featured 10m tall splice laminated glass columns that had never been used before on a project of this scale.

2009 **Apple Pudong**
Shanghai, China
Bohlin Cywinski Jackson
We worked with fabricator, North Glass, who built the first machine of its kind to be able to make these 13 large, curved glass panels - never before developed at this scale.

2012 **Apple Jungfernsteig,**
Hamburg, Germany
Bohlin Cywinski Jackson
In partnership with Sedak, this first-of-its kind project laminated the titanium fittings into the middle of the glass stringer (balustrade) as opposed to a traditional hole in the glass.

2012 **Venus**
Philippe Starck
Replacing small glass windows with 10m long curved glass - the first time ever used on a yacht.

2014 **Apple Zorlu**
Istanbul, Turkey
Foster + Partners
Another first, with glass used to structurally support a CFRP (carbon fibre reinforced polymer) roof, sitting on only four panes of glass.

2015 **Apple Sky Plaza**
Guangzhou, China
Foster + Partners
The first-ever finless monolithic glass facade, reaching 12.5m in height.

2017 **Apple Park**
California, US
Foster + Partners
This curved glass facade is the largest format ever to use cold bent glass, with 800 panels (14m long and 3m high).

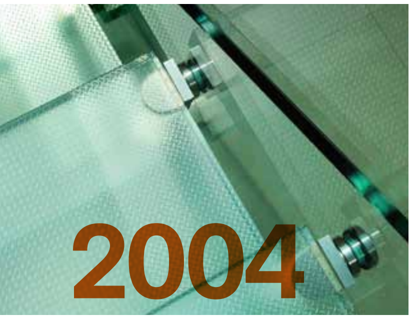
2017 **Steve Jobs Theater**
California, US
Foster + Parters
The largest carbon fibre roof in the world supported solely by glass.

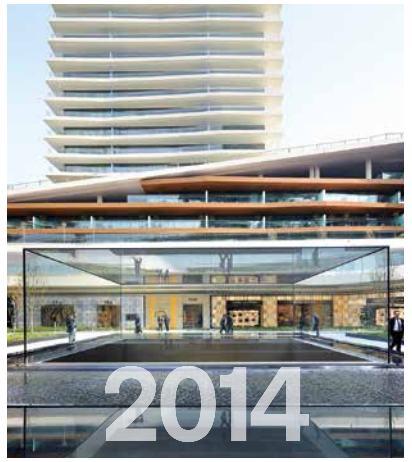
2018 **Apple Sands Cotai**
Macau, China
Foster + Parters
First stone interlayer laminated within glass.

2018 **Glass Wippe GlassTec Messe Dusseldorf**
Sedak
Glass seesaw constructed entirely from transparent components, including its bearing mechanism, utilising transparent structural silicone in a way never attempted before.

2019 **Thin and flexible glass**
An R&D study concept utilising cold-bent high-strength glass to create a pavilion.

2021 **Apple Marina Bay Sands**
Singapore
Foster + Partners
The largest structure in the world to use glass as the primary bracing element.





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3D printed glass lattice structures
Research project with the Centre for Additive Manufacturing at the University of Nottingham, using finite element analysis (FEA) to optimise the potentially revolutionary Powder Bed Fusion process used to manufacture this new part

Future of glass

With cast glass introducing new possibilities to increase the sustainability credentials of this widely used material, the future of glass could not be more exciting.

Through our own research and development, we are also investigating the possibility of using thin, flexible glass technologies (more commonly used on mobile phones) for use in buildings, as well as ways to make 3D printing of glass more viable.

We are also capitalising on the advances being made in curved glass industrial processes to make it more efficient, working with manufacturers to integrate media into the fabric of glass, and looking into new transparent materials for new and different applications.

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Awards
— IStructE Structural Artistry Award 2018
— SentryGlas Innovation Award for Engineering 2018

02 Our in-depth understanding of complex materials and technologies makes us world leaders in our field

Steve Jobs Theater
California, US
Foster + Partners
The pure simplicity of the structure belies its complex engineering

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How do you apply innovative design and engineering technology for a true technology pioneer?

The largest structure in the world to be solely supported by glass, the Steve Jobs Theater includes several features that have never been seen before on a structure of this scale.

Location	Cupertino, California
Client	Apple
Architect	Foster + Partners
Date	2017

12.8m
the tallest free-standing glass elevator in the world

47m
diameter of carbon fibre roof

80 tonnes
roof supported by a 7m tall glass cylinder

44
radial panels assembled on site

Over the last 15 years, Eckersley O'Callaghan's close relationship with Apple has been accompanied by a rapid evolution in structural glass technology, and the Steve Jobs Theater represents a culmination of these advances.

As a true technology pioneer, it is fitting that Apple's new landmark venue for product launches was designed using innovative technology, some of which has never been seen before on a structure of this scale.

For example, it is the largest structure in the world solely supported by glass, with an 80 tonnes roof supported by a 7m tall glass cylinder, made up of glass panels, each consisting of four layers of 12mm thick plies, which hold up the roof without any additional support.

We also designed the structural system so that the conduits, sprinkler pipes, data, audio and security systems in the roof could be accommodated in the 30mm joints between the glass panels.

Awards
— IStructE Structural Artistry Award 2018
— SentryGlas Innovation Award for Engineering 2018

In addition, the structural criteria were also particularly challenging given the properties of glass with its inherent brittleness requiring detailed analysis to fully justify safe design – not to mention the fact that Cupertino is in a highly seismic zone.

Consequently, we employed several strategies to protect against earthquakes and transfer seismic energy, including curved glass panels fixed at their base with structural silicone into a steel channel. Steel plates were also engineered to deform before the glass breaks, safeguarding the integrity and robustness of the overall structure.

Working closely with Foster + Partners, we also engineered the design of the world's tallest free-standing glass elevator, which stands 12.8m tall and corkscrews on helical guides to facilitate an exit point 171 degrees rotation from entry.

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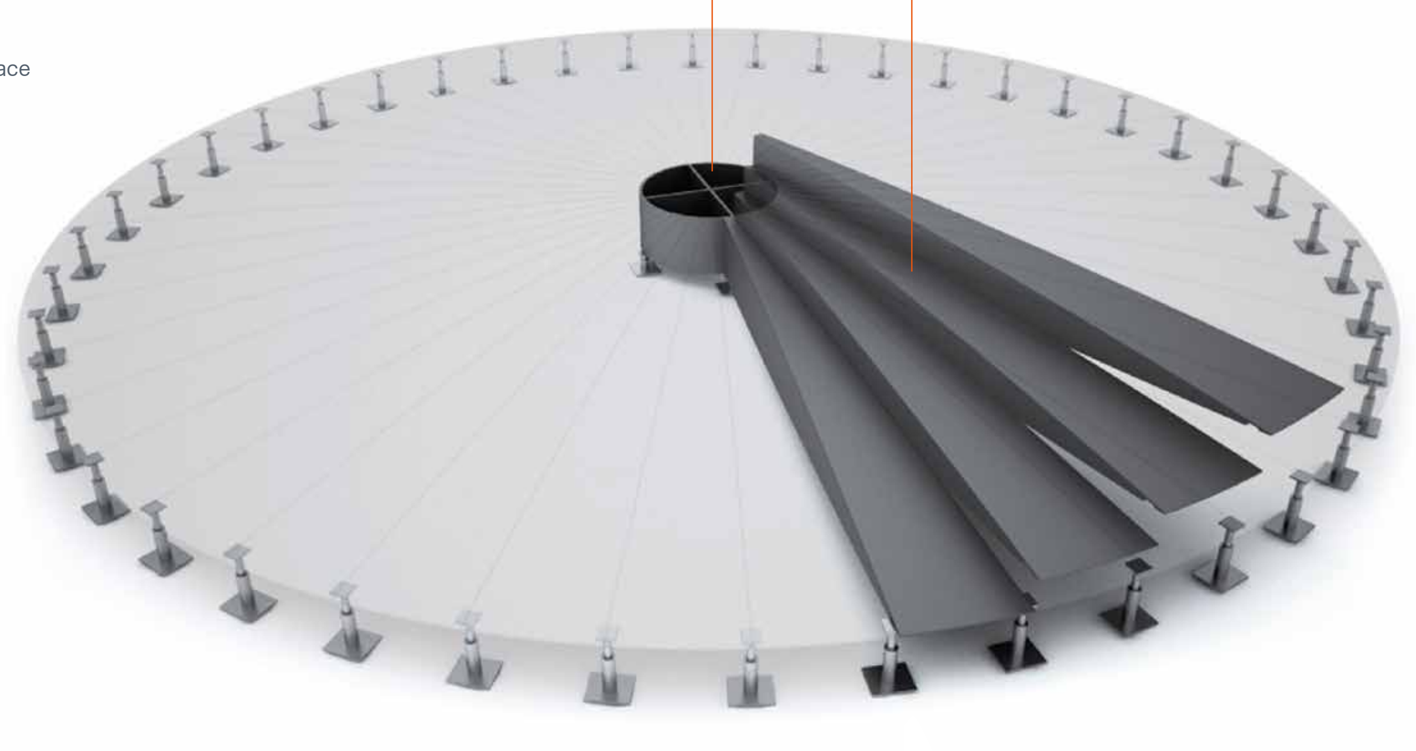
— IStructE Structural Artistry Award 2018
— SentryGlas Innovation Award for Engineering 2018

1 **47m diameter carbon fibre roof** Construction sequence of roof panels

2 **Design for simplicity** Fit out of internal space



> The inherent complexity of working with glass has given me a rigour in my design approach which I now apply to all of my projects."

Ian Langham
Director of Advanced Engineering

3 **Construction engineering** Lifting of roof onto glass cylinder

4 **Roof blade** CFRP panel fabrication

5 **Creating unique** The world's tallest free-standing glass elevator to rotate on helical guides supported by glass

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Two Taikoo Place

Reshaping the office landscape

Accreditation
— LEED Platinum
— BEAM Plus (HK)

Two Taikoo Place
The full-height glazing of the lobby creates a dramatic entrance to this stunning building

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Accreditation
— LEED Platinum
— BEAM Plus (HK)

How do you contribute to a bold sustainability strategy that will set new standards in Hong Kong?

Standing 195m tall, Two Taikoo Place has a 15m tall podium at its base, which features the world's tallest prestressed rod full-height glass facade and the first of its kind in Hong Kong.

Location	Hong Kong
Client	Swire Properties
Architect	Wong & Ouyang | NBBJ
Date	2021

15m
tall glazing fabricated from four 12mm glass plies

235mm
deflection accommodated in the glass under typhoon load

14 tonnes
load supported by 52mm x 48mm high strength stainless steel rods

20m
long steel beams supporting pre-tensioned rods

Eckersley O'Callaghan provided facade and specialist glass engineering services for Swire Properties' iconic new addition to their Taikoo Place development which sets new standards in energy performance.

Across the 190m tall facade, we used the latest developments in glazing production to ensure high levels of light transmission, designed external shading fins to reduce solar gain and chose insulated glass units with high performance coatings. Together, these measures formed part of an energy efficiency strategy that enabled the project to achieve BEAM Plus (HK) and LEED Platinum certifications.

The facade was designed as a unitised system with 3m wide units offering uninterrupted views to Hong Kong Harbour. In addition, geometric optimisation studies of the conically curved corner panels were performed to reduce the number of unique panels by 60% and maximise the number of glass fabricator suppliers. This resulted in a cost reduction without affecting the architectural intent.

The building's base also features a 15m tall podium facade, realised in a frameless structural glazed system using integrated pre-tensioned stainless steel rods – a first of its kind in Asia.

Geometric optimisation studies
This process transformed the cone geometry panels briefed by the architect (Step 1) into as close to cylindrical panels as possible which, in turn, saved cost. We analysed different cylinders (Step 2) – measuring their radius, orientation, and position – to find the best fitting. We then looked at how much this deviated from the original cone (Step 3) where corners are usually the toughest measurement to match. Finally, we placed the optimised cylinders back into the building model (Step 4) to find a very small deviation which would not be noticeable to the eye.

Step 1: Original conical panel

Step 2: Optimising cylindrical panel to find best cylinder (radius, orientation, and position)

Step 3: Measuring deviation

Step 4: Rationalised glass facade geometry

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Two Taikoo Place

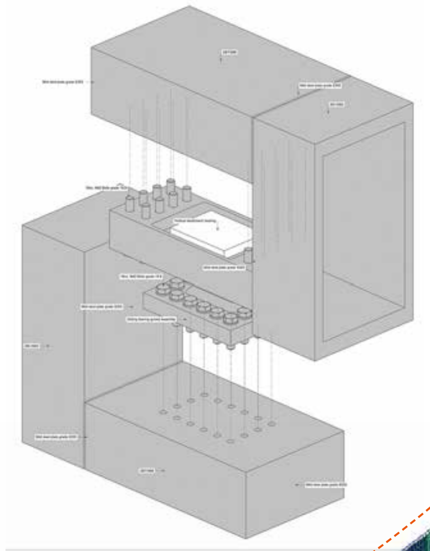
Reshaping the office landscape

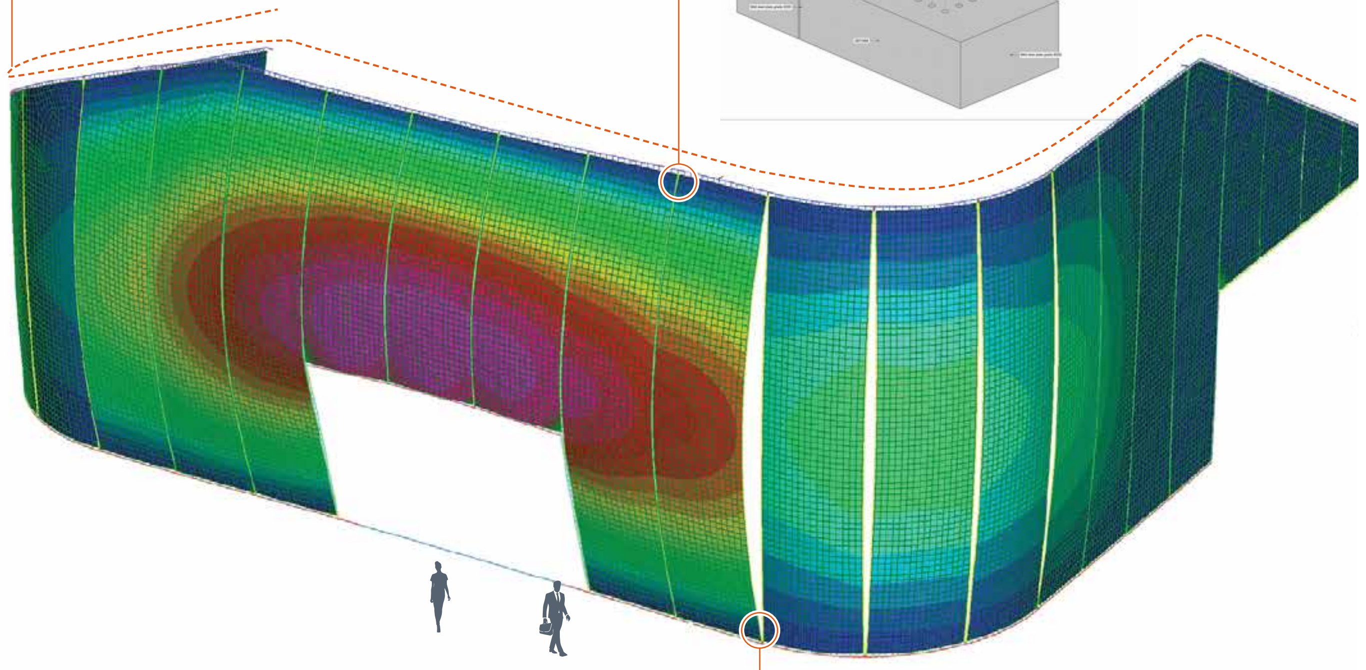
Accreditation
— LEED Platinum
— BEAM Plus (HK)

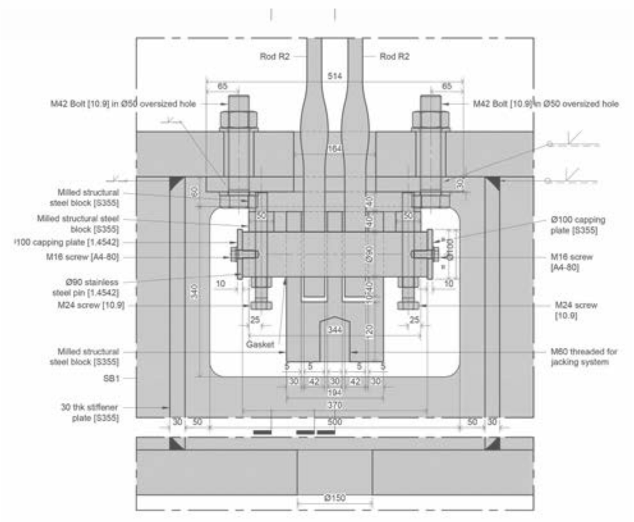
Deflection analysis of the 15m tall pre-tensioned rod facade under typhoon load

Pre-tensioned facade area supported by steel beams spanning up to 20m between reinforced concrete columns

Inspired by footbridge design, this unique facade features a slide bearing joint to allow for thermal deformation of steel beam







Rod connection details hidden in the supporting beam. With tall facade panels, high wind loads and complex geometry, this was the first time the design was used on a project of this scale as the Hong Kong building department had never approved a system like this before

Curtain wall detailing

Unitised curtain wall crown glazed facade with extruded aluminium shading fins

Unitised curtain wall 3m wide units – which are unusually large – including 1.5m wide operable windows and vertical aluminium shading fins

Corner units curved panels

Podium facade- world's tallest prestressed rod and full height facade

Ground floor facade

Two Taikoo Place
Installation of the glazed curtain wall

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Apple Marina Bay Sands
Singapore
Foster + Partners
Combining sophistication, refinement and simplicity, the dome's slender steel frame appears to float on the iridescent Marina Bay with the glass used to brace the structure

03
We are part of a strong network of industry experts, working to better understand new challenges and how best to overcome them

Eckersley O'Callaghan

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How do you get a 30m wide glass domed retail store to appear to float on water?

Apple Marina Bay Sands is the tech giant's most ambitious and iconic store to date. It uses sleek steel framing and individual glass panels to brace the structure – a world-first on this scale.

Location	Singapore
Client	Apple
Architect	Foster + Partners
Date	2020

17m
tall structure giving extensive views across the bay

10
slender vertical mullions for structural framing

114
glass panels to create a first-of-its-kind, self-supporting structure

30m
wide structure creates a stunning open and column free space inside

Eckersley O'Callaghan carried out the structural and facade engineering for the first-ever Apple Store to sit directly on water. We also undertook a site supervisory role for this amazing, unique building which appears as a sphere that floats on Singapore's iridescent Marina Bay.

The sphere itself is a first-of-its-kind, glazed dome structure that is fully self-supported and comprises 114 panels of glass with only 10 narrow vertical mullions for structural support.

This stunning, complex and yet deceivingly simple-looking dome structure creates a wide open and column free space inside, and in a feat not done before on this scale anywhere in the world, we designed the individual glass panels to brace and stiffen the structure rather than use additional diagonal steel bracing or large moment connections at the joints.

We also maximised the size of the insulated glass panels to limit the number of joints, hiding them only where there is structure, and increasing the overall transparency of the building (the largest of these panels measures 10m wide x 3m tall). To give the dome its geometry and to meet the required environmental performance, the panels were designed to be conical in shape with each individual panel 'warm' or lamination bent into shape. Again, this was the first time that this type of bending had ever been used at this scale before.

A central circular domed panel of glass, the Oculus, crowns the top of the dome. In the event of a fire, the adjacent glass panels rise up to release smoke inside the building. In addition, circumferential baffles around the dome act as glare protection and acoustic attenuation panels. We provided the full superstructure design from concept through to supervision on site and completion.

Careful consideration of the combination of multiple coatings and constantly changing frit patterns was key to achieving the strict environmental performance criteria.

The dome's super slender steel structure was designed to retain its lightweight appearance. The ability to contain the various services (including lighting and sprinkler system) within the cladding and still meet the overall architectural vision was vital to creating Apple's trademark minimalist look inside.

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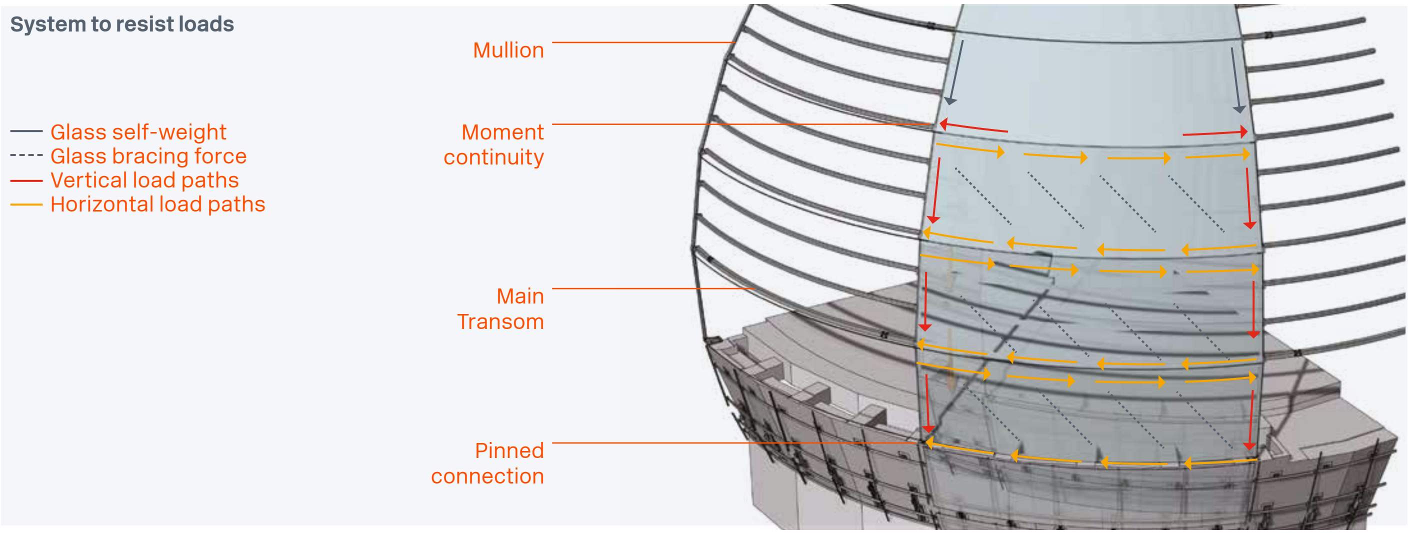


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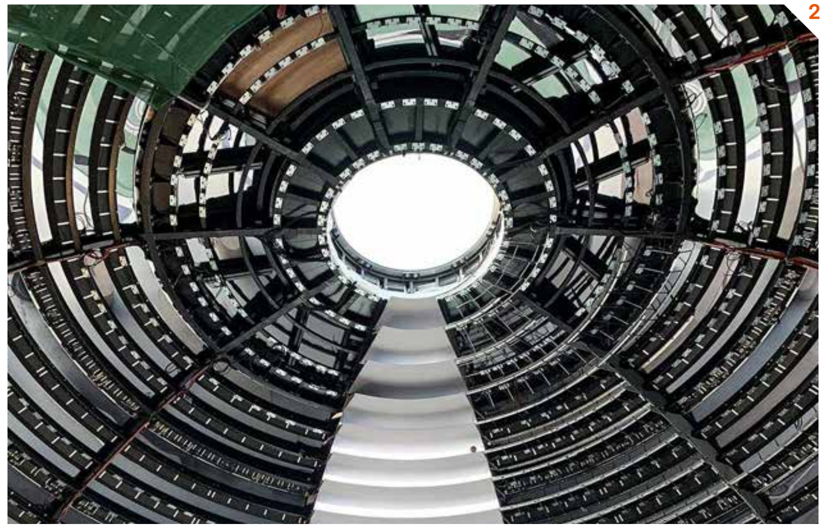
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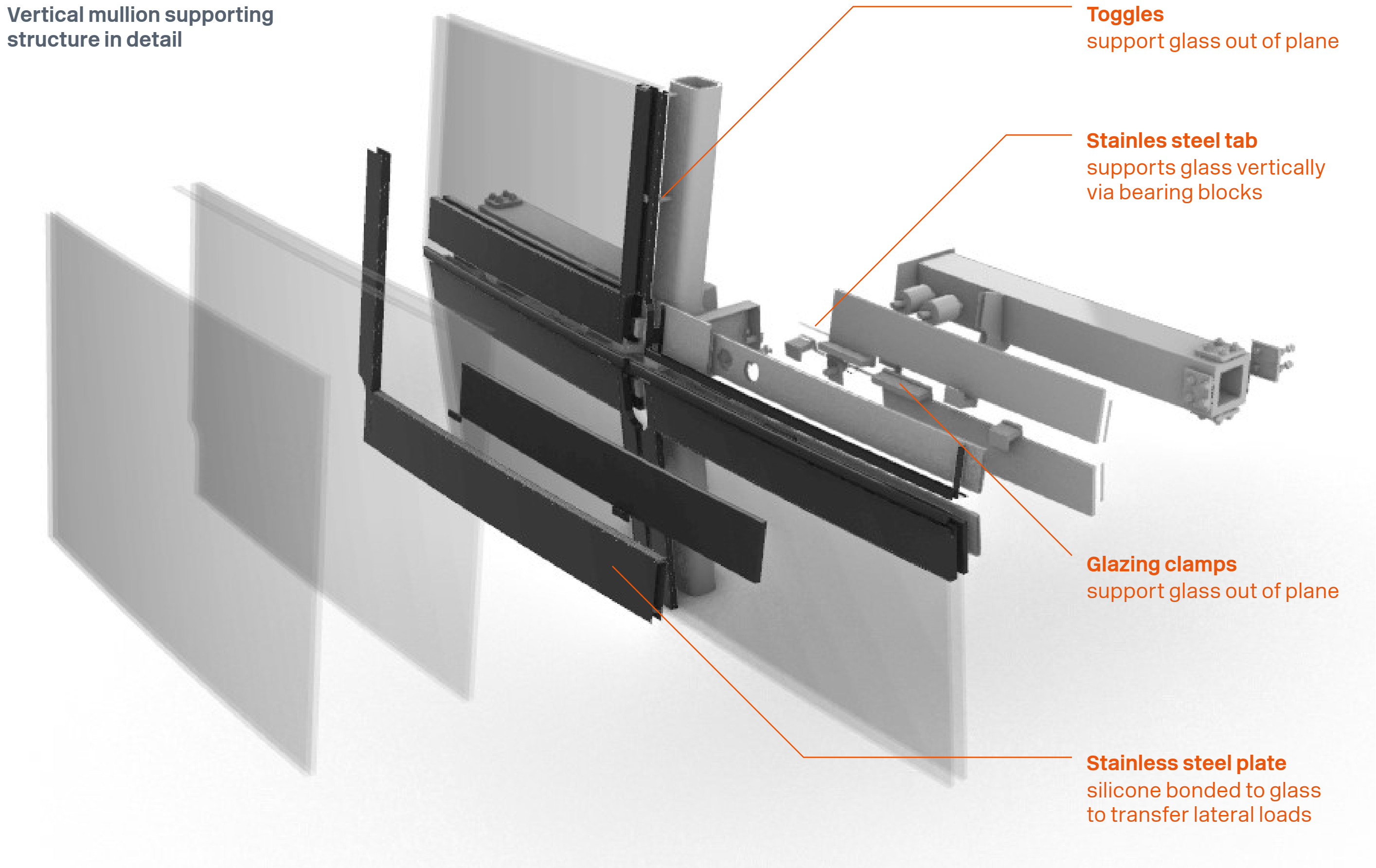
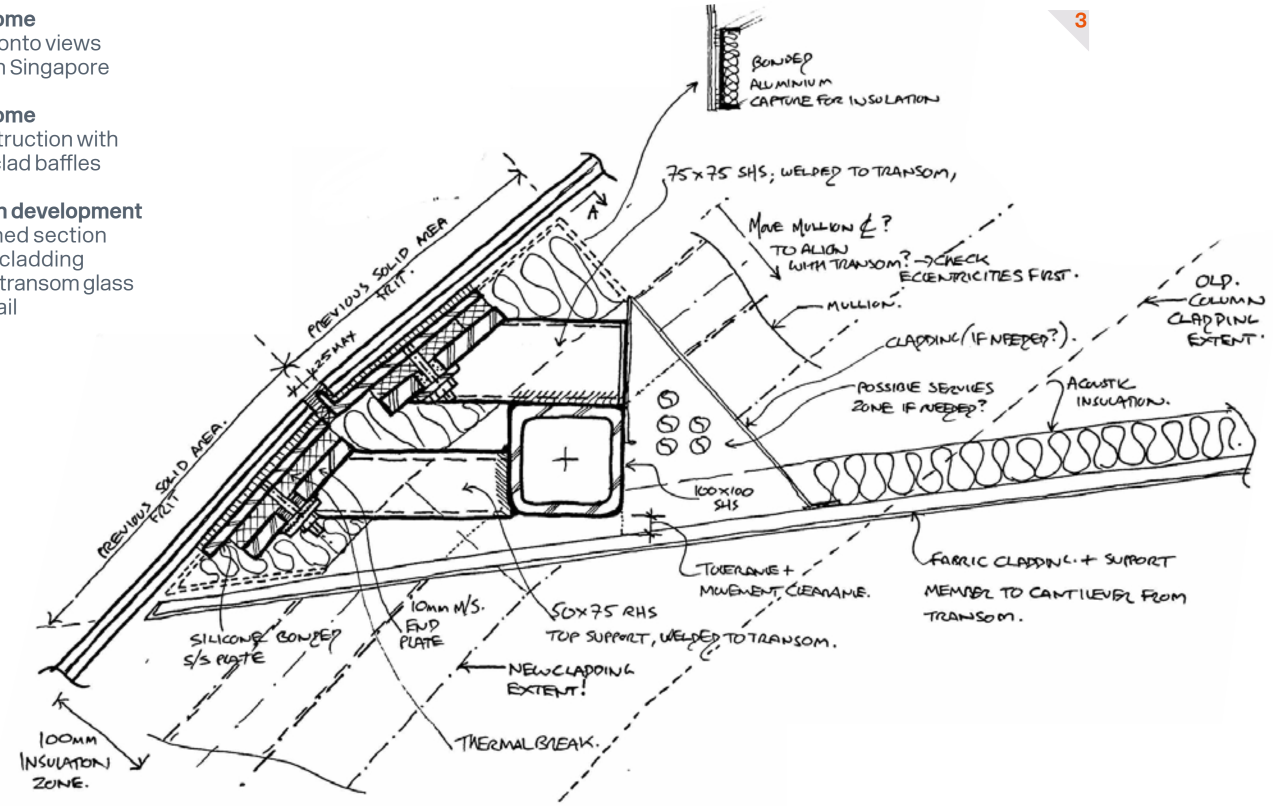


1 **Inside the dome**
Looking out onto views of downtown Singapore

2 **Inside the dome**
During construction with clad and unclad baffles

3 **Detail design development**
Initial sketched section through the cladding showing the transom glass support detail



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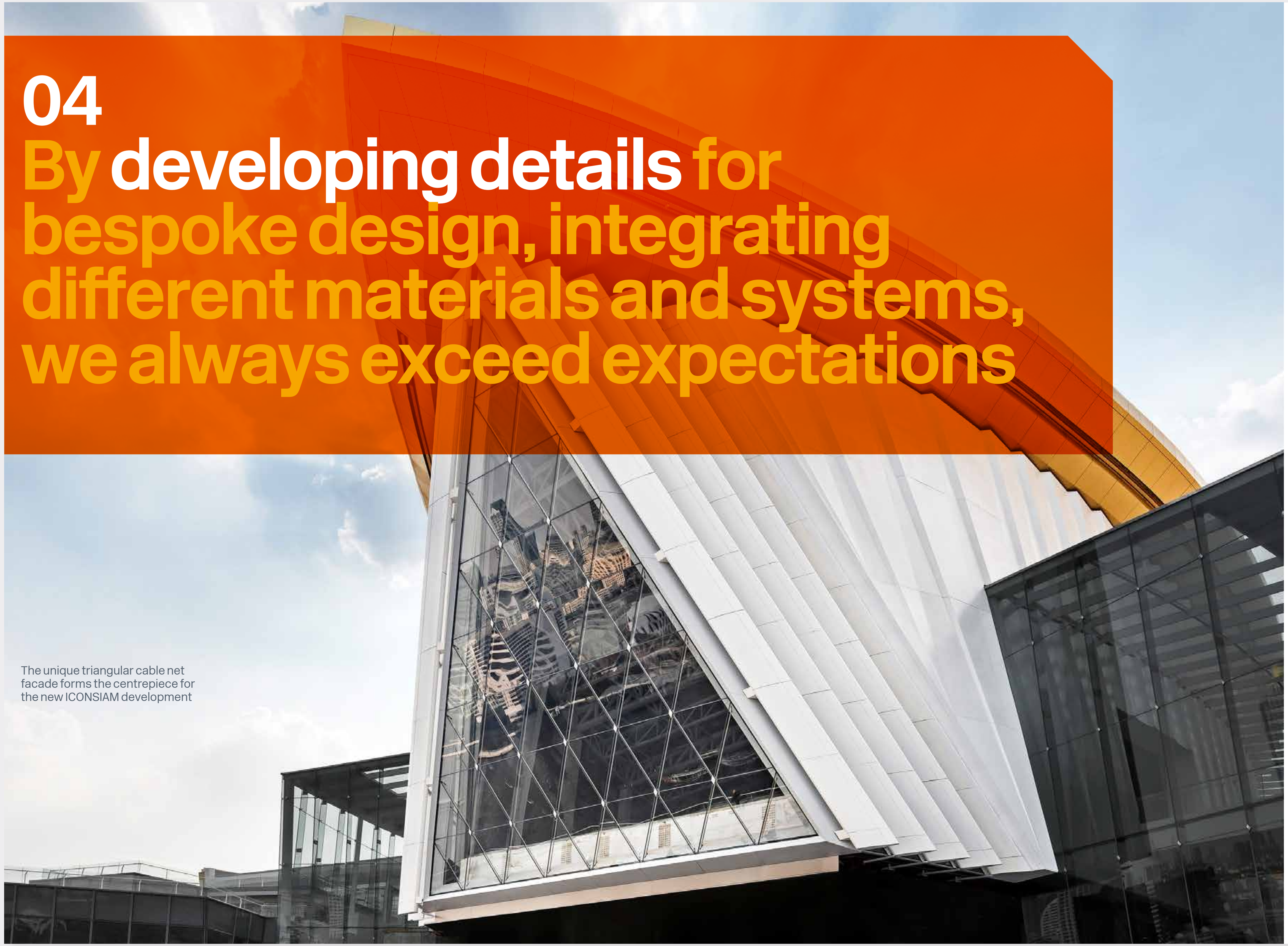


04
By developing details for bespoke design, integrating different materials and systems, we always exceed expectations

The unique triangular cable net facade forms the centrepiece for the new ICONSIAM development

1 **Looking up**
The 20m cable net facade of the world-class ICONSIAM development provides spectacular views across the Bangkok skyline

Contents

How do you push the boundaries to create the most awe-inspiring view?

New landmark museum of Thai history and culture, with a unique triangular cable net facade designed to optimise transparency, user comfort and give breathtaking views across the Chao Phraya River.

Location	Bangkok
Client:	SiamPiwat
Architect	Carpenter | Lowings Architecture & Design
Date	2019

20m
tall unique triangular cable net facade

80 tonnes
weight of the facade

64
triangular panes of glass

14
tensioned steel cables connected at 21 nodes

Facing towards the Chao Phraya River, ICONSIAM is a new national landmark for Thailand and an unprecedented breakthrough in all-glass design.

ICONSIAM extends over three storeys and, at its highest point, is home to the Wisdom Hall – a museum celebrating Thai history and culture – whose unique triangular front facade and glazed sidewalls were engineered by Eckersley O'Callaghan.

We were challenged to design an triangular frame with sides that span over 20m and can support cable loads, while also considering constructibility and allowing for the anchorages to be hidden within the cross section. Our solution avoided any internal structural elements, using the external shading fins as the support structure.

The complex assembly of the 20m tall system undertaken by Seele, was largely done on site to account for the significant sizes.

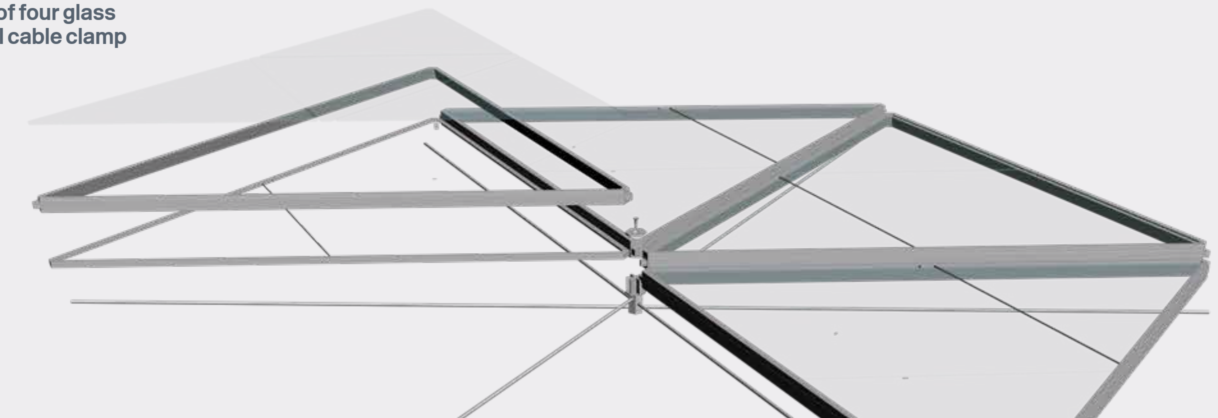
The triangular frame was welded together, and the cable net tensioned on top of a crash deck. The two lower corners of the frame were attached to the main structure using pins that allowed the whole assembly to rotate into position while being pulled from the apex.

The sidewall glazing is made up of 72 pieces of on-site bent glass. Providing contrast to the cable net, the truss structure is positioned externally and is clad with an aluminium skin to provide shading to the interior.

Standing 20m tall and weighing 80 tonnes, the cable net is formed with clamps that support up to six glass panels each to provide an optimum view of the river and the city.

Overall, the facade consists of 64 triangular panes of glass held in place by 14 tensioned steel cables connected at 21 nodes and works in a similar way to the strings of a tennis racket. As all structural elements and connections are visible, we worked very closely with the architect to realise the design intent of transparency.

Exploded diagram of four glass frames with central cable clamp



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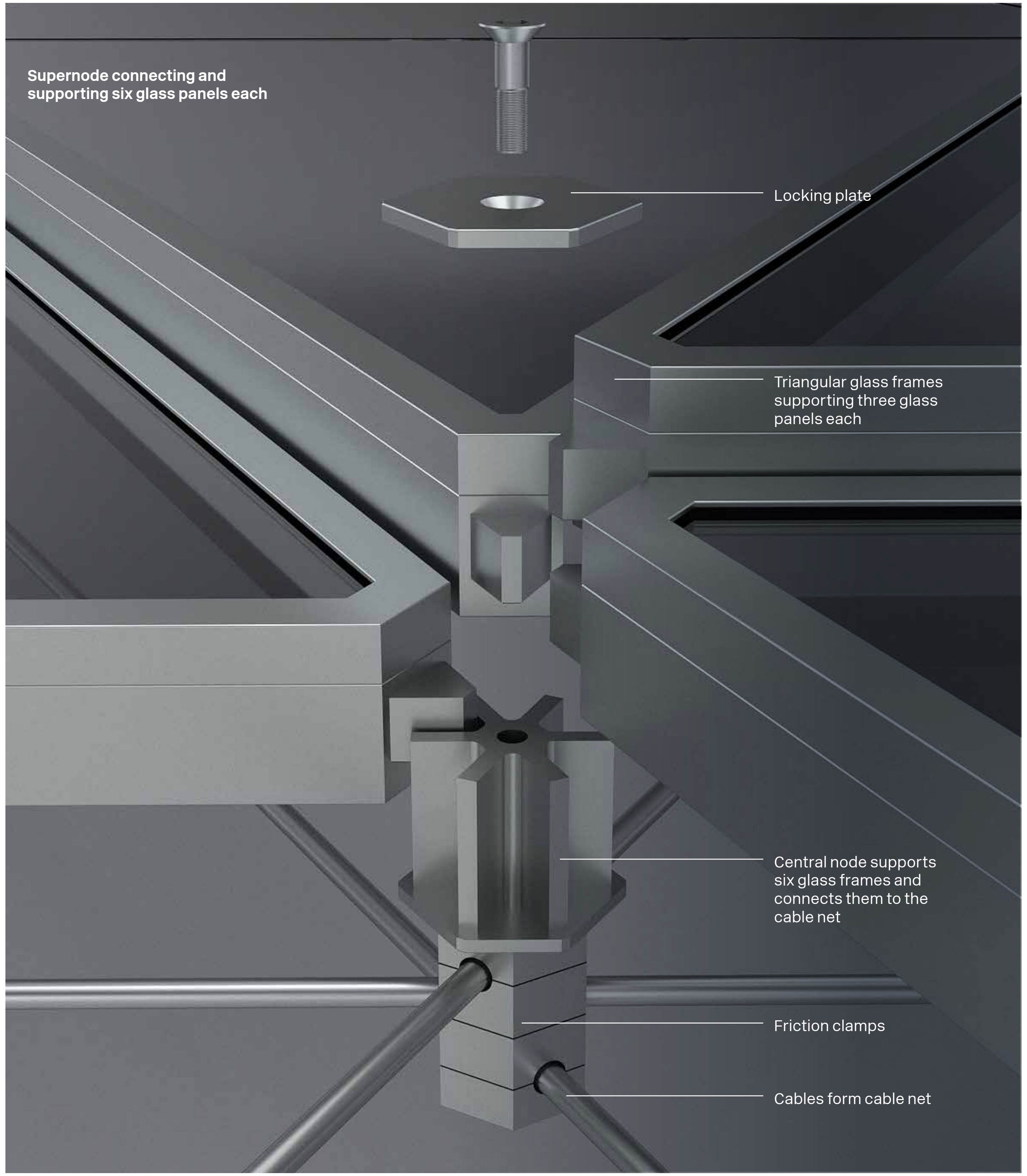

1 **Whole facade assembly**
Rotated into position while being pulled from the apex

2 **Local analysis model**
Showing cable clamp stresses (cables not shown)

3 **Local analysis model**
Showing glass frame stresses (cables not shown)

4 **Constructing the facade**
Torquing of the cable end anchors

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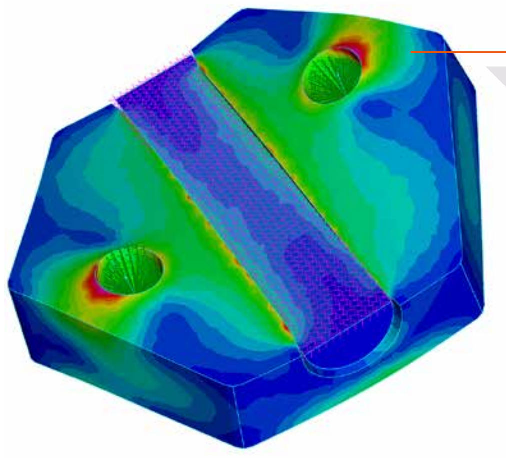

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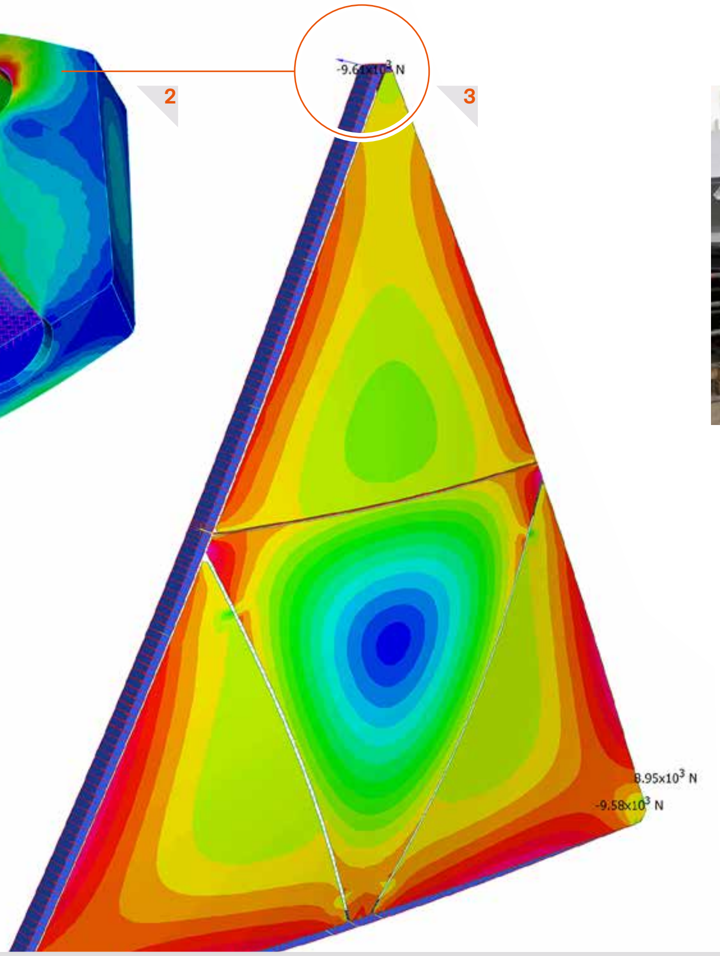

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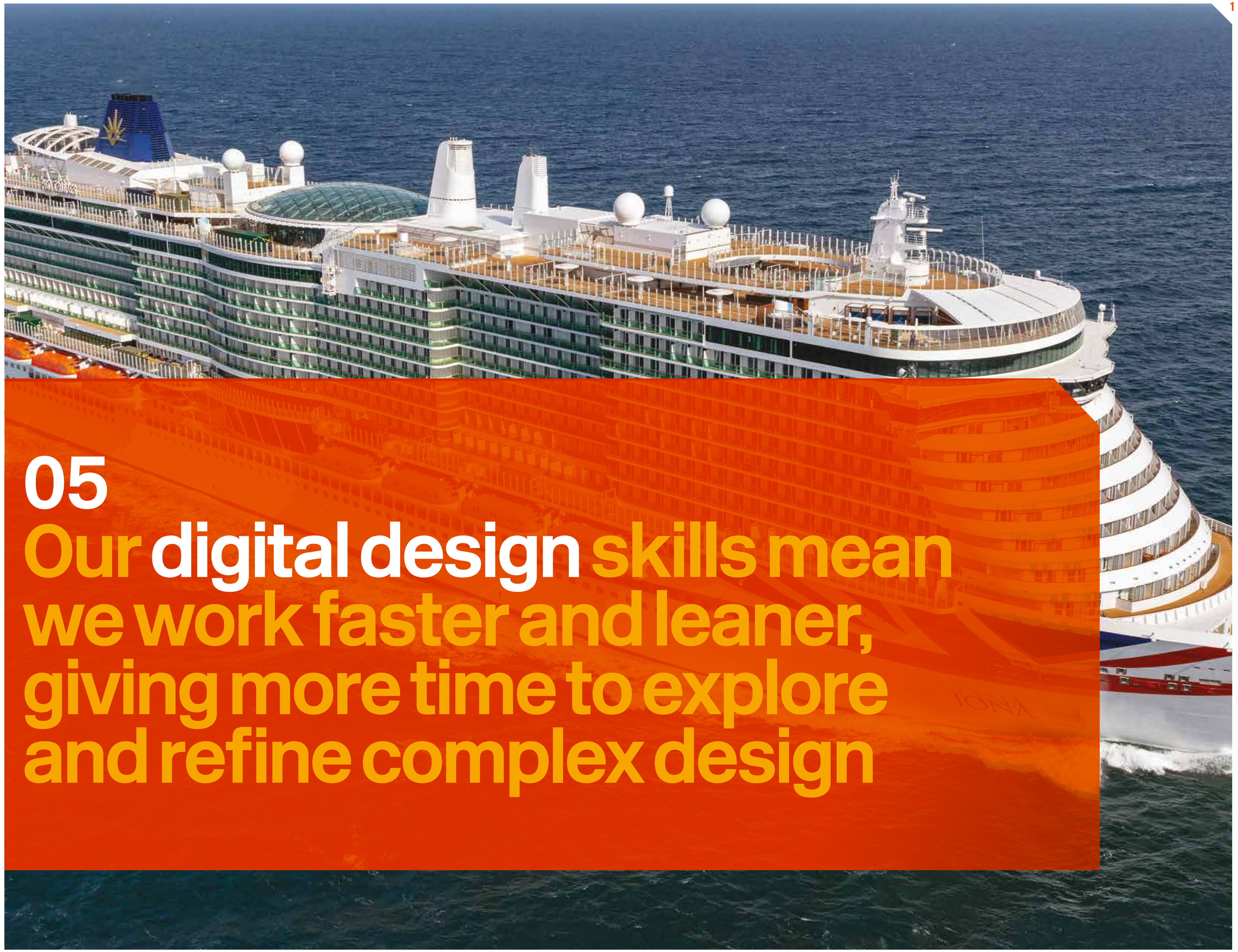

05
Our digital design skills mean we work faster and leaner, giving more time to explore and refine complex design

2

1 **Iona SkyDome**
Martin Francis
The completed dome on Iona

2 **SkyDome**
Interior pool area and night-time entertainment venue

3 **Construction engineering**
Dome lifted into place in one prefabricated assembly

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How do you optimise a glass dome to be light enough to create a cruise ship world-first?

The unique Iona SkyDome is engineered to withstand large forces at sea, while giving passengers spectacular uninterrupted views of the sky and the ocean. No structure of its complexity had ever been built on a cruise ship before.

Location	The sea
Client	Carnival Group
Designer	Martin Francis
Date	2021

1st
dome ever to be built on a cruise ship

970m²
glass dome

350
panels of 3x3m triangular insulated glass units

131 tonnes
structure and glazing

Designed to be the focal point of Iona, P&O Cruises' most innovative ocean liner, the stunning, elliptical glass SkyDome is 131 tonnes, 41m long, 30m wide, 4.3m high and spread over two decks.

No structure of this complexity had ever been built on a ship before, with the space underneath featuring a poolside environment by day that transforms into an entertainment venue at night.

As such, the SkyDome's design had to overcome a number of substantial challenges, with weight minimisation a key consideration. To achieve this, the shape of the dome was optimised using gravity loading as a form-finding method for the roof geometry, as were the individual member sizes to use the minimum material possible. In doing this we also had to balance the weight with the dome stiffness so that the frequency of the structure was within the allowable range. Moreover, to reduce wasted glass material, the shape of each panel was defined based on the maximum width the glass panes could be cut.

The deformation of the support structure due to the ship movement under hogging, sagging and torque were applied in the FEA model. Apart from the movements at ultimate limit state, the impact of these movements on the behaviour of the dome against fatigue was also investigated.

As the ship will travel the world many times, the SkyDome also needed to be tested to withstand all kinds of climatic loads such as wind, snow, rain and hail – for which we conducted tests which involved firing 45mm diameter balls of hard packed ice, with mass 45gr at 30m/s terminal velocity.

Thermal performance requirements had to balance temperatures ranging between +35/-10˚C. To meet this, we used an insulated glass unit (IGU) with a high-performance coating, helping us to reduce the thermal losses (U-value = 1.6 W/m2K), limit the solar gain (g-value=0.34) and keep the transparency of the glass at a high level (Light Transmission =70%).

Given the SkyDome's unique structure and situation, Eckersley O'Callaghan also had to overcome strict design codes set by the marine regulatory bodies. This meant we had to take a sensitive approach to design, with each innovative aspect having to prove its structural capabilities from first principles and by rigorous testing before approval.

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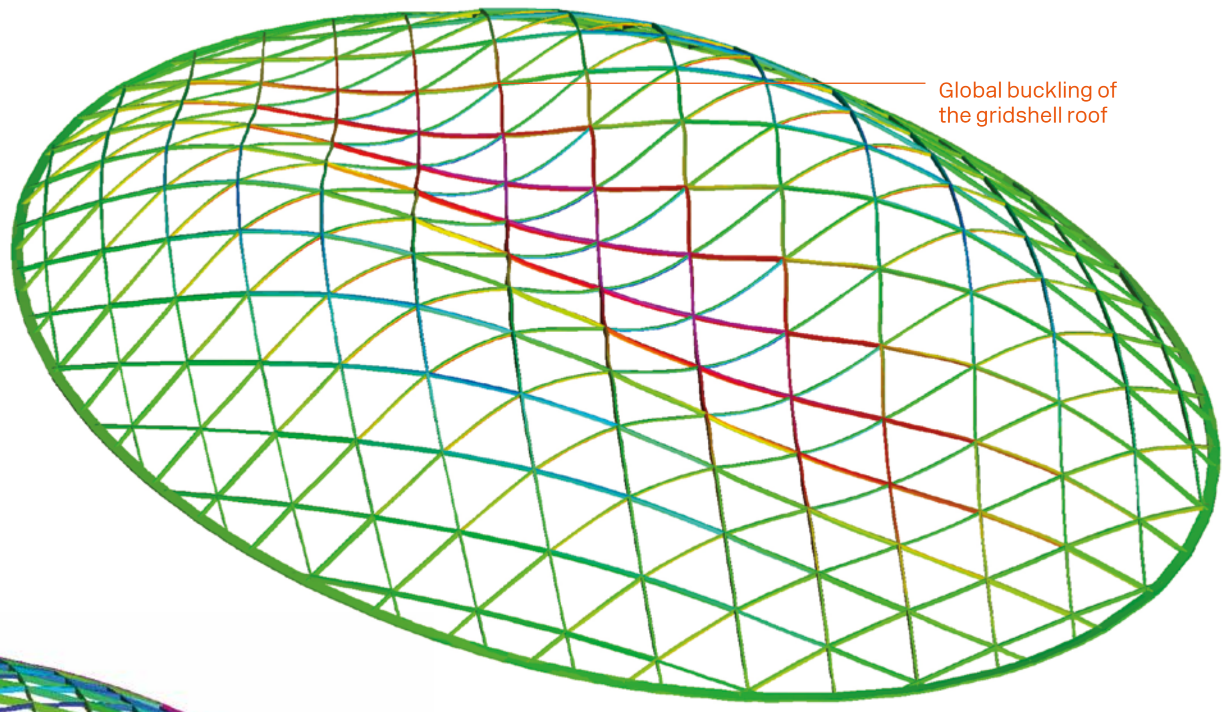
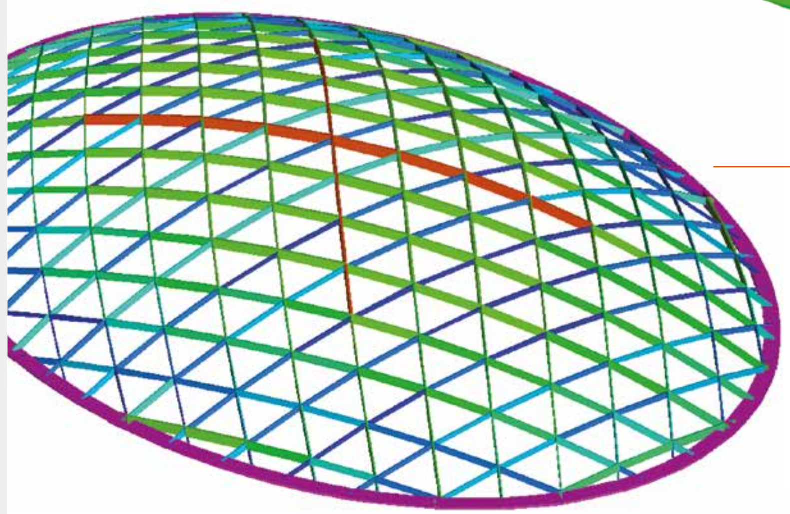
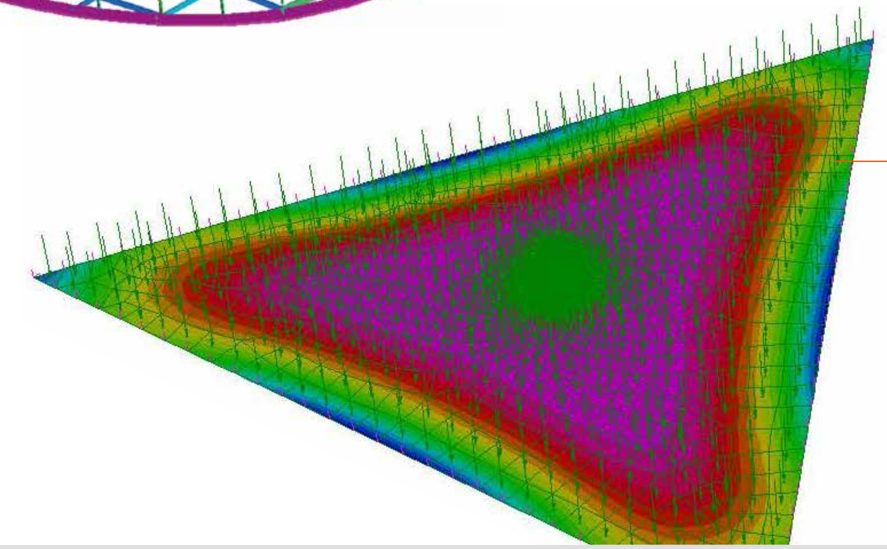
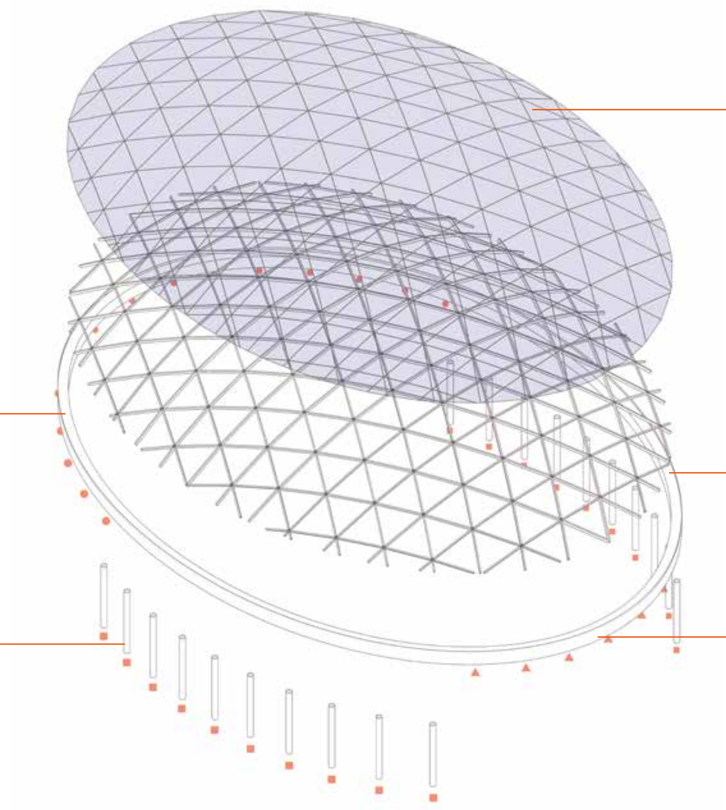
While automated beam sizing isn't innovative in itself, our novel implementation accounted for the global buckling behaviour – often critical in the design of gridshell structures







The structure of the SkyDome is an elliptical structural steel grid-shell roof made up of equilateral triangles. The shape has been optimized using gravity loading as a form-finding method for the roof geometry



1 **Construction**
Quality inspection of joints

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Eckersley O'Callaghan

Advanced Engineering, Materials & Technologies Group

1 **K11 Art and Cultural Centre, Hong Kong**
KPF | SO-IL Architects
Completed facade

2 **James O'Callaghan**
Performing quality inspections on tube edges

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How do you sculpt an innovative new facade while accounting for severe environmental conditions?

The K11 Art & Cultural Centre is a new art museum in Hong Kong, with a unique facade that pushes the boundaries of glass fabrication technology.

Location	Hong Kong
Client	New World Development
Architects	KPF | SO-IL Architects
Date	2020

450mm
radius for the tightly bent glass cylinders

307
cylinders wrap around the building perimeter

9m
tall glass tubes

300m
facade linear length

Located at the top of the multi-storey K11 development, the cutting-edge Art & Cultural Centre in Hong Kong's cultural district is wrapped around a rooftop sculpture terrace with magnificent views out across the city.

Eckersley O'Callaghan worked with SO-IL architects and specialist contractor Seele to engineer a tubular glass facade that would envelop the curved spaces and create a distinctive visual statement.

Unique and ground-breaking, this sculptural glass facade pushes new boundaries in fabrication, installation, and the advancement of the closed cavity facade system (CCF) used. It consists of 300 glass half and full tubes (9m tall and 900mm diameter), wrapping 170m around the sixth and seventh floors.

Translating SO-IL's vision into reality required a process of research and working collaboratively with the client, architect, fabricators and M&E consultants to overcome the never-been-done-before aspects of the design.

The facade underwent year-long testing and development before it was installed on site. Producing glass tubes of such tight radius on this scale had not been done before, either.

Having investigated different fabrication techniques to produce the tubes, the project used gravity bending to slump the heated flat sheets of glass over a mould and join the two halves. Considering the curvature of the glass, we were able to minimise the thickness of the build-up which in turn increased its transparency.

All tubes are base supported, with the panels over the entrance and openings supported on the adjacent full-height glass cylinders via a mechanical connection bolted through the glass. Movements from the supporting structure are accommodated through vertically released connection details at the top restraint.

The tubes have been designed to withstand typhoon loading, with climatic loading and condensation being another consideration. The required volume of air to be circulated in the facade far exceeded that in a traditional double layer facade, requiring a novel solution. Together with Seele, we were able to implement a new, state-of-the-art CCF system within the tubes to stop the risk of condensation building up.

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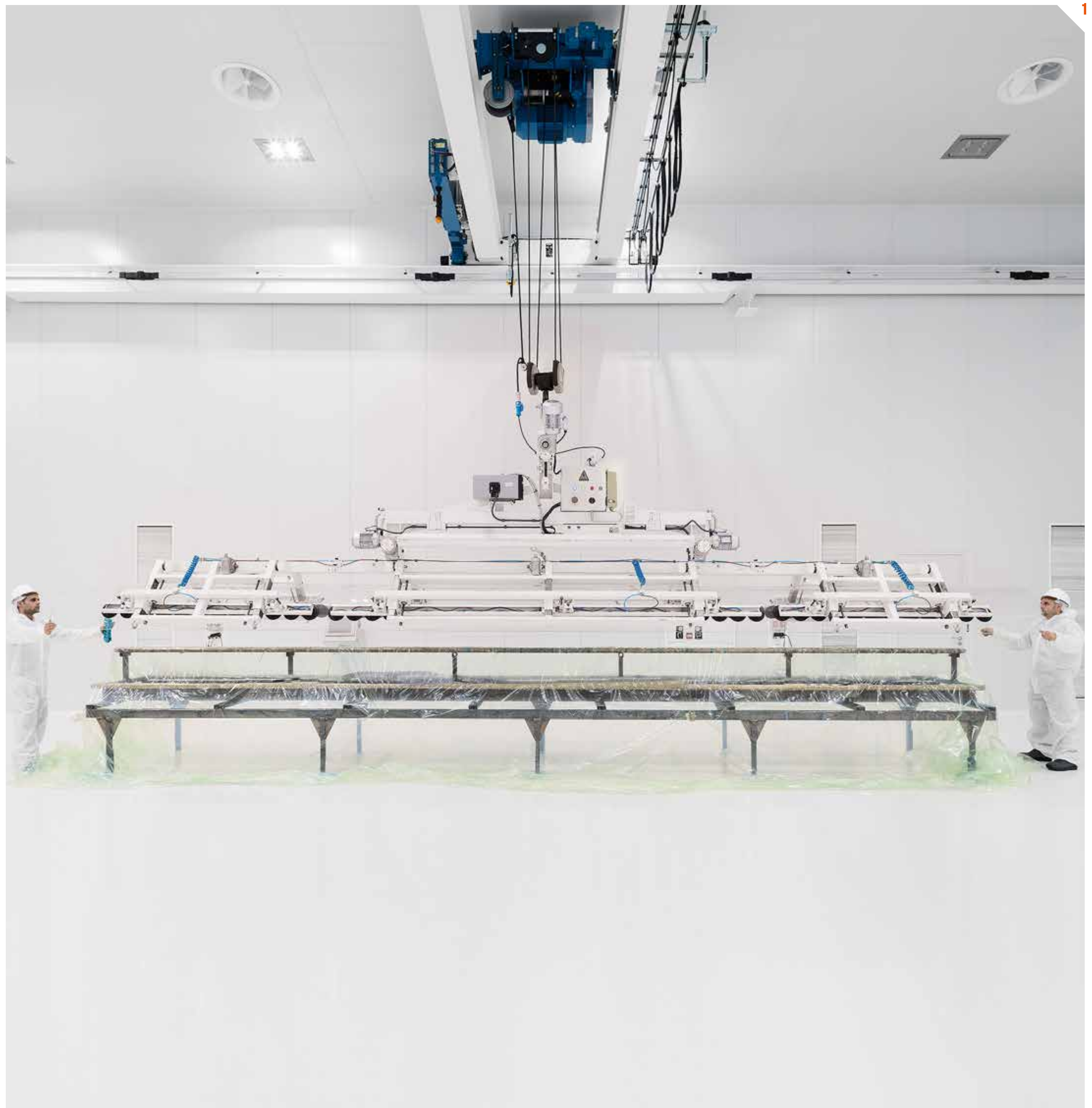
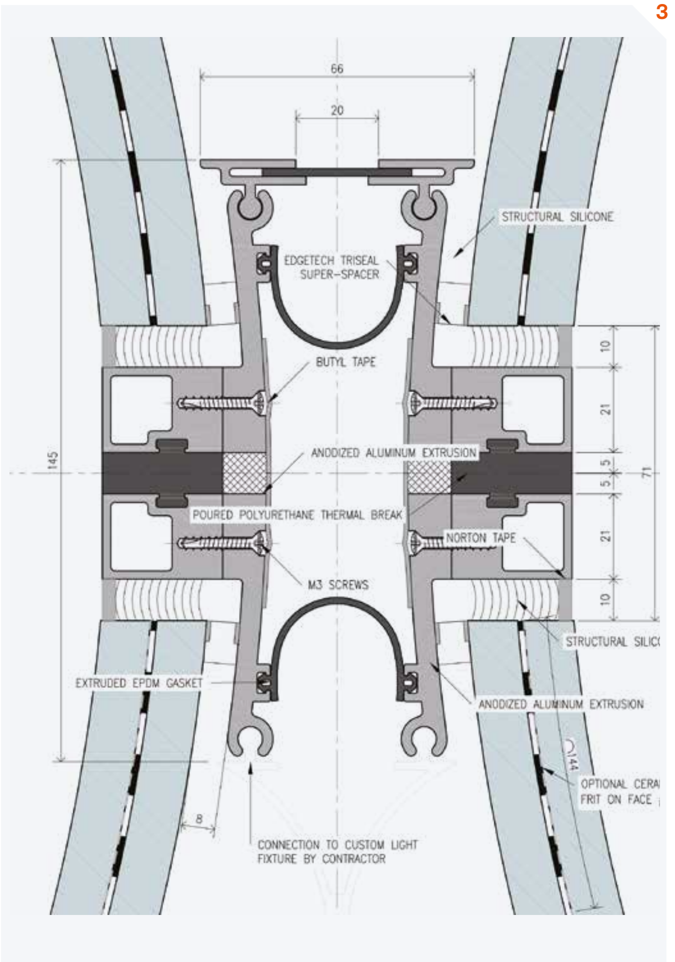
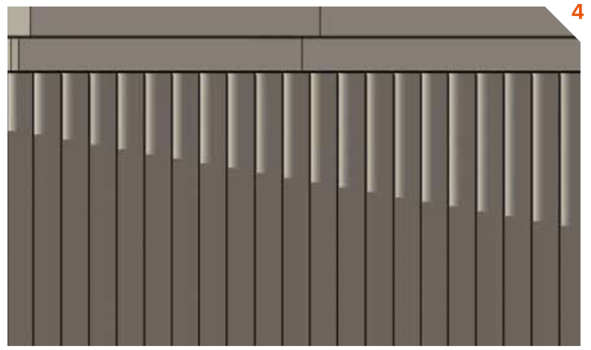
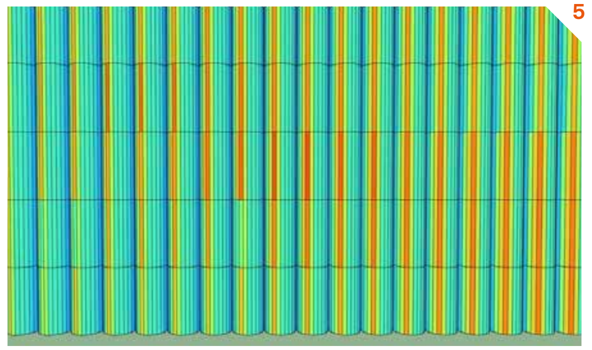
1 **Laminating clean room**
Bonding together separate plies of glass









2 **Inside the tubes**
Sleek connection detailing creates increased transparency through the facade

3 **Pivotal connection detail between the two half tubes**
Creating the seal to keep the tubes airtight and form the waterproofing for the building

4 **Simulation of solar radiation**
Sun exposure at different times of the day to check temperature and consequent stress differentials across the tubes

5 **Simulation analysis of sun exposure**
Ground-breaking analysis of the shading around a building

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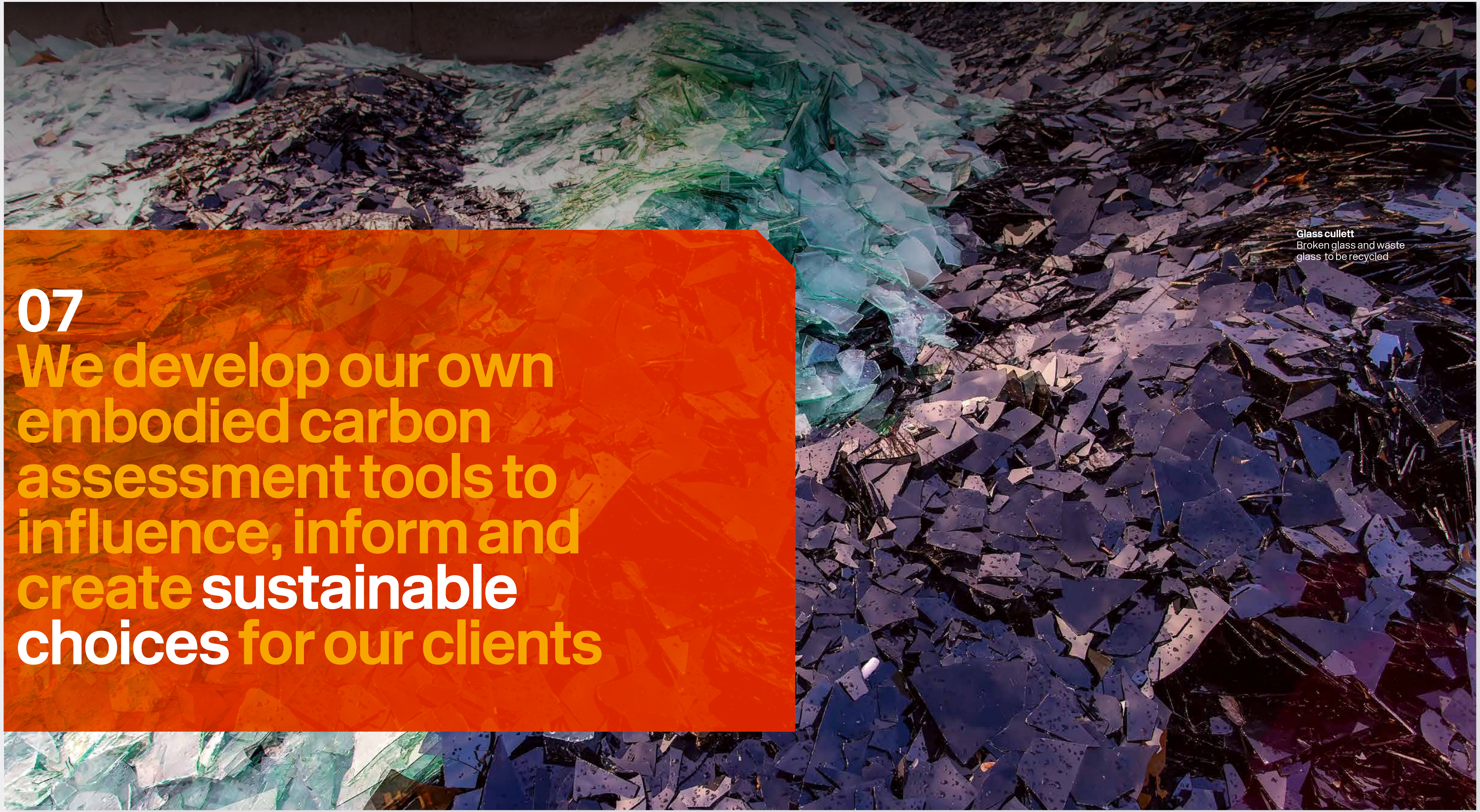

Glass cullett
Broken glass and waste glass to be recycled

07
We develop our own embodied carbon assessment tools to influence, inform and create sustainable choices for our clients

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How do we change the way our industry thinks about recycled glass?

Glass has a big part to play in our future, but it is facing headwinds.

We recognise that its use is being challenged by the need for better energy efficiency and needs to evolve, but it is also vital not to lose sight of what we compromise by rationing light into our buildings.

As a key player in the glass industry, we believe that it is our responsibility to help resolve this conflict, to fully participate in the dialogue ahead and, as a practice, to focus on the technology and innovations associated with energy control, as well as its future as a structural material.

<1%
glass recovered from buildings

180,000
tonnes of carbon downgraded each year

1.2 tonnes
raw material saved for every tonne of recycled glass used in cullet

300 kWh
saved for every tonne of recycled glass used in cullet

Currently, less than 1% of glass is recovered from buildings in the UK. That represents more than 180,000 tonnes of embodied carbon being downgraded each year. In the context of the Climate Emergency, those figures are unacceptable. Over the last two years, we have tasked one of our research groups with finding out why so little flat glass is being recycled, and what our industry can do to turn things around.

While previous studies have analysed glass production in the construction industry, our team considered the glass industry as a whole, investigating production and delivery processes for glass packaging and glass fibre in addition to flat glass, and then evaluating the ways these different uses are subsequently reused and recycled (see diagram on next page).

Our team has conducted hundreds of hours of interviews with experts from every link in the supply chain, from raw mineral extraction, manufacture and supply, transport, installation, right through to demolition, disposal and recycling. We have been able to identify the areas where the different production processes overlap and where our industry falls short in terms of reusing the material. For example, in glass packaging, there is a steady recycling rate of approximately 75% and a well-established supply chain for recycling.

This is the result of a successful legislation within the packaging industry. All of us in the supply chain have responsibility to provide solutions within individual spheres of influence, providing a framework for simple and effective impact. Ultimately legislation and regulation will follow and will be forced on those in the industry that aren't already participating.

There are already individual companies leading by example and providing opportunities for flat glass collection while profiting from the services they provide. But as it stands, this is just a drop in the ocean, so together we must bring about the change that's needed.

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Eckersley O'Callaghan

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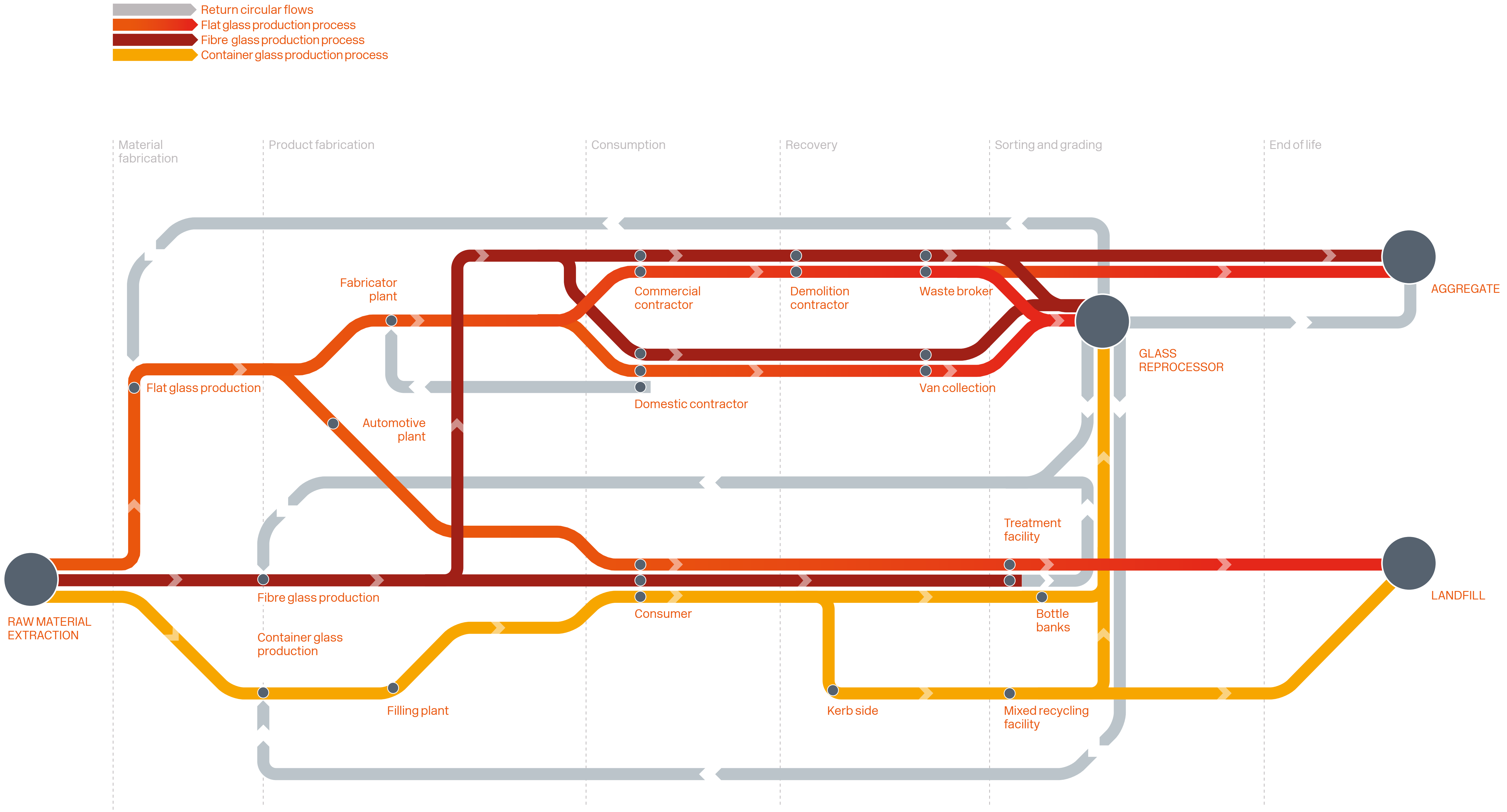
Glass production cycle
The links we have identified for each strand of the glass supply chain, from production through to disposal and recycling, while identifying the potential for the application of circular economy principles.



Eckersley O'Callaghan

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08 Curiosity and thinking differently enables us to investigate new materials and systems and to solve the most technically challenging problems

First of its kind
Constructed from transparent acrylic panels and connecting two apartment buildings, Sky Pool is a truly remarkable feat of 21st century engineering

Contents

How do you create a completely transparent swimming pool 10 floors up?

The first of its kind and a truly remarkable feat of engineering, Sky Pool is a transparent swimming pool spanning 15m between two apartment buildings ten storeys in the air.

Location	London
Client	EcoWorld Ballymore
Architects	HAL Architects
Date	2021

15m
bridge span between buildings

148,000
litres of water contained in the pool

35m
suspended high in the air

7
separate acrylic elements bonded together to form the pool

The world's first fully transparent swimming pool, Sky Pool is a lightweight structure that bridges the 10th floors of two residential buildings which form part of developer EcoWorld Ballymore's Embassy Gardens development in south London.

Constructed in clear acrylic, the side walls of the pool are 180mm thick, 3.2m deep and its base is 360mm thick. The whole pool weighs 50 tonnes and contains a total of 150 tonnes of water (100 tonnes of which is carried by the acrylic 'bridge').

Because of its size, Sky Pool was constructed by Reynolds Polymer in separate sections with transparent bonded joints cleverly designed to maximise the bond area and avoid areas of high stress.

While Sky Pool forms the spectacular centrepiece of the new Estate, allowing swimmers a dizzyingly clear view of the park 35m below, Eckersley O'Callaghan addressed some significant engineering challenges when developing the structural solution for this project.

The side walls, for example, form deep beams capable of spanning the 15m distance between the buildings, whilst carrying the weight of the water, and resisting the hydrostatic water pressure on the sides and the wind loads.

In addition, the two buildings are subject to normal movements, which are inherent to buildings of this scale including wind sway and foundation settlement. The pool structure deals with these movements by avoiding rigid connection at both ends; it slides on bridge bearings while maintaining watertightness.

An additional 5m length of pool sits over the buildings at each end – constructed in stainless steel – to make a total length of 25m. They are tied together across the acrylic by two high strength, spring-tensioned, stainless steel rods 38mm in diameter which sit beneath the pool.

A bonded acrylic structure also offers less intrusive joints and connections and greater transparency. The refractive index of acrylic, close to the value for water, will also result in much less distortion than glass when viewing through the water or from outside.

Fabricated in the US, it was shipped to London and lifted into position in one piece.

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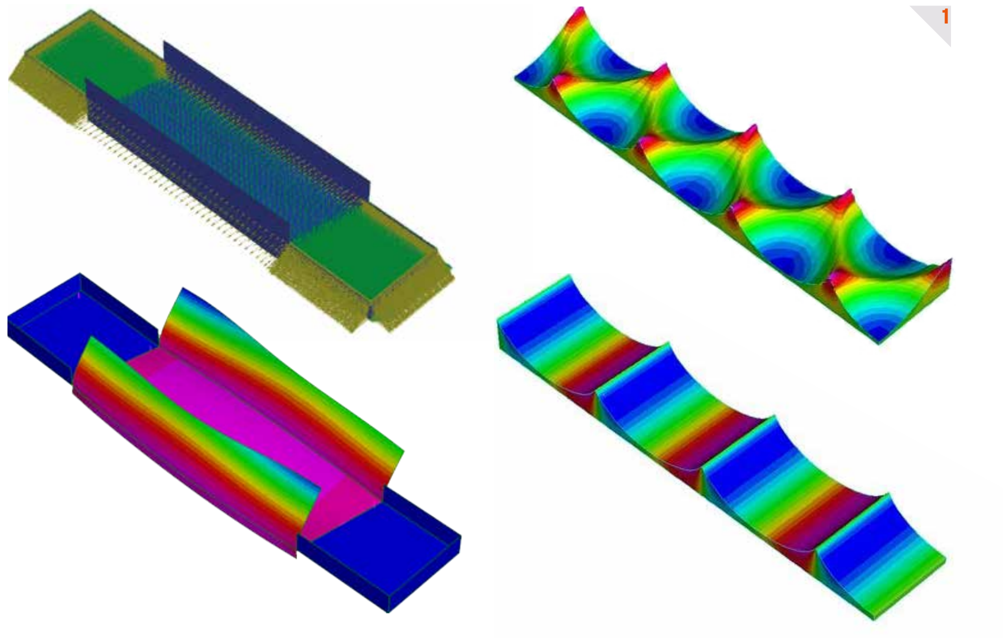
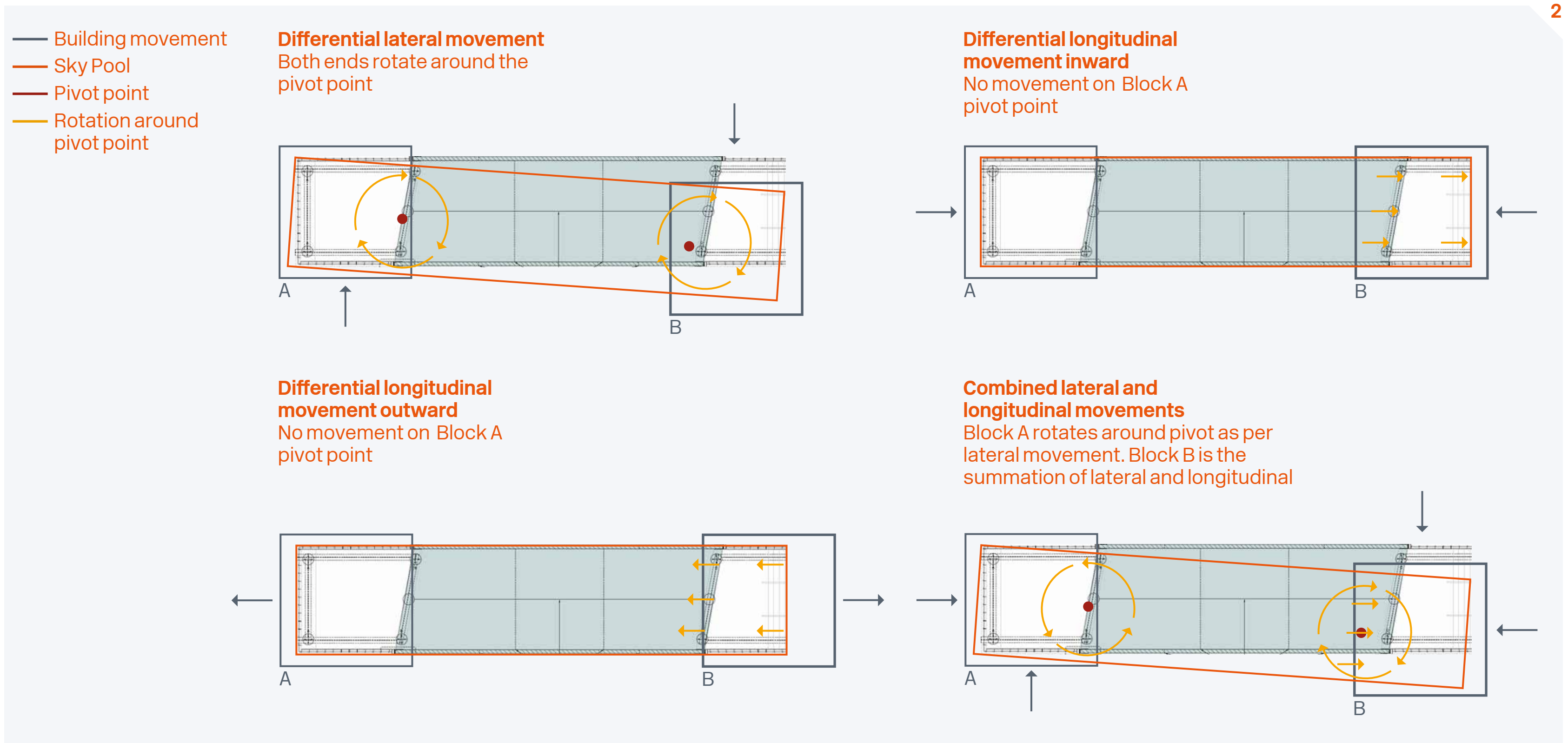
A technical and aesthetic tour de force

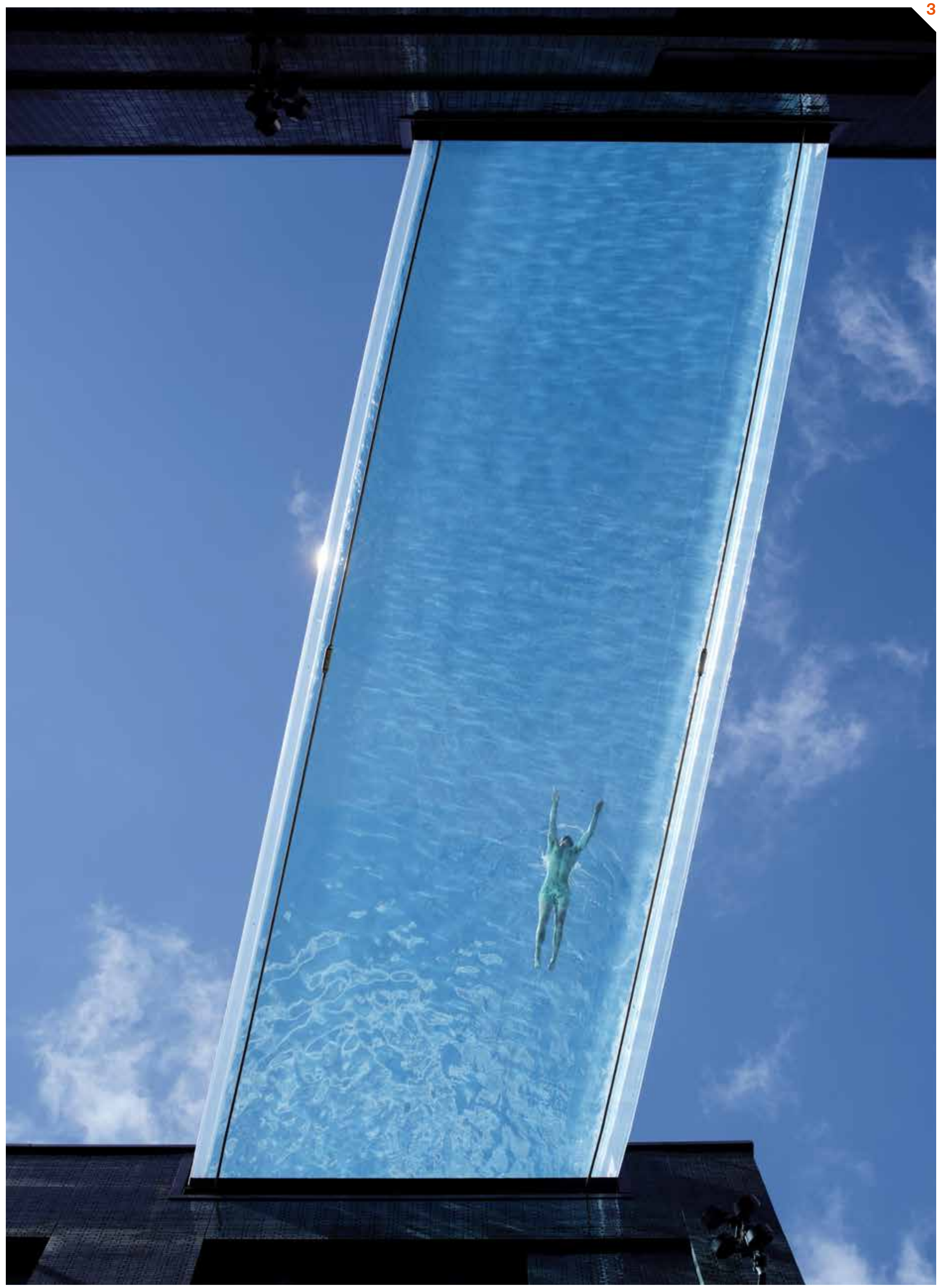


1 **What's the frequency?**
Analysis of natural frequencies of the pool structure and water sloshing frequencies. These were compared to each other to assess whether interaction of the vibration modes was likely

2 **Unique attention to detail**
Analysis of differential building movement on structure and bearings

3 **Transparent and effortless**
The lack of visible structure gives the Sky Pool a magical quality





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