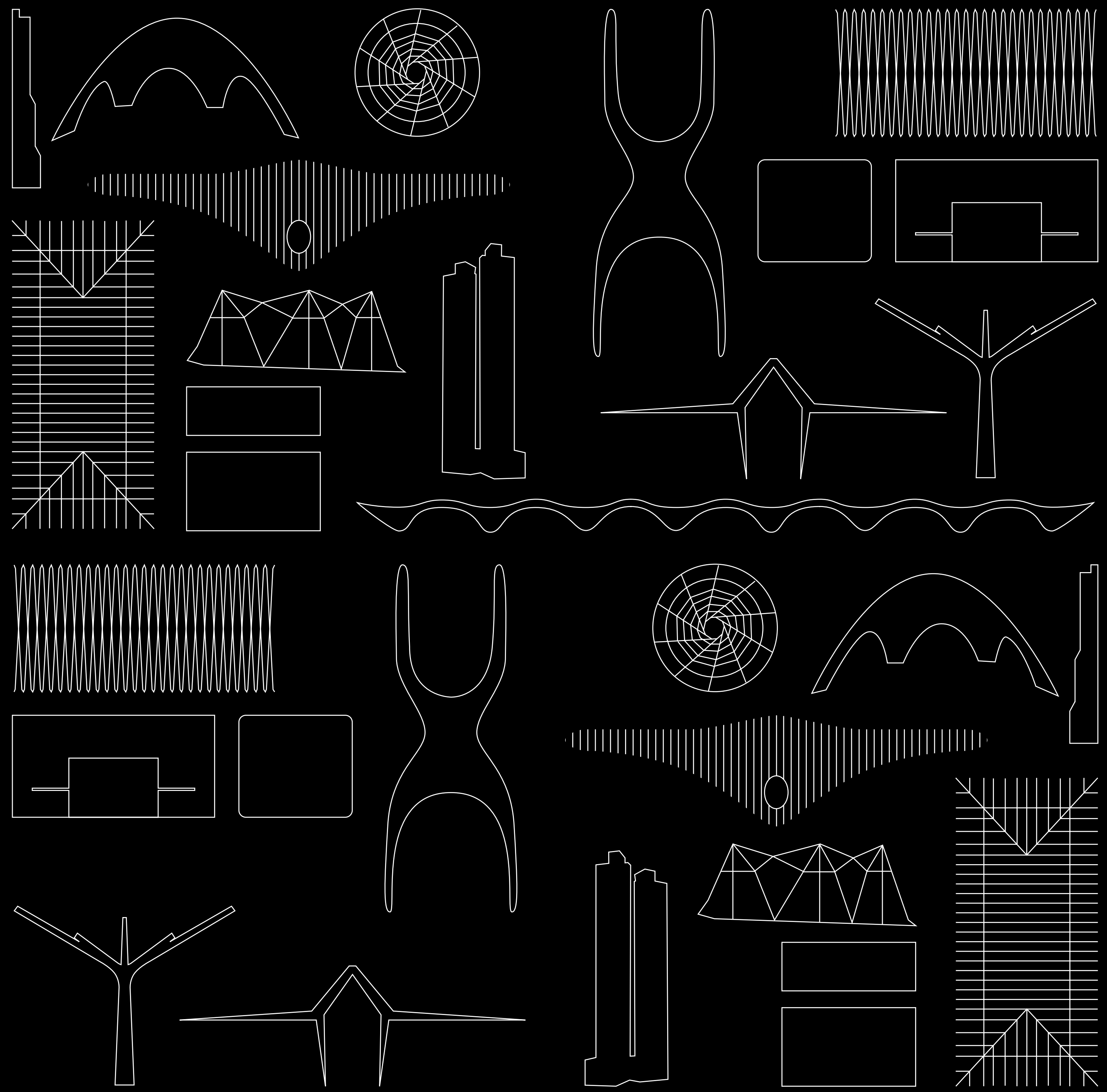
Structures
Foster + Partners



The creation of a building is the result of a process of discussion, collaborations, and decisions, between the client, designers, contractors and external authorities. It is possible to gain an insight into this process, to read a building, through the finished product. At Foster + Partners, our integrated design team acts as an orchestra, bringing together experts in different disciplines and specialisms to contribute towards a holistic solution.

This book focusses on the contribution made by the practice's structural engineering team to a selection of projects over the last ten years. For some projects this has been the development of the original concept, whilst for others our team has seen the project through to completion. In all cases, our work involves collaboration and partnerships around the world.

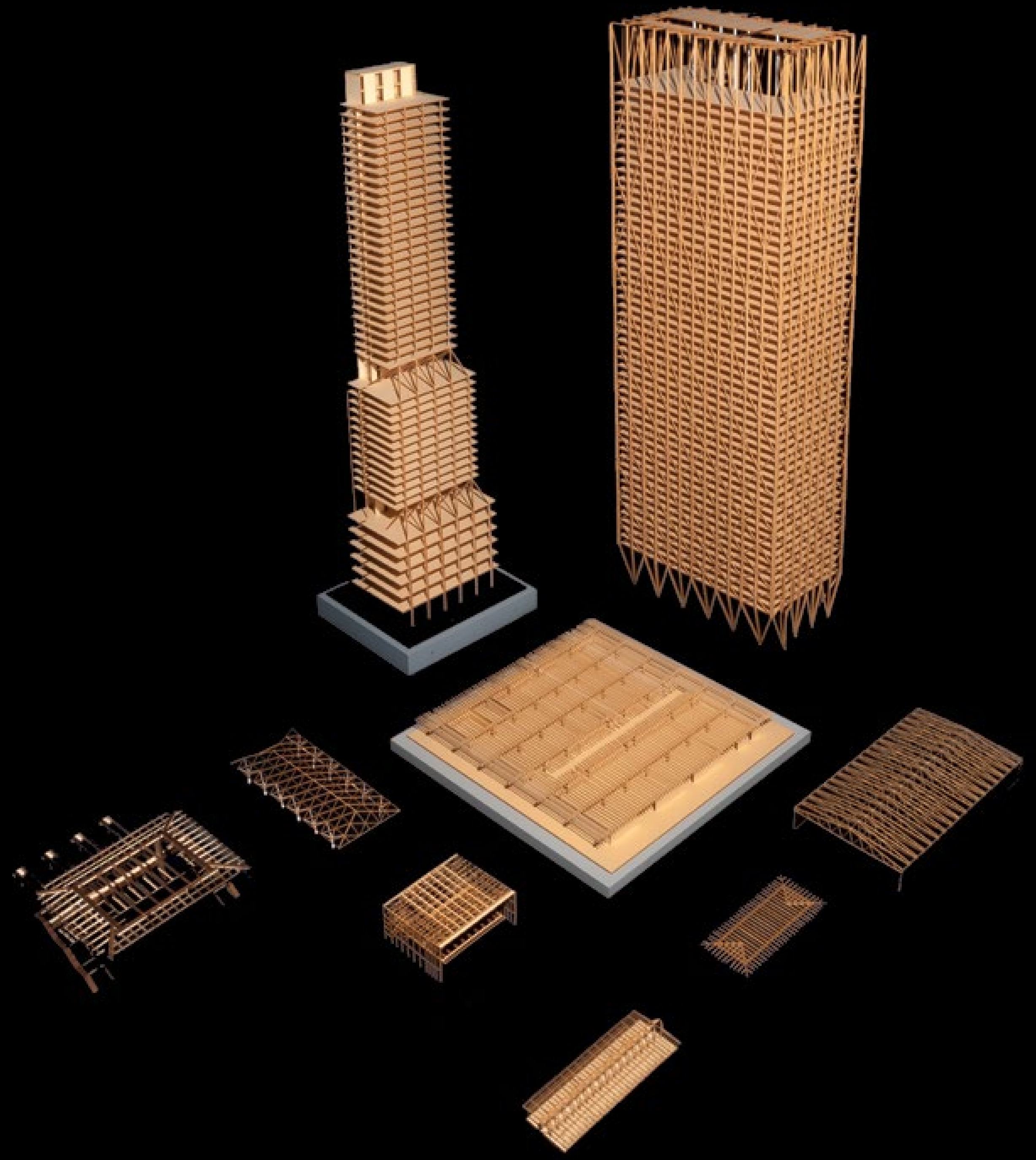
A building should be explained without complexity or technical jargon. It should be a clear reflection of its purpose, and this clarity also applies to the building structure. Our philosophy is that structural design should be legible, have integrity, and reflect the underlying values of the architecture. When we approach a project, we look for efficiency wherever possible, seeking to distil the structure to the point where nothing further can be removed. Any departure from this objective needs to be justified by the benefit that it provides.

The focus of the structural engineering team at Foster + Partners is to bring technical strength to the design process. We have specific knowledge in tall and complex buildings and have delivered projects in extreme climatic and seismic environments around the world.

As part of our design process, we make structural models. Built from card and glue, they are intended to aid design evolution rather than for formal presentation. With the façade removed, the structure can be appreciated for its own qualities.

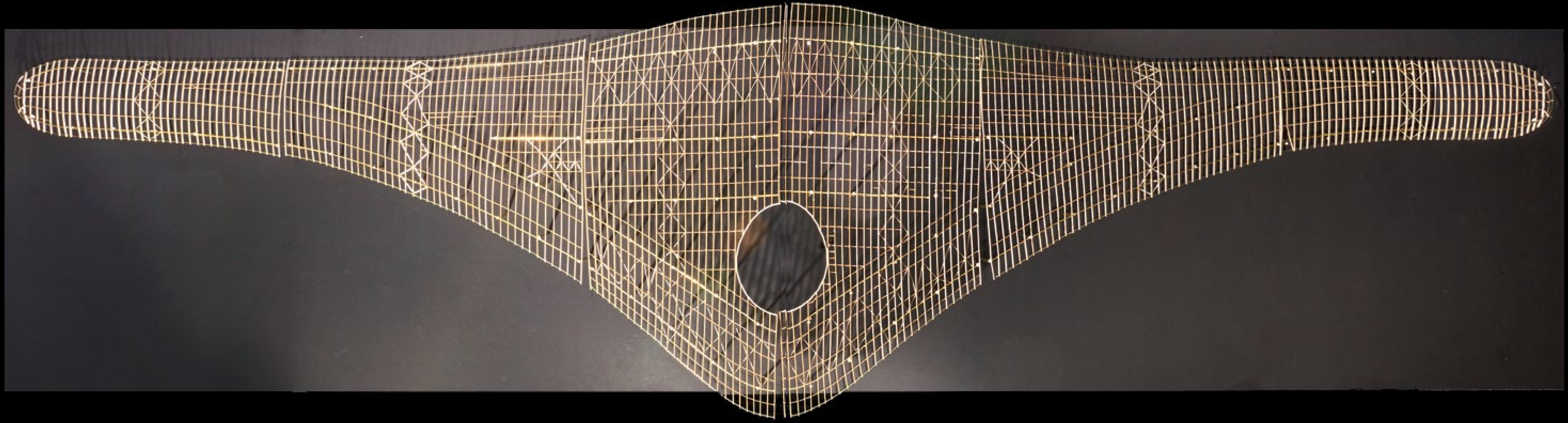
This book presents some of these skeletal models constructed during the design process, and the projects that resulted.

Roger Ridsdill Smith
Head of Structural Engineering

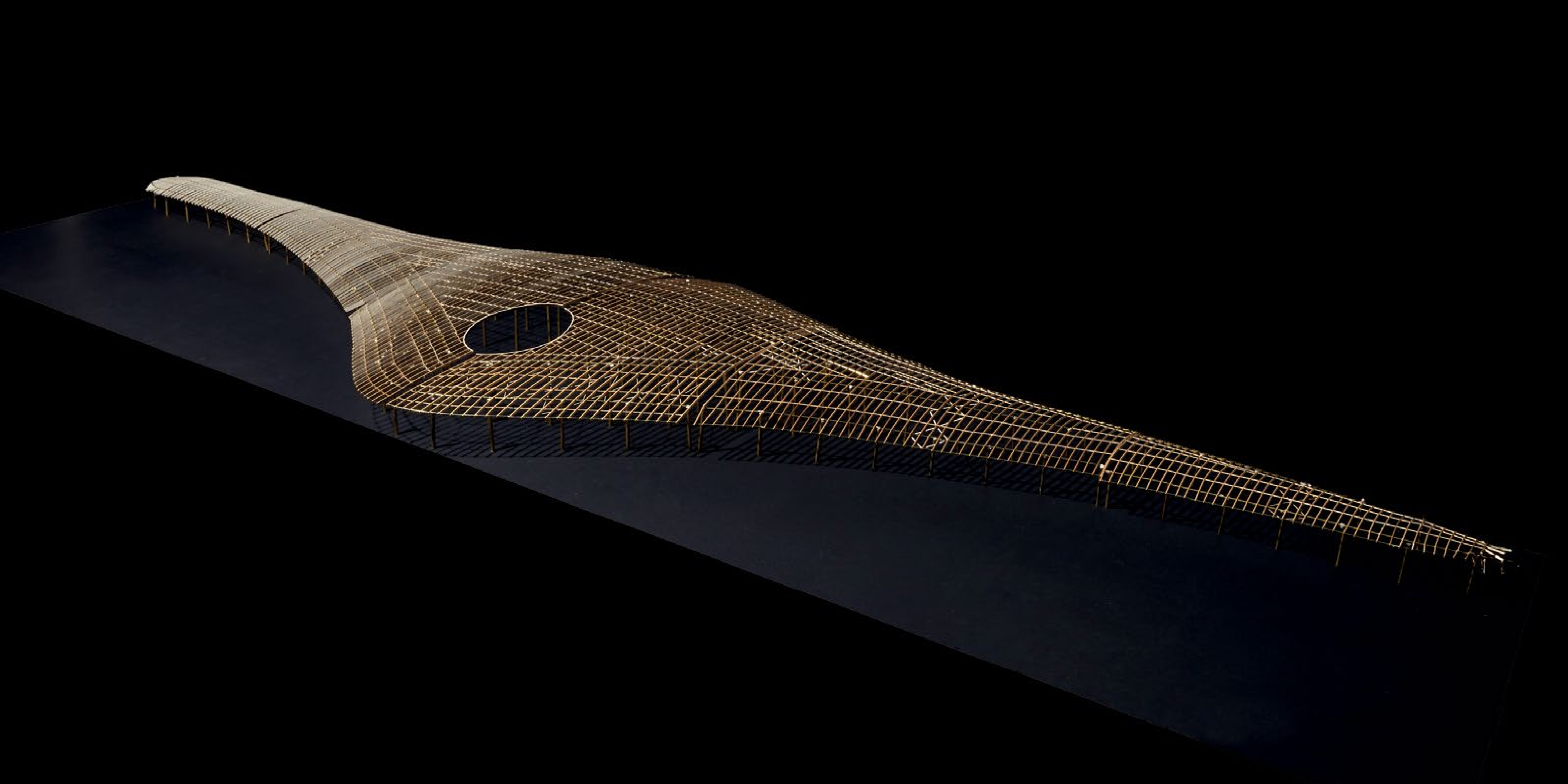


Selected Projects

Tocumen International Airport
Samson Pavilion, Cleveland Clinic
Château Margaux
Narbo Via
Marseille Vieux Port
Le Dome Winery
Apple Michigan Avenue
425 Park Avenue
Ocean Towers
New International Airport Mexico City
Vatican Chapel, Pavilion of the Holy See
Maggie's Manchester
Apple Westlake
Apple Marina Bay Sands



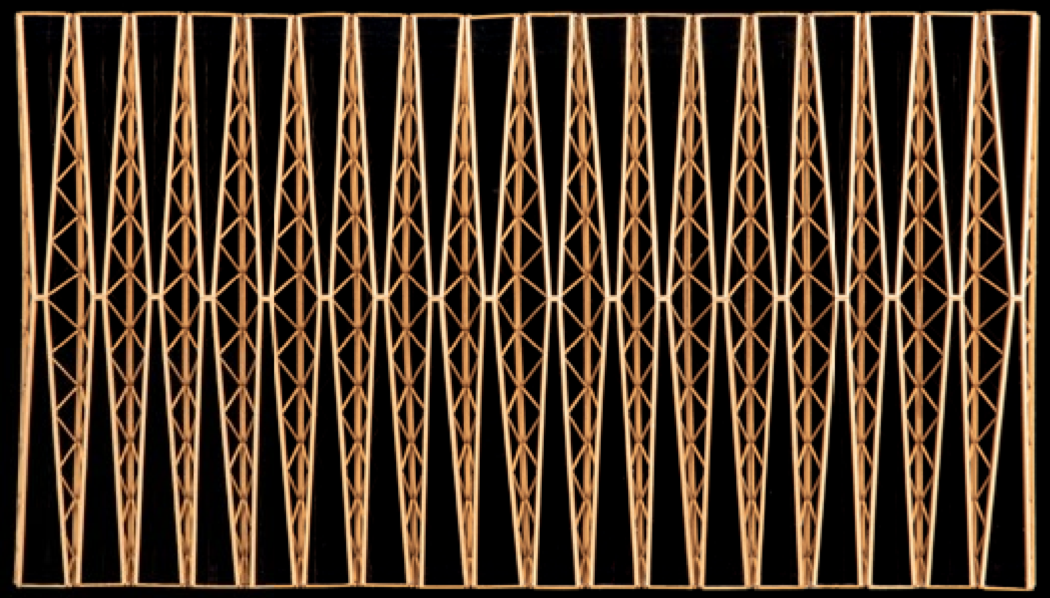
Tocumen International Airport
Panama
2011 — 2020



The design intent at Panama's Tocumen Airport was to create a series of long span beams that defined the gently curving form of the roof along the full length of the building. In order to avoid the substantial seismic loads of the region reaching the steel roof structure, a ductile 'fuse' for the top of the reinforced concrete columns was conceived and designed by the structural engineering team.

Client: Construtora Norberto Odebrecht S.A.
Area: 106,000 m^2
Capacity: 18 mppa
Structural Engineer: Foster + Partners, O.M.Ramirez y Asociados (Engineer of Record)
Environmental Engineer: Foster + Partners, Idelso, Carpen, Electro Systemas
Award: Engineering News Record - Global Best Project Award in the Airport Category
Publication: ACI Symposium Paper and ASCE Structures Congress

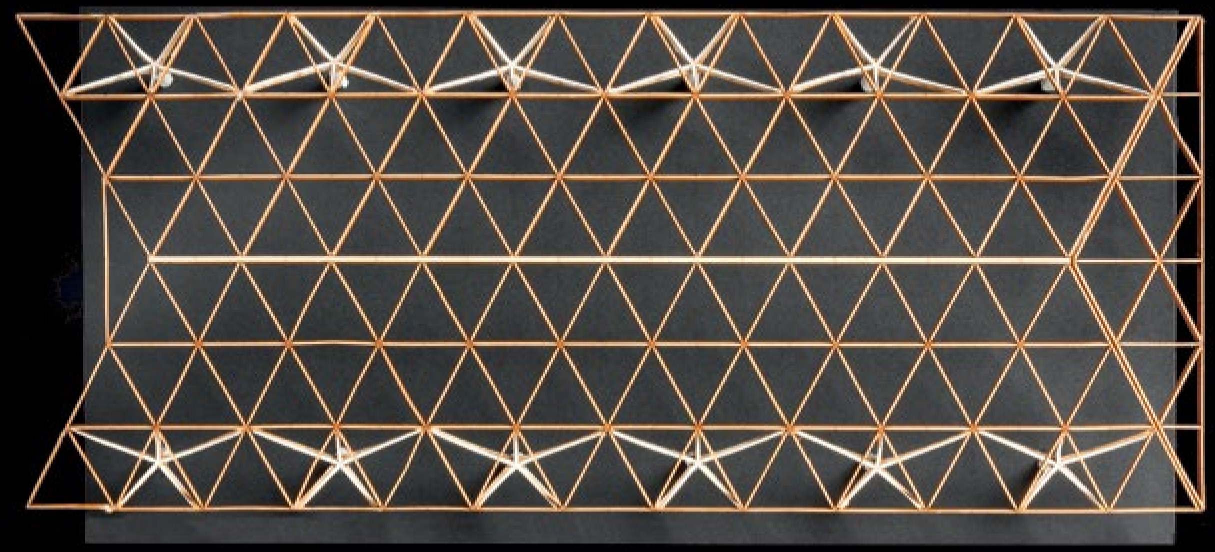
Samson Pavilion,
CWRU and Cleveland Clinic
USA
2015 — 2019



The courtyard roof of this new building spans 150ft (46m) and is supported by a series of V-shaped steel warren trusses. These elements taper in plan and elevation in order to reduce their mass, and to increase the amount of daylight reaching the courtyard. Given the heavy snowfalls in the region, physical modelling in a sand and water flume was used to shape the cross section of the trusses. As a result, the snow is naturally blown away from the glazed areas and gathers above the trusses, maximising daylight in the courtyard.

Client: Cleveland Clinic, Case Western Reserve University
Area: 45,500 m²
Structural Engineer: Foster + Partners, DLR/Westlake Reed Leskosky
Environmental Engineer: Foster + Partners, Smith Seckman Reid, Inc.

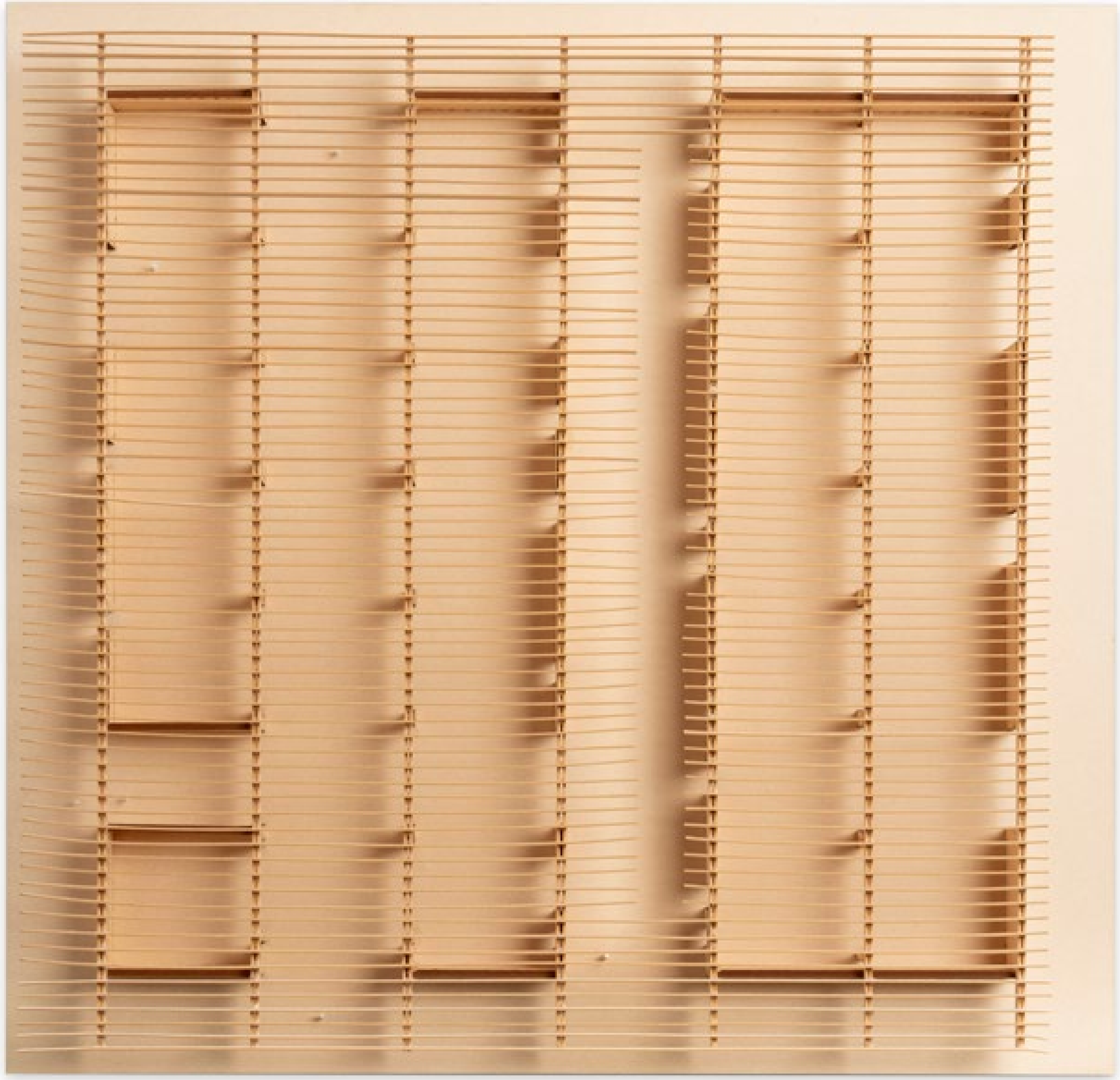
Château Margaux
France
2009 — 2015

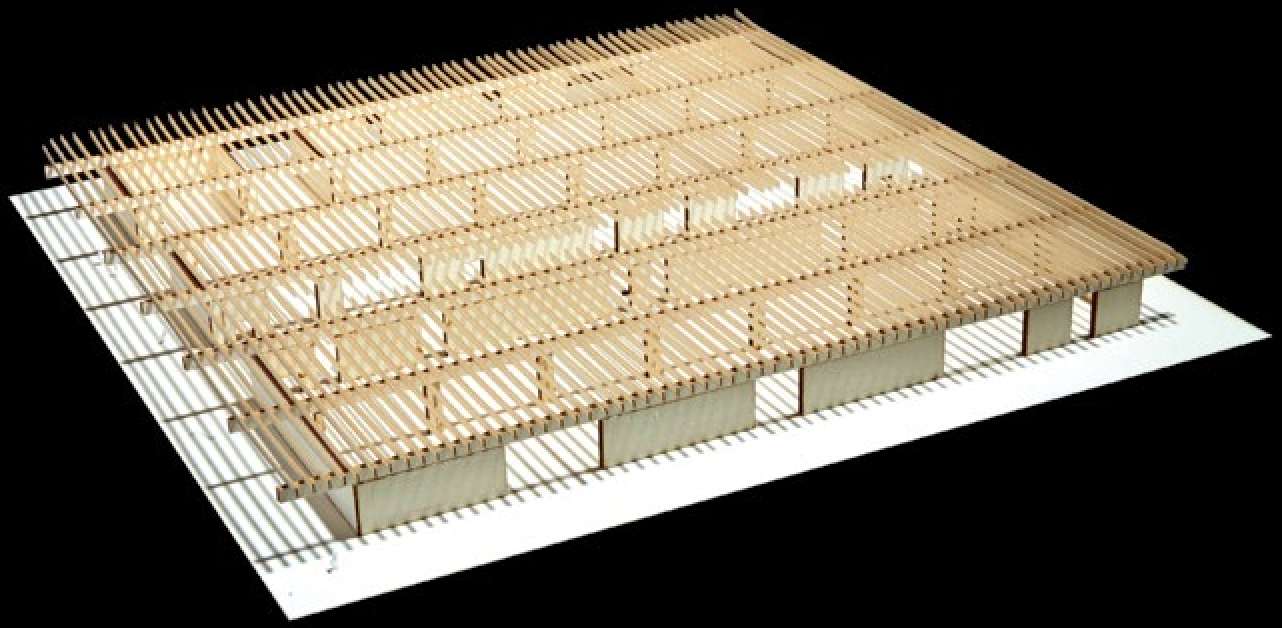


The roof structure of the new winery spans the 28 metres across the central space with a grid of beams that are three times shallower than what would be achieved with a classic beam system. The roof uses the pitched geometry to resist the applied loads through compression as well as bending.
The supporting 'tree' structures provide both the vertical and lateral support to the roof.

Client: SCA Château Margaux
Area: 1,825 m²
Structural Engineer: Foster + Partners, Ingerop
Environmental Engineer: Foster + Partners, Secath

Narbo Via
France
2012 — 2021

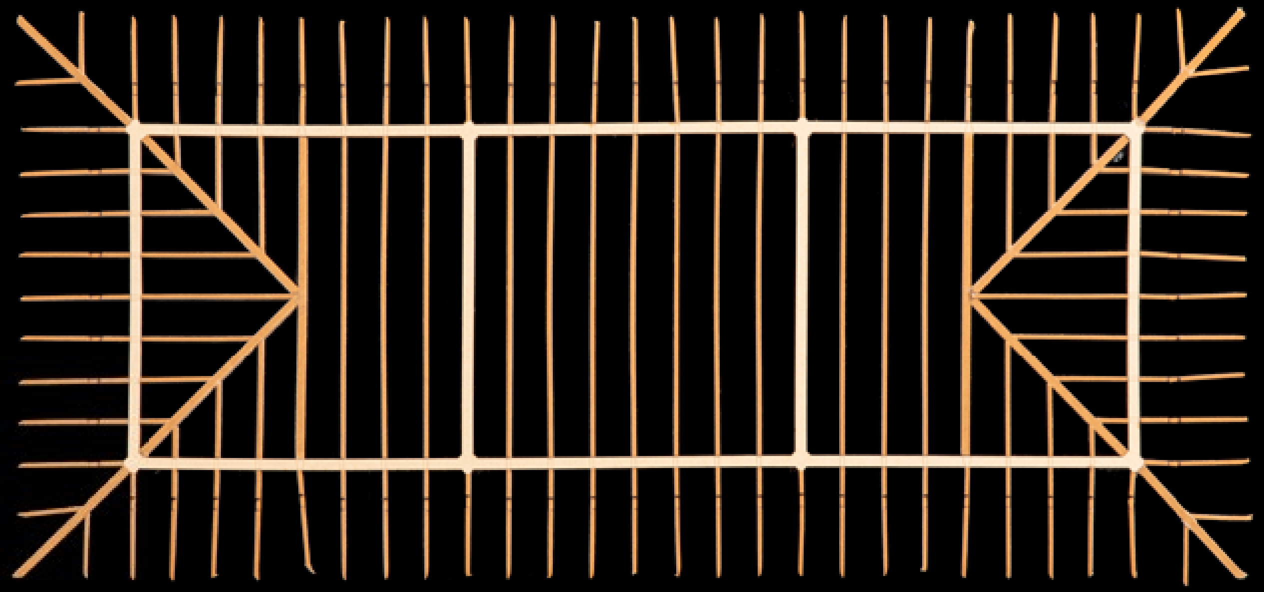




The structure is designed to be exposed, with almost no additional finishes. The walls are loadbearing and insulated, supporting the dead load of the roof and resisting the wind and seismic loads. They are constructed with aggregates from the region in a dry cementitious mix, and tamped in horizontal layers. The roof is based on a standard industrial product – reinforced concrete double-T beams – which span onto a grid of reinforced concrete beams. The exposed structure of the roof and walls provides a high thermal mass and reduces the heating and cooling requirements of the internal volume.

Client: Région Languedoc Roussillon
Area: 8,765 m²
Structural Engineer: Foster + Partners, SECIM
Environmental Engineer: Foster + Partners, Technisphere

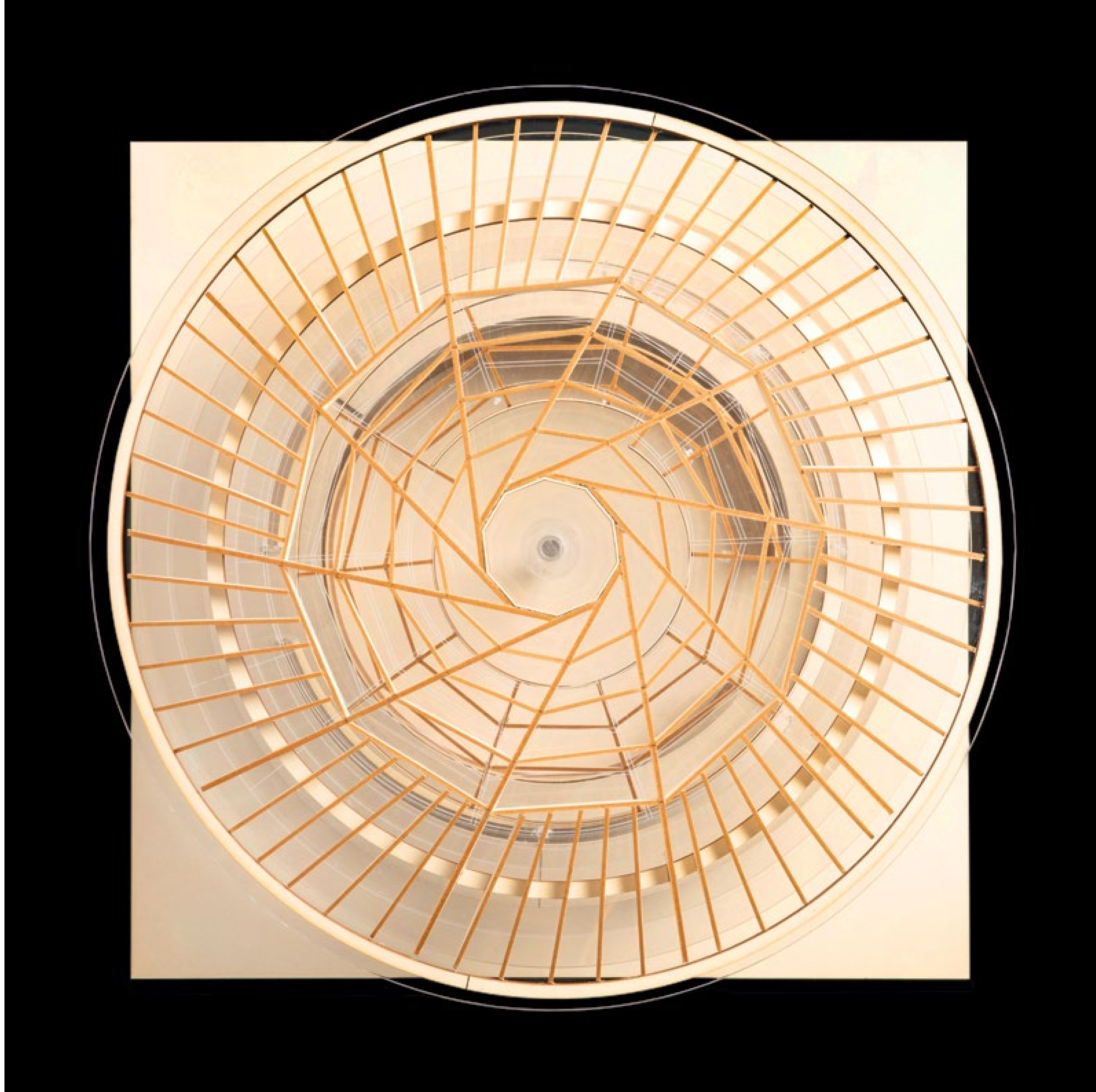

Marseille Vieux Port
France
2011 — 2013



Conceived as a single element to provide shading beside the old port in Marseille, the detailing of this canopy is minimal. The perimeter is a single thin line, with the gutter set back inside the roof, with the canopy structure orientated to avoid an edge beam. Lateral stability is provided through frame action of the columns, which are fixed both at roof level and by the ground beams that connect the column bases.

Client: Marseille Provence Metropole
Area: 1000 m^2
Structural Engineer: Foster + Partners, Ingerop
Awards: Eiffel d'architecture en acier - Prix Special

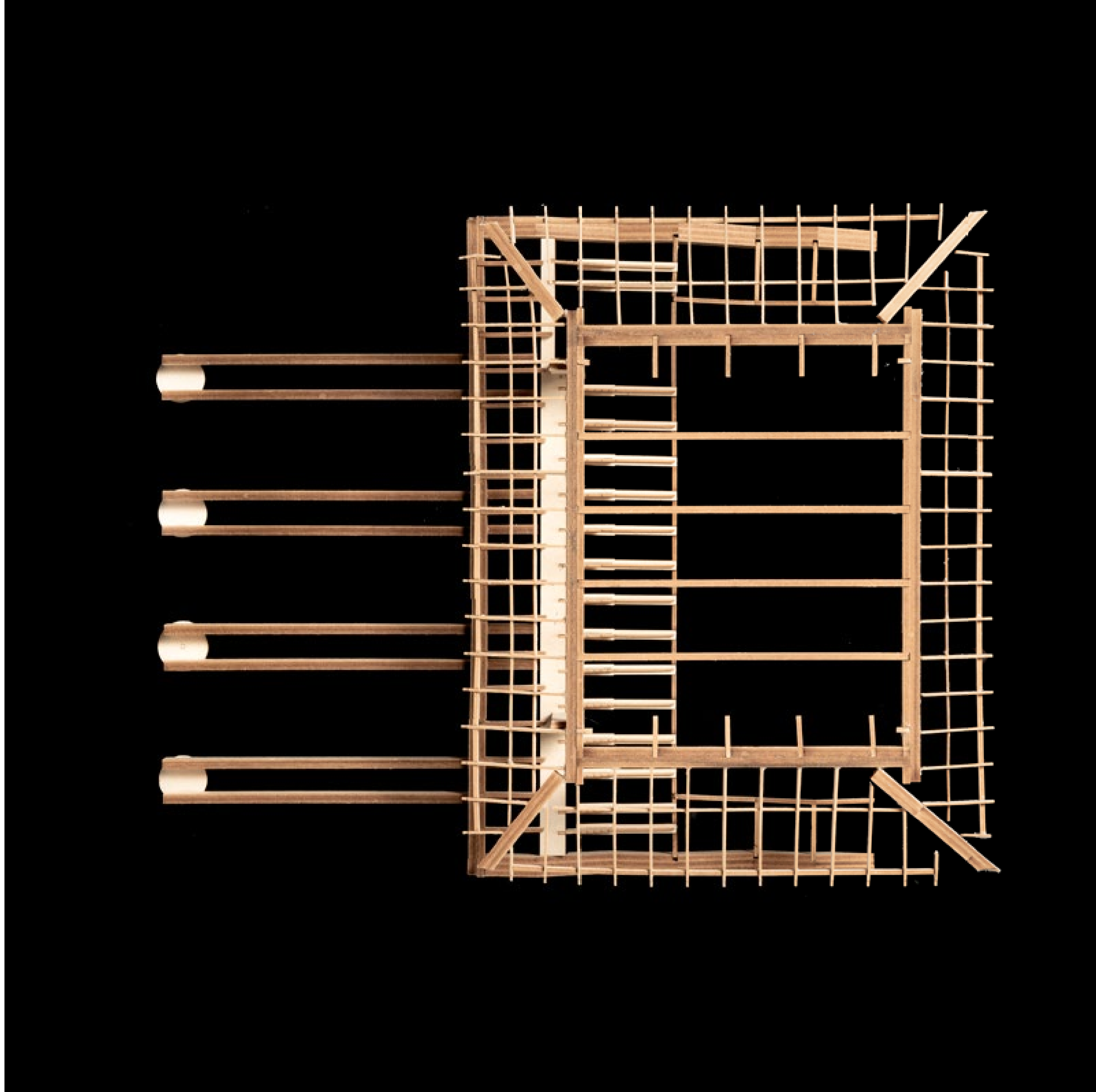
Le Dome Winery
France
2019 — 2022

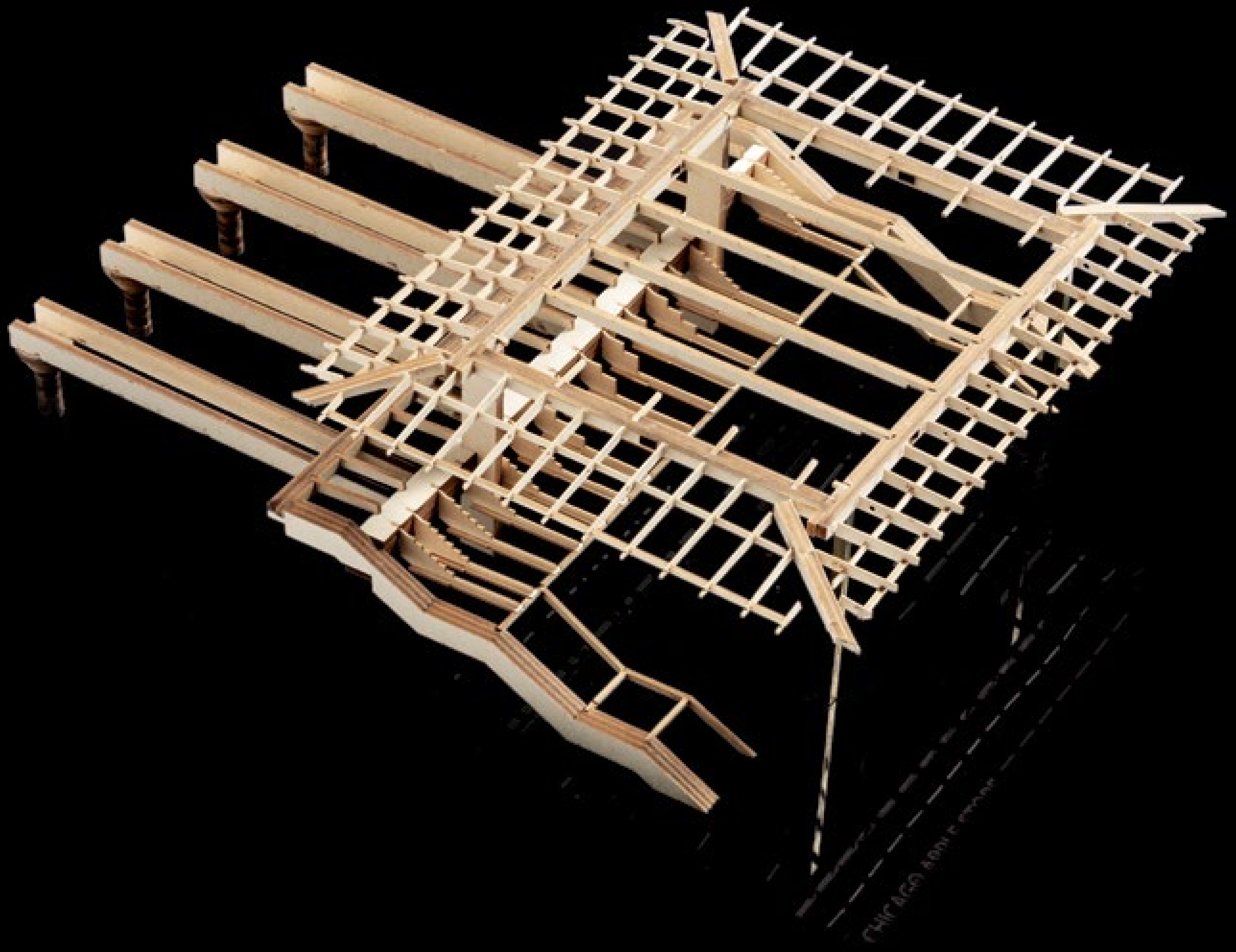


The structure of this new winery spirals up through the fermentation space to the top floor with panoramic views across the vineyards of the Le Dome Domaine. The roof is a structural timber dome where a central opening is created by rotating each of the roof beams. The circular structural geometry continues down through the volume to create a single cohesive building form.

Client: Château Teyssier
Area: 1200 m^2
Structural Engineer: Foster + Partners
Contractor: Bau + Empty

Apple Michigan Avenue
USA
2015 — 2017



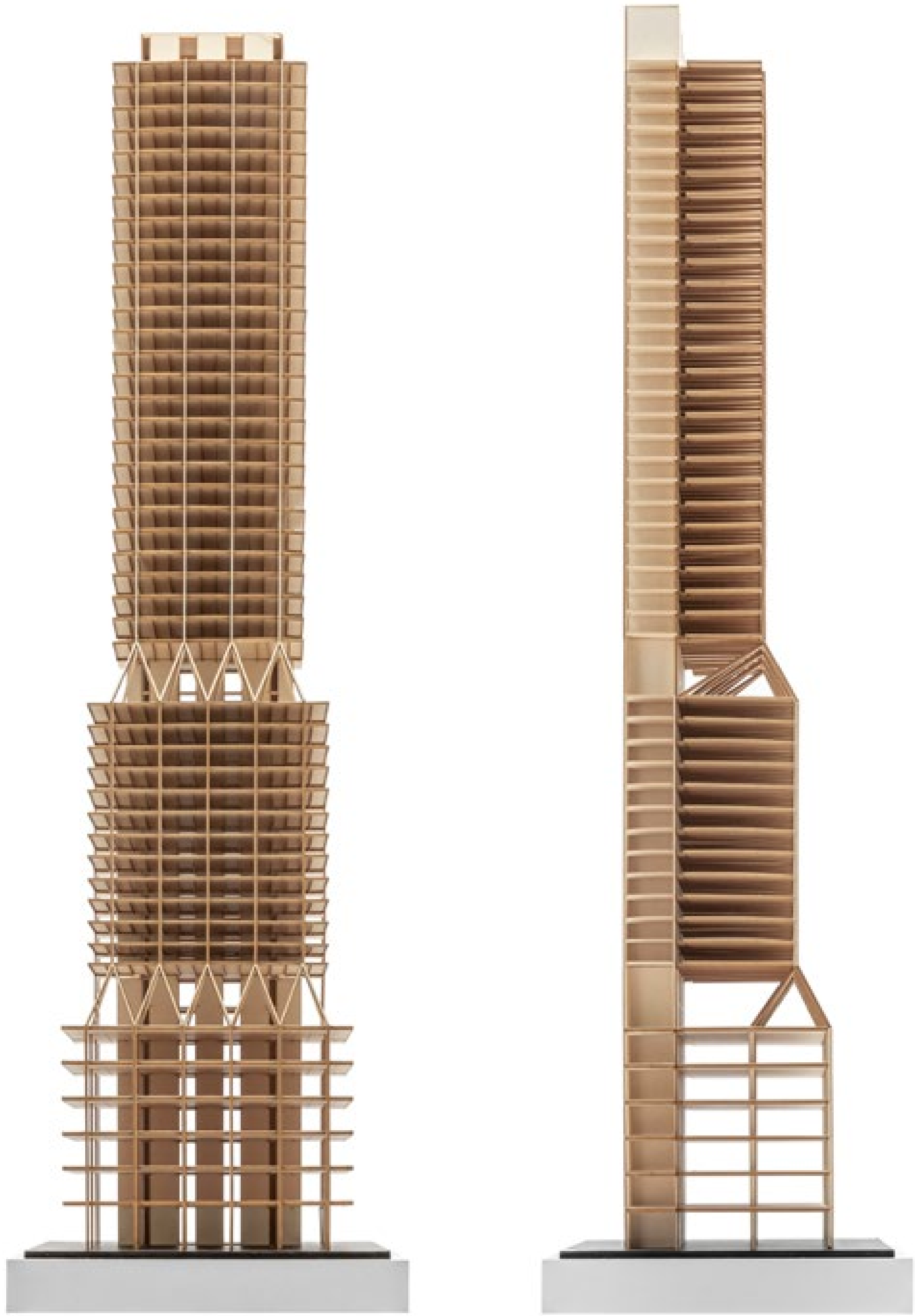


The central space is covered by a thin tapering roof that cantilevers approximately eight metres beyond the façade on each of the four sides. This structure is supported on only four steel columns to minimise the structure, while a mezzanine balcony cantilevers into the generous interior.

Client: Apple Inc.
Area: 2,415 m²
Structural Engineer: Foster + Partners, Simpson Gumpertz Heger (Engineer of Record)
Environmental Engineer: Foster + Partners, Cosentini Associates
Award: American Institute of Steel Construction – Merit Award


HOWELLS & HOOD

425 Park Avenue
USA
2012 — 2021



The design concept initially arose through the detailed analysis of the prescriptive volumetric requirements of New York's planning laws.
The structural philosophy is a direct manifestation of the vertical and lateral forces acting on the building. A single line of vertical columns on the front of the tower works with the core at the rear to provide the vertical support to the floors. The bifurcation of these columns at two levels over the building height connects them to the tower core and resists lateral loads. There are no hidden trusses or bracing – the tower structure is a visible reflection of the forces that it resists.

Client: L&L Holding Company
Area: 64,193 m²
Height: 260 m
Structural Engineer: Foster + Partners (Conceptual Design), WSP Cantor Seinuk
Environmental Engineer: Foster + Partners (Conceptual design), WSP Flack + Kurtz

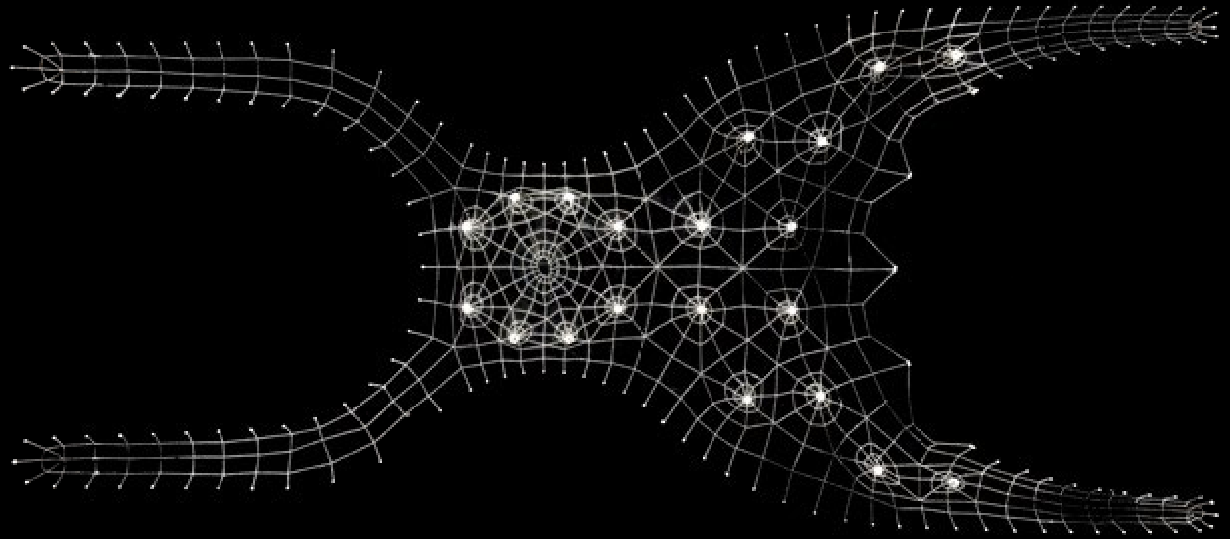
Ocean Towers
India
2016 — 2020 (Design)

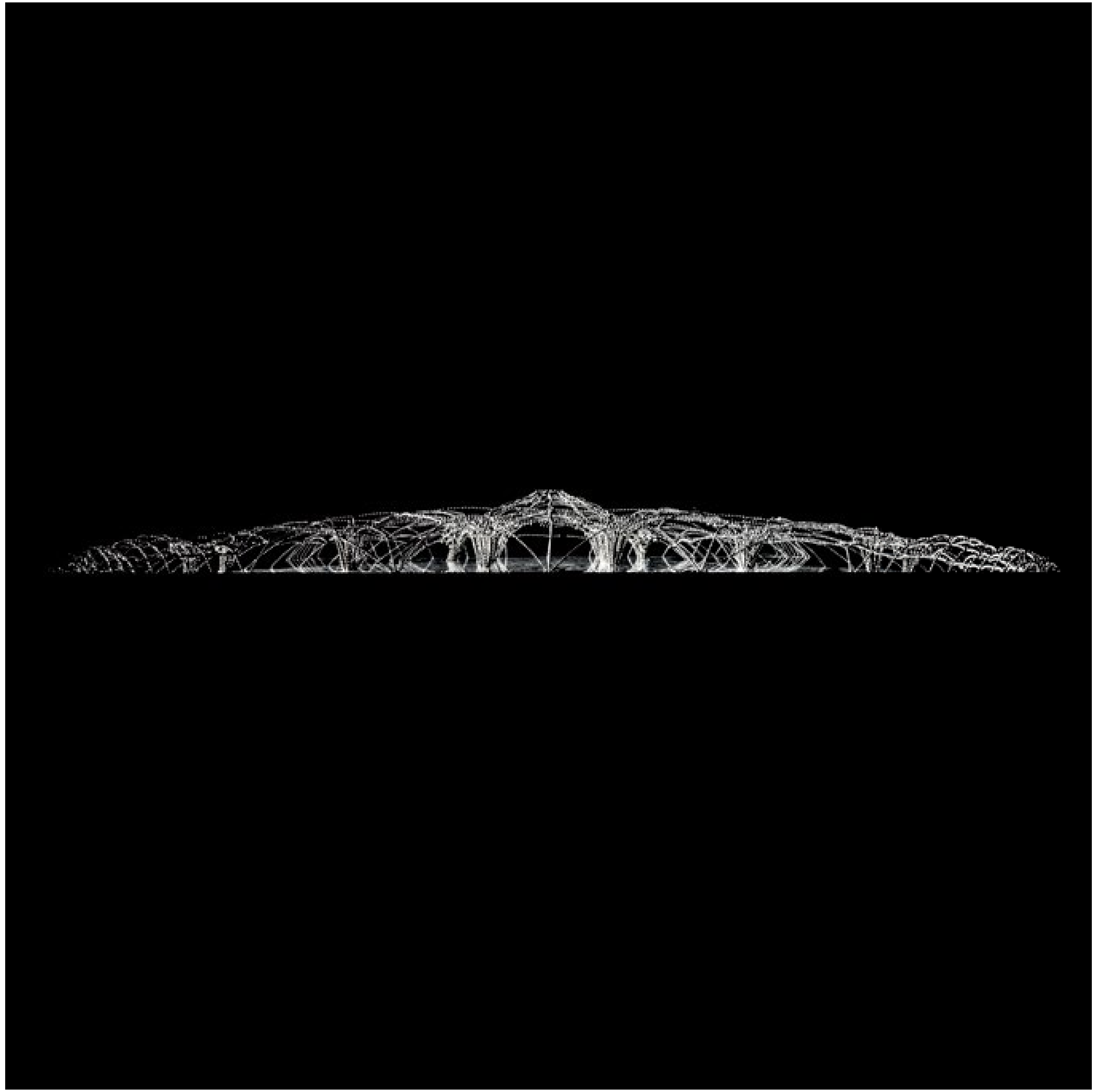


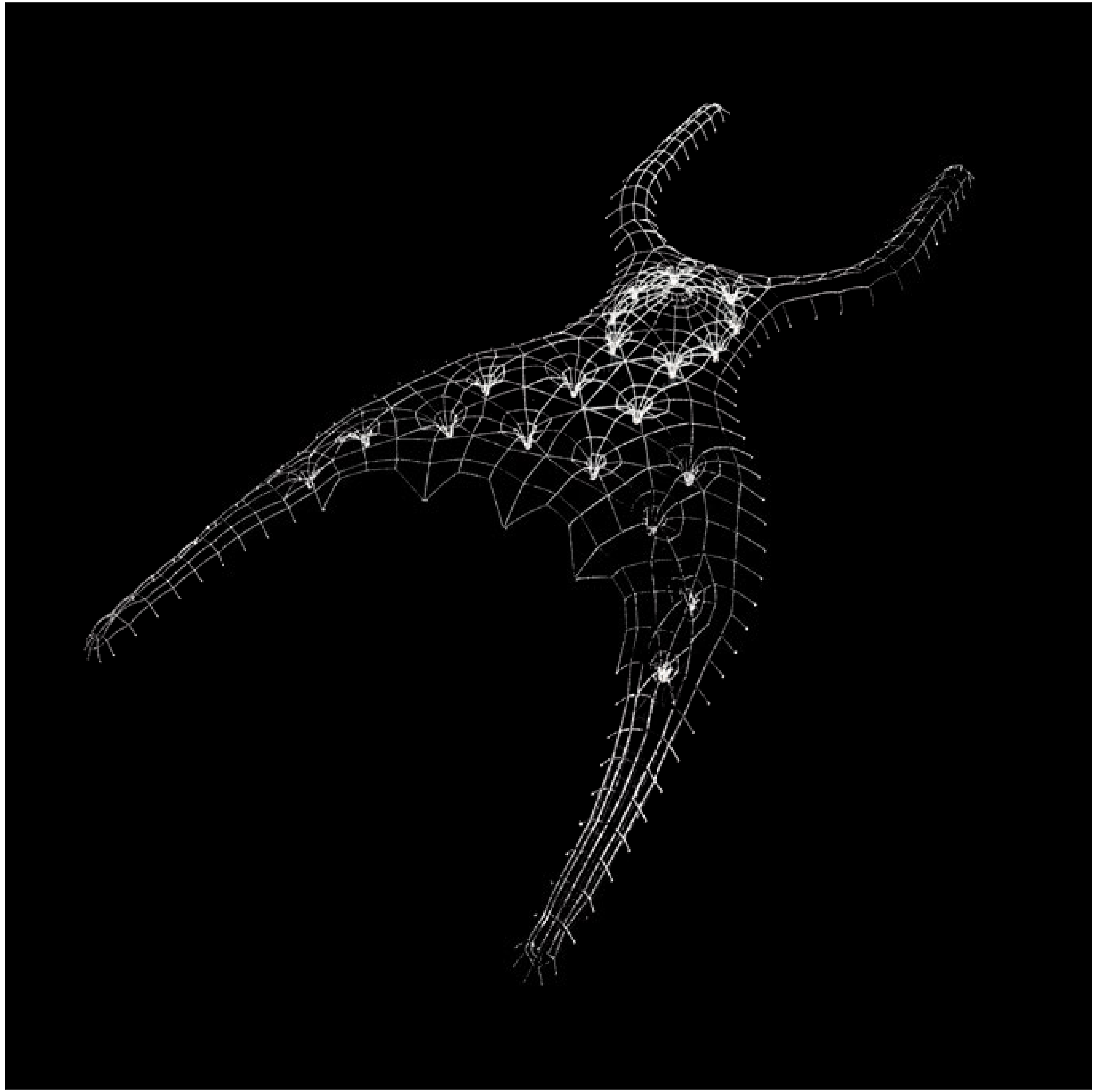
The structural concept for the proposed Ocean Towers in Mumbai arose through the client's strong preference for the living rooms of all apartments to have the same view - facing the sea. This gave a single orientation to the tower, with the aim being to keep all service rooms and circulation to the rear. The cores are deep enough to provide the lateral stability. Three sets of outriggers over the tower's height provide the strength and stiffness required in the orthogonal axis. As a result, there is no need for additional columns around the perimeter and views to the sea are maximised.

Client: DB Hospitality Private Limited
Area: 156,453 m^2
Height: 331 m
Structural Engineer: Foster + Partners (towers), Meinhardt (basement)
Environmental Engineer: Foster + Partners, Meinhardt

New International Airport Mexico City
Mexico City
2014 — 2018 (Design)







This new airport was to be situated on the site of a drained lake in Mexico City. The roof was designed as a doubly curved shell, This resulted in an exceptionally lightweight structure, minimising the seismic loads, which are proportional to the selfweight of the building. The soil of the area was extremely soft, with a high water content, and in addition the site has undergone significant settlement due to the extraction of water from the sub-surface aquifer. The roof form was designed to be inherently capable of accommodating the resulting ground movements that occur on the site. A hanging chain model demonstrates the load carrying capabilities of the roof's structural form.

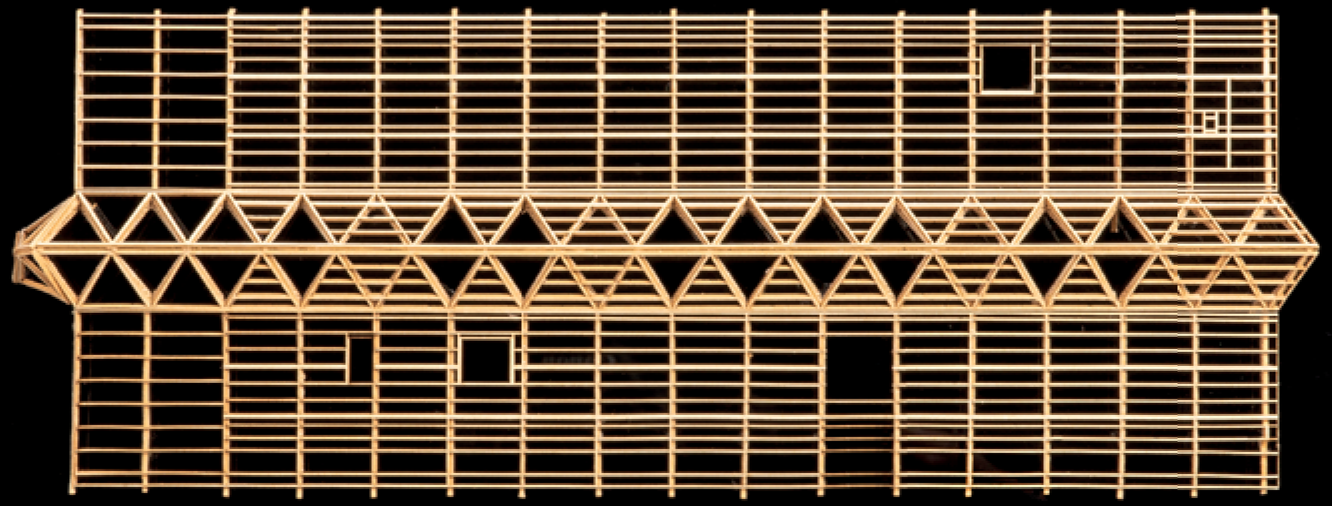
Client: Grupo Aeroportuario de la Ciudad de Mexico
Area: 743,000 m²
Structural Engineer: Foster + Partners (Conceptual Design), Arup
Environmental Engineer: Foster + Partners, Arup

Vatican Chapel,
Pavilion of the Holy See
Venice Biennale, Italy
2017 — 2018


The superstructure is a tensegrity structure of steel masts and cross-arms, braced by prestressed steel cables and small circular hollow sections. Thin larch timber slats create the shaded enclosure. The connections between the timber slats and the tensegrity structure are designed to slide independently to ensure that the slender slats are not overloaded by the wind. While each slat is unique, the design and detailing of the end connections ensured that they could be rapidly fabricated and constructed to meet the tight installation schedule.

Client: Pontificio Consiglio della Cultura, The Vatican
Area: 128 m^2
Height: 6.80 m
Structural Engineer: Foster + Partners, Tecnobrevetti

Maggie’s Manchester
UK
2013 — 2016



The timber structure defines the interior and overall geometry for this building. A central spine contains the administrative and services spaces, with the roof spanning over each side to enclose the public and meeting spaces.
Laminated veneer lumber trusses are used for both roof and spine. They provide both the lateral stability across the building, and vertical support to the roof. The form and density of the trusses is optimised according to the forces they resist; any part that is superfluous has been removed.

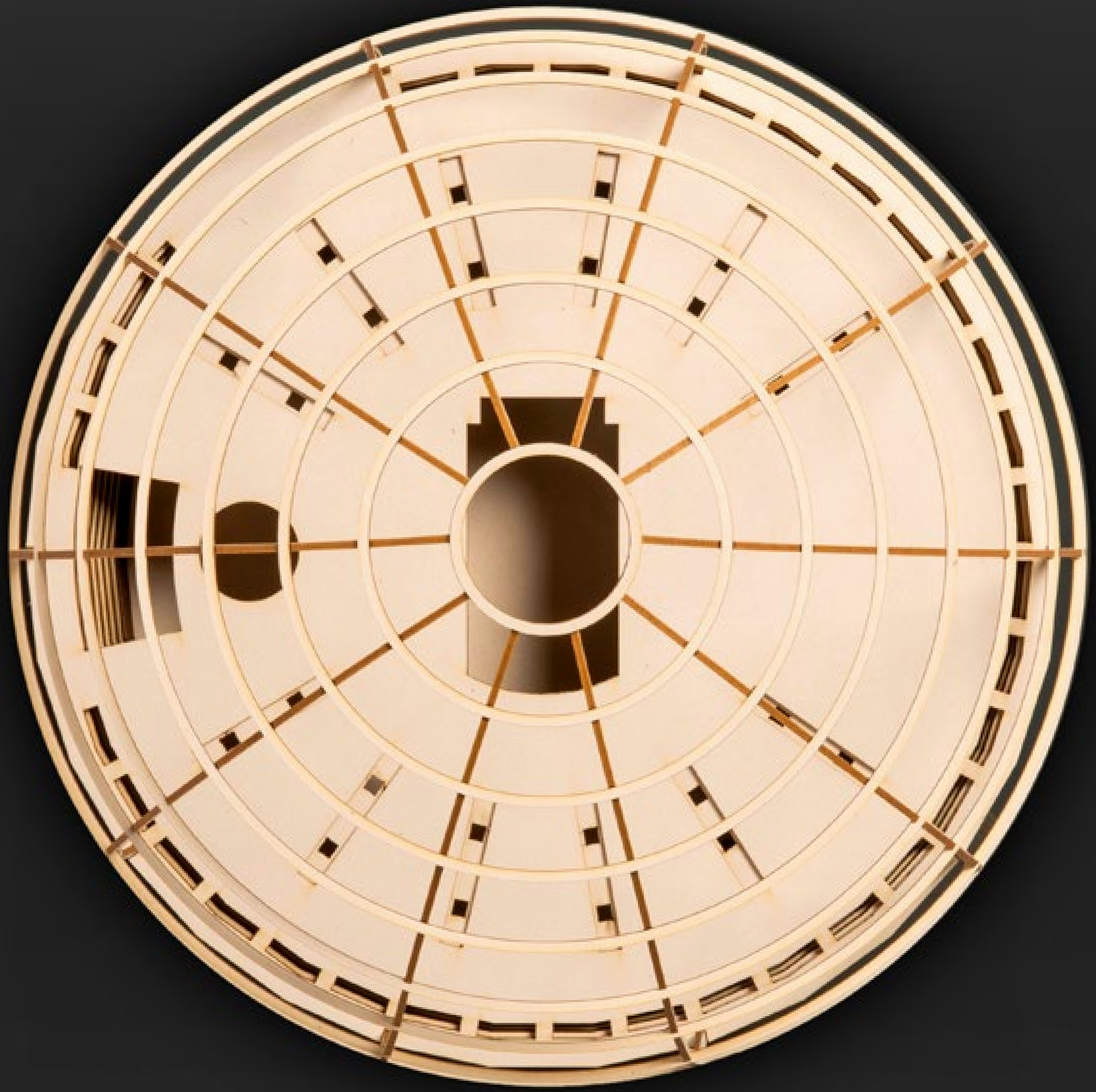
Client: Maggie's Centres
Area: 730 m²
Structural Engineer: Foster + Partners, SJP (RIBA 4)
Environmental Engineer: Foster + Partners
Awards: UK Wood Awards - Arnold Laver Gold Award, UK Wood Awards – Structural Award

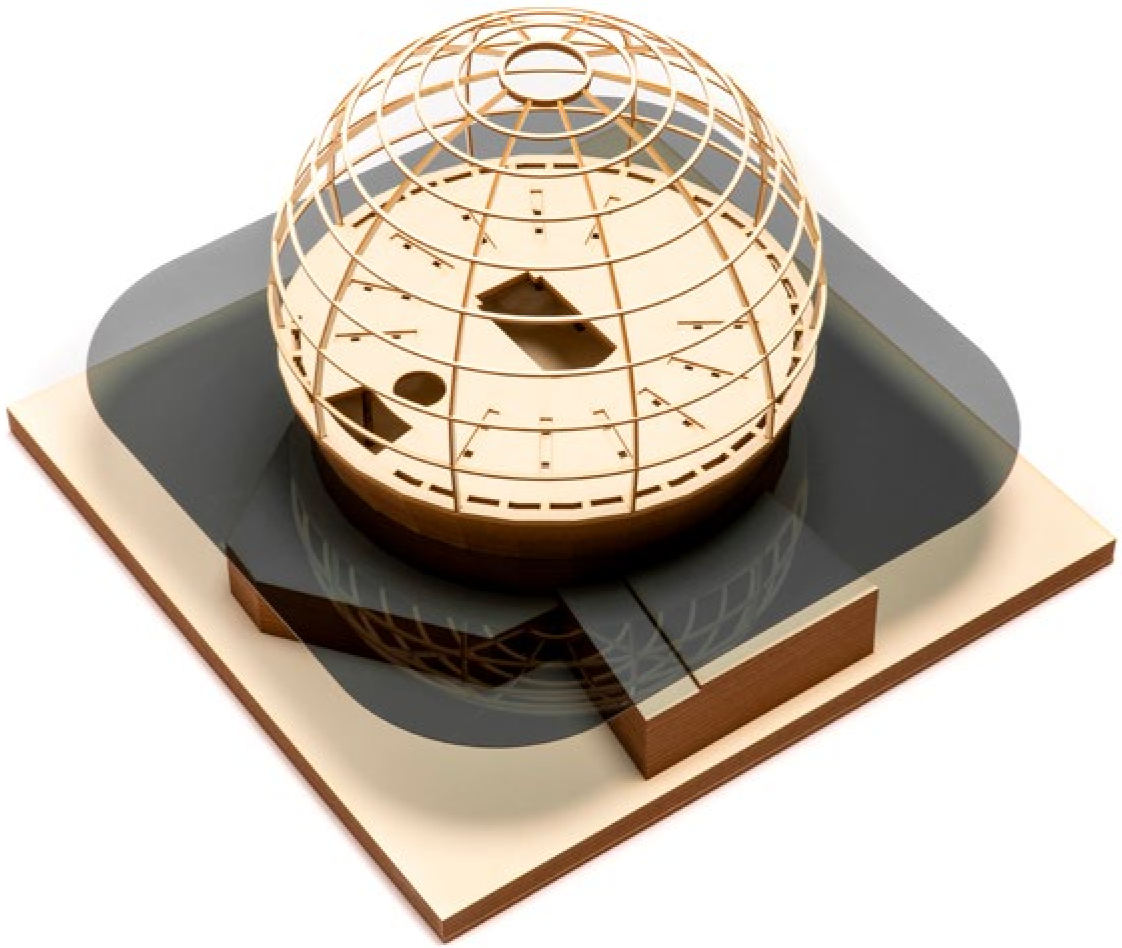
Apple Westlake
China
2013 — 2015

The first of a new generation of store designs for Apple, the mezzanine floor cantilevers 12 metres into the space and tapers to ten centimetres at its tip. Tuned Mass Dampers installed inside the steel structure control movements at this level. Services and lighting are tightly coordinated into the confined floor and wall spaces.

Client: Apple Inc.
Area: 2,896 m²
Structural Engineer: Foster + Partners, Tongji
Environmental Engineer: Foster + Partners, Tongji

Apple Marina Bay Sands
Singapore
2016 — 2020





One of the unique features of this 30 metre dome structure is the structural interaction between the steel ribs and the glass panels. The glass panels provide bracing against buckling to the steel members, as well as stiffening the entire enclosure against lateral loads. The resulting steel structure is exceptionally small, with the ribs dimensioned at less than 1/200 of the dome span.

Client: Apple Inc.
Area: 2,575 m^2
Structural Engineer: Foster + Partners (Concept and Schematic Design), EOC, Gartner
Environmental Engineer: Foster + Partners (Concept and Schematic Design), Mott Macdonald, Grand Work
Award: UK Institution of Structural Engineers – Construction Innovation Award

Structural engineering team
Since 2011

Roger Ridsdill Smith ▪ Adrian Parkinson ▪ Andrea Soligon ▪ Xiaonian Duan ▪ Jeng Neo ▪ Nathan Langdon
Yue-Qi Hou ▪ Eli Barone ▪ Matthew Thomas ▪ Rupert Inman ▪ Wenyi Wang ▪ Ash Rahman ▪ Giuseppe Maugeri
Kamil Dassouli ▪ Keith Lam ▪ Miguel Martinez Paneda ▪ Mingchen Liu ▪ Riccardo Carapellese ▪ Sylvain Pihet ▪ Brian Nolan
Amy Burruss ▪ Marti Nagy ▪ Achilles Pistolas ▪ Akos Medek ▪ Alessandro Bordigoni ▪ Andrea Calabrese ▪ Andrew Davis
Andy Coward ▪ Angela Vanezi ▪ Antonio Villani ▪ Arthur Lapeyrere ▪ Babak Niai Tizkar ▪ Bhavik Sondagar ▪ Bo Miao
Carole Frising ▪ Davide Conti ▪ Dimitra Kotsi ▪ Diogo Botelho ▪ Eleni Toumpanaki ▪ Franek Ryczer ▪ Frederick Ellul
Giuseppe Lucibello ▪ Harry Rogers ▪ Helene Huang ▪ Ilyas Pisirici ▪ Irene Del Valle De La Sen ▪ James Bishop
Jessica Wade ▪ John Larkey ▪ Joseph Camajani ▪ Joseph Dimery ▪ Karl Micallef ▪ Loukas Oikonomakis ▪ Mateusz Bloch
Nikolaos Lantzounis ▪ Francisco Cedron ▪ Pedro Carvalho Costa Pedro Nave ▪ Ricardo Candel Gurrea ▪ Sean Kelly
Shuo Tian ▪ Simone Avellini ▪ Stavros Tseranidis ▪ Thang Vu ▪ Tom Carr ▪ Tommy Browne ▪ Yasmine Granger ▪ Zhi Zhao
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