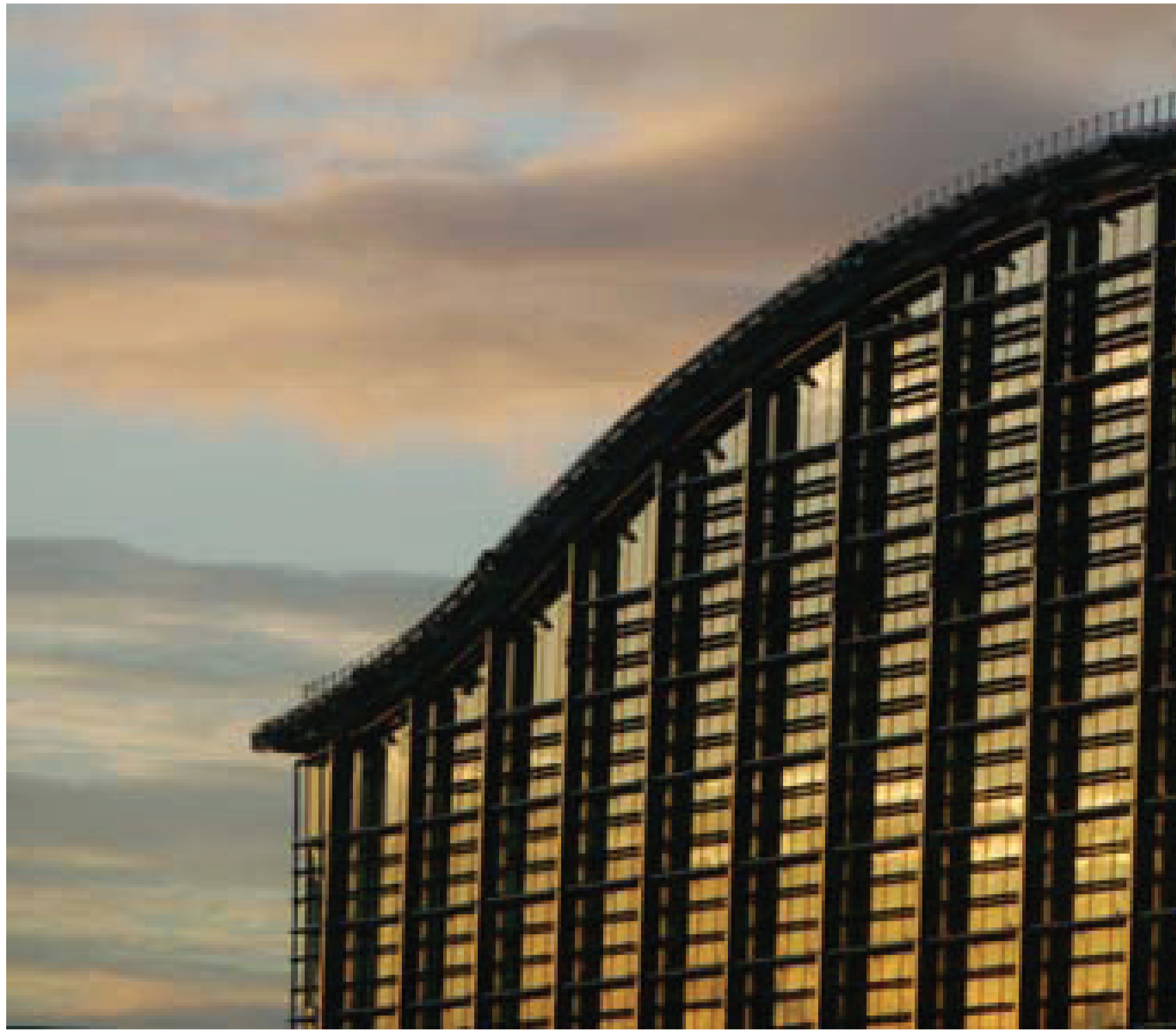


IABSE Outstanding Structure Award – Heathrow T5A

IABSE British Group – June 2009



Terminal 5 at Heathrow is a major new transport interchange for London. The client, BAA, wanted to create a building that would have a place amongst the great interchanges of the world and provide a memorable experience for travelers. As a result, the main terminal, T5A, is characterised by open space, natural light, simplified passenger circulation, shorter walking distances and spectacular airfield views.

T5 Agreement

The T5 project was of such importance to BAA, that the firm was willing to bear all the financial risk of the project, ensuring its suppliers were able to work together in integrated teams – essential for delivering a project of this size, on time and on budget. The T5 Agreement, a bespoke partnering contract, was fundamental in allowing the project team to tackle the technical challenges involved.

Design

All aspects of T5 were planned and designed for every stage of construction to ensure maximum safety and minimal site risk. However, neither the visual quality nor usability of the building was compromised. The architects used this focus as an opportunity to express the building's engineering. The structure and its connections and details became sculptural objects in themselves. Exposed welds, as-cast steel surfaces, and visible bolts create a feeling of scale and a grain to the building

Structure

The 156m clear span roof encloses 3 million square feet of floor space

framed in steel over 3 storeys. A 5 storey basement houses the rail station and plant spaces. The unconventional height of the building was in response to the challenge of having to build within the constraints of two runways and the greenbelt beyond them.

The shell of the building, along with all the columns and beams supporting it, is completely separate from the four floors of accommodation it encloses. As well as providing open spaces all round the perimeter and across the top of the building, this has a significant practical long-term purpose; it provides the ultimate in flexibility, as the four floors can be completely demolished and rebuilt in a different configuration without touching the perimeter walls and roof.

The structural form moves most under asymmetrical or uneven wind loading, so the project team had to protect the façade and roofing from damage by excessive movement. It was uneconomical to make highly pessimistic assumptions about how wind pressures might be distributed so 'Dynamic time history wind analysis' allowed the team to apply data to a computer model of the roof to understand the movements, taking into account the varying wind pressures, the building's structural behaviour, and its inertia. This ground-breaking technique gave a more accurate estimate of deflections in service, resulting in the saving of 800 tonnes of steel by reducing the rafter flange thickness from 85mm to 70mm.

Roof

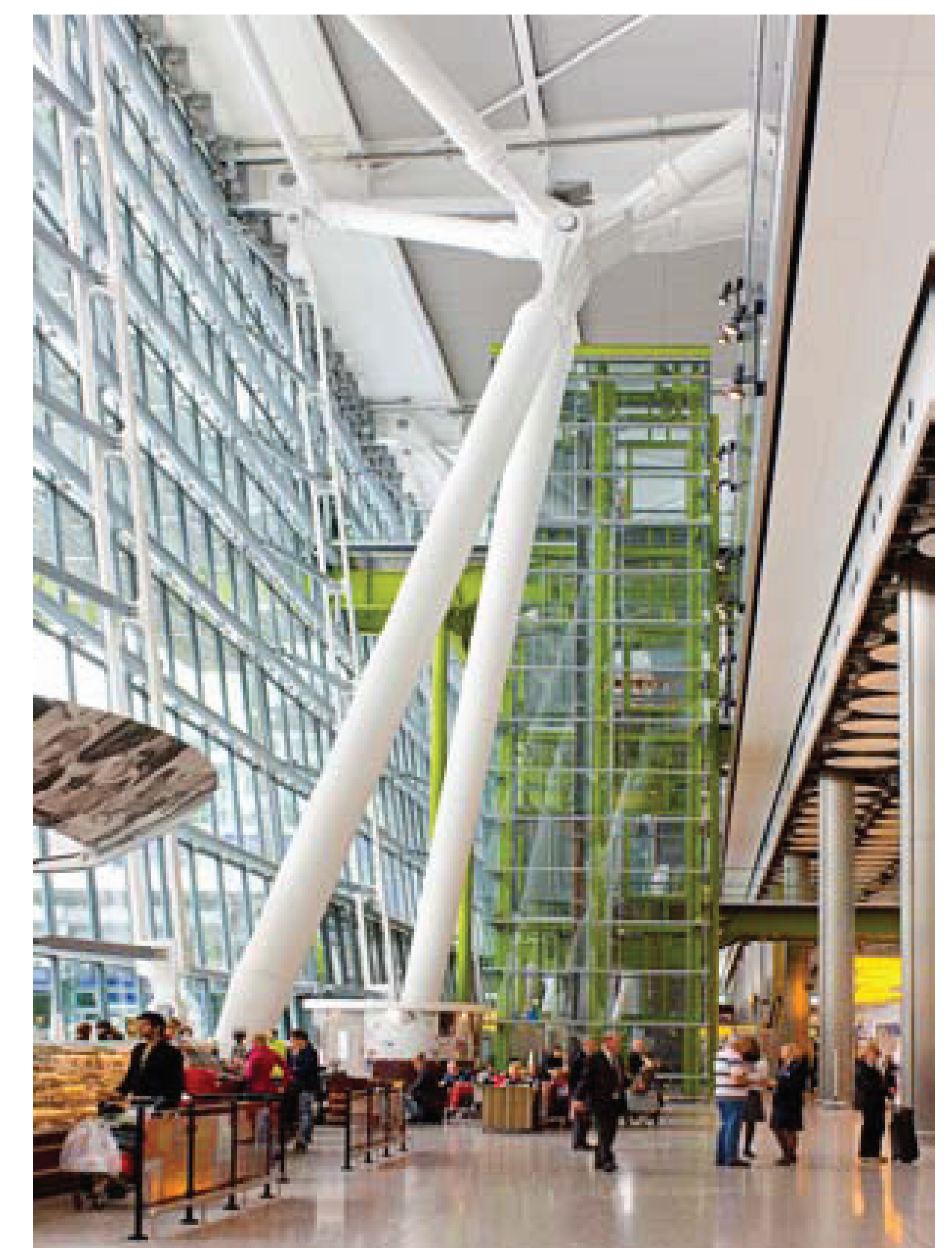
The T5A roof is an awe inspiring structure that arches over the terminal building. The roof carries huge compression forces which are essential to prevent the buckling of its individual parts and of the structure as a whole. One of the pioneering analysis techniques employed on this project was modal buckling analysis. This calculated the effective reduction in lateral stiffness that is caused by compression forces within the structure and used eigenvector analysis to predict the most critical possible buckling modes. The mode

shape data was then processed to give sets of design forces, ensuring a consistent reserve of strength against buckling, without providing extra strength where it was not needed.

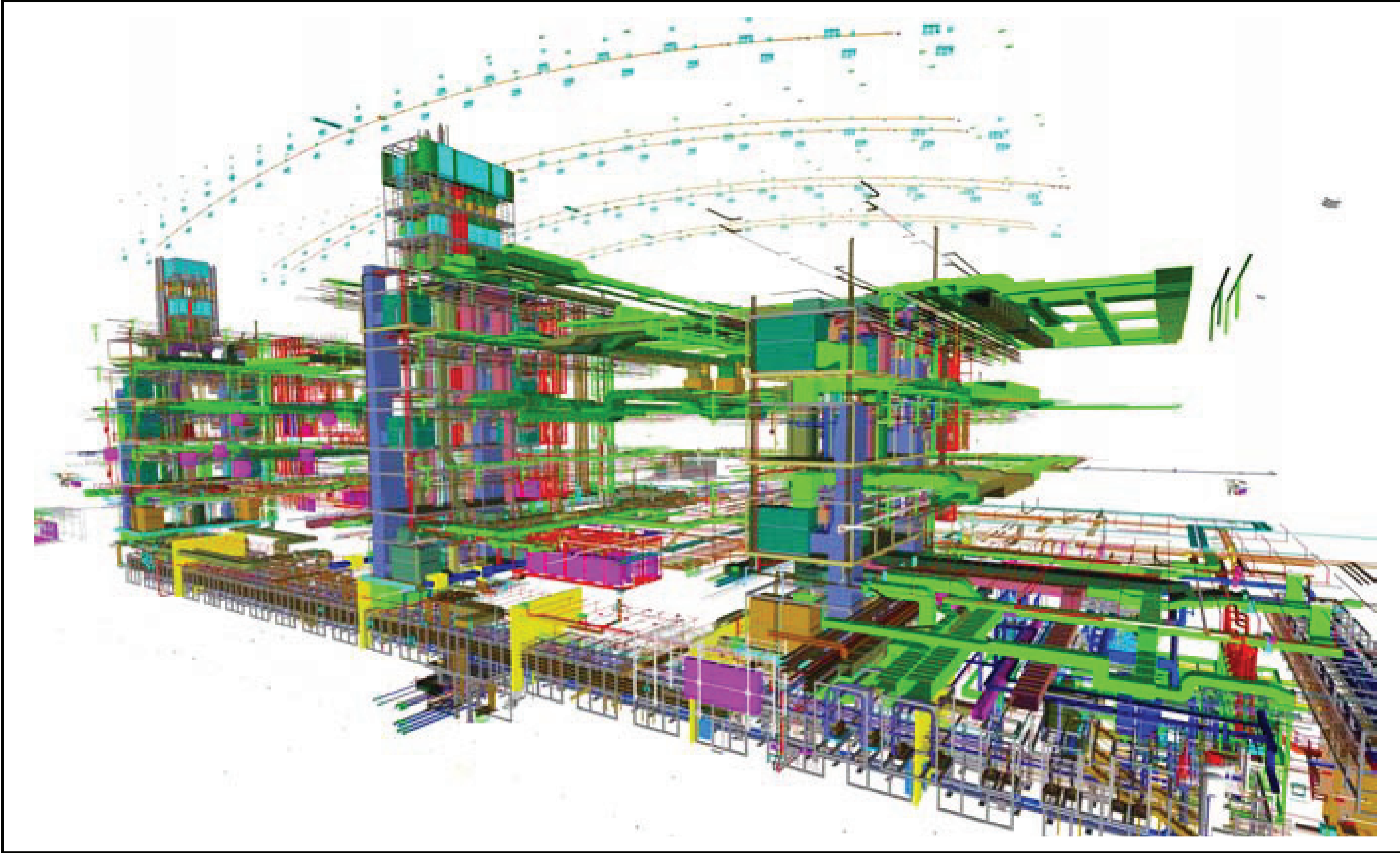
However, the clear-span roof could only be realised if there was an erection method that would make the structure fast and efficient to build. The central arched section of the roof needed to be assembled, clad, and pre-stressed at ground level before being lifted into position using strand jacks. This creative approach was vital to ensure that the whole operation could be carried out below the airport radar ceiling and that the risk from working at height would be reduced. This idea became an integral part of the building design and construction planning of the whole terminal. The critical path went straight from completion of the basement slab to roofing and facades, resulting in an early watertight date and notable time reduction in the overall programme.



Departures lounge



Arrivals lounge



3D model of internal structure and services

Rafters

The massive steel rafters fly for 175m over check-in, security, and the gate seating. They define the direction of travel from land-side to air-side, diffusing daylight into the space. They are the primary structural elements of the 156.6m span. The central sections, where primary forces are compressive, are fabricated box sections up to 3.8m deep. Over the abutments where forces were tensile, and lateral torsional buckling was not an issue, I sections were used. The central section became a self contained element in the temporary state once it had been pre-stressed by the high level tie cables. This allowed the central section of the roof to be lifted by strand jacks.

Torso Node

The engineering of the torso node was a turning point in the aesthetic definition of the structure. The aim was to find a way to carry compressive forces of up to 18,000 kN through a complex geometry, in a way that was adjustable. This was to address difficulties with fit on site and to avoid heavy site welding with its safety risk and the risk of weld failure. The creative solution used simple plates, flame-cut to shape and fitted together dry, using machined surfaces only where force was transferred. The distinctive and inspiring result of this piece of pure engineering is an iconic part of the building.

The hand node transfers the vertical roof load from the rafter into the supporting CHS structure. To minimise the eccentricity of the connection, the node was placed at the centroid of the rafter, allowing force to be applied at the most efficient point possible. The node is the connection point for the pre-stressed high tie cables and it is also the springing point for the central arch section in the temporary state. The main rafter splice just outboard of this node was the last major connection to be made in the erection process.

Façade

In order to enhance the traveller experience, the façade needed to allow passengers to view the airfield. Maximum visual transparency was vital. The primary vertical elements, or straps, had no web plate to form a visual barrier; instead relying on vierendeel action and tension stiffening from their role as a part of the roof structure. The weight of glass and steel is carried to apron level by a series of 139 diameter steel props. Threaded rods were incorporated into the prop design, allowing the support steel to be adjusted and preventing a mis-match of tolerances between steel and the cladding system. Brises-soleils reduced the building cooling loads and consequent carbon emissions. On the land side of the building the glass was laminated and the framing was enhanced to resist blast loading from a terrorist attack.

Sustainability

From the outset, T5 targeted the 'triple bottom line' of people, planet, and profit. The project minimised the use of non-sustainable materials and re-used aggregates produced on-site from demolition. Energy efficient fittings were specified throughout T5 and waste heat from the CHP station supplies 85% of the buildings heat demand. A rainwater harvesting scheme and groundwater boreholes reduce the demand from the public water supply by 70%, whilst all toilets, taps and showers are fitted with water saving devices. Surrounding communities and ecosystems also received careful attention throughout the design, construction and operation of T5.

Owner:
BAA Airports Ltd

Architects:
Rogers Stirk Harbour
Pascall + Watson
Chapman Taylor (retail)
HOK (Stations)

Structural Design:
Above apron level: Arup
Below Apron level: Mott Macdonald

Contractor:
Laing O'Rourke, Mace, Amec, Rowan Watson,
Schmidlen, Hathaway Roofing, Spie Matthew Hall
Services