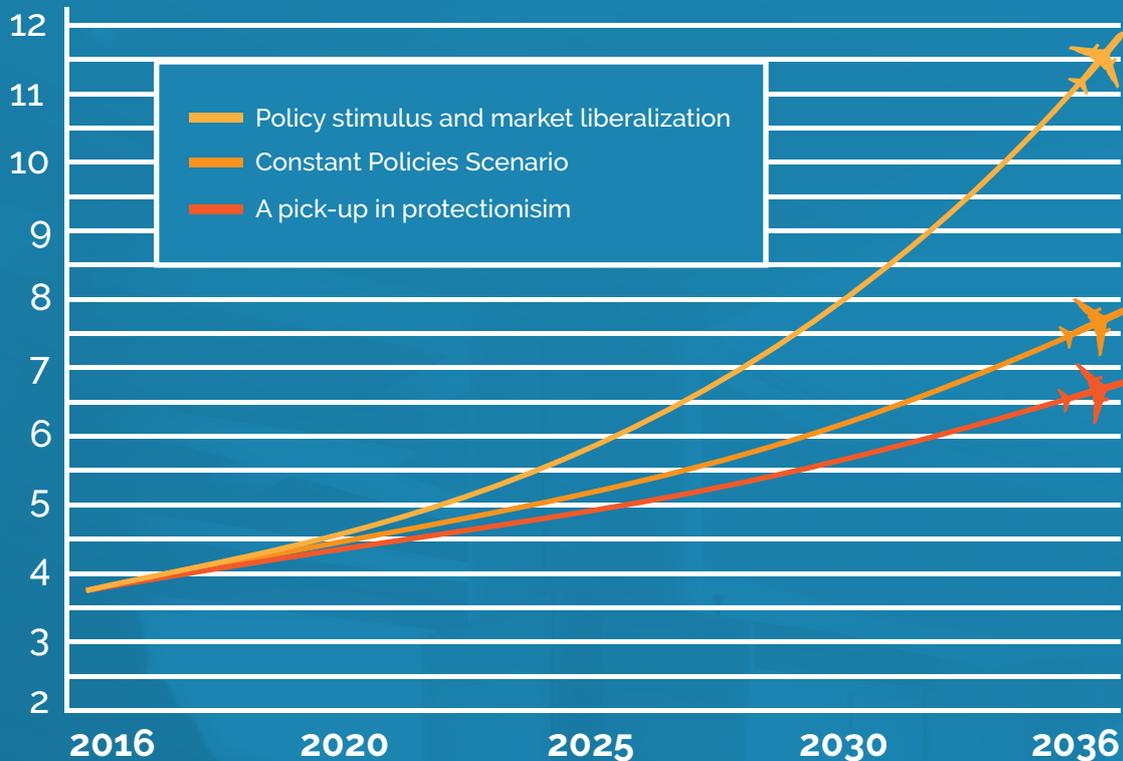




QR5

Quarterly Review
2019

Global Passengers (billion, segment basis)



The global volume of airline travel is expected to almost double in the next 20 years – from 3.8 billion in 2016 to an estimated 7.2 billion in 2035.

There are many reasons why aviation will remain one of our most dynamic industries. For starters, apps like Skype or WeChat that bring people together virtually seem to spur the desire to replace online experiences with real ones. Browse Google Maps for an hour, get drawn into a newly discovered place, then awaken the desire to see it for yourself. In today's world, more and more people dream of sharing those experiences in real life, with closest friends and family, in a way that Instagram and Facebook can never replicate.

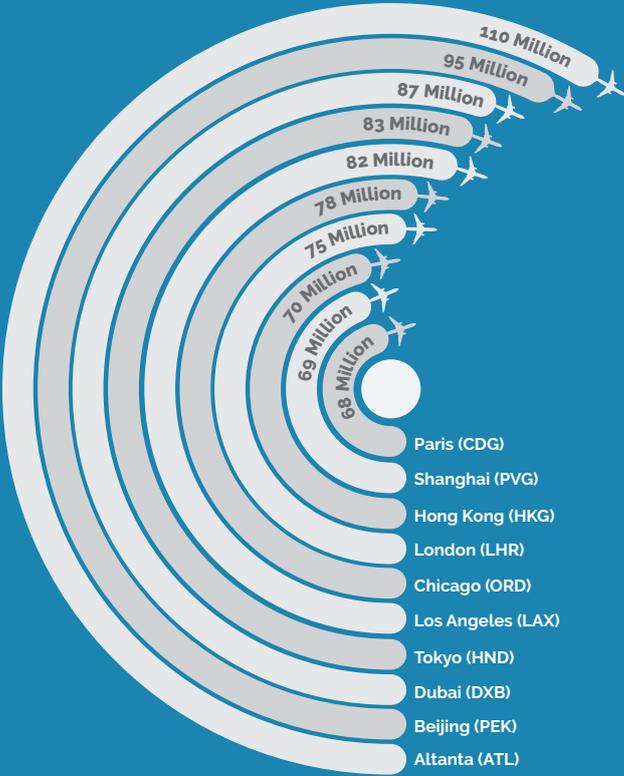
A parallel phenomenon is the world's rapidly expanding middle class - the most notable being China. From 1995 to 2015, Chinese airline passenger travel soared from 68 to 728 billion kilometres. As the aeronautical industry develops more efficient and diversified modes of air transportation, literally billions of people can afford to fly for the first time in their lives, and they have more destinations than ever to choose from. Voyages that were once-in-a-lifetime for our great-grand-parents are routine for many of today's millennials.

The online retail revolution is yet another driver of the aviation industry's relentless need to grow. Amazon has launched its own air freight service, PrimeAir, and plans to upgrade the existing air-cargo facilities in Cincinnati, USA. The new air logistics hub will feature a three-million-square-foot facility, with capacity to dock up to one hundred aircraft. Amazon is leading the tens of thousands of emerging on-line retailers that will rely critically on aviation to service their global customers.

It's not surprising, then, that investors are flocking to the aviation industry. The Economist (June 5, 2018) declared that "Investors' appetite for transport infrastructure remains undiminished." The report cites predictable long-term cash flows as a principal reason. In a world increasingly seeking sustainable, long-term investments with good cash flows, the aviation industry looks increasingly more attractive.

Aviation is its own unique, expanding "world wide web", with smaller terminals feeding into larger, regional hubs. The largest of these is Hartsfield-Jackson Atlanta Airport, which served 103 million passengers in 2017. Beijing Capital Airport is second, at just under 97 million. Dubai is third at 88 million, with London Heathrow ranked seventh at 78 million.

Top Ten Busiest Global Airports



With demand for new, larger and more hi-tech aviation facilities at a global high and only increasing, the challenge shifts to delivering this volume of infrastructure quickly, whilst still achieving high quality construction and regionally-appropriate design solutions to suit local climate and culture. In facing this challenge, Robert Bird Group continues to show leadership in the development of structural, civil and construction engineering solutions – innovations that unlock the ability to deliver massive, complex airline hubs on time, on budget, and with minimised risk.

The following pages highlight how our globally integrated team of specialists can achieve even the grandest visions of aviation's exciting future.





Addressing Complexities, Developing Solutions

RBG's involvement with Dubai International Airport, Terminal 3 demonstrates its ability to streamline performance through global teamwork.

Completed in 2008, Expansion Phase 2 made Dubai International one of the largest airports in the world, with the capacity to accommodate some 60 million passengers annually. Its Terminal 3 is a multi-level underground structure that included the world's largest baggage handling facility. The contractor, Al Naboodah Laing O'Rourke (ANLOR), brought in Robert Bird Group to explore and recommend engineering solutions to optimise budget and programme targets.

ANLOR set RBG project director Scott Wheeler, design leader Jason Langer, and a project team of about 30 staff, the challenge of aligning the structural design with their preferred construction methodology. This meant converting the large precast flooring units in the reference design – requiring massive crane capacity – into post-tensioned in-situ floors that required much less crane capacity. RBG's value-engineering solutions for over 300,000 square metres of floor plates – delivered in 14 months and approved by the Dubai Civil Aviation Authority following rigorous independent verification – included:

- Redesign of the Concourse apron, Departures level and Arrivals level, incorporating an alternative structural floor solution of in situ one-way band beams and slabs. Post-tensioned beams were adopted for the larger spans of up to 12 metres at the Departures level.
- Integration of travelator recesses into the structural design, to avoid the need for excessive floor toppings to achieve a flush finish for travelator users.
- The redesign of the carpark structure incorporating one-way post-tensioned band beams and slabs aligning with ANLOR preferred construction methodology and procurement strategy. Spans of up to 18 metres were achieved between columns, with beams only 800mm deep.

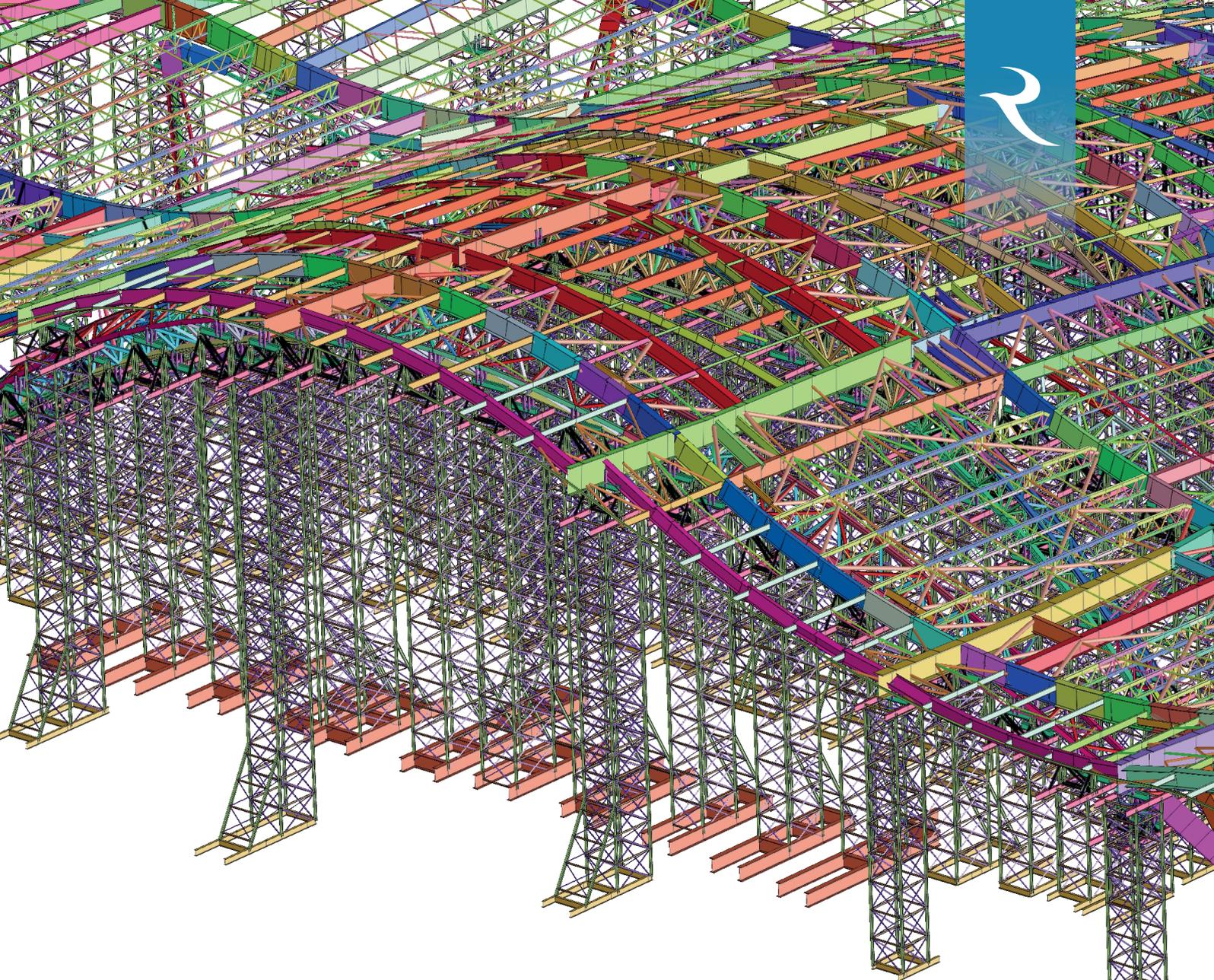
The detailed design, documentation, and approval submissions for the above alternative designs were a joint effort by RBG's Dubai and Brisbane offices. Just as importantly, Robert Bird Group ensured continuous support through all phases of its involvement, which was critical to addressing the project's 24/7 schedule and rigorous target dates.

The Mighty Arch of Abu Dhabi Midfield Terminal

When it opens in late 2019, the Midfield Terminal at Abu Dhabi International Airport will increase capacity to 84 million passengers annually, processing 11,000 passengers per hour along with their 19,200 pieces of baggage. The central space has the footprint of 21 football fields, including 35,000 square metres of duty-free shops, restaurants and entertainment. Spanning this mega-complex are some of the world's largest internal arches, some 180 metres across and 52 metres tall at their highest point.

For RBG engineers Ben Ringrose, John Ward and their team, the challenge was not only how to develop a construction method and sequence for the 20,000-tonne steel roof so that erection could be completed in an efficient manner, but also how to demonstrate the safety of the process at every stage of construction. Robert Bird Group was engaged by the contractor to undertake erection stress analysis of the roof to fully understand its performance in temporary conditions. To quote the team's professional paper, Construction Stage Analysis of a Long-Span Roof, "Analysis of this phase of a building's life can be difficult to undertake rigorously and is often overlooked."

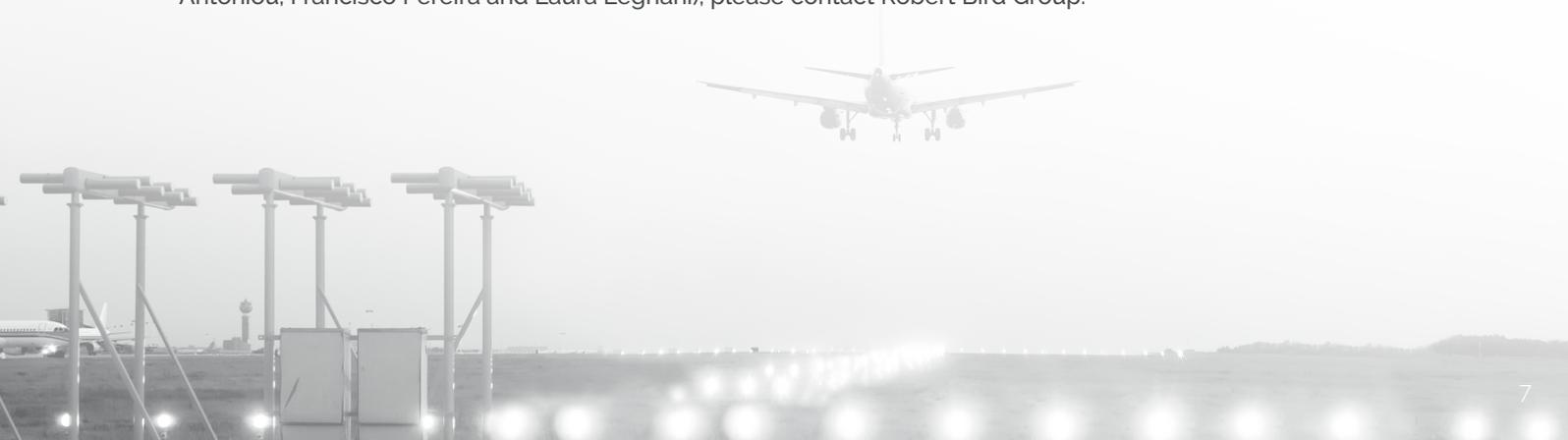




The RBG team used 4D staged analysis models to investigate over 200 construction stages. The finite element model of the roof structure used Strand7 software to fully capture the behaviour of over 95,000 beam elements with more than 1000 unique beam properties. The analysis results were used to identify which roof members required alternative temporary support along with information about loading, temporary bracing and roof movement during construction and de-propping.

The teamwork of Robert Bird Group and the contractor's teams resulted in management of the project to ensure safety for the thousands of workers on the site, and to effectively deliver one of the new wonders of the airport industry.

For a copy of the paper, *Construction Stage Analysis of a Long-Span Roof* (John Ward, Jon Chadwick, Nicolas Antoniou, Francisco Pereira and Laura Legnani), please contact Robert Bird Group.



Attaining Higher Expectations

With all projects, Robert Bird Group focuses on delivering holistic, value-based solutions that deliver the ideal balance between cost, time, risk and other project criteria.

Early Involvement and Conceptual Work

The earlier RBG is involved with the entire project team, the more value we can bring by thoroughly understanding the project and evaluating all of its aspects. This enables us to suggest concepts that can inform decisions.

Value Management

At key points in the design process, RBG will prepare option studies on different structural and civil solutions.

Design and Documentation

Drawing upon the experience and knowledge throughout the Group, we translate our design scheme into working 3D models, followed by ongoing data exchange and detailed design updates.



Advanced Structural Analysis

Robert Bird Group has the analytical capacity to develop active and passive control systems to address complex structural behaviour, including high-rise buildings subjected to unstable ground conditions, seismic occurrences and extreme weather conditions.

Building Information Modelling

Our 3D models accelerate internal design, resulting in more rapid procurement and construction programmes.

Additional Services for Construction

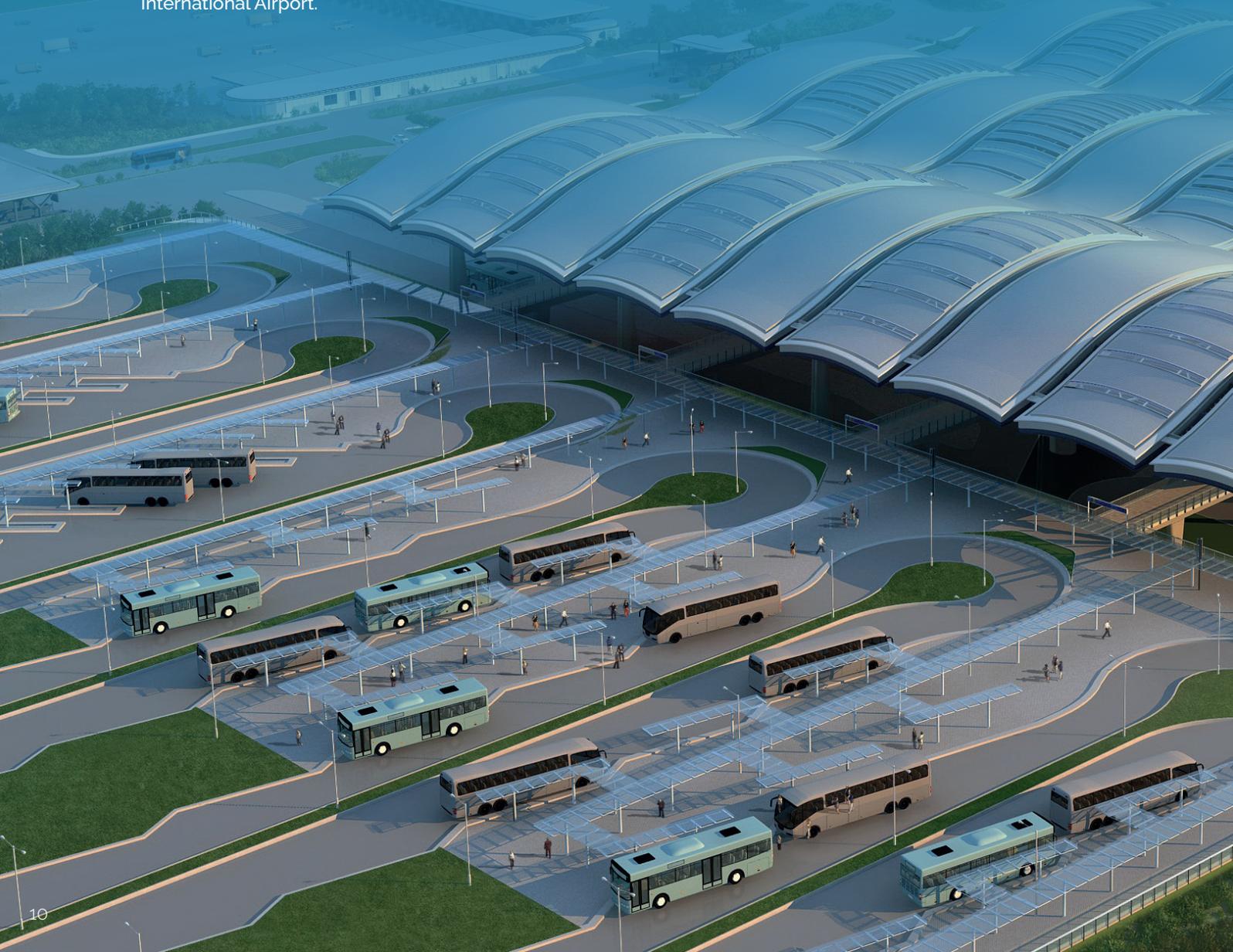
Specific services at the construction phase include RBG's independent monitoring and design of temporary works.

Hong Kong's Passenger Clearance Building: A new wave in engineering

Passengers entering and leaving the Hong Kong Special Administrative Region via the Hong Kong-Zhuhai-Macao Bridge clear customs and immigration through the Hong Kong Passenger Clearance Building (PCB). Envisioned to be an impressive, iconic structure, the PCB's signature feature is its waveform roof, inspired by the surrounding sea. Engineering for the roof was itself a distinctive achievement.

Robert Bird Group was engaged by the Leighton Chun Wo Joint Venture to provide specialist construction engineering consulting services for the project, with a focus on the development of the roof's construction methodology and erection sequence (CMES).

The construction of the PCB involved the innovation of offsite modularisation of the 60,000m² roof to satisfy the serious height and site constraints related to its location on a manmade island adjacent to the Hong Kong International Airport.









The need for offsite roof modularisation and compliance with the airport height restrictions required the development of a unique construction approach that was based predominately on the horizontal and restricted vertical movements of the fully-preassembled roof modules. The largest of these 81 modules were 60 metres long and 25 metres wide, and weighed more than 670 tonnes (including their temporary transport frames).

The modules were fabricated in a dedicated assembly yard. Each module was then transported on a temporary transport frame using barges, self-propelled modular transporters, vertical strand jacking, horizontal launching on temporary rails, lowering into position, stitching together, and removal of the temporary transport frame for re-use.

Now completed, the Passenger Clearance Building has received widespread praise. Mr. Daniel Chung, director of the Hong Kong Government Highways Department has called the PCB a highlight of the construction of the boundary crossing facilities, noting its “full utilisation of innovative construction methods.” Iain Hubert, project director for the Leighton-Chun Wo Joint Venture, stated, “The construction of the roof of the PCB has been an outstanding success, and RBG was an important partner in that success.” The PCB roof also garnered the Temporary Works Excellence Award and and silver award for International Design for Safety.



Sydney Airport An Ongoing Relationship

From preparation for the 2000 Olympic Games to the present, Robert Bird Group has played a role in the continuing expansion and renovations of Sydney Airport.

SACL Expansion 2000

Year Completed: 2000

A major expansion of the international terminal was completed prior to the 2000 Olympic Games, to increase capacity while at the same time limiting disruption to ongoing operations. RBG's role included new buildings over an existing rail tunnel, and strengthening and underpinning of existing terminal piers for the new basement baggage hall. Working with contractor Lend Lease, the project team also developed a composite steel and concrete structure scheme which minimised on-site labor and reduced craneage, construction and installation time.

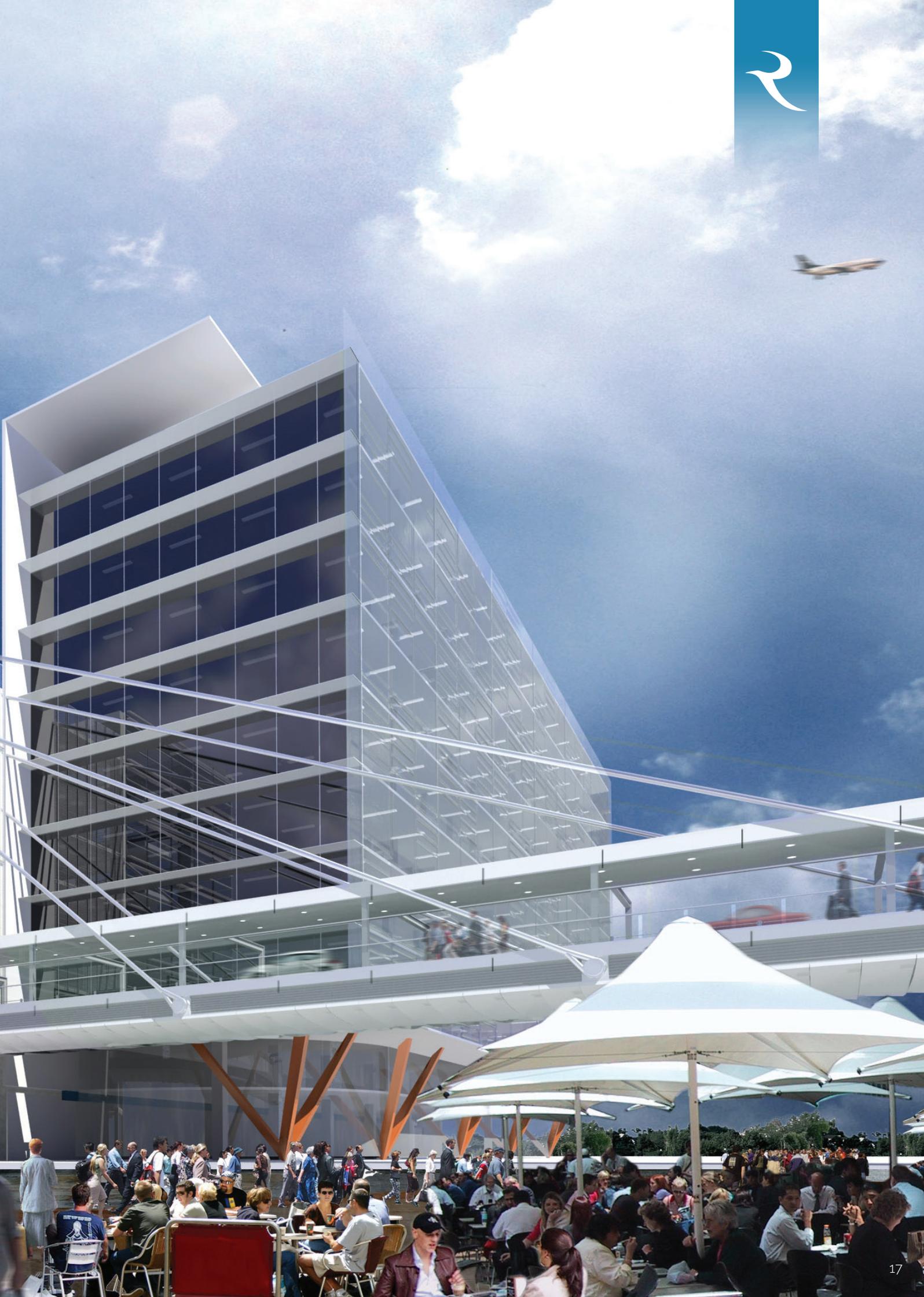


International Terminal Car Park

Year Completed: 2007

The \$60 million AUD eight-storey car park is adjacent to the terminal, providing approximately 2800 parking spaces plus valet and car rental space. The design allows for expansion to 12 levels. RBG engineered a dual-helix internal ramp system which offers optimum space efficiency and exit times. The work of RBG included a concrete moment frame which resists lateral horizontal loads to minimize the need for shear walls. The internal two-lane circulation ramp eliminated transition loads at each level.





Central Terrace Building

Year Completed: 2010

Situated between the terminal and car park, the Central Terrace Building features 12,000 square metres of commercial space over ten levels, along with retail space at ground level. Interestingly, bored piers had been constructed two years prior to construction. RBG incorporated the piers and all design changes from the past two years, including using the existing piers to avoid additional piling costs, and upgraded the building's earthquake resistance. The floor plate design incorporated post-tensioned beams and slabs for maximum clear spans. A significant architectural feature was the two-storey-high triangle splayed columns.





The relentless pursuit of Engineering Excellence

Robert Bird Group is a global structural and civil engineering firm with over 650 staff in Australia, the United Kingdom, the United Arab Emirates and South East Asia. We create quantifiable value for our clients through advanced engineering and comprehensive planning.

Established in 1982, we have fostered long-term relationships with our public and private sector clients that have led to a diverse portfolio of industry and government projects. We apply our specialist engineering expertise throughout the built environment including high-rise and waterfront developments, retail projects, public buildings, heritage-listed properties, and major projects for urban regeneration, health, education, sports, transportation infrastructure, power and renewable energy.

Our Group is committed to environmentally sustainable design as demonstrated by our portfolio of accredited projects including six-star Green Star rated buildings in Australia, BREEAM rated projects in the UK, and LEED Gold and Platinum projects.

RBG values design thinking that fully addresses complex challenges. Inspired by our involvement in prestigious projects and our relentless pursuit of engineering excellence, our professional project-specific teams are delivering superior results for our clients worldwide.

For more information on renewable energy and the unique capabilities of Robert Bird Group, please contact your nearest RBG office.

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The Robert Bird Group Quarterly Review is published in the hope of stimulating and contributing to the important discussions about engineering and its impact throughout our world. We welcome your suggestions, comments and inquiries, please contact Lilli Fender lilli.fender@robertbird.com, or for any project related inquiries please contact Jason Langer jason.langer@robertbird.com



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