BUILDING AIRPORT

OF THE FUTURE

THE NEW TERMINAL 4 AT SINGAPORE CHANGI AIRPORT WAS OPENED TO THE PUBLIC IN OCTOBER 2017. IT WAS COMPLETED AFTER THREE YEARS OF CONSTRUCTION, COMPRISING A TWO-STOREY TERMINAL WITH A TOTAL FLOOR AREA OF 225,000 SQ M. RSP ARCHITECTS PLANNERS & ENGINEERS WAS APPOINTED BY CHANGI AIRPORT GROUP (CAG) AS CIVIL & STRUCTURAL CONSULTANT FOR THE PROJECT. HERE, RSP SHARES THE CHALLENGES IT FACED AND HOW THE COMPANY OVERCAME THEM THROUGH INNOVATIVE METHODS.

The new Terminal 4 (T4) has a capacity of 16 million passengers per year, bringing the total annual handling capacity at Changi Airport to 82 million passengers. It is Singapore's first airport terminal that introduces a fully automated departure process – known as FAST (Fast And Seamless Travel) – to enhance efficiency and convenience for passengers. The terminal also has a centralised departure, arrival and pre-board security screening area, which is located on the second storey.

The development of T4 was carried out in three phases, with a total construction cost of S$1.147 billion. Phase 1 took about 30 months, including the main terminal building and south finger pier; Phase 2 was completed within 34 months, comprising the north finger pier and a multi-storey car park; and Phase 3 lasted for 37 months, consisting of another multi-storey car park and the taxi holding area.

Working together with the design and build contractor - Takenaka Corporation - RSP faced several challenges throughout the project. Among them included the tight schedule of 30 months for the first phase, as well as complex roof designs to achieve a spatial and column-free environment such as the 60 m large-span roof at the departure check-in hall, 18.5 m large-span cantilever roof at the departure kerbside and massive transfer trusses at the arrival immigration hall.

Plus, there was a site constraint. The fixed gangway structures are located within airside with live aircraft parking stands, and they have to meet strict security requirements and airside operational needs.

To solve the problems, RSP adopted the DfMA (Design for Manufacture and Assembly) methodology to increase work productivity and safety on the project. BIM technology was used in the design stage to provide better-informed decisions and assess design solutions; identify construction risks before commencement of site works; and maximise site productivity and safety by minimising abortive works on site.

'Hat-first' method

To speed up the construction of Phase 1, the project team implemented an innovative 'hat-first' method for the main terminal building. The second storey and roof were completed first, then works continued on to the first storey and Mezzanine floors - starting at the centre of the building and moving outwards.

Combining the hat-first method with a middle-out approach allowed the internal finishing and M&E works to start quickly, and also enabled an early installation of the baggage handling system (BHS). This also meant that a temporary roof was not required and the works could be sheltered from the rain.

"Back in 2014 when we first started, the hat-first method was considered new in Singapore for such a massive scale project, and it required an early contractor involvement," said Er. Lai Huen Poh, senior managing director at RSP who oversaw the T4 project. "The traditional way we build here has always been a bottom-up approach," pointed out Er. Lai, "but it wouldn't have helped us to finish this project on schedule."

There were also other benefits gained from the hat-first method, added Er. Jessica Lim, director at RSP and also a key engineer in charge of the T4 project. "It allowed us to perform a multiple slab construction. Upon completion of the second storey and the roof, the team could proceed with the slab construction for the first storey, Mezzanine 1 and Mezzanine 2 at the same time."

RSP was appointed as civil & structural consultant for the construction of Changi Airport Terminal 4. Lai Huen Poh (left), senior managing director at RSP and Jessica Lim, director at RSP, were both key engineers in charge of the project.

Furthermore, precast columns could be installed directly on pile caps before the slab construction for the first storey began, continued Er. Lim. Also, because the slab concreting work for the first storey was carried out under the shade, it produced a good quality of concrete. What's more, facade works could be completed earlier, even before the internal finishing and M&E works commenced.

'First beam shoe connectors in Singapore'

RSP also adopted a full precast system using mechanical connectors, which comprised beam shoes and anchor bolts. Manufactured in Finland, it was the first of its kind to be used in Singapore, revealed Er. Lim. "Although the system has been

LEFT AND RIGHT: **Singapore Changi Airport's new Terminal 4 has a capacity of 16 million passengers per year and it utilises a fully automated departure process – known as FAST (Fast And Seamless Travel) – to enhance efficiency and convenience for passengers. The terminal also features a centralised departure, arrival and pre-board security screening area.**

The project team implemented the 'hat-first' construction method for the main terminal building. The second storey and roof were completed first, then works continued on to the first storey and Mezzanine floors - starting at the centre of the building and moving outwards. This approach allowed the internal finishing and M&E works to start quickly, and also enabled an early installation of the baggage handling system.

applied to a number of precast projects in Europe, it was the first time we brought it to Singapore, and so we needed to conduct several tests in advance."

According to RSP, the full precast system with mechanical beam shoe connectors was selected in view of its buildability and flexibility for future upgrading of the airport. The system was easy to install without compromising the robustness of the precast elements, and it allowed the continuity of rebar at the bottom.

A total of 2,829 precast elements were used in the Phase 1 of the project, including 555 precast columns (22 t each); 159 precast main beams (55 t each); 502 precast secondary beams (13.5 t each) and 1,613 precast planks. These occupied 70 percent of the second-storey main terminal building, covering 36,000 sq m out of 46,300 sq m area. Overall, RSP managed to achieve about 64 percent of time savings using the precast system compared to the conventional cast in-situ method.

A full precast system with mechanical beam shoe connectors was adopted in the project - the first of its kind in Singapore. The system was chosen in view of its buildability and flexibility for future upgrading of the airport.

Prefab roof trusses and 'magic carpet'

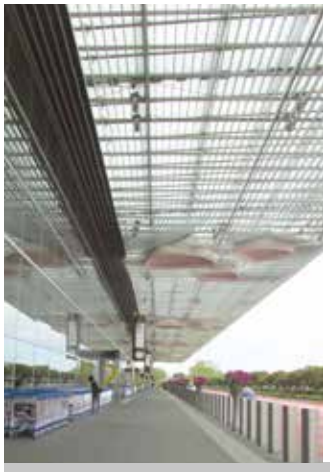
The complex roof structure at the T4 was another challenge for RSP, which involves a 60 m large-span column-free roof at the departure hall, an 18.5 m large-span cantilever roof at the departure kerbside, a hanging 70 m x 5 m LED immersive screen and a 300-m-long Galleria Skylight.

RSP decided on the slopping top-chord pitched truss design to support the roof with truss heights varying between 3 and 4.05 m. This led to a reduction in steel weight by approximately 20 percent, in comparison to a flat roof design for 60-m span truss.

The use of repetitive plane-frame steel roof trusses with a secondary beam system enabled easy and quick off-site prefabrication and erection. Moreover, the addition of 'knee braces' between trusses gave the lateral restraint for continuous truss bottom chord in compression at column supports.

To mitigate risks on site, the project team also created a mobile hanging platform – named 'magic carpet' – that was able to move along the entire Galleria Skylight for easy and quick installation of glass panels. "The magic carpet replaced scaffoldings, making works safer and more productive, and it saved 40 percent of our time," stated Er. Lai.

ABOVE IMAGES: **A total of 2,829 precast elements covered 70 percent of the second-storey main terminal building, including precast columns, precast main and secondary beams, and precast planks.**



The 18.5 m large-span cantilever roof at the departure kerbside (left) and the 60 m large-span column-free roof at the departure hall were among the challenges faced by RSP.

'Magic carpets' being used to install glass panels on the Galleria Skylight. These mobile hanging platforms were able to move along the entire roof safely.

He further mentioned that for the Galleria Skylight, the magic carpet was deemed safer than mass climbing work platforms. Takenaka received the SCAL WSH Innovation Gold Award 2015 for the innovative use of the mobile hanging platform.

Extensive catwalks have also been incorporated throughout the roof, in order to provide safe and easy access for regular building inspection and maintenance.

Prefab gangways

There are 21 fixed gangways at the T4, comprising 17 single/double gangways and four MARS (Multiple Apron Ramp System) long-span gangways. They are located within airside with live aircrafts parking stands, and must meet strict security requirements and airside operational needs.

To simplify works at the airside, the gangways were prefabricated offsite and assembled onsite – two at a time and without any welding works, given they are located just metres away from where aircrafts are parked. This prefabricated steel volumetric design and construction method not only eliminated steel welding works, but also reduced temporary works and in turn improved productivity in general. ■

Website: www.rsp.com.sg

Fixed gangways were prefabricated offsite and assembled onsite – two at a time and without any welding works. This method improved productivity in general.

The slopping top-chord pitched trusses supporting the terminal roof were also prefabricated offsite.

Note: *Changi Airport Terminal 4 is one of the winners of this year's BCA Design and Engineering Safety Excellence Awards (please see page 102 for details of the award and other winners).*