The Magazine of The Institution of Engineers, Singapore

www.ies.org.sg

# The SINGAPORE ENGINEER

Mar 2008
MICA (P) 239/08/2007

*Civil & Structural • Infrastructural • Environmental Edition*

**COVER STORY:**
**CHANGI AIRPORT TERMINAL 3**

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# Changi Airport Terminal 3

*Exterior view of Terminal 3. Photocredit: Civil Aviation Authority of Singapore.*

**Whilst responding to the expansion of the air travel business, including the introduction of the new large aircraft Airbus A380, the new T3 at Singapore Changi Airport is also designed and constructed to offer passengers and the non-travelling public an unprecedented experience, on top of the service efficiency and convenience that has been the hallmark of Changi's success.**

## INTRODUCTION

Changi Airport's new passenger terminal, Terminal 3 (T3), opened for scheduled flight operations on 9 January 2008. Since early 2007, the Civil Aviation Authority of Singapore (CAAS) had been conducting integrated trials to prepare the terminal for flight operations.

The trials allowed CAAS and airport agencies to test the airport systems and procedures in an integrated manner, ahead of the terminal's opening. The trials were carried out on airport systems such as the passenger check-in system, baggage handling system and immigration clearance system. Over 50 trial flights were carried out at T3 before it opened, including about 20 actual Singapore Airlines passenger flights.

The 380,000 sq m terminal, located directly opposite Terminal 2 (T2), is a 7-storey building with three basement levels that also provide the car park spaces, and four above-ground levels. T3 received its Temporary Occupation Permit (TOP) on 30 April 2007, signifying the completion of the construction and interior fit-out.

Built at a total development cost of S$ 1.75 billion (which includes the cost of associated airfield works), the terminal extends the capacity of Changi Airport by an additional 22 million passengers per annum, bringing the airport's total annual capacity to about 70 million passenger movements. T3 is designed for a peak hour flow of around 4,600 passengers.

The terminal also adds another 28 aerobridge gates to Changi Airport, including eight that can serve the new large Airbus A380 aircraft. The total number of A380 gates across all three main terminals at Changi Airport, is 19, while the total number of aerobridge gates in Changi Airport is now 92.

### Airlines operating from T3

T3 allows Singapore Airlines to expand its operations at the airline's hub airport. Generally, its long-haul flights will operate out of T3 while its regional flights will operate out of T2. In addition, China Eastern Airlines, Jet Airways, Qatar Airways, and United Airlines have moved their operations to T3 since April 2008.

## PASSENGER & PUBLIC SERVICES

T3 incorporates several distinctive features that cater to both the needs of air passengers as well as the general public.

### Retail and F&B

Over 20,000 sq m of floor space have been set aside for more than 100 retail and over 40 food & beverage (F&B) outlets and over 20 service concessions. Many businesses have entered the airport retail sector for the first time, at T3.

To complement the open design concept of the terminal, the Departure/Transit Mall is designed to provide a compact single shopping street layout that enhances the visibility of the retail outlets. The extensive use of glass in the terminal, allows passengers a vantage view of both the airside and landside shopping and dining zones.

A consideration by CAAS in commercial space planning at T3, is the allocation of a considerably larger floor area for shopping and dining outlets in the public areas.

Of the 20,000 sq m retail and F&B floor space in T3, 11,400 sq m are within the Departure/Transit Mall, accommodating about 55 retail and 20 F&B outlets. The public area, with about 45 retail and 20 F&B outlets, across five levels of the terminal, has 8,600 sq m of space, representing an increase of 10% over the combined retail and F&B areas in T1 and T2.

With T3, Changi Airport's total retail and F&B space has increased from the current 28,000 sq m, in T1 and T2, to 48,000 sq m, representing an increase of over 70%. There are now about 230 retail and over 110 F&B outlets at Changi Airport.

To cater to the increasing patronage of the retail and F&B outlets at Changi Airport, mainly by Singaporeans and local residents, in addition to larger floor space, new shopping and dining zones have been introduced at T3's public areas.

Besides having retail and F&B outlets at the departure and arrival levels, there are also outlets located on Basement 2, Level 3 and at the Viewing Mall on Level 4 where airport visitors can enjoy the view of planes taking-off and landing. Basement 2, which is accessible to the Mass Rapid Transit train station, bus station and car parks, has a food court and several retail and dining outlets. On Level 3, a lighted 'orchid' design structure features as the location for a theme restaurant.

*Departure/Transit Mall. Photocredit: Civil Aviation Authority of Singapore.*

*Arrival Hall Baggage Claim Belt 41. Photocredit: Civil Aviation Authority of Singapore.*

Travellers in the Departure/Transit Mall can also look forward to enjoying a mix of interesting new dining concepts from established local and international brands.

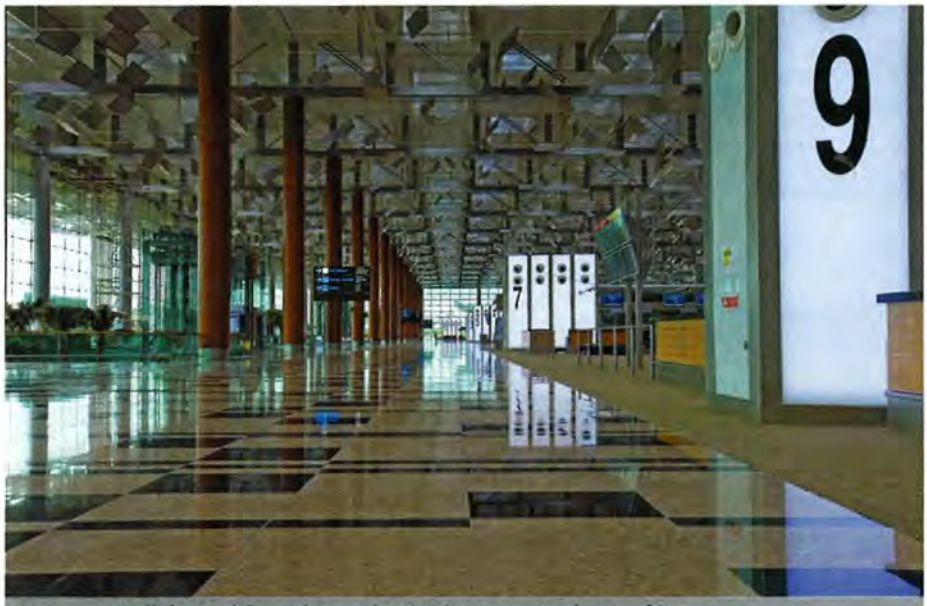
While T3 has the usual travel-retail offerings such as liquor & tobacco, perfumes & cosmetics, books, watches and pharmacy, innovative retail concepts and features have also been introduced. For example, travellers can enjoy innovative elements at the terminal's perfumes & cosmetics outlets which have a full suite of beauty services.

### Baggage handling system

T3 is equipped with a S$ 121 million, fully-automated baggage system which includes a high-speed, inter-terminal baggage transfer system and an automated early bag storage facility. The baggage of transfer passengers making connections at different terminals will be transported individually through underground tunnels at a speed of 7 m/sec. This means it will take only about 3 minutes for a bag to be transported through the underground baggage tunnel between T2 and T3.

The baggage handling system also has an automated early baggage storage system, where bags that are checked-in early, or transfer bags with long connection times, are stored. Besides allowing for automatic bag storage and retrieval,

*Automated People Mover System (Skytrain). Photocredit: Civil Aviation Authority of Singapore.*




*Departure Hall thoroughfare. Photocredit: Civil Aviation Authority of Singapore.*

the system is also able to automatically update changes in the flight itineraries of passengers and thus discharge the bags to the right connecting flights. The new baggage system also has an integrated, multi-level, baggage security screening system to automatically screen bags.

**Automated People Mover System (Skytrain)**

The new S$ 142 million Automated People Mover System comprises 10 train services linking Changi Airport's three terminals through 6.5 km of elevated train tracks.

The new system has a total of seven train stations - two stations each, in T1 and T2, and three stations in T3.

The new trains are equipped with liquid crystal display (LCD) screens providing flight information and other airport information. The trains' cabins have more vertical stanchions and handholds, as well as designated areas for baggage trolleys, enhancing the convenience of users. There are plasma displays at the train stations, to inform passengers of the time of arrival of the next train.

**Airport hotel**

Scheduled for opening in mid-2008, the 4-star Crowne Plaza Changi Airport occupies an approximately 7,700 sq m site, located next to T3.

The airport hotel will be a 9-storey building with up to 350 guest rooms. It will be equipped with amenities and facilities such as a swimming pool, restaurants, meeting and conference rooms, spa lounges, as well as a health and fitness club.

The airport hotel will be physically linked to T3. Hotel guests will also be able to reach T1 and T2 via the Skytrain system that will link all the three passenger terminals. In addition, there will be easy access from the hotel to the Changi Airport Mass Rapid Transit train station, for guests heading to other parts of Singapore.

**ARCHITECTURAL DESIGN**

For its planning, on the airside, the configuration and length of the terminal were driven by the need to accommodate the required number of aircraft parking stands, and requirements for the efficient and safe movement of the aircraft.

On the landside kerbside, the convenient and efficient flow of people and baggage, through segregation of carparks, taxi-queues and coach stands, the focal points for the various modes of transportation, were the major considerations.

Within the terminal, the key design requirement was the flow of passengers through the terminal, and this is similar to that in T1 and T2, for user-friendliness and seamless operations amongst the three terminals. Furthermore, there is the need to create more generous spaces in order to accommodate higher peak hour flows, including those from the larger aircraft fleet.

At the same time, T3 has a slightly different infrastructure compared to the other two terminals. T3 has a centralised Departure Immigration, in comparison with two Departure Immigrations at T1 and T2. There are 18 departure immigration counters with 8 departure immigration Auto Clearance Systems.

Passengers using T3 can expect to move around with ease and minimum dependence on signages. This is possible as T3 has adopted an open design concept, making it easier for travellers to orientate themselves.

This is part of the four guiding principles adopted by CAAS when designing T3, namely, Clarity, Natural Lighting, External Views, and

Maintainability.

*Clarity*

Travellers should be able to find their passage through T3, simple and natural. Dependency on signage should be minimal as individuals easily orientate themselves.

*Natural Lighting*

The abundance of daylighting in T3 is part of the design strategy that creates the airy and spacious interior, as well as the light and bright ambience.

The distinctive roof has computer-controlled panels to admit natural daylight through double-glazed low iron glass skylight panels so that no artificial illumination is needed during a normal day with good weather.

*External Views*

Passengers should have extensive visual access to the external landscaping and activity surrounding them, including the taking-off and landing of aircraft. Such attractions make queuing less tedious and contribute to the terminal's overall sense of openness.

*Maintainability*

T3 has been designed for ease of maintenance. Various systems have been provided with maintenance spaces, accesses and catwalks to facilitate maintenance with minimum interruption and downtime.

Appropriate spare capacity has also been incorporated in the system for maintenance and future expansion.

*Reliability*

The availability and reliability of the provision of the various services will be critical to the continuous operation of the airport. The power supply, water supply, telecommunication services, airconditioning systems, security system, fire services systems, and other building services have been carefully designed to ensure that sufficient redundancy has been allowed to avoid single points of failure.

The consideration of reliability is not limited to the number of incoming supplies, but also to the supply location and the distribution routes up to the connection to the terminal equipment.

A low-energy design optimises the use of mechanical systems and makes the building responsive to the local climate in achieving a comfortable and healthy building. This passive design process involves the consideration of area-specific information, such as local climate conditions and the sun's position at different times of the day and during different seasons.

Other important factors include location-specific information regarding prevailing wind direction and speed, seasonal humidity, and average combined temperature.

The architectural brief was for a landmark passenger terminal building of long-span structure, that offers maximum flexibility in space planning within.

**Feature Roof**

The response to the architectural brief was to create a tropically-inspired, giant trellis roof which is simple in its concept, but with underlying sophistication in its details, including layering of ceiling-panels, 'flip-flop' baffles, some 919 skylights, and high-tech, operable 'butterfly' sun shading louvres, that articulate the 'random-patterned' roof build-up, between the large, hollow-section steel trusses.

The skylights allow soft natural and uniform lighting into the terminal building while keeping the tropical heat out. The butterfly-shaped sun shading louvres intelligently adjust themselves according to the position of the sun and clouds, to allow an adequate amount of sunlight into the terminal. On a sunny day, natural lighting alone lights up the terminal.

The specially designed, double glazed, low-e, low-iron glass also rejects heat while admitting sunlight into the terminal. The overall effect is a soothing ambience at all times of the day. At night, the skylights glow with artificial lighting delicately concealed below the sun shading louvres.

**Other architectural finishes**

The architectural finishes employed throughout the terminal, highlight and provide a backdrop to the daylight coming through the main roof, with warm tones of timber, limestone, sandstone and granite patterns introduced, along with extensive internal and external glazing, to ensure clarity within the building and in the external environment.

Areas where the architectural design and structural engineering had to work closely, to ensure the desired technological expression in the final product, included, apart from the main roof and its daylight system, the Green Wall, and the Cable-Net front façade.

**Green Wall**

The 5-storey high vertical garden, called the 'Green Wall', spans 300 m across the main building, and can be admired from both the Departure and Arrival Halls. The 'Green Wall' is covered with climbing plants and is interspersed with four cascading waterfalls.

There are 225 types of plants including trees, shrubs and climbers in the terminal.

In addition, a sculptured sandstone art wall display located below the 'Green Wall' offers an artistic treat for arriving passengers waiting for their baggage.

## STRUCTURAL DESIGN

**Foundations**

T3 sits on a site with relatively good soil conditions. The soil profile generally consists of 6 m to 7 m backfill underlaid with Old Alluvium, which consists mainly of clayey/silty sand whose density increases with depth.

With such soil conditions and column loads varying from 150 tonnes to 3000 tonnes, cast-in-situ bored piles were adopted as the most suitable and cost-effective foundation system.

Altogether, more than 4000 piles of sizes varying from 500 mm to 1500 mm in diameter were installed. Where uplift forces due to ground water pressure were substantial at the deeper parts of the basement, tension piles were introduced between the columns.

**Basements**

There are three levels of basement floors – B1, B2, and B3, of which B2 and B3 are the floors in contact with the earth. For these floors, structural efficiency, buildability, as well as ease of waterproofing, were considerations in selecting the structural

*Giant trellis roof with skylights. Photocredit: Civil Aviation Authority of Singapore.*

*Green Wall and baggage claim belt. Photocredit: Civil Aviation Authority of Singapore.*


*Sandstone art wall. Photocredit: Civil Aviation Authority of Singapore.*

system. A reinforced concrete flat slab system with drop panels at pile positions, was adopted as the most suitable system. The slab thickness varies from 600 mm to 900 mm, depending on the depth of the basement and span of the slab, with 500 mm deep drop panels at the pile locations.

Basement walls up to the B2 floor, were designed as simple cantilever walls with thickness up to 1 m at the base. For higher walls up to B3, the walls are either counterfort or buttress walls with thickness up to 1 m at the base, and 800 mm thick brackets spaced at 6 m.

A portion of T3 sits directly on top of MRT tunnels serving Changi Airport. The building loads in this area are supported on a matrix of large transfer beams at the B2 level, to transfer the loads onto barettes or bored piles straddling between the tunnels. These transfer beams form part of the basement floor in this area.

To ensure watertightness of the basement, a system of waterproofing using waterproofing admixture that crystallises on contact with water to form an impermeable waterproofing barrier within the concrete, was adopted. This not only speeded up the construction of the basement tremendously, it also proved to be effective in achieving watertightness within the basement.

**Superstructure**

The building was designed as a framed structure with vertical loads carried by floors to the columns or walls down to the foundations. Lateral stability is achieved by diaphragm action of the floors transmitting horizontal loads to the shear walls at the various staircase or lift cores.

The main criteria for selecting the structural system were cost-effectiveness, buildability, flexibility and robustness in making penetrations and future alterations in structural members, and ease of taking hanging loads from various services. The standard column grids are 15 m by 15 m at the Main Building, 12 m by 12 m at the Piers, and 9 m by 8.2 m at the Car Parks.

Columns and walls are all cast-in-situ elements with high standardisation of sizes, to enable repetition of formwork to achieve good buildability. Taking advantage of the scale of T3 and the large

repetition of standardised column grids, the typical floor system adopted, consists of cast-in-situ, post-tensioned banded beams of width varying from 2 m to 4 m, and depth varying from 800 mm to 1000 mm, spanning continuously between columns and supporting precast single T or double T slabs. These slabs were designed as composite slab with 75 mm concrete topping, and spanning typically 15 m continuously between the banded beams. Their depths vary from 400 mm to 800 mm, depending on the length of spans and loadings.

**Main Roof (Feature Roof)**

The main roof of the T3 building has a frontage of 300 m in length and a depth of 215 m, spanning from airside to landside.

The main steel structure frame is a series of steel trusses, alternating between depths of 4.1 m and 4.5 m. Each of these trusses is 215m long and was designed as a continuous truss, starting with a 20 m cantilever at the Departure Kerbside, traversing the Main Departure Hall with internal spans of 20 m, 60 m, 45 m, and 60 m, and ending with a 10 m cantilever at the airside apron. These trusses are supported by 850 mm diameter and 12 m high reinforced concrete columns.

The main trusses are connected by a series of Warren space trusses, 15 m in length that form the secondary truss frame. The roof slab is made up of 155 mm thick lightweight concrete slab with shear studs forming the connections to the steel trusses. The structural steel members are all built-up sections, except for the diagonal Macalloy tension rods.

## CONSTRUCTION

A highly mechanised and buildable construction method was used for the construction of floor elements to achieve high construction speed.

First, standard soffit formwork and falsework were put up for the banded beams. Single 'T'/double 'T' slabs which were precast with end plates to act as side formwork for the beams, were manufactured in precasting yards off-site and delivered and stored on-site. They were installed in place by cranes and supported on temporary props. Concrete was then cast for the banded beams and toppings

*View of T3 basement. Photocredit: CPG Consultants Pte Ltd.*

*Modular Precast Double T Slab System. Photocredit: CPG Consultants Pte Ltd.*

*Main roof trusses. Photocredit: CPG Consultants Pte Ltd.*

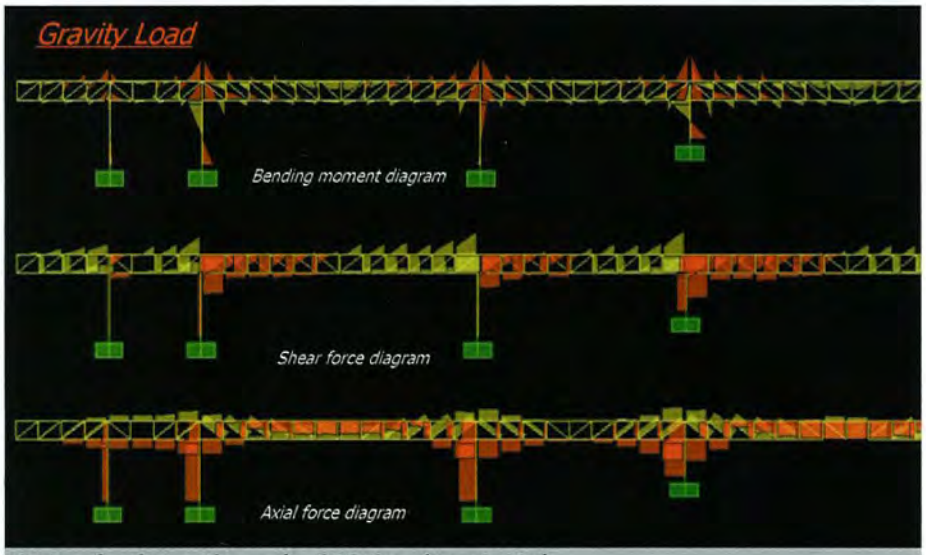
for the slab panels, in one casting.

The banded beams were then tensioned once the concrete reached the required strength, typically in 3 to 4 days. Soffit formwork and falsework were then dismantled and moved to the next area of construction.

The main roof trusses were fabricated in a fabrication yard, as truss segments of 12 m length, which were then delivered and welded together on site, on the Departure Level slab, to form the complete 215 m long main truss.

After adjacent pairs of the main roof trusses had been completely fabricated, they were connected to each other through the series of secondary Warren Space trusses, as well as to some temporary bracing structures for added stability in preparation for the lifting process. Special temporary steel frames and hydraulic jacks were erected to provide the lifting. The trusses were then lifted as a pair over to the top of the respective supporting columns. Each lift took approximately 5 to 6 hours.

The subsequent activities involved the erection of the profiled steel sheets to act as soffit formwork and shear studs, and the final casting of the lightweight concrete to complete the construction of the main roof slab.




*Design of roof truss. Photocredit: CPG Consultants Pte Ltd.*

**Comparison of Changi Airport's T1, T2 and T3**

| | Terminal 1 | Terminal 2 | Terminal 3 |
|---|---|---|---|
| Terminal floor area | 280,020 sq m | 358,000 sq m | 380,000 sq m |
| Handling capacity per annum | 21 million | 23 million | 22 million |
| No. of aerobridge gates | 29 | 35 | 28 |
| Cost of terminal building | S$ 585 million | S$ 838 million | S$ 1.75 billion |

*Note: Changi Airport also has a Budget Terminal which is being expanded to handle 7 million passengers per annum.*

**PROJECT DATA**

**Project Cost**
S$ 1.75 billion

**Gross Floor Area**
380,000 sq m

**Quantity of steel used**
91,000 tonnes

**Quantity of concrete used**
173,000 cu m

**Quantity of glass used**
40,000 sq m

**PROJECT CREDITS**

**CLIENT**
Civil Aviation Authority of Singapore

**Architect**
CPG Consultants Pte Ltd

**Civil & Structural Engineer**
CPG Consultants Pte Ltd

**Mechanical & Electrical Engineer**
CPG Consultants Pte Ltd

**Project Manager**
CPG Consultants Pte Ltd

**Quantity Surveyor**
CPG Consultants Pte Ltd

**Specialist Sub-Consultants**
Skidmore & Owings Merrill LLP (Roof Form)

Hugh Dutton Associates (Cable-Net and Façade)

Bartenbach LichtLabor GmbH (Daylighting)

**Interior Design Consultant**
Wilson Woodhead

**Landscape Consultant**
Tierra Design

**Main Contractor**
Shimizu Corporation (Japan)