HSS in the Far East

By M. James Chen, P.E.

The main terminal features tilted and battered HSS columns of varying cross section, composed of three pipe shapes with plate stiffeners.

Three runways and modern terminal buildings featuring exposed HSS steel framing have made Guangzhou Baiyun International Airport a modern hub for international trade in southern China.

Located at the mouth of China's Pearl River, Guangzhou has been a center of trade for centuries. Now, with the construction of the Guangzhou Baiyun International Airport, the city is primed for a new era of international exchanges.

Construction of the three-phase project began in early 2000. Phase one was completed in August 2004. Construction of phase two began in late 2004, while construction of phase three will begin at a future date. The completed project will encompass 21 km² (8.1 sq. miles) and will be divided into three zones: aircraft maintenance and cargo facilities, offices, and terminal.

Approximately 26,500 metric tons (29,200 tons) of steel have been erected, including 8,000 metric tons (8,800 tons) of pipes, 6,000 metric tons (6,600 tons) of HSS, and 5,500 metric tons (6,100 tons) of roof deck (excluding the curtain wall back-up structure).

The phase one terminal buildings cover 350,000 m² (3.8 million sq. ft). They are comprised of one main terminal building, two connecting buildings, four pedestrian bridges between the main terminal and connecting buildings, and four airside concourses with jet bridges.

The main terminal is symmetrical about both principal axes. Along arc lines, there are two rows of giant interior concrete columns and two rows of exterior battered built-up steel columns. The lowest below-grade levels of the terminal accommodate rail transportation facilities.

Built-Up Steel Columns

The battered columns (as long as 35.7 m (117′)) are comprised of three large pipe sections with varying spaces between the pipes. The pipes are farthest apart at the mid-height of the column and then become progressively closer to one another towards the ends of the columns, where the outer pipes are cut away and appear to merge with the central pipe. Several stiffener plates connect the three pipes together where they were separated.

Two of these built-up steel columns support the end of each truss. Due to the complicated geometry of the columns, finite element analyses with ANSYS were conducted using large deflection elasticity-plasticity theory, including the effects of fabrication tolerances. Several full-scale columns were load tested, and capacity approximately matched the finite element analysis results.

Main Terminal

The roof structure consists mainly of 76.9 m (252′)-span triangulated HSS trusses, which span between the interior and exterior columns at 18 m (59′) on center with 7 m to 23 m (23′ to 75′) outer cantilevers. A series of arched trusses between two rows of concrete columns form a spine used to balance the horizontal forces from the battered columns and to support a tensioned fabric roof over the east-west center strip of the main terminal.

The roof structure is intended to closely approximate the geometric shape of a sphere. This was accomplished by varying the bearing elevations of the trusses and by rotating the trusses. Typical 5 m (16′)-deep roof trusses consist of two top chords and one bottom chord of 508 mm (20″) dia. pipe with diagonal pipe web members. In order to minimize fabrication and welding costs, the web members are offset from the centerline of the chords. This eccentricity provides a connection where web member overlap is avoided, thus increasing member and connection stresses slightly, but providing a much more economical design. A 14 m (46′)-long span deck works as the roof diaphragm and braces the rotated trusses. Because the battered columns are pinned at both ends, the central concrete columns must resist all lateral loads in the direction of the truss spans.

Connecting Buildings

Each connecting building has 26 curved HSS triangulated trusses at 18 m (59′) on center, with three 245 mm (9.6″) dia. chords and diagonal webs that are offset from the centerline of the chords. Each truss curves up from the ground at one end. The truss is supported on a concrete column 25 m (82′) away from this end, and on battered built-up steel columns 55 m (180′) from this end.

Large dormers between the main trusses are covered with tensioned fabric. Five secondary trusses, perpendicular to the main trusses, act as the lateral system at the column locations and support the dormers and curtain walls. The secondary trusses are supported on the bottom chords of the main trusses to avoid possible torsion created from the secondary trusses and asymmetrical tensioned fabric loads.

The airside concourses feature curved planar tube trusses at 12 m (39′) on center. The trusses bear at different elevations on top of two concrete columns to form the curved roof.

The pedestrian bridges are covered with tensioned fabric extended from the main terminal roof. Each of the four

Triangulated trusses composed of round HSS create a dramatic interior space in the baggage claim area.

The central spine of the airside concourses consists of curved, planar HSS trusses spaced at 12 m (39'), supported by massive concrete columns.

bridges is made primarily of HSS supported on four steel columns spanning 54 m (177′) with 7 m (23′) cantilevers.

Erection of Main Terminal Trusses

The erection of the main terminal curved trusses was extremely challenging. The trusses were rotated from the vertical plane and sloped from giant concrete columns to tilted and battered steel columns. No single erection method could be used repeatedly because each truss was different from the adjacent one. Specifications required a positioning tolerance of 2 mm (0.1″) at truss panel points.

To facilitate erection, two platform systems were constructed at the southwest and southeast ends of the building. The platform systems had wheels on two curved tracks at 18 m (59′) apart built on the third floor, following the curved column lines with 5 mm (0.2″) tolerance.

Pieces of each truss were shop welded and shipped to the site. At each end of the building, the pieces were lifted, positioned, and welded to install two trusses, including secondary trusses to form a stable system, supported on a jack system, on the platform. The platform and the two trusses weighed 600 metric tons (660 tons) and were slid together on the tracks from the ends to the final position. Erection proceeded from each end simultaneously to increase erection speed.

Tensioned Fabric Systems

60,000 m² (646,000 sq. ft) of PTFE-tensioned fabric covers the roof. The tensioned fabric system is made of glass fiber and Teflon membrane. The 15% transparent fabric is thermally resistant, waterproof, fireproof, and tear-resistant.

The fabric was shop-fabricated in pieces and installed on the backup structure with a pretensioned force of around 4.4 kN/m (300 lb/ft) on the perimeter support. In order to resist load on the fabric, the prestressed fabric had to be curved oppositely in two directions like a saddle. The external load increased tension stress in one direction and reduced stress in another direction. Special software was required to find the shape of the tensioned fabric under the external loads. By cutting the curved surface into many small, planar pieces as finite elements with shape finding, the software determined if a given shape of the support structure worked to form a stable fabric curvature and what size of fabric was needed.

The airport, with its three runways and modern terminal buildings featuring exposed HSS steel framing, is equipped to serve millions of passengers and move millions of tons of cargo each year. ★

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Architects and Structural Engineers

URS Corporation, Columbus, OH (preliminary design)

The Architectural Design and Research Institute of Guangdong Province, Guangzhou, China (final design)

Engineering Software

STAAD Pro (with Chinese design code)
SAP2000

General Contractor

Civil Aviation Administration of China, Beijing, China