Steel **Security**

By Ruben Martinez, P.E., S.E.

Photo by Warren Stickrod – W&W Steel

The new Federal Inspection Services (FIS) building at George Bush Intercontinental Airport in Houston sets the bar for aviation security centers.

The new Federal Inspection Services (FIS) building at George Bush Intercontinental Airport in Houston takes flight January 2005, and when it does, it will be one of a handful of new U.S. airport facilities to incorporate the latest criteria for security screening for both international travelers and their baggage.

Originally scheduled for bidding one month after 9/11, the project was delayed three months to incorporate significant security improvements, such as providing space for luggage screening equipment. The structural design, performed by Houston-based Walter P. Moore Engineers and Consultants, was modified for security protocol changes even as construction continued, making the large and complex structural steel design even more of a challenge.

Welcome Aboard

The new FIS building will include the passport control (U.S. Immigration and Naturalization Service), baggage control (Customs), and other federal agencies currently housed in the existing airport Terminal D. The building is just one component of a major ongoing facility expansion at Bush Intercontinental and will be a new port of entry for international visitors who flow through the increasingly busy airport.

The building is situated between the bustling Terminal C, the existing international Terminal D, the newly constructed Terminal E and is directly over an extension of the end of the airport's Inter-Terminal Train (ITT) tunnel. The building will provide 875,000 sq. ft of space to process new international arrivals in accordance with the airport's updated security screening protocols. Passenger arrivals and departures, U.S. customs processing and baggage processing are located on three levels. Security checkpoints divide the building into public, secure, and sterile areas.

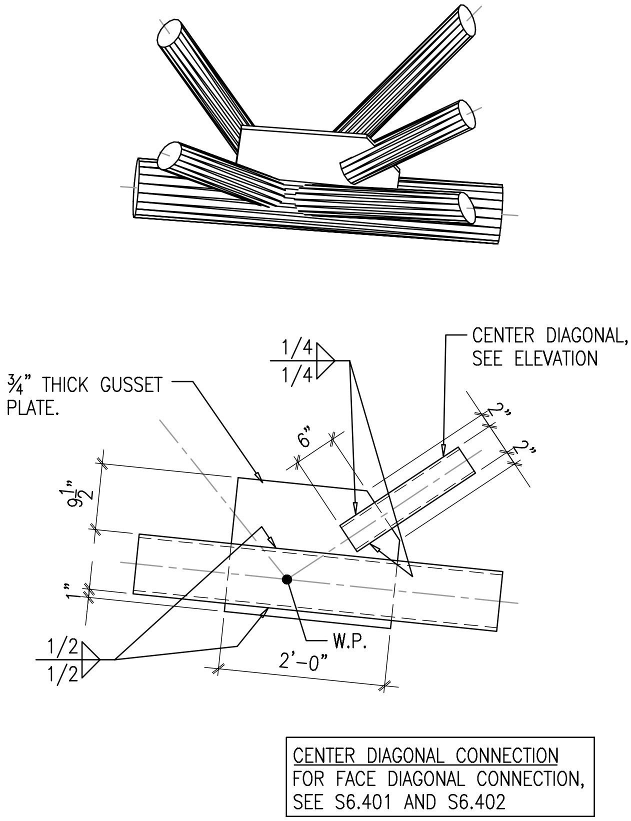
Walter P. Moore's team conducted studies comparing a steel-framed building to a concrete-framed one and the steel scheme was selected. As with many airport projects, the architectural design presented significant structural challenges demanding creativity and non-traditional structural design solutions.

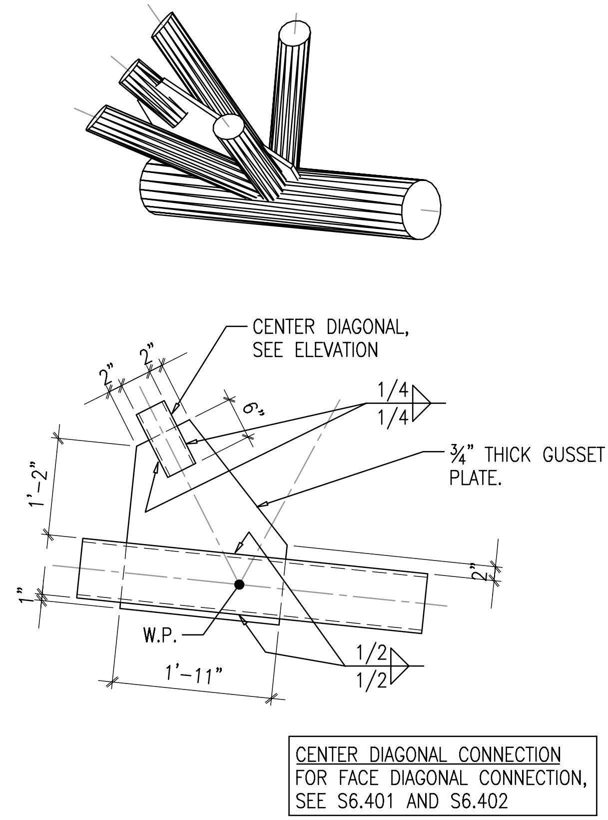
The architects presented three different options for the roofs over the main ticket lobby and INS Hall. Each featured highly articulated roof shapes intended to draw light into the spaces below and create memorable spaces for travelers.

To meet this plan, structural engineers designed curved, 3D trusses to gracefully and economically frame the long-span roofs. The overall building is 350′ by 770′, with a single expansion joint dividing the building into two almost square structures. A 50′ grid was selected for efficient planning of the spaces.

Bird of a Different Feather

To distinguish the FIS building from the other airport buildings, designers developed major curved roofs, an arched central corridor and a 3D atrium along the east façade. Two elliptical elevator towers and a complex façade of pre-cast concrete, metal panel and glazing complete the distinctive architectural design. Each architectural element called for imaginative structural engineering design and careful steel detailing and fabrication.





Above: Details of the HSS connections for the tri-chord trusses in the INS Hall. (Details courtesy Walter P. Moore.)

Left: Construction photo showing INS Hall trusses, as well as the curtain wall support trusses. (Photo by Warren Stickrod – W&W Steel.)

Dynamic Design

Designers chose a floor system of 4.5″ normal-weight concrete over 2″-deep composite metal deck, providing excellent performance of the open 50′ bays against vibrations and the required two-hour fire rating. A 3″ deep, 18-gage deck was used at level 2 to further control vibrations in the busy departure areas. In these areas, the typical 50′ by 76′ bay is framed with W30x108 beams at 10′ centers framing to W44x235 girders. At the lower arrivals level, additional columns were provided to reduce the bay sizes to 46′ by 50′ and 30′ by 50′, reducing the typical beam sizes to W24s and W16s, respectively. The 50′ bays allowed for an efficient layout of baggage-claim devices.

The main ticket lobby at the departures level required a column-free area of 140′ by 350′. Eight signature steel tri-chord trusses at 44′ centers create this distinctive ticket lobby space. These tri-chord trusses do not line up with any of the building column lines and are supported by planar trusses that transfer their loading.

The tri-chord trusses are made up of three 10.75″-diameter pipe chords with diagonal web members of 4.5″ to 5.63″-diameter pipes. The top chords of the tri-chord trusses are curved, while the bottom chord is made up of two straight segments of pipe, creating trusses that vary in depth from 4′-6″ at the supports to 17′ at mid-span.

The existing below-grade inter-terminal train station precluded the possibility of building columns at the west ends of the main roof tri-chords. Instead, engineers designed a full-story tall planar truss to span the existing station. The two-span planar truss is 218′ long and 29′-6″ deep and supports both the roof and the composite steel-framed floor at level 2. This truss comprises wide-flange chords and HSS web members. At the east end, an architecturally distinct, exposed planar pipe truss supports the tri-chord trusses. This pipe

Graceful curves of the roof trusses lend a distinctive identity to the FIS building.

truss is located behind a curved and sloping curtain wall that allows a significant amount of ambient light into the ticket lobby.

Curved-top, tri-chord trusses span 76′ to create a roof over the main INS Hall. These roof trusses, composed of three 8.625″-diameter pipe chords with 4.5″-diameter web members, are located at 50′ centers and are supported directly on building columns. At the exterior edges of the building, these trusses cantilever 11′ past the columns to support the roof.

The ticket lobby and INS Hall long-span tri-chord trusses were designed to resist Houston's hurricane-force winds. To provide adequate torsional resistance, designers laced the pipe chords together on all three faces with pipe web members. As an aesthetic requirement of the trusses, its connections could not employ gusset plates. Welded pipe-to-pipe connections efficiently and attractively connected the truss elements; pipe-wall punching shear rupture, chord-wall plastification and general collapse were all checked using the relevant criteria in AISC and AWS.

Designers selected a 3″-deep, 18-gage roof deck throughout for two reasons. First, the relatively deep deck allowed an efficient typical purlin spacing of between 10′ and 12′-6″. Second, this deck provided the necessary diaphragm strength and stiffness—without too much supplementary reinforcement—to transfer the large lateral forces developed by this building to the primary lateral system.

Two main banks of two elevators each serve the FIS building and its new parking garage. These elevator towers extend above the roof to create distinctive icons. Designers chose to support each tower with vertical trusses made up of four columns and vertical bracing configured around the elevator door openings. The bracing was designed to limit the lateral drift of the towers to less than 2″ under wind forces, ensuring proper elevator function even during maximum windstorms.

Each elevator tower is clad in elliptical metal panels, which are supported by cantilever beams at each level of the towers. Curved tubes spanning between the cantilever beams support vertical girts that back-up the metal panel.

Arrivals and Departures

Travelers will enter the FIS building from Terminal D on the north and Terminal E on the south, using one of four pedestrian bridges. The North Secure and the North Sterile bridges each span approximately 140′ between the face of the FIS and the face of Terminal D. Support frames in a median of the North Terminal Road between the two buildings provide intermediate support for the bridges. The South Secure and South Sterile bridges provide 100′-long free-span linkages from the FIS to Terminal E.

After checking through INS, travelers will move down to the baggage claim level on grand escalators that will feature striking views of the East Atrium facade.

Supporting the distinctive glass façade presented special structural challenges. The walls are shaped as inverted cones, with neither straight nor planar surfaces anywhere in the wall. The geometry for each of these frames was distinct, and from the 3D drawing, designers were able to extract the relevant detailed dimensions for the East Atrium frames. To support the portion of the horizontally projected wall from the face of the building, designers arranged six horizontal HSS frames into a "sombrero" and attached its ends to the building structure. The members are HSS 12×3's with the long dimension horizontal and located directly behind the curtain wall mullions. Pipes with 8.625″-diameters support the vertical loads.

That's the Ticket!

To support the portion of the East Atrium glass walls that projects above the roof of the FIS building, designers added vertical steel frames made of pipe columns and bent HSS beams. Bracing in the plane of the glass walls consists of 1″-diameter stainless steel rod diagonals attached with clevises to specially detailed gusset plates off 2.875″-diameter pipe horizontals and the vertical pipes. Out-of-plane of the curtain wall, bracing was not feasible. So, the challenge was to design a series of moment frames made up of the 8.625″-diameter pipe columns and HSS 12×6 bent beams.

The majority of columns supporting the building are 24″-diameter steel pipe columns filled with 5,000 psi normal-weight concrete for additional stiffness. Pipe walls vary in thickness from 0.50″ to 1.218″. Twelve pipe columns supporting the INS Hall framing and roof are 30″-diameter steel pipe columns filled with a special concrete mix design containing steel fibers to provide an inherent fire resistance. These 12 columns are exposed at the exterior and are braced in both directions at the roof. However, at level 2, they support only flying beams at 50′ centers and were therefore only braced in one direction. Designers were able to provide sufficient bracing per the column-bracing requirements now found in the 3rd Edition of AISC's *LRFD Specification*, Chapter C. This required plating the flying portions of the wide-flange beams at level 2, which is possible since they are clad.

Eighteen one- and two-story lateral braced frames, discretely located throughout the building, provide lateral-sway bracing. These efficient braces are composed primarily of steel HSS connected to the building columns and floor beams.

Separate groups of anchor rods at the base of the frames resist uplift and horizontal shear. The shear rods connect "drag plates" with gussets to the diagonal HSS braces. All anchor rods at the braces are 1″-diameter A354 Grade BD anchor rods with F_y = 130 ksi and F_u = 150 ksi.

The tri-chord trusses at the INS Hall high roof are connected at the columns to create lateral moment frames. As mentioned, the ticket lobby tri-chord trusses do not line up with the building columns. This meant that the trusses could not transfer lateral loads directly into the building columns, and the roof diaphragm would require supplemental strengthening. Therefore, two horizontal trusses made up of wide-flange framing were provided to transfer the ticket lobby roof-diaphragm forces to the building columns.

Schedule Change

Superstructure drawings were originally scheduled for construction issue in October 2001. Delayed by the events of 9/11, construction stalled until early 2002, thus allowing modifications to accommodate more CTX luggage-screening machines. The formation of the Transportation Security Administration (TSA) generated even more security upgrades.

The entire design and construction team responded to continually improving security requirements—some of which were incorporated throughout construction—as security protocols were refined. When it opens, the FIS will incorporate all published security requirements post 9/11 for TSA and FIS facilities. ★

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Structural Engineering Software:
SAP 2000
ETABS
RAM Structural System

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AutoCAD 2000, 2002
Tekla Xsteel