Exposed Steel at Airport Challenges Structural Designers

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

Travelers can stop and relax before claiming their bags at the glazed façade of the East Atrium. (Photo© Richard Payne)

Striking nighttime view of completed International Arrivals Building in Houston, Texas. (Photo courtesy of the PBTeam)

The International Arrivals Building (IAB) is George Bush Intercontinental Airport's newest passenger services addition. Opened in January 2005, the state-of-the-art facility was designed to streamline the customs, immigration and baggage process for visitors coming to Houston. The new building provides 875,000 s.f. of space to process new arrivals in accordance with the airport's updated security screening protocols.

The structural design, performed by Houston-based Walter P. Moore, was modified for security protocol changes even as construction continued, making the large and complex structural steel design an even greater challenge. Superstructure drawings were originally scheduled for construction issue in October of 2001. After September 11th, the building design was temporarily delayed to incorporate various security upgrades. Among these were revisions to the building egress, the design of additional areas of assembly in the adjacent contract parking garage and the accommodation of an increased number of CTX luggage screening machines at the Ticket Lobby. Fortunately, none of these security upgrades impacted the design of the various architecturally exposed steel elements.

The building features various exposed steel structures that make it distinct from other buildings. The bold design by PGAL Architects features major curved roofs, an arched central corridor and a three-dimensional atrium along the east façade. The highly articulated roof shapes were intended to draw light into the spaces below, and create grand and memorable spaces for travelers. Each architectural element demanded imaginative structural engineering design plus careful steel detailing and fabrication.

Now, as international travelers pass though the IAB, ambient light is ever-present throughout the building, and at night, the IAB is also very prominent from the adjacent roadways, buildings and runways.

Exposed Tri-Chord Pipe Roof Trusses

The main ticket lobby at the Departures Level required a column-free area of 140-by 350-feet. Eight exposed signature steel tri-chord trusses at 44-foot centers create this distinctive ticket lobby space. These tri-chord trusses do not line up with any of the building columns and are supported by planar trusses at each end. The planar truss on the west end is concealed, and is comprised of wide flange chords and tube web members. The exposed 25-foot deep planar pipe truss on the east end is located behind a curved and sloping curtain wall that allows a considerable amount of ambient light into the ticket lobby.

The ticket lobby tri-chord trusses are made up of three 10.75-inch diameter pipe chords with diagonal web members of 4.5-inch to 5.63-inch 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 feet-6 inches at the supports to 17 feet at mid-span.

Sloped and curved glazing allows ticket lobby to be bathed in ambient sunlight. (Photo taken by Bill O'Bar, PBTeam)

After a long international flight, it sure is nice to arrive in this airport!

There are a total of 24 exposed trichord trusses supporting the roof over the main Immigration Hall. These roof trusses, comprised of three 8.625-inch diameter pipe chords with 4.5-inch diameter web members, are located at 50-foot centers and are supported directly on building columns. The building columns supporting these exposed trusses were also exposed, so ultimately they were fabricated as integral parts of the trusses. Then each was field spliced to the portion of the columns below. At the exterior edges of the building, these trusses cantilever 11 feet past the columns to support the roof. As with the ticket lobby trusses, these trusses have curved top chords and straight bottom chords.

The ticket lobby and Immigration Hall long-span, tri-chord trusses were designed to resist Houston's potential hurricane-force winds. To provide adequate torsional resistance, the pipe chords were laced together on all three faces with the pipe web members. Furthermore, one of the aesthetic requirements of the trusses was that the connections not employ gusset plates. Therefore, welded pipe-to-pipe connections efficiently and attractively connected the truss elements. Pipe wall punching shear rupture, chord wall plastification and general collapse were checked using all the relevant criteria in AISC and AWS.

The project specifications did not define these trusses as Architecturally Exposed Structural Steel (AESS) as defined by AISC. However, given that they were exposed, PGAL visited W&W Steel's fabrication shop, early on, to visually inspect the quality of welds, instead of relying on a fabricated mock-up. At that visit, the architect asked that W&W maintain consistency from joint to joint.

W&W Steel used a programmable saddle and elbow pipe cutting machine (manufactured by Cypress Welding Company) to cut the typical pipe-to-pipe joints. When three pipes came together, an additional cut was made with the aid of "wrap around templates" that were furnished from the X-Steel drafting program. The truss joints were then fitted and welded with flux core wire which allowed W&W Steel to lay down very neat and symmetrical welds that did not require any grinding or filler material.

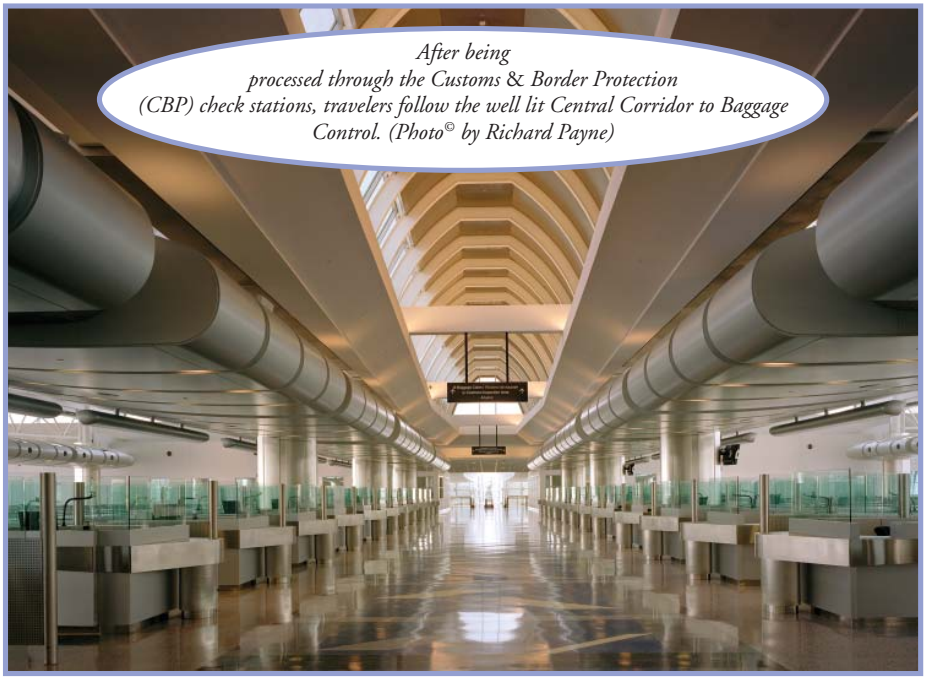
Central Spine

At the Immigration Hall level, between the Customs & Border Protection (CBP) check stations, there is a 40-foot wide corridor down the center of the building. The roof over this corridor is made of a series of exposed wide flange arches, each distinct in geometry from the others. On one side there is a strip of continuous glazing that brings yet more light into the building. PGAL provided the dimensions for each arch, and we, in turn, designed and detailed each accordingly. To coordinate our efforts, both PGAL and Walter P. Moore indicated the arch dimensions on our drawings.

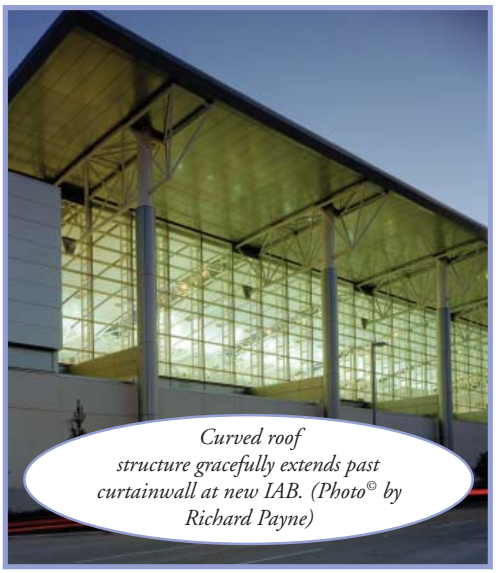
East Atrium

One of the more prominent architectural features of the building is the East Atrium, which is defined in the project specifications as AESS. After being processed at the Customs and Border Protection check stations, travelers will proceed down to the Baggage Control Level on grand escalators that feature striking views of the East Atrium façade. The support of this distinctive glass façade presented special structural challenges mainly because the walls are shaped as inverted cones, with neither straight nor planar surfaces anywhere in the wall. Ultimately, the result was a unique geometry for each of the structural frames supporting the façade. PGAL generated the complex 3-dimensional model from which all of the design was generated. The designers extracted the relevant detailed dimensions for the East Atrium frames, which were put on both the structural and architectural drawings.

To laterally support the curtainwall that projected off the building, six horizontal tube frames were arranged and attached at their ends to the building structure. The tubes are HSS 12x3's, with the long dimension



After being processed through the Customs & Border Protection (CBP) check stations, travelers follow the well lit Central Corridor to Baggage Control. (Photo© by Richard Payne)



Curved roof structure gracefully extends past curtainwall at new IAB. (Photo© by Richard Payne)

Acknowledgements

Owner – Houston Airport System (HAS), Houston, TX
Program Manager – The PB Team, Houston, TX
Architect – PGAL Architects, Houston, TX and Alexandria, VA
Structural Engineer – Walter P. Moore, Houston, TX
Contractor – Clark/Mission, a joint venture of The Clark Construction Group, Inc. and Mission Constructors, Inc., Houston, TX
Steel Fabricator – W&W Steel, Oklahoma City, OK
Detailing Software – AutoCAD 2000, 2002 and Tekla Xsteel

horizontal and located directly behind the curtain wall mullions. We designed 8.625-inch diameter pipes to support the vertical loads.

Bracing in the plane of the glass walls is comprised of 1-inch diameter stainless steel rod diagonals attached with clevises to gusset plates off 2.875-inch diameter pipe horizontals and the vertical pipes. Out of plane of the curtain wall, a series of exposed moment frames made up of the 8.625-inch diameter pipe columns and HSS 12x6 bent beams was designed.

Another interesting detailing feature of the East Atrium occurred along the edge of the roof – a 16-inch diameter round HSS member along the edge assisted in transitioning the curved roof edge down to the top of the curtainwall below. The size of the round HSS was not required structurally, but helped make the roof transition work. This round HSS was also specified to be AESS.

Due to the complexity of the design of the East Atrium, from beginning to end, a considerable amount of coordination, discussion and cooperation was required. During the design phase, this required careful coordination between PGAL and Walter P. Moore and was followed during the construction phase with careful coordination between PGAL, Walter P. Moore, Clark Construction and W&W Steel. The striking final product is a fine testament to that cooperative teamwork.▪

Ruben Martinez, P.E., S.E., is a Senior Associate & Project Manager at Walter P. Moore. Mr. Martinez provided project design and management services for the new International Arrivals Building, and had an active role in the construction administration. He would also like to acknowledge Javier F. Horvilleur, P.E., who passed away in September of 2002. Javier was the Principal in Charge and a mentor to the author, whose guidance and leadership proved invaluable during this project.