Design-Build Takes Flight

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Innovation and coordination were key components in the quick design and construction of the Boeing South Carolina 787 final assembly building.

THE SUCCESS OF ANY CONSTRUCTION PROJECT is a direct result of a cohesive and cooperative team of designers and contractors with positive attitudes assembled to deliver the owner's expectations on time and within budget, and this project was no exception. The extreme challenge was to provide a 1,000-ft-long roofed area with a 460-ft clear span between two 75-ft-wide, 86-ft-high towers—on an extraordinarily short timeline. The new facility serves as the final assembly operation for assembling the Boeing 787. Boeing selected the design-build construction project delivery method to minimize the cost and construction duration.

Boeing's expert in-house group of architects, engineers, and construction administration staff kept this project moving smoothly by understanding the design-build process and providing the resources to make quick decisions. Boeing's staff was amenable to value-added design suggestions and made the design submittal approvals both fast and efficient.

This is only the third site in the world where large commercial airplanes will be fully assembled and delivered. The other two are Boeing's Everett, Wash., site and the Airbus facility in Toulouse, France. The new South Carolina facility is adjacent to Boeing's existing aft and midbody fuselage fabrication, assembly and paint facilities, which were also designed and constructed by primarily the same design-build team, of which CMC was a part.

All photos courtesy of CMC South Carolina Steel

The 610-ft-long trusses were assembled on the ground in two sections.

The initial sway brace assembly being hoisted into place.

Sway trusses 100 ft long and 25 ft apart provide the bracing for the main trusses and were also assembled on the ground before being hoisted into place.

The Selection and Design

After Boeing selected the BE&K/Turner Joint Venture, with design partner BRPH, to design and build the facility, the design-fabrication-erection of the steel portion of the project was awarded to CMC South Carolina Steel and CMC Cary Engineering. The selection was based primarily on CMC's innovative design approach, which allowed the depth of the trusses to be approximately 10 ft shallower than other designs, and CMC's ability to consistently expedite project schedules. The 10-ft height savings was significant because it kept the structure just below the airport's radar cone.

The design phase began in mid-November 2009 with a visit to Boeing's current operations in Everett, Wash., by the CMC Cary Engineering Design Coordination Team. That visit allowed the design team to explore a number of value-engineering options prior to beginning final structural design, as well as confirming what Boeing's needs were for this facility.

Preliminary structural design models were completed during December 2009 and the team worked closely with domestic mills to facilitate time-sensitive mill rollings of the large W14×311 and W14×211 columns as well as truss sections as large as W14×605. Additionally, the extremely large bolt quantity requirements made it necessary to coordinate the manufacturing of the more than 250,000 tension control (TC) bolts, of which 100,000 1⅛-in.-diameter TC bolts would be used to assemble the trusses.

The owner's specifications required a Building Information Modeling (BIM) product be used to generate construction documents and to provide a final "as-built" model. The design team used Revit to generate the 3D model. This model was instrumental in formulating material take-offs, clash detection, and for meeting the aggressive design/construction schedule. The Revit model also enhanced the team's ability to generate and review structural shop drawings.

In addition to being designed for 130 mph hurricane force wind loads, the structure is designed to resist extremely high earthquake loads associated with Seismic Design Category D requirements. The roof trusses are

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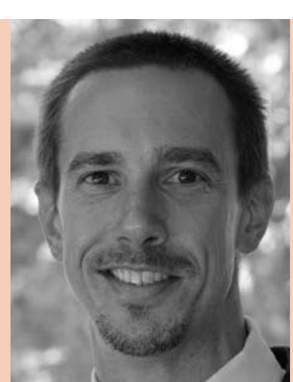

Lifting the first truss section.

also designed to support 12 underhung moveable crane bridges, with three four-hook cranes that can be coordinated for lifts involving multiple cranes when necessary. CMC engineers used innovative design concepts in order to minimize the quantity of costly slip-critical connections, many of which required 300 1⅛-in.-diameter A490 bolts.

The confidence between CMC engineers and CMC detailing managers as well as the use of SDS/2 modeling software enabled the 3D connection design to be seamlessly integrated into the fabrication details. The use of 3D modeling enhanced the team's ability to integrate design revisions and avoid schedule impact. CMC South Carolina Steel deployed several detailing teams, each team focusing on one portion of the structure including one for the mezzanine structures, the main roof, and the door pockets. This was key to meeting the extremely aggressive shop fabrication schedules.

The Building

The final building configuration is 618 ft by 1,041 ft and includes four elevated composite steel-framed floors 75-ft wide and 1,000-ft long that form the two sides of the larger structure. The floors house offices, training rooms, mechanical, electrical, crane maintenance, storage and other operations. The 11 main roof trusses, each weighing 450 tons, create a clear span of 460 ft. The wide-flange members that make up the trusses were field bolted with approximately 10,000 1⅛-in.-diameter A490 bolts per truss. The clear height created from the bottom of the trusses to the finished floor is 86 ft.

The hangar doors on each end of the building are the largest doors of this kind in the world. The two end door enclosures were cantilevered from the main trusses and designed to enclose the 81-ft-high, 450-ft-wide rolling stacked door sections. The result is a 20-ft cantilevered roof system.

The crane bridges and roof joist systems are supported by 100-ft sway trusses spaced on 25-ft centers spanning between the main trusses. Access to the suspended crane systems and emergency egress for the crane operators required 4,500 linear ft of catwalks and 9,000 ft of handrail with access to the crane bridges every 12 ft to 16 ft.

The Construction

The construction process started on November 1, 2009, at the facility adjacent to the Charleston International Airport. The BE&K/Turner Joint Venture contracted immediately to begin clearing the site and removing approximately 10 ft of extremely poor soil, which existed over the entire 90 acres and was replaced with structural fill. This site had been a phosphorus strip mining operation during the 1700s and 1800s. That nine-month process ran around the clock seven days a week throughout the duration of the steel erection.

CMC South Carolina Steel contracted with the BE&K/Turner Joint Venture to provide turnkey structural steel fabrication and erection services for the structure. During the preliminary budget and pricing phases, CMC South Carolina Steel carefully priced the preliminary budget but also made commitments for a very aggressive schedule. The erection of both towers started as originally promised on April 5, 2010, approximately six weeks after mill material was received. The last girt was hung and the topping-out celebration was held on September 24, 2010, the exact date for which it had been scheduled at the start of the design nine months earlier. To ensure that the project remained on this extremely aggressive schedule CMC South Carolina Steel teamed up with FabArc Steel, Oxford, Ala., to provide fabrication of the main truss members and other components.

Buckner Companies, Graham, N.C., under contract to CMC South Carolina Steel, provided erection services for the project. Buckner played

As each section of the main truss was lifted, it had to be swung into the proper alignment perpendicular to the side buildings. The first two trusses were placed using a single falsework tower for each, as the side building provided support for the outer end.

Landing the first truss section on the side building.

With the first truss section in place but still supported by the crane, the second truss section was hoisted into place.

a major role in the success of the project by providing erection plans and services, including professional design services for the rigging, shoring, and site-specific planning. Providing personnel, equipment, management, logistics, and erection expertise, Buckner worked seven days a week to absorb weather delays and incorporate an additional 15% in scope changes and remain on the original schedule.

Buckner Companies orchestrated delivery of approximately 208 truckloads of equipment and 1,000 truckloads of materials, at times receiving in excess of 70 trucks per week. The 11 main trusses were assembled in the field in two halves, hoisted, bolted at the centerline and erected on the supporting towers. The smaller sway frame assemblies including two sway frames, joists, and bottom chord bracing were placed as units. Once assembled, Buckner was able to erect in place nearly 600 tons of steel in a single day, enough structure to support a roof area of 60,000 sq. ft.

The number of ironworkers and supervisors peaked at nearly 150 at the height of activity. Equipment included two 600-ton Kobelco SL-6000 crawler cranes, each with a super-lift derrick attachment; two 440-ton Liebherr LR-1400 crawler cranes; a host of smaller cranes from 60-ton to 200-ton capacity; 20 manlifts ranging from 40 ft to 120 ft; and countless welding machines and other small equipment.

The success of this complex, schedule-critical project resulted from the cooperative efforts of all participants working effectively together. Each member of the team fulfilled its role in the project, leading all involved to be proud to call themselves part of what the participants came to consider "The Ultimate Design-Build Team."

▲ Seats on the main truss connection plates provide the support for the sway bracing.

MSC

Owner
The Boeing Company, Chicago

Architect and Structural Engineer (foundations)
BRPH, Melbourne, Fla.

Structural Engineer (steel frame) and Steel Detailer
CMC Cary Engineering, Greenville, S.C. (AISC Member)

Steel Fabricators
CMC South Carolina Steel, Greenville, S.C. (AISC Member)
FabArc Steel Supply, Oxford, Ala. (AISC Member)

Steel Erector
Buckner Companies, Graham, N.C. (AISC and SEAA Member)

Design/Build Contractor
BE&K/Turner Joint Venture, Greenville, S.C.

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