Ocean View

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INSPIRED BY ITS LOCATION ON THE ATLANTIC COAST, the recently opened Virginia Beach Convention Center's architectural design is based on nautical themes and seagoing vessels, with a strong emphasis on exposed structural support related to such endeavors.

Images such as sails, yacht fittings, lighthouses, waves, and water all find their way into the design vocabulary for the facility. A monumental steel-framed glass curtain that forms the front entry to the center resembles a wind-filled sail and appears to float in pools of water. Visitors walk across wooden boardwalks to make their entrance into the building, where they stroll on carpet that evokes images of seaweed, beach towels, and sand. The steel and glass observation tower is reminiscent of a lighthouse, offering breathtaking views of the ocean and the beach. Exposed structural steel elements are used throughout the convention center as a common and unifying theme while supporting the architectural metaphor of modern, sleek, ocean-going vessels.

The overall footprint of the convention center is 880 ft by 430 ft in plan. The project was built in two phases. The adjacent, existing convention center was used during construction of the first half of the new facility. Once this phase was completed and operational, the existing convention center was demolished and the adjoining second phase was completed. The full facility opened in December 2006.

Exhibition Halls

The convention center contains a total of 516,000 sq. ft of space, 150,000 sq. ft of which is dedicated to column-free exhibition halls. Structural steel Pratt trusses with arched top chords were designed to span 256 ft between bearing supports, also creating a 40-ft-tall unencumbered exhibition space. These open hall spaces, economically covered by the structural steel roof structure, are seen as a distinct marketing advantage in terms of heightened flexibility by the convention center operators; Virginia Beach is in direct business competition for exhibitions and conventions with other facilities in nearby cities located along the central eastern seaboard.

The long-span roof trusses over the ballroom and exhibition hall spaces are spaced at 30 ft on center along the length of the convention center, and are 22 ft deep between the top and bottom chords at the roof high point and 9 ft at the north bearing. The roof cantilevers approx-

Wide open spaces, made possible by long spans, are part of a coastal theme at the new Virginia Beach Convention Center.

imately 60 ft beyond the north support and over the facility's 21 loading docks.

The exhibition hall trusses were shipped to the site in individual pieces, assembled on the floor of the hall in the lay-down position with specified cambers, and then lifted into place as an entire assembly (approximately 60 tons total) with one fixed-leg and two crawler cranes without temporary support towers. ASTM A913, Grade 65 yield steel was used for all long-span roof truss top and bottom chords. In addition to reducing the total quantity of steelwork for the roof, the use of 65 ksi grade steel for the truss chords also required somewhat less crane capacity for the truss lifts. The arched top chord was fabricated in straight-line segments between bolted field splices. Diagonal and vertical members of the roof trusses were specified as ASTM A992 Grade 50 ksi yield steel. All W14-series roof truss chord and web members are oriented in bridge-type arrangement with flanges aligned and double gusset plates at the joints.

Field bolting at the gusset plates is accomplished with 1⅛-in.-diameter A490 bolts designed in bearing within standard holes. Truss camber ordinates up to 3½ in. were supplied on the construction documents at each chord splice location. The roof trusses span between reinforced concrete structures to the north and south of the exhibit hall. The southern support is formed from a fixed manufactured pot bearing, whereas the north bearing is of guided expansion type.

All structural steel trusses, ceiling and roof purlins, diaphragm bracing, and roof decking are left entirely exposed in the final built condition in the exhibition halls, staying consistent with the notions of exposed structure and inherent strength throughout the facility. All structural steel received a multi-coat paint system including sand-blasted substrate, zinc-rich metal primer, and final finish coats. A consistent birch finish color was used throughout to tie all exposed steel elements into the overall architectural design.

Pre-function Area

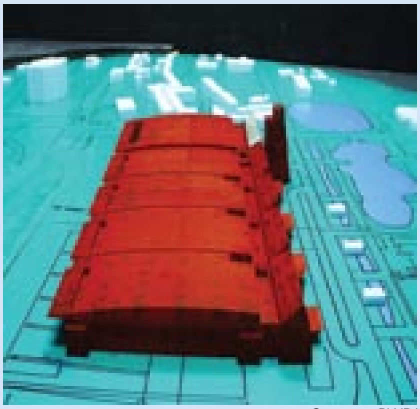
Housing the convention center's pre-function space is a striking 80-ft-tall glass window wall, subtly curved along its vertical surface, emulating the profile of a boat's sail in the wind. This glass façade is thermally and visually separated into three individual modules by reinforced concrete stair towers. Each pre-function module is approximately 120 ft long in plan and consists of nine vertically spanning cable trusses spaced at 15 ft on center. Each cable truss is ground-supported at its base and supported at its top by a structural steel frame, which is anchored to the reinforced concrete frame of the main convention center. In addition, each truss consists of an 8-in.-diameter double-extra strong structural steel pipe with rigidly connected structural steel "arms" of cruciform cross-section extending out at various lengths from opposite sides of the 8-in.-diameter central "spine" column. Following the profile created by these cruciform arms, two 1⅝-in.-diameter structural steel cables flank the central spine and give the trusses their "fishbone" profile. The glass panels at the building façade span vertically between supporting rectangular HSS that span horizontally between fishbone trusses. Each pre-function module is diagonally braced at its roof and back face, and is tied into the main structure R/C frame to provide lateral stability to the overall system.

The primary function of the vertically spanning fishbone trusses is to resist the high design wind loads imposed upon

Wind Tunnel Testing

The Virginia Beach Convention Center is located less than a mile from the Atlantic shoreline in a region prone to hurricanes and very strong winds. Therefore, engineering for wind loads was clearly a critical component in the design of the structure and its external cladding. The "fishbone" cable trusses that support the pre-function window wall, as well as the long-span roof trusses over the exhibition hall and ballroom, are relatively flexible, lightly damped, low-frequency structures. An understanding of these elements' deformations under the applied loads, as well as any inertial forces that may be generated through their dynamic response to wind, needed to be understood. These structural characteristics, along with the complex characteristics of hurricane force wind events, meant that code-prescribed wind loads alone would not be appropriate in this instance for developing the design wind loads; specialized wind tunnel testing would be required.

The design team turned to Rowan, Williams, Davies & Irwin (RWDI, Guelph, Ontario, Canada) to provide wind tunnel testing and consulting services for the project, and a 1:400 scale model was created for the testing. Due to the limited overall height of the convention center and the importance of obtaining accurate loads for cladding design, a pressure model was created, utilizing the high-frequency pressure integration method for obtaining equivalent static design wind loads from measurements taken from more than 700 pressure taps at the model surface.



Courtesy RWDI

A 50-year return period, three-second gust design wind speed of approximately 130 mph, which includes an importance factor of 1.15, was used for testing. The objectives of the wind tunnel testing program were to determine the peak local winds for cladding design and overall structural wind loads for the design of the primary lateral load resisting elements. Wind loads for secondary structural elements of the building, including the long-span roof trusses over the exhibition hall and ballroom and the fishbone trusses at the pre-function space, were also determined.

Wind pressures for the design of these elements are discovered through a combination of external pressures measured directly from the scale model in the wind tunnel, and internal pressures determined through a combination of numerical techniques along with the wind tunnel tests.

the structure from the coastal environment. Under the action of wind, the central pipe acts as the compression chord of the truss, while the cables act as the tension chords.

The cruciform arms linking the central pipe with the cables act to link the compression and tension elements of the fishbone truss. Because the trusses are pin-supported at each end, the moment is at a maximum at mid-height. An initial pretension of 80 kips was introduced to each cable in order to offset the loss of tension in the cable and ensure that the cables remained in tension under wind loads. The main compression chord of the fishbone truss is extremely slender when considering its height between its pin-ended support points. This central spine relies upon the adjacent cables in tension to maintain its stability. Under lateral loads, the fishbone truss central spine develops destabilizing axial compression while the cable chord develops stabilizing axial tension. Essentially, the individual fishbone trusses are self-stabilizing mechanisms; the compression chord's tendency to buckle is resisted by the cable's tensile stabilization forces. The cruciform arms act to link these balancing mechanisms, and therefore serve as brace points along the height of the compression spine.

The performance of the fishbone trusses is dependent upon the fitting and connection detailing to ensure system behavior consistent with the intent of the engineering design and analysis. The trusses were fabricated and tensioned at Josef Gartner & Co.'s fabrication plant in Gundelfingen, Germany, where the long main pipe and cruciform arms were placed in a setting frame and the cables were stressed to the specified pretension using a hydraulic jack anchored at the fishbone truss end plate. The setting frame ensured that the cruciform arms did not restrain the elongation of the cables through the end fittings during the cable-tensioning operation, avoiding locked-in stresses and deformations in the cruciform arms and non-uniform force distribution in the cable trusses.

Once the specified tension had been achieved, the cable end was locked into place and the cable fittings at the cruciform arm ends were fastened around the cables. The fishbone trusses were mounted as fully assembled and tensioned units within a supporting frame to ensure that the transport of the assemblies did not induce loading conditions and stresses that were not intended in the design of the trusses. The trusses were then transported to Virginia Beach for erection.

Towering Above

The 150-ft-tall observation tower serves as a focal point and meeting place for patrons of the convention center. In addition to a publicly accessible rooftop deck, the tower houses two special 40-ft-tall meeting rooms that may be used for special functions, convention center meetings, and more intimate receptions. Overall, the $202 million facility is an example of architects, structural engineers, and multiple steel fabricators and erectors working together to exploit the potential for a wide variety of structural steel shapes and assemblies within an overall composition of exposed steel design. MSC

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Vertical "fishbone" trusses (at left in photo)—consisting of round HSS, cruciform cross-section arms, and tension cables—support the glass enclosure of the pre-function space.

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City of Virginia Beach, Va.

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Skidmore, Owings & Merrill LLP, Chicago

Architect
Skidmore, Owings & Merrill LLP, Chicago

Construction Manager
Turner Construction, Chicago

Steel Detailer
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