Supporting Role

By Peter J. Cheever, P.E., and Aaron C. White, P.E.

The new Boston Convention and Exhibition Center features signature V-columns that support a one-acre ballroom and provide lateral stability to large, column-free exhibit areas.

HNTB/Rafael Viñoly Architects/Photographer: Brad Feinknopf

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80'-tall pipe columns support the 300'-wide high roof, while its lateral stability is provided through bracing down to the low roof at only four locations between expansion joints. Low roof V-columns provide both gravity support and lateral stability to the entire exhibit hall roof while maximizing useable exhibit hall floor space.

At 1.7 million sq. ft, the $850 million Boston Convention and Exhibition Center (BCEC) is the largest public building ever constructed in New England. To provide a largely column-free exhibition floor, the structural engineering team of LeMessurier Consultants and Walter P. Moore collaborated closely with the architects to develop efficient structural steel solutions, including the signature V-columns used throughout the building. The creative use of structural steel proved crucial to the aesthetic, functional, and budgetary success of this South Boston waterfront venue.

Challenging Spaces

The 516,000 sq. ft exhibit hall presented the most obvious structural challenges. Planners required that it be virtually column free to support a wide variety of events, with a 45′ ceiling and rigging capacity of 1,500 lb on a 10′ by 10′ grid. Floor loading of the exhibit hall was 400 psf. The loading is on a floor slab that occurred at grade level; however, because of poor soil conditions, the slab was supported by deep foundations instead of being simply a slab-on-grade.

Meeting rooms with 15′ ceilings and 60′ clear spans between columns were originally programmed to support 250 psf live loads. However, framing studies demonstrated that a 100 psf loading, combined with strategic concentrated load criteria, could satisfy the user requirements and save significant cost.

The 41,000 sq. ft column-free ballroom is raised 75′ above grade at the north end of the building to provide harbor views. The ballroom was designed with a 45′ ceiling and a 150 psf capacity floor that can also accommodate rhythmic floor excitations without objectionable vibrations. Lobby spaces below dictated 60′ clear spans for the floor framing.

Conceptual design of the floor system followed the rhythmic excitation criteria in AISC *Design Guide 11: Floor Vibrations Due to Human Activity*. While it was not practical from a design point of view to satisfy these criteria rigorously in the final design, collaborative work with vibration consultants led to the addition of mass to the ballroom floor by adding a topping slab in one region and a by hanging a kitchen from the floor in another region. Validation testing conducted on the completed floor system showed that the measured frequency, damping, and accelerations conformed to perceptibility thresholds that were even lower than those required for design.

The scale of the building presented other challenges. At 1,595′ long and 811′ wide, expansion joints for thermal and seismic movements were carefully located and sized. Most of the steel structure is exposed to view, requiring careful design and coordination with the architects. Certain connection details were specified to have shop fabricated mockups for review by the engineers and architects. Once approved in the shop, these became the prototypes for subsequent production connections. Even typical interior wall partitions demanded extra thought: The high floor-to-floor distances required by the large, open spaces necessitated supplementary steel framing so standard wall components could be used. Exterior walls incorporated horizontal ladder frames composed of HSS spanning 30′ from column to column, creating a mid-height support for the curtain wall systems. Also, exhibition support services for power, air, water, and Internet connections required that hundreds of floor boxes be carefully integrated within the floor framing system.

The 60-acre site provided another major structural challenge. Like much of Boston, it lies outside the original shoreline on man-placed fill susceptible to amolified seismic forces. This dictated deep foundations for the superstructure and at-grade floor construction. With the water table hovering just 8′ below the surface, below-grade space was eliminated from consideration. The structural slab-on-grade, including the exhibit hall slab and meeting room columns with up to 800 kip loads, were supported on 4,300 driven precast (120 ton capacity) concrete piles. More heavily loaded columns (1,200-4,000 kips) at the exhibit hall and ballroom were supported on drilled caissons. Over 54 miles of precast piles and three miles of caisson shafts were installed to support the structure. Choosing structural steel for the majority of the elevated framing reduced foundation costs and provided needed ductility.

The structural engineers specified a 7.5″ floor slab—3″ composite steel deck with 4.5″ normal weight concrete—to provide adequate composite beam capacity and to accommodate more highly concentrated floor loads. The floor assembly also provided the significant diaphragm strength needed in a building of this scale, while providing sufficient thickness to integrate floor boxes.

The signature roof over the 1,200′ by 480′ exhibit hall gives the building much of its architectural character. The highest part of the roof is 300′-wide and gently

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An efficient erection scheme simplified the construction of the exhibit hall's low roof V-columns and trusses.

curves as it rises from the south end of the building, resulting in a double-curved roof that cantilevers at the northern end and overhangs the main entrance.

V-Columns

Low roofs flank the high roof, covering meeting rooms and creating 90′-wide "snow pockets." The structural engineers placed four V-columns at 90′ centers to efficiently support the heavy roof snow loads and simultaneously provide adequate lateral resistance while taking up minimum exhibit floor space.

The V-columns consist of two diagonal 16″ round HSS pipes. Each is supported on a conical pedestal consisting of a W14 steel core encased in cast-in-place concrete. The Vs start 7.5′ above the exhibit floor to clear pedestrian and forklift traffic.

The main roof trusses, comprised of web-horizontal W14 segmented chords and W14 web members, were shop fabricated in two 60′ cantilevered sections and two 90′ interior sections to efficiently span the overall 300′ width. Maximum truss depths of 14′ allowed economical shop assembly and over-the-road shipment. V-columns were also used to create distinctive cantilevered balconies and visual cues at the four main building entrances from the encircling ring road. The one-acre ballroom and its clear-span roof are also elegantly supported by pairs of V-columns.

Originality and Innovation

The architects and structural engineers used structural steel throughout the building to creatively solve a multitude of challenges. For example:

- A steel bracing system provided lateral-load resistance for the high roof while it simultaneously supported crucial pedestrian passageways between the east and west meeting rooms. The soffits of these passageways also cleverly support operable partitions that subdivide the exhibition space.
- A lightweight steel-framed wall with glass infill hung from the roof skillfully blocks noise between adjacent spaces while preserving the aesthetic and hiding the expansion joint in the roof.
- To economically access one mile of rigging points above the massive exhibit hall, designers collaborated with the fabricator and erector to devise a prefabricated catwalk system comprised of bent plate walking surfaces and Vierendeel truss handrails in 30′ sections.

Collaborative Effort

Basic floor framing and columns were designed using software developed by LeMessurier Consultants. More complex roof framing and lateral load systems were analyzed and designed using SAP2000. A common origin for all computer models allowed linking of work produced in different offices of the two structural engineers. During the shop drawings process, data files were shipped via Internet to the fabricator for loading into SDS/2 detailing software. Engineers worked closely with a fabricator expeditor to speed processing of RFIs, shop drawings, and other submittals.

BCEC opened June 2004 in time to host events peripheral to the Democratic National Convention. Its architecture—and especially its elegant structural systems—received immediate acclaim, including an AISC Innovative Design and Excellence in Architecture with Steel (I.D.E.A.S.) Award in 2005. ★

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Read more about the Boston Convention & Exhibition Center in the I.D.E.A.S. Awards coverage featured in the June 2005 issue of MSC *at* **www.modernsteel.com**.

Architects
HNTB Architecture, New York
Rafael Viñoly Architects, New York
Primary Group, Boston (associated)

Structural Engineers
LeMessurier Consultants, Cambridge
Walter P. Moore & Associates, Tampa, FL (associated)

Engineering Software
SAP2000
Chiquita (LeMessurier in-house design program)

Detailers
Canam Steel Corporation, Boucherville, QC, AISC member
Steltec, Inc., Ste-Therese, QC, AISC member, NISD member
Les Dessins Trusquin, Inc., Laval, QC, NISD member
M & D Drafting Ltd., Edmonton, AB, AISC member, NISD member

Detailing Software
SDS/2
Xsteel

Fabricator
Canam Steel Corporation, Easton, MA, AISC member

Erectors
CDSP Erectors
Capco Steel Corporation, Providence, RI, AISC member

General Contractors
Clark Construction Group, LLC, Bethesda, MD
Huber Hunt & Nichols, Indianapolis
William A. Berry Construction, Danvers, MA