Vibration concerns set the stage for a new dance facility.


# Dancing to a New Beat

BY RACHEL CALAFELL AND KARIM ZULFIQAR, P.E.

**WHEN IT OPENS** in early spring 2011, Houston Ballet's Center for Dance will be the largest professional dance company facility in the United States. The sleek 115,000-sq.-ft, six-story steel structure will house nine dance studios for the Houston Ballet and its Academy, a 200-seat dance lab, administrative offices, and support spaces. The anticipated final project cost is $53 million.

Located in the heart of the Theater District in downtown Houston, the Center for Dance was constructed adjacent to Wortham Center, the theater at which the Houston Ballet has performed since 1987. A private-access steel trussed bridge spans 130 ft diagonally from the Center for Dance to backstage of Wortham Theater Center so the dancers can easily walk in costume from the practice facility to the performance stage. The ultra-modern looking bridge engages the public into Houston's Theater District, the second largest theater district in the United States, as it spans over the main entrance to downtown from the north.

The new facility will more than double the space that Houston Ballet has had at its home since 1984, a renovated commercial building approximately three miles from downtown. That structure was not designed for floor vibrations resulting from dancing, so occupants in conference rooms and offices were often disturbed by vibrations resulting from dancers leaping overhead. The new prime location, structural design to reduce vibration, and enhanced use of space make the new Center for Dance a tremendous improvement for Houston Ballet.

## Steel Backbone

The use of steel was an ideal choice for the Center for Dance due to the unique requirements for the facility's use of space, which includes underground parking, a ground-level vehicular drive-through and two-story dance lab, and support spaces, offices, and two-story studios for the academy and professional dancers on the upper levels. These programming requirements resulted in 32 ft floor-to-floor heights in the dance lab and studios to enable lifting of ballerinas, spans up to 62 ft in length, and transferring columns above the dance lab to provide a column-free theater space.

Walter P Moore engineers conducted full analyses of both a concrete and a steel structure and determined the steel structure was more economical because of the post-tensioning required for a reinforced concrete structure with the long spans and the expense of shoring the two-story heights. In addition, the atypical column grid due to the distinctive requirements of each space would have

View of the two 62-ft-long transfer trusses installed at Level 3, above the dance lab.

involved the use of many custom built forms for the reinforced concrete option. The ducts required through the transfer girders and catwalks around the girders would have been difficult to accommodate with solid concrete transfer girders, while steel transfer trusses have open regions and can be much narrower than concrete transfer girders.

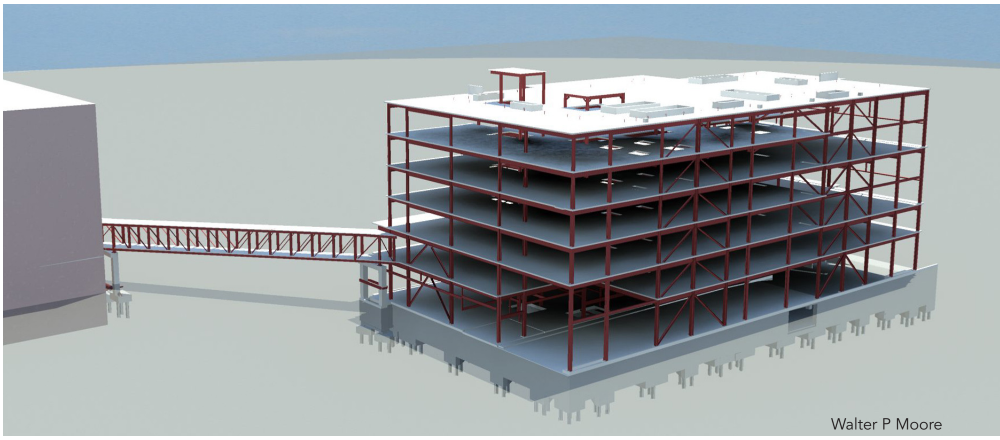
Double-angle inverted steel chevron braced frames provide lateral support for the new steel structure. Typical sizes of the braces are 2L8×6×⅝ for the 33-ft to 40-ft spans between columns, and 2L6×4×½ for the shorter spans. All columns are W14s. The braces are hidden from view in mechanical spaces, storage rooms, and along the east wall.

Although all of the upper floors were built of composite concrete framing, a 12-in. structural concrete slab was constructed at the first elevated level to minimize the floor depth and therefore the amount of excavation required for the basement. The extent of excavation was a concern due to the high water table level at the project site.

Levels 2 through Roof Level are constructed using 4½-in. normal-weight concrete on 2-in., 18-gage composite metal deck. Due to the thickness of the concrete deck, no fireproofing was applied to the steel framing members. The roof level was constructed with a composite deck due to the mechanical equipment located on it, which is hidden from view by means of screen walls.

To provide a column-free space in the two-story dance lab at ground level, two 62-ft-long trusses were required to transfer the column load from upper levels to outer columns at Level 3. Because a dance studio is located on Level 3 directly above the dance lab, the transfer truss designs were controlled by stiffness. The transfer trusses are 10 ft deep, with W24×335 top chords and W14×550 bottom chords. A 275-ton crane was used to erect the 50,000 and 60,000 lb transfer trusses. Due to the building location in downtown Houston and the limited space on site, the tower crane used for steel erection was located in the center of the new building.

Some transfer truss members had flanges more than 2 in. thick that were welded with complete joint penetration welds, so ultrasonic testing of the steel member and weld material was performed to verify that lamellar tearing and other defects were not present at the connections.




A 3D Revit model was created to develop the structural drawings.

The project site was tight in a busy urban location.


## Good Vibrations

An extensive analytical vibration analysis was conducted on the floors of the new facility, including the dance studios and neighboring office spaces and conference rooms, due to the classes and rehearsals of Houston Ballet that will occur in the studios. Engineers used results from a time history analysis to determine the required composite floor thickness and girder sizes necessary to limit vibrations to an acceptable level.

The procedure outlined by AISC Steel Design Guide 11, *Floor Vibrations Due to Human Activity*, was followed for areas with

*Rachel Calafell is a graduate engineer and Karim Zulfiqar, P.E., is a principal and project manager with Walter P Moore. Both are AISC professional members. They can be reached at 713.630.7300.*

Fabrication under way on one of the 62-ft-long transfer trusses.

Photos this page by Walter P Moore.


Erection of the 130-ft-long Pratt truss bridge connecting the Center for Dance to Wortham Theater Center.

Installation of cold-formed metal framing for back-up of the black granite cladding.

rhythmic excitation. The jumping exercise loading was applied, which is more stringent than the general dance loading. In an effort to balance occupant comfort and an economical design, engineers consulted with the owner to determine the required level of vibration control for the structure. Optimization strategies employed in the vibration study included alternating the orientation of beams in adjacent bays and adding an additional girder in the center of some bays to reduce beam spans. In addition, based on recent industry research, the stiffness of full-height interior partitions was considered in the vibration analysis. Because the partition locations generally coincided with steel beam locations, stiffness provided by the partitions was accounted for by applying modification factors to the beam stiffness.

Without considering floor vibration the weight of the steel for this structure would have been 10 lb per sq. ft (psf) to 12 psf. Because of the planned use of the building and its unusually long bay widths, providing the required stiffness would have increased the steel weight to 22 psf. However, application of these optimization strategies lessened the required increase in tonnage resulting from vibration design and resulted in a steel weight of just 16 psf.

For acoustical purposes, some of the new dance lab floors incorporate floating slabs and the walls include 18 in. of air space for soundproofing.

## Ballerina Bridge

The private-access Ballerina Bridge, a signature element of the new Center for Dance, spans 130 ft across the intersection of Smith and Preston Streets. The bridge is clad with futuristic-looking metal panels, which have images of leaping dancers lightly screened onto the top portion, while the bottom portion is slotted for ventilation and for lighting effect at night. Vehicles traveling under the bridge or pedestrians might glimpse dancers traversing the bridge on the evenings of performances.

The bridge cross section measures 8 ft wide by 11 ft tall and the concrete abutments at each end are constructed on augercast piles. The typical size of the Pratt truss bridge diagonals and verticals are $2L3\times3\times\frac{5}{16}$. The bridge top chords are W12×26 and the bottom chords are W12×35. Steel moment frames using W12×65 members were provided above each abutment to resolve wind loads perpendicular to the bridge span. The 34-ton steel bridge was shipped in two 65-ft-long segments, which were spliced together at the site prior to lifting the bridge into place with two 90-ton cranes.

## Structural Feet and Skin

Due to the site's poor soil conditions and the water table being almost at grade level, 18-in.-diameter, 95-ft-deep augercast piles were a more economical option for the project than drilled piers. Proximity of the structure to the neighboring bayou made site drainage an important consideration. To alleviate drainage concerns, a building setback was incorporated and provisions were made for a future stairwell to the bayou.

Several value-engineering items were incorporated in the project to reduce the construction cost because the original cost estimate was approximately 50% over budget. These items included eliminating a proposed seventh story of the new structure, reducing the size of the floor plan, and selecting a cladding system of 3 cm black granite, CMU and plaster on the east wall, and ceramic-etched glass as opposed to other cladding systems considered, such as wood paneling.

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View of the Center for Dance facing northeast (left) and southeast (right).

With its unique architectural appearance and structural features, the Center for Dance is an icon in Houston's Theater District. This state-of-the-art facility allows Houston Ballet to significantly expand its education and dance training programs and facilitates its commitment to improving the art form of ballet on all levels. When the Center for Dance opens in the spring of 2011, Houston Ballet will truly be dancing to a new beat. MSC

**Owner**
Houston Ballet, Houston

**Architect**
Gensler, Houston

**Structural Engineer**
Walter P Moore, Houston

**General Contractor**
W.S. Bellows Construction Corporation, Houston

**Structural Software**
Revit, ETABS, SAP, SAFE