Facilitating Creativity

Eye-catching architecture and innovative structural design are all but requirements when building a school geared toward the arts.

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THE ARTS ARE THRIVING IN LOS ANGELES—and not just in Hollywood and the area's mega-studios. Central L.A., with the Walt Disney Concert Hall, Museum of Contemporary Art, and sprawling Music Center complex, has become a center for arts and culture in the area. And next year, the High School for the Visual and Performing Arts will bring an educational component to this nexus of creativity.

As part of the Los Angeles Unified School District's (LAUSD) 12-year, $20 billion construction program, the high school stands at the north end of the Grand Avenue Cultural Corridor, within easy walking distance of the above institutions. The state-of-the-art campus, built to accommodate 1,800 students, will merge sustainability, security, and a dedication to the arts in a new cultural icon.

Elements of Design

To express the LAUSD's educational visions, designers created three sculptural expressions of form in the project: a theater tower, a main performance lobby, and a library.

The tower, visible from surrounding buildings and a neighboring freeway, cuts against the downtown landscape and proclaims the school's identity. Elevated above the theater, the tower is part of the theater building's two integrated structural systems. The main building is a concrete shear wall system with steel gravity framing, with the steel tower projected from the main roof via steel braces.

The primary lateral resisting system uses concrete shear walls resting on continuous footings or concrete grade beams, and steps down with various grade changes along the building. While the engineers worked with the architect to incorporate concrete as a design feature, structural steel was chosen for the main building's primary and secondary framing systems. The steel framing system accommodates the unique functional and patial requirements of the theater, accounting for numerous floor elevations and irregularly-shaped platforms between the orchestra pit and the roof above the stage. The main seating area is formed by a series of bent steel composite girders ranging from W10 at shorter spans to W24 at the center of the space for increased headroom. These

Photos: HMC Architects

Steel being erected for the theater tower.

members slope and fan out to support a metal deck with concrete topping.

The "Grid-Iron" platform was constructed with a combination of steel channel-shaped beams and steel grating to accommodate the increased live load. The 60-ft-tall rigging wall, which supports the heavy arbors, was constructed with HSS members, forming a grid system (vertical and horizontal) to resist induced seismic force. Framing for acoustic reflectors and clouds employed round steel pipes, channels, tubes, and angles.

The Tower

The elevated tower is an unoccupied space with an enlarged box (referred to as the tower head) located 150 ft above the lowest building grade. Early in the process, the design team decided on a structural steel braced frame system as the basic lateral resisting method. The major structural objective was to keep the tower as light as possible, thus minimizing the unnecessary burden on and demand for the main building's lateral resisting elements. By virtue of the vertical massing, a result of an unoccupied tower head with a lighter mass, and the stiffness provided by the braced members and frames, the design minimized an extra lateral load at the top level, creating a "whiplash effect."

The tower structure consisted of W14 diagonal steel braces, columns, and beams. All steel members are connected concentrically at their work point with weld and gusset plates. The tower's columns are extended to the foundation 80 ft below and encased in concrete, working with the main building's concrete shear wall and acting as composite columns. This design resulted in an increased slenderness ratio and enhanced compression-and-tension capacity. The positive load path for the tower's induced lateral load is to the shear wall and foundation below.

The Spiral

Hovering around the tower, a second architectural feature, called the "Spiral," projects from the main structural system high above the adjacent freeway crossing through downtown L.A. As with the tower, the major structural objective was to keep the design as light as possible. The spiral assembly consists of fabricated steel pipes, each 3 ft in diameter, with a series of transverse stiffener plates inside each pipe. The spiral's exterior cover is an 8-ft square section built with structural steel tubes and angles and cladded with architectural metal panels. The pipe acts as a spine, providing the necessary support for the assembly. The pipe supports a series of steel outrigger beams cantilevered from the tower's structure and reinforced with added steel side plates on each side. These plates improve the weak axis bending and torsion resistance of the W27 outrigger beam for the induced lateral force seismic or wind, which can originate from any direction.

The Lobby

During the preliminary design phase of the lobby, several "stick models" were used to illustrate the architectural form, and a collaboration of aesthetics, function, and structural performance was achieved.

The lobby structure makes use of 10-in. square hollow structural section (HSS) members as the primary structural system, the skeleton of the form. HSS members are welded together to form a moment resisting connection. Secondary HSS members support the lobby's exterior wall and architectural metal panel glazing system.

Continuity steel plates, added to all joints of the HSS members and acting as a rigid box, ensure a direct and strong load path for the induced joint moment developed at the intersection of the HSS members. An upper-level horizontal ring truss system, referred to as the "donut," was constructed at the same level as the main building's primary roof elevation. The donut level consists of HSS members to provide diaphragm action and positive load transfer for the lobby's framing above the primary roof. All HSS columns and braces are embedded into the foundation concrete. Additionally, the insides of the lower portion of these HSS members are filled solid with non-shrink and non-metallic grout to increase their torsion resistance at the critical section.

Analyzing the Theater

The theater consists of three components: the main building, the tower, and the lobby. The engineering team developed a SAP 2000 3D finite element computer program to simulate the structural behavior of all three components to capture all possible structural demand for them. Three major computer runs included one for the lobby as a stand-alone structure, one for the tower with the main building only, and a third with the three components combined. Through this effort, the engineering team captured the entire loading envelope of the structural design.

Library Research and Design

Designers originally considered the form of the library as an asymmetrical, cone-shaped concrete structure. In design development, however, a more economical structural steel system emerged that would set the central campus quadrant apart from traditionally designed schools. The team used a 3D ETAB model to analyze the structure.

The primary lateral resisting system for the library is the steel special concentric braced frame (SCBF) on composite steel and concrete grade beams. The library's base is approximately 91 ft in diameter, with a total of 16 steel columns sloping to a top ring at varied angles. The top compression ring is constructed with HSS members. The bottom tension ring is constructed with steel beams embedded inside the 4-ft, 6-in.-deep concrete grade beam. Round HSS was used for the bracing members of the SCBF, along with W14 members at the frame columns and beams. The complex interior layout of the library challenged the engineering team to provide secondary framing for the support of the compound, and interior walls and soffits were constructed with HSS members and angles with infill metal stud framing.

Testing and Inspection

Welding is the most critical and vital element for interconnecting the structural steel members in the lobby and tower structures. In a process with no margin for error, a new technique was used in the lobby to check the joint welding. With the understanding of the client and technical assistance from Smith Emery (the material testing lab representing LAUSD), joint welds were inspected by phased array ultrasonic inspection in addition to conventional ultrasonic techniques. This recommendation from the testing lab is a more user-friendly technique than conventional ultrasonic testing (UT), simple in principle but complex in practice. Increased restrictions on

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weld testing requirements were also needed with the steel in the tower. Inspection and testing was based on Table 6.3 of the America Welding Standard (AWS) - UT Acceptance-Rejection Criteria (cyclically loaded non-tubular connections) rather than the industry standard AWS D1 Table 6.2 (statically loaded non-tubular connections).

As with any complex project, solutions depended upon the input from various sources and open communication within the team. The early decisions of the engineering group facilitated the construction process and laid the groundwork for a successful, structurally innovative facility. The High School for the Visual and Performing Arts is on schedule to be completed next year, less than 30 months after the initial groundbreaking. MSC

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