Typical structural schemes and height requirements are overruled in San Diego's new federal courthouse.

All Rise

BY THOMAS A. SABOL, S.E., PH.D.

Thomas A. Sabol is a principal with Englekirk and Sabol, Inc., in Los Angeles. You can reach him at **tom.sabol@englekirk.com**.

JUSTICE HAS COME to San Diego.

Or at least it was expanded there in the form of a new U.S. Courthouse, which opened late last year. Located adjacent to the existing Schwartz United States Courthouse at the western edge of downtown San Diego, the new $300 million facility comprises a 16-story, 463,700-sq.-ft annex adding 14 courtrooms and support space.

The tower, whose ultrathin massing frees up space at ground level for a public plaza linking adjacent buildings, is clad in wafer-like layers of Terracotta and glass composed in response to the building program and orientation.

One of the building's marquee visual and structural elements, the elliptical main lobby, expresses its San Diego roots by paying homage to the locally beloved 1915 Balboa Park Botanical Building; curved HSS and exposed steel framing mirror

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▲ Entrance lobby ceiling with skylight and exposed exterior steel curtain wall framing.

➤ Braces and columns were spliced to this prefabricated base after the concrete slab was cast.

the lath house design employed in that structure.

In fact, architecturally exposed structural steel is expressed throughout the structure, including the lobby curtain wall and screen as well as site amenities such as the trellis along the main entrance ramp. Weathering steel plate retaining walls along the accessible path between the plaza and raised entrance lobby boldly complement the subdued colors of the building.

Concrete-filled metal deck supported by steel wide-flange beams and columns resists the gravity loads; the beams are 24 in. deep and the girders are approximately 27

Hensel Phelps Construction Co.

▲ Status of steel erection as of spring 2011, looking southeast. The existing Schwartz Courthouse and Federal Building are toward the left.

▼ Southwest view of the illuminated entrance lobby. The clerestory to the U.S. Marshall's work area illuminates the bottom of the lobby.

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An exposed structural steel stair in the entrance lobby floats between Levels 1 and 2.

in. deep. The columns are W14X, including plated W14X730 used to satisfy progressive collapse requirements at the lower levels of the building. Open space requirements at the public level call for a relatively small number of columns and result in typical spans of 45 ft. Meeting the sound requirements of the courtrooms called for stringent floor vibration criteria, which were satisfied by carefully analyzing selected applications of framing continuity used to satisfy progressive collapse requirements. Floor-to-floor heights throughout the building vary significantly—from 25 ft. at the public level to 13.75 ft. at the typical office levels to 22 ft. at the courtroom levels.

Security considerations required that no essential part of the building's structural system resisting catastrophic blast loads could encroach beyond the blast setback zone, yet urban design goals pushed to bring the north and west building lines as close as possible to the property edge to maintain alignment with adjacent buildings. These conflicting goals were satisfied using double cantilevered girders at the northwest corner, allowing the building to project beyond the blast setback while protecting the lower portions of the building from blast effects. The north half of the floor plate above Level 4 cantilevers 9 ft, 3 in. to the west and a secondary cantilever of 23 ft extends to the north; a W36X282 and W30X108 are used to execute the double cantilever.

Early Adjournment

The project benefited from early retention of the construction manager, Hensel Phelps Construction Company, which is not always possible on publicly funded projects. The design and construction team took advantage of this opportunity to reduce overall construction time. The team also worked to carefully coordinate the building systems within the tight envelope demanded by the high-ceilinged spaces, and the structural steel fabricator, SME Steel Contractors, helped identify where penetrations in the structural steel framing would be required to accommodate late changes to the mechanical system. This up-front work allowed the project to be finished a month ahead of the original completion date.

Judging Seismicity

The primary structural design challenges were posed by the high seismicity of the project site and architectural constraints of a narrow building plan. Tall floor-to-floor heights found on many floors and challenging drift limits made an all-moment frame structure relatively expensive. At 320 ft tall, the tower exceeded the building code-mandated 240-ft. maximum height for an all-shear wall and all-braced frame structure. Although many dual systems do not have height limitations, Hensel Phelps advised that mixing the major subcontracting trades required for dual systems (using concrete shear walls and steel moment frames) would not be cost-effective—plus the tall floor-to-floor height at the courtroom floors made erection of the plate sections problematic. In addition, trial designs of various steel dual systems involving both wide-flange and plate suggested that the required moment frames would not participate effectively in the overall lateral system due to their flexibility relative to the stiffer elements in such a dual system.

Faced with these constraints, we encouraged the owner, the U.S. General Services Administration (GSA), to use a performance-based design approach as we felt it could be used to demonstrate that an all-braced frame lateral system exceeding the prescriptive building code height limits would be an effective seismic system. One of the primary motivations behind the use of performance-based seismic design recognizes that typical building code requirements may not be well-suited for atypical structures. Properly applied, project-specific design criteria can result in a better seismic performance because member proportioning better matches anticipated demand. Plus, the capital invested in a building designed using performance-based criteria will be more effectively deployed than is likely to happen with a conventionally designed building. In the case of this project, the final design, which ended up being based on the performance-based design criteria, was several million dollars less expensive than the dual system alternatives mandated by the building code.

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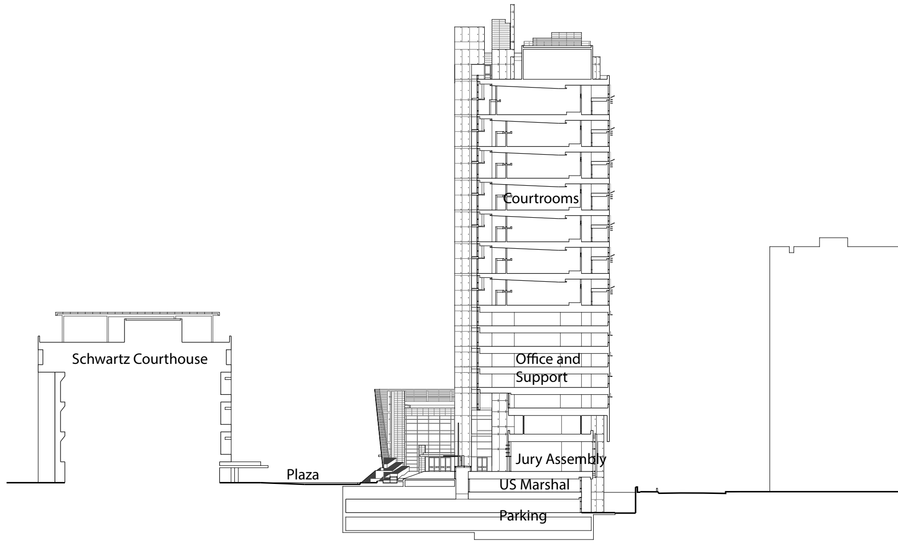
A weathering steel ramp from the public plaza to the entrance lobby.



East-west section view of the building.

No Objection to Project-Specific

Once permission was given to go the project-specific route, a number of structural steel schemes were evaluated. Those involving special concentrically braced frames were not selected because eccentrically braced frames (EBFs) were judged to possess better performance characteristics. Buckling-restrained braced frames (BRBFs), although anticipated to exhibit good seismic performance, were not pursued due to concerns about limited competition in what was, at that time, an overheated construction market.

Based on an evaluation of alternative link limit states, the EBF links were proportioned as shear links. As a result, link lengths were set between 4 ft and 6 ft depending on the frame span. EBF beams in the tower are typically W27×194 to W27×258 and the largest EBF column is a W14×730, with some of these columns plated to satisfy progressive collapse loading demands. The EBF braces range from W14×159 to W14×211.

The geotechnical engineer, taking into consideration site seismicity, recommended a suite of earthquake time history records to be used in the nonlinear response analysis. The original records were scaled for the site seismicity and the building fundamental period. Each earthquake time history was selected to reflect ground motion characteristics that might have a significant influence on the dynamic response of the building.

The records corresponded to an earthquake with an average return period of 2,475 years or 2% probability of exceedance in 50 years. This level of earthquake is identified as the maximum considered earthquake (MCE), which was used to evaluate the collapse potential of the building. The records were also scaled to simulate a design basis earthquake (DBE), which was approximately equal to an earthquake with an average return period of 475 years or 10% probability of exceedance in 50 years. Each record was divided into a pair of time histories representing the "fault normal" direction and the "fault parallel" components compared to the major axes of the building.

In addition to analytical modeling requirements, project-specific performance-based criteria specified limits on overall building response and EBF component demands. The criteria considered such things as maximum link beam rotation, maximum interstory drift, beam-to-column connection rotation, column and EBF brace performance, beam-outside-the-link performance and special shear link modeling parameters. The final structural design, which used approximately 8,000 tons of structural steel in all, was based on the results of the nonlinear response analyses.

The use of an EBF system and AESS satisfied the challenges of producing an inspiring architectural design, stringent user program requirements, a rapid construction schedule and a demanding budget. Performance-based seismic design requirements further advanced the project's goals by demonstrating that an all-braced frame could provide excellent seismic performance despite the fact that the building was taller than normally permitted by the building code for this type of seismic force resisting system. MSC

Owner
U.S. General Services Administration

Architect
Richard Meier and Partners, Los Angeles

Structural Engineer
Englekirk and Sabol, Inc., Los Angeles

Construction Manager
Hensel Phelps Construction Company, San Diego

Steel Team

Fabricator and Erector
SME Steel Contractors, Inc., West Jordan, Utah (AISC Member/AISC Certified Fabricator and Advanced Certified Steel Erector)

Detailer
Prodraft, Inc., Chesapeake, Va. (AISC Member)

Southeast exterior elevation with the entrance lobby structure in the foreground. The curtain wall on the east elevation expresses change in building use, from offices to courtrooms, at level 7 and above.