Elevated Efficiency

By Mark Whiteley, SE, PE

Chancellor Merchant

A NEW TWO-TOWER DEVELOPMENT is further solidifying downtown Bellevue as the most prominent business district in the Seattle metropolitan area outside of downtown Seattle itself.

The Lincoln Square Expansion (LSE) is one of the largest mixed-use projects in the state of Washington, adding more than 2.6 million gross sq. ft of office, retail and residential space to the urban core of Bellevue, a suburb located across Lake Washington to the east of Seattle.

The project includes two 450-ft-tall towers, a three-level retail podium and six levels of subterranean parking. The 41-story hotel/residential tower houses a W Hotel and upscale apartments, and the 31-story structural steel office tower features Class A office space with exceptional views of Mt. Rainier, Lake Washington and Puget Sound. Both towers integrate with a steel-framed podium housing retail shops, an upscale theater and a wide variety of restaurants. A total of 6,500 tons of structural steel was fabricated and installed throughout all portions of the development, with the majority in the office tower and retail podium. The subterranean parking provides 2,200 new parking spaces and is connected via tunnel to existing underground parking at the adjacent One Lincoln Tower development. The project illustrates how structural design can respond to demanding owner building program requirements, allow for future tenant changes and reduce overall costs.

Efficiency in material selection, design coordination and floor systems optimizes a new steel tower in suburban Seattle.

Coordination Creates Value

The office tower design targeted 9-ft, 6-in. ceilings within a floor-to-floor height of 12 ft, 9 in. With that in mind, the developer and design team recognized the opportunity to squeeze in one additional level within the office tower without exceeding the zoning height limit of 450 ft. The structural steel framing, concrete on metal deck, lighting fixtures, ceilings and MEP systems (accommodating the high-tech tenant power demands of 5 watts per sq. ft) were all placed within a limited interstitial space of 39 in.

The design task was accomplished by integrating the MEP systems within the depth of the structural steel framing. Through careful coordination, the design team determined an acceptable layout and pattern for the 14-in.-deep by 28-in.-wide rectangular openings and 16-in.-diameter openings to be fabricated within the web of the W24 beams and girders by fabricator Supreme Steel. The beam penetrations were placed approximately 10 ft on center, with additional locations and sizes incorporated as required by the MEP systems' predetermined layout.

Additionally, a series of 6-in.-deep to 10-in.-deep haunches were introduced in the steel beams and girders around the central core of the tower to accommodate the primary ducting loop. Both the beam web openings and flange haunches were included in the analytical structural models. The analysis results were then used to design local reinforcement of the steel members as required. Even though the custom beam openings and haunches required a more rigorous design approach, as well as greater coordination to accommodate the required MEP geometry, the design proved to be more cost-effective than a fully castellated or cellular beam option and allowed for larger openings within the same beam depth. In the end, the reduced floor-to-floor heights were achieved without compromising the desired ceiling heights and with the substantial benefit of being able to add the extra leasable floor to the project.

High-Strength Columns Decrease Costs

The 24-in.-deep structural steel beam and girder framing members were laid out in 40-ft by 50-ft bays, a scheme that allowed for the elimination of essentially all interior columns within the leasable space. The girders span between the central concrete core and the exterior steel columns. This framing scheme was selected in order to modulate with the long-span post-tensioned concrete beams used at the subterranean parking levels below the tower, avoiding complicated and expensive transfer elements and creating exceptionally open floor plans. With 50-ft column spacing at the glazing line, the views to the outside feel virtually uninterrupted.

The Lincoln Square Expansion is one of the largest mixed-use projects in Washington State.

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The open-floor and long-span layout, however, did not come without some additional considerations. The long-span framing led to larger-than-usual building loads at each vertical support. While the same framing effect was beneficial to the lateral system, providing increased dead load to resist uplift and overturning forces at the shear wall core, the structural design team also realized that the column axial demands at the lower levels of the tower were large enough that the available strength of standard column shapes using ATSM A992 steel would not be enough. A number of design options were evaluated to provide vertical members capable of supporting the weight of the structure above. Some of the design considerations included investigation of custom steel shapes, built-up shapes of standard sections and plated wide-flange columns—but in the end, none of these provided an economical solution for the project.

The solution came from ASTM A913 Grade 65 steel, which provided the required axial capacity using standard column shapes. This high-strength steel solution eliminated the need for additional plates or the expense of welding built-up shapes. The Grade 65 steel reduced the total cost of the columns by approximately $500,000 compared to standard grade alternatives.

The strength of the heavily loaded columns was not the only consideration; axial shortening also needed to be addressed. While the Grade 65 columns provided the required strength, the axial stiffness of the steel is essentially the same as traditional 50 ksi steel. This raised the question of axial shortening in the columns, as the Grade 65 columns experience higher axial stress and therefore higher axial shortening.


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above: Atrium space in the office tower.

left: The office tower under construction.

below: HVAC ductwork taking advantage of beam penetrations.


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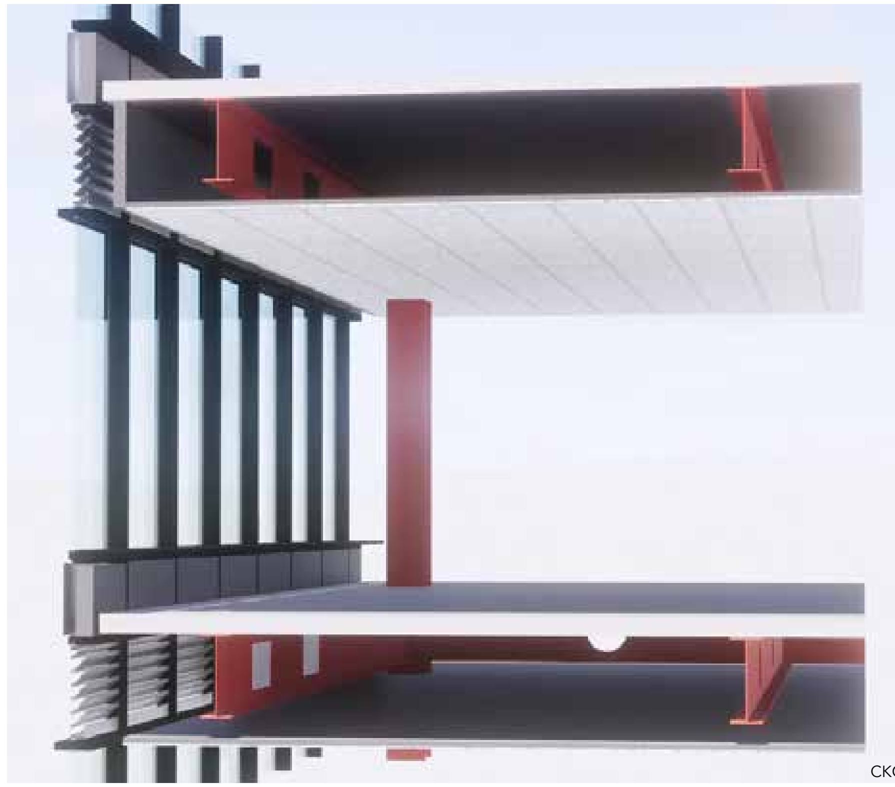
After evaluating a number of different loading scenarios, the structural team determined that approximately ⅛ in. of column shortening should be accounted for at each floor. The best approach to address the column shortening effect was determined after coordination with the general contractor (GLY), steel erector and steel fabricator and detailer (Supreme). The columns were lengthened 1 in. every eight floors. The floor system was super-elevated and attached to the columns in increasing ¼-in. increments every two floors and resetting every eight floors. This proved to be an economical and straightforward means of addressing vertical column shortening.

Flexible Floor Systems

Due to the project's location in a region of high seismicity, lateral load transmission through the floor diaphragms was a significant design consideration. The floors at typical tower levels consisted of a 5½ in. normal weight concrete slab on a 3-in. metal deck. Selecting an efficient slab helped limit the seismic mass, reduced column and foundation demands and contributed to minimizing the depth of the floor framing system. Lateral forces were transferred to the concrete shear walls using a combination of steel beams, wire mesh and reinforcing bars embedded in the concrete slab. At the upper levels of the tower, a two-celled concrete core stepped back to a single-cell core at the same location where the lower bank of elevators terminated at the 21st floor. The resulting geometry produced a horizontal diaphragm extension of roughly 120 ft, requiring tension collectors to transfer the forces to the shear walls. The challenge was to design placement of the reinforcing bars in the concrete slab and then into the special boundary elements of the concrete shear wall. Extensive detailing using 3D modeling of steel beams, embedded steel connection plates, wall reinforcing and diaphragm bars created the solution.

Shortly after office tower construction completed, two major tenants each leased multiple levels of the tower. Both tenants wanted to create unique open spaces, so major tenant improvement projects were undertaken to create open atriums and interconnecting grand stairs over many levels. Structurally, this required the creation of very large openings through the steel-framed floor and composite metal deck. The floor design allowed for rea-



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above: The office tower design allows for 9-ft, 6-in. office ceilings within a floor-to-floor height of 12 ft, 9 in.

below: A haunched beam at the core and a haunched girder detail.

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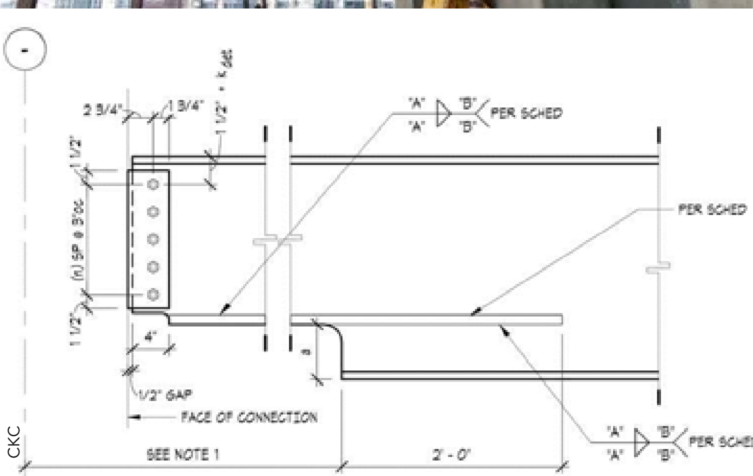

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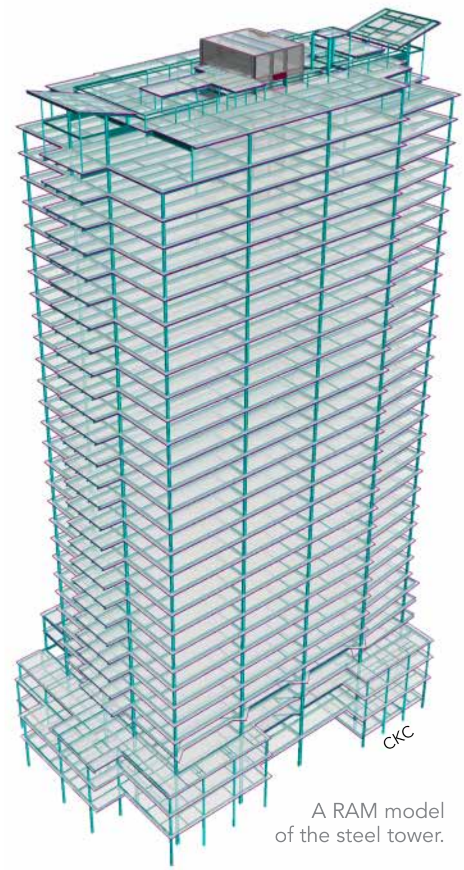
sonable post-construction flexibility and provided the design team with a practical way to enhance the space. The retrofit design included the addition of new steel members, modification of connections, stiffening of web openings and the incorporation of rectangular-shaped carbon fiber bars into the composite slab to accommodate the large diaphragm openings. The flexibility of the steel framing system allowed for major tenant improvements to be accommodated with minimal impact to the overall building frame.

The LSE office tower makes a major contribution to the Bellevue skyline. While the project presented a number of design challenges, the team was able to use these as opportunities to create greater value for the owner. By integrating the MEP system into the plenum depth of the long-span steel floor framing, one additional leasable floor was added to the project; Grade 65 steel for the columns reduced steel costs and eliminated the need for custom column shapes; and the use of a steel framing system provided enhanced flexibility for future tenant improvements. ■


Kemper Development

The LSE office tower project makes a major contribution to the Bellevue skyline.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A RAM model of the steel tower.

The south entrance of the office tower and fabrication of a truss.


Chris Eden


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Owner/Developer
Kemper Development Company

General Contractor
GLY Construction

Architects
HKS Architects/Sclater Architects

Structural Engineer
CKC Structural Engineers

Steel Team

Fabricators

Supreme Steel Portland, Portland, Ore. *Office Tower*

Metals Fabrication Company, Inc., Spokane, Wash. *Podium and Exterior Façade, Hotel/Residential Misc. Steel*

Haskell Corporation, Bellingham, Wash. (also detailer) *Garage*

Erector

Superior Steel and Ironworkers, Issaquah, Wash., *Hotel/Residential Tower and Podium Misc. Steel*

Detailer

Steel Systems Engineering, Inc., Sherman Oaks, Calif., *Office Tower*