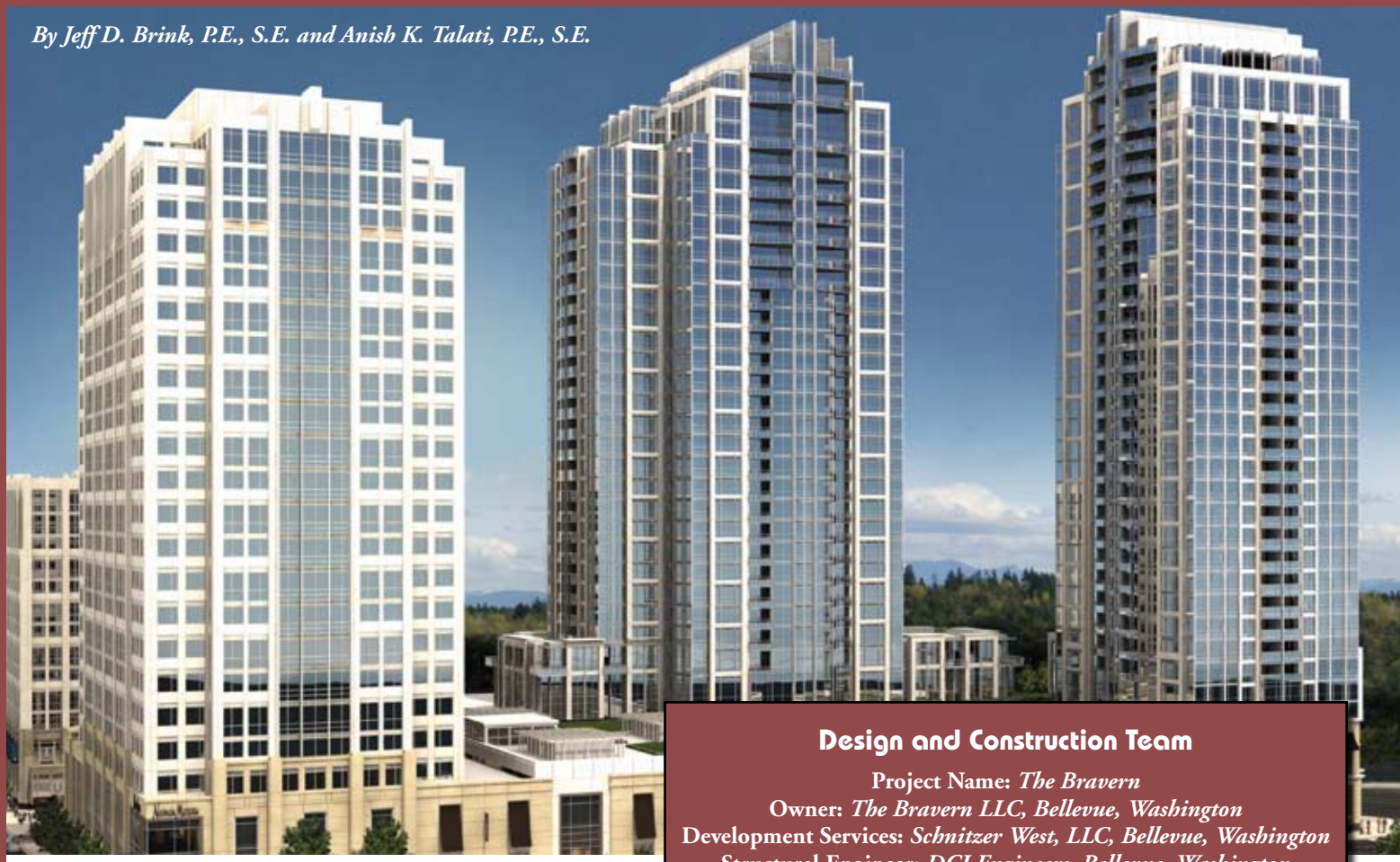
The Bravern - A World-Class Superblock for Seattle's Eastside

Designing the Pacific Northwest's Largest Construction Project

By Jeff D. Brink, P.E., S.E. and Anish K. Talati, P.E., S.E.



Architectural rendering of completed Bravern project showing the two pre-cast clad office towers (left) and two residential towers (right).

Design and Construction Team

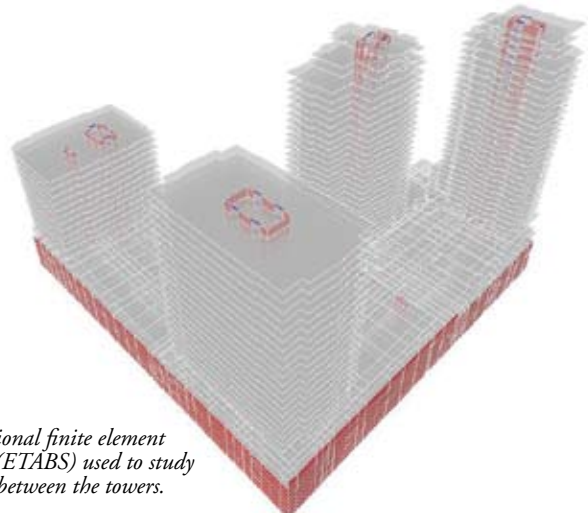
Project Name: *The Bravern*
Owner: *The Bravern LLC, Bellevue, Washington*
Development Services: *Schnitzer West, LLC, Bellevue, Washington*
Structural Engineer: *DCI Engineers, Bellevue, Washington*
Architect: *Callison and NBBJ*
General Contractor: *Skanska USA and PCL Construction*

The Bravern is located in Bellevue, Washington, one of the nation's fastest growing cities. The project is designed to increase urban density and provide an all-inclusive living environment that includes residential, office, restaurant and retail space. At three million square feet, The Bravern is the largest project in the Pacific Northwest to be built in a single construction phase.

Covering almost four and a half acres, The Bravern features two grand arrival courtyards, Las Vegas style outdoor escalators, seven-levels of subterranean parking for 3,100 vehicles, two class-A office towers, two exclusive 33-story condominium towers, and a three-story podium boasting over 300,000 square feet of high-end retail space. This new superblock will be anchored by the northwest's first Neiman Marcus department store, and the impressive 750,000 square feet of office space occupied by Microsoft.

Unique Project Challenges

Any project of this magnitude is certain to offer numerous challenges for the design team. The Bravern is no exception; half the project had to be developed, designed and permitted after construction had already begun.The original project plan called for a phased construction process with Phase I including only the 14- and 24-story office towers, along with the associated podium and parking below. The remainder of the retail, along with the two 33-story condominium towers, was to follow at a later date. As construction on the office portion of the project was set to begin, Neiman Marcus signed a lease to become the anchor retail tenant for the project. This required the redesign and expansion of a large portion of the office tower's retail area, and initiated the development of the remainder of the project. The challenge was now to incorporate 1.6 million square feet of new space, including two additional high-rise condominium towers, without delaying the construction team which was currently mobilizing on-site.



A three-dimensional finite element analysis model (ETABS) used to study the interaction between the towers.

Due to the large scale and fast schedule, the two residential towers above the parking and retail levels had a different architect and contractor than the remainder of the project. Therefore, the two design teams had to ensure the continuity of the critical life-safety systems was maintained through the transition zone. In addition, the division of scope made the coordination of the tower columns through the residential, retail and parking extremely challenging. With the Structural Engineer as the common link between the two teams, a column layout was achieved which required only five column transfer beams and saved the developer significant cost.

Early photo showing the various construction stages of the seven below-grade parking levels.

Accelerated Tenant Upgrades

In the late fall of 2007, when the upper slab of the parking levels was being formed and the structure was about to daylight, Microsoft signed a lease to take all 750,000 square feet of office space. The high-tech tenant had a list of technical and special use requirements, which they wanted to incorporate into the building's design in order to meet their particular program. The team began redesigning the office towers to facilitate on-going construction and the new design parameters while ensuring the schedule was not delayed.

In contrast to the original building plan, the tenant demanded significantly higher design loads in critical areas. These areas included: lab space, cafeteria and catering facilities, and upgraded mechanical and electrical systems. As the construction progressed, design directives from the tenant often came just weeks prior to placing concrete. Therefore, multiple configurations for each floor were designed based on the various potential uses. Once the tenant designated each floor's use, the design team performed last minute checks and issued the updated drawings to the contractor. The capacity of the floor was increased by altering the concrete drop band and slab thickness, as well as increasing the number of post-tensioning tendons and quantity of reinforcing steel. This allowed the decision regarding the floor usage to be delayed until the day the columns below were cast. As long as the contractor knew the thickness for the floor, before he poured the columns below, construction was not delayed. This system also required the structural engineer to review various configurations of mechanical and electrical system block-outs to assure there were no potential conflicts with the structure. In many cases, the structural, mechanical, and electrical consultants were all on-site during the forming of the deck to field-design acceptable solutions.

Flying table forms for the acelerated construction of the tower slabs.

Lateral System Design

With the four towers at The Bravern varying in height between 14- and 33-stories, the structural engineer chose to use ductile concrete shear wall cores as the lateral system for all of the towers. This system is the most economical for buildings of this height, and allows maximum flexibility for the floor space. However, three of the four towers exceed the 240-foot height limit that the International Building Code specifies for a pure shear wall building. In order to get an exemption from this section of the code and assure an economical design, the structural engineer used a performance based seismic design approach. Three types of analysis were completed to verify the performance of the concrete core towers.

1) **Response Spectrum Analysis** was used for the initial shear and flexure design of the shear walls and the coupling beams.
2) **Linear Time History Analysis** was performed using a three-dimensional finite element analysis (ETABS) model containing all four towers, retail levels and seven-levels of below-grade parking. Seven pairs of site specific Maximum Considered Earthquake (MCE) level ground motions were applied for this analysis.

As requested by the peer reviewer, mass was added to the floor slabs below the seismic base and horizontal springs were incorporated to include the effects of soil. A maximum back-stay model, consisting of stiffer basement walls and softer shear cores, was used for the design of the diaphragms and shear design of the basement walls. A minimum back-stay model was used for the design of the below-grade portion of the core walls. Mean plus sigma of the time history results was used for the elastic design of these elements.

3) **Non Linear Time History Analysis** was completed using a *PERFORM 3D* model consisting of the two residential towers and the base of the West office tower. Similar to the linear time history analysis, mass was added to the floors below the seismic base. Rayleigh damping was used to reduce the effects of the higher modes resulting from this added mass. This model was used to determine the foundation forces, the hinge location in the shear walls, the shear demands and to confirm that all elements outside of the hinge zone remained elastic under the MCE level forces. Mean plus sigma of the time history results was used for the design and performance of the above mentioned elements. This analysis confirmed that the building met the specified drift limits, and that the nonlinear seismic behavior of the structure was governed by flexural yielding of the wall near the ground level and coupling beam flexural behavior.

The building code required a peer review of the lateral system, since a non-linear performance based seismic design was utilized. Peer reviews have the potential to prolong the design schedule due to third party involvement in the process. Incorporating a dual system, which utilized moment frames in addition to the shear cores, would have alleviated the need for a peer review. However, the dual system would have added significant cost to the project, and hindered the open floor plan and unobstructed exterior of the buildings. Therefore, the Structural Engineer and the design team decided to pursue the peer review option, and successfully integrated it into the schedule without impacting construction.

Concrete Floor Systems

The contractor was involved in the project very early, providing valuable construction input for the design team. Two framing studies were developed by the Structural Engineer. One was a conventional structural steel and composite metal deck system and the other was a post-tensioned concrete slab system with wide shallow drop beams. These systems were priced by the contractor and analyzed by the design and development team. Factors such as material cost, price stability and schedule were evaluated, leading to the selection of the cast in place concrete option. This system was chosen not only for the residential towers and below grade parking, but also for the office towers and retail space. The decision to use concrete construction turned out to be very fortuitous due to the tight design schedule for the office tenant modifications. Concrete eliminated any problems created with steel fabrication lead times, and allowed for modifications to the floors strength and other performance characteristics just weeks before construction.

Aerial view of the four and a half acre construction site for The Bravern.

Concrete construction progress on one of the two residential towers.

In addition to reducing floor-to-floor heights and saving millions of dollars on façade costs, the concrete slab system eliminated the need for spandrel beams at the exterior of the buildings. This became extremely beneficial for the office tenant modifications, which called for additional exterior louvers around the building perimeter.

Running the Numbers

The Bravern was created in the mind of the developers to "Inspire Greatness" and it has not fallen short of that goal. This four tower, four and a half acre superblock is currently the largest construction project on the west coast, with an average of 250 people on-site daily over the last two and a half years. When completed, the crew will have poured 150,000 cubic yards of concrete, placed more than 18,000 tons of reinforcing steel, and laid 1,400 miles of post-tension cable. All of this was made possible by upholding the fast-track schedule which dictated that the design and construction, with multiple architects and contractors, occurred almost simultaneously throughout the project. These challenges were embraced by the entire design team to create a one-of-a-kind, world-class development for the Puget Sound region.▪

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