Fox Tower Rises over Portland

By Clinton Ambrose, P.E.

The Fox Tower is a 600,000-sq. ft., 27-story, high-rise structure located on a full block in the heart of downtown Portland, OR. The building boasts five levels of below grade parking, two levels of retail on the first and second floors, one level of cinemas on the third floor, 23 floors of office space and a penthouse.

Many significant features are associated with the design and engineering of the Fox Tower. For example, the main lateral force resisting system consists of a 30′ by 80′ central elevator core shear wall system. The elevator core is supported on an 80′ by 100′ by 11′ thick conventional concrete spread footing. Another significant engineering feature includes the below-grade parking, which extends approximately 60′ under the building, making it one of Portland's deepest downtown excavations.

The building also had to abide by several unique design restrictions. City regulations mandated that the shadow of the Fox Tower cover no more than half of Portland's Pioneer Courthouse Square (known as Portland's living room) at 3:00 PM on April 21, the spring equinox. To meet this requirement, 23 of the building's 27 stories are set back one-third of a block. The building's height was also limited to 372′ because it sits within a view corridor of Mount Hood, which protects the view of Mount Hood as seen from one of Portland's most prominent tourist attractions, the Rose Garden in Washington Park.

The Elevator Core—Lateral Load Resisting System

In order to meet a fast-track construction schedule, a dual system composed of the concrete elevator core shear walls and perimeter special moment resisting steel frames was chosen for the lateral load resisting system.

The system provided many advantages during construction. For example, while the structural steel mill order was being filled, the concrete core wall was being constructed using the "jump-form" construction technique. The jump-form system consisted of an independent, self-raising platform, which was supported off of each completed lift of concrete. By using this system, Hoffman Construction placed a 12′ lift every seven days. As a result, the core construction was approximately 75% complete when the structural steel erection began.

The concrete core wall also provided lateral bracing of the structural steel framing during steel erection, which eliminated the need for temporary bracing and further expedited steel erection.

Reduced Beam Section (RBS) or "dogbone" connections were used at the beam-column joints for the special moment resisting frames. The dogbone connection eliminated the need for cover plates while satisfying Uniform Building Code ductility requirements. In order to provide the necessary stiffness in the frames to control drift and cut down on weight, built-up column sections were used in combination with standard rolled shapes. The columns were fabricated from ASTM A572 grade 50 plate. The built-up sections also formed the sloped columns between the fourth and sixth floors where the building transitions from retail to office space. W27 shapes were used for the moment frame girders and ranged in size from W27x94 to W27x178. All column splices were made using high strength bolted connections. Above the penthouse floor, braced frames comprised of HSS bracing members were used to resist lateral loads.

The tower was designed to 1994 Uniform Building Code (UBC) requirements for seismic zone 3 and an 80 mph wind speed. A three-dimensional dynamic lateral analysis was performed on the structure using ETABS.

Below Grade Parking And Foundation

The parking garage extends approximately 60′ below grade making it one of Portland's deepest downtown excavations. The entire perimeter was shored using a conventional tied-back soldier pile system with horizontal lagging. The below grade parking framing consists of one-way post-tensioned beams and slabs supported by perimeter concrete walls, interior concrete columns and the concrete elevator core wall. The concrete columns rest upon conventional spread footings and extend to the first floor where they provide support for the structural steel framing. The concrete elevator core wall rests on an 80′ by 100′ by 11′ thick concrete mat foundation, which provides much of the overturning resistance. The concrete elevator core wall is isolated from the floor framing from level two down to the foundation. This was done to prevent the transfer of shear from the core wall into the first and second floor diaphragms, which contained openings and vertical discontinuities. Steel plate corbel connections supported the concrete girders and slabs as well as the steel framing at the concrete elevator core wall. A 1.5″ joint between the framing and core wall accommodated lateral movement due to seismic and wind forces.

Floor and Roof Framing

In order to minimize floor-to-floor heights and accommodate mechanical system requirements, a composite steel floor with concrete topping was chosen. The typical composite steel floor framing in the office tower consists of W24x94 girders spanning 41′ with W14x22 beams at 10′ on center spanning 25′ between the girders. The typical office floor deck consists of three-inch deep, 20-gage composite floor deck with 2.5″ normal weight concrete topping. The floor decking was placed perpendicular to the perimeter beams along the edge of each floor to support the curtain wall loads imparted on the deck through Halfen anchors installed along the slab edge. To allow for installation of a continuous mechanical duct loop around the core, the W24x94 girders were notched 9″ for a distance of 8′ from the face of the core wall. Furthermore, to minimize the typical floor-to-floor height to 12′-2″, multiple beam penetrations were made in the girders to allow for ducting.

To allow for tolerance in the installation of the beams and girders to the concrete core wall, welded shear tab connections were fitted with 3″ horizontal long slotted holes, which allowed for a construction tolerance of 1″. This detail worked well and mitigated the need for cutting beams in the field.

At the second, third and fourth levels, larger girder and beam sizes were used to accommodate longer

An ironworker on the steel frame just below a column splice.

Construction of steel frame around concrete core elevator wall looking from Pioneer Square.

spans and heavier retail and cinema floor loading. To create the barrel roof over the third floor cinema space at the east side of the tower, pre-engineered bowstring steel roof trusses spanning approximately 53′ were used. A three-inch, 18-gage roof deck spanned the trusses and created the roof diaphragm.

The architect designed a canopy system around the base of the structure, which cantilevered off of the structure at varying heights. To accommodate this, extensive use of tapered HSS tube sections created the profile of the canopies and resisted the torsional loading induced by the canopy outriggers between the supporting columns.

Sloped Columns

To accommodate the change in the tower's floor plate from level four to level five, the perimeter columns along the west and east walls were sloped inward 7′ over a height of 25′ from the fourth to sixth floors. This presented a challenge since the layout created large tensile forces at the fourth floor and compression forces at the sixth floor. In order to resist the compression force at the sixth floor, W14x311 beam-column members were used. The members were continuous between the columns at the west and east ends of the tower and spliced at the core wall to maintain continuity.

To resist the "kick" force at the fourth floor, six 1.375″ diameter DYWIDAG threadbars were run continuously between the sloped columns at the west and east ends of the tower. In order to accommodate the installation of the threadbars, a two-inch deep, composite floor deck with 3.5″ normal weight concrete topping was used at the fourth floor. The threadbars were greased and placed in PVC ducts within the 3.5″ concrete topping to allow for movement. The bars were then stage post-tensioned at three stages during erection of the structural steel and floors. The threadbars were designed to limit the elongation in the bars to one-half inch in the event that full live loading is achieved, minimizing impact to the cladding system. Close coordination with the steel fabricator and erector was required to detail the threadbar end connections at the columns and to develop tensioning procedures.

Fast track construction of the Fox Tower involved intense coordination and planning by the design team. Because changes were inevitable throughout the design process, it was important to design a structural system that allowed for change throughout the project, while retaining its structural integrity. The dual system used in this project is noteworthy of that. The Fox Tower, a welcome addition to Portland's skyline, has turned out to be a huge success for the developer.

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