Exposed concrete proudly expresses the structural system of Reston Station OB1

Naked Concrete

Mixed-use building features a 16-story exposed concrete exoskeleton

by Jennifer Kearney, Zachary Kates, and Mark J. Tamaro

Building structures are often concealed behind architectural finishes, so the occupants never see the material that supports their edifice. Reston Station OB1 is a welcome exception to this norm. This new mixed-use building located in Reston, VA, uses exposed concrete to not only meet the architectural design, but to also proudly express the building's structural system. Exposed concrete is featured in the ceiling of the double-height lobby area as well as the perimeter exoskeleton columns along the east and west sides of the building. Paired with steel grating spandrel panels in the curtainwall, the exposed concrete gives the building its unique industrial look. While there were numerous design and constructability challenges associated with architecturally exposed concrete, the Reston Station design and construction team overcame them to create a dramatic landmark.

The Design

The vision for Reston Station OB1 was to redefine the suburban commercial development. In the words of the project's architectural firm, JAHN: "Reston Station marks a new direction in the development of the suburban office complex. It creates a strong image and identity; one that is formally simple, functionally efficient, technologically advanced and (sub)urbanistically significant—delineated by modern architectural language."

Building Description

Visible to the thousands of people who travel to Dulles International Airport each day, Reston Station OB1 is a striking 16-story office tower showcasing a unique lateral force-resisting system comprising a diagonalized, exposed concrete exoskeleton. Thornton Tomasetti provided structural engineering for the building, working in collaboration with JAHN, owner Comstock Partners, contractor DAVIS, and concrete subcontractor Miller & Long. The 371,000 ft^2 (34,500 m^2) tower is located at the Wiehle-Reston East Washington Metro Station and is one of several buildings making up the Reston Station complex. It sits along the Silver line Metrorail, the new Metrorail extension between Dulles International Airport and Washington, DC. The office building includes an open-air plaza on the north side, immediately adjacent to the double-height lobby space; an outdoor roof terrace on the south side, providing views of northern Virginia; and eight levels of below-grade parking for the building occupants and Metrorail riders.

Tower Structural System

The gravity force-resisting system and lateral force-resisting system for Reston Station OB1 are not exclusive systems. The architecturally exposed concrete exoskeleton columns resist both gravity loads and lateral loads in the north-south direction. A three-dimensional (3-D) isometric model of the building's structural system is shown in Fig 1. The exoskeleton columns were constructed of high-strength concrete and slope at 11 degrees from vertical, matching the slope of the building's north and south faces. The five-story, open-air plaza is surrounded by "tree columns." These start at the base and splay out like a tree to support the 11 levels above the plaza.

Fig. 1: The building structure features a unique lateral system consisting of a diagonalized, architecturally exposed concrete exoskeleton

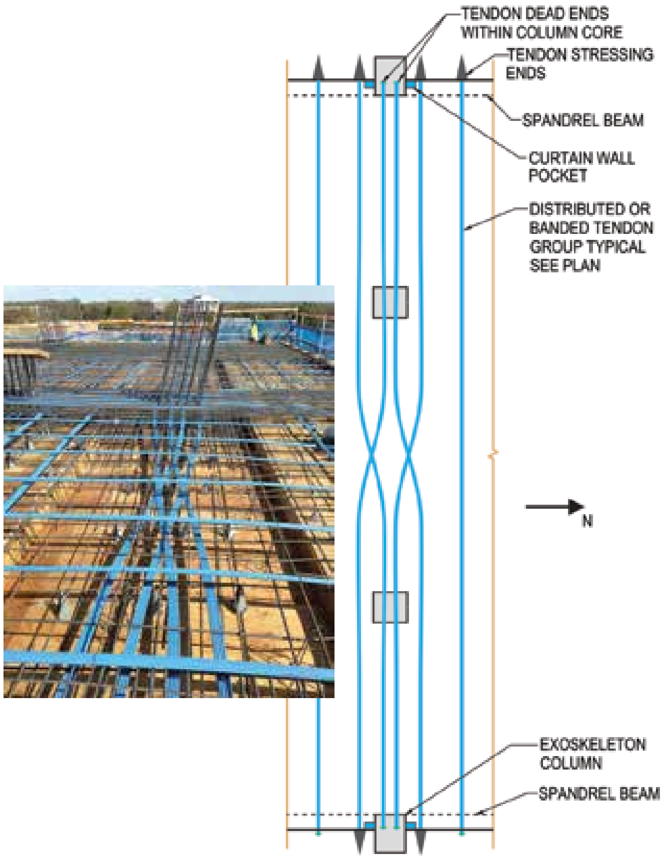

Fig. 2: The post-tensioned (PT) tendons were crossed at midspan to conceal the dead-end anchors inside the exoskeleton columns *(photo courtesy of DAVIS)*

Fig. 3: Each floor slab has 15 ft (4.6 m) cantilevers in the north and south directions

Gravity force-resisting system

The tower's floors comprise two-way, post-tensioned (PT), 10 in. (254 mm) thick concrete slabs with 6 in. (152 mm) drop panels. The distributed PT tendons in the east-west direction were crossed at midspan, as shown in Fig. 2, to conceal dead-end anchors inside the exterior columns and allow the tendons to be stressed at the spandrel beams. This tendon stressing layout maintains a clean, finished look on the face of the architecturally exposed exoskeleton columns. The stressing ends at the spandrel beams were concealed by the spandrel panels in the curtain wall. Typical slab spans are approximately 40 ft (12.2 m) with 15 ft (4.6 m) cantilever slabs to the north and south, as shown in Fig 3. Spandrel beams are located along the east and west edges of each slab to accommodate the variable slab edge spans, up to 40 ft, resulting from the sloping support columns (shown in Fig. 4).

The exposed exterior columns are typically 36 x 45 in. (914 x 1143 mm). Column strength was dictated by stresses at critical column intersection points at the base and midheight of the structure. However, a consistent concrete mixture, with 10,000 psi (68.9 MPa) compressive strength, was used for the full height of the building to maintain a uniform color and meet the desired architectural finish requirements. There are six interior gravity columns that slope in the north and south direction at the same angle as the exoskeleton columns. The mixtures for the interior columns were allowed to vary over the height. A maximum concrete strength of 12,000 psi (82.7 MPa) was used at the base, decreasing to 7000 psi (48.3 MPa) at the upper levels.

The exoskeleton frame has a tendency to spread under gravity loads, like a folding drying rack. Spandrel beams were designed and detailed as tension ties to resist this action. To avoid congestion within spandrel beams and at beam-column intersections, couplers were used at all splices of the continuous spandrel beam reinforcement. Close coordination of the beam reinforcement was required to accommodate curtain wall anchor pockets and post-tensioning anchorages (Fig. 4).

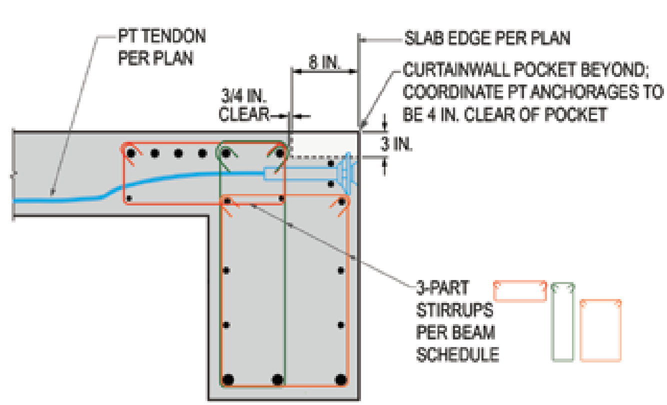

Fig. 4: The spandrel beam reinforcing was coordinated with curtainwall anchor pockets and PT tendon anchorages (Note: 1 in. = 25.4 mm)

Lateral force-resisting system

Six shearwalls, located in the core of the building along the elevator and stair shafts, serve as the lateral force-resisting system in the east-west direction. The exoskeleton frames on the east and west sides of the building function as the lateral force-resisting system in the north-south direction (Fig. 1 and 5). The frames predominantly act as braced frames due to triangulation of the columns resulting from column intersections at the top, bottom, and midheight of the structure. In addition to axial loads, column sections located between the column intersections experience flexural loads from the bending of the spandrel beam-column frames between the stiff braced frame intersections. ETABS® (an integrated analysis, design, and drafting of building systems software program) was used to analyze the lateral system for the building. Two-dimensional (2-D) frame analyses were performed to validate the design and envelope loads in the horizontal spandrel beam tie elements.

Fig. 5: The exposed concrete exoskeleton columns act as both braced frames and moment frames

Tree columns

Two sets of tree columns form key architectural features of the design (shown in Fig. 6). At each tree, three columns splay out from a single intersection point on the ground floor. The columns were designed as structural steel and concrete composite members to accommodate unbraced column lengths maxing out at 72 ft (21.9 m). Each column contains a steel core constructed of two W30 flanges and a W24 web, forming a built-up H-shaped member. Figure 7 shows the

Fig. 6: The "tree columns" consist of three columns originating at a common node at the ground floor. Two branches inclined at 34 degrees from vertical support interior columns at level 6

Fig. 7: Built-up structural steel core and deformed bars inside a tree column form *(photo courtesy of DAVIS)*

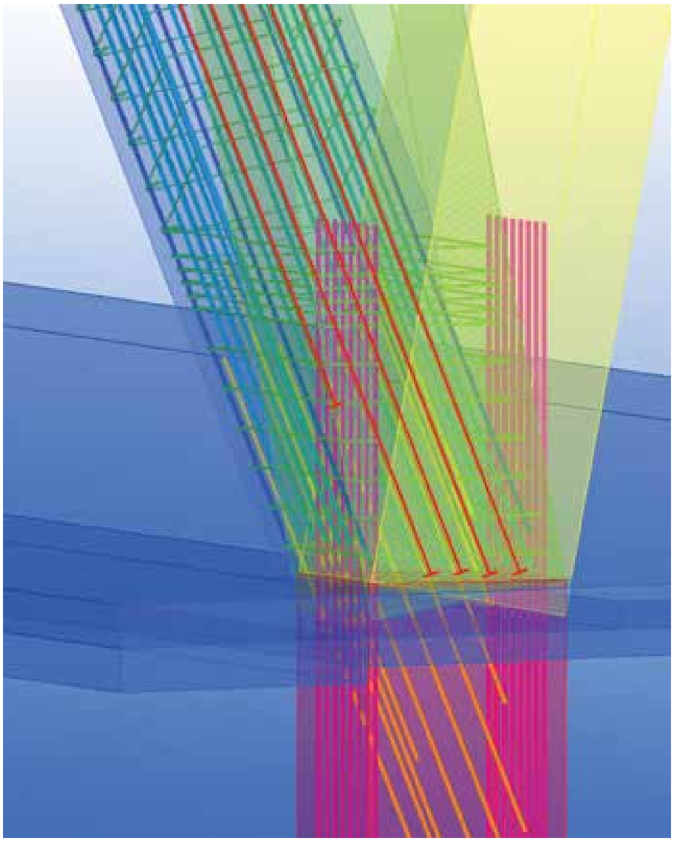

Fig. 8: A Tekla 3-D model was used for reinforcement coordination at the base of the tree columns

built-up steel core with the surrounding deformed bar reinforcement, before concrete placement. Two columns from each tree slope at 11 degrees from vertical and are incorporated into the exoskeleton frames. The remaining two tree columns slope in two directions at 34 degrees from vertical to support interior columns at level 6. The cross section of each of these columns is a rhombus, which allows the column faces to seamlessly merge with the perimeter tree columns at the base. The ground floor slab includes a large, continuously reinforced tension tie oriented in the east-west direction to resist the outward thrust of the tree columns. Tekla 3-D modeling of the tree column node was used to evaluate reinforcement congestion. Figure 8 shows an image of a Tekla model of the tree column node with reinforcement modeled for coordination to ensure all proper clearances were met.

Tower Construction

The special architectural requirements, coupled with the complex structural design, resulted in unconventional construction techniques. The mixture design, formwork, and finishing techniques for the exoskeleton columns were all driven by the strict architectural requirements for the exposed columns. The columns were not stained or sealed, so coordinating the locations of placement breaks was critical to meet the final desired appearance. The tree columns also necessitated custom formwork to accommodate the geometric requirements of the columns and base node. Due to the unique building configuration, a staged construction analysis was performed during design to evaluate the incremental impacts of the sloping columns on the lateral displacements of the frame during construction.

Considerations for exposed concrete

Close coordination with the design and construction team was required to achieve the architect's vision for the project's exposed elements. The concrete contractor carefully coordinated construction joint locations, formwork joints, plywood seams, and form tie locations on the exoskeleton and tree columns, and this information was submitted to the design team for approval prior to construction. The contractor also provided formwork layout drawings and slab construction joints at the exposed lobby ceiling for careful review by the design team. Architectural reveals were located at construction joints where possible. Concrete cover on the exposed elements was detailed for exterior exposures, even at column reveals. Careful inspection of the reinforcement during construction was performed at exposed elements to ensure cover was maintained. In addition, all exposed horizontal surfaces were detailed to drain water.

All mixture designs were produced by Vulcan Materials Company. For most of the exoskeleton, the high-strength concrete mixture was produced with a normal consistency using a high-range water-reducing admixture. Both internal and external vibrators were used in the exoskeleton columns to consolidate the concrete and produce a blemish-free, smooth, and high-quality architectural concrete finish. For constructability and to meet architectural design requirements, however, a 10,000 psi self-consolidating concrete (SCC) mixture was used in the composite tree columns.

Exoskeleton columns

The formwork for the exoskeleton columns was hand framed using single-use, high-density plywood. The forms were held together with steel wales and wall ties placed outside the formwork or in line with the curtain wall to ensure that the columns appeared tie-free. The exoskeleton columns were placed monolithically with the floor slabs and perimeter spandrel beams to eliminate a construction joint at the bottom of the beam. Architectural reveals were provided at the floor levels. These were horizontally aligned with the curtain wall window mullion and the steel grating feature, which concealed the construction joints at the top of each slab.

Tree columns

Construction of the tree columns was completed using EFCO steel plate girder shoring and formwork lined with a 3/4 in. (19 mm) high-density Finnish white birch plywood (Finnform). In addition to serving as formwork, the plate girder system was designed to provide temporary support and bracing for the structural steel built-up sections in the composite columns. Some of the plate girder pieces at the tree column bases were custom produced to meet the node geometry requirements. Also, most of the plate girder panels used for the columns with rhombus cross sections required bolt-up modifications to achieve the necessary geometry. The formwork was laterally braced using 5/8 to 1-1/4 in. (16 to 32 mm) cable guy wires to limit movement during placement of the concrete.

Analysis and monitoring

Of the six sloping interior columns, four slope toward the north and two slope toward the south. The imbalance in the number of sloping columns in each direction results in a constant lateral load on the structure under its self-weight. Thornton Tomasetti performed a staged construction analysis to evaluate the impact of these forces on the lateral displacements of the frame during construction. Based on the results of this analysis, Thornton Tomasetti instructed the contractor to place each column along its theoretical centerline and correct for any lateral displacements of the building occurring during construction. Analyses showed that the building would have displaced laterally several inches at the top of the structure if these corrections were not made during construction. The general contractor, DAVIS, monitored displacements at regular intervals, and the tower was constructed within design limits.

Conclusions

Architecturally exposed concrete is a prominent feature of Reston Station OB1, particularly at the exoskeleton and tree columns. The structural design is complex because the exoskeleton columns act as both braced frames and moment frames and support the gravity loads for the building. The need to meet stringent structural requirements and architectural design intent created challenges.

The project team successfully met design and construction challenges, resulting in an iconic structure. Although just recently completed, this unique and highly visible structure has already earned the name "the upside-down building."

Acknowledgments

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Selected for reader interest by the editors.

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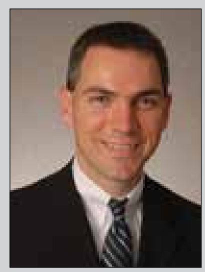

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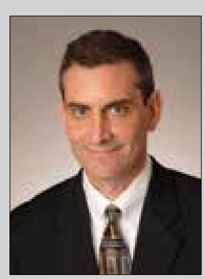

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