Construction of the FORTH Atlanta

With a structural diagrid of concrete

by Robert M. Weilacher, Jesse Fortner, and Todd Hamby

The 760 Ralph McGill Development is located on the BeltLine in the historic Fourth Ward of Atlanta, GA, USA. The mixed-use development by New City Properties consists of a three-office buildings and retail space (Parcel A), a hotel (Parcel B), and multifamily residences (Parcel C). Parcel B, the FORTH Atlanta social club and hotel, is the subject of this article. The architectural firms HKS and Morris Adjmi (MA) designed the building. The structural engineer was Uzun+Case, LLC, and the project was constructed by Brasfield & Gorrie. Thomas Concrete supplied the concrete, and CMC supplied mild steel reinforcement and post-tensioning.

The FORTH Atlanta has subterranean parking within an area of 189,065 ft^2 (17,565 m^2), including the guest rooms and public areas. The hotel has 157 rooms in the tower and 40 more in Levels 02 and 03 of the podium.

The vision for the FORTH Atlanta was to call attention to this larger development; another parcel will be included in future construction. The developer, Jim Irwin of New City Properties, explained: "Our goal with Parcel B was to create a dramatic, eye-catching addition to the BeltLine's Eastside Trail using a design typology that had not yet been utilized in Atlanta (or in the southeast for that matter). We partnered with a world-class architectural team in Morris Adjmi and HKS and came up with the concept of a structural diagrid where we would literally bring the tower's structural system outside the building's skin to show off the intricacy of the system. We found an ample number of examples in America and Europe where this had been done with steel construction but were excited about the challenge of doing it out of concrete. We knew that Uzun + Case would not only be up for the challenge, but excited about the concept and motivated to find a way to make it both functional and beautiful."

Foundations and Below-Ground Floors

The FORTH Atlanta has three underground levels and 16 aboveground levels. The lowest levels are contained around the perimeter by permanent shoring walls consisting of H-piles, lagging, and soil nails. On the west side, this shoring wall had to be carefully coordinated with the Atlanta Utility Trunk line, which passes between Parcel B and Parcel C of the project. The Parcel B footprint includes a cistern for water reclamation and control.

The column foundations are drilled piers founded on rock. The building also has an internal shear wall, which goes through all levels and is founded on a concrete mat supported by drilled piers.

Below ground, the lowest level is a slab-on-ground immediately above the drilled pier foundations supporting the columns and shear walls. The two subterranean levels above the slab-on-ground are post-tensioned flat slabs, 8 to 10 in. (203 to 254 mm) thick, with a few isolated beams. Coordination of the post-tensioning tendons with the perimeter walls was challenging.

Overview of Elevated Concrete Systems Above Grade

Level 01, which is at grade, is a reinforced concrete slab system spanning between reinforced concrete beams; longer-span beams and girders are post-tensioned. The system is generally 21 in. (533 mm) deep, but it is deeper in areas with steps in the slab and landscaping loads. This level is comprised of the hotel lobby, support spaces, meeting spaces, and exterior landscaped areas. The design of this level had to be somewhat flexible, as it was constructed prior to the completion of the hotel's interior design.

Levels 02 and 03 are generally comprised of guest rooms and hotel amenity spaces (such as the gym and kitchen). The framing systems are like that of Level 01, with a reinforced concrete slab system spanning between reinforced concrete beams. Again, longer-span beams and girders are post-tensioned.

Level 04 is the hotel amenity level with a restaurant, garden, and pool deck. This level was framed with more

heavily reinforced concrete slabs and beams but is otherwise similar to Levels 01 through 03. Level 04 includes more elevation changes in the slabs as well as heavier landscaping loads and topping slabs. The pool area is elevated a few feet and required numerous unique details, such as stair pop-ups, cabanas, restaurant awnings, and planters.

Levels 05 through 15 are the hotel levels and feature the exterior "diagrid" column system (Fig. 1 and 2). Those levels are supported by only three interior columns, the shear wall, and the diagrid columns. Because the diagrid columns frame into the floor plates at different locations along the floor perimeters, three floor designs were required over the tower height. The diagrid system is discussed in more detail in the following section.

Level 16 is the final concrete level: a 12 in. (305 mm) thick post-tensioned flat plate supporting areas with a topping slab, a bar and gathering place, and mechanical units. Level 16 also includes a flying beam around its perimeter at the termination of the diagrid column system (Fig. 3). The roof above the bar comprises a light steel frame.

Fig. 1: Oblique view of the façade showing the façade slips behind the exterior diagrid column system

Fig. 2: View of the façade showing the columns sitting 12 in. (305 mm) proud of the slab

Diagrid Complexities

The aesthetic requirements for the FORTH Atlanta's diagrid (Fig. 1 and 2) created many structural complexities. Architecturally, the columns were to be placed outboard of the slab edge to express the diagrid, the corners at the top and bottom needed to "fold" inward to emphasize the three-dimensional form of the structure, and the flying beam at the roof perimeter was designed to cap off the diagrid (Fig. 3). Column formwork quality and consistency were important to ensure the aesthetic character of the building.

As a result of the diagonal columns, the columns engage the floors at different locations in plan. This led to the need for three floor plate designs with very different post-tensioning and mild steel reinforcement layouts. In addition, the upper and lower levels of the diagrid were significantly different than other floors, as the floor plate corners folded in at these levels.

With regard to structural detailing, the perimeter columns carry a significant portion of the building vertical load. In addition, the columns protrude 12 in. beyond the slab edge, so only half of each 24 x 24 in. (610 x 610 mm) diagrid column

Fig. 3: View of the project from the south showing a flying ring beam around the roof level

is engaged with the slab (Fig. 2). This partial engagement of the slab necessitated the use of headed stud shear reinforcement in the slab, and it required that each perimeter column condition was carefully detailed in the construction documents.

Another detailing issue occurs where the columns engage the corners of the slab. In addition to the reduction in slab area available for resisting punching shear, the column geometries result in high tension forces in the slab-to-column connections. Transfer of these forces to the slab required the inclusion of post-tensioning anchorage and headed reinforcing slab bars that terminated in the columns, and these systems had to be routed through column bars converging at four different angles (Fig. 4).

The top and the bottom of the diagrid had additional complications, as the corners of the floors were held back and "tucked" the corners in. Figure 1 shows this at the base of one corner of the diagrid.

Exposed Concrete Considerations

The architectural design of the diagrid called for the building frame at the perimeter to be exposed, so concrete mixture designs had to include consideration of permanent weather exposure in addition to the aesthetic requirements for color and appearance of the finished concrete. The mixtures for exposed columns and slabs contained a combination of Scofield Integral Color to create a slightly darker and more uniform color than standard concrete and Sika Watertight Concrete Powder to help control water infiltration. Mixtures needed for repairs to small surface imperfections were created in Thomas Concrete's lab.

Brasfield & Gorrie used expanded metal stay-in-place formwork at the perimeter slab edges, allowing the use of a standard concrete mixture for the interior of the floor slabs. Each level was placed using a boom and concrete bucket simultaneously to keep the colored and standard mixtures separate. The structure required the use of both high strength concrete and high early strength concrete, all with integral color at different binder contents. This entire operation and finish were approved after a trial on the mockup.

Construction Challenges

The first construction challenge was created by the need to construct the underground levels and Level 01 before many of the hotel layout and design requirements were complete. This required a bit of a flexible approach to the Level 01 design. It also necessitated the protection of column dowels during a break of several months in the schedule. Much of the floor was designed to accept a topping slab or thickened concrete as an option. During construction, slabs were thickened where it was known that depressions were not necessary. The kitchen and other areas received topping slabs later, where appropriate.

The construction team was concerned with diagrid connections to the floor at the corners where reinforcement was significant. Being able to install what was required, as well as having good concrete consolidation around reinforcing bars was the focus of the concerns. It was decided to construct a mockup of the corner reinforcing steel (Fig. 4), including the column bars. This was extremely helpful and facilitated the construction of the corners in the building.

For diagonal column formwork, Brasfield and Gorrie looked at several different approaches but settled on one that minimized the complexity for the formwork crews. Simply by inverting it, a single metal form could be used for both the top and bottom of the "V" formed at the column-to-floor connection (shown in Fig. 5 and 6). This eliminated layout

Fig. 4: Reinforcement mockup of the corner column/slab joint

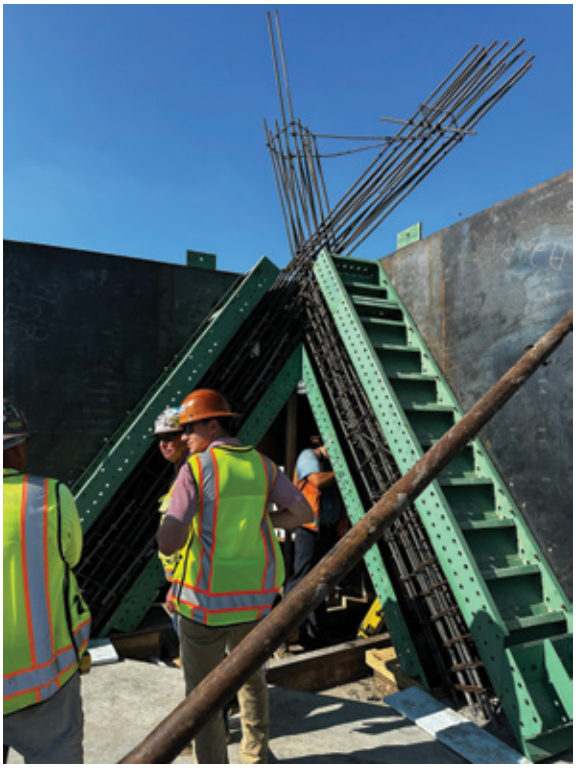

Fig. 5: Formwork for the corner columns being set in place

Fig. 6: Formwork for the edge columns at the rooftop

errors (or made them less of an issue) as well as assembly errors, and the metal provided a consistent, smooth finish. A lot of thought went into how to brace the columns temporarily, how to make sure the form could be removed easily, and how to allow for some tolerance. The only significant field adjustment was the addition of access holes in the forms to help minimize damage to the forms during assembly. The plan worked as expected.

Different floor-to-floor elevation on the lower floors as well as the top were concerning, as this might not allow the prefabricated forms to perform at all levels. The solution was to add different additional bolt holes to the form to accommodate two different angles. Once the lower two floors were completed, the forms were adjusted to work for the typical floors. The roof level was another place where the forms were adjusted for a change in elevation. Lail Bridge, the company that engineered and built the form, did a great job on figuring this out and getting it correct.

Early in the project, Brasfield & Gorrie chose to construct each floor using two placements due to the complex nature of the floor reinforcement, as it was expected that the construction time of the floors would dictate the schedule. However, when construction reached the upper floors, crews were able to set and place the floors more rapidly than originally planned, allowing the construction of the floors with a single placement.

Statistics

The FORTH Atlanta's structure and podium used 8300 yd^3 (6346 m^3) of concrete, 790 tons (717 tonnes) for mild steel reinforcement, and 158,440 lb (71,867 kg) of post-tensioning tendons. The underground parking levels used an additional 7000 yd^3 (5352 m^3) of concrete, 565 tons (513 tonnes) of mild steel reinforcement, and 78,790 lb (35,739 kg) of post-tensioning tendons.

Conclusion

The collaboration between the architect (HKS, MA), the structural engineer (Uzun+Case), and the contractor (Brasfield & Gorrie) helped to bring this project out of the ground and topped out in a smooth and logical fashion. By listening to the concerns of each party, the design and construction team was able to adapt and overcome all challenges.

This Ralph McGill Development by New City Properties has been very successful, both for them and for the City of Atlanta, by extending the enterprise zone created with Ponce City Market and 725 Ponce. They have been able to attract several important tenants, and their lease-up projections have been far exceeded. The exposed structural concrete diagrid frame and detailing was vital to the vision and success of the FORTH Atlanta. The project was the first-place winner in the high-rise category of the ACI Georgia Chapter's Dan R. Brown ACI Awards program.

Selected for reader interest by the editors.

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