

An efficient framing scheme drives a Boston high-rise to become one of the first major residential towers in an up-and-coming neighborhood.

FIRST on the Block

BY DAVID J. ODEH, S.E., P.E.

Photos: Odeh Engineers; Renderings: ADD, Inc.

BOSTON'S BOOMING “innovation economy” has driven a growing need to build efficient and sustainable housing in proximity to new workplaces in the city.

One of these is Troy Boston. Located in Boston’s historic South End, the development consists of 12-story and 20-story apartment towers that surround a four-level parking structure. There are 378 apartments ranging from 380 sq. ft to 870 sq. ft—studios, one-bedroom units and two-bedroom units—with extensive shared amenity spaces like rooftop terraces with barbecues and fire pits, an outdoor swimming pool with a cabana deck and a yoga and fitness studio.



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New on top of Old

The project fulfills the developer’s goal of creating a very high apartment yield on a tight urban site formerly occupied by an old industrial building. Like many new buildings in the South End, the site was covered with a deep layer of unsuitable soils. The challenge was compounded by the presence of old building foundations and other underground obstructions. To manage the risk, extensive exploration was performed using ground-penetrating radar and test pits, revealing a grid of old bell pier caisson foundations. Odeh Engineers, as the structural engineer for the entire project, worked carefully with the contractor and geotechnical engineer to design new pile foundations that could bridge over or around the existing piers. Significant cost savings were achieved by eliminating the need to remove the existing bell piers (only a small number had to be removed).

The complex urban site also required careful logistics and planning for erecting the building, given the small amount of staging area available. The team was able to integrate foundations for a centrally located tower crane within the building foundations. The contractor phased construction to allow for lay-down in the parking garage area during erection of the mid-rise and high-rise buildings, and located the crane such that steel could be reached in almost all cases. The garage, which had smaller and lighter pieces of steel, was erected last by moving material through a passageway beneath the high-rise tower.



- ▲ Troy Boston is one of the first residential high-rise buildings in the city's South End.
- The 20-story tower, under construction. The project includes 378 apartments between the two towers.

- ▲ The development consists of 12-story and 20-story apartment towers that surround a four-level parking structure.

Floor to Floor

Early in the design stage, Odeh Engineers worked with architect ADD, Inc. (now part of Stantec) and construction manager Suffolk Construction to study multiple design options for the superstructure in both steel and concrete. The team compared structural options based on overall cost, speed of construction and ability to achieve the aesthetic and design goals of the project, and ultimately chose to use a Girder-Slab system (the project is the tallest building in New England that uses this system).

The system consists of specially fabricated “disymmetric” steel beams (also called “D-Beams”) and hollow-core precast concrete planks. The D-beam sections are composed of the lower tee of a castellated wide-flange section with a continuous flat bar welded along the top. Planks are arranged such that they bear on the bottom flange of the D-Beam, essentially eliminating any projection of the steel beam below the plane of the floor planks. This arrangement of members allows for a very shallow floor structure—in this case only 10 in.—and thus lower floor-





- ◀ The contractor phased construction to allow for lay-down in the parking garage area during erection of the mid-rise and high-rise buildings, and located the crane such that steel could be reached in almost all cases.



- ▲ A typical floor. The apartment types include studios, one-bedroom units and two-bedroom units.



to-floor heights. For Troy Boston, this low floor-to-floor height provided an important advantage by significantly reducing the cost of the building façade.

The system is constructed in two steps. First, the erector constructs the D-beams, columns and un-topped planks in the desired arrangement. The D-beams are sized such that they can safely support the dead load of the planks without shoring. Second, slots are cut in the ends of each plank in order to pump grout into the plank cores and through the castellations of the beams. This second step creates a composite section capable of supporting the combined dead and live loads of the completed structure. Notably, the grouting operations can be performed after the building is enclosed. A key advantage for the Troy Boston project was that this work could be performed without the costs and delays of winter conditions in New England.

D-beams are typically constructed as simple spans between columns using bolted end plate or seated connections. However, to improve the economy of the system and provide the architect with more flexibility in unit planning, we designed the structure using “tree column” connections at each floor. The tree columns, which have shop welded D-beam outriggers on each face, take advantage of reverse curvature to allow for longer D-beam spans. This approach allowed for fewer columns in the building and accommodated the large number of demising walls required to achieve a high yield of apartments on each floor.

The economy of the system was also improved by carefully considering the layout, design and coordination of precast planks on each floor. By using 8-ft-wide planks and coordinating the plank layout with the architectural ceiling plans and unit layouts, the drywall ceiling could be eliminated in much of the building without compromising the aesthetic look of the apartments.

- ◀ The top side of a typical D-beam, showing the tree column connection.

Mock-ups made during construction confirmed that the exposed planks created the loft-like feel that the architect and developer desired for the project.

Lateral Issues

Creative design solutions were required to integrate the floor diaphragms with larger-scale lateral force resisting system elements in the towers. While floor plates are functionally connected at the lower three levels, the building is separated by expansion joints into three different structures. Odeh designed each structure using a different lateral force resisting system to optimize costs based on the geometry and layout.

The L-shaped mid-rise building, at 12 stories, has a combination of load-bearing cast-in-place concrete shear walls (in a central elevator core) with steel braced frames and moment resisting frames located at the building perimeter. Using multiple structural analysis computer models, Odeh was able to optimize the distribution of the steel frames, balancing the story drifts of each floor about the stiff concrete core to minimize torsional motions of the floor plate.

To integrate the concrete shear walls with the floor diaphragms, Odeh designed special D-beams to serve as collector elements, embedded within the depth of the floor system, that could drag loads to embedded plate connections in the walls. This system of collectors proved to be easy to build and eliminated the need for a more costly reinforced topping slab system.

The initial design of the 20-story tower included a cast-in-place concrete core similar to the 12-story building. However, the team decided that it would be more cost-effective to use a concentric steel braced frame system to control drift. The major factor in the decision to use steel was the larger incremental cost of the formwork and tower crane capacity required to construct what would have been a much taller concrete core compared to the mid-rise building.

Furthermore, Odeh worked with ADD to optimize the location of the bracing such that it fell within unit demising walls and at symmetrical locations in the floor plan to minimize torsional

drift. At the base of the structure, the transverse direction bracing was converted to shear walls at the center—and by supporting the shear wall by pile caps at the ends only (forcing it to act as a deep-grade beam spanning to a wider base), uplift in the pile foundations was nearly eliminated.

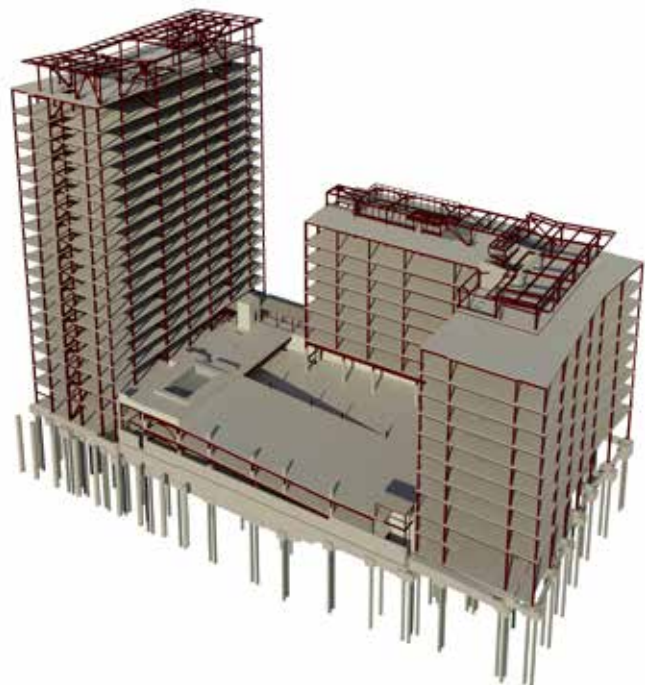
Immersive BIM

The design team had worked on numerous projects together and had mastered a system of detailed coordination during construction documentation to minimize and eliminate conflicts in the field. At the center of this was Odeh's Immersive BIM technology, which includes a conference room with a 32-ft-wide by 10-ft-tall video wall powered by ten high-resolution laser projectors. During design, Odeh collected models from the architect and the mechanical, electrical, plumbing and fire-protection engineers to prepare clash-detection sessions and building fly-throughs on the video wall. In each of these sessions, the benefits of the D-beam system proved to be extremely important, primarily due to the lack of beams below the precast planks. Furthermore, ADD could easily review the exposed structure for coordination with ceiling soffits, lighting and even furniture layouts using the full-scale immersive video wall.

These meetings produced some key lessons, including the need for careful coordination of vertical penetrations when this type of structural system is used. In particular, the weight of heavy vertical risers for the plumbing system required the introduction of special steel supports near the bottom levels of the structure, as the precast concrete planks could not support such loads, which are common in high-rise construction. In response, the team was able to come up with a BIM-driven solution consisting of steel framing members embedded within the depth of the precast plank floors that did not compromise the low floor-to-floor heights and high ceilings.



- ▲ Odeh Engineers' Immersive BIM room, showing a Troy Boston clash detection model.
- A structural model of the entire development.



Speed of Construction = Speed to Market

The most important measure of success for the design may have been the speed with which the structure was erected. By using precast planks, placed by the erector in parallel with the steel framing, Suffolk avoided the extra time required to prepare metal deck pours with reinforcing bars, slab edge closers and other detailing. The faster erection of the floors also allows other trades (such as plumbing, electrical and light-gauge metal stud framing) to begin working on the completed floors more quickly, further improving the overall critical path schedule of the project. At Troy Boston, the lower floors were rapidly enclosed while erection continued above, allowing the contractor to expedite the schedule of other trades while keeping the project less susceptible to the famously unpredictable New England weather.

Troy Boston topped off in October 2014, well ahead of schedule and within 10 months of the construction start, and

is on track to open early this year. By delivering the project so rapidly, the team allowed the developer to be “first to market” in attracting young professional tenants to what is expected to be one of Boston’s most vibrant places to live and work in the near future. ■

Owner/Developer

Gerding Edlen Development
Normandy Real Estate Partners

Construction Manager

Suffolk Construction

Architect

ADD, Inc. (now part of Stantec)

Structural Engineer

Odeh Engineers



▲ Erection of the 20-story tower, showing the sequence of enclosure on the lower levels during construction of the upper levels.



▲ The apartments range in size from 380 sq. ft to 870 sq. ft.