Leverage Value from Up-Down Construction

By Blake D. Patsy, P.E., S.E. and Nathan A. Ingraffea, P.E., S.E.

Figure 1: Excavation proceeds down to the P1 level while ground construction begins. (Photo by Pete Eckert)

Sometimes all it takes is a fresh perspective. When a technology is developed to overcome a particular obstacle, it's easy to overlook additional benefits that can apply to a wider range of projects. Such is the case with up-down construction. Also referred to as top-down construction, this method originated as a viable alternative for tight urban settings where conventional building shoring is not possible. As the name implies, up-down construction allows a building to be erected in two directions simultaneously. Regardless of where a building is located, this structural solution can reduce months from a project's schedule, which translates into considerable cost savings for the owner. Moreover, modifications to the conventional shoring and construction process can save time and materials.

Across the nation, a push toward intelligent land use and community-friendly designs is encouraging developers to place parking underground. Many local jurisdictions, such as the city of Portland, Oregon, offer incentives to those who utilize this approach. As a result, the benefits of up-down construction have the potential to positively impact an increasing number of high-rise projects with multilevel underground basements or garages.

The Set Point for Payback

When KPFF Consulting Engineers examined the program for the 570,000 square-foot, 31-story John Ross Condominium tower in Portland, it became clear that up-down construction was a winning proposition. As one of the first structures in the redevelopment of a former industrial area, there was ample room for a conventional construction process. But the building's developers, Gerding Edlen Development Company and Williams & Dame Development, specified three stories of below grade parking, which meant that up-down construction could offer increased value.

"We commonly locate parking underground on our projects to maintain the vitality of the urban space and maximize our available building area," says Dennis Wilde, Gerding Edlen's senior project manager. "Up-down techniques allow us to pursue this strategy without a significant schedule penalty, by shaving two to four months off the construction time."

With the up-down method, the amount of time saved in the construction schedule depends almost entirely on the depth of the below-grade construction. Calculations for the John Ross showed that three or more underground levels were necessary before the method became cost effective. This was verified by the estimates of the building's general contractor, Hoffman Construction Company of Oregon.

Modifications Increase Efficiency

The process involves two main structural components: drilled shafts, which serve as the tower's foundation system, and perimeter sheet pile retaining walls.

A drilled shaft is essentially a high capacity reinforced concrete column that is cast in-place inside of a pre-drilled, cased or uncased hole. For the John Ross, KPFF selected steel casings to be removed and reused as the concrete was poured. Each single drilled shaft supports the full load of one building column above.

Embedded into dense cemented gravels that underlay the city, the shafts achieved very high tip bearing pressures. A 3-foot

Figure 2: The conventional excavations portion of the site was used to facilitate up-down excavation under the tower. (Photo by Pete Eckert)

diameter shaft has an allowable capacity of 3500 kips. This capacity allowed for relatively high column loads on individual shafts to support the tall tower.

Rather than use concrete slurry walls common in some up-down construction projects, KPFF modified the process by opting for heavy steel sheet piles that will remain as the permanent below grade wall system.

"Maintaining the sheet piling as a permanent element offers an innovative perspective on a simple concept," says Dean Abbondanza, Manager of Market Development at Skyline Steel. "This versatility leads to significant savings by eliminating multiple stages of conventional below-grade construction. In addition, the sheet pile's corrugated profile provides depth and texture, which allows architects to use lighting and color for different effects."

The sheet pile segments are 24 inches long and 18 inches deep, and were installed in pre-welded, 4-foot long pairs. With three-quarter-inch thick flanges and one-half-inch thick webs made from A572 Grade 50 steel, the piles are strong enough to absorb the energy of driving them through dense gravelly soils to tip elevations that may be 50 feet or more below the surface. Interlocking ends allow the piles to be driven separately while maintaining good alignment with one another. Seal welding the sheets at their joints creates a watertight structure. The heavy sheet piles do not require a separate foundation system to support them and their tributary floor loads. They carry axial loads through the skin friction on their sides and end bearing.

Figure 3: The excavation continues straight down to P3, without forming P2, to offer the contractor maximum available head height. (Photo by Pete Eckert)

A Coordinated Staging Process

Prior to any on-site excavation work, KPFF provided a drawing that identified the sequence of construction. First, the contractor installed the sheet piles and drilled shafts simultaneously. Next, the contractor formed the ground floor level on-grade over a temporary rat slab in order to ensure that the underside of the permanent structural slab would be flat. The ground floor slab served as a working surface for the above-grade erection, as well as a protective barrier for the excavation and construction of the floors below. Once the slab was finished, the contractor was free to immediately begin building the 31-story tower. By allowing the contractor to initiate above-ground construction before the below-grade work was finished, the up-down process greatly shortened the overall construction schedule.

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The excavation of the soil below the ground floor slab is similar to a mining process, which requires low-overhead clearance equipment. While it takes considerably more time and planning than a conventional excavation, this work is removed from the critical path of the building construction. In sites with no staging area, openings must be left in the ground floor slab (and subsequent slabs below) to allow for the soils to be removed from the excavation. At the John Ross, however, the tower's footprint doesn't extend to the site's perimeter, so the team used a portion of the site for vertical soil removal. The larger the access area for soil removal, the faster and easier the excavation process becomes.

The construction of each below-grade floor generally proceeds by excavating down to its respective level, forming and pouring the floor, and then excavating the soil out from beneath the floor. As the excavation deepens, the shafts become exposed concrete columns. On the John Ross, the shafts were designed to handle the unbraced length of the lower two floors of the garage, which were excavated at the same time. This was done so that the lowest level could be constructed conventionally from the slab-on-grade at the base of the garage.

While removal of up to three floors worth of excavation may be possible, the span limitations of the perimeter sheet pile walls and the unbraced length limits of the columns start to restrict this type of sequencing. In the completed garage of the John Ross, the structured slabs and the slab-on-grade laterally brace the shafts and sheet pile walls.

Finishing Touches

The contractor attached the below-grade floors to the shafts using epoxy dowels drilled into the perimeter of the roughened shaft. The appearance of the shafts will be softened by encasing them in an architectural wrap. Another option is to leave the steel pipe casing used to support the augured hole in place for the future exposed height of the shaft. The casing can be cleaned and painted as needed after the excavation. The slabs can be supported directly by the casing by welded ledger angles or steel corbels. A similar ledger angle system can be employed to support the perimeter of the slab at the sheet pile walls.

Figure 4: Excavation bottoms out below the tower at P3. The bottom slab is now ready to be poured, and the P2 slab can be poured and formed conventionally. (Photo by Pete Eckert)

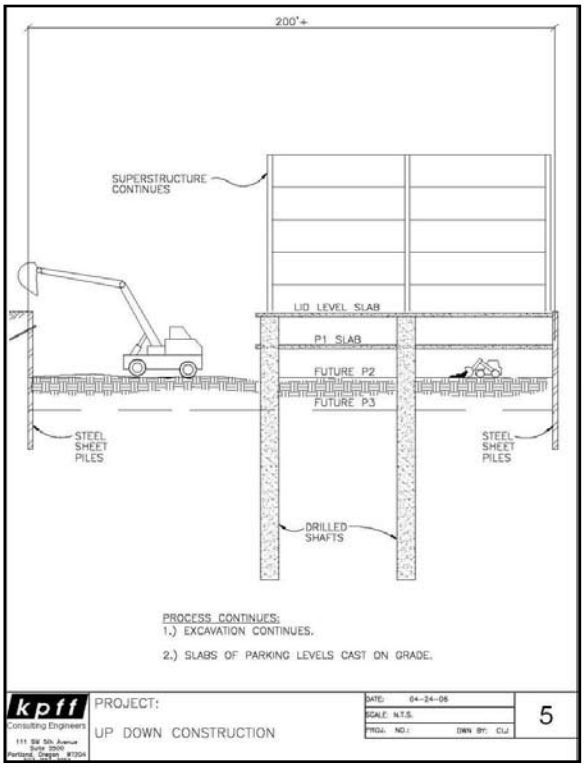

Figure 5: Diagram shows process of up-down construction on a partial site. (Image by KPFF Consulting Engineers)

The sheet pile walls can be left exposed after construction, or they can be cleaned and painted. Sheet pile walls must be fire-proofed in some jurisdictions if they are used to support major gravity loads from the garage and/or ground floor slabs. This can be expensive, but may be avoided by placing shafts near enough to the perimeter to support the slabs. Skyline Steel is obtaining their UL listing for a four-hour fire rating for the unprotected steel. Once this is obtained, the sheet piles can be used to support considerable gravity load from the floor slabs.

Summary

Faced with increasing construction costs, clients are in constant need of innovations that bring value to their projects. At the same time, many are wary of trying untested applications. Up-down construction offers a proven process that saves the owner time and money. For larger projects, the interest carrying cost on the construction loan can be millions of dollars a month. Shortening the construction schedule by several months also may substantially reduce the general contractor's cost for general conditions. In addition, owners benefit competitive advantage of getting their project to market faster.▪

Blake D. Patsy P.E., S.E., is a Principal at KPFF Consulting Engineers in Portland, OR. Mr. Patsy has served as the structural engineer for many of the region's more notable projects. In addition to his participation in Structural Engineers Association of Oregon (SEAO), Blake is a member of the National Institute of Building Sciences and Earthquake Engineering Research Institute.

Nathan A. Ingraffea, P.E., S.E. is an Associate and structural project manager at KPFF Consulting Engineers in Portland. He is an Adjunct Associate Professor at the University of Oregon and a member of Earthquake Engineering Research Institute and American Institute of Steel Construction.