SHORING *Facilitating* DESIGN at 100 STOCKTON

By Robert Graff, S.E.

The 100 Stockton Street project reimagines an eight-story former department store into a multi-use office, dining, event space, and boutique retail building. This reimagination of the building required significant structural shoring to facilitate the design.

The building in San Francisco's historic Union Square is a 1970s concrete building consisting of 250 thousand square feet. Modifications to the building required the demolition of the roof level, demolition of over one-third of the building floor plate, removal of half of the gravity columns, shortening of the existing post-tensioned (PT) girders, and demolition of the suspended first floor and the existing perimeter shear walls (*Figure 1*).

These elements were reconstructed in new locations, configurations, or to new extents to accommodate the design. Degenkolb Engineers designed the extensive shoring required to meet the needs of the project and the vision of the architect Gensler, building Structural Engineer of Record (SEoR) KPFF, and developers Morgan Stanley and Blatteis & Schnur. The shoring was closely coordinated with the design team as well as the general contractor Plant Construction, the demolition subcontractor Silverado, the shoring steel subcontractor Olson Steel, and the lifting contractor Sheedy Drayage.


Figure 2. Completed shoring columns and beams prior to column demolition.

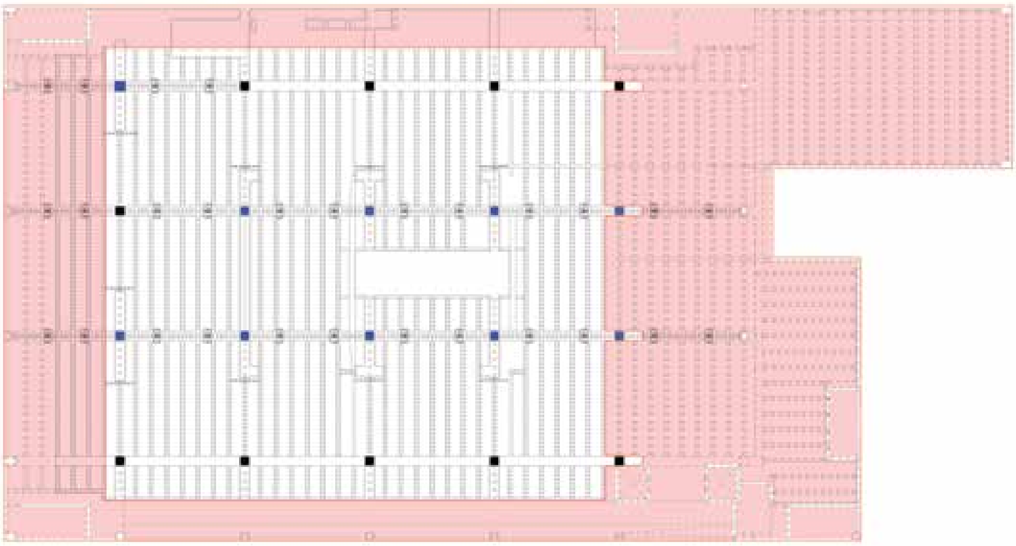
Figure 1. Demo plan – The red shaded area is demolished. Blue columns were demolished; other black columns remain.

Demolition

The roof level and all penthouses were demolished. A new roof was constructed using steel and concrete on metal deck. This rebuilt roof level allowed for a perimeter outdoor terrace for a restaurant and bar overlooking Union Square. Minimal shoring was needed for this work, but the structure was evaluated for its ability to support the necessary demolition equipment, including excavators and skid steers.

The exterior shear walls and the perimeter of the original floor plate were demolished. The floor plate was reconstructed, cantilevering out to new extents at all levels. The newly defined edge of slab accommodated a façade consisting of glass and terracotta, a significant change from the original nearly windowless exterior. Within the remaining seven stories of floor plate, there were twenty existing 24-inch square columns, of which ten columns and their foundations were demolished. The demolished columns each carried 7 stories of floor plate consisting of PT girder, PT joists, and a 4½-inch reinforced slab totaling over 100 psf. The columns carried 800 kips each, and the combined shoring load for the ten columns approached eight million pounds.

Shoring Requirements

Shores to support the loads from the demolished columns were designed for a maximum of 500 kips at the base of the building using two shoring posts for each building column. Fabricated structural steel was selected for the shoring at most

continued on next page

levels due to the size of the loads. The shores were designed as 18-inch pipes at the basement level but tapered in size up the building height. At the upper two levels, adjustable steel shores were used where loads were low enough that off-the-shelf shoring systems were adequate.

The PT girders on the four main column lines at all levels were de-tensioned. This allowed the girders to be shortened by a bay at each end and was accomplished by releasing the tendon stress, chipping back the girder, cutting the existing tendons, casting new PT tendon anchorages, and finally re-tensioning the original tendons. This all was completed to allow the perimeter of the building to be reconstructed to new extents for the façade.

In their temporary de-stressed state, the PT girders could not support the joists and slab with only the mild steel reinforcement they possessed. Shoring beams placed on top of the column shores provided nearly continuous support during the girder's extremely weakened state. Shoring beam deflections were calculated while supporting the load of the slab, joists, and de-stressed girders. Due to a temporary condition, the deflections would become locked in when the new columns and walls supporting the slab were cast. Detailed checks of the steel shoring beams were completed to control deflections within acceptable limits resulting in stiff W27×146 beams (*Figure 2, page 23*).

At the base of the shores, the total loads were beyond what could be supported by cribbing which would be a typical temporary shoring foundation solution. The project also required the demolition of the existing foundations and excavations for new foundations. This all occurred around the shoring system while it was supporting the building. To support the large loads and allow for the necessary excavation, 12-inch cased micropiles were used. The micropiles could be installed in the basement and could support the building load, while the top eleven feet of each pile were exposed due to the foundation excavation. In addition, the micropiles had a limited impact on the permanent foundations cast around them, making them an ideal solution.

A steel frame or *carriage* (as the contractor named it) was designed to transfer loads from the shores to the micropiles. The carriage consisted of 1½-inch-thick triangular gusset plates that were slotted into the shoring column. These gusset plates delivered the load of one shore down to a rectangular frame of wide flange beams. The frame, in turn, delivered the load to two piles for each shoring column. The carriage served a second purpose which was to link four piles together to provide additional stability. This stability was exceedingly important when excavating around the piles for the foundations.

Figure 3. Setting up for test lift.

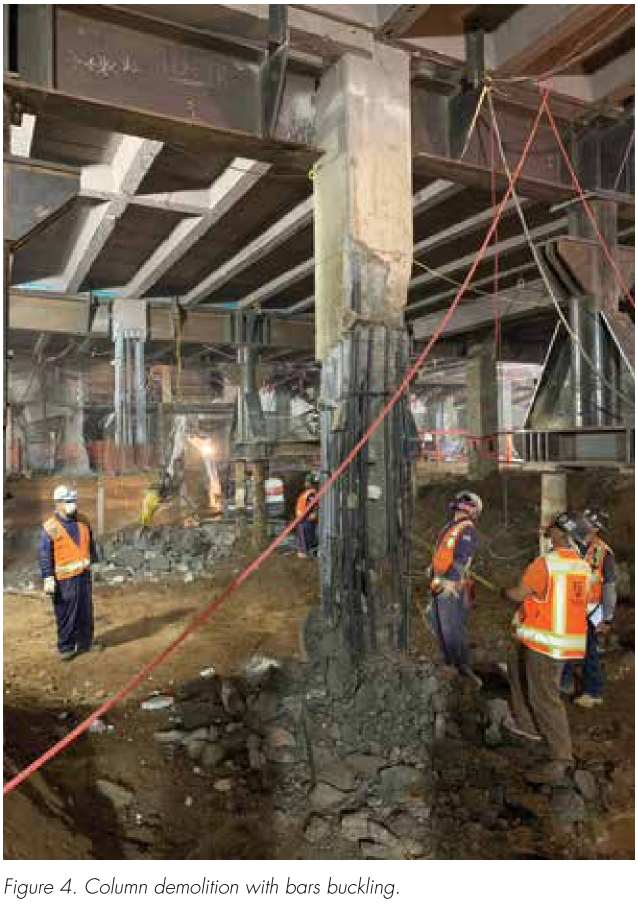

Figure 4. Column demolition with bars buckling.

System Deflections

With all the shoring elements determined, expected deflections of the system were calculated to be between ¾ inch to 1 inch. This resulted from a combination of column shortening, pile settlement, and beam deflections. If allowed to occur, this deflection would become permanent in the final building when columns and walls were cast. Due to the capacity of the existing floor framing, topping the slab to correct such deflections was not possible. To compensate, a jacking operation to transfer the building load was developed. Most of these deflections were eliminated or significantly reduced by transferring the load to the shoring prior to column demolition.

The jacking operation required the use of hydraulic jacks at each shore to transfer the loads. However, placing upward loads on PT girders which were stressed at this phase is dangerous. The upward force combined with the negative moment induced by the PT stress can cause a negative bending failure. Therefore, the girders were evaluated under the shoring loads and found to approach failure in the rebar on the top side of the girders. The evaluation included several conservative assumptions about the stresses remaining in the tendons after 50 plus years. The original tendon stresses were known, but initial stress losses and losses due to long-term creep had to be conservatively estimated. However, the possibility of inducing failure of the girders when jacking the building could not be easily disproven.

A section of the building scheduled for demolition was used to test the proposed procedure to prove the jacking could be completed successfully. The shoring was designed for

Figure 5. Steel foundation forms installed and building supported on exposed piles.

1000 kips maximum per column and had four jacks to lift the load (*Figure 3*). The jacks were incrementally increased in load, and the building was inspected for signs of damage at each increment. A surveyor monitored the structure for movement, providing real-time feedback. Arriving at nearly 800 kips, the surveyor recorded that the building column had moved $\frac{1}{16}$ of an inch upward, and the shoring system had deflected ⅝ inch at the shoring columns. The shores were shimmed using stacks of steel plates between the shoring column and beam to lock in the load before releasing the jacks. The building had no damage, and the full load was now supported on the shores. With the successful test, the remaining bays could be jacked to transfer the building loads from the columns to the shores, and column demo proceeded.

Column Demolition

Column demo started with a text of the picture shown in *Figure 4* and a concerned call from the demo contractor. He asked if it was ok that the column bars were buckling out about 2 inches as they demolished the concrete column. Quickly back-calculating, it was determined that around ⅛ inch of vertical deflection could cause a 2-inch buckle in a bar over the story height. A ⅛-inch vertical deflection was undoubtedly well within expectations of building movement when a column is removed. Fears of collapse were quelled, and demolition proceeded.

With columns demolished, they removed the old building foundations. As they excavated, they also removed the abandoned brick and concrete foundations of previously demolished buildings on this site that predated the current building. Excavating for the new footings exposed around 11 feet of the previously buried cased micropiles (*Figure 5*). The casing provided buckling resistance to the micropile, which the surrounding soil would typically provide. The shoring carried all 8 million pounds of load at this stage, and the shoring system was in its most vulnerable state.

One Last Challenge

A couple of months later, foundations were poured around the piles, and stability started to be restored. However, the project had one last significant shoring challenge. The exterior sidewalk elevation varies by 9 feet around the perimeter of the building. The original building, designed as a single department store, had two main entrances with steps to accommodate the change in grade. The renovated building was designed for individual boutique retail. The suspended first floor over the basement was demolished and reconstructed with a stepped floor plate to allow for level entrances to each business.

The column shoring system was still supporting the building, and the shoring stopped and started under and over the first-floor girders. The concrete girders temporally remained, but the slab and joist of the first floor were demolished. By demolishing the first floor, the shores would buckle without the bracing provided by the floor. A series of steel pipe kickers were anchored to the new building foundations and up to the shoring columns to provide bracing (*Figure 6*). The American Institute of Steel Construction (AISC) provides requirements for bracing. The bracing loads are relatively small, but the stiffness of the bracing is equally important and is what drove the design. With the bracing in place, the first-floor demo proceeded.

Figure 6. Shoring braced with the first floor demolished.

Once the first floor was removed, the building as designed by the SEoR could start to be constructed up and out of the basement. With every few weeks that passed, another floor was re-supported by the new columns and walls. Eventually, the new structure topped out. The shoring had done its job, and it was time for it to go. The demo sub returned to the job and removed the shoring, sending it off for recycling.

Shoring is often necessary to facilitate structural and architectural designs – especially those that reimagine existing buildings. Facilitating a design can be as simple as a few temporary wood shores or as complex as this project, which pushed the limits of what can be done with building shoring.▪

Robert Graff is a Principal at Degenkolb Engineers and is active in their Construction Engineering and Education practice groups (rgraff@degenkolb.com).