Floating a Building and Deepening a Site: How Strategic Decisions and Strong Collaboration Ensured the Success of a Complex Project

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ABSTRACT

The new home of the Berkeley Art Museum and Pacific Film Archive combines a challenging adaptive reuse project with a unique auditorium addition. Located on a tight parcel of land in downtown Berkeley, California, the site is bounded by three city streets, an operating bank, an occupied apartment building, and an existing parking garage. The architectural and structural scope on the project necessitated an elaborate suite of shoring systems to facilitate the downward and outward expansion of the existing facility on the site, including soldier beams and tiebacks, soil nail walls, concrete buttresses, braced-frame buttresses supported on drilled piers, hand-mined underpinning piers, and hydraulic jacking of steel support structures. The final design package reflected flexibility from the design team and versatility from the contractors, keeping all options open and ensuring the right shoring systems would be used in the right places.

INTRODUCTION

The new Berkeley Art Museum and Pacific Film Archive (BAM/PFA) will house a collection of artwork and film media in a unique structure that pairs the historical fabric of the 1930s-era University of California Printing Center with the modern amenities of an architecturally striking addition.

The architectural and structural requirements for the project, which included both a downward and outward expansion of the existing facility, required an aggressive and extensive shoring and underpinning operation. The project required a shored excavation up to 30 feet deep to facilitate the creation of a basement level across the site. Also, the adaptive re-use component of the project included the preservation of portions of the existing facility that would be suspended over the site while excavation took place below.

Degenkolb Engineers, the Construction Means and Methods engineer on the project, collaborated closely with general contractor Plant Construction Company, L.P. and shoring/underpinning contractor Condon Johnson & Associates, Inc. to select shoring and underpinning systems appropriate for the project's performance requirements and budgetary constraints. Each corner of the "L-shaped" site possessed unique challenges that required deliberate decision making processes before a final shoring system was selected. And contrary to how many traditional projects operate, the shoring systems selected for the site varied from bulkhead to bulkhead. The final product was an excavated site that utilized an efficient solution at each bulkhead, leading to efficiencies in both cost and schedule that directly benefited the owner.

THE PROJECT SITE

The 47,000 square-foot University of California Berkeley Printing Center was constructed in the late 1930s at the corner of Oxford and Center Streets in downtown Berkeley. Consisting of a three-story concrete office tower and a one-story warehouse structure with a distinct three-span sawtooth roof, the facility served the University for decades, printing everything from students' diplomas to the signatory copies of the United Nations Charter in 1945 (Bhattacharjee, 2010).

After originally considering demolishing the printing facility and the adjacent parking garage and building a completely new museum, BAM/PFA opted to pursue an adaptive reuse strategy that would incorporate features of the existing printing plant, including the sawtooth roof over gallery spaces and the use of the office tower for back-of-house space (Bhattacharjee, 2010). These features would be combined with additional construction both downward and outward to create an 83,000 square facility (Rinder, 2015). Figure 1 shows the various components of the project site. Note that in this paper the existing warehouse is referred to as the "Press Building" and the existing office tower is referred to as the "Admin Block."

Figure 1 illustrates many of the spatial constraints that the shoring team needed to account for when both designing and digging the excavation. These constraints drove the decision making processes for each of the shoring systems utilized on the project. The site is flanked on the north, south, and east sides by busy city streets, with only sidewalks separating the street traffic from the boundary of the project excavation. Furthermore, Center Street, on the south side of the site, serves as a main pedestrian thoroughfare between the Downtown Berkeley rapid transit station and the western edge of the UC Berkeley campus. The land directly west of the site is occupied by an operating bank building and parking lot and a three-story apartment building.

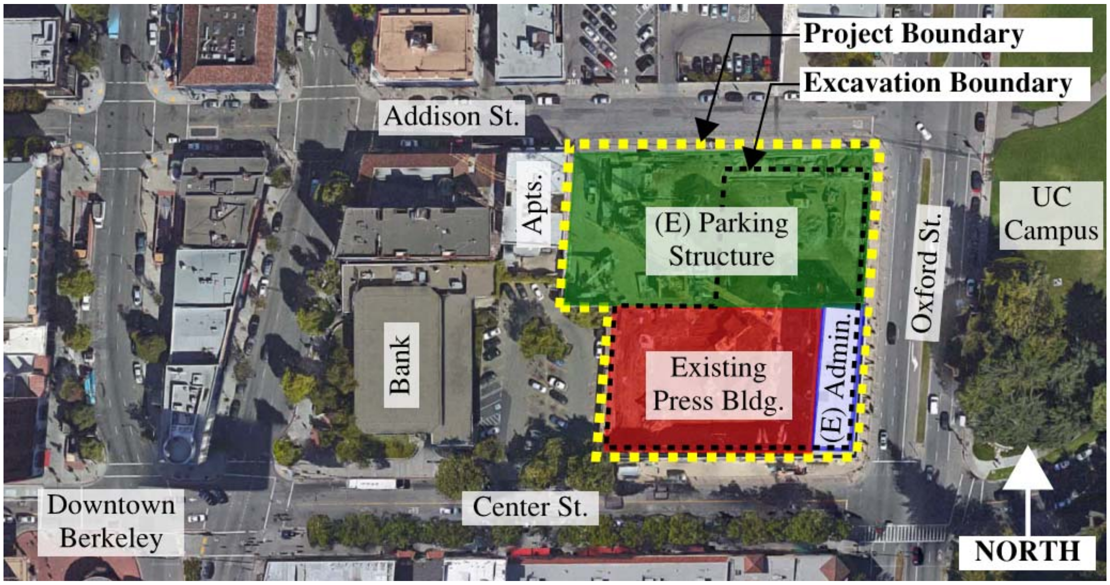


Figure 1. BAM/PFA Project Site (Base image adapted from Google Maps)

The architectural program for the project required the creation of a full basement underneath the existing Press Building, a downward expansion beneath the existing Admin Block, and the northward expansion of the facility into an area occupied by an existing parking structure. The entire building footprint required a shored excavation varying in depth between approximately 15 feet and 30 feet, along with the underpinning of approximately 75% of the existing Admin Block and the retention of portions of the Press Building.

ORGANIZATIONAL STRUCTURE OF THE SHORING TEAM

Degenkolb Engineers was retained by general contractor Plant Construction Company, L.P. to serve as the Construction Means and Methods engineer on the project and provide design services for the required shoring and underpinning scope. After several months of schematic-level discussions, Degenkolb delivered a shoring construction documents package in approximately six weeks. This package was put out to bid, and Shoring Contractor Condon Johnson and Associates, Inc. was selected as the low bidder for the Demolition, Shoring, Excavation, and Dewatering trade package. At this time, the start of the excavation process was still several months away. This allowed Plant, Condon Johnson, and Degenkolb to work together to streamline and value-engineer the shoring documents prior to the start of any construction activities. Figure 2 illustrates the organization of the shoring team.

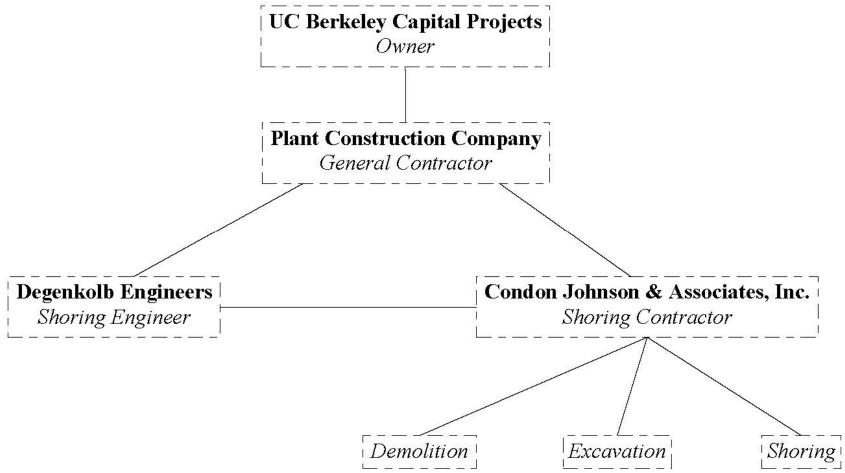


Figure 2. Organization of the Shoring Team

For this project, Degenkolb worked for Plant, instead of directly for the owner. This was beneficial to the project as it led to a condensed design and construction schedule with minimal risk for the owner. It also allowed for an open line of communication directly between Condon Johnson and Degenkolb, allowed for Degenkolb to quickly address questions during construction, and allowed for Condon Johnson to begin initial excavation activities while the final details of the Admin Block underpinning were still being worked out. Had the shoring engineer worked directly for the owner, the project schedule would have likely been extended to allow for value engineering to be completed prior to awarding the shoring trade package. This arrangement allowed for a shared risk approach for the design and the construction schedule.

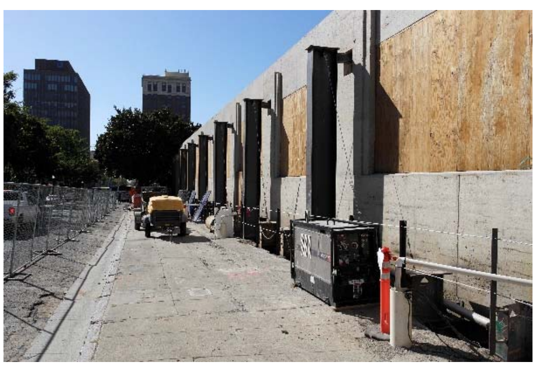
CASE STUDIES ON THE SHORING SYSTEMS USED ON THE PROJECT

The project site can be divided into multiple "sub-regions" each with a shoring approach selected specifically for that area. Unlike many traditional shoring projects of this size, the shoring at BAM/PFA varied from area to area, as each shoring system was selected to achieve maximum value for the owner while also satisfying performance requirements set by both Degenkolb and the rest of the design team. In this section of the paper, short case studies are presented for each shoring region, starting at the south side of the site and moving clockwise around the project perimeter.

South Bulkhead – Shoring for the Excavation and the South Press Building Wall

The shoring scope on the south side of the site included the retention of the existing Press Building wall and the construction of an 18-foot shored excavation. The challenge was to find a way to suspend the wall while excavation occurred directly below the wall and directly adjacent to the sidewalk on Center Street.

Degenkolb designed a soldier pile wall with a single row of tiebacks on this side of the site to provide adequate stiffness and prevent any substantial movement of the wall or the adjacent sidewalk. Instead of providing a completely separate system to suspend the wall, Degenkolb designed every third soldier beam to extend an extra 15 feet above grade and attach to the top of the Press Building wall, thus providing temporary lateral support for wind and seismic demands. Every soldier beam along the south wall also incorporated a small steel haunch at ground level to support the suspended wall for gravity loads. Condon Johnson installed all soldier beams from outside of the site and secured the south wall prior to the selective demolition activities within the Press Building, ensuring the stability of the wall throughout construction. Figures 3 and 4 show the shoring system from the outside and inside of the project site, respectively.



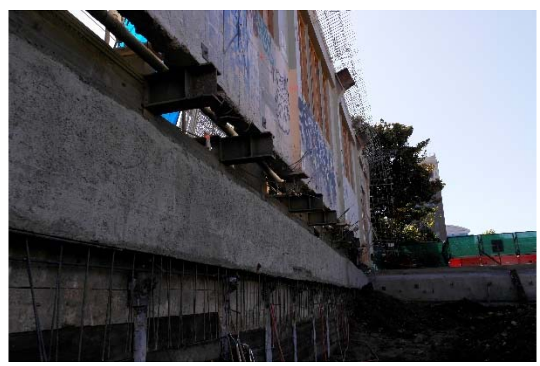


Figure 3 (left). Soldier Pile Extensions at South Wall
Figure 4 (right). Suspended South Wall at Interior of Site
(Photos by Degenkolb Engineers)

West Bulkheads – Soil Nail Shoring

Degenkolb originally designed the three shoring bulkheads forming the west sides of the "L" shaped site with steel soldier beams, tiebacks, timber lagging, and a shotcrete overlay. However, during the value engineering process, Condon Johnson suggested that Degenkolb consider a soil nail approach, citing that, although these walls reached depths of up to 30 feet, none of the bulkheads were directly adjacent to critical city streets and infrastructure and thus were subject to smaller surcharge loads and less stringent deflection criteria. Degenkolb redesigned these walls with three to four rows of soil nails and a 5-inch-thick shotcrete facing, eliminating 45 steel soldier beams from the project scope.

Unlike pre-loaded soldier beam and tieback systems, soil nail walls require a small amount of soil movement to occur before the soil nails are engaged with load. In general, at the bank parking lot and the contractor lay-down areas, this performance was deemed acceptable. However, the project's tower crane was situated directly adjacent to one of the soil nail walls, raising concerns that any movement from the soil nail wall could adversely affect the crane. To address this concern, Degenkolb developed a pre-load and lock-off criteria for the soil nails within the zone of the tower crane, creating a hybrid system that achieved the economy of a soil nail wall and the deflection-control of a soldier beam and tieback system. Figure 5 shows the soil nail walls at completion of excavation, and Figure 6 shows pre-loaded soil nails in the area adjacent to the project's tower crane.

Figure 5 (left). Soil Nail Bulkheads at Completion of Excavation
Figure 6 (right). Pre-Loaded Soil Nails w/ Angled Anchor Head
(Photos by Degenkolb Engineers)

<u>North Bulkhead – Wall Buttressing</u>

As was previously shown in Figure 1, the north half of the BAM/PFA project site was formerly occupied by a University-owned parking structure. While the majority of this two-story plus basement concrete structure was demolished to make way for the northern wing of the new museum, below-grade portions of the northern perimeter wall played a role in the excavation shoring on the project.

The total excavation depth below street level at the north side of the site was approximately 30 feet, but the first 12 feet was occupied by the below-grade wall of the existing parking structure. The project team desired to re-purpose the wall as part of the site shoring. The challenge was to take the wall in its current condition, braced at the top by the first floor slab and at the bottom by the basement slab on grade, and re-purpose it as a cantilevered shoring wall to allow removal of the first floor slab above.

Degenkolb detailed a series of 6 inch-thick concrete buttresses to brace the basement wall and allow it to act as a cantilevered shoring system. The buttresses were reinforced with a single curtain of rebar and doweled into the existing basement wall and the existing slab-on-grade. The slab-on-grade was retained to serve as a diaphragm to distribute loads from the buttresses to the soldier beams that carried the excavation the remaining 15 to 20 feet downward. The buttress solution was economical, straightforward to install, and robust enough to resist construction equipment surcharges expected on the sidewalk directly above. Figure 7 shows some of the concrete buttresses in place with the additional excavation starting to proceed downward.

Figure 7. Existing Parking Garage Wall Braced by Concrete Buttresses
(Photo by Degenkolb Engineers)

East Bulkhead – Underpinning of the Admin Block

The most challenging aspect of the shoring design was the underpinning of the Admin Block. The existing structure, three-stories above grade with a partial basement below, required underpinning over approximately 75% of its floor area to facilitate the deepening of the site both directly beneath the building and also directly adjacent to the west and north. In some areas the excavation below the bottoms of the existing Admin Block footings would reach 15 feet or more. Degenkolb examined multiple underpinning schemes for the Admin Block. Table 1 below lists the three schemes that were given the most consideration.

Scheme	1 **“60 Micropiles”**	2 **“Pseudo-Trusses”**	3 **“Needle Girders”**
Structural System	Micropiles and steel beams locally supporting each undermined footing.	New tension elements within first story to create story-deep trusses. Drilled piers outboard of building to support the truss reactions.	W36 girders flown through the first floor windows, pier supported each end. Cradle beams dropped into the basement.
Benefits	Excellent deflection control, predictable behavior.	Extremely efficient use of materials.	Clear site below for contractor to perform demolition/ excavation, simple load path.
Drawbacks	Difficult to install micropiles beneath building, difficult for construction crews to work around the micropiles during excavation.	Significant reliance on the existing building elements to transfer loads, risk of cracking and damage to the existing building.	Required a large amount of additional steel, required a complex load transfer sequence to prevent differential displacements in the existing building.

Table 1. Admin Block Underpinning Schemes

Degenkolb and Plant Construction worked together during the design phase to evaluate each scheme and weight the benefits and drawbacks. In addition to the standard constraints of time and budget, Plant desired a scheme that would give their sub-contractors ample space to perform swift construction activities beneath the building. Ultimately the “Needle Girder” scheme (Scheme 3 in Table 1 above) was selected. Condon Johnson bought additional value to the scheme by renting 18 W36 girders they had in their stockyard to the project, reducing the carbon footprint of Degenkolb’s steel scheme and also streamlining procurement and delivery of these large steel elements.

Degenkolb assisted the team in ensuring proper deflection control by developing a multi-step jacking sequence to transfer loads into the temporary underpinning system. To accomplish this, each 50-foot Needle Girder was pre-loaded at each end using 100-kip hydraulic jacks prior to removal of the existing foundation elements below. The result was over 2 inches of deflection the Needle Girders without any deflection in the building. Figure 8 shows the Needle Girder scheme in service beneath the Admin Block, and Figure 9 shows the external buttresses Degenkolb designed to stabilize the building during the underpinning operations.

Figure 8. Admin Building Underpinning from Inside the Site
(Photo by Degenkolb Engineers)

Figure 9. Buttresses Bracing the Admin Block from Outside the Site
(Photo by Degenkolb Engineers)

<u>East Bulkhead – Transition Between Shoring and Building Underpinning</u>

The project site at the northern end of the Admin Block was the most geometrically complex area of the project site. Construction for the new museum required a 30-foot excavation cut just north of the existing building, but also required that this excavation depth be carried one column bay into the building footprint. Degenkolb's original design incorporated a concrete cut-off wall within the building that would double as the foundation for a temporary three-story steel braced frame to stabilize the building during excavation activities.

Condon Johnson, Plant Construction, and Degenkolb worked together to understand the impacts of Degenkolb's cut-off wall scheme and determined that required depth of the concrete foundation wall was not feasible to dig from within the building. Condon Johnson recommended moving the braced frame outside the building to the north and founding it on two drilled piers instead of a continuous concrete wall. They also recommended replacing the internal concrete cut-off wall with a three-sided soil nail wall, as this scheme would be much easier to construct within the low head-height conditions. Furthermore, the two exterior piers had minimal impact to the permanent building design, each only requiring a blockout in the mat slab. Degenkolb redesigned the shoring and bracing accordingly, streamlining construction and helping save the project thousands of dollars. Figure 10 shows the final configuration of the exterior steel braced frame and the three-sided soil nail wall.

Figure 10. North End of Admin Block (Photo property of Alejandro Velarde)

CONCLUSIONS

The uniqueness of each area of the site necessitated the selection of a multitude of different shoring systems which under normal circumstances could add unnecessary complexity to a project and reduce efficiency. However, the collaborative and tight-knit nature of the shoring team, the flexibility of the general contractor, and the versatility of the shoring contractor enabled the right shoring systems to be used in the right places.

These deliberate decisions made collectively by all stakeholders on the shoring team facilitated an extremely successful shoring project. First and foremost, no notable movement was detected in any of the existing structures on and adjacent to the project site. In particular, the Admin Block remained remarkably stationary during the entire underpinning operation. Furthermore, Condon Johnson and their sub-contractors achieved success in schedule, performing the majority of the work in their trade package within a couple of months. During this time, Condon Johnson functioned primarily as a general contractor, taking control of the project site and coordinating the work of the various sub-contractors. Once the excavation was completed, Condon Johnson turned a clean, open site over to Plant Construction, who then proceeded to build the new facility. Figure 11 shows the completed excavation with new foundation construction underway.

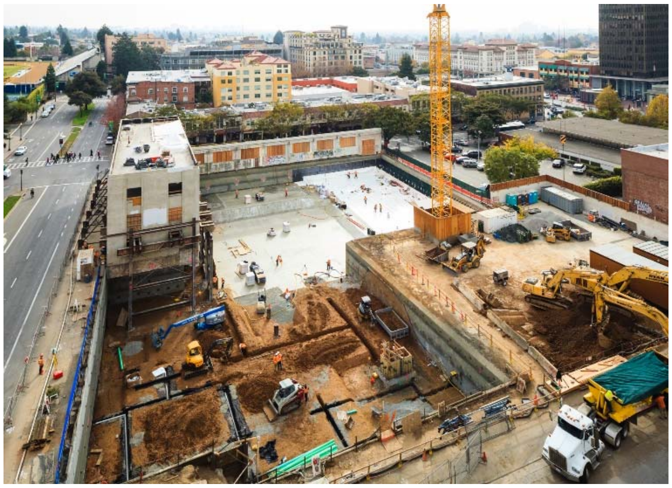


Figure 11. Completed Excavation (Photo property of Alejandro Velarde)

The shoring work at BAM/PFA is an example of a project that was designed and bid out in a traditional manner but was able to reap the technical and cost benefits of a collaborative, integrated design and construction approach.

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