Cutter Soil Mixing Comes to Seattle

by Dominic Parmantier, P.E.
Project Manager, and
David Giwosky – Project Manager
Condon-Johnson & Associates

Figure 1 – 505 1st Ave site surrounded by historic buildings and Alaskan Way Viaduct.

ADSC Contractor Member, Condon-Johnson & Associates, Inc. (CJA) completed the first application of the CSM (Cutter Soil Mixing) technology in Seattle, Washington. By providing the owner with an innovative package of integrated solutions for four levels of underground parking in difficult ground conditions, CJA proves once again that engaging an experienced shoring contractor, early in the planning stage of a project, can save the owner time and money and expedite the permitting process.

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Located in south Seattle in an area near the stadiums known as Pioneer Square, the 505 1st Avenue site consists of reclaimed land with a water table at a depth of approximately 8-ft. Unfortunately, the land had been reclaimed from the Elliot Bay Estuary with approximately 30 feet of wood debris from early sawmills and building remnants from the 1889 Seattle Fire. Interspersed in the fill material were a forest of timber piles which had served as foundations for old docks and more recent buildings. The presence of these obstructions had previously limited the extent of building excavations in Pioneer Square to no more than one level of below grade parking. The owners of the 505 1st Avenue site intended to build a new seven story office/retail building with four levels of below grade parking requiring a 43 feet deep excavation.

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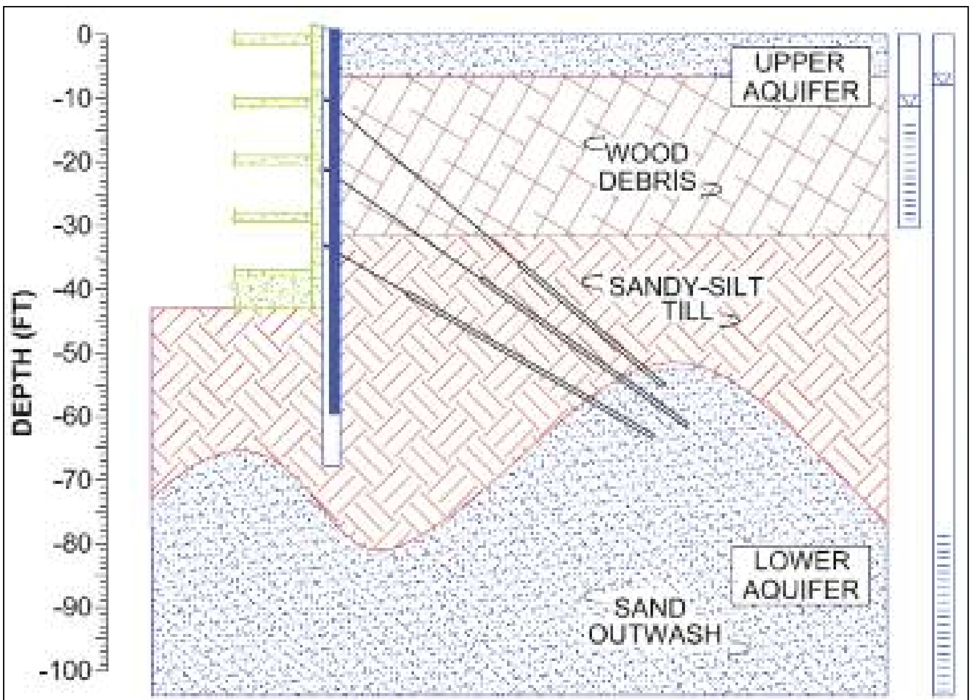

Figure 2 – Cross section of ground conditions and CSM shoring system.

Aside from the challenging ground con-

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Figure 3a and 3b below – Pre-trenching under cement-bentonite slurry to remove obstructions to 30 feet depth.

ditions, the site was sandwiched between two historic buildings, a major arterial into Seattle, and an on ramp to the Alaskan Way Viaduct (Figure 1). The ground water regime at the site consisted of an upper aquifer in the fill material and a deep aquifer in a granular outwash layer which was confined by a roughly 30 feet thick till layer which served as an aquitard (Figure 2). Since any dewatering of the upper aquifer would lead to unacceptable settlement of the upper fill material and potential damage to adjacent structures, the owner's engineer determined that a continuous cutoff to a depth of 68 feet would be necessary for the 43 feet deep excavation. It was also determined that the deep aquifer would need to be temporarily depressurized to safeguard against bottom heave in the completed excavation and uplift of the building under construction until the exterior cladding is installed.

Recognizing the need to engage a specialty shoring contractor early in the design process to coordinate the details of the shoring, underpinning, and dewatering with the building design and construction methods, the owner requested pricing and schedule information for two owner designed shoring systems: secant piles and ground freezing. The RFP was issued nearly a year before the scheduled start of excavation.

The successful shoring contractor was Condon-Johnson & Associates, Inc. (CJA). In addition to pricing the owner designed systems, CJA provided an alternate scheme utilizing the

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Figure 4 – Full extent of wood debris encountered during excavation and tiebeck installation

new Cutter Soil Mixing (CSM) method and removal of the wood debris prior to starting CSM installation. The owner recognized two important aspects of the alternate proposal. First, the proposed CSM equipment has the ability to provide real time control and monitoring of the location of the cutter head in the ground. This information provides a documented assurance that panel overlap is maintained so that when excavation begins, the continuity of the water cutoff is a known, not just a hoped for outcome. Second, CJA's proposal was predicated on pre-trenching using cement-bentonite slurry methods to remove the wood debris along the alignment in advance of the CSM installation. In addition to removing debris which could compromise the integrity of the future shoring system, the pre-trenching process allowed CJA to provide a fixed price and schedule for dealing with the wood debris while the other proposers left the owner holding the bag for cost and schedule impacts associated with dealing with these obstructions.

In the fall of 2006, CJA was awarded the contract for a shoring and cutoff wall using CSM technology. During the course of the next eight months, the project team met several times a month to refine the shoring design and integrate the dewatering, underpinning, deep foundations, and permanent tiedowns into the final building design. This process included several meetings with both Washington DOT and the Seattle DOT to insure that their concerns about the safety of the adjacent Alaskan Way Viaduct, buried utilities, and adjacent roadways were addressed through the many phases of shoring and dewatering construction. This level of involvement and planning prior to con-

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struction was essential to successfully introducing slurry wall methods for pre-trenching and CSM technology to Seattle, and insuring a timely review and approval of the construction plans.

By the time planning was completed and construction started in late summer 2007, the project scope and sequence included the following:

- 8 drilled shafts reinforced with steel beams to support an historic façade
- permanent micropiles to underpin the existing 83 King Street building
- 24 drilled shafts to support a small portion of the building which did not have below grade parking
- Pre-trenching and pre-drilling 860 lineal feet of alignment to a depth of 30 feet under cement-bentonite slurry to remove wood debris and obstructions for the subsequent CSM installation
- 48,000 square feet of CSM wall for water cutoff and excavation support
- 8 shallow unwatering wells to remove the water inside the cutoff
- 3 deep dewatering wells to depressurize the lower aquifer
- 450 tiebacks to provide lateral support to the CSM wall
- 360 permanent tiedowns to resist water uplift in the final building

Pre-trenching was selected to remove wood and uncontrolled fill from the CSM wall alignment to prevent delays to the CSM installation associated with obstructions and to prevent the wood debris from compromising the strength, continuity, and integrity of the future soil-cement shoring material. For the portions of CSM wall located just two feet from the existing 83 King Street Building, it was physically impossible to use an excavator for pre-trenching so it was necessary to use pre-drilling to remove the near surface wood obstructions. Pre-trenching was performed with a Hitachi ZX 800 excavator (Figure 3) capable of excavating a 3 feet trench to a depth of 30 feet. Cement-bentonite slurry was pumped into the trench to replace material being removed and to stabilize the walls of the excavation. The decision to use pre-trenching was vindicated by the fact that the fill material removed was almost entirely slab wood, mill ends, bark, sawdust, and timber piles up to 25 feet in length (Figure 4).

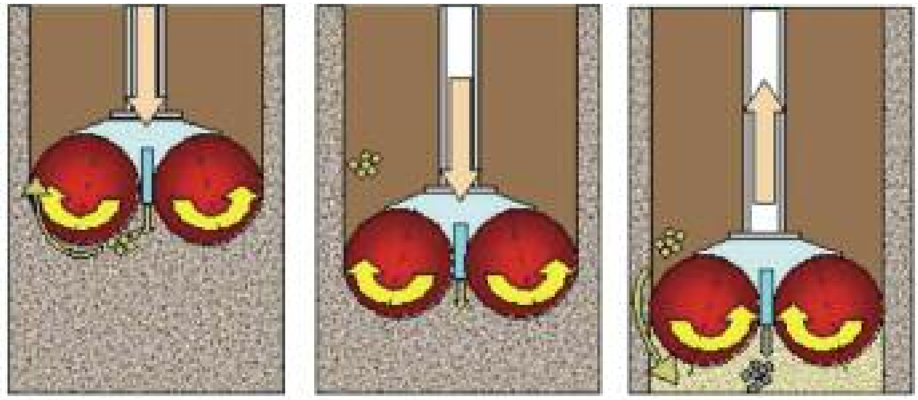

Figure 5 – Cutter Soil Mixing (CSM) Process.

Cutter Soil Mixing (CSM)

The CSM technology was initially developed in Europe by a joint venture of Soletanche and Bauer* and recently emerged in the United States as an economical method of deep soil mixing. In essence, the CSM is the marriage of soil mixing technology with hydrofraise equipment. While the CSM cuts down into the soil, slurry is injected and mixed with the native soil to create a soil-cement mixture. The CSM construction process for shoring applications consists of the following steps (Figure 5):

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- The cutter head penetrates and processes the soil while injecting bentonite, water, or cement grout to fluidify the soil.
- Upon reaching the specified depth, the cutter head is withdrawn while cement grout is injected and mixed with the processed soil to create a soil-cement.
- The steel reinforcing, e.g. wide flange beams, is installed.

Figure 6 – CSM: A marriage of soil mixing technology with hydro-fraise equipment.

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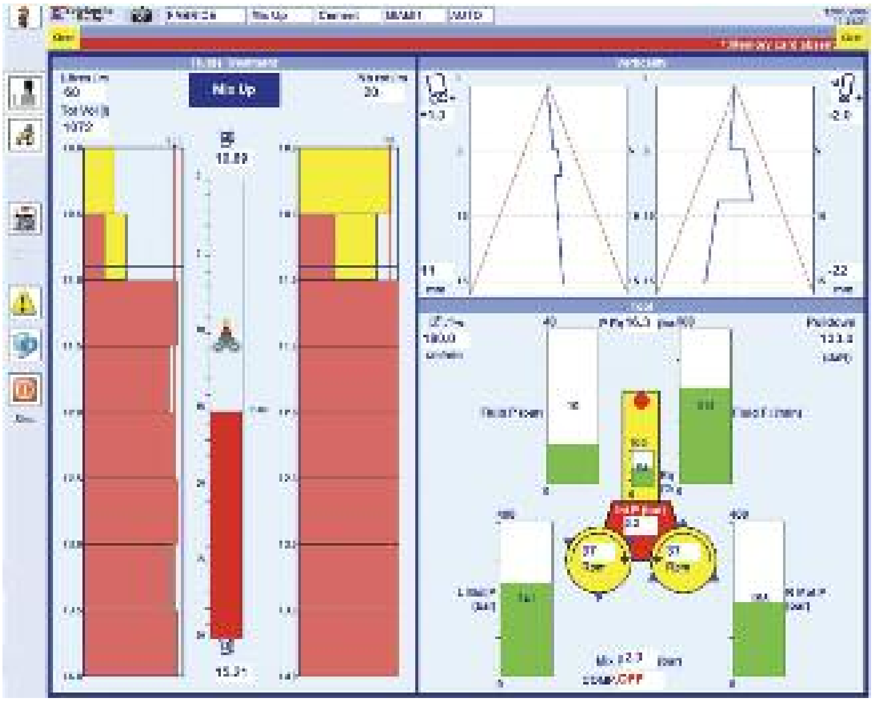

Figure 7 – CSM operator's in cab control and monitoring system for soil mixing.

The CSM cutter head and its kelly bar were manufactured by Soletanche and mounted on an ABI Mobilram TM 18/22*. The cutter head used on this project creates a 2.6 feet x 9.2 feet rectangular panel, which is a more efficient shape than the traditional circular hole used to drill secant piles as each stroke of the CSM creates a panel equivalent to 3 to 4 piles. The cutter head contains four wheels mounted on two drums with motors that have bidirectional rotation around a horizontal axis (Figure 6). The two motors operate independently and have variable speeds that enable the cutter to maintain left/right alignment during penetration and allow compensation when encountering non-uniform material within a panel. Initial panel alignment was insured with the use of shallow concrete guide walls (Figure 9). Spoils were handled with a mini-excavator, stockpiled with a loader, and hauled off-site routinely. The guide walls also provided support for beam installations. Beams were set into the wet soil-cement with an ABI Mobilram TM 16/20*.

Data acquisition and display measures are at the forefront of the industry. Depth, inclination, individual wheel speeds, crowd force, fluid pressures, volumes,

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densities and flow rates are all displayed in real time on a monitor in the cab for immediate modifications by the operator to ensure the highest level of accuracy in the industry to date (Figure 7).

While the soldier beam inserted into the wet soil mix material and the tiebacks are sized based on conventional design, the compressive strength of the soil-cement material is determined by analyzing the soil-cement between the soldier beams as essentially water proof lagging. The earth and water pressures acting on the shoring wall are transferred by the soil-cement to the soldier beams. For this project, the soil-cement had a minimum compressive strength of 200 psi, which included a healthy factor of safety. The CSM wall consisted of 108 contiguous panels installed around the 860 feet excavation perimeter to a maximum depth of 68 feet. Three levels of tiebacks were installed as

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Figure 8 – Completed excavation and tiedown installation prior to placement of mat foundation

Figure 9 – Guide walls for initial alignment.

the site was excavated. Since the CSM soil-cement is serving as the water proof lagging in this system, the face of the soil-cement is trimmed back during mass excavation but no timber lagging is required.

Tiebacks

Three levels of tiebacks, totaling 450, were installed using Klemm 806-3* hydraulic rotary drills through prefabricated pockets in the soldier beams.

The end product (Figure 8) was a stable excavation supporting an adjacent eight story building with no observable draw down in the upper aquifer and without any impacts to the Alaskan Way Viaduct.

Tieback installation was typical of the Seattle waterfront with the presence of wood, old foundations, dense till, sand outwashes, boulders, and timber piles. In addition to the obstructions encountered, drilling was made more difficult by a water head of up to 28 feet behind the CSM shoring. Cased hole drilling combined with sealing of the annulus of the casing were required to prevent significant ground loss during drilling. Once the multi-strand tiebacks were installed, an expanding bulkhead was installed in each pocket to seal against the ground water pressure and allow post grouting directly behind the CSM wall. In order to provide a 10-ft buffer between the anchor bond zones and the piles supporting the Alaskan Way Viaduct as required by Washington DOT, several temporary wales and tiebacks with lengths up to 135 feet were utilized.

Summary

Utilizing an innovative combination of tried and true slurry trench excavation methods, state of the art CSM equipment, and the know how to bring all the various pieces of the dewatering, underpinning, soil-mixing, and shoring together, CJA was able to construct a difficult water cutoff and excavation support system ahead of schedule with no major complications. The end product (Figure 8) was a stable excavation supporting an adjacent eight story building with no observable draw down in the upper aquifer and without any impacts to the Alaskan Way Viaduct.

**Indicates ADSC member company.*■

Project Team

Project Owner:	Starbucks, Inc.
Owners Representative:	Seneca Real Estate Group, Inc. Robert H. Wicklein, P.E. Laura Lohman
General Contractor:	Lease Crutcher Lewis Jim Lorenz, Project Manager Mark Portin, Project Superintendent Mike McCausland, Project Engineer
Structural Engineer:	Coughlin Porter Lundeen Steven Savage, P.E., S.E., Senior Associate Michael Armstrong, P.E., Project Manager
Geotechnical Engineer:	Hart Crowser Gary Horvitz, P.E., Senior Principal Ben Upsall, P.E., Project Manager
Shoring Contractor:	Condon-Johnson & Associates, Inc* Rowly Stow, Project Manager David Giwosky, Project Engineer Bob Hinthorn, Superintendent Jamie Renalde, CSM Superintendent
Shoring Designer:	Ground Support PLLC John Byrne, P.E.
Tiedown Supplier:	Williams Form Engineering* Tom Reed
Tieback Supplier:	Con-Tech Systems Ltd.* Horst Aschenbroich

**Indicates ADSC Member Companies.*