14 Aug 2008, 7:00 pm - 8:30 pm

Excavation Support for the Newseum Development at 555 Pennsylvania Avenue in Washington DC, USA

Victor Omelchenko
Schnabel Engineering, Gaithersburg, Maryland-USA 20878

Mamoud Hosseini
Clark Foundations, LLC., Bethesda, Maryland, USA 20814

6th International Conference on
Case Histories in Geotechnical Engineering, Arlington, VA, August 11-16, 2008

EXCAVATION SUPPORT FOR THE NEWSEUM DEVELOPMENT AT 555 PENNSYLVANIA AVENUE IN WASHINGTON, DC, USA

Victor Omelchenko, P.E.
Senior Principal
Schnabel Engineering
Gaithersburg, Maryland-USA 20878

Mamoud Hosseini, P.E.
President
Clark Foundations/Civil, LLC.
Bethesda, Maryland-USA 20814

ABSTRACT

The Newseum consists of a 650,000 square-foot development that includes a six-level, 215,000 square-foot interactive museum of news. Also included is office space for the Newseum and Freedom Forum staff, a 9,000 square-foot conference center, more than 30,000 square feet of retail space and approximately 100 condominiums. The Newseum is located on Pennsylvania Avenue, between the U.S. Capital and the White House next to the Washington, D.C. mall and its museums and monuments. The building is supported on a mat foundation. The project is located just north of the Old Tiber Creek that was filled in the early 1800's. Soft and compressible soils are present in the area that are prone to settlement from dewatering. These soils have also been associated with large movements of conventional H-pile and wood lagging excavation support systems and other problems in the past. Therefore, various "cut-off" walls were considered for excavation support that would not allow ground water levels around the building excavation to drop and would be less prone to soil erosion through wood lagging boards. Various cut-off walls were considered including a slurry wall, soil-mix wall, secant pile wall and Pile-in-Self-Hardening-Grout (PSHG) wall. A PSHG wall was selected for three sides of the excavation. The PSHG wall was constructed by inserting pre-fabricated panels consisting of steel H-piles and wood lagging into pre-excavated trenches using clamshell equipment normally used for slurry wall construction. A low strength self-hardening grout was used within the excavations to keep the sidewalls from caving, which hardened to strength of about 60 to 70 psi within a few days after installation of panels. The PSHG wall resulted in a relatively impermeable cutoff wall around three sides of the excavation. A secant pile wall was constructed at the east end of the excavation adjacent to the Canadian Embassy. The Canadian Embassy is founded on a mat foundation supported on relativity soft and compressible terrace age clay soils. A secant pile wall was selected adjacent to the Canadian Embassy to reduce the risk of settlement of the existing mat foundation. Ground water observation wells were monitored during construction to confirm that excessive ground water lowering below the Canadian Embassy mat did not occur. In addition, inclinometers and settlement points were monitored to measure movements of the Canadian Embassy, the secant pile wall, and PSHG wall. Both PSHG and secant pile walls were supported with tiebacks and both systems performed well within specified tolerances.

DESCRIPTION OF SITE AND PROPOSED CONSTRUCTION

The project site is located at 555 Pennsylvania Avenue in Northwest, Washington DC. The site location is presented on the Vicinity Map, (see fig. 1). The site is located north of Pennsylvania Avenue, south of C Street, east of 6th Street, and west of the existing Canadian Embassy. Prior to construction, the site was an asphalt-paved parking lot. Existing surface grades at the site varied from about El 11 in the southwest corner to about El 15 in the northeast. The Canadian Embassy was located to the east and adjacent to the site. The Canadian Embassy was supported on a mat foundation. The sub-grade for the Embassy mat foundation is at about El-16.

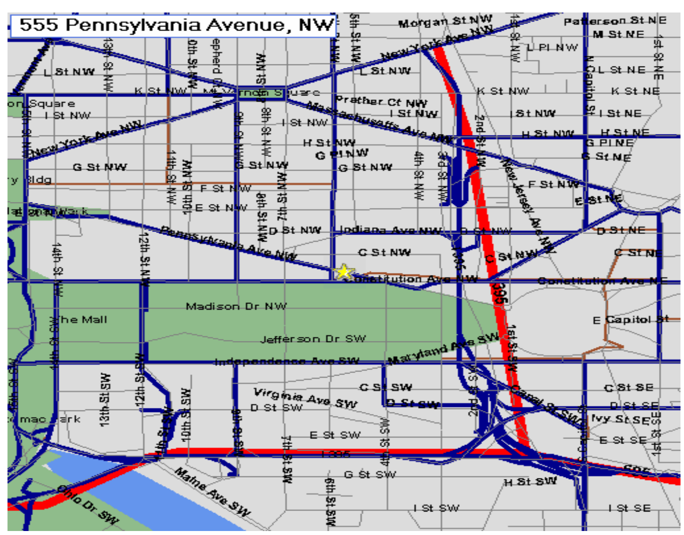

Fig. 1. Site vicinity map

The Newseum footprint covered the majority of the site within the property lines and has a lowest floor level at about El-28 and a sub-grade elevation at El-36. The building has eight stories with exhibit space and two levels of below-grade parking. The building consists of concrete construction with post-tensioned slabs and beams. Maximum column loads varied from about 3000 to 6000 kips.

SUBSURFACE CONDITIONS

Sixteen soil tests borings were drilled on the site by Schnabel Engineering in 2003. Soil borings indicated that the upper three to nine feet at the site consisted of loose to compact silty sand and sandy silt fill, with organics, bricks and asphalt. The existing fill was underlain by 38 to 48 feet of terrace age lean clay and sandy silt soils. These soils were very soft with Standard Penetration Test (SPT) values of 1 to 4 in the upper portion of this stratum. These soft terrace soils were associated with the Old Tiber Creek that was located south of the site and was filled in the early 1800's.

The terrace soils were underlain by very stiff fat clay soils and very compact clayey sandy soils. These soils extended to depths of 70 to 119 feet below original surface grades. These soils were part of the Potomac Group which were deposited during the Cretaceous Age. The Potomac group soils are the oldest sedimentary deposits in the Washington, DC area and are known to be preconsolidated to pressures of 4 tsf to 10 tsf in excess of existing overburden pressures.

Potomac Group soils were underlain by very compact Disintegrated Rock that was defined as residual material with SPT values of at least 60. The Disintegrated Rock material extended to a depth of about 140 feet below the site where bedrock was encountered. Bedrock generally consisted of highly fractured and moderately weathered Wissahickon Schist.

BUILDING FOUNDATION

Both spread footing and mat foundations were considered for support of the new building. Deep foundations were not considered necessary because soft, upper terrace age soils would be excavated prior to reaching the lowest basement floor elevation of El-28. Recommended soil bearing pressures varied from 4000 psf to 8000 psf, depending on the column load. Soil bearing pressures were set based on the criteria that foundation settlements would not exceed ¾ inch. Due to the large footing sizes, it was decided to support the building on a mat foundation.

EXCAVATION SUPPORT

The basement excavation extended between 46 feet to 51 feet below existing grades and about 31 feet below the level of the ground water table. Other projects in the area along Pennsylvania Avenue experienced problems with temporary excavation support systems due to the very soft terrace age soils in the upper 38 to 48 feet. Some of the problems consisted of portions of temporary excavation support systems that collapsed during construction, loss of soils that eroded through gaps in wood lagging boards, large lateral movements of excavation support systems and large settlements of adjacent buildings, streets and utilities. Also, the terrace soils were known to be difficult to dewater. Due to these problems, it was felt that significant risk would be associated with a conventional H-pile and wood lagging excavation support system. Therefore, only continuous excavation support systems that would result in a water-tight excavation that would not allow a significant lowering of the groundwater table were considered. Also, a stiffer water-tight barrier system was considered necessary for excavation support at the east end of the excavation to limit settlement and movement of the Canadian Embassy's mat foundation to less than 1/2 inch.

Various barrier-type excavation support systems considered were inter-locking steel sheet piles, slurry walls, tangent pile walls and deep soil mix walls. Inter-locking steel sheet piles were not considered feasible due to the large vibrations that would occur during driving of piles. Slurry walls were considered feasible and would result in the most watertight excavation support system; however, slurry walls were expected to be the most expensive excavation support system. Tangent pile walls consisting of interlocking drilled shafts or caissons were expected to be feasible and to be less expensive than a slurry wall; however, tangent pile walls would have more risk of water leakage than slurry walls. Deep soil mix walls constructed by mixing on-site soils with cement grout to produce a cementaceous material with a strength of about 50 psi to 70 psi were also considered feasible. Deep soil mix walls were expected to be less expensive than slurry walls, but would have more risk of water leakage.

The project was bid with a performance specification for the excavation support system. Specifications required that all four sides of the excavation be supported using a watertight barrier system that would consist of a slurry wall, tangent pile wall or soil mix wall. If a slurry wall or a tangent pile wall were used for support of the east face of the excavation adjacent to the Canadian Embassy, steel H-Piles within the walls would need to support the west end of the Canadian Embassy's mat foundation due to concerns about excessive movements of the Canadian Embassy due to the new construction. Specifications also allowed contractors to submit proposals for alternate excavation support systems.

Contractors were required to install two dewatering wells adjacent to the Canadian Embassy to verify that only a minimal drop in the ground water table occurred during construction. Two inclinometers were also to be installed adjacent to the excavation support system at the east excavation face to verify that lateral movements adjacent to the Canadian Embassy were acceptable. Monitoring points were also placed on all four sides of the excavation as well as on the existing Canadian Embassy to monitor both vertical and horizontal movements of the excavation support system and the Canadian Embassy.

Specification required that horizontal movements be limited to 3/4 inch and that vertical settlements be limited to 1/2 inch.

SELECTION OF A PSHG WALL AS AN EXCAVATION SUPPORT ALTERNATIVE

Before construction work began at the Newseum jobsite, Carr America Development, Inc. enlisted the services of Schnabel Engineering North, LLC to analyze the existing soil conditions and to recommend the type of excavation support system that should be utilized. After studying the site conditions Schnabel recommended the use of either a soil-mix wall or a slurry wall for the support of excavation. Based on the report and cost analysis the owner had specified a soil-mix wall as the type of support of excavation system to be employed.

The foundation structure of the previous buildings that occupied the site consisted of concrete pile caps with steel cased concrete Raymond Step Taper piles (see fig. 2). Clark Foundations was concerned with the constructability, cost and performance of the specified soil-mix wall as the equipment involved with the soil-mixing operations would not be able to go through the existing foundations if encountered. Therefore additional costs and time would be entailed in the removal of such obstructions. Clark Foundations looked for other innovative methods of providing a watertight and rigid system. The substitution of a reinforced slurry wall in lieu of the soil-mix wall was cost prohibitive due to the additional cost of concrete placed under tremie.

Fig. 2. Existing foundation system with Raymond Step Taper Piles

Clark being familiar with cement-bentonite cut-off walls and slurry wall procedures, proposed the construction of a PSHG wall, in lieu of a soil-mix wall. The evolution of the PSHG wall design came from the fact that a typical cement-bentonite slurry would not have provided enough strength to allow for a timely excavation At the same time, a slurry mix was required that would not set too fast so that it would allow for construction of adjacent panels. These requirements were achieved by a slurry mixture composed of clay (Attapulgite), Newcem cement, and water. This slurry is referred to as Self-Hardening Grout. The mix was designed and tested for both strength and permeability prior to construction by Liquid Earth Support, Inc.

The PSHG wall construction consisted of trenching 32 inch wide by 22 feet long by 59 feet deep panels under self-hardening slurry. Once the excavation for the panel was completed, a 60 feet deep prefabricated soldier beam and lagging panel was placed in the slurry. With this method of construction, if Raymond Step Taper piles were encountered they could be removed by trenching along the sides of the pile, making space to grab the pile with the clam bucket and pulling the pile over and out of the excavation (see fig 3.).

Fig. 3. Raymond Step Taper Piles removed with clam bucket.

PSHG SYSTEM AND CONSTRUCTION PROCEDURES

The Piles in Self Hardening Grout support wall is a hybrid sheeting system combining slurry wall excavation operation with soldier beams and wood lagging. This is a temporary shoring support system that greatly reduces groundwater inflow.

In lieu of excavating a panel under slurry and displacing the slurry with tremie concrete and a reinforcing steel cage, the slurry is self hardening. The soldier beams and lagging are prefabricated as a panel and placed in the liquid slurry. The soldier beams were pre-fabricated with reservations for future tiebacks, and paired together with wood lagging to make a panel (see fig. 4). Each panel once assembled weighed eleven tons. Conventional waterproofing was later applied to the face of the lagging, prior to the construction of the building foundation wall.

Equipment required in the mobilization of the PSHG wall operation was as follows:

a) A cement silo for bulk storage of Newcem cement.

b) A 4 cubic yard blender used to batch the self hardening grout.

c) Temporary storage tank for self hardening grout.

d) Two crawler cranes were mobilized. One 100 ton crane was used for the clamming operation while another 75 ton service crane was used for setting of the pre-fabricated soldier beams with wood lagging panels (see figs. 5 and 6).

e) Two 800mm wide clamming buckets (one used as a backup).

f) A front end loader to transport spoils from the trenching operations to the glory hole.

Fig. 4. Panel fabrication

The following procedure was used in the construction of the PSHG wall:

a) 15 feet deep by 5 feet wide pre-excavation was performed along the alignment of the PSHG wall to remove the shallow underground obstructions, including the gravity stone walls and the footings of the existing buildings.

b) A steel template was set in place to guide the clam bucket.

c) Trenching for the 32 inches wide by 59 feet deep panels under self-hardening grout was performed using a clam bucket, attached free hanging, to a 100 ton Link-Belt crawler crane. Since the majority of the panels were 22 feet wide, three sub-sections of steel H-pile and wood lagging were required for the construction of each panel.

d) The excavated materials (spoils) from the trenching operation were temporary stored on site in a pre-excavated glory hole, for off site disposal by the excavator at periodic intervals.

e) Once the panel excavation was completed, the reinforcing panel, which consisted of prefabricated soldier beams and lagging, was lowered into the self-hardening grout with a 75 ton Link-belt crawler service crane.

f) In order avoid communication of open excavated panels a sequence was planned to allow each "primary" panel to cure for seven days before the "secondary" panels were trenched. The secondary panels were installed in such a way that it bit 12" into the sides of the primary panels to ensure a water tight system.

g) Upon completion of all panels, excavation from within the PSHG walls began. As the excavation proceeded to sub-grade and the wall was exposed, the 7-foot gap between the embedded soldier beams in adjacent panels were lagged to sub-grade.

Fig. 5. Clamming operation for PSHG wall.

Fig. 6. Setting of Prefabricated Panel.

PSHG DESIGN CONSIDERATIONS

The soldier beam and lagging members are considered the main components of the support system. They transfer the lateral load from the soil, surcharge, and hydrostatic pressure to the external bracing system. The self-hardening grout is utilized to support the excavation during trenching and acts as a continuous filler to transfer the lateral load to the lagging. In addition, the self hardening grout acts as an impermeable barrier to make the PSHG wall watertight. The design of the soldier beam and lagging system is similar to the design of a conventional system with the following considerations:

a) The soldier beams were designed to resist hydrostatic pressure. The pressure diagram for a more rigid secant wall system was used for the design of the soldier beams in the PSHG wall.

b) Panel lengths were 22 feet long to minimize ground movements during panel excavation. To maintain the continuity between panels, the primary and secondary panels overlapped one another by 12 inches and ensured a watertight system.

c) The self-hardening grout's moisture needed to be maintained so that the grout would not crack and allow seepage of water. The moisture was maintained by the wood lagging between the soldier beams. Therefore, it was very important to install lagging in between the adjacent panel soldier beams immediately after excavations were made.

d) The lagging was designed to transfer the lateral load to the soldier beam because the grout was not designed with sufficient strength to transfer any load in bending. The PSHG panel's soldier beams were extended approximately 8 feet below sub-grade, while the wood lagging stopped at sub-grade.

e) Grout tubes were installed at the interface between the secant wall shoring system, used along the Canadian Embassy, and the PSHG wall to allow for grouting in case of groundwater leakage at these two system interfaces.

f) The quality of the self hardening grout, such as density and the viscosity, were checked on a continual basis. The weight of the self-hardening grout varied between 68 and 69 lbs per cubic foot, and its viscosity was maintained between 32-36 Marsh Seconds in the holding tank and 34-50 Marsh Seconds in the panel.

PERFORMANCE OF THE PSHG WALL SYSTEM AND SECANT PILE WALL

The use of the PSHG wall was a success in this application as it provided a watertight system and limited its movement within the acceptable limits. The permeability of the grout was less than 10^{-6} feet/sec. after 30 days of curing and the long term permeability ranged 10^{-7} and 10^{-8} feet/sec. Some desiccation of the grout wall occurred above the groundwater table due to anticipated loss of moisture. No sumping, except for rain water, was required within the excavation and the excavation within the PSHG wall was performed in the dry. The PSHG wall provided a rigid system as designed and the total horizontal movement was limited to less than 7/16" which was within the acceptable limit of 3/4" tolerance specified in the contract documents. No discernable movement of adjacent structures or settlement in the streets occurred as a result of construction.

At the east face of the excavation along the Canadian Embassy a secant pile wall system was utilized because of the concerns about excessive movement due to the new construction. The design specification required that the horizontal movements be limited to 3/4 inch and the vertical settlements be limited to 1/2 inch. Even though the PSHG wall is a rigid shoring system a secant wall system was chosen because it would have greater rigidity and there would be less chance of ground loss underneath the Canadian Embassy during the installation process. The horizontal movement at the Canadian Embassy was limited to less than 1/4 inch and the vertical movement was limited to less than 1/8 inch of settlement, which were well within the specified tolerances.

To avoid softening and disturbance to the foundation bearing soils the water table within the building excavation needed to be lowered at least 3 feet below the deepest foundation. If adequate construction dewatering was not performed, the foundation sub-grade soils would tend to soften making it necessary to perform extensive undercutting of soft soils. A series of fourteen interior deep wells were installed by Moretrench of America, within the perimeter of the PSHG wall to lower the water table and minimize any water infiltration from a lower water bearing aquifer that could be present. There was concern that the interior dewatering would lower the water table underneath the Canadian Embassy enough to cause settlement of the Canadian Embassy's mat foundation. During the construction piezometers were installed to measure the ground water levels underneath the embassy. Schnabel Engineering was retained to evaluate the dewatering operation. During the construction the groundwater table underneath the embassy lowered from El. -10 to El. -25 but returned back to its original level once the deep well pumps were turned off and decommissioned permanently. No significant settlement of the Canadian Embassy was observed due to this temporary water table reduction.

CONCLUSIONS

A Pile in Self Hardening Grout (PSHG) temporary excavation support system was successfully used at the Newseum Development as a value engineering substiution of a soil-mix wall system. A secant pile wall system was utilized for the east face of the excavation adjacent to the existing Canadian Embassy due to concerns about ground loss beneath the Canadian Embassy. The PSHG wall and secant pile wall systems were able to successfully reduce the quantity of groundwater inflow in the excavation and were rigid enough such that horizontal and vertical movements of the excavation support system and Canadian Embassy were within specified project criteria.

REFERENCES

Sylvester, Alan and Hosseini, Mamoud (1998). Design and Construction of an Earth Retaining Structure Using a Pile in Self Hardening Grout (PSHG) Wall. Deep Foundation Institute Conference in Toronto, Canada.