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## **‘O’ Street Anchored Precast Lagging and Soldier Pile Retaining Wall**

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## **ABSTRACT**

Significant movement to an existing slurry wall on 'O' Street in Southeast Washington, D.C. initiated the Department of Public Works for the District of Columbia to invite specialty contractors to propose a rehabilitation and stabilization for the failed slurry wall. Nicholson Construction Company proposed and was awarded a contract for the construction of an anchored precast lagging and soldier pile wall approximately 4 feet in front of the existing structure. Stabilization of the existing slurry wall also included drilling horizontal weep holes and demolishing the failed panels down to the existing ground surface. A new and improved drainage system was also constructed to increase the amount of water directed toward the existing storm sewer system running along 'O' Street. This paper provides a detailed account of these construction activities.

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## **INTRODUCTION**

In the Winter of 1995 significant movements were noted along a 150-foot section of the approximate 1100 foot long anchored slurry wall in the 3200 block of 'O' Street in Southeast Washington, D.C. These creep deformations continued with the maximum deflection being 13 feet at the conclusion of the failure investigation.

A geotechnical assessment of the wall determined that the global failure was caused by three contributing factors: 1. Improper drainage from behind the wall is believed to be the major cause of the stability failure due to the additional hydrostatic pressure acting on the slurry wall 2. Zones of highly plastic slickensided clay 3. Lack of corrosion protection on the initial thread bars used as tieback supports. Conclusions of the study suggested that while each defect in the wall is believed to be a contributing factor in the failure, the combination of all three factors acting simultaneously probably initiated the global failure.

Several of the property owners expressed a need for the rehabilitation and restabilization of the existing slurry wall. In July of 2000 the District of Columbia, Department of Public Works invited contractors to propose a design/build procedure for stabilizing the existing slurry wall.

Nicholson Construction Company (NCC) proposed to build an anchored precast lagging and soldier pile wall located approximately 4 feet in front of the existing retaining wall. Toe lengths for the soldier piles as well as the bond lengths of the ground anchors were designed to go below the slickensided clay.

However, before constructing the new wall the existing slurry wall and surrounding structures with in the failure area needed to be stabilized. Part of a foundation for one of the residences above the wall was underpinned to assure stability. Several failed slurry panels along with a condemned garage adjacent to the wall were demolished. Horizontal drains were then installed into the existing slurry wall to relieve the hydrostatic pressures. A cantilever retaining wall was also constructed after the completion of the anchored precast lagging wall to connect the remaining slurry wall panels after demolition.

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## **LOCAL GEOLOGY**

Southeastern Washington, D.C. is located on the western shore uplands region of the coastal plain province. Overburden consisting of unconsolidated sediments of gravel, sand, silt and clay exists over undifferentiated crystalline rock. This layer of overburden begins near the center of

the District of Columbia and increases with the gradual negative grade of the crystalline rock toward the East.

A probable depositional history of the site consists of a sequence of glaciofluvial to fluvial sediments consisting of silt and clay, which were deposited in primarily calm environments. Sporadic sand lenses can be attributed to small meandering channels related to glaciofluvial outwash.

Numerous geotechnical investigations have been completed with in the natural hillslope of the construction site. Overall results conclude two general soil profiles at the site. One of the sections could be generalized towards the western portion of the site and will be referred to as Section 1. Section 1 contains fill behind the wall just below the ground surface followed by a stratum of silty clay that can also be found on the downhill side of the slurry wall. This layer of silty clay contains preexisting slickened surfaces in the upper strata and gradually becomes denser with depth. Sporadic sandy silt lenses are also common in the silty clay stratum.

The second section is located near the eastern portion of the job site and is referred to as Section 2. This profile is very similar to the first cross section except for the fact that it contains a more distinct sandy silt material approximately 10 to 20 feet thick located between the upper fill and hard silty clay strata.

The water table throughout the job site is found to vary considerably. This can be attributed to the glaciofluvial processes retaining the water above deposited clay layers after the local water table has dropped.

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## **HISTORY OF SITE DEVELOPMENT**

'O' Street was constructed in the 1950's, which cut into the natural slope that ran from Highwood Drive to a drainage creek near 'O' Street. The creek followed the general layout of 'O' Street draining the local area of groundwater and surface runoff. This creek was redirected and filled in prior to road construction, thus permanently affecting the drainage of the surrounding area.

Residential development on Highwood Drive began in the 1940's with the majority of the residences on the street being constructed in the 1940's and 50's. Backyards for the residences on the South side of Highwood Drive terminated at 'O' Street.

Slope instabilities were noted throughout residential development in the surrounding areas after the construction of 'O' Street. Residential development on 'O' Street began soon after the road was completed in the late 1950's with property along the North side of 'O' Street beginning to be sold by the homeowners on Highwood Drive.

In the late 1970's the District of Columbia decided that permanent stabilization of the slope was required due to the continuous slope movements toward 'O' Street. In 1978 an anchored slurry wall was constructed between 'O' Street and Highwood Drive to retain the earth from further movements. A new drainage system was also installed both above and below the slurry wall to aid in redirecting the groundwater and surface runoff from the surrounding area.

The anchored slurry wall consisted of fifty, 22-foot wide reinforced concrete panels designed to be embedded into a hard clay stratum. Tiebacks, consisting of threaded bar, were installed through the slurry wall and designed to be socketed into the hard clay. During construction the bearing plates to the ground anchors were visually showing failure after they were stressed. Eventually the initial bearing plates were replaced with larger ones soon after construction. Corrosion protection was also applied to the anchor heads after they were installed and stressed.

In the winter of 1995 excessive ground movements were noted in approximately 150 feet of the slurry wall. Ground movements were recorded on this particular section of the wall and continued until the spring of 1996 when eventually this section failed. Maximum deflections in the order of 13 feet downslope were recorded. Through time the ground anchors became overloaded and failed causing a global stability failure with a distinct slide plane reaching completely under the toe of the slurry wall.



After the failure an extensive investigation was done to determine the cause of the global failure in this particular area. The forensic study determined the events that lead to the eventual failure of the section of slurry wall was first attributed to improper drainage from behind the wall, which increased the earth pressures acting on the wall. In turn this increase in earth pressure overloaded the tiebacks, failing in part due to the lack of sufficient corrosion protection around the ground anchors. Finally, subsurface investigations concluded that the toe of the slurry wall was actually embedded in a stratum of slickensided clay, which created a less resistant path for the failure plane.

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## **PRECONSTRUCTION DOCUMENTATION AND STABILIZATION**

### *Preconstruction Survey*

Prior to construction activities a report was prepared which defined the current conditions of the residences. The report was supplemented by pictures and videotape and paid specific attention to structural and aesthetic damage with documentation describing these flaws. Residences on Highwood Drive, Carpenter Avenue and 'O' Street were included in the report, which totaled twenty-six residences that surrounded the construction site.

### *Underpinning of #3253 Highwood Drive*

Differential settlement took place on the Southeast wing of #3253 Highwood Drive when the global failure occurred. Underpinning was performed using jacked in 3-inch Magnum Piers in order to close the crack widths that were a result of the global failure and also provided for future support.

The shallow footings were excavated and brackets were bolted flush with the face of the foundation wall. Hydraulic jacks were then attached to these brackets and used to push the 3-inch diameter, 3-foot long pipe sections through the overburden. A total of seven piles were installed with depths ranging from 8 to 24 feet below the bracket. Upon completion of the underpinning operations the piles were backfilled up to existing grade. Anchor drilling operations caused the load in the piles to be transferred back into the shallow foundation causing the Southeast wing to settle again. After anchor drilling was completed the footings were exposed again and the piles re-jacked. The footing was then undermined in sections and grouted underneath to assure proper load transition between the piles and footing.

### *Demolition of Condemned Garage at #3309 Highwood Drive*

Due to the global failure the garage at #3309 Highwood Drive, which fit flush against the slurry wall, experienced extreme differential settlements. Representatives from the District of Columbia declared the garage to be unstable. For safety reasons the garage was taken down prior to wall construction. This procedure used an excavator positioned on top of the slope. It demolished the

garage and pushed the debris down the failed slope topography in order for the material to be disposed of when the failed panels were removed.

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## SOIL AND EROSION CONTROL

Supersilt fence consisting of chain link fencing wrapped with a geotextile fabric on the uphill side was installed along 'O' Street near the West side of the job site and continued to the back of the residences on the eastern end. Both construction entrances were lined with the durable silt fence in order to reduce the amount of erosion from sheet flow due to heavy rains. Sediment from surface runoff was also prevented from entering the inlets on site by wrapping filter fabric over the covers and surrounding the inlets with hay bales.

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## BENCH CONSTRUCTION

### *Clearing and Grubbing*

Two entrances were constructed to offer two way access from 'O' Street. Topsoil was removed from these areas as well as a 30-foot wide zone for the length of the existing slurry wall. Topsoil in front of the existing wall was removed for the placement of a workbench used to install the anchored precast lagging wall.

### *Bench Installation*

Two gradations of recycled concrete, RC6 and RC4, and geotextile fabric were used to install a stabilized workbench for the construction site. Geotextile was laid down on natural ground approximately 1-foot below the proposed elevation of the workbench. RC6 material, which has a maximum particle size of 6 inches, was placed on top of the fabric at the construction entrances and along the bench. RC4 was used to cap the RC6 material in order to obtain a relatively smooth surface due to the smaller particle sizes found in the RC4 material.

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## STABILIZATION OF EXISTING SLURRY WALL

### *Demolition of Failed Slurry Wall Panels*

Approximately 50 feet of the failed slurry wall was demolished down to the ground line behind the wall using a hydraulic ram attached to the bucket of an excavator. Once the tops of these panels were removed the excessive lean and tension cracks in the panels was more visually noticeable and caused concern in tying the existing slurry wall together using a cast in place cantilever retaining wall. Due to the excessive lean an additional 100 feet of failed slurry wall was demolished down to the ground line in order to obtain an aesthetically pleasing connection for the cantilever retaining wall.



### *Weephole Installation*

Installing approximately nine weepholes on the downhill face of each panel relieved hydrostatic pressures built up behind the existing slurry wall. Each weephole consisted of a 1.5-inch diameter well screen approximately 5 feet long with a filter fabric sock, which covered the full length of the pipe to prevent any loss of ground from occurring behind the wall. These holes were

drilled through the existing slurry wall, which averages about 3 feet in thickness using an Ingersoll-Rand Hydraulic Crawler Drill and continued approximately 2 feet into the soil in order to promote a proper drainage path.

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## **TEST ANCHOR PROGRAM**

Geotechnical investigations of the site concluded silty clay and slickensided clay with sporadic sand lenses with in the toe area of the existing slurry wall. Below these stratum hard clay was found approximately 30 feet below the workbench.

The main objective of the test anchor program was to obtain adequate strength versus deflection results with in the hard clay stratum in conjunction with a productive drill method for the installation of anchors. The size of casing, drilling procedure, and post drilling operations needed to be determined based on a series of varying test anchors.

Four, six strand test anchors were initially installed altering drilling techniques and casing size. Results showed excessive deflections without obtaining the required design strengths. Installation procedures were reviewed with the probable cause for error being due to the introduction of water into the drill hole during drilling operations. This caused pour grout to soil strengths as well as pour anchor to grout strengths.

Four additional six strand anchors were drilled using the duplex drilling method without water in order to minimize contact between the corrugation and soil. Duplex drilling consists of casing the entire length of the hole, advancing the casing and rods simultaneously in order to minimize any loss of ground caused by the manmade void. Drill cuttings are removed from the hole using high-pressure air, which is released from the tip of the drill bit thus forcing the drill cuttings up from between the casing and drill rods.

Once the drill rods have been removed from the hole the anchor is installed with spacers placed in the bond zone in 5-foot increments in order to center the anchor in the hole. Grout is then pumped into the hole via tremie then the casing is removed in segments while topping off the hole with grout after each segment is removed. Post grout tubes were also installed along the length of the additional anchors with rubber sleeves covering holes with in the bond zone. After the initial grout has hardened, these sleeves are opened using high-pressure grout into the bond zone creating irregular shapes aiding in the bond strength of the anchor. Results of the additional six strand anchors showed adequate strength versus deflection for the larger casing size in addition to post grouting the anchor.

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## **WALL CONSTRUCTION**

### *Drilled Shaft Installation*

A rubber tire mounted drill rig with a 36-inch auger attached to a Kelly bar was used to drill the holes for the soldier piles. To reduce risk of any slurry wall movement some shafts were skipped and then drilled on another shift. Drilled shaft locations were laid out by surveyors and rechecked by field personnel using three predetermined points from the wall verifying the center of each hole.

Varying geological conditions varied the techniques used to maintain the circumference and depths of these holes. Open hole drilling was used on the western portion of the wall because of the clay soil encountered with little to no ground water. These conditions promoted very little loss of ground with in the drilled shafts.

Perched water tables on the eastern side of the construction site caused saturated sandy silt seams to develop in the upper 30 feet of each hole. A couple of techniques were utilized to try and remedy these problematic conditions. Casing approximately 36 inches in diameter was placed in the upper portion of the hole in order to eliminate any loss of ground. The beam was then placed in the drilled shaft and concrete was poured to the bottom of the casing. After the concrete had cured overnight the casing was filled with concrete and then removed using a Mantis crane. This particular method was found to cause



problems when setting the beams at their designed locations. Proper placement of the soldier beam was found to be very difficult once the lower portion of the beam was fixed.

An alternative to casing was to drill a 42-inch diameter hole approximately 5 feet past the running sands and then fill the hole with a low strength lean mix concrete. Lean mix concrete would then be redrilled the following day using a 36-inch auger. The lean concrete would then stabilize the upper portions of the hole and the lower portions would be self-supportive due to the hard clay consistency of the soil. Longer cure times on the lean concrete prompted a rock auger to be used when drill times began to exceed anticipated durations. This problem caused the field crew to reduce the amount of drilled shafts being opened and filled with lean mix each day. This particular method was found to be time consuming but more practical than casing. The lean concrete was used for drilled shaft stabilization throughout the eastern part of the wall.

Slurry wall panels were monitored with a total station approximately every ten minutes during drilled shaft installation by shooting prisms mounted to the slurry wall. Readings continued on the wall every half an hour until the soldier piles were placed in the drilled shafts and filled with structural concrete.

#### *Beam Installation*

Templates were made that would support the beams in the drilled shafts prior to the initial set of the structural concrete. Two templates were fabricated to span approximately 32 feet long with the cross section in the shape of an 'L' in order to keep the beam plumb. These two templates were used in new areas of the wall because they provided support without the help of previously set beams. The tops of the beams would also be cabled down to the template to avoid any side movements during concrete placement.

Two other templates were also fabricated with lengths of 32 feet but without the 'L' shaped cross section. These were used to attach to previously set beams for support while plumbing new beams. A 10-foot by 5-foot template was also made in order to install single beams whose orientation was not dependent on others. The front face of the template held the location of the beam while the top of the beam was tied down to the existing beams on either side with cables.

These templates were set using three predetermined distances from the wall for each beam representing the location for the front face of the soldier beam. Once the template was placed directly in line with the front face of the wall the beams were installed using a Mantis crane that would lower them into the drilled shaft. Each beam was then verified to be plumb and distances to previously set beams were checked in order to confirm each location for future precast lagging and waler installation.

134 beams were placed with the majority of them spaced approximately 8 feet apart. Structural concrete with a compressive strength of 3500 psi was placed in each drilled shaft to set the soldier pile. Seven of the beams had inclinometer casing set on the back flange of the beam in order to monitor wall movement after construction. The seven beams were placed in areas of design sections.

*Beam Touch-up Procedures*

Coating was applied to the exposed length of the soldier beam including 3 feet into the structural concrete. The first two coats were done to prevent corrosion. 4 mils of Carbozinc 859, an epoxy primer and 6 mils of Carboguard 890 were placed on the entire cross section of the beam. A polyurethane coating, Carbothane 133 HB, was put on the front face of the soldier beam in a thickness of 4 mils in order to protect the epoxy from damage caused by the sun.

Throughout bay preparation great detail was spent on repairing any damage caused to the three-coat paint system that was shop applied to the soldier piles. Each exposed portion of the beam was examined in the field for scratches that penetrated the coating system. If a scratch was shown to go through all three coats the area was sanded or wire wheeled until steel was showing. The edges of the damaged area were then feathered in order to remove the unbonded paint debris.

Mineral spirits were then wiped over the sanded area to remove any debris prior to touching up the coating. A mixture of one part Carbomastic 15 Part A (Alum C901) was then mixed with one part Carbomastic 15 Part B (0908). The two parts were individually mixed prior to blending them together. A second coat of this same mixture was then applied the following day after verifying that the first coat had dried.

Six parts of Carbothane 133 HB Part A (Grey C703) was then mixed with one part Urethane Converter 133 (0909) and then applied only to the front face of the beam in areas where the existing coating had been damaged.

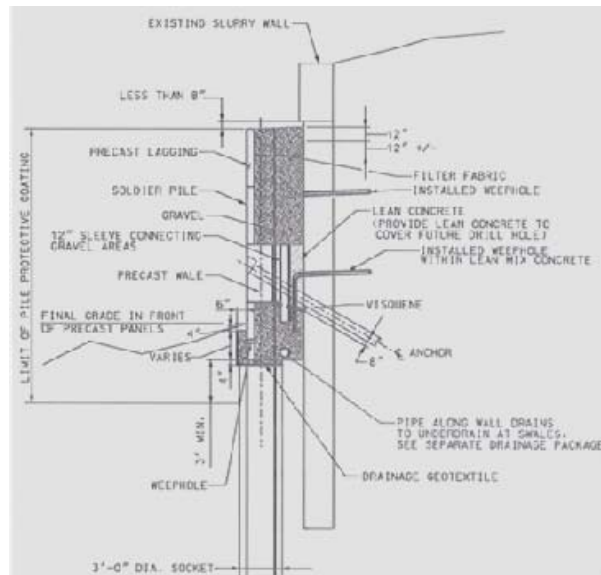
If the scratch was not found to expose steel the area was simply wiped with mineral spirits and two coats of the Carbomastic 15 mixture were applied.

*Bay Preparation*

Structural concrete for each drilled shaft was set to approximately the same elevation as required for the bottom precast concrete panel. Each predetermined elevation for the top of concrete was surveyed in using traverse points and a laser level. Bays were corrected for elevation by either chipping concrete away if too high or applying nonshrink leveling grout if determined to be too low.

Soil was excavated in each bay to approximately 8 inches below the desired bottom precast elevation. Filter fabric was then placed in the bay and around the surrounding soldier piles with cut pieces designed to overlap a distance of 18 inches. Approximately 12 inches of filter fabric was extended past the face of the wall.

To promote a drainage path for water to flow between the new and existing slurry wall a 4-foot wide prefabricated drainage composite was placed between each bay and extended 1-foot out from the face of the new wall. Gravel was



then placed on top of the prefabricated drainage composite with the extra filter fabric wrapped over the gravel and tucked behind the face of the wall. The bottom precast concrete panel was then set on top of this piece of filter fabric using a crane and wedged into place with wood braced against the back flange of the soldier beam. Additional gravel was then placed behind the panel and the existing slurry wall. All panels, with the exception of the top panel, were cool gray with a split slate texture.

#### *Waler Installation*

Prior to setting the 4-foot high by 2-foot wide plain smooth concrete waler, existing anchor locations on the slurry wall were compared to proposed anchors through the new wall. If any of the new anchors were expected to hit an existing anchor bearing plate the waler would be slid to one side if clearance of the bearing plate could be accomplished. As a last resort a portion of the bearing plate would be burned off to clear the way for the path of the new ground anchor. To help prevent new anchors from interfering with one another the right trumpet was set in the precast waler at 30 degrees while the left trumpet was set at 27 degrees. Walers were then set into their respective bays using a Mantis crane. Nonshrink grout was poured in the voids between the soldier pile and waler.



12-inch PVC sleeves were set into the gravel backfill behind the walers approximately 4 feet on center. This was done to connect the two gravel layers above and below the waler concrete. Plastic was then laid on top of the bottom gravel layer approximately 6 inches below the bottom of the waler. Concrete with a compressive strength of 3500 psi was then placed between the waler and existing slurry wall flush with the top of the waler using a bucket or a concrete pump. This was done to reduce deflection in the new wall during anchor stressing operations by transferring some of the load in the new wall to the existing slurry wall and ground.

#### *Ground Anchor Drilling and Installation*

Duplex drilling with high-pressure air was used for the majority of the western half of the wall. Anchor productivity was low due to the amount of time required to run casing the length of the hole. Alternative drilling methods were reviewed in order to increase anchor production.

Drills were set up to external flush with air and water using drop off bits. These techniques were found to be unsatisfactory because drill cuttings were not getting removed from the hole due to a loss of pressure. Air and water were found to be escaping through the more permeable soil layers during drilling operations.



Field personnel noted that the saturated clay and sand lenses were typically located within the top 50 feet of the anchor hole and suggested shortening the amount of casing installed. Drilling operations began to run casing for the first 30 to 50 feet of the hole and then drill the remaining

length with an open hole. Great care was taken to clean out the hole prior to anchor installation. PVC centralizers, 5 inches in diameter, were used to keep the corrugation from dragging through the soil and to concentrate the anchor in the center of the hole when installed. These centralizers were placed in 5-foot increments throughout the bond zone.

Results showed clean holes with good air return when casing went beyond the problem zone. A total of 262 anchors were installed with the majority drilled with open holes and surface casing. Three to six strand anchors were installed with all anchors having a free length of 55 feet. Surface casing was longer on the eastern side of the site because of the deeper saturated sandy silt found below the wall.

4000 psi grout mix was used for anchor installation. Approximately twenty-five bags per hole were used to grout each anchor. Individual anchors were post grouted with approximately six bags per tube. Post grouting ceased after operations went out of the failed portion of the wall. Ground anchors out of the failed zone were only post grouted when the stressing criteria were not met.

#### *Stressing Procedures for the Tiebacks*

Initially an alignment load of approximately 10% of the design load was placed on the anchor in order to hold the jack assembly in place. A dial gauge was then placed against the pulling head of the anchor with the other end fixed to an independent reference frame that did not move during stress intervals. The alignment of this dial gauge was in line with the direction of the anchor. A separate dial gauge measured the movement of the wall in the horizontal direction during anchor stressing. Wall movement was measured throughout the failed portion of the existing slurry wall and discontinued when stressing operations moved out of the failure area, due to minor amounts of wall movement.

Each anchor was tested and accepted according to the Post-Tensioning Institute, "Recommendations for Prestressed Rock and Soil Anchors" (1996). Two anchors were performance tested in the beginning along with 2% of the remaining anchors. Procedures for the performance test consisted of cyclic stress intervals, recording the movements of the anchor and wall at each interval in order to calculate the permanent set of the anchor.

Proof tests were performed on the remaining anchors. This test simply increased the load incrementally to 133% of the design load and held it there for ten minutes. After the anchor test was accepted the anchor was locked off at the required design load and an initial lift off test performed.

#### *Secondary Grouting and Closure Panel Installation*

Anchor tails from stressing were removed once the anchor data was proved to conform to the stressing criteria. Approximately two bags of grout were then placed in each anchor head to flush any remaining water existing in the hole. This was done to prevent any water from coming in contact with the anchor in the future. If particular anchors were found to be seeping water they were pressure grouted to remove the excess water and seal the anchor head with grout.

A 2-inch thick closure panel, approximately 2 feet high by 5 feet long, was placed over the two anchors in the recessed portion of the waler. The closure panel was cool gray with a split slate texture and temporarily braced from the front while grout was pumped from holes placed on top of the waler. Once the grout cured the closure panel was held in place by a metal loop previously precast into the panel and grouted in during closure panel installation.

#### *Upper Panel Installation*

Additional panels were placed on top of the enclosed water excluding the final panel in each bay. The upper precast panels were installed with gravel using the same procedures as the bottom precast panels.

#### *Beam Cutoff*

A needle scaler was used to remove a 2-inch wide strip around the beam to reduce the amount of paint fumes created during beam cutoff. Magnetic templates were made to hold the correct elevation for beam cut off while a torch was used to cut through the steel beam. Manlifts were used to reach the top of each beam.

Exposed steel was then ground down with a disc sander with particular care taken in feathering the paint edges to remove any loose coating material. Beams were then touched up with the same field coating procedures with a final polyurethane coat applied to the tops of the beams.

#### *Top Panel Installation*

Top panels, consisting of plain smooth concrete, were set flush with the cut off beam and wedged into place with wood. A geotextile was then placed with in the top 2 feet of the gravel backfill between the panels and existing slurry wall to reduce contamination of the fill. The fabric ran up the sides of the panels and slurry wall approximately 1-foot on either side. Gravel backfill was then placed flush to the top of the final precast panel.

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## **CAST IN PLACE CONCRETE CONSTRUCTION**

#### *Stubwall Construction and Backfill Operations*

The two existing slurry wall panels where demolition stopped were sawcut vertically through the existing concrete cap to get a flush tie in with the proposed cantilever retaining wall. Approximately 20 feet of the already demolished panels had additional demolition done in order to reduce the overturning moment on the failed panel and to also give a 2-foot clearance for the footing of the retaining wall. 2 feet of clearance was needed to reduce the variation in bearing material underneath the cantilever retaining wall. Therefore, with the additional demolition there was approximately 1 to 2 feet of gravel fill under the entire length of the wall footing.



Natural grade in the failure area was cut into slightly in order to account for the dimensions of the cantilever retaining wall. The existing subgrade was compacted to 95% of ASTM D698. Geotextile was then placed on top of the existing grade followed by gravel backfill up to the required footing elevation for the cantilever wall.

Forms were set to adhere to the specified footing and keyway dimensions of the wall. The footing was poured in two phases with a construction joint being placed at a designed step in the footing. Forms were stripped the following day and wet burlap was placed over the footing for seven days in order to maintain ideal curing conditions for the concrete.

While the footing was curing forms for the wall sections were being placed. The retaining wall was split up into six sections with the initial pour containing three alternating sections and the next pour finishing the remaining three. Two Expansion joints were installed approximately 90 feet apart. Construction joints were intermittently set in between the expansion joints approximately

every 30 feet. Once each phase of the wall pour was complete wet burlap was placed over the wall for seven days of curing.

Upon completion of the concrete placement the area behind the stubwall was backfilled and regraded in 6-inch lifts of on site material consisting of primarily silty clay and recycled concrete. Each lift was compacted according to ASTM D698. Drainage coming from the existing houses was diverted through 4-inch corrugated pipe that led to an inlet directing the flow through the gravel backfill behind the precast lagging wall.

#### *Closure Wall Construction and Fencing*

Two end walls were constructed to tie into the anchored precast lagging wall to the existing slurry wall. The walls were cast in place reinforced concrete with reinforcing bar tying into the existing slurry wall. Each wall was approximately 15 feet high with the bottom bearing onto existing ground.

Upon completion of the cast in place concrete chain link fence was installed on top of these structures. Fencing with gate access for the stub wall connected the existing fence along the existing slurry wall panels. The closure walls had new fencing put on them that connected to the slurry wall fence. A gate was also installed in the existing chain link fence near the eastern end of the wall in order to gain access to the inclinometers in that area.

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## **DRAINAGE CONSTRUCTION**

#### *Wall Drain Installation*

Water from in between the existing slurry wall and the new precast wall had to be diverted once it went through the gravel backfill. A wall drain was installed approximately 18 inches in front of the existing precast lagging wall. Excavation for the drain occurred directly in front of the wrapped filter fabric set prior to precast panel installation. Care was taken to not rip the filter fabric so the gravel backfill would not be contaminated with soil or perhaps even unravel from underneath the water panel.

Wall drain consisting of 8-inch corrugated pipe rested in a gravel trench wrapped in filter fabric fabric. The trench was dug at or below the elevation of the wrapped filter fabric that lead from underneath the precast lagging wall. Cleanouts were positioned at the beginning of each run and tied into additional 8-inch corrugated pipe running downhill of the wall, which also connected the existing underdrains located on the site.

#### *Drainage Work for Surface Flow*

Prior to construction four concrete swales collected the surface water from the site and directed the water to inlets near the curblin of 'O' Street. Underneath each swale was a 15-inch reinforced concrete pipe. The 15-inch pipe collected surface water through a series of pipes and inlets both above and below the slurry wall as well as groundwater leading from underdrains running laterally in front of the slurry wall.

Surface flow above the new wall drains to existing inlets located in line with the preexisting concrete swales below the retaining wall. The inlets then lead to 8-inch corrugated pipe that runs through the gravel backfill between the two walls leading to inlets located directly in front of the new wall. Inlets in front of the new wall were either reused or replaced depending on the existing inlet conditions found during construction. Water is then diverted into new 15-inch corrugated pipe that follows the locations of the existing swales and ties into existing manholes. Water flowing along the surface in front of the wall is collected in grasslined ditches, which lead to inlets or runs to cast in place concrete ditches that run laterally across the site and tie into one concrete swale.

#### *Underdrain Inspections and Installations*

All existing underdrains were inspected to verify proper drainage for groundwater downhill of the precast lagging retaining wall. These underdrains tie into new 8-inch reinforced corrugated pipe, located underneath the new 15-inch corrugated pipe, running downhill to existing manholes near the curb line along 'O' Street.

Numerous new french drains were installed to increase the probability of intersecting the groundwater seepage running from underneath the precast lagging retaining wall. A french drain was placed underneath the entire length of the lateral concrete ditch that runs across the majority of the site behind the residences and into a concrete swale. Underdrains were also installed along the curb of 'O' Street and running downhill in between residences. These French drains were placed on average 5 feet below the ground surface with in gravel backfill wrapped in filter fabric.

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## **FINAL GRADING**

Enormous amounts of fill material were present on site near the end of construction due to excavation of the drilled shafts, ground anchors, and the drainage network. The existing bench also included trucked in recycled concrete. Together these quantities amounted to approximately 4000 cubic yards.

An alternative solution to trucking this material off site was proposed to the District of Columbia and local residents of the community. The grading proposal incorporated building up the existing grade in the backyard of the residences and developing the empty lots on the West End of the job site for residential construction. Additional fill material in front of the wall would also aid in the stability of the new retaining wall and give the residents an exceptional view of downtown Washington. The benefits helped the existing on site material to be regraded into a buttress along the curb of the vacant lots and an elevated bench behind the residences of 'O' Street. All of the preexisting concrete swales and 18 inch reinforce concrete pipe were removed from the site during drainage construction.

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## **REFERENCES**

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