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DESIGN AND CONSTRUCTION OF ANCHORED FLEXIBLE FACING EXCAVATION SUPPORT AND SOLDIER PILE WALL

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ABSTRACT

After Hurricane Ivan made landfall in 2005, the Florida Department of Transportation required the replacement of two new high level multi-span bridges that carry Interstate I-10 across the Escambia Bay in Pensacola, Florida, USA. The project required widening an area under the existing pile-supported Scenic Highway abutments with limited headroom of approximately 15 feet. The Department required cutting back the concrete-faced slope pavement below the existing bridge abutment and installing a finished vertical wall facing that consisted of precast concrete panels rendering a look of a conventional Mechanical Stabilized Earth (MSE) wall. In order to gain space for the installation of the finished facing, it was necessary to perform a vertical cut at a location offset from the proposed finished wall face line. This 18-foot high temporary cut required excavation support, which was provided using an anchored flexible-facing wall. The facing consisted of welded wire mesh/geotextile combined with special mechanical plate anchors. The flexible facing for the temporary excavation support was utilized instead of a conventional soil nailed wall with reinforced shotcrete facing. A long-term tieback anchored soldier pile and lagging wall was installed in front of the temporary excavation support at a later time. Flowable fill was placed between the two walls before stressing and locking the long-term tieback anchors. The finished wall facing consisting of precast concrete panels that were attached to the steel soldier piles with specially designed connections.

This paper presents the design approaches and construction of the temporary excavation support, and the long-term soldier pile and lagging wall with tieback anchors and precast concrete panels. Utilization of flexible facing elements to temporarily support and stabilized the vertical cut face was discussed. Advantages and disadvantages, and performance are also presented.

INTRODUCTION

Soil nails are commonly used for temporary and long-term excavation support, as well as slope stabilization. A typical soil nail wall is composed of soil nails spaced at about 4 to 6 feet on centers, and a reinforced shotcrete facing that prevents raveling of the soils from the excavation face and transfers the anchorage soil nail load to the ground.

The soil nails are typically threaded steel bars grouted inside a drilled hole with a top anchorage plate embedded or placed against the shotcrete facing. Soil nails are passive anchors, which are typically grouted along their entire length. Therefore, usually they are not post-tensioned.

The conventional shotcrete facing typically ranges between 4 and 6 inches thick for temporary support applications and is reinforced with one layer of wire mesh. When necessary, pairs of reinforcing bars, or waler bars, extend from the anchorage plate of each nail to provide additional flexural capacity to the shotcrete.

Limited drainage of the retained soils is typically provided using geocomposite drainage strips installed vertically between the shotcrete and the soil, which are connected to suitable drainage grates near the bottom of the wall that allow drainage to the outside. It is important to note that shotcrete facings for temporary support applications protect the excavated soil face from raveling and deterioration, and also have a limited structural contribution to the wall performance. In the view of the authors, this structural contribution consists of transferring anchorage compression stresses from the soil nail anchorage plate to the retained soils, limiting horizontal deformations of the soil mass through its flexural capacity and stiffness, and limiting vertical deformations of the excavated face through its axial stiffness.

In some cases, it is possible to use flexible facing instead of shotcrete. Flexible facing commonly consists of a combination of steel wire mesh and geotextile fabric (GEOBRUGG, 2006). The flexible facing may induce larger deformations of the excavated face; however, in cases where larger deformation is not a critical issue, it may provide substantial savings in construction costs and scheduling.

This paper describes the application of a flexible-facing soil nail wall on Interstate Highway I-10 across the Escambia Bay in Pensacola, Florida, USA, which was completed in 2007. In this project, post-tensioned plate anchors instead of typical grouted soil nails to accelerate the construction schedule. The paper discusses the performance, advantages, and limitations of the anchored flexible-facing wall and the soldier pile and lagging wall.

PROJECT BACKGROUND

On September 16, 2004, Hurricane Ivan made landfall near the Florida Panhandle causing the partial collapse of the twin I-10 bridges connecting Escambia and Santa Rosa Counties. The Florida Department of Transportation (FDOT) was charged with three primary tasks: making temporary emergency repairs to the existing bridges so traffic flow could resume, the construction of two new bridges and opening the new eastbound bridge to traffic within one year.

The Design/Build partnership of Tidewater Skanska/Parsons Brinckerhoff was selected as the prime Contractor/Consultant for the bridge replacement project. In 2005, soon after the project was awarded and construction began, the Design/Build team had fallen behind schedule because of Tropical Storm Arlene and Hurricane Dennis. The Design/Build team came up with some innovative solutions to make up the schedule delays. One solution was to put both directions of traffic on the eastbound bridge as soon as it was completed so that simultaneous demolition of the two existing bridges could take place. Therefore, the eastbound bridge had to be widened to accommodate both directions of traffic. This required cutting the existing slope below the south abutment of Scenic Highway (See Photo 1).

Photo 1: South Abutment of Scenic Highway

The bridge carrying Scenic Highway over I-10 has a typical abutment consisting of 18-inch square pre-stressed concrete piles with a rectangular cap and backwall. The FDOT required maintaining lateral support for the abutment as well as maintaining the existing soil bearing pressure under the approach slab. Any problems encountered during construction around the abutment could have resulted in shutting down traffic on Scenic Avenue which was unacceptable.

The geotechnical engineer of the Design/Build team, Schnabel Engineering, Inc., proposed a two phase construction approach for the project. A vertical cut was performed on the slope, which was offset from the proposed long-term finished wall face. The temporary vertical cut was supported with mechanical anchors and flexible facing, which allowed significant time savings with respect to installation of grouted soil nails and shotcrete. Once the vertical cut was completed, the final facing was installed. The final facing consisted of an anchored soldier pile and lagging wall. Flowable fill was placed between the temporary flexible-facing wall, and the soldier pile and lagging wall before stressing and locking the long-term tieback anchors. The finished wall facing consisted of precast concrete panels attached to the steel soldier piles with specially designed connections.

SUBSURFACE CONDITIONS

The insitu soils consisted of loose to medium dense, poorly graded fine sand with a Standard Penetration Testing (SPT) N-value ranging from 4 to 12 within soil layers above the bottom of the vertical cut. The underlying soil to about 20 feet below bottom of the excavation consisted of medium dense to dense, poorly graded fine sand with the N-value ranging from 21 to 38. The groundwater level was at approximately 10 to 15 feet below bottom of the excavation. A typical soil gradation distribution of the poorly graded sand is shown in Fig. 1.

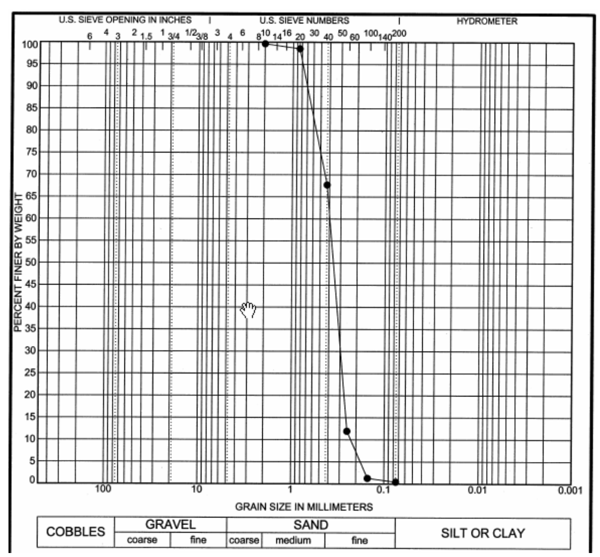

Fig. 1: Typical Gradation of the Retained Soils

DESIGN OF TEMPORARY EXCAVATION SUPPORT

Mechanical plate anchors, manufactured by Foresight Products, LLC (Manta Ray, Type MR-1 anchor), were driven horizontally to approximately 20 to 25 feet behind the face of vertical cut. While applying post-tension on the mechanical plate anchor, the bearing plate at the tip of the anchor turns 90-degree and engages the anchor resistance by mobilizing the passive resistance against the plate.

The design anchor lengths were determined by the following steps and criteria:

- Conservatively define the soil anchors spacing with a 4-foot by 4-foot grid pattern, which is commonly the minimum spacing for conventional grouted soil nails.

- Determine the holding capacity of the mechanical plate anchor depending upon the soil type and consistency, and define it as the anchor lock-off load. This requirement is different from the conventional soil nails that commonly required only hand tightening the nails.

- Perform an internal stability analysis to achieve a minimum factor of safety greater than 1.25 and determine the location critical slip surface passing between the anchors.

- Perform an internal stability analysis, with the anchor lock-off load acting at the tip of the anchor, to result in a critical slip surface passing between the anchors. The required minimum factor of safety is 1.25.

- Adjust the anchor lengths to extend a minimum of 6 feet beyond the critical slip surface defined in the previous step. Check the plate at the tip of the anchor that could mobilize sufficient resistance within area behind the critical slip surface.

- Perform a global slope stability analysis to confirm if the factor of safety of the critical slip surface passing beyond the soil anchors is greater than 1.25.

- A 2-foot by 4-foot and ¾-inch thick steel anchorage plate was designed to provide better anchor load distribution and a greater coverage to hold the steel wire mesh in tight contact with the retained earth. The punching shear resistance of the wire mesh along the perimeter of the steel anchorage plate was checked.

The final design consisted of:

- Four levels of Manta Ray anchors at a spacing of 4 feet in both vertical and horizontal directions. The anchors had lengths ranging from 20 to 25 feet and were driven into the cut face horizontally. The design anchor lock-off load is 15 kips.

- A medium grade non-woven geotextile fabric covered by 4x4 W2.9x2.9 welded wire meshes.

The flexible facing, consisting of geotextile fabric and wire mesh, supports the excavated face between the anchorage plates, and protects the face against erosion (See Photo 2). A preliminary study presented by GEOBRUGG (2006) indicates that the facial restraint contributes significantly in preventing relatively shallow instabilities. Practically, the flexible facing elements should be capable of prevent the cut face from progressive sloughing and washout of fines, and are not critical in governing the global and internal stability of the system.

Photo 2: Flexible Facing of Temporary Excavation Support

The computer software, SLOPE/W, developed by Geo-Slope International in Calgary, Alberta, Canada, was used to evaluate the internal and global stability of the temporary excavation support system.

DESIGN OF LONG-TERM WALL AND FINISHED FACING

The long-term anchored tieback soldier piles could not be installed within the area of limited headroom under the existing bridge with the concrete-faced slope in place. As a result, the long-term wall was designed and constructed practically independently in front of the temporary flexible-facing wall.

The final exterior of the retaining wall consisted of precast concrete panels that were attached to the soldier piles by steel strips with bolt connections. Design requirements and components of the long-term retaining wall system are:

- Soldier piles (HP 12x53, Grade 50) installed in predrilled boreholes (see Photo 3). Due to the limited headroom in the existing bridge abutment area, the soldier piles were spliced by using manufactured H-pile splicers that provided full flexural strength of the H-piles (FHWA 1989).

Photo 3: Soldier Pile Wall with Tieback Anchors

- Conservative design of the long-term soldier pile wall without considering the existence of the temporary anchored flexible-facing wall left in place. Each tieback anchor consisted of two 0.6-inch diameter, Grade 270 strands, with bond and unbonded lengths ranging from 22 to 24 feet and 9 to 11 feet, respectively. The design anchor loads range from 40 to 56 kips. The strand anchors were pre-installed at the same time when the temporary flexible facing wall was excavated in stage.

  Design of the soldier pile wall and tieback anchors followed the guidelines of FWWA (1999) and assisted by using computer software, SHORING, developed by CivilTech Software in Bellevue, WA, USA.

- Corrosion protection that was provided based upon a moderate corrosive environment defined by the FDOT. Two coats of galvanized paint were specified to all exterior metal components of the tieback anchor heads including the stiffener plates. Coal Tar Epoxy was applied to the local areas of the H piles where the precast concrete facing is connected. The purpose of the epoxy is to isolate the precast concrete panel galvanized attachment hardware from the H-piles. The H-piles were also sized slightly larger to provide an additional amount of sacrificial thickness.

- Flowable fill that was placed between the temporary excavation support and the soldier pile wall to ease the backfill compaction requirements in tight space. It also provided a base of reaction for post-tensioning the soldier pile tieback anchors. Since the ground water condition is not critical. The space between the soldier pile wall and the precast concrete panel facing was also filled with flowable fill (See Photo 4).

Photo 4: Panel Wall Construction

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- Left-in-place treated timber lagging, with a nominal thickness of 3-inch, that was encased within the flowable fill.

- The finished wall facing, consisted of precast concrete panels, was attached to the steel soldier piles with specially designed connections. The finished wall renders a look of a conventional Mechanical Stabilized Earth (MSE) wall (See Photo 5).

Photo 5: Final Finished Wall

CONSTRUCTION PERFORMANCE

Potential interference of the existing bridge abutment piles had to be addressed during the installation of the temporary mechanical plate anchors and the long-term tieback anchors. Field verification of the as-built pile locations resulted in some final adjustments of the spacing of mechanical anchors and flexible facing anchorage plates.

The poorly graded cohesionless soils to be retained by the anchored flexible-facing wall posed a significant challenge for design and construction. The main difficulty resides in maintaining stable cuts during each lift of the excavation before facing placement. The mechanical plate anchor was locked off shortly after the anchor was driven to the designed depth and the installation of geotextile fabric and wire mesh. Comparing to the conventional shotcrete facing installation, such an approach significantly shortened the exposed time of unsupported cuts.

The performance of the flexible facing throughout construction was as expected. Minor sloughing along the cut face occurred, particularly prior to placing the geotextile fabric and the welded wire mesh. Occasionally the nearby construction activities, such as vibration caused by pile driving operations, also caused minor surface sloughing.

During installation of the soldier pile tieback anchors, the contractor was able to install the strand anchors in uncased auger boreholes. The uncased borehole stability might be attributed to apparent cohesion of the moist poorly graded sand. Utilization of excavatable flowable fill in spaces behind the finished precast panels expedited the backfill operations. It also eliminated the difficulties associated with placement and compaction of soil backfill between the temporary excavation face and the permanent face.

CONCLUSIONS AND RECOMMENDATIONS

This project was a successful application of a flexible facing anchored wall. The design of the wall was relatively simple and it simplicity allowed significant savings in costs and schedule. We offer the following conclusions and recommendations based on the observed performance of this system:

1. Although flexible facing walls are preferably used for support of cohesive soils, they may also be used in poorly graded cohesionless soil. The application of driven mechanical plate anchors allows quick installation of the facing and aids in reducing the exposure time of the face of each excavation lift.

2. The anchored flexible facing prevents sloughing and washout of fines, and the anchor spacing and length are governed by global and internal stability of the wall.

3. In cases for stabilizing and supporting vertical or near vertical cuts, the flexible facing should only be utilized for temporary condition rather than a long term application.

4. It is important that a sufficiently steel anchorage plate be used for achieving the necessary bearing capacity against the cut face, and to improve the mechanical connection with the wire mesh.

5. The type of flexible facing described in this paper should not generally be used when or where significant seepage is expected through the facing, when or where weather is expected to produce significant surface runoff and erosion over the facing, or where saturation of the soils behind the facing can occur. In these instances, the use of flexible facing may require implementation of additional water control and face stabilization measures.

ACKNOWLEDGEMENT

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