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UNDERPINNING ATLANTA INTERNATIONAL AIRPORT CONCOURSE E FOR APM TUNNEL EXPANSION

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Hartsfield-Jackson Atlanta International Airport underwent a $1.2 billion dollar expansion project centered on the construction of the new Maynard H. Jackson International Terminal. Passenger access between the new International Terminal and the domestic airport facilities is primarily via underground Automated People Mover (APM) trains. Prior to this expansion, the APM tunnel terminated beneath Concourse E, which previously served all international flights. The new International Terminal is located approximately ½-mile from the previous terminus of the APM tunnel.

A paper describing the general approach to excavation support for construction of the entire APM tunnel extension from under Concourse E to the new International Terminal was published by two of the authors (Hurley and NeSmith, 2014). One of the features of note of the approach involved the intersection of the proposed new alignment of the APM tunnel extension under Concourse E with the old terminus. Specifically, the new tunnel extension conflicted with the location of the existing Auger Pressure Grouted (APG) piles supporting four columns in Concourse E. This paper presents design and installation details of the micropile underpinning approach used to support the existing columns to allow for the proposed excavation including the cutting and removal of the existing APG piles, while allowing Concourse E to remain in service during construction.

PROJECT DETAILS

General

The construction of the APM extension required an excavation support system for a 450-ft long, 55-ft deep excavation across Taxiway Dixie and a 900-ft long, 30-ft deep excavation beneath the basement of existing Concourse E. The excavation under Concourse E required both excavation support and support of the existing columns over the proposed excavation zone. A general overview of the work area is shown on Figure 1.

Support of Taxiway Dixie

While excavating across the taxiway, construction time was critical because the extension of the APM tunnel required the temporary closure of Taxiway Dixie, adding almost 13 minutes to every arriving and departing international flight. The scope of support required for the excavation is shown in Figure 2. A soldier pile and lagging wall with tiebacks was planned to support this portion of the excavation. Approximately 100 soldier piles and over 200 tiebacks were installed in the wall under the taxiway. More than half the soldier piles were battered which was an alternate approach from the original design. Further details of this aspect of the project are presented in Hurley and NeSmith (2014).

Excavation Below Concourse E

The challenges of excavating underneath Concourse E included the exposure and underpinning of much of the existing deep foundations. The original structure support consisted of Auger Pressure Grouted (APG) Piles that were installed in the early 1990's.

The work was performed in low-headroom conditions with limited access below Concourse E, which remained in service during the project. Planned bottom-of-excavation was about 35-ft below the concourse basement slab (55-ft below the apron level). Movements of existing structures were specified not to exceed 1/4-in. An overview of the excavation support requirements is shown on Figure 3.

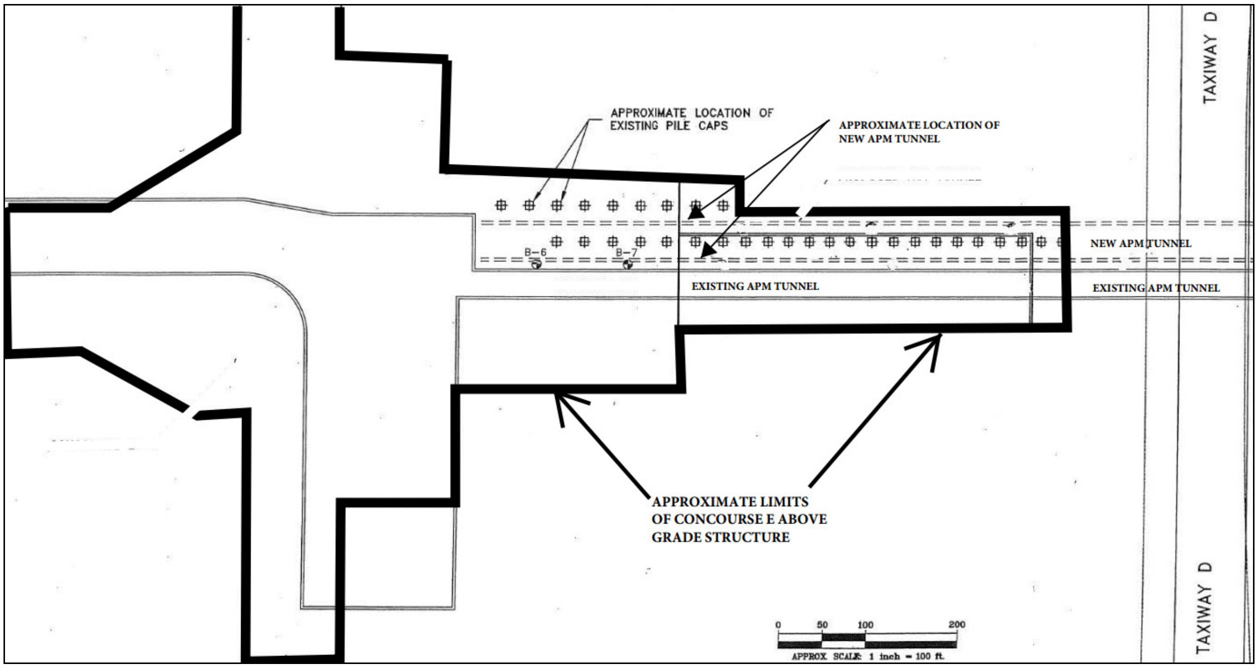

FIG. 1. General Overview of Project Area and Existing Structures / Site Features

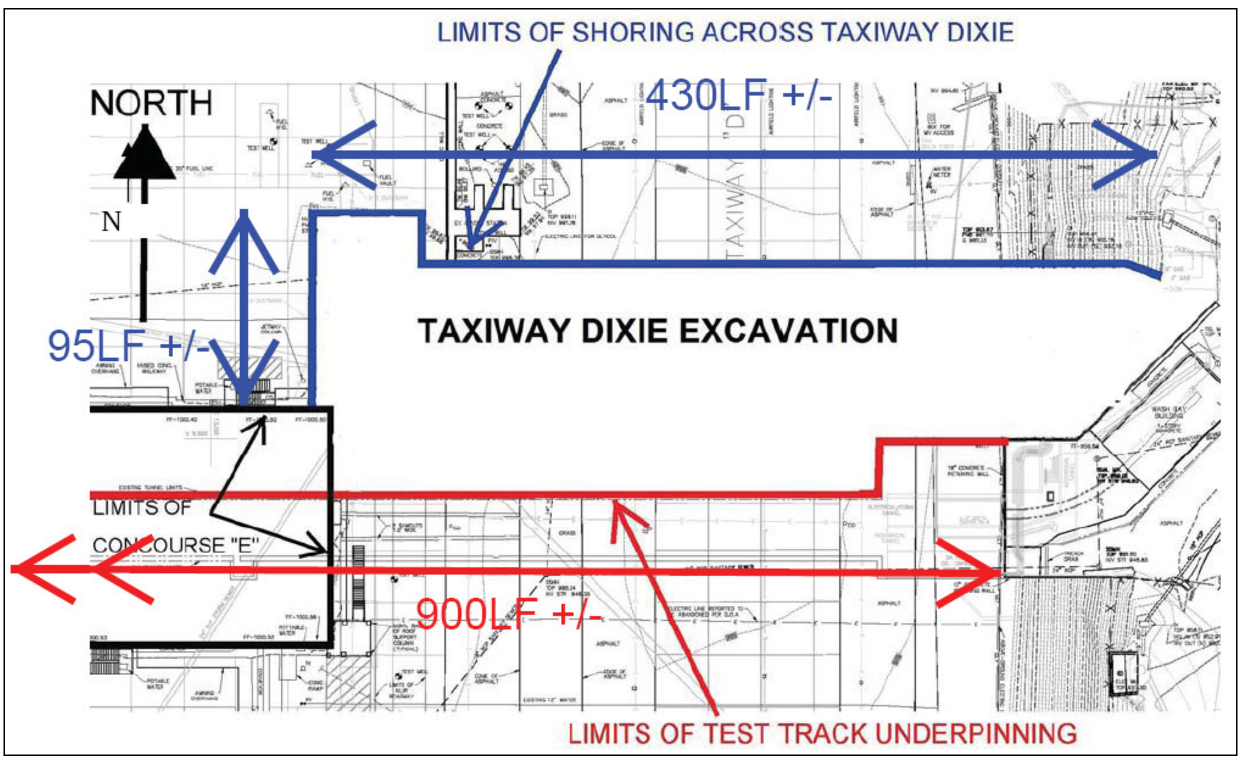

FIG. 2. Location of Excavation and Required Shoring for Taxiway Dixie

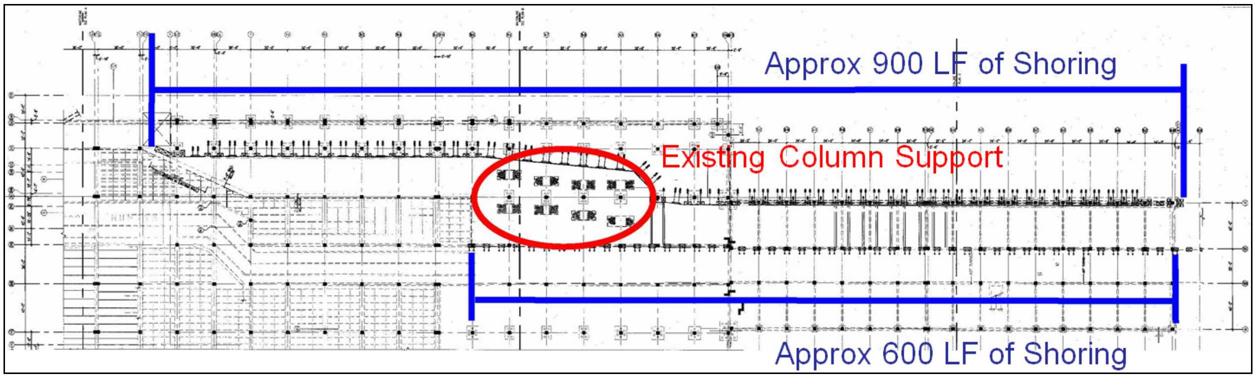

FIG 3. Overview of Excavation Support Requriements Below Concourse E

EXISTING CONDITIONS BELOW CONCROUSE E

Conflict with Existing Columns

A plan view of two sections of excavation support is shown on Figure 4. The proposed shoring configurations in these two sections required eight existing columns to be exposed and supported. An alternate support scheme (Figure 5) used a combined approach of soldier pile and lagging wall with tiebacks as per the original design along with hand-dug underpinning pits around the majority of the nine existing columns. This was done to limit the number of exposed columns requiring support to Columns W6, W7, W8 and W9. Additional details regarding the underpinning pits and tieback walls are available in Hurley and NeSmith (2014).

Geologic Setting and Subsurface Profile

The airport facilities are located within the Piedmont Physiographic Province of Georgia. The general geologic profile typically includes residual soils as a result of in-place physical and chemical weathering of the parent bedrock (igneous and metamorphic bedrock). The soils vary from highly-weathered, fine-grained to less-weathered, predominantly coarse-grained (often exhibiting the relic structure of the parent rock).

There is often a transitional intermediate geo-material between residual soil and the parent rock, locally referred to as partially weathered rock (PWR) and defined as residual soil with standard penetration test results (SPT N-value) of at least 100 blows per foot. Alluvial deposits (typically relatively thin) may be encountered over the residual materials.

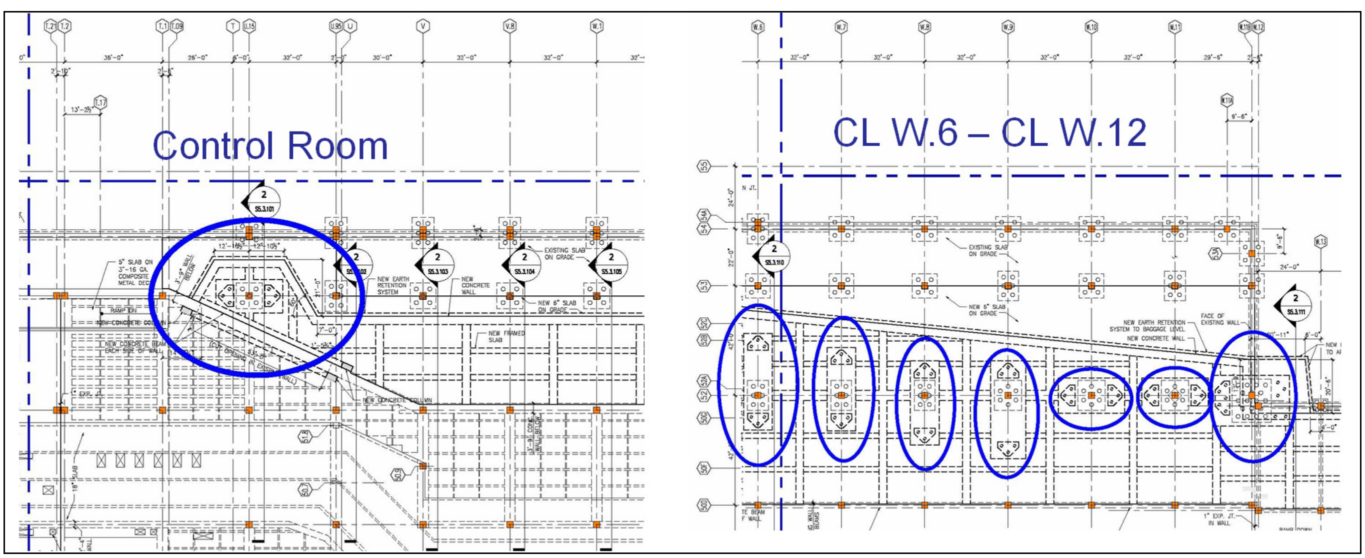

FIG 4. Plan of Original Support Support Scheme Below Concourse E and Existing Columns to be Supported

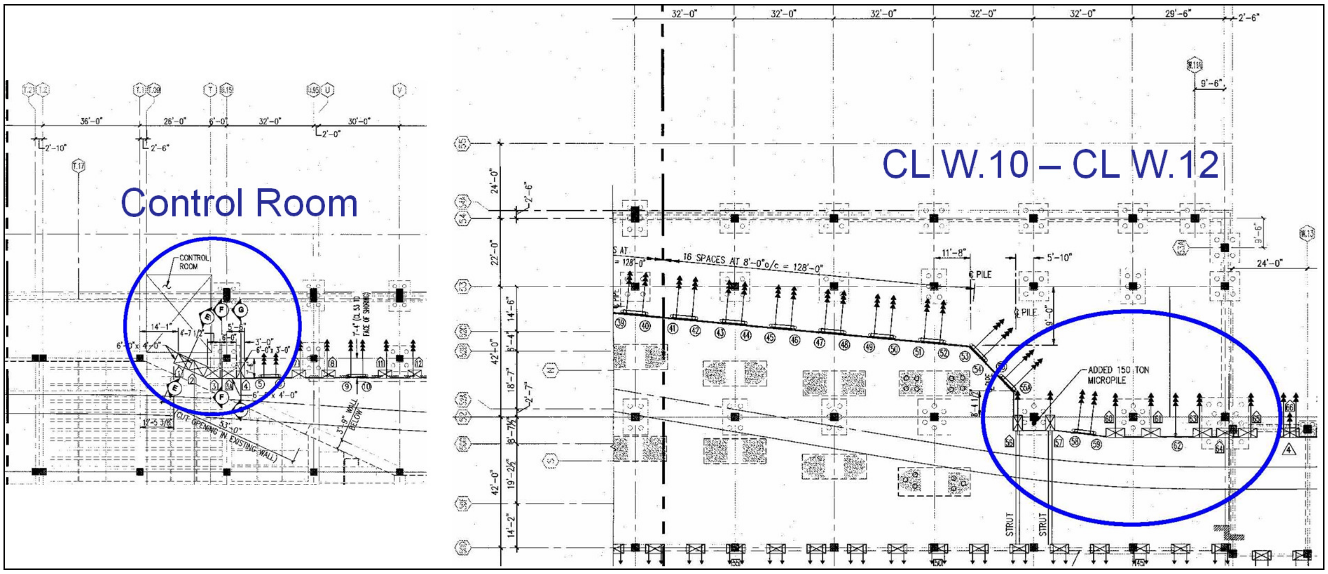

FIG 5. Plan of Alternate Support Scheme Below Concourse E Showing Existing Columns Removed from Interior Through Revised Support Approach

The excavation required for the new APM tunnel exposed up to 50-ft of fill. Some alluvium was encountered below smaller fill thicknesses. Typically, residual soils were encountered below the fill transitioning to PWR typically within the depth of excavation. Bedrock was encountered at a depth range of 50-ft to 100-ft. The depth and quality of the fill material, as well as the variability of residual soil, PWR, and rock elevation and thickness was a significant factor in the selection of the excavation method. A profile of the subsurface conditions under Concourse E is shown in Figure 6. A schematic of the conditions at the boring nearest the area of interest is shown in Figure 7.

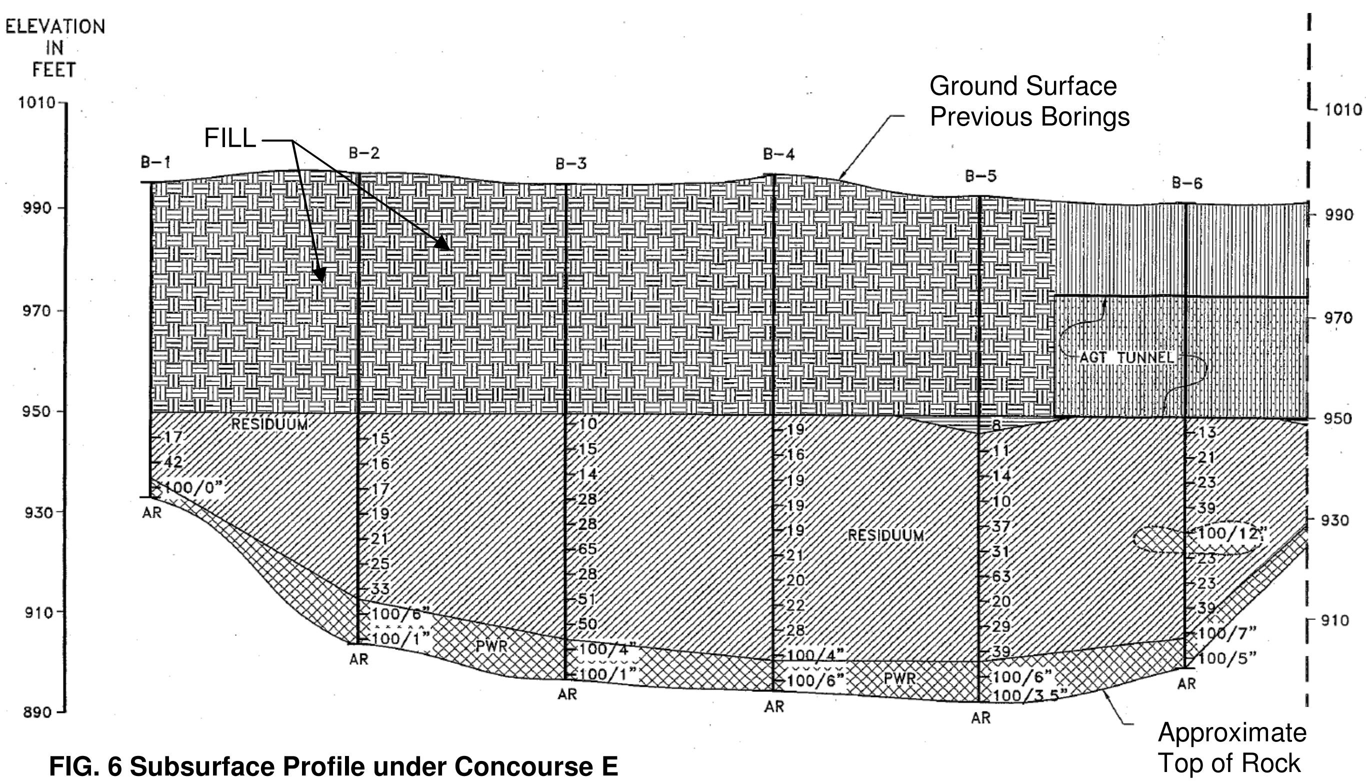

FIG. 6 Subsurface Profile under Concourse E

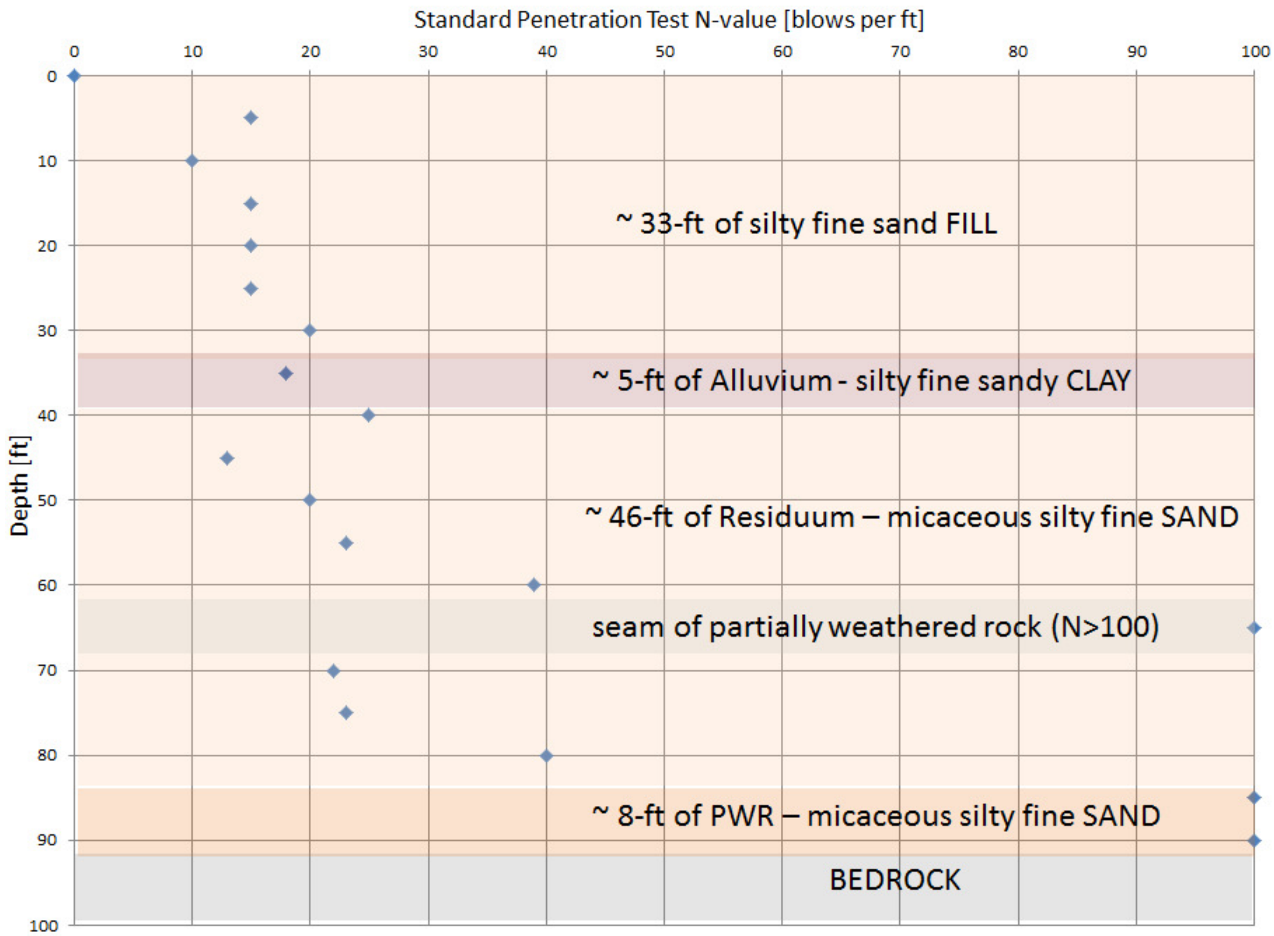

FIG. 7 Generalized Profile in Boring Nearest Area of Interest

Existing Foundation Support

Concourse E was supported on 18-in diameter APG piles installed in 1992. The piles typically were installed to refusal in very dense PWR or the top of bedrock throughout Concourse E. Individual piles were designed to resist a maximum of 150 tons of compressive load. The typical pile configuration per column is shown in Figure 8. Column W.9 was supported by an irregular configuration (Figure 9) due to the presence of numerous obstructions preventing installation at planned locations.

SUPPORT OF EXISTING COLUMNS

Concept

After completion of the excavation support system described in the previous section, four columns founded on APG piles remained that conflicted with the alignment of the new train extension. Figure 10 is a close-up of a portion of the profile of the original support system detailing the proposed support of existing columns exposed under Concourse E.

The initial concept in the bidding documents included low-headroom APG piles with an 8-ft to 10-ft concrete mass transferring the column load to these new piles. Figure 11 shows a portion of the final design profile which included changing the proposed new piles to micropiles and designing a revised load transfer system consisting of a system of steel beams encased in concrete which moved the new-pile tops closer to the existing cap level. Both the change in pile-type and top-of-pile level reduced constructability issues and the associated costs due to these potential issues.

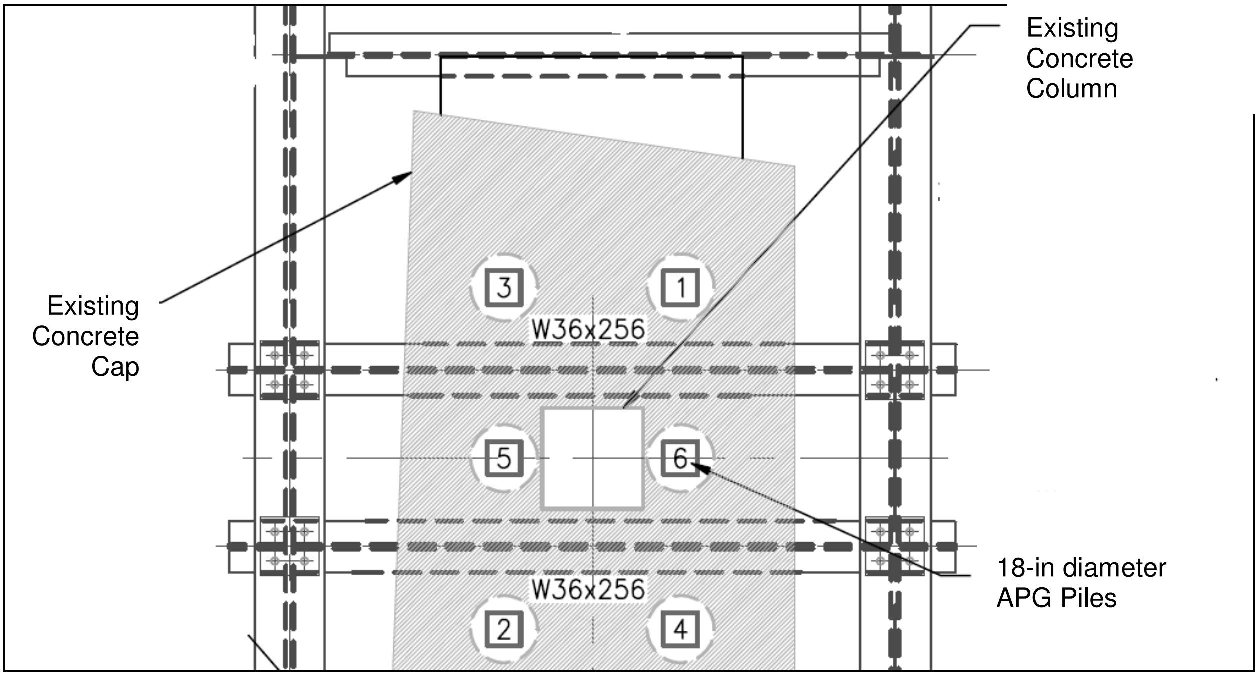

FIG. 8 Existing APG Pile Configuration under Cols. W.6, W.7 and W.8

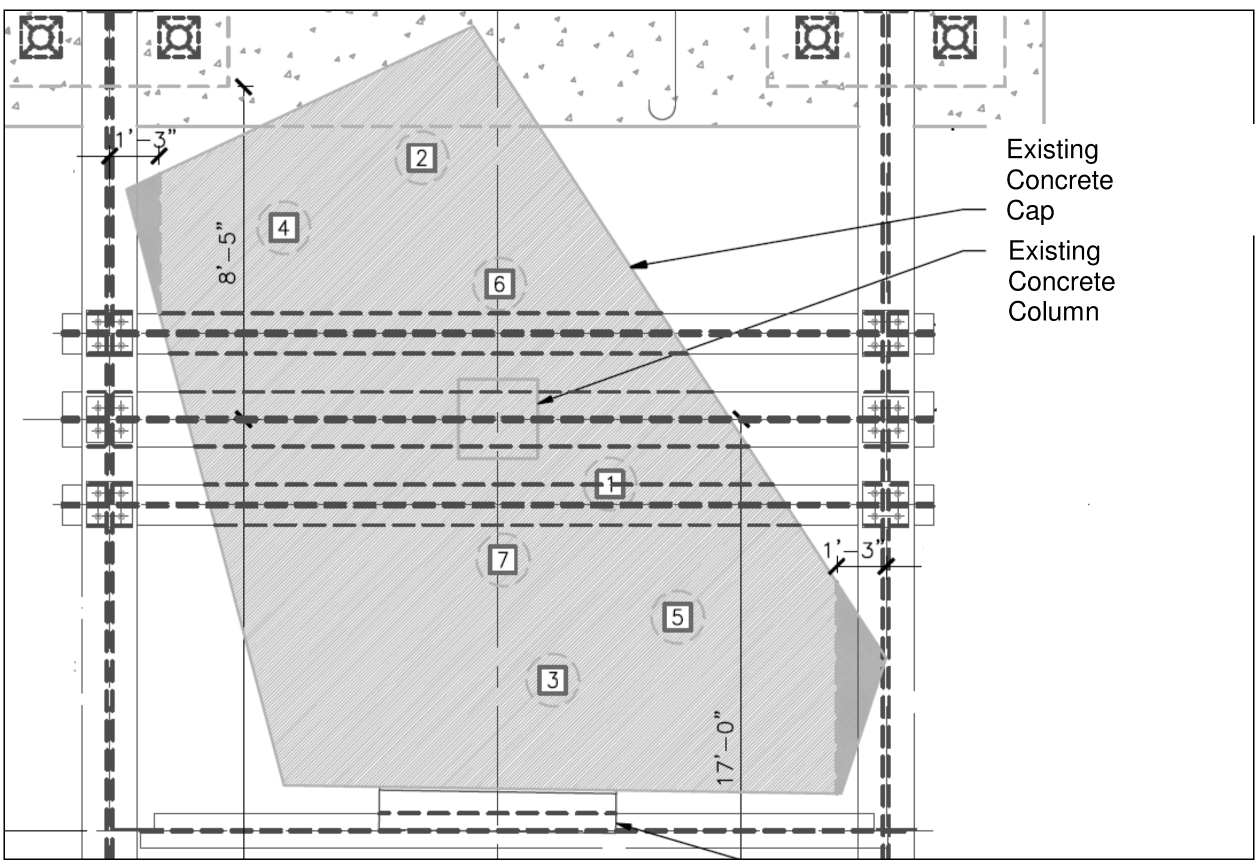

FIG. 9 Existing APG Pile Configuration under Cols. W.9

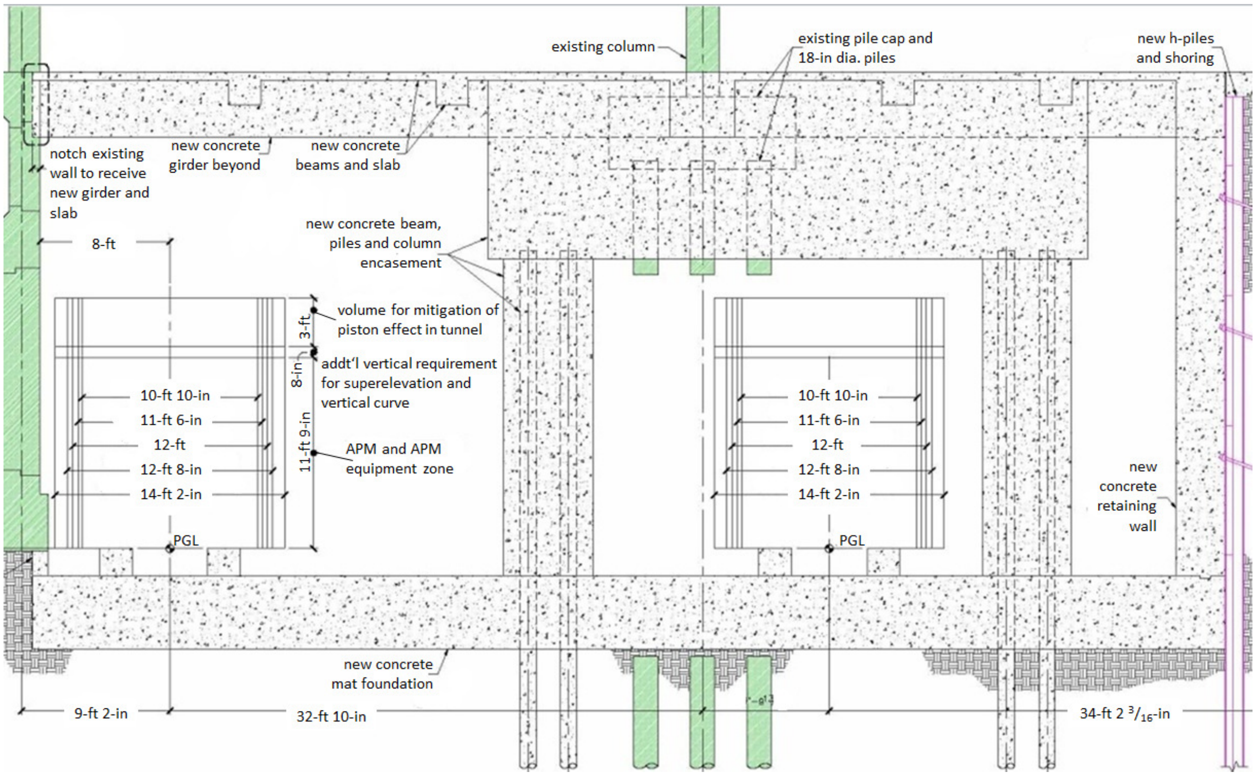

FIG 10. Portion of Original Support Profile for Columns Under Concourse E

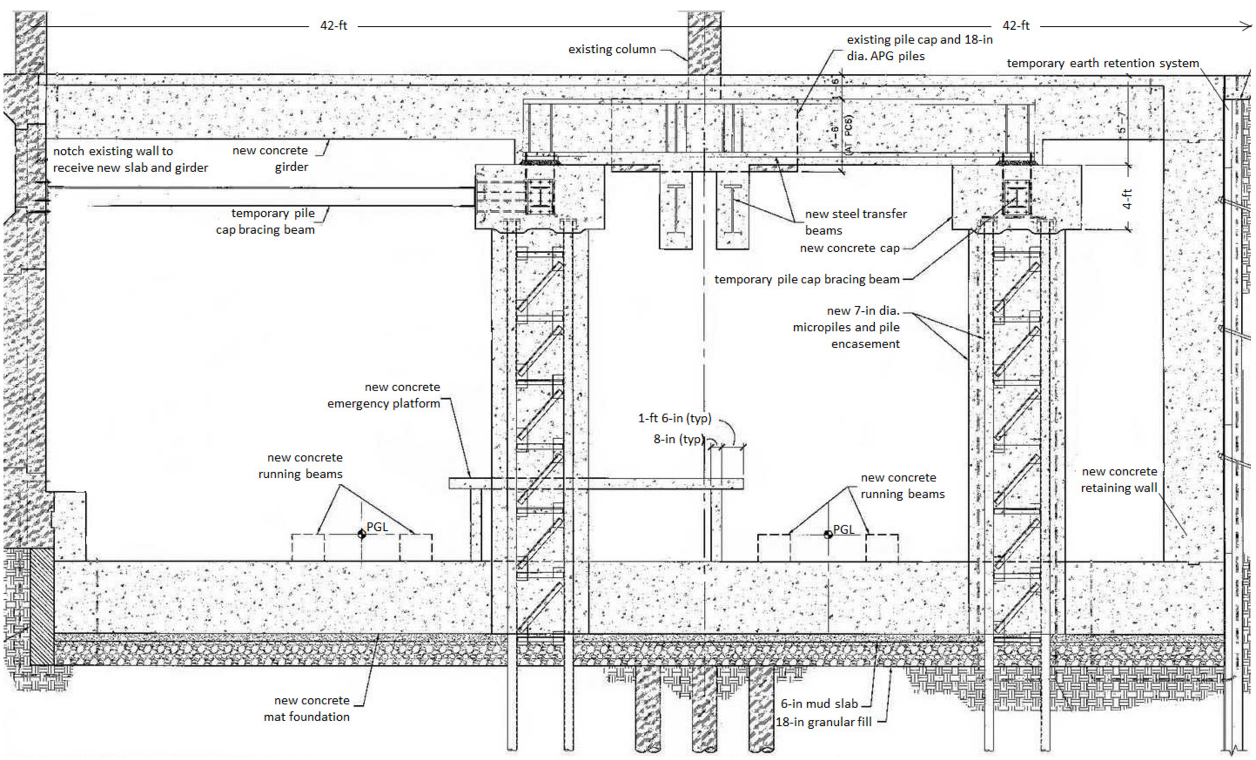

FIG 11. Portion of Alternate Support Profile for Columns Under Concourse E

The final approach included 60 new micropiles, installed straddling the new train extension. Micropiles with an outside diameter of 7-in (Figure 12) were selected to support design compressive loads of 56-tons to 150-tons. Preliminary micropile design considered a rock socket of 15-ft to resist these loads.

One issue with the original approach was the stability of the existing APG piles with a 10-ft unsupported length for concrete mass construction. The piles did not have any lateral reinforcement only 1 - #9 center bar. It was also considered that the low-headroom APG piles proposed might be limited by lenses of partially weathered rock lenses, which would require additional piles. Additionally, there was no access for ready-mix grout trucks. The concrete utilized in the micropiles was pumped up to 1,000 feet.

FIG 12. 7-in diameter micropiles

Verification Testing and Production Installation

Three micropiles were installed to about 115 ft below the installation level, which included the planned 15-ft socket into bedrock. The piles were also sleeved to a depth of 40-ft below the installation level to act as a bond breaker through the overburden soils that would later be excavated. Test loads were applied in 15-ton increments to a planned maximum of 300 tons, or two times the maximum design compression load to be resisted. An example of one of the test results in shown in Figure 13 and is representative of the behavior of all three piles under test loading. Very little deflection beyond that from the theoretical elastic shortening of the pile was observed to loads of about 200 tons. At 285 tons, approximately 0.75-in of deflection beyond that from the theoretical elastic shortening of the pile was observed. Loads greater than 285 tons could not be maintained on any test piles. While sufficient for a portion of the range of design loads, based on these results final micropile design included a 20-ft rock socket to resist the maximum design compression load of 150 tons. During production the average length of production piles was 120-ft.

LOAD TRANSFER TO MICROPILES

Column loads were transferred to the micropiles and the conflicting APG piles were removed. Figure 14 shows the exposed existing APG pile which were removed along with the same view after completion of the steel load transfer system connecting the existing columns to new caps on the installed micropiles. Figure 15 is a global view of the load transfer system. The steel was eventually encased in concrete during tunnel construction. During the load transfer process, a series of hydraulic rams were placed along the steel cross-beams at each connection to the beams under the cap. Reference beams and dial gages were arranged to monitor column movement during load transfer (Figure 16). Upward pressure was applied to the column through the rams until slight upward movement (< 0.1-in) was observed. The APG piles were then cut in sequence as numbered in Figures 8 and 9. During the removal of the APG piles the column deflections were monitored and additional upward pressure was applied as needed. Column deflections did not exceed 0.1-in below the original level at the start of the operation. Figure 17 is a view of the excavation in progress and Figure 18 is a view of the completed excavation showing the existing caps, load transfer system and new micropiles.

It is noted that the compression loads per micropile are static. The new micropile caps are laterally braced to resolve lateral loads on the new pile groups. They have also been cast in reinforced concrete for fire protection and protection against potential train impact (see Figure 19).

SUMMARY

The cut-and-cover approach to the excavation for the APM extension was selected to allow the design and construction team to address unknowns or obstructions encountered in the variable soil profile including significant variations in the depth and quality of fill materials as well variations in the residual soils and rock underlying the fill. The selection and inclusion of the construction team in the design evolution, particularly in the final pre-construction design phases, allowed for adjustments to the approach to further address budget and constructability concerns. In particular, this open collaboration on design and constructability allowed the team to adjust design and installation methods as work progressed during the construction phase to develop solutions to unusual challenges encountered. This allowed the team to minimize construction time and cost without compromising the functionality of the system. The APM has been successfully installed and in use as of early 2012.

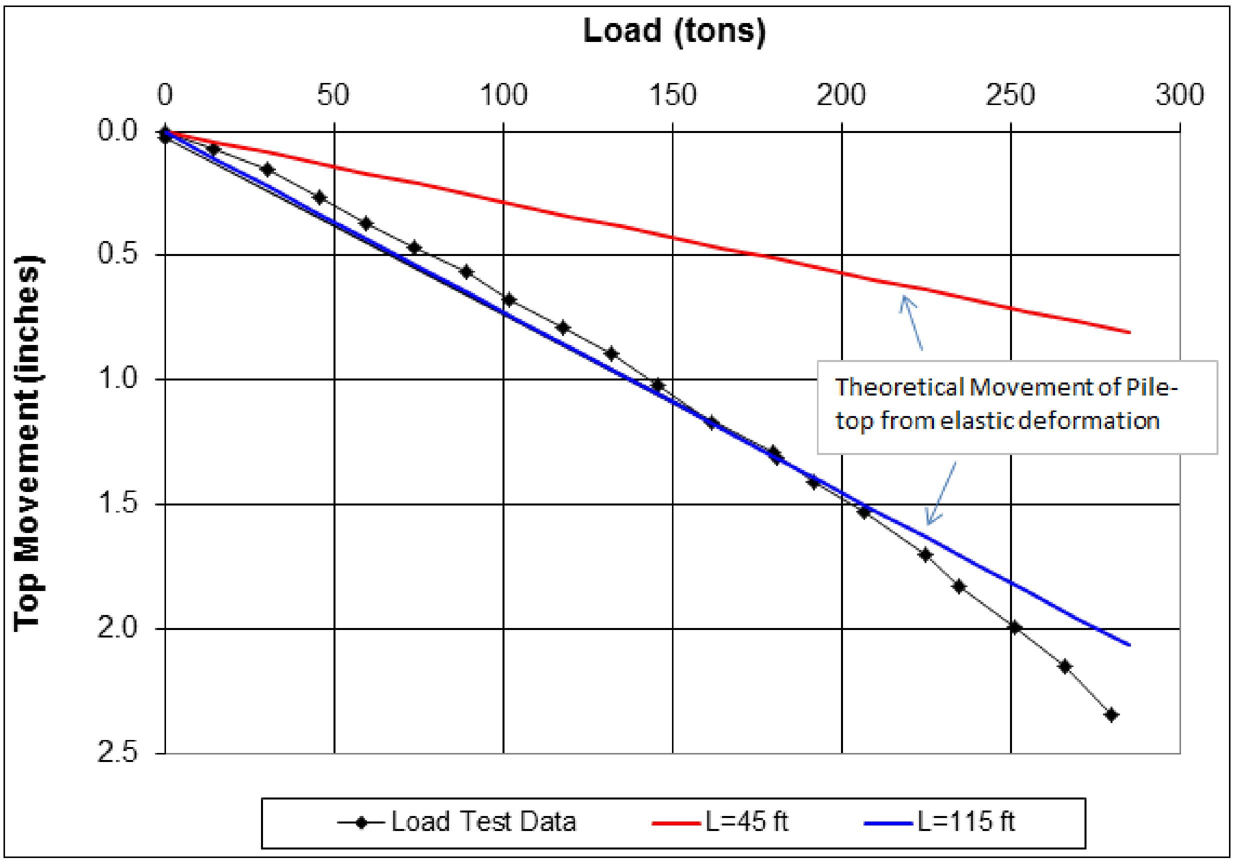

FIG 13. Load – Displacement Relationship of Test Micropile – 115-ft Long with 15-ft Rock Socket

FIG 14. Before (with exposed APG piles) and After View of Column Support Below Concourse E

FIG 15. Overview of Load Transfer System from Existing Columns to New Caps

FIG 16. Monitoring Column Deflection during Load Transfer to Micropiles (hydraulic rams circled in red)

FIG 17. Mid-excavation View of Supported Columns Under Concourse E

The authors would like to acknowledge the Holder, Manhattan, Moody, Hunt Joint Venture who were integral in spearheading the project design-construction approach and to thank ATC Associates, Inc. and Hartsfield–Jackson Development Program for their participation.

REFERENCES

Hurley, Adam S. and NeSmith, W.M. (2014). “APM Tunnel Extension for the Maynard H. Jackson Terminal at Hartsfield-Jackson Atlanta International Airport”. *Proceedings of the 2014 Geo-Congress. Geo-Characterization and Modelling for Sustainability*. Atlanta GA. 23 – 26 February 2014.

FIG 18. Post-excavation View of Supported Columns Under Concourse E

FIG 19. Completed Micropile Columns Encased in Reinforced Concrete