Atlanta—Plain Train Tunnel West Extension Project—Progressive Design-Build Risk Management Approach

Walter Klary ▪ Gall Zeidler Consultants
Dominic Reda ▪ Gall Zeidler Consultants
Vojtech Gall ▪ Gall Zeidler Consultants
Elmira Riahi ▪ Gall Zeidler Consultants
Jake Coibion ▪ Guy F. Atkinson Construction

ABSTRACT

Progressive Design-Build is becoming a more common delivery method in the tunneling industry. This approach allows the Owner to select a design-builder primarily based on qualification instead of lowest price. The delivery method promotes flexibility and collaboration at all levels from the initial design stage through construction. Using the example of the Atlanta Airport Plane Train Tunnel West Extension, value-added risk management was added during the initial design phase with an independent reviewer. This paper presents the independent reviewer transitioning from constructability review in the very early stages of design to independent design verification to on-site supervision during construction.

INTRODUCTION

The Plane Train Tunnel West Extension is located within the Hartfield-Jackson Atlanta International Airport in Georgia, USA. The purpose of the extension is to increase the capacity of the Automated People Mover (APM) system which is connecting domestic and international terminals to significantly decrease the turnaround time of the trains. The project consists of a approx. 900-ft. long, 22-ft. high and 20-ft. wide tunnel, providing the space to add a turnback switch to the APM system. As shown in Figure 1, the tunnel starts as a single tube tunnel from a secant piled wall shaft with a diameter of 36-ft and a depth of approximately 55-ft.. After approximately 400-ft, the tunnel transitions through a widened area (bifurcation) into two single tube tunnels up to the connection with the existing terminal station.

GROUND CONDITIONS

Fill

Encountered in the majority of project borings, Fill consists of very loose to dense silty sands (SM) with variable rock fragments, clayey sands (SC and SC-SM), and some sandy silt (ML). The Fill typically underlies asphalt or concrete at the ground surface. Fill along the single tube tunnel section consists primarily of silty sands (~60% SM), with remaining material consisting of clayey sands (SC), silts (ML) and clays (CL). The N-Values along the sections mentioned above, average 28 bpf (normalize for a penetration depth of 12-in) indicating medium dense material.

Residuum/Saprolite

Residuum/Saprolite consists predominantly of coarse-grained soils of silty sand (SM) with gravel and some fine-grained soils of sandy silt (ML). Layers and lenses of rock and Partially Weathered Rock (PWR) can occur locally within the Residuum/Saprolite

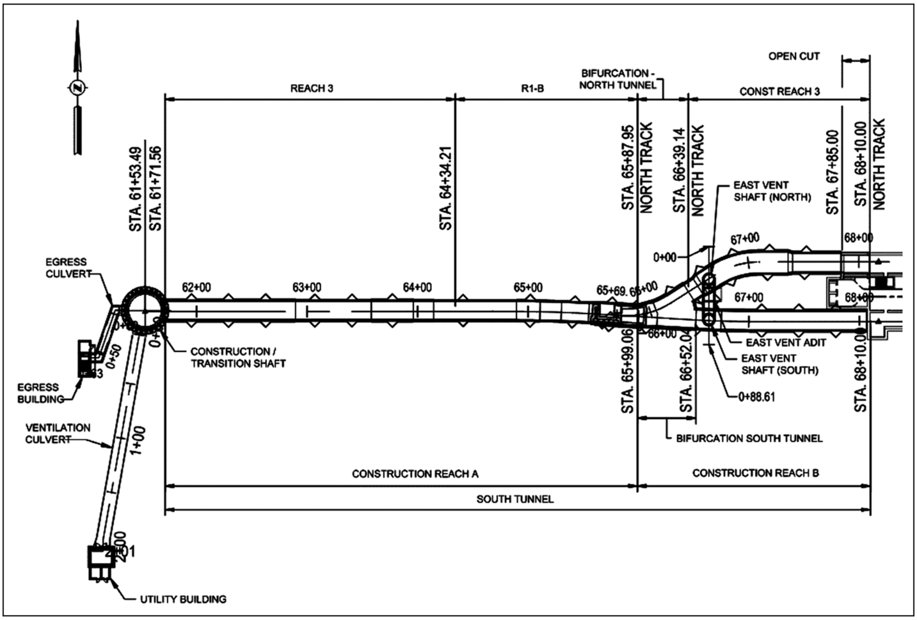

Figure 1. General layout of shaft, tunnel, and culverts

and have STP N-values of >100 bpf. The Residuum/Saprolite may retain the geologic structure of the underlying parent rock including foliation and jointing, acting as pathways for groundwater and along which failure may occur. Average SPT N-Value for Residuum/Saprolite in the single tube section is 32 bpf (medium density).

Partially Weathered Rock (PWR)

The PWR consists of rock-like remnants of decomposed gneiss surrounded and separated by Residuum/Saprolite. The PWR consists primarily of coarse-grained soils of silty sand (~87–100% SM) with some sandy silts (ML) and occasional gravel (GP). PWR thickness is variable along the tunnel and lenses of PWR were encountered within the Residuum/Saprolite. SPT N-values are consistently between 100 and 200 bpf; the upper values likely attributable to the presence of gravel to boulder-size rock fragments within a soil matrix.

Bedrock

Local bedrock consists of the Stonewall Gneiss, which is a medium- to high-grade metamorphic crystalline rock with well-developed foliation. Secondary quartz veins up to 3-ft in thickness are common through the rock. A weathered bedrock zone ranging in thickness from ~1.5-ft to 10-ft below the top of bedrock is indicated by borings. Depth to bedrock along the alignment varies as shown in Figure 2.

Groundwater and Hydrology

According to the GBR-C [1], the baseline groundwater table is at El. 1,001 ft with typical variation in the groundwater table depth ranging from 21.1 ft below ground surface (bgs) (El. 989.7 ft) and 29.0 ft bgs (El. 998.9 ft). Dewatering from ground surface will not be performed to lower the groundwater table during the construction of the

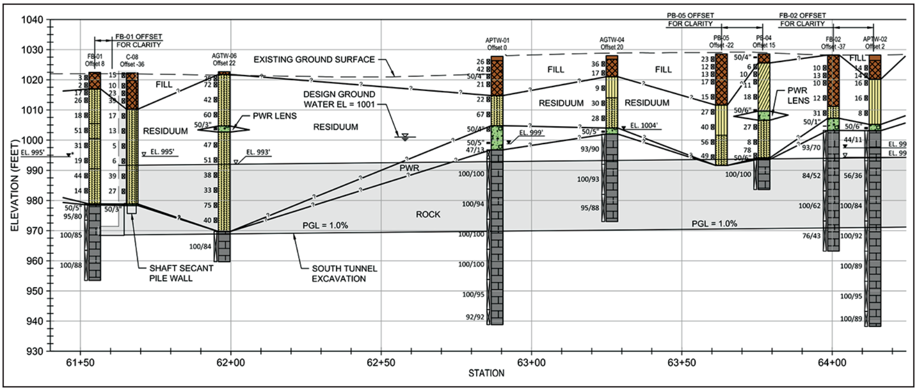

Figure 2. Geological long section—mixed ground condition

bifurcation portion but are required for single tube tunnel section. In-tunnel gravity or vacuum dewatering will be performed, if required, to minimize seepage forces in the around tunnel openings prior to installation of the initial shotcrete lining. In addition, weep holes in the initial shotcrete lining will be required to prevent buildup of groundwater pressure behind the lining.

Mixed Ground Conditions

In the first stretch of the tunnel starting from the shaft mixed ground conditions were present. The upper part of the tunnel was in PWR (Partially weathered rock) and was excavated utilizing an excavator with a hammer attachment. The lower part comprised of bedrock (Gneiss) and was excavated with blasting. In the area with soft ground pocket excavation was required and fiberglass face bolts were installed. Also, in the last stretch of the mixed ground conditions were encountered. The soft ground close to the end wall of the tunnel included backfill material which consisted of trash and steel from the building of the terminal.

TUNNELING CHALLENGES

Existing Structures

The tunnel was excavated in proximity of existing structures servicing the airport. The MARTA Station and the Skytrain foundations were selected for further evaluation of the impact of tunneling on existing structures. MARTA station is composed of a heavy rail system that connects the airport to the center of Atlanta. The Skytrain is connecting the terminal of the airport to the rental car center. Both have a station right outside of the domestic terminal (see Figure 3).

Blasting and Vibration Control

The owner restricted blasting to windows from midnight to 0400 where Skytrain and MARTA were in reduced operation and the activities in the terminal were at a minimum. Seismographs were installed on the surface and on the buildings to monitor the impact of blasting. To minimize impacts of excavation adjacent to existing structures, blasting was prohibited to protect foundations of buildings, the elevator shaft and the micropiles beneath the terminal building.

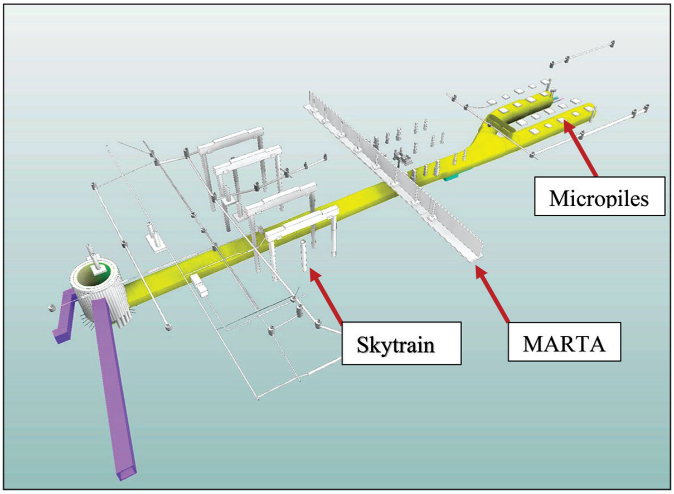

Figure 3. Tunnel with existing structures (MARTA, Skytrain) provided by McMillen Jacobs

Bifurcation

Due to low rock cover and proximity to the surface, the bifurcation was the most challenging area of the tunnel. During the design phase the geometry was adjusted, and a flat roof implemented to maximize the rock cover above the bifurcation. For this area Gall Zeidler Consultants (GZ) performed an independent design review (IDR) of this change by creating a fully independent three-dimensional (3D) model based on the available geotechnical data for the project. The IDR team used a different software package (Midas GTS NX) from the one that EOR has used to confirm the adequacy of the geometry and support. The results of the 3D analyses confirmed that the change in the design was beneficial. Figure 4 shows the 3D model set up in Midas for the Bifurcation; Figure 5 shows bifurcation during construction.

Excavation Adjacent to Micropiles

The last approximately 120 ft. of the tunnel was excavated beneath the domestic airport. Due to structural concerns and the nature of the existing foundation of the

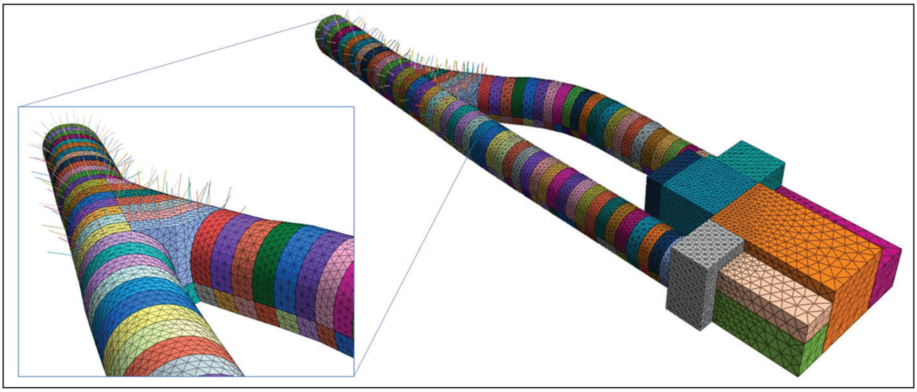

Figure 4. FE model of the bifurcation

building, micropiles were drilled into the bedrock to transfer the load of the building to bedrock. Several of these micropiles were exposed during excavation. No blasting zones were implemented adjacent to the piles and the rock was excavated with an excavator with hammer attachment; exposed micropiles during excavation is shown in Figure 6.

Figure 5. Excavation of the bifurcation

Figure 6. Exposed micropiles

PROGRESSIVE DESIGN-BUILD

Progressive Design-Build allows the Owner to select a design-build team during the procurement process based on qualification rather than costs. Typically, a project is divided into two phases; preliminary design (Phase 1) and detailed design, construction and commissioning (Phase 2). In Phase 1, the bridging documents, Geotechnical Baseline Report (GBR) and Geotechnical Data Report (GDR) are reviewed and subsequently, a lump sum for the project is negotiated. Phase 2 then proceeds with the final design, construction and commissioning, with milestones to review construction costs and schedule as the design is further developed. These Phases can be broken down into more granular components depending on how complicated the Project may be.

The City of Atlanta and the department of Aviation as the project Owner selected the Clark/Atkinson/Technique Joint Venture (JV) as the design-builder with McMillen Jacobs Associates (MJA) as the lead designer. The JV assigned Gall Zeidler Consultants (GZ) for peer review services, independent design reviews and on-site support services. In Progressive Design-Build, the design/builder is not obliged to hire an independent reviewer as part of the design process. During the negotiations between the Owner and the JV, it was agreed that due to the complexity and risk of the project an independent reviewer would help to mitigate the risk. This allowed GZ to be involved in the project starting from early in the design until the completion of the tunnel works.

Close collaboration with the JV and the lead designer MJA in the early phase allowed for refinements, and in some instances, optimization of the design. During construction, GZ provided on-site support which included SEM Superintendents for each shift and the SEM Engineer.

The constructability review included a review of the initial lining, the final CIP lining and waterproofing systems, recommendations for the distribution of support types along the tunnel alignment, the excavation and support sequence, groundwater control, pre-support measures, toolbox measures and specific support elements such as Lattice Girders, Roof Ribs and bolts.

As mentioned previously, GZ was chosen as independent reviewer in the early phases of the design. The main tasks performed by GZ was to review the design of the shaft at the breakout for the tunnel, the design for the tunnel excavation with temporary support, final lining and waterproofing. In addition, GZ performed independent design analyses/modeling for the tunnel including a 3D model for the bifurcation.

The independent design analyses/modeling included the verification of the adequacy of the structural stability of the excavation and support and the final lining. A three-dimensional finite element (FE) analysis has been performed, utilizing Midas GTS NX, to check temporary and permanent support. The bifurcation structure, the North and South Tunnels were constructed following the principles of the Sequential Excavation Method (SEM). The objectives for the FE analyses were to validate the adequacy of the SEM initial lining thicknesses for all support types for the portion of the APM Tunnel—Single tube tunnel and bifurcation—and to investigate the structural capacity of the initial lining and the final CIP lining.

The main changes during the design phase were condensing the support types into fewer support types, optimization of the support, change in rock bolt pattern and rock bolt types, eliminating roof ribs, changes in pre-support measures and optimization of the waterproofing system. The efficiency of the changes were verified in the field by the on-site SEM team during construction.

EXPERIENCE DURING CONSTRUCTION

Excavation Overview

The tunnel was excavated with a Top Heading and Bench excavation sequence. The full length of the Top Heading for both tunnels were excavated up to the terminal station prior to bench excavation. A combination of Drill and Blast and soft ground excavation techniques were utilized based on the ground conditions encountered. Four ground classes were developed during the design phase for the tunnel and one ground class for the bifurcation. The main challenges during excavation were mixed ground conditions, vibration control, shallow cover, and existing structures. GZ provided an on-site team during excavation, waterproofing and final lining. This included a SEM Engineer and SEM Superintendents for each shift. In the daily Required Excavation Support (RES) meetings the ground conditions encountered, probe drilling, instrumentation and monitoring, blast vibration monitoring, shotcrete test results were discussed by the SEM Engineer/Superintendent, the JV, the Engineer of Record's (EOR) onsite representative and the Owner's Engineer and the ground support type for the next excavation round was determined. This highly experienced onsite team was able to adjust support type etc. if required and verified that the design and adjustments/optimizations made during the design were adequate. This meeting also allowed for the review of quality items such as shotcrete performance and blast results from the previous shift. The main benefit of the Progressive Design-Build is that the design/builder in conjunction with the independent designer work together in the design phase as well in the construction phase.

Shotcrete

Fiber reinforced shotcrete was used for the initial support of the excavation. Extensive preconstruction testing was performed by the JV to validate and prepare the mix, the nozzlemen and the equipment for the demands of the Project. A batching plant was installed on the construction site, this guaranteed the permanent availability of shotcrete. During construction an extensive testing program was executed, this included early strength testing, compressive strength testing and round panel tests. After spraying shotcrete an exclusion zone was introduced where personnel were not allowed to enter. This was managed by the SEM Superintendents and eliminated the risk of personnel being exposed to fresh shotcrete. As in most projects the round panel testing was challenging, and special care had to be taken in handling the panels. The shotcrete was applied utilizing a Normet Minimec concrete spraying manipulator.

Instrumentation and Monitoring

A thorough monitoring program was implemented on the surface and in the tunnel. Surface monitoring included ground monitoring points, structural monitoring points on buildings, tiltmeters on building columns, inclinometers, extensometers, strain gauges on the foundation underpinning, hydrostatic level cells, and piezometers. In-tunnel monitoring utilized convergence monitoring arrays on 50-ft intervals. All data were compiled in real time on a web portal and were available online. Due to ongoing construction on the surface as well as in the terminal building, special care had to be taken in protecting the instruments and keep line of sight between targets and total station. All available date were reviewed in the daily RES meeting and potential issues discussed in a weekly meeting. The in-tunnel monitoring did not show any significant movement of the tunnel lining, therefore negligible settlements on the surface were observed. An important part of the monitoring included vibration monitoring during blasting. Based on the seismograph recorded data, the drill and blast design were adjusted and optimized in order to stay within the allowable limits.

Mixed Ground Conditions

In the first stretch of the tunnel adjacent from the shaft and along the last stretch beneath the Terminal building, mixed ground conditions were encountered. In particular, beneath the Terminal building soft ground was encountered in the upper half of the Top heading excavation (Figure 7). The lower part consisted of fresh, hard Gneiss. In the soft areas, pocket excavation was utilized and supported with shotcrete, the lower part was excavated by drill and blast. Figure 8 shows the highly weathered soft ground where pocket excavation was utilized. The number and sizes of the pockets was driven by the stability of the soil during mechanical excavation and was determined by the GZ Superintendent and SEM Engineer. Due to the highly experienced team, geological overbreak or instabilities of the face were not observed, geological overbreak was also prevented by the installation of grouted tube spiles. As shown in Figure 7 the lower part of the face comprised of fresh, hard Gneiss with only few discontinuities. In areas where blasting was restricted, a trial was performed to utilize rock splitters. It turned out that due to few discontinuities, this method was less effective than using a excavator with a chipping hammer.

Toolbox Items (Spiles, Pocket Excavation)

Toolbox items in the design included gravity dewatering, vacuum dewatering, pocket excavation, face wedge, spiling, grouting and face bolting. Due to favorable ground conditions only gravity dewatering, and pocket excavation were utilized. By design, the heavier support classes (3-A and 3-B) included 21 grouted pipe spiles (L = 12 ft.) for pre-support. However, in daily RES meetings, the ground conditions and required pre-support was discussed and due to favorable ground conditions in certain locations, the grouted pipe spiles were determined to be unnecessary as part of the excavation cycle. When unfavorable ground conditions were encountered, the RES meeting determined grouted pipe spiles in conjunction with pocket excavation was required. In total, a significant number (692) of spiles were eliminated. This led to cost savings and schedule benefits. Spiling impacted the cycle time significantly and to meet the narrow

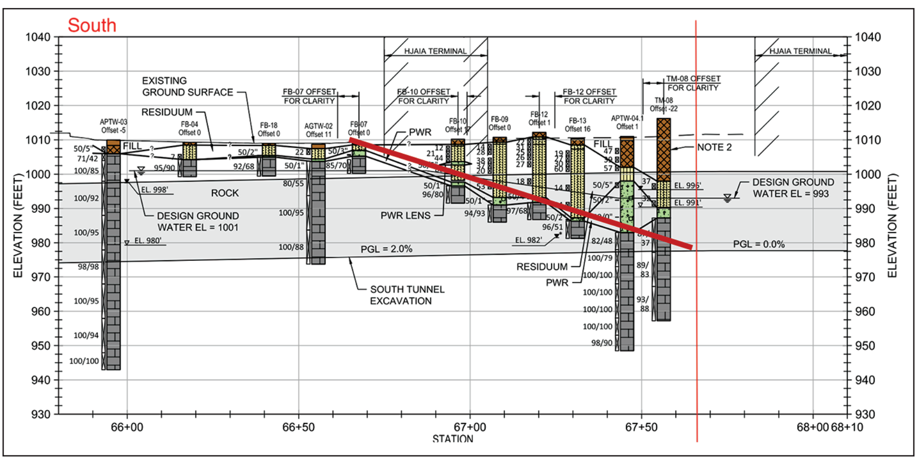

Figure 7. Geological long section showing mixed ground conditions

Figure 8. Pocket excavation in soft ground with spiles installed

blasting window each night adjusting the number or eliminating the spiles was one key for the success of the project. Spiling as toolbox items in ground support classes without spiles were not utilized. Toolbox measures included also pocket excavation. This was utilized in soft ground conditions and mixed face conditions. The number and sizes of pockets driven by the stability of the ground during excavation. Other toolbox items shown in the design drawings such as vacuum dewatering, face wedge, grouting and face bolting were not utilized due to the stable ground conditions.

Unexpected Utilities

During the excavation of the last 15 feet of the south tunnel backfill material from the original terminal foundation was encountered during tunnel excavation. During bench excavation in this location, an undocumented 4-inch steel pipe filled with water was encountered. The initial water inflow was measured at approx. 40 gpm. The Designer and Owner were immediately informed, and an investigation started. This unknown utility was not documented in any existing drawings, and it was decided to let the water drain and observe the change in quantity. Pouring the protection slab stopped the water inflow only temporarily and a grouting program was implemented. The grouting included chemical grouting of the invert slab and lower bench walls. Since the water pressure was building up water inflow returned, and it was decided to install a permanent drainpipe at one side of the tunnel and divert the water to a sump in the construction shaft.

CONCLUSION

Progressive Design-Build allows the independent reviewer of the contractor being involved in the very early stage of the project. The constructability review allowed to make impactful changes at very early stages of the project. In addition, the collaboration with the design team and the contractor established a relationship between the different parties which was beneficial for the project. The independent design review, especially of the bifurcation, built confidence that the changes in geometry and support was adequate and beneficial for the project. The on-site team with SEM Engineer and SEM Superintendent collaborated closely with the Designer Representative on site and the JV. This trust-based environment developed over years of collaboration led to open discussions when challenges emerged, or changes were required. This collaborative environment between the Owner, the JV, the EOR, and the IDR resulted zero major issues during construction for the Plane Train Tunnel West Extension Project.

REFERENCES

Murray, J. 2021. Concept for Contingency Measures of Bifurcation Excavation. Memorandum from J. Murray to R. Gould and L. Gilbert, CAT JV. April 9, 2021.

Sun Y, Murray J, Elbin D, Gould R, Gilbert L, 2022. Design and Construction of a Shallow Twin Tube Bifurcation—Atlanta Plane Train West Extension, NAT 2022.

Gould R, Murray J, Elbin D. 2022. Benefits and Challenges of Progressive Design-Build Procurement-Atlanta Plane Train Project, NAT 2022

Buckley J, Cidlik R, Sibley R, Pallua T, Schrank J, Giltner S, 2022. Analyses of Near Field Vibration Monitoring in Construction Blasting, NAT 2022

Gall Zeidler Consultants. 2020 Summary Memorandum 1711 MEM005 R00, Independent 3D Finite Element Analysis of APM Tunnel (Design Package 04 Bifurcation to the East End and Design Package 06 Final Lining), November 17, 2020. Prepared for: CAT JV.

Loulakis, M.C., Kinsley, P., Neumayr, G.W., Unger, C.H., and The Progressive Design-Build Task Force. 2017. Progressive Design-Build, Design- Build Procured with a Progressive Design & Price, A Design-Build Done RightTM Primer. A Design-Build Institute of America Publication. https://dbia.org/wp-content/uploads/2018/05/Primer-Progressive-Design-Build.pdf.