TAXIWAY ALPHA WEST RECONSTRUCTION & TAXIWAY BRAVO RECONFIGURATION (HOT SPOT 1)

Engineer's Report

Memphis International Airport
MSCAA Project No. 18-1413-01 & 18-14312-02

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Appendices

1.0 Introduction

This report has been prepared to supplement the preparation of construction plans and specifications for the reconstruction of Taxiway Alpha West and realignment of Taxiway Bravo located at Memphis International Airport in Shelby County, Tennessee. The owner and project sponsor is the Memphis Shelby County Airport Authority (MSCAA)

Taxiway Alpha is a full-length parallel taxiway located on the south side of Runway 9/27 and this taxiway provides east/west access across the airfield. Taxiway Alpha West provides airfield access to the Signature Ramp FBO. This project consists of the reconstruction of Taxiway Alpha West from east of Taxiway November to just east of the existing Taxiway Bravo Intersection. In conjunction with the Alpha project, Taxiway Bravo (Hot Spot) Reconfiguration was also combined with this project but will be bid separately.

2.0 Description of Work

The Taxiway Alpha West Reconstruction project will include:

- Reconstruction of Taxiway Alpha and the intersections with Taxiways B, C, N, S, and X pavements.
- New 30-foot paved shoulders for Taxiway Alpha, as well as crossing taxiways that are reconstructed due to new intersection geometry.
- Earthwork and grading of the existing ground surface in the Taxiway Safety Area to meet the requirements of Advisory Circular 150/5300-13A
- Replacement of existing airfield edge lights with new flush/inset LED lights
- Replacement of existing taxiway centerline lights with new LED Centerline lights and based on the MSCAA SMGCS system.
- Replacement of existing airfield signage with new LED signage
- Replacement of existing airfield electrical conduit and conductor with new conduit and conductor
- Replacement of herringbone underdrain & edge drain system in taxiway subgrade
- Replacement of stormwater conveyance piping and replacement of culverts underneath the reconstructed taxiway

The Taxiway Bravo Reconfiguration (Hot Spot 1) project will include:

- Realignment of existing Taxiway Bravo from a diagonal connection between Alpha and Sierra to a parallel/perpendicular alignment to eliminate confusion at the intersection of Taxiway Sierra, existing diagonal Bravo, and 18C which has been identified as (Hot Spot 1).
- New 30-foot paved shoulders for Taxiway Bravo and fillet transitions to existing Taxiway Sierra
- Earthwork and grading of the existing ground surface in the Taxiway Safety Area to meet the requirements of Advisory Circular 150/5300-13A
- Replacement of existing airfield edge lights with new flush/inset LED lights

- Replacement of existing taxiway centerline lights with new LED Centerline lights and based on the MSCAA SMGCS system.
- Replace existing LED airfield signage with new LED signage and sign panels where appropriate
- Replacement of existing airfield electrical conduit and conductor with new conduit and conductor
- Replacement of herringbone underdrain & edge drain system in taxiway subgrade

3.0 Existing Topographic Survey

A topographic survey of the Alpha West project area was performed by Geodesy and Allen & Hoshall and will be used for the design of the construction documents. The topographic survey is based on the Tennessee State Plane Coordinate System, NAD 1983. Additional control points were established for the topographic survey and this control point information will be included in the contract documents. The vertical elevation for the topographic survey is based on NAVD 1988.

The field work for the topographic survey included establishing the location of the above ground utility manholes, utility covers and the drainage systems. The field work did not include the investigation of the existing FAA and MSCAA electrical manholes, electrical conduit, underdrains, water utilities or sanitary sewers. MSCAA provided drawing files of the existing underground utility systems and this information will be included in the contract documents.

4.0 Surface Conditions of Existing Pavement

Allen & Hoshall made a site visit to document the existing pavement surface and site conditions on August 5, 2019. The pavement surface condition and various site pictures are included in Appendix A of this report. A&H will request a meeting with the FAA and MSCAA Airfield Electrical for a site visit to verify circuitry and to identify active circuits.

5.0 Subsurface Conditions - Geotechnical

The subsurface investigation for the Alpha West project was performed by KS Ware LLC. The subsurface investigation included 14 borings and 8 pavement cores located in the existing pavement surfaces of Taxiways A, B, C, & S.

The subsurface investigation for Taxiway Bravo Reconfiguration (Hot Spot 1) was performed by Athena (formerly KS Ware & Associates). The investigation for this project included 5 additional borings along the planned realignment of new Bravo.

The boring logs for each of the borings located in Taxiway A, B, C, & S are included in Appendix B of the report. A summary table of the pavement layer thickness and aggregate base material is also included in Appendix B.

6.0 Subsurface Conditions – Non-destructive Testing

The non-destructive testing (NDT) of the taxiway pavement was performed by RDM International, Inc. on April 29th and April 30th, 2019. NDTs were conducted in the center of the slabs and on transfer joints of the slabs with staggered spacing. For each lane, testing was conducted at 100 feet longitudinal spacing, i.e. every 4 slabs interval. A total of 122 center slab tests and 95 joint tests were conducted for Taxiway A. A total of 83 tests, including center and joint tests, were conducted for the crossing taxiways. NDT field data can be found in the attachments in Appendix E of this report.

The field data was analyzed and backcalculated to estimate the elastic moduli of the existing pavement section materials and the subgrade soils.

The report from RDM International "Taxiway A Rehabilitation Pavement Design" is included in Appendix E of the report.

7.0 Horizontal Geometry

Existing Taxiways

Existing Taxiway Alpha is nominally seventy-five feet wide PCC with 35-foot-wide AC paved shoulders on each side. Taxiway Alpha has a taxiway safety area of 214 feet. The existing section of Taxiway Alpha West consists of an average of 18.3" of PCC underlain by an average of 3.3" of AC on an average of 4.6" of Cemented Base. Taxiway Charlie, Sierra, and Bravo are composed of a similar paving section and are seventy-five' wide except for the fillet widening at intersections to accommodate aircraft turning movements. Existing Taxiway Bravo also has widened shoulders (60 foot) to accommodate the engine overhang on occasional Group VI operations. Once Bravo is reconstructed in its new alignment, the shoulders will be thirty foot wide.

The existing Taxiway X that connects the Signature FBO Ramp to Taxiway Alpha is an existing bituminous pavement connector with an AC thickness of 22" and has no paved shoulders. The existing alignment of Taxiway X meets Taxiway Alpha at an acute angle. This existing taxiway alignment will be corrected in the new taxiway design with a 90-degree intersection angle at Taxiway Alpha centerline.

Taxiway Design Group

The current and future aircraft fleet mix projected to travel on Taxiway Alpha West includes the Boeing 737-700, 757-200 Cargo, B767-3 and the B777F. Based on FAA Advisory Circular 150/5300 13A, the B-757-200 aircraft is classified as Airplane Design Group (ADG) IV and B777F aircraft is classified as Airplane Design Group (ADG) V. The Airplane Design Group (ADG) is an FAA-defined grouping of aircraft types which has six group classifications based on the aircraft wingspans and tail heights. The design aircraft chosen for this project is the B777F.

The second classification of aircraft is the Taxiway Design Group (TDG). This classification is based on the aircraft's outer width of the Main Gear Width (MGW) and the distance from the aircraft Cockpit to Main Gear distance (CMG). The B777F aircraft are classified as Taxiway Design Group 5. The B757-200 aircraft is classified as Taxiway Design Group 4 and was chosen as the design aircraft for the connector taxiway to the Signature FBO Ramp.

Taxiway Design

The current FAA Advisory Circular 150/5300-13A provides guidance on taxiway design based on the aircraft's Main Gear Width (MGW) and the Cockpit to Main Gear Distance (CMG). Taxiways are to be designed based on the "cockpit over centerline" taxiing with pavement widths to allow for aircraft wander. The taxiways are to be designed based on the aircraft nose gear steering angle of no more than 50 degrees to prevent excessive nose wheel tire scrubbing. The Taxiway Edge Safety Margin (TESM) is the distance measured from the outside of the (main) landing gear to the full-strength taxiway edge.

The minimum taxiway width for a TDG (Taxiway Design Group) 4 is 50 feet with a Taxiway Edge Safety Margin of 10 feet. The minimum taxiway width for a Taxiway Design Group 5 is 75 feet with a Taxiway Edge Safety Margin of 15 feet. The new FBO Taxiway to Signature Ramp (Taxiway X) will be designed as a TDG 4 taxiway. Taxiways Alpha, Bravo, Charlie, and Sierra will be designed to TDG 5 taxiway standards.

The existing taxiway pavement widths and intersection fillets of Taxiway A, C, B, N, S, and X were analyzed using the computer program *Transoft AviPlan Airside Pro*. Aircraft movements were analyzed with the most demanding aircraft expected to utilize Taxiway Alpha which was determined to be a Boeing 777 Freighter. Intersection analysis along Taxiway Alpha with Taxiways Charlie and Taxiway Sierra were simulated with a 92' centerline radius due to new intersection construction. The aircraft movement analysis from Taxiway November to Taxiway Alpha (185' radius on the south, 150' north radius) was modeled with existing centerline radius because of the existing lights that won't be relocated for this project. The same condition applies at the Taxiway Alpha and Taxiway Bravo intersection (north side) where existing centerline geometry will remain in place, and we'll tie to existing centerline radius lighting. The taxiway aircraft movement analysis is included in Appendix C of the report.

8.0 Vertical Alignment and Taxiway Cross-Slopes

Taxiway Alpha pavement surface includes areas with a normal crown pavement section and areas with a super-elevated pavement section. The super-elevated pavement section includes the section of pavement from Taxiway Sierra to Taxiway Bravo. The pavement section cross-slope falls from the south taxiway edge to the north pavement edge.

The taxiway pavement is required to have a cross-slope (transverse grade) ranging from 1.0% to 1.5% per FAA AC 150/5300-13A. The topographic survey of the pavement surface was used to check the existing pavement cross-slopes and the existing pavement cross-slopes are shown in Appendix D. Multiple sections of the existing pavement exceed the 1.5% slope. There are areas of pavement with cross-slopes less than 1.0% and these areas occur in the transition areas from a normal crown pavement to a super-elevated pavement section.

The new pavement sections will be designed based on a 1.25% normal crown cross-slope. There are certain areas of Taxiway Alpha and corresponding intersecting taxiways that exceed the 1.25% cross-slope due to superelevation to make the required tie-ins. At no time will the cross-slope exceed 1.50%.

The existing Taxiway A centerline profile has a longitudinal gradient less than 1.5% and this is in accordance with FAA AC 150/5300-13A for Aircraft Categories C, D, and E. The taxiway profiles will include vertical curve lengths of minimum 100 feet for each 1.0 percent of change.

9.0 Pavement Design

Aircraft Movements

The estimation of current aircraft movements on Taxiway Alpha West is based on the assumption that Taxiway Alpha is primarily used by cargo aircraft. Taxiway Alpha is assumed to have 40% of total airport cargo traffic. The fleet mix and annual departures were extrapolated from Table 26 of Memphis International Airport Masterplan 2019 and are tabulated below:

FedEx	Departure	20 years Total		Annual
Cargo Aircraft	Weight, lbs.	Airport	TW A	TW A
A300-600	380,518	133,287	53,315	2,666
A310-2CF	315,041	8,723	3,489	174
ATR-72		34,028	13,611	681
B757-200 Cargo	256,000	757,105	302,842	15,142
B767-3	413,000	1,948,215	779,286	38,964
B777F	768,800	389,218	155,687	7,784
DC-10-10	458,000	97,066	38,826	1,941
MD-11	633,000	107,802	43,121	2,156

The existing and future aircraft departure estimates for Taxiway A are included in Appendix E.

Proposed Pavement Sections

Taxiway A

The recommended pavement section for Taxiway A is 19.0” P-501 PCC / 4” ATPB (Asphalt Treated Permeable Base, formerly P-402) / 8” P-304 CTB / founded on 12” of P-220 Cement Treated Subgrade. We propose that the 12” lift of P-220 be installed in 2 lifts *if* the Contractor’s means or methods does not thoroughly mix the 12” lift in one pass.

Taxiway C

The recommended pavement section for Taxiway C is 19.0” P-501 PCC / 4” ATPB (Asphalt Treated Permeable Base, formerly P-402) / 8” P-304 CTB / founded on 12” of P-220 Cement Treated Subgrade.

Taxiway S

The recommended pavement section for Taxiway S is 19.0” P-501 PCC / 4” ATPB (Asphalt Treated Permeable Base, formerly P-402) / 8” P-304 CTB / founded on 12” of P-220 Cement Treated Subgrade.

Taxiway B

The recommended pavement section for Taxiway B is 19.0” P-501 PCC / 4” ATPB (Asphalt Treated Permeable Base, formerly P-402) / 8” P-304 CTB / founded on 12” of P-220 Cement Treated Subgrade.

Taxiway X (Taxiway connector to Signature FBO Ramp)

The recommended pavement section for Taxiway X is 9” P-401 AC / 6” P-209 Aggregate Base Course / founded on 12” of P-220 Cement Treated Subgrade. We propose that the 12” lift of P-

220 be installed in 2 lifts *if* the Contractor's means or methods does not thoroughly mix the 12" lift in one pass.

Taxiway Shoulders

The project will include the construction of bituminous shoulders on Taxiways A, B, C, S, and N. The pavement design for the new shoulders will be in accordance with Chapter 6 of the FAA Advisory Circular 150/5320-6F.

The shoulder pavement section is required to be designed to support the maximum loads estimated from either the loading from a total of 15 fully loaded passes of the most demanding aircraft or the loads from the anticipated airport maintenance and/or ARFF vehicle traffic. The flexible shoulder pavements sections are designed to allow for safe operation of an airplane on an emergency basis on the paved shoulder areas without damage to the aircraft.

The recommended pavement section for the new shoulders is 4" P-403 / 12" P-219 Aggregate Base Course / founded on 12" of P-220.

The design of the taxiways and shoulder pavement sections is included in the RDM International, Inc "Taxiway A West Reconstruction Pavement Design" and is included in Appendix E.

10.0 Project Sequence –

Taxiway Alpha Phasing

Taxiway Alpha will be reconstructed in 4 major phases with sub-phases of shorter durations when work is being done on adjacent taxiways and inside the Runway Safety Areas. The operational requirements for FedEx will require that no more than one north/south route be closed at any given time.

Phase 1A will include the area from station 12+25.98 Taxiway A at concrete panel joint line in Taxiway November heading East toward station 14+00. This subphase of the overall Phase 1, Phase 1a, is intended to allow the contractor to complete this smaller section of work first and limit the amount of closure of Taxiway November. Work in this phase also impacts the ILS Critical Area for Runway 9. Construction of the new ILS Service Road will also occur during this phase as access to this area from Taxiway November is needed for this work.

Phase 1B includes the area from station 14+00 to 31+25 and will include the construction of the new 90-degree connector taxiway to the Signature FBO Ramp. Direct access to Taxiway Alpha from the Signature FBO Ramp will be cutoff in this phase of work. This subphase of Phase 1 allows traffic on Taxiway November as well as Charlie to proceed as normal.

Phase 2A & 2B will include the area of Taxiway Alpha from 31+25 to 41+00. This phase will close the intersection of Alpha and Charlie. Phase 2A includes the actual intersection of Taxiway Alpha and Taxiway Charlie and will close Taxiway Alpha from 31+25 to 35+75. North/South Aircraft movements can use Taxiways N, S & B during this phase. The Phase 2B portion of the work is from station 35+75 to 41+00 and is work inside the Runway Safety Area for 18C. Care will be taken during this phase to not disturb FAA equipment to the north and 18C Localizer on the south side of Taxiway Alpha near this phase of work. Work during this phase will require a runway closure for 18C or restrict to departures only.

Phase 3 will include the area of Taxiway Alpha from station 41+00 to 47+50 and close the intersection of Taxiway Sierra and Taxiway Alpha. During this time, North/South Aircraft movements will be allowed on N, C, and B.

Phase 4 will include the area of Taxiway Alpha from station 47+50 to the end of project at station 53+50.11. This phase will close the North/South route of Taxiway Bravo and reconstruct the south and southwest part of that intersection. Taxiways N, C, & S will be available for North/South routing of aircraft across Runway 9/27 & Taxiway Alpha.

Taxiway Bravo Phasing

Taxiway Bravo will be reconstructed in 3 major phases with sub-phases of shorter durations when work is being done on adjacent taxiways and inside the Runway Safety Areas.

Phase 1 work on Bravo will consist of the portions of new Bravo alignment outside of the Taxiway Safety Areas of Sierra and Alpha while those two taxiways remain open to aircraft traffic.

Phase 2 and 2A work consists of new centerline striping and centerline lighting as well as fillet construction along Taxiway Sierra to facilitate northbound/southbound turning movements onto and from the realigned Taxiway Bravo. Phase 2A work is a subphase of Phase 2 and will be performed during short term, daily Runway closures (at least 3 days/week + weekends) as allowed and coordinated with MEM Ops with all equipment removed daily.

Phase 3 work will consist of reconstruction of Taxiway Alpha from Station 47+75 to Station 53+50. Taxiway Alpha will be closed from just east of new Bravo and Alpha intersection alignment to Taxiway Yankee to the east. The portion of Bravo between Runway 9-27 and Alpha will also be closed during this phase.

The contract documents will address the requirements of temporary electrical conduit and conductor to be installed for each phase of the project to keep the taxiway edge lights and signage operational during construction.

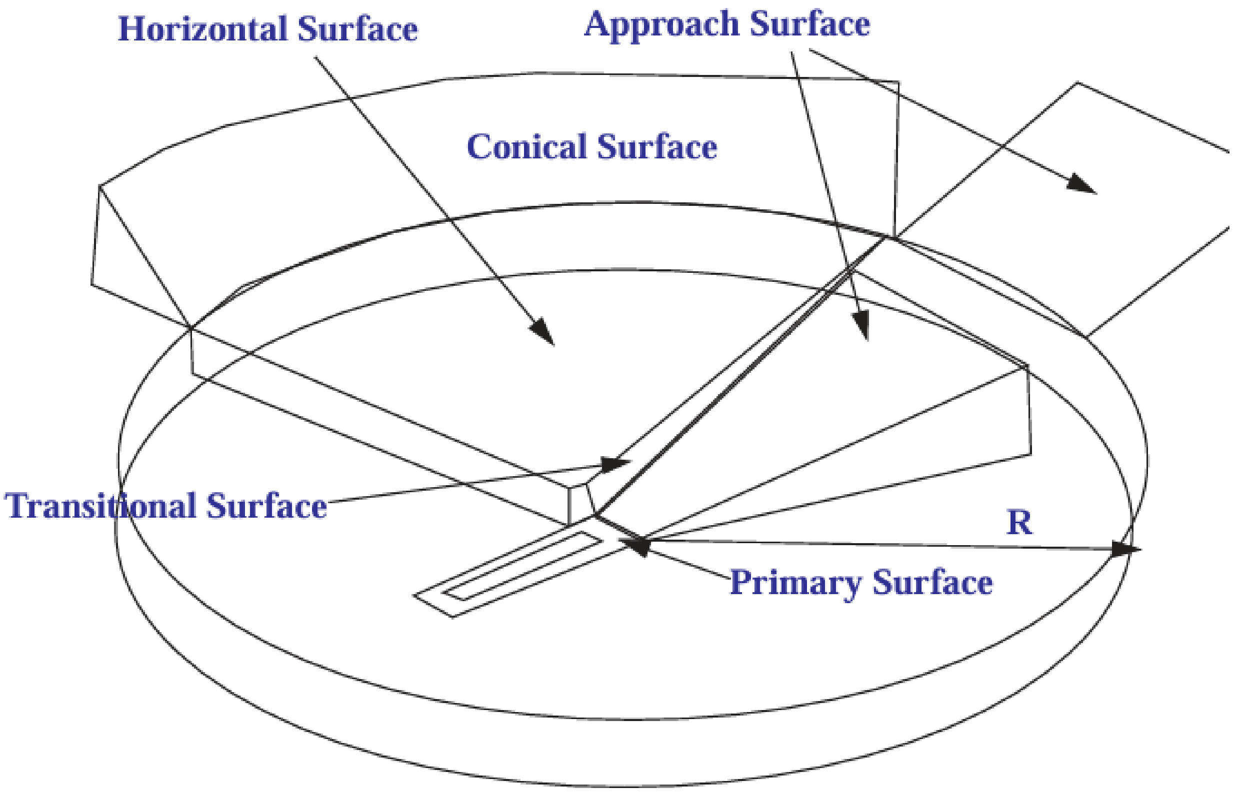
11.0 Taxiway Safety Area Grading

The new 30 foot shoulder areas will be graded at 1.25% cross-slope with a 1.5” drop at the outer pavement edge. All shoulders will be constructed with a cross-slope falling away from the taxiway pavement edge. The final ground surface for 10 feet from the shoulder outer edge will be graded at 5% cross-slope and the remaining Taxiway Safety Area ground surface will be graded 3% cross-slope for a minimum of 107 feet from taxiway Alpha centerline.   The new ground surface from the Taxiway Safety Area limits outward will be graded at 5:1 maximum slopes to match existing ground. See the Proposed Taxiway A Typical Section and Taxiway B Typical Section.

Taxiway X-ray will be realigned to a 90-degree intersection with Taxiway Alpha and lead into the Signature Ramp (FBO) from the north. This taxiway will be designed as a Group IV taxiway. This new taxiway will be 50 feet in nominal width with asphalt shoulders. The Taxiway Safety Area for this connector will be 171 feet total.

12.0 Imaginary Surfaces Evaluation

Federal Regulation 49 CFR Part 77 establishes standards and notification requirements for objects affecting navigable airspace. These surfaces include but are not limited to, Primary Surface, Approach Surface, Transitional Surface, Horizontal Surface, and Conical Surface.



Previously, the elevation difference between the Signature FBO ramp and the existing taxiway Alpha exceeded the allowable 1.5% centerline grade for a 90-degree connection so it was instead connected at an acute angle. The design and reconstruction of Taxiway Alpha raised the proposed profile of the new taxiway Alpha by approximately 4 feet in the vicinity of the new tie-in to the Signature Ramp FBO Apron to facilitate a perpendicular intersection.

Primary Surface

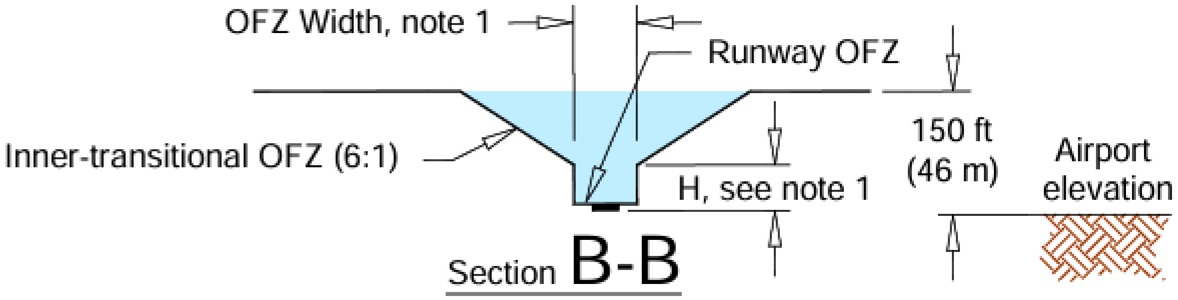
The FAR Part 77 Primary Surface for Runway 9-27 is a horizontal surface extending 1,000 feet wide (500’ each side of the runway centerline) and rectangular in shape and begins and ends 200’ past the threshold on each end. The elevation of any point on the Primary Surface is the same as the elevation of the nearest point on the runway centerline. At 500’ from the centerline, the Primary Surface then begins to rise at a rate of 7H:1V. The Primary Surface elevation varies along the centerline of Alpha relative to the profile of the runway.

PIA – Precision Instrument Approach surface begins 200 feet past the runway 9-27 threshold at the threshold elevation and rises at a rate of 50H:1V (2% grade) for a horizontal distance of 10,000 feet.

IT-OFZ Alpha lies within the Inner Transitional Object Free Zone of Runway 9-27. Taxiway Alpha is a parallel taxiway to Runway 9-27 with approximately 600’ of separation between them. The Runway Object Free zone (ROFZ) is centered about the runway centerline and is 400’ wide and follows the elevation of the runway centerline. No object may be within this clearing surface unless it is mounted in a frangible manner and fixed by function.

Diagram below shows a cross-section of the OFZ and IT-OFZ. Runway 9-27 supports approach visibilities of lower than ¾ mile (1.2 Km) but not lower than ½ mile (0.8 Km). To calculate the value of “H”, $H_{feet} = 61 - 0.094(S_{feet}) – 0.003(E_{feet})$, where S is equal to the most demanding wingspan of the RDC of the runway, E is equal to the runway threshold elevation above sea level. In our case, H = 61 – 0.094(211.5’ Boeing 747 wingspan) – 0.003(251.5). H_{feet} = 40.37’.

Since Taxiway Alpha is approximately 600’ south of Runway 9-27, a Boeing 747 plane taxiing along Alpha with a tail height of 63.5’ will still be approximately 43’ under the IT-OFZ of Runway 9-27 when taxiing along Alpha.

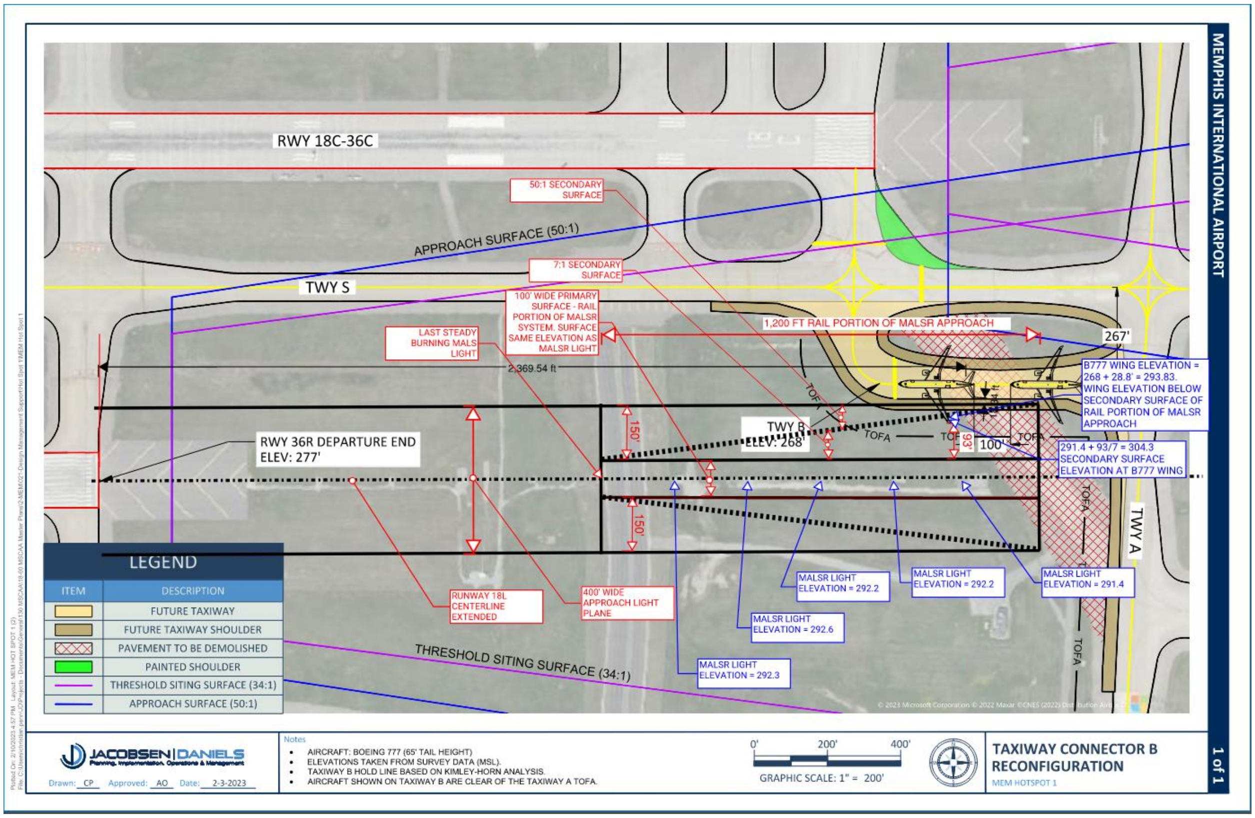


Visibility - Lower than 3/4 mile (1.2 Km) but not lower than 1/2 mile (0.8 Km)

Taxiway Bravo Realignment – Hot Spot 1

The realignment of Taxiway Bravo to eliminate the Hot Spot 1 presented an additional clearing surface to be evaluated. The MALSR for 18C extends north towards Alpha and existing diagonal Bravo. The realignment of Bravo required the analysis of the Approach Light Plane (ALP) of 18C to maintain and ensure visibility of all the lights in the MALSR to planes on approach if there were planes queued on realigned Bravo waiting for take-off. The typical installation of an ALS RAIL is that all sequence flashing lights be in a horizontal light plane with no obstruction penetrating the primary and secondary RAIL planes. The primary plane of the RAIL system begins at the last steady-burning light of the MALS portion and extends 200 feet beyond the last flashing light in the RAIL portion of the MALSR system. The primary plane has a total width of 100 feet, 50 feet each side of the extended runway centerline, and a surface that follows the plane of the MALSR RAIL System.

Beginning at the edge of the primary plane, a secondary plane having a slope of 7:1 extends outward from the edge of the primary plane for a distance of 150 feet. Both primary and secondary planes begin at the last steady-burning lights of the MALSR system and extend 200 feet beyond the last flashing light in the RAIL portion of the MALSR system. An additional secondary plane underlies the 7:1 plane, with a longitudinal slope of 50:1, beginning at the height of the last steady-burning light and extending outward (laterally) to 150 feet from the edge of the primary plane at zero gradient. The surface extends longitudinally to 200 feet beyond the last flashing light of the RAIL system. Objects must not penetrate either the primary or secondary plane. See diagram below for specifics of the 18C MALSR System and corresponding elevations of the horizontal ALP. In our case the B777 Wing elevation is below the transitional section.



Notes
- AIRCRAFT: BOEING 777 (65' TAIL HEIGHT)
- ELEVATIONS TAKEN FROM SURVEY DATA (MSL).
- TAXIWAY B HOLD LINE BASED ON KIMLEY-HORN ANALYSIS.
- AIRCRAFT SHOWN ON TAXIWAY B ARE CLEAR OF THE TAXIWAY A TOFA.

13.0 Drainage Design

The existing storm water runoff flows to existing grassed open ditch areas on each side of Taxiway A. The stormwater is collected and routed generally northward toward Nonconnah Creek north of the Airport. The storm water is carried via RCP storm drain piping and RCBC (Reinforced Concrete Box Culverts) to a collection system which eventually routes through FedEx's Hub, under Democrat Road, and discharges into Nonconnah Creek. This project will replace all drainage piping that crosses under the reconstructed areas of Taxiway Alpha with Class V Reinforced Concrete Pipes.

The grading and drainage plans will be in accordance with the FAA AC 150/5320-5D "Airport Drainage Design". Rainfall intensity data for pipe sizing and runoff calculations will be obtained from the Memphis and Shelby County Stormwater Management Manual.

14.0 Underdrains

New 4-inch underdrains will be installed in a herringbone pattern underneath the drainage layers of Taxiway Alpha and Taxiway Bravo. The 4" underdrains will be connected to larger 6" underdrain collection pipes and ultimately 6" laterals that will tie into nearby drainage system or daylight into grassed areas outside of the Taxiway Safety Area. The existing 6" underdrain collection system currently installed along the edges will be demolished.

15.0 Erosion Control

The project includes the construction of 30' paved shoulders each side of the taxiways and earthwork operations on the existing ground surfaces to fill and grade the slopes to meet the Taxiway Safety Area grading requirements. The earthwork operations will extend to a minimum of 107' each side of the taxiway centerline (85.5' for Taxiway X-ray) and new slopes at 5:1 will be graded to match existing ground elevations.

Based on a multiple phased project, a recommendation is made for the newly graded areas to be sodded.

The use of best management practices is required by the erosion control plan and specifications for control of erosion during construction. Erosion control devices to be installed to help control erosion include wattles, silt fence, temporary slope drains, inlet protection, and headwall protection will be utilized. All erosion control plans and specifications are in accordance with Tennessee Erosion and Sediment Control Handbook and the FAA AC 150/5320-5D "Airport Drainage Design".

16.0 Marking

The existing Taxiway centerlines consist of a 12” wide yellow reflective centerline with 6” wide non-reflective black borders. The centerlines of Taxiways N, X, C, S, and B are also along low-visibility SMGCS routes and will be 12” wide yellow reflective centerlines with 6” black borders and will be enhanced 150’ prior to the Runway 9-27 holding position marking.

Per FAA AC 150/5340-1M, the taxiway intermediate holding position marking is set back in accordance with the taxiway or taxilane centerline to fixed/movable object criteria (taxiway/taxilane object free area). These markings and corresponding geographic position markings (SMGCS) will be located 160’ from the centerline of Taxiway Alpha based on the requirement for objects to be outside the Taxiway Object Free Area for a Group V aircraft.

New taxiway edge markings will be provided along the taxiway and the optional 3’ wide taxiway shoulder markings will not be added at this time at the direction of MSCAA.

All taxiway centerline, holding position, edge lines, non-movement markings, and surface directional signage will be painted yellow with glass beads and non-reflective black borders.

The taxiway markings will be in accordance with the requirements of Advisory Circular 150/5340-1M “Standards for Airport Markings”.

17.0 Airfield Electrical

Taxiway Edge Lights

The existing taxiway edge lights and centerline lights along Taxiway A, C, S, and B, within project limits will be removed and new semi-flush LED edge lights and centerline lights will be installed. The existing demolition will include the lights, light cans, transformers and concrete base encasement. The existing underground conduit and conductor along the taxiways will be demolished and new conduit, conductor, and grounding system will be constructed.

The taxiway light and signage circuit conductors will tie-in to the existing circuits that will be intercepted in various handholes in close proximity to Airfield Electrical Vault #2 (See sheet E-LT-04).

Temporary electrical jumper conduit and conductor will be installed for each phase of the project to keep the edge light and signage circuits operational.

Airfield Signage

There is a current project that is replacing all the Airfield Signage with new LED signs and base foundations. Airfield Signage that is within our construction areas will be protected and covered on a phase by phase basis during construction. In instances where the sign is relocated, the contractor is removing/replacing the modular sign bases to the new locations. It is the preference of MSCAA to have the signage circuit separate from the edge light circuit.

Existing MSCAA and FAA Electrical Manholes

The existing MSCAA and FAA electrical and communication underground utilities have several existing manholes located near the existing taxiway pavement edges. The construction of new 30 foot wide shoulders and grading operations to meet the Taxiway Safety Area cross-slope requirements will require multiple manhole adjustments to raise the structures to the new final grades.

18.0 Project Construction Cost

The estimated project construction cost is based on cost data from recent construction projects and has been compiled by Connico.

The estimated probable construction cost is included in Appendix F.

Appendix A

Field Photos

Alpha @ November looking East

Typical Edge light on shoulder

Edge Light (existing)

Typical concrete joint and sealant

Existing underdrain cleanout (typical)

Looking north up Taxiway November at tie-in joint

Typical Delpatch Elastomeric Concrete repair (typical)

Delpatch surrounding existing cleanout

Existing centerline light can approximately 1.5’ off centerline stripe

Existing taxiway edge striping and shoulder striping at Alpha/November intersection

ILS Holding Position Sign @ Taxiway Alpha and November

Duct end marker along Taxiway Alpha @ November intersection

Existing Taxiway Signage (Typical)

Existing Inlet Grate near Taxiway Alpha/November intersection

Taxiway Guidance Sign

Airfield Electric Handhole

Fillet Panels

Runway 9 Localizer Antenna and access drive

Localizer and MALSR

Localizer and MALSR

Localizer and MALSR

Taxiway Edge Light and L-853 Blue Taxiway Reflector in the distance

Inch and a half drop off at existing PCC pavement/asphalt shoulder interface

Typical underdrain cleanout

Typical PCC joint

Centerline light along Taxiway Alpha approx..2’ from stripe

PCC Cracking

Glide Slope Antenna for Runway 9

Cracking along Alpha that has been routed and sealed

Crack/Edge Repair along centerline

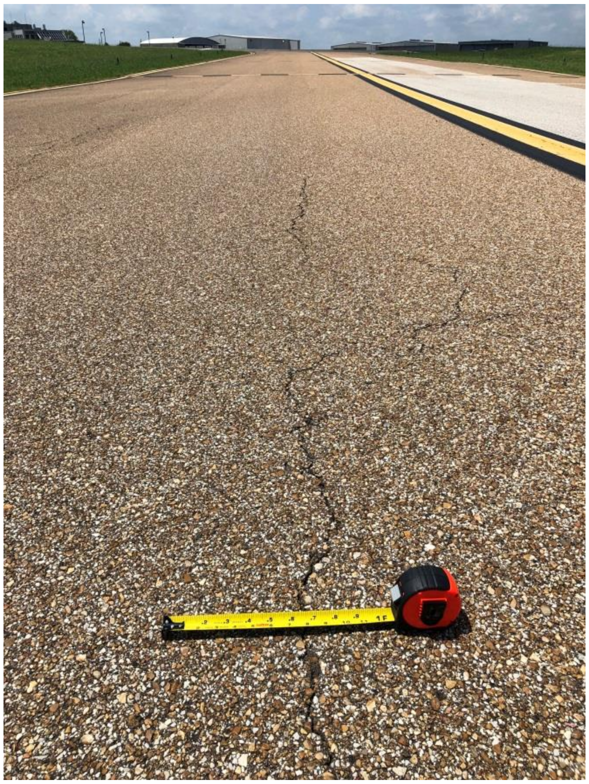
Grade differential at proposed tie-in with Taxiway X-Ray

Proposed taxiway tie-in at Signature Ramp for new Taxiway X-Ray

Signature Ramp GA Tie-down and Parking Area

Standing water (bird bath) at existing Taxiway X-Ray/Alpha intersection

Taxiway X-Ray looking Southwest towards Signature Ramp from Alpha



Longitudinal distress cracking in Taxiway X-Ray

Existing L-853 Blue Taxiway Edge Reflectors along Taxiway X-Ray

Taxiway X-Ray and Taxiway Alpha intersection looking towards Taxiway Charlie

Beginning of edge fillet for Taxiway Charlie

“Delpatch” Repairs along Taxiway Alpha near Taxiway Charlie

Taxiway Alpha intersection with Taxiway Charlie

Routed and Sealed longitudinal crack just south of centerline near Charlie

Delpatch corner break/spall repair

Geotechnical Boring # 6

Joint Spalling

Geotechnical Boring # 13

Along Taxiway Charlie looking north towards 9-27 Hold

Elevated Runway Guard light and LED Taxiway Edge Light

Taxiway Charlie repairs near 9-27 Hold

Taxiway Charlie @ 9-27 Hold looking north towards FedEx Hub

East fillet widening of Taxiway Charlie looking South towards Taxiway Alpha

Corner Repair along Taxiway Charlie

Extensive patching at Taxiway Charlie & Taxiway Alpha Intersection

Extensive patching at Taxiway Charlie & Taxiway Alpha Intersection

Extensive patching at Taxiway Charlie & Taxiway Alpha Intersection

Core Hole #7

Typical slab joint transition

In-pavement Runway Guard Lights @ 9-27 Hold

9-Way Can Plaza holding water

Elevated Runway Guard Light

Distressed Area at Taxiway Sierra Centerline north of Taxiway Alpha

Geotechnical Boring # 15

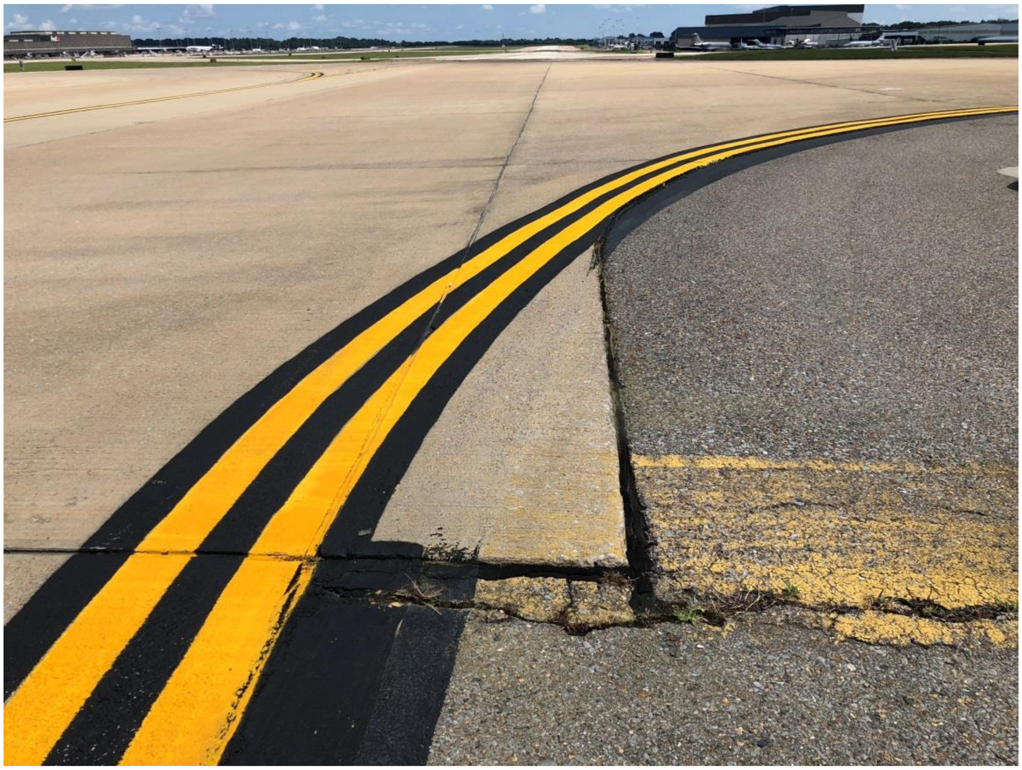
Crack Repair along Sierra looking South

Thickened-edge expansion joint along Taxiway Alpha

Repairs @ mid-intersection of Taxiway Sierra and Taxiway Alpha

PCC Panel Replacement on Taxiway Sierra looking South

Typical Taxiway Guidance Sign



Fillet widening along Taxiway Alpha for southern radius

4-Module sign

Delpatch repairs along Taxiway Bravo

Taxiway Bravo Delpatch Repairs with joint sealant

Geotechnical Boring #16

Existing shallow radius “pancake cans” installed at Bravo Intersection

Core Hole #11

Proposed tie-in joint at Taxiway Bravo Intersection (left half remains)

Proposed tie-in joint @ Bravo looking west. Right half remains

Taxiway Bravo @ Proposed tie-in joint (Right half remains)

Taxiway Alpha Centerline @ Bravo

Appendix B

Geotechnical Report

REPORT OF GEOTECHNICAL EXPLORATION

Taxiway Alpha West Reconstruction
Memphis International Airport
Memphis, Tennessee

Prepared For:
Allen & Hoshall
1661 International Drive, Suite 100
Memphis, Tennessee 38210

Prepared By:
K. S. Ware and Associates, L.L.C.
52 Lindsley Avenue, Suite 101
Nashville, Tennessee 37210

KSWA Project No. 100-19-0019

November 11, 2019

KSWA
K. S. Ware & Associates, L.L.C.
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52 Lindsley Avenue, Suite 101
Nashville, Tennessee 37210
Phone: 615-255-9702

November 11, 2019

Mr. Harry Pratt, PE
Allen & Hoshall
1661 International Drive, Suite 100
Memphis, Tennessee 38210

Subject: **Report of Geotechnical Engineering Services**
Taxiway Alpha West Reconstruction
Memphis International Airport
Memphis, Tennessee
KSWA Project No. 100-19-0019

Dear Mr. Pratt:

K. S. Ware & Associates, LLC (KSWA) is pleased to submit this report which provides the results of our pavement exploration for the Taxiway Alpha West Reconstruction project at the Memphis International Airport in Memphis, Tennessee. Our services were provided in general accordance with our proposal for Geotechnical Engineering Services dated December 18, 2018.

The attached report summarizes the project information provided to us, describes the site and subsurface conditions encountered, and details our geotechnical recommendations for the project. The Appendices include figures, descriptions of our field-testing procedures, and our field and laboratory test results.

We appreciate the opportunity to be of service to you on this project. Please contact us if you have any questions regarding this report. We look forward to serving as your geotechnical consultant on the remainder of this project.

Respectfully submitted,

K. S. Ware and Associates, L.L.C.

NATHAN LONG
REGISTERED ENGINEER
No. 111689
STATE OF TENNESSEE

Digitally signed by Nathan Long
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-06'00'

Bradley D. Kouchoukos

Bradley D. Kouchoukos, E.I.
Staff Professional

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Senior Geotechnical Engineer

Enclosures: Report of Geotechnical Exploration

Distribution: File (1)

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APPENDICES

1.0 INTRODUCTION

1.1 PROJECT INFORMATION

Our understanding of the project is based on information provided by Mr. Harry Pratt of Allen & Hoshall during multiple e-mail and telephone conversations throughout the project. The initial e-mail included a document titled “Exhibit A – Scope of Services”, which provided general project information and general requirements for the geotechnical study.

The project consists of reconstructing approximately 4,125 linear feet of Taxiway Alpha West at the Memphis International Airport. The reconstruction will extend from Taxiway November at the west end of Taxiway Alpha to east of Taxiway Bravo. The project will also include tie-ins along Taxiways November, Charlie, Sierra, and Bravo and along the Signature Ramp. The reconstructed taxiway will consist of new concrete pavement with asphalt shoulders. We understand full depth replacement of the existing pavement including the cemented base material is planned. The new taxiways will be designed for ADG Group V, while the Signature Ramp will be designed as ADG Group IV. We have assumed final pavement surface elevations will be similar to existing pavement surface elevations.

1.2 PURPOSE AND SCOPE OF EXPLORATION

The purpose of the exploration was to evaluate the subsurface conditions along the project alignment and provide geotechnical design recommendations for the project. Our scope of services was detailed in our proposal for Geotechnical Engineering Services, dated December 18, 2018.

Our geotechnical exploration services did not include sampling and testing of the soil, rock, surface water, groundwater, or air for the presence of environmental contaminants. Therefore, special procedures were not recommended for handling or managing sediments encountered during future construction or for handling the soil and rock samples from the borings in the geotechnical testing lab.

2.0 SITE GEOLOGY

2.1 GEOLOGIC FORMATION

Memphis International Airport is located in the Coastal Plain physiographic province. This province extends along the southeast and east coasts of the United States from the southern tip of Texas to the southern tip of Florida along the Gulf of Mexico and then extends north to New Jersey along the coast of the Atlantic Ocean. The Coastal Plain province generally lies along the coastal states but extends north from Louisiana and Mississippi through the eastern portions of Arkansas, the west portions of Tennessee, and the southern tip of Illinois. In Tennessee, the area between the Tennessee River and Mississippi River is considered to be part of the Coastal Plain province; there are three subcategories within this area. Starting from the east, along the western banks of the Tennessee River, is an approximately 10-mile wide section of hilly land which consists of sedimentary rocks overlain by residual soils (derived in place from weathering of the bedrock), alluvial soils (soils deposited by streams) locally, and about 4 feet of loess (wind-blown silts and clays). To the west of the hilly land is an area called the Tennessee Bottoms or the bottom land which extends to steep bluffs along the shores of the Mississippi River in Memphis. This area consists of rolling hills and streams formed from marine sediments consisting mainly of clays, silts and sands covered by loess at the surface. The loess can be up to 100 feet thick in the bluffs overlooking the Mississippi River; however, the loess can also be absent where streams have eroded these soils and filled the stream valley with alluvium. The third section is called the Mississippi Alluvial Plain. This area is west of the Tennessee Bottoms and consist of lowland areas, flood plains, and swamp land typically less than 300 feet above sea level.

The Surficial Geologic Map of the Southeast Memphis Quadrangle, Shelby County, Tennessee indicates the airport is underlain by loess and artificial fill. The late Pleistocene-aged loess deposits include wind-blown sediments consisting of generally of clayey silt brown and light-brown in color. These soils are relatively strong and stable when the water content is near the soil's Plastic Limit but become soft and unstable if the water content moves above the Plastic Limit. Artificial fill in Memphis typically consists of brown silt to clayey silt, but can also include construction debris, organics, and other deleterious materials. The strength, compressibility, and stability of artificial fill subgrades depend on the fill material type, lift thicknesses, water content, and compaction effort applied during placement.

2.2 SOIL SURVEY

The soil survey of Shelby County, Tennessee, downloaded from the United States Department of Agriculture website[1] indicates the soil types across Taxiway Alpha consist of Graded land (Gr). This land type consists of developed areas that primarily consisted of Grenada, Loring, and Memphis soils prior to grading. Typical engineering classifications for these soils include clays (CL), clayey silts (ML), and non-plastic sands (SC) by the Unified Soil Classification System (USCS) classification and A-4, A-6 and A-7 by American Association of State Highway and Transportation Officials (AASHTO) classification.

1- http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.asp

3.0 EXPLORATION PROCEDURES AND FINDINGS

3.1 GENERAL

We performed our subsurface exploration and field testing between May 8, 2019 and May 15, 2019, excluding the weekend days. Our proposed exploration consisted of coring through the existing pavement and cemented base material at 29 locations (13 coreholes and 16 borings) and extending the borings to a depth of 10 feet below existing grade. Due to limited access to the Memphis Airport property, we were unable to complete five of the proposed coreholes (C-3, C-5, C-6, C-11, and C-12) and two of the borings (B-7 and B-15).

The boring and corehole locations were marked in the field by Allen & Hoshall's surveying subcontractor prior to us arriving on-site. We had to offset some of the exploration locations due to underground utilities identified in the vicinity of the planned exploration locations. The corehole and boring locations shown on the Exploration Plan in Appendix A should be considered approximate. Additional discussion regarding the field procedures used during this exploration are provided in Appendix B.

3.2 SURFACE AND SUBSURFACE CONDITIONS

The existing Taxiway Alpha West consisted primarily of concrete pavement underlain by a thin layer of bituminous pavement and a cemented base material. The pavement surface generally slopes gradually downward away from the taxiway centerline towards the pavement edge.

Pavement Section

Each of the pavement cores, completed within Taxiway Alpha West, encountered an initial layer of concrete pavement ranging in thickness from approximately 16 to 21-½ inches. Below the surficial concrete, we encountered bituminous pavement ranging in thickness from about 2-½ to 5-½ inches. At the pavement cores completed within the Signature Ramp (C-2 and B-13), the concrete core consisted entirely of bituminous pavement with a thickness of approximately 22 and 22-½ inches, respectively. Below the bituminous pavement in the pavement cores completed within Taxiway Alpha West, we encountered a cemented base material ranging in thickness from 2 to 8-½ inches. We anticipate a cemented base material is present beneath the Signature Ramp as well; however, due to the limited number of borings completed within this area, it could not be confirmed that a cemented base material is present. We note that the cement treated base was not recovered during pavement coring, and we estimated the thickness based on the drilling observations. Table 1 on the following page includes the concrete pavement, bituminous pavement, and cemented base approximate thicknesses encountered at the 23 locations.

Table 1: Pavement Section Thicknesses

Corehole / Boring No.	Concrete Pavement Thickness (in.)	Bituminous Pavement Thickness (in.)	Cemented Base Thickness (in.)	Total Pavement Thickness (in.)
C-1	18.0	4.0	NA	NA
C-2	0.0	22.0	NA	NA
C-4	18.0	NA	NA	NA
C-7	18.0	2.5	NA	NA
C-8	21.5	NA	NA	NA
C-9	17.5	2.5	NA	NA
C-10	18.0	3.0	NA	NA
C-13	19.0	2.5	NA	NA
B-1	18.5	3.5	4.0	26.0
B-2	18.0	4.0	4.0	26.0
B-3	18.0	5.0	3.0	26.0
B-4	18.0	4.0	4.0	26.0
B-5	18.0	4.5	3.5	26.0
B-6	20.5	3.5	2.0	26.0
B-8	17.5	2.5	6.0	26.0
B-9	16.0	3.0	7.0	26.0
B-10	18.0	3.5	8.5	30.0
B-11	17.5	3.5	8.0	29.0
B-12	17.5	3.0	5.5	26.0
B-13	0.0	22.0	NA	22.5
B-14	18.0	3.0	3.0	24.0
B-16	19.0	3.0	2.0	24.0
AVG	**18.3****	**3.3***	**4.6**	**26.2**

*Bituminous pavement thickness within coreholes should be considered as minimal values. Due to limitations of coring equipment and thickness of overlying concrete pavement, the exact total bituminous pavement thickness could not be confirmed.

**Concrete pavement and bituminous pavement thickness averages neglect coring C-2 and boring B-13, which consisted entirely of bituminous pavement.

Existing Fill

Beneath the pavement section, Borings B-6 and B-16 encountered existing fill to respective depths of 5-½ and 6 feet. The fill at Boring B-6 consisted of very loose sandy silt (ML), and the fill at Boring B-16 consisted of stiff lean clay (CL).

Native Soils

Below the existing fill at Borings B-6 and B-16 and below the pavement section at the remaining borings, we encountered native soils to the boring termination depth of 10 feet. The native soils generally consisted of soft to stiff lean clays (CL) with a layer of very loose to medium dense silt (ML) generally present in the borings between approximate depths of 5-½ and 8 feet.

Groundwater

The majority of the borings were dry during our exploration. However, we encountered groundwater at an approximate depth of 8 feet during drilling operations at Borings B-1 and B-3. We backfilled the borings upon completion for safety precautions, so delayed groundwater measurements were not taken. Groundwater levels will differ depending on the time of year, climatic conditions, and construction activities. Perched groundwater conditions may develop within the overburden soils during seasonal wet periods of the year and after heavy precipitation events.

4.0 LABORATORY TESTING

KSWA performed laboratory testing on representative split-spoon, Shelby tube, and bulk soil samples in general accordance with ASTM procedures. The laboratory testing included:

- Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass (ASTM D2216)
- Standard Test Methods of Liquid Limit, Plastic Limit, and Plasticity Index (ASTM D4318)
- Standard Test Method for Determining the Amount of Material Finer than 75-µm (No. 200) Sieve in Soils by Washing (ASTM D1140)
- Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates (ASTM C136/C136M)
- Standard Test Method for Laboratory Compaction Characteristic of Soil Using Modified Effort (ASTM D1557)
- Standard Test Method for California Bearing Ratio (CBR) of Laboratory-Compacted Soils (ASTM D1883)

The moisture content data and Atterberg limit are presented on the individual boring logs in Appendix B. Laboratory test reports for grain size analysis, Modified Proctor, and CBR tests are within the Appendix C.

Table 2: Summary of Soil Laboratory Test Results

Boring No.	Sample Type	Sample Depth (ft)	Modified Proctor		CBR	LL (%)	PI (%)	Percent Passing #200 Sieve (%)	Unconfined Compression (psf)	USCS Class.
			Max. Dry Density (lbs/ft^3)	Optimum Moisture (%)						
B-1	ST	6 to 8	-	-	-	NP	NP	98.0	1,440	ML
B-2/B-5	Bulk	0 to 10	116.5	13.9	9.5	36	14	89.1	-	CL
B-3	ST	6 to 8	-	-	-	NP	NP	98.1	1,920	ML
B-5	SS	3.5 to 5	-	-	-	42	24	91.0	-	CL
B-8/B-10	Bulk	0 to 10	118.2	12.6	7.0	33	10	97.0	-	CL
B-9	ST	3.5 to 5.5	-	-	-	NP	NP	81.4	-	ML
B-11	ST	6 to 8	-	-	-	NP	NP	99.0	1,420	ML
B-12	SS	3.5 to 5	-	-	-	37	13	92.3	-	CL
B-12	Bulk	0 to 10	120.9	12.2	6.0	33	11	71.3	-	CL
B-13	SS	3.5 to 5	-	-	-	35	13	93.3	-	CL

*Bulk samples consist of soil material beneath pavement section and cemented base material

**Unconfined compression strength test samples were determined to be silt (ML) based on grain size analysis and Atterberg Limit testing. It should be noted, unconfined compression strengths of silt (ML) may not be representative of the soils strength due to lack of cohesion.

5.0 GEOTECHNICAL CONSIDERATIONS

5.1 GENERAL

The conclusions and recommendations presented herein were developed based upon our engineering reconnaissance of the site, the field test results, a visual examination of the samples recovered, laboratory tests on selected samples, our understanding of the proposed construction, and our experience. The conclusions and recommendations presented in this report have been derived by relating the general principles of the discipline of geotechnical engineering to the proposed construction outlined in the Project Information section of this report. Because changes in surface, subsurface, and climatic conditions can occur, the use of this report must be restricted to this specific project.

Our understanding of the proposed design and construction is based on the documents provided to us at the time this report was prepared and information referenced in the Project Information section of this report. We recommend we be consulted to review the final design documents, plans, and specifications to check the conclusions and recommendations of this geotechnical report have been interpreted correctly. Any changes or modifications which are made in the field during the construction phase which alter site grading, structure locations, infrastructure, or other related site work should also be reviewed by our office.

If conditions which vary from the facts of this report are encountered in the field during construction, we recommend the Geotechnical Engineer of Record be contacted immediately to review the changed conditions in the field and make appropriate recommendations.

5.2 SUBGRADE SUITABILITY

Based on the project information provided and the available subsurface data, it is our opinion the site is suitable for the planned reconstruction. The subgrade materials below the existing pavement generally consists of firm to stiff lean clay with some soft zones. Soft to firm soils are frequently unstable under a proofrolling load. Additionally, the moisture content of the near-surface soil samples was frequently higher than the optimum moisture content of the bulk samples tested. Soils with a relatively high moisture content are also frequently unstable under a proofrolling load.

The stability of the near-surface soils will likely be impacted by exposure to moisture and/or construction traffic, once the pavement materials have been stripped to prepare the site for construction. The near-surface soils consist of either existing fill or native loess. Loess is typically extremely sensitive to changes in moisture content. Dry loess materials are generally stable and will exhibit favorable strength characteristics. Conversely, when these soils are moist, as a result of local precipitation or climatic conditions, the soils become weak and unstable, particularly under repeated loading from heavy construction equipment. Also, due to the silt content of these soils, they can degrade rapidly even when favorable moisture conditions are present. Therefore, regardless of the time of year construction takes place, some remedial repair of weak subgrades will likely be required.

If construction occurs during warm, dry weather months, it may be possible to repair shallow instability through scarifying, moisture conditioning, and recompacting the upper 8 to 12 inches of subgrade. However, this process will likely not be practical during cooler, wet weather months when moisture conditioning can be problematic. During wet weather, it may be necessary to undercut unstable soils and use a borrow source to haul in drier soils for backfilling. If widespread subgrade instability is present, stabilizing the subgrade with cement is an option that may be considered (cement stabilization is typically more cost-effective over larger areas). KSWA recommends that a budget be established for subgrade repairs consistent with the time of year construction takes place.

5.3 PAVEMENT DEMOLITION

We understand that the taxiway pavements will be completely demolished and removed, which will include the underlying asphalt and cement treated base. We expect the amount of materials removed will be significant. The existing concrete can potentially be used for other functions, such as P-219 recycled concrete aggregate base, if the demolition methods allow for such crushing and gradation. Detailed analysis of the demolished materials would be required prior to use and approval.

6.0 GEOTECHNICAL EVALUATION & RECOMMENDATIONS

As stated in the Project Information section of this report, we understand the airport plans to complete a full-depth reconstruction of the existing concrete pavement along Alpha West Taxiway and tie-ins at four intersecting taxiways and the Signature Ramp. If the information contained in Project Information section changes, we recommend KSWA be contacted to confirm our design and construction recommendations are appropriate, in consideration of the new available information.

6.1 GENERAL PAVEMENT RECOMMENDATIONS

Based on our observations and classifications made in the field and tests performed in the laboratory, KSWA is providing the following pavement design parameters and general pavement recommendations.

As discussed in the previous section, remediation of soft to firm subgrade soil prior to final grading and paving should be expected. The stabilization method, the lateral extent, and the depth will depend on actual conditions exposed during construction and on actual grading plans for the pavement areas. On-site recommendations should be made by the geotechnical engineer-of-record or his representative. Additionally, we recommend that the upper 12 inches of the subgrade materials be compacted to at least 100 percent of the maximum dry density as determined by the modified Proctor test in accordance with Federal Aviation Administration's (FAA) Standard Specifications for Construction of Airports, dated December 21, 2018, Section 152-2.10.

6.2 PAVEMENT DESIGN RECOMMENDATIONS

The design CBR and subgrade modulus values are highly dependent on the type of near surface material and the level of compaction. Based on the limited information obtained from our field exploration, our laboratory testing, and our experience with similar soil conditions, KSWA recommends using a CBR value of 7 and a subgrade modulus of 150 pounds per cubic inch (pci) for the existing subgrade compacted to 98 percent of the Modified Proctor (ASTM D1557) maximum dry density within the upper 12 inches of subgrade.

Pavements and base courses may be placed after the subgrade has been properly compacted, fine graded, and proofrolled as recommended in the Construction Considerations section of this report. All activities should be accomplished in accordance with FAA Standard Specifications for Construction of Airports. Actual pavement section thickness should be determined by the designer based on actual loads, traffic volume, and the owner's design life requirements.

Experience has shown most pavement failures are caused by localized soft spots in the subgrade or inadequate drainage. Proof rolling, under the observation of our geotechnical engineer, will greatly reduce the incidents of weak spots in the subgrade. However, the civil design must include proper drainage to reduce softening of the subgrade, frost damage, heaving, soil migration, and pumping failures. The pavement surface and subgrade should have a minimum slope of 2 percent. Water infiltrating the mineral aggregate base should be designed to drain into catch basins (through weep holes), out-slope areas, or drainage trenches.

The soils exposed at the pavement subgrade level may be moisture sensitive. Experience indicates there is typically an extensive time lag between the time grading is completed and pavement construction occurs (i.e. grading may occur during hot, dry weather and pavement construction may occur during wet, cool weather). Once grading has been performed, the subgrade may be disturbed throughout the construction process due to utility excavations, construction traffic, desiccation, or rainfall. As a result, the pavement subgrade may become unsuitable for pavement construction over time and corrective action may be required. The subgrade should be carefully evaluated at the time of pavement construction by proof rolling with a heavily-loaded tandem-axle dump truck. Particular attention should be given to high traffic areas that displayed distressed and to areas where backfilled trenches are located.

Design pavement section thicknesses are typically determined based on post-construction traffic loading conditions, which do not account for heavy construction traffic during the early stages of development. A partially constructed structural section subjected to heavy construction traffic can result in pavement deterioration and premature failure. Our experience indicates this pavement construction practice can result in pavements which will not perform as intended. Considering this information, several alternatives are available to mitigate the impact of heavy construction traffic on the pavement construction. These include using thicker sections to account for construction traffic, using some method of stabilization to improve the support characteristics of the pavement subsurface, or by routing heavy construction traffic around paved areas using a “haul road” constructed for that purpose.

Maintenance is essential to good long-term performance of rigid and flexible pavements. Any distressed areas should be repaired promptly to prevent the failure from spreading due to loading and water infiltration.

7.0 CONSTRUCTION CONSIDERATIONS

7.1 SITE PREPARATION

Site preparation should initially include removing the existing concrete pavement, underlying bituminous pavement, and underlying cemented base material. Additionally, any topsoil or soils containing organic content should be removed in their entirety from any new planned pavement areas. At the completion of these activities, the subgrade should be evaluated as follows:

- Recompacting the upper 12 inches of exposed subgrade materials to 95 percent of the maximum dry density (100 percent if within 12 inches of the final subgrade elevation).
- Perform proof rolling prior to any fill or base material placement in fill areas and/or following cuts to grade in cut areas.
- Proof rolling should be performed using a fully-loaded tandem-axle dump truck or other rubber-tired equipment judged suitable by the geotechnical engineer.
- Our geotechnical engineer or his representative should observe proof rolling activities.
- Remediate soft, organic, or yielding subgrade materials encountered during the proof rolling operations as recommended by our geotechnical engineer.

7.1.1 Stabilization of Weak Soils

If areas of instability remain after scarifying and recompacting the existing soil in place, other options may be considered for stabilizing weak subgrade areas. These options are briefly described below.

- Scarify and Recompact – It may be possible to stabilize near-surface soils that are unstable due to excessive moisture by scarifying the unstable soils, allowing them to dry, and recompacting them in accordance with structural fill criteria. This process can be successful during hot, dry periods and when the construction schedule is flexible. Drying the soils can be problematic during cold, wet weather or when the construction schedule is not flexible.

- Undercut and Replace – This method involves the excavation of the soft/unstable soils until stiff soils are exposed. The undercut is then backfilled with compacted soil.

- Undercut and Stabilize with Geotextiles and/or Geogrids and Granular Fill – After the undercut surface has been made smooth, geotextiles and/or geogrids can be placed across the surface, followed by placement of granular fill (size and gradation of granular fill to be compatible with the geotextile/geogrid selected). Once a stable surface has been achieved, additional structural fill may be placed, if required.

- Stabilize with Cement or Lime Admixtures – Cement or lime stabilization is performed by a specialty contractor who mobilizes to the site, mixes the soils with cement or lime, and replaces and compacts these soils to the planned subgrade elevation. This stabilization method dries and treats the soils to provide a stable subbase.

As previously noted, the near-surface soils consist of loess. The stability of these soils is a function of the soil's water content. Experience indicates soils with water contents near the soil's Plastic Limit (usually in the teens) are typically strong and stable. Soils with water contents several points above the Plastic Limit are often weak and unstable. Some remedial subgrade work should be expected based on the water contents near ground level at the time of this exploration.

Protection of the subgrade is a critical issue for maintaining the stability of subgrades formed in loess. Positive surface drainage should be maintained throughout construction. Areas which break down because of construction traffic or exposure to moisture should be repaired to prevent the failed area from spreading. Heavy equipment such as concrete trucks should be restricted to using construction roads specifically prepared for that purpose. Such roads can consist of 2 or more feet of crushed stone or crushed concrete. Soil-cement is also a viable alternative.

7.2 COMPACTED FILL RECOMMENDATIONS

Once the subgrade has been properly prepared, compacted fill may be placed in accordance with the recommendations provided below to attain final desired construction elevations. Fill operations should not begin until representative soil samples are collected and tested (allow 3 to 4 days for sampling and testing). The test results will be used to determine whether the proposed fill material meets the specified criteria and for quality control during grading. Fill placement and compaction should be observed by a geotechnical representative on a full-time basis. Our limited laboratory testing indicates most of the on-site soils meet the criteria recommended below. Materials from both on-site and off-site sources proposed for use as structural fill should meet the criteria provided below.

- Liquid Limit less than 50
- Plasticity Index less than 25
- Maximum dry density (ASTM D1557) of 95 pcf or greater
- Free of large rock fragments (greater than 3 inches in diameter) and organic materials (less than 5 percent by weight)
- Amount of rock fragments retained on a 3/4-inch sieve should be less than 30 percent by weight

Structural fill should be placed and compacted using the following criteria:

- Soil fill should be placed in lifts of uniform thickness. The loose lift thickness should not exceed the amount which can be properly compacted throughout its entire depth with the equipment available, usually no more than 8 inches for cohesive material. In confined areas such as utility trenches, lift thicknesses of 3 to 4 inches may be required to achieve the recommended degree of compaction.
- Fill should be properly keyed into stripped and scarified subgrades. The upper one foot of remaining materials in cut areas or in areas which do not receive more than one foot of new fill should be scarified and recompacted using the guidelines outlined in this report section.

- So a positive tie is created along the interface of engineered fill and sloping ground (steeper than 4H:1V), we recommend the host slope be benched as the fill is placed. For this project, benching is defined as grading a saw tooth or terrace configuration into the slope. In general, at a minimum, we recommend benches should be about three feet tall and a minimum of eight feet wide, although some modification to bench geometry is permissible based upon conditions observed at particular locations. Further, fill placement should begin at the bottom of the slope and the working fill surface should be maintained approximately horizontal.
- Fill should not be placed on frozen or saturated subgrades.
- Based on the FAA Standard Specifications for Construction of Airports, dated December 21, 2018, Section 152-2.10 Compaction requirements, the top 12 inches of the pavement subgrade must be compacted to not less than 100 percent of the maximum dry density as determined by the Modified Proctor (ASTM D1557) and to within 2 percent of optimum moisture content immediately prior to paving. Additionally, the subgrade in areas outside of the limits of the pavement areas should be compacted to a depth of 12 inches to a density not less than 95 percent of the maximum dry density as determined by a Standard Proctor (ASTM D698). Additionally, the compacted fill should be stable under the moving load of a loaded tandem-axle dump truck.
- Density tests should be performed at a frequency of no less than one test per 5,000 square feet for pavement areas for each fill layer placed, with a minimum of two tests per lift. For utility trenches, one density test should be performed every 50 linear feet for each one-foot thick fill layer placed, with a minimum of two tests per lift. Any areas not meeting the recommended compaction should be reworked and recompacted to achieve compliance. The recommended test frequencies are for preliminary planning and should be adjusted in the field to account for material variability, rate of placement, weather and other factors.
- The soils should be placed near (within two percent of) the optimum water content (ASTM D1557). Aeration (i.e., drying) is often necessary to bring fill materials to the required water content during wet and rainy periods. During dry periods, water may need to be added to achieve the proper water content for compaction. Clayey and silty soils may require aeration prior to compaction, even during dry periods. The water content testing performed during this exploration suggests some of the on-site soils are significantly above the optimum water contents.
- Soil slopes should be protected from erosion by seeding, sodding, or other means, and surface run-off should be diverted away from slopes. For erosion protection, grass or other vegetation should be established on permanent slopes as soon as practical.
- Compacted soil fill embankments should be constructed no steeper than a ratio of 3 horizontal to 1 vertical (i.e., 3H:1V). We also recommend permanent cut slopes be constructed no steeper than 3H:1V.
- Compacted fills should extend horizontally outside of planned pavement areas at least 10 feet before sloping.
- Cut and fill slopes should be regularly evaluated during the construction for indications of movement.
- Excavations should be constructed in accordance with applicable Occupational Safety and Health Administration (OSHA) regulations.

7.3 GENERAL EARTHWORK CONSIDERATIONS

During earthwork operations, positive surface drainage should be maintained to prevent water from ponding on the exposed ground surface. The exposed subgrade may be rolled with a rubber-tired or steel drummed roller to improve surface run-off if precipitation is expected. Our geotechnical engineer should be consulted if the subgrade soils become excessively wet or dry, or frozen.

7.4 GROUNDWATER CONTROL RECOMMENDATIONS

Groundwater was not generally encountered in the borings, except for Borings B-1 and B-3, which encountered groundwater at a depth of 8 feet below the existing ground surface. We anticipate in most cases, depending on seasonal conditions, any seepage encountered can be handled by conventional dewatering methods (i.e., pumping from small sumps located near the source or in collector areas). If larger quantities of groundwater are encountered, the Geotechnical Engineer should be contacted.

8.0 QUALIFICATIONS OF RECOMMENDATIONS

The recommendations provided herein were developed in part using the subsurface information obtained from the pavement corings and soil test borings advanced at the site. Soil test borings depict the soil conditions only at the specific location and time at which they were completed. The soil conditions at other locations on the site or at other times may differ from those occurring at the boring locations.

The scope of this geotechnical exploration did not include assessment or exploration for the presence or absence of hazardous or toxic materials in the soil, rock, groundwater, surface water, or air within or beyond the site. Any statements in this report or indicated on the test boring logs regarding odors, staining of soils, or other unusual conditions observed are strictly for the information of KSWA's client.

KSWA's professional services were performed, findings obtained, and recommendations prepared in accordance with generally accepted geotechnical engineering principles and practices. KSWA is not responsible for the conclusions, opinions, or recommendations made by others based upon the data included herein.

KSWA's services include retaining the soil samples obtained during this study for 30 days after report submittal. Further storage or transfer of the samples can be made at the Client's expense upon a written request.

APPENDIX A

EXPLORATION PLAN

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

N

NOT TO SCALE

JOB NO. 100-19-0019

CLIENT: Allen & Hoshall

PROJECT NAME:
Taxiway Alpha West
Reconstruction

DATE: 6/12/19

Exploration Plan

Memphis International Airport
Memphis, Tennessee

DRAWN BY: BK

REVIEWED BY: NL

LEGEND

KSWA
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Figure 1

APPENDIX B

FIELD TESTING PROCEDURES
FIELD CLASSIFICATION SYSTEM
SOIL CLASSIFICATION CHART
TEST BORING LOGS
CORE PHOTOGRAPHS

FIELD TESTING PROCEDURES

Drilling, sampling, and testing were conducted in general accordance with methods of the American Society for Testing and Materials (ASTM) or other widely-accepted geotechnical engineering standards. Descriptions of the procedures used during this exploration are provided below.

BORING AND COREHOLE LOCATIONS AND ELEVATIONS

The boring and corehole locations were selected and marked in the field by the Client's surveying subcontractor prior to beginning our exploration. We located the exploration locations on the Exploration Location Plan by estimating distances and angles relative to on-site features. Surveying of boring and corehole coordinates was beyond the scope of our exploration and was performed by others.

TEST BORINGS
ASTM D 1586

Test borings were advanced using auger drilling techniques. At regular intervals, soil samples were obtained with a standard 1.4-inch I.D., 2.0-inch O.D., split-barrel sampler. The sampler was initially seated 6 inches to penetrate any loose cuttings and then driven an additional foot with blows of a 140-pound hammer falling 30 inches. The number of hammer blows required to drive the sampler the final foot is the *standard penetration resistance*, or N-value. Standard penetration resistance, when properly evaluated, is an index to the soil's strength and density. The criteria used during this exploration are presented on the Field Classification System sheet in this appendix. Representative portions of the soil samples obtained were placed in sealed containers and transported to our laboratory, where our engineer selected samples for laboratory testing.

The standard penetration tests were performed using an automatic hammer. The automatic hammer has a higher efficiency than the traditional rope and cathead hammer, thus yielding comparatively lower N-values. This reduction in N-value was accounted for during our engineering analysis. However, the consistencies presented on the boring logs were based on the customary relationships with N-value.

BORING LOGS

The soil samples obtained during the drilling were visually classified using the USCS as a guide (reference Soil Classification Chart in Appendix B). The Test Boring Logs in Appendix B provide the soil descriptions and penetration resistances, and represent our interpretation of the conditions encountered at each boring location. The stratification lines indicated on the boring records represent the approximate boundaries between material types, but these transitions may be gradual. The boring logs were prepared based on the field logs and review of the laboratory classification test results. The USCS designations indicated on the boring logs are based on visual-manual evaluation of the samples unless otherwise defined by laboratory testing.

The boring logs indicate estimated interfaces between soil strata. The interfaces indicated represent the approximate interface location, but the actual transition between strata may be gradual. Water levels indicated on the boring logs represent the conditions only at the time each measurement was taken.

FIELD CLASSIFICATION SYSTEM

Sands and Gravels

No. of Blows	Relative Density
0-5	Very Loose
6-10	Loose
11-30	Medium dense
31-50	Dense
51+	Very Dense

Silts and Clays

No. of Blows	Relative Consistency
0-2	Very Soft
3-4	Soft
5-9	Firm
10-15	Stiff
16-30	Very Stiff
31+	Hard

Particle Size Identification

Boulders:	8-inch diameter or larger
Cobbles:	3- to 8-inch diameter
Gravel:	
Coarse:	1- to 3-inch
Medium:	0.50- to 1-inch
Fine:	0.25- to 0.50-inch
Sand:	
Coarse:	2.00-mm to 0.25-inch (diameter of pencil lead)
Medium:	0.074-mm to 2.00-mm (diameter of broom straw)
Fine:	0.042-mm to 0.074-mm (diameter of human hair)
Silt:	0.002-mm to 0.042-mm (Cannot see particles)
Clay:	<0.002-mm

Relative Proportions

Descriptive Term	Percent
Trace	1-10
Little	11-20
Some	21-35
And	36-50

Relative Quality of Rock Cores

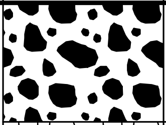
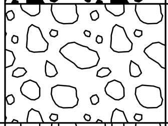
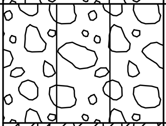
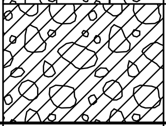
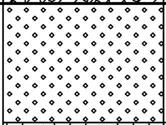
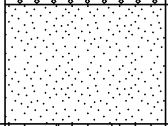
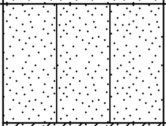
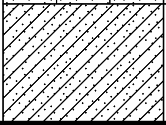
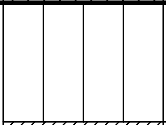
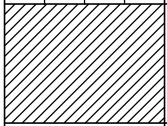
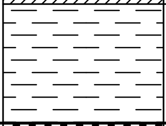
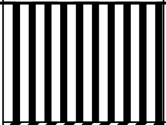
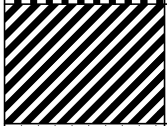
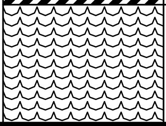
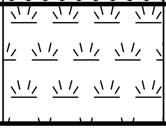
Quality	RQD
Very Poor	0-25%
Poor	25-50%
Fair	50-75%
Good	75-90%
Excellent	90-100%

$$\text{RQD} = \frac{\text{Total length of core recovered in pieces 4 inches long or longer x}}{\text{Total length of core run}} \text{ 100\%}$$

Rock Hardness

Very Soft	Rock disintegrates or easily compresses to touch; can be hard to very hard soil
Soft	Rock is coherent but breaks easily to thumb pressure at sharp edges and crumbles with firm hand pressure
Moderately Hard	Small pieces can be broken off along sharp edges by considerable hard thumb pressure; can be broken by light hammer blows
Hard	Rock cannot be broken by thumb pressure, but can be broken by moderate hammer blows
Very Hard	Rock can be broken by heavy hammer blows

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS		TYPICAL DESCRIPTIONS
			GRAPH	LETTER	
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
				SP	POORLY-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

KSWA BORING LOG

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BORING NO. B-01

PROJECT NAME: MSCAA Taxiway Alpha West
LOCATION: Memphis, TN
PROJECT NO.: 100-19-0019

Sheet 1 of 1

Approx. Surface El. (feet, MSL):
Location: **See Exploration Plan**

Depth, feet	MATERIAL DESCRIPTION	Samples	Recovery (%)	RQD (%)	SPT Values	N-Value	Pocket Pen (tsf)	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
0–1.6	CONCRETE (18.5 inches)										
1.6–1.8	ASPHALT (3.5 inches)										
1.8–2.2	CEMENTED BASE (4 inches)		100		50/2"						
2.2–5.5	LEAN CLAY (CL), little sand (upper 6"), oxidation, reddish black nodules, gray-brown, firm, moist		83		2-2-3	5	2.0	26.2			
5.5–8.0	SILT (ML), brown, loose, moist		83					30.2	NP	NP	NP
8.0–10.0	▽ LEAN CLAY (CL), oxidation, black nodules, gray-brown, soft, v. moist to wet		100		2-2-2	4	3.0	30.2			
10.0	BORING TERMINATED AT 10 FBGS										

Completion Depth (ft.): **10.0**
Date Started: **5/10/19**
Date Completed: **5/10/19**
Drilled By: **Geotechnology**
Logged By: **K. Andrus**

Remarks: **Groundwater encountered at an approximate depth of 8 feet during drilling operations. CME 55 Drill Rig. 6" Flight Auger. Backfilled with sand and patched with concrete.**

KSWA BORING LOG

KSWA
K. S. Ware & Associates, L.L.C.
Geotechnical • CEI • Environmental

BORING NO. B-02

PROJECT NAME: **MSCAA Taxiway Alpha West**
LOCATION: **Memphis, TN**
PROJECT NO.: **100-19-0019**

Sheet 1 of 1

Approx. Surface El. (feet, MSL):
Location: **See Map**

Depth, feet	Graphic Log	MATERIAL DESCRIPTION	Samples	Recovery (%)	RQD (%)	SPT Values	N-Value	Pocket Pen (tsf)	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
		CONCRETE (18 inches)										
1.5		ASPHALT (4 inches)										
1.8		CEMENTED BASE (4 inches)	☒	100		50/2"			12.4			
2.2		LEAN CLAY (CL), with silt, black nodules, gray-brown, stiff, moist										
4			☒	78		2-4-6	10	3.0	23.5			
5.5		SILT (ML), brown, v. loose, moist	☒	89		2-2-2	4	2.0	30.3			
8.0		LEAN CLAY (CL), with silt, black nodules, oxidation, gray, firm, moist	☒	78		1-2-3	5	2.0	31.1	35	22	13
10.0		BORING TERMINATED AT 10 FBGS										
12												
16												
20												

Completion Depth (ft.): **10.0**
Date Started: **5/10/19**
Date Completed: **5/10/19**
Drilled By: **Geotechnology**
Logged By: **K. Andrus**

Remarks: **CME 55 Drill Rig. 6" Flight Auger. Bulk Sample taken. Backfilled with sand and patched with concrete. Dry upon completion.**

KSWA BORING LOG

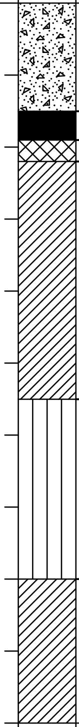
K. S. Ware & Associates, L.L.C.
Geotechnical • CEI • Environmental

BORING NO. B-03

PROJECT NAME: **MSCAA Taxiway Alpha West**
LOCATION: **Memphis, TN**
PROJECT NO.: **100-19-0019**

Sheet 1 of 1

Approx. Surface El. (feet, MSL):
Location: **See Map**



Depth, feet	MATERIAL DESCRIPTION	Samples	Recovery (%)	RQD (%)	SPT Values	N-Value	Pocket Pen (tsf)	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
	CONCRETE (18 inches) 1.5										
	ASPHALT (5 inches) 1.9										
	CEMENTED BASE (3 inches) 2.2	☒	0		50/2"						
4	LEAN CLAY (CL), black nodules, oxidation, light brown with gray streaking, firm, moist 5.5	☒	78		2-4-4	8	4.5	25.6			
	SILT (ML), brown, loose, moist 8.0	■	88					28.9	NP	NP	NP
8	▽ LEAN CLAY (CL), black nodules, oxidation, brown with light gray mottling, soft, wet 10.0	☒	100		1-1-2	3	2.0	34.0			
	BORING TERMINATED AT 10 FBGS										
12											
16											
20											

Completion Depth (ft.): **10.0**
Date Started: **5/10/19**
Date Completed: **5/10/19**
Drilled By: **Geotechnology**
Logged By: **K. Andrus**

Remarks: **Groundwater encountered at an approximate depth of 8 feet during drilling operations. CME 55 Drill Rig. 6" Flight Auger. Backfilled with sand and patched with concrete.**

KSWA BORING LOG

KSWA
K. S. Ware & Associates, L.L.C.
Geotechnical • CEI • Environmental

BORING NO. B-04

PROJECT NAME: **MSCAA Taxiway Alpha West**
LOCATION: **Memphis, TN**
PROJECT NO.: **100-19-0019**
Sheet 1 of 1

Approx. Surface El. (feet, MSL):
Location: **See Map**

Depth, feet	Graphic Log	MATERIAL DESCRIPTION	Samples	Recovery (%)	RQD (%)	SPT Values	N-Value	Pocket Pen (tsf)	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
1.5		CONCRETE (18 inches)										
1.8		ASPHALT (4 inches)										
2.2		CEMENTED BASE (4 inches)		100		50/1.5"			13.9			
5.5		LEAN CLAY (CL), black nodulus, brown with gray streaking, firm, moist		67		2-2-4	6	2.5	26.0			
8.0		SILT (ML), brown, v. loose, moist		94		1-1-2	3	1.5	30.3			
10.0		LEAN CLAY (CL), black nodules, brown with gray streaking, soft, moist		100		1-2-2	4	1.5	31.5			
		BORING TERMINATED AT 10 FBGS										

Depth scale: 4, 8, 12, 16, 20

Completion Depth (ft.): **10.0**
Date Started: **5/10/19**
Date Completed: **5/10/19**
Drilled By: **Geotechnology**
Logged By: **K. Andrus**

Remarks: **CME 55 Drill Rig. 6" Flight Auger. Backfilled with sand and patched with concrete. Dry upon completion.**

KSWA BORING LOG

K. S. Ware & Associates, L.L.C.
Geotechnical • CEI • Environmental

BORING NO. B-05

PROJECT NAME: **MSCAA Taxiway Alpha West**
LOCATION: **Memphis, TN**
PROJECT NO.: **100-19-0019**

Sheet 1 of 1

Approx. Surface El. (feet, MSL):
Location: **See Map**

Depth, feet	Graphic Log	MATERIAL DESCRIPTION	Samples	Recovery (%)	RQD (%)	SPT Values	N-Value	Pocket Pen (tsf)	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
		CONCRETE (18 inches) 1.5										
		ASPHALT (4.5 inches) 1.9										
		CEMENTED BASE (3.5 inches) 2.2										
		LEAN CLAY (CL), rock fragments, gray, stiff, moist 3.5	☒	67		25-6-5	11	4.5	22.5			
4		LEAN CLAY (CL), some silt, gray with brown mottling, firm, moist 5.5	☒	72		1-2-3	5	2.25	28.8	42	18	24
		SILT (ML), brown, loose, moist 8.0	☒	100		2-3-4	7	2.75	24.2			
8		LEAN CLAY (CL), black nodules, oxidation, gray with brown mottling, firm, moist 10.0	☒	100		2-2-3	5	2.5	26.6			
		BORING TERMINATED AT 10 FBGS										
12												
16												
20												

Completion Depth (ft.): **10.0**
Date Started: **5/8/19**
Date Completed: **5/8/19**
Drilled By: **Geotechnology**
Logged By: **V. Gallagher**

Remarks: **CME 55 Drill Rig. 6" Flight Auger. Backfilled with sand and patched with concrete. Dry upon completion.**

KSWA BORING LOG

K. S. Ware & Associates, L.L.C.
Geotechnical • CEI • Environmental

BORING NO. B-06

PROJECT NAME: MSCAA Taxiway Alpha West
LOCATION: Memphis, TN
PROJECT NO.: 100-19-0019

Sheet 1 of 1

Approx. Surface El. (feet, MSL):
Location: See Map

Depth, feet	MATERIAL DESCRIPTION	Samples	Recovery (%)	RQD (%)	SPT Values	N-Value	Pocket Pen (tsf)	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
1.7	CONCRETE (20.5 inches)										
2.0	ASPHALT (3.5 inches)	☒	100		50/2"						
2.2	CEMENTED BASE (2 inches)										
5.5	SANDY SILT (ML), roots, gray with red-brown mottling, v. moist (FILL)	☒	72		WoH-WoH-1	1		23.4			
8.0	SILT (ML), brown, loose, moist	☒	89		2-5-4	9	2.75	24.0			
10.0	LEAN CLAY (CL), some silt, gray with brown mottling, firm, moist	☒	100		1-3-3	6	1.75	32.6			
	BORING TERMINATED AT 10 FBGS										

4
8
12
16
20

Completion Depth (ft.): **10.0**
Date Started: **5/8/19**
Date Completed: **5/8/19**
Drilled By: **Geotechnology**
Logged By: **V. Gallagher**

Remarks: **CME 55 Drill Rig. 6" Flight Auger. Backfilled with sand and patched with concrete. WoH=Weight of Hammer. Dry upon completion.**

KSWA BORING LOG

K. S. Ware & Associates, L.L.C.
Geotechnical • CEI • Environmental

BORING NO. B-08

PROJECT NAME: **MSCAA Taxiway Alpha West**
LOCATION: **Memphis, TN**
PROJECT NO.: **100-19-0019**
Sheet 1 of 1

Approx. Surface El. (feet, MSL):
Location: **See Map**

Depth, feet	Graphic Log	MATERIAL DESCRIPTION		Samples	Recovery (%)	RQD (%)	SPT Values	N-Value	Pocket Pen (tsf)	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
		CONCRETE (17.5 inches)	1.5										
		ASPHALT (2.5 inches)	1.7										
		CEMENTED BASE (6 inches)	2.2										
		LEAN CLAY (CL), dark gray, firm, dry to moist	3.5	☒	72		4-3-4	7	3.5	21.0			
4		LEAN CLAY (CL), oxidation, light gray-brown, firm, moist	5.5	☒	89		3-3-4	7	2.0 - 2.5				
		SILT (ML), brown, loose, moist	8.0	☒	94		2-4-4	8	2.0	25.7			
8		LEAN CLAY (CL), oxidation, light gray, firm, moist	10.0	☒	94		2-2-3	5	2.5	26.3	33	23	10
		BORING TERMINATED AT 10 FBGS											
12													
16													
20													

Completion Depth (ft.): **10.0**
Date Started: **5/15/19**
Date Completed: **5/15/19**
Drilled By: **Geotechnology**
Logged By: **K. Andrus**

Remarks: **CME 55 Drill Rig. 6" Flight Auger. Bulk Sample taken. Backfilled with sand and patched with concrete. Dry upon completion.**

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BORING NO. B-09

PROJECT NAME: **MSCAA Taxiway Alpha West**
LOCATION: **Memphis, TN**
PROJECT NO.: **100-19-0019**

Sheet 1 of 1

Approx. Surface El. (feet, MSL):
Location: **See Map**

Depth, feet	Graphic Log	MATERIAL DESCRIPTION	Samples	Recovery (%)	RQD (%)	SPT Values	N-Value	Pocket Pen (tsf)	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
	░	CONCRETE (16 inches) 1.3										
	■	ASPHALT (3 inches) 1.6										
	▩	CEMENTED BASE (7 inches) 2.2										
	▨	LEAN CLAY (CL), black nodules, dark gray, firm, moist 3.5	☒	67		3-5-3	8	3.5	20.2			
4	▥	SILT (ML), brown, loose, moist	☒	100		1-4-5	9	2.0 - 2.5				
	▥		■	15								
8	▥	8.0										
	▨	LEAN CLAY (CL), rock fragments, black nodules, oxidation, brown, stiff, moist 10.0	☒	100		5-8-7	15	2.5 - 3.0	19.5			
		BORING TERMINATED AT 10 FBGS										
12												
16												
20												

Completion Depth (ft.): **10.0**
Date Started: **5/15/19**
Date Completed: **5/15/19**
Drilled By: **Geotechnology**
Logged By: **K. Andrus**

Remarks: **CME 55 Drill Rig. 6" Flight Auger. Backfilled with sand and patched with concrete. Dry upon completion.**

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BORING NO. B-10

PROJECT NAME: **MSCAA Taxiway Alpha West**
LOCATION: **Memphis, TN**
PROJECT NO.: **100-19-0019**
Sheet 1 of 1

Depth, feet	Graphic Log	**Approx. Surface El. (feet, MSL):** **Location: See Map** MATERIAL DESCRIPTION	Samples	Recovery (%)	RQD (%)	SPT Values	N-Value	Pocket Pen (tsf)	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
		CONCRETE (18 Inches) 1.5										
		ASPHALT (3.5 inches) 1.8										
		CEMENTED BASE (8.5 inches) 2.5										
		LEAN CLAY (CL), brown with gray mottling, stiff, moist	☒	67		2-5-9	14	4.5				
4		5.5	☒	89		2-5-6	11	2.5 - 3.0				
		SILT (ML), brown, m. dense, moist 8.0	☒	94		3-6-12	18	4.0	22.0			
8		LEAN CLAY (CL), little silt, black nodules, brown, v. stiff, moist 10.0	☒	100		6-8-10	18	2.75	18.6			
		BORING TERMINATED AT 10 FBGS										
12												
16												
20												

Completion Depth (ft.): **10.0**
Date Started: **5/14/19**
Date Completed: **5/14/19**
Drilled By: **Geotechnology**
Logged By: **K. Andrus**

Remarks: **CME 55 Drill Rig. 6" Flight Auger. Bulk Sample taken. Backfilled with sand and patched with concrete. Dry upon completion.**

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BORING NO. B-11

PROJECT NAME: **MSCAA Taxiway Alpha West**
LOCATION: **Memphis, TN**
PROJECT NO.: **100-19-0019**

Sheet 1 of 1

Approx. Surface El. (feet, MSL):
Location: **See Map**

Depth, feet	Graphic Log	MATERIAL DESCRIPTION	Samples	Recovery (%)	RQD (%)	SPT Values	N-Value	Pocket Pen (tsf)	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
		CONCRETE (17.5 Inches) 1.5										
		ASPHALT (3.5 inches) 1.8										
		CEMENTED BASE (8 inches) 2.4										
		LEAN CLAY (CL), dark gray to brown, v. stiff, moist 3.5	☒	67		4-10-11	21	4.5	18.5			
4		LEAN CLAY (CL), rock fragments, black nodules, gray to grown, stiff, moist 5.5	☒	89		5-6-6	12	2.0 - 2.5				
		SILT (ML), brown, loose, moist 8.0	■	88					26.2	NP	NP	NP
8		FAT CLAY (CH), oxidation, brown, soft, v. moist 10.0	☒	100		1-2-2	4	1.5	30.0			
		BORING TERMINATED AT 10 FBGS										
12												
16												
20												

Completion Depth (ft.):	**10.0**
Date Started:	**5/14/19**
Date Completed:	**5/14/19**
Drilled By:	**Geotechnology**
Logged By:	**K. Andrus**

Remarks: **CME 55 Drill Rig. 6" Flight Auger. Backfilled with sand and patched with concrete. Dry upon completion.**

KSWA BORING LOG

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BORING NO. B-12

PROJECT NAME: **MSCAA Taxiway Alpha West**
LOCATION: **Memphis, TN**
PROJECT NO.: **100-19-0019**
Sheet 1 of 1

Approx. Surface El. (feet, MSL):
Location: **See Map**

Depth, feet	Graphic Log	MATERIAL DESCRIPTION	Samples	Recovery (%)	RQD (%)	SPT Values	N-Value	Pocket Pen (tsf)	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
	░	CONCRETE (17.5 inches) 1.5										
	■	ASPHALT (3 inches) 1.7										
	▩	CEMENTED BASE (5.5 inches) 2.2										
	░	CLAYEY SAND (SC), some gravel, orange-red, m. dense, moist 3.5	☒	87		15-13-11	24	3.0 - 3.5	9.4			
4	▨	LEAN CLAY (CL), black nodules, gray-brown, stiff, moist 5.5	☒	94		4-5-7	12	2.5 - 3.0				
	▥	SILT (ML), brown, m. dense, moist 8.0	☒	89		4-5-7	12	2.25	22.6			
8	▨	LEAN CLAY (CL), black nodules, gray-brown, stiff, moist 10.0	☒	83		3-4-7	11	3.0	21.1	33	22	11
		BORING TERMINATED AT 10 FBGS										
12												
16												
20												

Completion Depth (ft.):	**10.0**
Date Started:	**5/14/19**
Date Completed:	**5/14/19**
Drilled By:	**Geotechnology**
Logged By:	**K. Andrus**

Remarks: **CME 55 Drill Rig. 6" Flight Auger. Bulk Sample taken. Backfilled with sand and patched with concrete. Dry upon completion.**

KSWA BORING LOG

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BORING NO. B-13

PROJECT NAME: **MSCAA Taxiway Alpha West**
LOCATION: **Memphis, TN**
PROJECT NO.: **100-19-0019**

Sheet 1 of 1

Approx. Surface El. (feet, MSL):
Location: **See Map**

Depth, feet	Graphic Log	MATERIAL DESCRIPTION	Samples	Recovery (%)	RQD (%)	SPT Values	N-Value	Pocket Pen (tsf)	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
	■	ASPHALT (22.5 inches)										
	▨	1.9 LEAN CLAY (CL), black nodules, oxidation, light brown, stiff, moist	☒	87		3-5-6	11	4.5	22.7			
4	▨		■	29								
	▥	5.5 SILT (ML), brown, v. loose, moist	☒	100		1-2-2	4	2.25	28.8			
8	▨	8.0 LEAN CLAY (CL), some silt, gray with brown mottling, soft, moist	☒	100		1-1-2	3	1.75	28.9			
		10.0 BORING TERMINATED AT 10 FBGS										
12												
16												
20												

Completion Depth (ft.): **10.0**
Date Started: **5/8/19**
Date Completed: **5/8/19**
Drilled By: **Geotechnology**
Logged By: **V. Gallagher**

Remarks: **CME 55 Drill Rig. 6" Flight Auger. Backfilled with sand and patched with concrete.**

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BORING NO. B-14

PROJECT NAME: MSCAA Taxiway Alpha West
LOCATION: Memphis, TN
PROJECT NO.: 100-19-0019

Sheet 1 of 1

Approx. Surface El. (feet, MSL):
Location: **See Map**

Depth, feet	Graphic Log	MATERIAL DESCRIPTION	Samples	Recovery (%)	RQD (%)	SPT Values	N-Value	Pocket Pen (tsf)	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
		CONCRETE (18 inches) 1.5										
		ASPHALT (3 inches) 1.8										
		CEMENTED BASE (3 inches) 2.0										
		LEAN CLAY (CL), rock fragments, dark gray, stiff, moist 3.5	☒	78		5-6-6	12	3.5				
4		SANDY LEAN CLAY (CL), rock fragments, dark brown, soft, moist 5.5	☒	67		4-2-2	4	2.5	11.5			
		SILT (ML), brown, loose, moist 8.0	☒	67		2-4-5	9	3.0	20.6			
8		LEAN CLAY (CL), black nodules, oxidation, gray, firm, moist 10.0	☒	94		2-3-4	7	2.75	24.8			
		BORING TERMINATED AT 10 FBGS										
12												
16												
20												

Completion Depth (ft.): **10.0**
Date Started: **5/15/19**
Date Completed: **5/15/19**
Drilled By: **Geotechnology**
Logged By: **K. Andrus**

Remarks: **CME 55 Drill Rig. 6" Flight Auger. Backfilled with sand and patched with concrete. Dry upon completion.**

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BORING NO. B-16

PROJECT NAME: **MSCAA Taxiway Alpha West**

LOCATION: **Memphis, TN**

PROJECT NO.: **100-19-0019**

Sheet 1 of 1

Approx. Surface El. (feet, MSL):

Location: **See Map**

Depth, feet	Graphic Log	MATERIAL DESCRIPTION	Samples	Recovery (%)	RQD (%)	SPT Values	N-Value	Pocket Pen (tsf)	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
1.6		CONCRETE (19 Inches)										
1.8		ASPHALT (3 inches)										
2.0		CEMENTED BASE (2 inches)										
3.5		LEAN CLAY (CL), gray, stiff, moist (FILL)	☒	67		3-7-6	13					
4 6.0		LEAN CLAY (CL), wood chips, black streaking, gray-brown, stiff, moist (FILL)	☒	67		6-6-7	13	4.5	18.6			
8.0		SILT (ML), brown, v. loose, moist	☒	56		3-1-2	3	1.5	21.2			
8 10.0		LEAN CLAY (CL), oxidation, gray-brown, firm, moist to dry	☒	67		2-3-4	7	2.5	22.4			
12 16 20		BORING TERMINATED AT 10 FBGS										

Completion Depth (ft.): **10.0**
Date Started: **5/14/19**
Date Completed: **5/14/19**
Drilled By: **Geotechnology**
Logged By: **K. Andrus**

Remarks: **CME 55 Drill Rig. 6" Flight Auger. Backfilled with sand and patched with concrete.**

PAVEMENT CORE PHOTOGRAPHS
TAXIWAY ALPHA WEST RECONSTRUCTION
MEMPHIS INTERNATIONAL AIRPORT
PROJECT NO. 100-19-0019

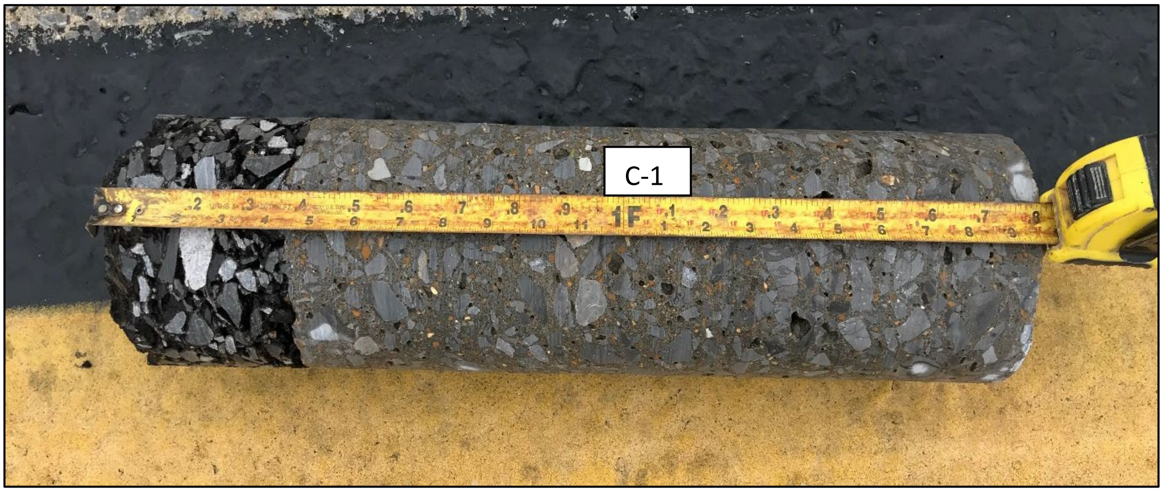

Photo 1: Concrete Core Location C-1

Photo 2: Concrete Core Location C-2

Photo 3: Concrete Core Location C-4

PAVEMENT CORE PHOTOGRAPHS
TAXIWAY ALPHA WEST RECONSTRUCTION
MEMPHIS INTERNATIONAL AIRPORT
PROJECT NO. 100-19-0019

Photo 4: Concrete Core Location C-7

Photo 5: Concrete Core Location C-8

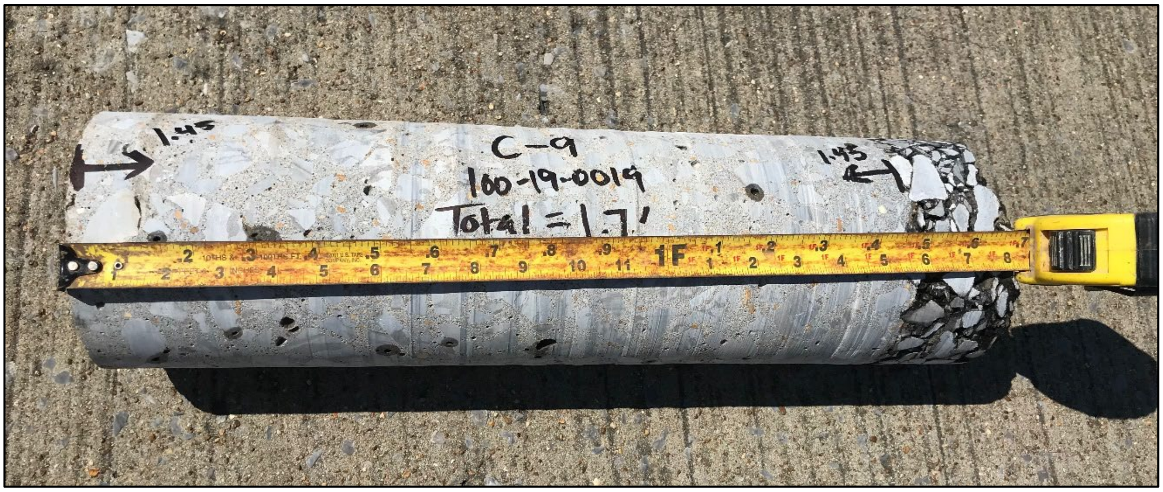

Photo 6: Concrete Core Location C-9

PAVEMENT CORE PHOTOGRAPHS
TAXIWAY ALPHA WEST RECONSTRUCTION
MEMPHIS INTERNATIONAL AIRPORT
PROJECT NO. 100-19-0019

Photo 7: Concrete Core Location C-10

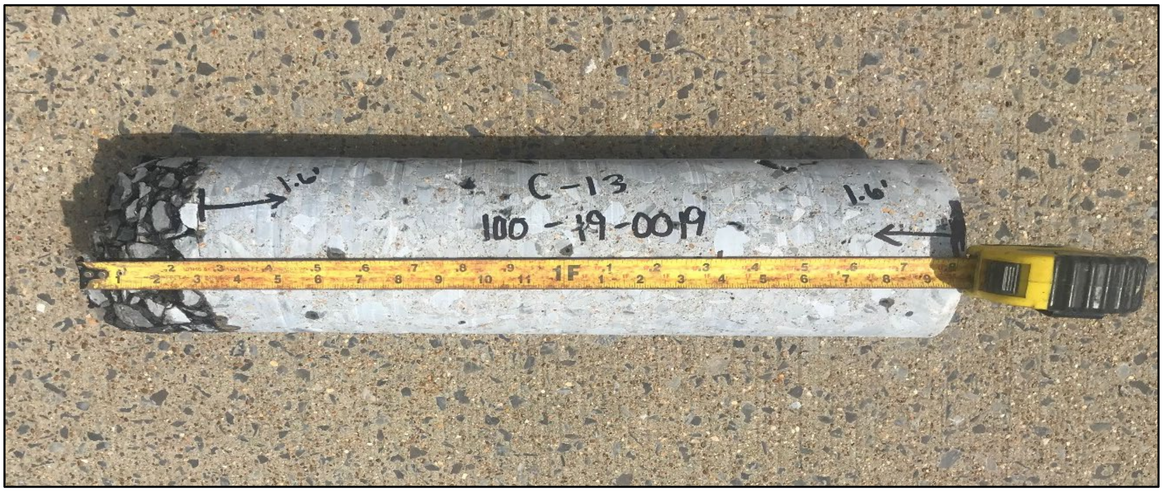

Photo 8: Concrete Core Location C-13

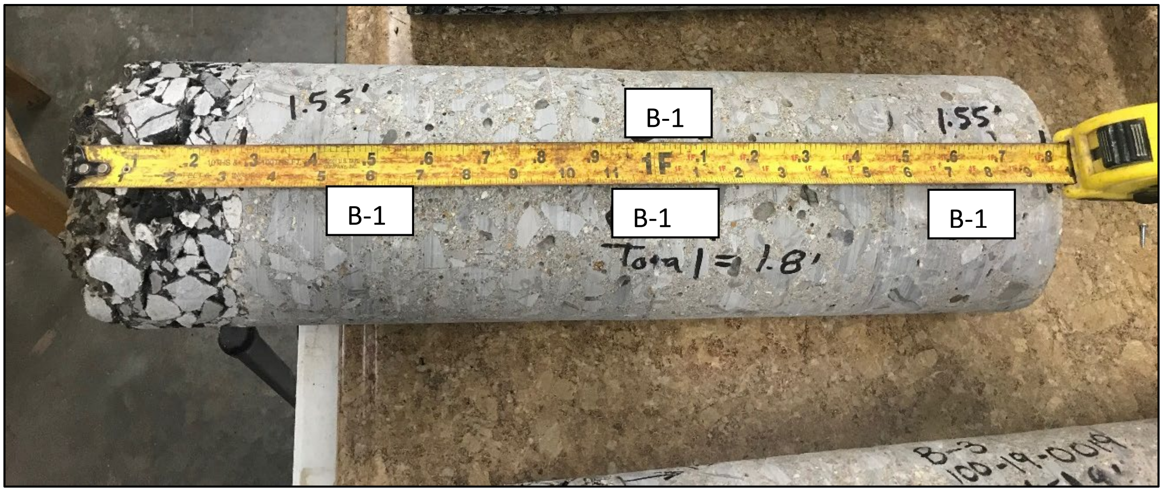

Photo 9: Concrete Core Location B-1

PAVEMENT CORE PHOTOGRAPHS
TAXIWAY ALPHA WEST RECONSTRUCTION
MEMPHIS INTERNATIONAL AIRPORT
PROJECT NO. 100-19-0019

Photo 10: Concrete Core Location B-2

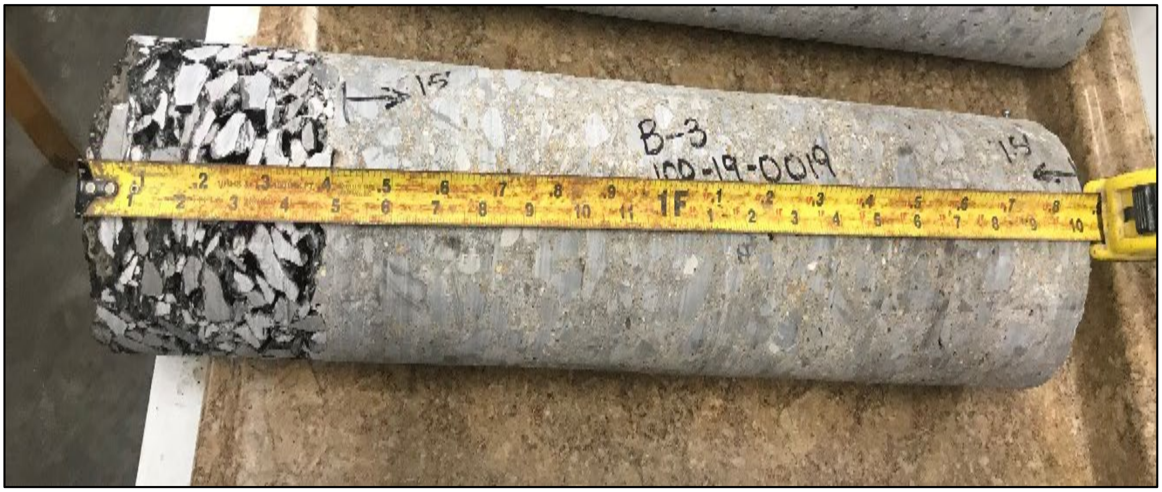

Photo 11: Concrete Core Location B-3

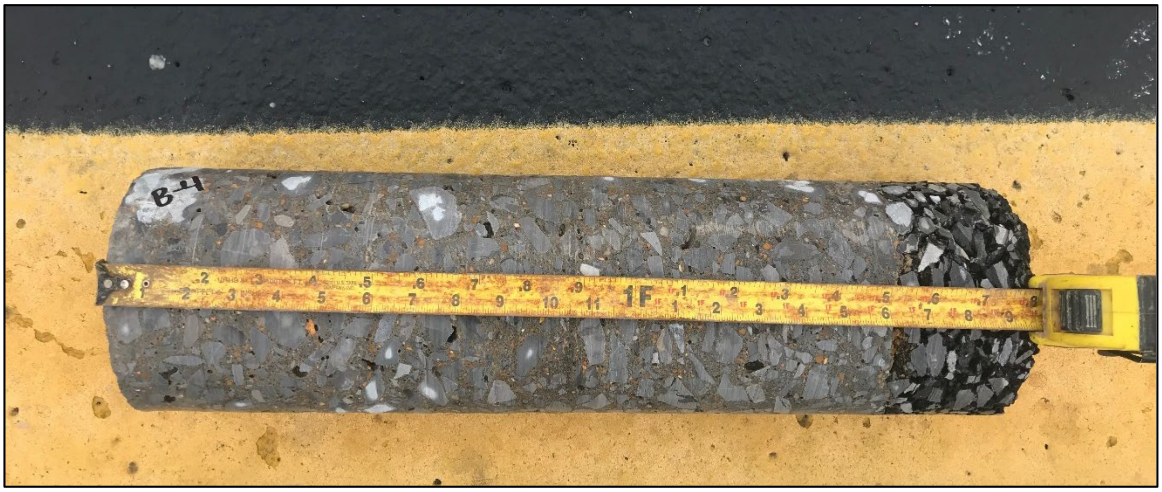

Photo 12: Concrete Core Location B-4

PAVEMENT CORE PHOTOGRAPHS
TAXIWAY ALPHA WEST RECONSTRUCTION
MEMPHIS INTERNATIONAL AIRPORT
PROJECT NO. 100-19-0019

Photo 13: Concrete Core Location B-5

Photo 14: Concrete Core Location B-6

Photo 15: Concrete Core Location B-8

PAVEMENT CORE PHOTOGRAPHS
TAXIWAY ALPHA WEST RECONSTRUCTION
MEMPHIS INTERNATIONAL AIRPORT
PROJECT NO. 100-19-0019

Photo 16: Concrete Core Location B-9

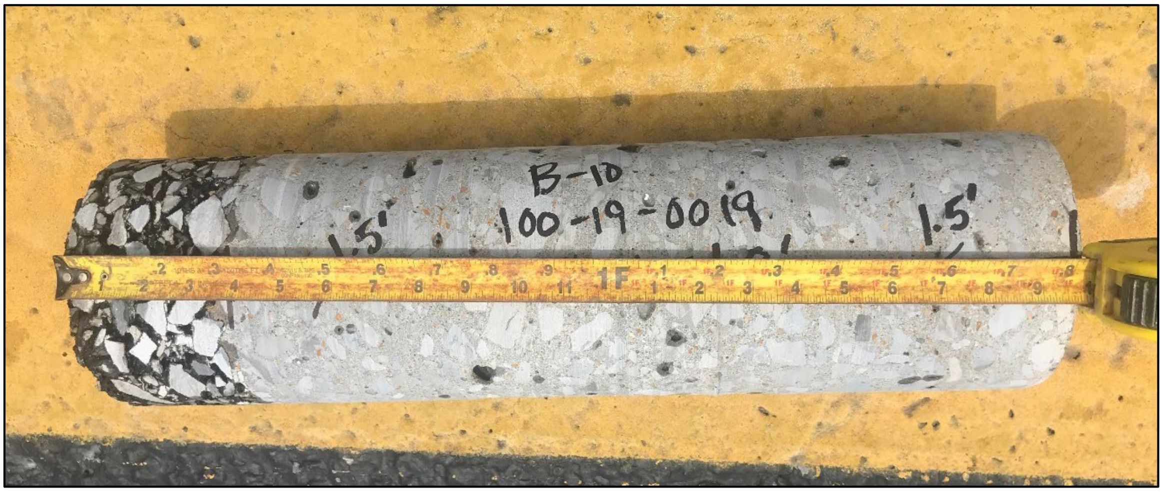

Photo 17: Concrete Core Location B-10

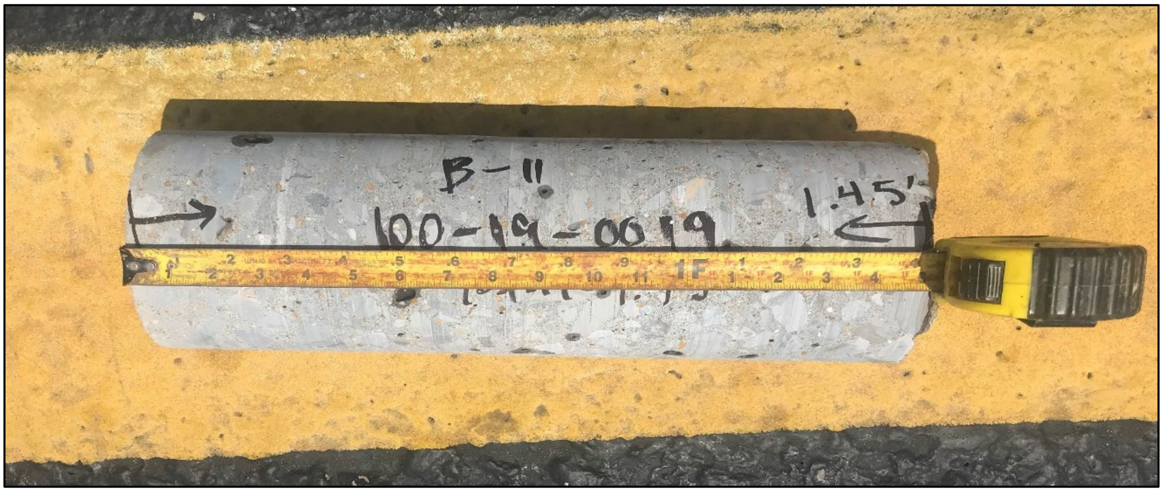

Photo 18: Concrete Core Location B-11

PAVEMENT CORE PHOTOGRAPHS
TAXIWAY ALPHA WEST RECONSTRUCTION
MEMPHIS INTERNATIONAL AIRPORT
PROJECT NO. 100-19-0019

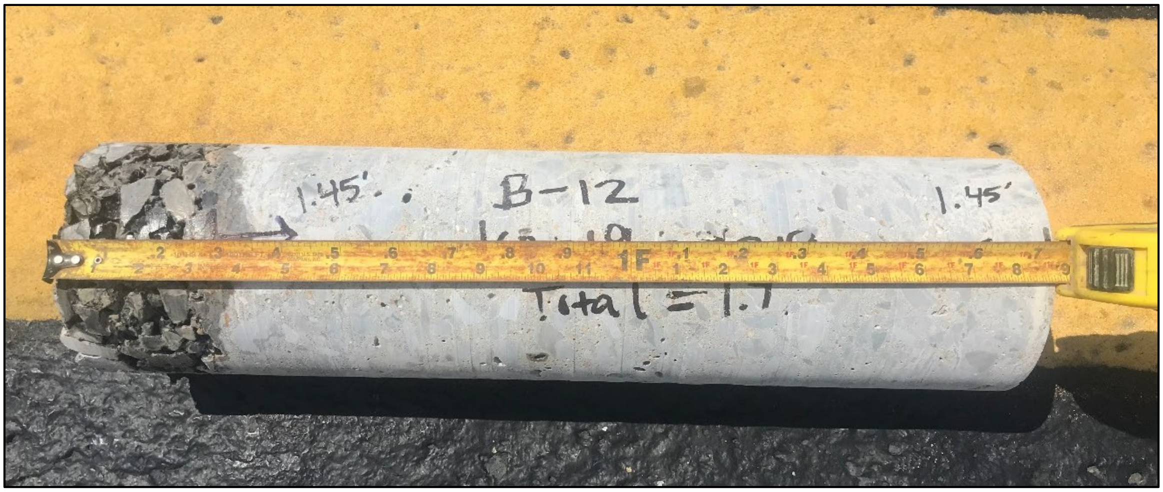

Photo 19: Concrete Core Location B-12

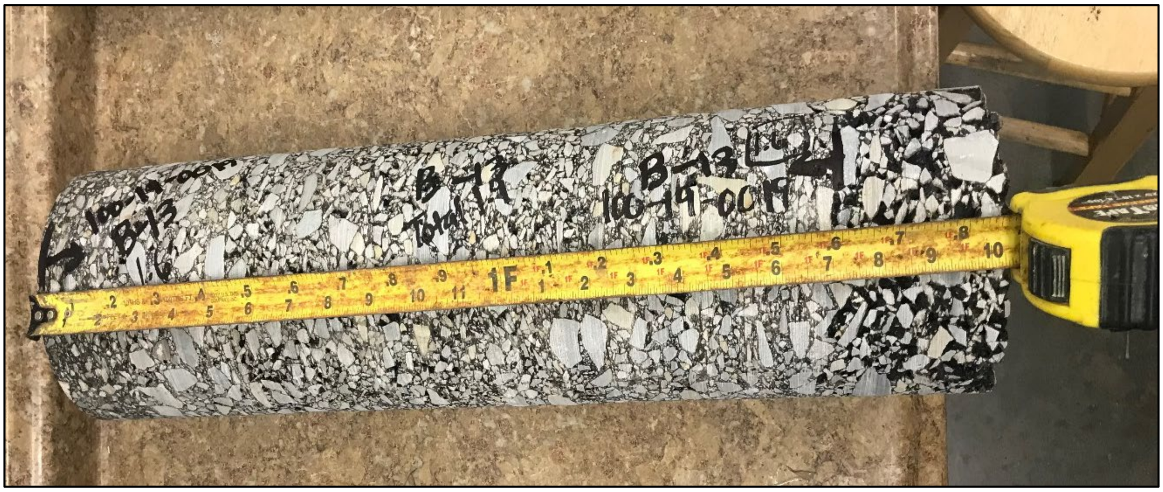

Photo 20: Concrete Core Location B-13

Photo 21: Concrete Core Location B-14

PAVEMENT CORE PHOTOGRAPHS
TAXIWAY ALPHA WEST RECONSTRUCTION
MEMPHIS INTERNATIONAL AIRPORT
PROJECT NO. 100-19-0019

Photo 22: Concrete Core Location B-15

Photo 23: Concrete Core Location B-16

APPENDIX C

Laboratory Test Results

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54 Lindsley Avenue
Nashville,Tennessee 37210
Phone: (615) 255-9702
Fax: (615) 256-5873

GRAIN SIZE DISTRIBUTION
ASTM D6913 - COARSE GRAIN SIZE
ASTM D7928 - FINE GRAIN SIZE

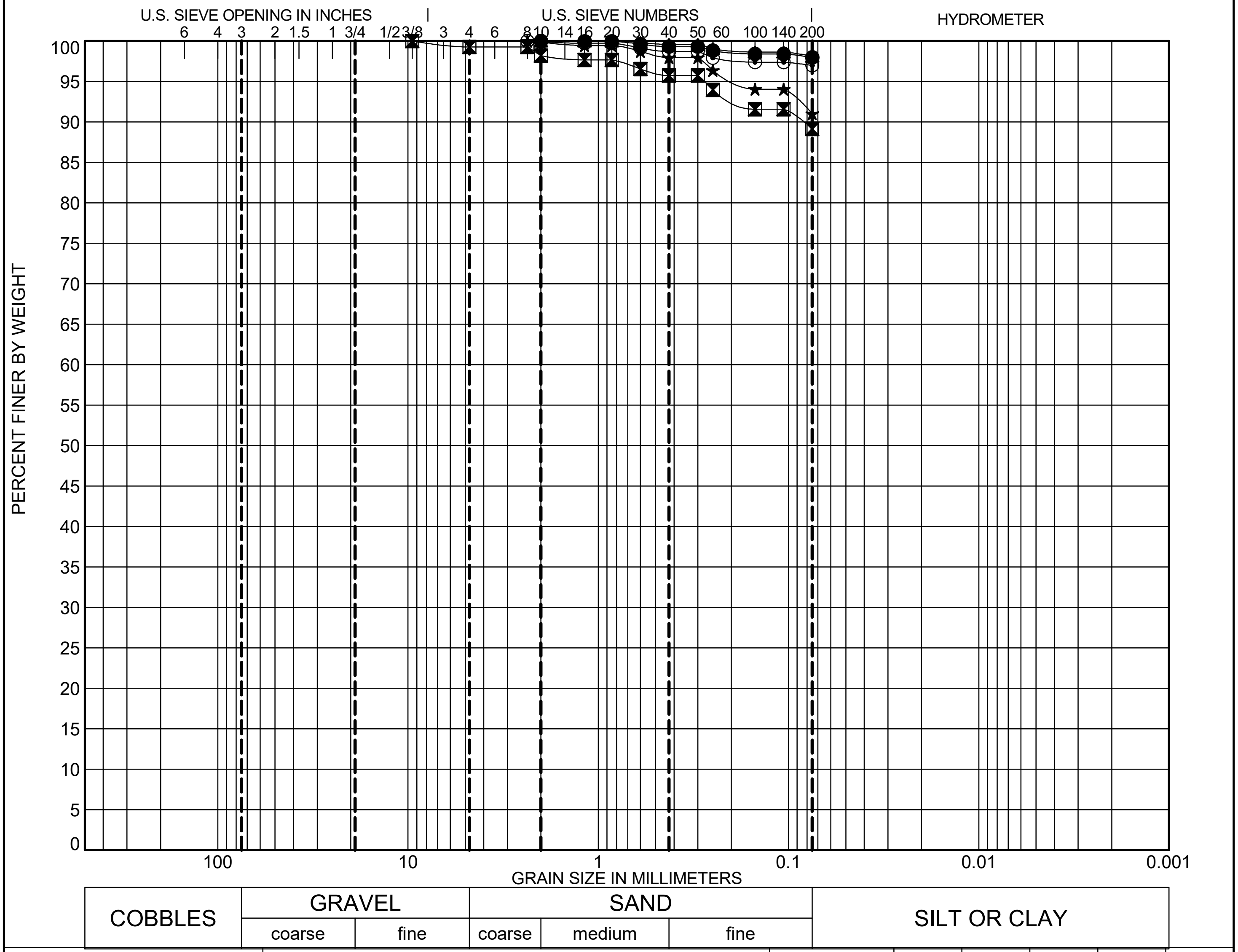
CLIENT: Allen & Hoshall

PROJECT NAME: MSCAA Taxiway Alpha West

PROJECT NUMBER 100-19-0019

PROJECT LOCATION: Memphis, TN

SOIL DESCRIPTION: Bulk sample from auger cuttings from depths of 2 to 10 feet



Specimen Identification	Classification	Spec. Grav.	LL	PL	PI	Cc	Cu
● **B-01, 6'**	**SILT (ML)**		**NP**	**NP**	**NP**		
⧗ **B-02, 10'**	**LEAN CLAY(CL)**		**36**	**22**	**14**		
▲ **B-03, 6'**	**SILT (ML)**		**NP**	**NP**	**NP**		
★ **B-05, 3.5'**	**LEAN CLAY(CL)**		**42**	**18**	**24**		
⊙ **B-08, 10'**	**LEAN CLAY(CL)**		**33**	**23**	**10**		

Specimen Identification	D_{100}	D_{60}	D_{30}	D_{10}	%Gravel	%Sand	%Silt	%Clay
● **B-01, 6'**	**2**				**0.0**	**2.0**	**98.0**	
⧗ **B-02, 10'**	**9.5**				**0.7**	**10.1**	**89.1**	
▲ **B-03, 6'**	**2**				**0.0**	**1.9**	**98.1**	
★ **B-05, 3.5'**	**2.36**				**0.0**	**9.0**	**91.0**	
⊙ **B-08, 10'**	**2.36**				**0.0**	**3.0**	**97.0**	

TESTED BY: Z. Shannon **TEST DATE**: 6/11/2019 **REVIEWED BY**: B. Kouchoukos **DATE**: 6/12/2019

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Nashville,Tennessee 37210
Phone: (615) 255-9702
Fax: (615) 256-5873

GRAIN SIZE DISTRIBUTION
ASTM D6913 - COARSE GRAIN SIZE
ASTM D7928 - FINE GRAIN SIZE

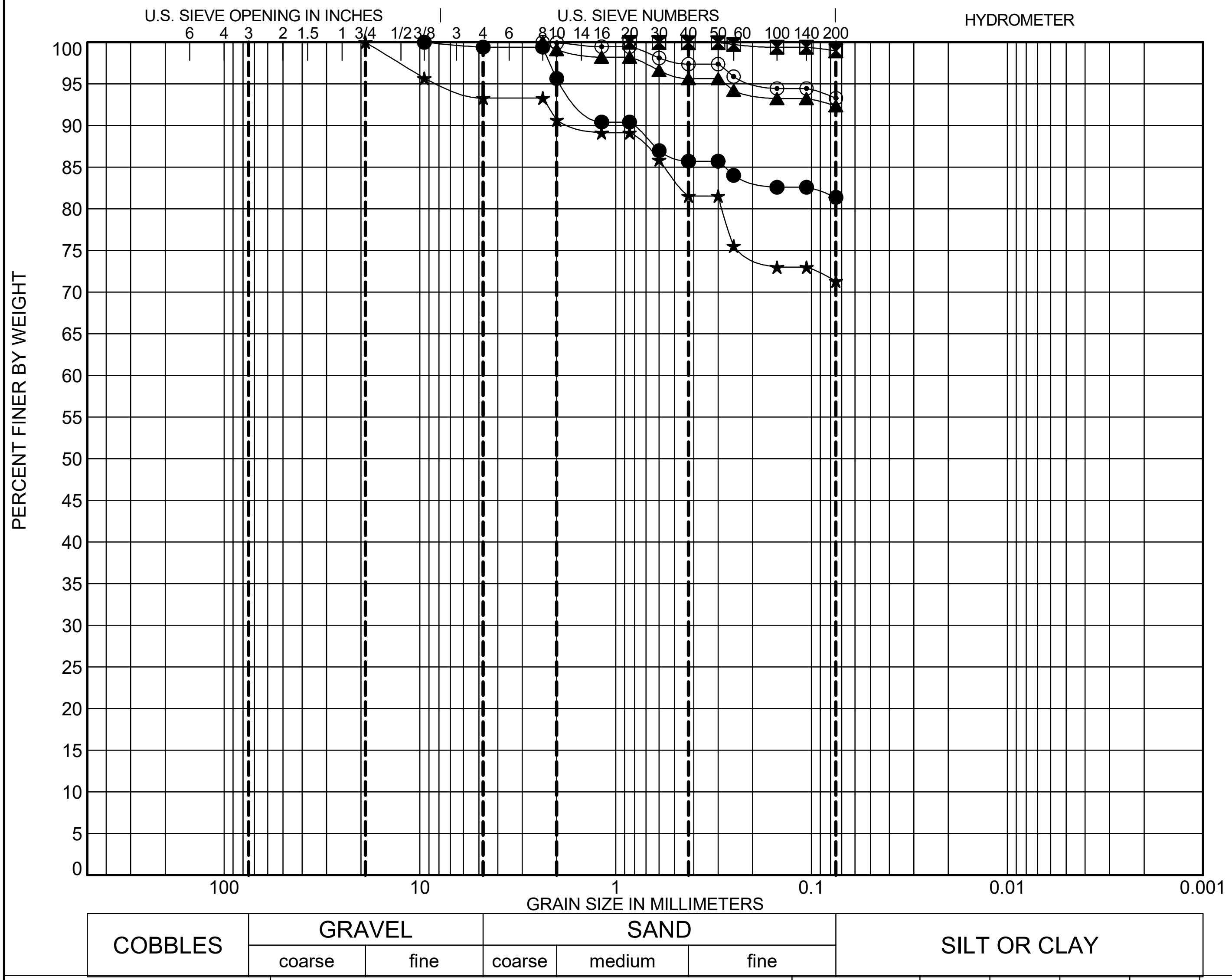
CLIENT: Allen & Hoshall

PROJECT NAME: MSCAA Taxiway Alpha West

PROJECT NUMBER 100-19-0019

PROJECT LOCATION: Memphis, TN

SOIL DESCRIPTION:



	Specimen Identification	Classification	Spec. Grav.	LL	PL	PI	Cc	Cu
●	**B-09, 3.5'**	**SILT (ML)**		**NP**	**NP**	**NP**		
☒	**B-11, 6'**	**SILT (ML)**		**NP**	**NP**	**NP**		
▲	**B-12, 3.5'**	**LEAN CLAY(CL)**		**37**	**24**	**13**		
★	**B-12, 10'**	**LEAN CLAY with SAND(CL)**		**33**	**22**	**11**		
⊙	**B-13, 3.5'**	**LEAN CLAY(CL)**		**35**	**22**	**13**		

	Specimen Identification	D_{100}	D_{60}	D_{30}	D_{10}	%Gravel	%Sand	%Silt	%Clay
●	**B-09, 3.5'**	**9.5**				**0.6**	**18.0**	**81.4**	
☒	**B-11, 6'**	**0.85**				**0.0**	**1.0**	**99.0**	
▲	**B-12, 3.5'**	**2.36**				**0.0**	**7.7**	**92.3**	
★	**B-12, 10'**	**19**				**6.7**	**22.0**	**71.3**	
⊙	**B-13, 3.5'**	**2.36**				**0.0**	**6.7**	**93.3**	

TESTED BY: Z. Shannon **TEST DATE**: 6/11/2019 **REVIEWED BY**: B. Kouchoukos **DATE**: 6/12/2019

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54 Lindsley Avenue
Nashville,Tennessee 37210
Phone: (615) 255-9702
Fax: (615) 256-5873

ATTERBERG LIMITS (ASTM D4318)

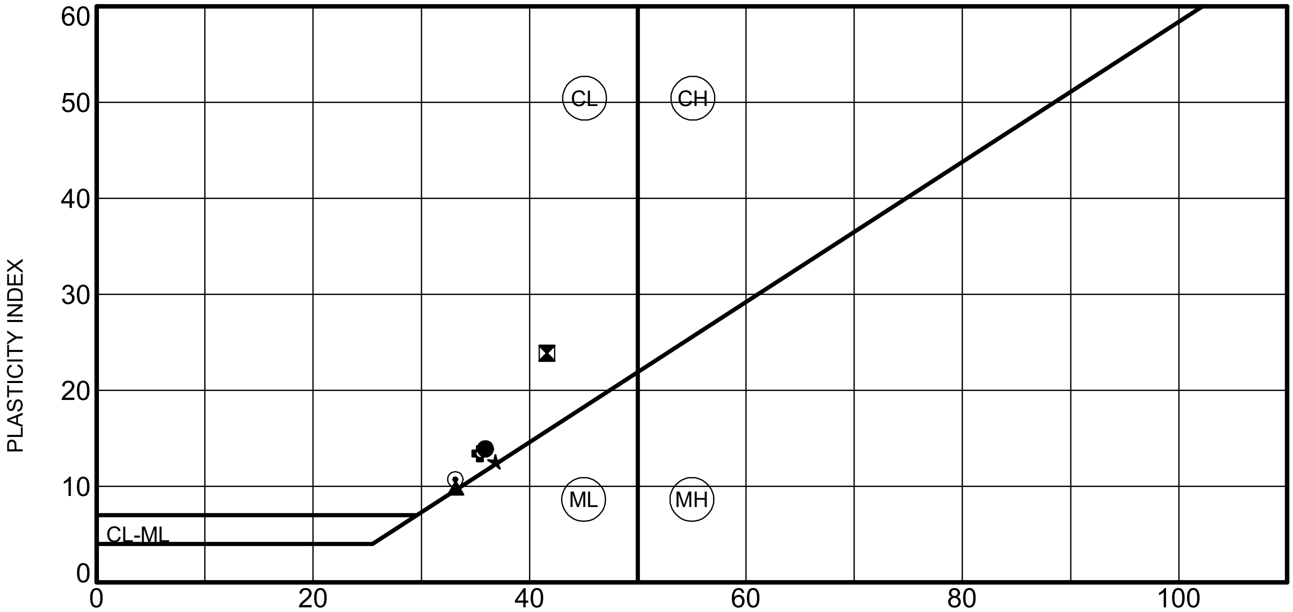
CLIENT: Allen & Hoshall

PROJECT NAME: MSCAA Taxiway Alpha West

PROJECT NUMBER 100-19-0019

PROJECT LOCATION: Memphis, TN

Equipment Used: Liquid Limit Device, Oven, Ohaus 3kg Scale, Metal Tares, Mortar and Pestle, Spatula, Plastic Grooving Tool



Specimen Identification		SAMPLE TYPE	LL	PL	PI	% Fines	Soil Description
●	**B-02, 10'**	**B**	**36**	**22**	**14**	**89**	**LEAN CLAY(CL)**
⊠	**B-05, 3.5'**	**SS**	**42**	**18**	**24**	**91**	**LEAN CLAY(CL)**
▲	**B-08, 10'**	**B**	**33**	**23**	**10**	**97**	**LEAN CLAY(CL)**
★	**B-12, 3.5'**	**SS**	**37**	**24**	**13**	**92**	**LEAN CLAY(CL)**
⊙	**B-12, 10'**	**B**	**33**	**22**	**11**	**71**	**LEAN CLAY with SAND(CL)**
✿	**B-13, 3.5'**	**SS**	**35**	**22**	**13**	**93**	**LEAN CLAY(CL)**
	B-1, 6'	**ST**	**NP**	**NP**	**NP**	**98**	**SILT(ML)**
	B-3, 6'	**ST**	**NP**	**NP**	**NP**	**98**	**SILT(ML)**
	B-9, 3.5'	**ST**	**NP**	**NP**	**NP**	**81**	**SILT(ML)**
	B-11, 6'	**ST**	**NP**	**NP**	**NP**	**99**	**SILT(ML)**

Abbreviations:
NP = Non-plastic
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
SS = Split Spoon
ST = Shelby Tube
G = Grab Sample
B = Bulk Sample

TESTED BY: Z. Shannon

TEST DATE: 6/6/2019

REVIEWED BY: B. Kouchoukos

DATE: 6/11/2019

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Geotechnical • CEI • Environmental

54 Lindsley Avenue
Nashville,Tennessee 37210
Phone: (615) 255-9702
Fax: (615) 256-5873

MODIFIED PROCTOR (ASTM D1557)

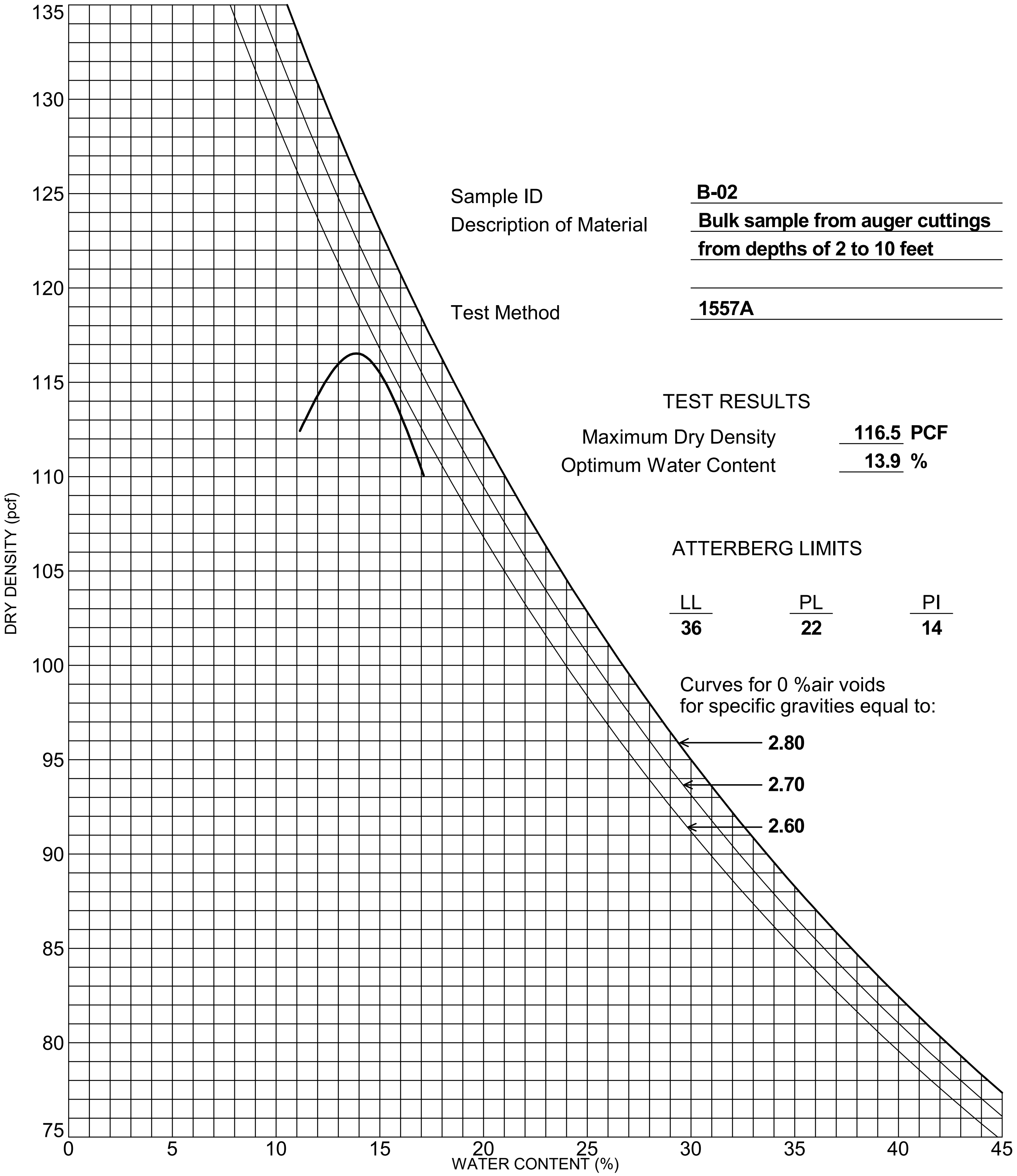
CLIENT: Allen & Hoshall

PROJECT NAME: MSCAA Taxiway Alpha West

PROJECT NUMBER 100-19-0019

PROJECT LOCATION: Memphis, TN

EQUIPMENT USED: Modified Hammer, 4 inch Mold, Ohaus 3 kilogram Scale, Oven, Ohaus 8 kilogram Scale



Sample ID **B-02**

Description of Material **Bulk sample from auger cuttings from depths of 2 to 10 feet**

Test Method **1557A**

TEST RESULTS

Maximum Dry Density **116.5 PCF**

Optimum Water Content **13.9 %**

ATTERBERG LIMITS

LL	PL	PI
36	**22**	**14**

TESTED BY: Z. Shannon
REVIEWED BY: B. Kouchoukos

TEST DATE: 5/23/2019
DATE: 6/12/2019

SAMPLE RECEIVED: 5/21/2019

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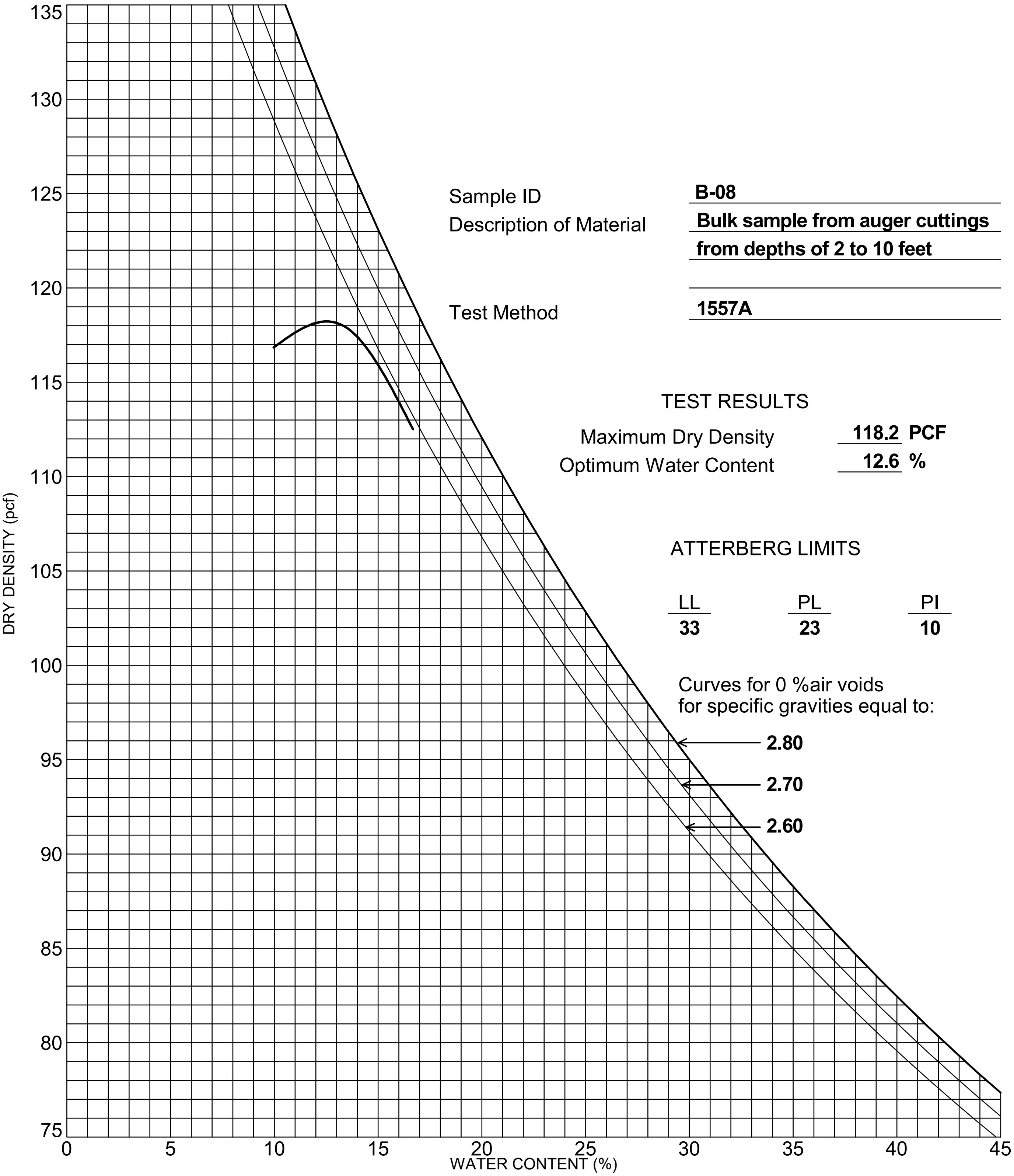

Sample ID **B-08**

Description of Material **Bulk sample from auger cuttings from depths of 2 to 10 feet**

Test Method **1557A**

TEST RESULTS

Maximum Dry Density **118.2 PCF**

Optimum Water Content **12.6 %**

ATTERBERG LIMITS

LL	PL	PI
33	**23**	**10**

TESTED BY: Z. Shannon
REVIEWED BY: B. Kouchoukos

TEST DATE: 6/5/2019
DATE: 6/12/2019

SAMPLE RECEIVED: 5/21/2019

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MODIFIED PROCTOR (ASTM D1557)

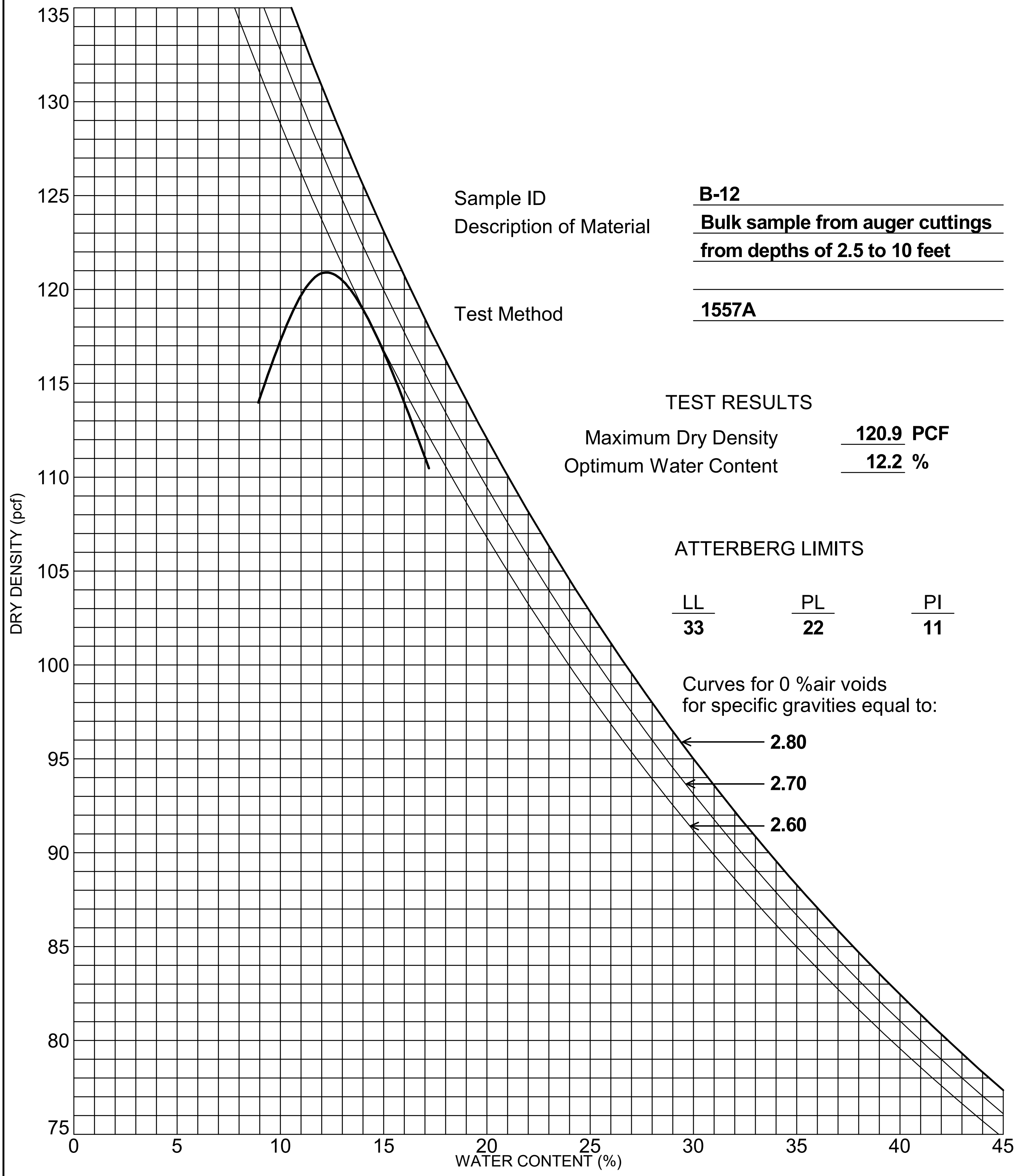
CLIENT: Allen & Hoshall

PROJECT NAME: MSCAA Taxiway Alpha West

PROJECT NUMBER 100-19-0019

PROJECT LOCATION: Memphis, TN

EQUIPMENT USED: Modified Hammer, 4 inch Mold, Ohaus 3 kilogram Scale, Oven, Ohaus 8 kilogram Scale



Sample ID **B-12**

Description of Material **Bulk sample from auger cuttings from depths of 2.5 to 10 feet**

Test Method **1557A**

TEST RESULTS

Maximum Dry Density **120.9 PCF**

Optimum Water Content **12.2 %**

ATTERBERG LIMITS

LL	PL	PI
33	**22**	**11**

TESTED BY: Z. Shannon
REVIEWED BY: B. Kouchoukos

TEST DATE: 6/5/2019
DATE: 6/12/2019

SAMPLE RECEIVED: 5/21/2019

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UNCONFINED COMPRESSIVE STRENGTH TEST COHESIVE SOIL (ASTM D2166)

CLIENT: Allen & Hoshall

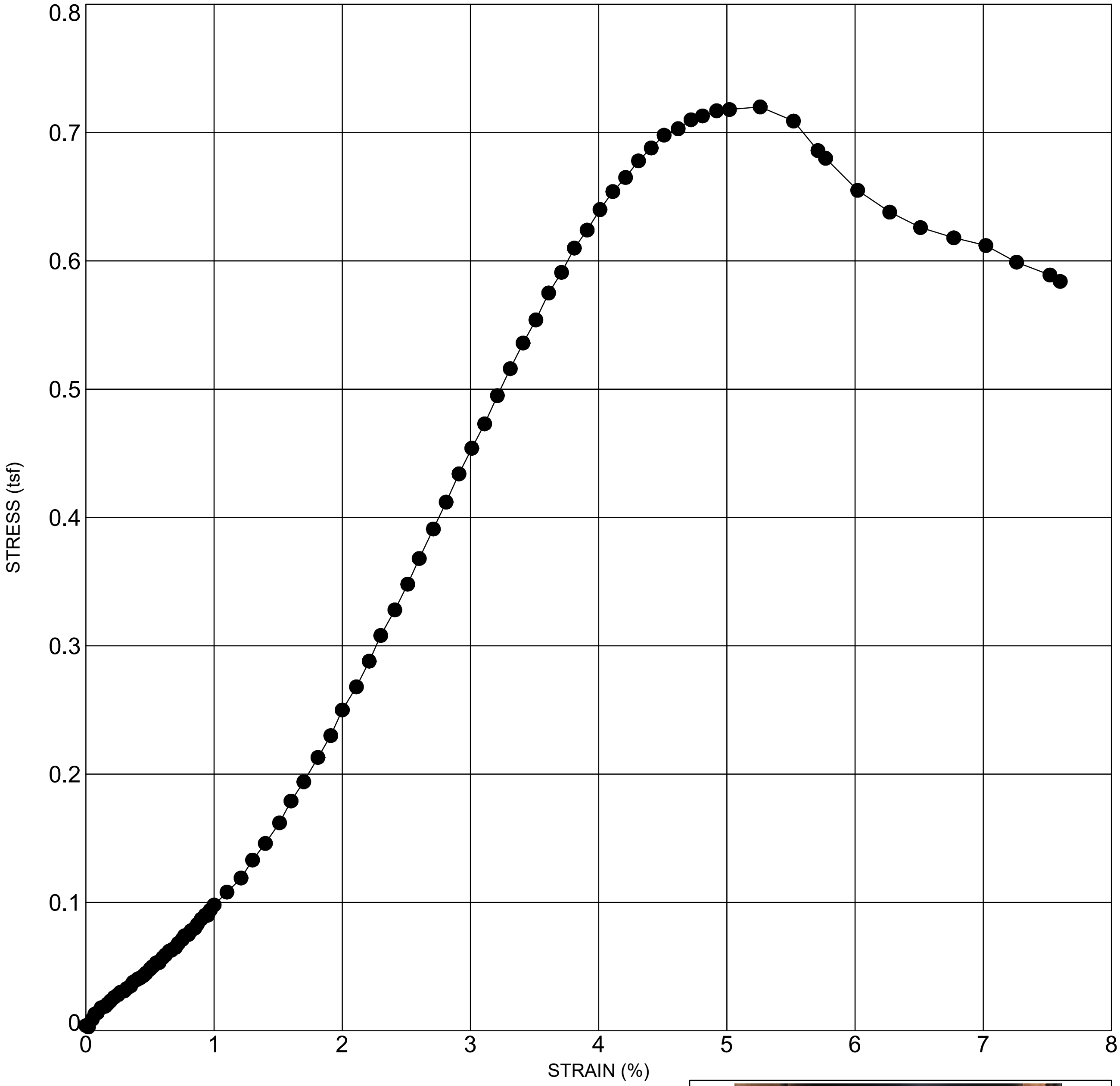
PROJECT NAME: MSCAA Taxiway Alpha West

PROJECT NUMBER 100-19-0019

PROJECT LOCATION: Memphis, TN

SOIL DESCRIPTION: SILT (ML), brown, loose

SAMPLE RECEIVED: 5/13/2019



SAMPLE: B-01

Diameter (in): 2.82

Strain at Failure (%): 5.26

Height (in): 5.52

Strength (tsf): 0.72

Ratio (h/d): 1.96

Dry Density (pcf): 93.40

LL: NP

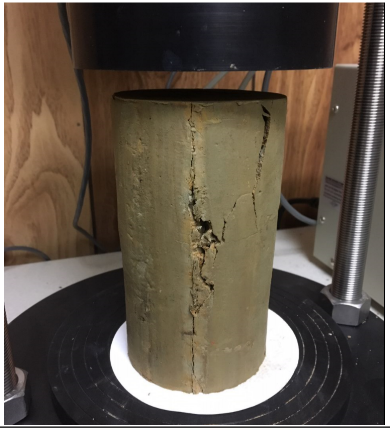
Water Content (%): 30.15922

PL: NP

Rate of Strain to Failure (%/min): 1

-Dry Density and Moisture content data were obtained after compression testing

-Specimen was an intact ST sample



TESTED BY: Z. Shannon
REVIEWED BY: B. Kouchoukos

TEST DATE: 6/11/2019
APPROVED DATE: 6/14/2019

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UNCONFINED COMPRESSIVE STRENGTH TEST COHESIVE SOIL (ASTM D2166)

CLIENT: Allen & Hoshall

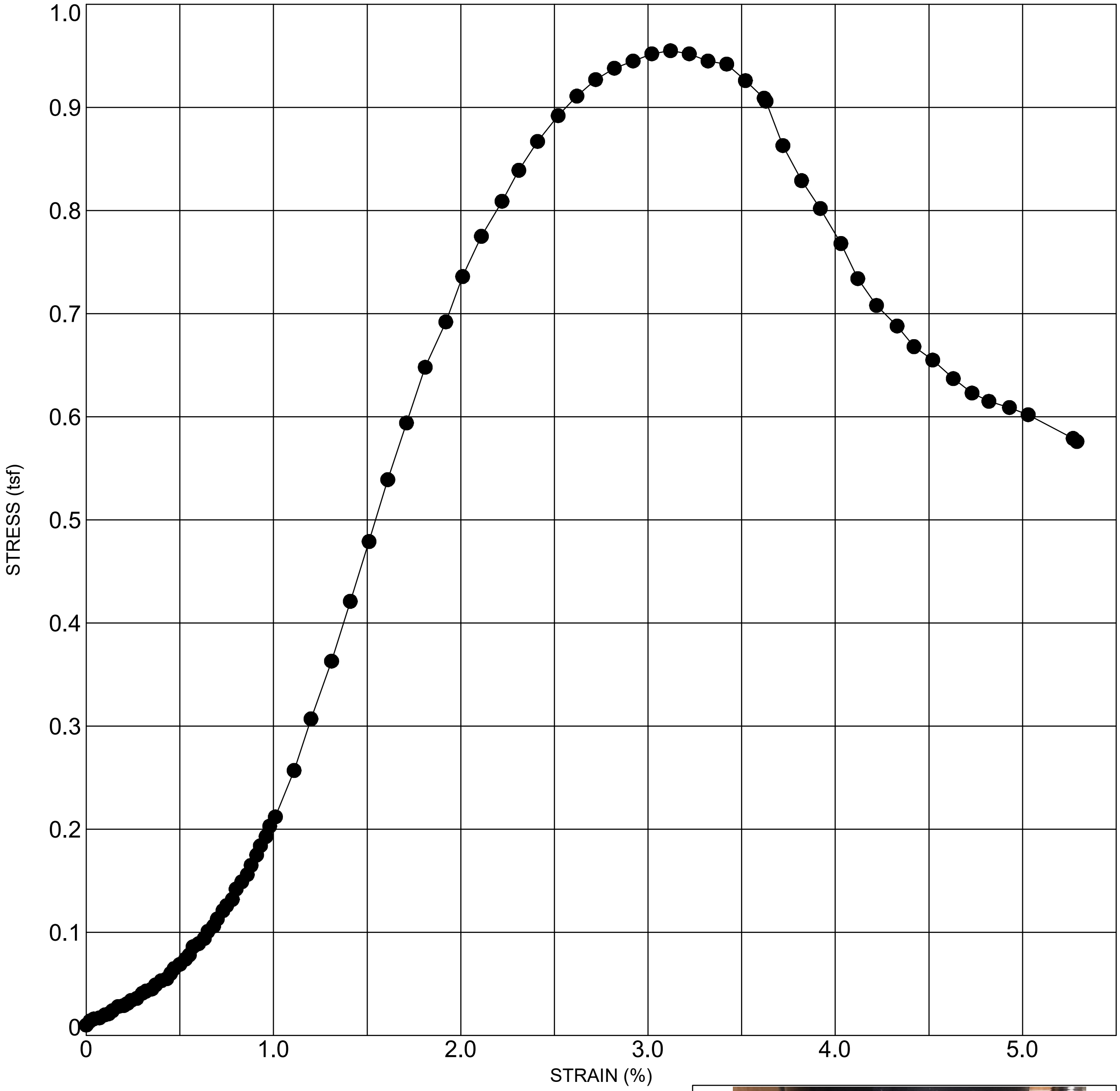
PROJECT NAME: MSCAA Taxiway Alpha West

PROJECT NUMBER 100-19-0019

PROJECT LOCATION: Memphis, TN

SOIL DESCRIPTION: SILT (ML), brown, loose

SAMPLE RECEIVED: 5/13/2019



SAMPLE: B-03

Diameter (in): 2.83

Strain at Failure (%): 3.12

Height (in): 5.51

Strength (tsf): 0.96

Ratio (h/d): 1.95

Dry Density (pcf): 96.00

LL: NP

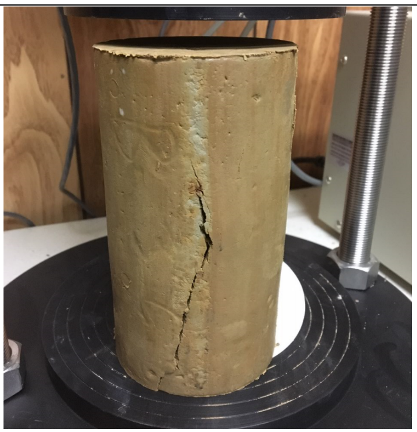
Water Content (%): 28.90529

PL: NP

Rate of Strain to Failure (%/min): 1

-Dry Density and Moisture content data were obtained after compression testing

-Specimen was an intact ST sample



TESTED BY: Z. Shannon
REVIEWED BY: B. Kouchoukos

TEST DATE: 6/11/2019
APPROVED DATE: 6/14/2019

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UNCONFINED COMPRESSIVE STRENGTH TEST COHESIVE SOIL (ASTM D2166)

CLIENT: Allen & Hoshall

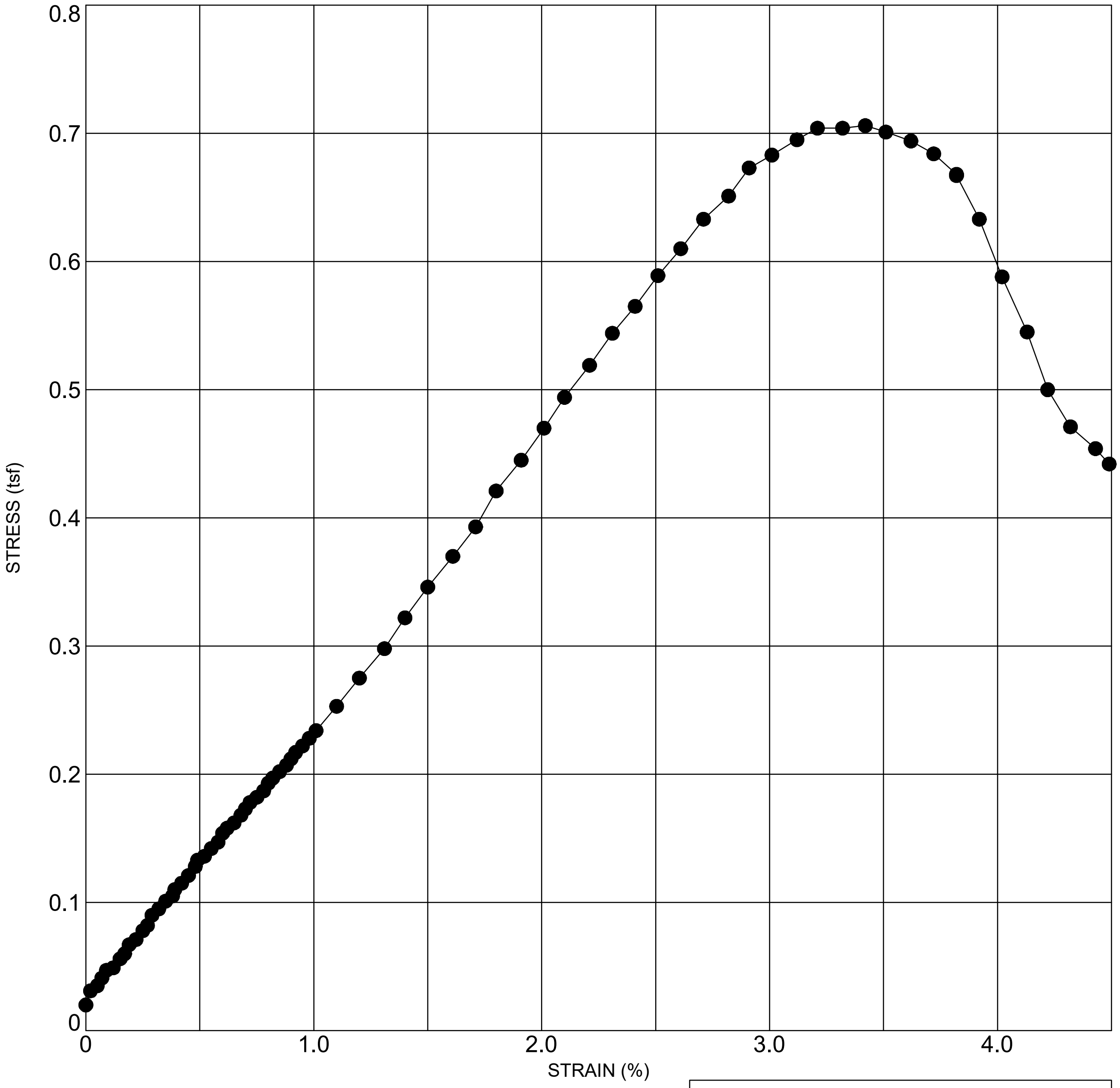
PROJECT NAME: MSCAA Taxiway Alpha West

PROJECT NUMBER 100-19-0019

PROJECT LOCATION: Memphis, TN

SOIL DESCRIPTION: SILT (ML), brown, loose

SAMPLE RECEIVED: 5/21/2019



SAMPLE: B-11

Diameter (in): 2.80

Height (in): 5.54

Ratio (h/d): 1.98

LL: NP

PL: NP

Strain at Failure (%): 3.42

Strength (tsf): 0.71

Dry Density (pcf): 95.60

Water Content (%): 26.23669

Rate of Strain to Failure (%/min): 1

-Dry Density and Moisture content data were obtained after compression testing

-Specimen was an intact ST sample

TESTED BY: Z. Shannon
REVIEWED BY: B. Kouchoukos

TEST DATE: 6/11/2019
APPROVED DATE: 6/14/2019

K. S. Ware & Associates, L.L.C.
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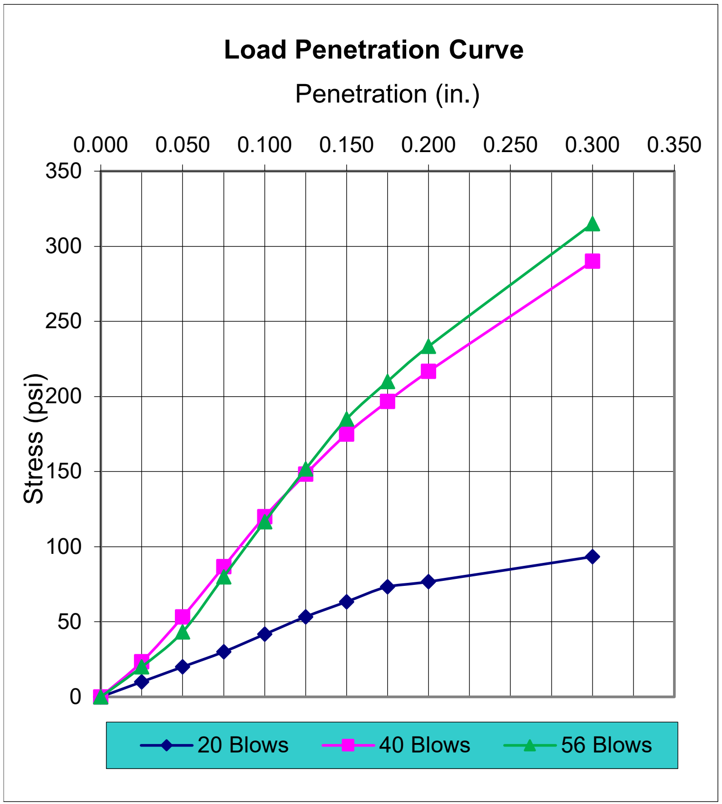
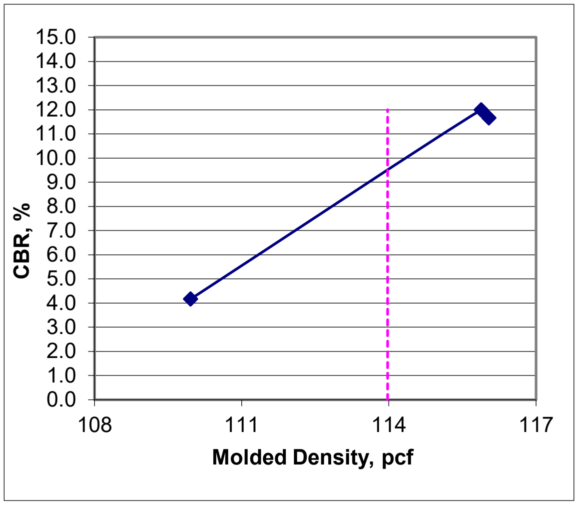
Report of California Bearing Ratio Test (ASTM D1883)

Project Name:	MSCAA	Proctor Type:	Modified
Project Number:	100-19-0019	Maximum Dry Density:	116.3
Sample ID:	B-2/B-5 Bulk	Optimum Moisture:	13.9
Date Received:	5/13/2019		
Sample Description:	LEAN CLAY (CL), brown, firm, moist		

Test	Pre-Test			Post-Test			CBR, %		Line	%
# Blows	DD	% Max	%m	DD	% Max	%m	0.1"	0.2"	Corr.	Swell
20	110.0	94.5	13.1	104.6	90.0	25.3	4.2	4.2	0	2.574
40	115.9	99.6	12.7	113.5	97.6	18.6	12.0	11.7	0	1.702
56	116.0	99.8	13.6	113.4	97.5	19.7	11.7	12.3	0	1.942





CBR* = 9.5

* for 98% max DD and
0.1 in. penetration

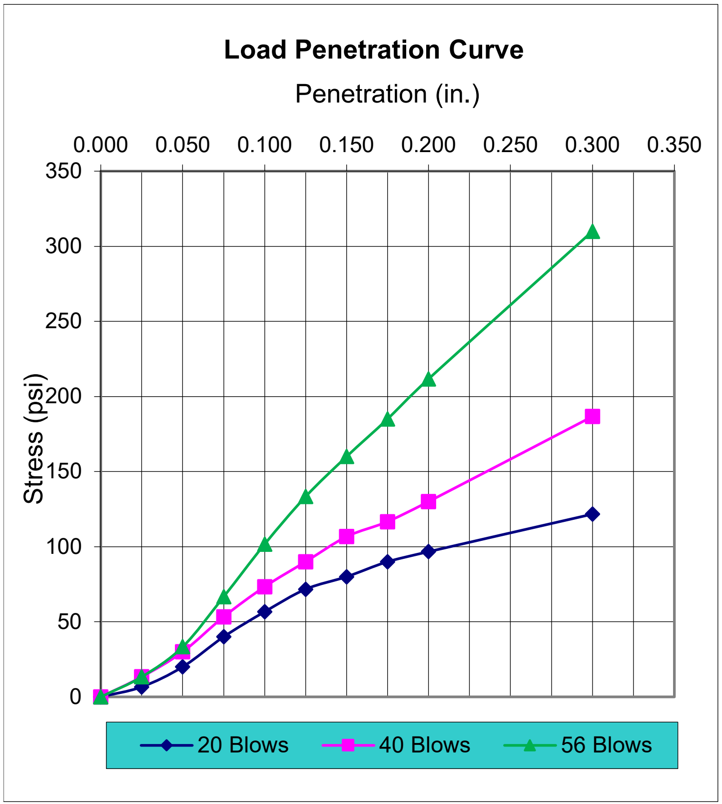
Submitted By:	Z. Shannon	Date:	6/11/2019
Reviewed By:	B. Kouchoukos	Date:	6/12/2019

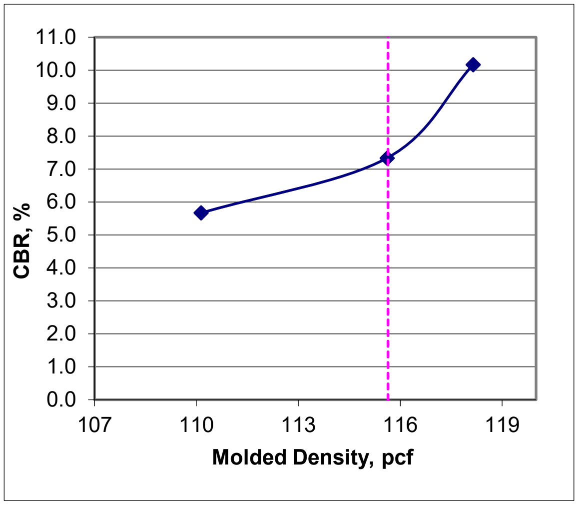
K. S. Ware & Associates, L.L.C.
Geotechnical • CEI • Environmental

Report of California Bearing Ratio Test (ASTM D1883)

Project Name:	MSCAA	Proctor Type:	Modified
Project Number:	100-19-0019	Maximum Dry Density:	118.0
Sample ID:	B-8/B10	Optimum Moisture:	12.6
Date Received:	5/21/2019		
Sample Description:	LEAN CLAY (CL), brown, firm, moist		

Test	Pre-Test			Post-Test			CBR, %		Line	%
# Blows	DD	% Max	%m	DD	% Max	%m	0.1"	0.2"	Corr.	Swell
20	110.1	93.3	13.6	107.6	91.2	21.8	5.7	5.3	0	1.942
40	115.6	98.0	13.0	112.7	95.5	20.0	7.3	7.1	0	2.225
56	118.1	100.1	13.0	114.7	97.2	19.3	10.2	10.7	0	1.876





CBR* = 7.0

* for 98% max DD and
0.1 in. penetration

Submitted By:	Z. Shannon	Date:	6/11/2019
Reviewed By:	B. Kouchoukos	Date:	6/12/2019

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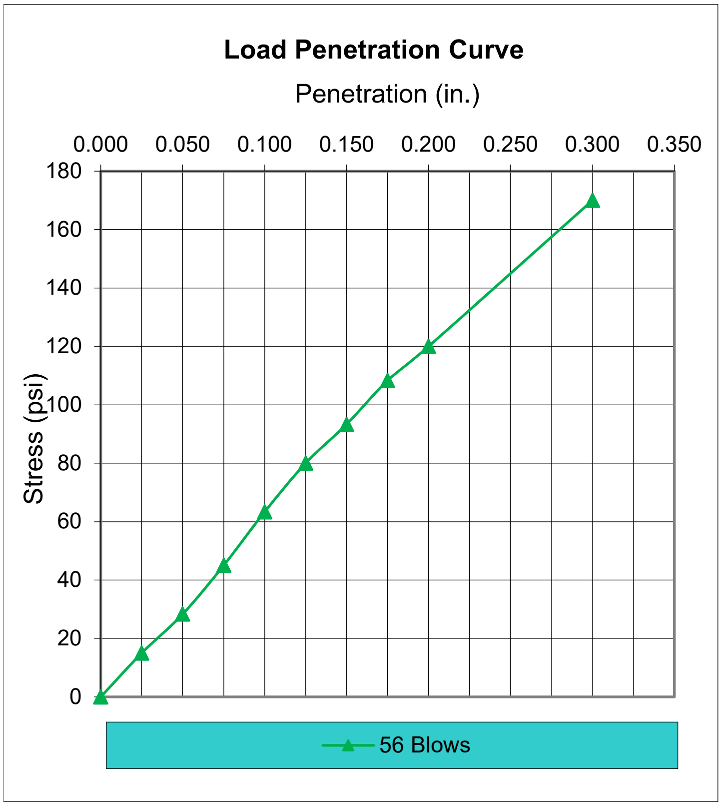
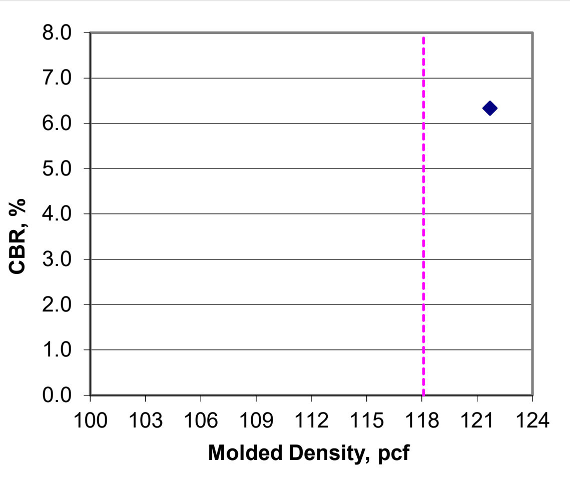
Report of California Bearing Ratio Test (ASTM D1883)

Project Name: MSCAA
Project Number: 100-19-0019
Sample ID: B-12 Bulk
Date Received: 5/21/2019
Sample Description: LEAN CLAY (CL), brown, firm, moist

Proctor Type: Modified
Maximum Dry Density: 120.5
Optimum Moisture: 11.8

Test	Pre-Test			Post-Test			CBR, %		Line	%
# Blows	DD	% Max	%m	DD	% Max	%m	0.1"	0.2"	Corr.	Swell
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
56	121.7	101.0	11.4	117.8	97.8	18.4	6.3	6.2	0	2.552





CBR* = 6.0

* for 98% max DD and
0.1 in. penetration

Submitted By: Z. Shannon Date: 6/11/2019
Reviewed By: B. Kouchoukos Date: 6/12/2019

ATHENA
[formerly KS Ware & Associates]

REPORT OF GEOTECHNICAL EXPLORATION

Taxiway Bravo Intersection Reconfiguration
Memphis International Airport
Memphis, Tennessee

Prepared For:
Allen & Hoshall
1661 International Drive, Suite 100
Memphis, Tennessee 38210

Prepared By:
Athena Engineering and Environmental, LLC
52 Lindsley Avenue, Suite 101
Nashville, Tennessee 37210

Athena Project No. 100-19-0019

March 29, 2023

ATHENA
[formerly KS Ware & Associates]

Nashville, TN | Bowling Green, KY | Chattanooga, TN | Pensacola, FL

March 29, 2023

Mr. Tim Gibson, PE
Allen & Hoshall
1661 International Drive, Suite 100
Memphis, Tennessee 38210

Subject: Report of Geotechnical Exploration
Taxiway Bravo Intersection Reconfiguration
Memphis International Airport
Memphis, Tennessee
Athena Project No. 100-19-0019

Dear Mr. Gibson:

Athena Engineering and Environmental, LLC (Formerly K. S. Ware & Associates, LLC) is pleased to submit this report which provides the results of our geotechnical exploration for the Taxiway Bravo Intersection Reconfiguration project at the Memphis International Airport in Memphis, Tennessee. Our services were provided in general accordance with our Proposal for Geotechnical Exploration dated April 14, 2022.

The attached report summarizes the project information provided to us, describes the site and subsurface conditions encountered, and details our geotechnical recommendations for the project. The Appendices include figures, descriptions of our field-testing procedures, and our field and laboratory test results.

We appreciate the opportunity to be of service to you on this project. Please contact us if you have any questions regarding this report. We look forward to serving as your geotechnical consultant on the remainder of this project.

Respectfully submitted,

Athena Engineering and Environmental, L.L.C.

NATHAN LONG
No. 111689

Bradley D. Kouchoukos

Bradley D. Kouchoukos, P.E., VMA
Geotechnical Project Engineer

Nathan Long, P.E., P.G.
VP of Geotechnical Services

Enclosures: Report of Geotechnical Exploration

Distribution: File (1)

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APPENDICES

1.0 INTRODUCTION

1.1 PROJECT INFORMATION

Our understanding of the project is based on information provided by Mr. Tim Gibson of Allen & Hoshall via e-mail correspondence on April 5, 2022. The initial e-mail included a document titled "Bravo Proposed Borings", which provided a proposed layout for Taxiway Bravo intersection reconfiguration and a proposed boring layout.

We understand the project consists of constructing a new taxiway near the intersections of Taxiways Alpha and Bravo and Taxiway Sierra and Bravo. The taxiway will be about 924 feet long and will generally run parallel to the east side of Taxiway Sierra. We assume the new taxiway section will be primarily concrete paved with asphalt shoulders. The existing taxiway in this section will be demolished and removed to make way for this replacement taxiway. We have assumed final pavement surface elevations will be similar to existing pavement surface elevations. Therefore, we anticipate maximum cut and fill of 3 feet each will be required to achieve final subgrade elevations.

We understand this intersection project will be incorporated into the Taxiway Alpha West Reconstruction project. Athena (formerly KSWA) completed a geotechnical exploration for the Taxiway Alpha West Reconstruction project in November 2019.

1.2 PURPOSE AND SCOPE OF EXPLORATION

The purpose of the exploration was to evaluate the subsurface conditions along the new taxiway alignment and provide geotechnical design recommendations for the project. Our scope of services was detailed in our Proposal for Geotechnical Exploration, dated April 14, 2022.

Our geotechnical exploration services did not include sampling and testing of the soil, rock, surface water, groundwater, or air for the presence of environmental contaminants. Therefore, special procedures were not recommended for handling or managing sediments encountered during future construction or for handling the soil and rock samples from the borings in the geotechnical testing lab.

2.0 SITE GEOLOGY

2.1 GEOLOGIC FORMATION

Memphis International Airport is located in the Coastal Plain physiographic province. This province extends along the southeast and east coasts of the United States from the southern tip of Texas to the southern tip of Florida along the Gulf of Mexico and then extends north to New Jersey along the coast of the Atlantic Ocean. The Coastal Plain province generally lies along the coastal states but extends north from Louisiana and Mississippi through the eastern portions of Arkansas, the west portions of Tennessee, and the southern tip of Illinois. In Tennessee, the area between the Tennessee River and Mississippi River is considered to be part of the Coastal Plain province; there are three subcategories within this area. Starting from the east, along the western banks of the Tennessee River, is an approximately 10-mile-wide section of hilly land which consists of sedimentary rocks overlain by residual soils (derived in place from weathering of the bedrock), alluvial soils (soils deposited by streams) locally, and about 4 feet of loess (wind-blown silts and clays). To the west of the hilly land is an area called the Tennessee Bottoms or the bottom land which extends to steep bluffs along the shores of the Mississippi River in Memphis. This area consists of rolling hills and streams formed from marine sediments consisting mainly of clays, silts and sands covered by loess at the surface. The loess can be up to 100 feet thick in the bluffs overlooking the Mississippi River; however, the loess can also be absent where streams have eroded these soils and filled the stream valley with alluvium. The third section is called the Mississippi Alluvial Plain. This area is west of the Tennessee Bottoms and consist of lowland areas, flood plains, and swamp land typically less than 300 feet above sea level.

The Surficial Geologic Map of the Southeast Memphis Quadrangle, Shelby County, Tennessee indicates the airport is underlain by loess and artificial fill. The loess deposits include wind-blown sediments consisting of generally of clayey silt brown and light-brown in color. These soils are relatively strong and stable when the water content is near the soil's Plastic Limit but become soft and unstable if the water content moves above the Plastic Limit. Artificial fill in Memphis typically consists of brown silt to clayey silt, but can also include construction debris, organics, and other deleterious materials. The strength, compressibility, and stability of artificial fill subgrades depend on the fill material type, lift thicknesses, water content, and compaction effort applied during placement.

2.2 SOIL SURVEY

The soil survey of Shelby County, Tennessee, downloaded from the United States Department of Agriculture website[1] indicates the soil types across the proposed Taxiway Bravo consist of Graded land (Gr). This soil type consists of developed areas that primarily consisted of Grenada, Loring, and Memphis soils prior to grading. Typical engineering classifications for these soils include clays (CL), clayey silts (ML), and non-plastic sands (SC) by the Unified Soil Classification System (USCS) classification and A-4, A-6 and A-7 by American Association of State Highway and Transportation Officials (AASHTO) classification.

1- http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.asp

3.0 EXPLORATION PROCEDURES AND FINDINGS

3.1 GENERAL

We performed our subsurface exploration and field testing on February 9, 2023. Our proposed exploration consisted of soil boring at three locations (Borings B-17, B-18, and B-21) within existing grass areas and pavement coring at two locations (Borings B-19 and B-20) within the existing taxiway along the proposed Taxiway Bravo alignment. We also completed dynamic cone penetrometer (DCP) testing at each borehole/corehole location. Due to a limited work window to access the Memphis Airport property, we were unable to complete soil sampling at Borings B-19 and B-20. Borings B-1 through B-16 were performed as part of our initial study for the Taxiway Alpha West Reconstruction project.

The exploration locations were marked in the field by Athena's representative with the client's surveyor prior to beginning fieldwork. The corehole and boring locations shown on the Exploration Location Plan in Appendix A should be considered approximate. Additional discussion regarding the field procedures used during this exploration are provided in Appendix B.

3.2 SURFACE AND SUBSURFACE CONDITIONS

The site primarily consists of grassed areas adjacent to existing Taxiways Bravo, Sierra, and Alpha. Taxiway Sierra is along the west end of the site, Taxiway Alpha is along the north end of the site, and Taxiway Bravo cuts across the site. The grassed areas are relatively flat and slope away from the pavements. The pavement surface generally slopes gradually downward away from the taxiway centerline towards the pavement edge. We estimate total relief across the site to be about 7 feet.

Surface Materials

Borings B-17, B-18, and B-21 initially encountered 12 to 14 inches of topsoil. Borings B-19 and B-20, completed within Taxiway Bravo, encountered an initial layer of asphalt pavement ranging in thickness from approximately 2½ to 3½ inches underlain by concrete pavement ranging in thickness from approximately 6½ to 12 inches. Based on our observations and test results from DCP testing, we do not believe this portion of Taxiway Bravo is underlain by a cemented base material. Table 1 below includes the asphalt and concrete pavement approximate thicknesses encountered at the two locations.

Table 1: Pavement Section Thicknesses

Boring No.	Asphalt Pavement Thickness (in.)	Concrete Pavement Thickness (in.)	Total Pavement Thickness (in.)
B-19	3.5	12.0	15.5
B-20	2.5	6.5	9.0
AVG	3.0	9.25	12.25

Native Soils

Below the existing surface materials, we encountered native soils to the boring termination depth of 10 feet. The native soils generally consisted of firm to stiff Silty Clay (CL-ML) with occasional soft and very stiff layers with Standard Penetration Test N-values ranging from 2 to 15 blows per foot. A layer of Silt (ML) was present between the approximate depths of 1 and 3½ feet in Boring B-18.

Groundwater

No measurable groundwater was encountered during or upon completion of drilling operations at the boring locations. We backfilled the borings upon completion for safety precautions, so delayed groundwater measurements were not taken. Groundwater levels will differ depending on the time of year, climatic conditions, and construction activities. Perched groundwater conditions may develop within the overburden soils during seasonal wet periods of the year and after heavy precipitation events.

Dynamic Cone Penetrometer (DCP) Test

We performed DCP testing (ASTM D6951) at each of the boring locations for the purpose of evaluating the strength of the subgrade materials currently present along the proposed Taxiway Bravo alignment. The DCP test results were plotted to determine the estimated CBR value of the subgrade material. The results of these tests are provided in Table 2 below. In the upper limits of DCP testing, unusually low soil values can often be attributed to disturbed soil due to auger operations. The DCP test data is included in Appendix B of this report.

Table 2 - DCP Estimated CBR Values

Boring No.	Starting Depth (in.)	Depth Range (in.)	Average Estimated CBR Value
B-17	0.0	0 - 34	>10
B-18	0.0	0 – 13	>10
		13 – 18	8
		18 – 34	>10
B-19	15.5*	0 – 16	9
		16 – 36	>10
B-20	9.0*	0 – 16	6
		16 – 35	>10
B-21	6.0	0 – 6	5
		6 – 11	8
		11 – 34	>10

*Borings B-19 and B-20 depth ranges begin at the bottom of the existing pavement section.

4.0 LABORATORY TESTING

Athena performed laboratory testing on representative split-spoon, Shelby tube, and bulk soil samples in general accordance with ASTM procedures. The laboratory testing included:

- Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass (ASTM D2216)
- Standard Test Methods of Liquid Limit, Plastic Limit, and Plasticity Index (ASTM D4318)
- Standard Test Method for Determining the Amount of Material Finer than 75-µm (No. 200) Sieve in Soils by Washing (ASTM D1140)
- Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates (ASTM C136/C136M)
- Standard Test Method for Laboratory Compaction Characteristic of Soil Using Modified Effort (ASTM D1557)
- Standard Test Method for California Bearing Ratio (CBR) of Laboratory-Compacted Soils (ASTM D1883)

The moisture content data and Atterberg limit are presented on the individual boring logs in Appendix B. Laboratory test reports for grain size analysis, Modified Proctor, and CBR tests are within Appendix C and Table 3 below.

Table 3: Summary of Soil Laboratory Test Results

Boring No.	Sample Type	Sample Depth (ft)	Modified Proctor		CBR (%)	LL (%)	PI (%)	Percent Passing #200 Sieve (%)	Unconfined Compression (psf)	USCS Class.
			Max. Dry Density (lbs/ft^3)	Optimum Moisture (%)						
B-18	ST	1 – 3	---	---	---	NP	NP	99.9	1,460*	ML
B-21	ST	1 – 3	---	---	---	29	7	98.7	2,380	CL-ML
B-21	Bulk	1 – 5	116.7	13.0	4.5	28	7	97.5	---	CL-ML

*Unconfined compression strength test sample was determined to be silt (ML) based on grain size analysis and Atterberg Limit testing. It should be noted, unconfined compression strengths of silt (ML) may not be representative of the soils strength due to lack of cohesion.

5.0 GEOTECHNICAL CONSIDERATIONS

5.1 GENERAL

Based upon an engineering reconnaissance of the site, the boring and laboratory data, visual-manual examination of the samples, and Athena's understanding of the proposed construction and experience as geotechnical engineers, Athena reached the conclusions and developed the recommendations provided herein. The conclusions and recommendations in this report have been derived by relating the general principles of the discipline of geotechnical engineering to the proposed construction outlined by the Project Information section of this report. Because changes in surface, subsurface, and climatic conditions can occur, the use of this report should be restricted to this specific project. Any changes or modifications which are made in the field during the construction phase which alter site grading, infrastructure, or other related site work, should also be reviewed by Athena. If conditions which vary from the facts of this report are encountered during construction, the Geotechnical Engineer of Record should be contacted immediately to review the changed conditions in the field and make appropriate recommendations.

5.2 SUBGRADE SUITABILITY

Based on the project information provided and the available subsurface data, it is our opinion the site is suitable for the planned reconfiguration. The subgrade materials along the proposed Taxiway Bravo alignment generally consists of firm to stiff silty clay with some soft zones. Soft to firm soils are frequently unstable under a proofrolling load. Additionally, the moisture content of the near-surface soil samples in the upper five feet was significantly higher than the optimum moisture content of 13 percent of the bulk sample tested. Soils with a relatively high moisture content are also frequently unstable under a proofrolling load.

The stability of the near-surface soils will likely be impacted by exposure to moisture and/or construction traffic, once the topsoil has been stripped to prepare the site for construction. The near-surface soils consist of native loess. Loess is typically extremely sensitive to changes in moisture content. Dry loess materials are generally stable and will exhibit favorable strength characteristics. Conversely, when these soils are moist, as a result of local precipitation or climatic conditions, the soils become weak and unstable, particularly under repeated loading from heavy construction equipment. Also, due to the silt content of these soils, they can degrade rapidly even when favorable moisture conditions are present. Therefore, regardless of the time of year construction takes place, some remedial repair of weak subgrades will likely be required.

If construction occurs during warm, dry weather months, it may be possible to repair shallow instability through scarifying, moisture conditioning, and recompacting the upper 8 to 12 inches of subgrade. However, this process will likely not be practical during cooler, wet weather months when moisture conditioning can be problematic. During wet weather, it may be necessary to undercut unstable soils and use a borrow source to haul in drier soils for backfilling. If widespread subgrade instability is present, stabilizing the subgrade with cement is an option that may be considered (cement stabilization is typically more cost-effective over larger areas). Athena recommends a budget be established for subgrade repairs consistent with the time of year construction takes place.

5.3 PAVEMENT DEMOLITION

We understand Taxiway Bravo between Taxiway Sierra and Taxiway Alpha will be completely demolished and removed, which will include the asphalt and underlying concrete pavements. The existing concrete can potentially be used for other functions, such as P-219 recycled concrete aggregate base, if the demolition methods allow for such crushing and gradation. Detailed analysis of the demolished materials would be required prior to use and approval.

6.0 GEOTECHNICAL EVALUATION & RECOMMENDATIONS

The pavement recommendations contained in this report section were developed in consideration of the project information detailed in Section 1.1 of this report. If this information is not correct or has been updated, we should be contacted to review the corrected or updated information and confirm the recommendations presented herein are appropriate.

6.1 GENERAL PAVEMENT RECOMMENDATIONS

Based on our observations and classifications made in the field and from tests performed in the laboratory, Athena is providing the following pavement design parameters and general pavement recommendations.

As discussed in the previous section, remediation of soft to firm subgrade soil prior to final grading and paving should be expected. The stabilization method, the lateral extent, and the depth will depend on actual conditions exposed during construction and on actual grading plans for the pavement areas. On-site recommendations should be made by the geotechnical engineer-of-record or his representative. Additionally, we recommend the upper 12 inches of the subgrade materials be compacted to at least 100 percent of the maximum dry density as determined by the modified Proctor test in accordance with Federal Aviation Administration's (FAA) Standard Specifications for Construction of Airports, dated December 21, 2018, Section 152-2.10.

6.2 PAVEMENT DESIGN RECOMMENDATIONS

The design CBR and subgrade modulus values are highly dependent on the type of near surface material and the level of compaction. Based on the soil conditions encountered during our field explorations (2019 and 2023), the field DCP test results, our laboratory testing results, and our experience with similar soil conditions, Athena recommends using a CBR value of 6 percent and a subgrade modulus of 150 pounds per cubic inch (pci) for the existing subgrade compacted to 100 percent of the Modified Proctor (ASTM D1557) maximum dry density within the upper 12 inches of subgrade.

Base courses and pavements may be placed after the subgrade has been properly compacted, fine graded, and proofrolled, as recommended in the Construction Considerations section of this report. All activities should be accomplished in accordance with FAA Standard Specifications for Construction of Airports. Actual pavement section thickness should be determined by the designer based on actual loads, traffic volume, and the owner's design life requirements.

Experience has shown most pavement failures are caused by localized soft spots in the subgrade or inadequate drainage. Proof rolling, under the observation of our geotechnical engineer, will greatly reduce the incidents of weak spots in the subgrade. However, the civil design must include proper drainage to reduce softening of the subgrade, frost damage, heaving, soil migration, and pumping failures. The pavement surface and subgrade should have a minimum slope of 2 percent. Water infiltrating the mineral aggregate base should be designed to drain into catch basins (through weep holes), out-slope areas, or drainage trenches.

The soils exposed at the pavement subgrade level may be moisture sensitive. Experience indicates there is typically an extensive time lag between the time grading is completed and pavement construction occurs (i.e. grading may occur during hot, dry weather and pavement construction may occur during wet, cool weather). Once grading has been performed, the subgrade may be disturbed throughout the construction process due to utility excavations, construction traffic, desiccation, or rainfall. As a result, the pavement subgrade may become unsuitable for pavement construction over time and corrective action may be required. The subgrade should be carefully evaluated at the time of pavement construction by proof rolling with a heavily-loaded tandem-axle dump truck. Particular attention should be given to high traffic areas that display distress and to areas where backfilled trenches are located.

Design pavement section thicknesses are typically determined based on post-construction traffic loading conditions, which do not account for heavy construction traffic during the early stages of development. A partially constructed structural section subjected to heavy construction traffic can result in pavement deterioration and premature failure. Our experience indicates this pavement construction practice can result in pavements which will not perform as intended. Considering this information, several alternatives are available to mitigate the impact of heavy construction traffic on the pavement construction. These include using thicker sections to account for construction traffic, using some method of stabilization to improve the support characteristics of the pavement subsurface, or by routing heavy construction traffic around paved areas using a “haul road” constructed for that purpose.

Maintenance is essential to long-term performance of rigid and flexible pavements. Any distressed areas should be repaired promptly to prevent the failure from spreading due to loading and water infiltration.

7.0 CONSTRUCTION CONSIDERATIONS

7.1 SITE PREPARATION

Site preparation should initially include removing the existing asphalt pavement and underlying concrete pavement associated with existing Taxiway Bravo and topsoil along the remainder of the proposed Taxiway Bravo alignment. Existing near-surface underground electrical lines may also be present along the shoulders of existing Taxiway Bravo and should be terminated and removed during pavement demolition. At the completion of these activities, the subgrade should be evaluated as follows:

- Recompacting the upper 12 inches of exposed subgrade materials to 95 percent of the maximum dry density (100 percent if within 12 inches of the final subgrade elevation).
- Perform proof rolling prior to any fill or base material placement in fill areas and/or following cuts to grade in cut areas.
- Proof rolling should be performed using a fully-loaded tandem-axle dump truck or other rubber-tired equipment judged suitable by the geotechnical engineer.
- Our geotechnical engineer or his representative should observe proof rolling activities.
- Remediate soft, organic, or yielding subgrade materials encountered during the proof rolling operations as recommended by our geotechnical engineer.

7.1.1 Stabilization of Weak Soils

The following options may be considered for stabilizing weak subgrade areas:

- Scarify and Recompact – It may be possible to stabilize near-surface soils that are unstable due to excessive moisture by scarifying the unstable soils, allowing them to dry, and recompacting them in accordance with structural fill criteria. This process can be successful during hot, dry periods and when the construction schedule is flexible. Drying the soils can be problematic during cold, wet weather or when the construction schedule is not flexible.

- Undercut and Replace – This method involves the excavation of the soft/unstable soils until stiff soils are exposed. The undercut is then backfilled with compacted soil.

- Undercut and Stabilize with Geotextiles and/or Geogrids and Granular Fill – After the undercut surface has been made smooth, geotextiles and/or geogrids can be placed across the surface, followed by placement of granular fill (size and gradation of granular fill to be compatible with the geotextile/geogrid selected). Once a stable surface has been achieved, additional structural fill may be placed, if required.

- Stabilize with Cement or Lime Admixtures – Cement or lime stabilization is performed by a specialty contractor who mobilizes to the site, mixes the soils with cement or lime, and replaces and compacts these soils to the planned subgrade elevation. This stabilization method dries and treats the soils to provide a stable subbase.

As previously noted, the near-surface soils consist of loess. The stability of these soils is a function of the soil's water content. Experience indicates soils with water contents near the soil's Plastic Limit (usually in the teens and low 20s) are typically strong and stable. Soils with water contents several points above the Plastic Limit are often weak and unstable. Remedial subgrade work should be expected based on the water contents of the near surface soils at the time of this exploration.

Protection of the subgrade is a critical issue for maintaining the stability of subgrades formed in loess. Positive surface drainage should be maintained throughout construction. Areas which break down because of construction traffic or exposure to moisture should be repaired to prevent the failed area from spreading. Heavy equipment such as concrete trucks should be restricted to using construction roads specifically prepared for that purpose. Such roads can consist of 2 or more feet of crushed stone or crushed concrete. Soil-cement is also a viable alternative.

7.2 COMPACTED FILL RECOMMENDATIONS

Once the subgrade has been properly prepared, compacted fill may be placed in accordance with the recommendations provided below to attain final desired construction elevations. Fill operations should not begin until representative soil samples are collected and tested (allow 3 to 4 days for sampling and testing). The test results will be used to determine whether the proposed fill material meets the specified criteria and for quality control during grading. Fill placement and compaction should be observed by a geotechnical representative on a full-time basis. Our limited laboratory testing indicates most of the on-site soils meet the criteria recommended below; however, significant drying will likely be required to achieve proper compaction. Materials from both on-site and off-site sources proposed for use as structural fill should meet the criteria provided below.

- Liquid Limit less than 50
- Plasticity Index less than 25
- Maximum dry density (ASTM D1557) of 95 pcf or greater
- Free of large rock fragments (greater than 3 inches in diameter) and organic materials (less than 5 percent by weight)
- Amount of rock fragments retained on a 3/4-inch sieve should be less than 30 percent by weight

Structural fill should be placed and compacted using the following criteria:

- Soil fill should be placed in lifts of uniform thickness. The loose lift thickness should not exceed the amount which can be properly compacted throughout its entire depth with the equipment available, usually no more than 8 inches for cohesive material. In confined areas such as utility trenches, lift thicknesses of 3 to 4 inches may be required to achieve the recommended degree of compaction.

- Fill should be properly keyed into stripped and scarified subgrades. The upper one foot of remaining materials in cut areas or in areas which do not receive more than one foot of new fill should be scarified and recompacted using the guidelines outlined in this report section.
- So a positive tie is created along the interface of engineered fill and sloping ground (steeper than 4H:1V), we recommend the host slope be benched as the fill is placed. For this project, benching is defined as grading a saw tooth or terrace configuration into the slope. In general, at a minimum, we recommend benches should be about three feet tall and a minimum of eight feet wide, although some modification to bench geometry is permissible based upon conditions observed at particular locations. Further, fill placement should begin at the bottom of the slope and the working fill surface should be maintained approximately horizontal.
- Fill should not be placed on frozen or saturated subgrades.
- Based on the FAA Standard Specifications for Construction of Airports, dated December 21, 2018, Section 152-2.10 Compaction requirements, the top 12 inches of the pavement subgrade must be compacted to not less than 100 percent of the maximum dry density as determined by the Modified Proctor (ASTM D1557) and to within 2 percent of optimum moisture content immediately prior to paving. Additionally, the subgrade in areas outside of the limits of the pavement areas should be compacted to a depth of 12 inches to a density not less than 95 percent of the maximum dry density as determined by a Standard Proctor (ASTM D698). Additionally, the compacted fill should be stable under the moving load of a heavily-loaded tandem-axle dump truck.
- Density tests should be performed at a frequency of no less than one test per 5,000 square feet for pavement areas for each fill layer placed, with a minimum of two tests per lift. For utility trenches, one density test should be performed every 50 linear feet for each one-foot-thick fill layer placed, with a minimum of two tests per lift. Any areas not meeting the recommended compaction should be reworked and recompacted to achieve compliance. The recommended test frequencies are for preliminary planning and should be adjusted in the field to account for material variability, rate of placement, weather, and other factors.
- The soils should be placed near (within two percent of) the optimum water content (ASTM D1557). Aeration (i.e., drying) is often necessary to bring fill materials to the required water content during wet and rainy periods. During dry periods, water may need to be added to achieve the proper water content for compaction. Clayey and silty soils may require aeration prior to compaction, even during dry periods. The water content testing performed during this exploration suggests the on-site soils are significantly above the optimum water contents.
- Soil slopes should be protected from erosion by seeding, sodding, or other means, and surface run-off should be diverted away from slopes. For erosion protection, grass or other vegetation should be established on permanent slopes as soon as practical.

- Compacted soil fill embankments should be constructed no steeper than a ratio of 3 horizontal to 1 vertical (i.e., 3H:1V). We also recommend permanent cut slopes be constructed no steeper than 3H:1V.
- Compacted fills should extend horizontally outside of planned pavement areas at least 10 feet before sloping.
- Cut and fill slopes should be regularly evaluated during the construction for indications of movement.
- Excavations should be constructed in accordance with applicable Occupational Safety and Health Administration (OSHA) regulations.

7.3 GENERAL EARTHWORK CONSIDERATIONS

During earthwork operations, positive surface drainage should be maintained to prevent water from ponding on the exposed ground surface. The exposed subgrade may be rolled with a rubber-tired or steel drummed roller to improve surface run-off if precipitation is expected. Our geotechnical engineer should be consulted if the subgrade soils become excessively wet or dry, or frozen.

7.4 GROUNDWATER CONTROL RECOMMENDATIONS

No measurable groundwater was encountered during or upon completion in the borings. Groundwater levels may fluctuate with season changes. If water-bearing strata are exposed at subgrade, the magnitude and duration of seepage will vary. We anticipate that in most cases, depending on seasonal conditions, any seepage encountered can be handled by conventional dewatering methods (i.e., pumping from small sumps located near the source or in collector areas). If larger quantities of groundwater are encountered, the Geotechnical Engineer should be contacted.

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8.0 QUALIFICATIONS OF RECOMMENDATIONS

The recommendations provided herein were developed in part using the subsurface information obtained from the pavement coreholes and soil test borings advanced at the site. Soil test borings depict the soil conditions only at the specific location and time at which they were completed. The soil conditions at other locations on the site or at other times may differ from those occurring at the boring locations.

The conclusions and recommendations contained in this report were based on the available subsurface information, the project information provided, and the assumptions previously stated. Revisions in the plans for the proposed construction from those anticipated in this report should be brought to the attention of an Athena geotechnical engineer or his representative to determine whether any changes in the pavement recommendations are necessary. If deviations from the noted pavement conditions are encountered during construction, they should also be brought to the attention of the geotechnical engineer.

The scope of our geotechnical services did not include assessment or investigation for the presence or absence of hazardous or toxic materials in the soil, groundwater, or surface water within or beyond the site studied. Any statements in this report or indicated on the test boring logs regarding odors, staining of soils or other unusual conditions observed are strictly for the information of our client.

Our professional services were performed, our findings obtained, and our recommendations prepared in accordance with generally accepted geotechnical engineering principles and practices. Athena is not responsible for the conclusions, opinions, or recommendations made by others based upon the data included herein.

Our services include retaining the soil samples obtained during this study for 60 days after report submittal. Further storage or transfer of the samples can be made at the Client’s expense upon a written request.

APPENDIX A

SITE VICINITY PLAN

EXPLORATION LOCATION PLAN

N

NOT TO SCALE

JOB NO. 100-19-0019

CLIENT: Allen & Hoshall

CLIENT ADDRESS:
1661 International Drive, Suite 100
Memphis, TN 38120

DATE: 3/14/2023

Site Vicnity Plan

Taxiway Bravo Intersection Reconfiguration
Memphis International Airport
Memphis, Tennessee

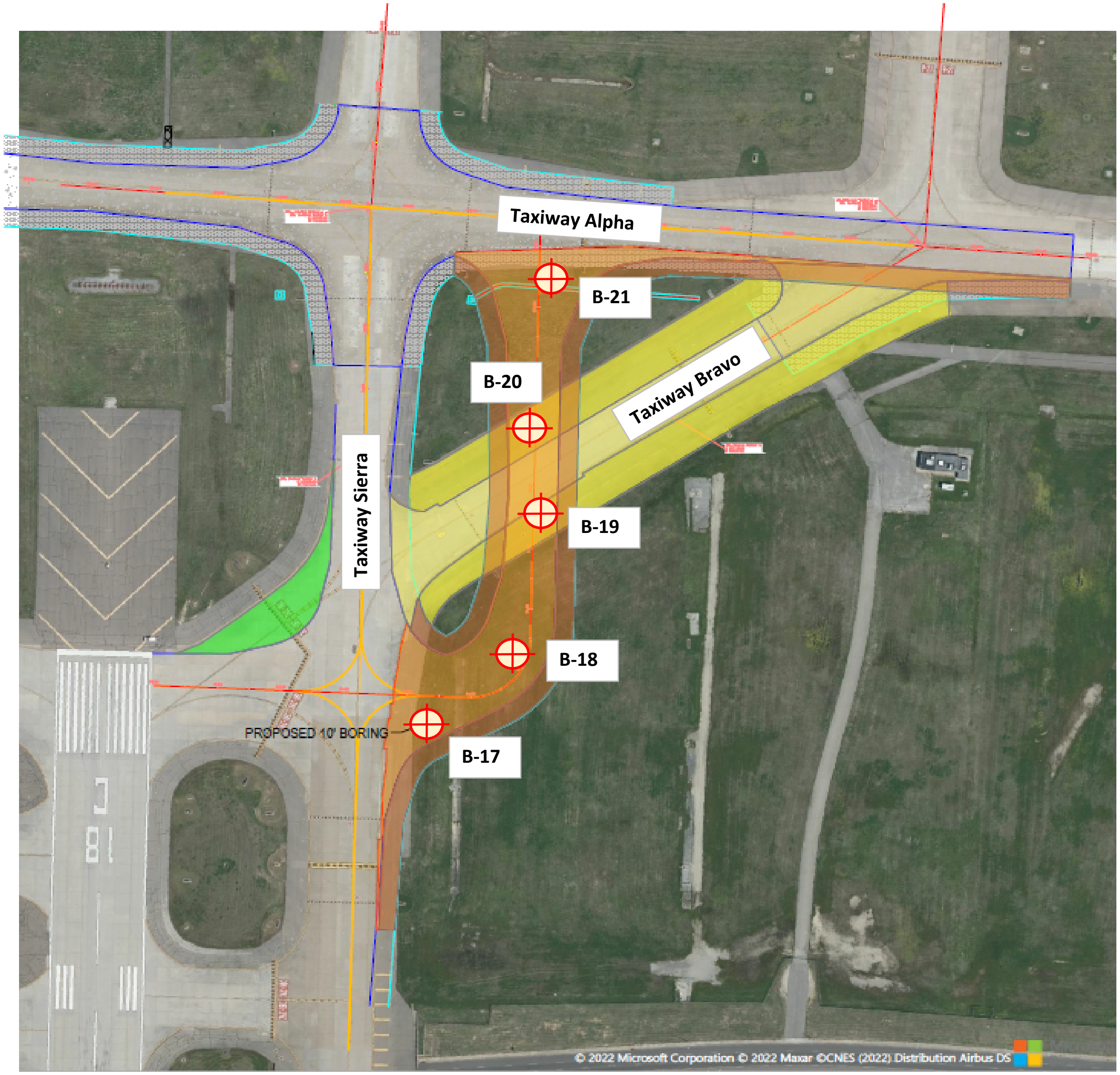
DRAWN BY: BK

REVIEWED BY: NL

LEGEND

ATHENA
[formerly KS Ware & Associates]

Figure 1



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LEGEND

🟨 PAVEMENT DEMOLITION

🟧 NEW CONSTRUCTION

🟩 PAINTED "SHOULDER"

Note: Base drawing "Bravo Proposed Borings" provided by client

N

NOT TO SCALE

JOB NO. 100-19-0019

CLIENT: Allen & Hoshall

CLIENT ADDRESS:
1661 International Drive, Suite 100
Memphis, TN 38120

DATE: 3/14/2023

Exploration Location Plan

Taxiway Bravo Intersection Reconfiguration
Memphis International Airport
Memphis, Tennessee

DRAWN BY: BK

REVIEWED BY: NL

LEGEND

⊕ Soil Test Boring Location

ATHENA
[formerly KS Ware & Associates]

Figure 2

APPENDIX B

FIELD TESTING PROCEDURES

FIELD CLASSIFICATION SYSTEM

SOIL CLASSIFICATION CHART

TEST BORING LOGS

PAVEMENT CORE PHOTOGRAPHS

DCP RESULTS

FIELD TESTING PROCEDURES

Drilling, sampling, and testing were conducted in general accordance with methods of the American Society for Testing and Materials (ASTM) or other widely-accepted geotechnical engineering standards. Descriptions of the procedures used during this exploration are provided below.

BORING AND COREHOLE LOCATIONS AND ELEVATIONS

The boring and corehole locations were selected by the Client and marked in the field by Athena's representative with the Client's surveyor prior to beginning our exploration. We located the exploration locations on the Exploration Location Plan by estimating distances and angles relative to on-site features. Surveying of boring and corehole coordinates was beyond the scope of our exploration.

TEST BORINGS
ASTM D 1586

Test borings were advanced using auger drilling techniques. At regular intervals, soil samples were obtained with a standard 1.4-inch I.D., 2.0-inch O.D., split-barrel sampler. The sampler was initially seated 6 inches to penetrate any loose cuttings and then driven an additional foot with blows of a 140-pound hammer falling 30 inches. The number of hammer blows required to drive the sampler the final foot is the *standard penetration resistance*, or N-value. Standard penetration resistance, when properly evaluated, is an index to the soil's strength and density. The criteria used during this exploration are presented on the Field Classification System sheet in this appendix. Representative portions of the soil samples obtained were placed in sealed containers and transported to our laboratory, where our engineer selected samples for laboratory testing.

The standard penetration tests were performed using an automatic hammer. The automatic hammer has a higher efficiency than the traditional rope and cathead hammer, thus yielding comparatively lower N-values. This reduction in N-value was accounted for during our engineering analysis. However, the consistencies presented on the boring logs were based on the customary relationships with N-value.

BORING LOGS

The soil samples obtained during the drilling were visually classified using the USCS as a guide (reference Soil Classification Chart in Appendix B). The Test Boring Logs in Appendix B provide the soil descriptions and penetration resistances, and represent our interpretation of the conditions encountered at each boring location. The stratification lines indicated on the boring records represent the approximate boundaries between material types, but these transitions may be gradual. The boring logs were prepared based on the field logs and review of the laboratory classification test results. The USCS designations indicated on the boring logs are based on visual-manual evaluation of the samples unless otherwise defined by laboratory testing.

The boring logs indicate estimated interfaces between soil strata. The interfaces indicated represent the approximate interface location, but the actual transition between strata may be gradual. Water levels indicated on the boring logs represent the conditions only at the time each measurement was taken.

FIELD CLASSIFICATION SYSTEM

Sands and Gravels

No. of Blows	Relative Density
0-5	Very Loose
6-10	Loose
11-30	Medium dense
31-50	Dense
51+	Very Dense

Silts and Clays

No. of Blows	Relative Consistency
0-2	Very Soft
3-4	Soft
5-9	Firm
10-15	Stiff
16-30	Very Stiff
31+	Hard

Particle Size Identification

Boulders:	8-inch diameter or larger
Cobbles:	3- to 8-inch diameter
Gravel:	
Coarse:	1- to 3-inch
Medium:	0.50- to 1-inch
Fine:	0.25- to 0.50-inch
Sand:	
Coarse:	2.00-mm to 0.25-inch (diameter of pencil lead)
Medium:	0.074-mm to 2.00-mm (diameter of broom straw)
Fine:	0.042-mm to 0.074-mm (diameter of human hair)
Silt:	0.002-mm to 0.042-mm (Cannot see particles)
Clay:	<0.002-mm

Relative Proportions

Descriptive Term	Percent
Trace	1-10
Little	11-20
Some	21-35
And	36-50

Relative Quality of Rock Cores

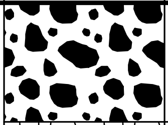
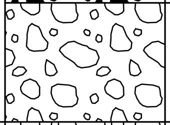
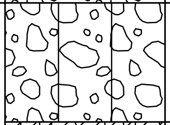
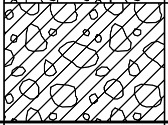
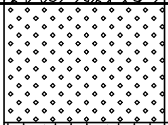
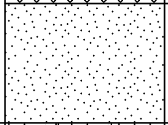
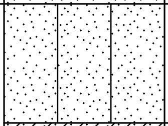
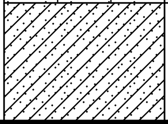
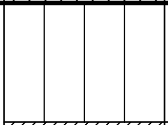
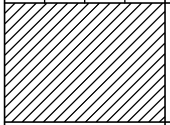
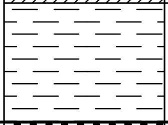
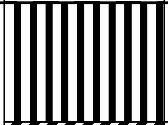
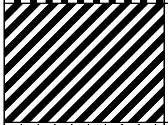
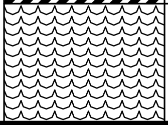
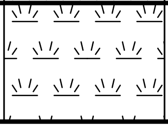
Quality	RQD
Very Poor	0-25%
Poor	25-50%
Fair	50-75%
Good	75-90%
Excellent	90-100%

$$\text{RQD} = \frac{\text{Total length of core recovered in pieces 4 inches long or longer}}{\text{Total length of core run}} \times 100\%$$

Rock Hardness

Very Soft	Rock disintegrates or easily compresses to touch; can be hard to very hard soil
Soft	Rock is coherent but breaks easily to thumb pressure at sharp edges and crumbles with firm hand pressure
Moderately Hard	Small pieces can be broken off along sharp edges by considerable hard thumb pressure; can be broken by light hammer blows
Hard	Rock cannot be broken by thumb pressure, but can be broken by moderate hammer blows
Very Hard	Rock can be broken by heavy hammer blows

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS		TYPICAL DESCRIPTIONS
			GRAPH	LETTER	
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
				SP	POORLY-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

ATHENA BORING LOG

ATHENA
[formerly KS Ware & Associates]

BORING NO. B-17

PROJECT NAME: Taxiway Bravo Intersection Reconfiguration
LOCATION: Memphis International Airport
PROJECT NO.: 100-19-0019
Sheet 1 of 1

Approx. Surface El. (feet, MSL):
Location: See Location Plan

Depth, feet	MATERIAL DESCRIPTION	Samples	Recovery (%)	RQD (%)	SPT Values	N-Value	Pocket Pen (tsf)	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
	TOPSOIL (12 Inches)										
	1.0										
	SILTY CLAY (CL-ML), brown, firm to stiff, moist	☒	67		4-7-3	10	3.5	18.1			
4		☒	94		1-2-3	5	2.25	23.8			
	5.5										
	SILTY CLAY (CL-ML), light brown, trace black nodules, firm to stiff, moist	☒	100		3-3-4	7	2.75	24.0			
8											
	8.5										
	SILTY CLAY (CL-ML), light brown with orange mottling, stiff, moist	☒	100		3-5-9	14	2.5	23.4			
	10.0										
	BORING TERMINATED AT 10.0 FBGS										
12											

Completion Depth (ft.): **10.0**
Date Started: **2/9/23**
Date Completed: **2/9/23**
Drilled By: **Geotechnology**
Logged By: **J. Benoit**

Remarks: **No measurable groundwater observed during or upon completion of drilling operations. Backfilled with auger cuttings. Geoprobe track-mounted drill rig with auto-hammer. 3-1/4" I.D. HSA, AWJ Split-Spoon sampling**

ATHENA BORING LOG

ATHENA
[formerly KS Ware & Associates]

BORING NO. B-18

PROJECT NAME: Taxiway Bravo Intersection Reconfiguration
LOCATION: Memphis International Airport
PROJECT NO.: 100-19-0019

Sheet 1 of 1

Approx. Surface El. (feet, MSL):
Location: **See Location Plan**

Depth, feet	MATERIAL DESCRIPTION	Samples	Recovery (%)	RQD (%)	SPT Values	N-Value	Pocket Pen (tsf)	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
	TOPSOIL (12 Inches)										
1.0	SILT (ML), brown, firm, moist	■	100					29.0	NP	NP	NP
3.5	SILTY CLAY (CL-ML), brown with light brown mottling, soft to firm, v. moist	☒	100		1-1-1	2	1.5	26.9			
6.0	SILTY CLAY (CL-ML), brown, firm to stiff, moist	☒	100		1-3-2	5	1.25	25.7			
		☒	100		1-2-4	6	1.5	24.9			
10.0	BORING TERMINATED AT 10.0 FBGS										

Depth scale: 4, 8, 12

Completion Depth (ft.): **10.0**
Date Started: **2/9/23**
Date Completed: **2/9/23**
Drilled By: **Geotechnology**
Logged By: **J. Benoit**

Remarks: **No measurable groundwater observed during or upon completion of drilling operations. Backfilled with auger cuttings. Geoprobe track-mounted drill rig with auto-hammer. 3-1/4" I.D. HSA, AWJ Split-Spoon sampling**

ATHENA BORING LOG

ATHENA
[formerly KS Ware & Associates]

BORING NO. B-21

PROJECT NAME: Taxiway Bravo Intersection Reconfiguration
LOCATION: Memphis International Airport
PROJECT NO.: 100-19-0019

Sheet 1 of 1

Approx. Surface El. (feet, MSL):
Location: See Location Plan

Depth, feet	Graphic Log	MATERIAL DESCRIPTION	Samples	Recovery (%)	RQD (%)	SPT Values	N-Value	Pocket Pen (tsf)	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index
		TOPSOIL (14 Inches)										
		1.2 SILTY CLAY (CL-ML), light brown, stiff, moist		100					25.3	29	22	7
4		3.5 SILTY CLAY (CL-ML), trace gravel, light brown, trace black nodules, firm to stiff, moist		89		1-3-4	7	2.25	21.5			
		6.0 SILTY CLAY (CL-ML), light brown with brown mottling and black nodules, stiff to v. stiff, moist		100		3-6-9	15	4.0	21.4			
8				100		3-7-8	15	4.0	20.3			
12		10.0 BORING TERMINATED AT 10.0 FBGS										

Completion Depth (ft.): **10.0**
Date Started: **2/9/23**
Date Completed: **2/9/23**
Drilled By: **Geotechnology**
Logged By: **J. Benoit**

Remarks: **No measurable groundwater observed during or upon completion of drilling operations. Backfilled with auger cuttings. Geoprobe track-mounted drill rig with auto-hammer. 3-1/4" I.D. HSA, AWJ Split-Spoon sampling**

PAVEMENT CORE PHOTOGRAPHS
TAXIWAY BRAVO INTERSECTION RECONFIGURATION
MEMPHIS INTERNATIONAL AIRPORT
PROJECT NO. 100-19-0019

Photo 1: Concrete Core Location B-19

*Due to equipment issues, Athena's subcontractor had to switch to a small diameter core barrel when concrete was encountered as can be observed in Photo 1.

Photo 2: Concrete Core Location B-20

DCP TEST DATA

B-17

Project: *Taxiway Bravo Intersection*
Date: 2/9/2023
Location: Memphis International Airport
Soil Type(s): SILTY CLAY (CL-ML)

Hammer
● 10.1 lbs.
○ 17.6 lbs.
○ Both hammers used

Soil Type
○ CH
○ CL
● All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	20	2
5	85	2
13	140	2
17	200	2
17	260	2
14	325	2
7	380	2
6	445	2
7	500	2
7	560	2
9	625	2
9	685	2
9	740	2
10	800	2
10	855	2
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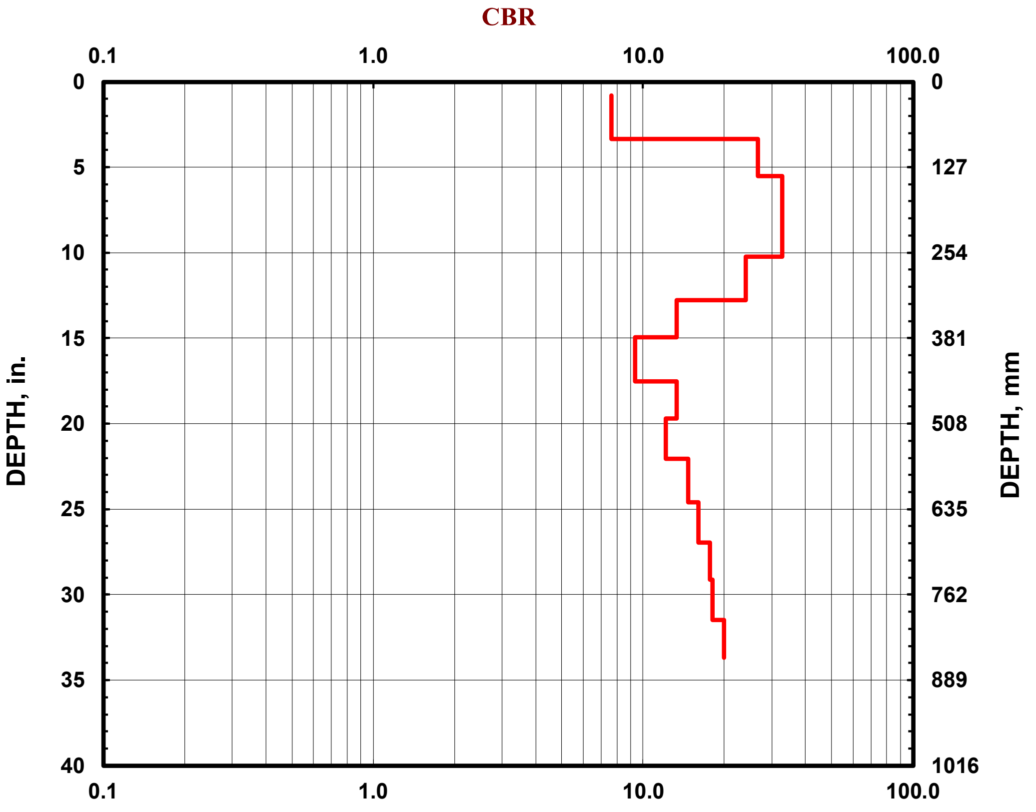

DCP TEST DATA

B-18

Project: *Taxiway Bravo Intersection*
Date: 2/9/2023
Location: Memphis International Airport
Soil Type(s): SILT (ML)

Hammer
● 10.1 lbs.
○ 17.6 lbs.
○ Both hammers used

Soil Type
○ CH
○ CL
● All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	40	2
16	100	2
28	160	2
33	240	2
9	320	2
5	380	2
5	450	2
6	505	2
7	565	2
6	620	2
7	680	2
7	720	2
9	805	2
7	860	2
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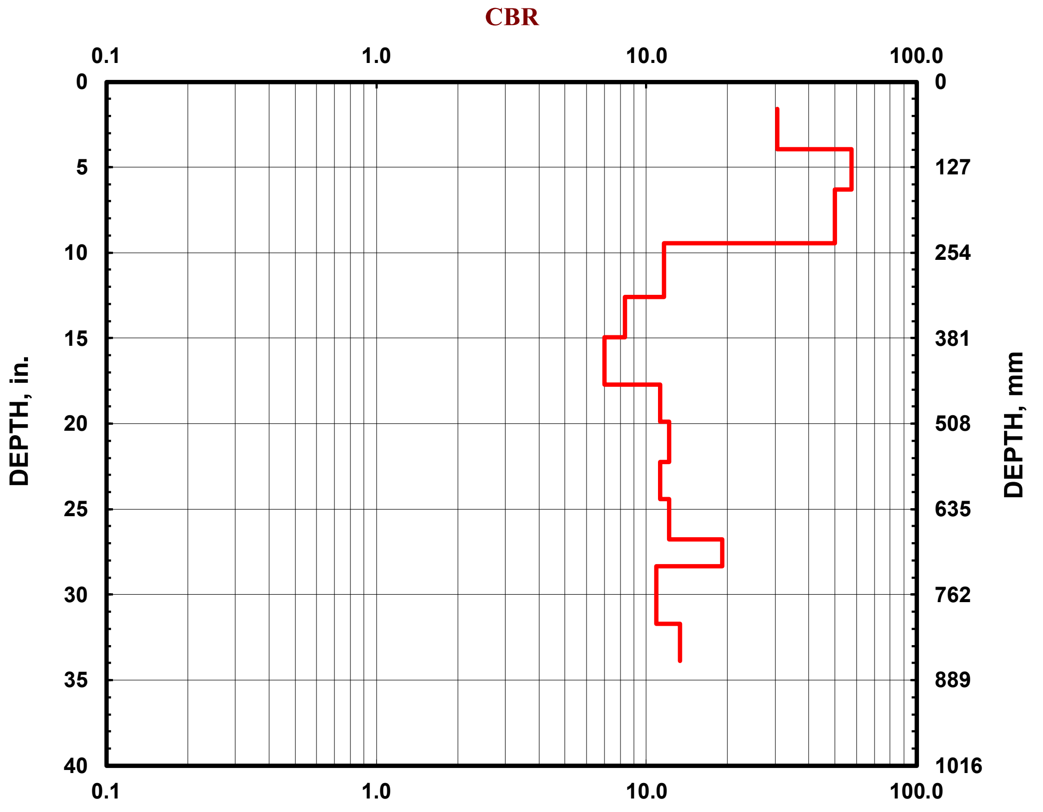

DCP TEST DATA

B-19

Project: *Taxiway Bravo Intersection*
Date: 2/9/2023
Location: Memphis International Airport
Soil Type(s): SILTY CLAY (CL-ML)

Hammer
● 10.1 lbs.
○ 17.6 lbs.
○ Both hammers used

Soil Type
○ CH
○ CL
● All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	80	2
5	140	2
5	210	2
6	275	2
6	340	2
7	410	2
7	470	2
7	535	2
7	600	2
7	660	2
7	735	2
8	790	2
8	855	2
8	910	2
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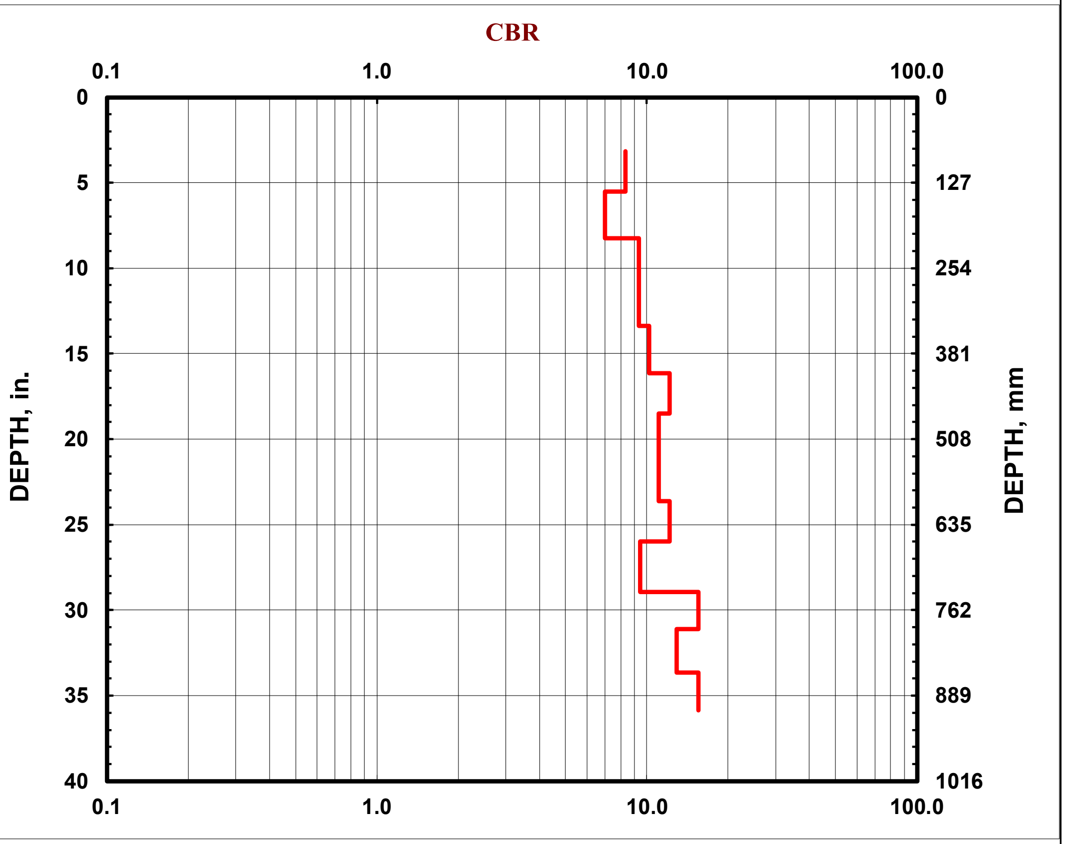

DCP TEST DATA

B-20

Project: *Taxiway Bravo Intersection*
Date: 2/9/2023
Location: Memphis International Airport
Soil Type(s): SILTY CLAY (CL-ML)

Hammer
● 10.1 lbs.
○ 17.6 lbs.
○ Both hammers used

Soil Type
○ CH
○ CL
● All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	20	2
3	80	2
3	140	2
3	200	2
4	270	2
4	330	2
6	395	2
6	450	2
7	515	2
7	570	2
8	630	2
9	695	2
8	750	2
10	820	2
10	890	2
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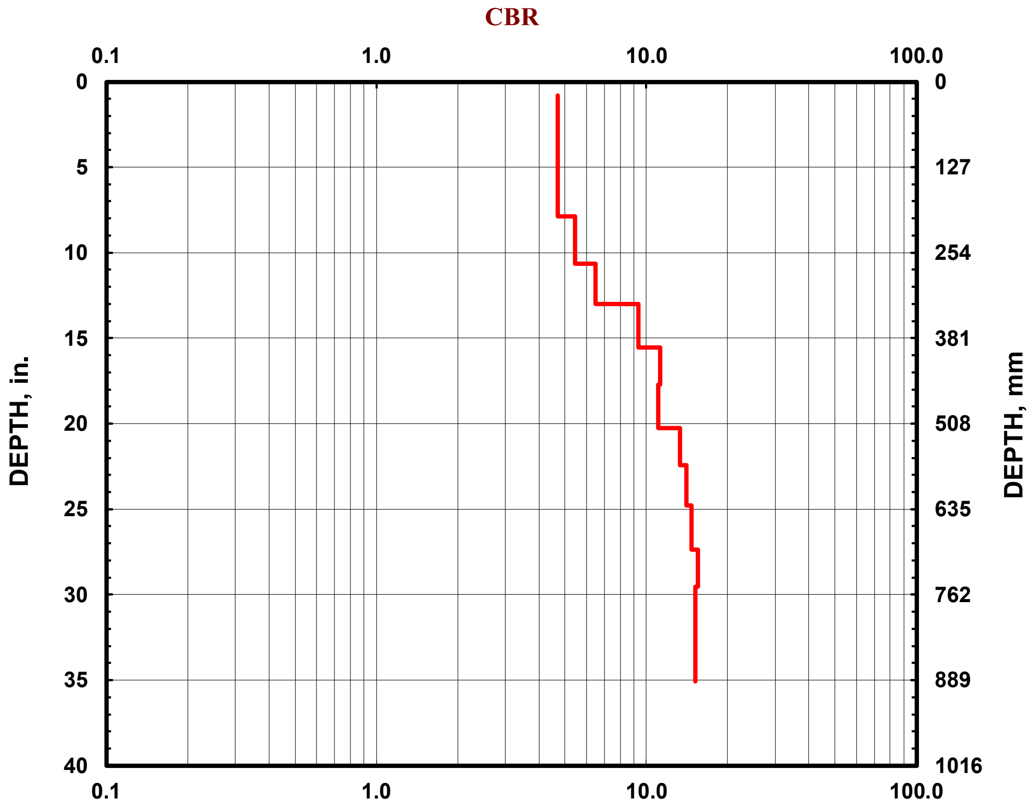

DCP TEST DATA

B-21

Project: *Taxiway Bravo Intersection*
Date: 2/9/2023
Location: Memphis International Airport
Soil Type(s): SILTY CLAY (CL-ML)

Hammer
● 10.1 lbs.
○ 17.6 lbs.
○ Both hammers used

Soil Type
○ CH
○ CL
● All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	25	2
3	90	2
4	155	2
5	220	2
5	285	2
5	340	2
7	400	2
8	470	2
8	535	2
8	595	2
8	655	2
8	710	2
9	770	2
11	830	2
10	880	2
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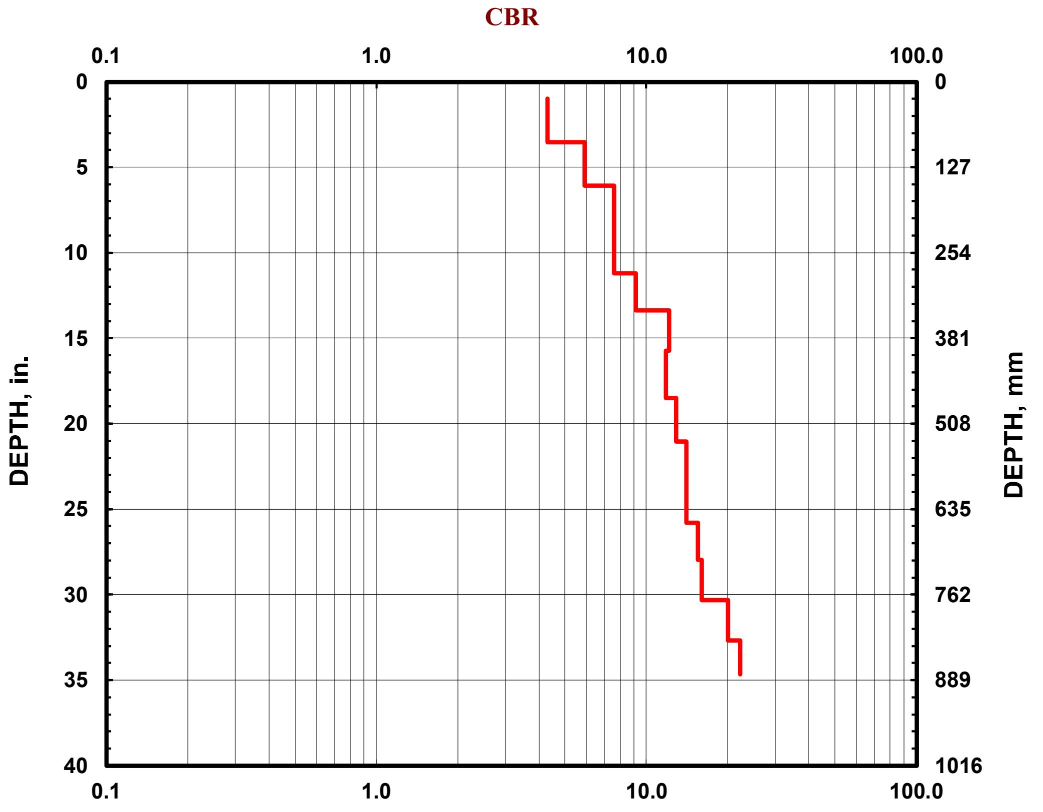


APPENDIX C

Laboratory Test Results

ATHENA
[formerly KS Ware & Associates]

350 Cal Batsel Road
Bowling Green, KY 42101
Phone: (615) 255-9702

ATTERBERG LIMITS (ASTM D4318)

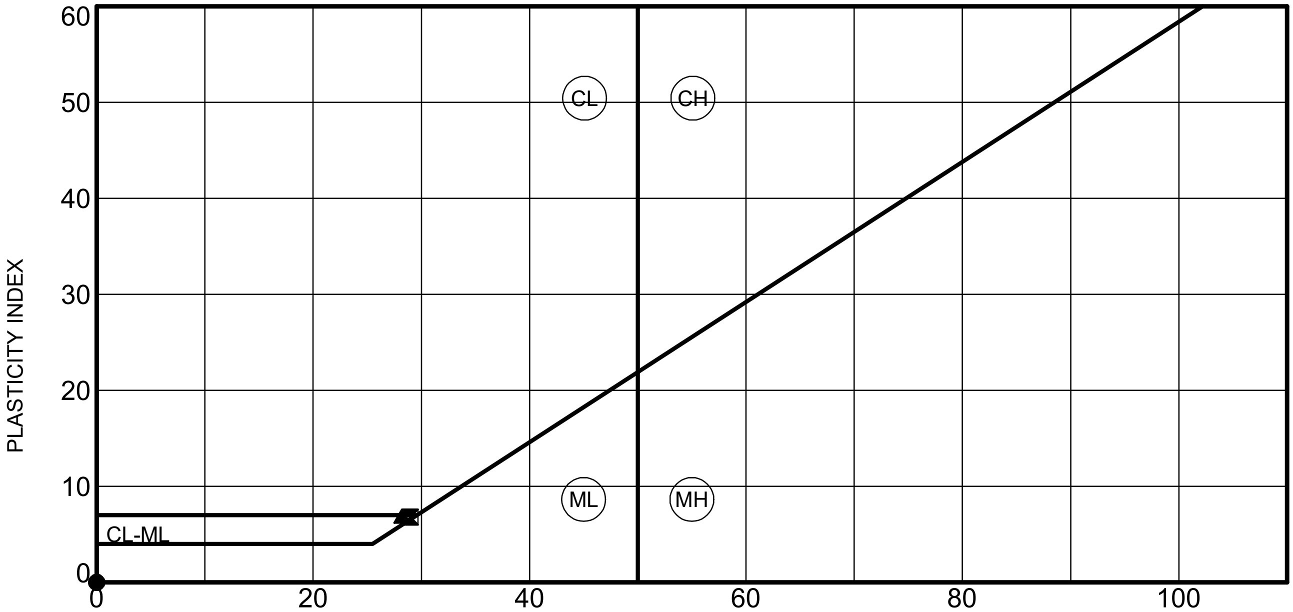
CLIENT: Allen & Hoshall

PROJECT NAME: Taxiway Bravo Intersection Reconfiguration

PROJECT NUMBER 100-19-0019

PROJECT LOCATION: Memphis International Airport

Equipment Used: Liquid Limit Device, Oven, Ohaus 3kg Scale, Metal Tares, Mortar and Pestle, Spatula, Plastic Grooving Tool



	Specimen Identification	SAMPLE TYPE	LL	PL	PI	% Fines	Soil Description
●	**B-18, 1'**	**ST**	**0**	**0**	**NP**	**100**	**SILT(ML)**
☒	**B-21, 1'**	**ST**	**29**	**22**	**7**	**99**	**SILTY CLAY(CL-ML)**
▲	**Bulk, 1'**	**B**	**28**	**21**	**7**	**98**	**SILTY CLAY(CL-ML)**

Abbreviations:
NP = Non-plastic
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
SS = Split Spoon
ST = Shelby Tube
G = Grab Sample
B = Bulk Sample

TESTED BY: S. Krikorian

TEST DATE: 3/2/2023

REVIEWED BY: B. Kouchoukos

DATE: 3/14/2023

ATHENA
[formerly KS Ware & Associates]

350 Cal Batsel Road
Bowling Green, KY 42101
Phone: (615) 255-9702

GRAIN SIZE DISTRIBUTION
ASTM D6913 - COARSE GRAIN SIZE
ASTM D7928 - FINE GRAIN SIZE

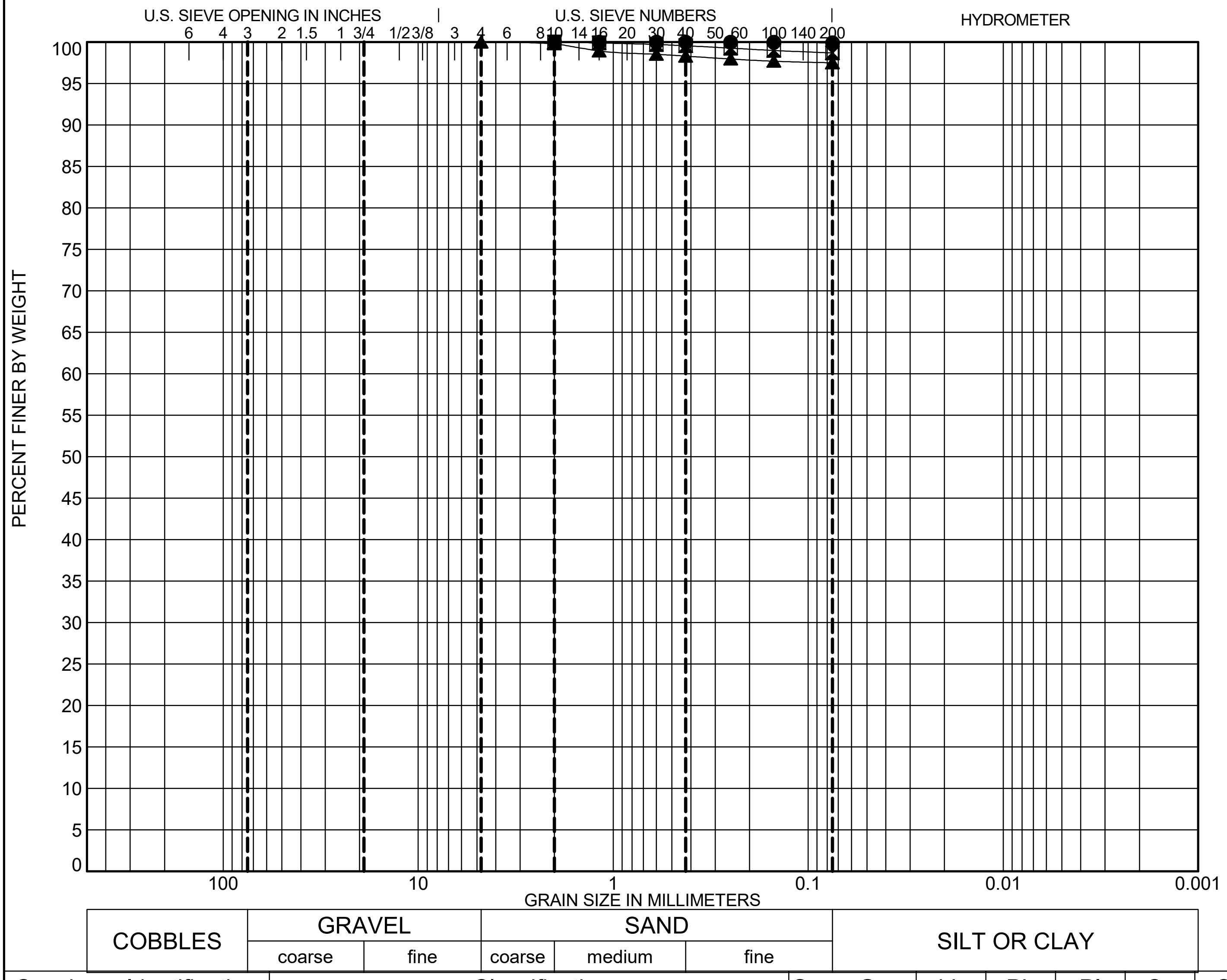
CLIENT: Allen & Hoshall

PROJECT NAME: Taxiway Bravo Intersection Reconfiguration

PROJECT NUMBER 100-19-0019

PROJECT LOCATION: Memphis International Airport

SOIL DESCRIPTION: Varies



	Specimen Identification	Classification	Spec. Grav.	LL	PL	PI	Cc	Cu
●	**B-18, 1'**	SILT(ML)		**NP**	**NP**	**NP**		
☒	**B-21, 1'**	SILTY CLAY(CL-ML)		**29**	**22**	**7**		
▲	**Bulk, 1'**	SILTY CLAY(CL-ML)		**28**	**21**	**7**		

	Specimen Identification	D_{100}	D_{60}	D_{30}	D_{10}	%Gravel	%Sand	%Silts	%Clays
●	**B-18, 1'**	**2**				**0.0**	**0.1**	**99.9**	
☒	**B-21, 1'**	**2**				**0.0**	**1.3**	**98.7**	
▲	**Bulk, 1'**	**4.75**				**0.0**	**2.5**	**97.5**	

TESTED BY: S. Krikorian **TEST DATE**: 2/27/2023 **REVIEWED BY**: B. Kouchoukos **DATE**: 3/14/2023

ATHENA
[formerly KS Ware & Associates]

350 Cal Batsel Road
Bowling Green, KY 42101
Phone: (615) 255-9702

UNCONFINED COMPRESSIVE STRENGTH TEST COHESIVE SOIL (ASTM D2166)

CLIENT: Allen & Hoshall

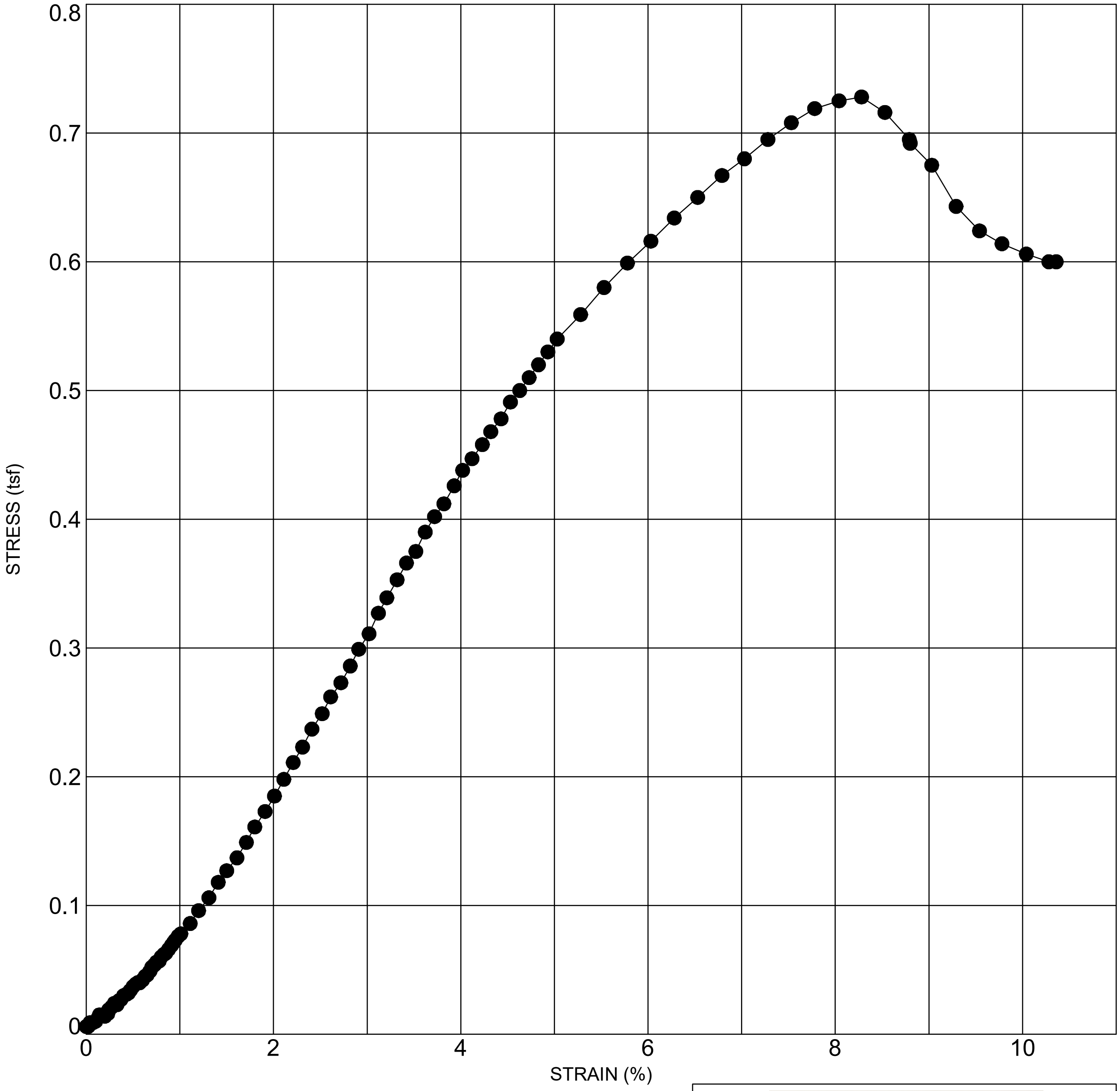
PROJECT NAME: Taxiway Bravo Intersection Reconfiguration

PROJECT NUMBER 100-19-0019

PROJECT LOCATION: Memphis International Airport

SOIL DESCRIPTION: SILT (ML)

SAMPLE RECEIVED: 2/9/2023



SAMPLE: B-18 1'

Diameter (in): 2.80

Strain at Failure (%): 8.28

Height (in): 5.76

Strength (tsf): 0.73

Ratio (h/d): 2.06

Dry Density (pcf): 95.30

LL: NP

Water Content (%): 28.98

PL: NP

Rate of Strain to Failure (%/min): 1

-Specimen was taken from Shelby Tube sample

-

TESTED BY: S. Krikorian

TEST DATE: 2/24/2023

REVIEWED BY: B. Kouchoukos

APPROVED DATE: 3/14/2023

ATHENA
[formerly KS Ware & Associates]
350 Cal Batsel Road
Bowling Green, KY 42101
Phone: (615) 255-9702

UNCONFINED COMPRESSIVE STRENGTH TEST COHESIVE SOIL (ASTM D2166)

CLIENT: Allen & Hoshall

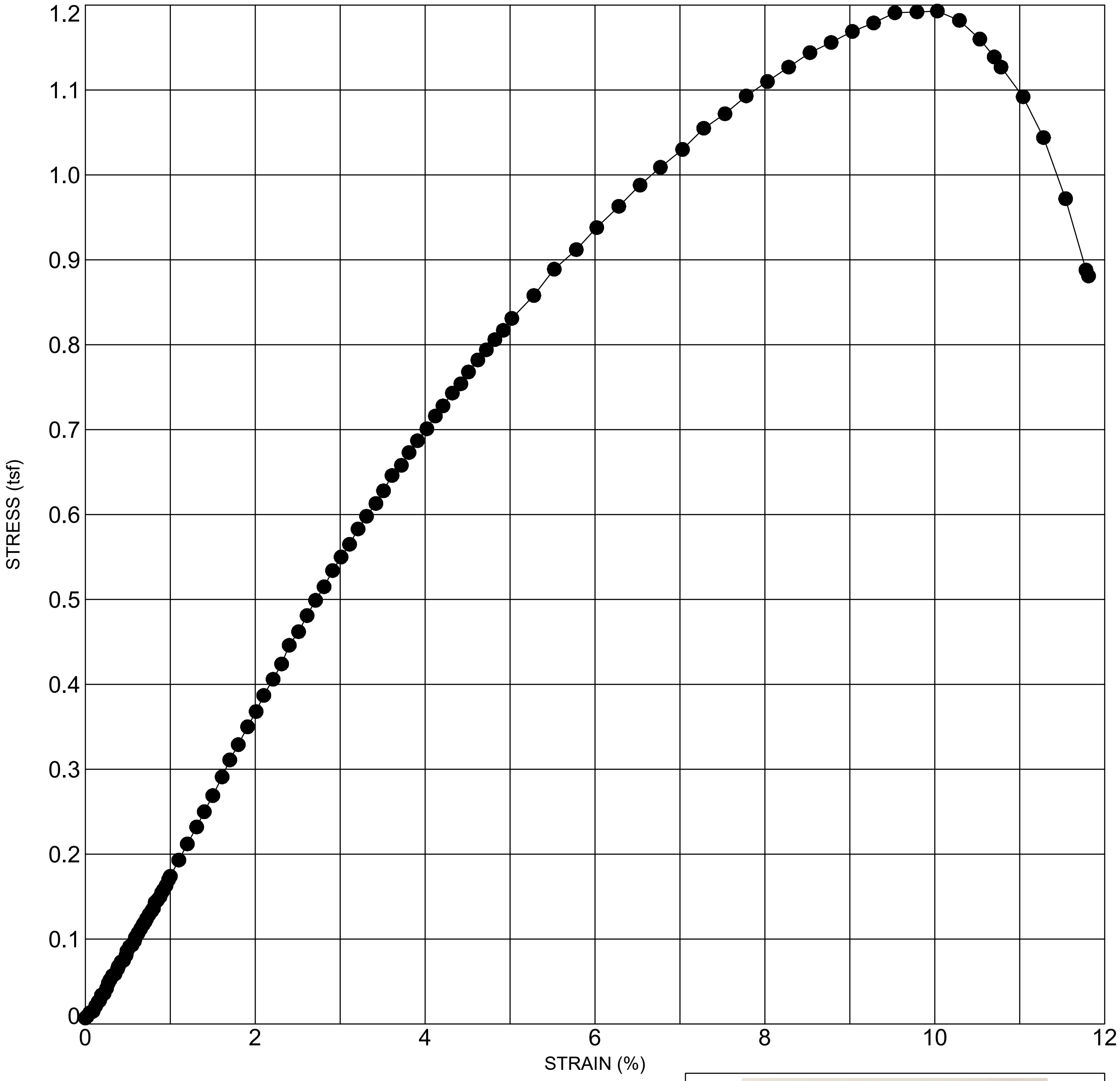
PROJECT NAME: Taxiway Bravo Intersection Reconfiguration

PROJECT NUMBER: 100-19-0019

PROJECT LOCATION: Memphis International Airport

SOIL DESCRIPTION: SILTY CLAY (CL-ML)

SAMPLE RECEIVED: 2/9/2023



SAMPLE: B-21 1'

Diameter (in): 2.85

Strain at Failure (%): 10.03

Height (in): 5.73

Strength (tsf): 1.19

Ratio (h/d): 2.01

Dry Density (pcf): 99.60

LL: 29

Water Content (%): 25.30

PL: 22

Rate of Strain to Failure (%/min): 1

-Specimen was taken from Shelby Tube sample

-

TESTED BY: S. Krikorian

TEST DATE: 2/24/2023

REVIEWED BY: B. Kouchoukos

APPROVED DATE: 3/14/2023

ATHENA
[formerly KS Ware & Associates]

350 Cal Batsel Road
Bowling Green, KY 42101
Phone: (615) 255-9702

MODIFIED PROCTOR (ASTM D1557)

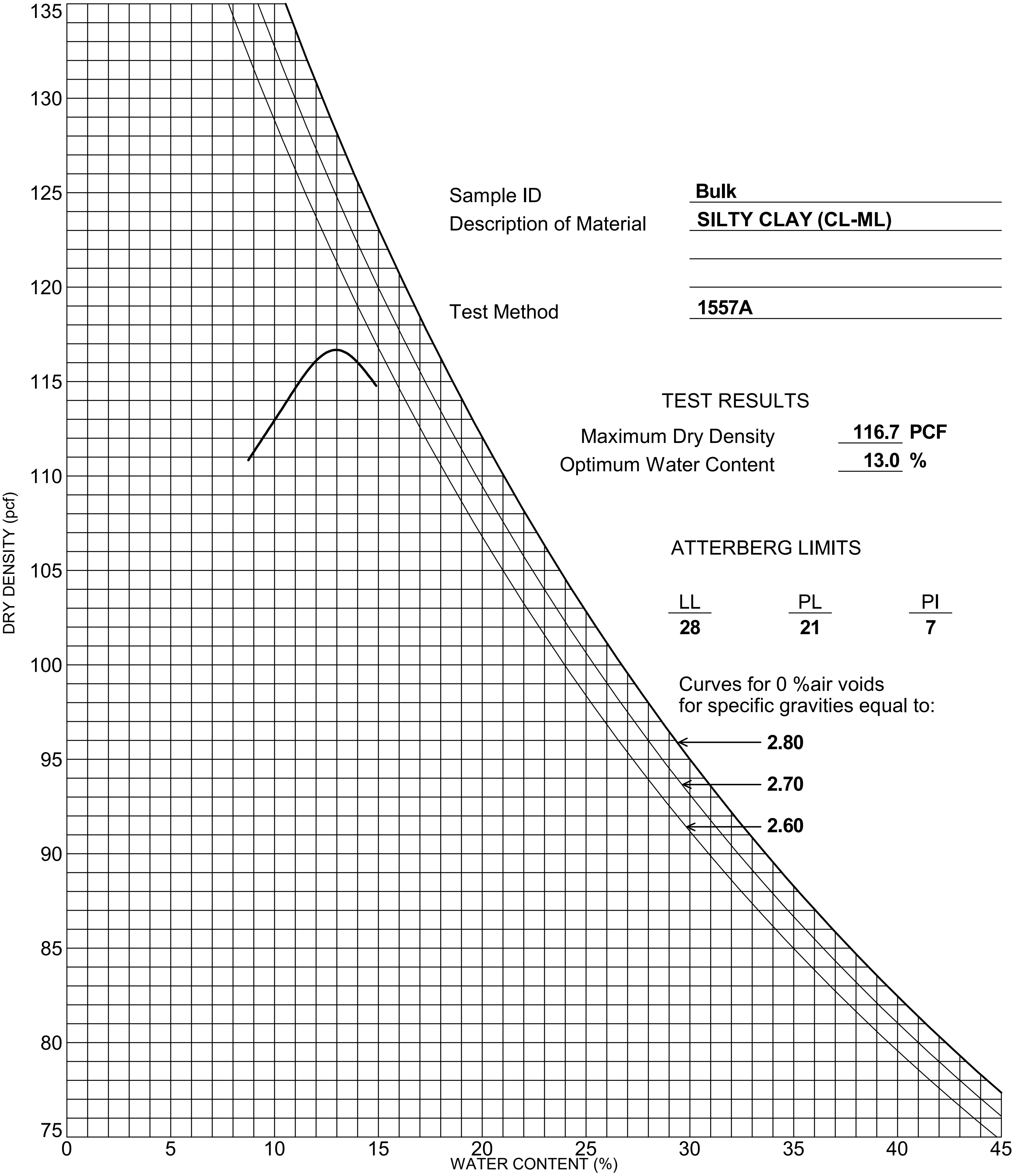
CLIENT: Allen & Hoshall

PROJECT NAME: Taxiway Bravo Intersection Reconfiguration

PROJECT NUMBER 100-19-0019

PROJECT LOCATION: Memphis International Airport

EQUIPMENT USED: Modified Hammer, 4 inch Mold, Ohaus 3 kilogram Scale, Oven, Ohaus 8 kilogram Scale



Sample ID **Bulk**

Description of Material **SILTY CLAY (CL-ML)**

Test Method **1557A**

TEST RESULTS

Maximum Dry Density **116.7** **PCF**

Optimum Water Content **13.0** **%**

ATTERBERG LIMITS

LL	PL	PI
28	**21**	**7**

TESTED BY: S. Krikorian
REVIEWED BY: K. Andrus

TEST DATE: 2/28/2023
DATE: 3/13/2023

SAMPLE RECEIVED: 2/20/2023

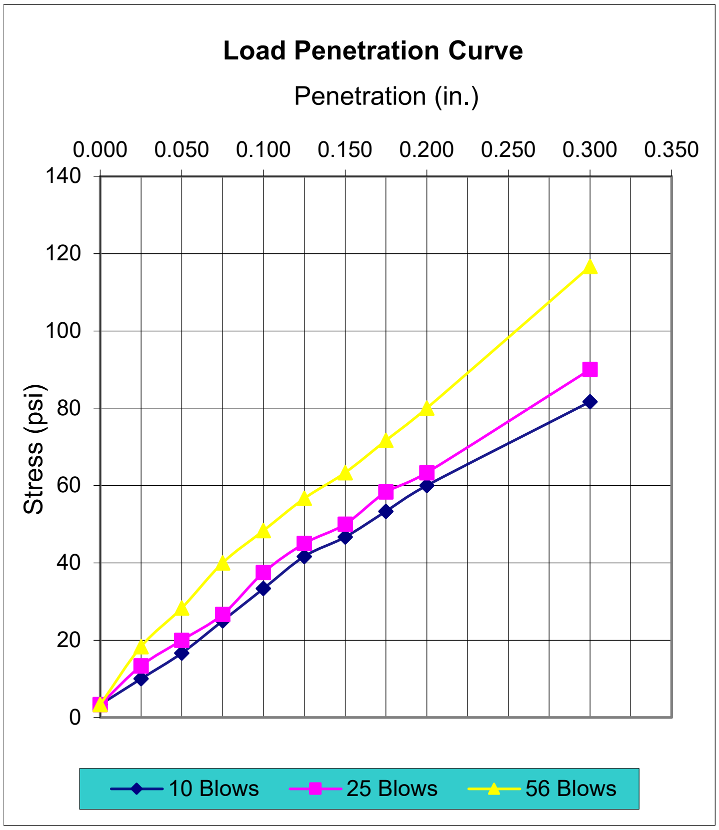
ATHENA
[formerly KS Ware & Associates]

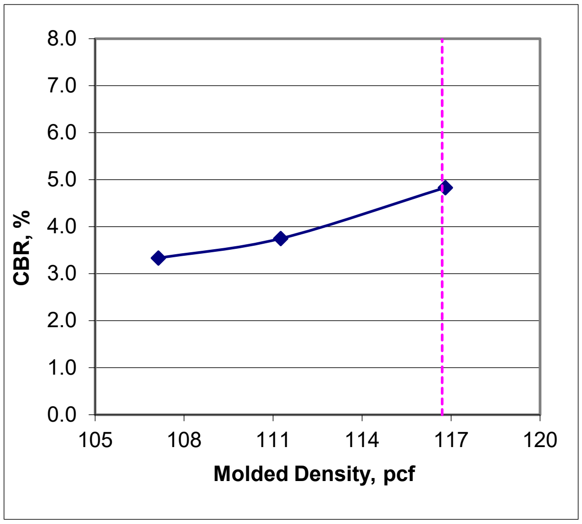
Report of California Bearing Ratio Test (ASTM D1883)

Project Name: Taxiway Bravo Intersection
Project Number: 100-19-0019
Sample ID: B-21 Bulk
Date Received: 2/15/2023
Sample Description: Brown Silty Clay

Proctor Type: Modified
Maximum Dry Density: 116.7
Optimum Moisture: 13.0

Test	Pre-Test			Post-Test			CBR, %		Line	%
# Blows	DD	% Max	%m	DD	% Max	%m	0.1"	0.2"	Corr.	Swell
20	107.1	91.8	12.5	103.0	88.2	25.1	3.3	4.0	0	2.2251
30	111.3	95.3	12.6	105.2	90.2	25.0	3.8	4.2	0	1.9634
65	116.8	100.1	13.2	110.7	94.8	24.3	4.8	5.3	0	2.0506





CBR* = 4.5

* for 100% max DD and
0.1 in. penetration

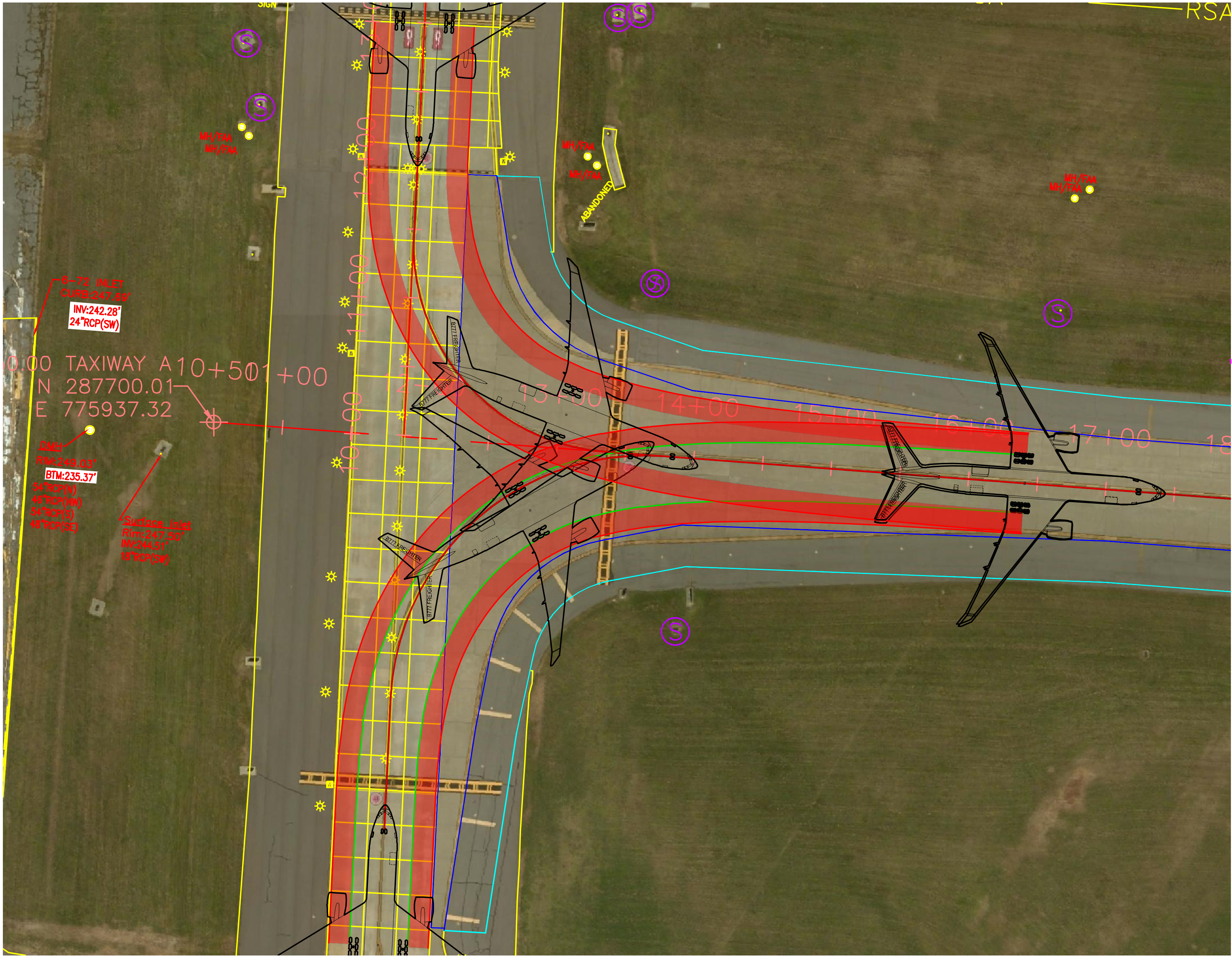
Submitted By: S. Krikorian
Date: 3/21/2023
Reviewed By: B. Kouchoukos
Date: 3/23/2023

Athena Engineering and Environmental
52 Lindsley Avenue Ste 101
Nashville, Tennessee 37210

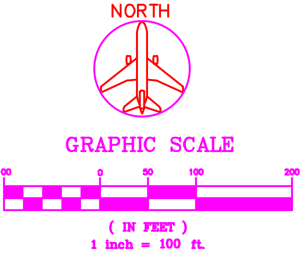
Phone (615) 255-9702
Fax (615) 256-5873

Appendix C

Horizontal Geometry
Aircraft Movements – Taxiway Edge Safety Margin



Allen&Hoshall
engineers-architects-surveyors



1661 International Drive
Memphis, TN 38120

72198
Job Number

5/10/21
Date

1 OF 5
Sheet Number

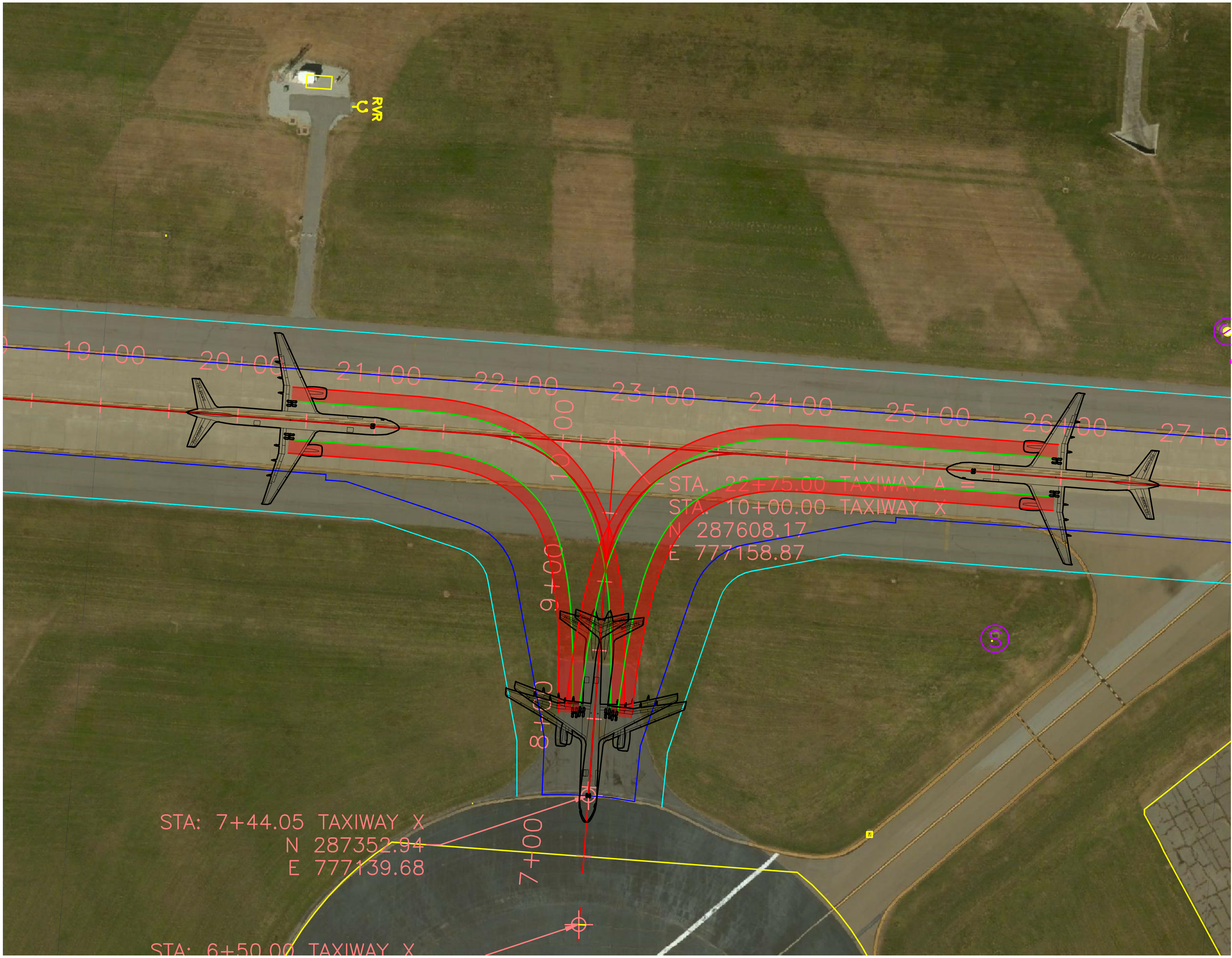
B777F Turning Movements with TESM

MEMPHIS SHELBY COUNTY AIRPORT AUTHORITY

TAXIWAY ALPHA WEST RECONSTRUCTION 18-1413

1" = 100'

Allen&Hoshall
engineers-architects-surveyors



NORTH

GRAPHIC SCALE

100 0 50 100 200

(IN FEET)
1 inch = 100 ft.

1661 International Drive
Memphis, TN 38120

72198
Job Number

5/10/21
Date

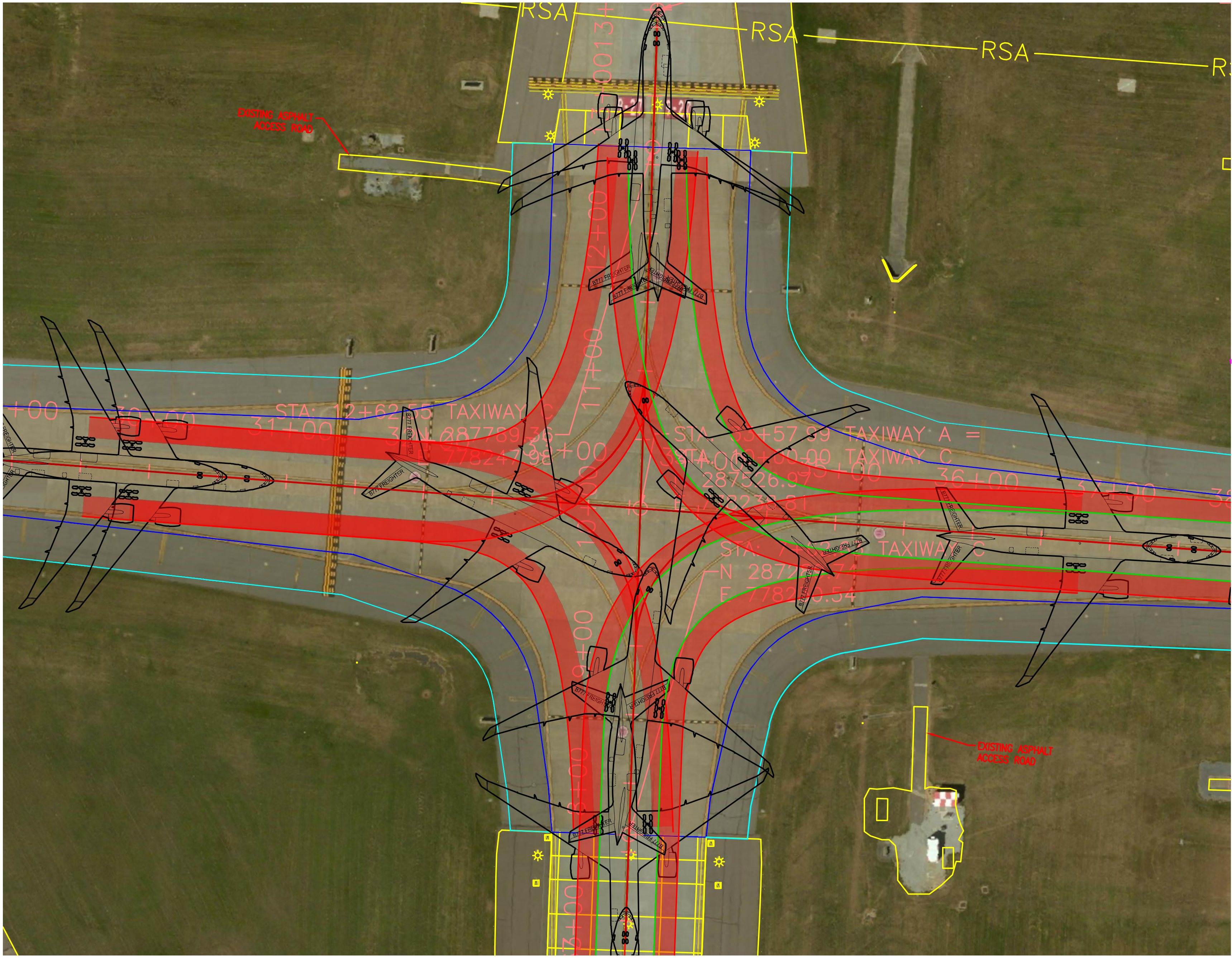
B757 Turning Movements with TESM

MEMPHIS SHELBY COUNTY AIRPORT AUTHORITY

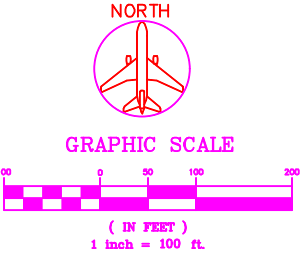
TAXIWAY ALPHA WEST RECONSTRUCTION 18-1413

1" = 100'

2 OF 5
Sheet Number



Allen&Hoshall
engineers-architects-surveyors



1661 International Drive
Memphis, TN 38120

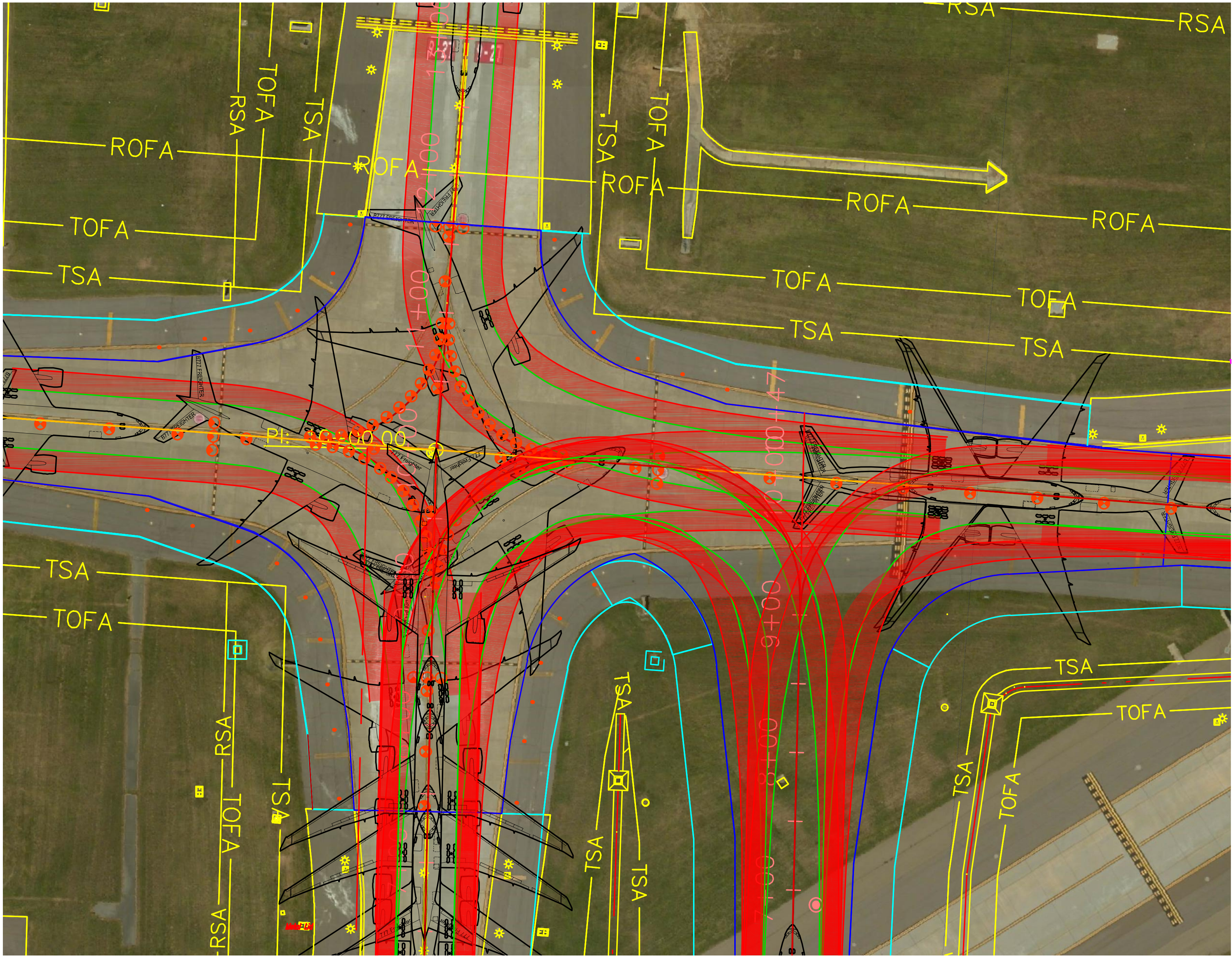
B777F Turning Movements with TESM

MEMPHIS SHELBY COUNTY AIRPORT AUTHORITY

TAXIWAY ALPHA WEST RECONSTRUCTION 18-1413

1" = 100'

72198	Job Number
5/10/21	Date
3 OF 5	Sheet Number



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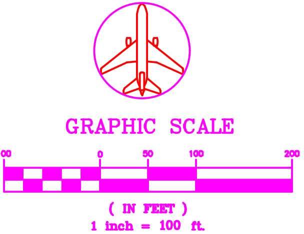
NORTH



1661 International Drive
Memphis, TN 38120

72198
Job Number

5/10/21
Date

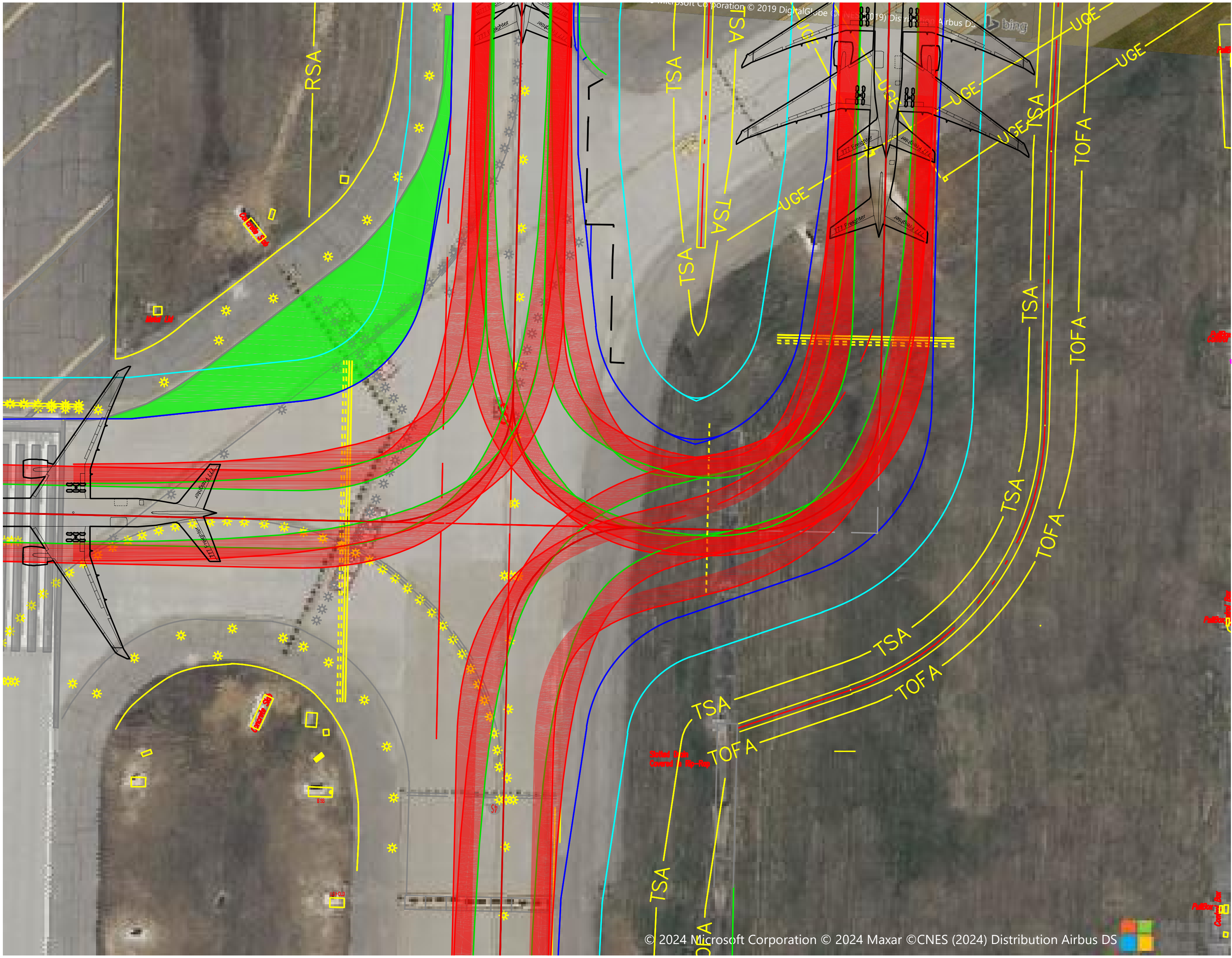
4 OF 5
Sheet Number

B777F Turning Movements with TESM

MEMPHIS SHELBY COUNTY AIRPORT AUTHORITY

TAXIWAY ALPHA WEST RECONSTRUCTION 18-1413

1" = 100'



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NORTH

GRAPHIC SCALE
100 0 50 100 200
(IN FEET)
1 inch = 100 ft.

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72198
Job Number

5/10/21
Date

B7777F Turning Movements with TESM

MEMPHIS SHELBY COUNTY AIRPORT AUTHORITY

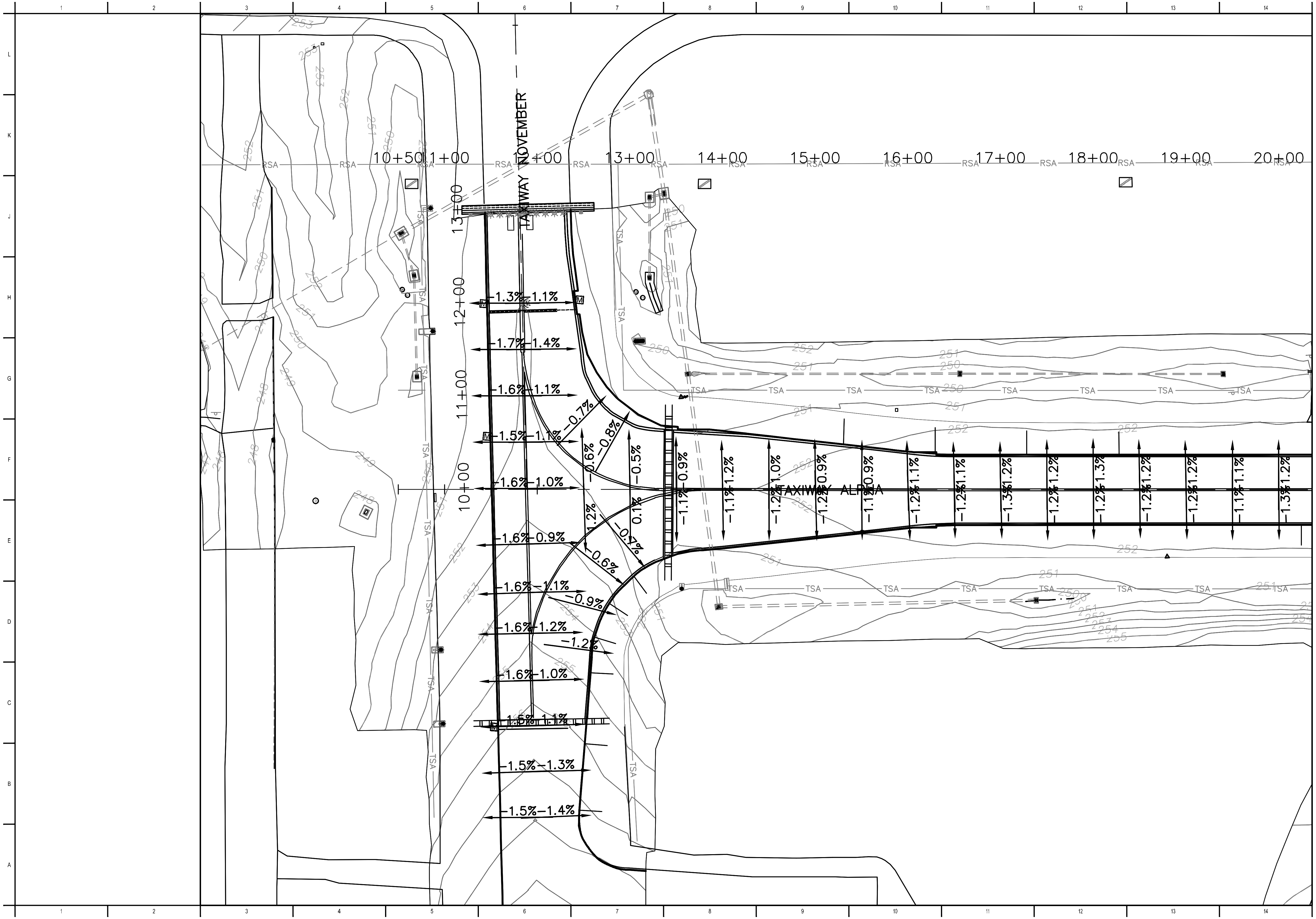
TAXIWAY ALPHA WEST RECONSTRUCTION 18-1413

1" = 100'

5 OF 5
Sheet Number

Appendix D

Vertical Surface
Existing Taxiway Cross-Slopes



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Memphis, Tennessee

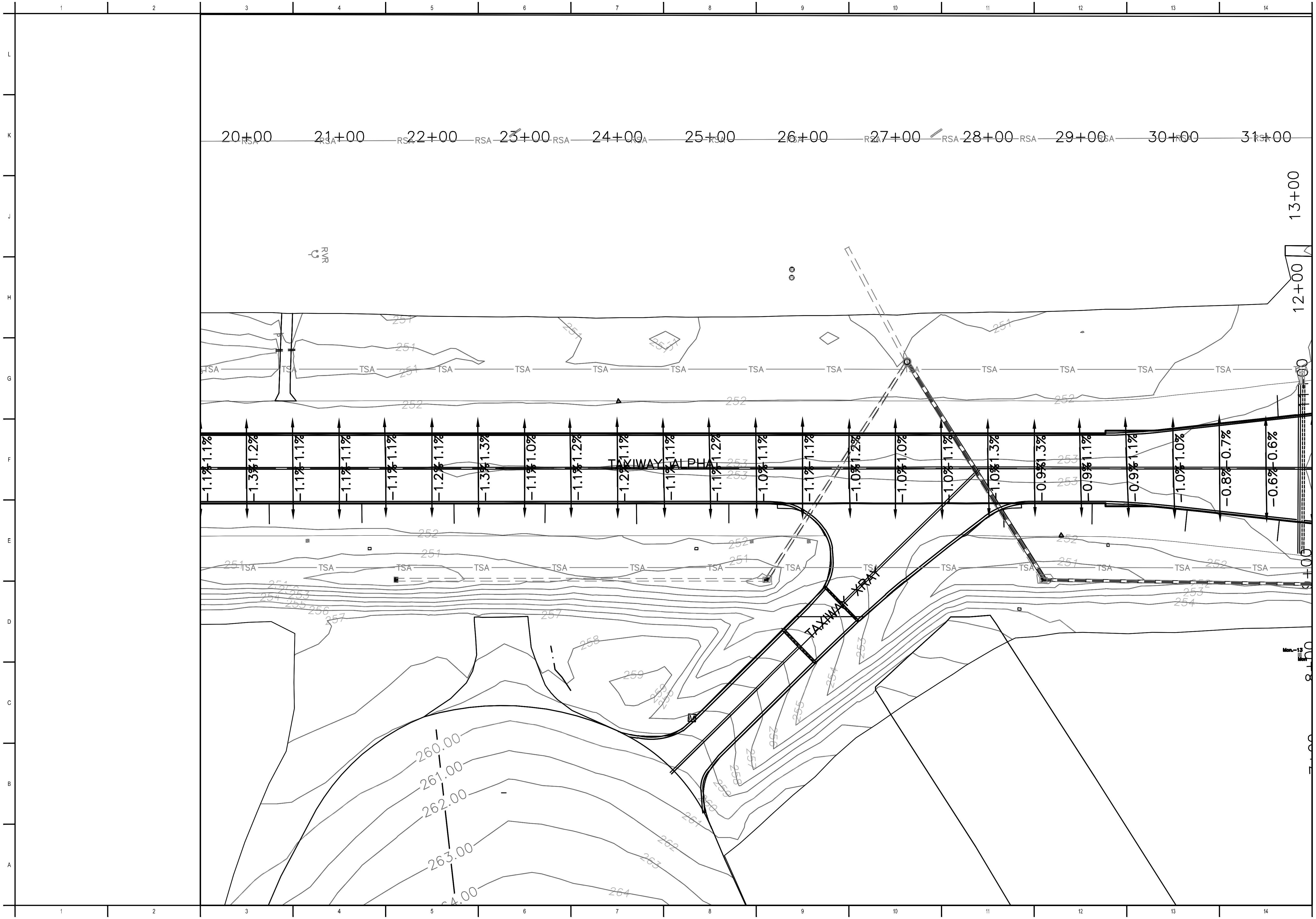
No.	Revision	Date

SLOPE ANALYSIS
TAXIWAY ALPHA WEST RECONSTRUCTION

EXISTING TAXIWAY ALPHA CROSS SLOPES

JOB NO: 72198
DATE: 7/31/2020
DRAWN:
CHECKED:
CAD FILE:

EXHIBIT 1



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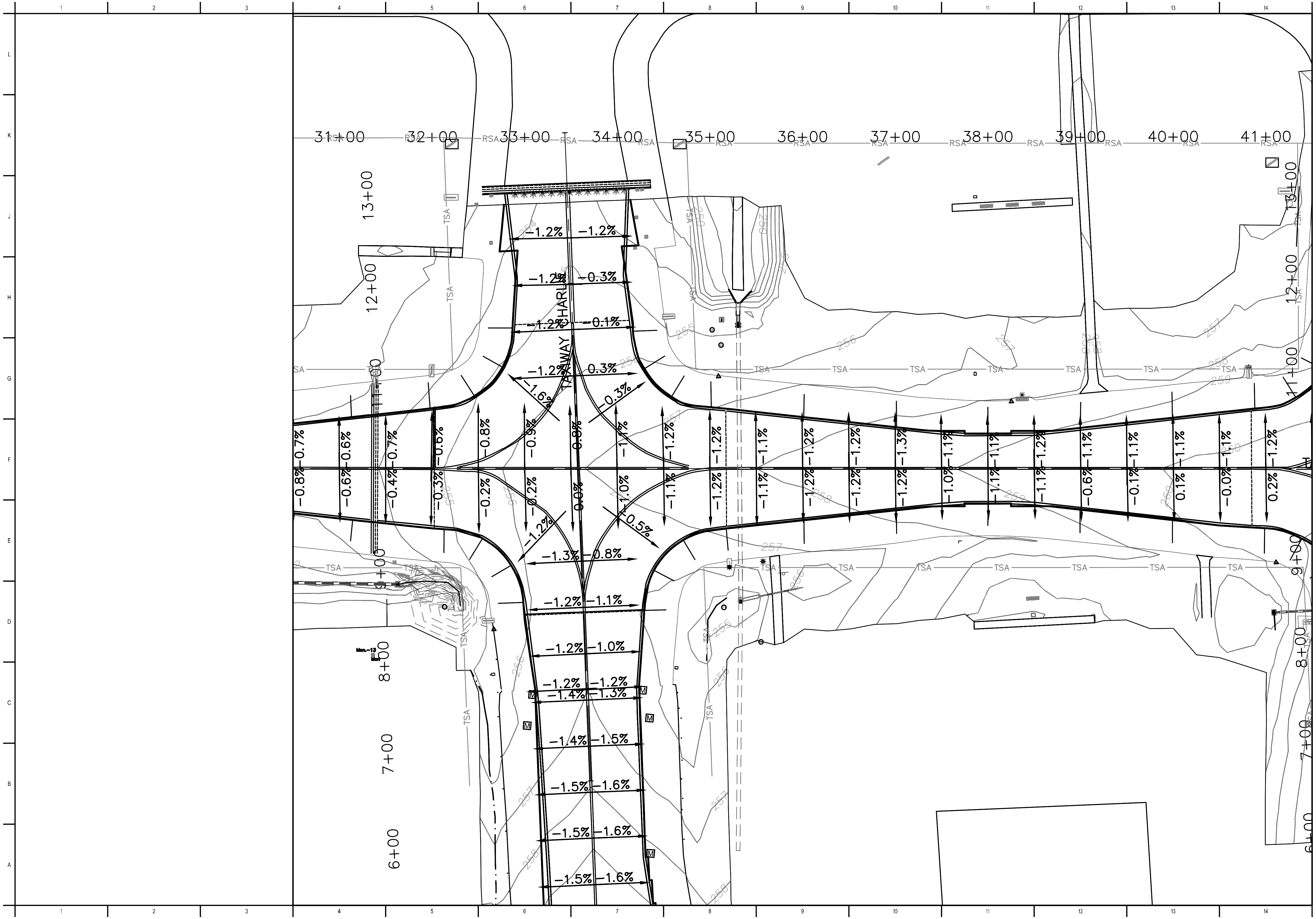
SLOPE ANALYSIS
TAXIWAY ALPHA WEST RECONSTRUCTION

EXISTING TAXIWAY ALPHA CROSS SLOPES

JOB NO: 72198
DATE: 7/31/2020
DRAWN:
CHECKED:
CAD FILE:

EXHIBIT 2



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SLOPE ANALYSIS
TAXIWAY ALPHA WEST RECONSTRUCTION

EXISTING TAXIWAY ALPHA CROSS SLOPES

JOB NO: 72198
DATE: 7/31/2020
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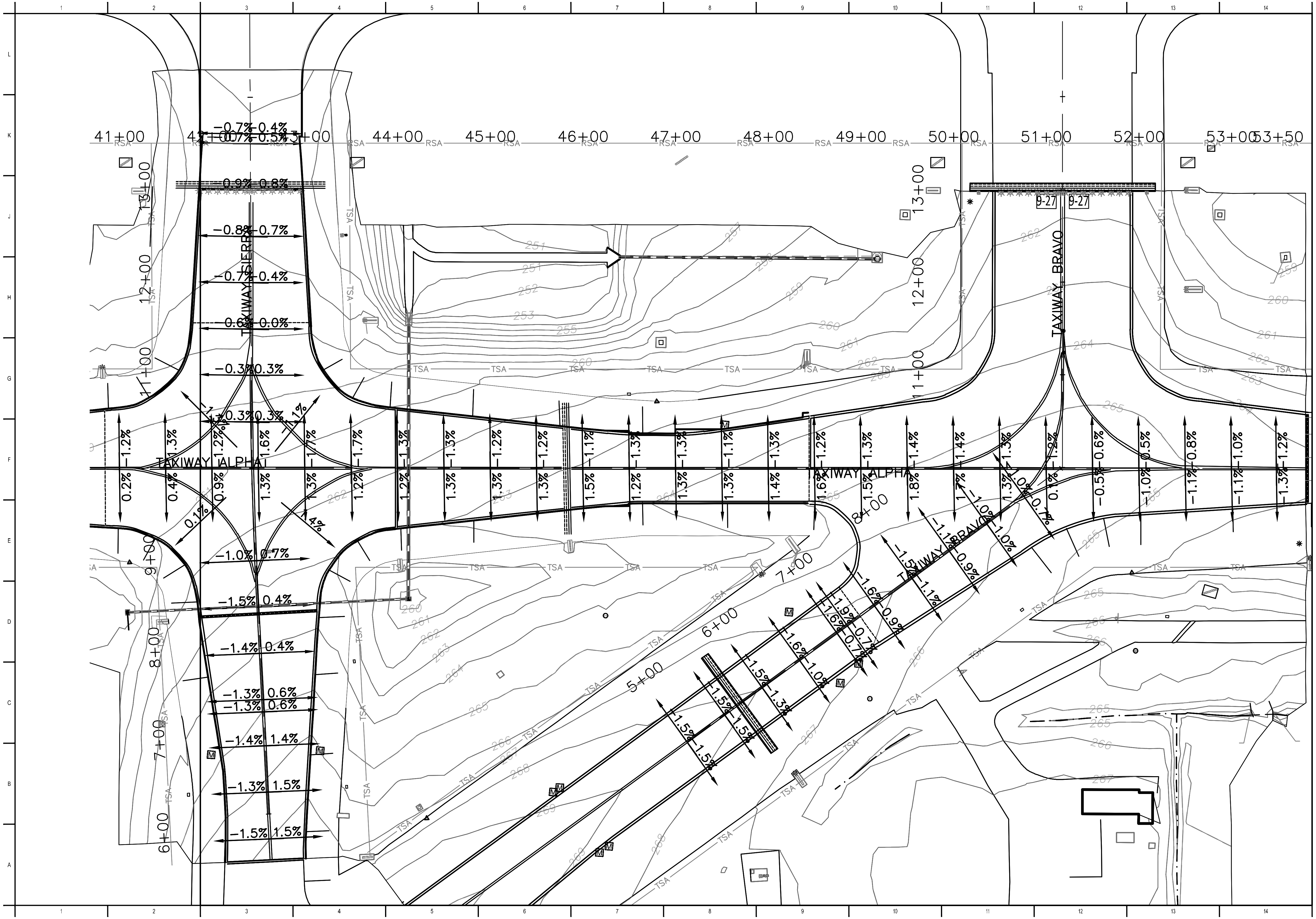
CAD FILE:

EXHIBIT 3



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Memphis, Tennessee

No.	Revision	Date

SLOPE ANALYSIS
TAXIWAY ALPHA WEST RECONSTRUCTION

EXISTING TAXIWAY A CROSS SLOPES

JOB NO: 72198
DATE: 7/31/2020
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CAD FILE:

EXHIBIT 4

Appendix E

NDT Report & Pavement Design

TAXIWAY A WEST RECONSTRUCTION PAVEMENT DESIGN

at

TAKE OFF WITH US.
Memphis
INTERNATIONAL AIRPORT

Memphis, TN

REPORT

June 15, 2020

Prepared for:

Allen&Hoshall
engineers-architects-surveyors

Memphis, TN

Prepared by:

RDM
Engineering Technology Research

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

RDM International, Inc. (RDM) was retained by Allen & Hoshall, Inc. (A&H) to perform pavement evaluation and design services for the reconstruction of Taxiway A West at Memphis International Airport (MEM), Memphis, Tennessee. Taxiway A West is approximately 4.200 feet between Taxiway N and Taxiway B. Taxiway C and Taxiway S intersect Taxiway A along its length. Portions of these crossing taxiways are included in this project. An unnamed taxiway between Taxiway N and Taxiway C leading to the Signature Ramp was also included in this project. The primary objective of this report is to provide A&H with a structural evaluation and reconstruction design for the pavement areas within the project limits.

In April 2019, RDM conducted a visual survey to record medium or high severity level pavement distresses in the taxiway and shoulder pavements. Except for the connector taxiway to the Signature Ramp, all taxiways are Portland cement concrete (PCC) surfaced. Based on the results, the existing pavements were identified with a minimal amount of structural or functional related medium and high severity distresses. It was reported that certain locations of Taxiway A and associated connector taxiways had subgrade ‘pumping’ related concerns. RDM’s survey identified minor faulting in isolated locations and pumping was not witnessed. The condition of the shoulder pavements recorded a wide spread of medium to high severity distresses. The distribution of the witnessed distresses can be found on the maps in Appendix A.

Non-Destructive Tests (NDT) were performed on the pavements in the project limits during the distress survey. Taxiway A pavements are basically composed of 3 each, 25 feet wide PCC slabs across the taxiway width. NDT was performed on the 3 lanes with each lane consisting of one column of slabs. A total of 122 center slab tests and 95 joint tests were conducted for Taxiway A. NDT field data can be found in Appendix B. The Impulse Stiffness Modulus (ISM) in kips/in. was evaluated and indicated variation in the overall pavement strength over the length of Taxiway A. The ISM results were mapped and can be reviewed in Appendix C.

NDT data was analyzed to evaluate the elastic moduli of the pavement materials and subgrade soils. The pavement structures used for the NDT data analysis were based on 22 pavement cores conducted in the project limits. It was indicated that subgrade *k*-values varied from 130 psi/in. to 177 psi/in. Taxiway A pavements near the intersection with Taxiway B were identified as weaker than other areas.

The load transfer efficiency was evaluated using the NDT data conducted at the slab joints. The load transfer efficiency, especially in the center lane, is poor and may be completely lost based on the data. This appears to be the primary cause of faulting and reported pumping within the designated areas. The load carrying capacity will be significantly impacted.

The geotechnical investigation results were provided by K.S. Ware & Associates, L.L.C. (KSWA) based on 14 borings and 8 cores. The PCC thickness is generally consistent ranging from 16 to 21.5 inches with majority around 18 inches. The base was shown to be thin asphalt concrete (AC) on top of cement stabilized material. The AC base thickness varies from 2.5 to 5 inches and the cemented base material varies from 2 inches to 8.5 inches. The combined thicknesses of the AC and soil cement vary from 5 to 12 inches. The existing PCC pavement may be normalized as 18 inches of PCC on 8 inches of stabilized base. The AC pavement of the taxiway to the Signature Ramp is nominally 22 inches of AC.

Subgrade soils were indicated to be lean clay or lean clay fill classified as CL according to the Unified Soil Classification System (USCS). The N-values in blow counts per foot from the Standard Penetration Test (SPT) for the upper portion of the subgrade generally vary from 5 to 14 blows/ft., indicating relatively weak subgrade strength.

KSWA conducted 3 laboratory CBR tests on CL soil samples and the CBR values are 6.0%, 7.0%, and 9.5%, respectively. KSWA recommended that design subgrade CBR and *k*-value are 7% and 150 psi/in. when compacted to 98% modified proctor. The test and recommended subgrade strengths appear to be consistent with the back-calculated results with *k*-values ranging from 130 psi/in. to 177 psi/in.

A&H provided future aircraft fleet mix for the pavement design. The taxiways in the project limits are the primary routes for the heavy cargo aircraft traffic. It is expected to have 7,784 annual departures from the B777F. The connector taxiway to the Signature Ramp is required for 1,200 annual departures of the B757 aircraft.

Structural conditions of the existing pavements were analyzed based on remaining structural life. The Federal Aviation Administration (FAA) design procedures in Advisory Circular 150/5320-6F, "*Airport Pavement Design and Evaluation*", were followed using the FAARFIELD (v. 1.42) computer software. The existing PCC pavements are not structurally adequate for the future cargo traffic due primarily to the poor load transfer efficiency even though condition survey identified a current surface with minimal medium and high severity level distresses. Therefore, reconstruction is justified.

The PCC pavement was designed to be consistent with the previously designed and constructed Taxiway A East. The required PCC thicknesses were computed for the base system consisting of 4-inch asphalt treated permeable base (ATPB) on 8-inch cement treated base (CTB). A 12-inch cement treated subgrade layer was considered as the subgrade improvement measure. The designs were performed with variations of design inputs, including the variation of ATPB elastic modulus, cement treated soils, and the strength of the native subgrade soils. Standard construction materials in the Advisory Circular, AC150/5370-10H, "Standard Specifications for Construction of Airports," were considered for the design. The ATPB is not a standard FAA material and the specification should be developed to establish a modification to standard for the project. The following section is recommended.

19.0" P-501/4" ATPB/8" P-304/12" P-301 or P-156

For the connector taxiway to the Signature Ramp, the AC pavement has been designed for 1,200 annual departures of the B757 aircraft. The following section is recommended.

9" P-401/6" P-219/12" P-156

The shoulder pavement was designed for 15 passes of the B777F aircraft over the 20-year design period. The following sections is recommended.

4" P-403/12" P-219/12" P-156, or

5" P-403/10" P-219/12" P-156

The PCC slab joint spacing is requested to be 25 feet based on past performance history. Prior projects at MEM with thick PCC design thicknesses have been approved for the larger slab sizes. This is not consistent with the recommended maximum joint spacing by the FAA and a modification to standard (MOS) should be prepared and approved by the FAA. All joints should be doweled to provide adequate load transfer. Reinforcements should be provided for irregular slabs and slabs out of maximum aspect ratio of 1.25.

At the transition between the PCC and AC pavements and the PCC pavement and the shoulders, the details can be different from the provided design sections. The variation depends on the arrangement of the underdrains and the construction efficiency. RDM will provide further review when the plans are developed.

SECTION 1.0

INTRODUCTION

SECTION 1.0 INTRODUCTION

RDM International, Inc. (RDM) was retained by Allen & Hoshall, Inc. (A&H) to perform pavement evaluation and design services for the reconstruction of Taxiway A West pavements at Memphis International Airport (MEM), Memphis, Tennessee. The primary objective of this report is to provide A&H reconstruction designs based on the functional and structural evaluations of the existing pavement structures and future heavy cargo traffic.

Taxiway A West portion is approximately 4,200 feet between Taxiway N and Taxiway B. Taxiway C and Taxiway S cross Taxiway A within the proposed limits. Portions of these crossing taxiways are included in this project. An unnamed taxiway between Taxiway N and Taxiway C leading to the Signature Ramp was also included in this project.

The technical approach to the rehabilitation study consists of the following basic elements:

- **Distress Survey** – to inspect, locate, and quantify the medium to high severity pavement distresses shown on the pavement surface.
- **Nondestructive Testing** – to obtain data on the strength of the existing pavement layers and subgrade.
- **Review of Geotechnical Data** – to review the geotechnical investigation results for the existing pavement areas regarding pavement materials, layer thickness, and subgrade strengths.
- **Traffic Analysis** – to establish pavement design traffic for the pavement areas in the project limits based on data provided by A&H.
- **Pavement Evaluation and Design** – to evaluate the structural condition of the existing pavements and provide new pavement design section.

All analytical procedures utilized for this study conform to the Federal Aviation Administration (FAA) criteria for airfield pavement design. The observations, comments, and recommendations contained in this report have been prepared for the exclusive use of A&H for this project in accordance with generally accepted engineering practice. No other warranty is expressed or implied.

Performance of any engineering investigation is subject to many qualifications inherent to the practice of that profession and to the accuracy of data obtained. Although a reasonable effort was made to interpret data and correctly depict existing conditions, variations could exist between tested locations, and the historical documents provided by others that could contain discrepancies.

SECTION 2.0

DISTRESS SURVEY

SECTION 2.0 DISTRESS SURVEY

From April 29 to 30, 2019, RDM personnel conducted a visual survey of the distresses on the pavements within the project limit. This involved recording all the distresses in medium to high severities over the entire paved areas, including the shoulders. The specific objectives are:

- To identify the medium or high severity distress types on the pavement surface.
- To locate and map the distresses on the pavement surface.
- To quantify the recorded distresses for the establishment of rehabilitation measures in conjunction with structural evaluation results.

2.1 PROCEDURES

Using procedures detailed in FAA Advisory Circular 150/5380-7B, "*Airport Pavement Management Program (PMP)"* and Advisory Circular 150/5320-17A, "*Airfield Pavement Surface Evaluation and Rating Manuals."* a project level, detailed condition survey for the medium and high severities distresses was performed by RDM personnel.

The survey consisted of a project level visual inspection of the pavement surfaces for signs of pavement distresses resulting from the influence of aircraft traffic, the environment, pavement materials or construction deficiencies. The visual inspection survey included recording all medium and high severities distresses on the pavements included in the project scope. Hand-held GPS data collectors were utilized to record the location, quantity, and severity of each distress. Detailed maps showing the locations of all recorded distresses are included in Appendix A.

2.2 SURVEY RESULTS

Taxiway A and the crossing taxiways are Portland cement concrete (PCC) surfaced. The taxiway leading to the Signature Ramp is asphalt concrete (AC) overlaid PCC pavement. All the shoulders are AC surfaced. The slab counts with the identified medium or high severity distresses are shown in Table 2-1. As shown, three (3) slabs were recorded with load related medium severity cracking.

As shown on the distress maps, the cracked slabs are not on Taxiway A but on the crossing taxiways. The distresses appear to be concentrated within the three intersections with Taxiways B, C, and S. It is reported that pumping has also been an issue for this portion of Taxiway A. Pumping was not witnessed during RDM's survey, however, medium severity faulting was witnessed in the Taxiway S intersection north of Taxiway A. Faulting and pumping distresses are generally related with loss of support within the unbound pavement layers or subgrade. When the subbase is granular material, pumping is easier to be noticed. Repetitive pumping/faulting will cause the loss of the joint load transfer and lead to cracking and spalling of the slabs. Although pumping/faulting are not widely present visually, they may still exist and affect the load carrying capacity of the PCC slabs due to loss of joint load transfer.

The AC surfaced shoulders and the taxiway to the Signature Ramp were indicated to have widespread cracking. The severity and the density of the cracks indicate that a global maintenance should be provided.

TABLE 2-1 DISTRES SURVEY RESULTS

Distress	Severity	Slab Count
Corner Spall	High	5
Corner Spall	Medium	9
Joint Spall	Medium	12
Small Patch	High	1
Small Patch	Medium	6
Crack	Medium	3
Fault	Medium	2

2.3 REPAIR AND REHABILITATION

Based on the survey results, the PCC pavements are in good condition. The observed distresses can be addresses with typical repair methods such as partial depth patching and crack sealing. Major rehabilitation may not be necessary if the aircraft traffic will not change in terms of operating weights and frequencies.

The AC surfaced pavements, shoulders and the taxiway to the Signature Ramp were shown to have a high density of distresses. The AC surface materials can be milled and replaced to effectively rehabilitation the areas.

The structural condition of the existing pavement will be evaluated for load carrying capability using the forecasted traffic. Given potential grade constraints or expansion of the proposed project footprint, reconstruction is usually needed for the existing PCC pavement structure in need of strengthening.

SECTION 3.0

NONDESTRUCTIVE TESTING

SECTION 3.0 NONDESTRUCTIVE TESTING

On April 29, 2019, RDM performed nondestructive tests (NDT) in the pavement areas within the project limits. The primary purpose of the NDT is to measure the structural properties of the pavement systems. The load response data resulting from the dynamic force simulates the effect of moving aircraft loads. These data can be used as reliable input for structural analysis utilizing elastic theory for pavement design and evaluation. Additional advantages of NDT include:

- Minimal interference with airport operations.
- Measurement of in-situ structural response.
- Rapid data acquisition, and
- Low unit testing and data processing costs.

Normally, about 50 NDTs can be performed for an approximate cost equivalent to one (1) California Bearing Ratio (CBR) test. The NDT equipment used for the testing program is designed to generate a dynamic load on the pavement surface and measure the resultant vertical response of the pavement system, including subgrade, base courses, and surface layers. The equipment's microcomputer allows rapid data processing in the field. Therefore, NDT results can be directly referenced to field conditions, improving the reliability and speed of data acquisition. A primary value of NDT is the ability to economically evaluate much broader areas of pavement in a short time to better define variability in pavement strength.

NDT equipment, test procedures, and data reduction methods conformed to the requirements of FAA Advisory Circular 150/5370-11B, "*Use of Nondestructive Testing Device in the Evaluation of Airport Pavement*".

3.1 NDT PROCEDURES

To provide a meaningful database for evaluation, the following NDT sequences were utilized:

- Deflection Basin
- Impulse Stiffness Modulus (ISM)
- Load Transfer Efficiency

All tests were conducted under an impulse, (i.e., Falling Weight Deflectometer (FWD)) type forcing function, at a nominal amplitude of approximately 40,000 lbs.

3.1.1 DEFLECTION BASIN

This test method involves measuring deflections at the center of the machine loading plate and at fixed distances from the center. After the pavement thickness and composition are established, back-calculation procedures can be used to reduce the NDT data for structural evaluation purposes.

The PCC taxiway pavements are basically composed of 3 slabs across the taxiway width. The slab is 25 feet wide and 25 feet long. NDT was performed on 3 lanes with each lane consisting of one column of slabs. For the crossing taxiways, NDTs were primarily conducted on the center two slabs across the centerline.

NDTs were conducted in the center of the slabs and on transverse joints of the slabs with staggered spacing. For each lane, testing was conducted at 100 feet longitudinal spacing, i.e. every 4 slabs interval. A total of 122 center slab tests and 95 joint tests were conducted for Taxiway A. A total of 83 tests, including center and joint tests, were conducted for the crossing taxiways. NDT field data can be found in Appendix B.

The U.S. Army Corps of Engineers' (Report FAA RD-80-9) and subsequent FAA research found the back-calculated subgrade strength parameters from NDT to be a reliable estimate of in-situ subgrade strength. Sensitivity analyses also found the back-calculate subgrade strengths to be relatively insensitive to minor variations in base course and surface course moduli or thicknesses. Therefore, the subgrade strength from NDT is believed to be a reasonably accurate representation of in-situ subgrade strength.

For the PCC pavements, the closed-form back-calculation procedures can be used to process the NDT data. The closed-form procedures use the AREA method to compute the modulus of subgrade reaction (*k*-value) and elastic moduli (E) of Portland cement concrete (PCC) and base layers. This method is based on the unique relationship that exists between the normalized area under the deflection basin (i.e., AREA) and the radius of relative stiffness (ℓ) of the concrete slab. Once ℓ is computed from AREA, computation of k and E is a straightforward process.

For flexible pavements, layered elastic back-calculation procedures can be used to process the deflection basin data to compute the elastic moduli (*E*) of pavement layers and subgrade that provide best fit between the measured and computed deflection basins. The computer program developed by the FAA, BAKFAA, can be used for the back-calculation.

3.1.2 IMPULSE STIFFNESS MODULUS (ISM)

The ISM test procedure is defined as dynamic force divided by the pavement deflection measured at the loading plate. As such, it is a measure of overall support conditions from all influencing pavement and subgrade layers. For this study, the ISM data were used to find variation of overall pavement strength in the tested areas.

3.1.3 LOAD TRANSFER EFFICIENCY

As described in FAA Report DOT/FAA PM-83/22, *"Investigation of the FAA Overlay Design Procedures for Rigid Pavements"*, load transfer at Portland cement concrete (PCC) slab joints was also evaluated using the deflection ratio, defined as:

$$Deflection\ Ratio = \frac{Deflection - unloaded - side}{Deflection - loaded - side}$$

The deflection ratio is used in the elastic structural analysis computation to compute a load reduction factor that is used in determining allowable aircraft loading and rehabilitation requirements for existing pavements. From FAA Report DOT/FAA PM-83/22, it can be implied that a deflection ratio greater than 0.72 indicates adequate load transfer consistent with the FAA's design assumption of 25% load transfer between concrete slabs.

3.2 EQUIPMENT REQUIREMENTS

RDM's Heavy Falling Weight Deflectometer (HWD) was used for the testing program. The machine meets the requirements of FAA Advisory Circular 150/5370-11B and can perform deflection basin and ISM test sequences. The HWD has a dynamic force range of from 6,000 lbs. to 50,000 lbs. and utilizes seven (7) sensors to record pavement response (deflection). For this study, the tests were conducted at nominal force amplitude of approximately 40,000 lbs.

3.3 DATA ANALYSIS

The primary purpose of the NDT program was to develop inputs on the strength of pavement and subgrade layers for structural analysis. For the layered elastic design procedures used for the pavement analysis, the primary characteristic is the elastic modulus (*E*), or *k*-value value for rigid pavement structure, of the subgrade.

3.3.1 OVERALL PAVEMENT STRENGTHS

The deflections at the loading plate from NDT are attributed to the deformation from pavement structures, including all pavement layers and subgrade, from the applied loads. Therefore, the measured deflections at the loading plate can be qualitatively related to the overall pavement strength. The higher the ISM value, the stronger the overall pavement strength. Based on the definition of the ISM, it can be used to qualitatively evaluate the overall pavement strength from all layers and subgrade.

The ISM values were computed at each test location. The variation of the ISM values along Taxiway A can be seen on the ISM plot in the attachments. The computed ISM values were also mapped over the aerial image for Taxiway A. The ISM values were treated as elevation points in Autodesk's Civil 3D program and a 2D surface was created. The 2D surface depicts the distributions of the ISM values in a color-coded format and can be seen in the exhibit in Appendix B.

As shown on the ISM plot, the ISM values generally are consistent between the three lanes. The ISM values generally vary around 9,000 kips/in. for the first 3,500 feet (from Taxiway N to the west of Taxiway B). At the intersection area with Taxiway B, the ISM values decreased compared to the preceding section.

The ISM values were separated into 5 ranges and mapped accordingly. As shown on the exhibit, the majority of Taxiway A has ISM values greater than 9,194 kips/in. The lowest range of values is from 4,014 kips/in to 7,898 kips/in. and is predominantly located in the Taxiway B intersection area.

The ISM values for the PCC pavements are generally related to the PCC slab thickness and subgrade support condition. Based on the boring data, the thickness of the PCC is nominally 18 to 19 inches consistently over this section of Taxiway A. Given the PCC thickness and surface condition is relatively consistent throughout the length of the project, the low ISM ranges may be attributed to the subgrade support condition.

Extremely low ISM values were excluded from the ISM plot and the map for Taxiway A. At these locations, high deflections at the loading plate were measured resulting in the low ISM values. The deflections at the sensors away from the loading plate dropped rapidly. This implies that voids may be present below the surface and may be the result of the subgrade fines pumping through the joints during seasonal changes or wet / inclement weather. Similar measurements were also obtained in the connector taxiways.

3.3.2 LOAD TRANSFER EFFICIENCY

The load transfer efficiency was evaluated using the deflection data from the slab joint tests. The deflection ratio between unloaded side and loaded side across the joint was computed. When the deflection ratio is greater than 0.72, the load transfer can be considered efficient to meet the design assumption according to the research.

The deflection ratio from the three test lanes of Taxiway A was computed and plotted against the NDT station. As can be seen in Appendix B, the load transfer efficiency in the center lane changes from efficient (>0.72) to potentially loss of load transfer (<0.40) condition. Given the deflection ratio was computed to be less than 0.30 along the center slabs within Taxiway A, a complete loss of the load transfer between slabs is possible. Similar results were also obtained in Taxiway B, C, and S intersection.

The 3-slab width layout means that the center slab lane experiences the majority of the aircraft load repetitions. The reported pumping issue generally results in a loss of support at the joints. The low deflection ratio was recorded in the project limits, indicating inadequate or loss of load transfer. Load carrying capacity may be reduced in these areas.

3.3.3 BACK-CALCULATION RESULTS

The NDT data were analyzed using the closed-form back-calculation procedures. Subgrade *k*-values were evaluated from the back-calculation as well as the elastic moduli of the PCC and the base. A nominal pavement structure, 18” PCC/8” combined AC and soil cement base, was used for the back-calculation. Some of the connector taxiway sections (Taxiway B and Taxiway C) were identified with abnormal deflection basins which is consistent with the faulting/pumping. Given the limited test data collected, these areas were not evaluated for back-calculation. The evaluation results for Taxiway A and connector taxiways are shown in Table 3-1.

The average elastic moduli of the PCC range from 5,472,000 psi to 6,953,000 psi that are typical for the PCC materials constructed using the FAA’s P-501 specification. The equivalent elastic moduli of the combined AC and soil cement base is generally close to one million psi which is also typical for cement stabilized material constructed using the FAA’s P-304 specification.

Subgrade *k*-values were directly obtained from the closed-form back-calculation procedures. The design *k*-values were computed by subtracting one standard deviation (Std. Dev.) from the average in accordance with the FAA’s design procedures. The design *k*-values vary from 130 psi/in. to 177 psi/in.

The taxiway to the Signature Ramp is nominally 22 inches AC on what is assumed to be soil cement subgrade, based on geotechnical investigation. The effective subgrade elastic modulus was estimated based on limited NDT data in this taxiway. Subgrade design *k*-value was estimated to be approximately 170 psi/in.

Based on the coefficient of variation (C.O.V.), subgrade support condition has higher variation in the center slabs of Taxiway A. This seems to be consistent with the evaluation of the joint load transfer efficiency where presence of voids has been implied.

The design subgrade strength will be further evaluated with the geotechnical investigation results to be discussed in Section 4.0.

TABLE 3-1 BACK-CALCULATION SUMMARY

NDT Station		**Elastic Modulus, psi**		**Subgrade *k* -value, psi/in.**			
From	**To**	**PCC**	**Base**	**Average**	**Std. Dev.**	**C.O.V.**	**Desgin**
TW A, 0+00 at TW N							
Left Lane							
0+00	31+77	6,309,000	946,400	176	27	15%	149
32+13	41+15	5,085,000	762,700	175	19	11%	156
Center Lane							
0+00	35+65	5,472,000	820,800	220	51	23%	169
35+82	40+64	5,674,000	851,100	143	13	9%	130
Right Lane							
0+00	37+39	6,079,000	911,800	169	32	19%	137
TW B, North of TW A							
		6,953,000	1,043,000	189	45	24%	144
TW C, South of TW A							
		5,891,000	883,600	226	49	22%	177
TW S, North of TW A							
		5,559,000	833,900	225	59	26%	166
TW S, South of TW A							
		6,098,000	914,700	198	49	25%	149

SECTION 4.0

GEOTECHNICAL INVESTIGATION

SECTION 4.0 GEOTECHNICAL INVESTIGATION

A geotechnical investigation was performed by K.S. Ware & Associates, L.L.C. (KSWA). A total of 14 borings and 8 cores were conducted in the project limits to obtain information on pavement structures and subgrade soils. KSWA's report was provided for reference.

Table 4-1 shows the pavement materials and layer thicknesses from the cores and borings. The cores and borings were listed approximately in the order from Taxiway N to Taxiway B along Taxiway A. Core C-2 and boring B-13 are on the taxiway to the Signature Ramp. Boring B-14 is in Taxiway C south of Taxiway A. Boring B-16 is in Taxiway B south of Taxiway A.

As shown, the PCC thickness is generally consistent ranging from 16 to 21.5 inches with majority around 18 inches. The AC base thickness varies from 2.5 to 5 inches. Cemented base material was identified in the borings with a wide range of thicknesses from 2 inches to 8.5 inches. This layer may have been used as a means of subgrade improvement like soil cement. The combined thicknesses of the AC and soil cement vary from 5 to 12 inches. At the core locations, the soil cement was not extracted. The existing PCC pavement may be normalized as 18 inches of PCC on 8 inches of stabilized base. The AC pavement of the taxiway to the Signature Ramp is nominally 22 inches of AC. KSWA indicated that soil cement may also be present in this taxiway.

Subgrade soils were indicated to be lean clay or lean clay fill classified as CL according to the Unified Soil Classification System (USCS). The N-values in blow counts per foot from the Standard Penetration Test (SPT) for the upper portion of the subgrade generally vary from 5 to 14 blows/ft., indicating relatively weak subgrade strength.

KSWA conducted 3 laboratory CBR tests on CL soil samples and the CBR values are 6.0%, 7.0%, and 9.5%, respectively. KSWA recommended that design subgrade CBR and *k*-value are 7% and 150 psi/in. when compacted to 98% modified proctor. The test and recommended subgrade strengths appear to be consistent with the back-calculated results with *k*-values ranging from 130 psi/in. to 177 psi/in.

KSWA indicated that the CL soils at the site are sensitive to the moisture contents. Stabilization may be necessary to expedite the construction.

TABLE 4-1 BORING RESULTS SUMMARY

Core/Boring	Thickness, in.		
No.	PCC	AC	Soil Cement
C-1	18.0	4.0	n/a
B-1	18.5	3.5	4.0
B-2	18.0	4.0	4.0
B-3	18.0	5.0	3.0
B-4	18.0	4.0	4.0
B-5	18.0	4.5	3.5
B-6	20.5	3.5	2.0
C-4	18.0	n/a	n/a
B-8	17.5	2.5	6.0
C-9	17.5	2.5	n/a
B-9	16.0	3.0	7.0
C-8	21.5	n/a	n/a
C-10	18.0	3.0	n/a
B-10	18.0	3.5	8.5
B-11	17.5	3.5	8.0
C-13	19.0	2.5	n/a
B-12	17.5	3.0	5.5
C-2	n/a	22.0	n/a
B-13	n/a	22.0	
B-14	18.0	3.0	3.0
C-7	18.0	2.5	n/a
B-16	19.0	3.0	2.0

SECTION 5.0

DESIGN TRAFFIC

SECTION 5.0 DESIGN TRAFFIC

According to A&H, Taxiway A is primarily used by the cargo aircraft. Taxiway A was assumed to have 40% of total airport cargo traffic. The fleet mix and the annual departures were provided in Table 5-1 for Taxiway A pavement design.

As shown, Taxiway A is expected to have 7,784 annual departures from the B777F. At the indicated departure weights, the B777F can have controlling impact on the pavement thickness requirements.

According to A&H, the existing connector taxiway to the Signature Apron will be demolished and a new taxiway will be constructed on a realigned location. It is requested that the new pavement in the connector be designed for 1,200 annual departures of the B757 aircraft.

TABLE 5-1 TAXIWAY A WEST DESIGN TRAFFIC

FedEx	Departure	20 years Total		Annual
Cargo Aircraft	Weight, lbs.	Airport	TW A	TW A
A300-600	380,518	133,287	53,315	2,666
A310-2CF	315,041	8,723	3,489	174
ATR-72	50,706	34,028	13,611	681
B757-200 Cargo	256,000	757,105	302,842	15,142
B767-3	413,000	1,948,215	779,286	38,964
B777F	768,800	389,218	155,687	7,784
DC-10-10	458,000	97,066	38,826	1,941
MD-11	633,000	107,802	43,121	2,156

SECTION 6.0

STRUCTURAL ANALYSIS METHODS

SECTION 6.0 STRUCTURAL ANALYSIS METHODS

The FAA's Advisory Circular, AC 150/5320-6F, "*Airport Pavement Design and Evaluation,"* was followed for this project. The associated computer program, FAARFIELD (v. 1.42), was used for the computations.

6.1 MECHANISTIC DESIGN CONCEPT

The FAA design methods employ fundamental mechanistic theory to compute load induced pavement responses based on the engineering properties of the pavement materials and subgrade, i.e., elastic modulus and Poisson ratio. FAA's FAARFIELD program uses layered elastic theory for flexible pavement response calculations and 3-dimensional (3-D) methods to compute rigid pavement response.

For flexible pavement, two (2) failure modes, rutting and surface fatigue cracking, are considered to be critical to performance. Rutting is related to the vertical compressive strain at the top of the subgrade, while fatigue cracking is related to the tensile strain at the bottom of the asphalt concrete layer. For the rigid pavement system, the failure criterion is the PCC fatigue cracking related to the tensile stress at the bottom of the PCC slab, and computed at the edge of the slab. Mechanistic stress and strain criteria are contained in FAA Research Reports RD-74-199, "*Development of a Structural Design Procedure for Flexible Airport Pavements"*, and RD-77-81, "*Development of a Structural Design Procedure for Rigid Airport Pavements"*.

Modifications to the failure criteria and computational models have been made in recent years as results from the research programs conducted at the FAA's National Airport Pavement Test Facility (NAPTF) became available. These modifications have been incorporated in the recently updated Advisory Circular and the FAARFIELD program.

FAARFIELD utilizes a cumulative damage model, whereby the structural damage is computed for each aircraft and summed until the terminal condition is reached when the cumulative damage factor (CDF) is equal to 1.0. This concept essentially eliminates the need for the critical design aircraft as required in prior conventional design procedure.

6.2 EVALUATION INPUTS

For proper execution of FAA's design procedures, the following user inputs are required:

- Subgrade support in terms of elastic modulus (*E*) or CBR/*k*-value.
- Construction materials and properties.
- Traffic and design life.

Based on the discussions in Section 3.0 and Section 4.0, subgrade design *k*-values from NDT back-calculation and geotechnical investigations are consistent. Sensitivity analysis will be performed based on the range of the *k*-values. The structural evaluation is based on a 20-year design life based on the FAA's design procedures.

SECTION 7.0

EVALUATION AND REHABILITATION

SECTION 7.0 EVALUATION AND REHABILITATION

Based on the condition survey results in Section 2.0, minimal structural related distresses were recorded during the visual inspection. When the existing pavement can provide more than 10 years of structural life, strengthening is not necessary unless future traffic requires.

However, the observed faulting and reported pumping issues will affect future pavement performance. The NDT analysis also indicated a loss of joint load transfer in the trafficked PCC center lane of Taxiway A. The load carrying capacity would be reduced based on the observations and the test data. Major rehabilitation such as reconstruction is the primary way to address concerns relating to pavement strength and the subgrade support.

7.1 REMAINING STRUCTURAL LIFE

The existing pavement structure of Taxiway A is nominally 18 inches of PCC on 8 inches of combined stabilized materials consisting of AC and soil cement. The structural life was estimated for the future traffic using FAARFIELD. Assuming subgrade *k*-value of 150 psi/in. based on NDT and geotechnical investigation, the remaining structural life is less than 15 years for concrete flexural strength of 750 psi, if the current pavement provides adequate load transfer between joints. For slabs with loss of load transfer, the structural life will be less than 3 years for future heavy cargo traffic. Therefore, rehabilitation is necessary for Taxiway A.

7.2 PAVEMENT RECONSTRUCTION MATERIALS

The west section rehabilitation of Taxiway A should be consistent with the previously designed and constructed east section of PCC pavement. Therefore, the PCC pavement structure was evaluated for future traffic. For the connector taxiway to the Signature Ramp and taxiway shoulders, the AC pavement structure was evaluated. Standard construction materials conforming to the FAA's specifications prescribed in the Advisory Circular, AC150/5370-10H, "Standard Specifications for Construction of Airports," were considered for the following design materials.

P-501 – Cement Concrete Pavement

P-401 – Asphalt Mix Pavement

P-403 – Asphalt Mix Pavement Surface

P-304 - Cement Treated Aggregate Base Course (CTB)

P-220 (Previously P-301) – Cement Treated Soil Base Course

P-219 – Recycled Concrete Aggregate Base Course

P-156 – Cement Treated Subgrade

The P-401 should be used for AC pavement in the taxiway to the Signature Ramp. The P-403 can be used for the shoulders.

The east section of Taxiway A utilized a 4-inch asphalt treated permeable base (ATPB) underneath the PCC surface for drainage on top of an 8-inch P-304. It is noted that the ATPB is not a standard FAA material and would require that the airport secure a modification to standard for the proposed specification.

The elastic modulus of the ATPB may vary. Two values were considered for sensitivity analysis, i.e., 100,000 psi and 150,000 psi.

The P-220 (previously P-301) is a stabilized base while the P-156 is a subgrade treatment material. The elastic modulus of the P-220 is 250,000 psi. However, the elastic modulus of the P-156 is generally less stiff than the P-220. A conservative elastic modulus of 30,000 psi was assumed for the P-156 as a user defined layer in FAARFIELD.

The design flexural strength of the PCC is assumed to be 685 psi. Assuming 5% gain in strength, the mix design can be developed for 650 psi at 28 days.

7.3 PCC PAVEMENT THICKNESS DESIGN RESULTS

Using the base system consisting of 4” ATPB/8” P-304/12” P-220 or P-156, the required PCC thicknesses were computed using FAARFIELD. Based on the NDT and geotechnical investigation, the strength values of the native subgrade soils were considered to be 130 psi/in. and 150 psi/in. An effective subgrade model was also considered using an effective *k*-value of 200 psi/in. on top of the 12-inch soil cement or cement treatment subgrade. Table 6-1 presents the computed and rounded PCC thicknesses for the different design inputs. The rounded thicknesses are the results to the nearest half of an inch of the computed thicknesses according to the FAA’s design procedures.

As shown, the required PCC thicknesses vary from 18.0 inches to 19.5 inches. The use of the P-220 resulted in 18.5 inches of PCC for the weakest subgrade strength. Based on NDT, the 130 psi/in. subgrade is localized. Most of the existing pavement areas were shown to have a *k*-value greater than 150 psi/in. The geotechnical investigation also recommended 150 psi/in. subgrade strength. Therefore, the results from subgrade *k*-value of 150 psi/in. and effective subgrade model were reasonable. A conservative section consistent with the east section of Taxiway A is recommended as:

19.0” P-501/4” ATPB/8-inch P-304/12” P-301 or P-156

TABLE 6-1 PCC THICKNESS RESULTS

Subgrade	**Native Subgrade**		**Effective Subgrade**
Treatment	**130 psi/in.**	**150 psi/in.**	**200 psi/in.**
	Elastic Modulus of 4" ATPB =150,000 psi		
12" P-220 Soild Cement	18.40"=>18.5"	17.90"=>18.0"	18.53"=>19.0"
12" P-156 Cement Treatment	19.41"=>19.5"	18.99"=>19.0"	
	Elastic Modulus of 4" ATPB =100,000 psi		
12" P-156 Cement Treatment	19.48"=>19.5"	19.06"=>19.0"	18.60"=>18.5"

Note: All sections consist of 4” ATPB/8” P-304/12” P-301 or P-156 as the base system for the PCC. The elastic modulus of the P-156 is assumed to be 30,000 psi. The elastic moduli of all other materials are default values in the FAARFIELD.

7.4 AC TAXIWAY PAVEMENT AND SHOULDERS

The AC taxiway was designed for 1,200 annual departures of the B757 aircraft for the connector taxiway to the Signature Ramp. The P-156 cement treatment is considered as subgrade improvement. The effective subgrade CBR on top of the 12-inch P-156 is considered to be 12% and is consistent with the effective subgrade *k*-value of 200 psi/in., resulting in a relatively conservative thickness.

The minimum AC surface and base thickness is 4 inches and 5 inches based on the FAA’s design procedures. The required P-219 thicknesses were computed. The following section may be used:

9” P-401/6” P-219/12” P-156

Based on the FAA’s design procedures, the shoulder pavements should provide adequate support for 15 passes of the most demanding aircraft in the fleet mix over the 20-year design period. The FAARFIELD analysis indicated that the B777 is the most demanding aircraft. For the effective subgrade strength model, the following sections are provided:

4” P-403/12” P-219/12” P-156, or

5” P-403/10” P-219/12” P-156

7.5 CONSTRUCTIBILITY

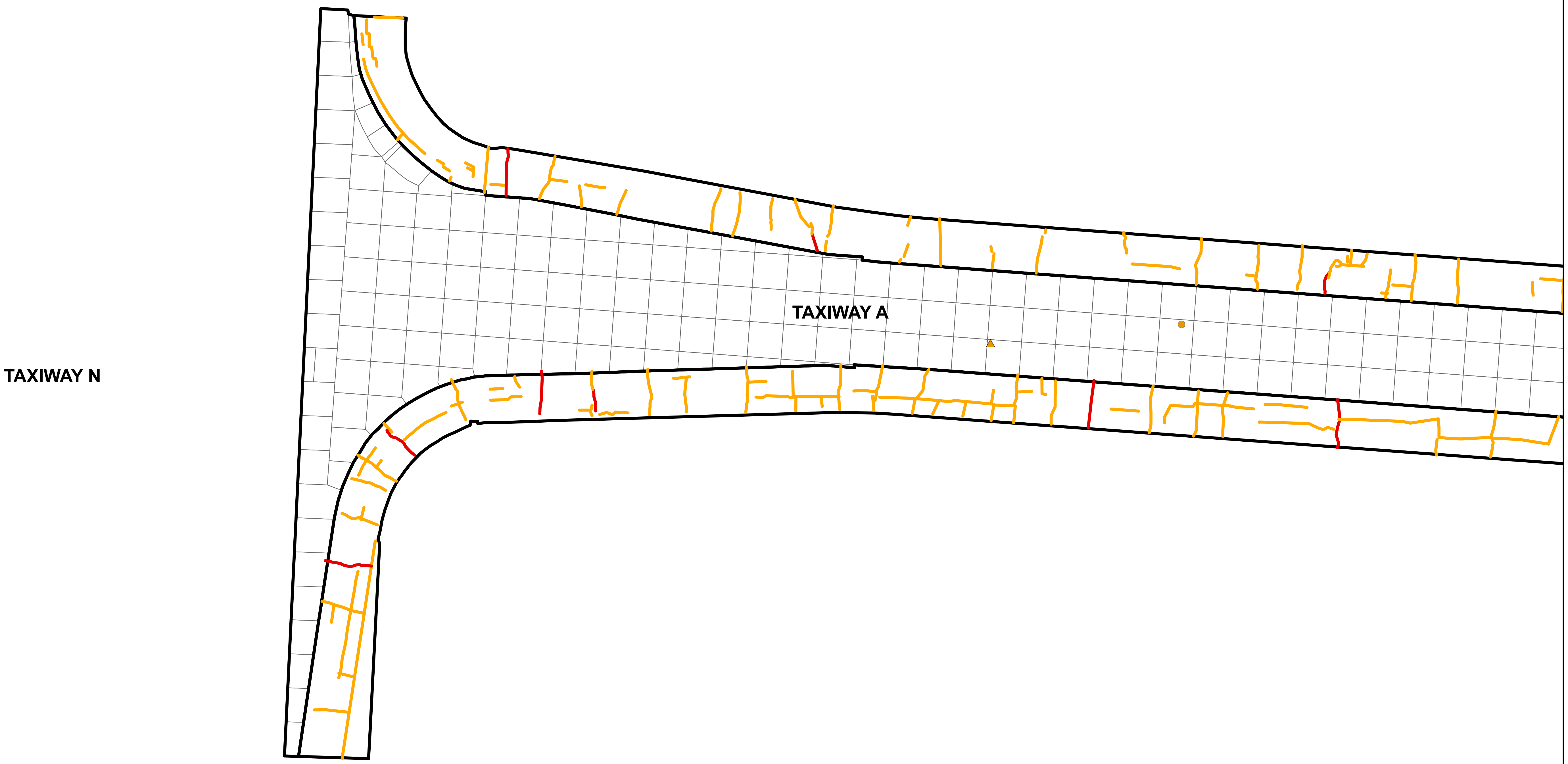
For PCC thicknesses greater than 16 inches, the current FAA's design procedures recommend a maximum joint spacing of 20 feet for PCC slabs supported on a stabilized base. The aspect ratio of the slab should not exceed 1.25. The slab size limitation is provided to minimize the warping and curling stresses that may be incurred by the changes in temperature and moisture within the depth of the slabs.

At MEM, the maximum joint spacing of 25 feet has been used for relatively thick PCC slabs for many years. The survey data provided for a prior project indicated that the 25 feet size slabs performed satisfactorily due to the substantial slab thickness, doweled joints, and high-quality concrete materials provided. If a Modification of Standard (MOS) to use the 25 feet slab size can be approved, the 25-foot joint spacing for the 19-inch thick slabs for this project may be considered. All joints should be doweled to provide adequate load transfer. Reinforcements should be provided for irregular slabs and slabs out of maximum aspect ratio.

At the transition between the PCC and AC pavements and the PCC pavement and the shoulders, the details can be different from the provided design sections. The variation depends on the arrangement of the underdrains and construction efficiencies required for paving set up. RDM will provide further review when the plans are developed.

APPENDIX A

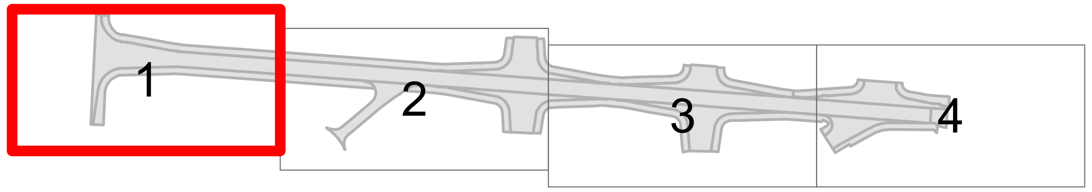
DISTRESS MAPS

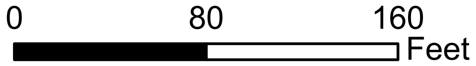


Asphalt shoulders exhibit medium weathering

Legend

▭ Sections ▭ Slabs ▲ Corner Spall, H ▲ Corner Spall, M ● Joint Spall, M ■ Small Patch, H ■ Small Patch, M — Crack, M — Crack, H — Fault, H





N
W E
S

Memphis International Airport
TAXIWAY A

DISTRESS MAP (2019)

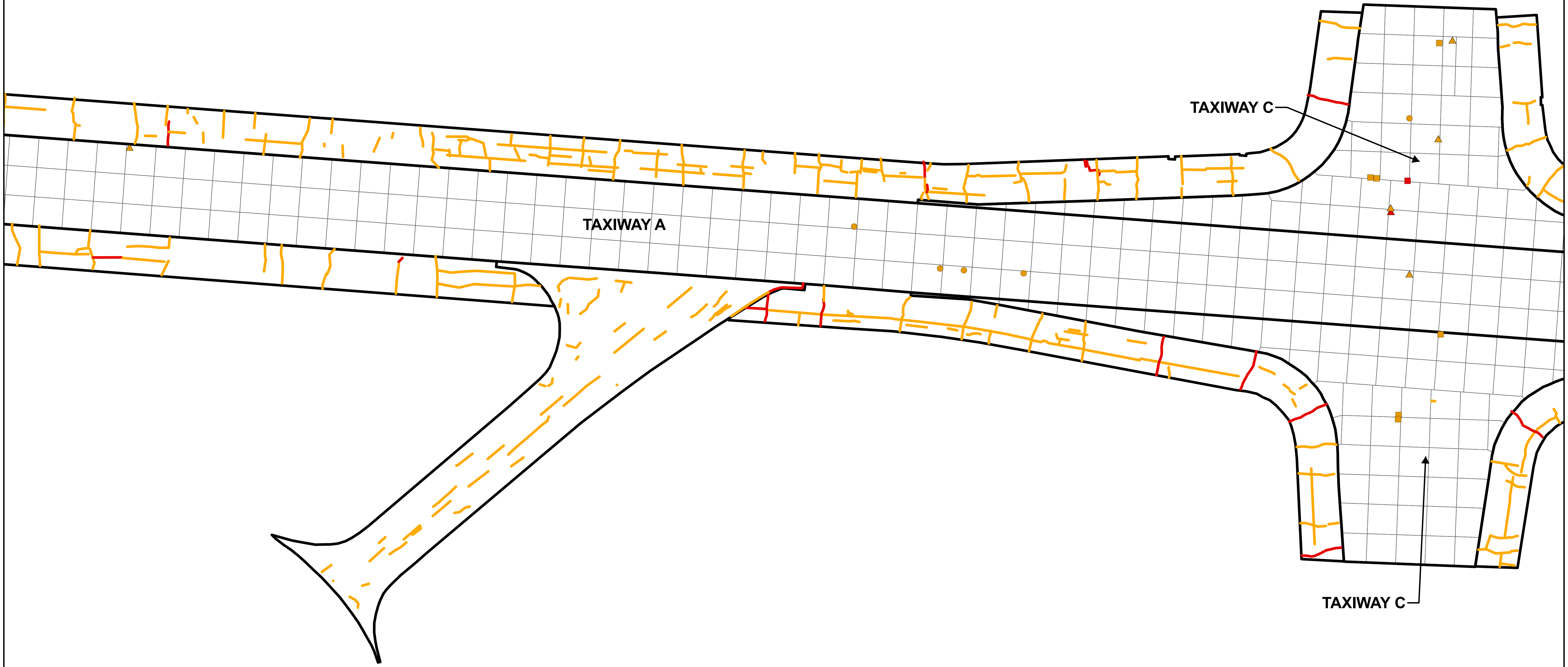
Engineering Technology Research
RDM INTERNATIONAL INC.
14310 SULLYFIELD CIRCLE, SUITE 600
CHANTILLY, VA 20151

DESIGNED:
CHECKED:
DRAWN:
ACCEPTED:
SUBMITTED:
APPROVED:

RDM-

SHEET NAME

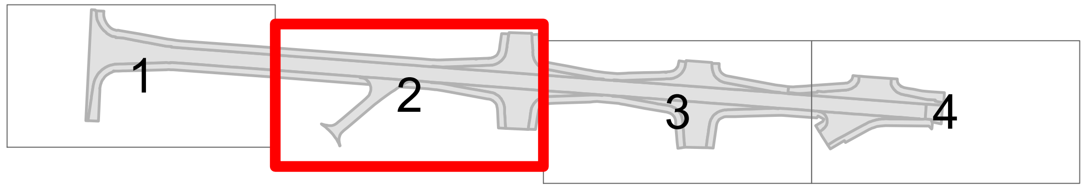
PAGE



Asphalt shoulders exhibit medium weathering

Legend

▭ Sections ▭ Slabs ▲ Corner Spall, H ▲ Corner Spall, M ● Joint Spall, M ■ Small Patch, H ■ Small Patch, M — Crack, M — Crack, H — Fault, H



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Memphis International Airport
TAXIWAY A

DISTRESS MAP (2019)

RDM INTERNATIONAL INC.
14310 SULLYFIELD CIRCLE, SUITE 600
CHANTILLY, VA 20151

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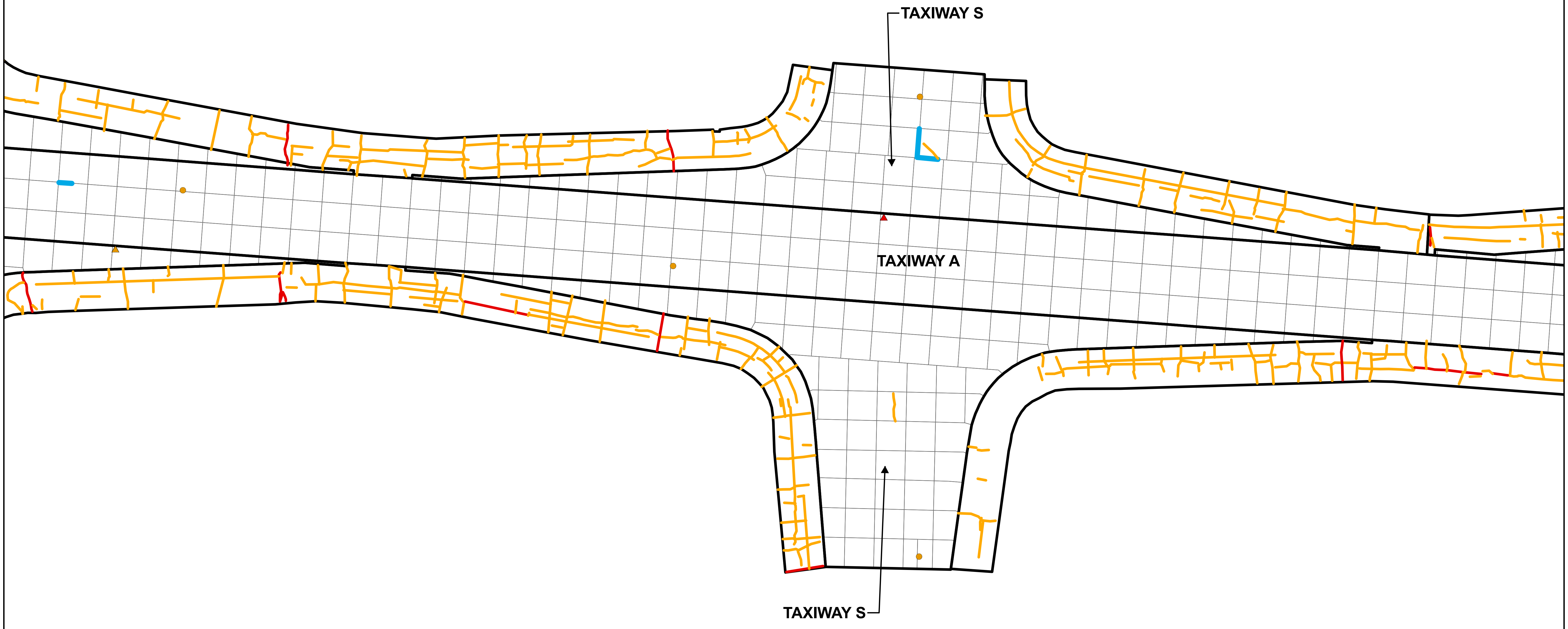
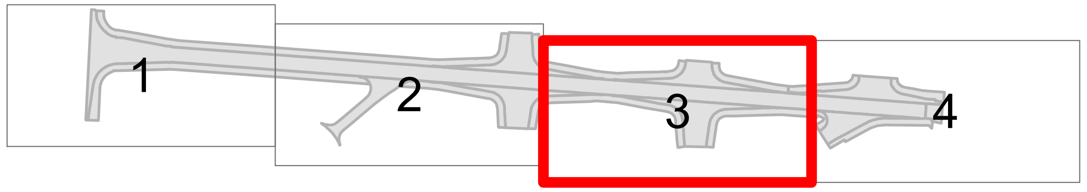


Asphalt shoulders exhibit medium weathering

Legend

▭ Sections
▭ Slabs
▲ Corner Spall, H
▲ Corner Spall, M
● Joint Spall, M
■ Small Patch, H
■ Small Patch, M
— Crack, M
— Crack, H
— Fault, H



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Memphis International Airport
TAXIWAY A

DISTRESS MAP (2019)

RDM
Engineering Technology Research
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DESIGNED:
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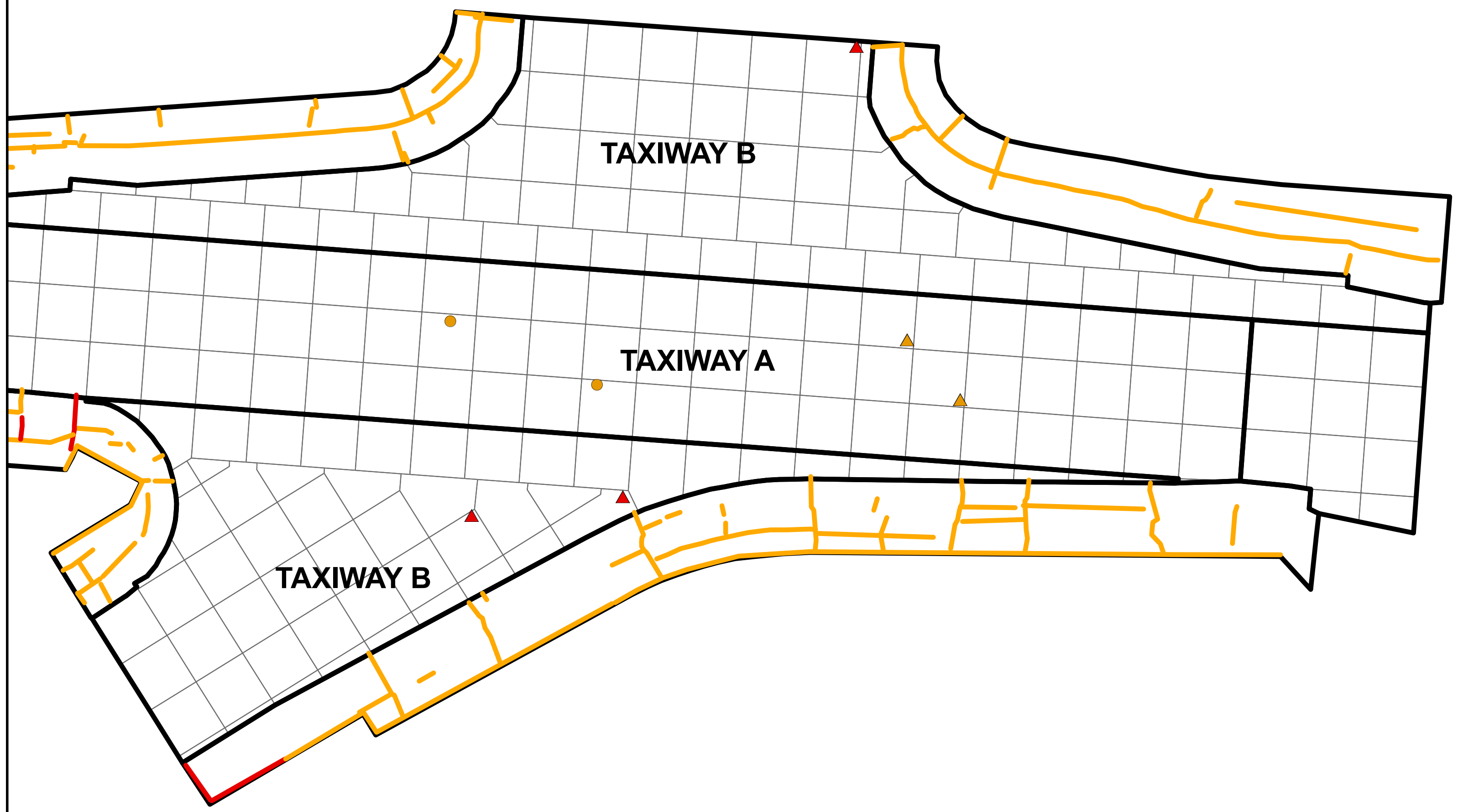
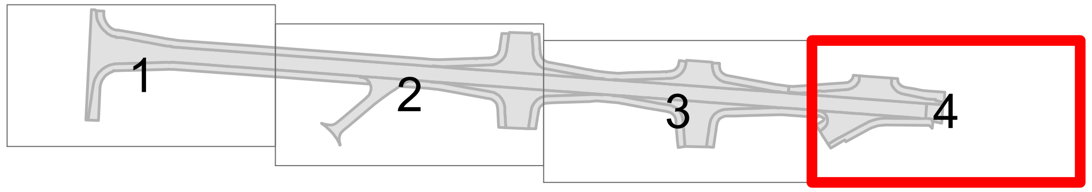


Asphalt shoulders exhibit medium weathering

Legend

▭ Sections ▭ Slabs ▲ Corner Spall, H ▲ Corner Spall, M ● Joint Spall, M ■ Small Patch, H ■ Small Patch, M — Crack, M — Crack, H — Fault, H



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Feet

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W E
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Memphis International Airport
TAXIWAY A

DISTRESS MAP (2019)

RDM INTERNATIONAL INC.
14310 SULLYFIELD CIRCLE, SUITE 600
CHANTILLY, VA 20151

DESIGNED: CHECKED:	RDM-
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APPENDIX B

NDT FIELD DATA

Memphis International Airport

Taxiway A West

NDT Field Data

NDT	Lane	NDT Station		Force	Displacement Sensors (mils)							Pvmnt	ISM
No.	No.	Distance	Offset	(kip)	d1 (0)	d2 (8")	d3 (12")	d4 (24")	d5 (36")	d6 (48")	d7 (60")	Temp (F)	(kip/in)
0+00 at edge of Taxiway N													
1	1	11	25' L	40	3.32	3.26	3.12	2.96	2.90	2.61	2.47	67.60	12,033
3	1	113	25' L	40	4.07	4.05	3.94	3.89	3.62	3.15	2.98	72.00	9,818
5	1	216	25' L	40	3.50	3.46	3.31	3.29	2.95	2.61	2.53	71.90	11,418
7	1	315	25' L	40	3.04	3.01	2.91	2.98	2.61	2.26	2.17	70.80	13,159
8	1	415	25' L	40	3.13	3.12	2.95	2.93	2.59	2.35	2.21	72.20	12,785
10	1	515	25' L	40	3.32	3.29	3.07	3.26	2.82	2.45	2.31	72.10	12,033
12	1	615	25' L	40	3.75	3.62	3.63	3.32	3.05	2.78	2.59	71.20	10,669
14	1	714	25' L	40	3.61	3.61	3.64	3.74	3.17	2.75	2.66	71.70	11,091
16	1	817	25' L	40	3.42	3.37	3.24	3.24	2.93	2.60	2.51	73.00	11,711
18	1	914	25' L	40	3.90	3.94	3.89	3.94	3.34	2.96	3.13	71.10	10,244
20	1	1015	25' L	40	4.24	4.16	4.07	3.98	3.38	3.04	2.88	73.60	9,431
22	1	1114	25' L	40	4.94	4.88	4.79	5.24	4.42	4.07	3.89	74.30	8,092
24	1	1213	25' L	40	3.80	3.79	3.70	3.44	3.19	2.82	2.70	74.00	10,538
26	1	1314	25' L	40	3.77	3.69	3.51	3.65	3.09	2.79	2.69	71.20	10,605
28	1	1412	25' L	40	3.92	3.92	3.77	3.63	3.48	3.14	2.92	74.70	10,198
30	1	1514	25' L	40	3.82	3.82	3.64	3.83	3.40	3.00	2.87	73.40	10,461
32	1	1616	25' L	40	4.08	4.04	3.91	3.74	3.58	3.22	3.04	73.50	9,811
33	1	1714	25' L	40	4.11	4.05	3.99	3.84	3.60	3.13	2.96	72.50	9,726
35	1	1815	25' L	40	3.26	3.21	3.06	3.05	2.71	2.38	2.13	74.40	12,275
39	1	2015	25' L	40	4.02	3.97	3.90	3.79	3.46	3.09	2.94	73.60	9,943
40	1	2113	25' L	40	3.71	3.72	3.55	3.52	3.21	2.84	2.73	73.30	10,787
42	1	2212	25' L	40	4.16	4.13	3.88	3.96	3.42	3.11	2.93	75.00	9,623
44	1	2312	25' L	40	4.53	4.51	4.43	4.11	3.76	3.37	3.13	75.00	8,837
45	1	2413	25' L	40	4.15	4.12	3.98	3.77	3.40	3.14	2.95	75.60	9,650
47	1	2513	25' L	40	4.33	4.32	4.14	3.96	3.66	3.23	3.03	74.80	9,240
48	1	2614	25' L	40	4.25	4.22	3.81	4.22	3.25	2.83	2.56	73.90	9,418
50	1	2715	25' L	40	3.51	3.48	3.40	3.36	2.81	2.47	3.74	75.80	11,402
52	1	2816	25' L	40	4.07	4.04	3.87	3.63	3.29	2.93	2.64	77.30	9,822
54	1	2912	25' L	40	3.39	3.30	3.04	3.02	2.58	2.23	2.05	72.50	11,814
56	1	3017	25' L	40	3.68	3.59	3.39	3.28	2.73	2.44	2.27	72.40	10,868
58	1	3117	25' L	40	3.63	3.61	3.30	3.20	2.79	2.44	2.22	74.80	11,033
60	1	3213	25' L	40	4.01	3.97	3.74	3.58	3.22	2.86	2.65	73.10	9,980
62	1	3315	25' L	40	4.53	4.50	4.22	4.16	3.69	3.29	2.99	74.90	8,833
64	1	3415	25' L	40	4.01	3.96	3.87	3.88	3.29	2.88	2.69	72.70	9,967
66	1	3512	25' L	40	4.03	4.01	3.76	4.10	3.13	2.83	2.58	72.60	9,917
68	1	3612	25' L	40	4.41	4.40	4.08	4.32	3.66	3.18	3.01	76.30	9,074
70	1	3713	25' L	40	5.06	4.67	4.52	4.70	3.84	3.60	3.39	74.30	7,898
71	1	3811	25' L	40	4.20	4.21	3.93	4.11	3.56	3.24	2.98	77.50	9,521
72	1	3915	25' L	40	4.98	4.62	4.51	4.41	4.14	3.71	3.41	75.50	8,040
74	1	4012	25' L	40	5.51	5.16	4.95	4.91	4.56	3.96	3.68	76.00	7,262
76	1	4115	25' L	40	5.60	5.40	5.07	4.89	4.47	4.01	3.69	74.20	7,149
84	2	160	Center	40	4.43	4.40	4.04	4.06	3.50	4.33	1.43	71.20	9,039
88	2	362	Center	40	3.50	3.25	3.12	2.91	2.76	2.44	2.37	76.00	11,439
90	2	466	Center	40	3.05	3.05	2.95	2.82	2.69	2.34	2.20	75.90	13,097
92	2	564	Center	40	3.69	3.64	3.38	3.18	2.94	2.68	2.47	79.20	10,849
94	2	663	Center	40	3.65	3.56	3.29	3.49	2.84	2.41	2.32	79.00	10,971
96	2	762	Center	40	4.40	3.30	3.15	3.14	2.74	2.47	2.33	78.00	9,101
98	2	863	Center	40	3.55	3.72	3.35	3.38	2.97	2.76	2.46	74.80	11,269
100	2	964	Center	40	3.27	3.59	3.43	3.28	3.01	2.66	2.59	79.60	12,249
102	2	1066	Center	40	4.38	4.21	4.12	3.77	3.57	3.21	3.04	78.00	9,141
105	2	1179	Center	40	6.12	4.49	4.32	3.92	3.51	3.16	2.84	77.80	6,539
106	2	1267	Center	40	3.69	3.46	3.26	3.12	2.84	2.61	2.43	79.30	10,840
107	2	1364	Center	40	4.19	3.87	3.54	3.63	3.23	2.81	2.63	78.30	9,539
109	2	1466	Center	40	4.38	3.79	3.51	3.44	3.10	2.87	2.65	78.10	9,130
110	2	1565	Center	40	4.60	3.70	3.63	3.65	3.15	2.87	2.65	77.00	8,695
112	2	1664	Center	40	3.97	3.76	3.71	3.49	3.22	2.94	2.72	76.40	10,067
114	2	1765	Center	40	3.80	3.80	3.52	3.34	3.17	2.82	2.64	77.80	10,521
115	2	1864	Center	40	4.03	3.93	3.70	3.81	3.19	3.00	2.56	77.40	9,920
116	2	1880	Center	40	4.70	4.22	4.06	3.77	3.45	2.96	2.75	76.40	8,505
117	2	1964	Center	40	3.92	4.01	3.73	3.76	3.51	3.06	2.82	81.60	10,209
119	2	2065	Center	40	4.08	3.92	3.57	3.57	3.27	2.98	2.82	81.70	9,799
120	2	2166	Center	40	3.84	3.96	3.77	3.74	3.36	3.11	2.94	76.50	10,424
122	2	2264	Center	40	4.42	4.36	4.13	4.21	3.40	3.37	3.18	78.30	9,046
123	2	2361	Center	40	4.35	4.34	4.09	3.98	3.81	3.37	3.14	76.70	9,201

Memphis International Airport

Taxiway A West

NDT Field Data

NDT	Lane	NDT Station		Force	Displacement Sensors (mils)							Pvmnt	ISM
No.	No.	Distance	Offset	(kip)	d1 (0)	d2 (8")	d3 (12")	d4 (24")	d5 (36")	d6 (48")	d7 (60")	Temp (F)	(kip/in)
0+00 at edge of Taxiway N													
125	2	2466	Center	40	4.78	4.25	4.09	3.94	3.66	3.38	3.13	78.20	8,375
127	2	2562	Center	40	4.71	4.11	3.94	3.70	3.52	3.04	2.76	78.00	8,489
129	2	2663	Center	40	4.05	3.44	3.33	3.28	2.78	2.53	2.35	79.70	9,865
131	2	2762	Center	40	3.45	3.42	3.19	3.09	2.78	2.41	2.20	80.30	11,588
133	2	2867	Center	40	3.19	3.62	3.55	3.31	3.00	2.64	2.40	76.00	12,544
135	2	2964	Center	40	4.41	3.31	3.13	2.94	2.60	2.33	2.14	81.30	9,070
136	2	3063	Center	40	4.03	3.53	3.32	3.31	2.82	2.44	2.23	80.00	9,916
138	2	3166	Center	40	3.85	3.91	3.79	3.78	3.20	2.85	2.80	75.60	10,395
140	2	3265	Center	40	4.56	4.50	4.45	4.16	3.91	3.40	3.11	79.00	8,767
142	2	3368	Center	40	5.28	5.22	4.99	4.76	4.27	3.81	3.48	79.90	7,582
144	2	3465	Center	40	3.85	3.83	3.73	3.55	3.10	2.68	2.51	80.10	10,398
146	2	3565	Center	40	4.34	4.27	3.72	3.65	3.29	2.92	2.54	79.00	9,221
147	2	3582	Center	40	5.85	4.72	4.54	4.02	3.59	3.18	2.88	79.00	6,837
148	2	3668	Center	40	6.65	4.67	4.46	4.29	3.97	3.61	3.32	78.80	6,016
149	2	3771	Center	40	6.34	6.16	6.06	5.64	5.04	4.54	4.13	75.20	6,312
150	2	3965	Center	40	4.53	4.46	4.20	4.22	3.82	3.33	3.15	78.20	8,838
152	2	4064	Center	40	5.01	4.95	4.70	4.60	4.25	3.83	3.50	78.80	7,986
158	3	40	25' R	40	3.87	3.88	3.73	3.92	3.39	3.12	2.79	74.40	10,345
160	3	137	25' R	40	4.46	4.44	4.36	4.30	3.80	3.40	3.23	79.60	8,960
161	3	236	25' R	40	4.35	3.76	3.64	3.62	3.21	2.94	2.72	81.40	9,194
163	3	337	25' R	40	4.28	4.13	4.07	4.02	3.41	3.09	2.90	81.60	9,354
164	3	440	25' R	40	4.94	3.55	3.45	3.27	3.07	2.82	2.62	83.20	8,096
165	3	537	25' R	40	3.78	3.87	3.61	3.91	3.25	2.87	2.65	78.10	10,589
169	3	738	25' R	40	3.85	3.50	3.26	3.15	2.88	2.53	2.36	85.10	10,400
171	3	838	25' R	40	4.40	4.32	4.13	4.08	3.71	3.29	3.05	85.10	9,094
172	3	937	25' R	40	4.78	4.80	4.65	4.49	4.08	3.66	3.41	81.00	8,370
174	3	1038	25' R	40	4.24	4.23	4.15	3.98	3.66	3.36	3.19	84.50	9,423
176	3	1138	25' R	40	4.05	4.06	3.84	3.79	3.38	3.02	2.92	80.30	9,868
178	3	1235	25' R	40	4.07	4.03	3.91	4.24	3.52	3.03	2.61	84.70	9,840
180	3	1338	25' R	40	3.62	3.49	3.35	3.67	3.14	2.73	2.48	80.10	11,049
181	3	1437	25' R	40	3.84	3.66	3.48	3.43	3.07	2.80	2.68	84.00	10,430
183	3	1539	25' R	40	3.98	3.85	3.69	3.63	3.32	3.01	2.85	81.90	10,050
185	3	1636	25' R	40	4.02	3.83	3.82	3.71	3.35	2.98	2.68	83.50	9,940
187	3	1738	25' R	40	4.48	4.21	4.07	3.92	3.65	3.32	1.29	85.20	8,930
188	3	1840	25' R	40	4.28	4.27	4.18	4.31	3.86	3.34	2.97	84.50	9,347
190	3	1937	25' R	40	4.62	4.53	4.16	4.45	3.66	3.34	3.10	84.30	8,665
191	3	1956	25' R	40	5.66	5.41	5.16	4.92	4.18	3.73	3.40	83.80	7,070
192	3	2039	25' R	40	4.26	4.24	4.06	4.41	3.51	3.14	2.91	85.20	9,396
194	3	2139	25' R	40	3.28	3.44	3.37	3.30	2.90	2.62	2.44	82.90	12,212
195	3	2240	25' R	40	4.30	4.26	4.04	4.12	3.71	3.36	3.17	83.40	9,310
197	3	2337	25' R	40	4.39	4.35	4.21	4.17	3.69	3.36	3.17	83.40	9,106
199	3	2439	25' R	40	5.12	4.90	4.75	4.56	4.15	3.71	3.43	78.40	7,813
200	3	2541	25' R	40	5.68	4.94	4.80	4.84	4.25	3.75	3.62	83.10	7,041
202	3	2640	25' R	40	5.62	5.55	5.34	5.21	4.40	3.95	3.57	83.90	7,112
204	3	2737	25' R	40	3.70	3.68	3.51	3.44	3.04	2.66	2.48	79.20	10,812
206	3	2839	25' R	40	3.66	3.45	3.21	3.05	2.70	2.34	2.11	84.40	10,923
208	3	2936	25' R	40	3.70	3.57	3.52	3.48	2.91	2.57	2.35	79.70	10,803
209	3	3039	25' R	40	4.25	4.81	4.67	4.66	4.04	3.61	3.12	84.10	9,414
211	3	3138	25' R	40	4.65	4.57	4.43	4.57	3.99	3.72	3.44	80.00	8,603
213	3	3238	25' R	40	4.30	4.29	4.05	3.88	3.55	3.11	2.83	85.10	9,306
215	3	3337	25' R	40	4.79	4.71	4.65	4.59	4.00	3.55	3.26	84.50	8,353
217	3	3438	25' R	40	4.84	4.60	4.47	4.45	3.87	3.42	3.12	80.50	8,268
219	3	3537	25' R	40	4.52	4.45	4.18	4.09	3.67	3.31	3.04	84.50	8,841
220	3	3641	25' R	40	4.78	4.74	4.52	4.43	4.00	3.57	3.30	80.10	8,371
222	3	3739	25' R	40	6.72	6.49	6.33	6.09	5.53	4.96	4.57	80.80	5,951
223	3	3837	25' R	40	5.86	4.55	4.38	4.51	3.92	3.54	3.36	81.00	6,828
224	3	3946	25' R	40	9.97	5.95	5.73	5.53	4.85	4.29	3.71	84.30	4,014
226	3	4037	25' R	40	6.71	6.66	6.55	6.36	5.80	5.27	4.80	84.30	5,964

Memphis International Airport

Taxiway A West

NDT Field Data

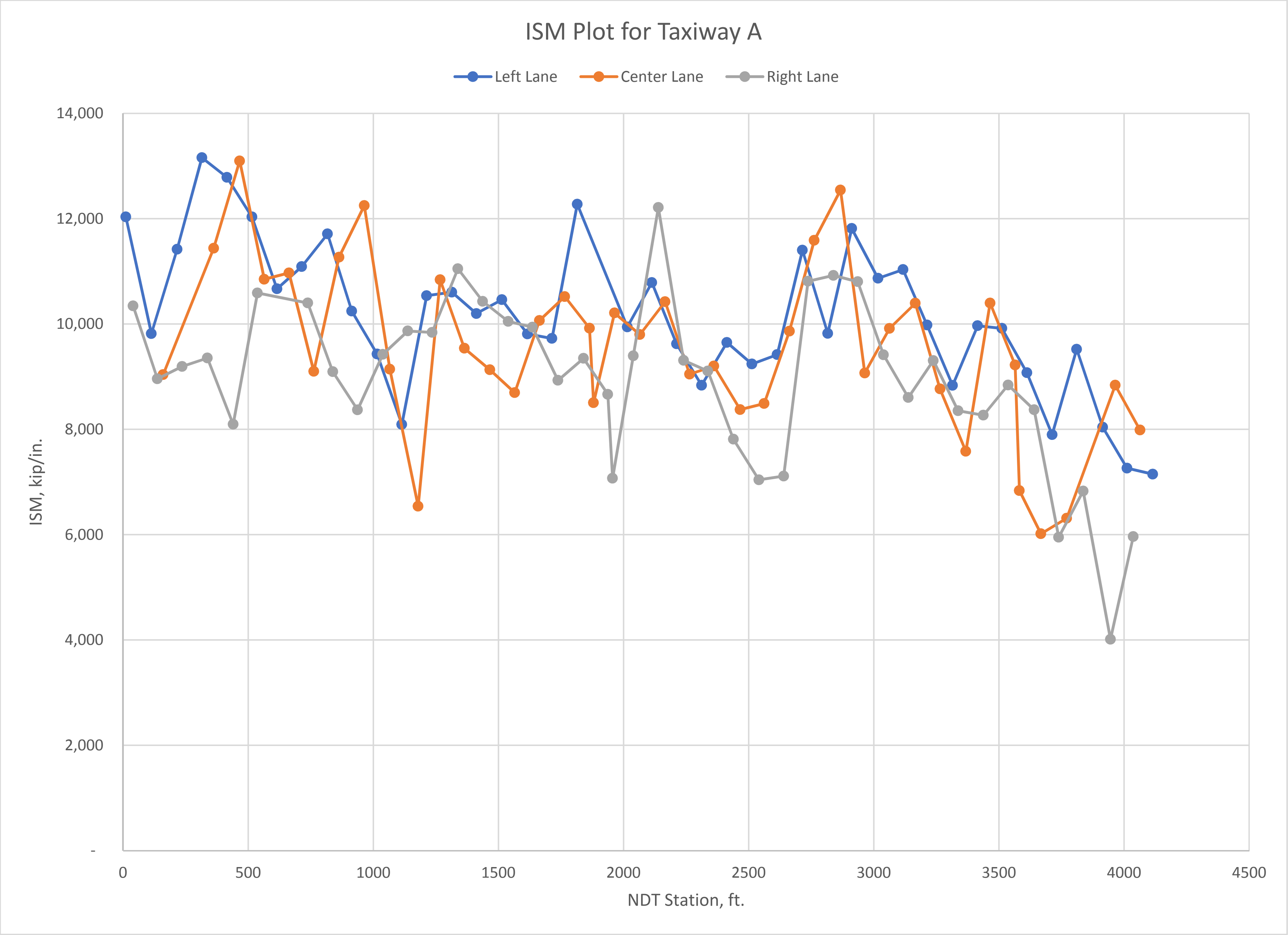
NDT	Lane	NDT Station		Force			Displacement Sensors (mils)					Pvmnt	ISM
No.	No.	Distance	Offset	(kip)	d1 (0)	d2 (8")	d3 (12")	d4 (24")	d5 (36")	d6 (48")	d7 (60")	Temp (F)	(kip/in)
0+00 at edge of Taxiway N													
Joint Tests													**d3/d1**
2	1	26	25' L	40	4.48	4.31	4.13	3.48	3.12	2.72	2.51	67.50	0.92
4	1	126	25' L	40	5.44	5.34	5.27	4.95	4.35	3.75	3.50	70.40	0.97
6	1	229	25' L	40	5.07	4.99	4.10	4.06	3.35	2.89	2.67	70.80	0.81
9	1	433	25' L	40	3.83	3.70	3.56	3.32	3.01	2.57	2.44	72.20	0.93
11	1	527	25' L	40	3.77	3.77	3.56	3.43	3.14	2.67	1.72	71.60	0.95
13	1	628	25' L	40	4.66	3.91	3.72	3.87	3.28	2.79	2.60	70.60	0.80
15	1	727	25' L	40	4.27	4.08	3.90	3.67	3.31	2.92	2.73	72.80	0.91
19	1	927	25' L	40	5.40	4.64	4.39	4.08	3.57	3.20	2.90	73.90	0.81
21	1	1027	25' L	40	5.32	4.81	4.46	4.16	3.65	3.25	2.93	73.90	0.84
23	1	1127	25' L	40	7.08	5.84	5.62	5.12	4.65	4.05	3.74	73.40	0.79
25	1	1225	25' L	40	5.04	4.34	4.23	3.95	3.35	3.04	2.84	72.70	0.84
27	1	1326	25' L	40	5.26	5.31	5.05	4.49	3.97	3.52	3.11	72.00	0.96
29	1	1427	25' L	40	5.36	5.37	5.17	4.86	4.21	3.63	3.37	74.20	0.97
31	1	1527	25' L	40	4.94	4.90	4.71	4.63	3.92	3.47	3.10	73.70	0.95
34	1	1726	25' L	40	4.90	4.86	4.75	4.48	4.02	3.72	3.41	73.80	0.97
36	1	1827	25' L	40	4.72	4.62	4.27	4.27	3.48	2.95	2.75	71.20	0.90
37	1	1912	25' L	40	3.99	3.97	3.74	3.58	3.27	2.98	2.75	75.60	0.94
38	1	1926	25' L	40	4.81	4.74	4.35	4.14	3.56	3.10	2.85	72.00	0.91
41	1	2125	25' L	40	4.65	4.54	4.14	3.94	3.55	3.10	3.06	75.40	0.89
43	1	2224	25' L	40	5.12	5.08	4.64	4.27	3.82	3.46	3.15	72.10	0.91
46	1	2425	25' L	40	5.61	5.61	5.30	5.20	4.25	3.70	3.80	75.10	0.95
49	1	2625	25' L	40	4.55	4.50	4.38	3.89	3.48	3.07	2.75	75.50	0.96
51	1	2726	25' L	40	3.70	3.70	3.49	3.25	2.96	2.56	2.32	75.70	0.94
53	1	2826	25' L	40	4.66	4.47	4.27	3.79	3.22	2.77	2.40	72.90	0.92
55	1	2926	25' L	40	5.33	5.29	4.64	3.99	3.44	2.77	2.40	74.70	0.87
57	1	3028	25' L	40	6.80	3.52	3.44	2.87	2.55	2.19	1.97	74.00	0.51
59	1	3128	25' L	40	7.11	3.81	3.66	3.27	2.78	2.42	2.13	76.60	0.51
61	1	3229	25' L	40	5.25	4.16	3.67	3.43	2.99	2.62	2.36	75.10	0.70
63	1	3330	25' L	40	6.11	5.73	5.37	5.19	4.20	3.50	3.44	75.20	0.88
65	1	3431	25' L	40	5.91	5.57	5.29	5.05	3.96	3.33	2.91	75.70	0.90
67	1	3525	25' L	40	6.00	5.71	5.48	5.16	4.30	3.58	2.70	75.50	0.91
69	1	3626	25' L	40	5.52	4.78	4.71	4.24	3.80	3.40	3.05	76.40	0.85
73	1	3928	25' L	40	6.69	6.58	6.31	5.67	5.01	4.31	3.91	76.00	0.94
75	1	4028	25' L	40	8.26	5.39	5.07	4.60	4.16	3.66	3.30	75.20	0.61
76	1	4114	25' L	40	5.47	5.42	4.96	4.80	4.31	3.90	3.79	74.70	0.91
77	1	4129	25' L	40	10.75	4.60	4.42	4.08	3.56	3.06	2.80	74.20	0.41
83	2	76	Center	40	6.12	6.82	5.71	5.24	4.75	4.05	3.89	70.40	0.93
85	2	177	Center	40	38.33	4.65	4.49	4.00	3.67	3.15	2.85	71.40	0.12

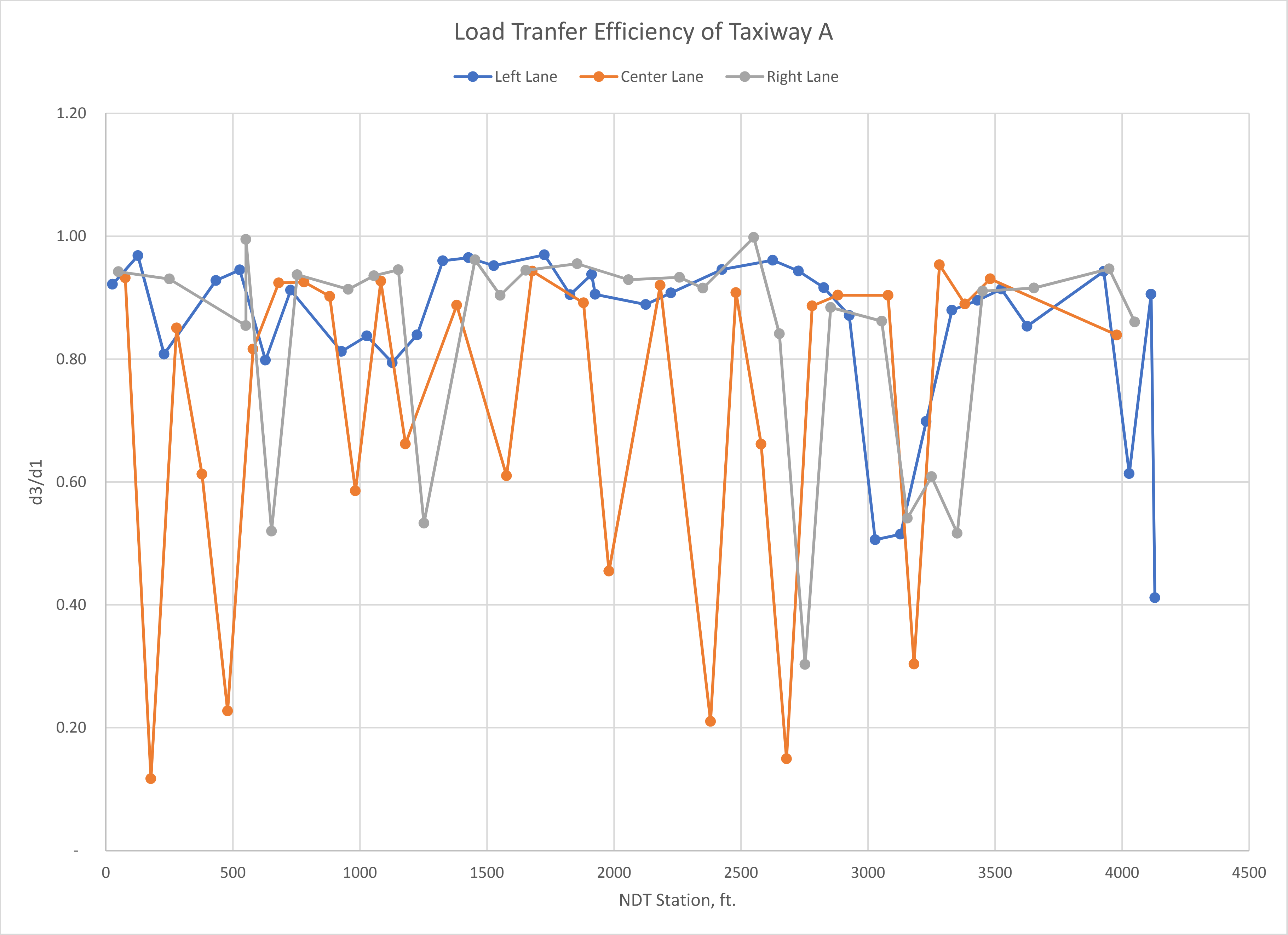
Memphis International Airport

Taxiway A West

NDT Field Data

NDT	Lane	NDT Station		Force	Displacement Sensors (mils)							Pvmnt	ISM
No.	No.	Distance	Offset	(kip)	d1 (0)	d2 (8")	d3 (12")	d4 (24")	d5 (36")	d6 (48")	d7 (60")	Temp (F)	(kip/in)
0+00 at edge of Taxiway N													
87	2	278	Center	40	4.80	4.27	4.09	3.83	3.32	2.96	2.71	75.30	0.85
89	2	378	Center	40	5.38	3.50	3.30	3.24	2.92	2.54	2.41	75.90	0.61
91	2	479	Center	40	15.21	3.68	3.46	3.26	2.91	2.62	2.41	74.00	0.23
93	2	579	Center	40	4.86	4.24	3.97	3.92	3.47	2.95	2.73	78.60	0.82
95	2	680	Center	40	4.20	4.04	3.88	3.86	3.02	2.68	2.45	77.00	0.92
97	2	780	Center	40	4.13	4.21	3.82	3.77	3.14	2.79	2.77	75.40	0.93
99	2	881	Center	40	4.59	4.29	4.14	3.79	3.53	3.10	2.85	77.60	0.90
101	2	982	Center	40	6.93	4.17	4.06	3.74	3.41	2.96	2.75	79.40	0.59
103	2	1082	Center	40	4.94	4.86	4.58	4.36	3.84	3.43	3.15	77.40	0.93
105	2	1179	Center	40	6.35	4.47	4.20	3.89	3.47	3.13	2.81	75.40	0.66
108	2	1381	Center	40	4.86	4.52	4.31	4.11	3.59	3.18	2.94	78.10	0.89
111	2	1577	Center	40	6.79	4.47	4.14	3.85	3.49	3.11	3.03	78.40	0.61
113	2	1678	Center	40	4.73	4.65	4.47	4.42	3.67	3.23	2.95	75.70	0.94
116	2	1880	Center	40	4.53	4.28	4.04	4.20	3.38	3.03	2.80	76.40	0.89
118	2	1980	Center	40	7.77	3.81	3.53	3.48	3.10	2.82	2.82	81.50	0.45
121	2	2182	Center	40	5.20	5.01	4.79	4.37	3.86	3.42	3.17	77.10	0.92
124	2	2380	Center	40	22.31	4.97	4.69	4.40	3.94	3.58	3.32	80.00	0.21
126	2	2480	Center	40	6.07	5.84	5.52	4.97	4.45	3.83	3.46	80.30	0.91
128	2	2579	Center	40	6.34	4.37	4.19	3.83	3.40	3.05	2.73	75.80	0.66
130	2	2679	Center	40	24.46	3.84	3.65	3.41	3.06	2.58	2.39	77.10	0.15
132	2	2780	Center	40	3.60	3.37	3.19	2.98	2.53	2.28	2.03	78.90	0.89
134	2	2881	Center	40	5.22	4.97	4.71	4.35	3.57	3.06	2.62	78.00	0.90
137	2	3079	Center	40	4.16	4.08	3.76	3.45	2.99	2.49	2.28	79.80	0.90
139	2	3181	Center	40	13.40	4.15	4.07	3.72	3.27	2.88	2.58	79.00	0.30
141	2	3281	Center	40	5.51	5.42	5.25	4.50	4.06	3.45	3.12	78.70	0.95
143	2	3381	Center	40	5.49	5.23	4.89	4.45	3.86	3.35	3.04	78.20	0.89
145	2	3481	Center	40	4.64	4.47	4.31	4.00	3.40	3.02	2.63	79.50	0.93
151	2	3979	Center	40	5.94	5.17	4.99	4.49	4.00	3.59	3.25	77.80	0.84
159	3	49	25' R	40	5.57	5.45	5.25	4.70	4.22	3.74	3.38	73.70	0.94
162	3	250	25' R	40	5.05	4.97	4.70	4.25	3.69	3.25	2.88	80.60	0.93
166	3	551	25' R	40	4.36	4.19	3.73	3.33	3.26	2.92	2.68	78.20	0.85
166	3	551	25' R	40	3.88	3.88	3.86	3.68	3.13	2.83	2.60	78.20	0.99
168	3	652	25' R	40	7.83	4.28	4.07	3.93	3.44	3.04	2.81	83.00	0.52
170	3	753	25' R	40	3.79	3.75	3.56	3.52	2.92	2.64	2.42	79.50	0.94
173	3	954	25' R	40	6.21	5.89	5.67	5.23	4.75	4.32	3.93	85.70	0.91
175	3	1055	25' R	40	5.72	5.71	5.35	4.97	4.37	3.84	3.48	83.60	0.94
177	3	1151	25' R	40	4.57	4.55	4.32	4.00	3.53	3.19	2.91	83.20	0.95
179	3	1252	25' R	40	8.22	4.69	4.38	4.07	3.55	3.13	2.86	84.40	0.53
182	3	1453	25' R	40	4.36	4.21	4.20	3.88	3.45	3.06	2.86	83.70	0.96
184	3	1552	25' R	40	4.67	4.49	4.22	3.91	3.47	3.05	2.83	82.60	0.90
186	3	1653	25' R	40	4.40	4.38	4.16	3.95	3.52	3.18	2.90	83.30	0.94
189	3	1855	25' R	40	5.55	5.55	5.30	4.93	4.16	3.81	3.47	83.20	0.96
193	3	2057	25' R	40	5.06	5.02	4.70	4.22	3.66	3.19	2.87	84.20	0.93
196	3	2258	25' R	40	5.86	5.78	5.47	4.98	4.42	3.91	3.49	83.50	0.93
198	3	2350	25' R	40	5.63	5.41	5.15	4.68	4.20	3.78	3.42	82.40	0.92
201	3	2550	25' R	40	5.25	5.24	5.24	4.97	4.07	3.59	3.25	83.20	1.00
203	3	2651	25' R	40	6.18	5.40	5.20	4.65	3.97	3.46	3.10	80.30	0.84
205	3	2752	25' R	40	15.10	4.86	4.57	4.21	3.61	3.04	2.71	84.20	0.30
207	3	2853	25' R	40	4.45	4.17	3.94	3.72	3.05	2.57	2.25	83.00	0.88
210	3	3054	25' R	40	5.73	5.32	4.94	5.06	3.87	3.26	2.91	80.10	0.86
212	3	3155	25' R	40	8.45	4.73	4.57	4.49	3.79	3.22	2.86	83.40	0.54
214	3	3250	25' R	40	7.04	4.33	4.28	4.11	3.20	2.74	2.47	83.20	0.61
216	3	3351	25' R	40	7.39	3.95	3.82	3.48	3.11	2.77	2.48	80.70	0.52
218	3	3451	25' R	40	5.08	4.94	4.62	4.58	3.79	3.17	2.91	83.80	0.91
221	3	3653	25' R	40	6.05	5.90	5.54	5.02	4.34	3.80	3.38	80.80	0.92
225	3	3949	25' R	40	5.57	5.45	5.28	4.79	4.30	3.88	3.55	84.70	0.95
227	3	4050	25' R	40	6.11	5.37	5.26	4.83	4.32	3.85	3.49	78.80	0.86


ISM Plot for Taxiway A
Left Lane
Center Lane
Right Lane
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
0
500
1000
1500
2000
2500
3000
3500
4000
4500
NDT Station, ft.
ISM, kip/in.


Load Tranfer Efficiency of Taxiway A
Left Lane
Center Lane
Right Lane
1.20
1.00
0.80
0.60
0.40
0.20
-
d3/d1
0
500
1000
1500
2000
2500
3000
3500
4000
4500
NDT Station, ft.

Memphis International Airport

Portion of Other Taxiways Within Project Limits

NDT Field Data

NDT	Lane	Force	Displacement Sensors (mils)							Pvmnt	ISM
No.	No.	(kip)	d1 (0)	d2 (8")	d3 (12")	d4 (24")	d5 (36")	d6 (48")	d7 (60")	Temp (F)	(kip/in)
Taxiway N, interface slabs with Taxiway A											
1	1	40	6.70	4.95	4.74	4.54	4.19	3.74	3.36	80.50	5,967
2	1	40	3.50	3.75	3.61	3.56	3.19	2.95	2.75	82.50	11,439
4	1	40	3.67	3.56	3.38	3.28	2.97	2.74	2.57	81.70	10,886
5	1	40	5.82	3.60	3.45	3.40	3.12	2.81	2.61	83.90	6,868
7	1	40	6.02	4.80	4.67	4.50	4.16	3.81	3.55	85.10	6,643
8	1	40	2.81	2.81	2.35	2.28	2.10	1.83	1.82	84.90	14,243
Joint Tests											**d3/d1**
3	1	40	4.93	4.65	4.48	4.09	3.69	3.36	3.08	82.10	0.91
9	1	40	2.71	2.62	2.60	2.46	2.10	1.86	1.74	86.40	0.96
Connecting Taxiway to GA Apron, AC Surfaced Pavement											
1	1	40	11.11	6.23	5.38	4.84	4.34	3.91	3.54	81.40	3,602
2	1	40	6.95	6.37	5.95	5.45	4.87	4.32	3.88	84.20	5,755
3	1	40	6.50	5.97	5.61	5.27	4.76	4.27	3.90	85.80	6,151
4	1	40	12.54	9.77	8.94	8.14	7.07	6.15	5.29	84.50	3,190
10	2	40	9.00	7.09	6.40	6.16	5.34	4.69	4.18	85.50	4,445
9	2	40	8.33	8.02	7.22	6.77	5.86	5.19	4.55	85.30	4,799
8	2	40	11.91	7.64	7.11	6.90	5.85	5.13	4.60	85.60	3,359
7	2	40	10.34	10.23	9.55	8.71	7.56	6.50	5.58	85.90	3,868
5	1	40	9.59	6.41	5.65	5.21	4.67	4.04	3.63	86.20	4,173
TW C, South of TW A, new slabs											
1	1	40	3.49	4.79	4.56	4.46	4.11	3.71	3.43	78.30	11,458
3	1	40	4.50	4.30	4.27	4.07	3.59	3.18	2.94	83.50	8,895
4	1	40	5.22	5.13	4.99	5.32	4.59	4.09	3.77	82.90	7,664
6	1	40	3.62	3.33	3.20	3.08	2.92	2.71	2.61	81.50	11,057
7	1	40	4.10	3.80	3.61	3.84	3.15	2.80	2.67	82.70	9,752
9	1	40	4.57	3.99	3.78	3.76	3.36	3.01	2.82	83.40	8,745
14	2	40	4.70	4.62	4.38	4.31	3.89	3.46	3.23	79.10	8,503
15	2	40	3.18	3.04	3.00	2.84	2.64	2.45	2.29	83.10	12,583
16	2	40	16.34	3.15	3.04	2.92	2.82	2.42	2.26	79.00	2,448
18	2	40	5.20	4.65	4.52	4.40	3.97	3.55	3.23	84.10	7,699
TW C, North of TW A. old slabs											
10	1	40	4.11	4.08	3.91	3.86	3.62	3.21	2.82	85.30	9,734
12	1	40	5.51	5.41	5.19	5.11	4.66	4.29	3.99	84.20	7,256
20	2	40	25.67	3.85	3.59	3.49	3.19	2.89	2.68	83.90	1,558
21	2	40	3.60	3.68	3.61	3.41	3.16	2.89	2.72	81.70	11,111
22	2	40	6.07	4.28	4.22	4.01	3.62	3.32	3.04	84.90	6,589
24	2	40	5.03	3.70	3.44	3.66	2.86	2.52	2.23	81.80	7,959
Joint Tests											**d3/d1**
2	1	40	4.55	4.50	4.27	3.93	3.59	3.27	3.01	81.40	0.94
5	1	40	4.62	4.52	4.14	3.80	3.35	2.95	2.68	81.30	0.90
8	1	40	4.77	4.75	4.55	4.29	3.71	3.30	2.99	83.70	0.95
11	1	40	19.78	4.32	4.07	3.81	3.45	3.11	2.85	84.60	0.21
13	1	40	9.36	5.78	5.33	4.74	4.19	3.70	3.23	83.10	0.57
17	2	40	4.35	4.23	4.09	3.66	3.27	2.94	2.64	81.50	0.94
19	2	40	8.26	4.59	4.41	4.07	3.63	3.23	2.93	84.40	0.53
23	2	40	7.39	4.92	4.63	4.26	3.83	3.45	3.12	83.30	0.63

Memphis International Airport

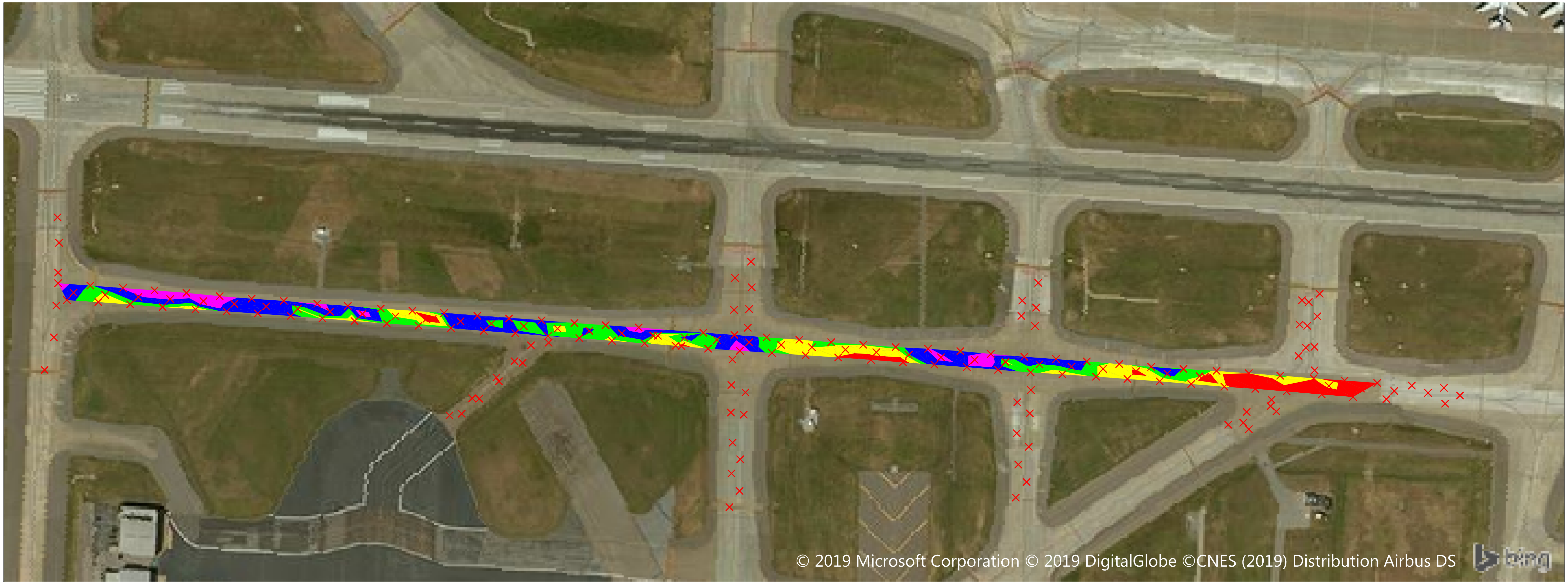
Portion of Other Taxiways Within Project Limits

NDT Field Data

NDT	Lane	Force	Displacement Sensors (mils)							Pvmnt	ISM
No.	**No.**	**(kip)**	**d1 (0)**	**d2 (8")**	**d3 (12")**	**d4 (24")**	**d5 (36")**	**d6 (48")**	**d7 (60")**	**Temp (F)**	**(kip/in)**
TW S, South of TW A											
1	1	40	11.31	3.23	3.13	2.99	2.74	2.49	2.29	80.00	3,536
2	1	40	3.88	3.69	3.49	3.36	3.11	2.76	2.52	81.10	10,320
3	1	40	5.44	3.61	3.61	3.58	3.13	2.77	2.34	80.30	7,353
5	1	40	3.96	3.29	2.94	2.69	2.44	2.09	1.95	80.80	10,101
9	2	40	4.42	4.37	4.26	4.04	3.80	3.40	3.10	81.10	9,055
10	2	40	38.34	3.75	3.60	3.25	2.92	2.53	2.24	81.10	1,043
12	2	40	5.04	4.98	4.94	4.68	3.97	3.49	3.10	80.40	7,935
13	2	40	2.92	2.91	2.77	2.63	2.45	2.24	2.09	79.00	13,700
TW S, North of TW A											
6	1	40	4.89	4.89	4.68	4.37	3.84	3.21	1.73	80.10	8,175
7	1	40	3.14	3.08	2.96	2.81	2.58	2.22	2.05	82.10	12,735
15	2	40	4.43	3.15	2.86	2.83	2.33	2.06	1.88	80.30	9,037
16	2	40	4.90	4.80	4.57	4.38	3.98	3.40	3.06	76.50	8,158
18	2	40	3.50	3.35	3.03	2.91	2.59	2.24	2.03	79.90	11,443
Joint Tests											**d3/d1**
4	1	40	5.05	4.63	4.42	3.92	3.33	2.86	2.43	79.10	0.88
8	1	40	4.20	3.57	3.44	3.03	2.64	2.31	2.03	80.20	0.82
11	2	40	8.86	2.72	2.64	2.42	2.17	1.92	1.71	80.30	0.30
14	2	40	7.83	4.49	4.34	3.86	3.30	2.89	2.59	82.30	0.55
17	2	40	3.90	3.74	3.37	3.06	2.57	2.16	1.96	80.70	0.86
TW B, South of TW A, old slabs											
1	1	40	5.59	5.52	5.37	5.27	4.76	4.33	3.98	83.40	7,151
2	1	40	7.38	7.35	7.33	7.18	6.75	6.36	5.95	79.20	5,417
4	1	40	4.22	4.25	3.97	3.99	3.57	3.22	2.37	83.10	9,476
17	2	40	6.59	6.45	6.27	6.29	5.61	5.09	4.61	84.30	6,066
15	2	40	5.77	5.80	5.61	5.45	5.03	4.58	4.18	86.40	6,932
18	3	40	5.24	5.29	5.19	5.04	4.60	4.13	3.79	79.40	7,629
20	3	40	6.42	6.40	6.38	6.27	5.96	5.58	5.22	85.90	6,227
TW B, North of TW A, new slabs											
5	1	40	4.47	4.41	4.22	4.18	3.75	3.37	3.12	81.60	8,952
7	1	40	3.49	3.48	3.36	3.28	3.05	2.84	2.65	81.40	11,461
9	1	40	4.78	4.44	4.19	4.41	3.86	3.53	3.24	86.50	8,373
14	2	40	3.46	2.98	2.82	2.92	2.49	2.29	2.16	86.90	11,545
13	2	40	3.47	3.43	3.28	3.21	2.89	2.60	2.37	86.90	11,528
11	2	40	4.57	4.50	4.37	4.28	3.83	3.45	3.15	87.00	8,761
10	2	40	4.38	4.22	4.10	4.06	3.51	2.99	2.65	87.30	9,136
21	3	40	3.51	3.46	3.21	3.15	2.75	2.46	2.27	83.00	11,383
22	3	40	3.75	3.69	3.61	3.52	3.23	2.98	2.75	82.30	10,661
24	3	40	3.14	3.13	3.10	3.11	2.86	2.63	2.47	83.90	12,740
Joint Tests											**d3/d1**
3	1	40	5.43	5.43	5.21	4.70	4.16	3.70	3.29	82.10	0.96
6	1	40	3.30	2.92	2.86	2.77	2.43	2.19	2.07	83.70	0.87
8	1	40	10.30	2.89	2.89	2.64	2.45	2.27	2.11	81.40	0.28
12	2	40	4.26	3.54	3.32	3.13	2.83	2.56	2.37	85.90	0.78
16	2	40	6.28	5.75	5.48	5.06	4.61	4.10	3.70	84.80	0.87
19	3	40	5.00	4.84	4.65	4.35	3.74	3.42	3.08	83.30	0.93
23	3	40	4.86	3.84	3.58	3.41	3.09	2.77	2.54	83.60	0.74

APPENDIX C

OVERALL PAVEMENT STRENGTH EXHIBIT



Taxiway A ISM Ranges

🟥 4,014kips/in.<ISM<7,898kips/in.
🟨 7,898kips/in.<ISM<9,194kips/in.
🟩 9,194kips/in.<ISM<9,967kips/in.
🟦 9,967kips/in.<ISM<11,269kips/in.
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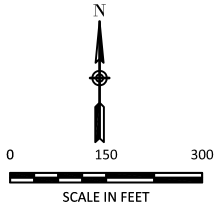
× NDT Location

Taxiway A Overall Pavement Strength



APPENDIX D

DESIGN OUTPUTS

FAARFIELD v 1.42 - Airport Pavement Design

Section PCC-1 in Job 1918-MEM.
Working directory is C:\Users\bxie\OneDrive\Documents\FAARFIELD\

The structure is New Rigid.
Design Life = 20 years.
A design for this section was completed on 05/22/20 at 15:36:28.

Pavement Structure Information by Layer, Top First

No.	Type	Thickness in	Modulus psi	Poisson's Ratio	Strength R,psi
1	PCC Surface	18.40	4,000,000	0.15	685
2	Variable St (flex)	4.00	150,000	0.35	0
3	P-304 CTB	8.00	500,000	0.20	0
4	P-301 SCB	12.00	250,000	0.20	0
5	Subgrade	0.00	10,438	0.40	0

Total thickness to the top of the subgrade = 42.40 in

Airplane Information

No.	Name	Gross Wt. lbs	Annual Departures	% Annual Growth
1	A300-600 LB	380,518	2,666	0.00
2	A310-200	315,041	174	0.00
3	B757-200	256,000	15,142	0.00
4	B767-300 ER Freighter	413,000	38,964	0.00
5	B777 Freighter (Preliminary)	768,800	7,784	0.00
6	DC10-10	458,000	1,941	0.00
7	MD11ER	633,000	2,156	0.00
8	MD11ER Belly	633,000	2,156	0.00

Additional Airplane Information

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	A300-600 LB	0.00	0.00	3.44
2	A310-200	0.00	0.00	3.69
3	B757-200	0.00	0.00	3.90
4	B767-300 ER Freighter	0.00	0.00	3.62
5	B777 Freighter (Preliminary)	1.00	1.00	3.89
6	DC10-10	0.00	0.00	3.81
7	MD11ER	0.00	0.00	3.68
8	MD11ER Belly	0.00	0.00	3.01

FAARFIELD v 1.42 - Airport Pavement Design

Section PCC-1 in Job 1918-MEM.
Working directory is C:\Users\bxie\OneDrive\Documents\FAARFIELD\

The structure is New Rigid.
Design Life = 20 years.
A design for this section was completed on 05/22/20 at 15:38:44.

Pavement Structure Information by Layer, Top First

No.	Type	Thickness in	Modulus psi	Poisson's Ratio	Strength R,psi
1	PCC Surface	17.90	4,000,000	0.15	685
2	Variable St (flex)	4.00	150,000	0.35	0
3	P-304 CTB	8.00	500,000	0.20	0
4	P-301 SCB	12.00	250,000	0.20	0
5	Subgrade	0.00	12,544	0.40	0

Total thickness to the top of the subgrade = 41.90 in

Airplane Information

No.	Name	Gross Wt. lbs	Annual Departures	% Annual Growth
1	A300-600 LB	380,518	2,666	0.00
2	A310-200	315,041	174	0.00
3	B757-200	256,000	15,142	0.00
4	B767-300 ER Freighter	413,000	38,964	0.00
5	B777 Freighter (Preliminary)	768,800	7,784	0.00
6	DC10-10	458,000	1,941	0.00
7	MD11ER	633,000	2,156	0.00
8	MD11ER Belly	633,000	2,156	0.00

Additional Airplane Information

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	A300-600 LB	0.00	0.00	3.44
2	A310-200	0.00	0.00	3.69
3	B757-200	0.00	0.00	3.90
4	B767-300 ER Freighter	0.00	0.00	3.62
5	B777 Freighter (Preliminary)	1.00	1.00	3.89
6	DC10-10	0.00	0.00	3.81
7	MD11ER	0.00	0.00	3.68
8	MD11ER Belly	0.00	0.00	3.01

FAARFIELD v 1.42 - Airport Pavement Design

Section PCC-1 in Job 1918-MEM.
Working directory is C:\Users\bxie\OneDrive\Documents\FAARFIELD\

The structure is New Rigid.
Design Life = 20 years.
A design for this section was completed on 05/22/20 at 12:21:18.

Pavement Structure Information by Layer, Top First

No.	Type	Thickness in	Modulus psi	Poisson's Ratio	Strength R,psi
1	PCC Surface	19.41	4,000,000	0.15	685
2	Variable St (flex)	4.00	150,000	0.35	0
3	P-304 CTB	8.00	500,000	0.20	0
4	User Defined	12.00	30,000	0.35	0
5	Subgrade	0.00	10,438	0.40	0

Total thickness to the top of the subgrade = 43.41 in

Airplane Information

No.	Name	Gross Wt. lbs	Annual Departures	% Annual Growth
1	A300-600 LB	380,518	2,666	0.00
2	A310-200	315,041	174	0.00
3	B757-200	256,000	15,142	0.00
4	B767-300 ER Freighter	413,000	38,964	0.00
5	B777 Freighter (Preliminary)	768,800	7,784	0.00
6	DC10-10	458,000	1,941	0.00
7	MD11ER	633,000	2,156	0.00
8	MD11ER Belly	633,000	2,156	0.00

Additional Airplane Information

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	A300-600 LB	0.00	0.00	3.44
2	A310-200	0.00	0.00	3.69
3	B757-200	0.00	0.00	3.90
4	B767-300 ER Freighter	0.00	0.00	3.62
5	B777 Freighter (Preliminary)	1.00	1.00	3.89
6	DC10-10	0.00	0.00	3.81
7	MD11ER	0.00	0.00	3.68
8	MD11ER Belly	0.00	0.00	3.01

FAARFIELD v 1.42 - Airport Pavement Design

Section PCC-1 in Job 1918-MEM.
Working directory is C:\Users\bxie\OneDrive\Documents\FAARFIELD\

The structure is New Rigid.
Design Life = 20 years.
A design for this section was completed on 05/22/20 at 13:29:53.

Pavement Structure Information by Layer, Top First

No.	Type	Thickness in	Modulus psi	Poisson's Ratio	Strength R,psi
1	PCC Surface	18.99	4,000,000	0.15	685
2	Variable St (flex)	4.00	150,000	0.35	0
3	P-304 CTB	8.00	500,000	0.20	0
4	User Defined	12.00	30,000	0.35	0
5	Subgrade	0.00	12,544	0.40	0

Total thickness to the top of the subgrade = 42.99 in

Airplane Information

No.	Name	Gross Wt. lbs	Annual Departures	% Annual Growth
1	A300-600 LB	380,518	2,666	0.00
2	A310-200	315,041	174	0.00
3	B757-200	256,000	15,142	0.00
4	B767-300 ER Freighter	413,000	38,964	0.00
5	B777 Freighter (Preliminary)	768,800	7,784	0.00
6	DC10-10	458,000	1,941	0.00
7	MD11ER	633,000	2,156	0.00
8	MD11ER Belly	633,000	2,156	0.00

Additional Airplane Information

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	A300-600 LB	0.00	0.00	3.44
2	A310-200	0.00	0.00	3.69
3	B757-200	0.00	0.00	3.90
4	B767-300 ER Freighter	0.00	0.00	3.62
5	B777 Freighter (Preliminary)	0.99	0.99	3.89
6	DC10-10	0.00	0.00	3.81
7	MD11ER	0.00	0.00	3.68
8	MD11ER Belly	0.00	0.00	3.01

FAARFIELD v 1.42 - Airport Pavement Design

Section PCC-1 in Job 1918-MEM.
Working directory is C:\Users\bxie\OneDrive\Documents\FAARFIELD\

The structure is New Rigid.
Design Life = 20 years.
A design for this section was completed on 05/22/20 at 13:42:23.

Pavement Structure Information by Layer, Top First

No.	Type	Thickness in	Modulus psi	Poisson's Ratio	Strength R,psi
1	PCC Surface	18.53	4,000,000	0.15	685
2	Variable St (flex)	4.00	150,000	0.35	0
3	P-304 CTB	8.00	500,000	0.20	0
4	Subgrade	0.00	18,148	0.40	0

Total thickness to the top of the subgrade = 30.53 in

Airplane Information

No.	Name	Gross Wt. lbs	Annual Departures	% Annual Growth
1	A300-600 LB	380,518	2,666	0.00
2	A310-200	315,041	174	0.00
3	B757-200	256,000	15,142	0.00
4	B767-300 ER Freighter	413,000	38,964	0.00
5	B777 Freighter (Preliminary)	768,800	7,784	0.00
6	DC10-10	458,000	1,941	0.00
7	MD11ER	633,000	2,156	0.00
8	MD11ER Belly	633,000	2,156	0.00

Additional Airplane Information

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	A300-600 LB	0.00	0.00	3.44
2	A310-200	0.00	0.00	3.69
3	B757-200	0.00	0.00	3.90
4	B767-300 ER Freighter	0.00	0.00	3.62
5	B777 Freighter (Preliminary)	1.00	1.00	3.89
6	DC10-10	0.00	0.00	3.81
7	MD11ER	0.00	0.00	3.68
8	MD11ER Belly	0.00	0.00	3.01

FAARFIELD v 1.42 - Airport Pavement Design

Section PCC-1 in Job 1918-MEM.
Working directory is C:\Users\bxie\OneDrive\Documents\FAARFIELD\

The structure is New Rigid.
Design Life = 20 years.
A design for this section was completed on 05/22/20 at 13:35:51.

Pavement Structure Information by Layer, Top First

No.	Type	Thickness in	Modulus psi	Poisson's Ratio	Strength R,psi
1	PCC Surface	19.06	4,000,000	0.15	685
2	User Defined	4.00	100,000	0.35	0
3	P-304 CTB	8.00	500,000	0.20	0
4	User Defined	12.00	30,000	0.35	0
5	Subgrade	0.00	12,544	0.40	0

Total thickness to the top of the subgrade = 43.06 in

Airplane Information

No.	Name	Gross Wt. lbs	Annual Departures	% Annual Growth
1	A300-600 LB	380,518	2,666	0.00
2	A310-200	315,041	174	0.00
3	B757-200	256,000	15,142	0.00
4	B767-300 ER Freighter	413,000	38,964	0.00
5	B777 Freighter (Preliminary)	768,800	7,784	0.00
6	DC10-10	458,000	1,941	0.00
7	MD11ER	633,000	2,156	0.00
8	MD11ER Belly	633,000	2,156	0.00

Additional Airplane Information

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	A300-600 LB	0.00	0.00	3.44
2	A310-200	0.00	0.00	3.69
3	B757-200	0.00	0.00	3.90
4	B767-300 ER Freighter	0.00	0.00	3.62
5	B777 Freighter (Preliminary)	1.00	1.00	3.89
6	DC10-10	0.00	0.00	3.81
7	MD11ER	0.00	0.00	3.68
8	MD11ER Belly	0.00	0.00	3.01

FAARFIELD v 1.42 - Airport Pavement Design

Section PCC-1 in Job 1918-MEM.
Working directory is C:\Users\bxie\OneDrive\Documents\FAARFIELD\

The structure is New Rigid.
Design Life = 20 years.
A design for this section was completed on 05/22/20 at 13:45:21.

Pavement Structure Information by Layer, Top First

No.	Type	Thickness in	Modulus psi	Poisson's Ratio	Strength R,psi
1	PCC Surface	18.60	4,000,000	0.15	685
2	User Defined	4.00	100,000	0.35	0
3	P-304 CTB	8.00	500,000	0.20	0
4	Subgrade	0.00	18,148	0.40	0

Total thickness to the top of the subgrade = 30.60 in

Airplane Information

No.	Name	Gross Wt. lbs	Annual Departures	% Annual Growth
1	A300-600 LB	380,518	2,666	0.00
2	A310-200	315,041	174	0.00
3	B757-200	256,000	15,142	0.00
4	B767-300 ER Freighter	413,000	38,964	0.00
5	B777 Freighter (Preliminary)	768,800	7,784	0.00
6	DC10-10	458,000	1,941	0.00
7	MD11ER	633,000	2,156	0.00
8	MD11ER Belly	633,000	2,156	0.00

Additional Airplane Information

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	A300-600 LB	0.00	0.00	3.44
2	A310-200	0.00	0.00	3.69
3	B757-200	0.00	0.00	3.90
4	B767-300 ER Freighter	0.00	0.00	3.62
5	B777 Freighter (Preliminary)	1.00	1.00	3.89
6	DC10-10	0.00	0.00	3.81
7	MD11ER	0.00	0.00	3.68
8	MD11ER Belly	0.00	0.00	3.01

FAARFIELD v 1.42 - Airport Pavement Design

Section PCC-1 in Job 1918-MEM.
Working directory is C:\Users\bxie\OneDrive\Documents\FAARFIELD\

The structure is New Rigid.
Design Life = 20 years.
A design for this section was completed on 06/08/20 at 13:19:26.

Pavement Structure Information by Layer, Top First

No.	Type	Thickness in	Modulus psi	Poisson's Ratio	Strength R,psi
1	PCC Surface	19.48	4,000,000	0.15	685
2	User Defined	4.00	100,000	0.35	0
3	P-304 CTB	8.00	500,000	0.20	0
4	User Defined	12.00	30,000	0.35	0
5	Subgrade	0.00	10,438	0.40	0

Total thickness to the top of the subgrade = 43.48 in

Airplane Information

No.	Name	Gross Wt. lbs	Annual Departures	% Annual Growth
1	A300-600 LB	380,518	2,666	0.00
2	A310-200	315,041	174	0.00
3	B757-200	256,000	15,142	0.00
4	B767-300 ER Freighter	413,000	38,964	0.00
5	B777 Freighter (Preliminary)	768,800	7,784	0.00
6	DC10-10	458,000	1,941	0.00
7	MD11ER	633,000	2,156	0.00
8	MD11ER Belly	633,000	2,156	0.00

Additional Airplane Information

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	A300-600 LB	0.00	0.00	3.44
2	A310-200	0.00	0.00	3.69
3	B757-200	0.00	0.00	3.90
4	B767-300 ER Freighter	0.00	0.00	3.62
5	B777 Freighter (Preliminary)	1.00	1.00	3.89
6	DC10-10	0.00	0.00	3.81
7	MD11ER	0.00	0.00	3.68
8	MD11ER Belly	0.00	0.00	3.01

FAARFIELD v 1.42 - Airport Pavement Design

Section Signature in Job 1918-MEM.
Working directory is C:\Users\bxie\OneDrive\Documents\FAARFIELD\

The aircraft list contains only one aircraft. Please see the introduction to the Help File for a discussion on using FAArfield to make single aircraft comparisons.
The structure is New Flexible. Asphalt CDF = 0.0809.
Design Life = 20 years.
A design for this section was completed on 06/08/20 at 16:59:21.

Pavement Structure Information by Layer, Top First

No.	Type	Thickness in	Modulus psi	Poisson's Ratio	Strength R,psi
1	P-401/ P-403 HMA Surface	4.00	200,000	0.35	0
2	P-401/ P-403 St (flex)	5.00	400,000	0.35	0
3	P-219 Recycled Conc. Agg.	5.95	46,006	0.35	0
4	Subgrade	0.00	18,000	0.35	0

Total thickness to the top of the subgrade = 14.95 in

Airplane Information

No.	Name	Gross Wt. lbs	Annual Departures	% Annual Growth
1	B757-300	273,500	1,200	0.00

Additional Airplane Information

Subgrade CDF

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	B757-300	1.00	1.00	1.73

HMA CDF

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	B757-300	0.00	0.00	1.46

P-401/P-403 St (flex) CDF

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	B757-300	0.08	0.08	1.11

FAARFIELD v 1.42 - Airport Pavement Design

Section Shoulder in Job 1918-MEM.
Working directory is C:\Users\bxie\OneDrive\Documents\FAARFIELD\

The section does not have a design life of 20 years. This constitutes a deviation from standards and requires FAA approval.
The aircraft list contains only one aircraft. Please see the introduction to the Help File for a discussion on using FAArfield to make single aircraft comparisons.
The structure is New Flexible. Asphalt CDF = 0.0001.
Design Life = 1 years.
A design for this section was completed on 06/08/20 at 16:54:47.

Pavement Structure Information by Layer, Top First

No.	Type	Thickness in	Modulus psi	Poisson's Ratio	Strength R,psi
1	P-401/ P-403 HMA Surface	4.00	200,000	0.35	0
2	P-219 Recycled Conc. Agg.	11.19	55,940	0.35	0
3	Subgrade	0.00	18,000	0.35	0

Total thickness to the top of the subgrade = 15.19 in

Airplane Information

No.	Name	Gross Wt. lbs	Annual Departures	% Annual Growth
1	B777 Freighter (Preliminary)	768,800	15	0.00

Additional Airplane Information

Subgrade CDF

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	B777 Freighter (Preliminary)	1.00	1.00	1.93

HMA CDF

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	B777 Freighter (Preliminary)	0.00	0.00	1.02

FAARFIELD v 1.42 - Airport Pavement Design

Section Shoulder in Job 1918-MEM.
Working directory is C:\Users\bxie\OneDrive\Documents\FAARFIELD\

The section does not have a design life of 20 years. This constitutes a deviation from standards and requires FAA approval.
The aircraft list contains only one aircraft. Please see the introduction to the Help File for a discussion on using FAArfield to make single aircraft comparisons.
The structure is New Flexible. Asphalt CDF = 0.0004.
Design Life = 1 years.
A design for this section was completed on 06/08/20 at 16:53:28.

Pavement Structure Information by Layer, Top First

No.	Type	Thickness in	Modulus psi	Poisson's Ratio	Strength R,psi
1	P-401/ P-403 HMA Surface	5.00	200,000	0.35	0
2	P-219 Recycled Conc. Agg.	9.81	53,866	0.35	0
3	Subgrade	0.00	18,000	0.35	0

Total thickness to the top of the subgrade = 14.81 in

Airplane Information

No.	Name	Gross Wt. lbs	Annual Departures	% Annual Growth
1	B777 Freighter (Preliminary)	768,800	15	0.00

Additional Airplane Information

Subgrade CDF

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	B777 Freighter (Preliminary)	1.00	1.00	1.96

HMA CDF

No.	Name	CDF Contribution	CDF Max for Airplane	P/C Ratio
1	B777 Freighter (Preliminary)	0.00	0.00	0.97

Appendix F

Estimate of Probable Construction Cost

Memphis International Airport

Memphis, TN

Taxiway A West Reconstruction

IFB Design Estimate

Report Date:

May 5, 2021

Prepared for:

Allen & Hoshall
1661 International Drive, STE 100
Memphis, TN 38120

CONNICO

CONNICO

2594 N. Mount Juliet Road
Mount Juliet, TN 37122

(615) 758-7474
www.connico.com

May 5, 2021

Tim Gibson, PE
Allen & Hoshall
1661 International Drive, STE 100
Memphis, TN 38120

RE: Taxiway A West Reconstruction
Memphis International Airport
Memphis, TN
IFB Design Estimate

Dear Mr. Gibson:

We are pleased to present the draft IFB Design Estimate for the referenced project. The Estimate has been drawn from the information noted in Exhibit A.

Included within the report are our Estimate Notes, which outline the criteria and allowances that were used to produce the estimate. Also included is our Variance Report between the 90% Design Estimate – July 29, 2020 and this IFB Estimate.

We appreciate the opportunity to work with you on this project. Should you have any questions or need additional information, please contact us at your convenience.

Sincerely,
CONNICO INCORPORATED

Charl J. Neser, MRICS, CCP
Director
cjneser@connico.com

Michael Feeney, EI
Project/Analyst II
mgfeeney@connico.com

CI File No. 4378.18

Table of Contents

INTRODUCTION

TASK OUTLINE

- Allen & Hoshall retained Connico Incorporated as cost consultants to provide an estimate of probable cost for the Taxiway A West Reconstruction project at Memphis International Airport in Memphis, TN. The estimate was based on plans, specifications, and other information, as noted in Exhibit A of this report.

- In providing estimates of probable construction cost, the Client understands that the Consultant has no control over the cost or availability of labor, equipment, or materials, or over market conditions or the Contractor's method of pricing, and that the Consultant's estimates of probable construction costs are made based on the Consultant's professional judgment and experience. The Consultant makes no warranty, express or implied, that the bids or the negotiated cost of the Work will not vary from the Consultant's estimate of probable construction cost.

- The Estimate of Probable Cost has been prepared based on information prepared/provided by others. Connico has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions that may be incorporated because of erroneous information provided by others.

PROJECT DESCRIPTION

The project includes the demolition and reconstruction of the western portion of Taxiway A, between Taxiway N and Taxiway Y. New pavement, drainage, lighting, signage, and electrical reconstruction are included within the scope of work. The project also includes modifications to an existing access road.

MARKET INFORMATION

- COVID-19 first started to impact the US economy in February 2020. Economic data suggest that the low point for the recession was in May 2020, and that recovery began in June 2020. As of 2Q 2021 viable COVID-19 vaccines have been developed and are becoming widely adopted. The US economy is slowly recovering but is not close to pre-COVID-19 levels. It is anticipated that this may not occur until 2022. However, if the COVID-19 pandemic resurges and continues to spread, the US economy would be severely impacted, with the possibility of local or regional shutdowns taking effect and the anticipated recovery to pre-COVID-19 levels delayed.

- The construction industry has been impacted by COVID-19 in multiple ways. The shortage of skilled construction labor that existed prior to the COVID-19 pandemic has been exacerbated by the pandemic. Funding for many construction projects has been suspended as State and Local Governments (and Airport Authorities) struggle to balance operational necessities against reduced income or tax revenue. Additionally, projects under construction during the pandemic have experienced significant supply chain disruptions and increases in basic construction material prices.

The culmination of all these factors has resulted in fewer bidding opportunities for contractors, leading to bid day pricing inconsistencies that are difficult to forecast.

- The commercial construction sector continues to lag behind the levels set in 2019, and the forecast for 2021 shows only limited growth over 2020 levels. It is hoped that Congress may pass an infrastructure bill in 2021 that would provide a significant boost to the construction industry.
- The estimate attempts to incorporate known impacts due to current market conditions, material pricing and labor impacts existing in the current market. However, the estimate cannot, and does not, reflect all potential economic impacts that may affect the construction market or the cost of the work. The impacts on material and labor availability have not been fully realized and the bidding and construction environment is in active flux as we continue to face uncertainty. Construction durations may be impacted by any of these conditions. We would recommend that the Owner carries a contingency fund in their project budget to address market volatility.

ESTIMATE NOTES

GENERAL

- Connico did not perform a limited site observation in preparing this estimate.

- Technical Specifications were not issued to Connico; therefore, it could not use it as reference to estimate this project. This can cause a lack of insight of design elements and details to certain pay items.

MARKUPS AND SOFT COSTS

General Contractor Markups

- An allowance for insurance is included in the unit costs of estimate. There are many variables that will impact the cost of insurance including, but not limited to, the contractor's performance history, project size, complexity, location and phasing. Additionally, insurance costs will change if the Owner selects an Owner or Contractor Controlled Insurance Policy.

- An allowance for payment and performance bonds is included in the unit costs of the estimate. There are many variables that will impact the cost of payment and performance bonds including, but not limited to, the contractor's performance history, project size, complexity, location and phasing.

- The estimate is costed on the understanding that there will be free and open competition at all levels of contracting, that there will not be a restricted bidders list either for general or trade contractors, that there will be a minimum three general contract bidders and at minimum three sub bids will be available for each trade involved. The Owner can facilitate these conditions by ensuring that the project is publicly advertised for bids in general circulation as well as trade publications where advertisements for bid are regularly posted, that prequalification requirements, if prequalification of either general or sub bidders is contemplated, are not unduly restrictive, and by maintaining good industry relations.

- The estimate does not include an Owner's construction contingency to be utilized for changes and / or additions to the scope of work during construction.

- The estimate does not include a project contingency.

- The estimate is based on second quarter 2021 dollars with no adjustment for escalation.

- The estimate is costed on the understanding that there will be a requirement to utilize "prevailing wages" on the project.

- The estimate excludes professional fees and testing and inspection fees. Also excluded are design/build fees, construction management fees, building permit and fees, overtime and after hours' work.

- The estimate does not include any allowance for fees normally attributed to the Owner such as Real Estate fees, Impact fees, Tap fees, etc.

- Sales tax is included at 9.25%.

- Allowances included in the estimate are amounts the Owner should expect to spend.

ESTIMATE DETAIL NOTES

- Mobilization is included at 5% of the project sum.

- Since the previous estimate, the cost of asphalt has become extremely volatile. Paving unit costs in this estimate are meant to reflect the potential of conservative costs being used by contractors.

- S-403 – Bituminous Surface Course (Service Road) line item includes the cost for the 8” base course required for the service road pavement section.

- D-701-5.3 – 12” Reinforced Concrete Pipe (Class V) was added to the project bid item list.

- D-752-5.3 – 12” Headwall was added to the project bid item list.

ESTIMATE QUANTITY NOTES

- Quantities shown on the provided construction document plant set were not used in preparing the estimate. The quantity list provided by Allen & Hoshall on 2021-04-08 was considered the most up-to-date quantities.

- In general, Connico performed a quantity check to ensure the accuracy of the quantities provided by Allen & Hoshall. If a discrepancy was determined, the higher quantity was selected to provide a more conservative estimate. Quantity changes and notes are listed below.

- P-152-4.6 – Pavement Excavation, Gravel Roadway: - quantity was updated to 920 sy.

- P-152-4.7 – Pavement Excavation, Full Depth Asphalt Roadway: - quantity was updated to 4,040 sy.

- P-152-4.9 – Pavement Excavation, Full Depth Asphalt Taxiway: - quantity was updated to 4,060 sy.

- C-102 – Silt Fence: - quantity was updated to 25,900 lf.

- P-620-5.3 – Taxiway Painting (Non-Reflective): - quantity was updated to 22,170 sf.

- P-620-5.7 – Runway Holding Position Marking: - quantity was updated to 290 lf.

- ✈ L-108-5.4 – No. 8 L-824C 5kV Temporary Jumper Cable, Including Counterpoise with Ground Rods & Connectors. Trench & Backfill, Conduit, Sawkerfs & Sealant, or Other Protection, Installed & Removed: - quantity was updated to 10,000 lf.

- ✈ L-125-5.10 – Furnish Materials and Construct Light Base Blockout, Complete: - quantity was updated to 12 ea.

- ✈ L-125-5.12 – Sign Base, Constructed-in-Place, Complete: - quantity was updated to 11 ea.

ESTIMATE SUMMARY

Project Title	Taxiway A West Reconstruction		
Location	Memphis International Airport		
Submittal Stage	IFB Design Estimate		
Client Name	Allen & Hoshall		
Client Project No.	18-1413-01	**Revision**	
Original Date	5/5/2021	**Revision Date**	
Assumed Bid Opening Date		**CI Project No.**	4378.18
Project Manager	MGF	**Checked by**	CJN

Taxiway A West Reconstruction

SUMMARY

DESCRIPTION		TOTAL
Opinion of Probable Construction Cost	$	22,529,773

The following markups are included in the project costs:

Estimating Design Evolution	0.0%

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VARIANCE REPORT (July 29, 2020 vs. May 5, 2021)

Project Title	Taxiway A West Reconstruction		
Location	Memphis International Airport		
Submittal Stage	IFB Design Estimate		
Client Name	Allen & Hoshall		
Client Project No.	18-1413-01	**Revision**	
Original Date	5/5/2021	**Revision Date**	
Assumed Bid		**CI Project No.**	4378.18
Project Manager	MGF	**Checked by**	CJN

COMPARISON OF 90% ESTIMATE DATED 07/29/2020 AND IFB ESTIMATE DATED 05/05/2021

VARIANCE SUMMARY

DESCRIPTION	90% ESTIMATE 2020-07-29	IFB ESTIMATE 2021-05-05	VARIANCE
Administration	$ 1,865,300.00	$ 1,382,300.00	$ (483,000)
Temporary Construction	$ 680,600.00	$ 852,800.00	$ 172,200
Demolition	$ 1,739,755.00	$ 1,790,960.00	$ 51,205
Earthwork and Grading	$ 725,000	$ 448,600.00	$ (276,400)
Temporary Erosion Control	$ 66,000	$ 161,000.00	$ 95,000
Storm and Underdrain	$ 1,062,510	$ 1,179,935.00	$ 117,425
Pavement	$ 12,590,771	$ 13,530,057.00	$ 939,286
Restoration	$ 220,000	$ 349,600.00	$ 129,600
Pavement Markings and Signage	$ 173,000	$ 116,382.50	$ (56,618)
Airfield Electrical	$ 2,244,750	$ 2,718,138.97	$ 473,389
Subtotal	***$ 21,367,686***	***$ 22,529,773***	***$ 1,162,087***
Estimating Design Evolution	$ 641,031	$ -	$ (641,031)
Opinion of Probable Construction Cost	***$ 22,008,717***	***$ 22,529,773***	***$ 521,057***

Project Title	Taxiway A West Reconstruction
Location	Memphis International Airport
Submittal Stage	IFB Design Estimate
Client Name	Allen & Hoshall
Client Project No.	18-1413-01
Original Date	5/5/2021
Assumed Bid Opening	
Project Manager	MGF
Revision	
Revision Date	
CI Project No.	4378.18
Checked by	CJN

COMPARISON OF 90% ESTIMATE DATED 07/29/2020 AND IFB ESTIMATE DATED 05/05/2021

VARIANCE DETAIL

DESCRIPTION	VARIANCE	NOTES REGARDING OBSERVED VARIANCE
Administration	$ (483,000)	Percentage based mobilization and insurance premium increases with increased total construction cost (+$111k); Demobilization line item removed from project (-$594k).
Temporary Construction	$ 172,200	Increased quantity of temporary construction items including: safety fence, guard houses, barricades, and gate arms (+$134k); Removal of reflective cone line item (-$3k); Traffic control increased to reflect increase in cost of work (+$41k).
Demolition	$ 51,205	Increased unit cost of drainage demolition items, manhole demo ($1,500/ea increase) and inlet demo ($800/ea increase) (+$9k); Updated electrical demolition scope (+$14k); Overall pavement demolition quantity increase (5,620 sy increase) (+$28k).
Earthwork and Grading	$ (276,400)	Total earthwork excavation quantity decreased (16,900 cy decrease) (-$276k).
Temporary Erosion Control	$ 95,000	Silt fence quantity increased (19,100 lf increase) (+$95k).
Storm and Underdrain	$ 117,425	Increased unit cost of RCP with updated quantities (+$68k); Decrease in unit cost of non-perforated underdrain ($3/lf decrease) (-$7k); Updated scope of storm drainage structures (+$26k); Added concrete apron line item (+$30k).
Pavement	$ 939,286	Aggregate base course scope has been updated (-$148k); HMA and PCC unit costs were updated to reflect recent volatile conditions shown in the market (+$1,182k); Reduced quantity and increased cost of prime and tack coat (-$94k).
Restoration	$ 129,600	Increase in restoration area (16,200 sy increase) (+$130k).
Pavement Markings and Signage	$ (56,618)	Pavement marking unit costs now based on individual work item quantities rather than lump sum values (-$57k).

COMPARISON OF 90% ESTIMATE DATED 07/29/2020 AND IFB ESTIMATE DATED 05/05/2021

VARIANCE DETAIL

DESCRIPTION	VARIANCE		NOTES REGARDING OBSERVED VARIANCE
Airfield Electrical	$	473,389	Cable, conduit, counterpoise, and duct bank quantity increase (25,339 lf increase) (+$429k); Electrical structure quantity increased (+$72); Updated scope and unit costs of light cans and light fixtures (+$28k); and reduced scope of taxiway signage (-$55k).
Subtotal	***$***	***1,162,087***	
Estimating Design Evolution	$	(641,031)	Design evolution reduced to 0% for last design development stage (-$641k).
Total Variance	***$***	***521,057***	

CONNICO

Taxiway A West Reconstruction
Memphis International Airport
May 5, 2021

ESTIMATE DETAIL

Project Title	Taxiway A West Reconstruction		
Location	Memphis International Airport		
Submittal Stage	IFB Design Estimate		
Client Name	Allen & Hoshall		
Client Project No.	18-1413-01	**Revision**	
Original Date	5/5/2021	**Revision Date**	
Assumed Bid Opening Date		**CI Project No.**	4378.18
Project Manager	MGF	**Checked by**	CJN

Taxiway A West Reconstruction

DETAIL

ITEM NO.	SPEC NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL
1000	C-150	Mobilization (5% of Total Sum)	1	ls	$1,072,900.00	$ 1,072,900
1001	S-100-3.1	Plastic Safety Fence	8,360	lf	$ 5.00	$ 41,800
1002	S-100-3.2	Guard House (Contractor Furnished)	3	ea	$ 35,000.00	$ 105,000
1003	S-100-3.3	Low Profile Barricade (Type 1) (Furnished)	163	ea	$ 200.00	$ 32,600
1004	S-100-3.6	Curing Facilities	1	ls	$ 50,000.00	$ 50,000
1005	S-100-3.7	Crossing Gate Arm (Contractor Furnished)	3	ea	$ 20,000.00	$ 60,000
1006	S-100-3.8	Traffic Control	1	ls	$ 523,400.00	$ 523,400
1007	SC-30-1	Soft-Dig Investigations During Construction (Contractor Furnished)	1	alw	$ 30,000.00	$ 30,000
1008	SC-30-2	Existing Access Road Repair	1	alw	$ 10,000.00	$ 10,000
1009	SC-30-3	Total Insurance Premium Cost (Form 2. Insurance Cost Identification Worksheet, Line E)	1	alw	$ 309,400.00	$ 309,400
1010	P-150-4.1	Demolition of Existing RCP Storm Drain Pipe	1,800	lf	$ 25.00	$ 45,000
1011	P-150-4.2	Demolition of Existing Headwall (All Sizes and Types)	1	ea	$ 500.00	$ 500
1012	P-150-4.3	Demolition of Manhole (All Sizes)	1	ea	$ 2,500.00	$ 2,500
1013	P-150-4.4	Demolition of Inlet (All Sizes and Types)	8	ea	$ 1,800.00	$ 14,400
1014	P-150-4.6	Miscellaneous Demolition	1	ls	$ 10,000.00	$ 10,000
1015	P-150-4.7	Remove Base Mounted Light Fixture	521	ea	$ 125.00	$ 65,125
1016	P-150-4.9	Demolition of Electrical Handhole	14	ea	$ 2,000.00	$ 28,000
1017	P-150-4.10	Demolition of Duct Bank	355	lf	$ 15.00	$ 5,325
1018	P-150-4.11	Demolition of Concrete Sign Base	11	ea	$ 1,000.00	$ 11,000
1019	P-150-4.12	Remove and Store Lighted Sign with Transformer	15	ea	$ 1,000.00	$ 15,000
1020	P-152-4.1	Unclassified Excavation	14,600	cy	$ 16.00	$ 233,600
1021	P-152-4.2	Undercut Excavation and Disposal	1,500	cy	$ 20.00	$ 30,000
1022	P-152-4.3	Unsuitable Material Excavation and Disposal	1,500	cy	$ 30.00	$ 45,000
1023	P-152-4.4	Borrow Excavation	5,000	cy	$ 28.00	$ 140,000
1024	P-152-4.5	Pavement Excavation, Mill Asphalt 1.5"	1,010	sy	$ 3.00	$ 3,030
1025	P-152-4.6	Pavement Excavation, Gravel Roadway	920	sy	$ 8.00	$ 7,360
1026	P-152-4.7	Pavement Excavation, Full Depth Asphalt Roadway	4,040	sy	$ 10.00	$ 40,400
1027	P-152-4.8	Pavement Excavation, Full Depth Asphalt Taxiway Shoulder	31,000	sy	$ 10.00	$ 310,000
1028	P-152-4.9	Pavement Excavation, Full Depth Asphalt Taxiway	4,060	sy	$ 12.00	$ 48,720
1029	P-152-4.10	Pavement Excavation, Full Depth Airfield Portland Cement Concrete Pavement	58,600	sy	$ 20.00	$ 1,172,000
1030	P-152-4.11	Recycled Concrete Backfill For Undercut and Unsuitable Material	4,500	sy	$ 12.50	$ 56,250

Taxiway A West Reconstruction

DETAIL

ITEM NO.	SPEC NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL
1031	P-152-4.12	Pavement Excavation, Mill Asphalt 1.5" for Haul Route Repair	4,200	sy	$ 3.00	$ 12,600
1032	C-102-	Silt Fence	25,900	lf	$ 5.00	$ 129,500
1033	C-102-	Catch Basin Sediment Trap	10	ea	$ 300.00	$ 3,000
1034	C-102-	Ditch Checks	10	ea	$ 750.00	$ 7,500
1035	C-102-	Inlet Protection	12	ea	$ 500.00	$ 6,000
1036	C-102-	Construction Entrances	2	ea	$ 7,500.00	$ 15,000
1037	P-220	Cement Treated Subgrade (12" Thick)	64,200	sy	$ 10.00	$ 642,000
1038	P-209	Aggregate Base Course	14,400	cy	$ 90.00	$ 1,296,000
1039	P-209	Aggregate Base Course (6" Thick)	3,440	sy	$ 15.00	$ 51,600
1040	P-304-6.1	Cement-Treated Aggregate Base Course (8" Thick)	61,500	sy	$ 35.00	$ 2,152,500
1041	P-401	Bituminous Surface Course (5" Thick)	3,010	sy	$ 33.00	$ 99,330
1042	P-401	Bituminous Surface Course (2.5" Thick)	34,980	sy	$ 16.00	$ 559,680
1043	P-401	Bituminous Base Course (4" Thick)	3,010	sy	$ 24.00	$ 72,240
1044	P-401	Bituminous Base Course (2.5" Thick)	34,980	sy	$ 14.25	$ 498,465
1045	P-401	Bituminous Surface Course Overlay (1.5" Thick)	1,010	sy	$ 11.00	$ 11,110
1046	P-401	Bituminous Surface Course Overlay (1.5" Thick) for Haul Route Repair	4,200	sy	$ 10.00	$ 42,000
1047	S-403	Bituminous Surface Course (Service Road)	1,406	sy	$ 22.00	$ 30,932
1048	P-402-6.1	Porous Bituminous Base Course (4" Thick)	62,000	sy	$ 35.00	$ 2,170,000
1049	P-501-8.1	Portland Cement Concrete Pavement (19" Thick)	57,900	sy	$ 100.00	$ 5,790,000
1050	P-602	Emulsified Asphalt Prime Coat @ .3 Gal/Sq	9,620	gal	$ 5.00	$ 48,100
1051	P-603	Emulsified Asphalt Tack Coat @ .05 Gal/Sq	1,970	gal	$ 5.00	$ 9,850
1052	P-620-5.1	Existing Paint Markings Removal	1,060	sf	$ 1.75	$ 1,855
1053	P-620-5.2	Taxiway Painting (Reflective)	19,750	sf	$ 2.25	$ 44,438
1054	P-620-5.3	Taxiway Painting (Non-Reflective)	22,170	sf	$ 2.00	$ 44,340
1055	P-620-5.4	Non-Movement Area Markings	90	lf	$ 5.25	$ 473
1056	P-620-5.5	Taxiway/Taxiway Intermediate Holding Pattern Marking	1,470	lf	$ 4.25	$ 6,248
1057	P-620-5.6	ILS Critical Area Hold Line	310	lf	$ 17.00	$ 5,270
1058	P-620-5.7	Runway Holding Position Marking	290	lf	$ 19.00	$ 5,510
1059	P-620-5.8	Geographic Position Marking	11	ea	$ 750.00	$ 8,250
1060	D-701-5.1	24" Reinforced Concrete Pipe (Class V)	303	lf	$ 140.00	$ 42,420
1061	D-701-5.2	36" Reinforced Concrete Pipe (Class V)	1,071	lf	$ 155.00	$ 166,005
1062	D-701-5.3	48" Reinforced Concrete Pipe (Class V)	557	lf	$ 200.00	$ 111,400
1063	D-701-5.3	12" Reinforced Concrete Pipe (Class V)	70	lf	$ 120.00	$ 8,400
1064	D-705-5.1	4" Perforated Underdrain Pipe	12,420	lf	$ 23.00	$ 285,660
1065	D-705-5.2	6" Perforated Underdrain Pipe	10,380	lf	$ 25.00	$ 259,500
1066	D-705-5.3	6" Non-Perforated Underdrain Outfall Pipe	2,200	lf	$ 25.00	$ 55,000
1067	D-705-5.4	Underdrain Cleanout	40	ea	$ 750.00	$ 30,000
1068	D-705-5.5	Underdrain Endwall	10	ea	$ 1,500.00	$ 15,000
1069	D-751-5.1	Type 2 Storm Drain Inlet	7	ea	$ 7,500.00	$ 52,500
1070	D-752-5.1	Safety Endwall For 36" RCP	1	ea	$ 5,000.00	$ 5,000
1071	D-752-5.2	9' Square Manhole	1	ea	$ 30,000.00	$ 30,000
1072	D-752-5.3	12" Headwall	4	ea	$ 1,200.00	$ 4,800
1073	D-754-5.1	Concrete Lined Swale	1,200	lf	$ 70.00	$ 84,000
1074	D-754-5.2	Concrete Apron Around Inlet	1,210	sf	$ 25.00	$ 30,250
1075	T-904-5.1	Sodding	43,700	sy	$ 5.00	$ 218,500

Taxiway A West Reconstruction

DETAIL

ITEM NO.	SPEC NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL
1076	T-905-5.1	Topsoiling (4" Thick)	43,700	sy	$ 3.00	$ 131,100
1077	L-108-5.1	No. 8 L-824C 5kV Cable Installed in Duct or Conduit	42,038	lf	$ 2.77	$ 116,445
1078	L-108-5.2	No. 6 Solid Cu Counterpoise, Installed with Ground Rods & Connectors	24,303	lf	$ 5.50	$ 133,667
1079	L-108-5.3	No. 6 Solid Cu Ground, Installed with Ground Rods & Connectors	2,330	lf	$ 5.50	$ 12,815
1080	L-108-5.4	No. 8 L-824C 5kV Temporary Jumper Cable, Including Counterpoise with Ground Rods & Connectors. Trench & Backfill, Conduit, Sawkerfs & Sealant, or Other Protection, Installed & Removed	10,000	lf	$ 10.00	$ 100,000
1081	L-110-5.1	1W-2" Sch. 40 PVC Conduit, Under New Rigid Pvmt, Including Trench & Backfill	14,117	lf	$ 25.58	$ 361,113
1082	L-110-5.2	1W-2" Sch. 40 PVC Conduit, Under New Flexible Pvmt, Including Trench & Backfill	10,186	lf	$ 23.35	$ 237,843
1083	L-110-5.3	1W-2" Sch. 40 PVC Conduit, Concrete Encased, Including Trench & Backfill	1,750	lf	$ 25.58	$ 44,765
1084	L-110-5.4	1W-2" Sch. 40 PVC DEB Drain Conduit, Including Trench & Backfill	300	lf	$ 12.58	$ 3,774
1085	L-110-5.5	Concrete Encased Electrical Duct Bank, 4W-	315	lf	$ 89.15	$ 28,082
1086	L-115-5.1	Aircraft Rated Pullbox	14	ea	$ 10,335.00	$ 144,690
1087	L-125-5.1	Furnish L-852C LED Bidirectional Taxiway Centerline Fixture & Transformer	93	ea	$ 1,318.00	$ 122,574
1088	L-125-5.2	Furnish L-852C LED Taxiway Clearance Bar Fixture & Transformer	33	ea	$ 1,242.00	$ 40,986
1089	L-125-5.3	Furnish L-852D LED Bidirectional Taxiway Centerline Fixture & Transformer	208	ea	$ 2,301.00	$ 478,608
1090	L-125-5.4	Furnish & Install L-852D LED Unidirectional Taxiway Centerline Fixture & Transformer	1	ea	$ 1,319.00	$ 1,319
1091	L-125-5.5	Furnish L-852F LED Omnidirectional Taxiway Centerline Fixture & Transformer	3	ea	$ 2,061.00	$ 6,183
1092	L-125-5.6	Furnish L-852T LED Taxiway Edge Fixture & Transformer	143	ea	$ 565.00	$ 80,795

Taxiway A West Reconstruction

DETAIL

ITEM NO.	SPEC NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL
1093	L-125-5.7	Install Fixture w/Transformer	481	ea	$ 435.00	$ 209,235
1094	L-125-5.8	Furnish & Install L-868B 3/4" Blank Cover on Existing Base	2	ea	$ 260.00	$ 520
1095	L-125-5.9-1	Furnish & Install 2-Piece L-868B w/Band Ring & Multihole Adapter in New Rigid Pvmt	299	ea	$ 1,250.00	$ 373,750
1096	L-125-5.9-2	Furnish & Install 2-Piece L-868B w/Band Ring & Multihole Adapter in New Flexible Pvmt	143	ea	$ 995.00	$ 142,285
1097	L-125-5.10	Furnish Materials and Construct Light Base Blockout, Complete	12	ea	$ 450.00	$ 5,400
1098	L-125-5.11	Furnish L-858 LED Sign, 1 Face, 3 Mod, w/Transformer	1	ea	$ 4,445.00	$ 4,445
1099	L-125-5.12	Sign Base, Constructed-in-Place, Complete	11	sf	$ 2,615.00	$ 28,765
1100	L-125-5.13	Install L-858 LED Sign on New or Existing Base, Complete	16	ea	$ 2,505.00	$ 40,080
Subtotal						***$ 22,529,773***
	0.0%	Estimating Design Evolution				$ -
Opinion of Probable Construction Cost						***$ 22,529,773***

EXHIBITS

Exhibit A
Document List

Exhibit A – Document List

✈ The estimate reflects the specifications and the drawings listed herein, as well as information received verbally from Allen & Hoshall.

Drawing No.	Description	Date
Copy of Summary of Quantities 2021-04-28		2021-04-30
MEM Taxiway Alpha 100% plans minus Electric		2021-04-21
MEM Electrical Sheets 100%		2021-05-03