REPORT

OF

SUBSURFACE EXPLORATION

FOR

MSE RETAINING WALLS

US 52 RAMP A AND RAMP B OVER OHIO RIVER ROAD AND US 52

PROJECT SCI-823-0.00 PORTSMOUTH BYPASS

SCIOTO COUNTY, OHIO

For:

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1.0 INTRODUCTION

This report includes the findings of the subsurface exploration and engineering evaluation for the embankment retaining walls along the proposed US 52 Ramp A and Ramp B. The walls are planned as part of the reconstruction project of existing US 52 and the construction of the proposed US 52 Ramp A and Ramp B Bridges over Ohio River Road and US 52 of the Portsmouth bypass project. Subsurface explorations were performed for the other features of the project but the results are presented in separate reports.

The purpose of this exploration was to 1) determine the subsurface conditions to the depths of the borings, 2) evaluate the engineering characteristics of the subsurface materials, and 3) provide information to assist in the design of the MSE walls. The exploration presented in this report was performed essentially in accordance with DLZ Ohio, Inc.'s (DLZ) proposal for the project.

The geotechnical engineer has planned and supervised the performance of the geotechnical engineering services, considered the findings, and prepared this report in accordance with generally accepted geotechnical engineering practices. No other warranties, either expressed or implied, are made as to the professional advice included in this report.

2.0 GENERAL PROJECT INFORMATION

It is understood that mechanically stabilized earth (MSE) retaining walls are planned along a portion of the embankments of the proposed US 52 Ramp A and Ramp B. According to the most recent site plans available and the cross-sections received from TranSystems on July 17 2007, the walls along the proposed Ramp A will begin approximately at Station 34+00 and end at Station 39+23.40, approximately the location of the rear abutment of the proposed Ramp A bridge over Ohio River Road. The length of the proposed wall is approximately 523 feet. The wall heights, as measured from the top of leveling pad to the top of coping, will range from 7.4 feet to 37.2 feet. MSE walls are planned along the west side of Ramp A approximately between Station 34+00 and Station 37+50 while back-to-back MSE walls are planned along the east and west sides of the ramp approximately between Station 37+50 and Station 39+23.40. The MSE walls along the proposed Ramp B will begin approximately at Station 29+50 and end at Station 35+51.55, approximately the location of the rear abutment of the proposed Ramp B bridge over Ohio River Road and existing US 52. The length of the proposed wall is approximately 602 feet. The wall heights, as measured from the top of leveling pad to the top of coping, will range from 20.3 feet to 34.8 feet. MSE walls are planned along the west side of Ramp B approximately between Station 29+50 and Station 32+50 while back-to-back MSE walls are planned along the east and west sides of the ramp approximately between Station 32+50 and Station 35+51.55. Please note that the above-mentioned stationing for the proposed Ramp A and Ramp B is referenced to their respective baseline unless noted otherwise. The Boring Location Plan and the Retaining Wall Plans are included in Appendix I.

MSE walls are not planned for the embankment sections between Station 25+00 and Station 34+00 of the proposed Ramp A and the embankment sections between Station 16+50 and Station 29+50 of the proposed Ramp B. Based on the site plans provided, these embankment sections will be constructed with side slopes of 2H:1V or flatter and the heights of the embankments will be less than the maximum height of the proposed MSE walls for their respective ramp. A review of the findings of the subsurface exploration in these embankment areas indicates that the stability conditions for the proposed embankment sections without MSE walls are less critical than those with MSE walls. As a result, detailed engineering evaluation was not performed on the proposed embankment sections without MSE walls. However, the existing foundation soils are considered adequately stable under the proposed embankment loads.

The analyses and recommendations presented in this report have been made on the basis of the foregoing information. If the proposed locations or structural concept are changed or differ from that assumed, DLZ should be informed of the changes so that recommendations and conclusions presented in this report may be revised as necessary.

3.0 FIELD EXPLORATION

The field exploration consisted of drilling a total of eleven structure borings for the proposed MSE walls. A total of five borings, Borings B-33, B-1501, B-1541, TR-75 and TR-76 were drilled along the wall alignment or near the wall for the proposed Ramp A. Borings TR-75 and TR-76 were drilled on March 30, 2005 and Boring B-1501 was drilled on December 28 and 29, 2005. Boring B-33 was drilled on February 1, 2007 and Boring B-1541 was drilled on May 29, 2007. The depths of these borings varied from 16.2 to 25.0 feet below the ground surface. Borings B-1520, TR-68A through TR-71A, and TR-73A were drilled along the wall alignment or near the wall for the proposed Ramp B. Boring B-1520 was drilled on January 16, 2006. Borings TR-68A through TR-71A and TR-73A were drilled between July 27 and August 15, 2006. These borings were drilled to depths between 23.9 and 27.5 feet. The boring logs for the wall borings are presented in Appendix II. Information concerning the drilling procedures is also presented in Appendix II.

The boring locations were planned and staked in the field by representatives of DLZ. The surveyed locations and ground surface elevations of the borings were determined by representatives of Lockwood, Lanier, Mathias & Noland, Inc. (2LMN). The surveyed locations of the borings are reflected on the structure site plan presented in Appendix I.

4.0 FINDINGS

4.1 Geology of the Site and General Observations

The area of this structure is characterized by gently to steeply sloping topography rising from of the floodplain of the Ohio River. The project area is located in the Shawnee-Mississippian Plateau of the unglaciated portion of the Appalachian Plateau Physiographic Region. The Shawnee-Mississippian Plateau is characterized by Devonian aged to Pennsylvanian aged rocks and contains residual, colluvial, alluvial, and lacustrine soils.

The genesis of the soils varies across the site. Soils in the floodplain consist primarily of alluvium and alluvial terraces, generally composed of silty clay, coarse sand, gravel, and cobbles. Below approximately elevation 700, the soils on the hillsides are generally lacustrine deposits. Lacustrine soils in this area are commonly known as "Minford Silts" or the Minford Complex. These deposits were formed during the early to middle Pleistocene age when the northward flowing Teays River system was blocked by the southward advance of the Kansan aged ice sheets. As the glaciers advanced, the course of the Teays River was blocked south of Chillicothe and a large lake was formed from the impoundment of the waterways. As a result of the impoundment, vast quantities of sediments were deposited ranging from 10 to 80 feet in thickness, thinning towards the margins. Bedrock within the structure area is primarily sandstone of the Logan Formation of Mississippian age. Bedrock of the Pennsylvanian Breathitt Formation can be found at the top of the slopes to typically above approximately elevation 770.

4.2 Subsurface Conditions

The following sections present the generalized subsurface conditions encountered by the borings. For more detailed information, refer to the boring logs presented in Appendix II. Laboratory test results are presented on the boring logs and also in Appendix III.

4.2.1 Soil Conditions

Generally, borings encountered 1 to 10 inches of topsoil at the ground surface except Borings B-1520 and B-1541. Boring B-1520 encountered 5 inches of asphalt concrete over 7 inches of aggregate base at the ground surface while Boring B-1541 encountered fill materials, consisting of silt (A-4b) and silt and clay (A-6a), between the ground surface and a depth of 8.5 feet.

Below the topsoil, asphalt pavement, aggregate base, or fill materials, the borings generally encountered natural cohesive soils interbedded with granular soils except Boring TR-75, where approximately 3.0 feet of fills, primarily consisting of silt and clay (A-6a), was encountered. Generally, the natural cohesive soils consisted of stiff to hard sandy silt (A-4a), stiff to very stiff silt (A-4b), stiff to hard silt and clay (A-6a), and very stiff to hard silty clay (A-6b) while the natural granular soils consisted of medium dense to very dense gravel with sand and silt (A-2-4) and medium dense coarse and fine sand (A-3a). Occasionally, medium dense sandy silt (A-4a) and loose to medium dense silt (A-4b) were also encountered. The native soil extended to depths ranging between 11.0 and 15.0 feet below the ground surface, where bedrock was encountered.

4.2.2 Bedrock Conditions

Bedrock was encountered in all borings and confirmed by coring in all borings except Boring B-1541. Severely weathered, argillaceous sandstone was generally encountered in all borings above the competent sandstone. The bedrock generally consisted of soft to hard, slightly to highly weathered, argillaceous sandstone. The amount of rock recovered in each core run varied between 85 and 100 percent. The rock quality designation (RQD) of the bedrock ranged between 0 and 100 percent with an average of 57 percent, indicating fair rock quality.

4.2.3 Groundwater Conditions

Seepage was encountered in all of the borings drilled for the MSE walls for the proposed Ramp B and was first observed at depths between 7.3 feet (Elevation 537.5) and 13.8 feet (Elevation 524.3). Seepage was not encountered in any of the borings drilled for the MSE walls for the proposed Ramp A. No measurable water levels were observed in any of the borings prior to rock coring. Final water levels, which include water that was used during rock coring operations, varied between 1.6 feet (Elevation 543.2) and 18.0 feet (Elevation 535.0) in depth.

It should be noted that groundwater levels may fluctuate with seasonal variations and following periods of heavy or prolonged precipitation, and therefore, the readings indicated on the boring logs may not be representative of the long-term groundwater level. Long-term monitoring would be needed to obtain a more accurate estimate of the groundwater table elevation.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 MSE Retaining Walls – General Infomration

It is understood that the embankment retaining walls will include MSE retaining walls. An MSE retaining wall essentially consists of good quality backfill material with layers of metal or plastic reinforcing that are attached to concrete facing panels. The MSE wall and associated backfill should be constructed in accordance with the specifications of the manufacturer of the MSE wall.

A global stability analysis, bearing capacity analysis and settlement analysis were performed for the MSE retaining walls, in accordance with ODOT and AASHTO guidelines. The MSE wall was also analyzed for sliding and overturning. The calculations are presented in Appendix IV. Other internal stability analyses (i.e. strap design) are required for the design of an MSE wall, but are considered outside the scope of this report. The parameters required to perform the stability analyses are presented in Table 1.

In accordance with ODOT guidelines, a unit weight of 120 pounds per cubic foot (pcf) and a friction angle of 34 degrees were selected for the backfill material in the reinforced zone. Similarly, the fill material used to construct the roadway embankments is assumed to have a unit weight of 120 pcf and a friction angle of 30 degrees. If the embankment fill material or backfill material for the reinforcing zone has properties significantly different from these values, DLZ should be informed so that the analyses may be revised as necessary.

Table 1 - Soil Parameters Used in Stability Analysis

Zone	Soil Type	Unit Weight (pcf)	Strength Parameters			
			Undrained		Drained	
			c	Φ	c'	Φ'
Reinforced Fill	Compacted Granular Fill	120	0	34	0	34
Retained Soil	Compacted Embankment Fill	120	0	30	0	30
Foundation Soil*	Stiff to hard silt, sandy silt, silty clay or silt and clay	120 to 125	1250 to 3000	0	0	28 to 29

*Refer to subsequent sections for parameters of foundation soil used in the stability analyses.

5.2 Embankment Retaining Wall (Ramp A)

According to the most recent site plans available and the cross-section received from TranSystems on July 17, 2007, the walls along the proposed Ramp A will begin approximately at Station 34+00 and end at Station 39+23.40. The length of the proposed wall is approximately 523 feet. The wall heights, as measured from the top of leveling pad to the top of coping, will range from 7.4 feet to 37.2 feet. MSE walls are planned along the west side of Ramp A between Station 34+00 and Station 37+50 while back-to-back MSE walls are planned along the east and west sides of the ramp between Station 37+50 and Station 39+23.40. The proposed roadway width is approximately 33.3 feet.

The existing foundation soils along the proposed wall alignment primarily consisted of stiff to very stiff silt and clay (A-6a) or very stiff to hard sandy silt (A-6b) underlain by sandy silt (A-4a), silt (A-4b), coarse and fine sand (A-3a) or gravel with sand and silt (A-2-4). Different wall sections were selected for stability analyses based on the wall height, wall configuration (single wall versus back-to-back walls), and the subsurface conditions. Generally, the most critical soil profile near the selected wall section was chosen for the analyses. Table 2 below summarizes the details of the selected wall sections and the parameters selected for the foundation soils.

Table 2 - Details of Selected Wall Sections and Parameters of Foundation Soils Used for Analyses (Ramp A)

Station	Wall Height, (H+D), ft*	Wall Configuration	Boring/Uppermost Layer of Foundation Soil	Unit Weight (pcf)	Strength Parameters			
					Undrained		Drained	
					c	Φ	c'	Φ'
34+00	7.4	Single	B-1541/A-6a	120	1250	0	28	0
34+50	17.4	Single	B-1541/A-6a	120	1250	0	28	0
37+00**	30.9	Single	TR-75/A-6a	120	1250	0	28	0
37+50	33.3	Back-to-Back	TR-75/A-6a	120	1250	0	28	0
38+00**	37.2	Back-to-Back	TR-75/A-6a	120	1250	0	28	0
38+50	31.8	Back-to-Back	B-33/A-4a	120	1750	0	29	0

*Wall heights are measured from the top of leveling pad to the top of coping. For back-to-back walls, the greatest wall height of the wall section is listed.
**Wall sections were selected for global stability analysis.

The minimum reinforcing length associated with the greatest wall height of each of these wall sections was determined based on the minimum acceptable factor of safety of 1.5 for the sliding resistance, 2.0 for the overturning resistance and 2.5 for the bearing capacity. Two wall sections, one with a single wall configuration and the other with back-to-back walls, were selected for global stability analysis. Using the maximum wall height for each of the wall configurations and the calculated minimum required reinforcing length, the global stability analyses were performed for undrained, drained, and seismic conditions. The seismic analysis was performed using a horizontal acceleration of 0.06, in accordance with ODOT guidelines.

Initially, analyses were performed based on the MSE walls bearing on the existing soils. The results of the analyses indicated that the factors of safety for global stability, sliding and overturning were adequate. However, bearing capacity calculations indicated that the factors of safety for the undrained bearing capacity for wall sections between Station 34+50 and Station 38+50 were between 1.2 to 2.3 and that the factors of safety for the drained bearing capacity for wall sections between Station 34+50 and Station 37+50 were between 1.9 and 2.1. These factors of safety are less than the recommended minimum value of 2.5 for both undrained and drained conditions.

Additional analyses indicated that an adequate factor of safety can be achieved if some of the existing foundation soils are removed and replaced with compacted granular fill in areas between Station 38+50 and Station 34+00. It is recommended that the existing foundations soils be overexcavated to an approximate depth of 4.5 feet below the bottom of the proposed leveling pad, or a minimum of 8 feet below the existing ground surface, which corresponds to an approximate elevation of 550.4 (based on Boring B-33) or an approximate elevation of 545.0 (based on Boring TR-75). The compacted granular fill below the leveling pad should conform to ODOT Supplemental Specification 840. The limits of the "remove and replace" area should extend beyond the edge of the MSE wall/select granular footprint by a distance equal to the depth of the aggregate base. For the back-to-back walls section with one wall height significantly different from the other, special benching within the back-to-back walls section may be used for the overexcavation. Each bench should be a minimum of 10 feet wide and the back slope of each bench should be cut at a typical 1H:1V slope. A schematic showing the use of the special benching within a back-to-back walls section is included in Appendix IV.

For sliding stability, calculations indicated that a minimum reinforcement length of 0.7 times the full wall height (H+D) is required. Given the proposed full wall heights between 7.4 and 37.2 feet, the minimum reinforcement length will vary approximately from 5.2 to 26.0 feet. However, a minimum reinforcement length of 8 feet should be used. The sliding resistance and the overturning resistance were both acceptable with these minimum reinforcement lengths. These lengths are a minimum for external stability and may be increased, if necessary, for internal stability. Note that these lengths are based on the assumption that discontinuous reinforcing will be used in the MSE fill. If the selected wall system uses continuous reinforcing, i.e., sheets or grids, the minimum reinforcing length may need to be increased.

The global stability analyses based on the parameters of the existing foundations soils resulted in critical factors of safety greater than the minimum factors of safety of 1.3 for both drained and undrained conditions and 1.1 for the seismic condition. Results of the bearing capacity, sliding, overturning and global stability analyses are presented in Appendix IV.

Settlement was calculated using the computer program EMBANK, using the "end of fill" option to model the non-continuous embankment loading. The total maximum settlement (without overexcavation) at the face of the proposed MSE wall was estimated to be approximately 2.7 inches and the maximum settlement (without overexcavation) at the centerline of the ramp was approximately 4.4 inches. MSE retaining walls are able to withstand relatively large amounts of differential settlement, typically up to 100 millimeters per 10 meters of wall length (1.0 percent). Differential settlements at the face of the MSE wall and at the centerline of the ramp were estimated to be approximately 0.04 and 0.05 percent, respectively. These percentages are less than the typically cited maximum value of 1.0 percent. The settlement calculations assumed no overexcavation within the MSE wall footprint area. Note that overexcavation is recommended to increase the bearing capacity of the MSE foundation soils. If the recommended overexcavation is performed, the settlements at the face of the proposed MSE wall and at the centerline of the ramp will be less than the estimated values.

Table 3 summaries the MSE retaining wall parameters and results of analyses for the MSE walls for Ramp A.

Table 3 - MSE Retaining Wall Parameters and Analyses Results (Ramp A)

Retained Soil (New Embankment) Unit Weight = 120 pcf Coefficient of Active Earth Pressure (K_a) = 0.00 to 0.33* (Based on Φ' = 30°)
Sliding along base of MSE wall Sliding Coefficient (μ) = tan 30° = 0.58** **Note: for discontinuous reinforcement and friction angle for compacted granular fill.
Allowable Bearing Capacity – Undrained Condition (With overexcavation) q_{all} = 3,563 to 7,687 psf
Allowable Bearing Capacity – Drained Condition (With overexcavation) q_{all} = 3,563 to 7,687 psf
Global Stability *(Without Overexcavation)* Factor of Safety – Undrained Condition = 1.7 to 2.4 Factor of Safety – Drained Condition = 1.7 to 4.3 Factor of Safety – Drained Seismic Condition = 1.5 to 3.5
Estimated Settlement of MSE volume (at wall face) Maximum Total Settlement = 2.7 inches (Without Overexcavation) Differential Settlement = 0.04% (maximum allowable is 1.0% ODOT BDM 204.6.2.1)
Full Height (H+D) of MSE Wall = 7.4 to 37.2 feet (including embedment depth) Minimum Embedment Depth = 3.0 feet Minimum Length of Reinforcement for External Stability, 0.7(H+D) = 8 to 26 feet**

*For external stability Ka=0.0, back to back wall analyses. Ref: FHWA-NHI-00-043
**The reinforcement length should be a minimum of 8 feet.

5.3 Embankment Retaining Wall (Ramp B)

The walls along the proposed Ramp B will begin approximately at Station 29+50 and end at Station 35+51.55. The length of the proposed wall is approximately 602 feet. The wall heights, as measured from the top of leveling pad to the top of coping, will range from 20.3 feet to 34.8 feet. MSE walls are planned along the west side of Ramp B between Station 29+50 and Station 32+50 while back-to-back MSE walls are planned along the east and west sides of the ramp approximately between Station 32+50 and Station 35+51.55. The proposed roadway width is approximately 33.3 feet.

The existing foundation soils along the wall alignments primarily consisted of stiff to very stiff sandy silt (A-4a), stiff silt and clay (A-6a), very stiff to hard sandy silt (A-6b) underlain by sandy silt (A-4a), silt (A-4b) or gravel with sand and silt (A-2-4). Different wall sections were selected for stability analyses based on the wall height, wall configuration (single wall versus back-to-back walls), and the subsurface conditions. Generally, the most critical soil profile near the selected wall section was chosen for the analyses. Table 4 below summarizes the details of the selected wall sections and the parameters selected for the foundation soils.

Table 4 -Details of Selected Wall Sections and Parameters of Foundation Soils Used for Analyses (Ramp B)

Station	Wall Height, (H+D), ft*	Wall Configuration	Boring/Upper -most Layer of Foundation Soil	Unit Weight (pcf)	Strength Parameters			
					Undrained		Drained	
					c	Φ	c'	Φ'
29+50	20.3	Single	TR-68A/A-6a	125	3000	0	30	0
32+00**	28.4	Single	TR-69A/A-6b	125	3000	0	30	0
32+50	30.0	Back-to-Back	TR-70A/A-6a	120	1250	0	28	0
33+50	33.2	Back-to-Back	TR-70A/A-6a	120	1250	0	28	0
34+00**	34.8	Back-to-Back	TR-70A/A-6a	120	1250	0	28	0
35+42.74	34.3	Back-to-Back	TR-73A/A-4b	120	1667	0	29	0

*Wall heights are measured from the top of leveling pad to the top of coping. For back-to-back walls, the greatest wall height of the wall section is listed.
**Wall sections selected for global stability analysis.

The minimum reinforcing length associated with the greatest wall height of each of these wall sections was determined based on the minimum acceptable factor of safety of 1.5 for the sliding resistance, 2.0 for the overturning resistance and 2.5 for the bearing capacity. Two wall sections, one with a single wall configuration and the other with back-to-back walls, were selected for global stability analysis. Using the maximum wall height for each of the wall configurations and the calculated minimum required reinforcing length, the global stability analyses were performed for undrained, drained, and seismic conditions. The seismic analysis was performed using a horizontal acceleration of 0.06, in accordance with ODOT guidelines.

Initially, analyses were performed based on the MSE walls bearing on the existing soils. The results of the analyses indicated that the factors of safety for global stability, sliding, overturning and drained bearing capacity were adequate. However, bearing capacity calculations indicated that the factors of safety for the undrained bearing capacity for wall sections between Station 32+50 and Station 35+42.74 were between 1.5 to 2.0, which are less than the recommended minimum value of 2.5.

Additional analyses indicated that an adequate factor of safety can be achieved if some of the existing foundation soils are removed and replaced with compacted granular fill in areas between Station 32+50 and Station 35+42.74. It is recommended that the existing foundations soils be overexcavated to an approximate depth of 5.0 feet below the bottom of the proposed leveling pad, or a minimum of 8 feet below the existing ground surface, which corresponds to an approximate elevation of 532.1 (based on Boring TR-70A) or an approximate elevation of 536.3 (based on Boring TR-73A). The compacted granular fill below the leveling pad should conform to ODOT Supplemental Specification 840. The limits of the "remove and replace" area should extend beyond the edge of the

MSE wall/select granular footprint by a distance equal to the depth of the aggregate base. For the back-to-back walls section with one wall height significantly different from the other, special benching within the back-to-back walls section may be used for the overexcavation. Each bench should be a minimum of 10 feet wide and the back slope of each bench should be cut at a typical 1H:1V slope. A schematic showing the use of the special benching within a back-to-back walls section is included in Appendix IV.

Note that undercutting is not necessary in areas between Station 29+50 and Station 32+00.

For sliding stability, calculations indicated that a minimum reinforcement length of 0.7 times the full wall height (H+D) is required. Given the proposed full wall heights between 20.3 and 34.8 feet, the minimum reinforcement length will vary approximately from 14.2 to 24.4 feet. The sliding resistance and the overturning resistance were both acceptable with these minimum reinforcement lengths. These lengths are a minimum for external stability and may be increased, if necessary, for internal stability. Note that these lengths are based on the assumption that discontinuous reinforcing will be used in the MSE fill. If the selected wall system uses continuous reinforcing, i.e., sheets or grids, the minimum reinforcing length may need to be increased.

The global stability analyses based on the parameters of the existing foundations soils resulted in critical factors of safety greater than the minimum factors of safety of 1.3 for both drained and undrained conditions and 1.1 for the seismic condition. Results of the bearing capacity, sliding, overturning and global stability analyses are presented in Appendix IV.

Settlement was calculated using the computer program EMBANK, using the "end of fill" option to model the non-continuous embankment loading. The total maximum settlement (without overexcavation) at the face of the proposed MSE wall was estimated to be approximately 3.4 inches and the maximum settlement (without overexcavation) at the centerline of the ramp was approximately 5.2 inches. MSE retaining walls are able to withstand relatively large amounts of differential settlement, typically up to 100 millimeters per 10 meters of wall length (1.0 percent). Differential settlements at the face of the MSE wall and at the centerline of the ramp were estimated to be approximately 0.03 and 0.04 percent, respectively. These percentages are less than the typically cited maximum value of 1.0 percent. The settlement calculations assumed no overexcavation within the MSE wall footprint area. Note that overexcavation is recommended to increase the bearing capacity of the MSE foundation soils. If the recommended overexcavation is performed, the settlements at the face of the proposed MSE wall and at the centerline of the ramp will be less than the estimated values.

Table 5 summaries the MSE retaining wall parameters and results of analyses for the MSE walls for Ramp B.

Table 5 - MSE Retaining Wall Parameters and Analyses Results (Ramp B)

Retained Soil (New Embankment) Unit Weight = 120 pcf Coefficient of Active Earth Pressure (K_a) = 0.00 to 0.33* (Based on $\Phi' = 30°$)
Sliding along base of MSE wall Sliding Coefficient (μ) = tan 30° = 0.58** **Note: for discontinuous reinforcement and friction angle for compacted granular fill or existing foundation soil.
Allowable Bearing Capacity – Undrained Condition (Between Station 29+50 and Station 32+00, without overexcavation) q_{all} = 6,243 psf Allowable Bearing Capacity – Undrained Condition (Between Station 32+50 and Station 35+42.74, with overexcavation) q_{all} = 6,360 to 7,558 psf
Allowable Bearing Capacity – Drained Condition (Between Station 29+50 and Station 32+00, without overexcavation) q_{all} = 4,304 to 5,538 psf Allowable Bearing Capacity – Drained Condition (Between Station 32+50 and Station 35+42.74, with overexcavation) q_{all} = 6,360 to 7,558 psf
Global Stability *(Without Overexcavation)* Factor of Safety – Undrained Condition = 3.0 to 3.4 Factor of Safety – Drained Condition = 1.8 to 4.9 Factor of Safety – Drained Seismic Condition = 1.7 to3.8
Estimated Settlement of MSE volume (at wall face) Maximum Total Settlement = 3.4 inches (Without Overexcavation) Differential Settlement = 0.03% (maximum allowable is 1.0% ODOT BDM 204.6.2.1)
Full Height (H+D) of MSE Wall = 20.3 to 34.8 feet (including embedment depth) Minimum Embedment Depth = 3.0 feet Minimum Length of Reinforcement for External Stability, 0.7(H+D) = 14.2 to 24.4 feet

*For external stability Ka=0.0, back to back wall analyses. Ref: FHWA-NHI-00-043

5.4 Groundwater Considerations

Seepage was encountered in all of the borings drilled for the MSE walls for the proposed Ramp B and was first observed at depths between 7.3 feet (Elevation 537.5) and 13.8 feet (Elevation 524.3). Seepage was not encountered in any of the borings drilled for the MSE walls for the proposed Ramp A. No measurable water levels were observed in any of the borings prior to rock coring. Final water levels, which include water that was used during rock coring operations, varied between 1.6 feet (Elevation 543.2) and 18.0 feet (Elevation 535.0) in depth. Note that overexcavation for the wall foundations to elevations between 545.0 and 550.4 for Ramp A and to elevations between 532.1 and

536.3 for Ramp B are recommended. Given the groundwater conditions during this field investigation, seepage is anticipated for the foundation excavations for Ramp B. The Contractor should be prepared to perform dewatering, likely with sumping and pumping. In addition, the Contractor should be prepared to deal with unexpected seepage and precipitation that enters any excavations.

5.5 General Earthwork Recommendations

The borings encountered 1 to 10 inches of topsoil or 5 inches of asphalt concrete over 7 inches of aggregate base. All topsoil, vegetation, and pavement materials within the footprint of the new embankment should be removed prior to the wall construction. All pavement materials and organic soil within 3 feet of subgrade level should also be removed prior to placing fill. However, overexcavation may need to be deeper if organic soils are encountered at depths greater than three feet.

Weak foundation soils were mostly encountered in the upper eight feet of the borings. It is recommended that the existing foundations soils be overexcavated along the proposed Ramp A wall alignments to an approximate depth of 4.5 feet below the bottom of the proposed leveling pad, or a minimum of 8 feet below the existing ground surface, which corresponds to an approximate elevation of 550.4 (based on Boring B-33) or an approximate elevation of 545.0 (based on Boring TR-75). Similarly, the existing foundations soils along the proposed Ramp B wall alignments should also be overexcavated to an approximate depth of 5.0 feet below the bottom of the proposed leveling pad, or a minimum of 8 feet below the existing ground surface, which corresponds to an approximate elevation of 532.1 (based on Boring TR-70A) or an approximate elevation of 536.3 (based on Boring TR-73A). The overexcavated material should be replaced with compacted granular fill. Organic and very soft soils may be encountered in areas other than the boring locations. Consequently, the contractor should be prepared to perform overexcavation of any poor soils or other unsuitable materials at other locations and replace the overexcavated soil with compacted engineered fill as needed.

The embankments should be constructed in accordance with ODOT Item 203. It is anticipated that the embankments along the proposed Ramp A and Ramp B will be constructed with side slopes of 2H:1V or flatter. Based on the materials encountered by the borings, the foundation soils are considered adequately stable under the proposed embankment loads.

Underground utilities or guardrails may be located within the wall locations. Please refer to ODOT Item 202 for requirements related to removal of any structures and their foundations, if any, as well as backfilling of excavations resulting from the removal of these structures.

Excavations for the footings for the leveling pads should be prepared in accordance with ODOT Item 503, "Excavation for Structures." Excavations deeper than 5.0 feet must be sloped or shored to protect workers entering the excavations. Refer to OSHA regulations (29CFR Part 1926) concerning sloping and shoring requirements for excavations.

It is recommended that earthwork be performed under continuous observation and testing by a soils technician with the general guidance of a geotechnical engineer.

Relative to the wall footing excavations, the following additional recommendations are presented:

1. All footings should be founded deep enough for frost protection, considered to be 36 inches in this area.

2. Excavation bottoms should be examined by the geotechnical engineer prior to placement of leveling pads in order to determine the suitability of the supporting soils.

3. Excavations should be undercut to suitable bearing material if such material is not encountered at the planned footing level. Such undercuts may be backfilled with a lean mix concrete (1,500 psi @ 28 days) or compacted engineered fill.

4. All footing excavations should be cut to stable side walls and flat bottoms with the bottoms comprised of firm soil undisturbed by the method of excavation or softened by standing water. Leveling pads should be placed the same day that the footings are excavated.

5. While excavating for the footings, unsuitable soils may be encountered deeper than indicated by the borings. These unsuitable materials will need to be overexcavated until suitable bearing material is encountered. Overexcavations should be backfilled with compacted engineered fill or lean mix concrete.

6.0 CLOSING REMARKS

We appreciate having the opportunity to be of service to you on this project. Please do not hesitate to call if you have any questions concerning our report.

Respectfully submitted,

DLZ OHIO, INC.

Eric W. Tse, P.E.
Senior Geotechnical Engineer

Bryan Wilson, P.E.
Senior Geotechnical Engineer

EWT

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APPENDIX A

DLZ

APPENDIX I

Boring Location Plan
Retaining Wall Plans

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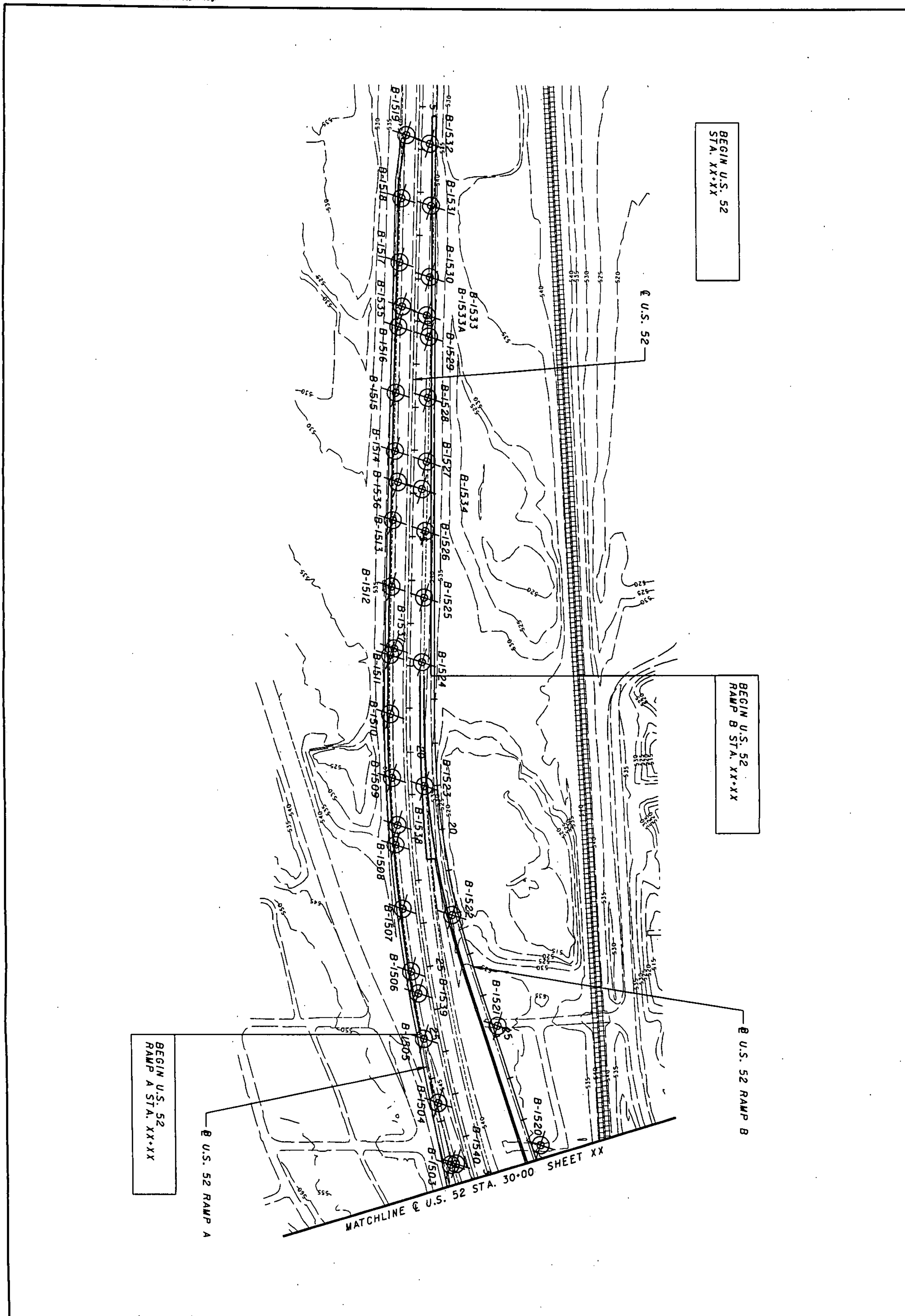

SCI-823-0.00	SOIL PROFILE U.S. 52 INTERCHANGE	CALCULATED BLS CHECKED AEN

HORIZONTAL SCALE IN FEET (0, 50, 100, 200)

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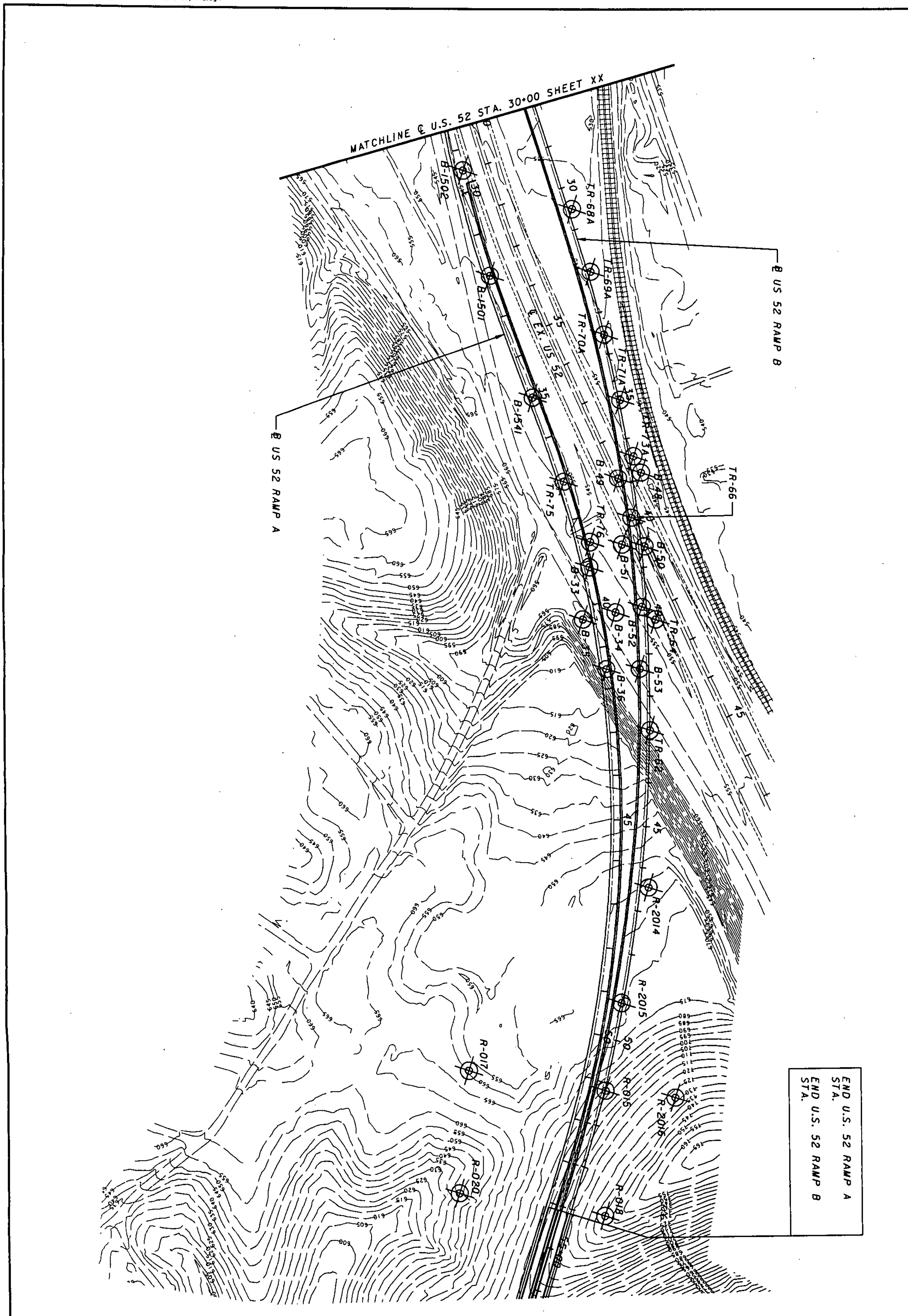

SCI-823-0.00	SOIL PROFILE U.S. 52 INTERCHANGE	CALCULATED BLS CHECKED AEN	HORIZONTAL SCALE IN FEET (0 50 100 200)

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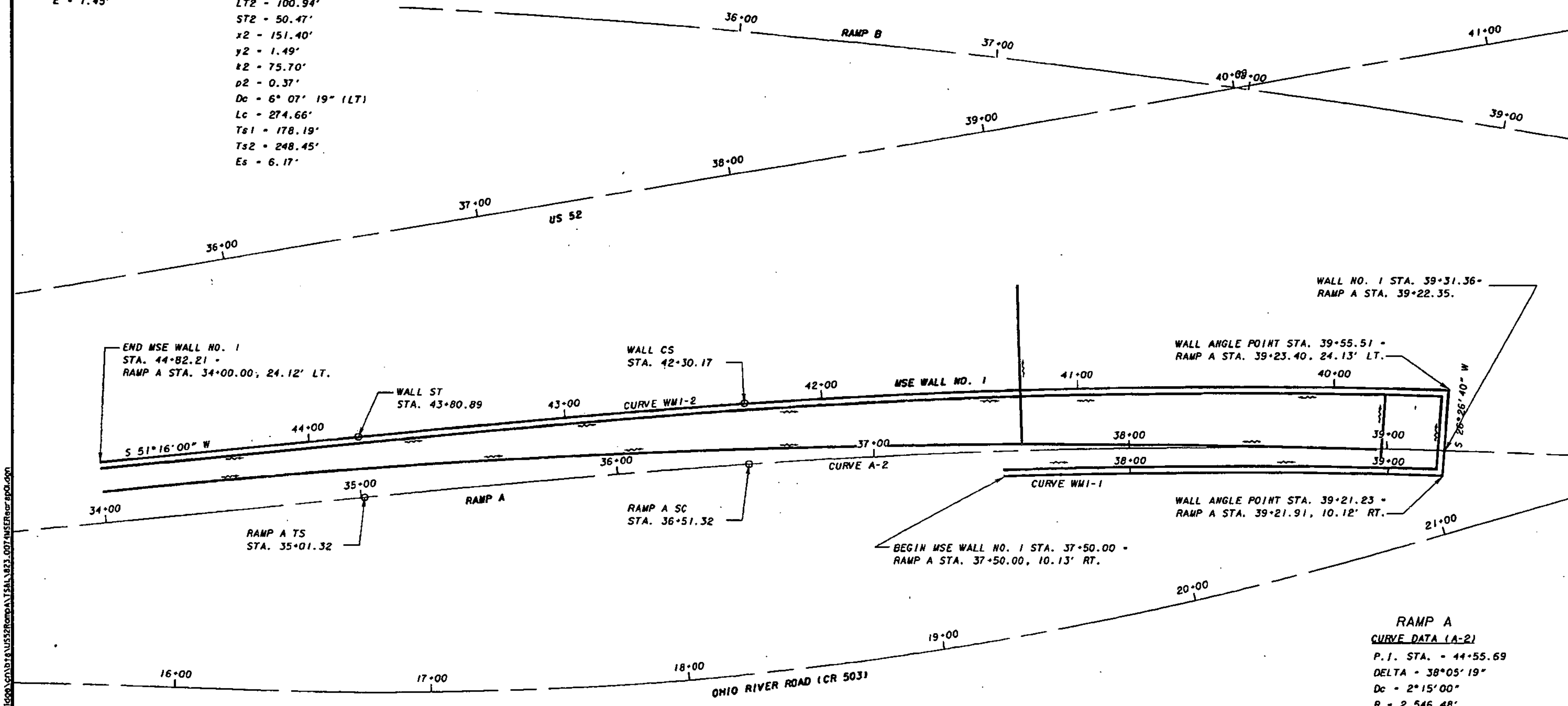
MSE WALL NO. 1

CURVE DATA (WM1-1)
P.I. Sta - 38+35.65
D - 3° 52' 05" (RT)
Dc - 2° 15' 32"
R - 2,536.35'
T - 85.65'
L - 171.23'
E - 1.45'

CURVE DATA (WM1-2)
P.I. Sta - 41+33.70
D - 7° 48' 33" (LT)
Dc - 2° 13' 44"
R - 2,570.60'
Ls2 - 151.41'
Theta2 - 1° 41' 15"
LT2 - 100.94'
ST2 - 50.47'
x2 - 151.40'
y2 - 1.49'
k2 - 75.70'
p2 - 0.37'
Dc - 6° 07' 19" (LT)
Lc - 274.66'
Ts1 - 178.19'
Ts2 - 248.45'
Es - 6.17'



RAMP A
CURVE DATA (A-2)
P.I. STA. - 44+55.69
DELTA - 38°05'19"
Dc - 2°15'00"
R - 2,546.48'
Ls1 - 150.00'
Ls2 - 175.00'
Theta1 - 1°41'15"
Theta2 - 1°58'08"
LT1 - 100.00'
LT2 - 116.67'
ST1 - 50.00'
ST2 - 58.34'
Lc - 1,560.32'
Ts1 - 954.36'
Ts2 - 966.48'
Es - 147.91'

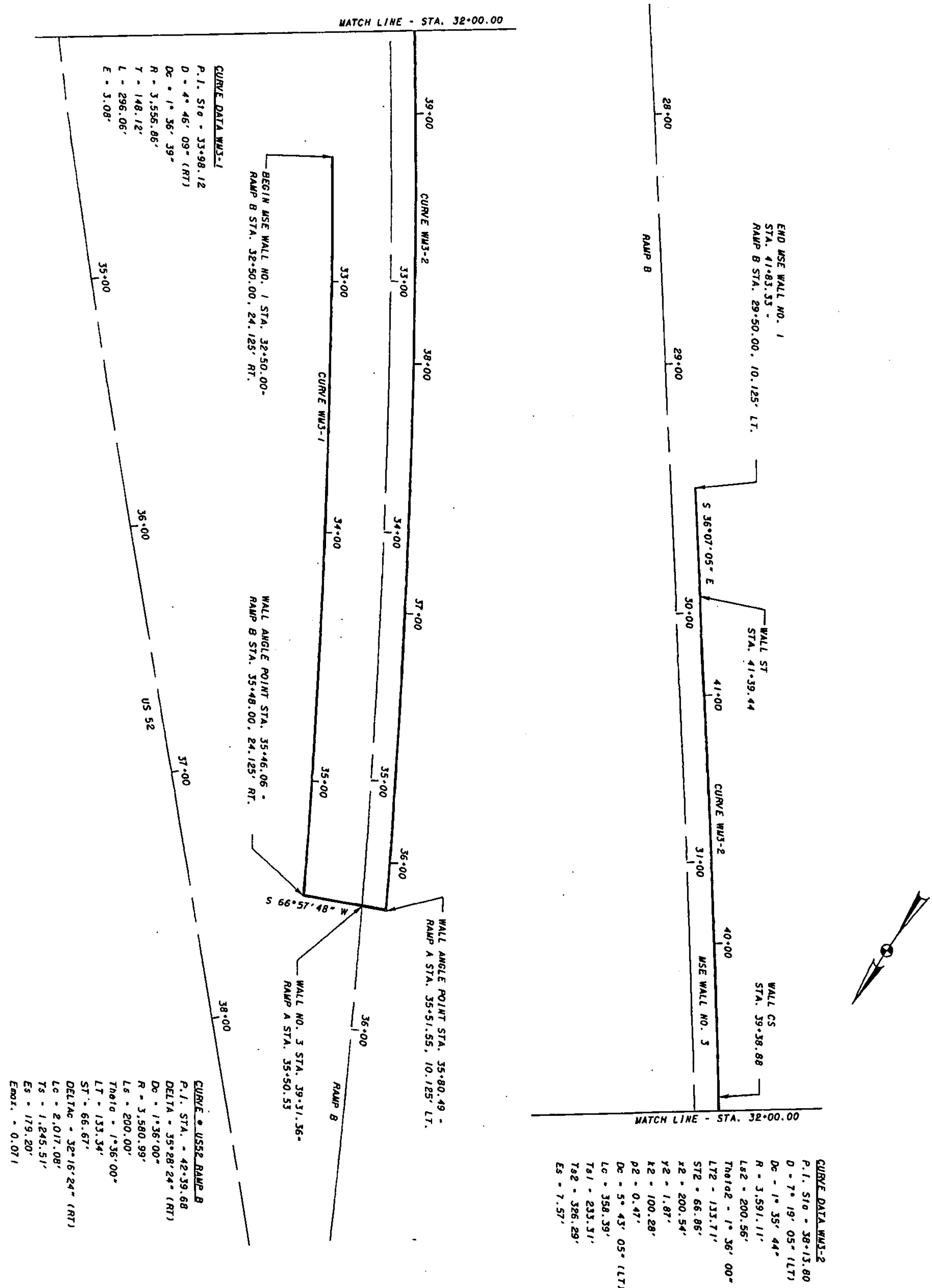
DESIGNED	DRAWN	REVIEWED	DATE
MTN	MSW	MSL	6/25/07
CHECKED	REVISED	STRUCTURE FILE NUMBER	
PJP		7306288	

DESIGN AGENCY
Systems

WALL SCHEMATIC PLAN - WALL NO. 1
BRIDGE NO. SCI-823-0074R
RAMP A OVER OHIO RIVER RD.

SCI-823-0.00
PID 77366

4/6



4/6

SCI-823-0.00
PID 77366

MSE WALL SCHEMATIC PLAN - WALL NO. 3
BRIDGE NO. SCI-823-0067L
RAMP B OVER US-52 AND CR-503

DESIGNED	DRAWN	REVIEWED	DATE
MTN	MSW	MSL	6/25/07
CHECKED	REVISED	STRUCTURE FILE NUMBER	
PJP		7306288	

DESIGN AGENCY: TranSystems

APPENDIX B

DLZ

APPENDIX II

General Information – Drilling Procedures and Logs of Borings
Legend – Boring Log Terminology
Boring Logs – Eleven (11) Borings

GENERAL INFORMATION
DRILLING PROCEDURES AND LOGS OF BORINGS

Drilling and sampling were conducted in accordance with procedures generally recognized and accepted as standardized methods of investigation of subsurface conditions concerning geotechnical engineering considerations. Borings were drilled with either a truck-mounted or ATV-mounted drill rig.

Drive split-barrel sampling was performed in 1.5 to 2 foot increments at intervals not exceeding 5 feet. In the event the sampler encountered resistance to penetration of 6 inches or less after 50 blows of the drop hammer, the sampling increment was discontinued. Standard penetration data were recorded and one or more representative samples were preserved from each sampling increment.

In borings where rock was cored, NXM or NQ size diamond coring tools were used.

In the laboratory all samples were visually classified by a geotechnical engineer. Moisture contents of representative fine-grained soil samples were determined. A limited number of samples, considered representative of foundation materials present, were selected for performance of grain-size analyses and plasticity characteristics tests. The results of these tests are shown on the boring logs.

The boring logs included in the Appendix have been prepared on the basis of the field record of drilling and sampling, and the results of the laboratory examination and testing of samples. Stratification lines on the boring logs indicating changes in soil stratigraphy represent depths of changes approximated by the driller, by sampling effort and recovery, and by laboratory test results. Actual depths to changes may differ somewhat from the estimated depths, or transitions may occur gradually and not be sharply defined. The boring logs presented in this report therefore contain both factual and interpretative information and are not an exact copy of the field log.

Although it is considered that the borings have disclosed information generally representative of site conditions, it should be expected that between borings conditions may occur which are not precisely represented by any one of the borings. Soil deposition processes and natural geologic forces are such that soil and rock types and conditions may change in short vertical intervals and horizontal distances.

Soil/rock samples will be stored at our laboratory for a period of six months. After this period of time, they will be discarded, unless notified to the contrary by the client.

LEGEND – BORING LOG TERMINOLOGY

Explanation of each column, progressing from left to right

1. Depth (in feet) – refers to distance below the ground surface.

2. Elevation (in feet) – is referenced to mean sea level, unless otherwise noted.

3. Standard Penetration (N) – the number of blows required to drive a 2-inch O.D., 1-3/8 inch I.D., split-barrel sampler, using a 140-pound hammer with a 30-inch free fall. The blows are recorded in 6-inch drive increments. Standard penetration resistance is determined from the total number of blows required for one foot of penetration by summing the second and third 6-inch increments of an 18-inch drive.

   50/n – indicates number of blows (50) to drive a split-barrel sampler a certain number of inches (n) other than the normal 6-inch increment.

4. The length of the sampler drive is indicated graphically by horizontal lines across the "Standard Penetration" and "Recovery" columns.

5. Sample recovery from each drive is indicated numerically in the column headed "Recovery".

6. The drive sample location is designated by the heavy vertical bar in the "Sample No., Drive" column.

7. The length of hydraulically pressed "Undisturbed" samples is indicated graphically by horizontal lines across the "Press" column.

8. Sample numbers are designated consecutively, increasing in depth.

9. Soil Description

   a. The following terms are used to describe the relative compactness and consistency of soils:

   Granular Soils – Compactness

Term	Blows/Foot Standard Penetration
Very Loose	0 – 4
Loose	4 – 10
Medium Dense	10 – 30
Dense	30 – 50
Very Dense	over 50

   Cohesive Soils – Consistency

Term	Unconfined Compression tons/sq.ft.	Blows/Foot Standard Penetration	Hand Manipulation
Very Soft	less than 0.25	below 2	Easily penetrated by fist
Soft	0.25 – 0.50	2 – 4	Easily penetrated by thumb
Medium Stiff	0.50 – 1.0	4 – 8	Penetrated by thumb with moderate pressure
Stiff	1.0 – 2.0	8 – 15	Readily indented by thumb but not penetrated
Very Stiff	2.0 – 4.0	15 – 30	Readily indented by thumb nail
Hard	over 4.0	over 30	Indented with difficulty by thumb nail

   b. Color – If a soil is a uniform color throughout, the term is single, modified by such adjective as light and dark. If the predominant color is shaded by a secondary color, the secondary color precedes the primary color. If two major and distinct colors are swirled throughout the soil, the colors are modified by the term "mottled".

   c. Texture is based on the Ohio Department of Transportation Classification System. Soil particle size definitions are as follows:

Description		Size	Description		Size
Boulders		Larger than 8"	Sand	– Coarse	2.0 mm to 0.42 mm
Cobbles		8" to 3"		– Fine	0.42 mm to 0.074 mm
Gravel	– Coarse	3" to ¾"	Silt		0.074 mm to 0.005 mm
	– Fine	¾" to 2.0 mm	Clay		smaller than 0.005 mm

d. The main soil component is listed first. The minor components are listed in order of decreasing percentage of particle size.

e. Modifiers to main soil descriptions are indicated as a percentage by weight of particle sizes.

trace	0 to 10%
little	10 to 20%
some	20 to 35%
"and"	35 to 50%

f. Moisture content of **cohesionless soils** (sands and gravels) is described as follows:

Term	Relative Moisture or Appearance
Dry	No moisture present
Damp	Internal moisture, but none to little surface moisture
Moist	Free water on surface
Wet	Voids filled with free water

g. The moisture content of **cohesive soils** (silts and clays) is expressed relative to plastic properties.

Term	Relative Moisture or Appearance
Dry	Powdery
Damp	Moisture content slightly below plastic limit
Moist	Moisture content above plastic limit but below liquid limit
Wet	Moisture content above liquid limit

10. Rock Hardness and Rock Quality Designation

a. The following terms are used to describe the relative hardness of the **bedrock**.

Term	Description
Very Soft	Permits denting by moderate pressure of the fingers. Resembles hard soil but has rock structure. (Crushes under pressure of fingers and/or thumb)
Soft	Resists denting by fingers, but can be abraded and pierced to shallow depth by a pencil point. (Crushes under pressure of pressed hammer)
Medium Hard	Resists pencil point, but can be scratched with a knife blade. (Breaks easily under single hammer blow, but with crumbly edges.)
Hard	Can be deformed or broken by light to moderate hammer blows. (Breaks under one or two strong hammer blow, but with resistant sharp edges.)
Very Hard	Can be broken only by heavy and in some rocks repeated hammer blows.

b. Rock Quality Designation, RQD – This value is expressed in percent and is an indirect measure of rock soundness. It is obtained by summing the total length of all core pieces which are at least four inches long, and then dividing this sum by the total length of the core run.

11. Gradation – when tests are performed, the percentage of each particle size is listed in the appropriate column (defined in Item 9c).

12. When a test is performed to determine the natural moisture content, liquid limit moisture content, or plastic limit moisture content, the moisture content is indicated graphically.

13. The standard penetration (N) value in blows per foot is indicated graphically.

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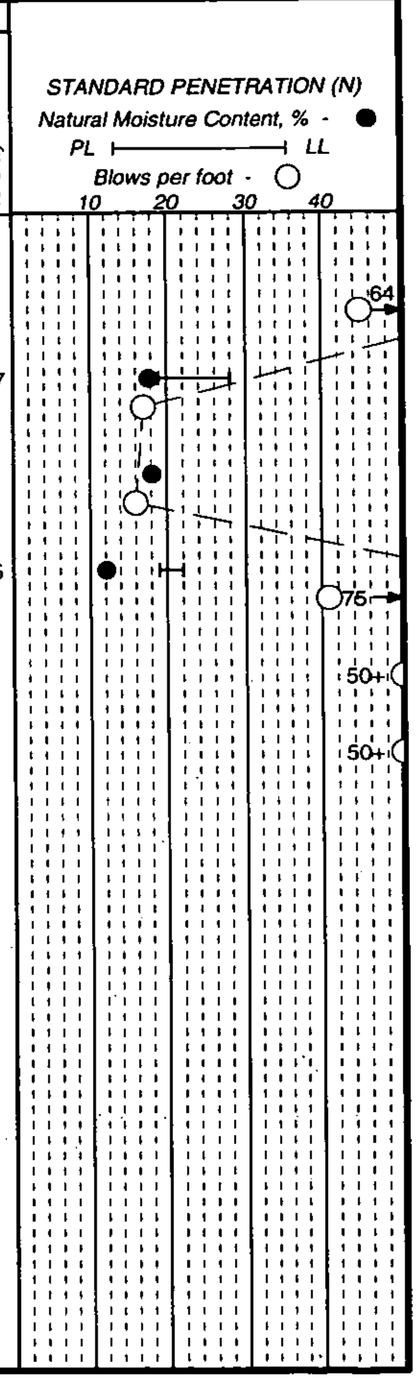
Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring B-33 | Location: Sta. 39+14.0, 11.2 ft. LT of US 52 Ramp A BL | Date Drilled: 02/01/07

WATER OBSERVATIONS: Water seepage at: None
Water level at completion: None (prior to coring)
10.6' (inside hollowstem augers, includes drilling water)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf) / * Point-Load Strength (psi)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	558.4												
0.4	558.0						Topsoil - 5"						
		22 32 32	18	1		3.0	Very stiff brown SANDY SILT (A-4a), little to some gravel, trace to little clay; contains sandstone fragments; dry to damp.						
		4 5 12	18	2		2.25		13	12	--	10	48	17
		7 8 8	18	3		1.5	@ 6.0' stiff, moist.						
8.0	550.4	38 48 27	18	4		1.5	Very dense brown GRAVEL WITH SAND AND SILT (A-2-4), trace clay; dry to damp.	26	26	--	17	26	5
11.0	547.4	48 50/5	4	5			Severely weathered brown SANDSTONE, argillaceous.						
		50/5	5	6									
14.5	543.9	Core 120"	Rec 116"	RQD 60%	R1		Soft to medium hard brown and gray SANDSTONE; very fine to medium grained, highly weathered, argillaceous, laminated, highly fractured, contains clay seams. @ 14.7'-15.1', lost recovery.						
20.0	538.4						Medium hard to hard gray SANDSTONE; fine grained, slightly weathered, micaceous, argillaceous, thinly bedded, slightly fractured. @ 20.8'-21.3', qu = 9,284 psi.						
24.5	533.9						Bottom of Boring - 24.5'						



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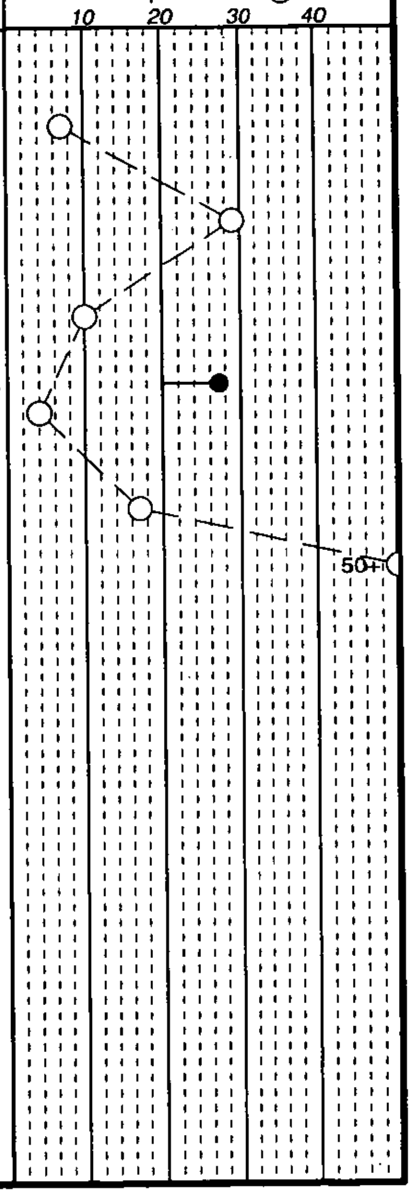
Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring B-1501 | Location: Sta. 32+00.5, 7.8 ft. LT of US 52 Ramp A BL | Date Drilled: 12/28/05 to 12/29/05

WATER OBSERVATIONS: Water seepage at: None
Water level at completion: None (prior to coring)
17.8' (inside hollowstem augers)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf) / * Point-Load Strength (psi)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	548.9												
0.5	548.4						Topsoil - 6"						
		3 3 4	14	1		1.25	Stiff brown SILT AND CLAY (A-6a), trace fine to coarse sand, trace gravel; damp.						
3.5	545.4	7 13 16	17	2			Medium dense brown COARSE AND FINE SAND (A-3a), trace silty clay, trace gravel; damp.						
5.0	543.9	6 6 4	13	3		2.5	Very stiff brown SILT AND CLAY (A-6a), trace fine to coarse sand, trace gravel; damp.						
8.5	540.4	2 2 2	18	4		1.0	Stiff to very stiff brown SILT (A-4b), little clay, trace fine sand; moist to wet.	0	0	--	4	78	18
		2 9 8	16	5		2.5							
13.5	535.4	50/3	2	6			Severely weathered brown SANDSTONE.						
14.0	534.9	Core 120"	Rec 102"	RQD 58%	R-1		Medium hard to hard brown SANDSTONE; very fine to fine grained, highly weathered, argillaceous, micaceous, thickly bedded to massive, highly fractured to broken. @ 16.1'-16.2',20.8'-21.2', broken zones. @ 16.2'-17.7', lost recovery, possible broken zone. @ 17.7', gray. @ 21.5', slightly fractured.						
24.0	524.9						Bottom of Boring - 24.0'						

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ├──┤ LL
Blows per foot - ○



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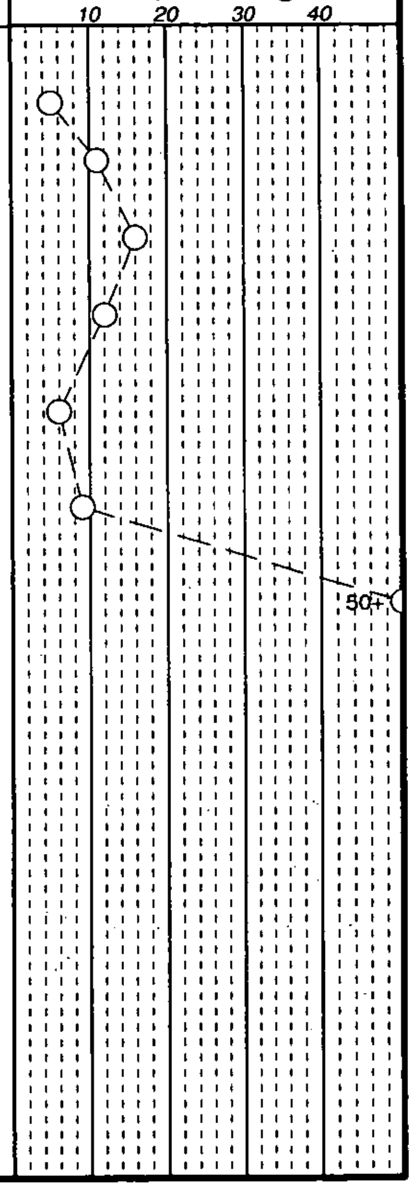
Client: TranSystems, Inc.	Project: SCI-823-0.00	Job No. 0121-3070.03
LOG OF: Boring B-1520	Location: Sta. 27+68.3, 25.8 ft. LT of US 52 Ramp B BL	Date Drilled: 1/16/06

WATER OBSERVATIONS: Water seepage at: 13.5'
Water level at completion: None (Prior to coring)
10.7' (Includes drilling water)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf) / * Point-Load Strength (psi)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	534.7						Asphalt Concrete Pavement - 5" Aggregate Base - 7"						
1.0	533.7	1 2 3	14	1		2.25	Very stiff to hard gray SILT AND CLAY (A-6a), trace fine to coarse sand, trace gravel; damp to moist.						
		3 4 7 9	20	2		4.5+							
5		4 8 8 7	24	3		4.5+							
		4 5 7	18	4		4.0							
10		2 3 3	18	5		2.0							
		4 4 5	18	6		1.5	@ 11.0'-12.5', stiff.						
13.5	521.2	6 39 50/3	12	7			Very dense brown GRAVEL WITH SAND AND SILT (A-2-4); moist.						
15.0	519.7						Medium hard brown SANDSTONE; very fine to fine grained, highly weathered, argillaceous, micaceous, massive, highly fractured to broken. @ 18.0'-18.4', high angle fracture.						
19.6	515.1	Core 120"	Rec 120"	RQD 56%	R-1		Medium hard to hard gray SANDSTONE; very fine to fine grained, slightly to moderately weathered, argillaceous, micaceous, massive, slightly fractured to unfractured. @ 16.4'-17.5', 18.7'-18.8', broken.						
25.0	509.7						Bottom of Boring - 25.0'						
30													

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ├──┤ LL
Blows per foot - ○



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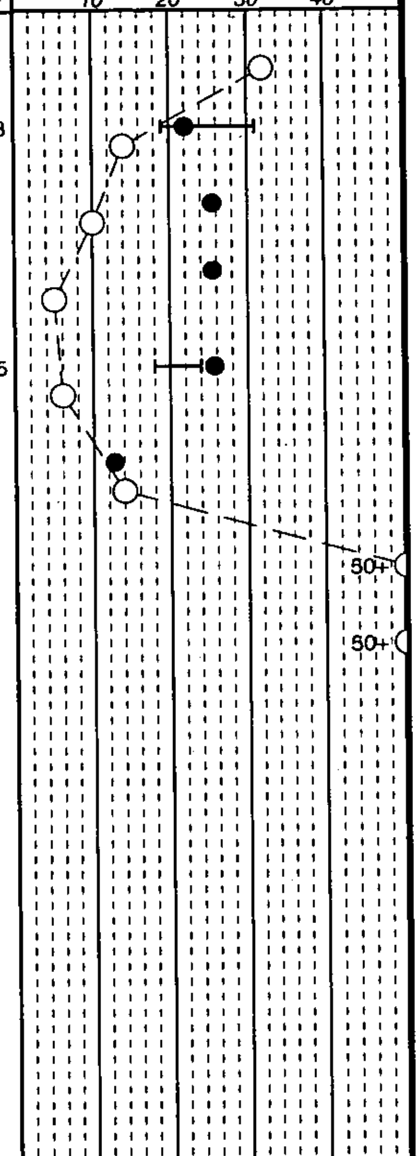
Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring B-1541 | Location: Sta. 35+01.5, 4.1 ft. LT of US 52 Ramp A BL | Date Drilled: 05/29/07 to 05/29/07

WATER OBSERVATIONS: Water seepage at: None
Water level at completion: None

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf) / * Point-Load Strength (psi)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	551.5	4 14 18 12	22	1			FILL: Dense brown SILT (A-4b), some gravel, little to some fine to coarse sand; damp.						
2.0	549.5	9 7 7 7	24	2		2.0	FILL: Stiff to very stiff brown and gray SILT AND CLAY (A-6a), trace to little fine to coarse sand, trace to little gravel; damp to moist.	0	2	--	4	61	33
5		4 4 6 6	24	3		1.25							
		2 2 3	18	4		1.25	@ 6.0'-10.0', wet on sample surface.						
8.5	543.0	3 3 3	18	5		1.0	Stiff brown SILT (A-4b), some clay, trace fine sand; moist to wet.	0	0	--	3	72	25
10		5 4 10	18	6		--							
13.5	538.0	12 50+	12	7			Severely weathered brown SANDSTONE.						
15													
16.2	535.3	50/2	2	8			Bottom of Boring - 16.2'						
20													
25													
30													

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ⊢—⊣ LL
Blows per foot - ○
10 20 30 40



FILE: 0121-3070-03 | 11/13/2007 7:09 PM |

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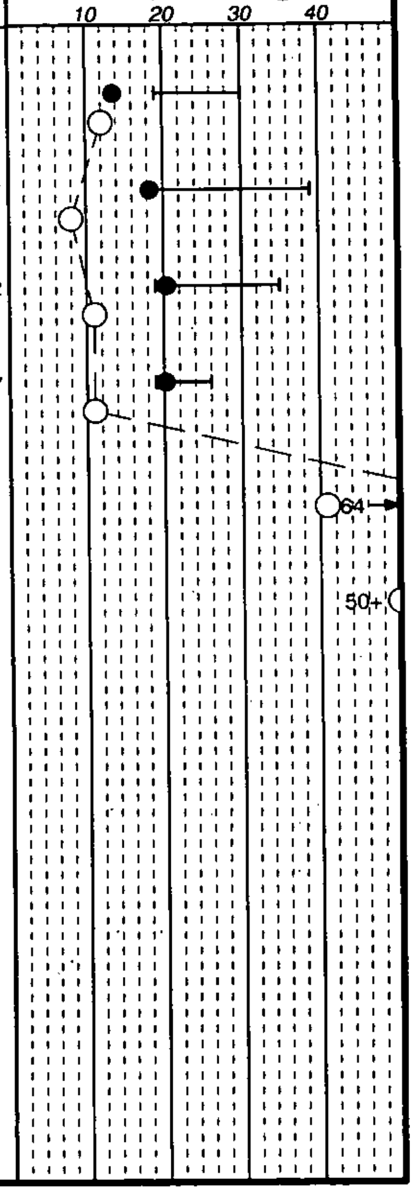
Client: TranSystems, Inc. | **Project:** SCI-823-0.00 | **Job No.** 0121-3070.03

LOG OF: Boring TR-68A | **Location:** Sta. 30+53.6, 14.9 ft. LT of US 52 Ramp B BL | **Date Drilled:** 08/15/06

WATER OBSERVATIONS:
Water seepage at: 13.8'
Water level at completion: None (prior to coring)
3.9' (includes drilling water)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf) / * Point-Load Strength (psi)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	538.1												
0.4	537.7						Topsoil - 5"						
		8 6 6	14	1		4.5+	Very stiff to hard brown SILT AND CLAY (A-6a), little fine to coarse sand, trace gravel; contains trace organic debris; damp.	2	7	--	12	55	24
3.5	534.6	3 3 5	13	2		3.75	Very stiff brown SILTY CLAY (A-6b), trace to little fine to coarse sand, trace gravel; damp to moist. @ 3.5'-5.0', mottled brown and gray.	5	5	--	10	43	37
		3 5 6	16	3		2.75		0	2	--	6	60	32
8.0	530.1	2 5 6	18	4			Loose brown SILT (A-4b), little clay, little fine to coarse sand ; damp to moist.	0	4	--	13	66	17
11.0	527.1	18 31 33	9	5			Severely weathered brownish gray SANDSTONE.						
		8 49 50/3	12	6									
15.0	523.1	Core 27"	Rec 26"	RQD 0%	R-1		Medium hard brown SANDSTONE; fine grained, highly weathered, micaceous, broken, clay filled fractures. @ 16.4', high angle fracture. @ 17.7', 18.0', iron stained high angle fractures. @ 18.0', gray. @ 18.9'-19.2', high angle fracture.						
19.4	518.7	Core 60"	Rec 60"	RQD 46%	R-2		Medium hard to hard gray SANDSTONE; fine to medium grained, moderately to highly weathered, micaceous, highly fractured. @ 20.0'-20.3', qu = 9,500 psi. @ 22.3', moderately fractured. @ 23.5'-23.6', turbidity zone. @ 24.3'-24.7', qu = 12,266 psi.						
		Core 60"	Rec 60"	RQD 100%	R-3								
27.3	510.8						Bottom of Boring - 27.3'						

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ├──┤ LL
Blows per foot - ○



FILE: 0121-3070-03 [11/13/2007 7:09 PM]

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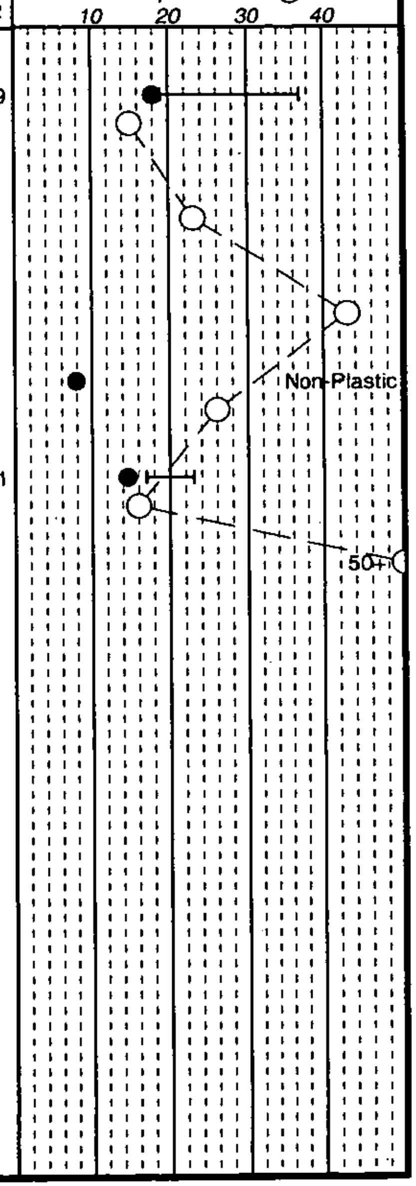
Client: TranSystems, Inc.	Project: SCI-823-0.00	Job No. 0121-3070.03
LOG OF: Boring TR-69A	Location: Sta. 32+03.9, 12.7 ft. LT of US 52 Ramp B BL	Date Drilled: 08/15/06

WATER OBSERVATIONS: Water seepage at: 11.0' - 12.5'
Water level at completion: None (prior to coring)
27.5' (includes drilling water)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf) / * Point-Load Strength (psi)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	539.0												
0.4	538.6						Topsoil - 5"						
		7 7 8	16	1		4.5+	Hard brown SILTY CLAY (A-6b), trace to little fine to coarse sand; damp.	0	2	--	6	53	39
5		5 10 13	14	2		4.5+							
		5 16 27	15	3		4.5+							
8.5	530.5	7 13 13	18	4			Medium dense to dense brown GRAVEL WITH SAND AND SILT (A-2-4); encountered sandstone fragments; damp.	58	11	--	16	15	
10													
11.0	528.0	4 9 7	16	5			Medium dense brown SANDY SILT (A-4a); damp to moist.	23	8	--	17	41	11
13.5	525.5	50/5	4	6			Severely weathered brown SANDSTONE.						
14.5	524.5												
15		Core 36"	Rec 34"	RQD 22%	R-1		Medium hard brown SANDSTONE; fine to medium grained, moderately to highly weathered, highly fractured to broken.						
17.4	521.6												
20		Core 60"	Rec 59"	RQD 81%	R-2		Hard gray SANDSTONE; fine grained, slightly to moderately weathered, highly fractured. @ 18.6'-18.9', qu = 11,910 psi. @ 19.3', moderately to slightly fractured.						
25		Core 60"	Rec 60"	RQD 100%	R-3								
27.5	511.5						Bottom of Boring - 27.5'						
30													

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ├──┤ LL
Blows per foot - ○



FILE: 0121-3070-03 (11/13/2007 7:09 PM)

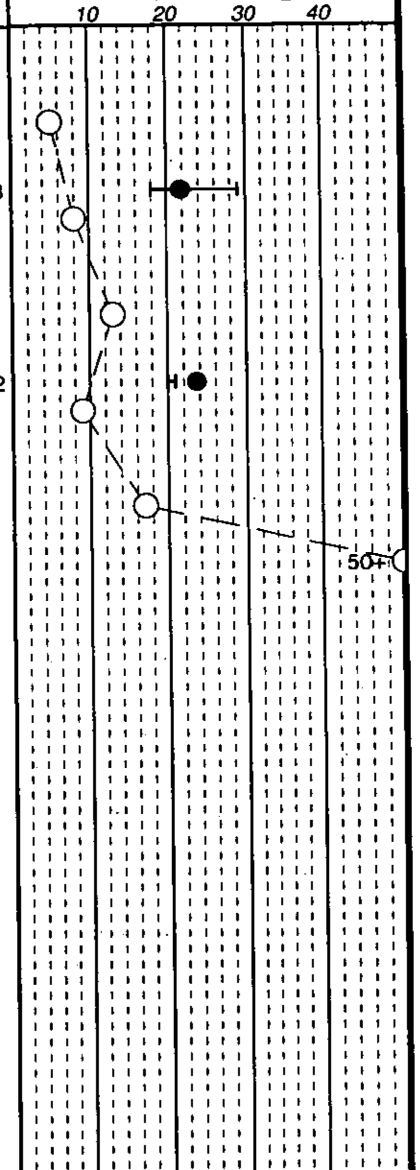
Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring TR-70A | Location: Sta. 33+52.3, 5.3 ft. LT of US 52 Ramp B BL | Date Drilled: 07/31/06 to 08/01/06

WATER OBSERVATIONS: Water seepage at: 9.5' - 12.5'
Water level at completion: None (prior to coring)
5.9' (includes drilling water)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf) / * Point-Load Strength (psi)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	540.6						Topsoil - 10"						
0.8	539.8	1 2 3	6	1		1.5	Stiff brown SILT AND CLAY (A-6a), trace to little fine sand; damp to moist.						
		3 4 4	18	2		1.25	@ 3.0', trace organics.	2	4	--	14	57	23
		5 8 5	18	3		1.0	@ 5.5', little fine sand, trace coarse sand, moist.						
8.0	532.6	4 4 5	18	4			Loose to medium dense brown SILT (A-4b), some fine to coarse sand, trace to little gravel, trace to little clay; wet.	6	1	--	23	58	12
		4 8 9	18	5									
13.5	527.1	50/3	3	6			Severely weathered brownish gray SANDSTONE.						
14.5	526.1	Core 120"	Rec 104"	RQD 52%	R-1		Medium hard brown SANDSTONE; fine grained, moderately to highly weathered, micaceous, highly fractured. @ 14.5'-15.1', possible core loss. @ 16.1', high angle fracture. @ 18.6', gray. @ 20.2', high angle fracture.						
20.9	519.7						Hard gray SANDSTONE; fine grained, slightly weathered, micaceous, moderately fractured.						
24.5	516.1						Bottom of Boring - 24.5'						

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ├──┤ LL
Blows per foot - ○



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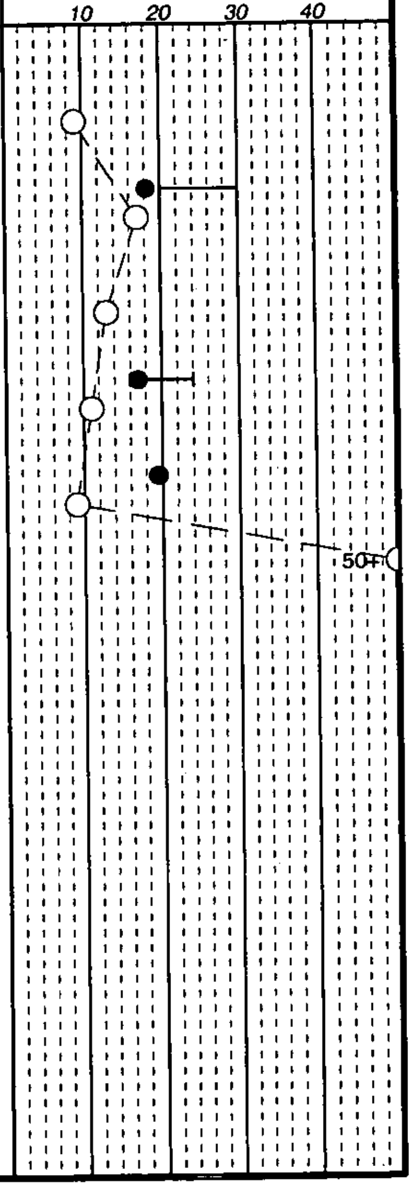
Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring TR-71A | Location: Sta. 35+09.8, 9.1 ft. LT of US 52 Ramp B BL | Date Drilled: 07/31/06

WATER OBSERVATIONS: Water seepage at: 9.5'-12.5'
Water level at completion: None (prior to coring)
3.3' (includes drilling water)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf) / * Point-Load Strength (psi)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	542.8												
0.5	542.3						Topsoil - 6"						
		4 5 4	15	1		2.25	Stiff to very stiff brown SANDY SILT (A-4a); damp to moist.						
		3 7 10	16	2		2.25	@ 3.0', mottled brown and gray.	0	1	--	8	91	
		3 5 8	18	3		3.0							
		2 3 8	18	4		--		14	8	--	23	42	13
		1 4 5	18	5		--	@ 10.5', moist to wet.						
13.5	529.3	50/3		6			Severely weathered brown SANDSTONE.						
13.9	528.9		2				Medium hard brown SANDSTONE; fine to medium grained, moderately to highly weathered, broken, contains argillaceous seams. @ 16.7', high angle fracture. @ 16.9', highly fractured.						
		Core 120"	Rec 110"	RQD 49%	R-1								
19.8	523.0						Hard gray SANDSTONE; fine to medium grained, slightly to moderately weathered, pyritic (halos), micaceous, thickly bedded to massive, highly to moderately fractured. @ 21.6', qu = 10,209 psi.						
23.9	518.9						Bottom of Boring - 23.9'						

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ⊢—⊣ LL
Blows per foot - ○



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Client: TranSystems, Inc. | *Project:* SCI-823-0.00 | *Job No.* 0121-3070.03

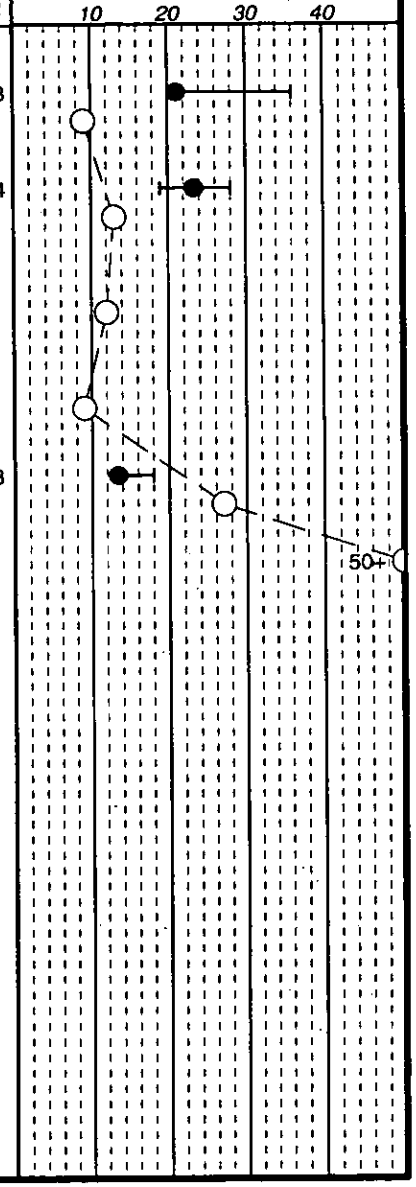
LOG OF: Boring TR-73A | *Location:* Sta. 36+42.9, 16.2 ft. LT of US 52 Ramp B BL | *Date Drilled:* 07/27/06

WATER OBSERVATIONS: Water seepage at: 7.3'-7.4', 11.0'-12.0'
Water level at completion: None (prior to coring)
1.6' (includes drilling water)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf) / * Point-Load Strength (psi)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	544.8												
0.5	544.3						Topsoil - 6"						
		4 4 5	16	1			Stiff to very stiff brown SILT AND CLAY (A-6a), trace fine to coarse sand, trace gravel; damp to moist.	1	1	--	4	61	33
3.0	541.8	4 7 6	18	2		2.0	Stiff brown SILT (A-4b), some clay, trace fine to coarse sand, trace gravel; moist.	1	1	--	7	67	24
		4 4 8	18	3		1.5							
		3 5 4	18	4		1.5							
10.5	534.3	5 8 19	18	5A 5B			Medium dense brown GRAVEL WITH SAND AND SILT (A-2-4); damp to moist.	28	15	--	27	22	8
12.0	532.8						Severely weathered brown SANDSTONE.						
		50/3	3	6									
13.9	530.9	Core 120"	Rec 107"	RQD 55%	R-1		Medium hard brown SANDSTONE; fine grained, highly weathered, micaceous, thickly bedded, broken, contains clay filled seams. @ 16.3'-17.9', argillaceous.						
19.2	525.6						Hard gray SANDSTONE; fine grained, slightly weathered, thickly bedded to massive, slightly fractured. @ 19.2'-19.6', qu = 11,260 psi.						
23.9	520.9						Bottom of Boring - 23.9'						

Depth scale: 0, 5, 10, 15, 20, 25, 30

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ├──┤ LL
Blows per foot - ○



FILE: 0121-3070-03 [11/13/2007 7:09 PM]

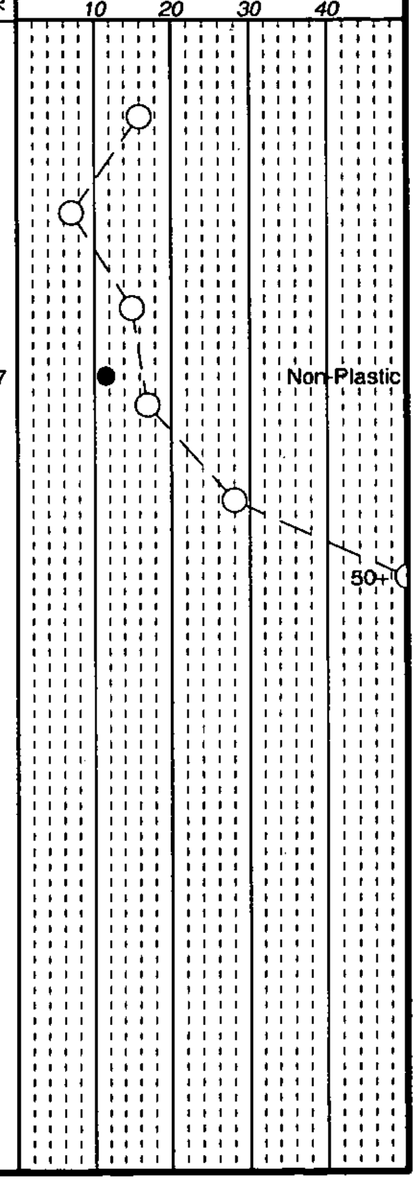
Client: TranSystems, Inc. | *Project:* SCI-823-0.00 | *Job No.* 0121-3070.03

LOG OF: Boring TR-75 | *Location:* Sta. 37+08.4, 6.8 ft LT of US 52 Ramp A BL | *Date Drilled:* 3/30/05

WATER OBSERVATIONS:
Water seepage at: None
Water level at completion: None (prior to coring)
18.0' (inside hollowstem augers, includes drilling water)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf) / * Point-Load Strength (psi)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0.0	553.0												
0.1	552.9						Topsoil - 1"						
		6 6 10	13	1		4.0	FILL: Hard brown SILT AND CLAY (A-6a), trace fine to coarse sand, trace gravel; contains concrete fragments; damp.						
3.0	550.0	4 3 4	14	2		1.0	Stiff brown SILT AND CLAY (A-6a), trace fine to coarse sand, trace gravel; damp to moist.						
		4 5 10	16	3		1.5							
8.0	545.0	5 7 10	12	4			Medium dense brown COARSE AND FINE SAND (A-3a), some silt, little gravel, trace clay; contains sandstone fragments; damp.	13	26	--	30	24	7
		14 14 14	17	5									
		12 50/5	10	6			@ 13.5'-14.4', very dense.						
15.0	538.0	Core 120"	Rec 120"	RQD 61%	R1		Hard brown SANDSTONE; very fine to fine grained, slightly weathered, thickly bedded to massive, moderately fractured. @ 15.0'-15.9', highly fractured to broken. @ 15.4', 16.4', 17.3', 20.9', clay seams. @ 17.8', gray. @ 18.9', qu = 13,835 psi.						
25.0	528.0						Bottom of Boring - 25.0'						

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ├──┤ LL
Blows per foot - ○



FILE: 0121-3070-03 (11/13/2007 7:09 PM)

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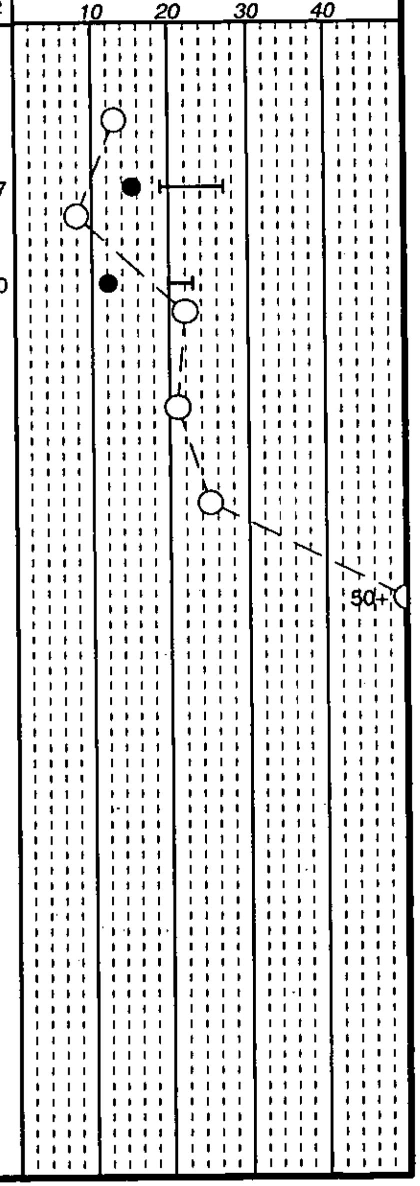
Client: TranSystems, Inc. | Project: SCI-823-0.00 | Job No. 0121-3070.03

LOG OF: Boring TR-76 | Location: Sta. 38+59.2, 27.1 ft LT of US 52 Ramp A BL | Date Drilled: 3/30/05

WATER OBSERVATIONS:
Water seepage at: None
Water level at completion: None (prior to coring)
4.0' (includes drilling water)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf) / * Point-Load Strength (psi)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0.2	555.1 / 554.9						Topsoil - 2"						
		4 6 7	12	1		4.5+	Hard brown SILT AND CLAY (A-6a), trace fine to coarse sand, trace gravel; damp.						
3.0	552.1	2 3 5	10	2		4.0	Very stiff to hard brown SANDY SILT (A-4a), trace to little clay, little gravel; damp.	15	10	--	11	47	17
		2 7 15	17	3		--		16	23	--	21	30	10
8.0	547.1	5 9 12	16	4			Medium dense brown SANDY SILT (A-4a), trace clay, little gravel; damp.						
		11 12 13	18	5			@ 11.0', contains sandstone fragments						
		1 6 50/5	17	6									
14.5	540.6						Severely weathered brown SANDSTONE.						
15.0	540.1	Core 120"	Rec 120"	RQD 64%	R1		Hard brown SANDSTONE; very fine to fine grained, moderately to highly weathered, medium bedded, moderately fractured. @ 16.4'-16.8', 17.3', 18.4', filled fractures. @ 19.4' gray @ 20.9'-21.3', fractured. @ 19.6', qu = 11,036 psi.						
25.0	530.1						Bottom of Boring - 25.0'						

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ├──┤ LL
Blows per foot - ○



APPENDIX C

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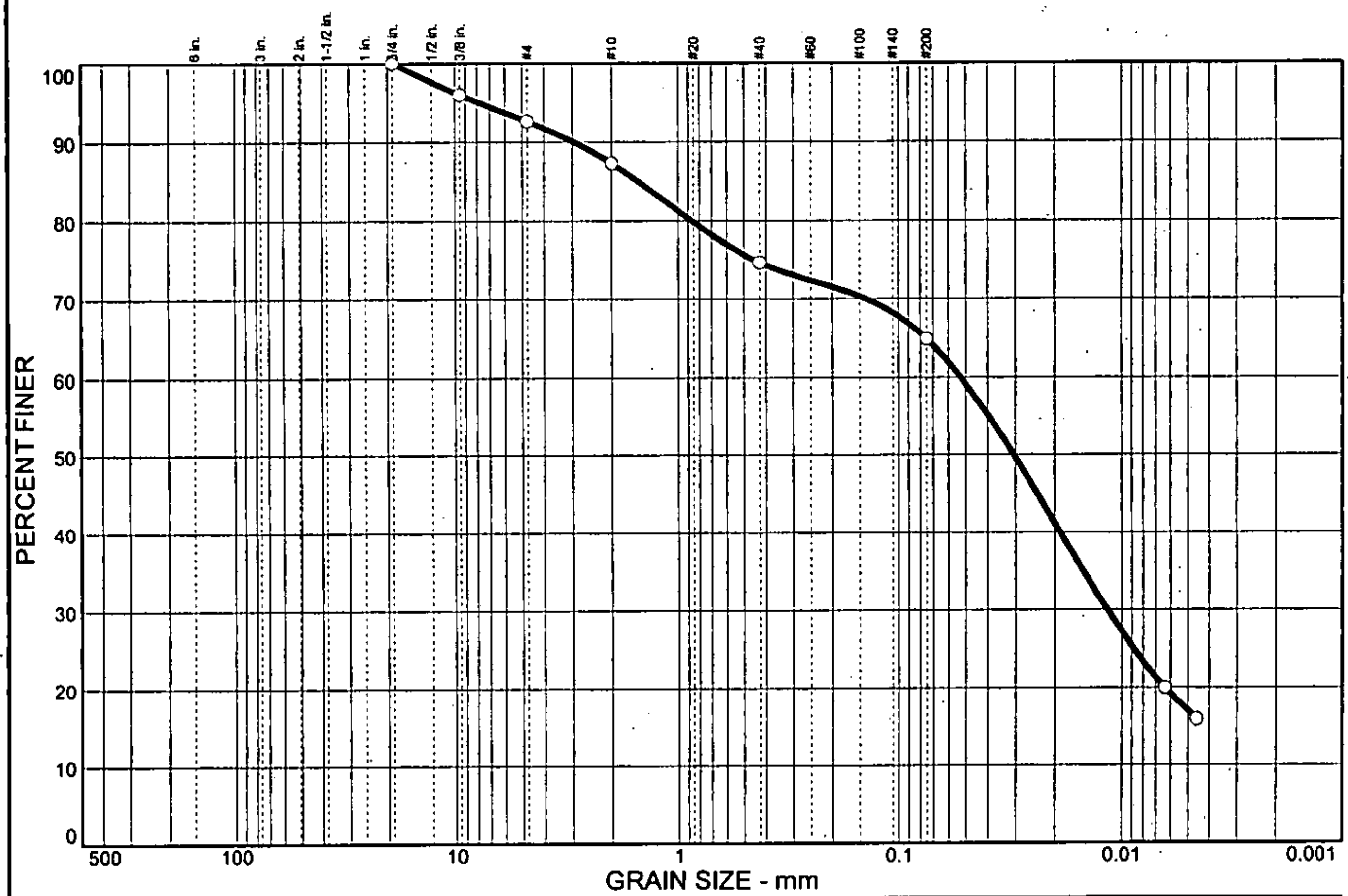
APPENDIX III

Laboratory Test Results

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	7.4	5.3	12.7	9.7	47.8	17.1

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
0.75 in.	100.0		
0.375 in.	96.0		
#4	92.6		
#10	87.3		
#40	74.6		
#200	64.9		

* (no specification provided)

Soil Description

Sandy lean clay

Atterberg Limits

PL= 19 LL= 28 PI= 9

Coefficients

D_{85}= 1.51 D_{60}= 0.0529 D_{50}= 0.0307
D_{30}= 0.0116 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO= A-4(4)

Remarks

Moisture Content= 17.7%

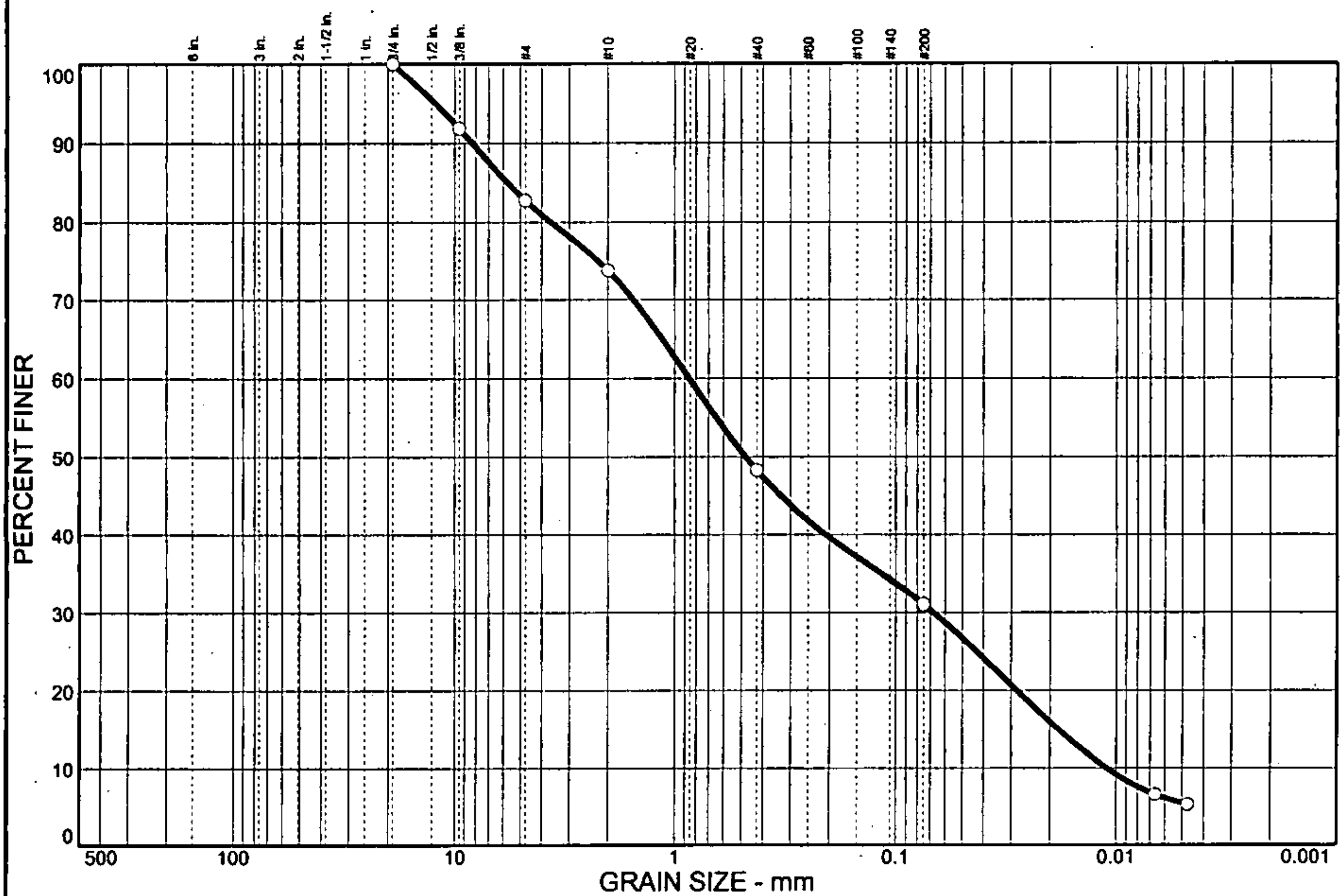
Sample No.: 2 **Source of Sample:** B-33 **Date:** 2/23/07
Location: **Elev./Depth:** 3.5

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00

Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	17.2	9.1	25.5	17.2	25.6	5.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
0.75 in.	100.0		
0.375 in.	91.8		
#4	82.8		
#10	73.7		
#40	48.2		
#200	31.0		

* (no specification provided)

Soil Description

Silty sand with gravel

Atterberg Limits

PL= 19 LL= 22 PI= 3

Coefficients

D_{85}= 5.70 D_{60}= 0.859 D_{50}= 0.479
D_{30}= 0.0679 D_{15}= 0.0183 D_{10}= 0.0111
C_u= 77.67 C_c= 0.48

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

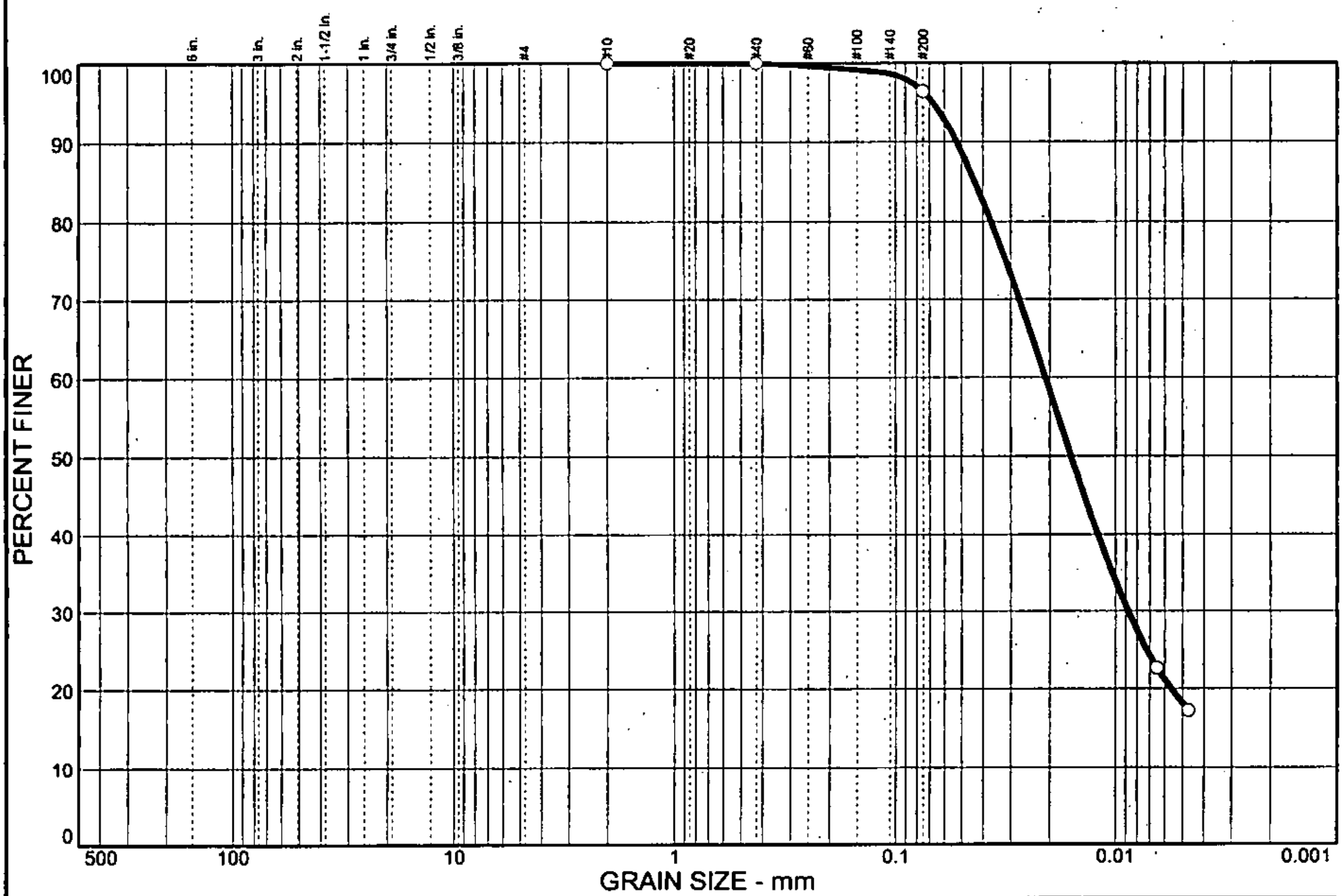
Moisture Content= 12.1%

Sample No.: 4 **Source of Sample:** B-33 **Date:** 2/23/07
Location: **Elev./Depth:** 8.5

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00
Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	0.0	3.7	78.1	18.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#40	100.0		
#200	96.3		

* (no specification provided)

Soil Description

Silty clay

Atterberg Limits

PL= 20 LL= 27 PI= 7

Coefficients

D_{85}= 0.0435 D_{60}= 0.0209 D_{50}= 0.0160
D_{30}= 0.0088 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL-ML AASHTO= A-4(6)

Remarks

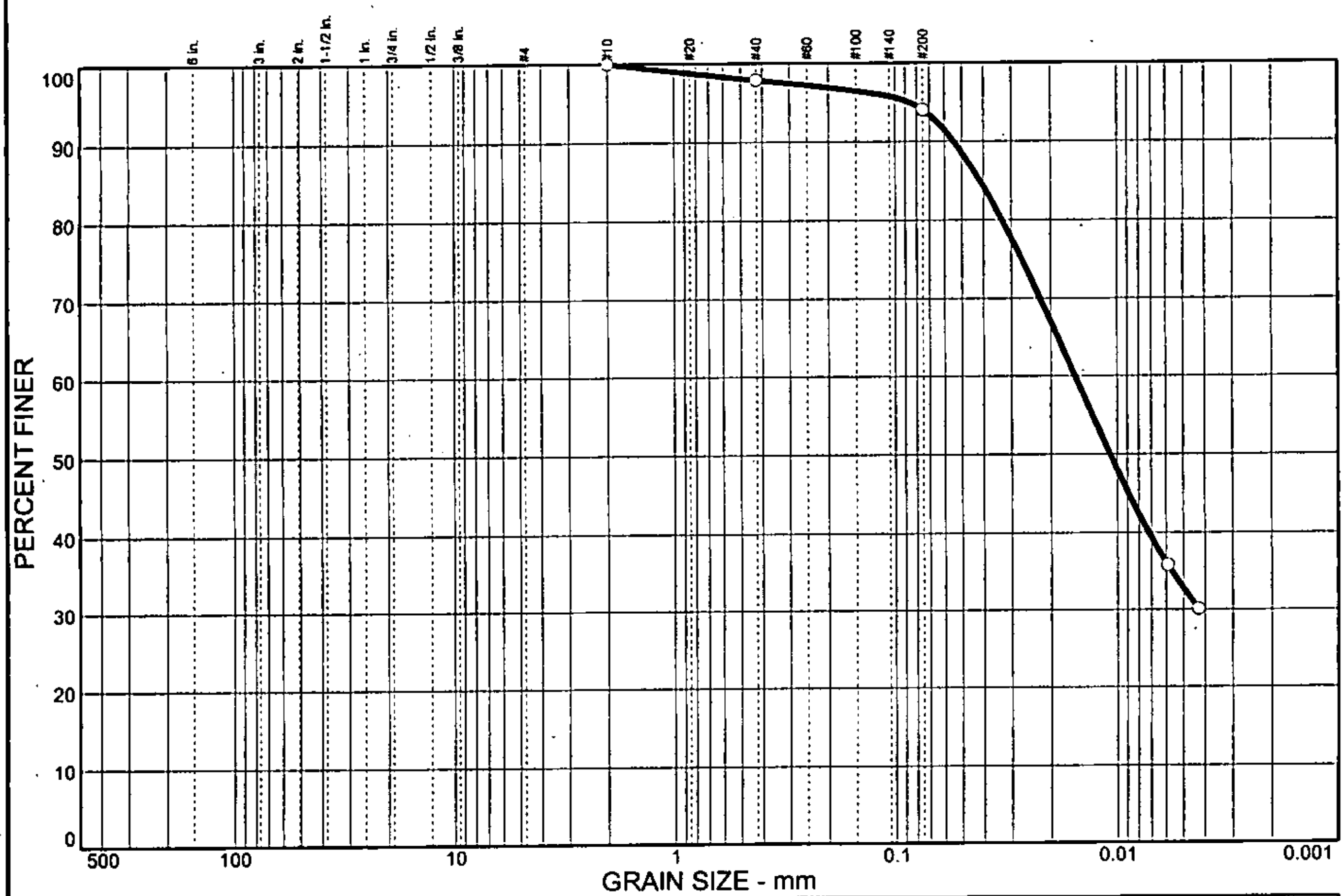
Moisture Cntent= 27.2%

Sample No.: 4 **Source of Sample:** B-1501 **Date:** 2/15/07
Location: **Elev./Depth:** 8.5

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00
Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	2.2	3.9	61.1	32.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#40	97.8		
#200	93.9		

* (no specification provided)

Soil Description

Lean clay

Atterberg Limits

PL= 19 LL= 31 PI= 12

Coefficients

D_{85}= 0.0415 D_{60}= 0.0156 D_{50}= 0.0108
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO= A-6(11)

Remarks

Moisture Content= 22.0%

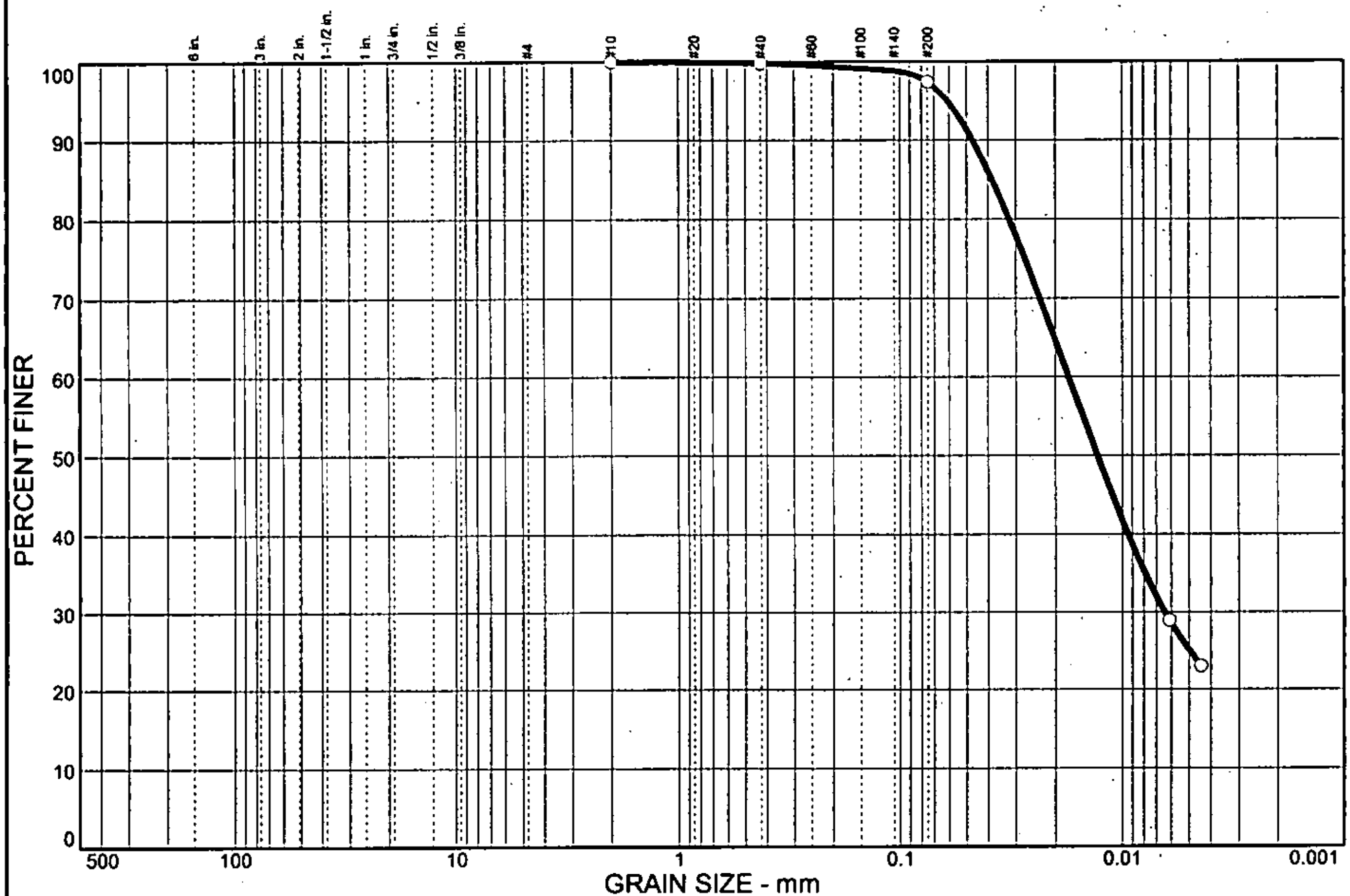
Sample No.: 2 **Source of Sample:** B-1541 **Date:** 6/11/07
Location: **Elev./Depth:** 2.0

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00

Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	0.2	2.4	72.3	25.1

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#40	99.8		
#200	97.4		

* (no specification provided)

Soil Description

Silty clay

Atterberg Limits

PL= 18 LL= 24 PI= 6

Coefficients

D_{85}= 0.0384 D_{60}= 0.0174 D_{50}= 0.0130
D_{30}= 0.0064 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL-ML AASHTO= A-4(4)

Remarks

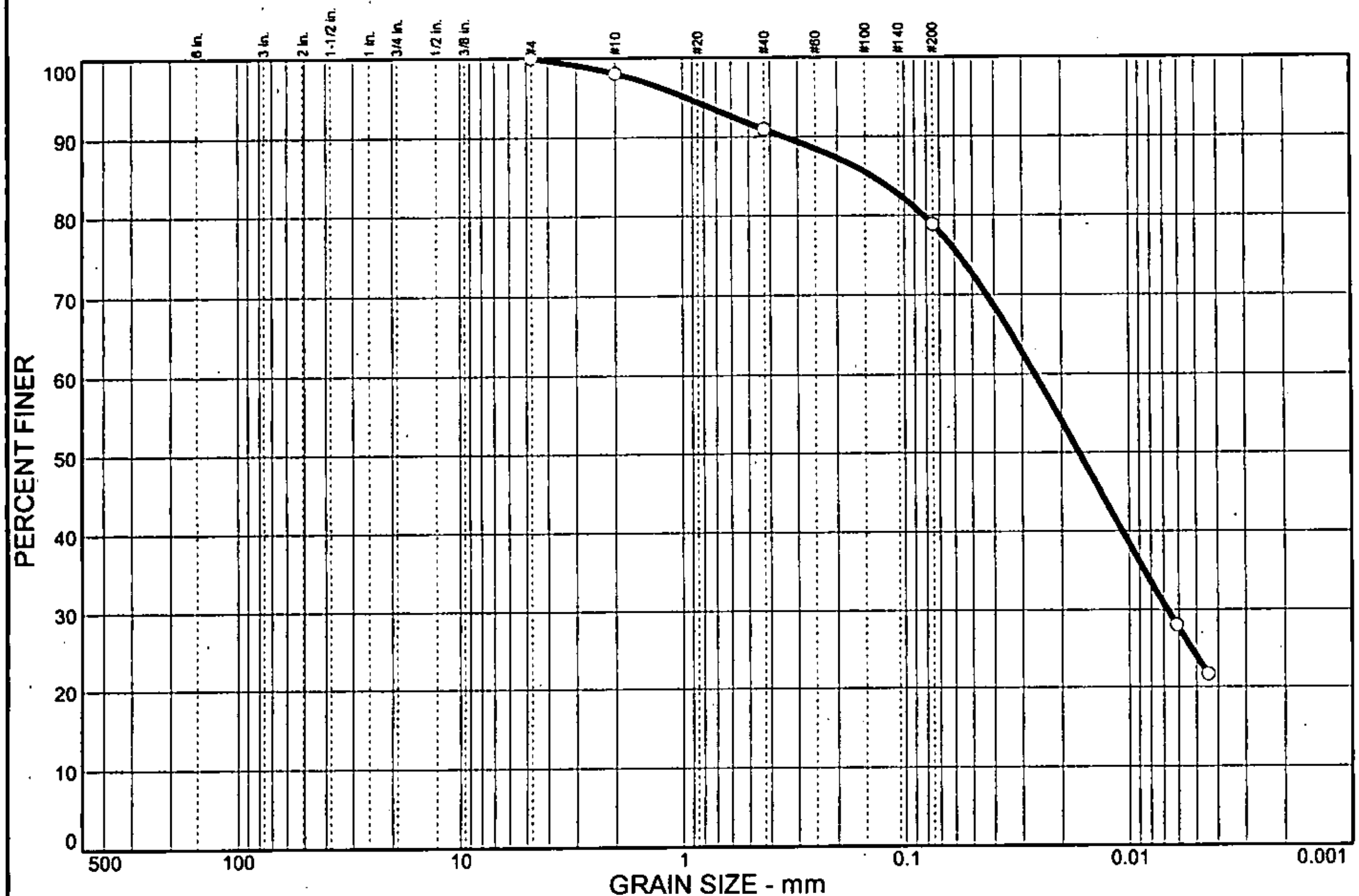
Moisture Content= 25.7%

Sample No.: 5 **Source of Sample:** B-1541 **Date:** 6/11/07
Location: **Elev./Depth:** 8.5

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00
Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	2.0	7.1	12.1	54.7	24.1

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	98.0		
#40	90.9		
#200	78.8		

* (no specification provided)

Soil Description

Lean clay with sand

Atterberg Limits

PL= 19 LL= 30 PI= 11

Coefficients

D_{85}= 0.139 D_{60}= 0.0263 D_{50}= 0.0167
D_{30}= 0.0067 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO= A-6(7)

Remarks

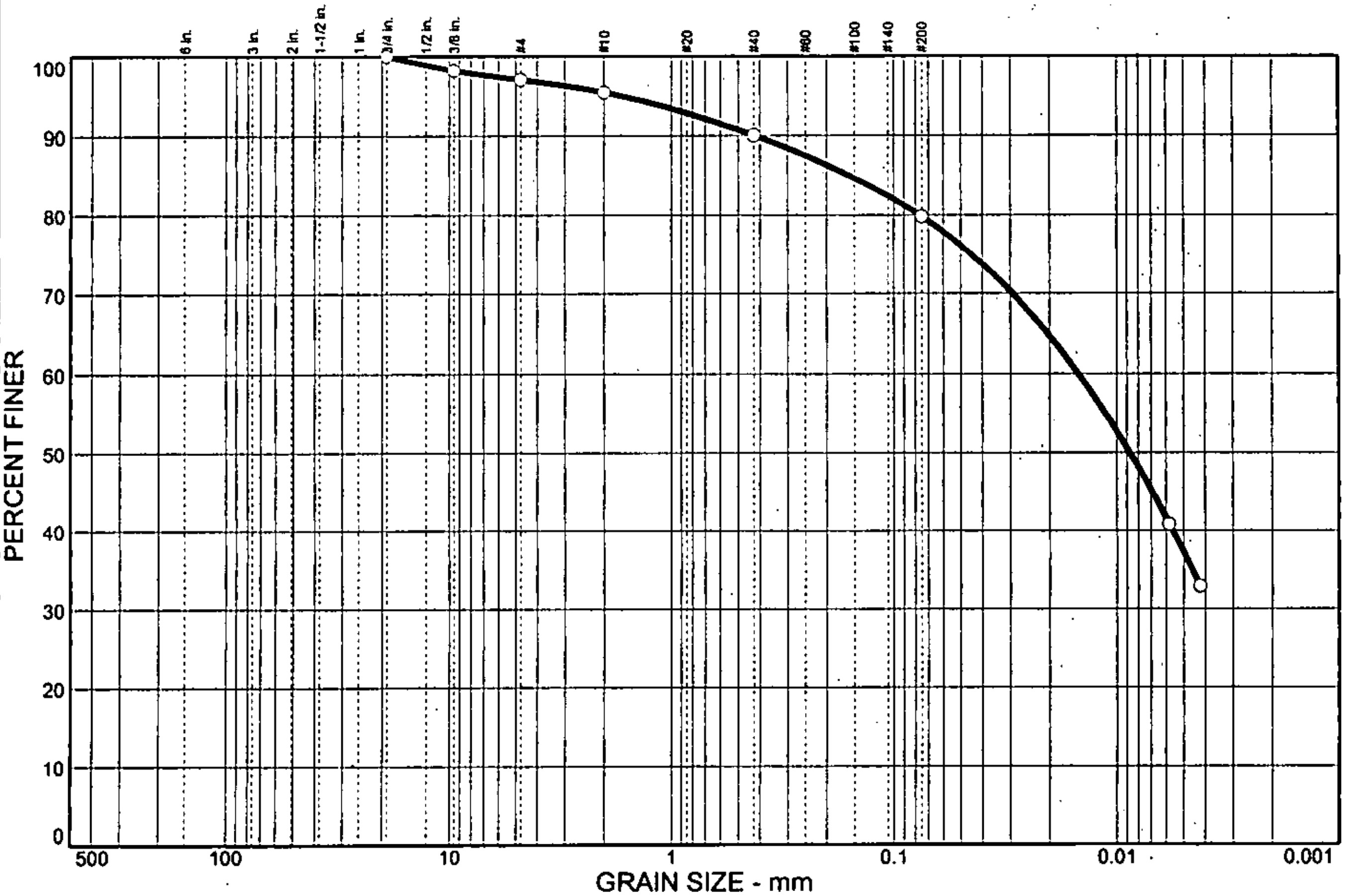
Moisture Content= 13.6%

Sample No.: 1 **Source of Sample:** TR-68A **Date:** 10/19/06
Location: **Elev./Depth:** 1.0

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00
Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	3.0	1.6	5.4	10.2	42.6	37.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
0.75 in.	100.0		
0.375 in.	98.2		
#4	97.0		
#10	95.4		
#40	90.0		
#200	79.8		

* (no specification provided)

Soil Description

Lean clay with sand

Atterberg Limits

PL= 19 LL= 39 PI= 20

Coefficients

D_{85}= 0.156 D_{60}= 0.0149 D_{50}= 0.0087
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO= A-6(15)

Remarks

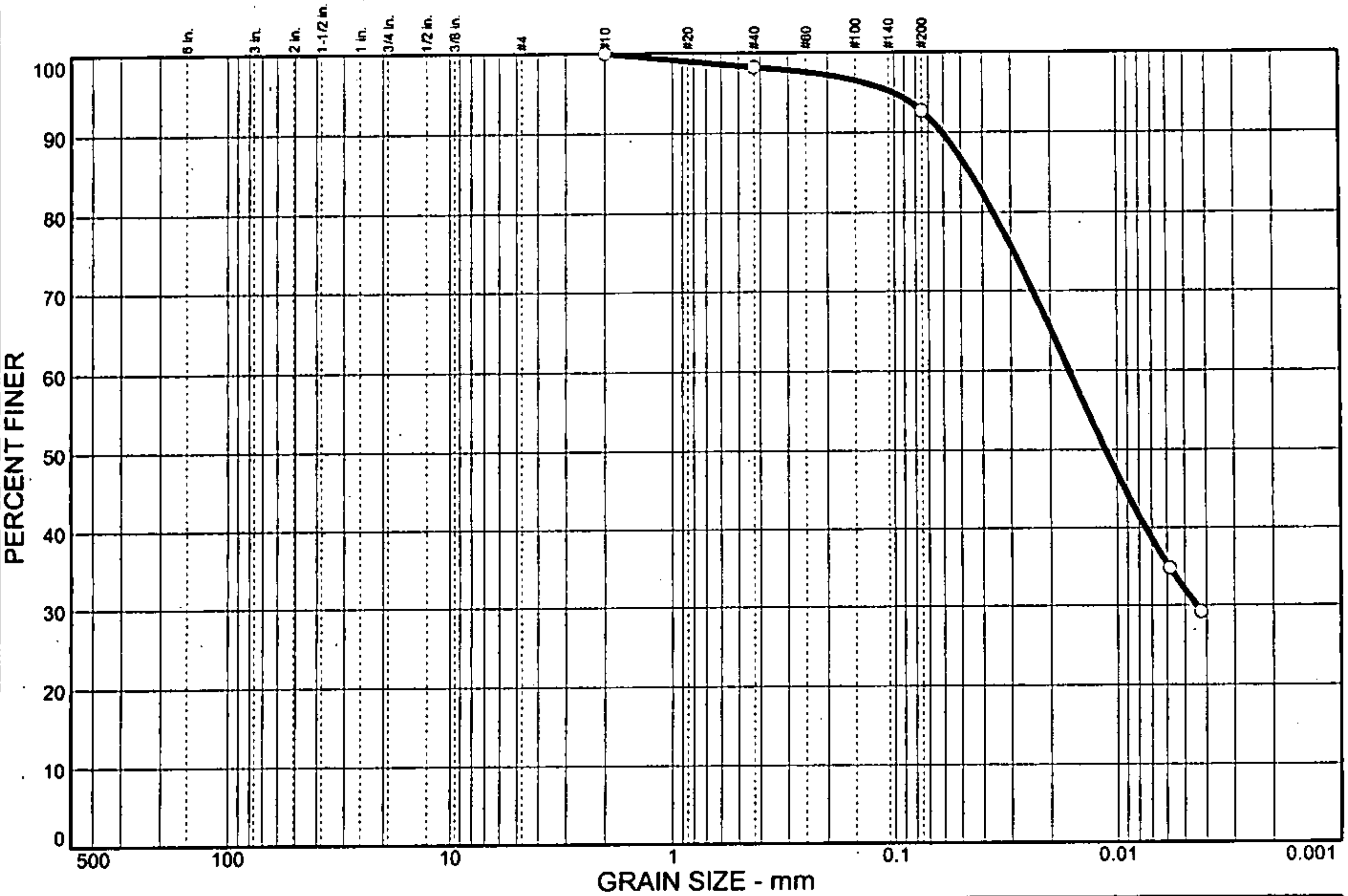
Moisture Content= 18.3%

Sample No.: 2 **Source of Sample:** TR-68A **Date:** 10/19/06
Location: **Elev./Depth:** 3.5

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00
Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	1.8	5.6	60.5	32.1

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#40	98.2		
#200	92.6		

* (no specification provided)

Soil Description

Lean clay

Atterberg Limits

PL= 19 LL= 35 PI= 16

Coefficients

D_{85}= 0.0456 D_{60}= 0.0164 D_{50}= 0.0113
D_{30}= 0.0044 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO= A-6(15)

Remarks

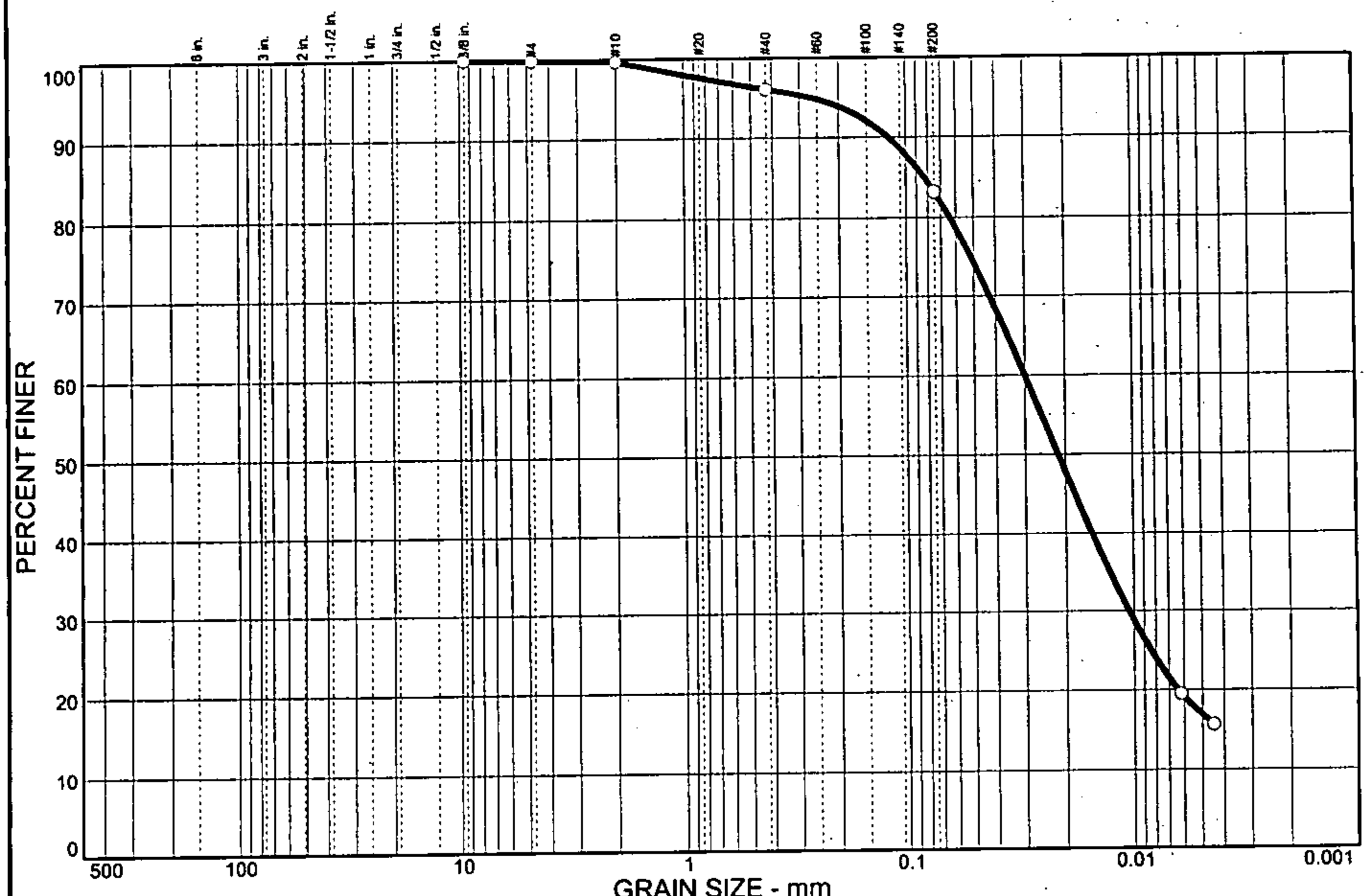
Moisture Content= 20.4%

Sample No.: 3 **Source of Sample:** TR-68A **Date:** 10/19/06
Location: **Elev./Depth:** 6.0

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00
Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.1	0.2	3.7	12.8	66.3	16.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
0.375 in.	100.0		
#4	99.9		
#10	99.7		
#40	96.0		
#200	83.2		

* (no specification provided)

Soil Description

Silty clay with sand

Atterberg Limits

PL= 19 LL= 26 PI= 7

Coefficients

D_{85}= 0.0830 D_{60}= 0.0300 D_{50}= 0.0215
D_{30}= 0.0105 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL-ML AASHTO= A-4(4)

Remarks

Moisture Content= 20.2%

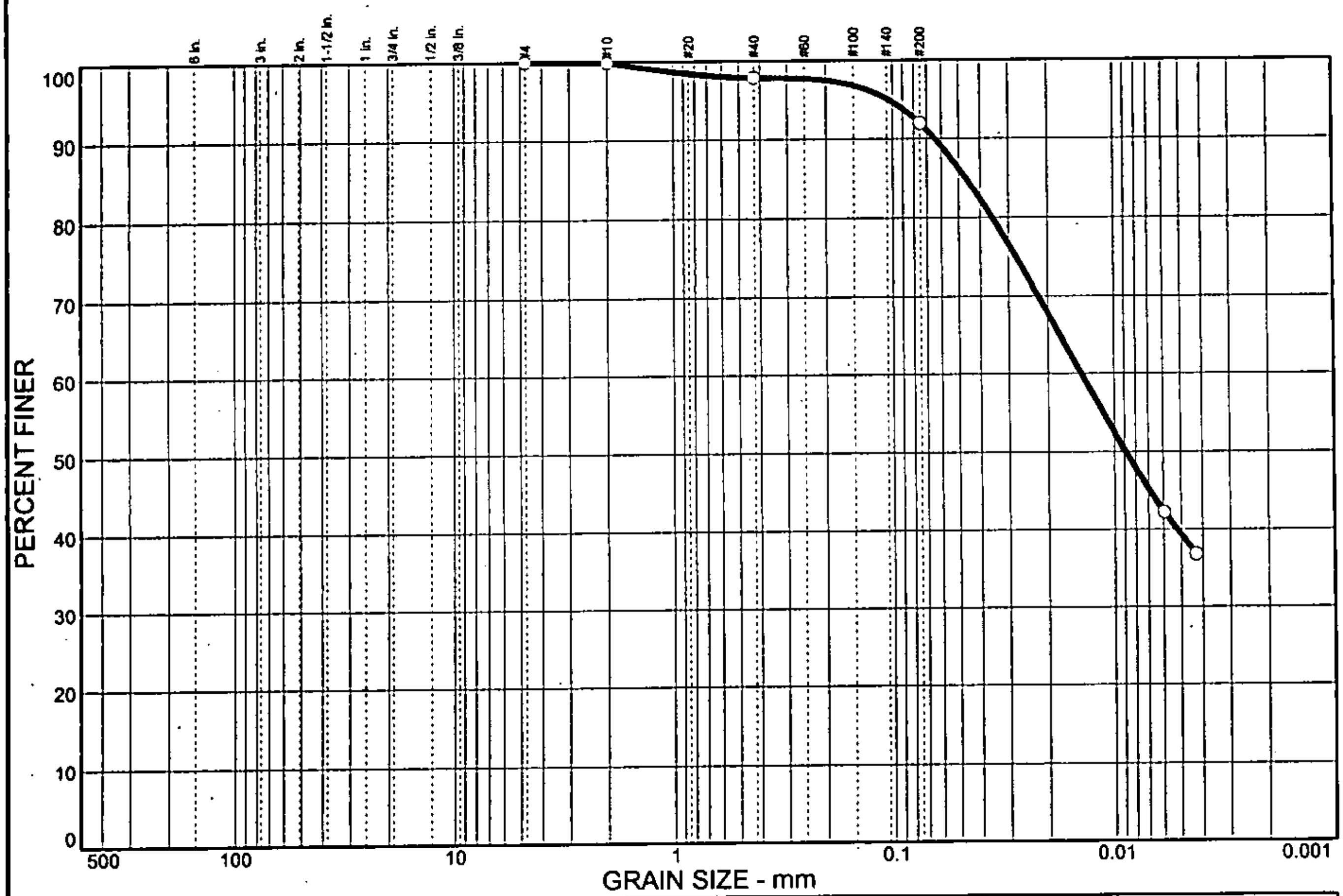
Sample No.: 4 **Source of Sample:** TR-68A **Date:** 10/19/06
Location: **Elev./Depth:** 8.5

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00

Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.1	2.1	5.9	52.6	39.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	99.9		
#40	97.8		
#200	91.9		

* (no specification provided)

Soil Description

Lean clay

Atterberg Limits

PL= 19 LL= 37 PI= 18

Coefficients

D_{85}= 0.0465 D_{60}= 0.0141 D_{50}= 0.0089
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO= A-6(17)

Remarks

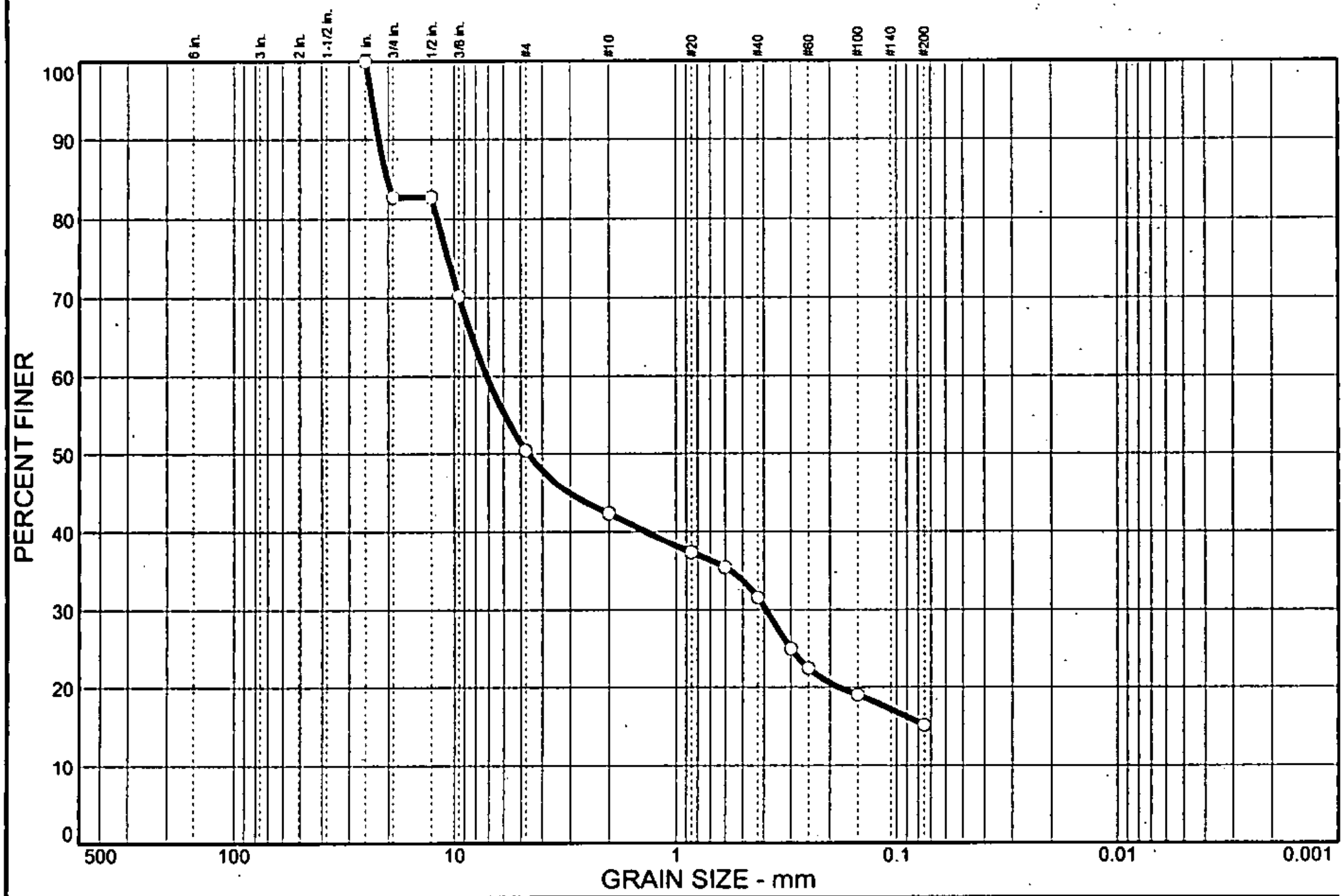
Moisture Content= 18.0%

Sample No.: 1 **Source of Sample:** TR-69A **Date:** 10/19/06
Location: **Elev./Depth:** 1.0

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00
Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	17.3	32.3	8.1	10.8	16.4	15.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.00 in.	100.0		
0.75 in.	82.7		
0.50 in.	82.7		
0.375 in.	70.2		
#4	50.4		
#10	42.3		
#20	37.3		
#30	35.4		
#40	31.5		
#50	24.9		
#60	22.4		
#100	19.0		
#200	15.1		

* (no specification provided)

Soil Description

Silty gravel with sand

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 20.3 D_{60}= 7.12 D_{50}= 4.64
D_{30}= 0.391 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= GM AASHTO= A-1-b

Remarks

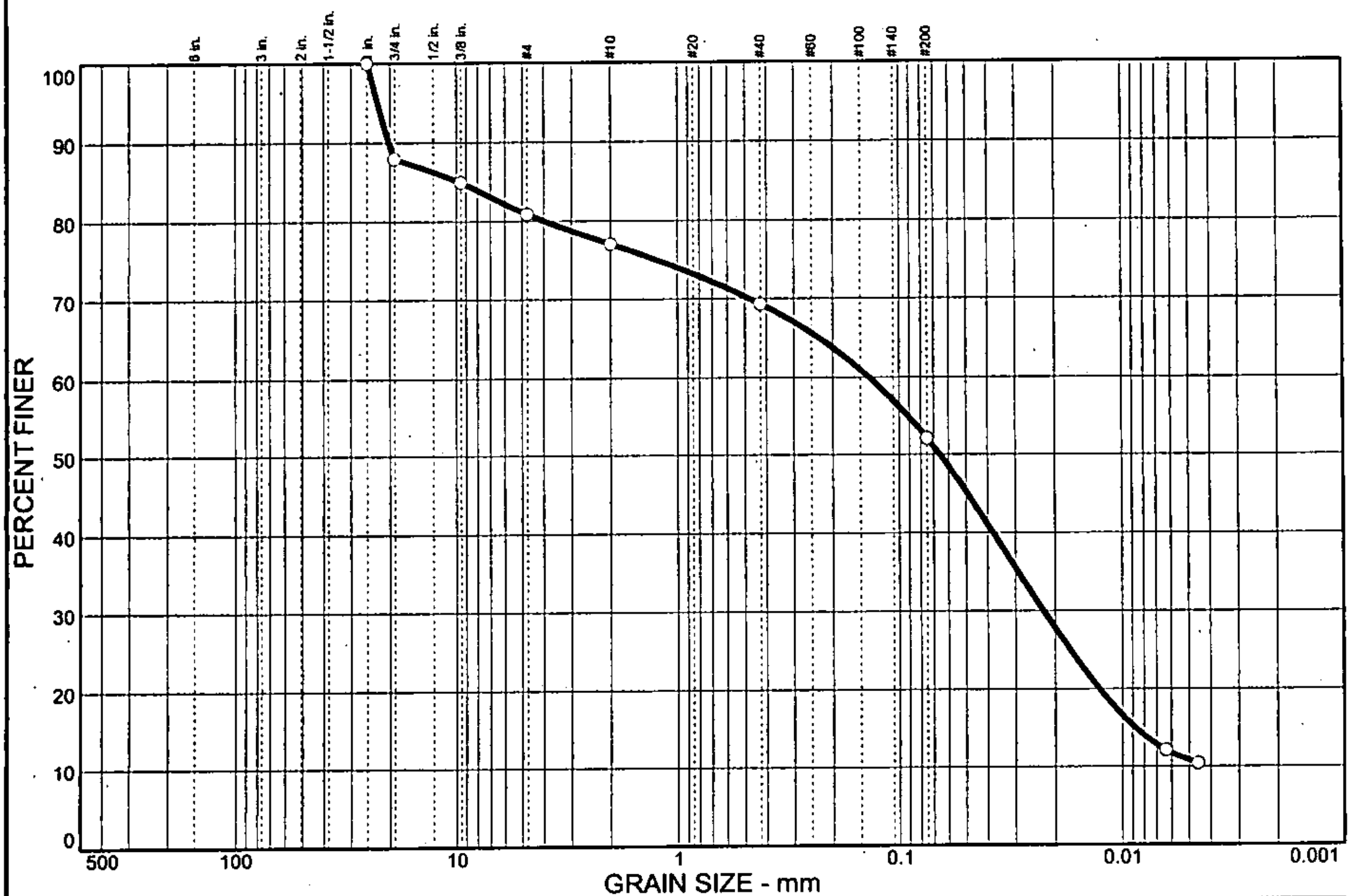
Moisture Content= 7.9%

Sample No.: 4 **Source of Sample:** TR-69A **Date:** 10/19/06
Location: **Elev./Depth:** 8.5

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00
Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	12.1	7.0	3.9	7.7	17.2	41.3	10.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.00 in.	100.0		
0.75 in.	87.9		
0.375 in.	84.9		
#4	80.9		
#10	77.0		
#40	69.3		
#200	52.1		

* (no specification provided)

Soil Description

Sandy silty clay with gravel

Atterberg Limits

PL= 17 LL= 23 PI= 6

Coefficients

D_{85}= 9.72 D_{60}= 0.137 D_{50}= 0.0658
D_{30}= 0.0225 D_{15}= 0.0087 D_{10}=
C_u= C_c=

Classification

USCS= CL-ML AASHTO= A-4(0)

Remarks

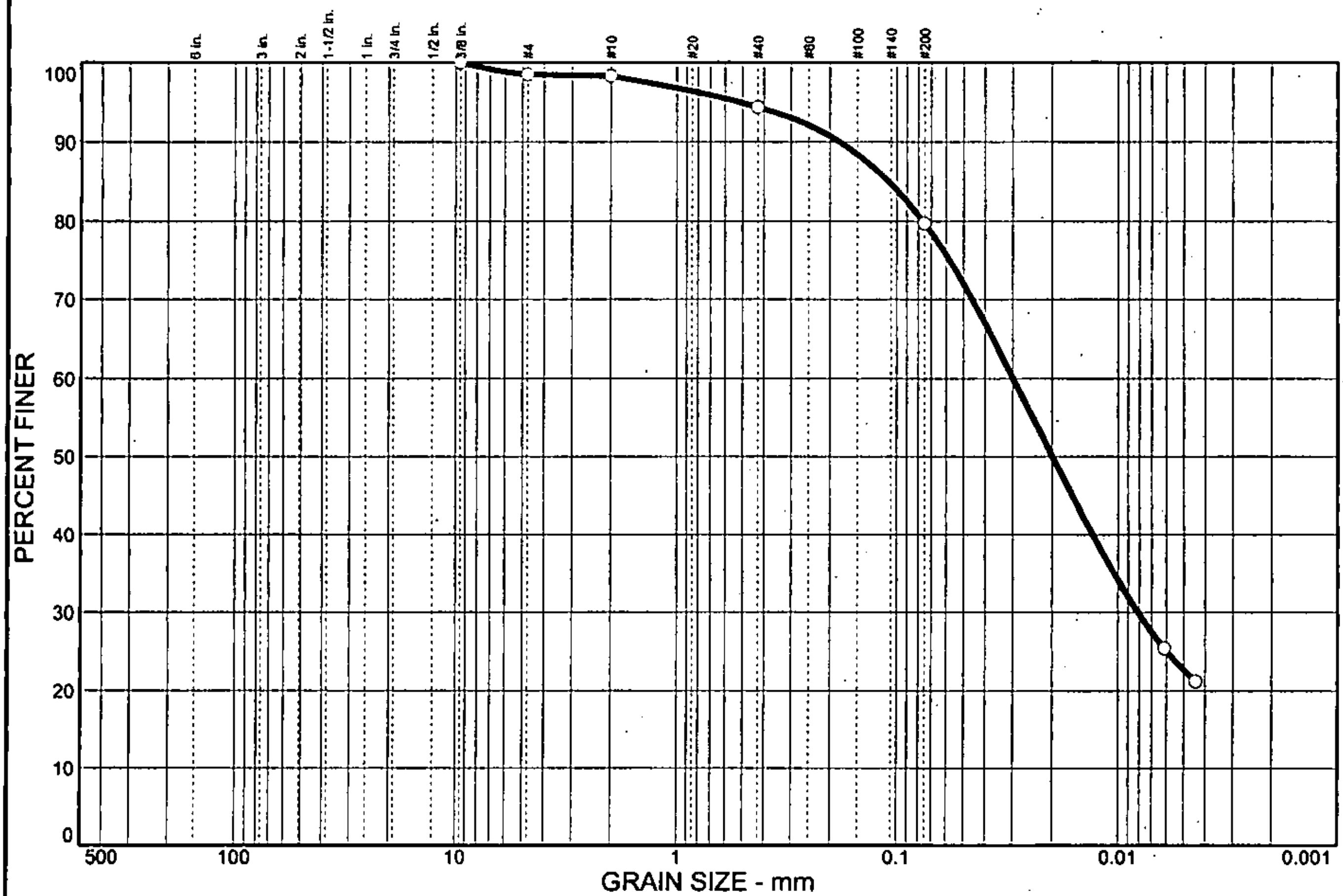
Moisture Content= 14.6%

Sample No.: 5 **Source of Sample:** TR-69A **Date:** 10/19/06
Location: **Elev./Depth:** 11.0

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00
Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	1.5	0.2	4.0	14.6	57.0	22.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
0.375 in.	100.0		
#4	98.5		
#10	98.3		
#40	94.3		
#200	79.7		

* (no specification provided)

Soil Description

Lean clay with sand

Atterberg Limits

PL= 18 LL= 29 PI= 11

Coefficients

D_{85}= 0.108 D_{60}= 0.0299 D_{50}= 0.0199
D_{30}= 0.0081 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO= A-6(7)

Remarks

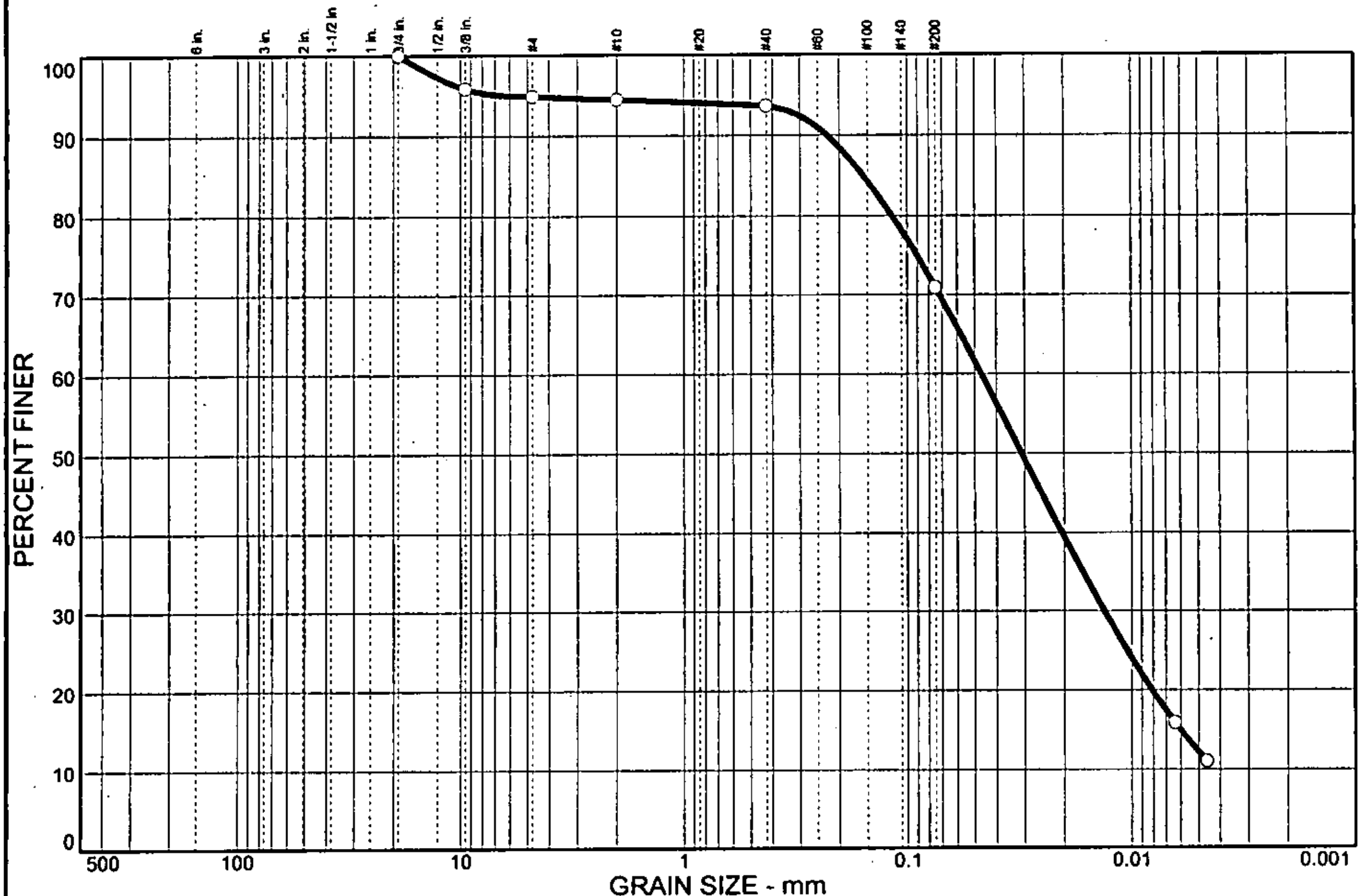
Moisture Content= 21.8%

Sample No.: 2 **Source of Sample:** TR-70A **Date:** 10/19/06
Location: **Elev./Depth:** 3.5

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00
Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	5.2	0.4	0.8	22.7	58.7	12.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
0.75 in.	100.0		
0.375 in.	95.8		
#4	94.8		
#10	94.4		
#40	93.6		
#200	70.9		

* (no specification provided)

Soil Description

Silt with sand

Atterberg Limits

PL= 20 LL= 21 PI= 1

Coefficients

D_{85}= 0.156 D_{60}= 0.0468 D_{50}= 0.0310
D_{30}= 0.0133 D_{15}= 0.0060 D_{10}=
C_u= C_c=

Classification

USCS= ML AASHTO= A-4(0)

Remarks

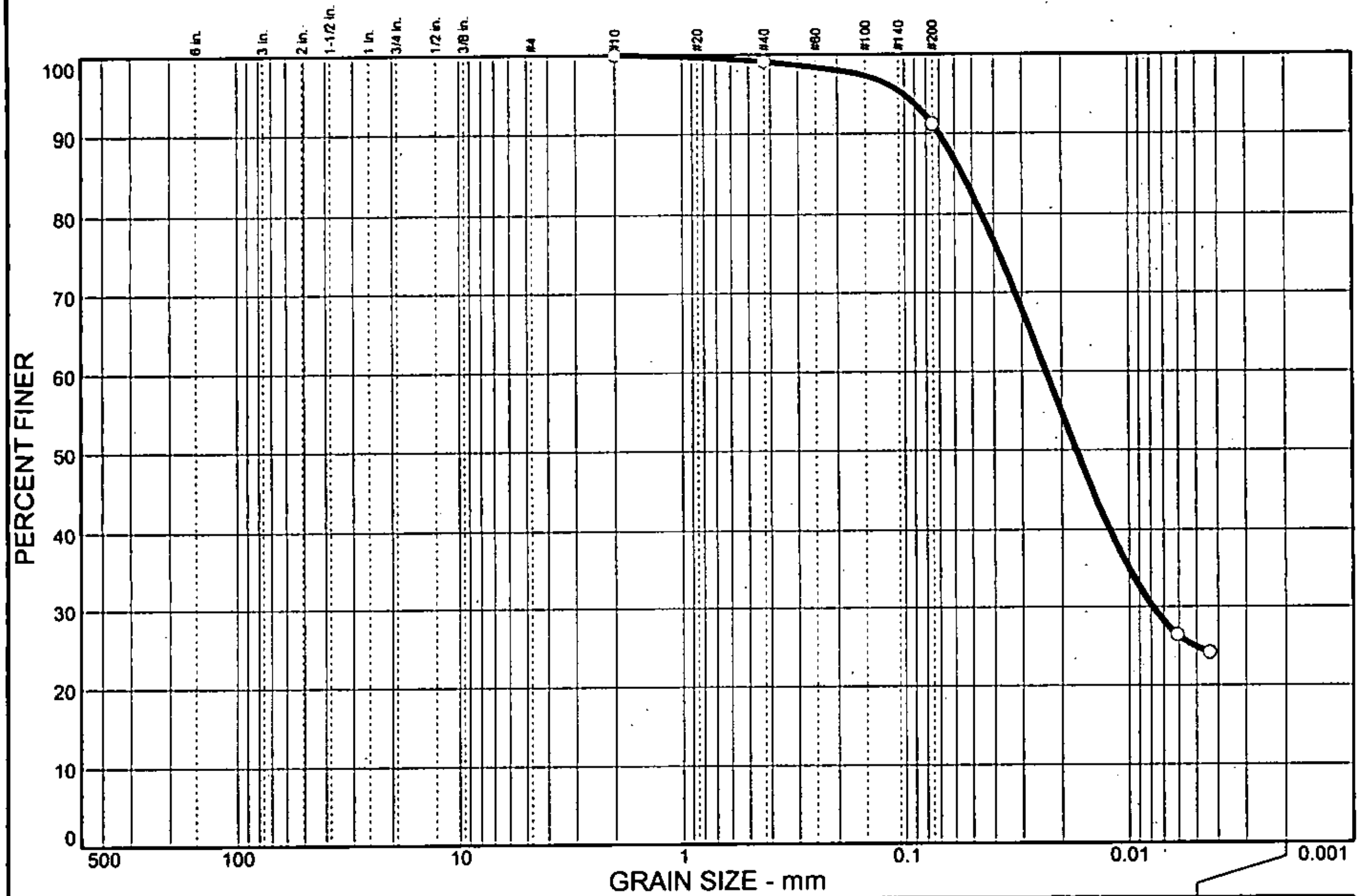
Moisture Content= 23.6%

Sample No.: 4 **Source of Sample:** TR-70A **Date:** 10/19/06
Location: **Elev./Depth:** 8.5

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00
Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	0.9	8.0	91.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#40	99.1		
#200	91.1		

* (no specification provided)

Soil Description

Lean clay

Atterberg Limits

PL= 20 LL= 30 PI= 10

Coefficients

D_{85}= 0.0553 D_{60}= 0.0235 D_{50}= 0.0172
D_{30}= 0.0078 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO= A-4(8)

Remarks

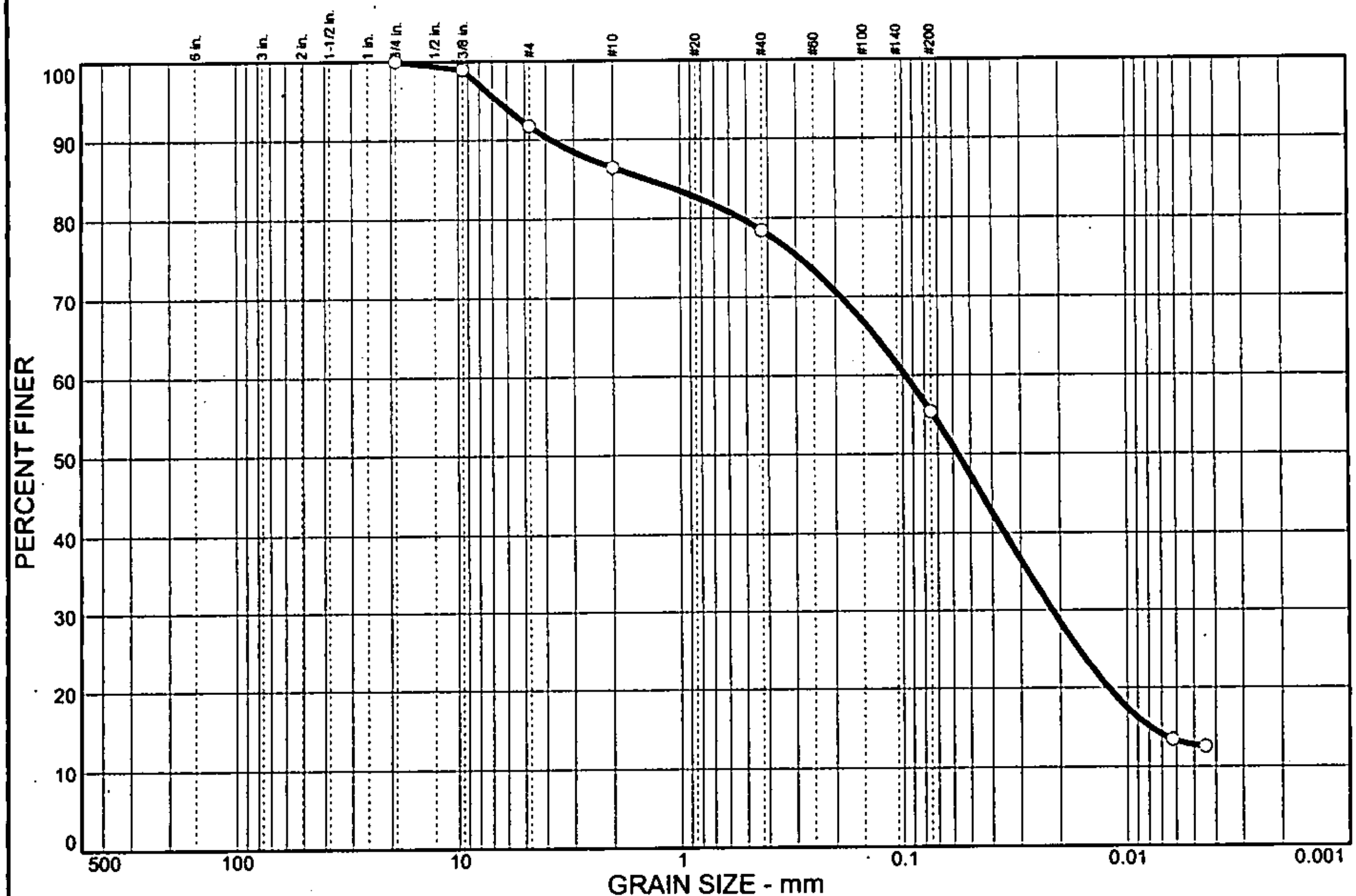
Moisture Content= 18.2%

Sample No.: 2 **Source of Sample:** TR-71A **Date:** 10/23/06
Location: **Elev./Depth:** 3.5

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00
Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	8.3	5.2	8.1	23.1	42.6	12.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
0.75 in.	100.0		
0.375 in.	98.9		
#4	91.7		
#10	86.5		
#40	78.4		
#200	55.3		

* (no specification provided)

Soil Description

Sandy lean clay

Atterberg Limits

PL= 16 LL= 24 PI= 8

Coefficients

D_{85}= 1.41 D_{60}= 0.0974 D_{50}= 0.0572
D_{30}= 0.0217 D_{15}= 0.0079 D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO= A-4(2)

Remarks

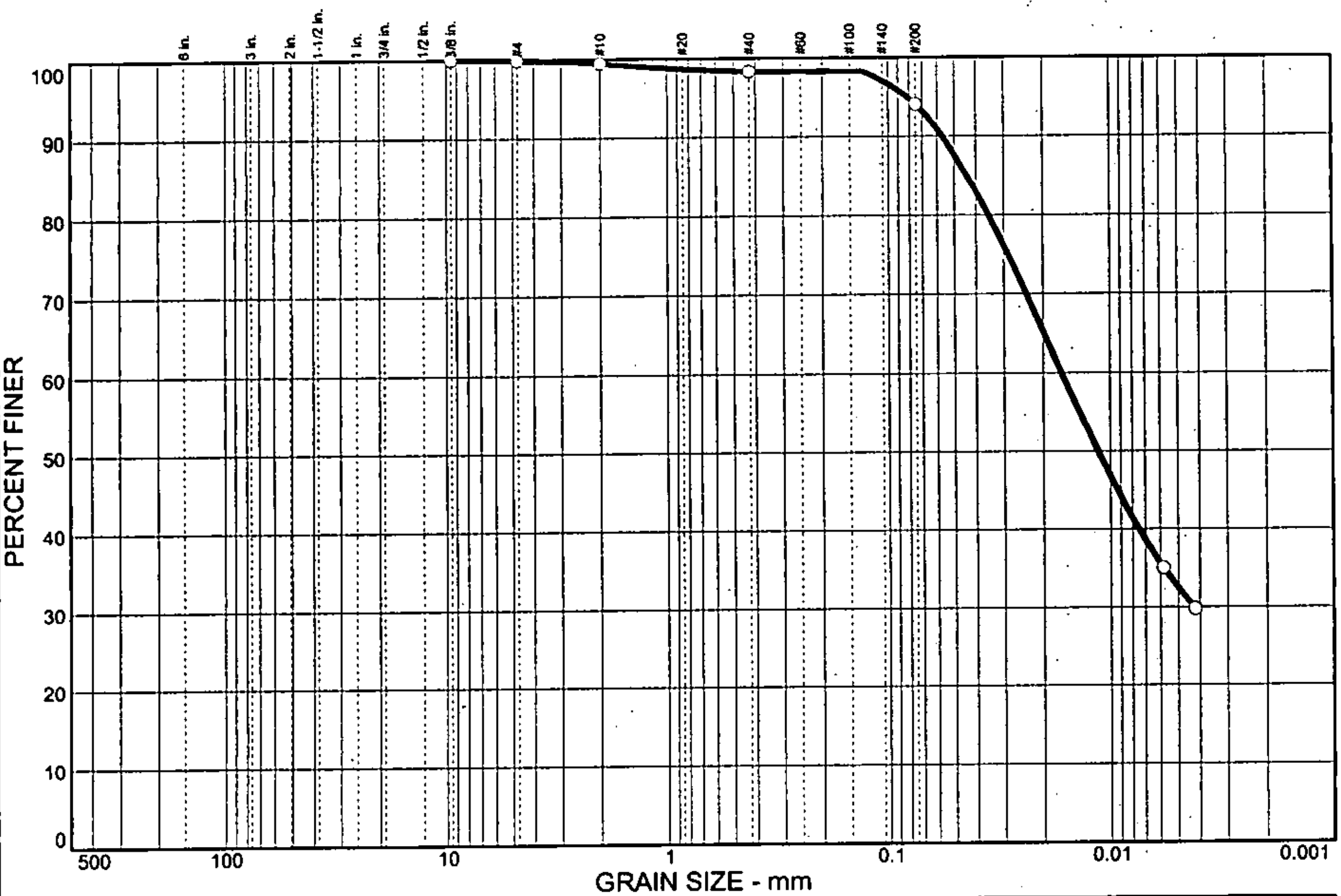
Moisture Content= 17.0%

Sample No.: 4 **Source of Sample:** TR-71A **Date:** 10/23/06
Location: **Elev./Depth:** 8.5

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00
Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.1	0.4	1.2	4.3	61.5	32.5

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
0.375 in.	100.0		
#4	99.9		
#10	99.5		
#40	98.3		
#200	94.0		

* (no specification provided)

Soil Description

Lean clay

Atterberg Limits

PL= 21 LL= 36 PI= 15

Coefficients

D_{85}= 0.0440 D_{60}= 0.0165 D_{50}= 0.0114
D_{30}= 0.0042 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO= A-6(15)

Remarks

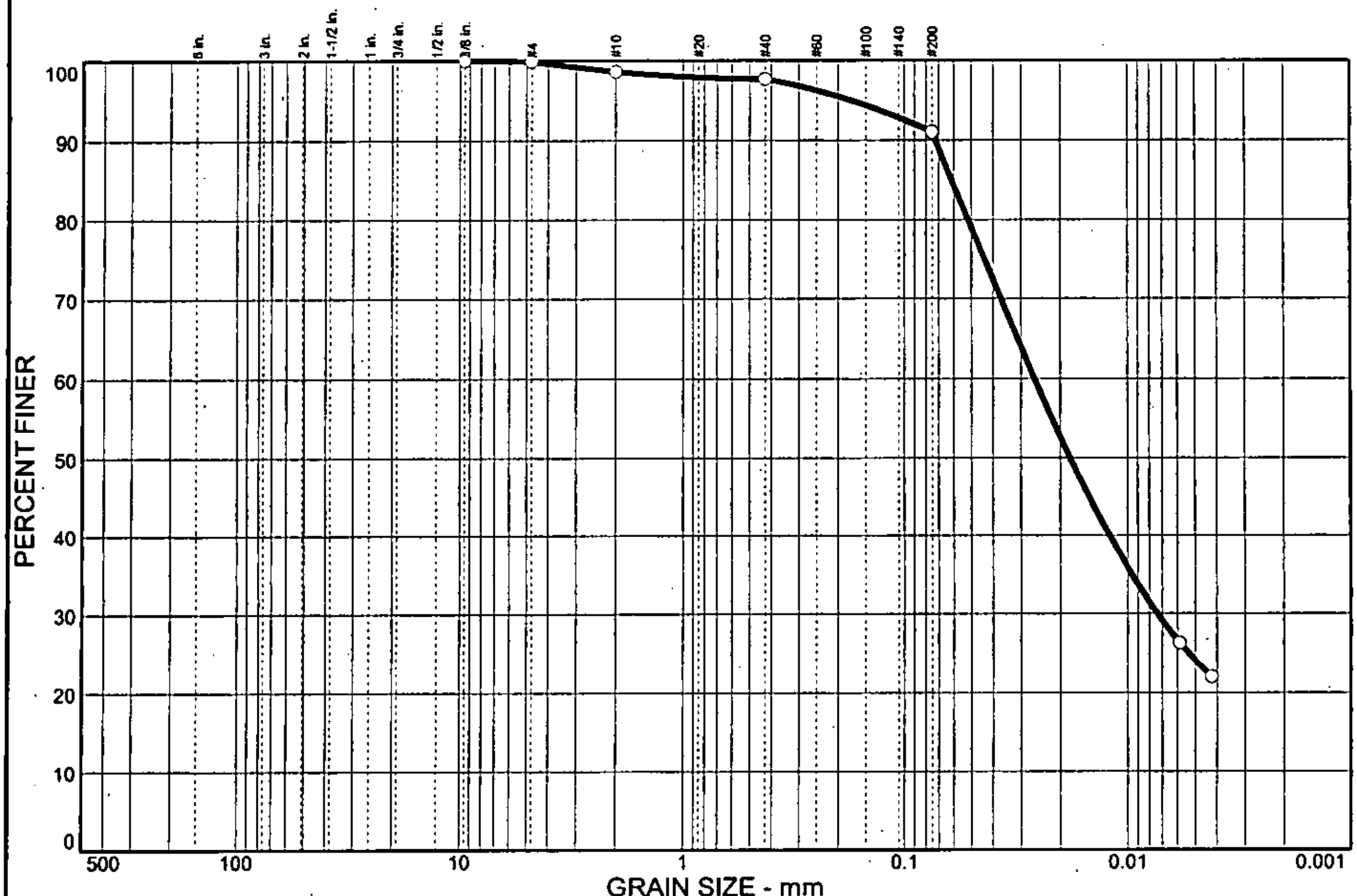
Moisture Content = 21.1%

Sample No.: 1 **Source of Sample:** TR-73A **Date:** 08/16/06
Location: **Elev./Depth:** 1.0

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00
Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.1	1.3	1.0	6.6	66.9	24.1

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
0.375 in.	100.0		
#4	99.9		
#10	98.6		
#40	97.6		
#200	91.0		

* (no specification provided)

Soil Description

Lean clay

Atterberg Limits

PL= 19 LL= 28 PI= 9

Coefficients

D_{85}= 0.0613 D_{60}= 0.0261 D_{50}= 0.0181
D_{30}= 0.0074 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO= A-4(7)

Remarks

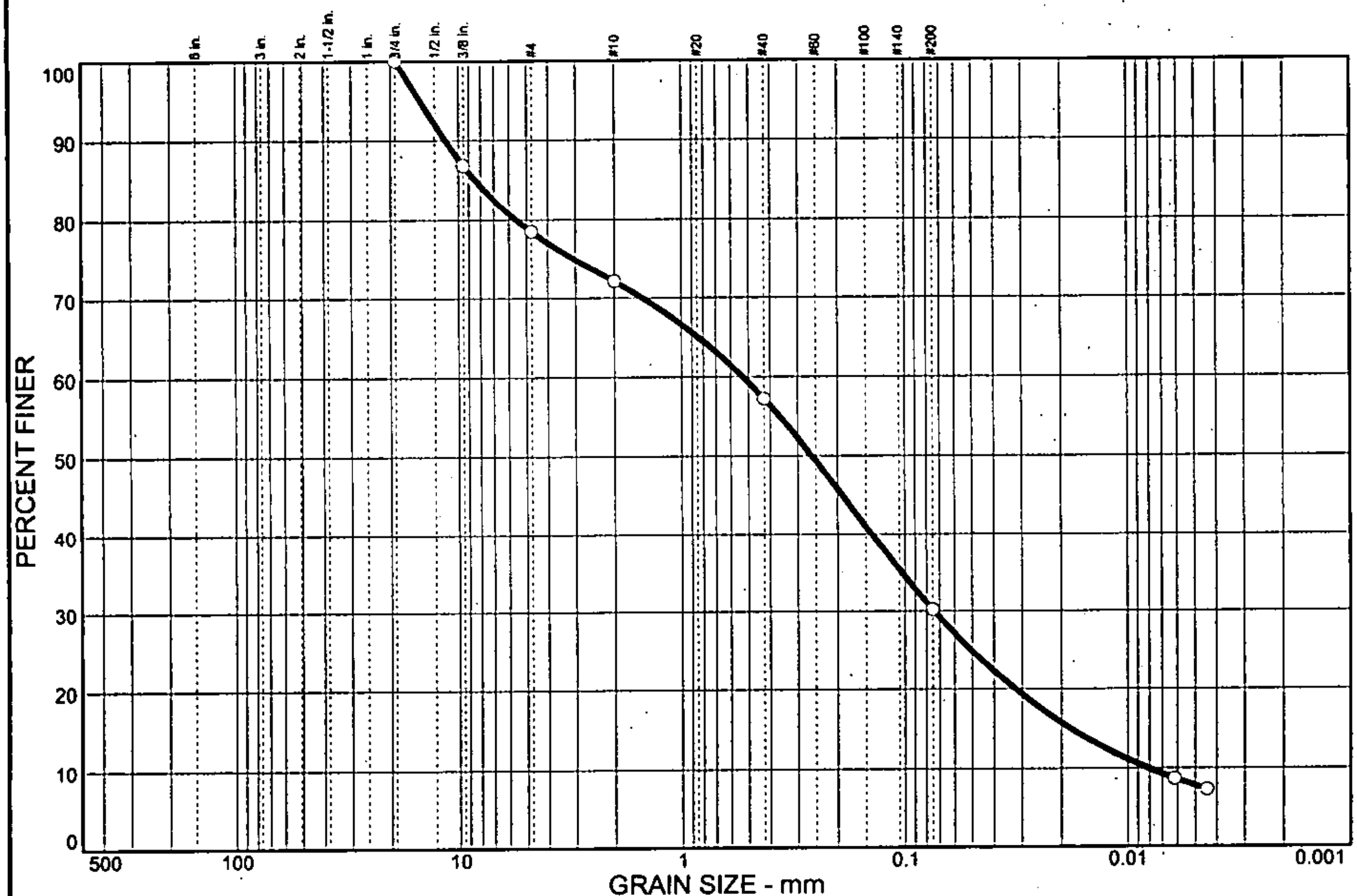
Moisture Content = 23.3%

Sample No.: 2 **Source of Sample:** TR-73A **Date:** 08/16/06
Location: **Elev./Depth:** 3.5

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00
Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	21.5	6.4	14.9	27.0	22.4	7.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
0.75 in.	100.0		
0.375 in.	86.9		
#4	78.5		
#10	72.1		
#40	57.2		
#200	30.2		

* (no specification provided)

Soil Description

Silty, clayey sand with gravel

Atterberg Limits

PL= 14 LL= 18 PI= 4

Coefficients

D_{85}= 8.40 D_{60}= 0.529 D_{50}= 0.261
D_{30}= 0.0739 D_{15}= 0.0180 D_{10}= 0.0081
C_u= 65.31 C_c= 1.27

Classification

USCS= SC-SM AASHTO= A-2-4(0)

Remarks

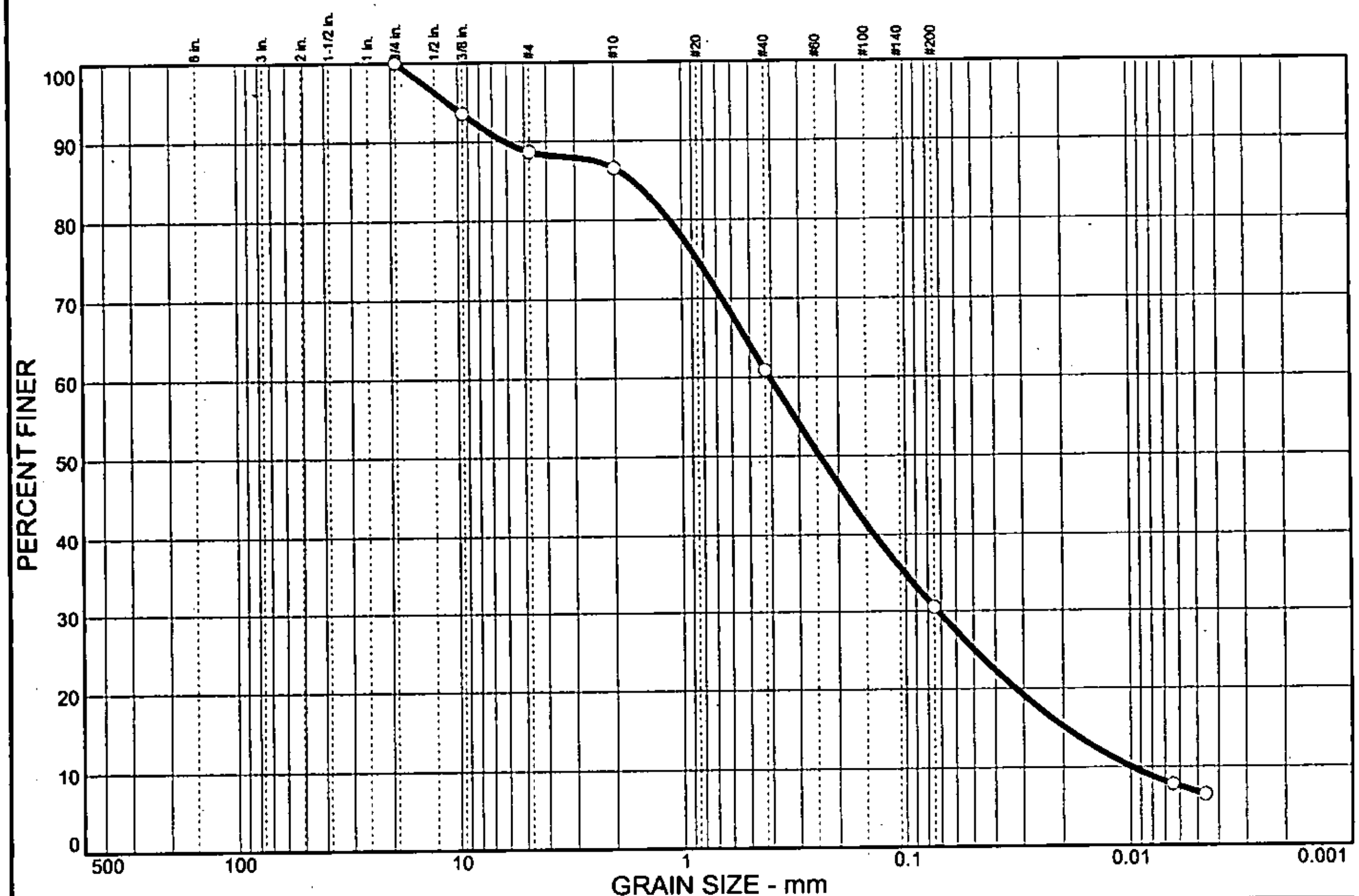
Moisture Content = 13.4%

Sample No.: 5A **Source of Sample:** TR-73A **Date:** 08/16/06
Location: **Elev./Depth:** 11.0

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00
Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	11.3	2.1	25.7	30.4	23.7	6.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
0.75 in.	100.0		
0.375 in.	93.5		
#4	88.7		
#10	86.6		
#40	60.9		
#200	30.5		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 1.65 D_{60}= 0.407 D_{50}= 0.244
D_{30}= 0.0724 D_{15}= 0.0195 D_{10}= 0.0099
C_u= 41.12 C_c= 1.30

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

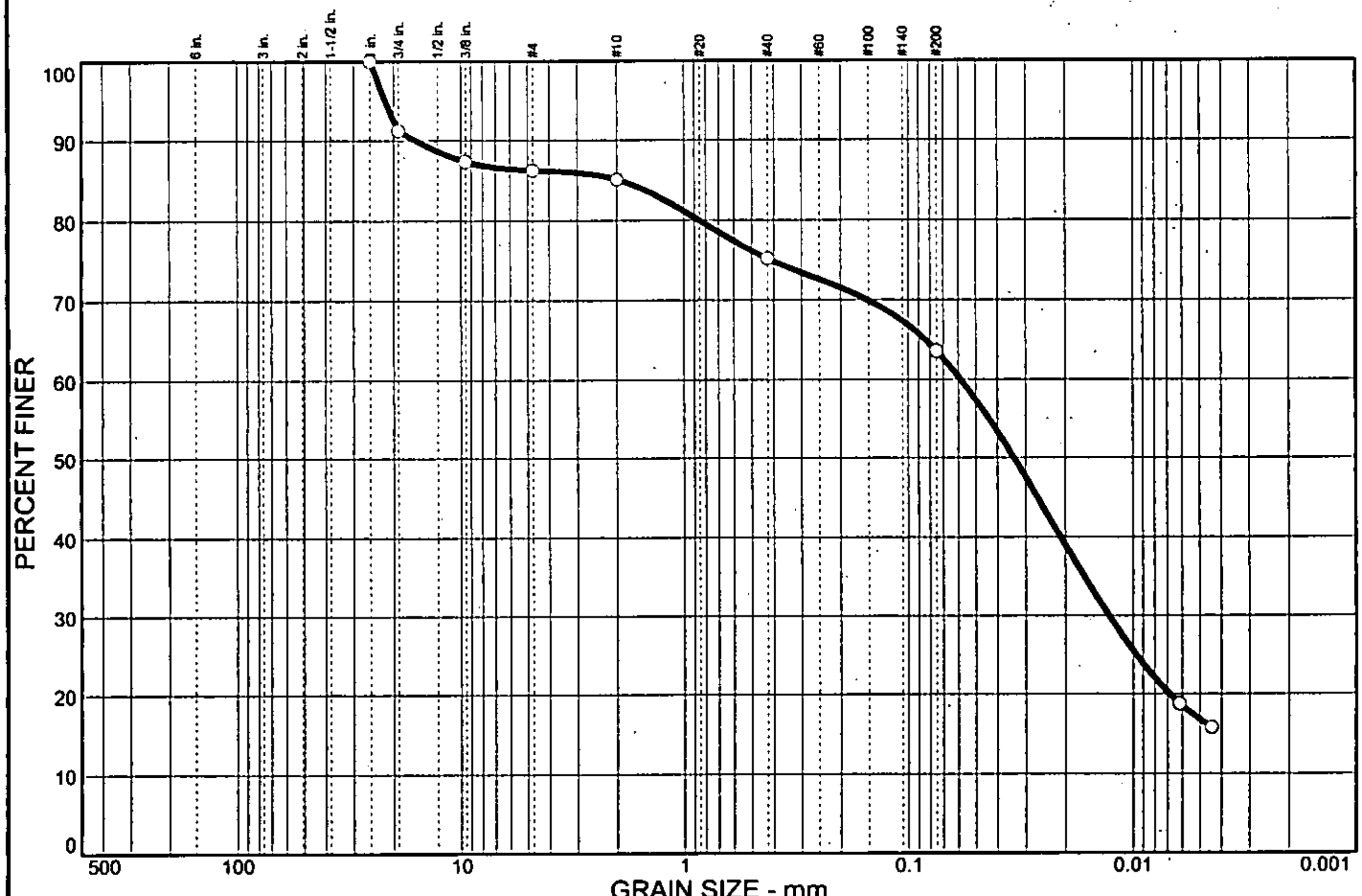
Moisture Content= 11.5%

Sample No.: 4 **Source of Sample:** TR-75 **Date:** 5/28/05
Location: **Elev./Depth:** 8.5

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00
Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	8.8	4.9	1.2	10.0	11.5	46.8	16.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.00 in.	100.0		
0.75 in.	91.2		
0.375 in.	87.4		
#4	86.3		
#10	85.1		
#40	75.1		
#200	63.6		

* (no specification provided)

Soil Description

Sandy lean clay

Atterberg Limits

PL= 19 LL= 27 PI= 8

Coefficients

D_{85}= 1.9574 D_{60}= 0.0585 D_{50}= 0.0339
D_{30}= 0.0128 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO= A-4(3)

Remarks

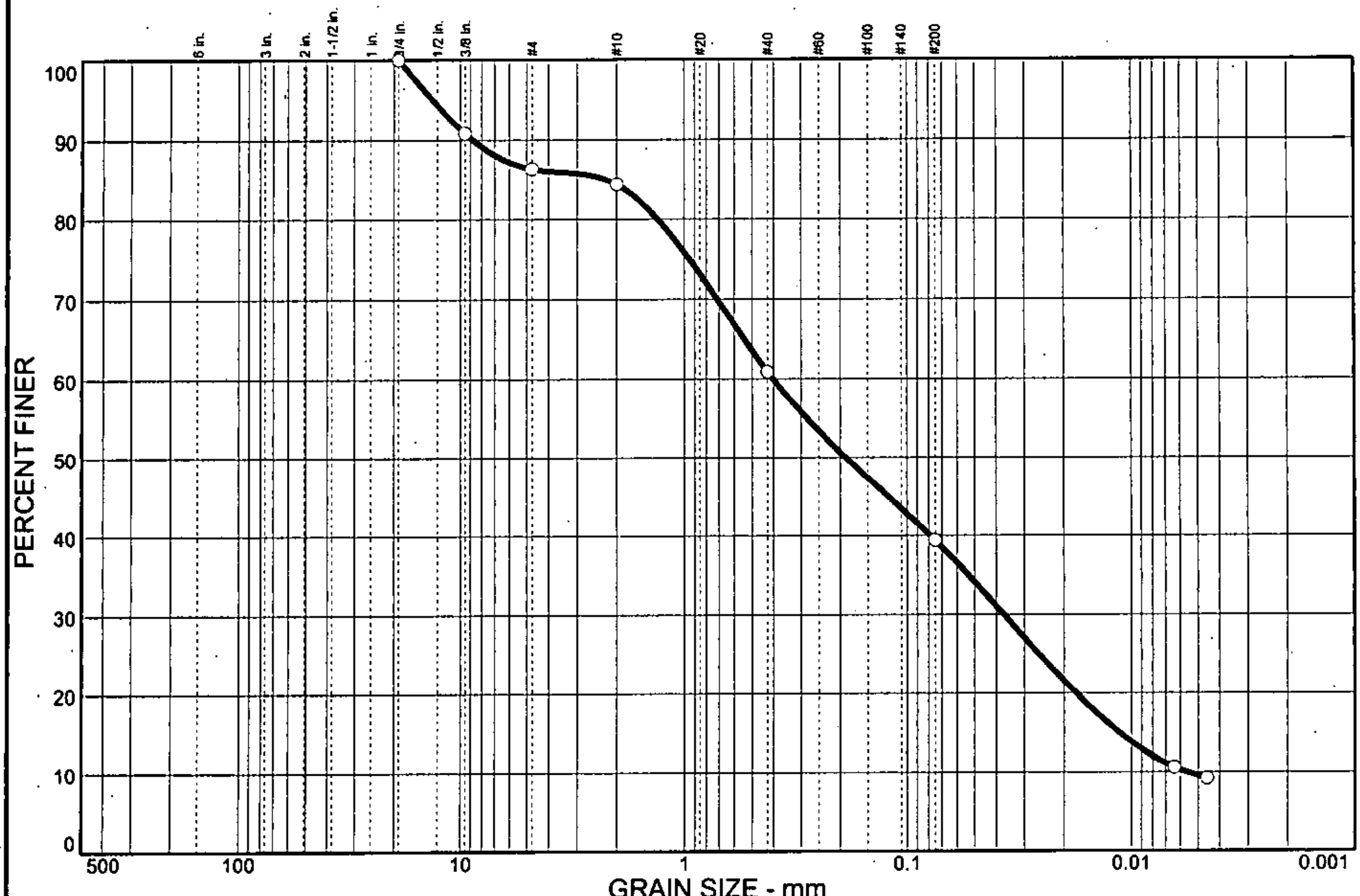
Moisture Content= 15.3%

Sample No.: 2 **Source of Sample:** TR-76 **Date:** 5/28/05
Location: **Elev./Depth:** 3.5

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00
Project No: 0121-3070.03 **Figure**

PARTICLE SIZE DISTRIBUTION TEST REPORT



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	13.6	2.0	23.5	21.5	29.9	9.5

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
0.75 in.	100.0		
0.375 in.	90.8		
#4	86.4		
#10	84.4		
#40	60.9		
#200	39.4		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= 20 LL= 23 PI= 3

Coefficients

D_{85}= 2.2334 D_{60}= 0.4015 D_{50}= 0.1888
D_{30}= 0.0371 D_{15}= 0.0113 D_{10}= 0.0056
C_u= 71.22 C_c= 0.61

Classification

USCS= SM AASHTO= A-4(0)

Remarks

Moisture Content= 12.1%

Sample No.: 3 **Source of Sample:** TR-76 **Date:** 5/28/05
Location: **Elev./Depth:** 6.0

DLZ

Client: TranSystems, Inc.
Project: SCI-823-0.00
Project No: 0121-3070.03 **Figure**

APPENDIX D

DLZ

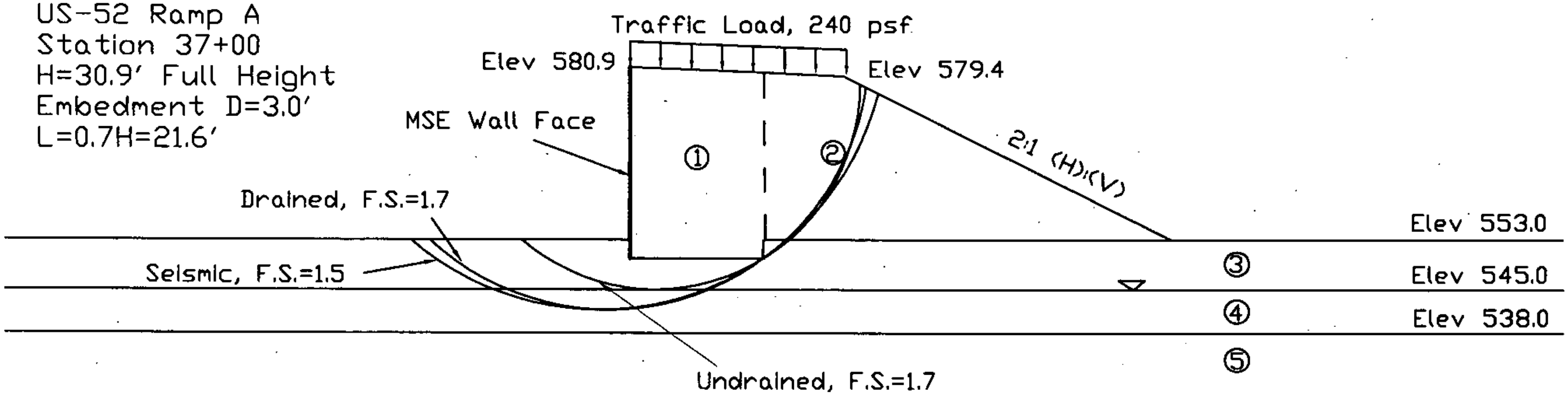
APPENDIX IV

Global Stability Analysis Results
Bearing Capacity and Stability Calculations
Settlement Calculations
Typical Section Showing the Use of Special Benching
Within a Back-To-Back Walls Section

MSE Wall Global Stability Analysis Results
(Ramp A)

			Undrained		Drained		
Material	Consistency	Soil Type	c (psf)	Φ (deg)	c' (psf)	Φ' (deg)	γ (pcf)
Material 1	Compacted	MSE Fill	0	34	0	34	120
Material 2	Compacted	Emb. Fill	0	30	0	30	120
Material 3	Stiff	Silt and Clay	1250	0	0	28	120
Material 4	M. Dense	Gravel	0	30	0	30	125
Material 5		BEDROCK	5000	45	5000	45	150

MSE Stability Analysis
TR-75 Profile
US-52 Ramp A
Station 37+00
H=30.9' Full Height
Embedment D=3.0'
L=0.7H=21.6'



EWT 11-14-07
BW 11-14-07
page 1/2

US-52 Ramp A over Ohio River Road
BASED ON BORING TR-75 PROFILE
WITHOUT UNDERCUT

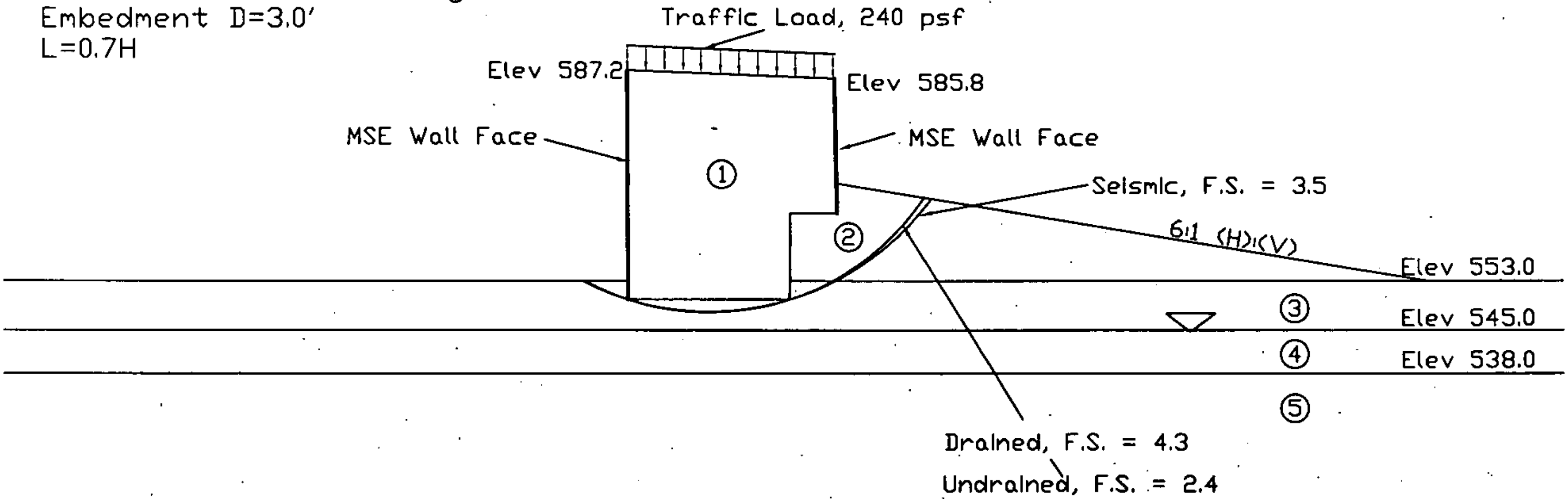
MSE STABILITY ANALYSIS

SCI-823-0.00

PROJECT NO. 0121-3070.03	CALC: EWT	DATE 10/12/07

			Undrained		Drained		
Material	Consistency	Soil Type	c (psf)	ϕ (deg)	c' (psf)	ϕ' (deg)	γ (pcf)
Material 1	Compacted	MSE Fill	0	34	0	34	120
Material 2	Compacted	Emb. Fill	0	30	0	30	120
Material 3	Stiff	Silt and Clay	1250	0	0	28	120
Material 4	M. Dense	Gravel	0	30	0	30	125
Material 5		BEDROCK	5000	45	5000	45	150

MSE Stability Analysis
TR-75 Profile
US-52 Ramp A
Station 38+00
H=37.2' and 21.9' Full Heights
Embedment D=3.0'
L=0.7H



EWT 11-14-07
BW 11-14-07
page 2/2

US-52 Ramp A over Ohio River Road
BASED ON BORING TR-75 PROFILE
WITHOUT UNDERCUT

MSE STABILITY ANALYSIS

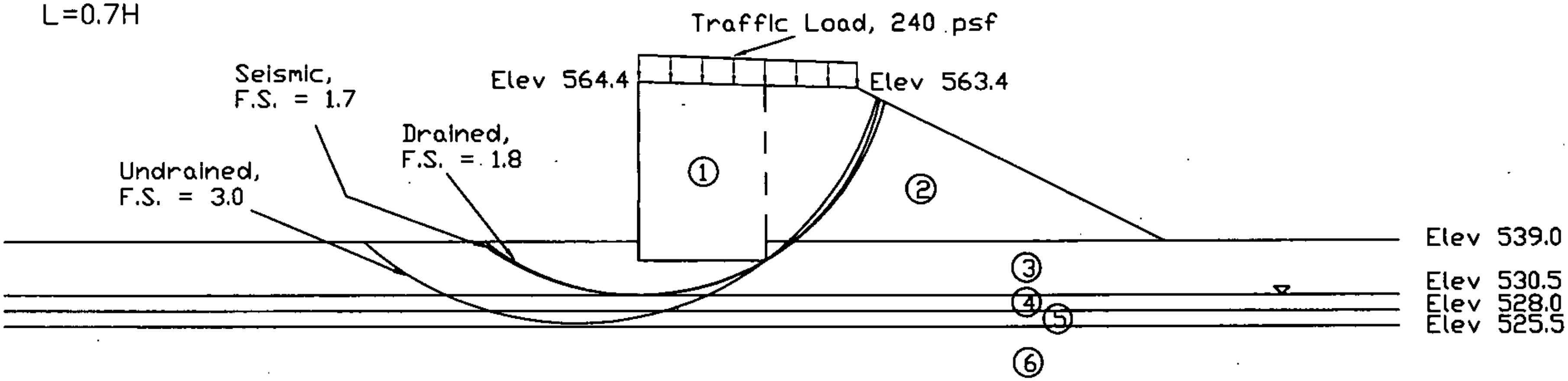
SCI-823-0.00

PROJECT NO. 0121-3070.03	CALC: EWT	DATE 10/11/07

MSE Wall Global Stability Analysis Results
(Ramp B)

Material	Consistency	Soil Type	Undrained c (psf)	Undrained φ (deg)	Drained c' (psf)	Drained φ' (deg)	γ (pcf)
Material 1	Compacted	MSE Fill	0	34	0	34	120
Material 2	Compacted	Emb. Fill	0	30	0	30	120
Material 3	Very Stiff	Silty Clay	3000	0	0	34	120
Material 4	M. Dense	Gravel	0	32	0	32	120
Material 5	M. Dense	Sandy Silt	0	30	0	30	125
Material 6		Bedrock	5000	45	5000	45	150

MSE Stability Analysis
TR-69A Profile
US-52 Ramp B
Station 32+00
H=28.4', Full Heights
Embedment D=3.0'
L=0.7H

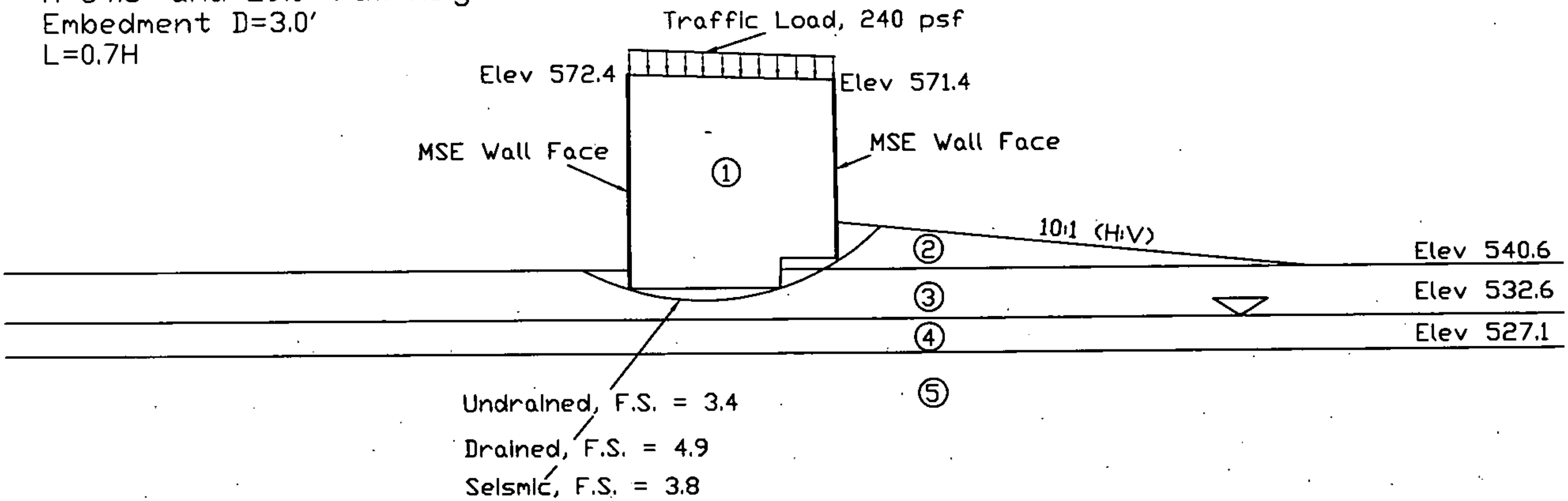


EWT 11-14-07
BW 11-14-07
page 1/2

US-52 Ramp B over Ohio River Road BASED ON BORING TR-69A PROFILE WITHOUT UNDERCUT		
MSE STABILITY ANALYSIS SCI-823-0.00		
PROJECT NO. 0121-3070.03	CALC: EWT	DATE 10/17/07

Material	Consistency	Soil Type	Undrained c (psf)	Undrained φ (deg)	Drained c' (psf)	Drained φ' (deg)	γ (pcf)
Material 1	Compacted	MSE Fill	0	34	0	34	120
Material 2	Compacted	Emb. Fill	0	30	0	30	120
Material 3	Stiff	Silt and Clay	1250	0	0	28	120
Material 4	M. Dense	Sandy Silt	0	29	0	29	125
Material 5		BEDROCK	5000	45	5000	45	150

MSE Stability Analysis
TR-70A Profile
US-52 Ramp B
Station 34+00
H=34.8' and 29.0' Full Heights
Embedment D=3.0'
L=0.7H



EWT 11-14-07
BW 11-14-07

US-52 Ramp B over Ohio River Road
BASED ON BORING TR-70A PROFILE
WITHOUT UNDERCUT

MSE STABILITY ANALYSIS

SCI-823-0.00

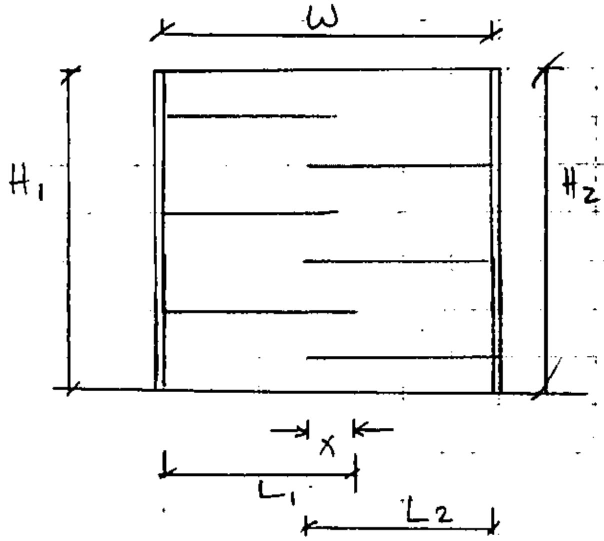
PROJECT NO. 0121-3070.03	CALC: EWT	DATE 10/15/07

MSE Wall Bearing Capacity and Stability Calculations
(Ramp A)

DLZ
ENGINEERS • ARCHITECTS • SCIENTISTS
PLANNERS • SURVEYORS

CLIENT: TranSystems Corp / ODOT D-9
PROJECT: SCI-823 Portsmouth ByPass
SUBJECT: MSE Wall Bearing Capacity Modification of Ka

PROJECT NO. 0121-3070.03
SHEET NO. 1 OF 34
COMP. BY GWT DATE 10-25-0?
CHECKED BY BW DATE 11-15-0?



x = overlap of reinforcing straps

H_1, H_2 = wall heights (between top of coping and top leveling pad)

L_1 & L_2 = reinforcing lengths

W = width of roadway

R_1 = overlap ratio = $\frac{x}{H_1}$

R_2 = overlap ratio = $\frac{x}{H_2}$

Dimensions based on cross-sections from TranSystems on 7-17-07:

Ramp A

Station 38+00 Left, $H_1 = 37.2$ ft, $L_1 = 0.7 H_1 = 0.7 \times 37.2 = 26.04'$

Station 38+00 Right, $H_2 = 21.9$ ft, $L_2 = 0.7 H_2 = 0.7 \times 21.9 = 15.33'$

W = 33.3'

(pg. 178 of FHWA-SA-96-071)

$R_1 = (15.33 - (33.3 - 26.04))/37.2 = 0.21 \Rightarrow k = 0.2 k_a$

$R_2 = (15.33 - (33.3 - 26.04))/21.9 = 0.37 \Rightarrow k = 0.0 k_a$

Station 38+50 Left, $H_1 = 31.8$ ft, $L_1 = 0.7 H_1 = 22.26'$

Station 38+50 Right $H_2 = 24.1$ ft, $L_1 = 0.7 H_2 = 16.87'$

W = 33.3'

$R_1 = (16.87 - (33.3 - 22.26))/31.8 = 0.18$

$\Rightarrow k = 0.2 k_a$

(p.178, FHWA-SA-96-071)

$R_2 = (16.87 - (33.3 - 22.26))/24.1 = 0.24 \Rightarrow k = 0.1 k_a$

BACK TO BACK WALLS – REDUCED E.P. AS f OF DISTANCE APART

AS SUGGESTED BY ROD SMITH – REINFORCED EARTH – U.K.
MODIFIED BY P. ANDERSON BASED ON SMALL SCALE MODEL

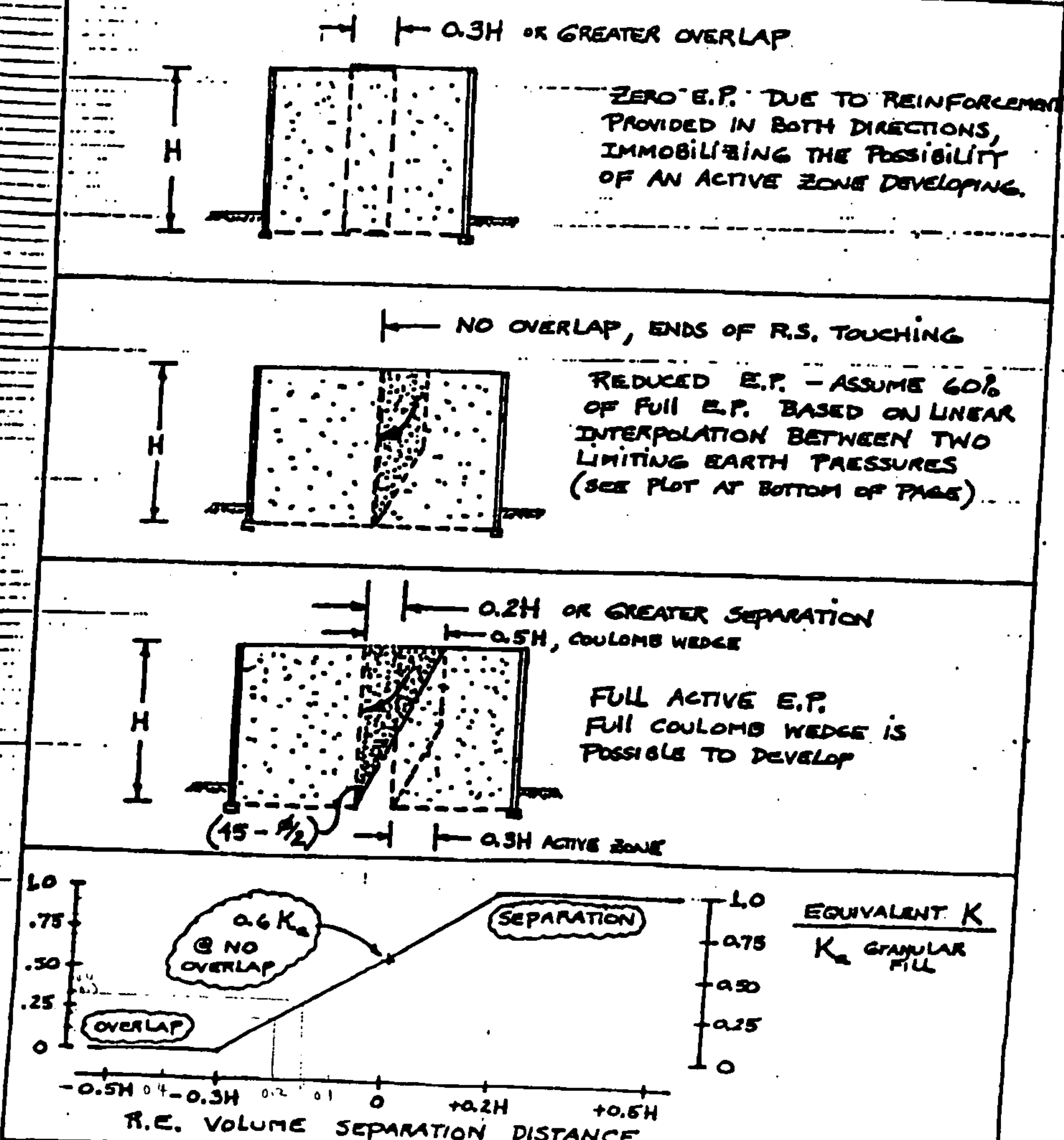


FIGURE 1

3/34
SWT 11-15-07
BW 11-15-07

FHWA-SA-96-071

5.4 BACK-TO-BACK WALLS

For walls which are built back-to-back as shown in figure 50, a modified value of backfill thrust influences the external stability calculations. As indicated in figure 50, two cases can be considered.

- For Case I, the overall base width is large enough so that each wall behaves and can be designed independently. In particular, there is no overlapping of the reinforcements. Theoretically, if the distance, D, between the two walls is shorter than:

  $$D = H_1 \tan(45° - \varphi/2) \qquad (55)$$

  then the active wedges at the back of each wall cannot fully spread out and the active thrust is reduced. However, it is assumed that for values of:

  $$D > H_1 \tan(45° - \varphi/2) \approx 0.5\, H_1 \qquad (56)$$

  full active thrust is mobilized.

- For Case II, there is an overlapping of the reinforcements such that the two walls interact. When the overlap, L_R, is greater than 0.3 H_2, where H_2 is the shorter of the parallel walls, no active earth thrust from the backfill needs to be considered for external stability calculations. For intermediate geometries between Case I and Case II, the active earth thrust may be linearly interpolated from the full active case to zero. For Case II geometries with overlaps greater than 0.3 H_2, L/H ratios for each wall as low as 0.6 may be considered.

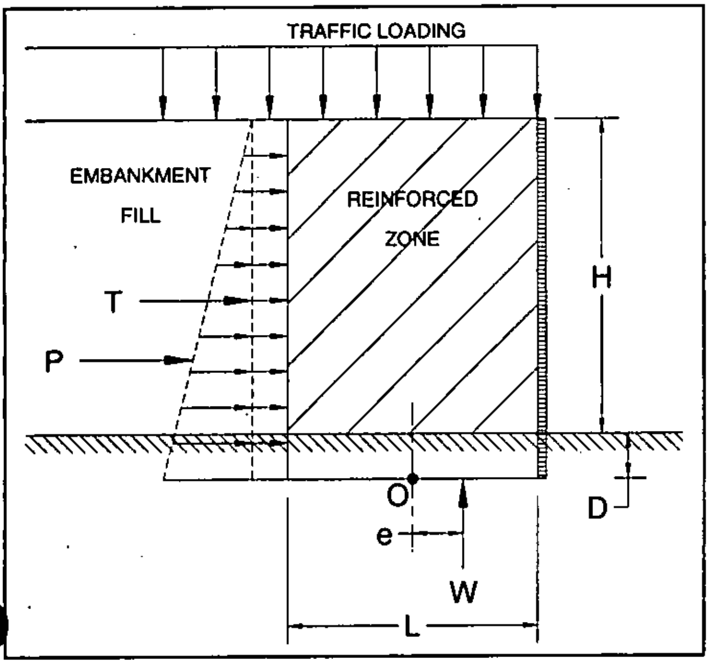
  Considering this case, designers might be tempted to use single reinforcements connected to both wall facings. This alternative completely changes the strain patterns in the structure and results in higher reinforcement tensions such that the design method in this manual is no longer applicable. In addition, difficulties in maintaining wall alignment could be encountered during construction, especially when the walls are not in a tangent section.

  Based on a performance review, back-to-back walls with overlapping reinforcements may be designed for static load conditions with a distance between parallel facing as low as L/H = 0.6, where H is the height of each wall, and for conditions where the seismic horizontal accelerations at the foundation level is less than 0.05g. For walls in more seismically active areas (up to 0.19g) a distance of 1.1 H_1 is presently recommended. For walls subjected to significant seismic loading (up to 0.40g) successful performance has been observed when the distance between parallel facings was at least 1.2 H_1.

  Justification of narrower back-to-back distances (< 1.1 H_1) between faces in seismically active areas require a more detailed analysis be performed to include effects of potential non-uniform distribution of seismic and inertial forces within the wall, as suggested by numerical studies and not provided for in the present design methodology.

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{EMB}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{EMB}	=	30	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	1250	psf	Cohesion	Foundation soil
ϕ	=	0	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	28	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	7.992	ft	Length of MSE reinforcement
L factor	=	1.08		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	7.4	ft	
H	=	4.4	ft	Height of wall
Ka	=	0.33		
Γ Pa	=	2.4667	ft	Moment arm
Γ Wt	=	3.7	ft	Moment arm
B'	=	6.91	ft	
γ'	=	57.6	pcf	
W_t		1,918	lb/ft of wall	Weight from traffic
W_{mse}	=	7,097	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 1,304 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 6,598 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 2,639 psf

Factor of Safety = **5.06** **OK**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 5,871 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 2,348 psf

Factor of Safety = **4.50** **OK**

Bearing Capacity Factors for Equations (AASHTO)

Undrained		Drained	
N_c	5.14	N_c	25.80
N_q	1.00	N_q	14.72
N_γ	0.00	N_γ	16.72

Eccentricity of Resultant Force

e = 0.54 ft

Kern

e < L/6 = 1.33 ft

Based on existing foundaton soils

STABILITY OF MSE WALL

Assumptions:

1 Estimated height of embankment; H=4.4'
2 Ground water; Dw=0.0'
3 Traffic loading is neglected in resisting forces
4
5

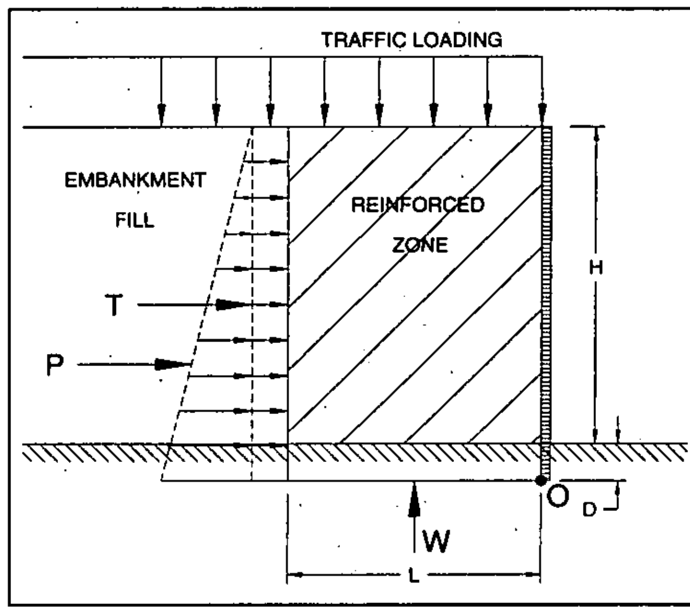
Wall Properties

$H+D$ = 7.4 feet
γ_{mse} = 120 pcf
L = 7.992 feet
L factor = 1.08
ϕ = 30 deg

Foundational Soil Properties

c = 1250 psf Cohesion
ϕ' = 28 deg Friction angle
ω_T = 240 psf Traffic loading
Length factor-range (0.7 - 1.0)
Friction Angle of Embankment Fill

RESISTANCE AGAINST SLIDING ALONG BASE



Thrust: $P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ K_a = 0.33

P_a = 1,670 lbs per foot of wall

Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu = \left(\frac{2}{3}\right)\tan(\phi)$ μ = 0.36

P_r = 2,484 lbs per foot of wall

USE THIS VALUE

$P_r = L(c)$ (Undrained)

P_r = 9,990 lbs per foot of wall

Use Drained Value

$FS = \frac{P_r}{P_a}$

	Calculated	Required
	FS = **1.49**	FS = 1.50

Resistance Against Sliding is **No Good**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 28,359 lb-ft $\Sigma M_{resisting} = \gamma HL\left(\frac{L}{2}\right)$

$\Sigma M_{overturning}$ = 4,843 lb-ft $\Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$

$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$

	Calculated	Required
	FS = **5.86**	FS = 2.00

Resistance Against Overturning is **OK**

DLZ

SUBJECT			
Client	ODOT9	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00 (US 52 Ramp A), B-1541	SHEET NO.	6 OF 34
Item	MSE Wall Stability(Sta 34+00)	COMP. BY	EWT DATE 10/10/07
		CHECKED BY	BW DATE 11-15-07

Based on existing foundaton soils

STABILITY OF MSE WALL

Assumptions:

1 Estimated height of embankment; H=4.4'
2 Ground water; Dw=0.0'
3 Traffic loading is neglected in resisting forces
4
5

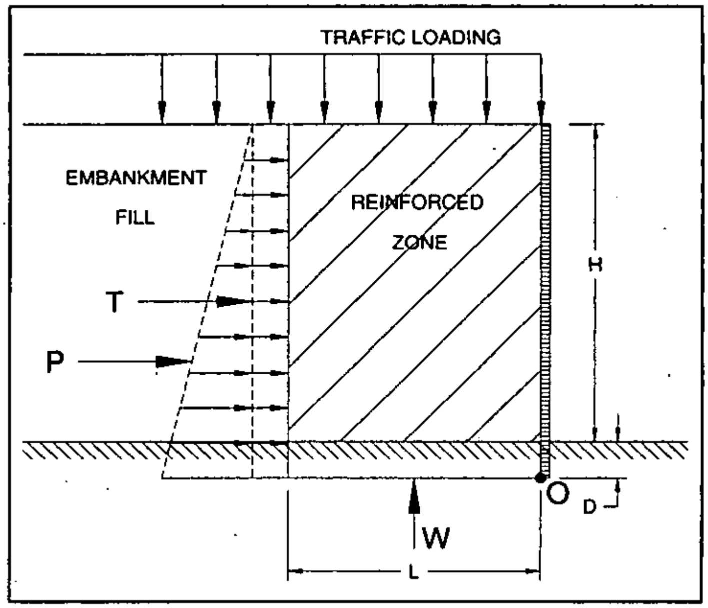
Wall Properties			Foundational Soil Properties			
H+D =	7.4	feet	c =	1250	psf	Cohesion
γ_{mse} =	120	pcf	ϕ' =	28	deg	Friction angle
L =	7.992	feet	ω_T =	240	psf	Traffic loading
L factor =	1.08		Length factor-range (0.7 - 1.0)			
ϕ =	30	deg	Friction Angle of Embankment Fill			

RESISTANCE AGAINST SLIDING ALONG BASE

Thrust: $P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ K_a = 0.33

P_a = 1,670 lbs per foot of wall



Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu^* = \tan(\phi)$ μ = 0.53

**Note: for non-continuous reinforcement*

P_r = 3,761 lbs per foot of wall

USE THIS VALUE

$P_r = L(c)$ (Undrained)

P_r = 9,990 lbs per foot of wall

Use Drained Value

$FS = \frac{P_r}{P_a}$

Calculated FS = **2.25** Required FS = 1.50

Resistance Against Sliding is **OK**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 28,359 lb-ft

$$\Sigma M_{resisting} = \gamma H L\left(\frac{L}{2}\right)$$

$\Sigma M_{overturning}$ = 4,843 lb-ft

$$\Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$$

$$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$$

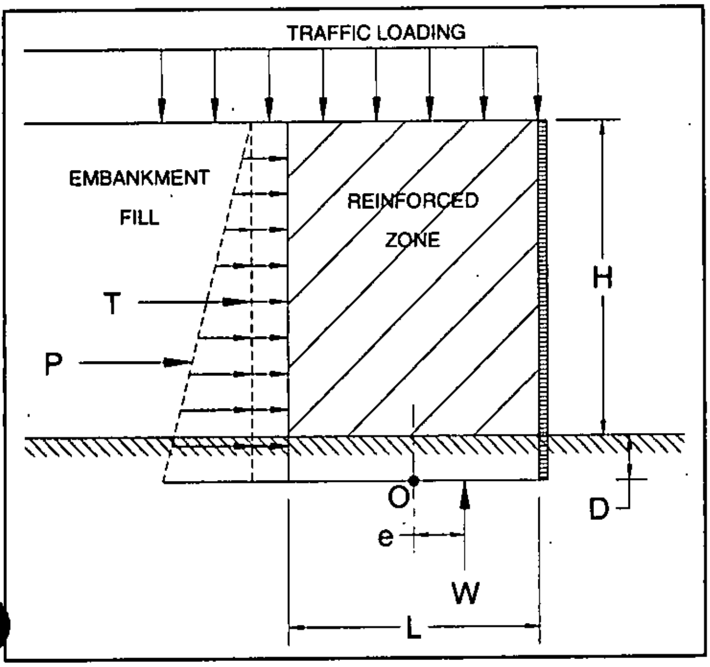
Calculated FS = **5.86** Required FS = 2.00

Resistance Against Overturning is **OK**

DLZ	SUBJECT		JOB NUMBER	0121-3070.03		
	Client	ODOT9	SHEET NO.	7	OF	34
	Project	SCI-823-0.00 (US 52, Ramp A), Boring B-1541	COMP. BY	EWT	DATE	10/10/07
	Item	MSE Wall Bearing Capacity (Sta 34+50)	CHECKED BY	BW	DATE	11-15-07
	Based on existing foundation soils					

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{EMB}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{EMB}	=	30	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	1250	psf	Cohesion	Foundation soil
ϕ	=	0	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	28	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	12.18	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	17.4	ft	
H	=	14.4	ft	Height of wall
Ka	=	0.33		
Γ Pa	=	5.8	ft	Moment arm
Γ Wt	=	8.7	ft	Moment arm
B'	=	8.88	ft	
γ'	=	57.6	pcf	
W_t		2,923	lb/ft of wall	Weight from traffic
W_{mse}	=	25,432	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 3,193 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 6,598 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 2,639 psf

Factor of Safety = 2.07 **No Good**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 6,820 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 2,728 psf

Factor of Safety = 2.14 **No Good**

Bearing Capacity Factors for Equations (AASHTO)

Undrained		Drained	
N_c	5.14	N_c	25.80
N_q	1.00	N_q	14.72
N_γ	0.00	N_γ	16.72

Eccentricity of Resultant Force

e = 1.65 ft

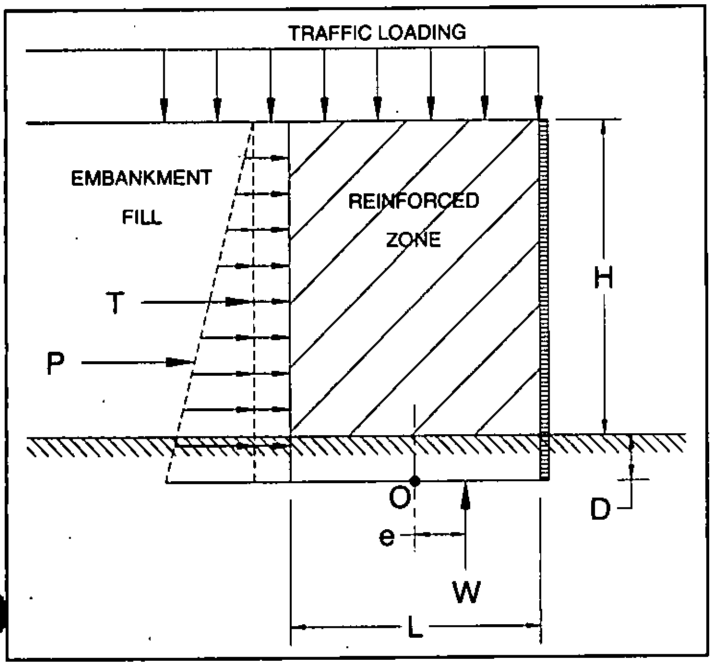
Kern

e < L/6 = 2.03 ft

Based on 4.5' undercut below bottom of leveling pad and replace with compacted granular material

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{EMB}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{EMB}	=	30	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	0	psf	Cohesion	Foundation soil
ϕ	=	30	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	30	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	12.18	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	17.4	ft	
H	=	14.4	ft	Height of wall
Ka	=	0.33		
Γ Pa	=	5.8	ft	Moment arm
Γ Wt	=	8.7	ft	Moment arm
B'	=	8.88	ft	
γ'	=	57.6	pcf	
W_t		2,923	lb/ft of wall	Weight from traffic
W_{mse}	=	25,432	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 3,193 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 8,908 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 3,563 psf

Factor of Safety = **2.79** **OK**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 8,908 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 3,563 psf

Factor of Safety = **2.79** **OK**

Bearing Capacity Factors for Equations (AASHTO)

Undrained		Drained	
N_c	30.14	N_c	30.14
N_q	18.40	N_q	18.40
N_γ	22.40	N_γ	22.40

Eccentricity of Resultant Force

e = 1.65 ft

Kern

e < L/6 = 2.03 ft

DLZ

SUBJECT			
Client	ODOT9	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00 (US 52 Ramp A), B-1541	SHEET NO.	9 OF 34
Item	MSE Wall Stability(Sta 34+50)	COMP. BY	EWT DATE 10/10/07
		CHECKED BY	BWJ DATE 11-15-07

Based on existing foundaton soils

STABILITY OF MSE WALL

Assumptions:

1 Estimated height of embankment; H=14.4'
2 Ground water; Dw=0.0'
3 Traffic loading is neglected in resisting forces
4
5

Wall Properties

H+D	=	17.4	feet
γ_{mse}	=	120	pcf
L	=	12.18	feet
L factor	=	0.70	
ϕ	=	30	deg

Foundational Soil Properties

c	=	1250	psf	Cohesion
ϕ'	=	28	deg	Friction angle
ω_T	=	240	psf	Traffic loading

Length factor-range (0.7 - 1.0)

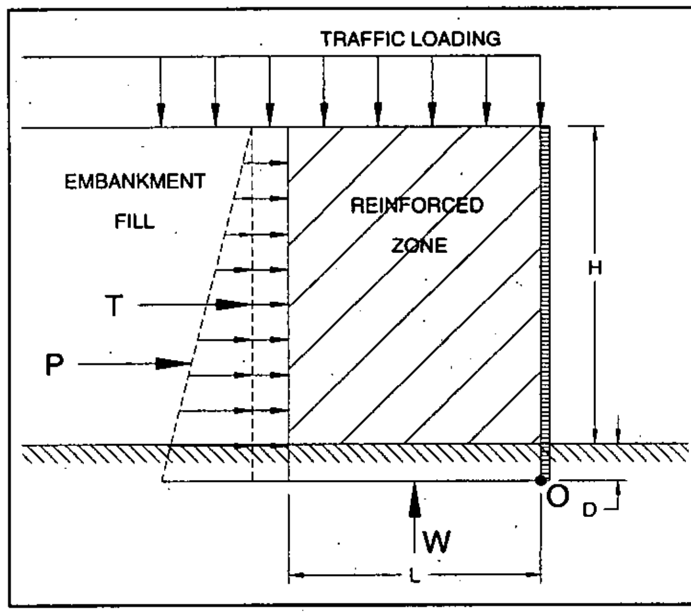
Friction Angle of Embankment Fill

RESISTANCE AGAINST SLIDING ALONG BASE

Thrust: $P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ K_a = 0.33

P_a = 7,373 lbs per foot of wall



Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu = \left(\frac{2}{3}\right)\tan(\phi)$ μ = 0.36

P_r = 8,901 lbs per foot of wall

USE THIS VALUE

$P_r = L(c)$ (Undrained)

P_r = 15,225 lbs per foot of wall

Use Drained Value

$FS = \frac{P_r}{P_a}$

Calculated FS = **1.21** Required FS = 1.50

Resistance Against Sliding is **No Good**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 154,880 lb-ft $\Sigma M_{resisting} = \gamma HL\left(\frac{L}{2}\right)$

$\Sigma M_{overturning}$ = 46,758 lb-ft $\Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$

$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$

Calculated FS = **3.31** Required FS = 2.00

Resistance Against Overturning is **OK**

DLZ	SUBJECT			JOB NUMBER	0121-3070.03		
		Client	ODOT9	SHEET NO.	10	OF	3[illegible]
		Project	SCI-823-0.00 (US 52 Ramp A), B-1541	COMP. BY	EWT	DATE	10/10/07
		Item	MSE Wall Stability(Sta 34+50)	CHECKED BY	BW	DATE	11-15-07

Based on existing foundaton soils

STABILITY OF MSE WALL

Assumptions:

1 Estimated height of embankment; H=14.4'
2 Ground water; Dw=0.0'
3 Traffic loading is neglected in resisting forces
4
5

Wall Properties

H+D	=	17.4	feet
γ_{mse}	=	120	pcf
L	=	12.18	feet
L factor	=	0.70	
ϕ	=	30	deg

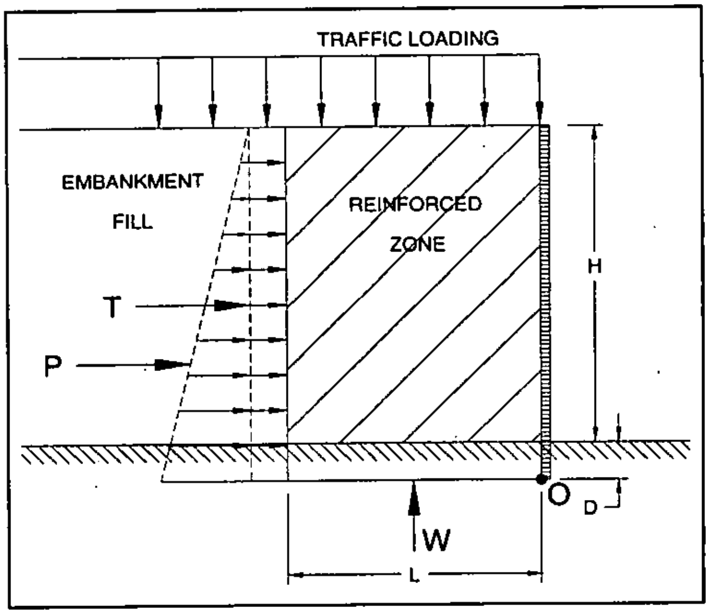
Length factor-range (0.7 - 1.0)

Friction Angle of Embankment Fill

Foundational Soil Properties

c	=	1250	psf	Cohesion
ϕ'	=	28	deg	Friction angle
ω_T	=	240	psf	Traffic loading

RESISTANCE AGAINST SLIDING ALONG BASE



Thrust: $P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ K_a = 0.33

P_a = 7,373 lbs per foot of wall

Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu^* = \tan(\phi)$ μ = 0.53

Note: for non-continuous reinforcement

P_r = 13,479 lbs per foot of wall

USE THIS VALUE

$P_r = L(c)$ (Undrained)

P_r = 15,225 lbs per foot of wall

Use Drained Value

$FS = \frac{P_r}{P_a}$

Calculated FS = **1.83**

Required FS = 1.50

Resistance Against Sliding is **OK**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 154,880 lb-ft

$\Sigma M_{overturning}$ = 46,758 lb-ft

$$\Sigma M_{resisting} = \gamma H L\left(\frac{L}{2}\right)$$

$$\Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$$

$$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$$

Calculated FS = **3.31**

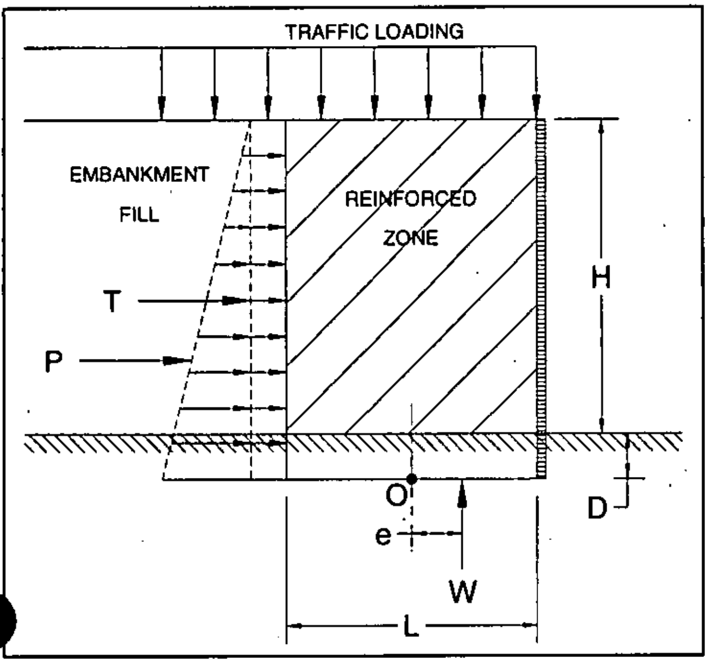
Required FS = 2.00

Resistance Against Overturning is **OK**

SUBJECT			
Client	ODOT9	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00 (US 52, Ramp A), Boring TR-75	SHEET NO.	11 OF 34
Item	MSE Wall Bearing Capacity (Sta 37+00)	COMP. BY	EWT DATE 10/10/07
Based on existing foundation soils		CHECKED BY	BW DATE 11-15-07

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{EMB}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{EMB}	=	30	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	1250	psf	Cohesion	Foundation soil
ϕ	=	0	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	28	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	21.63	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	30.9	ft	
H	=	27.9	ft	Height of wall
Ka	=	0.33		
Γ Pa	=	10.3	ft	Moment arm
Γ Wt	=	15.45	ft	Moment arm
B'	=	16.19	ft	
γ'	=	57.6	pcf	
W_t		5,191	lb/ft of wall	Weight from traffic
W_{mse}	=	80,204	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 5,275 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 6,598 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 2,639 psf

Factor of Safety = 1.25 **No Good**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 10,340 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 4,136 psf

Factor of Safety = 1.96 **No Good**

Bearing Capacity Factors for Equations (AASHTO)

Undrained		Drained	
N_c	5.14	N_c	25.80
N_q	1.00	N_q	14.72
N_γ	0.00	N_γ	16.72

Eccentricity of Resultant Force

e = 2.72 ft

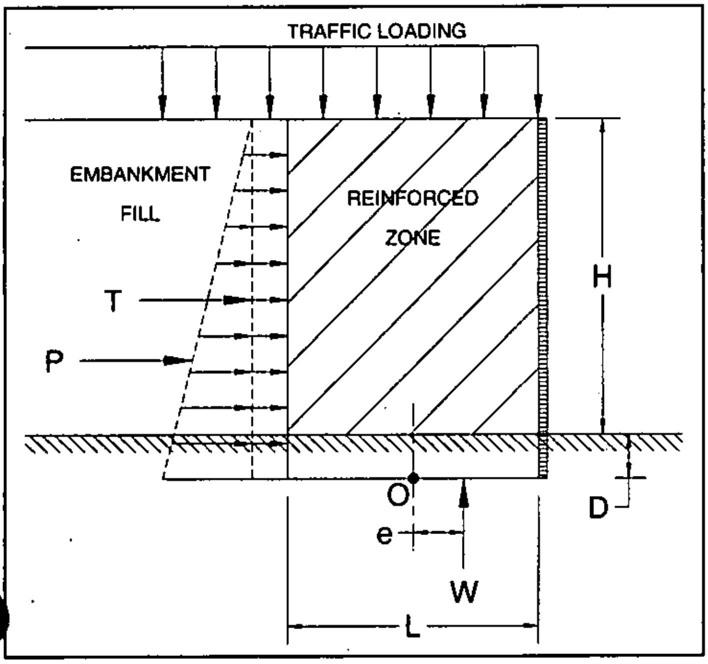
Kern

e < L/6 = 3.61 ft

Based on 4.5 feet undercut beneathe the bottom of leveling pad and replaced with compacted granular material

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{EMB}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{EMB}	=	30	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	0	psf	Cohesion	Foundation soil
ϕ	=	30	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	30	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	21.63	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	30.9	ft	
H	=	27.9	ft	Height of wall
Ka	=	0.33		
Γ Pa	=	10.3	ft	Moment arm
Γ Wt	=	15.45	ft	Moment arm
B'	=	16.19	ft	
γ'	=	57.6	pcf	
W_t		5,191	lb/ft of wall	Weight from traffic
W_{mse}	=	80,204	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 5,275 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B' N_\gamma$$

q_{ULT} = 13,624 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 5,450 psf

Factor of Safety = **2.58** **OK**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma' B N_\gamma$$

q_{ULT} = 13,624 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 5,450 psf

Factor of Safety = **2.58** **OK**

Bearing Capacity Factors for Equations (AASHTO)

Undrained		Drained	
N_c	30.14	N_c	30.14
N_q	18.40	N_q	18.40
N_γ	22.40	N_γ	22.40

Eccentricity of Resultant Force

e = 2.72 ft

Kern

e < L/6 = 3.61 ft

DLZ	SUBJECT			
	Client	ODOT9	JOB NUMBER	0121-3070.03
	Project	SCI-823-0.00 (US 52 Ramp A), TR-75	SHEET NO.	13 OF 34
	Item	MSE Wall Stability(Sta 37+00)	COMP. BY	EWT DATE 10/10/07
			CHECKED BY	BWJ DATE 11-15-07

Based on 4.5' undercut beneath the bottom of leveling pad and replaced with compacted mat'l

STABILITY OF MSE WALL

Assumptions:

1 Estimated height of embankment; H=27.9'
2 Ground water; Dw=0.0'
3 Traffic loading is neglected in resisting forces
4
5

Wall Properties

H+D	=	30.9	feet
γ_{mse}	=	120	pcf
L	=	21.63	feet
L factor	=	0.70	
ϕ	=	30	deg

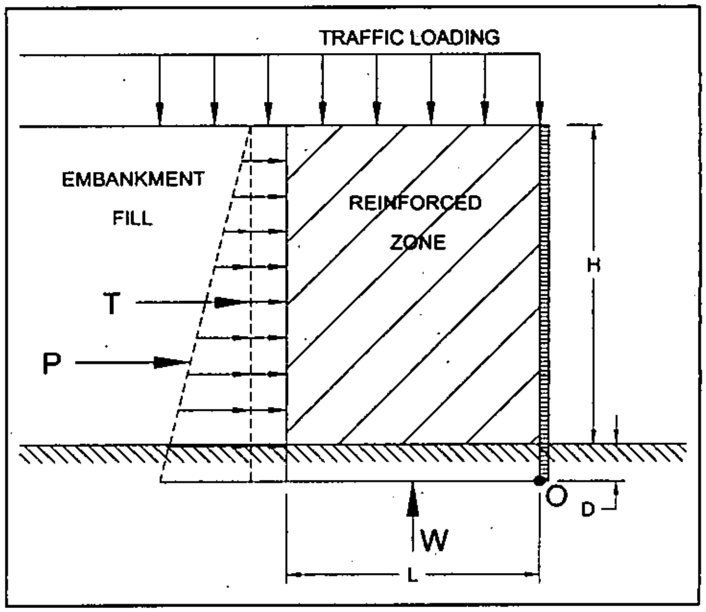
Length factor-range (0.7 - 1.0)

Friction Angle of Embankment Fill

Foundational Soil Properties

c	=	0	psf	Cohesion
ϕ'	=	30	deg	Friction angle
ω_T	=	240	psf	Traffic loading

RESISTANCE AGAINST SLIDING ALONG BASE



Thrust: $$P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ K_a = 0.33

P_a = 21,353 lbs per foot of wall

Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu = \left(\frac{2}{3}\right)\tan(\phi)$ μ = 0.39

P_r = 28,071 lbs per foot of wall

USE THIS VALUE

$$P_r = L(c)$$ (Undrained)

P_r = 0 lbs per foot of wall

Use Drained Value

$$FS = \frac{P_r}{P_a}$$

Calculated FS = **1.31** Required FS = 1.50

Resistance Against Sliding is **No Good**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 867,407 lb-ft $$\Sigma M_{resisting} = \gamma HL\left(\frac{L}{2}\right)$$

$\Sigma M_{overturning}$ = 232,534 lb-ft $$\Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$$

$$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$$

Calculated FS = **3.73** Required FS = 2.00

Resistance Against Overturning is **OK**

Based on existing foundaton soils

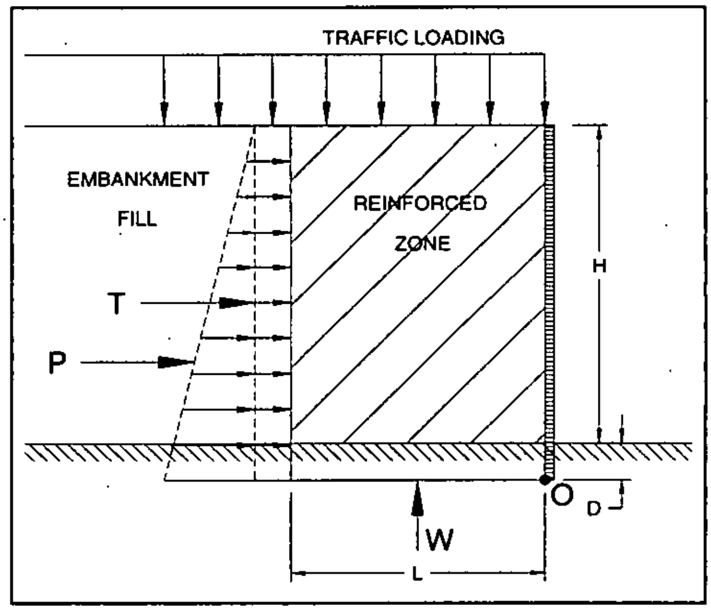
STABILITY OF MSE WALL

Assumptions:

1 Estimated height of embankment; H=27.9'
2 Ground water; Dw=0.0'
3 Traffic loading is neglected in resisting forces
4
5

Wall Properties			Foundational Soil Properties			
H+D =	30.9	feet	c =	1250	psf	Cohesion
γ_{mse} =	120	pcf	ϕ' =	28	deg	Friction angle
L =	21.63	feet	ω_T =	240	psf	Traffic loading
L factor =	0.70		Length factor-range (0.7 - 1.0)			
ϕ =	30	deg	Friction Angle of Embankment Fill			

RESISTANCE AGAINST SLIDING ALONG BASE



Thrust: $P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ K_a = 0.33

P_a = 21,353 lbs per foot of wall

Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu^* = \tan(\phi)$ μ = 0.53

**Note: for non-continuous reinforcement*

P_r = 42,508 lbs per foot of wall

Use Undrained Value

$P_r = L(c)$ (Undrained)

P_r = 27,038 lbs per foot of wall

USE THIS VALUE

$FS = \frac{P_r}{P_a}$

	Calculated	Required
	FS = **1.27**	FS = 1.50

Resistance Against Sliding is **No Good**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 867,407 lb-ft $\qquad \Sigma M_{resisting} = \gamma H L\left(\frac{L}{2}\right)$

$\Sigma M_{overturning}$ = 232,534 lb-ft $\qquad \Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$

$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$

	Calculated	Required
	FS = **3.73**	FS = 2.00

Resistance Against Overturning is **OK**

DLZ

SUBJECT			
Client	ODOT9	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00 (US 52 Ramp A), TR-75	SHEET NO.	15 OF 34
Item	MSE Wall Stability(Sta 37+00)	COMP. BY	EWT DATE 10/10/07
		CHECKED BY	BW DATE 11-15-07

Based on 4.5' undercut beneath the bottom of leveling pad and replaced with compacted mat'l

STABILITY OF MSE WALL

Assumptions:

1 Estimated height of embankment; H=27.9'
2 Ground water; Dw=0.0'
3 Traffic loading is neglected in resisting forces
4
5

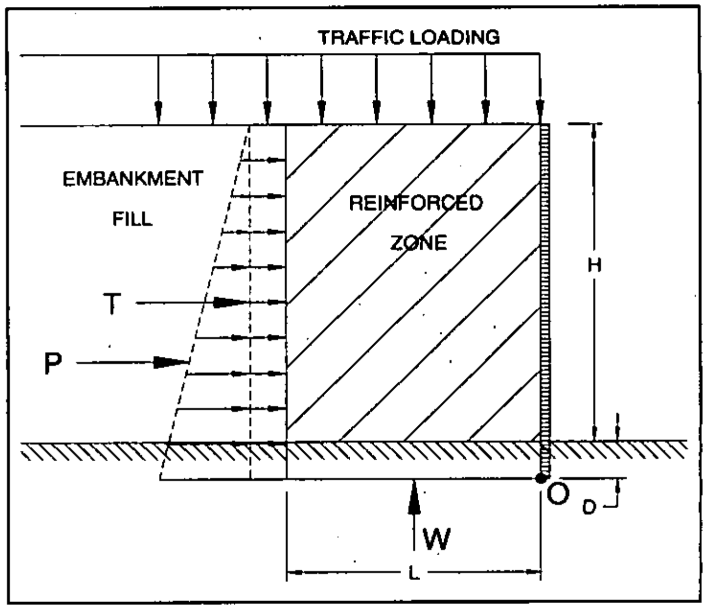
Wall Properties

H+D	=	30.9	feet
γ_{mse}	=	120	pcf
L	=	21.63	feet
L factor	=	0.70	Length factor-range (0.7 - 1.0)
ϕ	=	30	deg Friction Angle of Embankment Fill

Foundational Soil Properties

c	=	0	psf	Cohesion
ϕ'	=	30	deg	Friction angle
ω_T	=	240	psf	Traffic loading

RESISTANCE AGAINST SLIDING ALONG BASE



Thrust: $P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ K_a = 0.33

P_a = 21,353 lbs per foot of wall

Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu^* = \tan(\phi)$ μ = 0.58

**Note: for non-continuous reinforcement*

P_r = 46,518 lbs per foot of wall

USE THIS VALUE

$P_r = L(c)$ (Undrained)

P_r = 0 lbs per foot of wall

Use Drained Value

$FS = \frac{P_r}{P_a}$

	Calculated	Required
	FS = **2.18**	FS = 1.50

Resistance Against Sliding is **OK**

RESISTANCE AGAINST OVERTURNING

- Summation of Moments about point "O" (base of wall).
- Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 867,407 lb-ft $\qquad \Sigma M_{resisting} = \gamma H L\left(\frac{L}{2}\right)$

$\Sigma M_{overturning}$ = 232,534 lb-ft $\qquad \Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$

$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$

	Calculated	Required
	FS = **3.73**	FS = 2.00

Resistance Against Overturning is **OK**

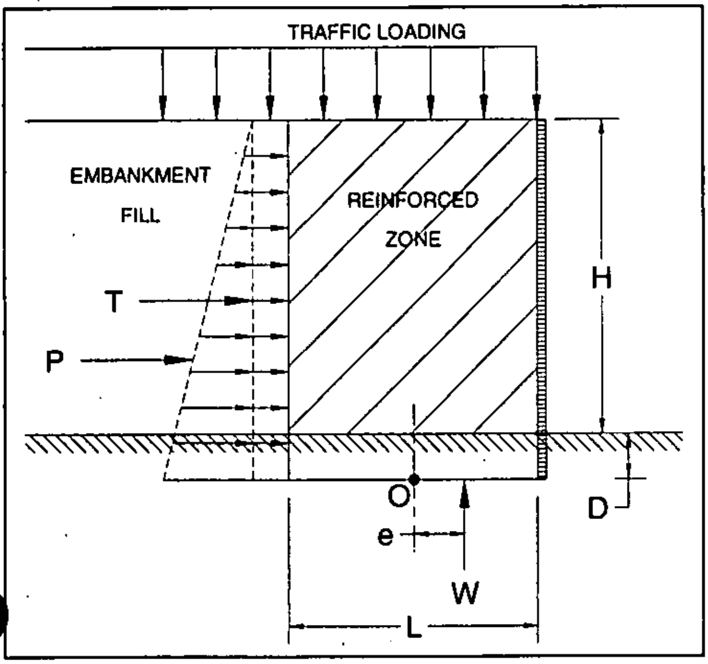
DLZ

SUBJECT	Client ODOT9	JOB NUMBER	0121-3070.03
	Project SCI-823-0.00 (US 52, Ramp A), Boring TR-75	SHEET NO.	16 OF 34
	Item MSE Wall Bearing Capacity (Sta 37+50)	COMP. BY	EWT DATE 10/10/07
	Full Ka, Left Wall	CHECKED BY	BWJ DATE 11-13-07

Based on existing foundation soils

BEARING CAPACITY OF A MSE WALL

Ref: (AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002)



Soil Properties

γ_{EMB}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{EMB}	=	30	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	1250	psf	Cohesion	Foundation soil
ϕ	=	0	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	28	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	23.31	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	33.3	ft	
H	=	30.3	ft	Height of wall
Ka	=	0.33		
Γ Pa	=	11.1	ft	Moment arm
Γ Wt	=	16.65	ft	Moment arm
B'	=	17.49	ft	
γ'	=	57.6	pcf	
W_t		5,594	lb/ft of wall	Weight from traffic
W_{mse}	=	93,147	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 5,646 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 6,598 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 2,639 psf

Factor of Safety = 1.17 **No Good**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma' B N_\gamma$$

q_{ULT} = 10,966 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 4,386 psf

Factor of Safety = 1.94 **No Good**

Bearing Capacity Factors for Equations (AASHTO)

Undrained		Drained	
N_c	5.14	N_c	25.80
N_q	1.00	N_q	14.72
N_γ	0.00	N_γ	16.72

Eccentricity of Resultant Force

e = 2.91 ft

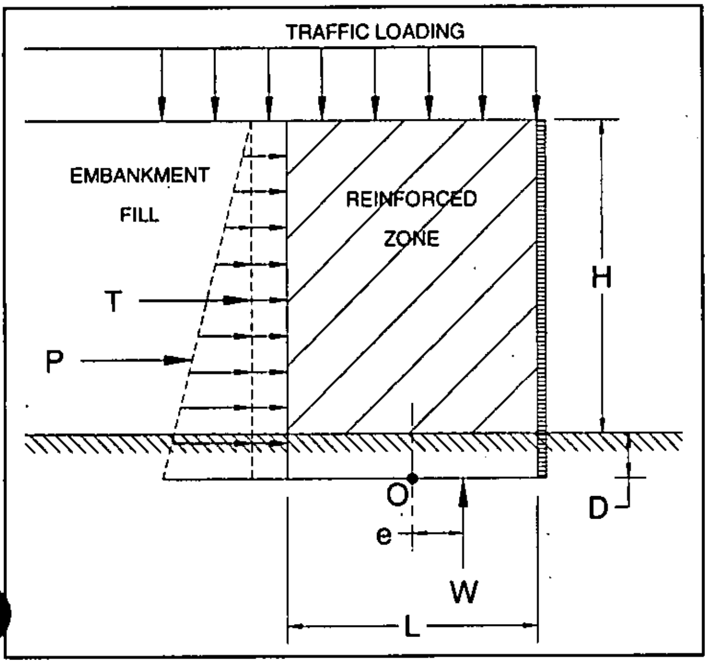
Kern

e < L/6 = 3.89 ft

Based upon 4.5' undercut beneath base of leveling pad and replace with compacted granular fill

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{EMB}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{EMB}	=	30	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	0	psf	Cohesion	Foundation soil
ϕ	=	30	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	30	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	23.31	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	33.3	ft	
H	=	30.3	ft	Height of wall
Ka	=	0.33		
Γ Pa	=	11.1	ft	Moment arm
Γ Wt	=	16.65	ft	Moment arm
B'	=	17.49	ft	
γ'	=	57.6	pcf	
W_t		5,594	lb/ft of wall	Weight from traffic
W_{mse}	=	93,147	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 5,646 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 14,463 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 5,785 psf

Factor of Safety = **2.56** **OK**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 14,463 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 5,785 psf

Factor of Safety = **2.56** **OK**

Bearing Capacity Factors for Equations (AASHTO)

Undrained		Drained	
N_c	30.14	N_c	30.14
N_q	18.40	N_q	18.40
N_γ	22.40	N_γ	22.40

Eccentricity of Resultant Force

e = 2.91 ft

Kern

e < L/6 = 3.89 ft

DLZ

SUBJECT			
Client	ODOT9	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00 (US 52 Ramp A), TR-75	SHEET NO.	18 OF 34
Item	MSE Wall Stability(Sta 37+50)	COMP. BY	EWT DATE 10/10/07
	Full Ka, left wall	CHECKED BY	BW DATE 11-15-07

Based on existing foundation soils

STABILITY OF MSE WALL

Assumptions:

1 Estimated height of embankment; H=30.3'

2 Ground water; Dw=0.0'

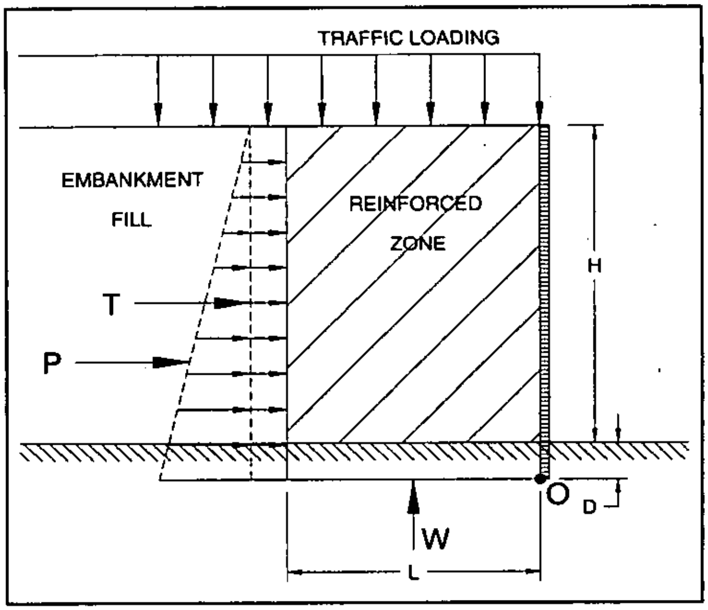
3 Traffic loading is neglected in resisting forces

4

5

Wall Properties			Foundational Soil Properties			
H+D =	33.3	feet	c =	1250	psf	Cohesion
γ_{mse} =	120	pcf	ϕ' =	28	deg	Friction angle
L =	23.31	feet	ω_T =	240	psf	Traffic loading
L factor =	0.70		Length factor-range (0.7 - 1.0)			
ϕ =	30	deg	Friction Angle of Embankment Fill			

RESISTANCE AGAINST SLIDING ALONG BASE



Thrust: $P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ K_a = 0.33

P_a = 24,593 lbs per foot of wall

Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu^* = \tan(\phi)$ μ = 0.53

**Note: for non-continuous reinforcement*

P_r = 49,368 lbs per foot of wall

Use Undrained Value

$P_r = L(c)$ (Undrained)

P_r = 29,138 lbs per foot of wall

USE THIS VALUE

$FS = \frac{P_r}{P_a}$

Calculated	Required
FS = **1.18**	FS = 1.50

Resistance Against Sliding is **No Good**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 1,085,625 lb-ft $\qquad \Sigma M_{resisting} = \gamma H L\left(\frac{L}{2}\right)$

$\Sigma M_{overturning}$ = 287,624 lb-ft $\qquad \Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$

$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$

Calculated	Required
FS = **3.77**	FS = 2.00

Resistance Against Overturning is **OK**

DLZ

SUBJECT			
Client	ODOT9	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00 (US 52 Ramp A), TR-75	SHEET NO.	19 OF 36
Item	MSE Wall Stability(Sta 37+50)	COMP. BY	EWT DATE 10/10/07
	Full Ka, left wall	CHECKED BY	BW DATE 11-15-07

Based on 4.5' undercut below the bottom of leveling pad and replace with compacted mat'l

STABILITY OF MSE WALL

Assumptions:

1 Estimated height of embankment; H=30.3'
2 Ground water; Dw=0.0'
3 Traffic loading is neglected in resisting forces
4
5

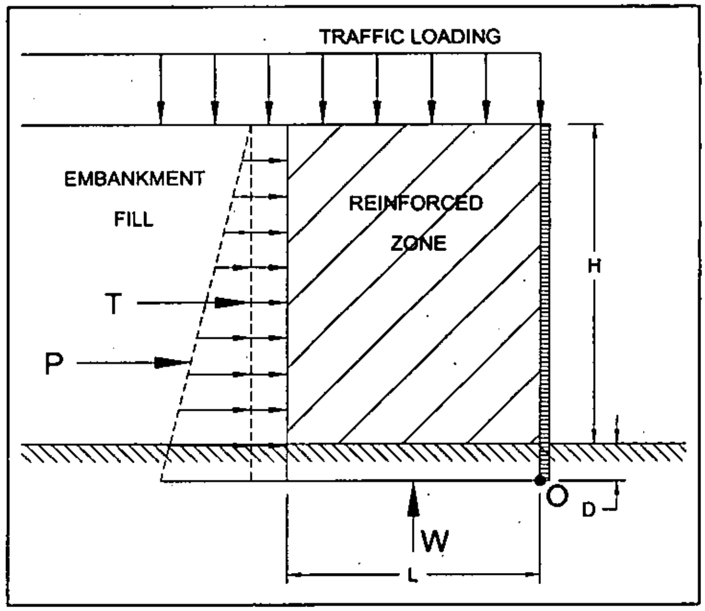
Wall Properties

H+D = 33.3 feet
γ_{mse} = 120 pcf
L = 23.31 feet
L factor = 0.70
ϕ = 30 deg

Foundational Soil Properties

c = 0 psf Cohesion
ϕ' = 30 deg Friction angle
ω_T = 240 psf Traffic loading
Length factor-range (0.7 - 1.0)
Friction Angle of Embankment Fill

RESISTANCE AGAINST SLIDING ALONG BASE



Thrust: $P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ K_a = 0.33

P_a = 24,593 lbs per foot of wall

Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu = \left(\frac{2}{3}\right)\tan(\phi)$ μ = 0.39

P_r = 32,601 lbs per foot of wall

USE THIS VALUE

$P_r = L(c)$ (Undrained)

P_r = 0 lbs per foot of wall

Use Drained Value

$FS = \frac{P_r}{P_a}$

Calculated FS = **1.33** Required FS = 1.50

Resistance Against Sliding is **No Good**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 1,085,625 lb-ft

$\Sigma M_{resisting} = \gamma HL\left(\frac{L}{2}\right)$

$\Sigma M_{overturning}$ = 287,624 lb-ft

$\Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$

$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$

Calculated FS = **3.77** Required FS = 2.00

Resistance Against Overturning is **OK**

DLZ

SUBJECT

Client	ODOT9	JOB NUMBER	0121-3070.03		
Project	SCI-823-0.00 (US 52 Ramp A), TR-75	SHEET NO.	20	OF	34
Item	MSE Wall Stability(Sta 37+50)	COMP. BY	EWT	DATE	10/10/07
	Full Ka, left wall	CHECKED BY	BW	DATE	11-15-07

Based on 4.5' undercut below the bottom of leveling pad and replace with compacted mat'l

STABILITY OF MSE WALL

Assumptions:

1 Estimated height of embankment; H=30.3'

2 Ground water; Dw=0.0'

3 Traffic loading is neglected in resisting forces

4

5

Wall Properties

$H+D$ = 33.3 feet

γ_{mse} = 120 pcf

L = 23.31 feet

L factor = 0.70

ϕ = 30 deg — Friction Angle of Embankment Fill

Foundational Soil Properties

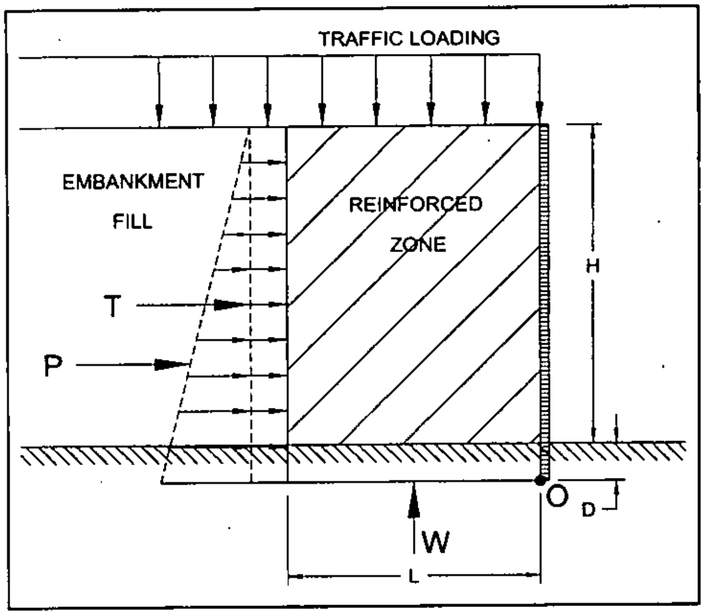
c = 0 psf — Cohesion

ϕ' = 30 deg — Friction angle

ω_T = 240 psf — Traffic loading

Length factor-range (0.7 - 1.0)

RESISTANCE AGAINST SLIDING ALONG BASE



Thrust: $P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ K_a = 0.33

P_a = 24,593 lbs per foot of wall

Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu^* = \tan(\phi)$ μ = 0.58

**Note: for non-continuous reinforcement*

P_r = 54,025 lbs per foot of wall

USE THIS VALUE

$P_r = L(c)$ (Undrained)

P_r = 0 lbs per foot of wall

Use Drained Value

$FS = \frac{P_r}{P_a}$ Calculated FS = **2.20** Required FS = 1.50

Resistance Against Sliding is **OK**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).

* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 1,085,625 lb-ft $\Sigma M_{resisting} = \gamma HL\left(\frac{L}{2}\right)$

$\Sigma M_{overturning}$ = 287,624 lb-ft $\Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$

$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$ Calculated FS = **3.77** Required FS = 2.00

Resistance Against Overturning is **OK**

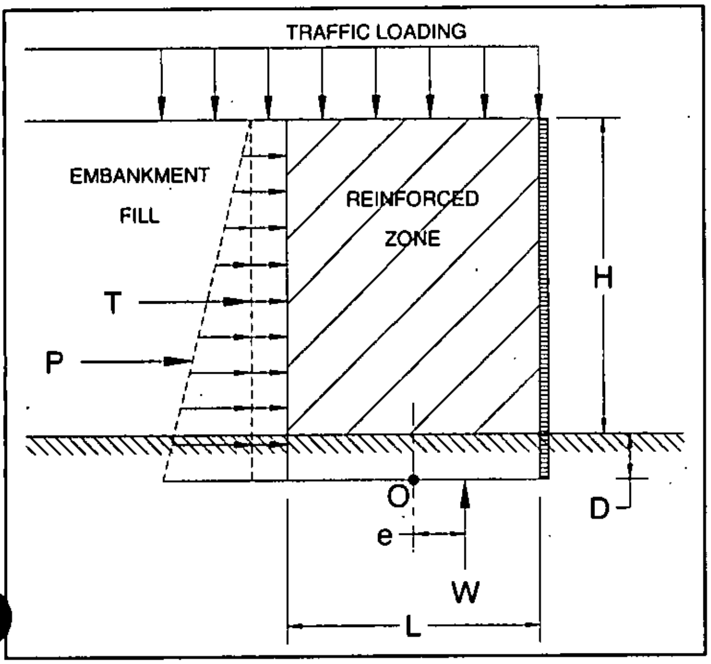
DLZ

SUBJECT			
Client	ODOT9	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00 (US 52, Ramp A), Boring TR-75	SHEET NO.	21 OF 34
Item	MSE Wall Bearing Capacity (Sta 37+50)	COMP. BY	EWT DATE 10/10/07
	Full Ka, right wall	CHECKED BY	RW DATE 11-15-07

Based on existing foundation soils

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{EMB}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{EMB}	=	30	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	1250	psf	Cohesion	Foundation soil
ϕ	=	0	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	28	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	7.98	ft	Length of MSE reinforcement
L factor	=	0.84		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	9.5	ft	
H	=	6.5	ft	Height of wall
Ka	=	0.33		
Γ Pa	=	3.1667	ft	Moment arm
Γ Wt	=	4.75	ft	Moment arm
B'	=	6.30	ft	
γ'	=	57.6	pcf	
W_t		1,915	lb/ft of wall	Weight from traffic
W_{mse}	=	9,097	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 1,748 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 6,598 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 2,639 psf

Factor of Safety = **3.77** **OK**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 5,577 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 2,231 psf

Factor of Safety = **3.19** **OK**

Bearing Capacity Factors for Equations (AASHTO)

Undrained		Drained	
N_c	5.14	N_c	25.80
N_q	1.00	N_q	14.72
N_γ	0.00	N_γ	16.72

Eccentricity of Resultant Force

e = 0.84 ft

Kern

e < L/6 = 1.33 ft

DLZ	SUBJECT	Client	ODOT9	JOB NUMBER	0121-3070.03	
		Project	SCI-823-0.00 (US 52 Ramp A), TR-75	SHEET NO.	22	OF 34
		Item	MSE Wall Stability(Sta 37+50)	COMP. BY	EWT	DATE 10/10/07
			Full Ka, right wall	CHECKED BY	BWJ	DATE 11-15-07
			Based on existing foundation soils			

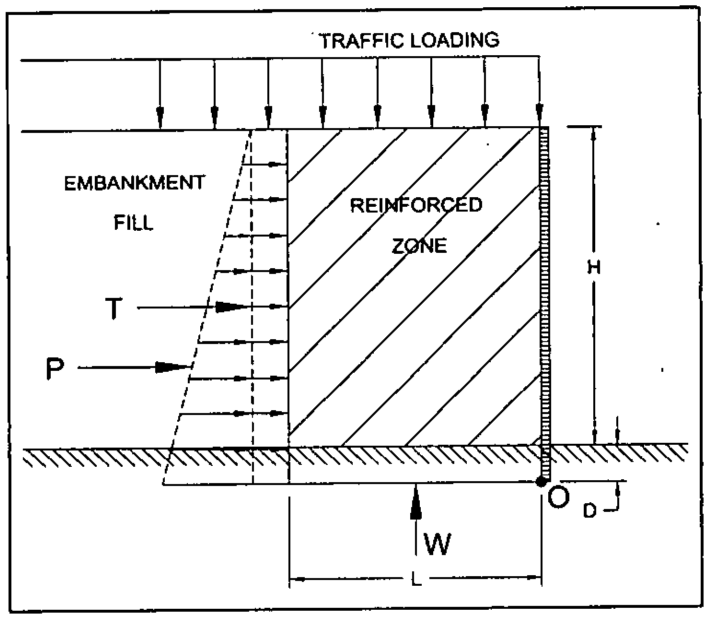
STABILITY OF MSE WALL

Assumptions:

1 Estimated height of embankment; H=6.5'
2 Ground water; Dw=0.0'
3 Traffic loading is neglected in resisting forces
4
5

Wall Properties			Foundational Soil Properties			
H+D =	9.5	feet	c =	1250	psf	Cohesion
γ_{mse} =	120	pcf	ϕ' =	28	deg	Friction angle
L =	7.98	feet	ω_T =	240	psf	Traffic loading
L factor =	0.84		Length factor-range (0.7 - 1.0)			
ϕ =	30	deg	Friction Angle of Embankment Fill			

RESISTANCE AGAINST SLIDING ALONG BASE



Thrust: $P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ K_a = 0.33

P_a = 2,539 lbs per foot of wall

Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu = \left(\frac{2}{3}\right)\tan(\phi)$ μ = 0.36

P_r = 3,184 lbs per foot of wall

USE THIS VALUE

$P_r = L(c)$ (Undrained)

P_r = 9,975 lbs per foot of wall

Use Drained Value

$FS = \frac{P_r}{P_a}$

	Calculated	Required
	FS = **1.25**	FS = 1.50

Resistance Against Sliding is **No Good**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 36,298 lb-ft $\quad \Sigma M_{resisting} = \gamma HL\left(\frac{L}{2}\right)$

$\Sigma M_{overturning}$ = 9,233 lb-ft $\quad \Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$

$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$

	Calculated	Required
	FS = 3.93	FS = 2.00

Resistance Against Overturning is **OK**

DLZ

SUBJECT		JOB NUMBER	0121-3070.03		
Client	ODOT9	SHEET NO.	23	OF	3k
Project	SCI-823-0.00 (US 52 Ramp A), TR-75	COMP. BY	EWT	DATE	10/10/07
Item	MSE Wall Stability(Sta 37+50)	CHECKED BY	BW	DATE	11-4-07
	Full Ka, right wall				

Based on existing foundation soils

STABILITY OF MSE WALL

Assumptions:

1. Estimated height of embankment; H=6.5'
2. Ground water; Dw=0.0'
3. Traffic loading is neglected in resisting forces
4.
5.

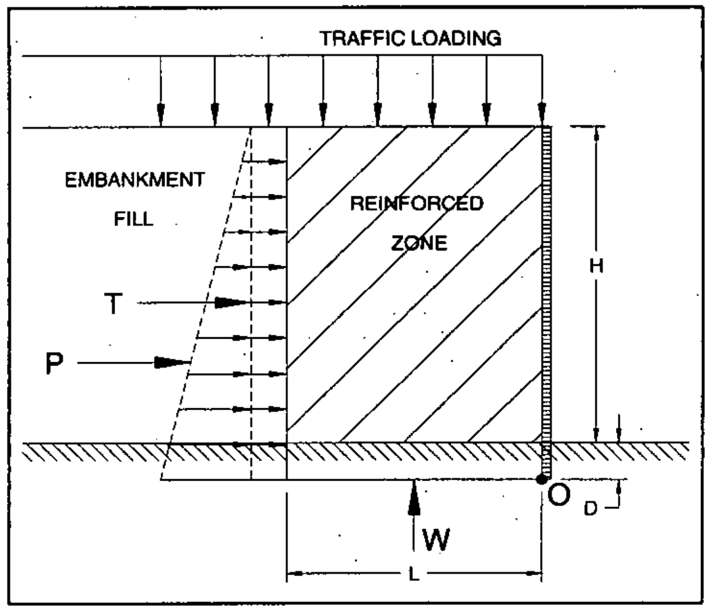
Wall Properties			Foundational Soil Properties			
H+D =	9.5	feet	c =	1250	psf	Cohesion
γ_{mse} =	120	pcf	ϕ' =	28	deg	Friction angle
L =	7.98	feet	ω_T =	240	psf	Traffic loading
L factor =	0.84		Length factor-range (0.7 - 1.0)			
ϕ =	30	deg	Friction Angle of Embankment Fill			

RESISTANCE AGAINST SLIDING ALONG BASE

Thrust: $$P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$$

where; $K_a = \tan^2(45-\frac{\phi}{2})$ K_a = 0.33

P_a = 2,539 lbs per foot of wall



Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu^* = \tan(\phi)$ μ = 0.53

**Note: for non-continuous reinforcement*

P_r = 4,822 lbs per foot of wall

USE THIS VALUE

$P_r = L(c)$ (Undrained)

P_r = 9,975 lbs per foot of wall

Use Drained Value

$$FS = \frac{P_r}{P_a}$$

Calculated: FS = **1.90** Required: FS = 1.50

Resistance Against Sliding is **OK**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).

* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 36,298 lb-ft $$\Sigma M_{resisting} = \gamma HL\left(\frac{L}{2}\right)$$

$\Sigma M_{overturning}$ = 9,233 lb-ft $$\Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$$

$$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$$

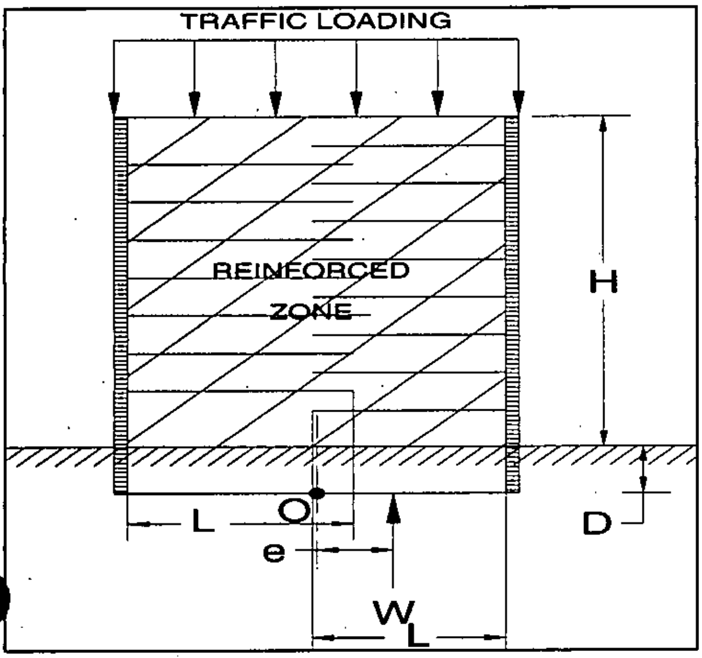
Calculated: FS = **3.93** Required: FS = 2.00

Resistance Against Overturning is **OK**

SUBJECT	Client	ODOT9	JOB NUMBER	0121-3070.03
	Project	SCI-823-0.00 (US 52, Ramp A)	SHEET NO.	24 OF 34
	Item	Bearing Capacity (Sta 38+00 LT), Boring TR-75	COMP. BY	EWT DATE 10/10/07
		0.21(H+D) overlapping, Ka = 0.2K	CHECKED BY	BW DATE 1-Oct-07
		Based on existing foundation soils		

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{REIN}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{REIN}	=	34	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	1250	psf	Cohesion	Foundation soil
ϕ	=	0	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	28	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	26.04	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	37.2	ft	
H	=	34.2	ft	Greatest height of dobule wall
Ka	=	0.06		**Ka=0.2*K due to overlap**
Γ Pa	=	12.4	ft	Moment arm
Γ Wt	=	18.6	ft	Moment arm
B'	=	24.86	ft	
γ'	=	57.6	pcf	
W_t		6,250	lb/ft of wall	Weight from traffic
W_{mse}	=	116,243	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 4,927 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 6,598 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 2,639 psf

Factor of Safety = **1.34** **No Good**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 14,515 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 5,806 psf

Factor of Safety = **2.95** **OK**

Bearing Capacity Factors for Equations

Undrained		Drained	
N_c	5.14	N_c	25.80
N_q	1.00	N_q	14.72
N_γ	0.00	N_γ	16.72

Eccentricity of Resultant Force

e = 0.59 ft

Kern

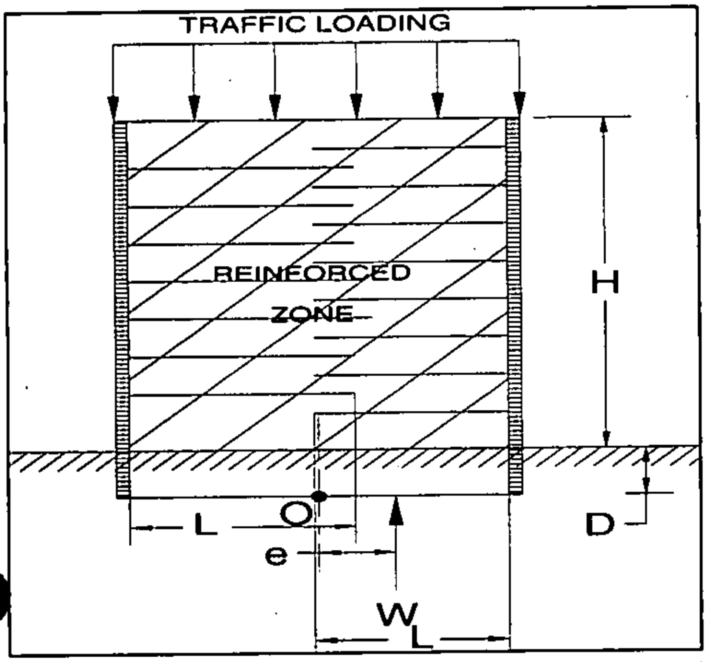
e < L/6 = 4.34 ft

DLZ	SUBJECT			
	Client	ODOT9	JOB NUMBER	0121-3070.03
	Project	SCI-823-0.00 (US 52, Ramp A)	SHEET NO.	25 OF 34
	Item	Bearing Capacity (Sta 38+00 LT), Boring TR-75	COMP. BY	EWT DATE 10/10/07
		0.21(H+D) overlapping, Ka = 0.2K	CHECKED BY	BW DATE 11-15-07

Based upon 4.5' undercut below base of leveling pad and replace with compacted granular material

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{REIN}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{REIN}	=	34	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	0	psf	Cohesion	Foundation soil
ϕ	=	30	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	30	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	26.04	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	37.2	ft	
H	=	34.2	ft	Greatest height of dobule wall
Ka	=	0.06		**Ka=0.2*K due to overlap**
Γ Pa	=	12.4	ft	Moment arm
Γ Wt	=	18.6	ft	Moment arm
B'	=	24.86	ft	
γ'	=	57.6	pcf	
W_t		6,250	lb/ft of wall	Weight from traffic
W_{mse}	=	116,243	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 4,927 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 19,217 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 7,687 psf

Factor of Safety = 3.90 **OK**

Ultimate drained bearing capacity, q'_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 19,217 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 7,687 psf

Factor of Safety = 3.90 **OK**

Bearing Capacity Factors for Equations

Undrained		Drained	
N_c	30.14	N_c	30.14
N_q	18.40	N_q	18.40
N_γ	22.40	N_γ	22.40

Eccentricity of Resultant Force

e = 0.59 ft

Kern

e < L/6 = 4.34 ft

DLZ

SUBJECT			
Client	ODOT9	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00 (US 52, Ramp A)	SHEET NO.	26 OF 34
Item	MSE Wall Stability (Sta 38+00, LT),TR-75	COMP. BY	EWT DATE 10/10/07
	0.21(H+D) overlapping; Ka = 0.2K	CHECKED BY	BW DATE 11-15-07
	Based on existing foundation soils		

STABILITY OF MSE WALL

Assumptions:

1 Estimated height of embankment; H=34.2'
2 Ground water; Dw=0.0'
3 Traffic loading is neglected in resisting forces
4 Ka=0.2K due to reinforcing strap overlapping
5

Wall Properties

H+D	=	37.2	feet
γ_{mse}	=	120	pcf
L	=	26.04	feet
L factor	=	0.70	Length factor-range (0.7 - 1.0)
ϕ	=	30	deg — Friction Angle of Embankment Fill

Foundational Soil Properties

c	=	1250	psf	Cohesion
ϕ'	=	28	deg	Friction angle
ω_T	=	240	psf	Traffic loading

RESISTANCE AGAINST SLIDING ALONG BASE

Thrust: $$P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ Ka = 0.07

Pa = 6,437 lbs per foot of wall

Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu = \left(\frac{2}{3}\right)\tan(\phi)$ μ = 0.36

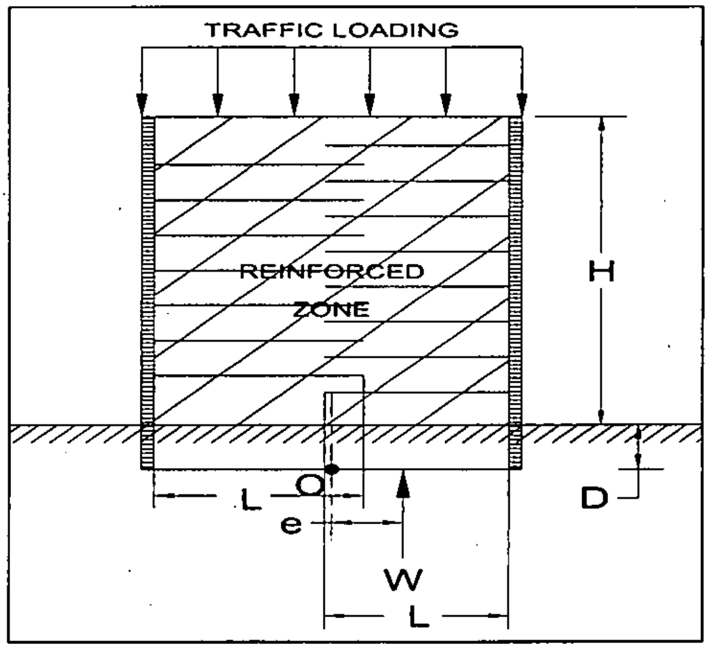
P_r = 40,685 lbs per foot of wall

Use Undrained Value

$P_r = L(c)$ (Undrained)

P_r = 32,550 lbs per foot of wall

USE THIS VALUE



$$FS = \frac{F_R}{F_O}$$

Calculated	Required	
FS = **5.06**	FS = 1.50	Resistance Against Sliding is **OK**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 1,513,478 lb-ft

$$\Sigma M_{resisting} = \gamma HL\left(\frac{L}{2}\right)$$

$\Sigma M_{overturning}$ = 83,695 lb-ft

$$\Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$$

$$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$$

Calculated	Required	
FS = **18.08**	FS = 2.00	Resistance Against Overturning is **OK**

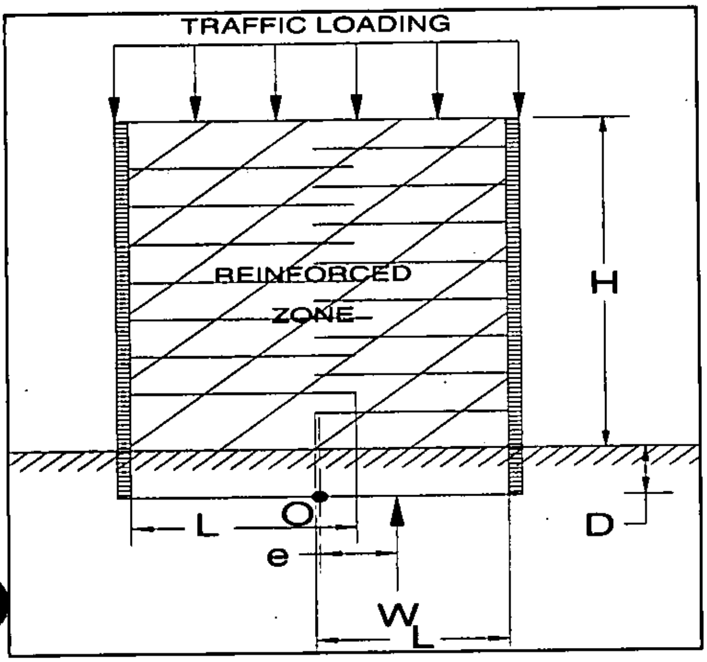
DLZ

SUBJECT			
Client	ODOT9	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00 (US 52, Ramp A)	SHEET NO.	27 OF 34
Item	Bearing Capacity (Sta 38+00 RT), Boring TR-75	COMP. BY	EWT DATE 10/10/07
	0.31(H+D) overlapping, Ka = 0.0K	CHECKED BY	RWJ DATE 11-15-07

Based on existing foundation soils

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{REIN}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{REIN}	=	34	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	1250	psf	Cohesion	Foundation soil
ϕ	=	0	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	28	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	15.33	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	21.9	ft	
H	=	18.9	ft	
Ka	=	0.00		**Ka=0.0*K due to overlap**
Γ Pa	=	7.3	ft	Moment arm
Γ Wt	=	10.95	ft	Moment arm
B'	=	15.33	ft	
γ'	=	57.6	pcf	
W_t		3,679	lb/ft of wall	Weight from traffic
W_{mse}	=	40,287	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 2,868 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 6,598 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 2,639 psf

Factor of Safety = **2.30** **No Good**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 9,926 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 3,970 psf

Factor of Safety = **3.46** **OK**

Bearing Capacity Factors for Equations

Undrained		Drained	
N_c	5.14	N_c	25.80
N_q	1.00	N_q	14.72
N_γ	0.00	N_γ	16.72

Eccentricity of Resultant Force

e = 0.00 ft

Kern

e < L/6 = 2.56 ft

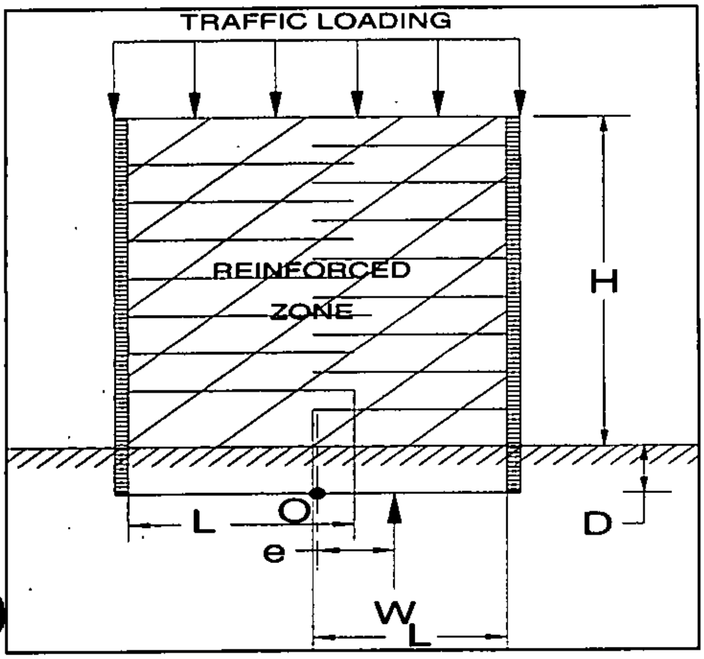
DLZ

SUBJECT			
Client	ODOT9	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00 (US 52, Ramp A)	SHEET NO.	28 OF 34
Item	Bearing Capacity (Sta 38+00 RT), Boring TR-75	COMP. BY	EWT DATE 10/10/07
	0.31(H+D) overlapping, Ka = 0.0K	CHECKED BY	BW DATE 11-15-07

Based upon 4.5' undercut below base of leveling pad and replace with compacted granular material

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{REIN}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{REIN}	=	34	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	0	psf	Cohesion	Foundation soil
ϕ	=	30	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	30	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	15.33	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	21.9	ft	
H	=	18.9	ft	
Ka	=	0.00		**Ka=0.0*K due to overlap**
Γ Pa	=	7.3	ft	Moment arm
Γ Wt	=	10.95	ft	Moment arm
B'	=	15.33	ft	
γ'	=	57.6	pcf	
W_t		3,679	lb/ft of wall	Weight from traffic
W_{mse}	=	40,287	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 2,868 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 13,069 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 5,228 psf

Factor of Safety = **4.56** **OK**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 13,069 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 5,228 psf

Factor of Safety = **4.56** **OK**

Bearing Capacity Factors for Equations

Undrained		Drained	
N_c	30.14	N_c	30.14
N_q	18.40	N_q	18.40
N_γ	22.40	N_γ	22.40

Eccentricity of Resultant Force

e = 0.00 ft

Kern

e < L/6 = 2.56 ft

DLZ	SUBJECT		JOB NUMBER	0121-3070.03		
	Client	ODOT9	SHEET NO.	29	OF	34
	Project	SCI-823-0.00 (US 52, Ramp A)	COMP. BY	EWT	DATE	10/10/07
	Item	MSE Wall Stability (Sta 38+00, RT),TR-75	CHECKED BY	BW	DATE	11-15-07
		0.31(H+D) overlapping; Ka = 0.0K				

Based on existing foundation soils

STABILITY OF MSE WALL

Assumptions:

1 Estimated height of embankment; H=18.9'
2 Ground water; Dw=0.0'
3 Traffic loading is neglected in resisting forces
4 Ka=0.0K due to reinforcing strap overlapping
5

Wall Properties				Foundational Soil Properties				
H+D	=	21.9	feet	c	=	1250	psf	Cohesion
γ_{mse}	=	120	pcf	ϕ'	=	28	deg	Friction angle
L	=	15.33	feet	ω_T	=	240	psf	Traffic loading
L factor	=	0.70		Length factor-range (0.7 - 1.0)				
ϕ	=	30	deg	Friction Angle of Embankment Fill				

RESISTANCE AGAINST SLIDING ALONG BASE

Thrust: $P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ Ka = 0.00

Pa = 0 lbs per foot of wall

Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu = \left(\frac{2}{3}\right)\tan(\phi)$ μ = 0.36

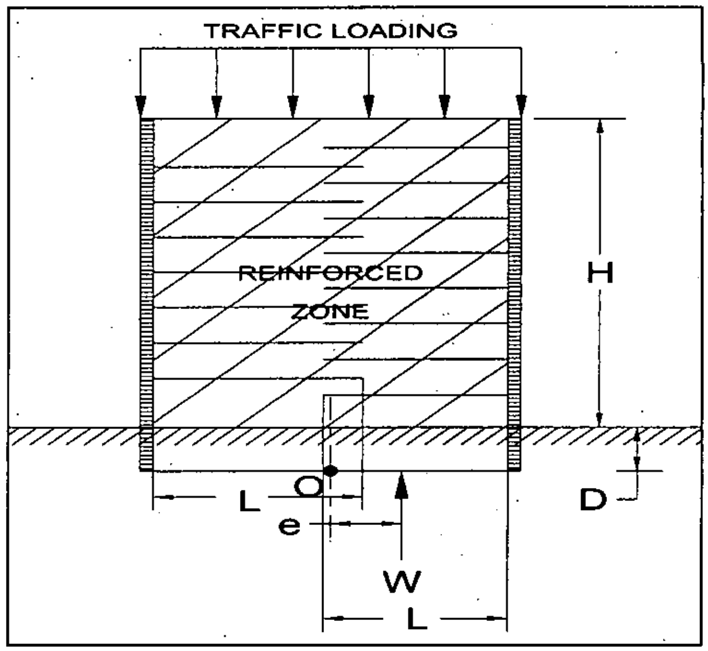
P_r = 14,101 lbs per foot of wall

USE THIS VALUE

$P_r = L(c)$ (Undrained)

P_r = 19,163 lbs per foot of wall

Use Drained Value



$FS = \frac{F_R}{F_O}$

	Calculated	Required
	FS = **#DIV/0!**	FS = 1.50

Resistance Against Sliding is **OK**

FS = ∞, FS > 1.5 due to Ka = 0.0

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 308,802 lb-ft

$$\Sigma M_{resisting} = \gamma HL\left(\frac{L}{2}\right)$$

$\Sigma M_{overturning}$ = 0 lb-ft

$$\Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$$

$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$

	Calculated	Required
	FS = **#DIV/0!**	FS = 2.00

Resistance Against Overturning is **OK**

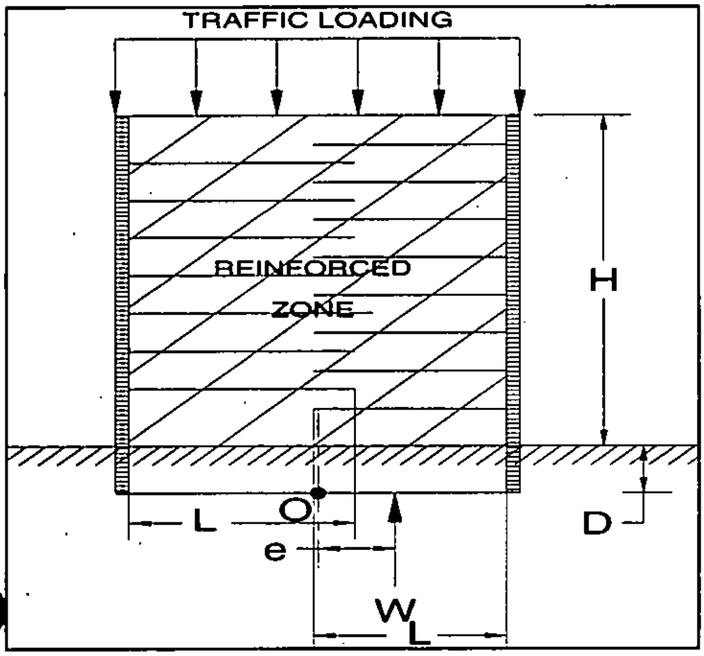
FS = ∞, FS > 1.5 due to Ka = 0.0

DLZ

SUBJECT			
Client	ODOT9	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00 (US 52, Ramp A)	SHEET NO.	30 OF 34
Item	Bearing Capacity (Sta 38+50 LT), Boring B-33	COMP. BY	EWT DATE 10/10/07
	0.18(H+D) overlapping, Ka = 0.2K	CHECKED BY	BW DATE 11-14-07
	Based on existing foundation soils		

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{REIN}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{REIN}	=	34	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	1750	psf	Cohesion	Foundation soil
ϕ	=	0	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	29	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	22.26	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	31.8	ft	
H	=	28.8	ft	Greatest height of dobule wall
Ka	=	0.06		**Ka=0.2*K due to overlap**
Γ Pa	=	10.6	ft	Moment arm
Γ Wt	=	15.9	ft	Moment arm
B'	=	21.24	ft	
γ'	=	57.6	pcf	
W_t		5,342	lb/ft of wall	Weight from traffic
W_{mse}	=	84,944	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 4,251 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 9,168 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 3,667 psf

Factor of Safety = **2.16** **No Good**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 14,671 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 5,868 psf

Factor of Safety = **3.45** **OK**

Bearing Capacity Factors for Equations

Undrained		Drained	
N_c	5.14	N_c	27.86
N_q	1.00	N_q	16.44
N_γ	0.00	N_γ	19.34

Eccentricity of Resultant Force

e = 0.51 ft

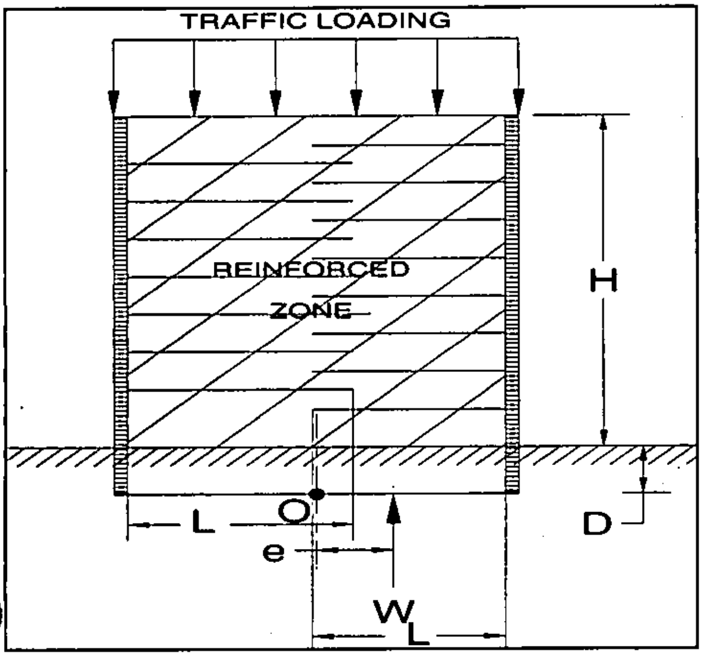
Kern

e < L/6 = 3.71 ft

Based upon 4.5' undercut below base of leveling pad and replace with compacted granular material

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{REIN}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{REIN}	=	34	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	0	psf	Cohesion	Foundation soil
ϕ	=	30	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	30	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	22.26	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	31.8	ft	
H	=	28.8	ft	Greatest height of dobule wall
Ka	=	0.06		**Ka=0.2*K due to overlap**
Γ Pa	=	10.6	ft	Moment arm
Γ Wt	=	15.9	ft	Moment arm
B'	=	21.24	ft	
γ'	=	57.6	pcf	
W_t		5,342	lb/ft of wall	Weight from traffic
W_{mse}	=	84,944	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 4,251 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = c N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 16,882 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 6,753 psf

Factor of Safety = **3.97** **OK**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c' N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 16,882 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 6,753 psf

Factor of Safety = **3.97** **OK**

Bearing Capacity Factors for Equations

Undrained		Drained	
N_c	30.14	N_c	30.14
N_q	18.40	N_q	18.40
N_γ	22.40	N_γ	22.40

Eccentricity of Resultant Force

e = 0.51 ft

Kern

e < L/6 = 3.71 ft

DLZ

SUBJECT		JOB NUMBER	0121-3070.03
Client	ODOT9	SHEET NO.	32 OF 34
Project	SCI-823-0.00 (US 52, Ramp A)	COMP. BY	EWT DATE 10/10/07
Item	MSE Wall Stability (Sta 38+50, LT),B-33	CHECKED BY	BW DATE 11-15-07
	0.18(H+D) overlapping; Ka = 0.2K		

Based on existing foundation soils

STABILITY OF MSE WALL

Assumptions:

1 Estimated height of embankment; H=28.8'
2 Ground water; Dw=0.0'
3 Traffic loading is neglected in resisting forces
4 Ka=0.2K due to reinforcing strap overlapping
5

Wall Properties			Foundational Soil Properties			
H+D =	31.8	feet	c =	1750	psf	Cohesion
γ_{mse} =	120	pcf	ϕ' =	29	deg	Friction angle
L =	22.26	feet	ω_T =	240	psf	Traffic loading
L factor =	0.70		Length factor-range (0.7 - 1.0)			
ϕ =	30	deg	Friction Angle of Embankment Fill			

RESISTANCE AGAINST SLIDING ALONG BASE

Thrust: $P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ Ka = 0.07

Pa = 4,781 lbs per foot of wall

Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu = \left(\frac{2}{3}\right)\tan(\phi)$ μ = 0.37

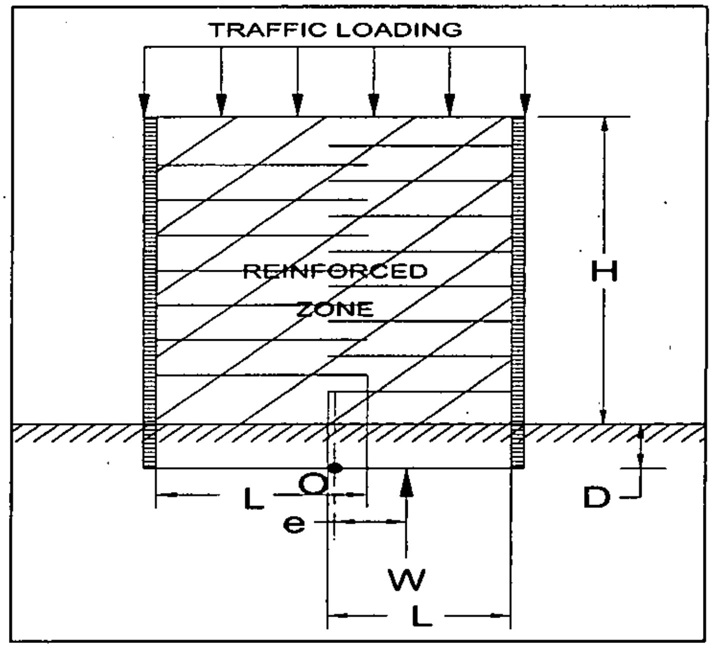
P_r = 29,730 lbs per foot of wall

USE THIS VALUE

$P_r = L(c)$ (Undrained)

P_r = 38,955 lbs per foot of wall

Use Drained Value



$FS = \frac{F_R}{F_O}$

	Calculated	Required
	FS = **6.22**	FS = 1.50

Resistance Against Sliding is **OK**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 945,429 lb-ft

$\Sigma M_{overturning}$ = 53,515 lb-ft

$$\Sigma M_{resisting} = \gamma HL\left(\frac{L}{2}\right)$$

$$\Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$$

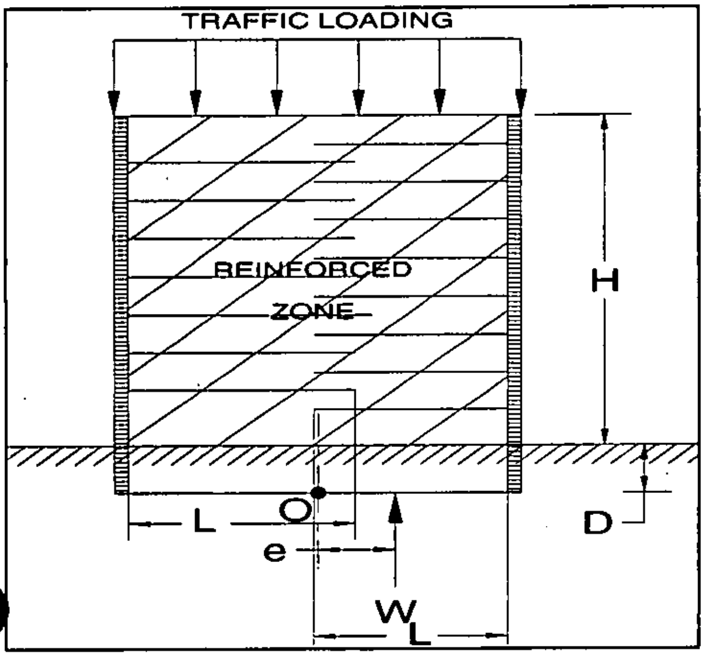
$$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$$

	Calculated	Required
	FS = **17.67**	FS = 2.00

Resistance Against Overturning is **OK**

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{REIN}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{REIN}	=	34	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	1750	psf	Cohesion	Foundation soil
ϕ	=	0	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	29	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	16.87	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	24.1	ft	
H	=	21.1	ft	
Ka	=	0.03		**Ka=0.1*K due to overlap**
Γ Pa	=	8.03	ft	Moment arm
Γ Wt	=	12.05	ft	Moment arm
B'	=	16.47	ft	
γ'	=	57.6	pcf	
W_t		4,049	lb/ft of wall	Weight from traffic
W_{mse}	=	48,788	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 3,208 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 9,168 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 3,667 psf

Factor of Safety = **2.86** **OK**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 12,014 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 4,806 psf

Factor of Safety = **3.75** **OK**

Bearing Capacity Factors for Equations

Undrained		Drained	
N_c	5.14	N_c	27.86
N_q	1.00	N_q	16.44
N_γ	0.00	N_γ	19.34

Eccentricity of Resultant Force

e = 0.20 ft

Kern

e < L/6 = 2.81 ft

DLZ

SUBJECT			
Client	ODOT9	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00 (US 52, Ramp A)	SHEET NO.	34 OF 34
Item	MSE Wall Stability (Sta 38+50, RT),B-33	COMP. BY	EWT DATE 10/10/07
	0.24(H+D) overlapping; Ka = 0.1K	CHECKED BY	BW DATE 11-15-07

Based on existing foundation soils

STABILITY OF MSE WALL

Assumptions:

1 Estimated height of embankment; H=21.1'
2 Ground water; Dw=0.0'
3 Traffic loading is neglected in resisting forces
4 Ka=0.1K due to reinforcing strap overlapping
5

Wall Properties

H+D = 24.1 feet
γ_{mse} = 120 pcf
L = 16.87 feet
L factor = 0.70 Length factor-range (0.7 - 1.0)
ϕ = 30 deg Friction Angle of Embankment Fill

Foundational Soil Properties

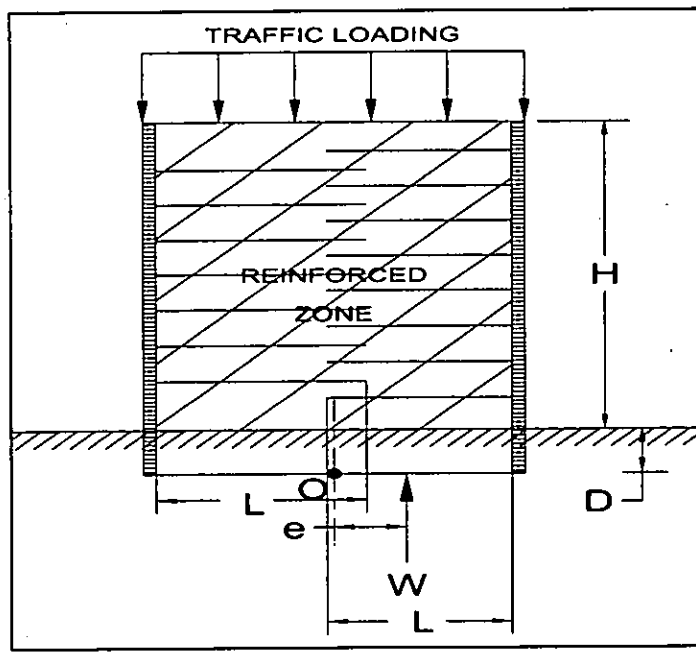
c = 1750 psf Cohesion
ϕ' = 29 deg Friction angle
ω_T = 240 psf Traffic loading

RESISTANCE AGAINST SLIDING ALONG BASE

Thrust: $P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ Ka = 0.03

Pa = 1,219 lbs per foot of wall



Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu = \left(\frac{2}{3}\right)\tan(\phi)$ μ = 0.37

P_r = 17,076 lbs per foot of wall

USE THIS VALUE

$P_r = L(c)$ (Undrained)

P_r = 29,523 lbs per foot of wall

Use Drained Value

$FS = \frac{F_R}{F_O}$ Calculated FS = **14.01** Required FS = 1.50

Resistance Against Sliding is **OK**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 411,527 lb-ft $\Sigma M_{resisting} = \gamma HL\left(\frac{L}{2}\right)$

$\Sigma M_{overturning}$ = 10,489 lb-ft $\Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$

$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$ Calculated FS = **39.23** Required FS = 2.00

Resistance Against Overturning is **OK**

MSE Wall Bearing Capacity and Stability Calculations
(Ramp B)

Ramp B

Station 32+50 Left, $H_1 = 30'$, $L_1 = 0.7H_1 = 21.0'$,
Station 32+50 Right, $H_2 = 24.2$, $L_2 = 0.7H_2 = 16.94'$
$W = 33.3'$ (FHWA-SA-96-071 pg 178)

$R_1 = (16.94 - (33.3 - 21.0))/30 = 0.16 \Rightarrow k = 0.3\,ka$

$R_2 = (16.94 - (33.3 - 21.0))/24.2 = 0.19 \Rightarrow k = 0.2\,ka$

Station 33+50 Left, $H_1 = 33.2$, $L_1 = 0.7 \times 33.2 = 23.24'$
Station 33+50 Right, $H_2 = 27.3$, $L_1 = 0.7 \times 27.3 = 19.11'$

$R_1 = (19.11 - (33.3 - 23.24))/33.2 = 0.27 \Rightarrow k = 0.05\,ka$

$R_2 = (19.11 - (33.3 - 23.243))/27.3 = 0.33 \Rightarrow k = 0.0\,ka$

Station 34+00 Left, $H_1 = 34.8$, $L_1 = 0.7 \times 34.8 = 24.36'$
Station 34+00 Right, $H_2 = 29$, $L_2 = 0.7 \times 29 = 20.3'$

$R_1 = (20.3 - (33.3 - 24.36))/34.8 = 0.33 \Rightarrow k = 0.0\,ka$

$R_2 = (20.3 - (33.3 - 24.36))/29 = 0.39 \Rightarrow k = 0.0\,ka$

Station 35+42.74 Left, $H_1 = 34.3$, $L_1 = 0.7 \times 34.3 = 24.01'$
Station 35+42.74 Right, $H_2 = 33.4$, $L_2 = 0.7 \times 33.4 = 23.38$
(End Approach Slab)

$R_1 = (23.38 - (33.3 - 24.01))/34.3 = 0.41 \Rightarrow k = 0.0\,ka$

$R_2 = (23.38 - (33.3 - 24.01))/33.4 = 0.42 \Rightarrow k = 0.0\,ka$

FHWA-SA-96-071

7/21

SW T 11-15-07
BW 11-15-07

5.4 BACK-TO-BACK WALLS

For walls which are built back-to-back as shown in figure 50, a modified value of backfill thrust influences the external stability calculations. As indicated in figure 50, two cases can be considered.

- For Case I, the overall base width is large enough so that each wall behaves and can be designed independently. In particular, there is no overlapping of the reinforcements. Theoretically, if the distance, D, between the two walls is shorter than:

$$D = H_1 \tan(45° - \varphi/2) \quad (55)$$

  then the active wedges at the back of each wall cannot fully spread out and the active thrust is reduced. However, it is assumed that for values of:

$$D > H_1 \tan(45° - \varphi/2) \approx 0.5\,H_1 \quad (56)$$

  full active thrust is mobilized.

- For Case II, there is an overlapping of the reinforcements such that the two walls interact. When the overlap, L_R, is greater than 0.3 H_2, where H_2 is the shorter of the parallel walls, no active earth thrust from the backfill needs to be considered for external stability calculations. For intermediate geometries between Case I and Case II, the active earth thrust may be linearly interpolated from the full active case to zero. For Case II geometries with overlaps greater than 0.3 H_2, L/H ratios for each wall as low as 0.6 may be considered.

  Considering this case, designers might be tempted to use single reinforcements connected to both wall facings. This alternative completely changes the strain patterns in the structure and results in higher reinforcement tensions such that the design method in this manual is no longer applicable. In addition, difficulties in maintaining wall alignment could be encountered during construction, especially when the walls are not in a tangent section.

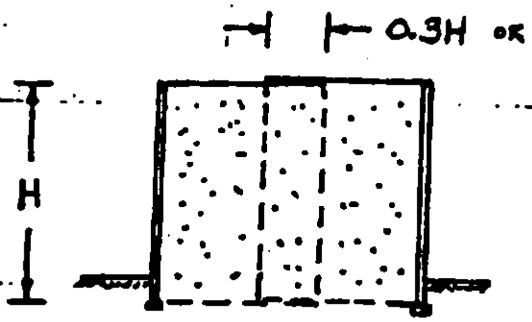
  Based on a performance review, back-to-back walls with overlapping reinforcements may be designed for static load conditions with a distance between parallel facing as low as L/H = 0.6, where H is the height of each wall, and for conditions where the seismic horizontal accelerations at the foundation level is less than 0.05g. For walls in more seismically active areas (up to 0.19g) a distance of 1.1H_1 is presently recommended. For walls subjected to significant seismic loading (up to 0.40g) successful performance has been observed when the distance between parallel facings was at least 1.2H_1.

  Justification of narrower back-to-back distances (< 1.1H_1) between faces in seismically active areas require a more detailed analysis be performed to include effects of potential non-uniform distribution of seismic and inertial forces within the wall, as suggested by numerical studies and not provided for in the present design methodology.

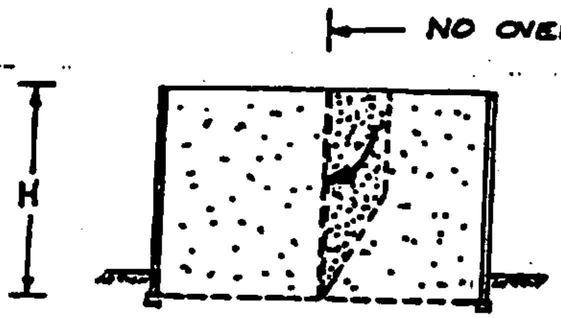
3/21
SWT 11-15-07
BW 11-15-07

BACK TO BACK WALLS – REDUCED E.P. AS f OF DISTANCE APART

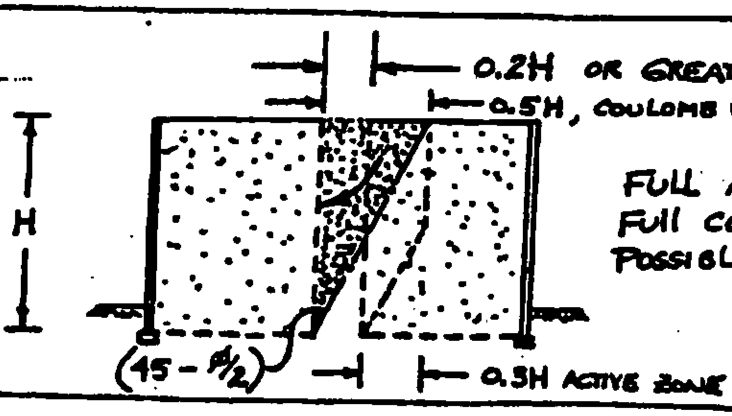
AS SUGGESTED BY ROD SMITH – REINFORCED EARTH – U.K.
MODIFIED BY P. ANDERSON BASED ON SMALL SCALE MODEL



ZERO E.P. DUE TO REINFORCEMENT PROVIDED IN BOTH DIRECTIONS, IMMOBILIZING THE POSSIBILITY OF AN ACTIVE ZONE DEVELOPING.



REDUCED E.P. – ASSUME 60% OF FULL E.P. BASED ON LINEAR INTERPOLATION BETWEEN TWO LIMITING EARTH PRESSURES (SEE PLOT AT BOTTOM OF PAGE)



FULL ACTIVE E.P.
FULL COULOMB WEDGE IS POSSIBLE TO DEVELOP

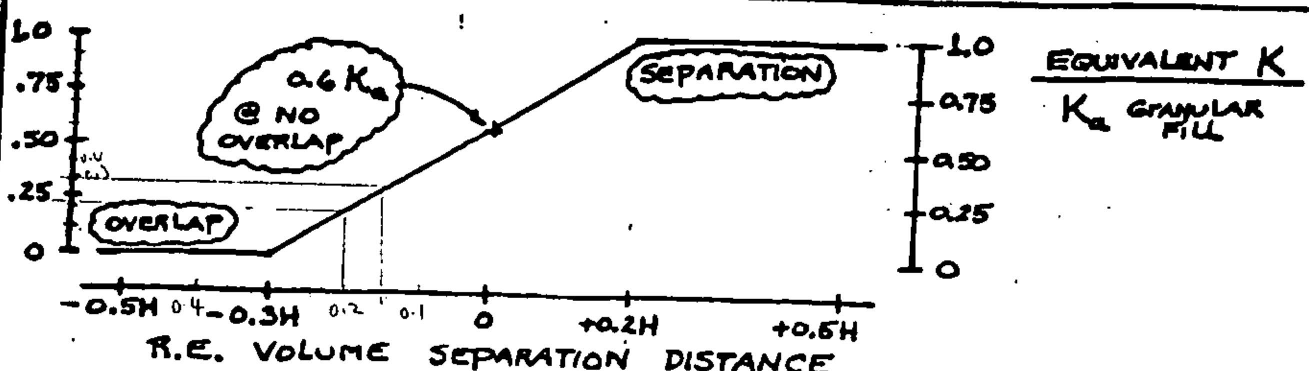


FIGURE 1

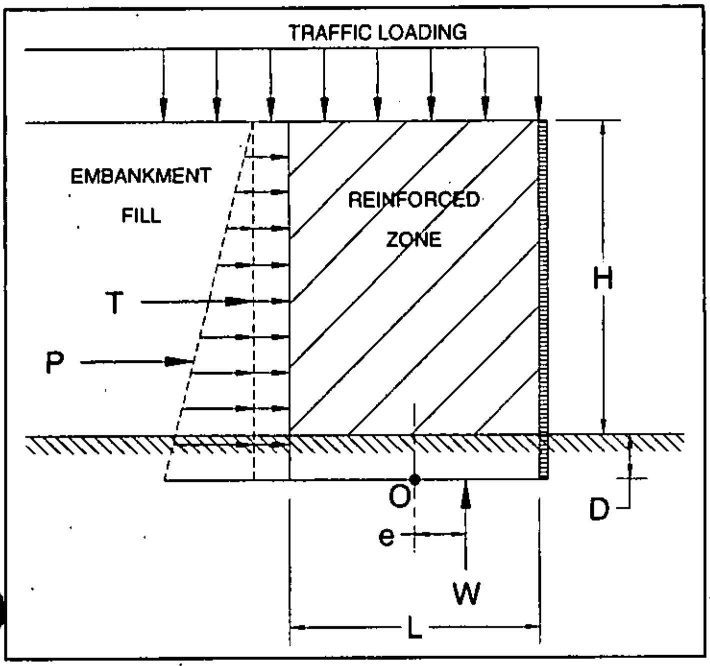
DLZ

SUBJECT			
Client	ODOT9	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00 (US 52, Ramp B)	SHEET NO.	4 OF 21
Item	MSE Wall Bearing Capacity (Sta 29+50), TR-68A	COMP. BY	EWT DATE 10/11/07
		CHECKED BY	BW DATE 11-13-07

Based on existing foundation soils

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{EMB}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{EMB}	=	30	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	125	pcf	Unit weight	Foundation soil
c	=	3000	psf	Cohesion	Foundation soil
ϕ	=	0	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	30	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	14.175	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	20.25	ft	
H	=	17.25	ft	Height of wall
Ka	=	0.33		
Γ Pa	=	6.75	ft	Moment arm
Γ Wt	=	10.125	ft	Moment arm
B'	=	10.42	ft	
γ'	=	62.6	pcf	
W_t		3,402	lb/ft of wall	Weight from traffic
W_{mse}	=	34,445	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 3,634 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 15,608 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 6,243 psf

Factor of Safety = **4.29** **OK**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 10,761 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 4,304 psf

Factor of Safety = **2.96** **OK**

Bearing Capacity Factors for Equations (AASHTO)

Undrained		Drained	
N_c	5.14	N_c	30.14
N_q	1.00	N_q	18.40
N_γ	0.00	N_γ	22.40

Eccentricity of Resultant Force

e = 1.88 ft

Kern

e < L/6 = 2.36 ft

DLZ

SUBJECT			
Client	ODOT9	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00 (US 52 Ramp B)	SHEET NO.	5 OF 21
Item	MSE Wall Stability(Sta 29+50), TR-68A	COMP. BY	EWT DATE 10/11/07
		CHECKED BY	BW DATE 11-14-07

Based on existing foundation soils

STABILITY OF MSE WALL

Assumptions:

1 Estimated height of embankment; H=17.25'
2 Ground water; Dw=0.0"
3 Traffic loading is neglected in resisting forces
4
5

Wall Properties

H+D	=	20.25	feet
γ_{mse}	=	120	pcf
L	=	14.175	feet
L factor	=	0.70	Length factor-range (0.7 - 1.0)
ϕ	=	30	deg Friction Angle of Embankment Fill

Foundational Soil Properties

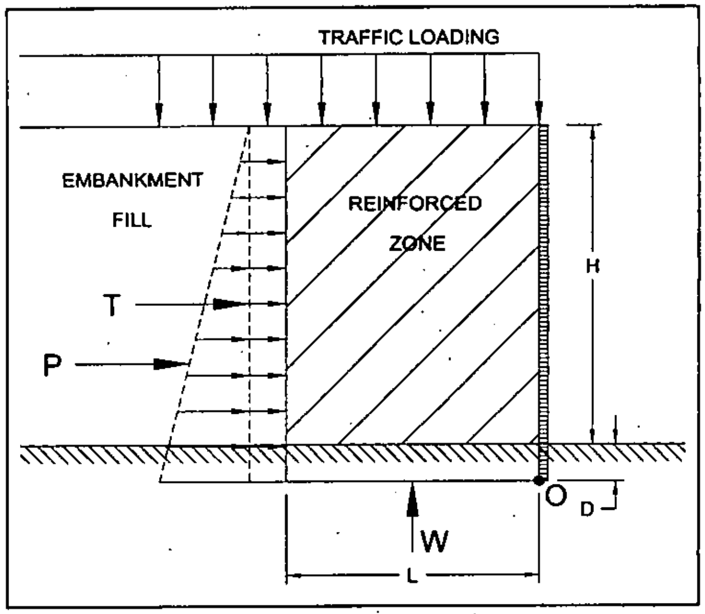
c	=	3000	psf	Cohesion
ϕ'	=	30	deg	Friction angle
ω_T	=	240	psf	Traffic loading

RESISTANCE AGAINST SLIDING ALONG BASE

Thrust: $P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ K_a = 0.33

P_a = 9,723 lbs per foot of wall



Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu = \left(\frac{2}{3}\right)\tan(\phi)$ μ = 0.39

P_r = 13,434 lbs per foot of wall

USE THIS VALUE

$P_r = L(c)$ (Undrained)

P_r = 42,525 lbs per foot of wall

Use Drained Value

$FS = \frac{P_r}{P_a}$ Calculated FS = **1.38** Required FS = 1.50

Resistance Against Sliding is **No Good**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 244,131 lb-ft $\qquad \Sigma M_{resisting} = \gamma H L\left(\frac{L}{2}\right)$

$\Sigma M_{overturning}$ = 71,043 lb-ft $\qquad \Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$

$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$ Calculated FS = 3.44 Required FS = 2.00

Resistance Against Overturning is **OK**

SUBJECT	Client ODOT9	JOB NUMBER	0121-3070.03
	Project SCI-823-0.00 (US 52 Ramp B)	SHEET NO.	6 OF 21
	Item MSE Wall Stability(Sta 29+50), TR-68A	COMP. BY EWT	DATE 10/11/07
		CHECKED BY BW	DATE 11-15-07

Based on existing foundation soils

STABILITY OF MSE WALL

Assumptions:

1 Estimated height of embankment; H=17.25'
2 Ground water; Dw=0.0"
3 Traffic loading is neglected in resisting forces
4
5

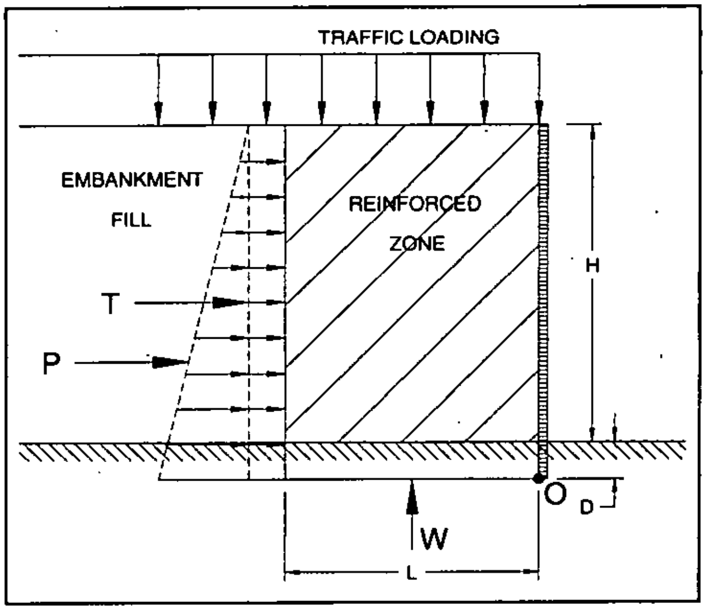
Wall Properties

$H+D$ = 20.25 feet
γ_{mse} = 120 pcf
L = 14.175 feet
L factor = 0.70 — Length factor-range (0.7 - 1.0)
ϕ = 30 deg — Friction Angle of Embankment Fill

Foundational Soil Properties

c = 3000 psf — Cohesion
ϕ' = 30 deg — Friction angle
ω_T = 240 psf — Traffic loading

RESISTANCE AGAINST SLIDING ALONG BASE



Thrust: $P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ K_a = 0.33

P_a = 9,723 lbs per foot of wall

Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu^* = \tan(\phi)$ μ = 0.58

**Note: for non-continuous reinforcement*

P_r = 19,978 lbs per foot of wall

USE THIS VALUE

$P_r = L(c)$ (Undrained)

P_r = 42,525 lbs per foot of wall

Use Drained Value

$FS = \frac{P_r}{P_a}$ Calculated FS = **2.05** Required FS = 1.50

Resistance Against Sliding is **OK**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 244,131 lb-ft $\Sigma M_{resisting} = \gamma HL\left(\frac{L}{2}\right)$

$\Sigma M_{overturning}$ = 71,043 lb-ft $\Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$

$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$ Calculated FS = 3.44 Required FS = 2.00

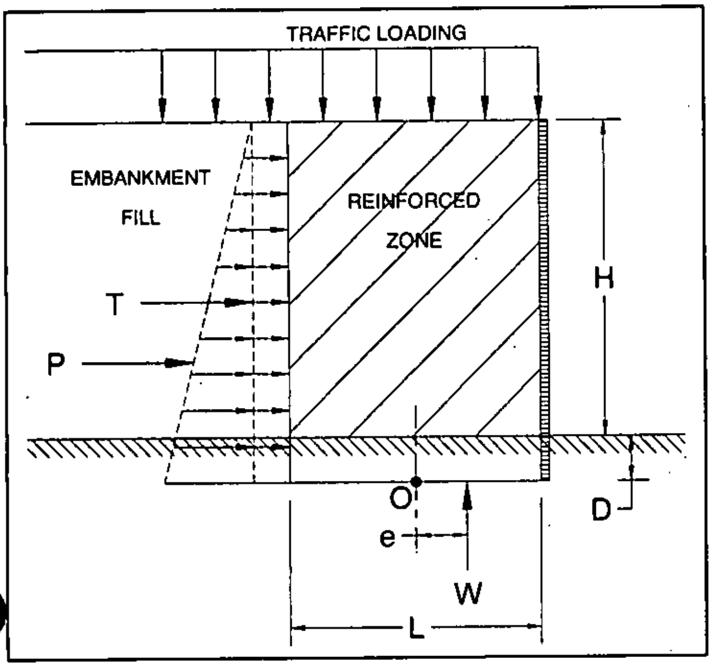
Resistance Against Overturning is **OK**

SUBJECT			
Client	ODOT9	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00 (US 52, Ramp B), Boring TR-69A	SHEET NO.	7 OF 21
Item	MSE Wall Bearing Capacity (Sta 32+00)	COMP. BY	EWT DATE 10/11/07
		CHECKED BY	BW DATE 11-15-07

Based on existing foundation soils

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{EMB}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{EMB}	=	30	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	125	pcf	Unit weight	Foundation soil
c	=	3000	psf	Cohesion	Foundation soil
ϕ	=	0	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	30	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	19.88	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	28.4	ft	
H	=	25.4	ft	Height of wall
Ka	=	0.33		
Γ Pa	=	9.4667	ft	Moment arm
Γ Wt	=	14.2	ft	Moment arm
B'	=	14.82	ft	
γ'	=	62.6	pcf	
W_t		4,771	lb/ft of wall	Weight from traffic
W_{mse}	=	67,751	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 4,894 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 15,608 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 6,243 psf

Factor of Safety = **3.19** **OK**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 13,846 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 5,538 psf

Factor of Safety = **2.83** **OK**

Bearing Capacity Factors for Equations (AASHTO)

Undrained		Drained	
N_c	5.14	N_c	30.14
N_q	1.00	N_q	18.40
N_γ	0.00	N_γ	22.40

Eccentricity of Resultant Force

e = 2.53 ft

Kern

e < L/6 = 3.31 ft

Based on existing foundation soils

STABILITY OF MSE WALL

Assumptions:

1 Estimated height of embankment; H=25.4'
2 Ground water; Dw=0.0'
3 Traffic loading is neglected in resisting forces
4
5

Wall Properties

$H+D$ = 28.4 feet
γ_{mse} = 120 pcf
L = 19.88 feet
L factor = 0.70 — Length factor-range (0.7 - 1.0)
ϕ = 30 deg — Friction Angle of Embankment Fill

Foundational Soil Properties

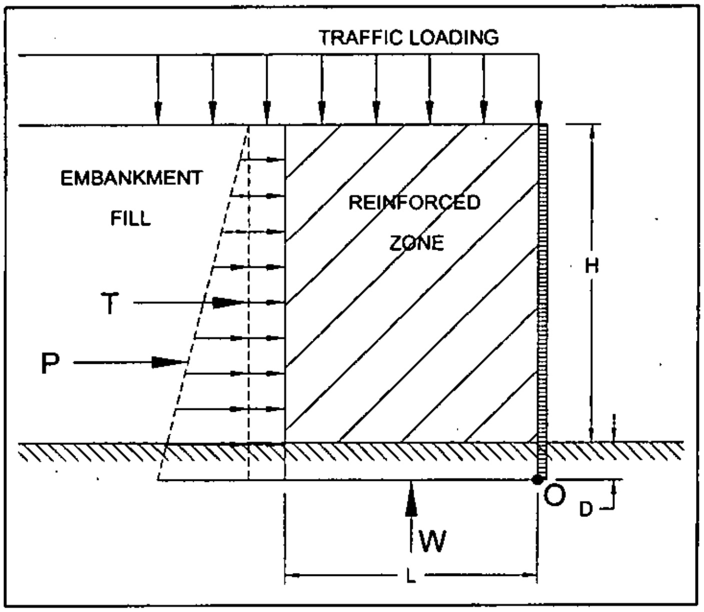
c = 3000 psf — Cohesion
ϕ' = 30 deg — Friction angle
ω_T = 240 psf — Traffic loading

RESISTANCE AGAINST SLIDING ALONG BASE

Thrust: $P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ K_a = 0.33

P_a = 18,219 lbs per foot of wall



Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu = \left(\frac{2}{3}\right)\tan(\phi)$ μ = 0.39

P_r = 26,423 lbs per foot of wall

USE THIS VALUE

$P_r = L(c)$ (Undrained)

P_r = 59,640 lbs per foot of wall

Use Drained Value

$FS = \frac{P_r}{P_a}$

	Calculated	Required
	FS = 1.45	FS = 1.50

Resistance Against Sliding is **No Good**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 673,445 lb-ft $\qquad \Sigma M_{resisting} = \gamma H L\left(\frac{L}{2}\right)$

$\Sigma M_{overturning}$ = 183,121 lb-ft $\qquad \Sigma M_{overturnig} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$

$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturnin\ g}}$

	Calculated	Required
	FS = 3.68	FS = 2.00

Resistance Against Overturning is **OK**

DLZ

SUBJECT

Client	ODOT9	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00 (US 52 Ramp B), TR-69A	SHEET NO.	9 OF 21
Item	MSE Wall Stability(Sta 32+00)	COMP. BY	EWT DATE 10/11/07
		CHECKED BY	BW DATE 11-15-07

Based on existing foundation soils

STABILITY OF MSE WALL

Assumptions:

1 Estimated height of embankment; H=25.4'
2 Ground water; Dw=0.0'
3 Traffic loading is neglected in resisting forces
4
5

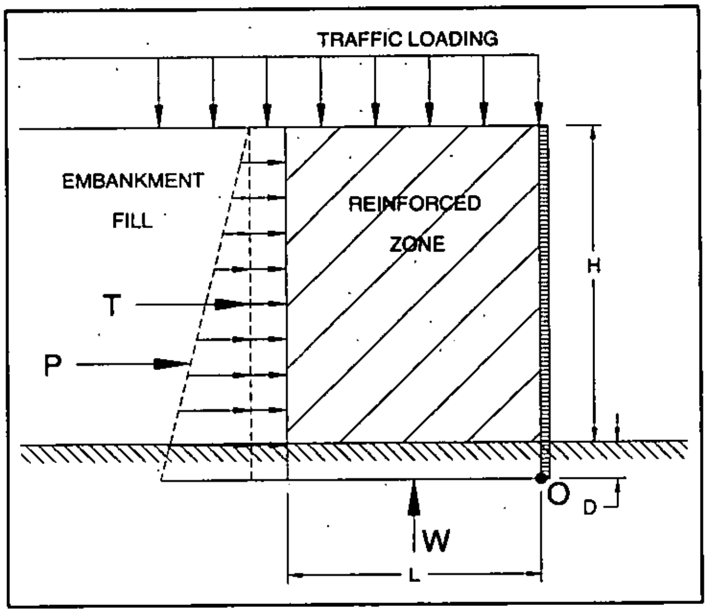
Wall Properties

H+D = 28.4 feet
γ_{mse} = 120 pcf
L = 19.88 feet
L factor = 0.70
ϕ = 30 deg

Foundational Soil Properties

c = 3000 psf Cohesion
ϕ' = 30 deg Friction angle
ω_T = 240 psf Traffic loading
Length factor-range (0.7 - 1.0)
Friction Angle of Embankment Fill

RESISTANCE AGAINST SLIDING ALONG BASE



Thrust: $P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ K_a = 0.33

P_a = 18,219 lbs per foot of wall

Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu^* = \tan(\phi)$ μ = 0.58

**Note: for non-continuous reinforcement*

P_r = 39,296 lbs per foot of wall

USE THIS VALUE

$P_r = L(c)$ (Undrained)

P_r = 59,640 lbs per foot of wall

Use Drained Value

$FS = \frac{P_r}{P_a}$ Calculated FS = **2.16** Required FS = 1.50

Resistance Against Sliding is **OK**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 673,445 lb-ft $\Sigma M_{resisting} = \gamma HL\left(\frac{L}{2}\right)$

$\Sigma M_{overturning}$ = 183,121 lb-ft $\Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$

$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$ Calculated FS = **3.68** Required FS = 2.00

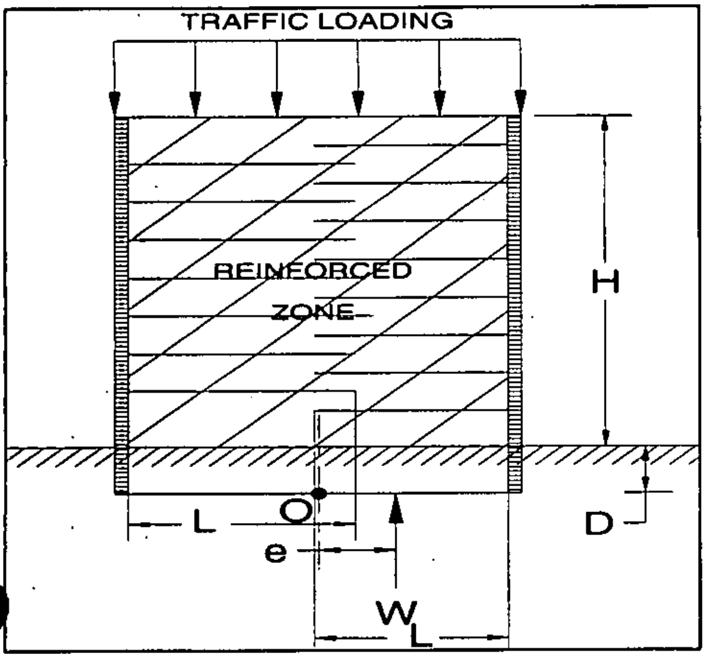
Resistance Against Overturning is **OK**

DLZ	SUBJECT	Client	ODOT9	JOB NUMBER	0121-3070.03		
		Project	SCI-823-0.00 (US 52, Ramp B)	SHEET NO.	10	OF	21
		Item	Bearing Capacity (Sta 32+50, Left), Boring TR-70A	COMP. BY	EWT	DATE	10/11/07
			0.16(H+D) overlapping, Ka = 0.30Ka	CHECKED BY	BRW	DATE	11-15-07

Based on existing foundation soils

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{REIN}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{REIN}	=	34	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	1250	psf	Cohesion	Foundation soil
ϕ	=	0	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	28	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	21	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	30	ft	
H	=	27	ft	Height of wall
Ka	=	0.08		**Ka=0.0K due to overlap**
Γ Pa	=	10	ft	Moment arm
Γ Wt	=	15	ft	Moment arm
B'	=	19.72	ft	
γ'	=	57.6	pcf	
W_t		5,040	lb/ft of wall	Weight from traffic
W_{mse}	=	75,600	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 4,089 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 6,598 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 2,639 psf

Factor of Safety = **1.61** **No Good**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 12,040 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 4,816 psf

Factor of Safety = **2.94** **OK**

Bearing Capacity Factors for Equations

Undrained		Drained	
N_c	5.14	N_c	25.80
N_q	1.00	N_q	14.72
N_γ	0.00	N_γ	16.72

Eccentricity of Resultant Force

e = 0.64 ft

Kern

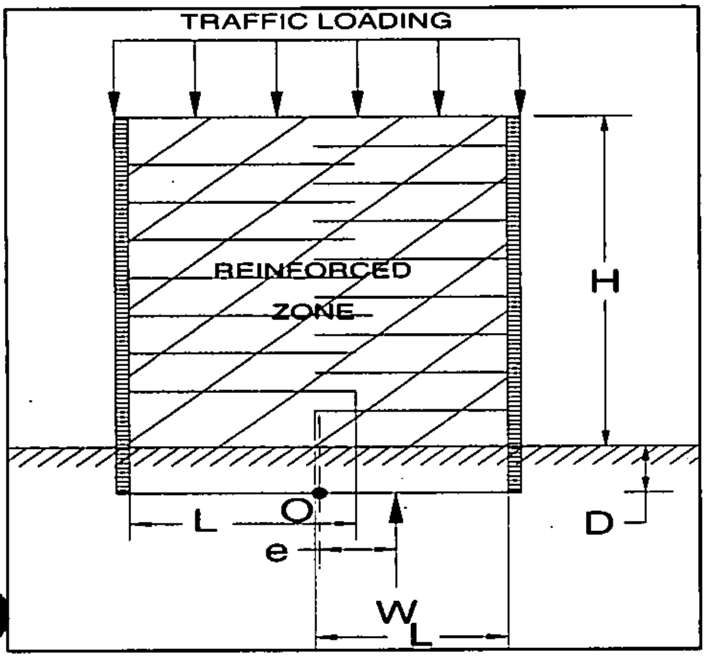
e < L/6 = 3.50 ft

DLZ	SUBJECT			
Client	ODOT9	JOB NUMBER	0121-3070.03	
Project	SCI-823-0.00 (US 52, Ramp B)	SHEET NO.	11	OF 21
Item	Bearing Capacity (Sta 32+50, Left), Boring TR-70A	COMP. BY	EWT	DATE 10/11/07
	0.16(H+D) overlapping, Ka = 0.30Ka	CHECKED BY	DW	DATE 11-23-07

Based on 5' undercut below bottom of leveling pad and replace with compacted granular material

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{REIN}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{REIN}	=	34	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	0	psf	Cohesion	Foundation soil
ϕ	=	30	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	30	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	21	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	30	ft	
H	=	27	ft	Height of wall
Ka	=	0.08		**Ka=0.0K due to overlap**
Γ Pa	=	10	ft	Moment arm
Γ Wt	=	15	ft	Moment arm
B'	=	19.72	ft	
γ'	=	57.6	pcf	
W_t		5,040	lb/ft of wall	Weight from traffic
W_{mse}	=	75,600	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 4,089 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 15,901 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 6,360 psf

Factor of Safety = **3.89** **OK**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 15,901 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 6,360 psf

Factor of Safety = **3.89** **OK**

Bearing Capacity Factors for Equations

Undrained		Drained	
N_c	30.14	N_c	30.14
N_q	18.40	N_q	18.40
N_γ	22.40	N_γ	22.40

Eccentricity of Resultant Force

e = 0.64 ft

Kern

e < L/6 = 3.50 ft

DLZ	SUBJECT			
	Client	ODOT9	JOB NUMBER	0121-3070.03
	Project	SCI-823-0.00 (US 52, Ramp B)	SHEET NO.	12 OF 21
	Item	MSE Wall Stability (Sta 32+50, Left)TR-70A	COMP. BY	EWT DATE 10/11/07
		0.16(H+D) overlapping; Ka = 0.30Ka	CHECKED BY	BJW DATE 11-15-07

STABILITY OF MSE WALL

Assumptions:

1. Estimated height of embankment; H=27.0'
2. Ground water; Dw=0.0'
3. Traffic loading is neglected in resisting forces
4. Ka=0.3Ka due to reinforcing strap overlap
5.

Wall Properties

H+D	=	30	feet
γ_{mse}	=	120	pcf
L	=	21	feet
L factor	=	0.70	Length factor-range (0.7 - 1.0)
ϕ	=	30	deg Friction Angle of Embankment Fill

Foundational Soil Properties

c	=	1250	psf	Cohesion
ϕ'	=	28	deg	Friction angle
ω_T	=	240	psf	Traffic loading

RESISTANCE AGAINST SLIDING ALONG BASE

Thrust: $P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ Ka = 0.10

Pa = 6,120 lbs per foot of wall

Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu = \left(\frac{2}{3}\right)\tan(\phi)$ μ = 0.36

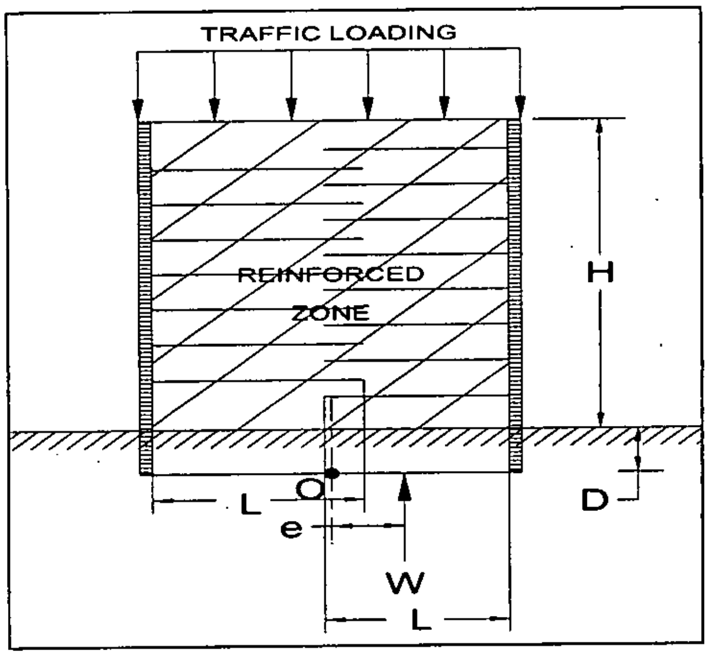
P_r = 26,460 lbs per foot of wall

Use Undrained Value

$P_r = L(c)$ (Undrained)

P_r = 26,250 lbs per foot of wall

USE THIS VALUE



	Calculated	Required	
$FS = \frac{F_R}{F_O}$	FS = **4.29**	FS = 1.50	Resistance Against Sliding is **OK**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 793,800 lb-ft $\qquad \Sigma M_{resisting} = \gamma H L\left(\frac{L}{2}\right)$

$\Sigma M_{overturning}$ = 64,800 lb-ft $\qquad \Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$

	Calculated	Required	
$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$	FS = **12.25**	FS = 2.00	Resistance Against Overturning is **OK**

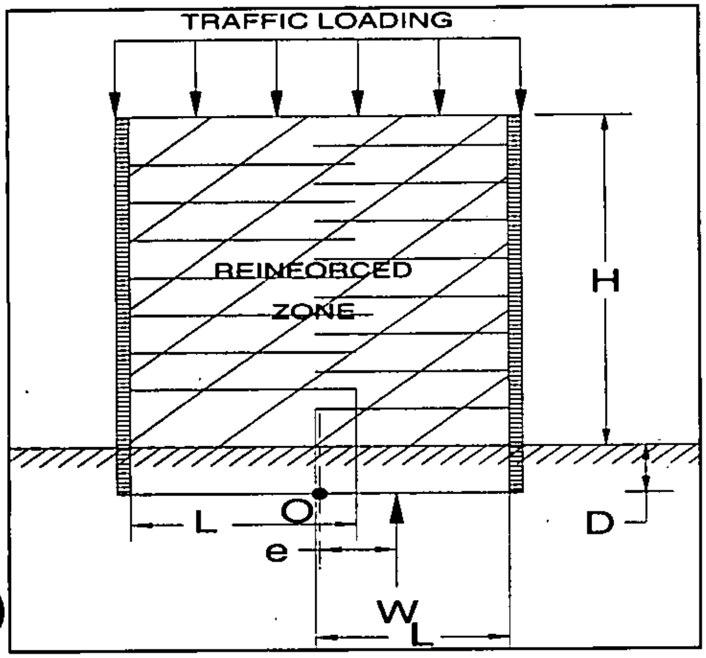
DLZ

SUBJECT			
Client	ODOT9	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00 (US 52, Ramp B)	SHEET NO.	13 OF 21
Item	Bearing Capacity (Sta 33+50, Left), Boring TR-70A	COMP. BY	EWT DATE 10/11/07
	0.27(H+D) overlapping, Ka = 0.05Ka	CHECKED BY	[illegible] DATE 11/15/07

Based on existing foundation soils

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{REIN}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{REIN}	=	34	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	1250	psf	Cohesion	Foundation soil
ϕ	=	0	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	28	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	23.24	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	33.2	ft	
H	=	30.2	ft	Height of wall
Ka	=	0.01		**Ka=0.05K due to overlap**
Γ Pa	=	11.07	ft	Moment arm
Γ Wt	=	16.6	ft	Moment arm
B'	=	23.06	ft	
γ'	=	57.6	pcf	
W_t		5,578	lb/ft of wall	Weight from traffic
W_{mse}	=	92,588	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 4,257 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = c N_c + \sigma'_D N_q + \frac{1}{2}\gamma' B N_\gamma$$

q_{ULT} = 6,598 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 2,639 psf

Factor of Safety = 1.55 **No Good**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c' N_c + \sigma'_D N_q + \frac{1}{2}\gamma' B N_\gamma$$

q_{ULT} = 13,648 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 5,459 psf

Factor of Safety = 3.21 **OK**

Bearing Capacity Factors for Equations

Undrained		Drained	
N_c	5.14	N_c	25.80
N_q	1.00	N_q	14.72
N_γ	0.00	N_γ	16.72

Eccentricity of Resultant Force

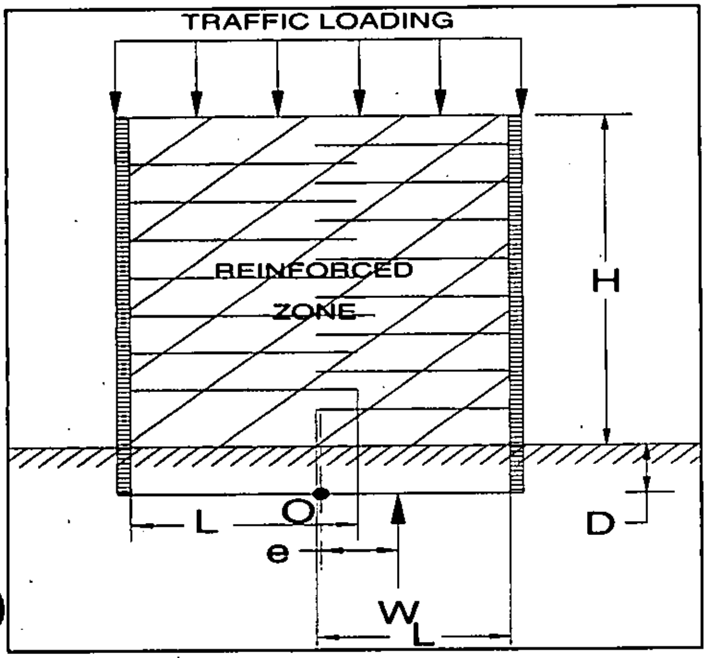
e = 0.09 ft

Kern

e < L/6 = 3.87 ft

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{REIN}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{REIN}	=	34	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	0	psf	Cohesion	Foundation soil
ϕ	=	30	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	30	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	23.24	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	33.2	ft	
H	=	30.2	ft	Height of wall
Ka	=	0.01		**Ka=0.05K due to overlap**
Γ Pa	=	11.07	ft	Moment arm
Γ Wt	=	16.6	ft	Moment arm
B'	=	23.06	ft	
γ'	=	57.6	pcf	
W_t		5,578	lb/ft of wall	Weight from traffic
W_{mse}	=	92,588	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 4,257 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 18,056 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 7,222 psf

Factor of Safety = 4.24 **OK**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 18,056 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 7,222 psf

Factor of Safety = 4.24 **OK**

Bearing Capacity Factors for Equations

Undrained		Drained	
N_c	30.14	N_c	30.14
N_q	18.40	N_q	18.40
N_γ	22.40	N_γ	22.40

Eccentricity of Resultant Force

e = 0.09 ft

Kern

e < L/6 = 3.87 ft

DLZ SUBJECT

Client	ODOT9	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00 (US 52, Ramp B)	SHEET NO.	15 OF 21
Item	MSE Wall Stability (Sta 33+50, Left),TR-70A	COMP. BY	EWT DATE 10/10/07
	0.27(H+D) overlapping; Ka = 0.05Ka	CHECKED BY	BW DATE 11-15-07

Based on existing foundation soils

STABILITY OF MSE WALL

Assumptions:

1. Estimated height of embankment; H=30.2'
2. Ground water; Dw=0.0'
3. Traffic loading is neglected in resisting forces
4. Ka=0.05Ka due to reinforcing strap overlap
5.

Wall Properties

H+D = 33.2 feet
γ_{mse} = 120 pcf
L = 23.24 feet
L factor = 0.70
ϕ = 30 deg

Foundational Soil Properties

c = 1250 psf Cohesion
ϕ' = 28 deg Friction angle
ω_T = 240 psf Traffic loading
Length factor-range (0.7 - 1.0)
Friction Angle of Embankment Fill

RESISTANCE AGAINST SLIDING ALONG BASE

Thrust: $P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ Ka = 0.02

Pa = 1,482 lbs per foot of wall

Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu = \left(\frac{2}{3}\right)\tan(\phi)$ μ = 0.36

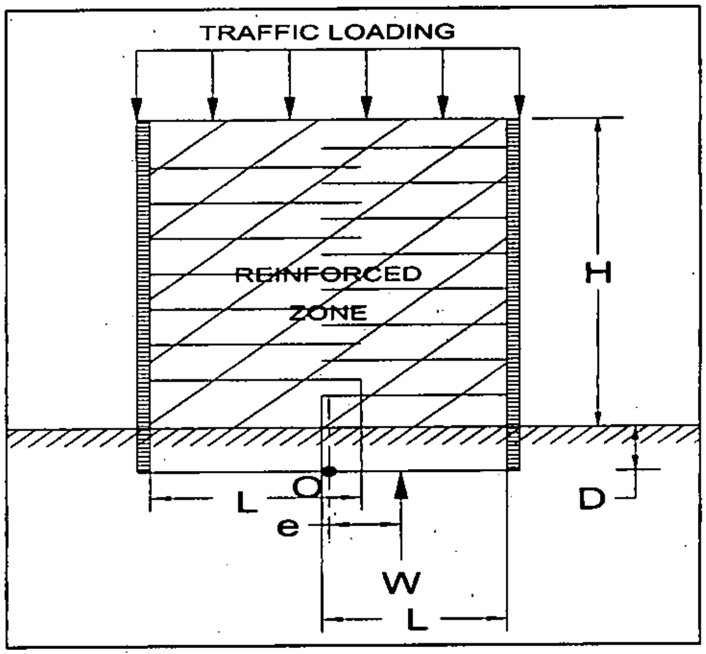
P_r = 32,406 lbs per foot of wall

Use Undrained Value

$P_r = L(c)$ (Undrained)

P_r = 29,050 lbs per foot of wall

USE THIS VALUE



$FS = \frac{F_R}{F_O}$ Calculated FS = **19.60** Required FS = 1.50

Resistance Against Sliding is **OK**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 1,075,874 lb-ft $\Sigma M_{resisting} = \gamma HL\left(\frac{L}{2}\right)$

$\Sigma M_{overturning}$ = 17,283 lb-ft $\Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$

$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$ Calculated FS = **62.25** Required FS = 2.00

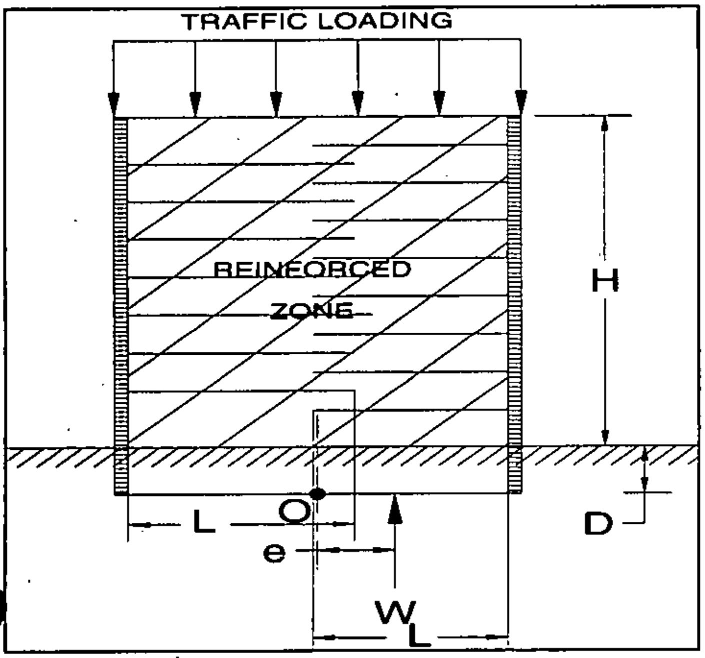
Resistance Against Overturning is **OK**

DLZ	SUBJECT			JOB NUMBER	0121-3070.03
		Client	ODOT9	SHEET NO.	16 OF 21
		Project	SCI-823-0.00 (US 52, Ramp B)	COMP. BY	EWT DATE 10/11/07
		Item	Bearing Capacity (Sta 34+00, Left), Boring TR-70A	CHECKED BY	BWJ DATE 11-15-07
			0.33(H+D) overlapping, Ka = 0.0Ka		

Based on existing foundation soils

BEARING CAPACITY OF A MSE WALL

Ref: (AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002)



Soil Properties

γ_{REIN}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{REIN}	=	34	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	1250	psf	Cohesion	Foundation soil
ϕ	=	0	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	28	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	24.36	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	34.8	ft	
H	=	31.8	ft	Height of wall
Ka	=	0.00		**Ka=0.0K due to overlap**
Γ Pa	=	11.6	ft	Moment arm
Γ Wt	=	17.4	ft	Moment arm
B'	=	24.36	ft	
γ'	=	57.6	pcf	
W_t		5,846	lb/ft of wall	Weight from traffic
W_{mse}	=	101,727	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 4,416 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 6,598 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 2,639 psf

Factor of Safety = **1.49** **No Good**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 14,274 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 5,710 psf

Factor of Safety = **3.23** **OK**

Bearing Capacity Factors for Equations

Undrained		Drained	
N_c	5.14	N_c	25.80
N_q	1.00	N_q	14.72
N_γ	0.00	N_γ	16.72

Eccentricity of Resultant Force

e = 0.00 ft

Kern

e < L/6 = 4.06 ft

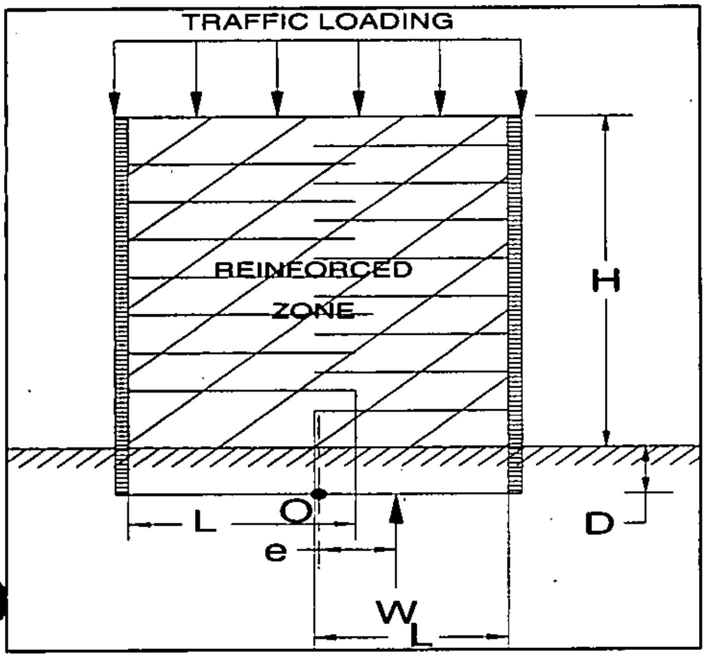
DLZ

SUBJECT				
Client	ODOT9	JOB NUMBER	0121-3070.03	
Project	SCI-823-0.00 (US 52, Ramp B)	SHEET NO.	17	OF 21
Item	Bearing Capacity (Sta 34+00, Left), Boring TR-70A	COMP. BY	EWT	DATE 10/11/07
	0.33(H+D) overlapping, Ka = 0.0Ka	CHECKED BY	BWJ	DATE 11-15-07

Based on 5' undercut below bottom of leveling pad and replace with compacted granular material

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{REIN}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{REIN}	=	34	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	0	psf	Cohesion	Foundation soil
ϕ	=	30	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	30	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	24.36	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	34.8	ft	
H	=	31.8	ft	Height of wall
Ka	=	0.00		**Ka=0.0K due to overlap**
Γ Pa	=	11.6	ft	Moment arm
Γ Wt	=	17.4	ft	Moment arm
B'	=	24.36	ft	
γ'	=	57.6	pcf	
W_t		5,846	lb/ft of wall	Weight from traffic
W_{mse}	=	101,727	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 4,416 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 18,895 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 7,558 psf

Factor of Safety = **4.28** **OK**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 18,895 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 7,558 psf

Factor of Safety = **4.28** **OK**

Bearing Capacity Factors for Equations

Undrained		Drained	
N_c	30.14	N_c	30.14
N_q	18.40	N_q	18.40
N_γ	22.40	N_γ	22.40

Eccentricity of Resultant Force

e = 0.00 ft

Kern

e < L/6 = 4.06 ft

DLZ SUBJECT	Client	ODOT9	JOB NUMBER	0121-3070.03	
	Project	SCI-823-0.00 (US 52, Ramp B)	SHEET NO.	18	OF 21
	Item	MSE Wall Stability (Sta 34+00, Left),TR-70A	COMP. BY	EWT	DATE 10/11/07
		0.33(H+D) overlapping; Ka = 0.0Ka	CHECKED BY	BW	DATE 11-15-07

STABILITY OF MSE WALL

Assumptions:

1. Estimated height of embankment; H=31.8'
2. Ground water; Dw=0.0'
3. Traffic loading is neglected in resisting forces
4. Ka=0.0Ka due to reinforcing strap overlap
5.

Wall Properties

- H+D = 34.8 feet
- γ_{mse} = 120 pcf
- L = 24.36 feet
- L factor = 0.70
- ϕ = 30 deg

Foundational Soil Properties

- c = 1250 psf — Cohesion
- ϕ' = 28 deg — Friction angle
- ω_T = 240 psf — Traffic loading
- Length factor-range (0.7 - 1.0)
- Friction Angle of Embankment Fill

RESISTANCE AGAINST SLIDING ALONG BASE

Thrust: $$P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ Ka = 0.00

Pa = 0 lbs per foot of wall

Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu = \left(\frac{2}{3}\right)\tan(\phi)$ μ = 0.36

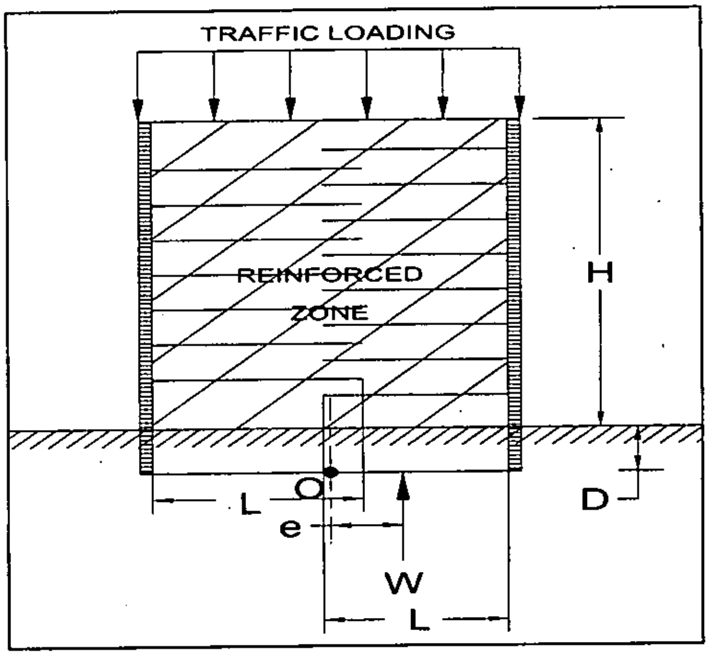
P_r = 35,605 lbs per foot of wall

Use Undrained Value

$P_r = L(c)$ (Undrained)

P_r = 30,450 lbs per foot of wall

USE THIS VALUE



$$FS = \frac{F_R}{F_O}$$

Calculated: FS = #DIV/0! Required: FS = 1.50

FS=∞ , F.S. >1.50 due to Ka=0.0

Resistance Against Sliding is **OK**

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 1,239,039 lb-ft $$\Sigma M_{resisting} = \gamma HL\left(\frac{L}{2}\right)$$

$\Sigma M_{overturning}$ = 0 lb-ft $$\Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$$

$$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$$

Calculated: FS = #DIV/0! Required: FS = 2.00

F.S.=∞, F.S >1.5 due to Ka=0.0

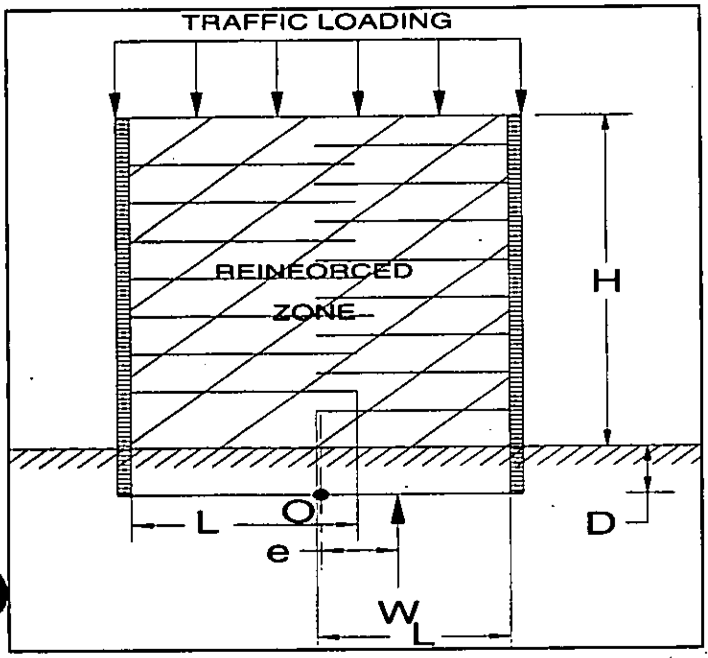
Resistance Against Overturning is **OK**

DLZ	SUBJECT			
	Client	ODOT9	JOB NUMBER	0121-3070.03
	Project	SCI-823-0.00 (US 52, Ramp B)	SHEET NO.	19 OF 21
	Item	Bearing Capacity (Sta 35+42.74, Left), TR-73A	COMP. BY	EWT DATE 10/11/07
		End Approach Slab 0.41(H+D) overlapping, Ka = 0.0Ka	CHECKED BY	BW DATE 11-15-07

Based on existing foundation soils

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 4,356 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 8,741 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 3,496 psf

Factor of Safety = 2.01 **No Good**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 16,214 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 6,486 psf

Factor of Safety = 3.72 **OK**

Soil Properties

γ_{REIN}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{REIN}	=	34	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	1667	psf	Cohesion	Foundation soil
ϕ	=	0	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	29	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	24.01	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	34.3	ft	
H	=	31.3	ft	Height of wall
Ka	=	0.00		**Ka=0.0*K due to overlap**
Γ Pa	=	11.43	ft	Moment arm
Γ Wt	=	17.15	ft	Moment arm
B'	=	24.01	ft	
γ'	=	57.6	pcf	
W_t		5,762	lb/ft of wall	Weight from traffic
W_{mse}	=	98,825	lb/ft of wall	Weight from MSE wall

Bearing Capacity Factors for Equations

Undrained		Drained	
N_c	5.14	N_c	27.86
N_q	1.00	N_q	16.44
N_γ	0.00	N_γ	19.34

Eccentricity of Resultant Force

e = 0.00 ft

Kern

e < L/6 = 4.00 ft

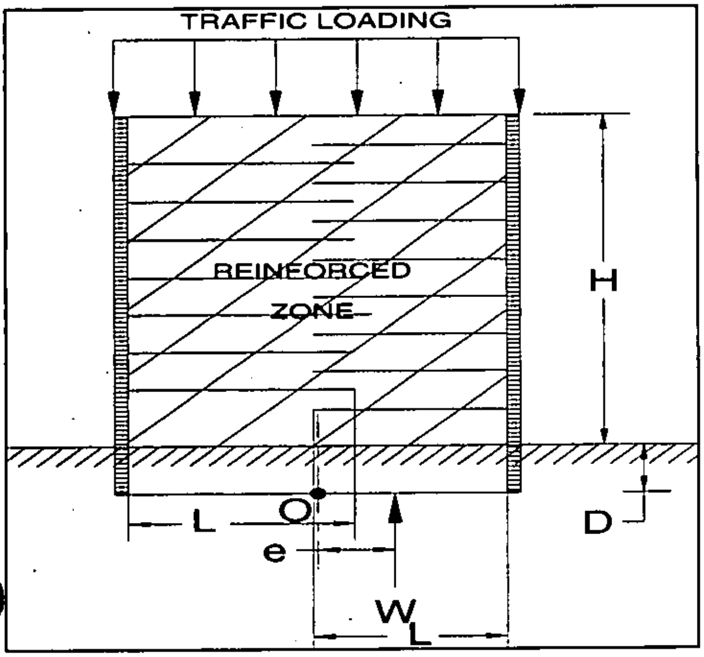
DLZ

SUBJECT			
Client	ODOT9	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00 (US 52, Ramp B)	SHEET NO.	20 OF 21
Item	Bearing Capacity (Sta 35+42.74, Left), TR-73A	COMP. BY EWT	DATE 10/11/07
End Approach Slab 0.41(H+D) overlapping, Ka = 0.0Ka		CHECKED BY BW	DATE 11-15-07

Based on 5' undercut below bottom of leveling pad and replace with compacted granular material

BEARING CAPACITY OF A MSE WALL

Ref: {AASHTO; STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, 17th Edition, 2002}



Soil Properties

γ_{REIN}	=	120	pcf	Unit weight	Embankment fill
ϕ'_{REIN}	=	34	deg.	Friction ang.	Embankment fill
γ_{FDN}	=	120	pcf	Unit weight	Foundation soil
c	=	0	psf	Cohesion	Foundation soil
ϕ	=	30	deg.	Friction ang.	Foundation soil
c'	=	0	psf	Cohesion	Foundation soil
ϕ'	=	30	deg.	Friction ang.	Foundation soil

Loads and Parameters

ω_t	=	240	psf	Traffic loading
L=B	=	24.01	ft	Length of MSE reinforcement
L factor	=	0.7		Length factor-range (0.7 - 1.0)
D	=	3	ft	Embedment depth
Dw	=	0	ft	Groundwater depth
H+D	=	34.3	ft	
H	=	31.3	ft	Height of wall
Ka	=	0.00		**Ka=0.0*K due to overlap**
Γ Pa	=	11.43	ft	Moment arm
Γ Wt	=	17.15	ft	Moment arm
B'	=	24.01	ft	
γ'	=	57.6	pcf	
W_t		5,762	lb/ft of wall	Weight from traffic
W_{mse}	=	98,825	lb/ft of wall	Weight from MSE wall

Effective Bearing Pressure

$$\sigma_v = \frac{W_t + W_{MSE}}{L - 2e}$$

σ_v = 4,356 psf

Ultimate undrained bearing capacity, q_{ult}

$$q_{ULT} = cN_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 18,669 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 7,468 psf

Factor of Safety = 4.29 **OK**

Ultimate drained bearing capacity, q_{ult}

$$q_{ULT} = c'N_c + \sigma'_D N_q + \frac{1}{2}\gamma B N_\gamma$$

q_{ULT} = 18,669 psf

$$q_{ALL} = \frac{q_{ULT}}{FS}$$

q_{ALL} = 7,468 psf

Factor of Safety = 4.29 **OK**

Bearing Capacity Factors for Equations

Undrained		Drained	
N_c	30.14	N_c	30.14
N_q	18.40	N_q	18.40
N_γ	22.40	N_γ	22.40

Eccentricity of Resultant Force

e = 0.00 ft

Kern

e < L/6 = 4.00 ft

DLZ

SUBJECT		JOB NUMBER	0121-3070.03		
Client	ODOT9	SHEET NO.	21	OF	21
Project	SCI-823-0.00 (US 52, Ramp B)	COMP. BY	EWT	DATE	10/11/07
Item	Wall Stability (Sta 35+42.74, Left),TR-73A	CHECKED BY	BW	DATE	11-15-07
	0.41(H+D) overlapping; Ka = 0.0Ka				

End Approach Slab Based on existing foundation soils

STABILITY OF MSE WALL

Assumptions:

1 Estimated height of embankment; H=31.3'
2 Ground water; Dw=0.0'
3 Traffic loading is neglected in resisting forces
4 Ka=0.0K due to reinforcing strap overlap
5

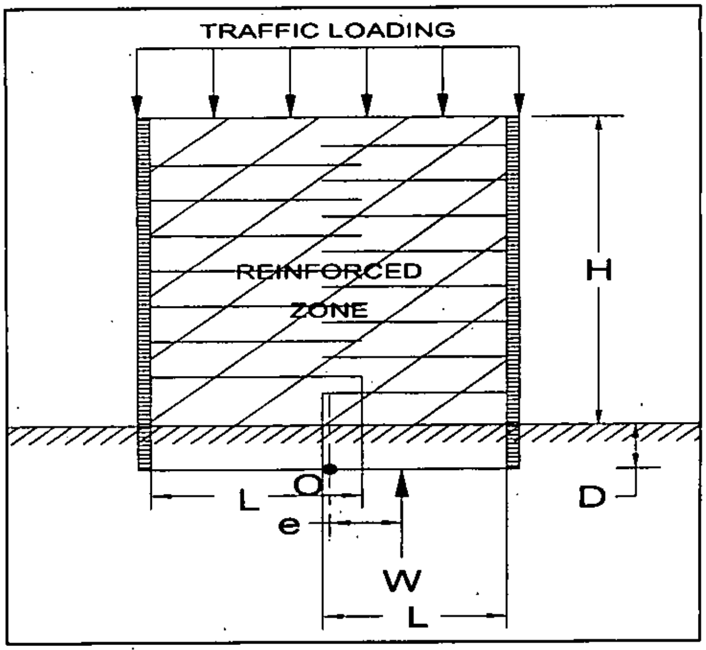
Wall Properties			Foundational Soil Properties			
H+D =	34.3	feet	c =	1667	psf	Cohesion
γ_{mse} =	120	pcf	ϕ' =	29	deg	Friction angle
L =	24.01	feet	ω_T =	240	psf	Traffic loading
L factor =	0.70		Length factor-range (0.7 - 1.0)			
ϕ =	30	deg	Friction Angle of Embankment Fill			

RESISTANCE AGAINST SLIDING ALONG BASE

Thrust: $P_a = K_a\left[\frac{1}{2}\gamma H^2 + \omega_T H\right]$

where; $K_a = \tan^2(45 - \frac{\phi}{2})$ Ka = 0.00

Pa = 0 lbs per foot of wall



Resistance: $P_r = W(\mu)$ (Drained)

where; $\mu = \left(\frac{2}{3}\right)\tan(\phi)$ μ = 0.37

P_r = 34,589 lbs per foot of wall

USE THIS VALUE

$P_r = L(c)$ (Undrained)

P_r = 40,025 lbs per foot of wall

Use Drained Value

$FS = \frac{F_R}{F_O}$

Calculated	Required
FS = #DIV/0!	FS = 1.50

Resistance Against Sliding is **OK**

FS=∞, FS > 1.5 due to Ka=0.0

RESISTANCE AGAINST OVERTURNING

* Summation of Moments about point "O" (base of wall).
* Traffic loading is neglected in resisting forces

$\Sigma M_{resisting}$ = 1,186,396 lb-ft $\Sigma M_{resisting} = \gamma HL\left(\frac{L}{2}\right)$

$\Sigma M_{overturning}$ = 0 lb-ft $\Sigma M_{overturning} = K_a\left[\frac{1}{2}\gamma H^2\left(\frac{H}{3}\right) + \omega_T H\left(\frac{H}{2}\right)\right]$

$FS = \frac{\Sigma M_{resisting}}{\Sigma M_{overturning}}$

Calculated	Required
FS = #DIV/0!	FS = 2.00

Resistance Against Overturning is **OK**

FS=∞, FS > 1.5 due to Ka=0.0

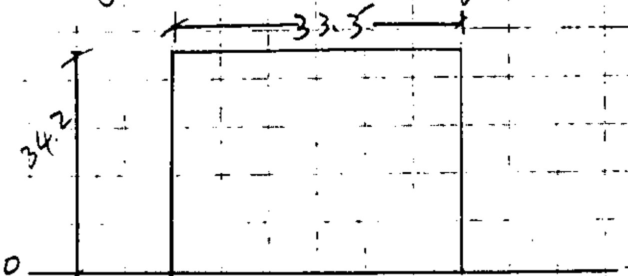
MSE Wall Settlement Calculations
(Ramp A)

According to cross-sections provided by TranSystems on 7-17-07, the highest wall section, approximately 37.2' (to the top leveling pad) will be at station 38+00.

Boring TR-75 was used for soil profile.

Ground surface elevation @ TR-75 = 553.0

Wall height = 37.2' (Top of coping to top of leveling pad)



Assume 90° turnback
Assume soils are normally consolidated
Assume $G_s = 2.65$

Elev. 553.0

① Compacted granular fill, $\gamma = 120$ pcf, Incompressible (MSE fill and 12" recompacted material)

548.5

② A-6a, $\gamma = 120$ pcf, $\bar{w} = 25\%$ (Ref. Boring B-15-4) ⇒ $C_c = 0.25$ + $C_r = 0.025$ (FHWA-NHI-00-045)
▽ (Assumed) Assumed saturated. $e_0 = w G_s = 0.66$

545.0

③ A-3a, $\gamma = 125$ pcf, $N_{min} = 17$, $\sigma_0' = 1179$ psf ⇒ $N' = 1.15 \cdot 17 \approx 19$ ⇒ $C' = 65$
$e_0 = 1$ (FHWA-NHI-00-045) pp. 6-8 & 6-9

538.0

④ Bedrock $\gamma = 150$ pcf

528.0

Consolidation parameters are estimated from FHWA-NHI-00-045 for cohesive soils based on moisture and cohesionless soils based on average SPT N-values

$$\frac{1}{C'} = \frac{C_c}{1+e_0} \qquad \text{Assumed } e_0 = 1.0$$

$$\frac{1}{C'} = \frac{C_c}{1+1} \Rightarrow \frac{2}{C'} = C_c$$

when $C' = 65$, $\Rightarrow C_c = \frac{2}{65} = 0.031$

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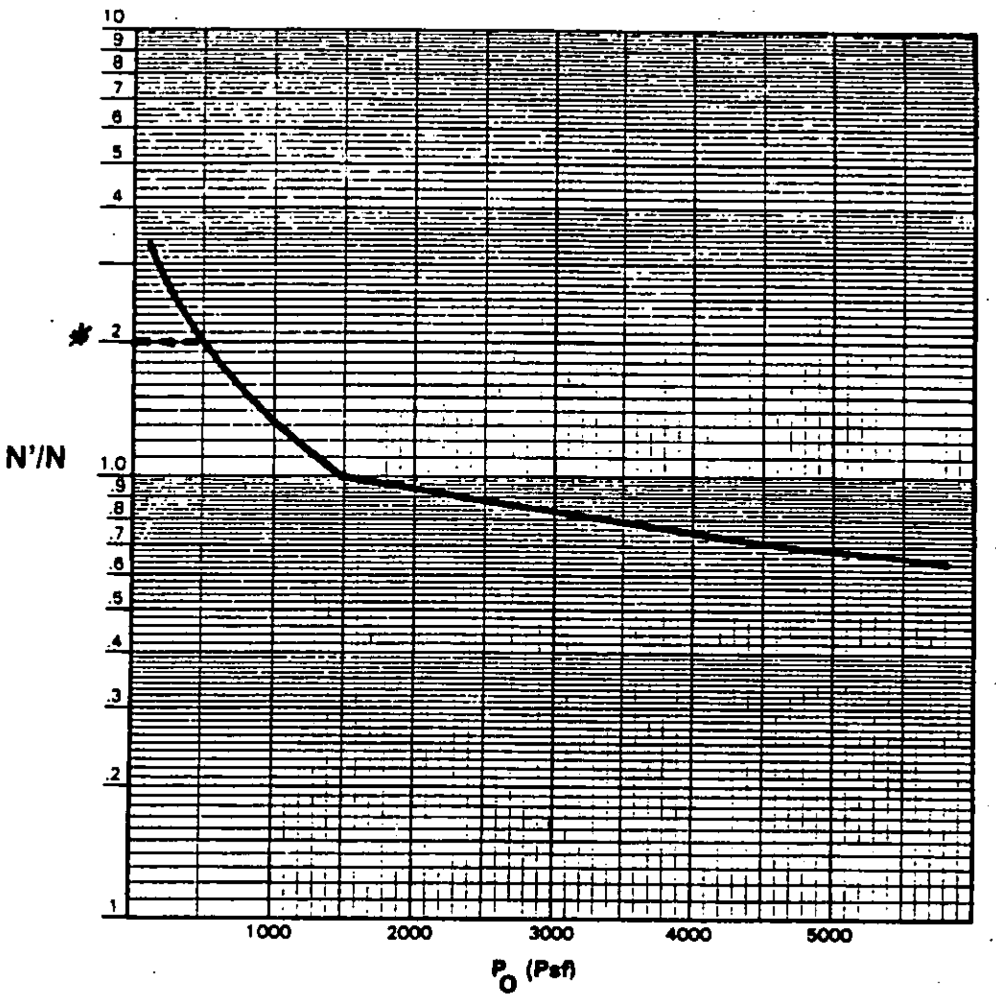
BW 11-15-07



Where: N' = Corrected SPT Value Blow Count
N = SPT Value
Po = Existing Effective Vertical Overburden Pressure
* = Suggested Maximum Value

Reference: Based on 1967, Bazaraa, The Use of Standard Penetration Test for Estimating Settlement of Shallow Foundation on Sand

Figure 6-5: Correcting SPT (N) blow counts for overburden pressure, P_o

Step 1. Determine corrected SPT value (N′) from Figure 6-5.

Step 2. Determine Bearing Capacity Index (C′) by entering Figure 6-6 with N′ value and the visual description of the soil,

Step 3. Compute settlement in 10′ ± increments of depth from

$$\Delta H = H\left(\frac{1}{C'}\right)\text{Log}\frac{P_o + \Delta P}{P_o} \qquad (6\text{-}1)$$

Where:
- ΔH = Settlement (Feet)
- H = Thickness of soil layer considered (Feet)
- C' = Bearing capacity index (Figure 6-6)
- P_o = Existing effective overburden pressure (psf) at center of considered layer. For

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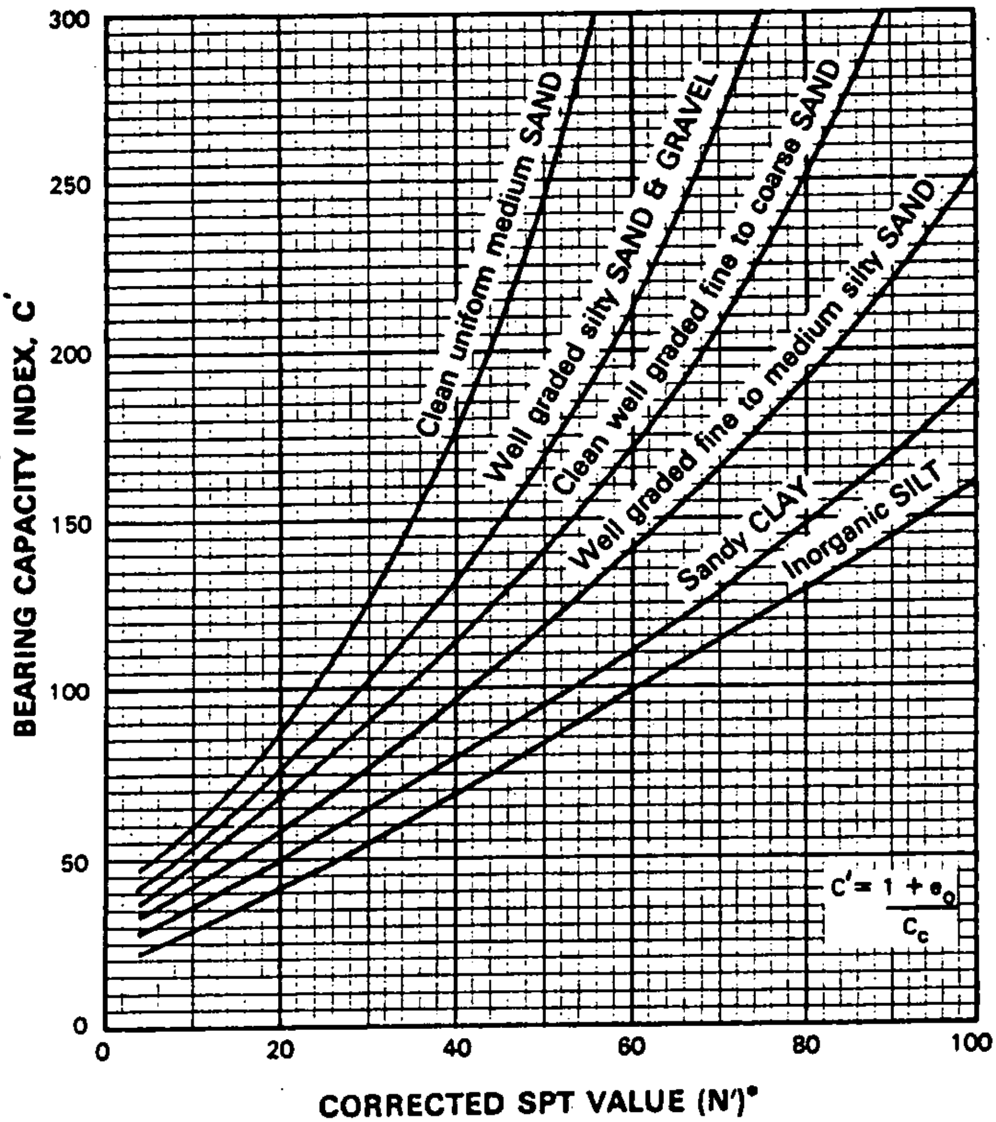
shallow surface deposits, a minimum value of 200 psf must be used to prevent unrealistic computation of settlement.

ΔP = Distributed embankment pressure (psf) at center of considered layer

P_F = Final pressure felt by foundation subsoil (psf)

Note: $P_F = P_o + \Delta P$



*N'—*SPT (N) Value Corrected for Overburden Pressure.*

Reference: Hough, "Compressibility as a Basis for Soil Bearing Value" ASCE 1959

Figure 6-6: Bearing capacity index (C') values for granular soils

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EWT 11-15-07
BW 11-15-07

ÚÄÄÄÄÄ ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration ÄÄÄÄÄ¿

INCREMENT OF STRESSES BENEATH THE END OF FILL CONDITION

Project Name : US52 A
File Name : Ramp A Wall
Date : 10/18/10

Client : ODOT9
Project Manager : PN
Computed by : EWT

Settlement for X-Direction

Embank. slope, x direc. = 0.10 (ft)
y direc. = 0.10 (ft)
Embankment top width = 33.30 (ft)
Embankment bottom width = 33.50 (ft)
Ground Surface Elev. = 553.00 (ft)
Water table Elev. = 545.00 (ft)

Height of fill H = 34.20 (ft)
Unit weight of fill = 120.00 (pcf)
p load/unit area = 4104.00 (psf)
Foundation Elev. = 553.00 (ft)
Unit weight of Wat. = 62.40 (pcf)

N§.	LAYER TYPE	THICK. (ft)	COEFFICIENT COMP.	RECOMP.	SWELL.	UNIT WEIGHT (pcf)	SPECIFIC GRAVITY	VOID RATIO
1	INCOMP.	4.5	-----	-----	-----	120.00	----	----
2	COMP.	3.5	0.250	0.025	0.000	120.00	2.65	0.66
3	COMP.	7.0	0.031	0.000	0.000	125.00	2.65	1.00
4	INCOMP.	10.0	-----	-----	-----	150.00	----	----

N§.	SUBLAYER THICK. (ft)	ELEV. (ft)	SOIL STRESSES INITIAL (psf)	MAX.PAST PRESS. (psf)
1	INCOMP.			
2	3.50	546.75	750.00	750.00
3	7.00	541.50	1179.10	1179.10
4	INCOMP.			

Layer	X = 0.00 Stress (psf)	Sett. (in.)	X = 3.30 Stress (psf)	Sett. (in.)	X = 6.60 Stress (psf)	Sett. (in.)	X = 9.90 Stress (psf)	Sett. (in.)
1	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
2	1023.19	2.36	1620.05	3.16	1895.18	3.46	1991.19	3.56
3	1010.48	0.35	1364.23	0.43	1626.65	0.49	1782.52	0.52
4	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
		2.71 (at wallface)		3.60		3.95		4.08

Layer	X = 13.20 Stress (psf)	Sett. (in.)	X = 16.50 Stress (psf)	Sett. (in.)	X = 19.80 Stress (psf)	Sett. (in.)	X = 23.10 Stress (psf)	Sett. (in.)
1	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
2	2024.69	3.59	2033.75	3.60	2027.21	3.60	1998.79	3.57
3	1860.20	0.54	1885.16	0.54	1866.94	0.54	1798.53	0.52
4	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
		4.13		4.14 (℄ of embankment)		4.13		4.09

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52 A

Layer	X = Stress (psf)	26.40 Sett. (in.)	X = Stress (psf)	29.70 Sett. (in.)	X = Stress (psf)	33.00 Sett. (in.)
1	INCOMP.	INCOMP.	INCOMP.			
2	1917.01	3.49	1681.08	3.23	1128.49	2.52
3	1656.59	0.50	1411.15	0.45	1066.94	0.36
4	INCOMP.	INCOMP.	INCOMP.			
		------		------		------
		3.98		3.68		2.89

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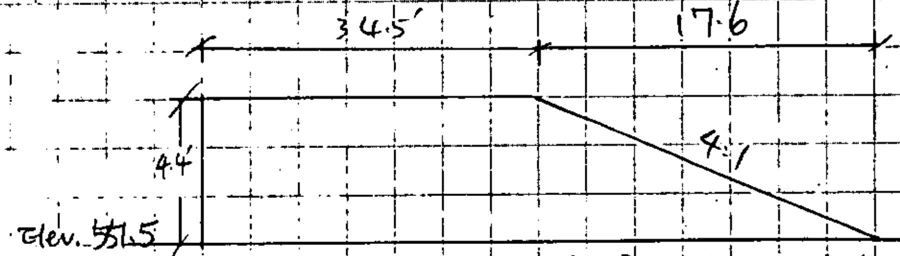
CLIENT: TranSystems Corp / ODOT D-9 | PROJECT NO. 0121-3070.03
PROJECT: SCI-823 Portsmouth ByPass | SHEET NO. 6 OF 8
SUBJECT: Consolidation Parameters U.S. 52 Ramp A | COMP. BY GWT DATE 10-18-07
CHECKED BY: BW DATE 11-15-07

MSE walls at sta 34+00 (the end of wall)
Wall height = 7.4' (Top of coping to top of leveling pad)
Use Boring B-1541 for soil profile
Ground surface elevation = 551.5



Assume soils are normally consolidated

Assume $G_s = 2.65$

① Compacted Granular fill, $\gamma = 120$ pcf, incompressible (MSE fill and 12" recompacted material.)

547.0

② A-6a $\gamma = 120$ pcf, $\overline{w} = 25\%$ ⇒ $C_c = 0.25$, $C_r = 0.025$ (FHWA-NHI-00-045) Assumed saturated $e_0 = wG_s = 0.66$

543.0

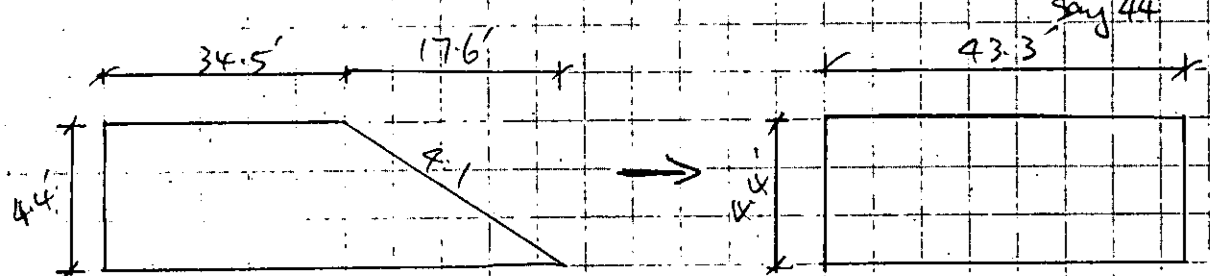
③ A-4b (cohesive) $\gamma = 120$ pcf, $w = 26\%$, $C_c = 0.25$, $C_r = 0.025$ Assumed saturated $e_0 = wG_s = 0.69$

538.0 ▽ (assumed)

④ Bedrock $\gamma = 145$ pcf

535.3

For analysis:



Differential settlement between station 38+00 and station 34+00:

L = 40.0 feet

@ wall face $= \frac{(2.71 - 0.86)/12}{400} \times 100\% = 0.04\%$

@ ℄ of embankment $= \frac{(4.14 - 1.59)/12}{400} \times 100\% = 0.05\%$

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BW 11-15-07

52 A END

ÚÄÄÄÄÄ ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration ÄÄÄÄÄ¿

INCREMENT OF STRESSES BENEATH THE END OF FILL CONDITION

Project Name	: US52 A	Client	: ODOT9
File Name	: A-End	Project Manager	: PN
Date	: 10/18/10	Computed by	: EWT

Settlement for X-Direction

Embank. slope, x direc.	= 0.10 (ft)	Height of fill H	= 4.40 (ft)
y direc.	= 0.10 (ft)	Unit weight of fill	= 120.00 (pcf)
Embankment top width	= 44.00 (ft)	p load/unit area	= 528.00 (psf)
Embankment bottom width	= 44.20 (ft)	Foundation Elev.	= 551.50 (ft)
Ground Surface Elev.	= 551.50 (ft)		
Water table Elev.	= 538.00 (ft)	Unit weight of Wat.	= 62.40 (pcf)

N§.	LAYER TYPE	THICK. (ft)	COEFFICIENT COMP.	RECOMP.	SWELL.	UNIT WEIGHT (pcf)	SPECIFIC GRAVITY	VOID RATIO
1	INCOMP.	4.5	-----	-----	-----	120.00	----	----
2	COMP.	4.0	0.250	0.025	0.000	120.00	2.65	0.66
3	COMP.	5.0	0.250	0.025	0.000	120.00	2.65	0.69
4	INCOMP.	2.7	-----	-----	-----	145.00	----	----

N§.	SUBLAYER THICK. (ft)	ELEV. (ft)	SOIL STRESSES INITIAL (psf)	MAX.PAST PRESS. (psf)
1	INCOMP.			
2	4.00	545.00	780.00	780.00
3	5.00	540.50	1320.00	1320.00
4	INCOMP.			

Layer	X = 0.00 Stress (psf)	Sett. (in.)	X = 4.00 Stress (psf)	Sett. (in.)	X = 8.00 Stress (psf)	Sett. (in.)	X = 12.00 Stress (psf)	Sett. (in.)
1	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
2	131.82	0.49	217.16	0.77	249.76	0.87	259.53	0.90
3	131.19	0.37	187.78	0.51	224.42	0.61	242.84	0.65
4	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
		------		------		------		------
		0.86 (at the wall face)		1.28		1.48		1.55

Layer	X = 16.00 Stress (psf)	Sett. (in.)	X = 20.00 Stress (psf)	Sett. (in.)	X = 24.00 Stress (psf)	Sett. (in.)	X = 28.00 Stress (psf)	Sett. (in.)
1	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
2	262.78	0.91	263.86	0.91	263.88	0.91	262.86	0.91
3	251.21	0.67	254.47	0.68	254.54	0.68	251.47	0.67
4	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
		------		------		------		------
		1.58		1.59 (← ~ ℄ of Embankment)		1.59		1.58

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52 A END

Layer	X = Stress (psf)	32.00 Sett. (in.)	X = Stress (psf)	36.00 Sett. (in.)	X = Stress (psf)	40.00 Sett. (in.)	X = Stress (psf)	44.00 Sett. (in.)
1	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
2	259.78	0.90	250.57	0.87	219.87	0.78	137.04	0.51
3	243.44	0.65	225.70	0.61	190.15	0.52	134.26	0.37
4	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
		------		------		------		------
		1.55		1.48		1.30		0.88

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MSE Wall Settlement Calculations
(Ramp B)

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CLIENT: TranSystems Corp. / ODOT D-9
PROJECT: SCI-823 Portsmouth Bypass
SUBJECT: Consolidation Parameters, US 52 Ramp B

PROJECT NO. 0121-3070.03
SHEET NO. 1 OF 9
COMP. BY GWT DATE 10-18-07
CHECKED BY BW DATE 11-15-07

MSE Walls at Rear Abutments of Ramp B Bridge @ Station 35 + 51.55

Comparing subsurface conditions at Borings TR71A and TR73A, Boring TR-73A appears to be more critical

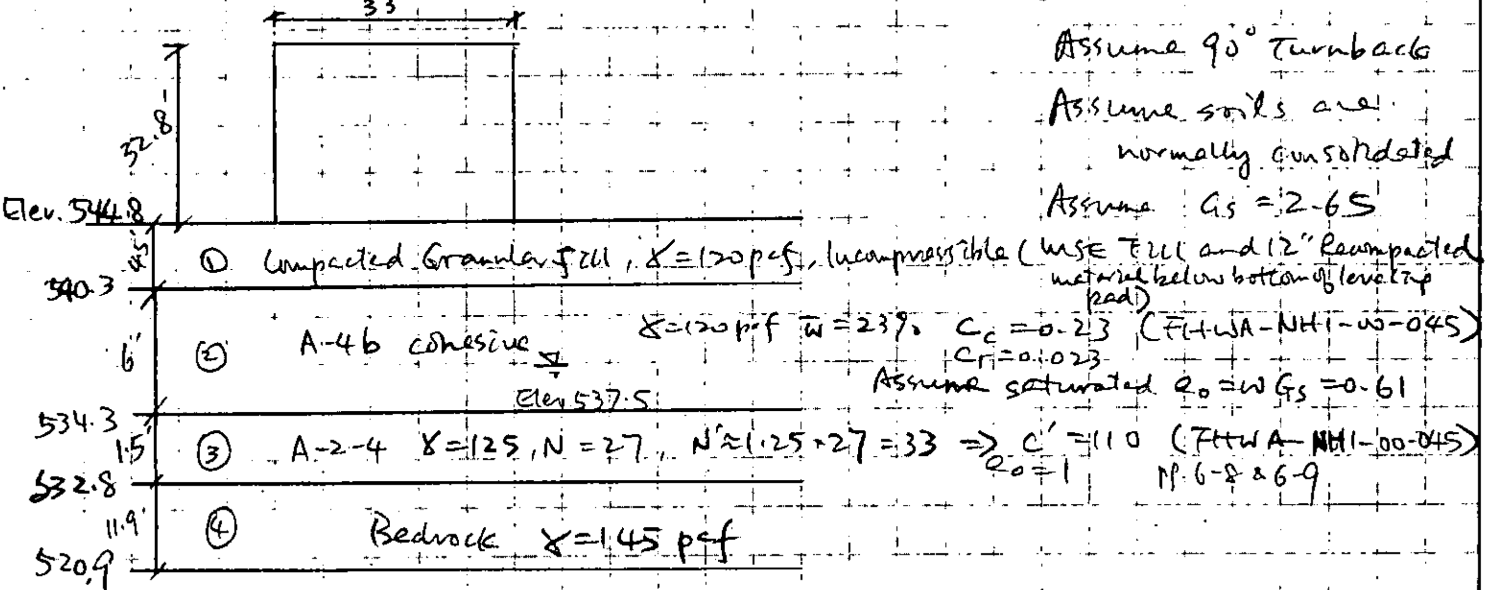
Boring TR-73A: Ground surface elevation @ TR-73A = 544.8

Wall height including embankment fill = 578.13 − 542.32 = 35.8′ (According to bridge profile)

Where Elev 578.13 is proposed finished grade

Wall height @ sta 35 + 51.55 (End Approach slab) ≈ 34.3 (According to cross-section from TranSystems on 7/17/07)

Use Wall Height = 35.8′ for settlement analyses



Assume 90° Turnback

Assume soils are normally consolidated

Assume $G_s = 2.65$

Consolidation parameters are estimated from FHWA-NHI-00-045 for cohesive soils based on moisture, and cohesionless soils based on average SPT N-values

$$\frac{1}{C'} = \frac{C_c}{1+e_0}$$

Assumed $e_0 = 1.0$

$$\frac{1}{C'} = \frac{C_c}{1+1.0} \Rightarrow C_c = \frac{2}{C'}$$

when $C' = 110 \Rightarrow C_c = \frac{2}{110} = 0.0182$

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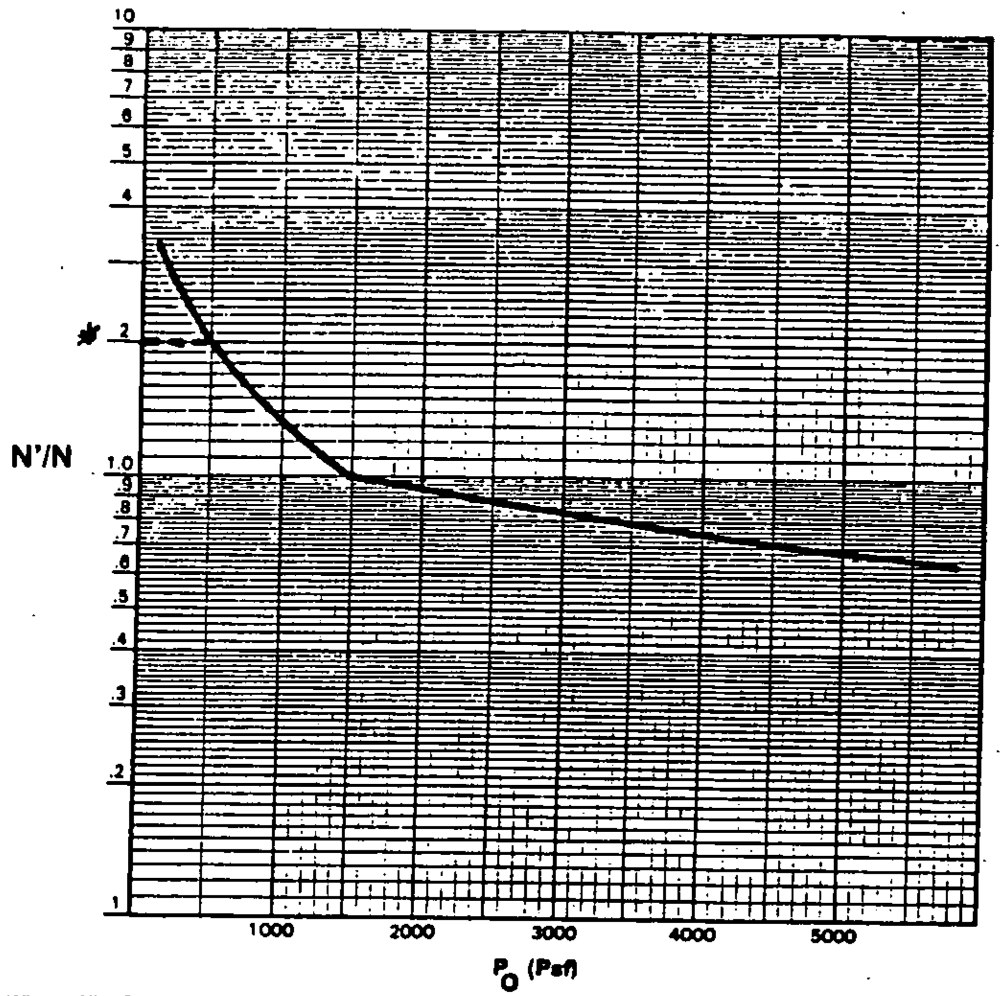

Where: N' = Corrected SPT Value Blow Count
N = SPT Value
Po = Existing Effective Vertical Overburden Pressure
* = Suggested Maximum Value

Reference: Based on 1967, Bazaraa, The Use of Standard Penetration Test for Estimating Settlement of Shallow Foundation on Sand

Figure 6-5: Correcting SPT (N) blow counts for overburden pressure, P_o

Step 1. Determine corrected SPT value (N') from Figure 6-5.

Step 2. Determine Bearing Capacity Index (C') by entering Figure 6-6 with N' value and the visual description of the soil;

Step 3. Compute settlement in 10' ± increments of depth from

$$\Delta H = H\left(\frac{1}{C'}\right)\text{Log}\frac{P_o + \Delta P}{P_o} \qquad (6\text{-}1)$$

Where:
- ΔH = Settlement (Feet)
- H = Thickness of soil layer considered (Feet)
- C' = Bearing capacity index (Figure 6-6)
- P_o = Existing effective overburden pressure (psf) at center of considered layer. For

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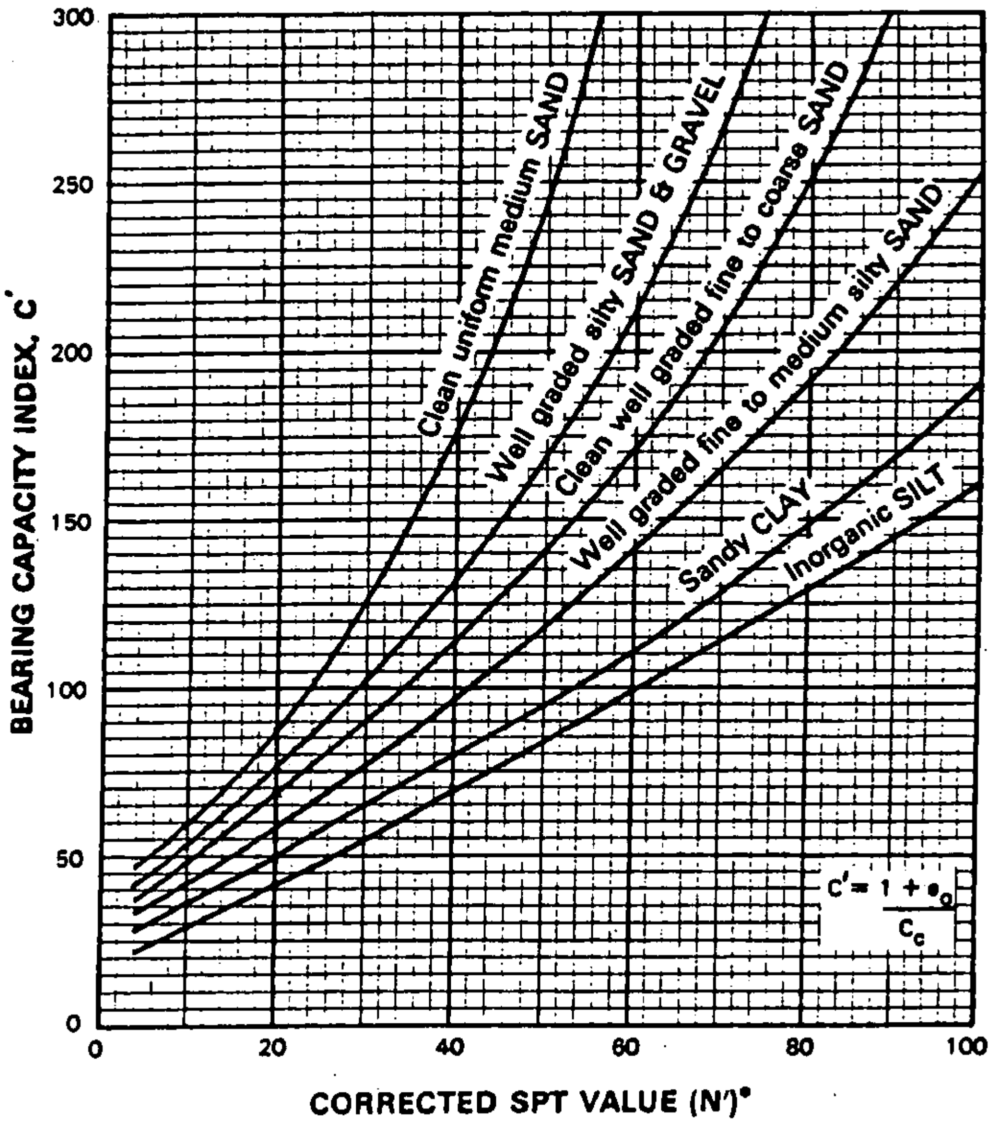
BW 11-15-07

shallow surface deposits, a minimum value of 200 psf must be used to prevent unrealistic computation of settlement.

ΔP = Distributed embankment pressure (psf) at center of considered layer

P_F = Final pressure felt by foundation subsoil (psf)

Note: $P_F = P_o + \Delta P$



*N'—SPT (N) Value Corrected for Overburden Pressure.

Reference: Hough, "Compressibility as a Basis for Soil Bearing Value" ASCE 1959

$$C' = \frac{1 + e_o}{C_c}$$

Figure 6-6: Bearing capacity index (C') values for granular soils

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EWT 11/15-07
BW 11-15-07

ÚÄÄÄÄÄ ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration ÄÄÄÄÄ¿

INCREMENT OF STRESSES BENEATH THE END OF FILL CONDITION

Project Name	: US52 B	Client	: ODOT9
File Name	: Ramp B Wall	Project Manager	: PN
Date	: 10/18/10	Computed by	: EWT

Settlement for X-Direction

Embank. slope, x direc.	= 0.10 (ft)	Height of fill H	= 32.80 (ft)
y direc.	= 0.10 (ft)	Unit weight of fill	= 120.00 (pcf)
Embankment top width	= 33.00 (ft)	p load/unit area	= 3936.00 (psf)
Embankment bottom width	= 33.20 (ft)	Foundation Elev.	= 544.80 (ft)
Ground Surface Elev.	= 544.80 (ft)		
Water table Elev.	= 537.50 (ft)	Unit weight of Wat.	= 62.40 (pcf)

N§.	LAYER TYPE	THICK. (ft)	COEFFICIENT COMP.	RECOMP.	SWELL.	UNIT WEIGHT (pcf)	SPECIFIC GRAVITY	VOID RATIO
1	INCOMP.	4.5	-----	-----	-----	120.00	----	----
2	COMP.	6.0	0.230	0.023	0.000	120.00	2.65	0.61
3	COMP.	1.5	0.018	0.000	0.000	125.00	2.65	1.00
4	INCOMP.	11.9	-----	-----	-----	145.00	----	----

N§.	SUBLAYER THICK. (ft)	ELEV. (ft)	SOIL STRESSES INITIAL (psf)	MAX.PAST PRESS. (psf)
1	INCOMP.			
2	6.00	537.30	887.52	887.52
3	1.50	533.55	1107.27	1107.27
4	INCOMP.			

y=0.1

Layer	X = Stress (psf)	0.00 Sett. (in.)	X = Stress (psf)	3.30 Sett. (in.)	X = Stress (psf)	6.60 Sett. (in.)	X = Stress (psf)	9.90 Sett. (in.)
1	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
2	979.38	3.32	1475.61	4.37	1750.88	4.87	1866.01	5.06
3	969.64	0.04	1315.95	0.06	1570.00	0.06	1718.46	0.07
4	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
		3.37 @ wall face		4.43		4.93		5.12

Layer	X = Stress (psf)	13.20 Sett. (in.)	X = Stress (psf)	16.50 Sett. (in.)	X = Stress (psf)	19.80 Sett. (in.)	X = Stress (psf)	23.10 Sett. (in.)
1	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
2	1910.41	5.13	1922.45	5.15	1911.87	5.13	1870.12	5.06
3	1791.06	0.07	1813.16	0.07	1793.66	0.07	1724.69	0.07
4	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
		5.20		5.22 @ ℄ of Embankment		5.20		5.13

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52 B

Layer	X = Stress (psf)	26.40 Sett. (in.)	X = Stress (psf)	29.70 Sett. (in.)	X = Stress (psf)	33.00 Sett. (in.)
1	INCOMP.	INCOMP.	INCOMP.			
2	1761.24	4.88	1498.92	4.42	1013.04	3.40
3	1581.78	0.06	1334.51	0.06	991.82	0.04
4	INCOMP.	INCOMP.	INCOMP.			
		------		------		------
		4.95		4.47		3.45

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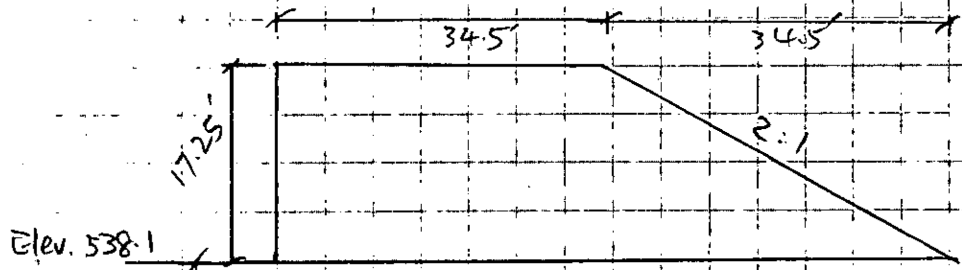
DLZ — ENGINEERS • ARCHITECTS • SCIENTISTS • PLANNERS • SURVEYORS

CLIENT: TranSystems Corp / ODOT D-9 PROJECT NO. 0121-3070.03
PROJECT: SCI-823 Portsmouth ByPass SHEET NO. 6 OF 9
SUBJECT: Consolidation Parameters U.S. 52 Ramp B COMP. BY: SWT DATE: 10-18-07
CHECKED BY: BW DATE: 11-14-07

MSE Walls at Sta 29 + 50 (the end of wall)
Wall height = 20.25' (Top of coping to tip of leveling pad)
Use Boring TR-68A for soil profile
Ground surface elevation @ TR-68A = 538.1



Assume soils are normally consolidated
Assume $G_s = 2.65$

Elev.	Thickness	Layer
538.1 – 533.6	4.5'	① Compacted Granular fill, $\gamma = 120$ pcf, (incompressible) (MSE fill and 12" recompacted material)
533.6 – 530.1	3.5'	② A-6b, $\gamma = 120$ pcf, $w = 20\%$ → $C_c = 0.2\%$ (FHWA-NHI-00-045), $C_r = 0.02$; Assume saturated, $e_0 = wG_s = 0.53$
530.1 – 527.1	3.0'	▽ (Assume) ③ A-4b, $\gamma = 120$ pcf, N = 11, $\sigma_0' = 1046$ psf, $N' \approx 1.3 \times 11 = 14.3$, $C' = 35$ (FHWA-NHI-00-045 pg 6-9), $e_0 = 1$ (pg 6-8 FHWA-NHI-00-045)
527.1 – 510.8	16.3'	④ Bedrock $\gamma = 145$ pcf

Consolidation parameters are estimated from FHWA-NHI-00-045 for cohesive soils based on moisture, and cohesionless soils based on average SPT N-values.

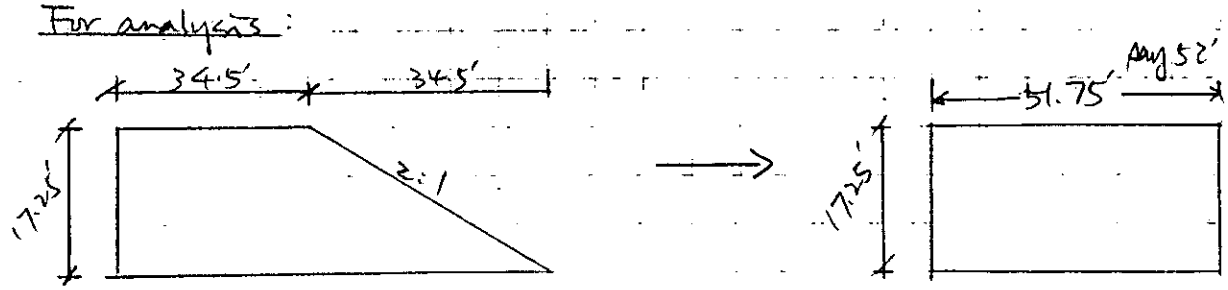
$$\frac{1}{C'} = \frac{C_c}{1+e_0}$$

Assumed $e_0 = 1.0$

$$\frac{1}{C'} = \frac{C_c}{1+1.0} \Rightarrow C_c = \frac{2}{C'}$$

where $C' = 35 \Rightarrow C_c = \frac{2}{35} = 0.057$

For analysis:



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BW 11-15-07

52 B END

ÚÄÄÄÄÄ ONE DIMENSIONAL SETTLEMENT ANALYSIS/Federal Highway Administration ÄÄÄÄÄ¿

INCREMENT OF STRESSES BENEATH THE END OF FILL CONDITION

Project Name	: US 52 Ramp B End	Client	: ODOT9
File Name	: B-End	Project Manager	: PN
Date	: 10/18/10	Computed by	: EWT

Settlement for X-Direction

Embank. slope, x direc. =	0.10 (ft)	Height of fill H =	17.25 (ft)
y direc. =	0.10 (ft)	Unit weight of fill =	120.00 (pcf)
Embankment top width =	52.00 (ft)	p load/unit area =	2070.00 (psf)
Embankment bottom width =	52.20 (ft)	Foundation Elev. =	538.10 (ft)
Ground Surface Elev. =	538.10 (ft)		
Water table Elev. =	530.10 (ft)	Unit weight of Wat. =	62.40 (pcf)

N§.	LAYER TYPE	THICK. (ft)	COEFFICIENT COMP.	RECOMP.	SWELL.	UNIT WEIGHT (pcf)	SPECIFIC GRAVITY	VOID RATIO
1	INCOMP.	4.5	-----	-----	-----	120.00	----	----
2	COMP.	3.5	0.200	0.020	0.000	120.00	2.65	0.53
3	COMP.	3.0	0.057	0.000	0.000	120.00	2.65	1.00
4	INCOMP.	16.3	-----	-----	-----	145.00	----	----

N§.	SUBLAYER THICK. (ft)	ELEV. (ft)	SOIL STRESSES INITIAL (psf)	MAX.PAST PRESS. (psf)
1	INCOMP.			
2	3.50	531.85	750.00	750.00
3	3.00	528.60	1046.40	1046.40
4	INCOMP.			

y=0.1

Layer	X = Stress (psf)	0.00 Sett. (in.)	X = Stress (psf)	3.00 Sett. (in.)	X = Stress (psf)	6.00 Sett. (in.)	X = Stress (psf)	9.00 Sett. (in.)
1	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
2	517.09	1.25	797.96	1.73	942.00	1.94	998.46	2.02
3	516.20	0.18	713.45	0.23	854.19	0.27	935.12	0.28
4	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
		1.43 (at wall face)		1.96		2.21		2.30

Layer	X = Stress (psf)	12.00 Sett. (in.)	X = Stress (psf)	15.00 Sett. (in.)	X = Stress (psf)	18.00 Sett. (in.)	X = Stress (psf)	21.00 Sett. (in.)
1	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
2	1021.18	2.05	1031.27	2.06	1036.14	2.07	1038.57	2.07
3	978.18	0.29	1001.04	0.30	1013.38	0.30	1019.94	0.30
4	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
		2.34		2.36		2.37		2.38

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52 B END

Layer	X = Stress (psf)	24.00 Sett. (in.)	X = Stress (psf)	27.00 Sett. (in.)	X = Stress (psf)	30.00 Sett. (in.)	X = Stress (psf)	33.00 Sett. (in.)
1	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
2	1039.65	2.07	1039.82	2.07	1039.13	2.07	1037.32	2.07
3	1022.99	0.30	1023.46	0.30	1021.51	0.30	1016.53	0.30
4	INCOMP.	INCOMP.	INCOMP.	INCOMP.				
		------		------		------		------
		2.38		2.38 @ ℄ of embankment		2.38		2.37

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CLIENT Transystems Corp / ODOT D-9
PROJECT SCI-823 Portsmouth ByPass
SUBJECT Consolidation Parameters
US. 52 Ramp B

PROJECT NO. 0121-3070.03
SHEET NO. 9 OF 9
COMP. BY GWT DATE 10-18-07
CHECKED BY BW DATE 11-15-07

Differential settlement between station 35+51.55 and station 29+50

$L = 3551.55 - 2950 = 602$

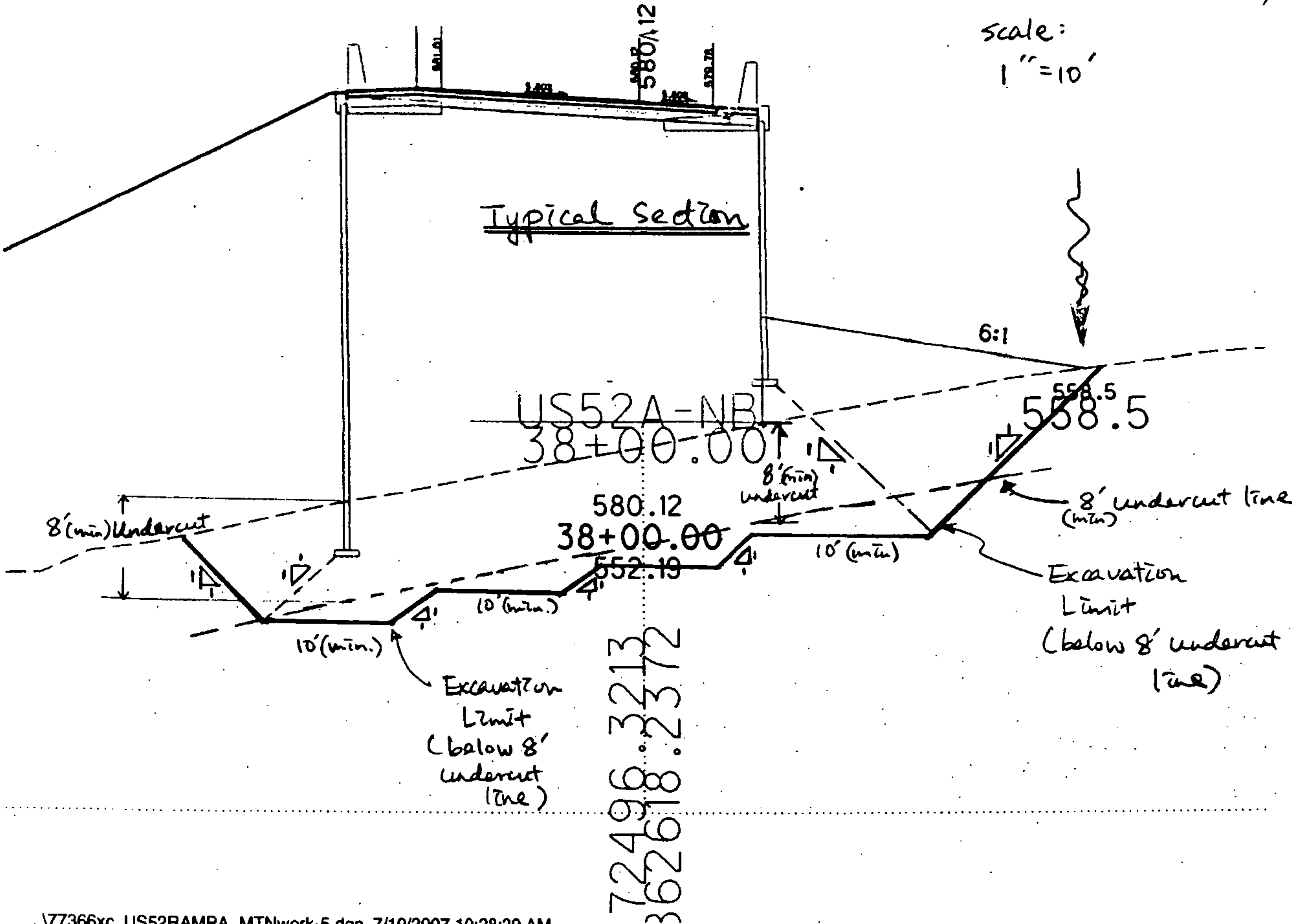
@ wall face $\Rightarrow \frac{(3.37 - 1.43)/12}{602} \times 100\% = 0.03\%$

@ ℄ of embankment $\Rightarrow \frac{(5.22 - 2.38)/12}{602} \times 100\% = 0.04\%$

Typical Section Showing the Use of Special Benching
Within a Back-To-Back Walls Section

1/1
EWT 11-15-07
BW 11-15-07

scale:
1" = 10'



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APPENDIX E

APPENDIX V

ODOT Retaining Wall Checklist

IV.B. Retaining Wall Checklist

C-R-S: Sci-823-0.00 (US 52)	PID: 77366	Reviewer: E. Tse/B. Wilson	Date: 11-15-07

If you do not have a retaining wall on the project, you do not have to fill out this checklist.

Soil Data and Preliminary Calculations	
Y N X 1 Has a justification study been performed to determine the necessity of a wall as opposed to ROW purchase or other project alternatives?	
Y N X 2 Have the necessary soil strength parameters and unit weights been determined? Check method used: ☒ laboratory shear tests ☒ estimation from SPT or field tests	
Y N X 3 Has the groundwater elevation been determined?	
Y N X 4 Have the proper loading conditions been determined? a If yes, check which loading conditions apply: Backfill: ☒ flat or ☐ sloped Surcharge: ☒ yes or ☐ no	
Y N X 5 If applicable, has the influence of groundwater been taken into account with regards to soil unit weights and active pressures?	
Y N **X** 6 Has the Coulomb method been utilized to determine the lateral earth pressure?	Not applicable – MSE Wall.

Notes:

IV.B. Retaining Wall Checklist

Design			
Y N X	7	For preliminary wall design, has the design criteria and wall type selection process been followed as instructed in BDM 204.6?	
Y N X	8	Was an economic analysis performed to evaluate the cost benefits of the chosen wall type compared to others?	
Y N **X**	9	Have all the required F.S. been calculated?	
		a Do the F.S. meet or exceed the minimums listed below (for non-proprietary walls):	Not applicable – MSE Wall.
Y N **X**		Bearing Capacity (minimum F.S. = 3.0)	
Y N **X**		External Stability (minimum F.S. = 1.3 when not supporting abutments)	
Y N **X**		Overturning (minimum F.S. = 2.00)	
Y N **X**		Sliding (minimum F.S. = 1.50)	
	10	If poor foundation soils are present, has a solution been determined with respect to the following:	Criteria for settlement, sliding and global stability are met.
Y N **X**		a excessive settlement?	
Y N X		b inadequate bearing capacity?	Recommended undercutting and replacement with compacted fill.
Y N **X**		c sliding?	
Y N **X**		d global stability?	
	11	For non-proprietary walls, each wall type has design recommendations which need to be determined. For the wall type being evaluated, have the following design recommendations been determined by accepted design methods or, where applicable, FHWA design guidelines:	Not applicable – MSE Wall.
Y N **X**		a Cantilever, Gravity - footing width, allowable bearing capacity (BDM 204 & 303.4)	
Y N **X**		b Cellular - type, bearing pressure, fill material	
Y N **X**		c Drilled H-Pile - type, embedment, spacing, lagging, maximum moment, section modulus, maximum deflection	
Y N **X**		d Drilled Shafts - diameter, embedment, spacing, maximum moment, maximum deflection (see BDM 303.4.3)	
Y N **X**		e H-pile Lagging - pile size, embedment, lagging design, spacing, facing, maximum deflection	
Y N **X**		f Sheet Pile - embedment, section modulus, maximum deflection	

IV.B. Retaining Wall Checklist

Y N **X**		g	Soil Nailing - spacing, loading per nail, facing, embedment	Not applicable –MSE Wall.
Y N **X**		h	Tieback - load per tieback, number of rows, wale design, type of anchor	
Y N X	12		Proprietary wall designs require a special process for detail design, as outlined in BDM 303.5. Has this procedure been followed for this project?	
	13		The presence and quality of water behind the wall structure and in the backfill can be a major source of overloading and failure.	
Y N **X**		a	Has the quality / chemistry of the groundwater been accounted for in the drainage system?	Not applicable – No apparent water source.
Y N **X**		b	Has an adequate drainage system been included in the detail wall design?	
Y N **X**		c	If there is a water source behind the wall, has additional drainage been added to control the effect of this water source on the wall?	
Y N X	14		Have the effects of the wall design and construction procedure been determined and accounted for on the construction schedule?	
Y N X	15		Has the effect of the wall design and construction been evaluated with regard to structures (e.g., culverts, utilities), which may be subject to unusual stresses or require special design or construction considerations?	

Notes:

IV.B. Retaining Wall Checklist

Plans and Contract Documents				
Y N **X**	16	Have all the necessary notes, specifications, special provisions, and details for the construction of the wall system been included in the plans?	Plans not prepared for Stage 1.
Y N **X**	17	Has the need, location, type, plan notes, and reading schedule for any instrumentation been determined and included in the plans? Check the types of instrumentation specified: ☐ inclinometers ☐ strain gages ☐ load cells ☐ settlement platforms ☐ monitoring wells / piezometers ☐ other List other items:	No instrumentation needed.

Notes: