# ATTACHMENT E

## Appendix C-1 – Supplemental Veneer Stability Analyses Under Residual Conditions

# APPENDIX C-1

## SLOPE STABILITY ANALYSIS UNDER RESIDUAL STRENGTH CONDITIONS

## I. PURPOSE

The purpose of this analysis is to evaluate the veneer stability of the final cover system at the proposed Dow Salzburg Hazardous Waste Disposal Facility by evaluating shallow translational failure potential in those areas under residual shear strength parameters. These analyses were performed to supplement the original calculations provided in Appendix E of the Basis of Design Report.

## II. SHALLOW TRANSLATIONAL FAILURE ANALYSIS – METHODOLOGY

The method used in this analysis closely follows the methods outlined by Koerner and Soong (Koerner and Soong, 2005). The analysis is performed by use of force equilibrium to balance the driving forces due to gravity pulling on the cover soils and the resistance to sliding due to friction between the underlying subsurface and cover material. Resistance to sliding is also due in part to the toe support (passive wedge) located at the base of the sliding mass. This is conceptually illustrated in Figure 1.

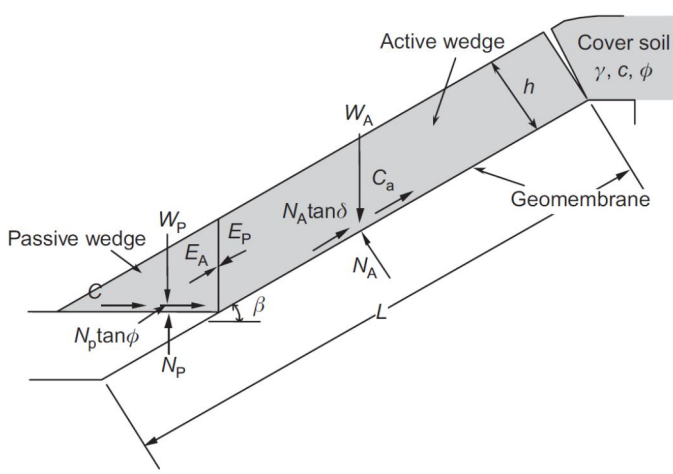


Figure 1. Conceptual Veneer Stability Analysis Cross Section/Free Body Diagram

Where,

$W_A$ = Total Weight of the Active Wedge
$W_P$ = Total Weight of the Passive Wedge
$N_A$ = Effective Force Normal to the Failure Plane of the Active Wedge
$N_P$ = Effective Force Normal to the Failure Plane of the Passive Wedge
$\gamma$ = Unit Weight of the Cover Soil
$h$ = Thickness of the Cover Soil

$L$ = Length of Slope Measured Along the Geomembrane
$b$ = Soil Slope Angle Beneath The Geomembrane
$f$ = Friction Angle of The Cover Soil
$d$ = Interface Friction Angle Between Cover Soil and Geomembrane
$C_a$ = Adhesive Force Between Active Wedge Cover Soil and Geomembrane
$c_a$ = Adhesion Between Active Wedge Cover Soil and the Geomembrane
$C$ = Cohesive Force Along The Failure Plane Of The Passive Wedge
$c$ = Cohesion of the Cover Soil
$E_A$ = Interwedge Force Acting on the Active Wedge from the Passive Wedge
$E_P$ = Interwedge Force Acting on the Passive Wedge from the Active Wedge
$FS$ = Factor of Safety Against Cover Soil Sliding on the Geomembrane

The shallow translational failure analysis is analyzed by fully satisfying the equilibrium of forces in the vertical and horizontal directions. By taking force summation parallel to the slope and comparing the resisting force with the driving or mobilizing force, a global factor of safety (FS) results:

$$\text{FS} = \frac{\sum \text{Resisting Forces}}{\sum \text{Driving Forces}}$$

As noted in the procedure contained in the Koerner and Soong paper, the FS for veneer stability (as depicted in Figure 1) is determined by solving the following quadratic equation:

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

Where,

$$a = (W_A - N_A cos\beta)cos\beta$$

$$b = -\begin{bmatrix} (W_A - N_A cos\beta)sin\beta tan\varphi \\ +(N_A tan\delta + C_a)sin\beta cos\beta \\ +sin\beta(C + W_P tan\phi) \end{bmatrix}$$

$$c = (N_A tan\delta + C_a)sin^2\beta tan\phi$$

When the calculated FS value falls below 1.0, sliding of the critical interface is to be anticipated.

For these supplemental analyses, the FS will remain the same as for peak shear strength conditions, but residual shear strength parameters will be utilized to represent large displacement due to differential

settlement of a mixed waste mass. Although this condition is unlikely in the case of the Salzburg Landfill, it represents a conservative approach to long term stability of the final cover system. For these analyses, the following conditions and target factors of safety were used:

- Static Conditions (Residual Strength): FS ≥ 1.50 (long term conditions)
- Static Conditions (Full Drainage Layer, Residual Strength): FS ≥ 1.10
- Static Conditions (Equipment Loads, Residual Strength): FS ≥ 1.25
- Seismic Conditions (Residual Strength): FS ≥ 1.00

## III. SELECTION OF PARAMETERS

For the final cover systems, the following assumptions and design parameters were used. Slope lengths and angles used in all analyses correspond to the maximum (i.e. worst case) values relative to each respective system.

### a. Slope Geometry

The final cover system for the facility will have a maximum slope angle of 4H:1V. Based on the final cover design grades, the maximum slope length is approximately 91 feet.

### b. Layers

Layers and layer thicknesses for the cover system and liner system are anticipated as follows:

Table 1. Layer Summary for the Final Cover System

| THICKNESS | LAYER |
|---|---|
| Final Cover | |
| 6 in | Vegetative Cover Soil |
| 18 in | Protective Cover Soil |
| n/a | Double-Sided Geocomposite Drainage Layer |
| n/a | Textured LLDPE Geomembrane |
| n/a | GCL – two layers |
| 12 in | Intermediate Cover Soil |

n/a – thickness of layer is small (negligible)

### c. Critical Interfaces

The critical interfaces analyzed represent preferential pathways for mass sliding and typically between adjacent geosynthetic materials or between geosynthetic and soil materials. The geosynthetics are of negligible thickness relative to the thickness of the cover soils, so the depth to the failure surface does not require adjustment for the individual geosynthetic components when they are stacked.

For the final cover system, the critical interfaces analyzed are as follows:

- Protective Soil/Geocomposite Drainage Layer
- Geocomposite Drainage Layer/Textured LLDPE Geomembrane
- Textured LLDPE Geomembrane /GCL
- GCL to GCL
- GCL to Intermediate Cover Soils

Interface shear testing was performed for each interface as part of the design process.

### d. Material Parameters

The various material parameters used in the veneer analyses are tabulated in Table 2.

Table 2. Final Cover Variables

| PARAMETER | VALUE | COMMENTS |
|---|---|---|
| Final Cover | | |
| Dry Unit Weight of Veg. Cover Soil, $g_{D\text{-}VC}$ | 90 pcf | Assumed (typical of veg. material) |
| Moisture Content of Veg. Cover Soil, $w_{F\text{-}VC}$ | 26% | Assumed (typical of veg. material) |
| Dry Unit Weight of Protective Cover Soil, $g_{D\text{-}CS}$ | 100 pcf | Typical unit weight of in-situ lab samples |
| Moisture Content of Protective Cover Soil, $w_{F\text{-}CS}$ | 24% | Typical moisture of in-situ lab samples |
| Specific Gravity of Protective Cover Soil, $G_S$ | 2.72 | Typical $G_S$ of in-situ lab samples |
| Friction Angle of Protective Cover Soil, f | 30 deg | Conservatively assumed cover soil |
| Cohesion of Protective Cover Soil, c | 0 psf | strength parameters |
| Equipment Loads | | |
| Weight of Construction Equip ($W_b$) | 87,733 lbs | CAT D8 LGP Dozer |
| Length of Equip. Track (w) | 10.5 ft | CAT D8 LGP Dozer |
| Width of Equip. Track (b) | 2.8 ft | CAT D8 LGP Dozer |
| Seismic Loads | | |
| Seismic Coefficient (Cover) | 0.04g | USGS seismic coefficient for 2% Exceedance in 50 Years |

Interface shear testing was performed for each interface as part of the design process. The Interface Shear Results are provided as Attachment A. A summary of the interface shear testing results is below:

Table 3. Interface Shear Results

| INTERFACE | PEAK INTERFACE FRICTION, f (DEGREES) | PEAK ADHESION (PSF) | RESIDUAL INTERFACE FRICTION, f (DEGREES) | RESIDUAL ADHESION (PSF) |
|---|---|---|---|---|
| Protective Cover to Geocomposite Drainage Layer (GDM) | 28.3 | 3 | 27.8 | 0 |
| Geocomposite Drainage Layer (GDM) to Textured Geomembrane (GMB) | 30 | 39 | 20.3 | 31 |
| Textured Geomembrane (GMB) to GCL | 28.8 | 35 | 23 | 28 |
| GCL to GCL | 34.3 | 34 | 17.3 | 52 |
| GCL to Intermediate Cover Soils | 28.6 | 17 | 28.9 | 2 |

The most likely interface to fail is the interface with the lowest peak strength (i.e. the weakest link) is the Protective Cover to Geocomposite Drainage Layer. However, for illustrative purposes, AECOM has treated each interface as a critical interface. Each critical interface was utilized to calculate the factors of safety under residual shear strength conditions.

## IV. RESULTS OF ANALYSIS

The analysis consists calculating the factors of safety against translational failure based on the interface shear testing results. The results of the analysis are summarized below. Detailed calculations are included as Attachment B.

Table 4. Residual Strength Calculation Summary

| Condition | Calculated Factor of Safety | | | | | Required Factor of Safety |
|---|---|---|---|---|---|---|
| | Prot. Cover to GDM | GDM to GMB | GMB to GCL | GCL to GCL | GCL to Int. Cover | |
| Static | 2.25 | 2.14 | 2.31 | 2.27 | 2.38 | 1.50 |
| Static (Full Drainage Layer) | 2.19 | 1.58 | 1.79 | 1.35 | 2.28 | 1.10 |
| Static (Equipment Loads) | 2.19 | 1.86 | 2.05 | 1.83 | 2.31 | 1.25 |
| Seismic | 1.90 | 1.81 | 1.95 | 1.91 | 2.01 | 1.00 |

Based on these results, the proposed configuration for the Dow Salzburg Landfill is calculated to be stable using the materials proposed in the project specifications for all conditions evaluated even if residual strengths for all interfaces are mobilized.

## V. REFERENCES

Koerner, R. M. (2005) Designing with Geosynthetics, 5th edn. Prentice Hall, Englewood Cliffs, NJ, 801 pp.- 1445.

Koerner, R. M. and Soong, T.-Y. (2005), “Analysis and Design of Veneer Cover Soils,”. Geosynthetics International, Vol. 12, No. 1, pp. 28-49.

McKelvey, J. A. & Deutsch, W. L. (1991). The effect of equipment loading and tapered cover soil layers on geosynthetic lined landfill slopes. Proceedings of the 14th Annual Madison Waste Conference, Madison, WI, University of Wisconsin, pp. 395–411.

Richardson, G. and Zhao, A., Design of Lateral Drainage Systems for Landfills, Tenax Corp., Baltimore, MD, 2000.

# ATTACHMENT A

## Interface Shear Testing Results

# INTERFACE FRICTION TEST RESULTS
## ASTM D 6243

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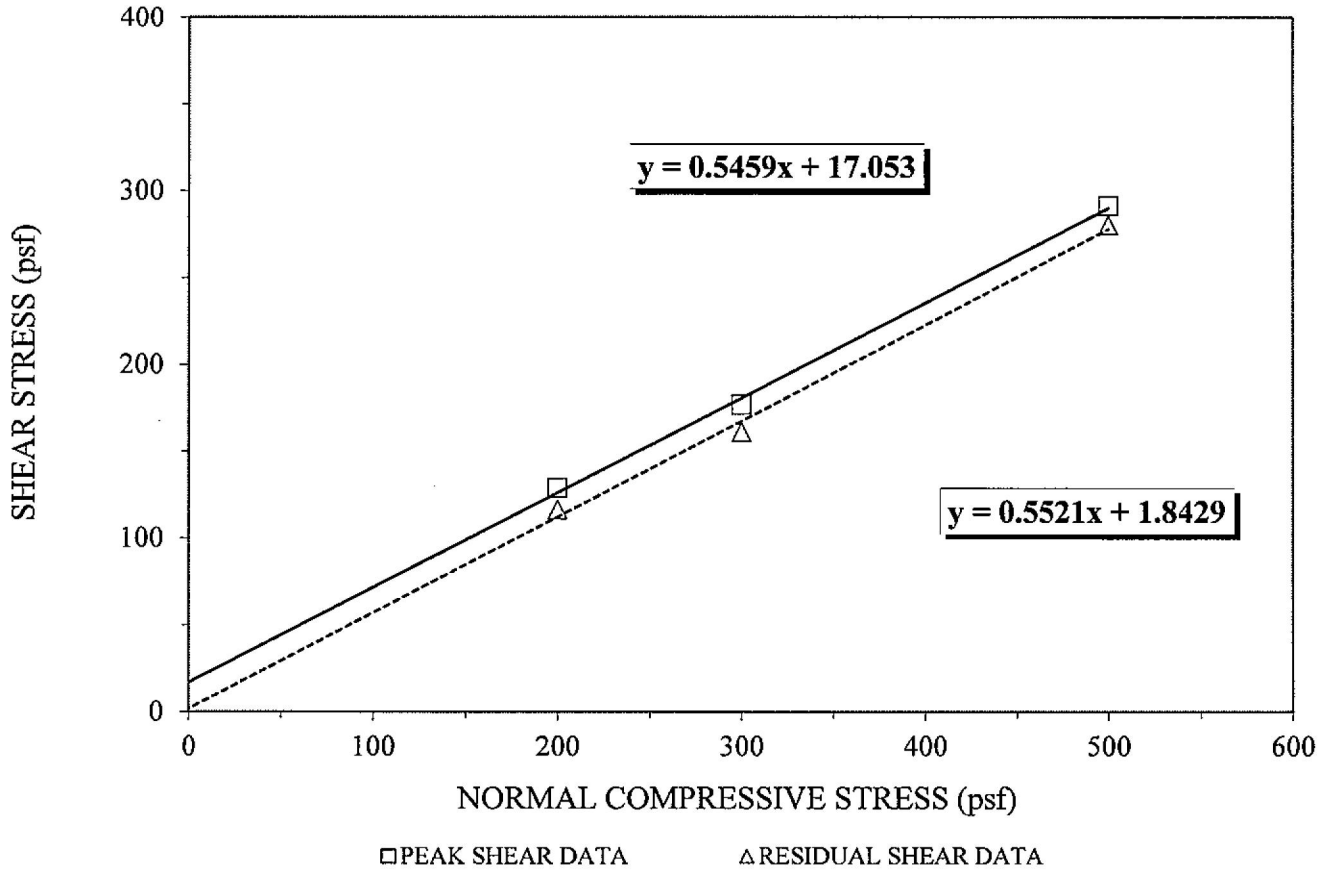
INTEGRITY IN TESTING

CLIENT : AECOM
CLIENT PROJECT : Salzburg Landfill Cells 20-22 Cap
PROJECT NO. : L15067-02
LAB I. D. NO.: Subgrade Soil, Buckets 1 & 2 Composite Sample (L15067-02-06)
GSE BentoLiner NWL, Roll # 135039508 (L15067-02-03)

INTERFACE : **Soil @ 122.7 pcf & 12.8 % M.C.**
**vs. GCL (Scrim-Nonwoven Side)**

| | PEAK SHEAR | | RESIDUAL SHEAR | |
|---|---|---|---|---|
| FRICTION ANGLE (deg) : | Φ = | **28.6** | Φ = | **28.9** |
| COEFFICIENT OF FRICTION : | = | **0.546** | = | **0.552** |
| ADHESION [Calculated] (psf): | a = | **17** | a = | **2** |

NOTES:
1.) The GCL was hydrated @ 144 psf normal load for 24 hours.
2.) Soil placement was based on 90% maximum dry density and a moisture content + 6% of optimum of the average of modified proctor values.
3.) The interface was loaded, inundated with water and seated for 24 hours prior to shearing.
4.) The peak friction angle was calculated using linear regression on the three data points.
5.) The residual friction angle was calculated using linear regression on the end of test values.



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# INTERFACE FRICTION TEST RESULTS
## ASTM D 6243

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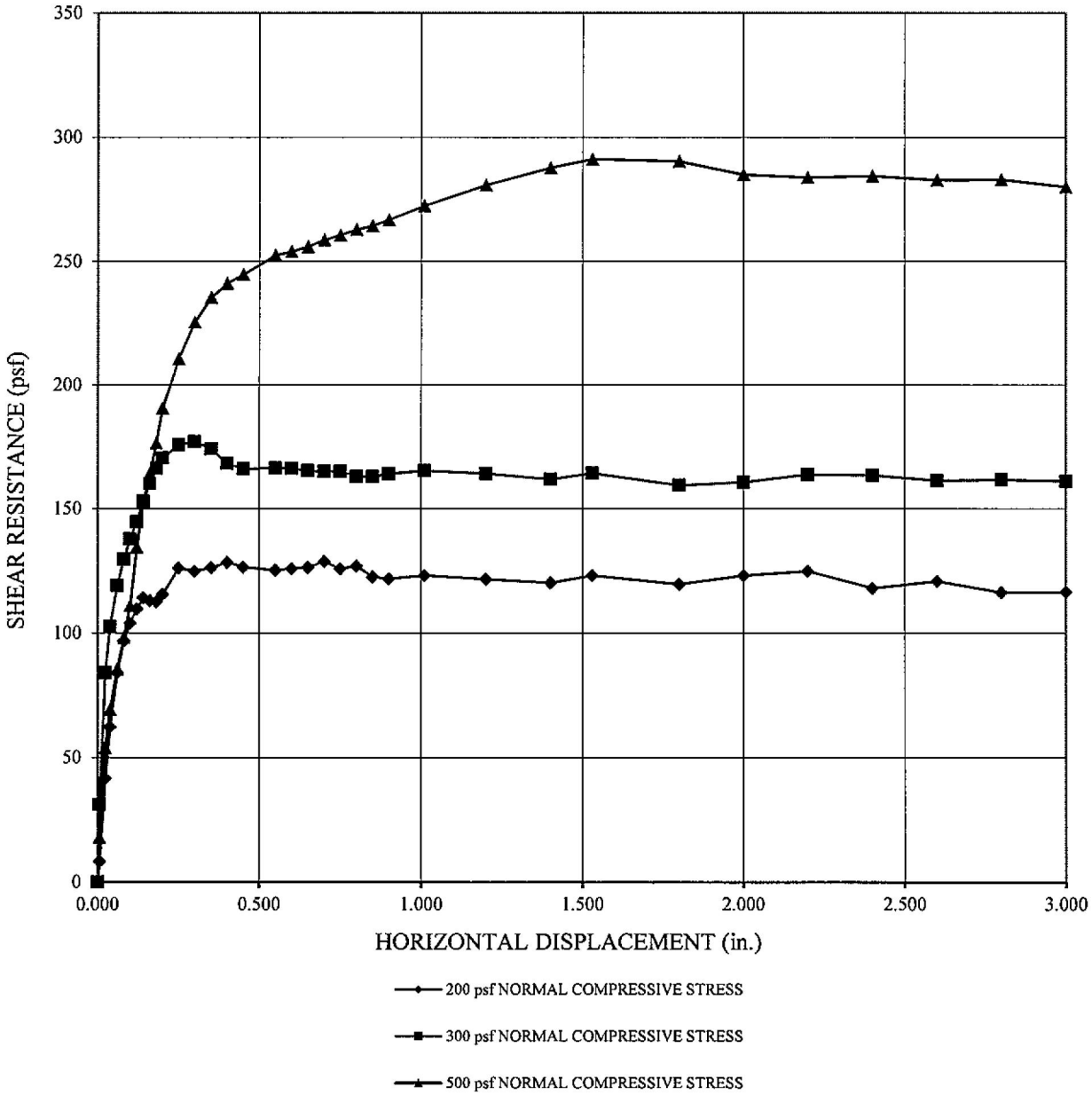
INTEGRITY IN TESTING

CLIENT : AECOM
CLIENT PROJECT : Salzburg Landfill Cells 20-22 Cap
PROJECT NO. : L15067-02
LAB I. D. NO.: Subgrade Soil, Buckets 1 & 2 Composite Sample (L15067-02-06)
GSE BentoLiner NWL, Roll # 135039508 (L15067-02-03)

INTERFACE : **Soil @ 122.7 pcf & 12.8 % M.C.**
**vs. GCL (Scrim-Nonwoven Side)**

SHEAR RESISTANCE VS HORIZONTAL DISPLACEMENT



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INTEGRITY IN TESTING

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PROJECT NO. : L15067-02
LAB I. D. NO.S: Subgrade Soil, Buckets 1 & 2 Composite Sample (L15067-02-06)
GSE BentoLiner NWL, Roll # 135039508 (L15067-02-03)

INTERFACE : **Soil @ 122.7 pcf & 12.8 % M.C.**
**vs. GCL (Scrim-Nonwoven Side)**

STRAIN RATE ( in / min ) : 0.04 DIRECT SHEAR UNIT: LNL
PLACEMENT CONDITION: Inundated NORMAL LOAD: Platen Weight

| NORMAL LOAD (psf) | 200 | NORMAL LOAD (psf) | 300 | NORMAL LOAD (psf) | 500 |
|---|---|---|---|---|---|
| PEAK SHEAR STRESS (psf) | 129 | PEAK SHEAR STRESS (psf) | 177 | PEAK SHEAR STRESS (psf) | 291 |
| PEAK SECANT ANGLE (deg) | 32.8 | PEAK SECANT ANGLE (deg) | 30.5 | PEAK SECANT ANGLE (deg) | 30.2 |
| RESIDUAL SHEAR (psf) | 117 | RESIDUAL SHEAR (psf) | 161 | RESIDUAL SHEAR (psf) | 280 |
| RESID. SECANT ANGLE (deg) | 30.2 | RESID. SECANT ANGLE (deg) | 28.2 | RESID. SECANT ANGLE (deg) | 29.2 |

| HORIZONTAL | | | HORIZONTAL | | | HORIZONTAL | | |
|---|---|---|---|---|---|---|---|---|
| DISPLACE. (in.) | SHEAR FORCE (lbs) | STRESS (psf) | DISPLACE. (in.) | SHEAR FORCE (lbs) | STRESS (psf) | DISPLACE. (in.) | SHEAR FORCE (lbs) | STRESS (psf) |
| 0.000 | 0 | 0 | 0.000 | 0 | 0 | 0.000 | 0 | 0 |
| 0.005 | 8 | 8 | 0.005 | 31 | 31 | 0.005 | 18 | 18 |
| 0.023 | 42 | 42 | 0.023 | 84 | 84 | 0.023 | 54 | 54 |
| 0.038 | 62 | 62 | 0.038 | 103 | 103 | 0.038 | 69 | 69 |
| 0.060 | 84 | 84 | 0.060 | 119 | 119 | 0.060 | 86 | 86 |
| 0.080 | 97 | 97 | 0.080 | 130 | 130 | 0.080 | 98 | 98 |
| 0.100 | 104 | 104 | 0.100 | 138 | 138 | 0.100 | 111 | 111 |
| 0.120 | 110 | 110 | 0.120 | 145 | 145 | 0.120 | 134 | 134 |
| 0.140 | 114 | 114 | 0.140 | 153 | 153 | 0.140 | 153 | 153 |
| 0.160 | 113 | 113 | 0.160 | 160 | 160 | 0.160 | 164 | 164 |
| 0.180 | 112 | 112 | 0.180 | 166 | 166 | 0.180 | 176 | 176 |
| 0.200 | 116 | 116 | 0.200 | 170 | 170 | 0.200 | 191 | 191 |
| 0.250 | 126 | 126 | 0.250 | 176 | 176 | 0.250 | 211 | 211 |
| 0.300 | 125 | 125 | 0.300 | 177 | 177 | 0.300 | 225 | 225 |
| 0.350 | 126 | 126 | 0.350 | 174 | 174 | 0.350 | 235 | 235 |
| 0.400 | 128 | 128 | 0.400 | 168 | 168 | 0.400 | 241 | 241 |
| 0.450 | 126 | 126 | 0.450 | 166 | 166 | 0.450 | 245 | 245 |
| 0.550 | 125 | 125 | 0.550 | 166 | 166 | 0.550 | 252 | 252 |
| 0.600 | 126 | 126 | 0.600 | 166 | 166 | 0.600 | 254 | 254 |
| 0.650 | 126 | 126 | 0.650 | 165 | 165 | 0.650 | 256 | 256 |
| 0.700 | 129 | 129 | 0.700 | 165 | 165 | 0.700 | 259 | 259 |
| 0.750 | 126 | 126 | 0.750 | 165 | 165 | 0.750 | 261 | 261 |
| 0.800 | 127 | 127 | 0.800 | 163 | 163 | 0.800 | 263 | 263 |
| 0.850 | 123 | 123 | 0.850 | 163 | 163 | 0.850 | 264 | 264 |
| 0.900 | 122 | 122 | 0.900 | 164 | 164 | 0.900 | 267 | 267 |
| 1.010 | 123 | 123 | 1.010 | 165 | 165 | 1.010 | 272 | 272 |
| 1.200 | 122 | 122 | 1.200 | 164 | 164 | 1.200 | 281 | 281 |
| 1.400 | 120 | 120 | 1.400 | 162 | 162 | 1.400 | 288 | 288 |
| 1.530 | 123 | 123 | 1.530 | 164 | 164 | 1.530 | 291 | 291 |
| 1.800 | 120 | 120 | 1.800 | 159 | 159 | 1.800 | 290 | 290 |
| 2.000 | 123 | 123 | 2.000 | 161 | 161 | 2.000 | 285 | 285 |
| 2.200 | 125 | 125 | 2.200 | 164 | 164 | 2.200 | 284 | 284 |
| 2.400 | 118 | 118 | 2.400 | 164 | 164 | 2.400 | 284 | 284 |
| 2.600 | 121 | 121 | 2.600 | 161 | 161 | 2.600 | 283 | 283 |
| 2.800 | 116 | 116 | 2.800 | 162 | 162 | 2.800 | 283 | 283 |
| 3.000 | 117 | 117 | 3.000 | 161 | 161 | 3.000 | 280 | 280 |


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# INTERFACE FRICTION TEST RESULTS
## ASTM D 6243

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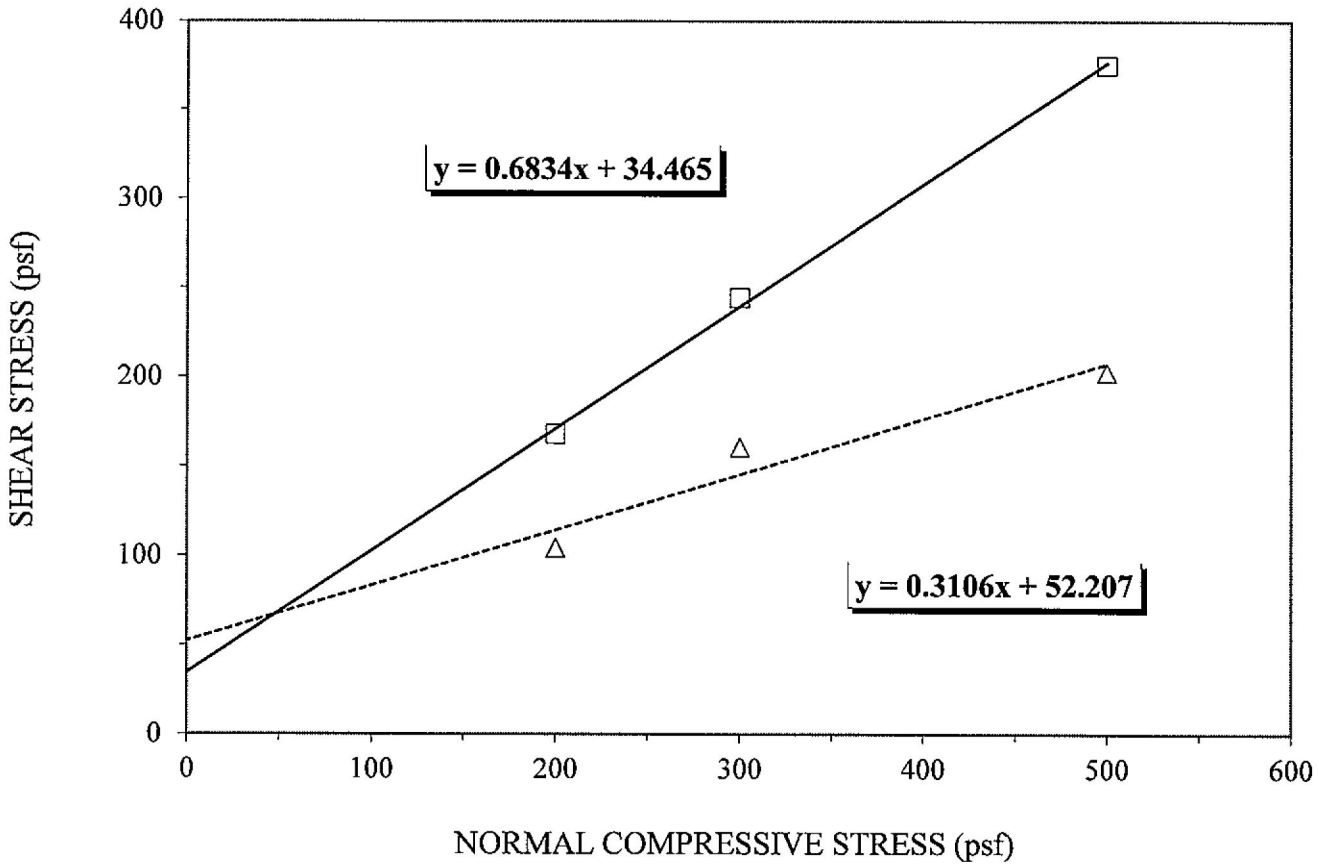
INTEGRITY IN TESTING

CLIENT : AECOM
CLIENT PROJECT : Salzburg Landfill Cells 20-22 Cap
PROJECT NO. : L15067-02
LAB I. D. NO.: GSE BentoLiner NWL GCL, Roll # 135039572 (L15067-02-04)
GSE BentoLiner NWL GCL, Roll # 135039508 (L15067-02-03)

INTERFACE : **GCL (Scrim-Nonwoven Side)**
**vs. GCL (Non-Woven Side)**

| | PEAK SHEAR | | RESIDUAL SHEAR | |
|---|---|---|---|---|
| FRICTION ANGLE (deg) : | Φ = | **34.3** | Φ = | **17.3** |
| COEFFICIENT OF FRICTION : | = | **0.683** | = | **0.311** |
| ADHESION [Calculated] (psf): | a = | **34** | a = | **52** |

NOTES:
1.) GCL was hydrated @ 144 psf normal load for 24 hours.
2.) The interface was loaded, inundated with water and seated for 1 hour prior to shearing.
3.) The peak friction angle was calculated using linear regression on the three data points.
4.) The residual friction angle was calculated using linear regression on the end of test values.



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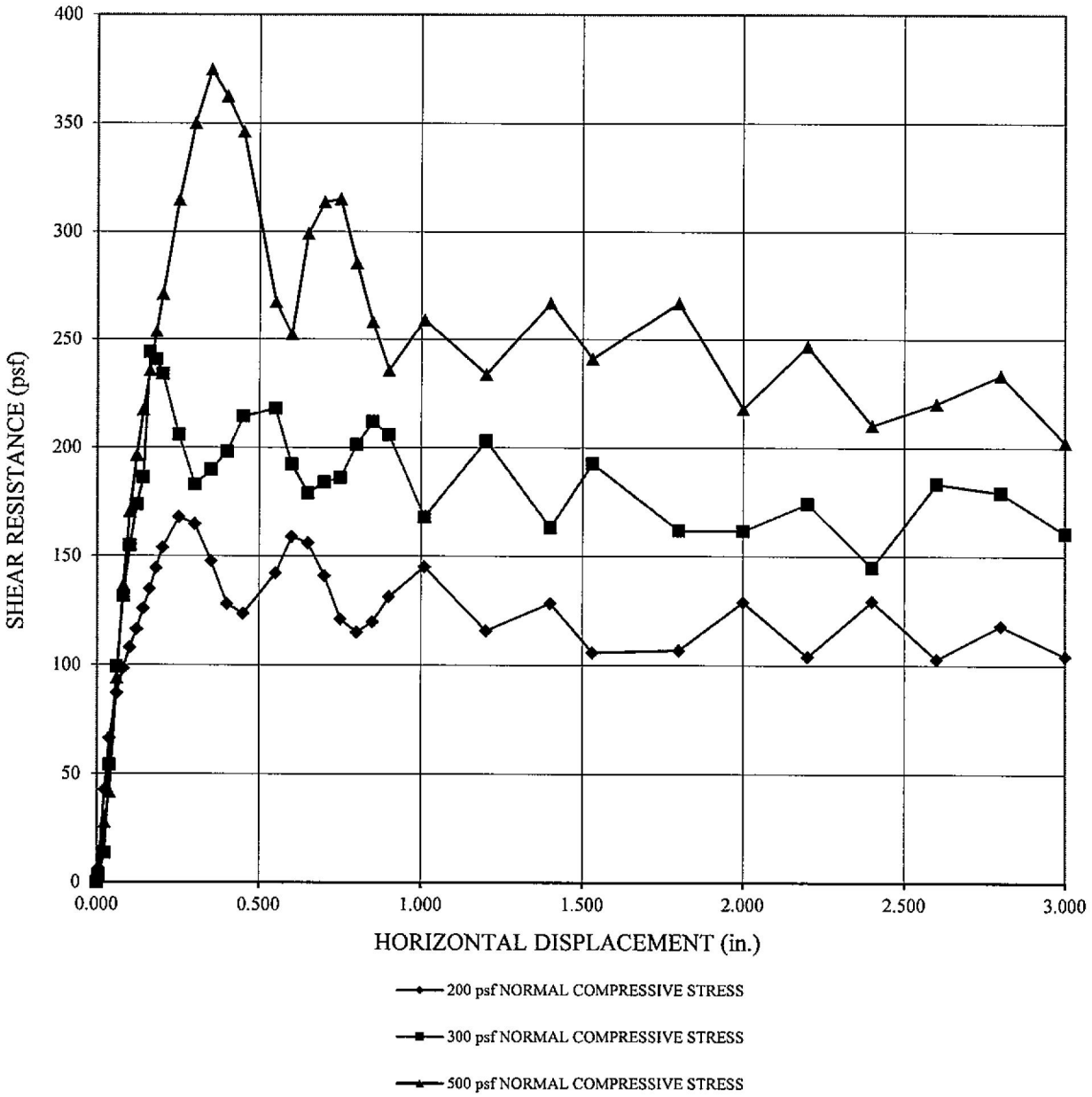
INTERFACE : **GCL (Scrim-Nonwoven Side)**
**vs. GCL (Non-Woven Side)**

SHEAR RESISTANCE VS HORIZONTAL DISPLACEMENT



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GSE BentoLiner NWL GCL, Roll # 135039508 (L15067-02-03)

INTERFACE : **GCL (Scrim-Nonwoven Side)**
**vs. GCL (Non-Woven Side)**

STRAIN RATE ( in / min ) : 0.04 DIRECT SHEAR UNIT: LNL
PLACEMENT CONDITION: Inundated NORMAL LOAD: Platen Weight

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| NORMAL LOAD (psf) | | 200 | NORMAL LOAD (psf) | | 300 | NORMAL LOAD (psf) | | 500 |
| PEAK SHEAR STRESS (psf) | | 168 | PEAK SHEAR STRESS (psf) | | 244 | PEAK SHEAR STRESS (psf) | | 375 |
| PEAK SECANT ANGLE (deg) | | 40.0 | PEAK SECANT ANGLE (deg) | | 39.1 | PEAK SECANT ANGLE (deg) | | 36.8 |
| RESIDUAL SHEAR (psf) | | 104 | RESIDUAL SHEAR (psf) | | 160 | RESIDUAL SHEAR (psf) | | 202 |
| RESID. SECANT ANGLE (deg) | | 27.5 | RESID. SECANT ANGLE (deg) | | 28.1 | RESID. SECANT ANGLE (deg) | | 22.0 |
| HORIZONTAL | | | HORIZONTAL | | | HORIZONTAL | | |
| DISPLACE. (in.) | SHEAR FORCE (lbs) | STRESS (psf) | DISPLACE. (in.) | SHEAR FORCE (lbs) | STRESS (psf) | DISPLACE. (in.) | SHEAR FORCE (lbs) | STRESS (psf) |
| 0.000 | 0 | 0 | 0.000 | 0 | 0 | 0.000 | 0 | 0 |
| 0.005 | 6 | 6 | 0.005 | 3 | 3 | 0.005 | 6 | 6 |
| 0.023 | 43 | 43 | 0.023 | 14 | 14 | 0.023 | 28 | 28 |
| 0.038 | 67 | 67 | 0.038 | 54 | 54 | 0.038 | 42 | 42 |
| 0.060 | 87 | 87 | 0.060 | 99 | 99 | 0.060 | 94 | 94 |
| 0.080 | 99 | 99 | 0.080 | 132 | 132 | 0.080 | 137 | 137 |
| 0.100 | 108 | 108 | 0.100 | 155 | 155 | 0.100 | 171 | 171 |
| 0.120 | 116 | 116 | 0.120 | 174 | 174 | 0.120 | 197 | 197 |
| 0.140 | 126 | 126 | 0.140 | 186 | 186 | 0.140 | 217 | 217 |
| 0.160 | 135 | 135 | 0.160 | 244 | 244 | 0.160 | 236 | 236 |
| 0.180 | 145 | 145 | 0.180 | 241 | 241 | 0.180 | 254 | 254 |
| 0.200 | 154 | 154 | 0.200 | 234 | 234 | 0.200 | 271 | 271 |
| 0.250 | 168 | 168 | 0.250 | 206 | 206 | 0.250 | 315 | 315 |
| 0.300 | 165 | 165 | 0.300 | 183 | 183 | 0.300 | 350 | 350 |
| 0.350 | 148 | 148 | 0.350 | 190 | 190 | 0.350 | 375 | 375 |
| 0.400 | 128 | 128 | 0.400 | 198 | 198 | 0.400 | 362 | 362 |
| 0.450 | 124 | 124 | 0.450 | 214 | 214 | 0.450 | 346 | 346 |
| 0.550 | 142 | 142 | 0.550 | 218 | 218 | 0.550 | 268 | 268 |
| 0.600 | 159 | 159 | 0.600 | 192 | 192 | 0.600 | 252 | 252 |
| 0.650 | 156 | 156 | 0.650 | 179 | 179 | 0.650 | 299 | 299 |
| 0.700 | 141 | 141 | 0.700 | 184 | 184 | 0.700 | 314 | 314 |
| 0.750 | 121 | 121 | 0.750 | 186 | 186 | 0.750 | 315 | 315 |
| 0.800 | 115 | 115 | 0.800 | 201 | 201 | 0.800 | 286 | 286 |
| 0.850 | 120 | 120 | 0.850 | 212 | 212 | 0.850 | 258 | 258 |
| 0.900 | 131 | 131 | 0.900 | 206 | 206 | 0.900 | 236 | 236 |
| 1.010 | 145 | 145 | 1.010 | 168 | 168 | 1.010 | 259 | 259 |
| 1.200 | 116 | 116 | 1.200 | 203 | 203 | 1.200 | 234 | 234 |
| 1.400 | 128 | 128 | 1.400 | 163 | 163 | 1.400 | 267 | 267 |
| 1.530 | 106 | 106 | 1.530 | 193 | 193 | 1.530 | 241 | 241 |
| 1.800 | 107 | 107 | 1.800 | 162 | 162 | 1.800 | 267 | 267 |
| 2.000 | 129 | 129 | 2.000 | 162 | 162 | 2.000 | 218 | 218 |
| 2.200 | 104 | 104 | 2.200 | 174 | 174 | 2.200 | 247 | 247 |
| 2.400 | 129 | 129 | 2.400 | 145 | 145 | 2.400 | 210 | 210 |
| 2.600 | 103 | 103 | 2.600 | 184 | 184 | 2.600 | 220 | 220 |
| 2.800 | 118 | 118 | 2.800 | 179 | 179 | 2.800 | 234 | 234 |
| 3.000 | 104 | 104 | 3.000 | 160 | 160 | 3.000 | 202 | 202 |


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# INTERFACE FRICTION TEST RESULTS
## ASTM D 6243

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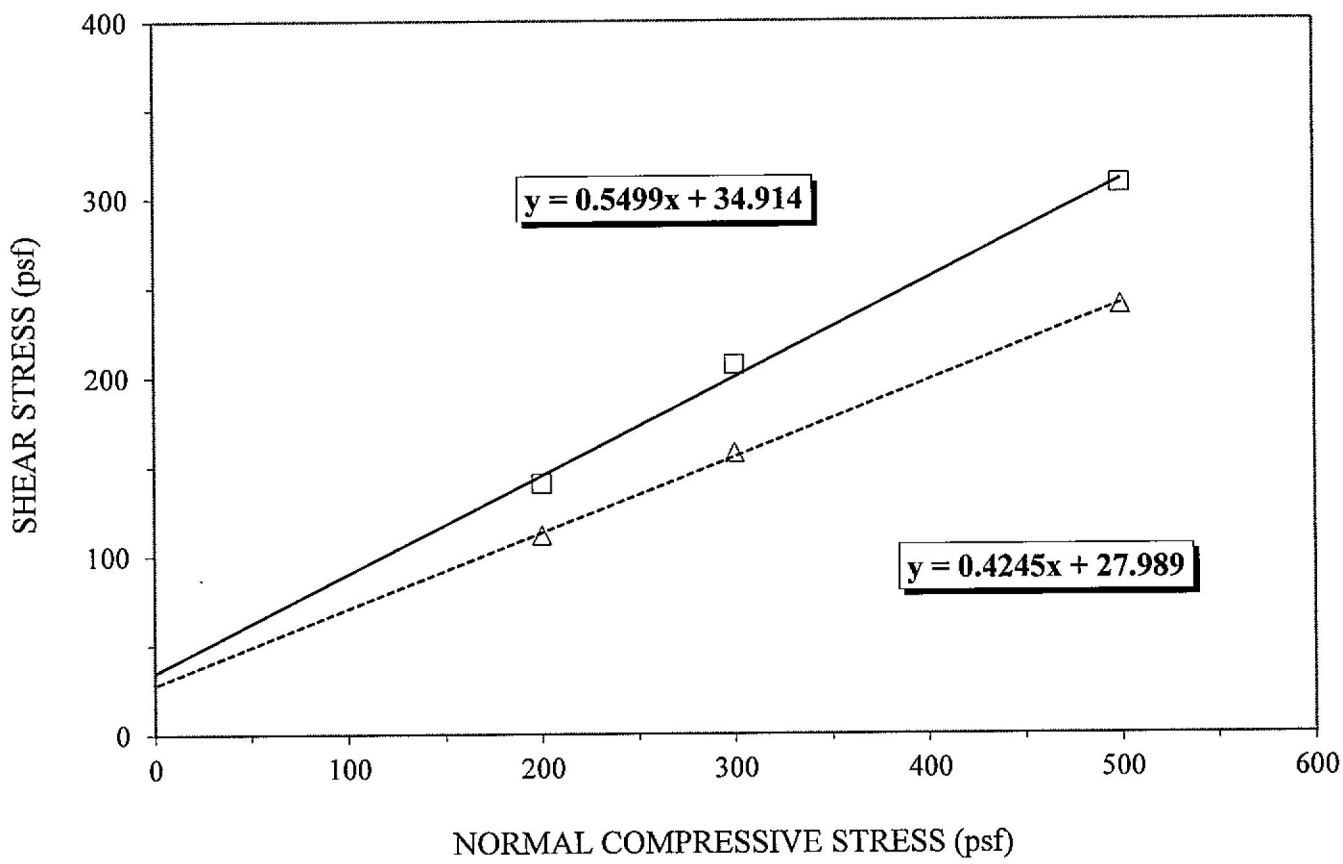
INTEGRITY IN TESTING

CLIENT : AECOM
CLIENT PROJECT : Salzburg Landfill Cells 20-22 Cap
PROJECT NO. : L15067-02
LAB I. D. NO.: GSE BentoLiner NWL, Roll # 135039508 (L15067-02-03)
GSE HDT-060-WBB, Roll # 105174867 (L15067-02-01)

INTERFACE : **GCL (Non-Woven Side)**
**vs. 60 mil Textured HDPE (Black Side)**

| | PEAK SHEAR | | RESIDUAL SHEAR | |
|---|---|---|---|---|
| FRICTION ANGLE (deg) : | Φ = | **28.8** | Φ = | **23.0** |
| COEFFICIENT OF FRICTION : | = | **0.550** | = | **0.425** |
| ADHESION [Calculated] (psf): | a = | **35** | a = | **28** |

NOTES:
1.) GCL was hydrated at 144 psf normal load for 24 hours..
2.) The interface was loaded, inundated with water and seated for 1 hour prior to shearing.
3.) The peak friction angle was calculated using linear regression on the three data points.
4.) The residual friction angle was calculated using linear regression on the end of test values.




□PEAK SHEAR DATA △RESIDUAL SHEAR DATA



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# INTERFACE FRICTION TEST RESULTS
## ASTM D 6243

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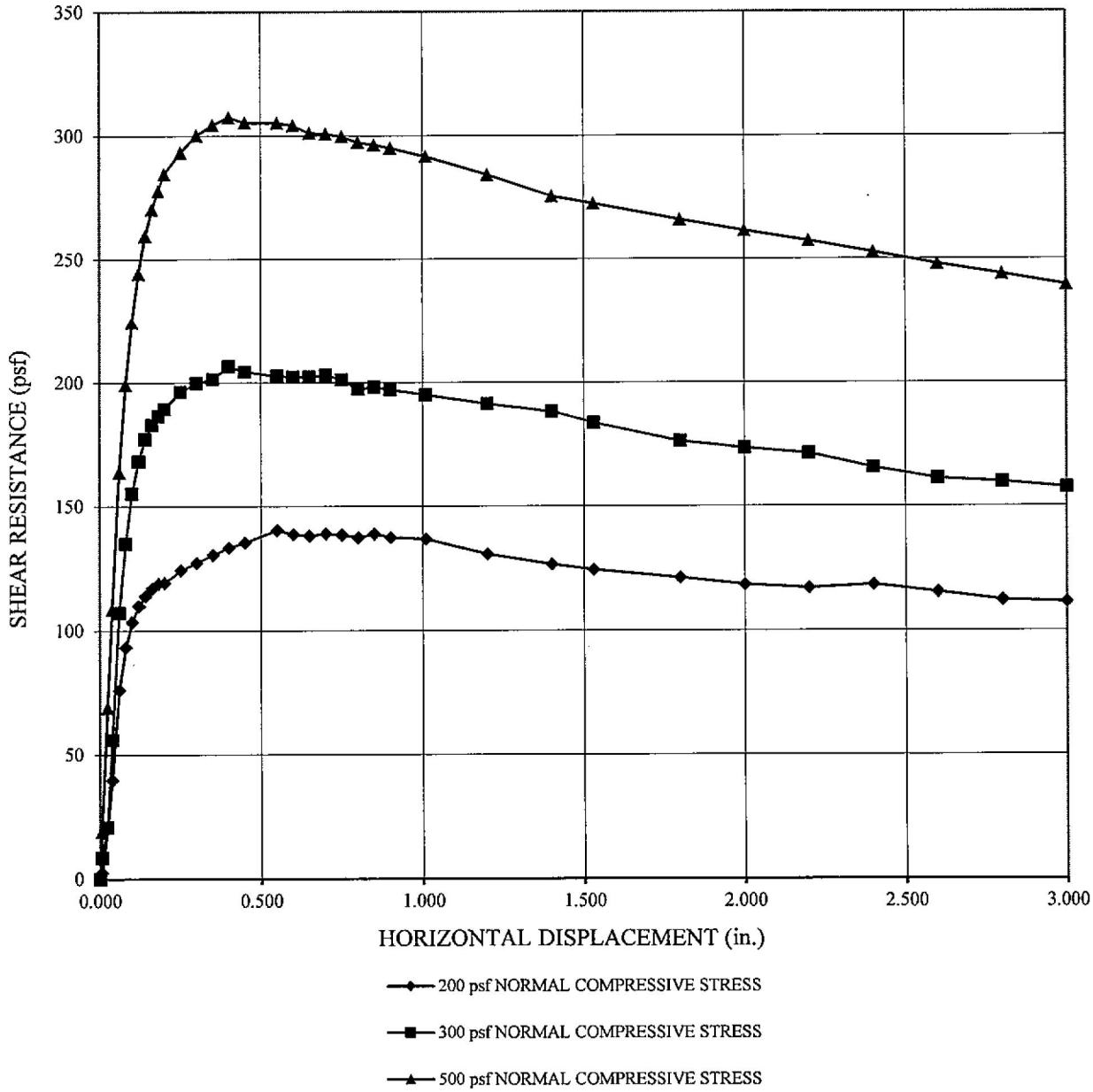
INTEGRITY IN TESTING

CLIENT : AECOM
CLIENT PROJECT : Salzburg Landfill Cells 20-22 Cap
PROJECT NO. : L15067-02
LAB I. D. NO.: GSE BentoLiner NWL, Roll # 135039508 (L15067-02-03)
GSE HDT-060-WBB, Roll # 105174867 (L15067-02-01)

INTERFACE : **GCL (Non-Woven Side)**
**vs. 60 mil Textured HDPE (Black Side)**

SHEAR RESISTANCE VS HORIZONTAL DISPLACEMENT



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# INTERFACE FRICTION TEST RESULTS
## ASTM D 6243

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INTEGRITY IN TESTING

CLIENT : AECOM
CLIENT PROJECT : Salzburg Landfill Cells 20-22 Cap
PROJECT NO. : L15067-02
LAB I. D. NO.S: GSE BentoLiner NWL, Roll # 135039508 (L15067-02-03)
GSE HDT-060-WBB, Roll # 105174867 (L15067-02-01)

INTERFACE : **GCL (Non-Woven Side)**
**vs. 60 mil Textured HDPE (Black Side)**

STRAIN RATE ( in / min ) : 0.04 DIRECT SHEAR UNIT: LNL
PLACEMENT CONDITION: Inundated NORMAL LOAD: Platen Weight

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| NORMAL LOAD (psf) | | 200 | NORMAL LOAD (psf) | | 300 | NORMAL LOAD (psf) | | 500 |
| PEAK SHEAR STRESS (psf) | | 140 | PEAK SHEAR STRESS (psf) | | 207 | PEAK SHEAR STRESS (psf) | | 308 |
| PEAK SECANT ANGLE (deg) | | 35.1 | PEAK SECANT ANGLE (deg) | | 34.6 | PEAK SECANT ANGLE (deg) | | 31.6 |
| RESIDUAL SHEAR (psf) | | 111 | RESIDUAL SHEAR (psf) | | 158 | RESIDUAL SHEAR (psf) | | 240 |
| RESID. SECANT ANGLE (deg) | | 29.1 | RESID. SECANT ANGLE (deg) | | 27.7 | RESID. SECANT ANGLE (deg) | | 25.6 |
| ASPERITY | | 19 | ASPERITY | | 19 | ASPERITY | | 19 |
| HORIZONTAL | | | HORIZONTAL | | | HORIZONTAL | | |
| DISPLACE. (in.) | SHEAR FORCE (lbs) | STRESS (psf) | DISPLACE. (in.) | SHEAR FORCE (lbs) | STRESS (psf) | DISPLACE. (in.) | SHEAR FORCE (lbs) | STRESS (psf) |
| 0.000 | 0 | 0 | 0.000 | 0 | 0 | 0.000 | 0 | 0 |
| 0.005 | 3 | 3 | 0.005 | 9 | 9 | 0.005 | 19 | 19 |
| 0.023 | 20 | 20 | 0.023 | 21 | 21 | 0.023 | 69 | 69 |
| 0.038 | 40 | 40 | 0.038 | 56 | 56 | 0.038 | 109 | 109 |
| 0.060 | 76 | 76 | 0.060 | 107 | 107 | 0.060 | 164 | 164 |
| 0.080 | 93 | 93 | 0.080 | 135 | 135 | 0.080 | 199 | 199 |
| 0.100 | 103 | 103 | 0.100 | 155 | 155 | 0.100 | 224 | 224 |
| 0.120 | 110 | 110 | 0.120 | 168 | 168 | 0.120 | 244 | 244 |
| 0.140 | 114 | 114 | 0.140 | 177 | 177 | 0.140 | 259 | 259 |
| 0.160 | 117 | 117 | 0.160 | 183 | 183 | 0.160 | 270 | 270 |
| 0.180 | 119 | 119 | 0.180 | 186 | 186 | 0.180 | 278 | 278 |
| 0.200 | 119 | 119 | 0.200 | 189 | 189 | 0.200 | 285 | 285 |
| 0.250 | 124 | 124 | 0.250 | 196 | 196 | 0.250 | 293 | 293 |
| 0.300 | 127 | 127 | 0.300 | 200 | 200 | 0.300 | 300 | 300 |
| 0.350 | 130 | 130 | 0.350 | 201 | 201 | 0.350 | 304 | 304 |
| 0.400 | 133 | 133 | 0.400 | 207 | 207 | 0.400 | 308 | 308 |
| 0.450 | 135 | 135 | 0.450 | 204 | 204 | 0.450 | 305 | 305 |
| 0.550 | 140 | 140 | 0.550 | 203 | 203 | 0.550 | 305 | 305 |
| 0.600 | 139 | 139 | 0.600 | 202 | 202 | 0.600 | 304 | 304 |
| 0.650 | 138 | 138 | 0.650 | 202 | 202 | 0.650 | 301 | 301 |
| 0.700 | 139 | 139 | 0.700 | 203 | 203 | 0.700 | 301 | 301 |
| 0.750 | 139 | 139 | 0.750 | 201 | 201 | 0.750 | 300 | 300 |
| 0.800 | 137 | 137 | 0.800 | 197 | 197 | 0.800 | 297 | 297 |
| 0.850 | 139 | 139 | 0.850 | 198 | 198 | 0.850 | 296 | 296 |
| 0.900 | 137 | 137 | 0.900 | 197 | 197 | 0.900 | 295 | 295 |
| 1.010 | 137 | 137 | 1.010 | 195 | 195 | 1.010 | 292 | 292 |
| 1.200 | 131 | 131 | 1.200 | 191 | 191 | 1.200 | 284 | 284 |
| 1.400 | 127 | 127 | 1.400 | 188 | 188 | 1.400 | 275 | 275 |
| 1.530 | 124 | 124 | 1.530 | 184 | 184 | 1.530 | 272 | 272 |
| 1.800 | 121 | 121 | 1.800 | 176 | 176 | 1.800 | 266 | 266 |
| 2.000 | 118 | 118 | 2.000 | 173 | 173 | 2.000 | 261 | 261 |
| 2.200 | 117 | 117 | 2.200 | 171 | 171 | 2.200 | 257 | 257 |
| 2.400 | 118 | 118 | 2.400 | 166 | 166 | 2.400 | 253 | 253 |
| 2.600 | 115 | 115 | 2.600 | 161 | 161 | 2.600 | 248 | 248 |
| 2.800 | 112 | 112 | 2.800 | 160 | 160 | 2.800 | 244 | 244 |
| 3.000 | 111 | 111 | 3.000 | 158 | 158 | 3.000 | 240 | 240 |


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# INTERFACE FRICTION TEST RESULTS
## ASTM D 5321

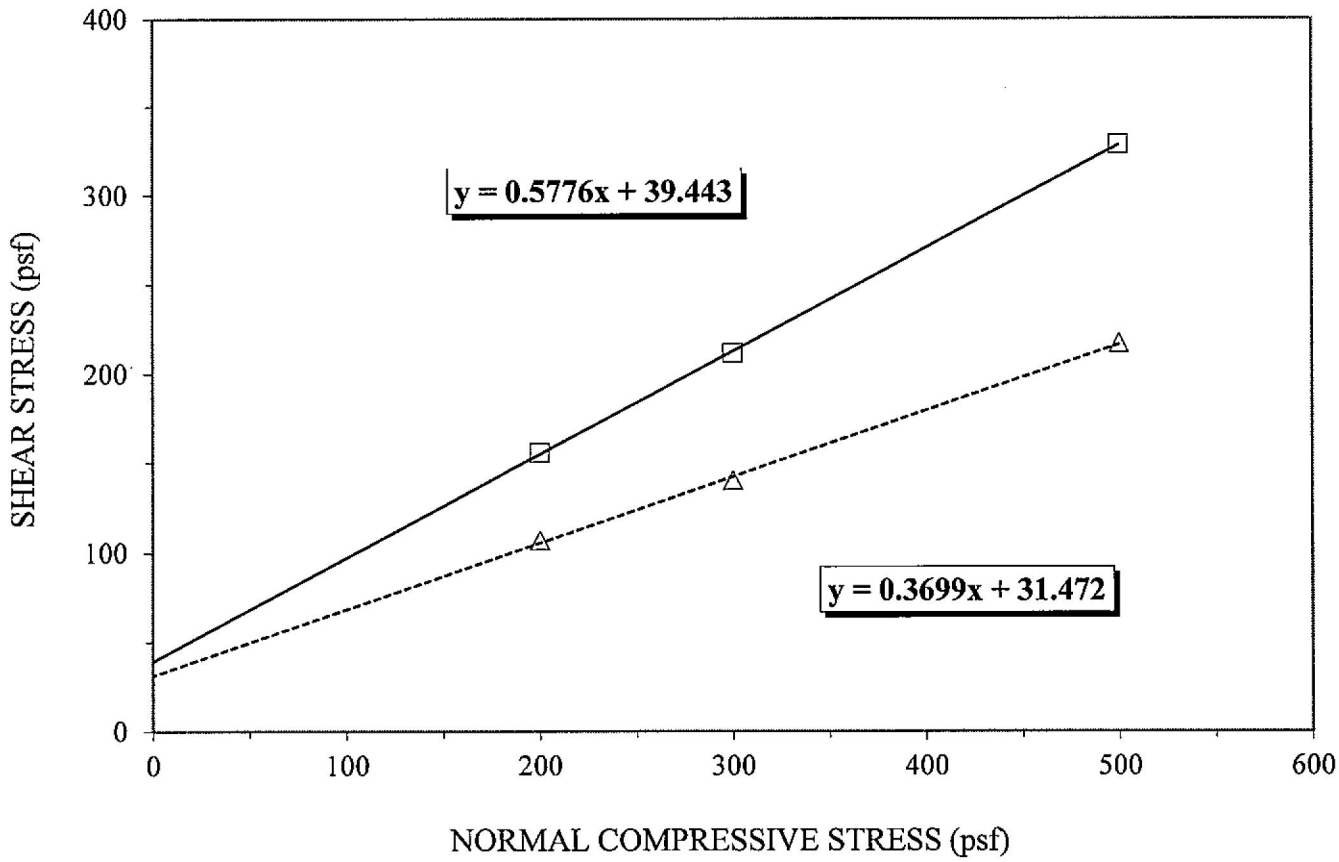
geotechnics
INTEGRITY IN TESTING

CLIENT : AECOM
CLIENT PROJECT : Salzburg Landfill Cells 20-22 Cap
PROJECT NO. : L15067-02
LAB I. D. NO.: GSE FS2-300E-08-08 Geocomposite, Roll # 131477765 (L15067-02-02)
GSE HDT-060-WBB, Roll # 105174867 (L15067-02-01)

INTERFACE : **Geocomposite**
**vs. 60 mil Texuted HDPE (White Side)**

| | PEAK SHEAR | | RESIDUAL SHEAR | |
|---|---|---|---|---|
| FRICTION ANGLE (deg) : | Φ = | **30.0** | Φ = | **20.3** |
| COEFFICIENT OF FRICTION : | = | **0.578** | = | **0.370** |
| ADHESION [Calculated] (psf): | a = | **39** | a = | **31** |

NOTES:
1.) The interface was loaded, inundated with water and seated for 1 hour prior to shearing.
2.) The peak friction angle was calculated using linear regression on the three data points.
3.) The residual friction angle was calculated using linear regression on the end of test values.




□PEAK SHEAR DATA △RESIDUAL SHEAR DATA



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## ASTM D 5321

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INTEGRITY IN TESTING

CLIENT : AECOM
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PROJECT NO. : L15067-02
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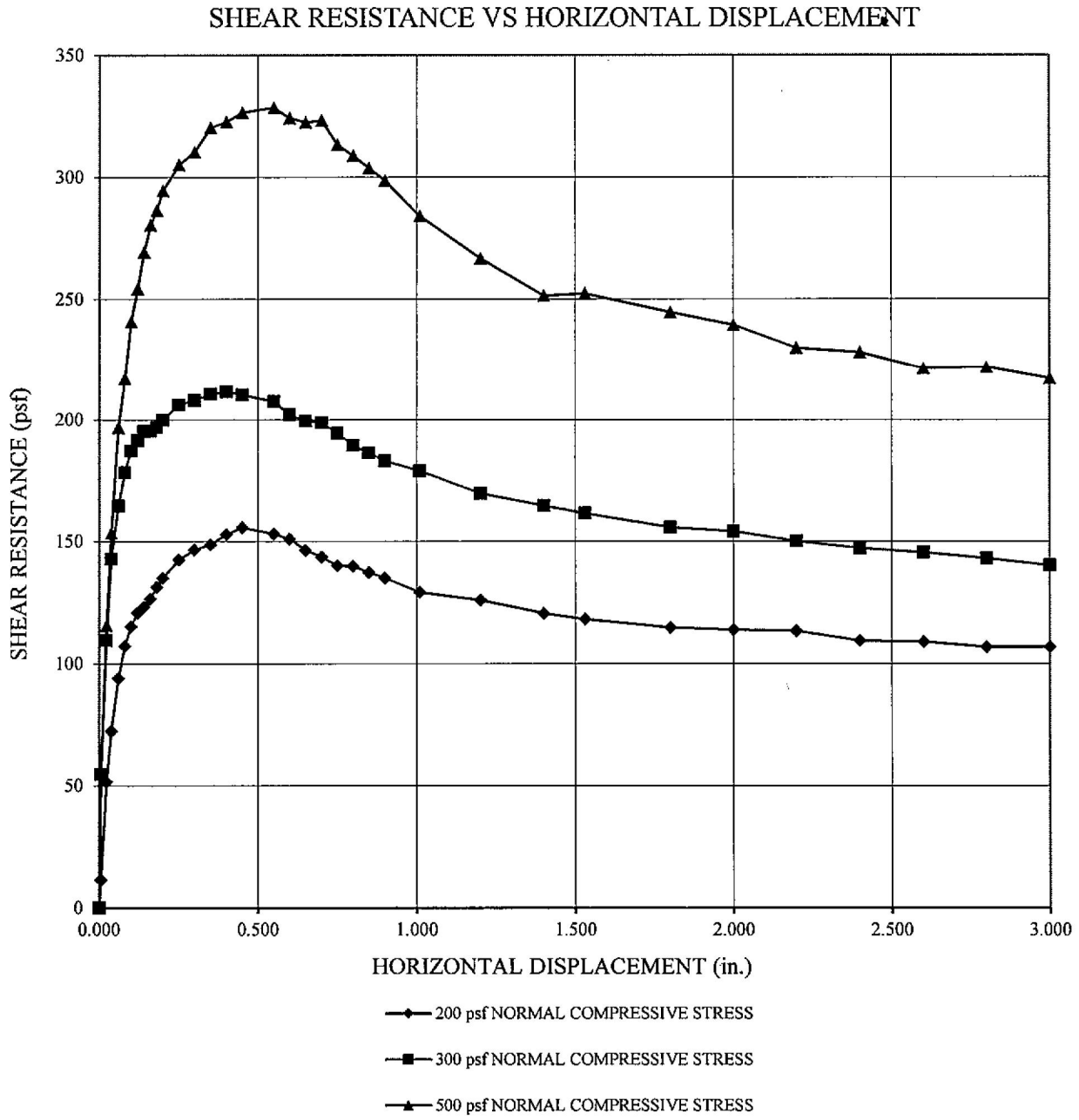
INTERFACE : **Geocomposite**
**vs. 60 mil Texuted HDPE (White Side)**



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# INTERFACE FRICTION TEST RESULTS
## ASTM D 5321

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INTEGRITY IN TESTING

CLIENT : AECOM
CLIENT PROJECT : Salzburg Landfill Cells 20-22 Cap
PROJECT NO. : L15067-02
LAB I. D. NO.S: GSE FS2-300E-08-08 Geocomposite, Roll # 131477765 (L15067-02-02)
GSE HDT-060-WBB, Roll # 105174867 (L15067-02-01)

INTERFACE : **Geocomposite**
**vs. 60 mil Texuted HDPE (White Side)**

STRAIN RATE ( in / min ) : 0.20 DIRECT SHEAR UNIT: LNL
PLACEMENT CONDITION: Inundated NORMAL LOAD: Platen Weight

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| NORMAL LOAD (psf) | | 200 | NORMAL LOAD (psf) | | 300 | NORMAL LOAD (psf) | | 500 |
| PEAK SHEAR STRESS (psf) | | 156 | PEAK SHEAR STRESS (psf) | | 212 | PEAK SHEAR STRESS (psf) | | 329 |
| PEAK SECANT ANGLE (deg) | | 37.9 | PEAK SECANT ANGLE (deg) | | 35.2 | PEAK SECANT ANGLE (deg) | | 33.3 |
| RESIDUAL SHEAR (psf) | | 107 | RESIDUAL SHEAR (psf) | | 140 | RESIDUAL SHEAR (psf) | | 217 |
| RESID. SECANT ANGLE (deg) | | 28.1 | RESID. SECANT ANGLE (deg) | | 25.1 | RESID. SECANT ANGLE (deg) | | 23.5 |
| ASPERITY | | 22 | ASPERITY | | 22 | ASPERITY | | 22 |
| HORIZONTAL | | | HORIZONTAL | | | HORIZONTAL | | |
| DISPLACE. (in.) | SHEAR FORCE (lbs) | STRESS (psf) | DISPLACE. (in.) | SHEAR FORCE (lbs) | STRESS (psf) | DISPLACE. (in.) | SHEAR FORCE (lbs) | STRESS (psf) |
| 0.000 | 0 | 0 | 0.000 | 0 | 0 | 0.000 | 0 | 0 |
| 0.005 | 12 | 12 | 0.005 | 55 | 55 | 0.005 | 55 | 55 |
| 0.023 | 52 | 52 | 0.023 | 110 | 110 | 0.023 | 116 | 116 |
| 0.038 | 73 | 73 | 0.038 | 143 | 143 | 0.038 | 153 | 153 |
| 0.060 | 94 | 94 | 0.060 | 165 | 165 | 0.060 | 197 | 197 |
| 0.080 | 107 | 107 | 0.080 | 178 | 178 | 0.080 | 217 | 217 |
| 0.100 | 115 | 115 | 0.100 | 187 | 187 | 0.100 | 241 | 241 |
| 0.120 | 121 | 121 | 0.120 | 191 | 191 | 0.120 | 254 | 254 |
| 0.140 | 123 | 123 | 0.140 | 195 | 195 | 0.140 | 269 | 269 |
| 0.160 | 127 | 127 | 0.160 | 195 | 195 | 0.160 | 280 | 280 |
| 0.180 | 131 | 131 | 0.180 | 197 | 197 | 0.180 | 286 | 286 |
| 0.200 | 135 | 135 | 0.200 | 200 | 200 | 0.200 | 295 | 295 |
| 0.250 | 143 | 143 | 0.250 | 206 | 206 | 0.250 | 305 | 305 |
| 0.300 | 147 | 147 | 0.300 | 208 | 208 | 0.300 | 310 | 310 |
| 0.350 | 149 | 149 | 0.350 | 211 | 211 | 0.350 | 320 | 320 |
| 0.400 | 153 | 153 | 0.400 | 212 | 212 | 0.400 | 323 | 323 |
| 0.450 | 156 | 156 | 0.450 | 210 | 210 | 0.450 | 327 | 327 |
| 0.550 | 153 | 153 | 0.550 | 207 | 207 | 0.550 | 329 | 329 |
| 0.600 | 151 | 151 | 0.600 | 202 | 202 | 0.600 | 324 | 324 |
| 0.650 | 146 | 146 | 0.650 | 199 | 199 | 0.650 | 323 | 323 |
| 0.700 | 144 | 144 | 0.700 | 199 | 199 | 0.700 | 323 | 323 |
| 0.750 | 140 | 140 | 0.750 | 194 | 194 | 0.750 | 313 | 313 |
| 0.800 | 140 | 140 | 0.800 | 189 | 189 | 0.800 | 309 | 309 |
| 0.850 | 137 | 137 | 0.850 | 186 | 186 | 0.850 | 304 | 304 |
| 0.900 | 135 | 135 | 0.900 | 183 | 183 | 0.900 | 299 | 299 |
| 1.010 | 129 | 129 | 1.010 | 179 | 179 | 1.010 | 284 | 284 |
| 1.200 | 126 | 126 | 1.200 | 170 | 170 | 1.200 | 267 | 267 |
| 1.400 | 121 | 121 | 1.400 | 165 | 165 | 1.400 | 251 | 251 |
| 1.530 | 118 | 118 | 1.530 | 162 | 162 | 1.530 | 252 | 252 |
| 1.800 | 115 | 115 | 1.800 | 156 | 156 | 1.800 | 245 | 245 |
| 2.000 | 114 | 114 | 2.000 | 154 | 154 | 2.000 | 239 | 239 |
| 2.200 | 113 | 113 | 2.200 | 150 | 150 | 2.200 | 230 | 230 |
| 2.400 | 109 | 109 | 2.400 | 147 | 147 | 2.400 | 228 | 228 |
| 2.600 | 109 | 109 | 2.600 | 146 | 146 | 2.600 | 221 | 221 |
| 2.800 | 107 | 107 | 2.800 | 143 | 143 | 2.800 | 222 | 222 |
| 3.000 | 107 | 107 | 3.000 | 140 | 140 | 3.000 | 217 | 217 |


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# INTERFACE FRICTION TEST RESULTS
## ASTM D 5321

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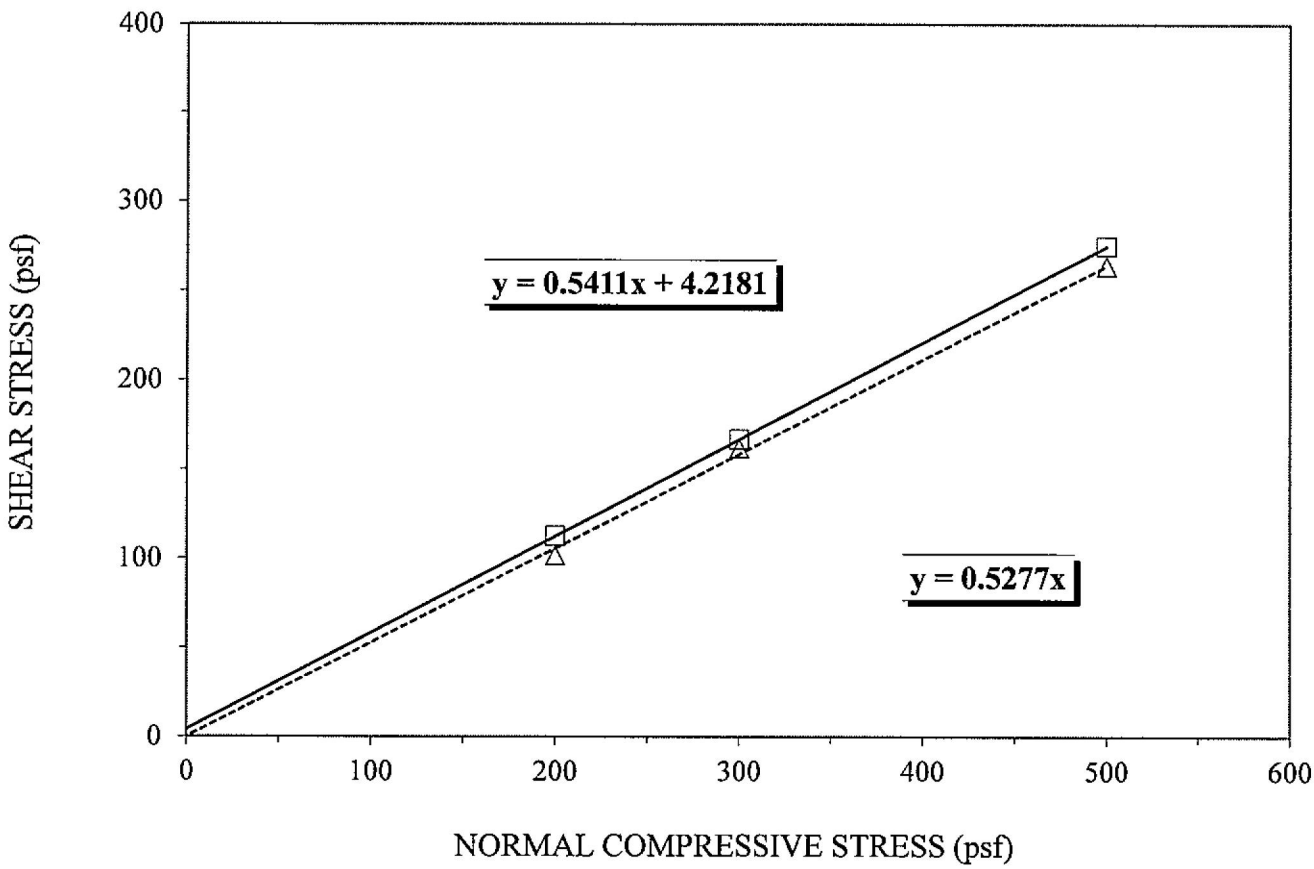
INTEGRITY IN TESTING

CLIENT : AECOM
CLIENT PROJECT : Salzburg Landfill Cells 20-22 Cap
PROJECT NO. : L15067-02
LAB I. D. NO.: Protective Cover, Buckets 3, 5 & 6 Composite Sample (L15067-02-05)
GSE FS2-300E-08-08 Geocomposite, Roll # 131477765 (L15067-02-02)

INTERFACE : **Soil @ 80.3 pcf & 7.2 % M.C.**
**vs. Geocomposite**

| | PEAK SHEAR | | RESIDUAL SHEAR | |
|---|---|---|---|---|
| FRICTION ANGLE (deg) : | Φ = | **28.5** | Φ = | **27.8** |
| COEFFICIENT OF FRICTION : | = | **0.542** | = | **0.528** |
| ADHESION [Calculated] (psf): | a = | **3** | a = | **0** |

NOTES:
1.) Soil was lighty compacted at the as-received moisture content.
2.) The interface was loaded, inundated with water and seated for 24 hours prior to shearing.
3.) The peak friction angle was calculated using linear regression on the three data points.
4.) The residual friction angle was calculated using linear regression on the end of test values.




□PEAK SHEAR DATA △RESIDUAL SHEAR DATA



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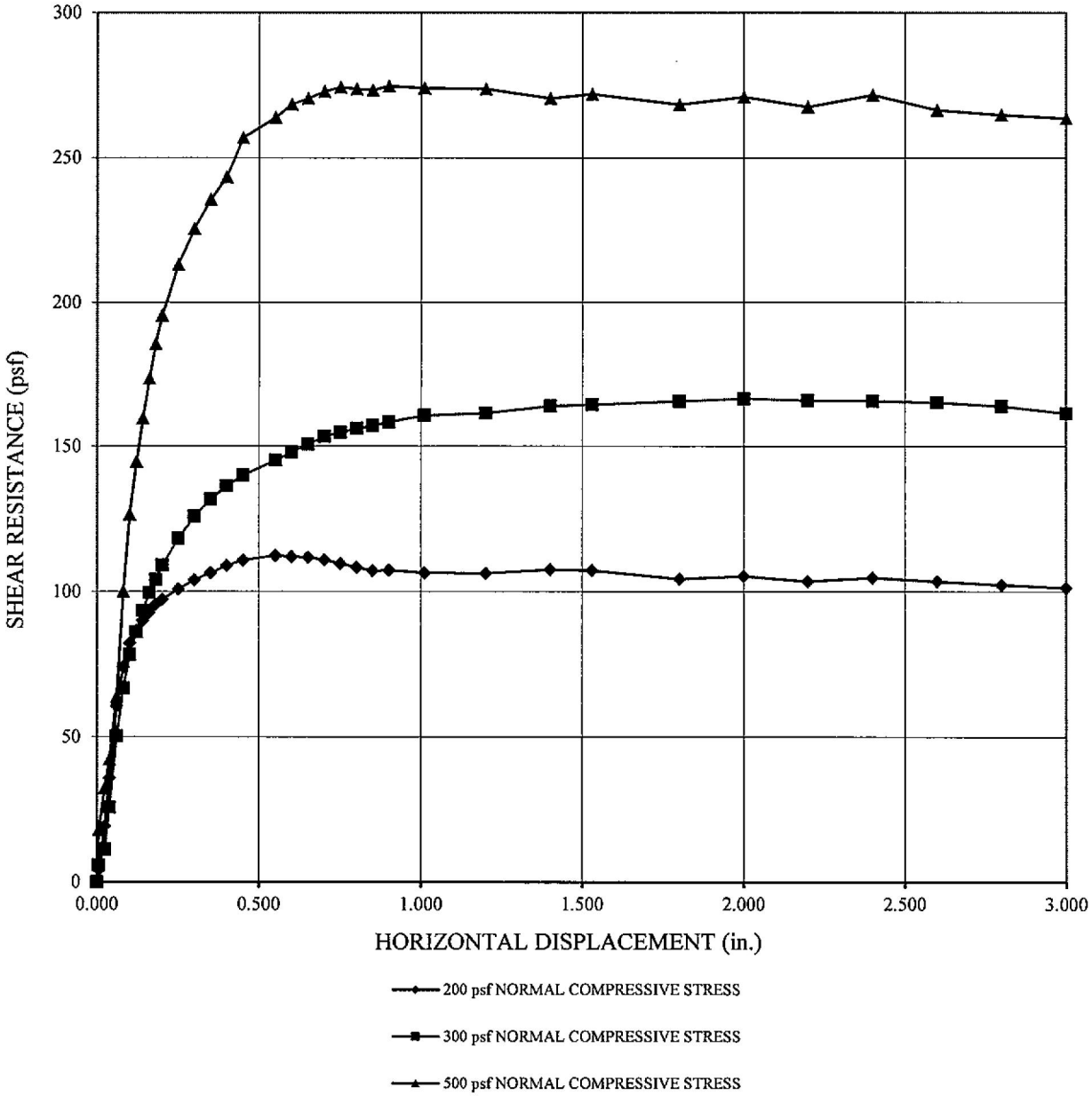
## ASTM D 5321

geotechnics
INTEGRITY IN TESTING

CLIENT : AECOM
CLIENT PROJECT : Salzburg Landfill Cells 20-22 Cap
PROJECT NO. : L15067-02
LAB I. D. NO.: Protective Cover, Buckets 3, 5 & 6 Composite Sample (L15067-02-05)
GSE FS2-300E-08-08 Geocomposite, Roll # 131477765 (L15067-02-02)

INTERFACE : **Soil @ 80.3 pcf & 7.2 % M.C.**
**vs. Geocomposite**

SHEAR RESISTANCE VS HORIZONTAL DISPLACEMENT



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# INTERFACE FRICTION TEST RESULTS
## ASTM D 5321

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INTEGRITY IN TESTING

CLIENT : AECOM
CLIENT PROJECT : Salzburg Landfill Cells 20-22 Cap
PROJECT NO. : L15067-02
LAB I. D. NO.S: Protective Cover, Buckets 3, 5 & 6 Composite Sample (L15067-02-05)
GSE FS2-300E-08-08 Geocomposite, Roll # 131477765 (L15067-02-02)

INTERFACE : **Soil @ 80.3 pcf & 7.2 % M.C.**
**vs. Geocomposite**

STRAIN RATE ( in / min ) : 0.04 DIRECT SHEAR UNIT: LNL
PLACEMENT CONDITION: Inundated NORMAL LOAD: Platen Weight

| NORMAL LOAD (psf) | 200 | NORMAL LOAD (psf) | 300 | NORMAL LOAD (psf) | 500 |
|---|---|---|---|---|---|
| PEAK SHEAR STRESS (psf) | 112 | PEAK SHEAR STRESS (psf) | 167 | PEAK SHEAR STRESS (psf) | 275 |
| PEAK SECANT ANGLE (deg) | 29.3 | PEAK SECANT ANGLE (deg) | 29.0 | PEAK SECANT ANGLE (deg) | 28.8 |
| RESIDUAL SHEAR (psf) | 101 | RESIDUAL SHEAR (psf) | 162 | RESIDUAL SHEAR (psf) | 264 |
| RESID. SECANT ANGLE (deg) | 26.9 | RESID. SECANT ANGLE (deg) | 28.3 | RESID. SECANT ANGLE (deg) | 27.8 |

| HORIZONTAL | | | HORIZONTAL | | | HORIZONTAL | | |
|---|---|---|---|---|---|---|---|---|
| DISPLACE. (in.) | SHEAR FORCE (lbs) | STRESS (psf) | DISPLACE. (in.) | SHEAR FORCE (lbs) | STRESS (psf) | DISPLACE. (in.) | SHEAR FORCE (lbs) | STRESS (psf) |
| 0.000 | 0 | 0 | 0.000 | 0 | 0 | 0.000 | 0 | 0 |
| 0.005 | 4 | 4 | 0.005 | 6 | 6 | 0.005 | 18 | 18 |
| 0.023 | 19 | 19 | 0.023 | 11 | 11 | 0.023 | 32 | 32 |
| 0.038 | 36 | 36 | 0.038 | 26 | 26 | 0.038 | 42 | 42 |
| 0.060 | 61 | 61 | 0.060 | 50 | 50 | 0.060 | 64 | 64 |
| 0.080 | 74 | 74 | 0.080 | 67 | 67 | 0.080 | 100 | 100 |
| 0.100 | 82 | 82 | 0.100 | 78 | 78 | 0.100 | 127 | 127 |
| 0.120 | 87 | 87 | 0.120 | 86 | 86 | 0.120 | 145 | 145 |
| 0.140 | 90 | 90 | 0.140 | 93 | 93 | 0.140 | 160 | 160 |
| 0.160 | 93 | 93 | 0.160 | 100 | 100 | 0.160 | 174 | 174 |
| 0.180 | 96 | 96 | 0.180 | 104 | 104 | 0.180 | 186 | 186 |
| 0.200 | 97 | 97 | 0.200 | 109 | 109 | 0.200 | 195 | 195 |
| 0.250 | 101 | 101 | 0.250 | 118 | 118 | 0.250 | 213 | 213 |
| 0.300 | 104 | 104 | 0.300 | 126 | 126 | 0.300 | 226 | 226 |
| 0.350 | 107 | 107 | 0.350 | 132 | 132 | 0.350 | 236 | 236 |
| 0.400 | 109 | 109 | 0.400 | 136 | 136 | 0.400 | 243 | 243 |
| 0.450 | 111 | 111 | 0.450 | 140 | 140 | 0.450 | 257 | 257 |
| 0.550 | 112 | 112 | 0.550 | 145 | 145 | 0.550 | 264 | 264 |
| 0.600 | 112 | 112 | 0.600 | 148 | 148 | 0.600 | 269 | 269 |
| 0.650 | 112 | 112 | 0.650 | 151 | 151 | 0.650 | 271 | 271 |
| 0.700 | 111 | 111 | 0.700 | 153 | 153 | 0.700 | 273 | 273 |
| 0.750 | 110 | 110 | 0.750 | 155 | 155 | 0.750 | 274 | 274 |
| 0.800 | 108 | 108 | 0.800 | 156 | 156 | 0.800 | 274 | 274 |
| 0.850 | 107 | 107 | 0.850 | 157 | 157 | 0.850 | 273 | 273 |
| 0.900 | 107 | 107 | 0.900 | 158 | 158 | 0.900 | 275 | 275 |
| 1.010 | 107 | 107 | 1.010 | 161 | 161 | 1.010 | 274 | 274 |
| 1.200 | 106 | 106 | 1.200 | 162 | 162 | 1.200 | 274 | 274 |
| 1.400 | 108 | 108 | 1.400 | 164 | 164 | 1.400 | 270 | 270 |
| 1.530 | 107 | 107 | 1.530 | 164 | 164 | 1.530 | 272 | 272 |
| 1.800 | 104 | 104 | 1.800 | 166 | 166 | 1.800 | 268 | 268 |
| 2.000 | 105 | 105 | 2.000 | 167 | 167 | 2.000 | 271 | 271 |
| 2.200 | 104 | 104 | 2.200 | 166 | 166 | 2.200 | 268 | 268 |
| 2.400 | 105 | 105 | 2.400 | 166 | 166 | 2.400 | 272 | 272 |
| 2.600 | 104 | 104 | 2.600 | 165 | 165 | 2.600 | 267 | 267 |
| 2.800 | 102 | 102 | 2.800 | 164 | 164 | 2.800 | 265 | 265 |
| 3.000 | 101 | 101 | 3.000 | 162 | 162 | 3.000 | 264 | 264 |


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# ATTACHMENT B

## Detailed Calculations

| AECOM<br>564 White Pond Drive<br>Akron, OH 44320<br>Tel. (330) 836-9111 | DOW Chemical<br><br>COVER VENEER STABILITY<br>Salzburg Landfill Cells 20-22 | JOB | 60440134 | | |
|---|---|---|---|---|---|
| | | SHT NO | 1 | OF | 9 |
| | | CALC BY | JAD | DATE | 03/29/16 |
| | | CHK BY | NSG | DATE | 03/30/16 |
| | | SCALE | NA | | |

Objective:

Determine the veneer stability of the cover system at the Salzburg Landfill - Cells 20 - 22. Each interface was analyzed using residual strength parameters to reflect large displacement conditions.

Method:

Use methods outlined in the paper by Koerner and Soong, *Analysis and Design of Veneer Cover Soils* published in Geosynthetics International, 2005, 12, No.1.

Procedure:

Determine the static stability of the veneer cover system to evaluate the minimum factor of safety for the cover system. Balance the forces as shown in Figure 1 and compare to the required factor of safety (FS).

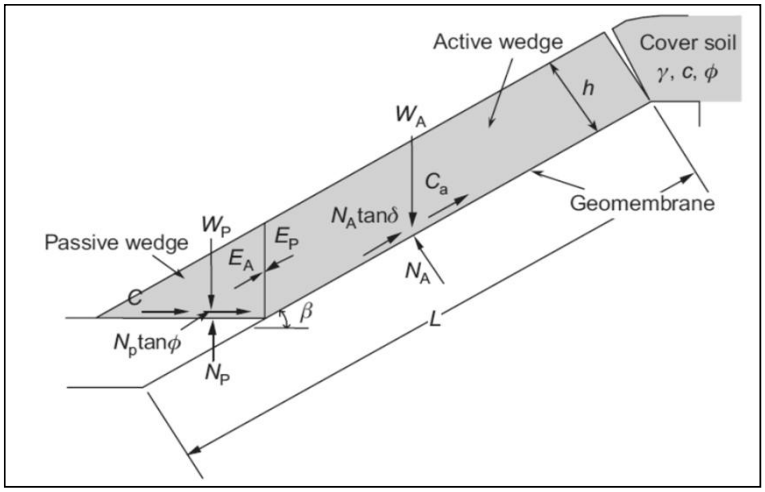


Figure 1. Limit equilibrium forces involved in a finite length slope analysis for a uniformly thick cover soil

Determine: Static factor of safety for cover system based on gravitational forces only and peak strength.

Assumptions:

1. No geosynthetic reinforcements
2. No interface adhesion for geosynthetic components.
3. No tension allowed in geosynthetics
4. Minimum cohesion for multilayered systems

Veg. Cover Soil (VC)/Prot. Cover Soil (CS) and Slope Parameters

| | VC | CS | Utilized | | Source |
|---|---|---|---|---|---|
| Thickness (h) | 0.5 | 1.5 | 2.0 | ft | Design |
| Dry Unit Weight ($g_D$) | 90.0 | 100.0 | 97.5 | pcf | Conservatively assumed based on lab tests |
| Mois. Cont. (field cond.) ($w_F$) | 26.0 | 24.0 | 24.5 | % | Conservatively assumed based on lab tests |
| Avg Field Unit Wt (g) | - | - | 121.4 | pcf | |
| Reference Stress | - | - | 235.5 | pcf | |
| Min. Friction Angle (f ) | 30.0 | 30.0 | 30.0 | deg | Assumed (conservative for sandy cover) |
| Min. Cohesion (c) | 0.0 | 0.0 | 0.0 | psf | Assumed (conservative for sandy cover) |
| Slope Angle Beneath the Geom. (b) | - | - | 14.03 | deg | Design |
| Ht. of Slp. Meas. Along Geom. ($H_L$) | - | - | 22.06 | ft | Design |
| Lng. of Slp. Meas. Along Geom. (L) | - | - | 91.00 | ft | |
| Inter. Frict. Angle for Prot. Soil & GDM (d) | - | - | 27.8 | deg | Resid. shear strength parameters from interface shear testing |
| Adhesion for Prot. Soil & GDM ($c_a$) | - | - | 0.0 | psf | |
| Required Factor of Safety ($FS_R$) | - | - | 1.50 | | Min. req. FS for long term conditions |

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|---|---|---|---|---|---|
| | | SHT NO | 2 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Active Wedge Calculations

Determine the total weight of the active wedge ($W_A$),the effective force normal to the failure plan of the active wedge ($N_A$), the adhesive force between the cover soil of the active wedge and the geomembrane ($C_a$), and the interwedge force acting on the active wedge from the passive wedge ($E_A$) using the following eqs:

$$W_A = \gamma h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right)$$ = 20,028 lbs

$$N_A = W_A \cos\beta$$ = 19,430 lbs

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right)$$ = - lbs

$$E_A = \frac{(FS)(W_A - N_A\cos\beta) - (N_A\tan\delta + C_a)\sin\beta}{\sin\beta(FS)}$$ = (1,974) lbs

Passive Wedge Calculations

Determine the total weight of the passive wedge ($W_P$),the effective force normal to the failure plan of the passive wedge ($N_P$), the cohesive force along the failure plane (C), and the interwedge force acting on the passive wedge from the active wedge ($E_P$) using the following eqs:

$$W_P = \frac{\gamma h^2}{\sin 2\beta}$$ = 1,032 lbs

$$C = \frac{ch}{\sin\beta}$$ = - lbs

$$E_P = \frac{C + W_P\tan\phi}{\cos\beta(FS) - \sin\beta\tan\phi}$$ = 453 lbs

$$N_P = W_P + E_P\sin\beta$$ = 1,142 lbs

## Static Factor of Safety

Determine the calculated Factor of Safety ($FS_A$) using a quadratic equation relationship where the constants are defined as follows:

$$a = (W_A - N_A\cos\beta)\cos\beta$$ = 1,142 lbs/ft

$$b = -\begin{bmatrix}(W_A - N_A\cos\beta)\sin\beta\tan\phi \\ +(N_A\tan\delta + C_a)\sin\beta\cos\beta \\ +\sin\beta(C + W_P\tan\phi)\end{bmatrix}$$ = (2,719) lbs/ft

$$c = (N_A\tan\delta + C_a)\sin^2\beta\tan\phi$$ = 348 lbs/ft

Allow Exceeds Req'd - OK

| | | |
|---|---|---|
| $FS_R$ = | 1.50 | |
| $FS_A$ = | 2.25 | |
| Min. Resid. d | 27.8 | deg |
| Min. Resid. $c_a$ | 0.0 | pst |

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|---|---|---|---|---|---|
| | | SHT NO | 3 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Determine: Static factor of safety for cover system based on additional seepage forces.
Procedure:

Determine the static stability of the veneer cover system to determine the minimum required interface friction angle for all engineered components of the cover system. Balance the forces as shown in Figure 1 and the required factor of safety (FS) then solve for minimum interface shear strength parameters. Account for seepage forces in drainage layer as noted in Figure 2.

Assumptions:

In addition to the static case assumptions:
1. Seepage is parallel to slope
2. The drainage layer is sized such that liquid not build up beyond the thickness of the drainage layer.
3. Drainage layer has adequate capacity to handle maximum surface water flow
4. If geocomposite is used - it is less than 0.75 inches thick.
5. Max accumulation of up to 1 foot head on top of FML barrier to account for drainage aggregate in lieu of geocomposite.
6. No seepage forces outside drainage layer.

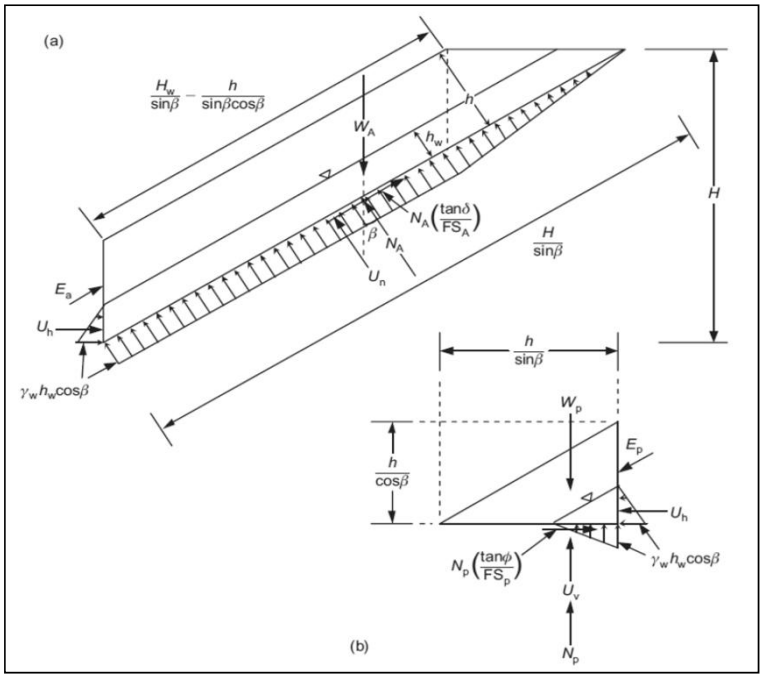


Figure 2. Limit equilibrium forces involved in finite-length slope of uniform cover soil with parallel-to-slope seepage build-up: (a) active wedge; (b) passive wedge

| Veg. Cover Soil (VC)/Prot. Cover Soil (CS) and Slope Parameters | VC | CS | Utilized | | Source |
|---|---|---|---|---|---|
| Thickness (h) | 0.5 | 1.5 | 2.0 | ft | Design |
| Dry Unit Weight ($g_D$) | 90.0 | 100.0 | 97.5 | pcf | Conservatively assumed based on lab tests |
| Mois. Cont. (field cond.) ($w_F$) | 26.0 | 24.0 | 24.5 | % | Conservatively assumed based on lab tests |
| Avg Field Unit Wt (g) | - | - | 121.4 | pcf | |
| Specific Gravity of the ($G_S$) | 2.72 | 2.72 | 2.72 | | Assumed conservative |
| Unit Weight of Water ($g_W$) | - | - | 62.4 | pcf | |
| Saturated Unit Weight ($g_{SAT}$) | - | - | 124.1 | pcf | |
| Min. Friction Angle (f ) | 30.0 | 30.0 | 30.0 | deg | Assumed (conservative for sandy cover) |
| Min. Cohesion (c) | 0.0 | 0.0 | 0.0 | psf | Assumed (conservative for sandy cover) |
| Slope Angle Beneath the Geom. (b) | - | - | 14.0 | degrees | Design |
| Ht. of Slp. Meas. Along Geom. ($H_L$) | - | - | 22.06 | ft | Design |
| Lng. of Slp. Meas. Along Geom. (L) | - | - | 91.0 | ft | |
| Depth of Water in DL ($h_W$) | - | - | 0.07 | ft | Max. thickness of DL (conservative) |
| Inter. Frict. Angle for Prot. Soil & GDM (d) | - | - | 27.8 | deg | Resid. shear strength parameters from interface shear testing |
| Adhesion for Prot. Soil & GDM ($c_a$) | - | - | 0.0 | psf | |
| Required Factor of Safety ($FS_R$) | - | - | 1.10 | | Min. req. FS for temporary conditions |

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|---|---|---|---|---|---|
| | | SHT NO | 4 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Active Wedge Calculations

Determine the total weight of the active wedge ($W_A$), resultant of the pore pressures acting on the interwedge surfaces ($U_h$), resultant of the pore pressures acting perpendicular to the slope ($U_n$), the effective force normal to the failure plan of the active wedge ($N_A$), and the interwedge force acting on the active wedge from the passive wedge ($E_A$) using the following eqs:

$$W_A = \frac{\gamma_D (h - h_W)[2H\cos\beta - (h + h_W)]}{\sin 2\beta} + \frac{\gamma_{SAT}(h_W)(2H\cos\beta - h_W)}{\sin 2\beta} = 17{,}084 \text{ lbs}$$

$$U_h = \frac{\gamma_w h_W^2}{2} = 0.15 \text{ lbs}$$

$$U_n = \frac{\gamma_w (h_w)(\cos\beta)(2H\cos\beta - h_w)}{\sin 2\beta} = 385 \text{ lbs}$$

$$N_A = W_A \cos\beta + U_h \sin\beta - U_n = 16{,}189 \text{ lbs}$$

$$E_A = W_A \sin\beta - U_h \cos\beta - \frac{N_A \sin\delta}{(FS)} = (2{,}723) \text{ lbs}$$

Passive Wedge Calculations

Determine the total weight of the passive wedge ($W_P$), resultant of the vertical pore pressures acting on the passive wedge ($U_V$), and the interwedge force acting on the pass wedge from the active wedge ($E_P$) using the following eqs:

$$W_P = \frac{\gamma_D (h^2 - h_w^2) + \gamma_{SAT} h_w^2}{\sin 2\beta} = 829.4 \text{ lbs}$$

$$U_V = U_h \cot\beta = 0.6 \text{ lbs}$$

$$E_P = \frac{U_h (FS) - (W_P - U_V \tan\phi)}{\sin\beta \tan\phi - \cos\beta (FS)} = 894 \text{ lbs}$$

## Static Factor of Safety w/ Seepage Forces

Determine the calculated Factor of Safety ($FS_A$) using a quadratic equation relationship where the constants are defined as follows:

$$a = W_A \sin\beta \cos\beta - U_h \cos^2\beta + U_h = 4{,}018 \text{ lbs/ft}$$

$$b = -W_A \sin^2\beta \tan\phi + U_h \sin\beta \cos\beta \tan\phi - N_A \cos\beta \tan\delta - (W_P - U_V)\tan\phi = (9{,}339.2) \text{ lbs/ft}$$

$$c = N_A \sin\beta \tan\delta \tan\phi = 1{,}195 \text{ lbs/ft}$$

| Allow Exceeds Req'd - OK | | |
|---|---|---|
| $FS_R$ = | 1.10 | |
| $FS_A$ = | 2.19 | |
| Min. Peak $\phi$ | 27.8 | deg |
| Min. Peak $c_a$ | 0.0 | psf |

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|---|---|---|---|---|---|
| | | SHT NO | 5 | OF | 9 |
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| | | SCALE | NA | | |

Determine: Static factor of safety for cover system based on additional equipment loads.

Procedure:

Determine the static stability of the veneer cover system to determine the minimum required interface friction angle for all engineered components of the cover system. Balance the forces as shown in Figure 1 and the required factor of safety (FS) then solve for minimum interface shear strength parameters. Account for equipment loads ($W_b$) as final cover is placed as noted in Figure 3.

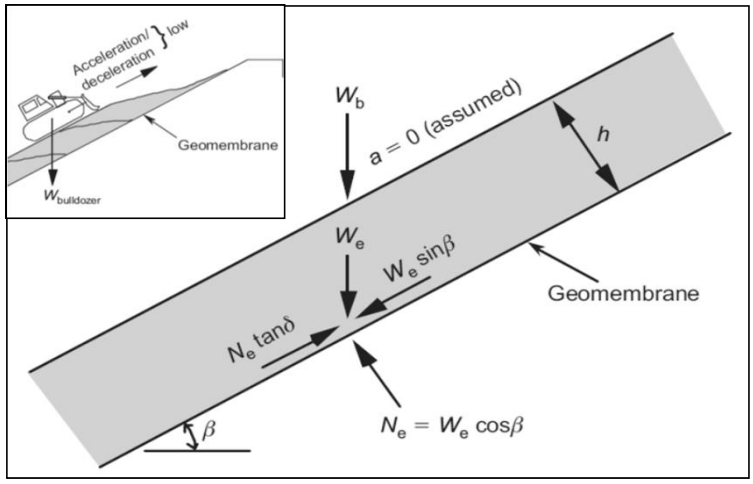


Figure 3. Additional load due to construction equipment moving on cover soil.

Assumptions:

In addition to the static case assumptions:
1. The equipment pushes material up slope leaving a toe buttress behind.
2. The equipment accelerates slowly with no sudden starts or turns to minimize additional loads besides the weight of the machine.

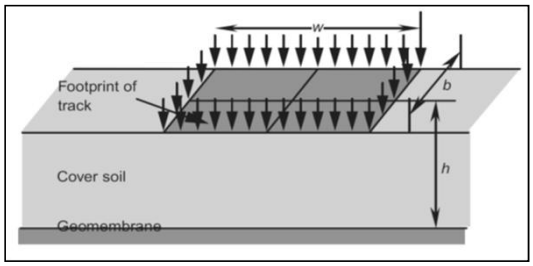


Figure 4. Illustration of stress distribution from overlying equipment.

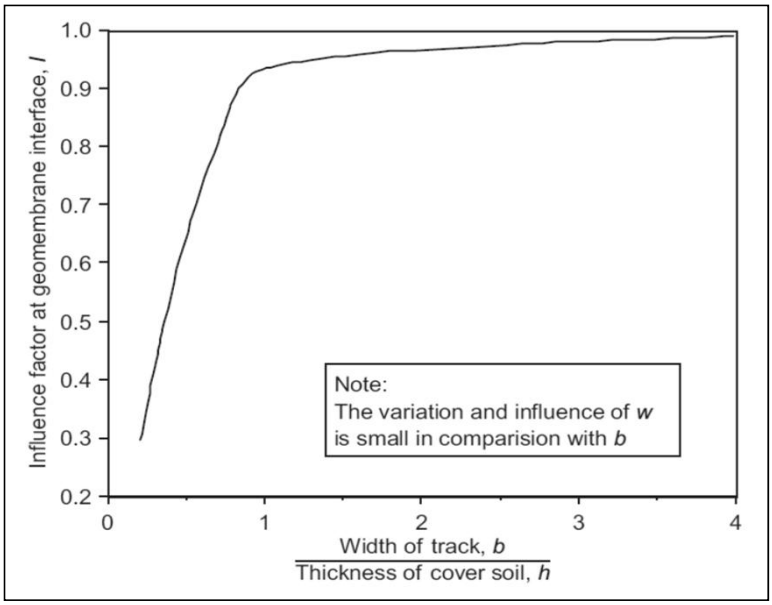


Figure 5. Values of influence factor I to dissipate surface force through cover soil to geomembrane interface (after Poulos and Davis 1974)

Equipment Parameters

| | | | Source |
|---|---|---|---|
| Equiv. Equipment Load per Unit Width ($W_e$) | 14939 | lbs | $W_e = qwl$ |
| Influence Factor at the Geom. Interface (I) | 0.95 | | See Figure 5 above. |
| Track Width to Cover Soil Thickness Ratio (b/h) | 1.40 | | |
| Distributed Equipment Load (q) | 1492 | psf | $q = W_b/(2 \times w \times b)$ |
| Weight of Equipment ($W_b$) | 87,733 | lbs | Typical weight of CAT D8 dozer |
| Length of Equipment Track (w) | 10.50 | ft | Typical track dimensions of CAT D8 dozer |
| Width of Equipment Track (b) | 2.80 | ft | |

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|---|---|---|---|---|---|
| | | SHT NO | 6 | OF | 9 |
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| | | SCALE | NA | | |

Veg. Cover Soil (VC)/Prot. Cover Soil (CS) and Slope Parameters

| | VC | CS | Utilized | | Source |
|---|---|---|---|---|---|
| Thickness (h) | 0.5 | 1.5 | 2.0 | ft | Design |
| Dry Unit Weight ($g_D$) | 90.0 | 100.0 | 97.5 | pcf | Conservatively assumed based on lab tests |
| Mois. Cont. (field cond.) ($w_F$) | 26.0 | 24.0 | 24.5 | % | Conservatively assumed based on lab tests |
| Avg Field Unit Wt (g) | - | - | 121.4 | pcf | |
| Min. Friction Angle (f ) | 30.0 | 30.0 | 30.0 | deg | Assumed (conservative for sandy cover) |
| Min. Cohesion (c) | 0.0 | 0.0 | 0.0 | psf | Assumed (conservative for sandy cover) |
| Slope Angle Beneath the Geom. (b) | - | - | 14.0 | deg | Design |
| Ht. of Slp. Meas. Along Geom. ($H_L$) | - | - | 22.06 | ft | Design |
| Lng. of Slp. Meas. Along Geom. (L) | - | - | 91.00 | ft | |
| Inter. Frict. Angle for Prot. Soil & GDM (d) | - | - | 27.8 | deg | Resid. shear strength parameters from interface shear testing |
| Adhesion for Prot. Soil & GDM ($c_a$) | - | - | 0.0 | psf | |
| Required Factor of Safety ($FS_R$) | - | - | 1.25 | | Min. req. FS for temporary conditions |

Active Wedge Calculations

Determine the total weight of the active wedge ($W_A$),the effective force normal to the failure plan of the active wedge ($N_A$), the adhesive force between the cover soil of the active wedge and the geomembrane ($C_a$), and the interwedge force acting on the active wedge from the passive wedge ($E_A$) using the following eqs:

$$W_A = \gamma h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right) + W_e$$ = 34,967 lbs

$$N_A = W_A \cos\beta$$ = 33,924 lbs

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right)$$ = - lbs

$$E_A = \frac{(FS)(W_A - N_A\cos\beta) - (N_A\tan\delta + C_a)\sin\beta}{\sin\beta(FS)}$$ = (5,832) lbs

Passive Wedge Calculations

Determine the total weight of the passive wedge ($W_P$),the effective force normal to the failure plan of the passive wedge ($N_P$), the cohesive force along the failure plane (C), and the interwedge force acting on the passive wedge from the active wedge ($E_P$) using the following eqs:

$$W_P = \frac{\gamma h^2}{\sin 2\beta}$$ = 1,032 lbs

$$C = \frac{ch}{\sin\beta}$$ = - lbs

$$E_P = \frac{C + W_P\tan\phi}{\cos\beta(FS) - \sin\beta\tan\phi}$$ = 556 lbs

$$N_P = W_P + E_P\sin\beta$$ = 1,167 lbs

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|---|---|---|---|---|---|
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| | | SCALE | NA | | |

## Static Factor of Safety w/ Equipment Load

Determine the calculated Factor of Safety ($FS_A$) using a quadratic equation relationship where the constants are defined as follows:

$$a = (W_A - N_A \cos\beta)\cos\beta \quad = \quad 1{,}994 \text{ lbs/ft}$$

$$b = -\begin{bmatrix} (W_A - N_A \cos\beta)\sin\beta\tan\phi \\ +(N_A \tan\delta + C_a)\sin\beta\cos\beta \\ +\sin\beta(C + W_P \tan\phi) \end{bmatrix} \quad = \quad (4{,}639) \text{ lbs/ft}$$

$$c = (N_A \tan\delta + C_a)\sin^2\beta\tan\phi \quad = \quad 607 \text{ lbs/ft}$$

| Allow Exceeds Req'd - OK | | |
|---|---|---|
| $FS_R$ = | 1.25 | |
| $FS_A$ = | 2.19 | |
| Min. Peak d | 27.8 | deg |
| Min. Peak $c_a$ | 0.0 | psf |

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|---|---|---|---|---|---|
| | | SHT NO | 8 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Determine: Static factor of safety for cover system based on additional seismic loads.

Procedure:

Determine the static stability of the veneer cover system to determine critical factor of safety for all engineered components of the cover system. Balance the forces as shown in Figure 1 and compare to the required factor of safety (FS). Account for seismic loads ($C_S$) as noted in Figure 6.

Assumptions:

In addition to the static case assumptions:
1. Seismic force acts on the centroid of the cover soil.
2. Seismic force is horizontal.
3. Deformation analysis not required.

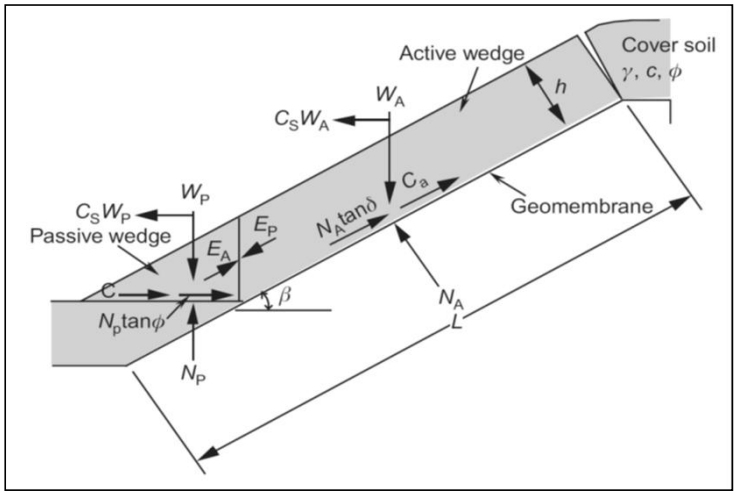


Figure 6. Limit equilibrium forces involved in pseudo-static analysis using average seismic coefficient.

| Veg. Cover Soil (VC)/Prot. Cover Soil (CS) and Slope Parameters | VC | CS | Utilized | | Source |
|---|---|---|---|---|---|
| Thickness (h) | 0.5 | 1.5 | 2.0 | ft | Design |
| Dry Unit Weight ($g_D$) | 90.0 | 100.0 | 97.5 | pcf | Conservatively assumed based on lab tests |
| Mois. Cont. (field cond.) ($w_F$) | 26.0 | 24.0 | 24.5 | % | Conservatively assumed based on lab tests |
| Avg Field Unit Wt (g) | - | - | 121.4 | pcf | |
| Min. Friction Angle (f ) | 30.0 | 30.0 | 30.0 | deg | Assumed (conservative for sandy cover) |
| Min. Cohesion (c) | 0.0 | 0.0 | 0.0 | psf | Assumed (conservative for sandy cover) |
| Slope Angle Beneath the Geom. (b) | - | - | 14.0 | degrees | Design |
| Ht. of Slp. Meas. Along Geom. ($H_L$) | - | - | 22.06 | ft | Design |
| Lng. of Slp. Meas. Along Geom. (L) | - | - | 91.00 | ft | |
| Inter. Frict. Angle for Prot. Soil & GDM (d) | - | - | 27.8 | deg | Min. req. shear strength parameters from static analysis |
| Adhesion for Prot. Soil & GDM ($c_a$) | - | - | 0.0 | psf | |
| Seismic Coefficient ($C_S$ or $K_S$) | - | - | 0.040 | %g | PGA for 2% Exceedance in 50 Years |
| Required Factor of Safety ($FS_R$) | - | - | 1.00 | | Min. req. FS for seismic conditions |

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|---|---|---|---|---|---|
| | | SHT NO | 9 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Active Wedge Calculations

Determine the total weight of the active wedge ($W_A$),the effective force normal to the failure plan of the active wedge ($N_A$), the adhesive force between the cover soil of the active wedge and the geomembrane ($C_a$), and the interwedge force acting on the active wedge from the passive wedge ($E_A$) using the following eqs:

$$W_A = \gamma h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right)$$ = 20,028 lbs

$$N_A = W_A \cos\beta$$ = 19,430 lbs

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right)$$ = - lbs

$$E_A = \frac{(FS)(C_S W_A + N_A \sin\beta)}{(FS)\cos\beta} + \frac{(N_A \tan\delta + C_a)\cos\beta}{(FS)\cos\beta} =$$ 15,926 lbs

Passive Wedge Calculations

Determine the total weight of the passive wedge ($W_P$),the effective force normal to the failure plan of the passive wedge ($N_P$), the cohesive force along the failure plane (C), and the interwedge force acting on the passive wedge from the active wedge ($E_P$) using the following eqs:

$$W_P = \frac{\gamma h^2}{\sin 2\beta}$$ = 1,032 lbs

$$C = \frac{ch}{\sin\beta}$$ = - lbs

$$E_P = \frac{C + W_P \tan\phi - C_S W_P (FS)}{\cos\beta(FS) - \sin\beta\tan\phi}$$ = 668 lbs

$$N_P = W_P + E_P \sin\beta$$ = 1,194 lbs

## Seismic Factor of Safety

Determine the calculated Factor of Safety ($FS_A$) using a quadratic equation relationship where the constants are defined as follows:

$$a = (C_S W_A + N_A \sin\beta)\cos\beta + C_S W_P \cos\beta$$ = 5,411 lbs/ft

$$b = -\begin{bmatrix} (C_S W_A + N_A \sin\beta)\sin\beta\tan\phi \\ + (N_A \tan\delta + C_a)\cos^2\beta \\ + (C + W_P \tan\phi)\cos\beta \end{bmatrix}$$ = (10,992) lbs/ft

$$c = (N_A \tan\delta + C_a)\cos\beta\sin\beta\tan\phi$$ = 1391 lbs/ft

| Allow Exceeds Req'd - OK | | |
|---|---|---|
| $FS_R$ = | 1.00 | |
| $FS_A$ = | 1.90 | |
| Min. Peak d | 27.8 | deg |
| Min. Peak $c_a$ | 0.0 | psf |

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|---|---|---|---|---|---|
| | | SHT NO | 1 | OF | 9 |
| | | CALC BY | JAD | DATE | 03/29/16 |
| | | CHK BY | NSG | DATE | 03/30/16 |
| | | SCALE | NA | | |

Objective:

Determine the veneer stability of the cover system at the Salzburg Landfill - Cells 20 - 22. Each interface was analyzed using residual strength parameters to reflect large displacement conditions.

Method:

Use methods outlined in the paper by Koerner and Soong, *Analysis and Design of Veneer Cover Soils* published in Geosynthetics International, 2005, 12, No.1.

Procedure:

Determine the static stability of the veneer cover system to evaluate the minimum factor of safety for the cover system. Balance the forces as shown in Figure 1 and compare to the required factor of safety (FS).

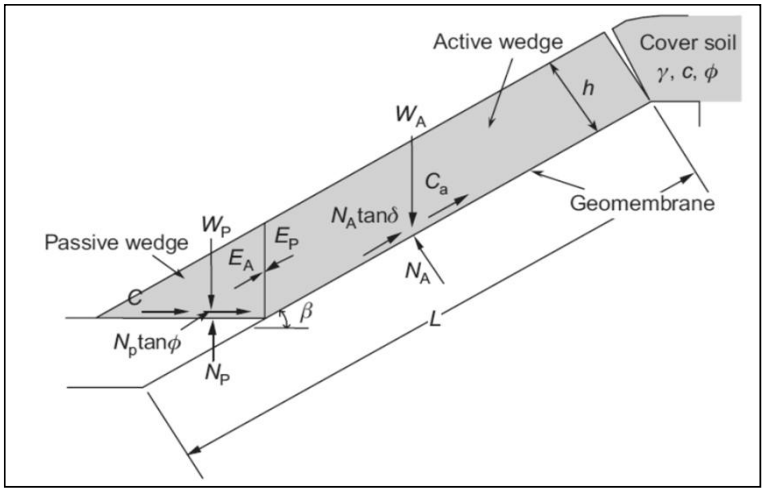


Figure 1. Limit equilibrium forces involved in a finite length slope analysis for a uniformly thick cover soil

Determine: Static factor of safety for cover system based on gravitational forces only and peak strength.

Assumptions:

1. No geosynthetic reinforcements
2. No interface adhesion for geosynthetic components.
3. No tension allowed in geosynthetics
4. Minimum cohesion for multilayered systems

Veg. Cover Soil (VC)/Prot. Cover Soil (CS) and Slope Parameters

| | VC | CS | Utilized | | Source |
|---|---|---|---|---|---|
| Thickness (h) | 0.5 | 1.5 | 2.0 | ft | Design |
| Dry Unit Weight ($g_D$) | 90.0 | 100.0 | 97.5 | pcf | Conservatively assumed based on lab tests |
| Mois. Cont. (field cond.) ($w_F$) | 26.0 | 24.0 | 24.5 | % | Conservatively assumed based on lab tests |
| Avg Field Unit Wt (g) | - | - | 121.4 | pcf | |
| Reference Stress | - | - | 235.5 | pcf | |
| Min. Friction Angle (f ) | 30.0 | 30.0 | 30.0 | deg | Assumed (conservative for sandy cover) |
| Min. Cohesion (c) | 0.0 | 0.0 | 0.0 | psf | Assumed (conservative for sandy cover) |
| Slope Angle Beneath the Geom. (b) | - | - | 14.03 | deg | Design |
| Ht. of Slp. Meas. Along Geom. ($H_L$) | - | - | 22.06 | ft | Design |
| Lng. of Slp. Meas. Along Geom. (L) | - | - | 91.00 | ft | |
| Inter. Frict. Angle for GDM & GMB (d) | - | - | 20.3 | deg | Resid. shear strength parameters from interface shear testing |
| Adhesion for GDM & GMB ($c_a$) | - | - | 31.0 | psf | |
| Required Factor of Safety ($FS_R$) | - | - | 1.50 | | Min. req. FS for long term conditions |

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|---|---|---|---|---|---|
| | | SHT NO | 2 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Active Wedge Calculations

Determine the total weight of the active wedge ($W_A$),the effective force normal to the failure plan of the active wedge ($N_A$), the adhesive force between the cover soil of the active wedge and the geomembrane ($C_a$), and the interwedge force acting on the active wedge from the passive wedge ($E_A$) using the following eqs:

$$W_A = \gamma h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right)$$ = 20,028 lbs

$$N_A = W_A \cos\beta$$ = 19,430 lbs

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right)$$ = 2,565 lbs

$$E_A = \frac{(FS)(W_A - N_A\cos\beta) - (N_A\tan\delta + C_a)\sin\beta}{\sin\beta(FS)}$$ = (1,646) lbs

Passive Wedge Calculations

Determine the total weight of the passive wedge ($W_P$),the effective force normal to the failure plan of the passive wedge ($N_P$), the cohesive force along the failure plane (C), and the interwedge force acting on the passive wedge from the active wedge ($E_P$) using the following eqs:

$$W_P = \frac{\gamma h^2}{\sin 2\beta}$$ = 1,032 lbs

$$C = \frac{ch}{\sin\beta}$$ = - lbs

$$E_P = \frac{C + W_P\tan\phi}{\cos\beta(FS) - \sin\beta\tan\phi}$$ = 453 lbs

$$N_P = W_P + E_P\sin\beta$$ = 1,142 lbs

## Static Factor of Safety

Determine the calculated Factor of Safety ($FS_A$) using a quadratic equation relationship where the constants are defined as follows:

$$a = (W_A - N_A\cos\beta)\cos\beta$$ = 1,142 lbs/ft

$$b = -\begin{bmatrix}(W_A - N_A\cos\beta)\sin\beta\tan\phi \\ +(N_A\tan\delta + C_a)\sin\beta\cos\beta \\ +\sin\beta(C + W_P\tan\phi)\end{bmatrix}$$ = (2,603) lbs/ft

$$c = (N_A\tan\delta + C_a)\sin^2\beta\tan\phi$$ = 331 lbs/ft

Allow Exceeds Req'd - OK

$FS_R$ = 1.50

$FS_A$ = 2.14

Min. Resid. d 20.3 deg

Min. Resid. $c_a$ 31.0 pst

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|---|---|---|---|---|---|
| | | SHT NO | 3 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Determine: Static factor of safety for cover system based on additional seepage forces.
Procedure:

Determine the static stability of the veneer cover system to determine the minimum required interface friction angle for all engineered components of the cover system. Balance the forces as shown in Figure 1 and the required factor of safety (FS) then solve for minimum interface shear strength parameters. Account for seepage forces in drainage layer as noted in Figure 2.

Assumptions:

In addition to the static case assumptions:
1. Seepage is parallel to slope
2. The drainage layer is sized such that liquid not build up beyond the thickness of the drainage layer.
3. Drainage layer has adequate capacity to handle maximum surface water flow
4. If geocomposite is used - it is less than 0.75 inches thick.
5. Max accumulation of up to 1 foot head on top of FML barrier to account for drainage aggregate in lieu of geocomposite.
6. No seepage forces outside drainage layer.

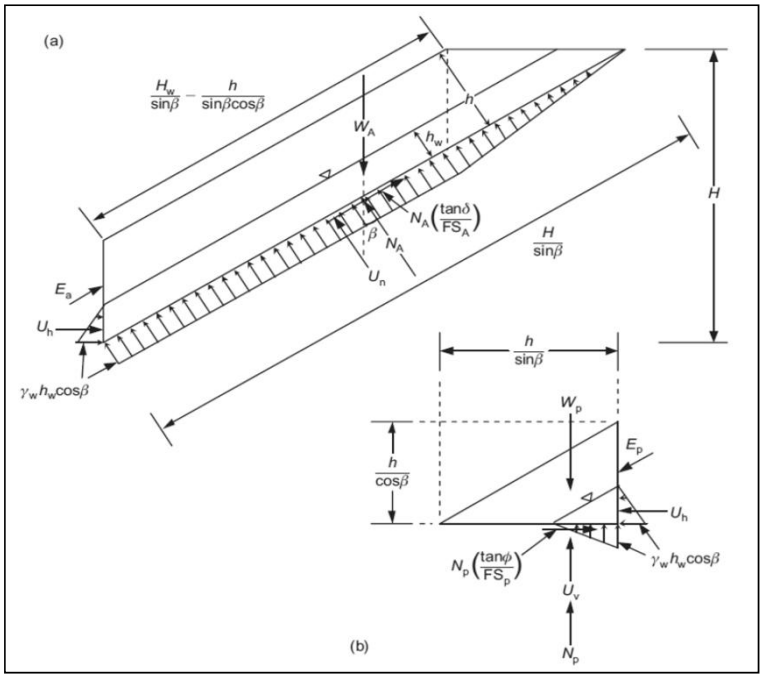


Figure 2. Limit equilibrium forces involved in finite-length slope of uniform cover soil with parallel-to-slope seepage build-up: (a) active wedge; (b) passive wedge

| Veg. Cover Soil (VC)/Prot. Cover Soil (CS) and Slope Parameters | VC | CS | Utilized | | Source |
|---|---|---|---|---|---|
| Thickness (h) | 0.5 | 1.5 | 2.0 | ft | Design |
| Dry Unit Weight ($g_D$) | 90.0 | 100.0 | 97.5 | pcf | Conservatively assumed based on lab tests |
| Mois. Cont. (field cond.) ($w_F$) | 26.0 | 24.0 | 24.5 | % | Conservatively assumed based on lab tests |
| Avg Field Unit Wt (g) | - | - | 121.4 | pcf | |
| Specific Gravity of the ($G_S$) | 2.72 | 2.72 | 2.72 | | Assumed conservative |
| Unit Weight of Water ($g_W$) | - | - | 62.4 | pcf | |
| Saturated Unit Weight ($g_{SAT}$) | - | - | 124.1 | pcf | |
| Min. Friction Angle (f ) | 30.0 | 30.0 | 30.0 | deg | Assumed (conservative for sandy cover) |
| Min. Cohesion (c) | 0.0 | 0.0 | 0.0 | psf | Assumed (conservative for sandy cover) |
| Slope Angle Beneath the Geom. (b) | - | - | 14.0 | degrees | Design |
| Ht. of Slp. Meas. Along Geom. ($H_L$) | - | - | 22.06 | ft | Design |
| Lng. of Slp. Meas. Along Geom. (L) | - | - | 91.0 | ft | |
| Depth of Water in DL ($h_W$) | - | - | 0.07 | ft | Max. thickness of DL (conservative) |
| Inter. Frict. Angle for GDM & GMB (d) | - | - | 20.3 | deg | Resid. shear strength parameters from interface shear testing |
| Adhesion for GDM & GMB ($c_a$) | - | - | 31.0 | psf | |
| Required Factor of Safety ($FS_R$) | - | - | 1.10 | | Min. req. FS for temporary conditions |

Active Wedge Calculations

Determine the total weight of the active wedge ($W_A$), resultant of the pore pressures acting on the interwedge surfaces ($U_h$), resultant of the pore pressures acting perpendicular to the slope ($U_n$), the effective force normal to the failure plan of the active wedge ($N_A$), and the interwedge force acting on the active wedge from the passive wedge ($E_A$) using the following eqs:

$$W_A = \frac{\gamma_D (h - h_W)[2H\cos\beta - (h + h_W)]}{\sin 2\beta} + \frac{\gamma_{SAT}(h_W)(2H\cos\beta - h_W)}{\sin 2\beta} = 17{,}084 \text{ lbs}$$

$$U_h = \frac{\gamma_w h_W^2}{2} = 0.15 \text{ lbs}$$

$$U_n = \frac{\gamma_w (h_w)(\cos\beta)(2H\cos\beta - h_w)}{\sin 2\beta} = 385 \text{ lbs}$$

$$N_A = W_A \cos\beta + U_h \sin\beta - U_n = 16{,}189 \text{ lbs}$$

$$E_A = W_A \sin\beta - U_h \cos\beta - \frac{N_A \sin\delta}{(FS)} = (965) \text{ lbs}$$

Passive Wedge Calculations

Determine the total weight of the passive wedge ($W_P$), resultant of the vertical pore pressures acting on the passive wedge ($U_V$), and the interwedge force acting on the pass wedge from the active wedge ($E_P$) using the following eqs:

$$W_P = \frac{\gamma_D (h^2 - h_w^2) + \gamma_{SAT} h_w^2}{\sin 2\beta} = 829.4 \text{ lbs}$$

$$U_V = U_h \cot\beta = 0.6 \text{ lbs}$$

$$E_P = \frac{U_h (FS) - (W_P - U_V \tan\phi)}{\sin\beta \tan\phi - \cos\beta (FS)} = 894 \text{ lbs}$$

## Static Factor of Safety w/ Seepage Forces

Determine the calculated Factor of Safety ($FS_A$) using a quadratic equation relationship where the constants are defined as follows:

$$a = W_A \sin\beta \cos\beta - U_h \cos^2\beta + U_h = 4{,}018 \text{ lbs/ft}$$

$$b = -W_A \sin^2\beta \tan\phi + U_h \sin\beta \cos\beta \tan\phi - N_A \cos\beta \tan\delta - (W_P - U_V)\tan\phi = (6{,}868.1) \text{ lbs/ft}$$

$$c = N_A \sin\beta \tan\delta \tan\phi = 838 \text{ lbs/ft}$$

| Allow Exceeds Req'd - OK | | |
|---|---|---|
| $FS_R$ = | 1.10 | |
| $FS_A$ = | 1.58 | |
| Min. Peak $\phi$ | 20.3 | deg |
| Min. Peak $c_a$ | 31.0 | psf |

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|---|---|---|---|---|---|
| | | SHT NO | 5 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Determine: Static factor of safety for cover system based on additional equipment loads.

Procedure:

Determine the static stability of the veneer cover system to determine the minimum required interface friction angle for all engineered components of the cover system. Balance the forces as shown in Figure 1 and the required factor of safety (FS) then solve for minimum interface shear strength parameters. Account for equipment loads ($W_b$) as final cover is placed as noted in Figure 3.

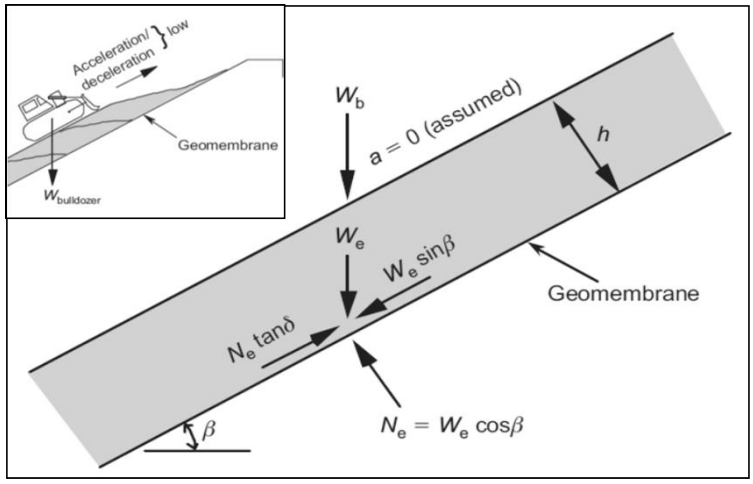


Figure 3. Additional load due to construction equipment moving on cover soil.

Assumptions:

In addition to the static case assumptions:
1. The equipment pushes material up slope leaving a toe buttress behind.
2. The equipment accelerates slowly with no sudden starts or turns to minimize additional loads besides the weight of the machine.

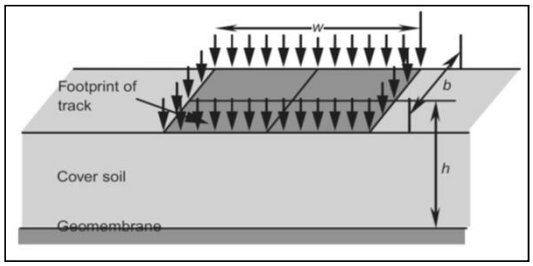


Figure 4. Illustration of stress distribution from overlying equipment.

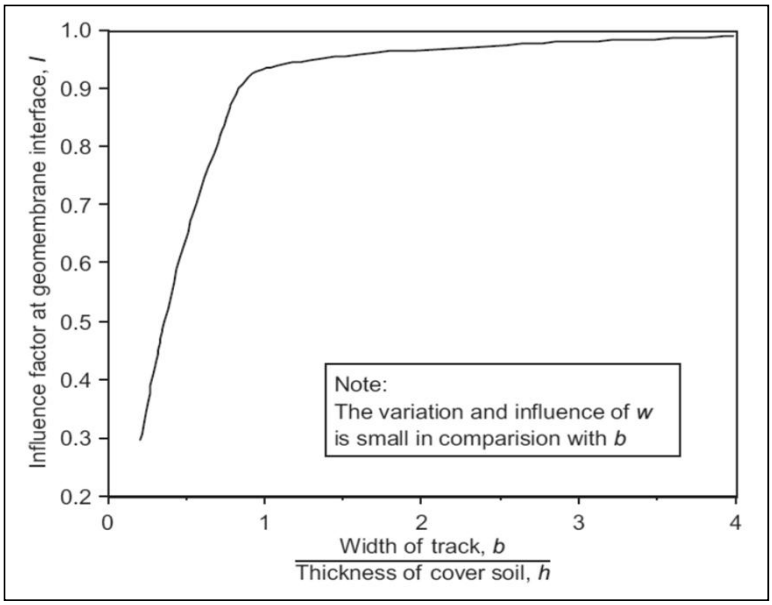


Figure 5. Values of influence factor I to dissipate surface force through cover soil to geomembrane interface (after Poulos and Davis 1974)

Equipment Parameters

| | | | Source |
|---|---|---|---|
| Equiv. Equipment Load per Unit Width ($W_e$) | 14939 | lbs | $W_e = qwl$ |
| Influence Factor at the Geom. Interface (I) | 0.95 | | See Figure 5 above. |
| Track Width to Cover Soil Thickness Ratio (b/h) | 1.40 | | |
| Distributed Equipment Load (q) | 1492 | psf | $q = W_b/(2 \times w \times b)$ |
| Weight of Equipment ($W_b$) | 87,733 | lbs | Typical weight of CAT D8 dozer |
| Length of Equipment Track (w) | 10.50 | ft | Typical track dimensions of CAT D8 dozer |
| Width of Equipment Track (b) | 2.80 | ft | |

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|---|---|---|---|---|---|
| | | SHT NO | 6 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Veg. Cover Soil (VC)/Prot. Cover Soil (CS) and Slope Parameters

| | VC | CS | Utilized | | Source |
|---|---|---|---|---|---|
| Thickness (h) | 0.5 | 1.5 | 2.0 | ft | Design |
| Dry Unit Weight ($g_D$) | 90.0 | 100.0 | 97.5 | pcf | Conservatively assumed based on lab tests |
| Mois. Cont. (field cond.) ($w_F$) | 26.0 | 24.0 | 24.5 | % | Conservatively assumed based on lab tests |
| Avg Field Unit Wt (g) | - | - | 121.4 | pcf | |
| Min. Friction Angle (f ) | 30.0 | 30.0 | 30.0 | deg | Assumed (conservative for sandy cover) |
| Min. Cohesion (c) | 0.0 | 0.0 | 0.0 | psf | Assumed (conservative for sandy cover) |
| Slope Angle Beneath the Geom. (b) | - | - | 14.0 | deg | Design |
| Ht. of Slp. Meas. Along Geom. ($H_L$) | - | - | 22.06 | ft | Design |
| Lng. of Slp. Meas. Along Geom. (L) | - | - | 91.00 | ft | |
| Inter. Frict. Angle for GDM & GMB (d) | - | - | 20.3 | deg | Resid. shear strength parameters from interface shear testing |
| Adhesion for GDM & GMB ($c_a$) | - | - | 31.0 | psf | |
| Required Factor of Safety ($FS_R$) | - | - | 1.25 | | Min. req. FS for temporary conditions |

Active Wedge Calculations

Determine the total weight of the active wedge ($W_A$),the effective force normal to the failure plan of the active wedge ($N_A$), the adhesive force between the cover soil of the active wedge and the geomembrane ($C_a$), and the interwedge force acting on the active wedge from the passive wedge ($E_A$) using the following eqs:

$$W_A = \gamma h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right) + W_e$$ = 34,967 lbs

$$N_A = W_A \cos\beta$$ = 33,924 lbs

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right)$$ = 2,565 lbs

$$E_A = \frac{(FS)(W_A - N_A\cos\beta) - (N_A\tan\delta + C_a)\sin\beta}{\sin\beta(FS)}$$ = (3,614) lbs

Passive Wedge Calculations

Determine the total weight of the passive wedge ($W_P$),the effective force normal to the failure plan of the passive wedge ($N_P$), the cohesive force along the failure plane (C), and the interwedge force acting on the passive wedge from the active wedge ($E_P$) using the following eqs:

$$W_P = \frac{\gamma h^2}{\sin 2\beta}$$ = 1,032 lbs

$$C = \frac{ch}{\sin\beta}$$ = - lbs

$$E_P = \frac{C + W_P\tan\phi}{\cos\beta(FS) - \sin\beta\tan\phi}$$ = 556 lbs

$$N_P = W_P + E_P\sin\beta$$ = 1,167 lbs

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|---|---|---|---|---|---|
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| | | SCALE | NA | | |

## Static Factor of Safety w/ Equipment Load

Determine the calculated Factor of Safety ($FS_A$) using a quadratic equation relationship where the constants are defined as follows:

$$a = (W_A - N_A \cos\beta)\cos\beta$$ = 1,994 lbs/ft

$$b = -\begin{bmatrix} (W_A - N_A \cos\beta)\sin\beta\tan\phi \\ +(N_A \tan\delta + C_a)\sin\beta\cos\beta \\ +\sin\beta(C + W_P \tan\phi) \end{bmatrix}$$ = (3,987) lbs/ft

$$c = (N_A \tan\delta + C_a)\sin^2\beta\tan\phi$$ = 513 lbs/ft

| Allow Exceeds Req'd - OK | | |
|---|---|---|
| $FS_R$ = | 1.25 | |
| $FS_A$ = | 1.86 | |
| Min. Peak $\phi$ | 20.3 | deg |
| Min. Peak $c_a$ | 31.0 | psf |

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|---|---|---|---|---|---|
| | | SHT NO | 8 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Determine: Static factor of safety for cover system based on additional seismic loads.

Procedure:

Determine the static stability of the veneer cover system to determine critical factor of safety for all engineered components of the cover system. Balance the forces as shown in Figure 1 and compare to the required factor of safety (FS). Account for seismic loads ($C_S$) as noted in Figure 6.

Assumptions:

In addition to the static case assumptions:
1. Seismic force acts on the centroid of the cover soil.
2. Seismic force is horizontal.
3. Deformation analysis not required.

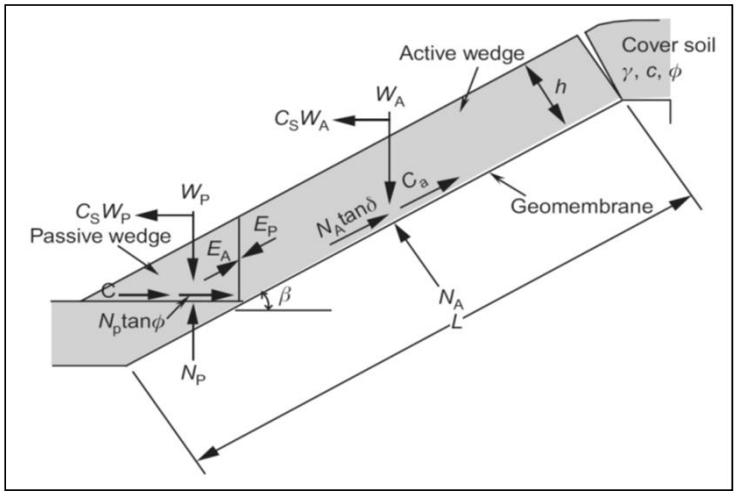


Figure 6. Limit equilibrium forces involved in pseudo-static analysis using average seismic coefficient.

| Veg. Cover Soil (VC)/Prot. Cover Soil (CS) and Slope Parameters | VC | CS | Utilized | | Source |
|---|---|---|---|---|---|
| Thickness (h) | 0.5 | 1.5 | 2.0 | ft | Design |
| Dry Unit Weight ($g_D$) | 90.0 | 100.0 | 97.5 | pcf | Conservatively assumed based on lab tests |
| Mois. Cont. (field cond.) ($w_F$) | 26.0 | 24.0 | 24.5 | % | Conservatively assumed based on lab tests |
| Avg Field Unit Wt (g) | - | - | 121.4 | pcf | |
| Min. Friction Angle (f ) | 30.0 | 30.0 | 30.0 | deg | Assumed (conservative for sandy cover) |
| Min. Cohesion (c) | 0.0 | 0.0 | 0.0 | psf | Assumed (conservative for sandy cover) |
| Slope Angle Beneath the Geom. (b) | - | - | 14.0 | degrees | Design |
| Ht. of Slp. Meas. Along Geom. ($H_L$) | - | - | 22.06 | ft | Design |
| Lng. of Slp. Meas. Along Geom. (L) | - | - | 91.00 | ft | |
| Inter. Frict. Angle for GDM & GMB (d) | - | - | 20.3 | deg | Min. req. shear strength parameters from static analysis |
| Adhesion for GDM & GMB ($c_a$) | - | - | 31.0 | psf | |
| Seismic Coefficient ($C_S$ or $K_S$) | - | - | 0.040 | %g | PGA for 2% Exceedance in 50 Years |
| Required Factor of Safety ($FS_R$) | - | - | 1.00 | | Min. req. FS for seismic conditions |

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|---|---|---|---|---|---|
| | | SHT NO | 9 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Active Wedge Calculations

Determine the total weight of the active wedge ($W_A$),the effective force normal to the failure plan of the active wedge ($N_A$), the adhesive force between the cover soil of the active wedge and the geomembrane ($C_a$), and the interwedge force acting on the active wedge from the passive wedge ($E_A$) using the following eqs:

$$W_A = \gamma h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right)$$ = 20,028 lbs

$$N_A = W_A \cos\beta$$ = 19,430 lbs

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right)$$ = 2,565 lbs

$$E_A = \frac{(FS)(C_S W_A + N_A \sin\beta)}{(FS)\cos\beta} + \frac{(N_A \tan\delta + C_a)\cos\beta}{(FS)\cos\beta} =$$ 15,434 lbs

Passive Wedge Calculations

Determine the total weight of the passive wedge ($W_P$),the effective force normal to the failure plan of the passive wedge ($N_P$), the cohesive force along the failure plane (C), and the interwedge force acting on the passive wedge from the active wedge ($E_P$) using the following eqs:

$$W_P = \frac{\gamma h^2}{\sin 2\beta}$$ = 1,032 lbs

$$C = \frac{ch}{\sin\beta}$$ = - lbs

$$E_P = \frac{C + W_P \tan\phi - C_S W_P (FS)}{\cos\beta(FS) - \sin\beta\tan\phi}$$ = 668 lbs

$$N_P = W_P + E_P \sin\beta$$ = 1,194 lbs

## Seismic Factor of Safety

Determine the calculated Factor of Safety ($FS_A$) using a quadratic equation relationship where the constants are defined as follows:

$$a = (C_S W_A + N_A \sin\beta)\cos\beta + C_S W_P \cos\beta$$ = 5,411 lbs/ft

$$b = -\begin{bmatrix} (C_S W_A + N_A \sin\beta)\sin\beta\tan\phi \\ + (N_A \tan\delta + C_a)\cos^2\beta \\ + (C + W_P \tan\phi)\cos\beta \end{bmatrix}$$ = (10,529) lbs/ft

$$c = (N_A \tan\delta + C_a)\cos\beta\sin\beta\tan\phi$$ = 1324 lbs/ft

| Allow Exceeds Req'd - OK | | |
|---|---|---|
| $FS_R$ = | 1.00 | |
| $FS_A$ = | 1.81 | |
| Min. Peak d | 20.3 | deg |
| Min. Peak $c_a$ | 31.0 | psf |

| AECOM<br>564 White Pond Drive<br>Akron, OH 44320<br>Tel. (330) 836-9111 | DOW Chemical<br><br>COVER VENEER STABILITY<br>Salzburg Landfill Cells 20-22 | JOB | 60440134 | | |
|---|---|---|---|---|---|
| | | SHT NO | 1 | OF | 9 |
| | | CALC BY | JAD | DATE | 03/29/16 |
| | | CHK BY | NSG | DATE | 03/30/16 |
| | | SCALE | NA | | |

Objective:

Determine the veneer stability of the cover system at the Salzburg Landfill - Cells 20 - 22. Each interface was analyzed using residual strength parameters to reflect large displacement conditions.

Method:

Use methods outlined in the paper by Koerner and Soong, *Analysis and Design of Veneer Cover Soils* published in Geosynthetics International, 2005, 12, No.1.

Procedure:

Determine the static stability of the veneer cover system to evaluate the minimum factor of safety for the cover system. Balance the forces as shown in Figure 1 and compare to the required factor of safety (FS).

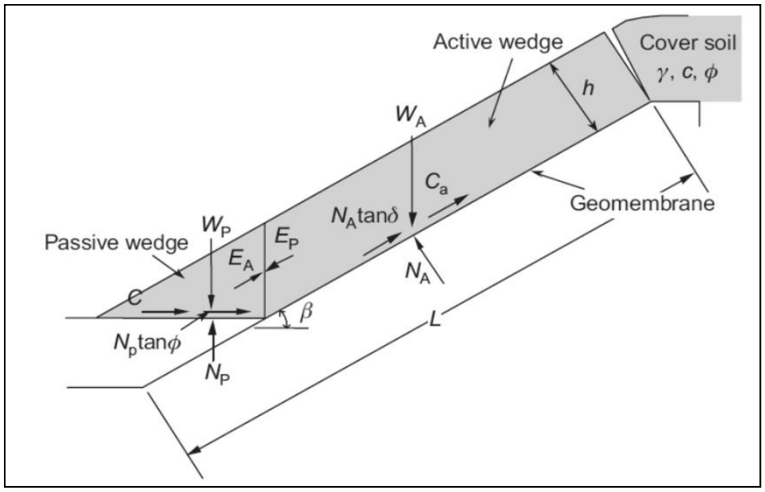


Figure 1. Limit equilibrium forces involved in a finite length slope analysis for a uniformly thick cover soil

Determine: Static factor of safety for cover system based on gravitational forces only and peak strength.

Assumptions:

1. No geosynthetic reinforcements
2. No interface adhesion for geosynthetic components.
3. No tension allowed in geosynthetics
4. Minimum cohesion for multilayered systems

Veg. Cover Soil (VC)/Prot. Cover Soil (CS) and Slope Parameters

| | VC | CS | Utilized | | Source |
|---|---|---|---|---|---|
| Thickness (h) | 0.5 | 1.5 | 2.0 | ft | Design |
| Dry Unit Weight ($g_D$) | 90.0 | 100.0 | 97.5 | pcf | Conservatively assumed based on lab tests |
| Mois. Cont. (field cond.) ($w_F$) | 26.0 | 24.0 | 24.5 | % | Conservatively assumed based on lab tests |
| Avg Field Unit Wt (g) | - | - | 121.4 | pcf | |
| Reference Stress | - | - | 235.5 | pcf | |
| Min. Friction Angle (f ) | 30.0 | 30.0 | 30.0 | deg | Assumed (conservative for sandy cover) |
| Min. Cohesion (c) | 0.0 | 0.0 | 0.0 | psf | Assumed (conservative for sandy cover) |
| Slope Angle Beneath the Geom. (b) | - | - | 14.03 | deg | Design |
| Ht. of Slp. Meas. Along Geom. ($H_L$) | - | - | 22.06 | ft | Design |
| Lng. of Slp. Meas. Along Geom. (L) | - | - | 91.00 | ft | |
| Inter. Frict. Angle for GMB & GCL (d) | - | - | 23.0 | deg | Resid. shear strength parameters from interface shear testing |
| Adhesion for GMB & GCL ($c_a$) | - | - | 28.0 | psf | |
| Required Factor of Safety ($FS_R$) | - | - | 1.50 | | Min. req. FS for long term conditions |

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|---|---|---|---|---|---|
| | | SHT NO | 2 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Active Wedge Calculations

Determine the total weight of the active wedge ($W_A$),the effective force normal to the failure plan of the active wedge ($N_A$), the adhesive force between the cover soil of the active wedge and the geomembrane ($C_a$), and the interwedge force acting on the active wedge from the passive wedge ($E_A$) using the following eqs:

$$W_A = \gamma h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right)$$ = 20,028 lbs

$$N_A = W_A \cos\beta$$ = 19,430 lbs

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right)$$ = 2,317 lbs

$$E_A = \frac{(FS)(W_A - N_A\cos\beta) - (N_A\tan\delta + C_a)\sin\beta}{\sin\beta(FS)}$$ = (2,188) lbs

Passive Wedge Calculations

Determine the total weight of the passive wedge ($W_P$),the effective force normal to the failure plan of the passive wedge ($N_P$), the cohesive force along the failure plane (C), and the interwedge force acting on the passive wedge from the active wedge ($E_P$) using the following eqs:

$$W_P = \frac{\gamma h^2}{\sin 2\beta}$$ = 1,032 lbs

$$C = \frac{ch}{\sin\beta}$$ = - lbs

$$E_P = \frac{C + W_P\tan\phi}{\cos\beta(FS) - \sin\beta\tan\phi}$$ = 453 lbs

$$N_P = W_P + E_P\sin\beta$$ = 1,142 lbs

## Static Factor of Safety

Determine the calculated Factor of Safety ($FS_A$) using a quadratic equation relationship where the constants are defined as follows:

$$a = (W_A - N_A\cos\beta)\cos\beta$$ = 1,142 lbs/ft

$$b = -\begin{bmatrix}(W_A - N_A\cos\beta)\sin\beta\tan\phi \\ +(N_A\tan\delta + C_a)\sin\beta\cos\beta \\ +\sin\beta(C + W_P\tan\phi)\end{bmatrix}$$ = (2,794) lbs/ft

$$c = (N_A\tan\delta + C_a)\sin^2\beta\tan\phi$$ = 358 lbs/ft

Allow Exceeds Req'd - OK

$FS_R$ = 1.50

$FS_A$ = 2.31

Min. Resid. d 23.0 deg

Min. Resid. $c_a$ 28.0 pst

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|---|---|---|---|---|---|
| | | SHT NO | 3 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Determine: Static factor of safety for cover system based on additional seepage forces.
Procedure:

Determine the static stability of the veneer cover system to determine the minimum required interface friction angle for all engineered components of the cover system. Balance the forces as shown in Figure 1 and the required factor of safety (FS) then solve for minimum interface shear strength parameters. Account for seepage forces in drainage layer as noted in Figure 2.

Assumptions:

In addition to the static case assumptions:
1. Seepage is parallel to slope
2. The drainage layer is sized such that liquid not build up beyond the thickness of the drainage layer.
3. Drainage layer has adequate capacity to handle maximum surface water flow
4. If geocomposite is used - it is less than 0.75 inches thick.
5. Max accumulation of up to 1 foot head on top of FML barrier to account for drainage aggregate in lieu of geocomposite.
6. No seepage forces outside drainage layer.

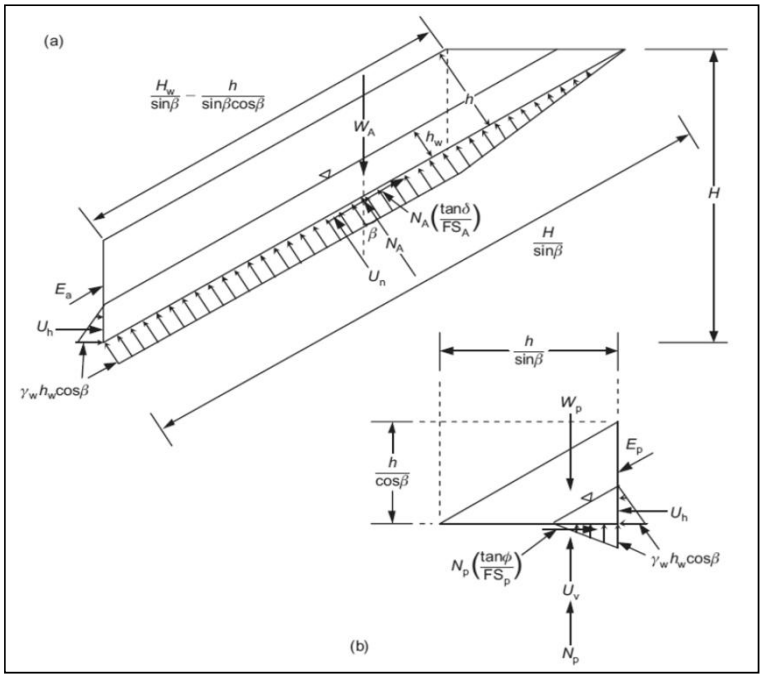


Figure 2. Limit equilibrium forces involved in finite-length slope of uniform cover soil with parallel-to-slope seepage build-up: (a) active wedge; (b) passive wedge

| Veg. Cover Soil (VC)/Prot. Cover Soil (CS) and Slope Parameters | VC | CS | Utilized | | Source |
|---|---|---|---|---|---|
| Thickness (h) | 0.5 | 1.5 | 2.0 | ft | Design |
| Dry Unit Weight ($g_D$) | 90.0 | 100.0 | 97.5 | pcf | Conservatively assumed based on lab tests |
| Mois. Cont. (field cond.) ($w_F$) | 26.0 | 24.0 | 24.5 | % | Conservatively assumed based on lab tests |
| Avg Field Unit Wt (g) | - | - | 121.4 | pcf | |
| Specific Gravity of the ($G_S$) | 2.72 | 2.72 | 2.72 | | Assumed conservative |
| Unit Weight of Water ($g_W$) | - | - | 62.4 | pcf | |
| Saturated Unit Weight ($g_{SAT}$) | - | - | 124.1 | pcf | |
| Min. Friction Angle (f ) | 30.0 | 30.0 | 30.0 | deg | Assumed (conservative for sandy cover) |
| Min. Cohesion (c) | 0.0 | 0.0 | 0.0 | psf | Assumed (conservative for sandy cover) |
| Slope Angle Beneath the Geom. (b) | - | - | 14.0 | degrees | Design |
| Ht. of Slp. Meas. Along Geom. ($H_L$) | - | - | 22.06 | ft | Design |
| Lng. of Slp. Meas. Along Geom. (L) | - | - | 91.0 | ft | |
| Depth of Water in DL ($h_W$) | - | - | 0.07 | ft | Max. thickness of DL (conservative) |
| Inter. Frict. Angle for GMB & GCL (d) | - | - | 23.0 | deg | Resid. shear strength parameters from interface shear testing |
| Adhesion for GMB & GCL ($c_a$) | - | - | 28.0 | psf | |
| Required Factor of Safety ($FS_R$) | - | - | 1.10 | | Min. req. FS for temporary conditions |

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|---|---|---|---|---|---|
| | | SHT NO | 4 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Active Wedge Calculations

Determine the total weight of the active wedge ($W_A$), resultant of the pore pressures acting on the interwedge surfaces ($U_h$), resultant of the pore pressures acting perpendicular to the slope ($U_n$), the effective force normal to the failure plan of the active wedge ($N_A$), and the interwedge force acting on the active wedge from the passive wedge ($E_A$) using the following eqs:

$$W_A = \frac{\gamma_D (h - h_W)[2H\cos\beta - (h + h_W)]}{\sin 2\beta} + \frac{\gamma_{SAT}(h_W)(2H\cos\beta - h_W)}{\sin 2\beta} = 17{,}084 \text{ lbs}$$

$$U_h = \frac{\gamma_w h_W^2}{2} = 0.15 \text{ lbs}$$

$$U_n = \frac{\gamma_w (h_w)(\cos\beta)(2H\cos\beta - h_w)}{\sin 2\beta} = 385 \text{ lbs}$$

$$N_A = W_A \cos\beta + U_h \sin\beta - U_n = 16{,}189 \text{ lbs}$$

$$E_A = W_A \sin\beta - U_h \cos\beta - \frac{N_A \sin\delta}{(FS)} = (1{,}609) \text{ lbs}$$

Passive Wedge Calculations

Determine the total weight of the passive wedge ($W_P$), resultant of the vertical pore pressures acting on the passive wedge ($U_V$), and the interwedge force acting on the pass wedge from the active wedge ($E_P$) using the following eqs:

$$W_P = \frac{\gamma_D (h^2 - h_w^2) + \gamma_{SAT} h_w^2}{\sin 2\beta} = 829.4 \text{ lbs}$$

$$U_V = U_h \cot\beta = 0.6 \text{ lbs}$$

$$E_P = \frac{U_h (FS) - (W_P - U_V \tan\phi)}{\sin\beta \tan\phi - \cos\beta (FS)} = 894 \text{ lbs}$$

## Static Factor of Safety w/ Seepage Forces

Determine the calculated Factor of Safety ($FS_A$) using a quadratic equation relationship where the constants are defined as follows:

$$a = W_A \sin\beta \cos\beta - U_h \cos^2\beta + U_h = 4{,}018 \text{ lbs/ft}$$

$$b = -W_A \sin^2\beta \tan\phi + U_h \sin\beta \cos\beta \tan\phi - N_A \cos\beta \tan\delta - (W_P - U_V)\tan\phi = (7{,}725.1) \text{ lbs/ft}$$

$$c = N_A \sin\beta \tan\delta \tan\phi = 962 \text{ lbs/ft}$$

| Allow Exceeds Req'd - OK | | |
|---|---|---|
| $FS_R$ = | 1.10 | |
| $FS_A$ = | 1.79 | |
| Min. Peak $\phi$ | 23.0 | deg |
| Min. Peak $c_a$ | 28.0 | psf |

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| | | SHT NO | 5 | OF | 9 |
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| | | SCALE | NA | | |

Determine: Static factor of safety for cover system based on additional equipment loads.

Procedure:

Determine the static stability of the veneer cover system to determine the minimum required interface friction angle for all engineered components of the cover system. Balance the forces as shown in Figure 1 and the required factor of safety (FS) then solve for minimum interface shear strength parameters. Account for equipment loads ($W_b$) as final cover is placed as noted in Figure 3.

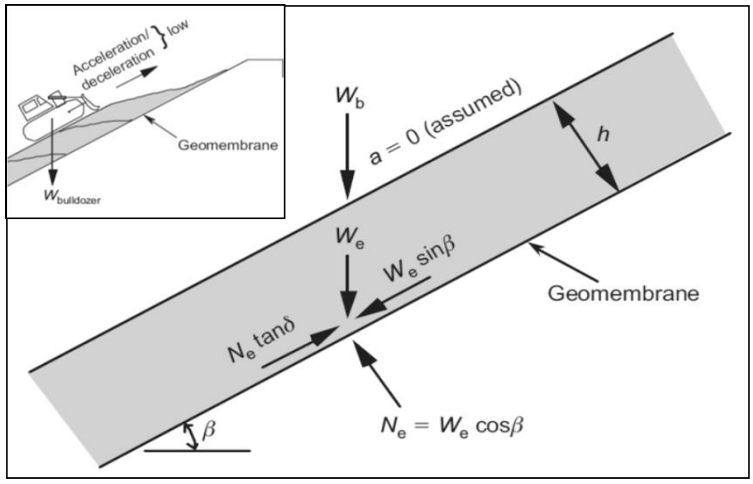


Figure 3. Additional load due to construction equipment moving on cover soil.

Assumptions:

In addition to the static case assumptions:
1. The equipment pushes material up slope leaving a toe buttress behind.
2. The equipment accelerates slowly with no sudden starts or turns to minimize additional loads besides the weight of the machine.

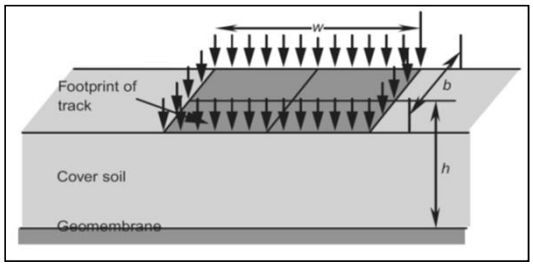


Figure 4. Illustration of stress distribution from overlying equipment.

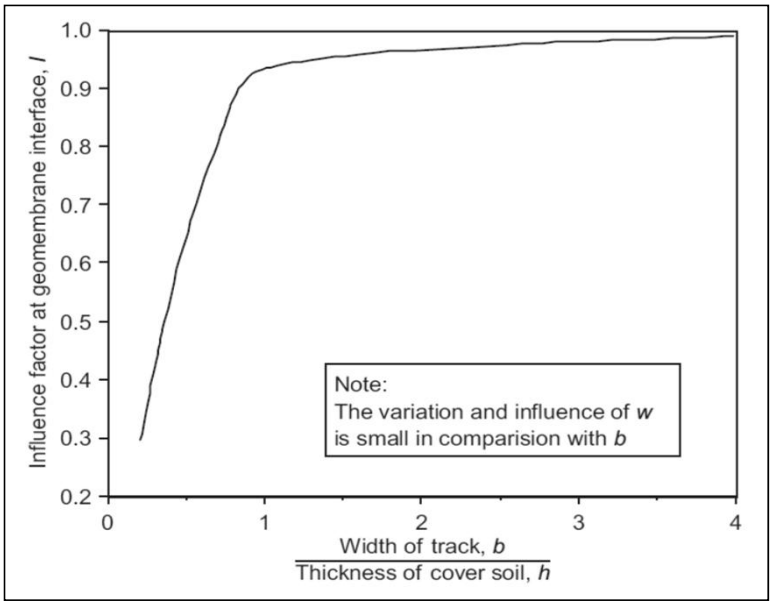


Figure 5. Values of influence factor I to dissipate surface force through cover soil to geomembrane interface (after Poulos and Davis 1974)

Equipment Parameters

| | | | Source |
|---|---|---|---|
| Equiv. Equipment Load per Unit Width ($W_e$) | 14939 | lbs | $W_e = qwl$ |
| Influence Factor at the Geom. Interface (I) | 0.95 | | See Figure 5 above. |
| Track Width to Cover Soil Thickness Ratio (b/h) | 1.40 | | |
| Distributed Equipment Load (q) | 1492 | psf | $q = W_b/(2 \times w \times b)$ |
| Weight of Equipment ($W_b$) | 87,733 | lbs | Typical weight of CAT D8 dozer |
| Length of Equipment Track (w) | 10.50 | ft | Typical track dimensions of CAT D8 dozer |
| Width of Equipment Track (b) | 2.80 | ft | |

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| | | SHT NO | 6 | OF | 9 |
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| | | SCALE | NA | | |

Veg. Cover Soil (VC)/Prot. Cover Soil (CS) and Slope Parameters

| | VC | CS | Utilized | | Source |
|---|---|---|---|---|---|
| Thickness (h) | 0.5 | 1.5 | 2.0 | ft | Design |
| Dry Unit Weight ($g_D$) | 90.0 | 100.0 | 97.5 | pcf | Conservatively assumed based on lab tests |
| Mois. Cont. (field cond.) ($w_F$) | 26.0 | 24.0 | 24.5 | % | Conservatively assumed based on lab tests |
| Avg Field Unit Wt (g) | - | - | 121.4 | pcf | |
| Min. Friction Angle (f ) | 30.0 | 30.0 | 30.0 | deg | Assumed (conservative for sandy cover) |
| Min. Cohesion (c) | 0.0 | 0.0 | 0.0 | psf | Assumed (conservative for sandy cover) |
| Slope Angle Beneath the Geom. (b) | - | - | 14.0 | deg | Design |
| Ht. of Slp. Meas. Along Geom. ($H_L$) | - | - | 22.06 | ft | Design |
| Lng. of Slp. Meas. Along Geom. (L) | - | - | 91.00 | ft | |
| Inter. Frict. Angle for GMB & GCL (d) | - | - | 23.0 | deg | Resid. shear strength parameters from interface shear testing |
| Adhesion for GMB & GCL ($c_a$) | - | - | 28.0 | psf | |
| Required Factor of Safety ($FS_R$) | - | - | 1.25 | | Min. req. FS for temporary conditions |

Active Wedge Calculations

Determine the total weight of the active wedge ($W_A$),the effective force normal to the failure plan of the active wedge ($N_A$), the adhesive force between the cover soil of the active wedge and the geomembrane ($C_a$), and the interwedge force acting on the active wedge from the passive wedge ($E_A$) using the following eqs:

$$W_A = \gamma h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right) + W_e$$ = 34,967 lbs

$$N_A = W_A \cos\beta$$ = 33,924 lbs

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right)$$ = 2,317 lbs

$$E_A = \frac{(FS)(W_A - N_A\cos\beta) - (N_A\tan\delta + C_a)\sin\beta}{\sin\beta(FS)}$$ = (4,896) lbs

Passive Wedge Calculations

Determine the total weight of the passive wedge ($W_P$),the effective force normal to the failure plan of the passive wedge ($N_P$), the cohesive force along the failure plane (C), and the interwedge force acting on the passive wedge from the active wedge ($E_P$) using the following eqs:

$$W_P = \frac{\gamma h^2}{\sin 2\beta}$$ = 1,032 lbs

$$C = \frac{ch}{\sin\beta}$$ = - lbs

$$E_P = \frac{C + W_P\tan\phi}{\cos\beta(FS) - \sin\beta\tan\phi}$$ = 556 lbs

$$N_P = W_P + E_P\sin\beta$$ = 1,167 lbs

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|---|---|---|---|---|---|
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| | | SCALE | NA | | |

## Static Factor of Safety w/ Equipment Load

Determine the calculated Factor of Safety ($FS_A$) using a quadratic equation relationship where the constants are defined as follows:

$$a = (W_A - N_A \cos\beta)\cos\beta \quad = \quad 1{,}994 \text{ lbs/ft}$$

$$b = -\begin{bmatrix} (W_A - N_A \cos\beta)\sin\beta\tan\phi \\ +(N_A \tan\delta + C_a)\sin\beta\cos\beta \\ +\sin\beta(C + W_P \tan\phi) \end{bmatrix} \quad = \quad (4{,}364) \text{ lbs/ft}$$

$$c = (N_A \tan\delta + C_a)\sin^2\beta\tan\phi \quad = \quad 567 \text{ lbs/ft}$$

| Allow Exceeds Req'd - OK | | |
|---|---|---|
| $FS_R$ = | 1.25 | |
| $FS_A$ = | 2.05 | |
| Min. Peak d | 23.0 | deg |
| Min. Peak $c_a$ | 28.0 | psf |

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|---|---|---|---|---|---|
| | | SHT NO | 8 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Determine: Static factor of safety for cover system based on additional seismic loads.

Procedure:

Determine the static stability of the veneer cover system to determine critical factor of safety for all engineered components of the cover system. Balance the forces as shown in Figure 1 and compare to the required factor of safety (FS). Account for seismic loads ($C_S$) as noted in Figure 6.

Assumptions:

In addition to the static case assumptions:
1. Seismic force acts on the centroid of the cover soil.
2. Seismic force is horizontal.
3. Deformation analysis not required.

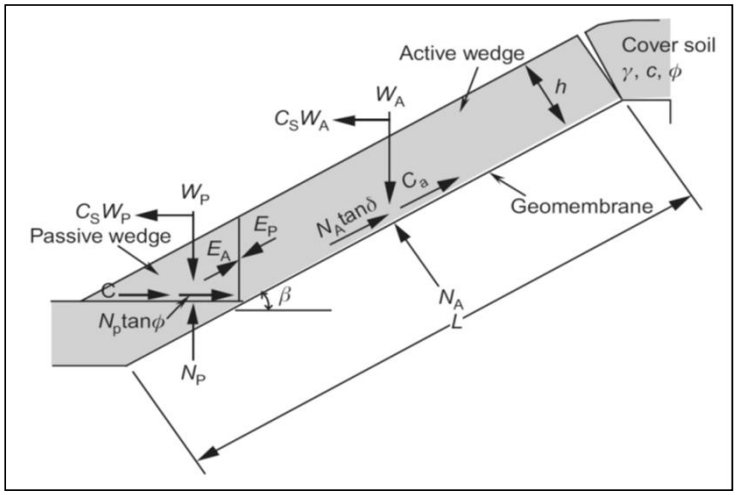


Figure 6. Limit equilibrium forces involved in pseudo-static analysis using average seismic coefficient.

| Veg. Cover Soil (VC)/Prot. Cover Soil (CS) and Slope Parameters | VC | CS | Utilized | | Source |
|---|---|---|---|---|---|
| Thickness (h) | 0.5 | 1.5 | 2.0 | ft | Design |
| Dry Unit Weight ($g_D$) | 90.0 | 100.0 | 97.5 | pcf | Conservatively assumed based on lab tests |
| Mois. Cont. (field cond.) ($w_F$) | 26.0 | 24.0 | 24.5 | % | Conservatively assumed based on lab tests |
| Avg Field Unit Wt (g) | - | - | 121.4 | pcf | |
| Min. Friction Angle (f ) | 30.0 | 30.0 | 30.0 | deg | Assumed (conservative for sandy cover) |
| Min. Cohesion (c) | 0.0 | 0.0 | 0.0 | psf | Assumed (conservative for sandy cover) |
| Slope Angle Beneath the Geom. (b) | - | - | 14.0 | degrees | Design |
| Ht. of Slp. Meas. Along Geom. ($H_L$) | - | - | 22.06 | ft | Design |
| Lng. of Slp. Meas. Along Geom. (L) | - | - | 91.00 | ft | |
| Inter. Frict. Angle for GMB & GCL (d) | - | - | 23.0 | deg | Min. req. shear strength parameters from static analysis |
| Adhesion for GMB & GCL ($c_a$) | - | - | 28.0 | psf | |
| Seismic Coefficient ($C_S$ or $K_S$) | - | - | 0.040 | %g | PGA for 2% Exceedance in 50 Years |
| Required Factor of Safety ($FS_R$) | - | - | 1.00 | | Min. req. FS for seismic conditions |

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|---|---|---|---|---|---|
| | | SHT NO | 9 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Active Wedge Calculations

Determine the total weight of the active wedge ($W_A$),the effective force normal to the failure plan of the active wedge ($N_A$), the adhesive force between the cover soil of the active wedge and the geomembrane ($C_a$), and the interwedge force acting on the active wedge from the passive wedge ($E_A$) using the following eqs:

$$W_A = \gamma h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right)$$ = 20,028 lbs

$$N_A = W_A \cos\beta$$ = 19,430 lbs

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right)$$ = 2,317 lbs

$$E_A = \frac{(FS)(C_S W_A + N_A \sin\beta)}{(FS)\cos\beta} + \frac{(N_A \tan\delta + C_a)\cos\beta}{(FS)\cos\beta} =$$ 16,246 lbs

Passive Wedge Calculations

Determine the total weight of the passive wedge ($W_P$),the effective force normal to the failure plan of the passive wedge ($N_P$), the cohesive force along the failure plane (C), and the interwedge force acting on the passive wedge from the active wedge ($E_P$) using the following eqs:

$$W_P = \frac{\gamma h^2}{\sin 2\beta}$$ = 1,032 lbs

$$C = \frac{ch}{\sin\beta}$$ = - lbs

$$E_P = \frac{C + W_P \tan\phi - C_S W_P (FS)}{\cos\beta(FS) - \sin\beta\tan\phi}$$ = 668 lbs

$$N_P = W_P + E_P \sin\beta$$ = 1,194 lbs

## Seismic Factor of Safety

Determine the calculated Factor of Safety ($FS_A$) using a quadratic equation relationship where the constants are defined as follows:

$$a = (C_S W_A + N_A \sin\beta)\cos\beta + C_S W_P \cos\beta$$ = 5,411 lbs/ft

$$b = -\begin{bmatrix} (C_S W_A + N_A \sin\beta)\sin\beta\tan\phi \\ + (N_A \tan\delta + C_a)\cos^2\beta \\ + (C + W_P \tan\phi)\cos\beta \end{bmatrix}$$ = (11,293) lbs/ft

$$c = (N_A \tan\delta + C_a)\cos\beta\sin\beta\tan\phi$$ = 1435 lbs/ft

| Allow Exceeds Req'd - OK | | |
|---|---|---|
| $FS_R$ = | 1.00 | |
| $FS_A$ = | 1.95 | |
| Min. Peak d | 23.0 | deg |
| Min. Peak $c_a$ | 28.0 | psf |

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|---|---|---|---|---|---|
| | | SHT NO | 1 | OF | 9 |
| | | CALC BY | JAD | DATE | 03/29/16 |
| | | CHK BY | NSG | DATE | 03/30/16 |
| | | SCALE | NA | | |

Objective:

Determine the veneer stability of the cover system at the Salzburg Landfill - Cells 20 - 22. Each interface was analyzed using residual strength parameters to reflect large displacement conditions.

Method:

Use methods outlined in the paper by Koerner and Soong, *Analysis and Design of Veneer Cover Soils* published in Geosynthetics International, 2005, 12, No.1.

Procedure:

Determine the static stability of the veneer cover system to evaluate the minimum factor of safety for the cover system. Balance the forces as shown in Figure 1 and compare to the required factor of safety (FS).

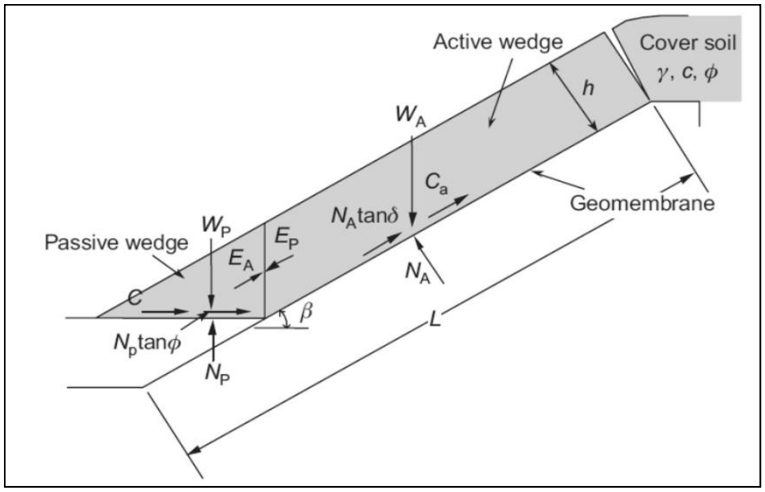


Figure 1. Limit equilibrium forces involved in a finite length slope analysis for a uniformly thick cover soil

Determine: Static factor of safety for cover system based on gravitational forces only and peak strength.

Assumptions:

1. No geosynthetic reinforcements
2. No interface adhesion for geosynthetic components.
3. No tension allowed in geosynthetics
4. Minimum cohesion for multilayered systems

Veg. Cover Soil (VC)/Prot. Cover Soil (CS) and Slope Parameters

| | VC | CS | Utilized | | Source |
|---|---|---|---|---|---|
| Thickness (h) | 0.5 | 1.5 | 2.0 | ft | Design |
| Dry Unit Weight ($g_D$) | 90.0 | 100.0 | 97.5 | pcf | Conservatively assumed based on lab tests |
| Mois. Cont. (field cond.) ($w_F$) | 26.0 | 24.0 | 24.5 | % | Conservatively assumed based on lab tests |
| Avg Field Unit Wt (g) | - | - | 121.4 | pcf | |
| Reference Stress | - | - | 235.5 | pcf | |
| Min. Friction Angle (f ) | 30.0 | 30.0 | 30.0 | deg | Assumed (conservative for sandy cover) |
| Min. Cohesion (c) | 0.0 | 0.0 | 0.0 | psf | Assumed (conservative for sandy cover) |
| Slope Angle Beneath the Geom. (b) | - | - | 14.03 | deg | Design |
| Ht. of Slp. Meas. Along Geom. ($H_L$) | - | - | 22.06 | ft | Design |
| Lng. of Slp. Meas. Along Geom. (L) | - | - | 91.00 | ft | |
| Inter. Frict. Angle for GCL & GCL (d) | - | - | 17.3 | deg | Resid. shear strength parameters from interface shear testing |
| Adhesion for GCL & GCL ($c_a$) | - | - | 52.0 | psf | |
| Required Factor of Safety ($FS_R$) | - | - | 1.50 | | Min. req. FS for long term conditions |

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|---|---|---|---|---|---|
| | | SHT NO | 2 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Active Wedge Calculations

Determine the total weight of the active wedge ($W_A$),the effective force normal to the failure plan of the active wedge ($N_A$), the adhesive force between the cover soil of the active wedge and the geomembrane ($C_a$), and the interwedge force acting on the active wedge from the passive wedge ($E_A$) using the following eqs:

$$W_A = \gamma h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right)$$ = 20,028 lbs

$$N_A = W_A \cos\beta$$ = 19,430 lbs

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right)$$ = 4,303 lbs

$$E_A = \frac{(FS)(W_A - N_A\cos\beta) - (N_A\tan\delta + C_a)\sin\beta}{\sin\beta(FS)}$$ = (2,048) lbs

Passive Wedge Calculations

Determine the total weight of the passive wedge ($W_P$),the effective force normal to the failure plan of the passive wedge ($N_P$), the cohesive force along the failure plane (C), and the interwedge force acting on the passive wedge from the active wedge ($E_P$) using the following eqs:

$$W_P = \frac{\gamma h^2}{\sin 2\beta}$$ = 1,032 lbs

$$C = \frac{ch}{\sin\beta}$$ = - lbs

$$E_P = \frac{C + W_P\tan\phi}{\cos\beta(FS) - \sin\beta\tan\phi}$$ = 453 lbs

$$N_P = W_P + E_P\sin\beta$$ = 1,142 lbs

## Static Factor of Safety

Determine the calculated Factor of Safety ($FS_A$) using a quadratic equation relationship where the constants are defined as follows:

$$a = (W_A - N_A\cos\beta)\cos\beta$$ = 1,142 lbs/ft

$$b = -\begin{bmatrix}(W_A - N_A\cos\beta)\sin\beta\tan\phi \\ +(N_A\tan\delta + C_a)\sin\beta\cos\beta \\ +\sin\beta(C + W_P\tan\phi)\end{bmatrix}$$ = (2,745) lbs/ft

$$c = (N_A\tan\delta + C_a)\sin^2\beta\tan\phi$$ = 351 lbs/ft

Allow Exceeds Req'd - OK

$FS_R$ = 1.50

$FS_A$ = 2.27

Min. Resid. d 17.3 deg

Min. Resid. $c_a$ 52.0 pst

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|---|---|---|---|---|---|
| | | SHT NO | 3 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Determine: Static factor of safety for cover system based on additional seepage forces.
Procedure:

Determine the static stability of the veneer cover system to determine the minimum required interface friction angle for all engineered components of the cover system. Balance the forces as shown in Figure 1 and the required factor of safety (FS) then solve for minimum interface shear strength parameters. Account for seepage forces in drainage layer as noted in Figure 2.

Assumptions:

In addition to the static case assumptions:
1. Seepage is parallel to slope
2. The drainage layer is sized such that liquid not build up beyond the thickness of the drainage layer.
3. Drainage layer has adequate capacity to handle maximum surface water flow
4. If geocomposite is used - it is less than 0.75 inches thick.
5. Max accumulation of up to 1 foot head on top of FML barrier to account for drainage aggregate in lieu of geocomposite.
6. No seepage forces outside drainage layer.

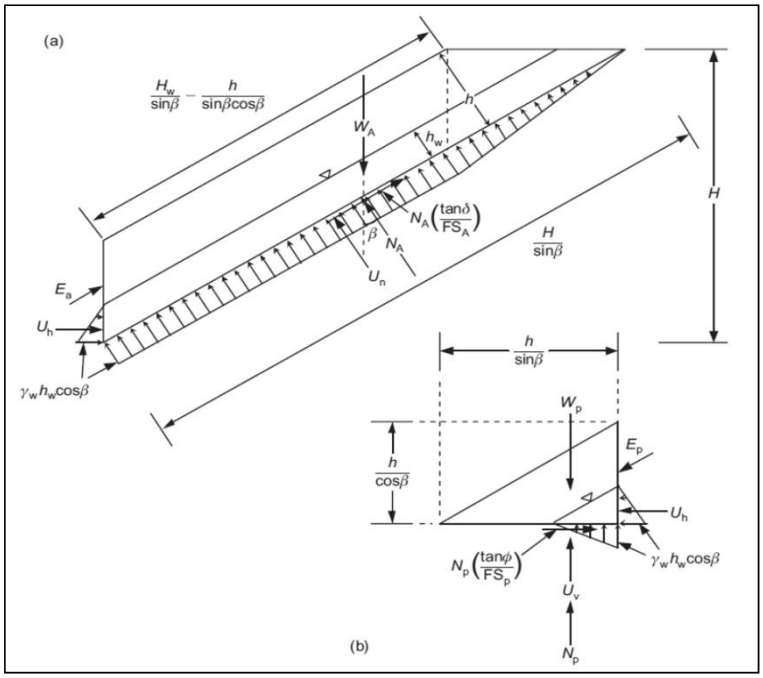


Figure 2. Limit equilibrium forces involved in finite-length slope of uniform cover soil with parallel-to-slope seepage build-up: (a) active wedge; (b) passive wedge

| Veg. Cover Soil (VC)/Prot. Cover Soil (CS) and Slope Parameters | VC | CS | Utilized | | Source |
|---|---|---|---|---|---|
| Thickness (h) | 0.5 | 1.5 | 2.0 | ft | Design |
| Dry Unit Weight ($g_D$) | 90.0 | 100.0 | 97.5 | pcf | Conservatively assumed based on lab tests |
| Mois. Cont. (field cond.) ($w_F$) | 26.0 | 24.0 | 24.5 | % | Conservatively assumed based on lab tests |
| Avg Field Unit Wt (g) | - | - | 121.4 | pcf | |
| Specific Gravity of the ($G_S$) | 2.72 | 2.72 | 2.72 | | Assumed conservative |
| Unit Weight of Water ($g_W$) | - | - | 62.4 | pcf | |
| Saturated Unit Weight ($g_{SAT}$) | - | - | 124.1 | pcf | |
| Min. Friction Angle (f ) | 30.0 | 30.0 | 30.0 | deg | Assumed (conservative for sandy cover) |
| Min. Cohesion (c) | 0.0 | 0.0 | 0.0 | psf | Assumed (conservative for sandy cover) |
| Slope Angle Beneath the Geom. (b) | - | - | 14.0 | degrees | Design |
| Ht. of Slp. Meas. Along Geom. ($H_L$) | - | - | 22.06 | ft | Design |
| Lng. of Slp. Meas. Along Geom. (L) | - | - | 91.0 | ft | |
| Depth of Water in DL ($h_W$) | - | - | 0.07 | ft | Max. thickness of DL (conservative) |
| Inter. Frict. Angle for GCL & GCL (d) | - | - | 17.3 | deg | Resid. shear strength parameters from interface shear testing |
| Adhesion for GCL & GCL ($c_a$) | - | - | 52.0 | psf | |
| Required Factor of Safety ($FS_R$) | - | - | 1.10 | | Min. req. FS for temporary conditions |

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|---|---|---|---|---|---|
| | | SHT NO | 4 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Active Wedge Calculations

Determine the total weight of the active wedge ($W_A$), resultant of the pore pressures acting on the interwedge surfaces ($U_h$), resultant of the pore pressures acting perpendicular to the slope ($U_n$), the effective force normal to the failure plan of the active wedge ($N_A$), and the interwedge force acting on the active wedge from the passive wedge ($E_A$) using the following eqs:

$$W_A = \frac{\gamma_D (h - h_W)[2H\cos\beta - (h + h_W)]}{\sin 2\beta} + \frac{\gamma_{SAT}(h_W)(2H\cos\beta - h_W)}{\sin 2\beta} = 17{,}084 \text{ lbs}$$

$$U_h = \frac{\gamma_w h_W^2}{2} = 0.15 \text{ lbs}$$

$$U_n = \frac{\gamma_w (h_w)(\cos\beta)(2H\cos\beta - h_w)}{\sin 2\beta} = 385 \text{ lbs}$$

$$N_A = W_A \cos\beta + U_h \sin\beta - U_n = 16{,}189 \text{ lbs}$$

$$E_A = W_A \sin\beta - U_h \cos\beta - \frac{N_A \sin\delta}{(FS)} = (235) \text{ lbs}$$

Passive Wedge Calculations

Determine the total weight of the passive wedge ($W_P$), resultant of the vertical pore pressures acting on the passive wedge ($U_V$), and the interwedge force acting on the pass wedge from the active wedge ($E_P$) using the following eqs:

$$W_P = \frac{\gamma_D (h^2 - h_w^2) + \gamma_{SAT} h_w^2}{\sin 2\beta} = 829.4 \text{ lbs}$$

$$U_V = U_h \cot\beta = 0.6 \text{ lbs}$$

$$E_P = \frac{U_h (FS) - (W_P - U_V \tan\phi)}{\sin\beta \tan\phi - \cos\beta (FS)} = 894 \text{ lbs}$$

## Static Factor of Safety w/ Seepage Forces

Determine the calculated Factor of Safety ($FS_A$) using a quadratic equation relationship where the constants are defined as follows:

$$a = W_A \sin\beta \cos\beta - U_h \cos^2\beta + U_h = 4{,}018 \text{ lbs/ft}$$

$$b = -W_A \sin^2\beta \tan\phi + U_h \sin\beta \cos\beta \tan\phi - N_A \cos\beta \tan\delta - (W_P - U_V)\tan\phi = (5{,}950.1) \text{ lbs/ft}$$

$$c = N_A \sin\beta \tan\delta \tan\phi = 706 \text{ lbs/ft}$$

| Allow Exceeds Req'd - OK | | |
|---|---|---|
| $FS_R$ = | 1.10 | |
| $FS_A$ = | 1.35 | |
| Min. Peak d | 17.3 | deg |
| Min. Peak $c_a$ | 52.0 | psf |

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| | | SHT NO | 5 | OF | 9 |
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| | | SCALE | NA | | |

Determine: Static factor of safety for cover system based on additional equipment loads.

Procedure:

Determine the static stability of the veneer cover system to determine the minimum required interface friction angle for all engineered components of the cover system. Balance the forces as shown in Figure 1 and the required factor of safety (FS) then solve for minimum interface shear strength parameters. Account for equipment loads ($W_b$) as final cover is placed as noted in Figure 3.

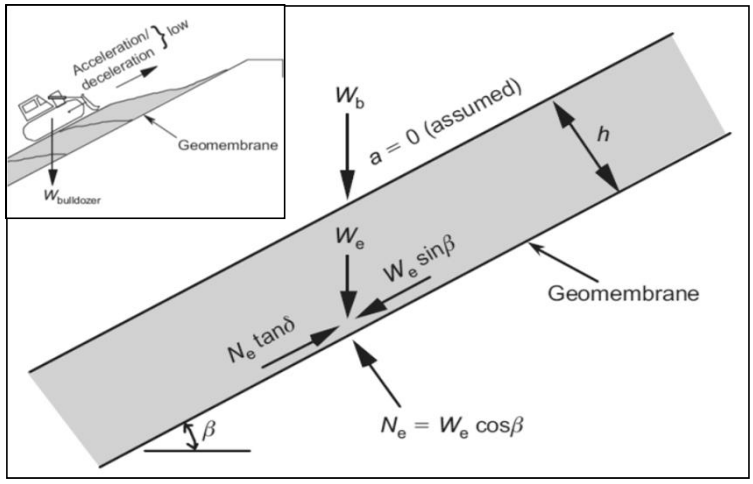


Figure 3. Additional load due to construction equipment moving on cover soil.

Assumptions:

In addition to the static case assumptions:
1. The equipment pushes material up slope leaving a toe buttress behind.
2. The equipment accelerates slowly with no sudden starts or turns to minimize additional loads besides the weight of the machine.

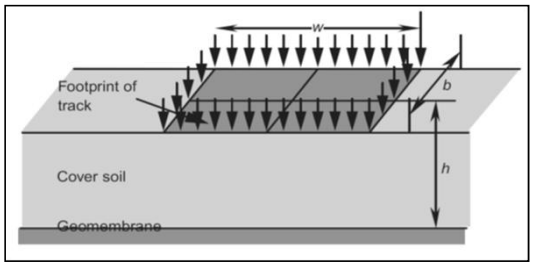


Figure 4. Illustration of stress distribution from overlying equipment.

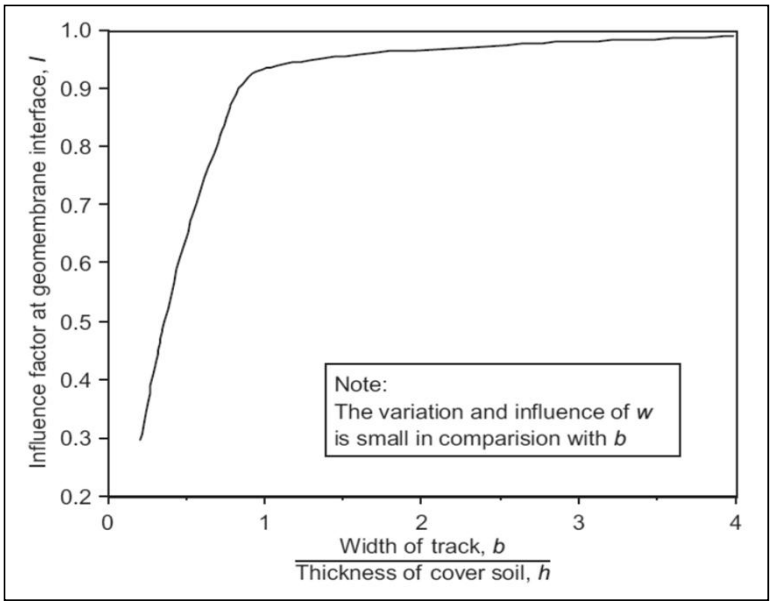


Figure 5. Values of influence factor I to dissipate surface force through cover soil to geomembrane interface (after Poulos and Davis 1974)

Equipment Parameters

| | | | Source |
|---|---|---|---|
| Equiv. Equipment Load per Unit Width ($W_e$) | 14939 | lbs | $W_e = qwl$ |
| Influence Factor at the Geom. Interface (I) | 0.95 | | See Figure 5 above. |
| Track Width to Cover Soil Thickness Ratio (b/h) | 1.40 | | |
| Distributed Equipment Load (q) | 1492 | psf | $q = W_b/(2 \times w \times b)$ |
| Weight of Equipment ($W_b$) | 87,733 | lbs | Typical weight of CAT D8 dozer |
| Length of Equipment Track (w) | 10.50 | ft | Typical track dimensions of CAT D8 dozer |
| Width of Equipment Track (b) | 2.80 | ft | |

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|---|---|---|---|---|---|
| | | SHT NO | 6 | OF | 9 |
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| | | SCALE | NA | | |

Veg. Cover Soil (VC)/Prot. Cover Soil (CS) and Slope Parameters

| | VC | CS | Utilized | | Source |
|---|---|---|---|---|---|
| Thickness (h) | 0.5 | 1.5 | 2.0 | ft | Design |
| Dry Unit Weight ($g_D$) | 90.0 | 100.0 | 97.5 | pcf | Conservatively assumed based on lab tests |
| Mois. Cont. (field cond.) ($w_F$) | 26.0 | 24.0 | 24.5 | % | Conservatively assumed based on lab tests |
| Avg Field Unit Wt (g) | - | - | 121.4 | pcf | |
| Min. Friction Angle (f ) | 30.0 | 30.0 | 30.0 | deg | Assumed (conservative for sandy cover) |
| Min. Cohesion (c) | 0.0 | 0.0 | 0.0 | psf | Assumed (conservative for sandy cover) |
| Slope Angle Beneath the Geom. (b) | - | - | 14.0 | deg | Design |
| Ht. of Slp. Meas. Along Geom. ($H_L$) | - | - | 22.06 | ft | Design |
| Lng. of Slp. Meas. Along Geom. (L) | - | - | 91.00 | ft | |
| Inter. Frict. Angle for GCL & GCL (d) | - | - | 17.3 | deg | Resid. shear strength parameters from interface shear testing |
| Adhesion for GCL & GCL ($c_a$) | - | - | 52.0 | psf | |
| Required Factor of Safety ($FS_R$) | - | - | 1.25 | | Min. req. FS for temporary conditions |

Active Wedge Calculations

Determine the total weight of the active wedge ($W_A$),the effective force normal to the failure plan of the active wedge ($N_A$), the adhesive force between the cover soil of the active wedge and the geomembrane ($C_a$), and the interwedge force acting on the active wedge from the passive wedge ($E_A$) using the following eqs:

$$W_A = \gamma h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right) + W_e$$ = 34,967 lbs

$$N_A = W_A \cos\beta$$ = 33,924 lbs

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right)$$ = 4,303 lbs

$$E_A = \frac{(FS)(W_A - N_A\cos\beta) - (N_A\tan\delta + C_a)\sin\beta}{\sin\beta(FS)}$$ = (3,418) lbs

Passive Wedge Calculations

Determine the total weight of the passive wedge ($W_P$),the effective force normal to the failure plan of the passive wedge ($N_P$), the cohesive force along the failure plane (C), and the interwedge force acting on the passive wedge from the active wedge ($E_P$) using the following eqs:

$$W_P = \frac{\gamma h^2}{\sin 2\beta}$$ = 1,032 lbs

$$C = \frac{ch}{\sin\beta}$$ = - lbs

$$E_P = \frac{C + W_P\tan\phi}{\cos\beta(FS) - \sin\beta\tan\phi}$$ = 556 lbs

$$N_P = W_P + E_P\sin\beta$$ = 1,167 lbs

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|---|---|---|---|---|---|
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| Tel. (330) 836-9111 | Salzburg Landfill Cells 20-22 | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

## Static Factor of Safety w/ Equipment Load

Determine the calculated Factor of Safety ($FS_A$) using a quadratic equation relationship where the constants are defined as follows:

$$a = (W_A - N_A \cos\beta)\cos\beta$$ = 1,994 lbs/ft

$$b = -\begin{bmatrix} (W_A - N_A \cos\beta)\sin\beta\tan\phi \\ +(N_A \tan\delta + C_a)\sin\beta\cos\beta \\ +\sin\beta(C + W_P \tan\phi) \end{bmatrix}$$ = (3,929) lbs/ft

$$c = (N_A \tan\delta + C_a)\sin^2\beta\tan\phi$$ = 505 lbs/ft

| Allow Exceeds Req'd - OK | | |
|---|---|---|
| $FS_R$ = | 1.25 | |
| $FS_A$ = | 1.83 | |
| Min. Peak $\phi$ | 17.3 | deg |
| Min. Peak $c_a$ | 52.0 | psf |

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|---|---|---|---|---|---|
| | | SHT NO | 8 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Determine: Static factor of safety for cover system based on additional seismic loads.

Procedure:

Determine the static stability of the veneer cover system to determine critical factor of safety for all engineered components of the cover system. Balance the forces as shown in Figure 1 and compare to the required factor of safety (FS). Account for seismic loads ($C_S$) as noted in Figure 6.

Assumptions:

In addition to the static case assumptions:
1. Seismic force acts on the centroid of the cover soil.
2. Seismic force is horizontal.
3. Deformation analysis not required.

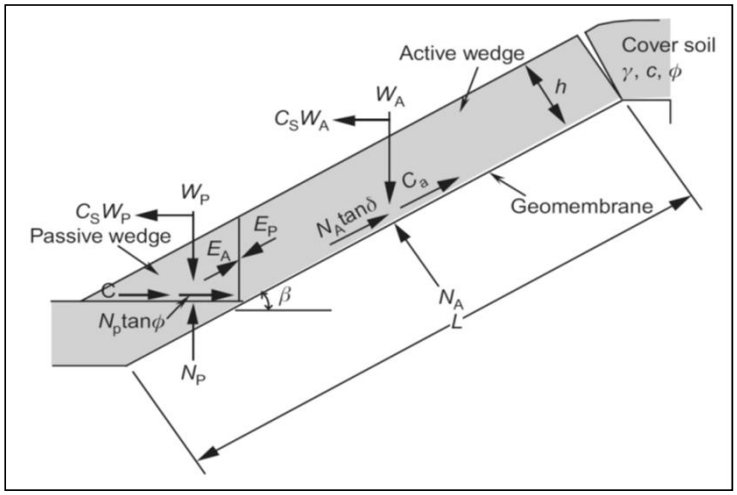


Figure 6. Limit equilibrium forces involved in pseudo-static analysis using average seismic coefficient.

Veg. Cover Soil (VC)/Prot. Cover Soil (CS) and Slope Parameters

| | VC | CS | Utilized | | Source |
|---|---|---|---|---|---|
| Thickness (h) | 0.5 | 1.5 | 2.0 | ft | Design |
| Dry Unit Weight ($g_D$) | 90.0 | 100.0 | 97.5 | pcf | Conservatively assumed based on lab tests |
| Mois. Cont. (field cond.) ($w_F$) | 26.0 | 24.0 | 24.5 | % | Conservatively assumed based on lab tests |
| Avg Field Unit Wt (g) | - | - | 121.4 | pcf | |
| Min. Friction Angle (f ) | 30.0 | 30.0 | 30.0 | deg | Assumed (conservative for sandy cover) |
| Min. Cohesion (c) | 0.0 | 0.0 | 0.0 | psf | Assumed (conservative for sandy cover) |
| Slope Angle Beneath the Geom. (b) | - | - | 14.0 | degrees | Design |
| Ht. of Slp. Meas. Along Geom. ($H_L$) | - | - | 22.06 | ft | Design |
| Lng. of Slp. Meas. Along Geom. (L) | - | - | 91.00 | ft | |
| Inter. Frict. Angle for GCL & GCL (d) | - | - | 17.3 | deg | Min. req. shear strength parameters from static analysis |
| Adhesion for GCL & GCL ($c_a$) | - | - | 52.0 | psf | |
| Seismic Coefficient ($C_S$ or $K_S$) | - | - | 0.040 | %g | PGA for 2% Exceedance in 50 Years |
| Required Factor of Safety ($FS_R$) | - | - | 1.00 | | Min. req. FS for seismic conditions |

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|---|---|---|---|---|---|
| | | SHT NO | 9 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Active Wedge Calculations

Determine the total weight of the active wedge ($W_A$),the effective force normal to the failure plan of the active wedge ($N_A$), the adhesive force between the cover soil of the active wedge and the geomembrane ($C_a$), and the interwedge force acting on the active wedge from the passive wedge ($E_A$) using the following eqs:

$$W_A = \gamma h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right)$$ = 20,028 lbs

$$N_A = W_A \cos\beta$$ = 19,430 lbs

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right)$$ = 4,303 lbs

$$E_A = \frac{(FS)(C_S W_A + N_A \sin\beta)}{(FS)\cos\beta} + \frac{(N_A \tan\delta + C_a)\cos\beta}{(FS)\cos\beta} =$$ 16,036 lbs

Passive Wedge Calculations

Determine the total weight of the passive wedge ($W_P$),the effective force normal to the failure plan of the passive wedge ($N_P$), the cohesive force along the failure plane (C), and the interwedge force acting on the passive wedge from the active wedge ($E_P$) using the following eqs:

$$W_P = \frac{\gamma h^2}{\sin 2\beta}$$ = 1,032 lbs

$$C = \frac{ch}{\sin\beta}$$ = - lbs

$$E_P = \frac{C + W_P \tan\phi - C_S W_P (FS)}{\cos\beta(FS) - \sin\beta\tan\phi}$$ = 668 lbs

$$N_P = W_P + E_P \sin\beta$$ = 1,194 lbs

## Seismic Factor of Safety

Determine the calculated Factor of Safety ($FS_A$) using a quadratic equation relationship where the constants are defined as follows:

$$a = (C_S W_A + N_A \sin\beta)\cos\beta + C_S W_P \cos\beta$$ = 5,411 lbs/ft

$$b = -\begin{bmatrix} (C_S W_A + N_A \sin\beta)\sin\beta\tan\phi \\ + (N_A \tan\delta + C_a)\cos^2\beta \\ + (C + W_P \tan\phi)\cos\beta \end{bmatrix}$$ = (11,096) lbs/ft

$$c = (N_A \tan\delta + C_a)\cos\beta\sin\beta\tan\phi$$ = 1406 lbs/ft

| Allow Exceeds Req'd - OK | | |
|---|---|---|
| $FS_R$ = | 1.00 | |
| $FS_A$ = | 1.91 | |
| Min. Peak d | 17.3 | deg |
| Min. Peak $c_a$ | 52.0 | psf |

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|---|---|---|---|---|---|
| | | SHT NO | 1 | OF | 9 |
| | | CALC BY | JAD | DATE | 03/29/16 |
| | | CHK BY | NSG | DATE | 03/30/16 |
| | | SCALE | NA | | |

Objective:

Determine the veneer stability of the cover system at the Salzburg Landfill - Cells 20 - 22. Each interface was analyzed using residual strength parameters to reflect large displacement conditions.

Method:

Use methods outlined in the paper by Koerner and Soong, *Analysis and Design of Veneer Cover Soils* published in Geosynthetics International, 2005, 12, No.1.

Procedure:

Determine the static stability of the veneer cover system to evaluate the minimum factor of safety for the cover system. Balance the forces as shown in Figure 1 and compare to the required factor of safety (FS).

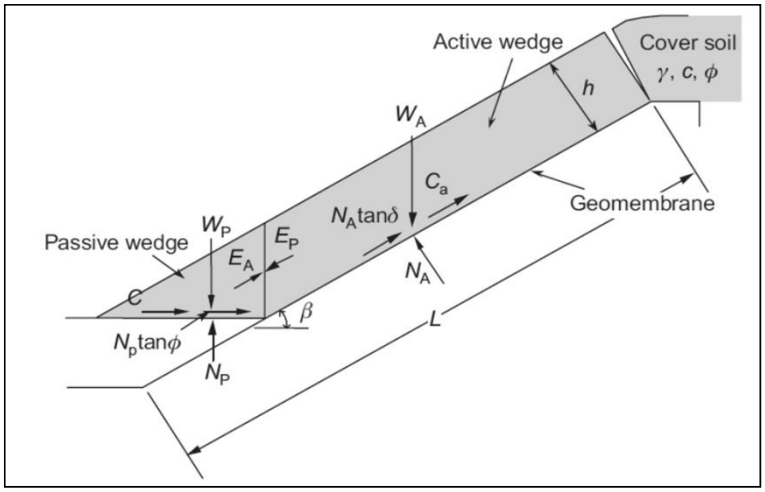


Figure 1. Limit equilibrium forces involved in a finite length slope analysis for a uniformly thick cover soil

Determine: Static factor of safety for cover system based on gravitational forces only and peak strength.

Assumptions:

1. No geosynthetic reinforcements
2. No interface adhesion for geosynthetic components.
3. No tension allowed in geosynthetics
4. Minimum cohesion for multilayered systems

Veg. Cover Soil (VC)/Prot. Cover Soil (CS) and Slope Parameters

| | VC | CS | Utilized | | Source |
|---|---|---|---|---|---|
| Thickness (h) | 0.5 | 1.5 | 2.0 | ft | Design |
| Dry Unit Weight ($g_D$) | 90.0 | 100.0 | 97.5 | pcf | Conservatively assumed based on lab tests |
| Mois. Cont. (field cond.) ($w_F$) | 26.0 | 24.0 | 24.5 | % | Conservatively assumed based on lab tests |
| Avg Field Unit Wt (g) | - | - | 121.4 | pcf | |
| Reference Stress | - | - | 235.5 | pcf | |
| Min. Friction Angle (f ) | 30.0 | 30.0 | 30.0 | deg | Assumed (conservative for sandy cover) |
| Min. Cohesion (c) | 0.0 | 0.0 | 0.0 | psf | Assumed (conservative for sandy cover) |
| Slope Angle Beneath the Geom. (b) | - | - | 14.03 | deg | Design |
| Ht. of Slp. Meas. Along Geom. ($H_L$) | - | - | 22.06 | ft | Design |
| Lng. of Slp. Meas. Along Geom. (L) | - | - | 91.00 | ft | |
| Inter. Frict. Angle for GCL & Int. Cover (d) | - | - | 28.9 | deg | Resid. shear strength parameters from interface shear testing |
| Adhesion for GCL & Int. Cover ($c_a$) | - | - | 2.0 | psf | |
| Required Factor of Safety ($FS_R$) | - | - | 1.50 | | Min. req. FS for long term conditions |

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|---|---|---|---|---|---|
| | | SHT NO | 2 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Active Wedge Calculations

Determine the total weight of the active wedge ($W_A$),the effective force normal to the failure plan of the active wedge ($N_A$), the adhesive force between the cover soil of the active wedge and the geomembrane ($C_a$), and the interwedge force acting on the active wedge from the passive wedge ($E_A$) using the following eqs:

$$W_A = \gamma h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right)$$ = 20,028 lbs

$$N_A = W_A \cos\beta$$ = 19,430 lbs

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right)$$ = 165 lbs

$$E_A = \frac{(FS)(W_A - N_A\cos\beta) - (N_A\tan\delta + C_a)\sin\beta}{\sin\beta(FS)}$$ = (2,406) lbs

Passive Wedge Calculations

Determine the total weight of the passive wedge ($W_P$),the effective force normal to the failure plan of the passive wedge ($N_P$), the cohesive force along the failure plane (C), and the interwedge force acting on the passive wedge from the active wedge ($E_P$) using the following eqs:

$$W_P = \frac{\gamma h^2}{\sin 2\beta}$$ = 1,032 lbs

$$C = \frac{ch}{\sin\beta}$$ = - lbs

$$E_P = \frac{C + W_P\tan\phi}{\cos\beta(FS) - \sin\beta\tan\phi}$$ = 453 lbs

$$N_P = W_P + E_P\sin\beta$$ = 1,142 lbs

## Static Factor of Safety

Determine the calculated Factor of Safety ($FS_A$) using a quadratic equation relationship where the constants are defined as follows:

$$a = (W_A - N_A\cos\beta)\cos\beta$$ = 1,142 lbs/ft

$$b = -\begin{bmatrix}(W_A - N_A\cos\beta)\sin\beta\tan\phi \\ +(N_A\tan\delta + C_a)\sin\beta\cos\beta \\ +\sin\beta(C + W_P\tan\phi)\end{bmatrix}$$ = (2,871) lbs/ft

$$c = (N_A\tan\delta + C_a)\sin^2\beta\tan\phi$$ = 370 lbs/ft

Allow Exceeds Req'd - OK

$FS_R$ = 1.50

$FS_A$ = 2.38

Min. Resid. d 28.9 deg

Min. Resid. $c_a$ 2.0 pst

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|---|---|---|---|---|---|
| | | SHT NO | 3 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Determine: Static factor of safety for cover system based on additional seepage forces.
Procedure:

Determine the static stability of the veneer cover system to determine the minimum required interface friction angle for all engineered components of the cover system. Balance the forces as shown in Figure 1 and the required factor of safety (FS) then solve for minimum interface shear strength parameters. Account for seepage forces in drainage layer as noted in Figure 2.

Assumptions:

In addition to the static case assumptions:
1. Seepage is parallel to slope
2. The drainage layer is sized such that liquid not build up beyond the thickness of the drainage layer.
3. Drainage layer has adequate capacity to handle maximum surface water flow
4. If geocomposite is used - it is less than 0.75 inches thick.
5. Max accumulation of up to 1 foot head on top of FML barrier to account for drainage aggregate in lieu of geocomposite.
6. No seepage forces outside drainage layer.

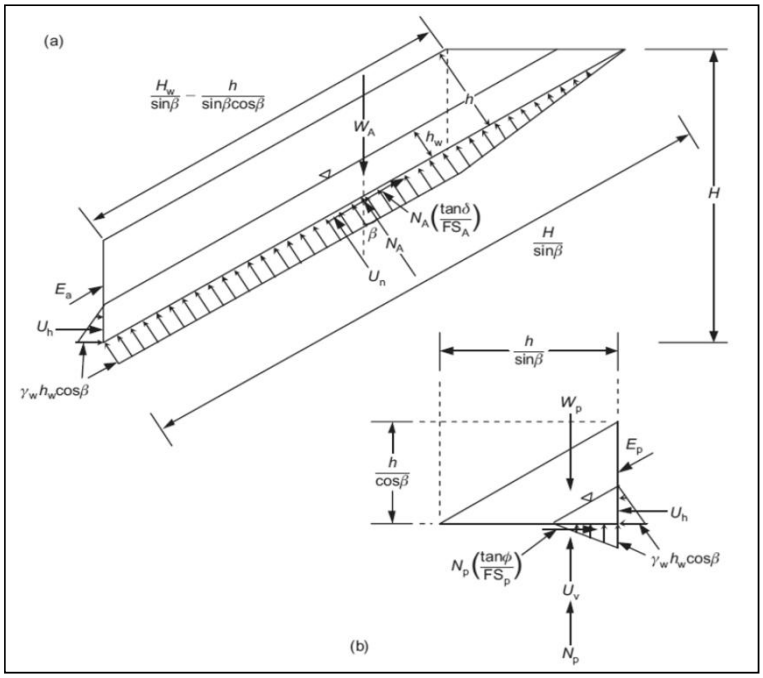


Figure 2. Limit equilibrium forces involved in finite-length slope of uniform cover soil with parallel-to-slope seepage build-up: (a) active wedge; (b) passive wedge

| Veg. Cover Soil (VC)/Prot. Cover Soil (CS) and Slope Parameters | VC | CS | Utilized | | Source |
|---|---|---|---|---|---|
| Thickness (h) | 0.5 | 1.5 | 2.0 | ft | Design |
| Dry Unit Weight ($g_D$) | 90.0 | 100.0 | 97.5 | pcf | Conservatively assumed based on lab tests |
| Mois. Cont. (field cond.) ($w_F$) | 26.0 | 24.0 | 24.5 | % | Conservatively assumed based on lab tests |
| Avg Field Unit Wt (g) | - | - | 121.4 | pcf | |
| Specific Gravity of the ($G_S$) | 2.72 | 2.72 | 2.72 | | Assumed conservative |
| Unit Weight of Water ($g_W$) | - | - | 62.4 | pcf | |
| Saturated Unit Weight ($g_{SAT}$) | - | - | 124.1 | pcf | |
| Min. Friction Angle (f ) | 30.0 | 30.0 | 30.0 | deg | Assumed (conservative for sandy cover) |
| Min. Cohesion (c) | 0.0 | 0.0 | 0.0 | psf | Assumed (conservative for sandy cover) |
| Slope Angle Beneath the Geom. (b) | - | - | 14.0 | degrees | Design |
| Ht. of Slp. Meas. Along Geom. ($H_L$) | - | - | 22.06 | ft | Design |
| Lng. of Slp. Meas. Along Geom. (L) | - | - | 91.0 | ft | |
| Depth of Water in DL ($h_W$) | - | - | 0.07 | ft | Max. thickness of DL (conservative) |
| Inter. Frict. Angle for GCL & Int. Cover (d) | - | - | 28.9 | deg | Resid. shear strength parameters from interface shear testing |
| Adhesion for GCL & Int. Cover ($c_a$) | - | - | 2.0 | psf | |
| Required Factor of Safety ($FS_R$) | - | - | 1.10 | | Min. req. FS for temporary conditions |

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|---|---|---|---|---|---|
| | | SHT NO | 4 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Active Wedge Calculations

Determine the total weight of the active wedge ($W_A$), resultant of the pore pressures acting on the interwedge surfaces ($U_h$), resultant of the pore pressures acting perpendicular to the slope ($U_n$), the effective force normal to the failure plan of the active wedge ($N_A$), and the interwedge force acting on the active wedge from the passive wedge ($E_A$) using the following eqs:

$$W_A = \frac{\gamma_D (h - h_W)[2H\cos\beta - (h + h_W)]}{\sin 2\beta} + \frac{\gamma_{SAT}(h_W)(2H\cos\beta - h_W)}{\sin 2\beta} = 17{,}084 \text{ lbs}$$

$$U_h = \frac{\gamma_w h_W^2}{2} = 0.15 \text{ lbs}$$

$$U_n = \frac{\gamma_w (h_w)(\cos\beta)(2H\cos\beta - h_w)}{\sin 2\beta} = 385 \text{ lbs}$$

$$N_A = W_A \cos\beta + U_h \sin\beta - U_n = 16{,}189 \text{ lbs}$$

$$E_A = W_A \sin\beta - U_h \cos\beta - \frac{N_A \sin\delta}{(FS)} = (2{,}971) \text{ lbs}$$

Passive Wedge Calculations

Determine the total weight of the passive wedge ($W_P$), resultant of the vertical pore pressures acting on the passive wedge ($U_V$), and the interwedge force acting on the pass wedge from the active wedge ($E_P$) using the following eqs:

$$W_P = \frac{\gamma_D (h^2 - h_w^2) + \gamma_{SAT} h_w^2}{\sin 2\beta} = 829.4 \text{ lbs}$$

$$U_V = U_h \cot\beta = 0.6 \text{ lbs}$$

$$E_P = \frac{U_h (FS) - (W_P - U_V \tan\phi)}{\sin\beta \tan\phi - \cos\beta (FS)} = 894 \text{ lbs}$$

## Static Factor of Safety w/ Seepage Forces

Determine the calculated Factor of Safety ($FS_A$) using a quadratic equation relationship where the constants are defined as follows:

$$a = W_A \sin\beta \cos\beta - U_h \cos^2\beta + U_h = 4{,}018 \text{ lbs/ft}$$

$$b = -W_A \sin^2\beta \tan\phi + U_h \sin\beta \cos\beta \tan\phi - N_A \cos\beta \tan\delta - (W_P - U_V)\tan\phi = (9{,}728.5) \text{ lbs/ft}$$

$$c = N_A \sin\beta \tan\delta \tan\phi = 1{,}251 \text{ lbs/ft}$$

| Allow Exceeds Req'd - OK | | |
|---|---|---|
| $FS_R$ = | 1.10 | |
| $FS_A$ = | 2.28 | |
| Min. Peak $\phi$ | 28.9 | deg |
| Min. Peak $c_a$ | 2.0 | psf |

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| | | SHT NO | 5 | OF | 9 |
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| | | SCALE | NA | | |

Determine: Static factor of safety for cover system based on additional equipment loads.

Procedure:

Determine the static stability of the veneer cover system to determine the minimum required interface friction angle for all engineered components of the cover system. Balance the forces as shown in Figure 1 and the required factor of safety (FS) then solve for minimum interface shear strength parameters. Account for equipment loads ($W_b$) as final cover is placed as noted in Figure 3.

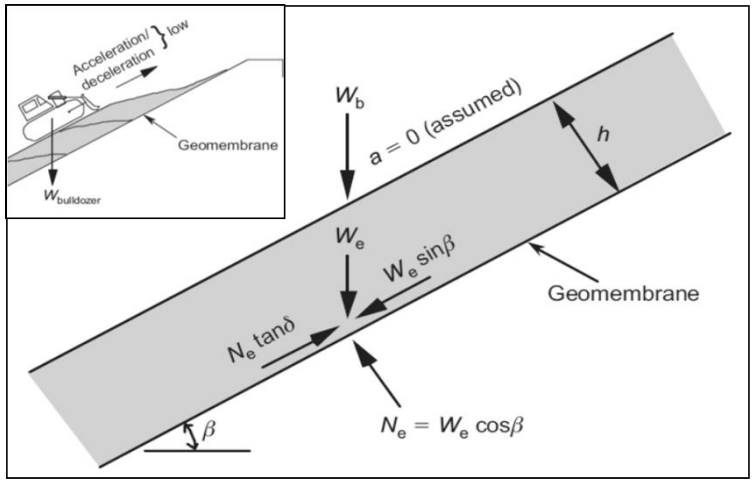


Figure 3. Additional load due to construction equipment moving on cover soil.

Assumptions:

In addition to the static case assumptions:
1. The equipment pushes material up slope leaving a toe buttress behind.
2. The equipment accelerates slowly with no sudden starts or turns to minimize additional loads besides the weight of the machine.

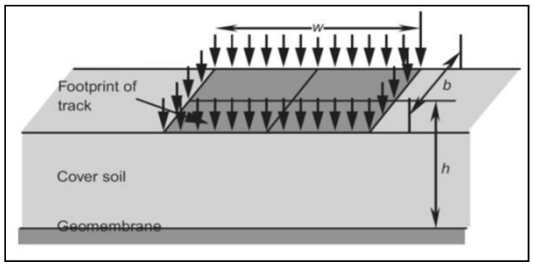


Figure 4. Illustration of stress distribution from overlying equipment.

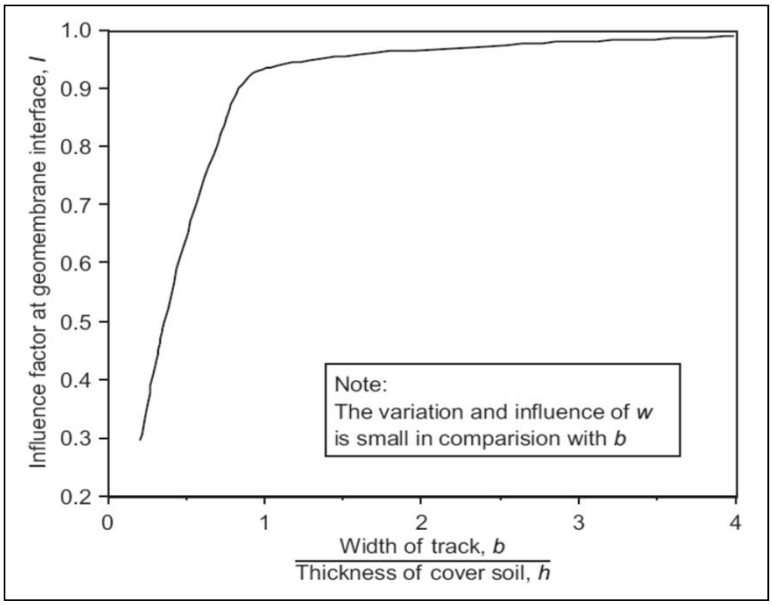


Figure 5. Values of influence factor I to dissipate surface force through cover soil to geomembrane interface (after Poulos and Davis 1974)

Equipment Parameters

| | | | Source |
|---|---|---|---|
| Equiv. Equipment Load per Unit Width ($W_e$) | 14939 | lbs | $W_e = qwl$ |
| Influence Factor at the Geom. Interface (I) | 0.95 | | See Figure 5 above. |
| Track Width to Cover Soil Thickness Ratio (b/h) | 1.40 | | |
| Distributed Equipment Load (q) | 1492 | psf | $q = W_b/(2 \times w \times b)$ |
| Weight of Equipment ($W_b$) | 87,733 | lbs | Typical weight of CAT D8 dozer |
| Length of Equipment Track (w) | 10.50 | ft | Typical track dimensions of CAT D8 dozer |
| Width of Equipment Track (b) | 2.80 | ft | |

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| | | SHT NO | 6 | OF | 9 |
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| | | SCALE | NA | | |

Veg. Cover Soil (VC)/Prot. Cover Soil (CS) and Slope Parameters

| | VC | CS | Utilized | | Source |
|---|---|---|---|---|---|
| Thickness (h) | 0.5 | 1.5 | 2.0 | ft | Design |
| Dry Unit Weight ($g_D$) | 90.0 | 100.0 | 97.5 | pcf | Conservatively assumed based on lab tests |
| Mois. Cont. (field cond.) ($w_F$) | 26.0 | 24.0 | 24.5 | % | Conservatively assumed based on lab tests |
| Avg Field Unit Wt (g) | - | - | 121.4 | pcf | |
| Min. Friction Angle (f ) | 30.0 | 30.0 | 30.0 | deg | Assumed (conservative for sandy cover) |
| Min. Cohesion (c) | 0.0 | 0.0 | 0.0 | psf | Assumed (conservative for sandy cover) |
| Slope Angle Beneath the Geom. (b) | - | - | 14.0 | deg | Design |
| Ht. of Slp. Meas. Along Geom. ($H_L$) | - | - | 22.06 | ft | Design |
| Lng. of Slp. Meas. Along Geom. (L) | - | - | 91.00 | ft | |
| Inter. Frict. Angle for GCL & Int. Cover (d) | - | - | 28.9 | deg | Resid. shear strength parameters from interface shear testing |
| Adhesion for GCL & Int. Cover ($c_a$) | - | - | 2.0 | psf | |
| Required Factor of Safety ($FS_R$) | - | - | 1.25 | | Min. req. FS for temporary conditions |

Active Wedge Calculations

Determine the total weight of the active wedge ($W_A$),the effective force normal to the failure plan of the active wedge ($N_A$), the adhesive force between the cover soil of the active wedge and the geomembrane ($C_a$), and the interwedge force acting on the active wedge from the passive wedge ($E_A$) using the following eqs:

$$W_A = \gamma h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right) + W_e$$ = 34,967 lbs

$$N_A = W_A \cos\beta$$ = 33,924 lbs

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right)$$ = 165 lbs

$$E_A = \frac{(FS)(W_A - N_A\cos\beta) - (N_A\tan\delta + C_a)\sin\beta}{\sin\beta(FS)}$$ = (6,637) lbs

Passive Wedge Calculations

Determine the total weight of the passive wedge ($W_P$),the effective force normal to the failure plan of the passive wedge ($N_P$), the cohesive force along the failure plane (C), and the interwedge force acting on the passive wedge from the active wedge ($E_P$) using the following eqs:

$$W_P = \frac{\gamma h^2}{\sin 2\beta}$$ = 1,032 lbs

$$C = \frac{ch}{\sin\beta}$$ = - lbs

$$E_P = \frac{C + W_P\tan\phi}{\cos\beta(FS) - \sin\beta\tan\phi}$$ = 556 lbs

$$N_P = W_P + E_P\sin\beta$$ = 1,167 lbs

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| Tel. (330) 836-9111 | Salzburg Landfill Cells 20-22 | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

## Static Factor of Safety w/ Equipment Load

Determine the calculated Factor of Safety ($FS_A$) using a quadratic equation relationship where the constants are defined as follows:

$$a = (W_A - N_A \cos\beta)\cos\beta \quad = \quad 1{,}994 \text{ lbs/ft}$$

$$b = -\begin{bmatrix} (W_A - N_A \cos\beta)\sin\beta\tan\phi \\ +(N_A \tan\delta + C_a)\sin\beta\cos\beta \\ +\sin\beta(C + W_P \tan\phi) \end{bmatrix} \quad = \quad (4{,}876) \text{ lbs/ft}$$

$$c = (N_A \tan\delta + C_a)\sin^2\beta\tan\phi \quad = \quad 641 \text{ lbs/ft}$$

| Allow Exceeds Req'd - OK | | |
|---|---|---|
| $FS_R$ = | 1.25 | |
| $FS_A$ = | 2.31 | |
| Min. Peak d | 28.9 | deg |
| Min. Peak $c_a$ | 2.0 | psf |

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|---|---|---|---|---|---|
| | | SHT NO | 8 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Determine: Static factor of safety for cover system based on additional seismic loads.

Procedure:

Determine the static stability of the veneer cover system to determine critical factor of safety for all engineered components of the cover system. Balance the forces as shown in Figure 1 and compare to the required factor of safety (FS). Account for seismic loads ($C_S$) as noted in Figure 6.

Assumptions:

In addition to the static case assumptions:
1. Seismic force acts on the centroid of the cover soil.
2. Seismic force is horizontal.
3. Deformation analysis not required.

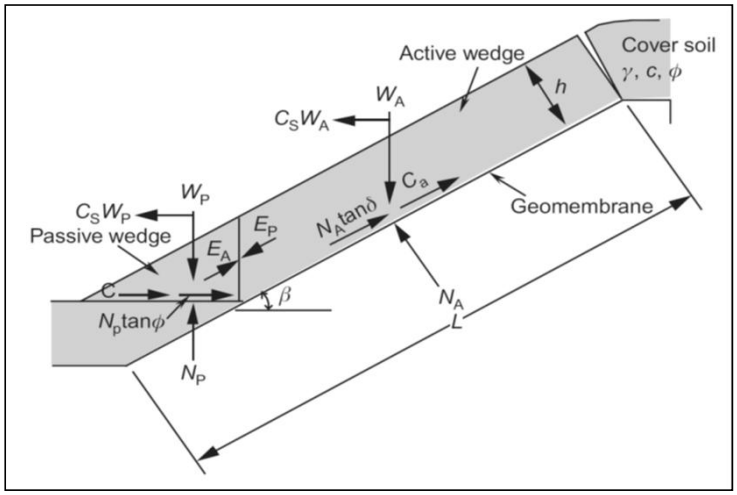


Figure 6. Limit equilibrium forces involved in pseudo-static analysis using average seismic coefficient.

| Veg. Cover Soil (VC)/Prot. Cover Soil (CS) and Slope Parameters | VC | CS | Utilized | | Source |
|---|---|---|---|---|---|
| Thickness (h) | 0.5 | 1.5 | 2.0 | ft | Design |
| Dry Unit Weight ($g_D$) | 90.0 | 100.0 | 97.5 | pcf | Conservatively assumed based on lab tests |
| Mois. Cont. (field cond.) ($w_F$) | 26.0 | 24.0 | 24.5 | % | Conservatively assumed based on lab tests |
| Avg Field Unit Wt (g) | - | - | 121.4 | pcf | |
| Min. Friction Angle (f ) | 30.0 | 30.0 | 30.0 | deg | Assumed (conservative for sandy cover) |
| Min. Cohesion (c) | 0.0 | 0.0 | 0.0 | psf | Assumed (conservative for sandy cover) |
| Slope Angle Beneath the Geom. (b) | - | - | 14.0 | degrees | Design |
| Ht. of Slp. Meas. Along Geom. ($H_L$) | - | - | 22.06 | ft | Design |
| Lng. of Slp. Meas. Along Geom. (L) | - | - | 91.00 | ft | |
| Inter. Frict. Angle for GCL & Int. Cover (d) | - | - | 28.9 | deg | Min. req. shear strength parameters from static analysis |
| Adhesion for GCL & Int. Cover ($c_a$) | - | - | 2.0 | psf | |
| Seismic Coefficient ($C_S$ or $K_S$) | - | - | 0.040 | %g | PGA for 2% Exceedance in 50 Years |
| Required Factor of Safety ($FS_R$) | - | - | 1.00 | | Min. req. FS for seismic conditions |

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|---|---|---|---|---|---|
| | | SHT NO | 9 | OF | 9 |
| | | CALC BY | JAD | DATE | 3/29/16 |
| | | CHK BY | NSG | DATE | 3/30/16 |
| | | SCALE | NA | | |

Active Wedge Calculations

Determine the total weight of the active wedge ($W_A$),the effective force normal to the failure plan of the active wedge ($N_A$), the adhesive force between the cover soil of the active wedge and the geomembrane ($C_a$), and the interwedge force acting on the active wedge from the passive wedge ($E_A$) using the following eqs:

$$W_A = \gamma h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right)$$ = 20,028 lbs

$$N_A = W_A \cos\beta$$ = 19,430 lbs

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right)$$ = 165 lbs

$$E_A = \frac{(FS)(C_S W_A + N_A \sin\beta)}{(FS)\cos\beta} + \frac{(N_A \tan\delta + C_a)\cos\beta}{(FS)\cos\beta} =$$ 16,573 lbs

Passive Wedge Calculations

Determine the total weight of the passive wedge ($W_P$),the effective force normal to the failure plan of the passive wedge ($N_P$), the cohesive force along the failure plane (C), and the interwedge force acting on the passive wedge from the active wedge ($E_P$) using the following eqs:

$$W_P = \frac{\gamma h^2}{\sin 2\beta}$$ = 1,032 lbs

$$C = \frac{ch}{\sin\beta}$$ = - lbs

$$E_P = \frac{C + W_P \tan\phi - C_S W_P (FS)}{\cos\beta(FS) - \sin\beta\tan\phi}$$ = 668 lbs

$$N_P = W_P + E_P \sin\beta$$ = 1,194 lbs

## Seismic Factor of Safety

Determine the calculated Factor of Safety ($FS_A$) using a quadratic equation relationship where the constants are defined as follows:

$$a = (C_S W_A + N_A \sin\beta)\cos\beta + C_S W_P \cos\beta$$ = 5,411 lbs/ft

$$b = -\begin{bmatrix} (C_S W_A + N_A \sin\beta)\sin\beta\tan\phi \\ + (N_A \tan\delta + C_a)\cos^2\beta \\ + (C + W_P \tan\phi)\cos\beta \end{bmatrix}$$ = (11,601) lbs/ft

$$c = (N_A \tan\delta + C_a)\cos\beta\sin\beta\tan\phi$$ = 1479 lbs/ft

Allow Exceeds Req'd - OK

| | | |
|---|---|---|
| $FS_R$ = | 1.00 | |
| $FS_A$ = | 2.01 | |
| Min. Peak d | 28.9 | deg |
| Min. Peak $c_a$ | 2.0 | psf |

# ATTACHMENT F

## Appendix I – Infiltration Rate Through Protective Soil Layer Analysis

# APPENDIX I

## INFILTRATION RATE THROUGH PROTECTIVE SOIL COVER

# ENGINEERING COMPUTATION SHEET



| PROJECT / PROPOSAL NAME | PREPARED | CHECKED | PROJECT / PROPOSAL NUMBER |
|---|---|---|---|
| Dow Chemical<br>Salzburg Landfill<br>Cells 20 through 22 Final Cover | BY: JAD<br>DATE: 03/25/16 | BY: TR<br>DATE: 03/30/16 | 60440134 |

SUBJECT:

Determine the infiltration rate of the protective soil layer.

PURPOSE AND OBJECTIVE:

The following computations were performed to calculate the infiltration rate of the protective soil layer overlying the geosynthetic layers of the final cover system. The purpose is to determine whether the flow rate used as a basis for sizing geocomposite drainage layer, in addition to the analysis of veneer stability under seepage conditions, is driven by the infiltration of water from the 100-year storm event or the permeability of the protective layer soils. The simplified water balance method of determining the infiltration rate, as developed by Koerner and Daniel (1997) and presented in Chapter 27 of the Geotechnical and Geoenvironmental Engineering Handbook (Rowe, 2001) was used to determine the appropriate infiltration rate for sizing the geocomposite drainage layer and subsequent veneer stability calculation under seepage conditions.

DESIGN ASSUMPTIONS AND CONDITIONS:

1. The grades and elevations for the top of the foundation layer soils and the protective soil layer conform to the surfaces shown on the plan drawings.

2. The overlying protective soil layer is at field capacity and no additional storage capacity is available so infiltration water all passes through the soil column as percolation.

3. The protective soil layer will be comprised of soils from the Overburden Stockpile within the SLF site which is identified as gray, lean clay with a Unified Soil Classification System classification of CL. The approximate permeability of the protective soil layer is conservatively determined by increasing the average of the two highest laboratory remolded permeability test results of the soil to be used by two orders of magnitude to account for lower compactive effort and freeze/thaw effects. This permeability is estimated to be $5.5 \times 10^{-5}$ cm/sec.

# ENGINEERING COMPUTATION SHEET



| PROJECT / PROPOSAL NAME | PREPARED | CHECKED | PROJECT / PROPOSAL NUMBER |
|---|---|---|---|
| Dow Chemical<br>Salzburg Landfill<br>Cells 20 through 22 Final Cover | BY: JAD<br>DATE: 03/25/16 | BY: TR<br>DATE: 03/30/16 | 60440134 |

METHODOLOGY:

In order to properly size the geocomposite drainage layer the infiltration rate through the protective soil layer must be determined. This will be calculated using the simplified manual method using the following equation:

$$PERC^0 = P - R = P(1 - C)$$

Where,
$PERC^0$ = infiltration rate (cm/sec)
P = precipitation (cm/sec)
R = runoff (cm/sec)
C = runoff coefficient

For this case the 100-year storm event was used for Midland, Michigan with a time of concentration of 15 minutes which corresponds to storm intensity of 4.76 inches/hour. This was based on the Michigan Department of Transportation Drainage Manual, Appendix B, provided as Attachment B.

The runoff coefficient used for this analysis was based on final land cover as determined in the hydraulic analysis found in Appendix G of the Basis of Design report. The runoff coefficient varied from 0.46 to 0.55. Therefore, the runoff coefficient was conservatively estimated to be 0.46.

The above formula only applies to the condition where the protective soil layer has sufficient permeability to accept the infiltration. In the case of the SLF, the permeability rate of the protective soil layer was conservatively estimated to be $5.5 \times 10^{-5}$ cm/sec. This was based on actual laboratory remolded permeability tests performed on representative samples of the Overburden Stockpile, the source for the protective soil layer. A total of five samples of the soil were analyzed for remolded hydraulic conductivity. Of those five, the two highest permeability results were averaged which produced a result of $5.5 \times 10^{-7}$ cm/sec. The average was then increased by two orders of magnitude to reflect lower compactive effort as well as impacts from freeze/thaw. The laboratory results are provided as Attachment C.

# ENGINEERING COMPUTATION SHEET



| PROJECT / PROPOSAL NAME | PREPARED | CHECKED | PROJECT / PROPOSAL NUMBER |
|---|---|---|---|
| Dow Chemical<br>Salzburg Landfill<br>Cells 20 through 22 Final Cover | BY: JAD<br>DATE: 03/25/16 | BY: TR<br>DATE: 03/30/16 | 60440134 |

COMPUTATIONS:

The computations are performed on the attached spreadsheets provided as Attachment A.

CONCLUSIONS:

The attached calculations indicate that the computed infiltration rate is approximately $1.81 \times 10^{-3}$ cm/sec. However, the hydraulic conductivity of the protective soil layer is calculated to be $5.5 \times 10^{-5}$ cm/sec. Since hydraulic conductivity of the protective soil layer is less than the calculated infiltration rate, the hydraulic conductivity of the protective soil layer will control the rate of infiltration the geocomposite drainage layer will encounter. Therefore, the infiltration rate used to size the geocomposite drainage layer will be equal to the hydraulic conductivity of the protective soil layer.

REFERENCES:

(1) Rowe, R.K., 2001, "Geotechnical and Geoenvironmental Engineering Handbook".
(2) Michigan Department of Transportation, Tetra Tech MPS, 2008, "Drainage Manual".

# ATTACHMENT A

## Detailed Calculations

## INFILTRATION THROUGH COVER SOIL ANALYSIS

**Calculate the Infiltration Rate Through Cover Soils**

$PERC^o = P - R = P(1 - C)$ — Geotechnical and Geoenvironmental Engineering Handbook, Equation 27.8, Page 841

- where -

$PERC^o$ = infiltration rate through cover soil (cm/sec)
P = precipitation (cm/sec)
R = Runoff (cm/sec)
C = Runoff Coefficient

| | | | |
|---|---|---|---|
| P = | 4.76 | in/hour | MDOT Drainage Manual, Appendix B, Midland, MI = zone 6, 100-year storm event, page 3-B-20 |
| | 3.36E-03 | cm/sec | |
| C = | 0.46 | | Basis of Design Report, Appendix G-1, varies from 0.46 to 0.55 |
| $PERC^o$ = | 1.81E-03 | cm/sec | |

**Compare Calculated Infiltration Rate to Cover Soil Hydraulic Conductivity**

$k_{cs}$ = hydraulic conductivity of cover soil (cm/sec)

| | | | |
|---|---|---|---|
| | 5.50E-05 | cm/sec | Average of two highest remolded permeability results for overburden stockpile (USCS classification CL), increased by 2 orders of magnitude |
| P(1-C) = | 1.81E-03 | cm/sec | |
| $PERC^o$ = | lesser of Infiltration Rate or Hydraulic Conductivity of Cover Soil | cm/sec | Geotechnical and Geoenvironmental Engineering Handbook, Equations 27.9a and 27.9b, Page 841 |
| $PERC^o$ = | **5.50E-05** | **cm/sec** | |

REFERENCE:
Rowe, R.K., 2001, "Geotechnical and Geoenvironmental Engineering Handbook".
Michigan Department of Transportation, Tetra Tech MPS, 2008, "Drainage Manual".

# ATTACHMENT B

## MDOT Drainage Manual, Appendix B

# Appendix 3-B

# MDOT Rainfall Tables

**Rainfall Frequency Zones**

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.1 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 1 | | | Zone 2 | | | Zone 3 | | | Zone 4 | | | Zone 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 10.0 | 3.85 | 4.86 | 5.28 | 3.67 | 4.63 | 5.04 | 3.95 | 4.99 | 5.40 | 3.86 | 4.87 | 5.28 | 4.24 | 5.34 | 5.82 |
| 10.1 | 3.83 | 4.84 | 5.25 | 3.65 | 4.61 | 5.02 | 3.93 | 4.96 | 5.37 | 3.84 | 4.85 | 5.25 | 4.21 | 5.32 | 5.79 |
| 10.2 | 3.81 | 4.81 | 5.23 | 3.63 | 4.59 | 4.99 | 3.91 | 4.94 | 5.35 | 3.82 | 4.82 | 5.23 | 4.19 | 5.29 | 5.76 |
| 10.3 | 3.79 | 4.79 | 5.20 | 3.62 | 4.56 | 4.97 | 3.89 | 4.91 | 5.32 | 3.80 | 4.80 | 5.20 | 4.17 | 5.26 | 5.74 |
| 10.4 | 3.78 | 4.77 | 5.18 | 3.60 | 4.54 | 4.94 | 3.87 | 4.89 | 5.30 | 3.78 | 4.78 | 5.18 | 4.15 | 5.24 | 5.71 |
| 10.5 | 3.76 | 4.74 | 5.15 | 3.58 | 4.52 | 4.92 | 3.85 | 4.87 | 5.27 | 3.76 | 4.75 | 5.15 | 4.13 | 5.21 | 5.68 |
| 10.6 | 3.74 | 4.72 | 5.13 | 3.56 | 4.50 | 4.90 | 3.83 | 4.84 | 5.25 | 3.74 | 4.73 | 5.13 | 4.11 | 5.19 | 5.65 |
| 10.7 | 3.72 | 4.70 | 5.11 | 3.54 | 4.48 | 4.87 | 3.81 | 4.82 | 5.23 | 3.73 | 4.71 | 5.11 | 4.09 | 5.16 | 5.63 |
| 10.8 | 3.70 | 4.68 | 5.08 | 3.53 | 4.46 | 4.85 | 3.80 | 4.80 | 5.20 | 3.71 | 4.69 | 5.08 | 4.07 | 5.14 | 5.60 |
| 10.9 | 3.68 | 4.66 | 5.06 | 3.51 | 4.44 | 4.83 | 3.78 | 4.78 | 5.18 | 3.69 | 4.66 | 5.06 | 4.05 | 5.12 | 5.58 |
| 11.0 | 3.66 | 4.63 | 5.04 | 3.49 | 4.42 | 4.81 | 3.76 | 4.75 | 5.16 | 3.67 | 4.64 | 5.04 | 4.03 | 5.09 | 5.55 |
| 11.1 | 3.65 | 4.61 | 5.01 | 3.47 | 4.40 | 4.79 | 3.74 | 4.73 | 5.13 | 3.65 | 4.62 | 5.01 | 4.01 | 5.07 | 5.53 |
| 11.2 | 3.63 | 4.59 | 4.99 | 3.46 | 4.38 | 4.76 | 3.72 | 4.71 | 5.11 | 3.64 | 4.60 | 4.99 | 3.99 | 5.05 | 5.50 |
| 11.3 | 3.61 | 4.57 | 4.97 | 3.44 | 4.36 | 4.74 | 3.71 | 4.69 | 5.09 | 3.62 | 4.58 | 4.97 | 3.97 | 5.03 | 5.48 |
| 11.4 | 3.60 | 4.55 | 4.95 | 3.43 | 4.34 | 4.72 | 3.69 | 4.67 | 5.07 | 3.60 | 4.56 | 4.95 | 3.95 | 5.00 | 5.45 |
| 11.5 | 3.58 | 4.53 | 4.93 | 3.41 | 4.32 | 4.70 | 3.67 | 4.65 | 5.05 | 3.59 | 4.54 | 4.93 | 3.93 | 4.98 | 5.43 |
| 11.6 | 3.56 | 4.51 | 4.91 | 3.39 | 4.30 | 4.68 | 3.65 | 4.63 | 5.03 | 3.57 | 4.52 | 4.91 | 3.92 | 4.96 | 5.41 |
| 11.7 | 3.55 | 4.49 | 4.89 | 3.38 | 4.28 | 4.66 | 3.64 | 4.61 | 5.01 | 3.55 | 4.50 | 4.89 | 3.90 | 4.94 | 5.38 |
| 11.8 | 3.53 | 4.47 | 4.86 | 3.36 | 4.26 | 4.64 | 3.62 | 4.59 | 4.99 | 3.54 | 4.48 | 4.86 | 3.88 | 4.92 | 5.36 |
| 11.9 | 3.51 | 4.46 | 4.84 | 3.35 | 4.24 | 4.62 | 3.61 | 4.57 | 4.97 | 3.52 | 4.46 | 4.84 | 3.86 | 4.90 | 5.34 |
| 12.0 | 3.50 | 4.44 | 4.82 | 3.33 | 4.23 | 4.60 | 3.59 | 4.55 | 4.95 | 3.51 | 4.44 | 4.82 | 3.85 | 4.88 | 5.32 |
| 12.1 | 3.48 | 4.42 | 4.80 | 3.32 | 4.21 | 4.58 | 3.57 | 4.53 | 4.93 | 3.49 | 4.43 | 4.80 | 3.83 | 4.86 | 5.30 |
| 12.2 | 3.47 | 4.40 | 4.79 | 3.30 | 4.19 | 4.57 | 3.56 | 4.51 | 4.91 | 3.47 | 4.41 | 4.79 | 3.81 | 4.84 | 5.27 |
| 12.3 | 3.45 | 4.38 | 4.77 | 3.29 | 4.17 | 4.55 | 3.54 | 4.50 | 4.89 | 3.46 | 4.39 | 4.77 | 3.80 | 4.82 | 5.25 |
| 12.4 | 3.44 | 4.36 | 4.75 | 3.28 | 4.16 | 4.53 | 3.53 | 4.48 | 4.87 | 3.44 | 4.37 | 4.75 | 3.78 | 4.80 | 5.23 |
| 12.5 | 3.42 | 4.35 | 4.73 | 3.26 | 4.14 | 4.51 | 3.51 | 4.46 | 4.85 | 3.43 | 4.35 | 4.73 | 3.76 | 4.78 | 5.21 |
| 12.6 | 3.41 | 4.33 | 4.71 | 3.25 | 4.12 | 4.49 | 3.50 | 4.44 | 4.83 | 3.42 | 4.34 | 4.71 | 3.75 | 4.76 | 5.19 |
| 12.7 | 3.40 | 4.31 | 4.69 | 3.23 | 4.11 | 4.48 | 3.48 | 4.42 | 4.81 | 3.40 | 4.32 | 4.69 | 3.73 | 4.74 | 5.17 |
| 12.8 | 3.38 | 4.30 | 4.67 | 3.22 | 4.09 | 4.46 | 3.47 | 4.41 | 4.79 | 3.39 | 4.30 | 4.67 | 3.72 | 4.72 | 5.15 |
| 12.9 | 3.37 | 4.28 | 4.65 | 3.21 | 4.08 | 4.44 | 3.45 | 4.39 | 4.78 | 3.37 | 4.29 | 4.65 | 3.70 | 4.70 | 5.13 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.1 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 1 | | | Zone 2 | | | Zone 3 | | | Zone 4 | | | Zone 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 13.0 | 3.35 | 4.26 | 4.64 | 3.19 | 4.06 | 4.42 | 3.44 | 4.37 | 4.76 | 3.36 | 4.27 | 4.64 | 3.69 | 4.68 | 5.11 |
| 13.1 | 3.34 | 4.25 | 4.62 | 3.18 | 4.04 | 4.41 | 3.43 | 4.36 | 4.74 | 3.35 | 4.25 | 4.62 | 3.67 | 4.67 | 5.09 |
| 13.2 | 3.33 | 4.23 | 4.60 | 3.17 | 4.03 | 4.39 | 3.41 | 4.34 | 4.72 | 3.33 | 4.24 | 4.60 | 3.66 | 4.65 | 5.07 |
| 13.3 | 3.31 | 4.21 | 4.58 | 3.16 | 4.01 | 4.37 | 3.40 | 4.32 | 4.71 | 3.32 | 4.22 | 4.58 | 3.64 | 4.63 | 5.05 |
| 13.4 | 3.30 | 4.20 | 4.57 | 3.14 | 4.00 | 4.36 | 3.39 | 4.31 | 4.69 | 3.31 | 4.20 | 4.57 | 3.63 | 4.61 | 5.03 |
| 13.5 | 3.29 | 4.18 | 4.55 | 3.13 | 3.98 | 4.34 | 3.37 | 4.29 | 4.67 | 3.29 | 4.19 | 4.55 | 3.61 | 4.60 | 5.02 |
| 13.6 | 3.27 | 4.17 | 4.53 | 3.12 | 3.97 | 4.33 | 3.36 | 4.28 | 4.66 | 3.28 | 4.17 | 4.53 | 3.60 | 4.58 | 5.00 |
| 13.7 | 3.26 | 4.15 | 4.52 | 3.11 | 3.95 | 4.31 | 3.35 | 4.26 | 4.64 | 3.27 | 4.16 | 4.52 | 3.58 | 4.56 | 4.98 |
| 13.8 | 3.25 | 4.14 | 4.50 | 3.10 | 3.94 | 4.29 | 3.33 | 4.24 | 4.62 | 3.25 | 4.14 | 4.50 | 3.57 | 4.55 | 4.96 |
| 13.9 | 3.24 | 4.12 | 4.49 | 3.08 | 3.93 | 4.28 | 3.32 | 4.23 | 4.61 | 3.24 | 4.13 | 4.49 | 3.56 | 4.53 | 4.94 |
| 14.0 | 3.22 | 4.11 | 4.47 | 3.07 | 3.91 | 4.26 | 3.31 | 4.21 | 4.59 | 3.23 | 4.11 | 4.47 | 3.54 | 4.51 | 4.93 |
| 14.1 | 3.21 | 4.09 | 4.45 | 3.06 | 3.90 | 4.25 | 3.30 | 4.20 | 4.57 | 3.22 | 4.10 | 4.45 | 3.53 | 4.50 | 4.91 |
| 14.2 | 3.20 | 4.08 | 4.44 | 3.05 | 3.88 | 4.23 | 3.28 | 4.18 | 4.56 | 3.21 | 4.08 | 4.44 | 3.52 | 4.48 | 4.89 |
| 14.3 | 3.19 | 4.06 | 4.42 | 3.04 | 3.87 | 4.22 | 3.27 | 4.17 | 4.54 | 3.19 | 4.07 | 4.42 | 3.50 | 4.46 | 4.87 |
| 14.4 | 3.18 | 4.05 | 4.41 | 3.03 | 3.86 | 4.20 | 3.26 | 4.15 | 4.53 | 3.18 | 4.06 | 4.41 | 3.49 | 4.45 | 4.86 |
| 14.5 | 3.16 | 4.03 | 4.39 | 3.01 | 3.84 | 4.19 | 3.25 | 4.14 | 4.51 | 3.17 | 4.04 | 4.39 | 3.48 | 4.43 | 4.84 |
| 14.6 | 3.15 | 4.02 | 4.38 | 3.00 | 3.83 | 4.18 | 3.24 | 4.13 | 4.50 | 3.16 | 4.03 | 4.38 | 3.46 | 4.42 | 4.82 |
| 14.7 | 3.14 | 4.01 | 4.36 | 2.99 | 3.82 | 4.16 | 3.22 | 4.11 | 4.48 | 3.15 | 4.01 | 4.36 | 3.45 | 4.40 | 4.81 |
| 14.8 | 3.13 | 3.99 | 4.35 | 2.98 | 3.80 | 4.15 | 3.21 | 4.10 | 4.47 | 3.14 | 4.00 | 4.35 | 3.44 | 4.39 | 4.79 |
| 14.9 | 3.12 | 3.98 | 4.33 | 2.97 | 3.79 | 4.13 | 3.20 | 4.08 | 4.45 | 3.12 | 3.99 | 4.33 | 3.43 | 4.37 | 4.78 |
| 15.0 | 3.11 | 3.97 | 4.32 | 2.96 | 3.78 | 4.12 | 3.19 | 4.07 | 4.44 | 3.11 | 3.97 | 4.32 | 3.42 | 4.36 | 4.76 |
| 15.1 | 3.10 | 3.95 | 4.31 | 2.95 | 3.77 | 4.11 | 3.18 | 4.06 | 4.43 | 3.10 | 3.96 | 4.31 | 3.40 | 4.34 | 4.74 |
| 15.2 | 3.09 | 3.94 | 4.29 | 2.94 | 3.75 | 4.09 | 3.17 | 4.04 | 4.41 | 3.09 | 3.95 | 4.29 | 3.39 | 4.33 | 4.73 |
| 15.3 | 3.08 | 3.93 | 4.28 | 2.93 | 3.74 | 4.08 | 3.16 | 4.03 | 4.40 | 3.08 | 3.93 | 4.28 | 3.38 | 4.32 | 4.71 |
| 15.4 | 3.07 | 3.91 | 4.26 | 2.92 | 3.73 | 4.07 | 3.15 | 4.02 | 4.38 | 3.07 | 3.92 | 4.26 | 3.37 | 4.30 | 4.70 |
| 15.5 | 3.05 | 3.90 | 4.25 | 2.91 | 3.72 | 4.05 | 3.13 | 4.00 | 4.37 | 3.06 | 3.91 | 4.25 | 3.36 | 4.29 | 4.68 |
| 15.6 | 3.04 | 3.89 | 4.24 | 2.90 | 3.71 | 4.04 | 3.12 | 3.99 | 4.36 | 3.05 | 3.90 | 4.24 | 3.35 | 4.27 | 4.67 |
| 15.7 | 3.03 | 3.88 | 4.22 | 2.89 | 3.69 | 4.03 | 3.11 | 3.98 | 4.34 | 3.04 | 3.88 | 4.22 | 3.33 | 4.26 | 4.65 |
| 15.8 | 3.02 | 3.87 | 4.21 | 2.88 | 3.68 | 4.02 | 3.10 | 3.97 | 4.33 | 3.03 | 3.87 | 4.21 | 3.32 | 4.25 | 4.64 |
| 15.9 | 3.01 | 3.85 | 4.20 | 2.87 | 3.67 | 4.00 | 3.09 | 3.95 | 4.31 | 3.02 | 3.86 | 4.20 | 3.31 | 4.23 | 4.62 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.1 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 1 | | | Zone 2 | | | Zone 3 | | | Zone 4 | | | Zone 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 16.0 | 3.00 | 3.84 | 4.19 | 2.86 | 3.66 | 3.99 | 3.08 | 3.94 | 4.30 | 3.01 | 3.85 | 4.19 | 3.30 | 4.22 | 4.61 |
| 16.1 | 2.99 | 3.83 | 4.17 | 2.85 | 3.65 | 3.98 | 3.07 | 3.93 | 4.29 | 3.00 | 3.83 | 4.17 | 3.29 | 4.21 | 4.60 |
| 16.2 | 2.98 | 3.82 | 4.16 | 2.84 | 3.64 | 3.97 | 3.06 | 3.92 | 4.28 | 2.99 | 3.82 | 4.16 | 3.28 | 4.19 | 4.58 |
| 16.3 | 2.97 | 3.81 | 4.15 | 2.83 | 3.62 | 3.95 | 3.05 | 3.90 | 4.26 | 2.98 | 3.81 | 4.15 | 3.27 | 4.18 | 4.57 |
| 16.4 | 2.97 | 3.79 | 4.14 | 2.82 | 3.61 | 3.94 | 3.04 | 3.89 | 4.25 | 2.97 | 3.80 | 4.14 | 3.26 | 4.17 | 4.55 |
| 16.5 | 2.96 | 3.78 | 4.12 | 2.82 | 3.60 | 3.93 | 3.03 | 3.88 | 4.24 | 2.96 | 3.79 | 4.12 | 3.25 | 4.16 | 4.54 |
| 16.6 | 2.95 | 3.77 | 4.11 | 2.81 | 3.59 | 3.92 | 3.02 | 3.87 | 4.22 | 2.95 | 3.78 | 4.11 | 3.24 | 4.14 | 4.53 |
| 16.7 | 2.94 | 3.76 | 4.10 | 2.80 | 3.58 | 3.91 | 3.01 | 3.86 | 4.21 | 2.94 | 3.77 | 4.10 | 3.23 | 4.13 | 4.51 |
| 16.8 | 2.93 | 3.75 | 4.09 | 2.79 | 3.57 | 3.89 | 3.00 | 3.85 | 4.20 | 2.93 | 3.75 | 4.09 | 3.22 | 4.12 | 4.50 |
| 16.9 | 2.92 | 3.74 | 4.08 | 2.78 | 3.56 | 3.88 | 2.99 | 3.83 | 4.19 | 2.92 | 3.74 | 4.08 | 3.21 | 4.11 | 4.49 |
| 17.0 | 2.91 | 3.73 | 4.06 | 2.77 | 3.55 | 3.87 | 2.98 | 3.82 | 4.18 | 2.91 | 3.73 | 4.06 | 3.20 | 4.09 | 4.47 |
| 17.1 | 2.90 | 3.72 | 4.05 | 2.76 | 3.54 | 3.86 | 2.98 | 3.81 | 4.16 | 2.90 | 3.72 | 4.05 | 3.19 | 4.08 | 4.46 |
| 17.2 | 2.89 | 3.70 | 4.04 | 2.75 | 3.53 | 3.85 | 2.97 | 3.80 | 4.15 | 2.90 | 3.71 | 4.04 | 3.18 | 4.07 | 4.45 |
| 17.3 | 2.88 | 3.69 | 4.03 | 2.75 | 3.52 | 3.84 | 2.96 | 3.79 | 4.14 | 2.89 | 3.70 | 4.03 | 3.17 | 4.06 | 4.44 |
| 17.4 | 2.87 | 3.68 | 4.02 | 2.74 | 3.51 | 3.83 | 2.95 | 3.78 | 4.13 | 2.88 | 3.69 | 4.02 | 3.16 | 4.05 | 4.42 |
| 17.5 | 2.87 | 3.67 | 4.01 | 2.73 | 3.50 | 3.82 | 2.94 | 3.77 | 4.12 | 2.87 | 3.68 | 4.01 | 3.15 | 4.04 | 4.41 |
| 17.6 | 2.86 | 3.66 | 4.00 | 2.72 | 3.49 | 3.81 | 2.93 | 3.76 | 4.11 | 2.86 | 3.67 | 4.00 | 3.14 | 4.02 | 4.40 |
| 17.7 | 2.85 | 3.65 | 3.98 | 2.71 | 3.48 | 3.79 | 2.92 | 3.75 | 4.09 | 2.85 | 3.66 | 3.98 | 3.13 | 4.01 | 4.39 |
| 17.8 | 2.84 | 3.64 | 3.97 | 2.70 | 3.47 | 3.78 | 2.91 | 3.73 | 4.08 | 2.84 | 3.65 | 3.97 | 3.12 | 4.00 | 4.37 |
| 17.9 | 2.83 | 3.63 | 3.96 | 2.70 | 3.46 | 3.77 | 2.90 | 3.72 | 4.07 | 2.84 | 3.64 | 3.96 | 3.11 | 3.99 | 4.36 |
| 18.0 | 2.82 | 3.62 | 3.95 | 2.69 | 3.45 | 3.76 | 2.90 | 3.71 | 4.06 | 2.83 | 3.63 | 3.95 | 3.10 | 3.98 | 4.35 |
| 18.1 | 2.81 | 3.61 | 3.94 | 2.68 | 3.44 | 3.75 | 2.89 | 3.70 | 4.05 | 2.82 | 3.62 | 3.94 | 3.09 | 3.97 | 4.34 |
| 18.2 | 2.81 | 3.60 | 3.93 | 2.67 | 3.43 | 3.74 | 2.88 | 3.69 | 4.04 | 2.81 | 3.61 | 3.93 | 3.08 | 3.96 | 4.33 |
| 18.3 | 2.80 | 3.59 | 3.92 | 2.67 | 3.42 | 3.73 | 2.87 | 3.68 | 4.03 | 2.80 | 3.60 | 3.92 | 3.07 | 3.95 | 4.31 |
| 18.4 | 2.79 | 3.58 | 3.91 | 2.66 | 3.41 | 3.72 | 2.86 | 3.67 | 4.02 | 2.79 | 3.59 | 3.91 | 3.07 | 3.94 | 4.30 |
| 18.5 | 2.78 | 3.57 | 3.90 | 2.65 | 3.40 | 3.71 | 2.85 | 3.66 | 4.01 | 2.79 | 3.58 | 3.90 | 3.06 | 3.93 | 4.29 |
| 18.6 | 2.77 | 3.56 | 3.89 | 2.64 | 3.39 | 3.70 | 2.85 | 3.65 | 4.00 | 2.78 | 3.57 | 3.89 | 3.05 | 3.91 | 4.28 |
| 18.7 | 2.77 | 3.55 | 3.88 | 2.63 | 3.38 | 3.69 | 2.84 | 3.64 | 3.98 | 2.77 | 3.56 | 3.88 | 3.04 | 3.90 | 4.27 |
| 18.8 | 2.76 | 3.54 | 3.87 | 2.63 | 3.37 | 3.68 | 2.83 | 3.63 | 3.97 | 2.76 | 3.55 | 3.87 | 3.03 | 3.89 | 4.26 |
| 18.9 | 2.75 | 3.53 | 3.86 | 2.62 | 3.37 | 3.67 | 2.82 | 3.62 | 3.96 | 2.76 | 3.54 | 3.86 | 3.02 | 3.88 | 4.25 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.1 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 1 | | | Zone 2 | | | Zone 3 | | | Zone 4 | | | Zone 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 19.0 | 2.74 | 3.53 | 3.85 | 2.61 | 3.36 | 3.66 | 2.81 | 3.61 | 3.95 | 2.75 | 3.53 | 3.85 | 3.01 | 3.87 | 4.24 |
| 19.1 | 2.74 | 3.52 | 3.84 | 2.61 | 3.35 | 3.65 | 2.81 | 3.60 | 3.94 | 2.74 | 3.52 | 3.84 | 3.01 | 3.86 | 4.22 |
| 19.2 | 2.73 | 3.51 | 3.83 | 2.60 | 3.34 | 3.64 | 2.80 | 3.60 | 3.93 | 2.73 | 3.51 | 3.83 | 3.00 | 3.85 | 4.21 |
| 19.3 | 2.72 | 3.50 | 3.82 | 2.59 | 3.33 | 3.64 | 2.79 | 3.59 | 3.92 | 2.72 | 3.50 | 3.82 | 2.99 | 3.84 | 4.20 |
| 19.4 | 2.71 | 3.49 | 3.81 | 2.58 | 3.32 | 3.63 | 2.78 | 3.58 | 3.91 | 2.72 | 3.49 | 3.81 | 2.98 | 3.83 | 4.19 |
| 19.5 | 2.71 | 3.48 | 3.80 | 2.58 | 3.31 | 3.62 | 2.77 | 3.57 | 3.90 | 2.71 | 3.48 | 3.80 | 2.97 | 3.82 | 4.18 |
| 19.6 | 2.70 | 3.47 | 3.79 | 2.57 | 3.30 | 3.61 | 2.77 | 3.56 | 3.89 | 2.70 | 3.48 | 3.79 | 2.97 | 3.81 | 4.17 |
| 19.7 | 2.69 | 3.46 | 3.78 | 2.56 | 3.30 | 3.60 | 2.76 | 3.55 | 3.88 | 2.70 | 3.47 | 3.78 | 2.96 | 3.80 | 4.16 |
| 19.8 | 2.68 | 3.45 | 3.77 | 2.56 | 3.29 | 3.59 | 2.75 | 3.54 | 3.87 | 2.69 | 3.46 | 3.77 | 2.95 | 3.79 | 4.15 |
| 19.9 | 2.68 | 3.44 | 3.76 | 2.55 | 3.28 | 3.58 | 2.75 | 3.53 | 3.87 | 2.68 | 3.45 | 3.76 | 2.94 | 3.78 | 4.14 |
| 20.0 | 2.67 | 3.44 | 3.75 | 2.54 | 3.27 | 3.57 | 2.74 | 3.52 | 3.86 | 2.67 | 3.44 | 3.75 | 2.93 | 3.77 | 4.13 |
| 20.1 | 2.66 | 3.43 | 3.74 | 2.54 | 3.26 | 3.56 | 2.73 | 3.51 | 3.85 | 2.67 | 3.43 | 3.74 | 2.93 | 3.77 | 4.12 |
| 20.2 | 2.66 | 3.42 | 3.74 | 2.53 | 3.26 | 3.55 | 2.72 | 3.50 | 3.84 | 2.66 | 3.42 | 3.74 | 2.92 | 3.76 | 4.11 |
| 20.3 | 2.65 | 3.41 | 3.73 | 2.52 | 3.25 | 3.55 | 2.72 | 3.50 | 3.83 | 2.65 | 3.41 | 3.73 | 2.91 | 3.75 | 4.10 |
| 20.4 | 2.64 | 3.40 | 3.72 | 2.52 | 3.24 | 3.54 | 2.71 | 3.49 | 3.82 | 2.65 | 3.41 | 3.72 | 2.90 | 3.74 | 4.09 |
| 20.5 | 2.64 | 3.39 | 3.71 | 2.51 | 3.23 | 3.53 | 2.70 | 3.48 | 3.81 | 2.64 | 3.40 | 3.71 | 2.90 | 3.73 | 4.08 |
| 20.6 | 2.63 | 3.39 | 3.70 | 2.50 | 3.22 | 3.52 | 2.70 | 3.47 | 3.80 | 2.63 | 3.39 | 3.70 | 2.89 | 3.72 | 4.07 |
| 20.7 | 2.62 | 3.38 | 3.69 | 2.50 | 3.22 | 3.51 | 2.69 | 3.46 | 3.79 | 2.63 | 3.38 | 3.69 | 2.88 | 3.71 | 4.06 |
| 20.8 | 2.62 | 3.37 | 3.68 | 2.49 | 3.21 | 3.50 | 2.68 | 3.45 | 3.78 | 2.62 | 3.37 | 3.68 | 2.87 | 3.70 | 4.05 |
| 20.9 | 2.61 | 3.36 | 3.67 | 2.48 | 3.20 | 3.49 | 2.67 | 3.45 | 3.77 | 2.61 | 3.37 | 3.67 | 2.87 | 3.69 | 4.04 |
| 21.0 | 2.60 | 3.35 | 3.67 | 2.48 | 3.19 | 3.49 | 2.67 | 3.44 | 3.76 | 2.61 | 3.36 | 3.67 | 2.86 | 3.68 | 4.03 |
| 21.1 | 2.60 | 3.35 | 3.66 | 2.47 | 3.18 | 3.48 | 2.66 | 3.43 | 3.76 | 2.60 | 3.35 | 3.66 | 2.85 | 3.68 | 4.02 |
| 21.2 | 2.59 | 3.34 | 3.65 | 2.47 | 3.18 | 3.47 | 2.65 | 3.42 | 3.75 | 2.59 | 3.34 | 3.65 | 2.85 | 3.67 | 4.01 |
| 21.3 | 2.58 | 3.33 | 3.64 | 2.46 | 3.17 | 3.46 | 2.65 | 3.41 | 3.74 | 2.59 | 3.33 | 3.64 | 2.84 | 3.66 | 4.00 |
| 21.4 | 2.58 | 3.32 | 3.63 | 2.45 | 3.16 | 3.45 | 2.64 | 3.40 | 3.73 | 2.58 | 3.33 | 3.63 | 2.83 | 3.65 | 3.99 |
| 21.5 | 2.57 | 3.31 | 3.62 | 2.45 | 3.16 | 3.45 | 2.63 | 3.40 | 3.72 | 2.57 | 3.32 | 3.62 | 2.82 | 3.64 | 3.98 |
| 21.6 | 2.56 | 3.31 | 3.62 | 2.44 | 3.15 | 3.44 | 2.63 | 3.39 | 3.71 | 2.57 | 3.31 | 3.62 | 2.82 | 3.63 | 3.98 |
| 21.7 | 2.56 | 3.30 | 3.61 | 2.44 | 3.14 | 3.43 | 2.62 | 3.38 | 3.70 | 2.56 | 3.30 | 3.61 | 2.81 | 3.62 | 3.97 |
| 21.8 | 2.55 | 3.29 | 3.60 | 2.43 | 3.13 | 3.42 | 2.62 | 3.37 | 3.70 | 2.55 | 3.30 | 3.60 | 2.80 | 3.62 | 3.96 |
| 21.9 | 2.55 | 3.28 | 3.59 | 2.42 | 3.13 | 3.41 | 2.61 | 3.37 | 3.69 | 2.55 | 3.29 | 3.59 | 2.80 | 3.61 | 3.95 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.1 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 1 | | | Zone 2 | | | Zone 3 | | | Zone 4 | | | Zone 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 22.0 | 2.54 | 3.28 | 3.58 | 2.42 | 3.12 | 3.41 | 2.60 | 3.36 | 3.68 | 2.54 | 3.28 | 3.58 | 2.79 | 3.60 | 3.94 |
| 22.1 | 2.53 | 3.27 | 3.58 | 2.41 | 3.11 | 3.40 | 2.60 | 3.35 | 3.67 | 2.54 | 3.27 | 3.58 | 2.78 | 3.59 | 3.93 |
| 22.2 | 2.53 | 3.26 | 3.57 | 2.41 | 3.10 | 3.39 | 2.59 | 3.34 | 3.66 | 2.53 | 3.27 | 3.57 | 2.78 | 3.58 | 3.92 |
| 22.3 | 2.52 | 3.25 | 3.56 | 2.40 | 3.10 | 3.38 | 2.58 | 3.33 | 3.66 | 2.52 | 3.26 | 3.56 | 2.77 | 3.57 | 3.91 |
| 22.4 | 2.52 | 3.25 | 3.55 | 2.39 | 3.09 | 3.38 | 2.58 | 3.33 | 3.65 | 2.52 | 3.25 | 3.55 | 2.76 | 3.57 | 3.90 |
| 22.5 | 2.51 | 3.24 | 3.54 | 2.39 | 3.08 | 3.37 | 2.57 | 3.32 | 3.64 | 2.51 | 3.24 | 3.54 | 2.76 | 3.56 | 3.90 |
| 22.6 | 2.50 | 3.23 | 3.54 | 2.38 | 3.08 | 3.36 | 2.57 | 3.31 | 3.63 | 2.51 | 3.24 | 3.54 | 2.75 | 3.55 | 3.89 |
| 22.7 | 2.50 | 3.23 | 3.53 | 2.38 | 3.07 | 3.35 | 2.56 | 3.31 | 3.62 | 2.50 | 3.23 | 3.53 | 2.74 | 3.54 | 3.88 |
| 22.8 | 2.49 | 3.22 | 3.52 | 2.37 | 3.06 | 3.35 | 2.55 | 3.30 | 3.62 | 2.49 | 3.22 | 3.52 | 2.74 | 3.54 | 3.87 |
| 22.9 | 2.49 | 3.21 | 3.51 | 2.37 | 3.06 | 3.34 | 2.55 | 3.29 | 3.61 | 2.49 | 3.21 | 3.51 | 2.73 | 3.53 | 3.86 |
| 23.0 | 2.48 | 3.20 | 3.51 | 2.36 | 3.05 | 3.33 | 2.54 | 3.28 | 3.60 | 2.48 | 3.21 | 3.51 | 2.73 | 3.52 | 3.85 |
| 23.1 | 2.48 | 3.20 | 3.50 | 2.36 | 3.04 | 3.32 | 2.54 | 3.28 | 3.59 | 2.48 | 3.20 | 3.50 | 2.72 | 3.51 | 3.85 |
| 23.2 | 2.47 | 3.19 | 3.49 | 2.35 | 3.04 | 3.32 | 2.53 | 3.27 | 3.58 | 2.47 | 3.19 | 3.49 | 2.71 | 3.50 | 3.84 |
| 23.3 | 2.46 | 3.18 | 3.48 | 2.35 | 3.03 | 3.31 | 2.52 | 3.26 | 3.58 | 2.47 | 3.19 | 3.48 | 2.71 | 3.50 | 3.83 |
| 23.4 | 2.46 | 3.18 | 3.48 | 2.34 | 3.02 | 3.30 | 2.52 | 3.26 | 3.57 | 2.46 | 3.18 | 3.48 | 2.70 | 3.49 | 3.82 |
| 23.5 | 2.45 | 3.17 | 3.47 | 2.33 | 3.02 | 3.30 | 2.51 | 3.25 | 3.56 | 2.46 | 3.17 | 3.47 | 2.69 | 3.48 | 3.81 |
| 23.6 | 2.45 | 3.16 | 3.46 | 2.33 | 3.01 | 3.29 | 2.51 | 3.24 | 3.55 | 2.45 | 3.17 | 3.46 | 2.69 | 3.48 | 3.81 |
| 23.7 | 2.44 | 3.16 | 3.46 | 2.32 | 3.00 | 3.28 | 2.50 | 3.23 | 3.55 | 2.44 | 3.16 | 3.46 | 2.68 | 3.47 | 3.80 |
| 23.8 | 2.44 | 3.15 | 3.45 | 2.32 | 3.00 | 3.28 | 2.50 | 3.23 | 3.54 | 2.44 | 3.15 | 3.45 | 2.68 | 3.46 | 3.79 |
| 23.9 | 2.43 | 3.14 | 3.44 | 2.31 | 2.99 | 3.27 | 2.49 | 3.22 | 3.53 | 2.43 | 3.15 | 3.44 | 2.67 | 3.45 | 3.78 |
| 24.0 | 2.43 | 3.14 | 3.43 | 2.31 | 2.99 | 3.26 | 2.49 | 3.21 | 3.53 | 2.43 | 3.14 | 3.43 | 2.66 | 3.45 | 3.77 |
| 24.1 | 2.42 | 3.13 | 3.43 | 2.30 | 2.98 | 3.26 | 2.48 | 3.21 | 3.52 | 2.42 | 3.13 | 3.43 | 2.66 | 3.44 | 3.77 |
| 24.2 | 2.42 | 3.12 | 3.42 | 2.30 | 2.97 | 3.25 | 2.47 | 3.20 | 3.51 | 2.42 | 3.13 | 3.42 | 2.65 | 3.43 | 3.76 |
| 24.3 | 2.41 | 3.12 | 3.41 | 2.29 | 2.97 | 3.24 | 2.47 | 3.19 | 3.50 | 2.41 | 3.12 | 3.41 | 2.65 | 3.42 | 3.75 |
| 24.4 | 2.40 | 3.11 | 3.41 | 2.29 | 2.96 | 3.24 | 2.46 | 3.19 | 3.50 | 2.41 | 3.11 | 3.41 | 2.64 | 3.42 | 3.74 |
| 24.5 | 2.40 | 3.11 | 3.40 | 2.28 | 2.96 | 3.23 | 2.46 | 3.18 | 3.49 | 2.40 | 3.11 | 3.40 | 2.64 | 3.41 | 3.74 |
| 24.6 | 2.39 | 3.10 | 3.39 | 2.28 | 2.95 | 3.22 | 2.45 | 3.17 | 3.48 | 2.40 | 3.10 | 3.39 | 2.63 | 3.40 | 3.73 |
| 24.7 | 2.39 | 3.09 | 3.39 | 2.27 | 2.94 | 3.22 | 2.45 | 3.17 | 3.48 | 2.39 | 3.10 | 3.39 | 2.62 | 3.40 | 3.72 |
| 24.8 | 2.38 | 3.09 | 3.38 | 2.27 | 2.94 | 3.21 | 2.44 | 3.16 | 3.47 | 2.39 | 3.09 | 3.38 | 2.62 | 3.39 | 3.71 |
| 24.9 | 2.38 | 3.08 | 3.37 | 2.26 | 2.93 | 3.20 | 2.44 | 3.16 | 3.46 | 2.38 | 3.08 | 3.37 | 2.61 | 3.38 | 3.71 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.1 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 1 | | | Zone 2 | | | Zone 3 | | | Zone 4 | | | Zone 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 25.0 | 2.37 | 3.07 | 3.37 | 2.26 | 2.93 | 3.20 | 2.43 | 3.15 | 3.46 | 2.38 | 3.08 | 3.37 | 2.61 | 3.38 | 3.70 |
| 25.1 | 2.37 | 3.07 | 3.36 | 2.25 | 2.92 | 3.19 | 2.43 | 3.14 | 3.45 | 2.37 | 3.07 | 3.36 | 2.60 | 3.37 | 3.69 |
| 25.2 | 2.36 | 3.06 | 3.35 | 2.25 | 2.91 | 3.18 | 2.42 | 3.14 | 3.44 | 2.37 | 3.06 | 3.35 | 2.60 | 3.36 | 3.68 |
| 25.3 | 2.36 | 3.06 | 3.35 | 2.25 | 2.91 | 3.18 | 2.42 | 3.13 | 3.44 | 2.36 | 3.06 | 3.35 | 2.59 | 3.36 | 3.68 |
| 25.4 | 2.35 | 3.05 | 3.34 | 2.24 | 2.90 | 3.17 | 2.41 | 3.12 | 3.43 | 2.36 | 3.05 | 3.34 | 2.59 | 3.35 | 3.67 |
| 25.5 | 2.35 | 3.04 | 3.33 | 2.24 | 2.90 | 3.17 | 2.41 | 3.12 | 3.42 | 2.35 | 3.05 | 3.33 | 2.58 | 3.34 | 3.66 |
| 25.6 | 2.34 | 3.04 | 3.33 | 2.23 | 2.89 | 3.16 | 2.40 | 3.11 | 3.42 | 2.35 | 3.04 | 3.33 | 2.58 | 3.34 | 3.66 |
| 25.7 | 2.34 | 3.03 | 3.32 | 2.23 | 2.89 | 3.15 | 2.40 | 3.11 | 3.41 | 2.34 | 3.03 | 3.32 | 2.57 | 3.33 | 3.65 |
| 25.8 | 2.34 | 3.03 | 3.32 | 2.22 | 2.88 | 3.15 | 2.39 | 3.10 | 3.40 | 2.34 | 3.03 | 3.32 | 2.56 | 3.32 | 3.64 |
| 25.9 | 2.33 | 3.02 | 3.31 | 2.22 | 2.87 | 3.14 | 2.39 | 3.09 | 3.40 | 2.33 | 3.02 | 3.31 | 2.56 | 3.32 | 3.63 |
| 26.0 | 2.33 | 3.01 | 3.30 | 2.21 | 2.87 | 3.14 | 2.38 | 3.09 | 3.39 | 2.33 | 3.02 | 3.30 | 2.55 | 3.31 | 3.63 |
| 26.1 | 2.32 | 3.01 | 3.30 | 2.21 | 2.86 | 3.13 | 2.38 | 3.08 | 3.38 | 2.32 | 3.01 | 3.30 | 2.55 | 3.30 | 3.62 |
| 26.2 | 2.32 | 3.00 | 3.29 | 2.20 | 2.86 | 3.12 | 2.37 | 3.08 | 3.38 | 2.32 | 3.01 | 3.29 | 2.54 | 3.30 | 3.61 |
| 26.3 | 2.31 | 3.00 | 3.28 | 2.20 | 2.85 | 3.12 | 2.37 | 3.07 | 3.37 | 2.31 | 3.00 | 3.28 | 2.54 | 3.29 | 3.61 |
| 26.4 | 2.31 | 2.99 | 3.28 | 2.20 | 2.85 | 3.11 | 2.36 | 3.06 | 3.36 | 2.31 | 2.99 | 3.28 | 2.53 | 3.29 | 3.60 |
| 26.5 | 2.30 | 2.99 | 3.27 | 2.19 | 2.84 | 3.11 | 2.36 | 3.06 | 3.36 | 2.30 | 2.99 | 3.27 | 2.53 | 3.28 | 3.59 |
| 26.6 | 2.30 | 2.98 | 3.27 | 2.19 | 2.84 | 3.10 | 2.35 | 3.05 | 3.35 | 2.30 | 2.98 | 3.27 | 2.52 | 3.27 | 3.59 |
| 26.7 | 2.29 | 2.97 | 3.26 | 2.18 | 2.83 | 3.09 | 2.35 | 3.05 | 3.35 | 2.30 | 2.98 | 3.26 | 2.52 | 3.27 | 3.58 |
| 26.8 | 2.29 | 2.97 | 3.25 | 2.18 | 2.83 | 3.09 | 2.34 | 3.04 | 3.34 | 2.29 | 2.97 | 3.25 | 2.51 | 3.26 | 3.57 |
| 26.9 | 2.28 | 2.96 | 3.25 | 2.17 | 2.82 | 3.08 | 2.34 | 3.03 | 3.33 | 2.29 | 2.97 | 3.25 | 2.51 | 3.25 | 3.57 |
| 27.0 | 2.28 | 2.96 | 3.24 | 2.17 | 2.81 | 3.08 | 2.33 | 3.03 | 3.33 | 2.28 | 2.96 | 3.24 | 2.50 | 3.25 | 3.56 |
| 27.1 | 2.28 | 2.95 | 3.24 | 2.16 | 2.81 | 3.07 | 2.33 | 3.02 | 3.32 | 2.28 | 2.96 | 3.24 | 2.50 | 3.24 | 3.55 |
| 27.2 | 2.27 | 2.95 | 3.23 | 2.16 | 2.80 | 3.07 | 2.33 | 3.02 | 3.32 | 2.27 | 2.95 | 3.23 | 2.49 | 3.24 | 3.55 |
| 27.3 | 2.27 | 2.94 | 3.23 | 2.16 | 2.80 | 3.06 | 2.32 | 3.01 | 3.31 | 2.27 | 2.94 | 3.23 | 2.49 | 3.23 | 3.54 |
| 27.4 | 2.26 | 2.94 | 3.22 | 2.15 | 2.79 | 3.05 | 2.32 | 3.01 | 3.30 | 2.26 | 2.94 | 3.22 | 2.48 | 3.23 | 3.53 |
| 27.5 | 2.26 | 2.93 | 3.21 | 2.15 | 2.79 | 3.05 | 2.31 | 3.00 | 3.30 | 2.26 | 2.93 | 3.21 | 2.48 | 3.22 | 3.53 |
| 27.6 | 2.25 | 2.93 | 3.21 | 2.14 | 2.78 | 3.04 | 2.31 | 3.00 | 3.29 | 2.26 | 2.93 | 3.21 | 2.47 | 3.21 | 3.52 |
| 27.7 | 2.25 | 2.92 | 3.20 | 2.14 | 2.78 | 3.04 | 2.30 | 2.99 | 3.29 | 2.25 | 2.92 | 3.20 | 2.47 | 3.21 | 3.52 |
| 27.8 | 2.24 | 2.92 | 3.20 | 2.14 | 2.77 | 3.03 | 2.30 | 2.99 | 3.28 | 2.25 | 2.92 | 3.20 | 2.47 | 3.20 | 3.51 |
| 27.9 | 2.24 | 2.91 | 3.19 | 2.13 | 2.77 | 3.03 | 2.29 | 2.98 | 3.27 | 2.24 | 2.91 | 3.19 | 2.46 | 3.20 | 3.50 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.1 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 1 | | | Zone 2 | | | Zone 3 | | | Zone 4 | | | Zone 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 28.0 | 2.24 | 2.90 | 3.19 | 2.13 | 2.76 | 3.02 | 2.29 | 2.97 | 3.27 | 2.24 | 2.91 | 3.19 | 2.46 | 3.19 | 3.50 |
| 28.1 | 2.23 | 2.90 | 3.18 | 2.12 | 2.76 | 3.02 | 2.29 | 2.97 | 3.26 | 2.23 | 2.90 | 3.18 | 2.45 | 3.18 | 3.49 |
| 28.2 | 2.23 | 2.89 | 3.17 | 2.12 | 2.75 | 3.01 | 2.28 | 2.96 | 3.26 | 2.23 | 2.90 | 3.17 | 2.45 | 3.18 | 3.48 |
| 28.3 | 2.22 | 2.89 | 3.17 | 2.12 | 2.75 | 3.01 | 2.28 | 2.96 | 3.25 | 2.23 | 2.89 | 3.17 | 2.44 | 3.17 | 3.48 |
| 28.4 | 2.22 | 2.88 | 3.16 | 2.11 | 2.74 | 3.00 | 2.27 | 2.95 | 3.25 | 2.22 | 2.89 | 3.16 | 2.44 | 3.17 | 3.47 |
| 28.5 | 2.22 | 2.88 | 3.16 | 2.11 | 2.74 | 3.00 | 2.27 | 2.95 | 3.24 | 2.22 | 2.88 | 3.16 | 2.43 | 3.16 | 3.47 |
| 28.6 | 2.21 | 2.87 | 3.15 | 2.10 | 2.73 | 2.99 | 2.26 | 2.94 | 3.23 | 2.21 | 2.88 | 3.15 | 2.43 | 3.16 | 3.46 |
| 28.7 | 2.21 | 2.87 | 3.15 | 2.10 | 2.73 | 2.98 | 2.26 | 2.94 | 3.23 | 2.21 | 2.87 | 3.15 | 2.42 | 3.15 | 3.45 |
| 28.8 | 2.20 | 2.86 | 3.14 | 2.10 | 2.73 | 2.98 | 2.26 | 2.93 | 3.22 | 2.21 | 2.87 | 3.14 | 2.42 | 3.15 | 3.45 |
| 28.9 | 2.20 | 2.86 | 3.14 | 2.09 | 2.72 | 2.97 | 2.25 | 2.93 | 3.22 | 2.20 | 2.86 | 3.14 | 2.42 | 3.14 | 3.44 |
| 29.0 | 2.20 | 2.85 | 3.13 | 2.09 | 2.72 | 2.97 | 2.25 | 2.92 | 3.21 | 2.20 | 2.86 | 3.13 | 2.41 | 3.13 | 3.44 |
| 29.1 | 2.19 | 2.85 | 3.13 | 2.08 | 2.71 | 2.96 | 2.24 | 2.92 | 3.21 | 2.19 | 2.85 | 3.13 | 2.41 | 3.13 | 3.43 |
| 29.2 | 2.19 | 2.84 | 3.12 | 2.08 | 2.71 | 2.96 | 2.24 | 2.91 | 3.20 | 2.19 | 2.85 | 3.12 | 2.40 | 3.12 | 3.43 |
| 29.3 | 2.18 | 2.84 | 3.12 | 2.08 | 2.70 | 2.95 | 2.24 | 2.91 | 3.20 | 2.19 | 2.84 | 3.12 | 2.40 | 3.12 | 3.42 |
| 29.4 | 2.18 | 2.84 | 3.11 | 2.07 | 2.70 | 2.95 | 2.23 | 2.90 | 3.19 | 2.18 | 2.84 | 3.11 | 2.39 | 3.11 | 3.41 |
| 29.5 | 2.18 | 2.83 | 3.11 | 2.07 | 2.69 | 2.94 | 2.23 | 2.90 | 3.19 | 2.18 | 2.83 | 3.11 | 2.39 | 3.11 | 3.41 |
| 29.6 | 2.17 | 2.83 | 3.10 | 2.07 | 2.69 | 2.94 | 2.22 | 2.89 | 3.18 | 2.17 | 2.83 | 3.10 | 2.39 | 3.10 | 3.40 |
| 29.7 | 2.17 | 2.82 | 3.10 | 2.06 | 2.68 | 2.93 | 2.22 | 2.89 | 3.18 | 2.17 | 2.82 | 3.10 | 2.38 | 3.10 | 3.40 |
| 29.8 | 2.16 | 2.82 | 3.09 | 2.06 | 2.68 | 2.93 | 2.22 | 2.88 | 3.17 | 2.17 | 2.82 | 3.09 | 2.38 | 3.09 | 3.39 |
| 29.9 | 2.16 | 2.81 | 3.09 | 2.06 | 2.67 | 2.92 | 2.21 | 2.88 | 3.17 | 2.16 | 2.81 | 3.09 | 2.37 | 3.09 | 3.39 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.2 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 1 | | | Zone 2 | | | Zone 3 | | | Zone 4 | | | Zone 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 30.0 | 2.16 | 2.81 | 3.08 | 2.05 | 2.67 | 2.92 | 2.21 | 2.87 | 3.16 | 2.16 | 2.81 | 3.08 | 2.37 | 3.08 | 3.38 |
| 30.2 | 2.15 | 2.80 | 3.07 | 2.04 | 2.66 | 2.91 | 2.20 | 2.86 | 3.15 | 2.15 | 2.80 | 3.07 | 2.36 | 3.07 | 3.37 |
| 30.4 | 2.14 | 2.79 | 3.06 | 2.04 | 2.66 | 2.90 | 2.19 | 2.86 | 3.14 | 2.14 | 2.79 | 3.06 | 2.35 | 3.07 | 3.36 |
| 30.6 | 2.14 | 2.78 | 3.05 | 2.03 | 2.65 | 2.89 | 2.19 | 2.85 | 3.13 | 2.14 | 2.78 | 3.06 | 2.34 | 3.06 | 3.35 |
| 30.8 | 2.13 | 2.77 | 3.05 | 2.02 | 2.64 | 2.88 | 2.18 | 2.84 | 3.13 | 2.13 | 2.78 | 3.05 | 2.34 | 3.05 | 3.35 |
| 31.0 | 2.12 | 2.77 | 3.04 | 2.02 | 2.63 | 2.87 | 2.17 | 2.83 | 3.12 | 2.12 | 2.77 | 3.04 | 2.33 | 3.04 | 3.34 |
| 31.2 | 2.12 | 2.76 | 3.03 | 2.01 | 2.63 | 2.86 | 2.16 | 2.83 | 3.11 | 2.12 | 2.76 | 3.03 | 2.32 | 3.03 | 3.33 |
| 31.4 | 2.11 | 2.75 | 3.02 | 2.01 | 2.62 | 2.85 | 2.16 | 2.82 | 3.10 | 2.11 | 2.75 | 3.02 | 2.31 | 3.02 | 3.32 |
| 31.6 | 2.10 | 2.74 | 3.01 | 2.00 | 2.61 | 2.84 | 2.15 | 2.81 | 3.09 | 2.10 | 2.75 | 3.02 | 2.31 | 3.02 | 3.31 |
| 31.8 | 2.10 | 2.74 | 3.01 | 1.99 | 2.61 | 2.83 | 2.14 | 2.80 | 3.09 | 2.10 | 2.74 | 3.01 | 2.30 | 3.01 | 3.30 |
| 32.0 | 2.09 | 2.73 | 3.00 | 1.99 | 2.60 | 2.83 | 2.14 | 2.79 | 3.08 | 2.09 | 2.73 | 3.00 | 2.29 | 3.00 | 3.29 |
| 32.2 | 2.08 | 2.72 | 2.99 | 1.98 | 2.59 | 2.82 | 2.13 | 2.79 | 3.07 | 2.08 | 2.72 | 2.99 | 2.29 | 2.99 | 3.29 |
| 32.4 | 2.08 | 2.71 | 2.98 | 1.97 | 2.59 | 2.81 | 2.12 | 2.78 | 3.06 | 2.08 | 2.72 | 2.99 | 2.28 | 2.98 | 3.28 |
| 32.6 | 2.07 | 2.71 | 2.98 | 1.97 | 2.58 | 2.80 | 2.12 | 2.77 | 3.05 | 2.07 | 2.71 | 2.98 | 2.27 | 2.98 | 3.27 |
| 32.8 | 2.06 | 2.70 | 2.97 | 1.96 | 2.58 | 2.79 | 2.11 | 2.77 | 3.05 | 2.06 | 2.70 | 2.97 | 2.26 | 2.97 | 3.26 |
| 33.0 | 2.06 | 2.69 | 2.96 | 1.96 | 2.57 | 2.78 | 2.10 | 2.76 | 3.04 | 2.06 | 2.70 | 2.96 | 2.26 | 2.96 | 3.26 |
| 33.2 | 2.05 | 2.68 | 2.95 | 1.95 | 2.56 | 2.77 | 2.10 | 2.75 | 3.03 | 2.05 | 2.69 | 2.96 | 2.25 | 2.95 | 3.25 |
| 33.4 | 2.04 | 2.68 | 2.95 | 1.94 | 2.56 | 2.76 | 2.09 | 2.74 | 3.02 | 2.04 | 2.68 | 2.95 | 2.24 | 2.95 | 3.24 |
| 33.6 | 2.04 | 2.67 | 2.94 | 1.94 | 2.55 | 2.76 | 2.08 | 2.74 | 3.02 | 2.04 | 2.68 | 2.94 | 2.24 | 2.94 | 3.23 |
| 33.8 | 2.03 | 2.66 | 2.93 | 1.93 | 2.54 | 2.75 | 2.08 | 2.73 | 3.01 | 2.03 | 2.67 | 2.94 | 2.23 | 2.93 | 3.22 |
| 34.0 | 2.03 | 2.66 | 2.92 | 1.93 | 2.54 | 2.74 | 2.07 | 2.72 | 3.00 | 2.03 | 2.66 | 2.93 | 2.22 | 2.93 | 3.22 |
| 34.2 | 2.02 | 2.65 | 2.92 | 1.92 | 2.53 | 2.73 | 2.06 | 2.72 | 3.00 | 2.02 | 2.66 | 2.92 | 2.22 | 2.92 | 3.21 |
| 34.4 | 2.02 | 2.64 | 2.91 | 1.92 | 2.53 | 2.72 | 2.06 | 2.71 | 2.99 | 2.01 | 2.65 | 2.91 | 2.21 | 2.91 | 3.20 |
| 34.6 | 2.01 | 2.64 | 2.90 | 1.91 | 2.52 | 2.71 | 2.05 | 2.70 | 2.98 | 2.01 | 2.64 | 2.91 | 2.20 | 2.90 | 3.19 |
| 34.8 | 2.00 | 2.63 | 2.90 | 1.91 | 2.52 | 2.71 | 2.05 | 2.70 | 2.97 | 2.00 | 2.64 | 2.90 | 2.20 | 2.90 | 3.19 |
| 35.0 | 2.00 | 2.62 | 2.89 | 1.90 | 2.51 | 2.70 | 2.04 | 2.69 | 2.97 | 2.00 | 2.63 | 2.89 | 2.19 | 2.89 | 3.18 |
| 35.2 | 1.99 | 2.62 | 2.88 | 1.89 | 2.50 | 2.69 | 2.03 | 2.68 | 2.96 | 1.99 | 2.62 | 2.89 | 2.19 | 2.88 | 3.17 |
| 35.4 | 1.99 | 2.61 | 2.88 | 1.89 | 2.50 | 2.68 | 2.03 | 2.68 | 2.95 | 1.99 | 2.62 | 2.88 | 2.18 | 2.88 | 3.17 |
| 35.6 | 1.98 | 2.60 | 2.87 | 1.88 | 2.49 | 2.68 | 2.02 | 2.67 | 2.95 | 1.98 | 2.61 | 2.87 | 2.17 | 2.87 | 3.16 |
| 35.8 | 1.98 | 2.60 | 2.86 | 1.88 | 2.49 | 2.67 | 2.02 | 2.66 | 2.94 | 1.97 | 2.60 | 2.87 | 2.17 | 2.86 | 3.15 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.2 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 1 | | | Zone 2 | | | Zone 3 | | | Zone 4 | | | Zone 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 36.0 | 1.97 | 2.59 | 2.86 | 1.87 | 2.48 | 2.66 | 2.01 | 2.66 | 2.93 | 1.97 | 2.60 | 2.86 | 2.16 | 2.86 | 3.14 |
| 36.2 | 1.97 | 2.58 | 2.85 | 1.87 | 2.48 | 2.65 | 2.00 | 2.65 | 2.93 | 1.96 | 2.59 | 2.86 | 2.15 | 2.85 | 3.14 |
| 36.4 | 1.96 | 2.58 | 2.84 | 1.86 | 2.47 | 2.65 | 2.00 | 2.64 | 2.92 | 1.96 | 2.59 | 2.85 | 2.15 | 2.84 | 3.13 |
| 36.6 | 1.95 | 2.57 | 2.84 | 1.86 | 2.46 | 2.64 | 1.99 | 2.64 | 2.91 | 1.95 | 2.58 | 2.84 | 2.14 | 2.84 | 3.12 |
| 36.8 | 1.95 | 2.57 | 2.83 | 1.85 | 2.46 | 2.63 | 1.99 | 2.63 | 2.91 | 1.95 | 2.57 | 2.84 | 2.14 | 2.83 | 3.12 |
| 37.0 | 1.94 | 2.56 | 2.82 | 1.85 | 2.45 | 2.62 | 1.98 | 2.63 | 2.90 | 1.94 | 2.57 | 2.83 | 2.13 | 2.82 | 3.11 |
| 37.2 | 1.94 | 2.55 | 2.82 | 1.84 | 2.45 | 2.62 | 1.98 | 2.62 | 2.89 | 1.94 | 2.56 | 2.82 | 2.13 | 2.82 | 3.10 |
| 37.4 | 1.93 | 2.55 | 2.81 | 1.84 | 2.44 | 2.61 | 1.97 | 2.61 | 2.89 | 1.93 | 2.56 | 2.82 | 2.12 | 2.81 | 3.10 |
| 37.6 | 1.93 | 2.54 | 2.80 | 1.83 | 2.44 | 2.60 | 1.97 | 2.61 | 2.88 | 1.93 | 2.55 | 2.81 | 2.11 | 2.81 | 3.09 |
| 37.8 | 1.92 | 2.54 | 2.80 | 1.83 | 2.43 | 2.60 | 1.96 | 2.60 | 2.88 | 1.92 | 2.54 | 2.81 | 2.11 | 2.80 | 3.08 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.5 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 1 | | | Zone 2 | | | Zone 3 | | | Zone 4 | | | Zone 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 38.0 | 1.92 | 2.53 | 2.79 | 1.82 | 2.43 | 2.59 | 1.96 | 2.60 | 2.87 | 1.92 | 2.54 | 2.80 | 2.10 | 2.79 | 3.08 |
| 38.5 | 1.91 | 2.51 | 2.78 | 1.81 | 2.42 | 2.57 | 1.94 | 2.58 | 2.85 | 1.90 | 2.52 | 2.79 | 2.09 | 2.78 | 3.06 |
| 39.0 | 1.89 | 2.50 | 2.76 | 1.80 | 2.40 | 2.55 | 1.93 | 2.57 | 2.84 | 1.89 | 2.51 | 2.77 | 2.08 | 2.76 | 3.05 |
| 39.5 | 1.88 | 2.49 | 2.75 | 1.79 | 2.39 | 2.54 | 1.92 | 2.55 | 2.82 | 1.88 | 2.50 | 2.76 | 2.06 | 2.75 | 3.03 |
| 40.0 | 1.87 | 2.47 | 2.73 | 1.78 | 2.38 | 2.52 | 1.90 | 2.54 | 2.81 | 1.87 | 2.48 | 2.74 | 2.05 | 2.73 | 3.02 |
| 40.5 | 1.86 | 2.46 | 2.72 | 1.77 | 2.37 | 2.51 | 1.89 | 2.53 | 2.80 | 1.85 | 2.47 | 2.73 | 2.04 | 2.72 | 3.00 |
| 41.0 | 1.85 | 2.45 | 2.71 | 1.76 | 2.35 | 2.49 | 1.88 | 2.51 | 2.78 | 1.84 | 2.46 | 2.72 | 2.02 | 2.71 | 2.99 |
| 41.5 | 1.84 | 2.43 | 2.69 | 1.75 | 2.34 | 2.47 | 1.87 | 2.50 | 2.77 | 1.83 | 2.44 | 2.70 | 2.01 | 2.69 | 2.97 |
| 42.0 | 1.83 | 2.42 | 2.68 | 1.74 | 2.33 | 2.46 | 1.86 | 2.49 | 2.75 | 1.82 | 2.43 | 2.69 | 2.00 | 2.68 | 2.96 |
| 42.5 | 1.82 | 2.41 | 2.67 | 1.73 | 2.32 | 2.44 | 1.85 | 2.47 | 2.74 | 1.81 | 2.42 | 2.68 | 1.99 | 2.67 | 2.95 |
| 43.0 | 1.80 | 2.40 | 2.65 | 1.72 | 2.31 | 2.43 | 1.84 | 2.46 | 2.73 | 1.80 | 2.41 | 2.66 | 1.98 | 2.65 | 2.93 |
| 43.5 | 1.79 | 2.38 | 2.64 | 1.71 | 2.30 | 2.42 | 1.82 | 2.45 | 2.71 | 1.79 | 2.40 | 2.65 | 1.96 | 2.64 | 2.92 |
| 44.0 | 1.78 | 2.37 | 2.63 | 1.70 | 2.29 | 2.40 | 1.81 | 2.44 | 2.70 | 1.78 | 2.38 | 2.64 | 1.95 | 2.63 | 2.91 |
| 44.5 | 1.77 | 2.36 | 2.62 | 1.69 | 2.28 | 2.39 | 1.80 | 2.43 | 2.69 | 1.77 | 2.37 | 2.63 | 1.94 | 2.62 | 2.89 |
| 45.0 | 1.76 | 2.35 | 2.60 | 1.68 | 2.27 | 2.37 | 1.79 | 2.41 | 2.68 | 1.76 | 2.36 | 2.62 | 1.93 | 2.60 | 2.88 |
| 45.5 | 1.75 | 2.34 | 2.59 | 1.67 | 2.26 | 2.36 | 1.78 | 2.40 | 2.67 | 1.75 | 2.35 | 2.60 | 1.92 | 2.59 | 2.87 |
| 46.0 | 1.75 | 2.33 | 2.58 | 1.66 | 2.25 | 2.35 | 1.77 | 2.39 | 2.65 | 1.74 | 2.34 | 2.59 | 1.91 | 2.58 | 2.85 |
| 46.5 | 1.74 | 2.31 | 2.57 | 1.65 | 2.24 | 2.33 | 1.76 | 2.38 | 2.64 | 1.73 | 2.33 | 2.58 | 1.90 | 2.57 | 2.84 |
| 47.0 | 1.73 | 2.30 | 2.56 | 1.64 | 2.23 | 2.32 | 1.75 | 2.37 | 2.63 | 1.72 | 2.32 | 2.57 | 1.89 | 2.56 | 2.83 |
| 47.5 | 1.72 | 2.29 | 2.55 | 1.63 | 2.22 | 2.31 | 1.74 | 2.36 | 2.62 | 1.71 | 2.31 | 2.56 | 1.88 | 2.55 | 2.82 |
| 48.0 | 1.71 | 2.28 | 2.53 | 1.62 | 2.21 | 2.30 | 1.73 | 2.35 | 2.61 | 1.70 | 2.30 | 2.55 | 1.87 | 2.53 | 2.81 |
| 48.5 | 1.70 | 2.27 | 2.52 | 1.62 | 2.20 | 2.29 | 1.73 | 2.34 | 2.60 | 1.69 | 2.29 | 2.54 | 1.86 | 2.52 | 2.80 |
| 49.0 | 1.69 | 2.26 | 2.51 | 1.61 | 2.19 | 2.27 | 1.72 | 2.33 | 2.59 | 1.68 | 2.28 | 2.53 | 1.85 | 2.51 | 2.78 |
| 49.5 | 1.68 | 2.25 | 2.50 | 1.60 | 2.18 | 2.26 | 1.71 | 2.32 | 2.57 | 1.68 | 2.27 | 2.52 | 1.84 | 2.50 | 2.77 |
| 50.0 | 1.67 | 2.24 | 2.49 | 1.59 | 2.17 | 2.25 | 1.70 | 2.31 | 2.56 | 1.67 | 2.26 | 2.51 | 1.83 | 2.49 | 2.76 |
| 50.5 | 1.67 | 2.23 | 2.48 | 1.58 | 2.17 | 2.24 | 1.69 | 2.30 | 2.55 | 1.66 | 2.25 | 2.50 | 1.82 | 2.48 | 2.75 |
| 51.0 | 1.66 | 2.22 | 2.47 | 1.58 | 2.16 | 2.23 | 1.68 | 2.29 | 2.54 | 1.65 | 2.24 | 2.49 | 1.81 | 2.47 | 2.74 |
| 51.5 | 1.65 | 2.21 | 2.46 | 1.57 | 2.15 | 2.22 | 1.67 | 2.28 | 2.53 | 1.64 | 2.23 | 2.48 | 1.80 | 2.46 | 2.73 |
| 52.0 | 1.64 | 2.20 | 2.45 | 1.56 | 2.14 | 2.21 | 1.66 | 2.27 | 2.52 | 1.64 | 2.22 | 2.47 | 1.80 | 2.45 | 2.72 |
| 52.5 | 1.63 | 2.19 | 2.44 | 1.55 | 2.13 | 2.19 | 1.66 | 2.26 | 2.51 | 1.63 | 2.21 | 2.46 | 1.79 | 2.44 | 2.71 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.5 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 1 | | | Zone 2 | | | Zone 3 | | | Zone 4 | | | Zone 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 53.0 | 1.63 | 2.18 | 2.43 | 1.55 | 2.12 | 2.18 | 1.65 | 2.25 | 2.50 | 1.62 | 2.20 | 2.45 | 1.78 | 2.43 | 2.70 |
| 53.5 | 1.62 | 2.18 | 2.42 | 1.54 | 2.12 | 2.17 | 1.64 | 2.24 | 2.49 | 1.61 | 2.19 | 2.44 | 1.77 | 2.42 | 2.69 |
| 54.0 | 1.61 | 2.17 | 2.41 | 1.53 | 2.11 | 2.16 | 1.63 | 2.23 | 2.48 | 1.60 | 2.18 | 2.43 | 1.76 | 2.41 | 2.68 |
| 54.5 | 1.60 | 2.16 | 2.40 | 1.53 | 2.10 | 2.15 | 1.63 | 2.22 | 2.48 | 1.60 | 2.18 | 2.42 | 1.75 | 2.40 | 2.67 |
| 55.0 | 1.60 | 2.15 | 2.39 | 1.52 | 2.09 | 2.14 | 1.62 | 2.21 | 2.47 | 1.59 | 2.17 | 2.41 | 1.75 | 2.39 | 2.66 |
| 55.5 | 1.59 | 2.14 | 2.39 | 1.51 | 2.08 | 2.13 | 1.61 | 2.21 | 2.46 | 1.58 | 2.16 | 2.40 | 1.74 | 2.39 | 2.65 |
| 56.0 | 1.58 | 2.13 | 2.38 | 1.50 | 2.08 | 2.12 | 1.60 | 2.20 | 2.45 | 1.58 | 2.15 | 2.40 | 1.73 | 2.38 | 2.64 |
| 56.5 | 1.58 | 2.12 | 2.37 | 1.50 | 2.07 | 2.11 | 1.60 | 2.19 | 2.44 | 1.57 | 2.14 | 2.39 | 1.72 | 2.37 | 2.63 |
| 57.0 | 1.57 | 2.12 | 2.36 | 1.49 | 2.06 | 2.10 | 1.59 | 2.18 | 2.43 | 1.56 | 2.13 | 2.38 | 1.71 | 2.36 | 2.62 |
| 57.5 | 1.56 | 2.11 | 2.35 | 1.48 | 2.06 | 2.10 | 1.58 | 2.17 | 2.42 | 1.55 | 2.13 | 2.37 | 1.71 | 2.35 | 2.61 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 1 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 1 | | | Zone 2 | | | Zone 3 | | | Zone 4 | | | Zone 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 58.0 | 1.56 | 2.10 | 2.34 | 1.48 | 2.05 | 2.09 | 1.57 | 2.16 | 2.41 | 1.55 | 2.12 | 2.36 | 1.70 | 2.34 | 2.60 |
| 59.0 | 1.54 | 2.08 | 2.33 | 1.47 | 2.03 | 2.07 | 1.56 | 2.15 | 2.40 | 1.53 | 2.10 | 2.35 | 1.69 | 2.33 | 2.59 |
| 60.0 | 1.53 | 2.07 | 2.31 | 1.45 | 2.02 | 2.05 | 1.55 | 2.13 | 2.38 | 1.52 | 2.09 | 2.33 | 1.67 | 2.31 | 2.57 |
| 61.0 | 1.51 | 2.04 | 2.28 | 1.44 | 2.00 | 2.03 | 1.53 | 2.11 | 2.35 | 1.50 | 2.06 | 2.30 | 1.65 | 2.28 | 2.54 |
| 62.0 | 1.49 | 2.02 | 2.26 | 1.42 | 1.97 | 2.01 | 1.51 | 2.09 | 2.33 | 1.48 | 2.04 | 2.28 | 1.63 | 2.26 | 2.51 |
| 63.0 | 1.47 | 2.00 | 2.23 | 1.40 | 1.95 | 2.00 | 1.49 | 2.06 | 2.30 | 1.47 | 2.02 | 2.25 | 1.61 | 2.23 | 2.48 |
| 64.0 | 1.46 | 1.97 | 2.21 | 1.39 | 1.93 | 1.98 | 1.48 | 2.04 | 2.28 | 1.45 | 1.99 | 2.23 | 1.59 | 2.20 | 2.46 |
| 65.0 | 1.44 | 1.95 | 2.18 | 1.37 | 1.91 | 1.96 | 1.46 | 2.02 | 2.25 | 1.43 | 1.97 | 2.20 | 1.58 | 2.18 | 2.43 |
| 66.0 | 1.42 | 1.93 | 2.16 | 1.36 | 1.89 | 1.94 | 1.44 | 2.00 | 2.23 | 1.41 | 1.95 | 2.18 | 1.56 | 2.16 | 2.40 |
| 67.0 | 1.41 | 1.91 | 2.13 | 1.34 | 1.87 | 1.93 | 1.43 | 1.98 | 2.21 | 1.40 | 1.93 | 2.15 | 1.54 | 2.13 | 2.38 |
| 68.0 | 1.39 | 1.89 | 2.11 | 1.33 | 1.85 | 1.91 | 1.41 | 1.95 | 2.18 | 1.38 | 1.91 | 2.13 | 1.52 | 2.11 | 2.36 |
| 69.0 | 1.37 | 1.87 | 2.09 | 1.31 | 1.83 | 1.90 | 1.40 | 1.93 | 2.16 | 1.37 | 1.89 | 2.11 | 1.51 | 2.09 | 2.33 |
| 70.0 | 1.36 | 1.85 | 2.07 | 1.30 | 1.81 | 1.88 | 1.38 | 1.92 | 2.14 | 1.35 | 1.87 | 2.09 | 1.49 | 2.07 | 2.31 |
| 71.0 | 1.34 | 1.83 | 2.05 | 1.29 | 1.79 | 1.87 | 1.37 | 1.90 | 2.12 | 1.34 | 1.85 | 2.07 | 1.48 | 2.05 | 2.29 |
| 72.0 | 1.33 | 1.81 | 2.03 | 1.27 | 1.78 | 1.85 | 1.35 | 1.88 | 2.10 | 1.32 | 1.83 | 2.05 | 1.46 | 2.03 | 2.26 |
| 73.0 | 1.32 | 1.79 | 2.01 | 1.26 | 1.76 | 1.84 | 1.34 | 1.86 | 2.08 | 1.31 | 1.81 | 2.03 | 1.45 | 2.01 | 2.24 |
| 74.0 | 1.30 | 1.78 | 1.99 | 1.25 | 1.74 | 1.82 | 1.33 | 1.84 | 2.06 | 1.30 | 1.79 | 2.01 | 1.43 | 1.99 | 2.22 |
| 75.0 | 1.29 | 1.76 | 1.97 | 1.23 | 1.73 | 1.81 | 1.32 | 1.83 | 2.04 | 1.28 | 1.78 | 1.99 | 1.42 | 1.97 | 2.20 |
| 76.0 | 1.28 | 1.74 | 1.95 | 1.22 | 1.71 | 1.80 | 1.30 | 1.81 | 2.02 | 1.27 | 1.76 | 1.97 | 1.41 | 1.95 | 2.18 |
| 77.0 | 1.26 | 1.72 | 1.93 | 1.21 | 1.69 | 1.78 | 1.29 | 1.79 | 2.01 | 1.26 | 1.74 | 1.95 | 1.39 | 1.93 | 2.16 |
| 78.0 | 1.25 | 1.71 | 1.91 | 1.20 | 1.68 | 1.77 | 1.28 | 1.78 | 1.99 | 1.25 | 1.73 | 1.93 | 1.38 | 1.91 | 2.14 |
| 79.0 | 1.24 | 1.69 | 1.90 | 1.19 | 1.66 | 1.76 | 1.27 | 1.76 | 1.97 | 1.23 | 1.71 | 1.92 | 1.37 | 1.90 | 2.12 |
| 80.0 | 1.23 | 1.68 | 1.88 | 1.18 | 1.65 | 1.75 | 1.26 | 1.74 | 1.95 | 1.22 | 1.70 | 1.90 | 1.35 | 1.88 | 2.10 |
| 81.0 | 1.22 | 1.66 | 1.86 | 1.17 | 1.63 | 1.74 | 1.24 | 1.73 | 1.94 | 1.21 | 1.68 | 1.88 | 1.34 | 1.86 | 2.08 |
| 82.0 | 1.20 | 1.65 | 1.85 | 1.16 | 1.62 | 1.72 | 1.23 | 1.71 | 1.92 | 1.20 | 1.67 | 1.87 | 1.33 | 1.85 | 2.07 |
| 83.0 | 1.19 | 1.63 | 1.83 | 1.15 | 1.61 | 1.71 | 1.22 | 1.70 | 1.91 | 1.19 | 1.65 | 1.85 | 1.32 | 1.83 | 2.05 |
| 84.0 | 1.18 | 1.62 | 1.81 | 1.14 | 1.59 | 1.70 | 1.21 | 1.69 | 1.89 | 1.18 | 1.64 | 1.84 | 1.31 | 1.81 | 2.03 |
| 85.0 | 1.17 | 1.60 | 1.80 | 1.13 | 1.58 | 1.69 | 1.20 | 1.67 | 1.87 | 1.17 | 1.62 | 1.82 | 1.29 | 1.80 | 2.02 |
| 86.0 | 1.16 | 1.59 | 1.78 | 1.12 | 1.57 | 1.68 | 1.19 | 1.66 | 1.86 | 1.16 | 1.61 | 1.80 | 1.28 | 1.78 | 2.00 |
| 87.0 | 1.15 | 1.58 | 1.77 | 1.11 | 1.55 | 1.67 | 1.18 | 1.65 | 1.84 | 1.15 | 1.60 | 1.79 | 1.27 | 1.77 | 1.98 |
| 88.0 | 1.14 | 1.56 | 1.76 | 1.10 | 1.54 | 1.66 | 1.17 | 1.63 | 1.83 | 1.14 | 1.58 | 1.78 | 1.26 | 1.75 | 1.97 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 1 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 1 | | | Zone 2 | | | Zone 3 | | | Zone 4 | | | Zone 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 89.0 | 1.13 | 1.55 | 1.74 | 1.09 | 1.53 | 1.65 | 1.16 | 1.62 | 1.82 | 1.13 | 1.57 | 1.76 | 1.25 | 1.74 | 1.95 |
| 90.0 | 1.12 | 1.54 | 1.73 | 1.08 | 1.52 | 1.64 | 1.15 | 1.61 | 1.80 | 1.12 | 1.56 | 1.75 | 1.24 | 1.73 | 1.94 |
| 91.0 | 1.11 | 1.53 | 1.71 | 1.07 | 1.50 | 1.63 | 1.14 | 1.59 | 1.79 | 1.11 | 1.54 | 1.73 | 1.23 | 1.71 | 1.92 |
| 92.0 | 1.10 | 1.51 | 1.70 | 1.06 | 1.49 | 1.62 | 1.13 | 1.58 | 1.78 | 1.10 | 1.53 | 1.72 | 1.22 | 1.70 | 1.91 |
| 93.0 | 1.09 | 1.50 | 1.69 | 1.05 | 1.48 | 1.61 | 1.12 | 1.57 | 1.76 | 1.09 | 1.52 | 1.71 | 1.21 | 1.69 | 1.89 |
| 94.0 | 1.08 | 1.49 | 1.67 | 1.05 | 1.47 | 1.60 | 1.12 | 1.56 | 1.75 | 1.08 | 1.51 | 1.69 | 1.20 | 1.67 | 1.88 |
| 95.0 | 1.08 | 1.48 | 1.66 | 1.04 | 1.46 | 1.59 | 1.11 | 1.55 | 1.74 | 1.07 | 1.50 | 1.68 | 1.19 | 1.66 | 1.87 |
| 96.0 | 1.07 | 1.47 | 1.65 | 1.03 | 1.45 | 1.58 | 1.10 | 1.54 | 1.72 | 1.06 | 1.49 | 1.67 | 1.18 | 1.65 | 1.85 |
| 97.0 | 1.06 | 1.46 | 1.64 | 1.02 | 1.44 | 1.57 | 1.09 | 1.52 | 1.71 | 1.06 | 1.47 | 1.66 | 1.17 | 1.64 | 1.84 |
| 98.0 | 1.05 | 1.45 | 1.62 | 1.01 | 1.43 | 1.56 | 1.08 | 1.51 | 1.70 | 1.05 | 1.46 | 1.65 | 1.17 | 1.62 | 1.83 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 2 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 1 | | | Zone 2 | | | Zone 3 | | | Zone 4 | | | Zone 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 100.0 | 1.03 | 1.43 | 1.60 | 1.00 | 1.41 | 1.54 | 1.07 | 1.49 | 1.68 | 1.03 | 1.44 | 1.62 | 1.15 | 1.60 | 1.80 |
| 102.0 | 1.02 | 1.40 | 1.58 | 0.99 | 1.39 | 1.53 | 1.05 | 1.47 | 1.65 | 1.02 | 1.42 | 1.60 | 1.13 | 1.58 | 1.78 |
| 104.0 | 1.00 | 1.39 | 1.56 | 0.97 | 1.37 | 1.51 | 1.04 | 1.45 | 1.63 | 1.00 | 1.40 | 1.58 | 1.12 | 1.56 | 1.75 |
| 106.0 | 0.99 | 1.37 | 1.54 | 0.96 | 1.35 | 1.49 | 1.02 | 1.43 | 1.61 | 0.99 | 1.38 | 1.56 | 1.10 | 1.54 | 1.73 |
| 108.0 | 0.97 | 1.35 | 1.52 | 0.94 | 1.33 | 1.48 | 1.01 | 1.41 | 1.59 | 0.97 | 1.36 | 1.54 | 1.09 | 1.52 | 1.71 |
| 110.0 | 0.96 | 1.33 | 1.50 | 0.93 | 1.32 | 1.46 | 1.00 | 1.40 | 1.57 | 0.96 | 1.35 | 1.52 | 1.07 | 1.50 | 1.68 |
| 112.0 | 0.95 | 1.31 | 1.48 | 0.92 | 1.30 | 1.45 | 0.98 | 1.38 | 1.55 | 0.95 | 1.33 | 1.50 | 1.06 | 1.48 | 1.66 |
| 114.0 | 0.94 | 1.30 | 1.46 | 0.91 | 1.28 | 1.44 | 0.97 | 1.36 | 1.53 | 0.93 | 1.31 | 1.48 | 1.04 | 1.46 | 1.64 |
| 116.0 | 0.92 | 1.28 | 1.44 | 0.90 | 1.27 | 1.42 | 0.96 | 1.35 | 1.51 | 0.92 | 1.29 | 1.46 | 1.03 | 1.44 | 1.62 |
| 118.0 | 0.91 | 1.26 | 1.42 | 0.89 | 1.25 | 1.41 | 0.95 | 1.33 | 1.50 | 0.91 | 1.28 | 1.44 | 1.02 | 1.42 | 1.60 |
| 120.0 | 0.90 | 1.25 | 1.41 | 0.87 | 1.24 | 1.40 | 0.93 | 1.31 | 1.48 | 0.90 | 1.26 | 1.43 | 1.01 | 1.41 | 1.59 |
| 122.0 | 0.89 | 1.23 | 1.39 | 0.86 | 1.22 | 1.38 | 0.92 | 1.30 | 1.46 | 0.89 | 1.25 | 1.41 | 0.99 | 1.39 | 1.57 |
| 124.0 | 0.88 | 1.22 | 1.37 | 0.85 | 1.21 | 1.36 | 0.91 | 1.28 | 1.44 | 0.88 | 1.23 | 1.39 | 0.98 | 1.37 | 1.55 |
| 126.0 | 0.87 | 1.20 | 1.36 | 0.84 | 1.19 | 1.34 | 0.90 | 1.27 | 1.43 | 0.86 | 1.22 | 1.37 | 0.97 | 1.35 | 1.53 |
| 128.0 | 0.86 | 1.19 | 1.34 | 0.83 | 1.18 | 1.33 | 0.89 | 1.25 | 1.41 | 0.85 | 1.20 | 1.36 | 0.96 | 1.34 | 1.51 |
| 130.0 | 0.85 | 1.18 | 1.32 | 0.82 | 1.16 | 1.31 | 0.88 | 1.24 | 1.39 | 0.84 | 1.19 | 1.34 | 0.95 | 1.32 | 1.49 |
| 132.0 | 0.84 | 1.16 | 1.31 | 0.81 | 1.15 | 1.30 | 0.87 | 1.22 | 1.38 | 0.84 | 1.17 | 1.33 | 0.93 | 1.31 | 1.47 |
| 134.0 | 0.83 | 1.15 | 1.30 | 0.80 | 1.14 | 1.28 | 0.86 | 1.21 | 1.36 | 0.83 | 1.16 | 1.31 | 0.92 | 1.29 | 1.46 |
| 136.0 | 0.82 | 1.14 | 1.28 | 0.80 | 1.12 | 1.27 | 0.85 | 1.19 | 1.35 | 0.82 | 1.15 | 1.30 | 0.91 | 1.28 | 1.44 |
| 138.0 | 0.81 | 1.12 | 1.27 | 0.79 | 1.11 | 1.25 | 0.84 | 1.18 | 1.33 | 0.81 | 1.13 | 1.28 | 0.90 | 1.26 | 1.43 |
| 140.0 | 0.80 | 1.11 | 1.25 | 0.78 | 1.10 | 1.24 | 0.83 | 1.17 | 1.32 | 0.80 | 1.12 | 1.27 | 0.89 | 1.25 | 1.41 |
| 142.0 | 0.79 | 1.10 | 1.24 | 0.77 | 1.09 | 1.23 | 0.82 | 1.15 | 1.30 | 0.79 | 1.11 | 1.25 | 0.88 | 1.24 | 1.40 |
| 144.0 | 0.78 | 1.09 | 1.23 | 0.76 | 1.07 | 1.21 | 0.81 | 1.14 | 1.29 | 0.78 | 1.10 | 1.24 | 0.87 | 1.22 | 1.38 |
| 146.0 | 0.77 | 1.08 | 1.22 | 0.75 | 1.06 | 1.20 | 0.80 | 1.13 | 1.28 | 0.77 | 1.09 | 1.23 | 0.87 | 1.21 | 1.37 |
| 148.0 | 0.77 | 1.07 | 1.20 | 0.75 | 1.05 | 1.19 | 0.80 | 1.12 | 1.26 | 0.77 | 1.08 | 1.21 | 0.86 | 1.20 | 1.35 |
| 150.0 | 0.76 | 1.06 | 1.19 | 0.74 | 1.04 | 1.18 | 0.79 | 1.11 | 1.25 | 0.76 | 1.06 | 1.20 | 0.85 | 1.18 | 1.34 |
| 152.0 | 0.75 | 1.05 | 1.18 | 0.73 | 1.03 | 1.17 | 0.78 | 1.10 | 1.24 | 0.75 | 1.05 | 1.19 | 0.84 | 1.17 | 1.33 |
| 154.0 | 0.74 | 1.04 | 1.17 | 0.73 | 1.02 | 1.15 | 0.77 | 1.09 | 1.23 | 0.74 | 1.04 | 1.18 | 0.83 | 1.16 | 1.31 |
| 156.0 | 0.74 | 1.03 | 1.16 | 0.72 | 1.01 | 1.14 | 0.76 | 1.07 | 1.21 | 0.74 | 1.03 | 1.17 | 0.82 | 1.15 | 1.30 |
| 158.0 | 0.73 | 1.02 | 1.15 | 0.71 | 1.00 | 1.13 | 0.76 | 1.06 | 1.20 | 0.73 | 1.02 | 1.16 | 0.82 | 1.14 | 1.29 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 2 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 1 | | | Zone 2 | | | Zone 3 | | | Zone 4 | | | Zone 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 160.0 | 0.72 | 1.01 | 1.14 | 0.70 | 0.99 | 1.12 | 0.75 | 1.05 | 1.19 | 0.72 | 1.01 | 1.14 | 0.81 | 1.13 | 1.27 |
| 162.0 | 0.72 | 1.00 | 1.13 | 0.70 | 0.98 | 1.11 | 0.74 | 1.04 | 1.18 | 0.72 | 1.00 | 1.13 | 0.80 | 1.12 | 1.26 |
| 164.0 | 0.71 | 0.99 | 1.12 | 0.69 | 0.97 | 1.10 | 0.74 | 1.03 | 1.17 | 0.71 | 0.99 | 1.12 | 0.79 | 1.11 | 1.25 |
| 166.0 | 0.70 | 0.98 | 1.11 | 0.69 | 0.96 | 1.09 | 0.73 | 1.02 | 1.16 | 0.70 | 0.99 | 1.11 | 0.79 | 1.10 | 1.24 |
| 168.0 | 0.70 | 0.97 | 1.10 | 0.68 | 0.95 | 1.08 | 0.72 | 1.02 | 1.15 | 0.70 | 0.98 | 1.10 | 0.78 | 1.09 | 1.23 |
| 170.0 | 0.69 | 0.96 | 1.09 | 0.67 | 0.95 | 1.07 | 0.72 | 1.01 | 1.14 | 0.69 | 0.97 | 1.09 | 0.77 | 1.08 | 1.22 |
| 172.0 | 0.68 | 0.95 | 1.08 | 0.67 | 0.94 | 1.06 | 0.71 | 1.00 | 1.13 | 0.68 | 0.96 | 1.08 | 0.76 | 1.07 | 1.21 |
| 174.0 | 0.68 | 0.95 | 1.07 | 0.66 | 0.93 | 1.05 | 0.70 | 0.99 | 1.12 | 0.68 | 0.95 | 1.07 | 0.76 | 1.06 | 1.20 |
| 176.0 | 0.67 | 0.94 | 1.06 | 0.66 | 0.92 | 1.04 | 0.70 | 0.98 | 1.11 | 0.67 | 0.94 | 1.06 | 0.75 | 1.05 | 1.19 |
| 178.0 | 0.67 | 0.93 | 1.05 | 0.65 | 0.91 | 1.03 | 0.69 | 0.97 | 1.10 | 0.67 | 0.93 | 1.06 | 0.74 | 1.04 | 1.18 |
| 180.0 | 0.66 | 0.92 | 1.04 | 0.64 | 0.90 | 1.03 | 0.69 | 0.96 | 1.09 | 0.66 | 0.93 | 1.05 | 0.74 | 1.03 | 1.17 |
| 182.0 | 0.66 | 0.91 | 1.03 | 0.64 | 0.90 | 1.02 | 0.68 | 0.95 | 1.08 | 0.65 | 0.92 | 1.04 | 0.73 | 1.02 | 1.16 |
| 184.0 | 0.65 | 0.91 | 1.03 | 0.63 | 0.89 | 1.01 | 0.67 | 0.95 | 1.07 | 0.65 | 0.91 | 1.03 | 0.73 | 1.01 | 1.15 |
| 186.0 | 0.64 | 0.90 | 1.02 | 0.63 | 0.88 | 1.00 | 0.67 | 0.94 | 1.06 | 0.64 | 0.90 | 1.02 | 0.72 | 1.00 | 1.14 |
| 188.0 | 0.64 | 0.89 | 1.01 | 0.62 | 0.87 | 0.99 | 0.66 | 0.93 | 1.05 | 0.64 | 0.89 | 1.01 | 0.71 | 1.00 | 1.13 |
| 190.0 | 0.63 | 0.88 | 1.00 | 0.62 | 0.87 | 0.98 | 0.66 | 0.92 | 1.05 | 0.63 | 0.89 | 1.00 | 0.71 | 0.99 | 1.12 |
| 192.0 | 0.63 | 0.88 | 0.99 | 0.61 | 0.86 | 0.98 | 0.65 | 0.92 | 1.04 | 0.63 | 0.88 | 1.00 | 0.70 | 0.98 | 1.11 |
| 194.0 | 0.62 | 0.87 | 0.98 | 0.61 | 0.85 | 0.97 | 0.65 | 0.91 | 1.03 | 0.62 | 0.87 | 0.99 | 0.70 | 0.97 | 1.10 |
| 196.0 | 0.62 | 0.86 | 0.98 | 0.60 | 0.85 | 0.96 | 0.64 | 0.90 | 1.02 | 0.62 | 0.87 | 0.98 | 0.69 | 0.97 | 1.09 |
| 198.0 | 0.61 | 0.86 | 0.97 | 0.60 | 0.84 | 0.95 | 0.64 | 0.89 | 1.01 | 0.61 | 0.86 | 0.97 | 0.69 | 0.96 | 1.08 |
| 200.0 | 0.61 | 0.85 | 0.96 | 0.59 | 0.83 | 0.95 | 0.63 | 0.89 | 1.01 | 0.61 | 0.85 | 0.96 | 0.68 | 0.95 | 1.08 |
| 202.0 | 0.60 | 0.84 | 0.95 | 0.59 | 0.83 | 0.94 | 0.63 | 0.88 | 1.00 | 0.60 | 0.85 | 0.96 | 0.68 | 0.94 | 1.07 |
| 204.0 | 0.60 | 0.84 | 0.95 | 0.58 | 0.82 | 0.93 | 0.62 | 0.87 | 0.99 | 0.60 | 0.84 | 0.95 | 0.67 | 0.94 | 1.06 |
| 206.0 | 0.59 | 0.83 | 0.94 | 0.58 | 0.81 | 0.92 | 0.62 | 0.87 | 0.98 | 0.59 | 0.83 | 0.94 | 0.67 | 0.93 | 1.05 |
| 208.0 | 0.59 | 0.82 | 0.93 | 0.58 | 0.81 | 0.92 | 0.61 | 0.86 | 0.98 | 0.59 | 0.83 | 0.94 | 0.66 | 0.92 | 1.04 |
| 210.0 | 0.59 | 0.82 | 0.92 | 0.57 | 0.80 | 0.91 | 0.61 | 0.85 | 0.97 | 0.58 | 0.82 | 0.93 | 0.66 | 0.92 | 1.04 |
| 212.0 | 0.58 | 0.81 | 0.92 | 0.57 | 0.80 | 0.90 | 0.60 | 0.85 | 0.96 | 0.58 | 0.81 | 0.92 | 0.65 | 0.91 | 1.03 |
| 214.0 | 0.58 | 0.80 | 0.91 | 0.56 | 0.79 | 0.90 | 0.60 | 0.84 | 0.95 | 0.58 | 0.81 | 0.92 | 0.65 | 0.90 | 1.02 |
| 216.0 | 0.57 | 0.80 | 0.90 | 0.56 | 0.79 | 0.89 | 0.59 | 0.84 | 0.95 | 0.57 | 0.80 | 0.91 | 0.64 | 0.90 | 1.01 |
| 218.0 | 0.57 | 0.79 | 0.90 | 0.55 | 0.78 | 0.88 | 0.59 | 0.83 | 0.94 | 0.57 | 0.80 | 0.90 | 0.64 | 0.89 | 1.01 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 2 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 1 | | | Zone 2 | | | Zone 3 | | | Zone 4 | | | Zone 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 220.0 | 0.56 | 0.79 | 0.89 | 0.55 | 0.77 | 0.88 | 0.58 | 0.82 | 0.93 | 0.56 | 0.79 | 0.90 | 0.63 | 0.88 | 1.00 |
| 222.0 | 0.56 | 0.78 | 0.89 | 0.55 | 0.77 | 0.87 | 0.58 | 0.82 | 0.93 | 0.56 | 0.79 | 0.89 | 0.63 | 0.88 | 0.99 |
| 224.0 | 0.56 | 0.78 | 0.88 | 0.54 | 0.76 | 0.87 | 0.58 | 0.81 | 0.92 | 0.55 | 0.78 | 0.88 | 0.62 | 0.87 | 0.99 |
| 226.0 | 0.55 | 0.77 | 0.87 | 0.54 | 0.76 | 0.86 | 0.57 | 0.81 | 0.92 | 0.55 | 0.77 | 0.88 | 0.62 | 0.86 | 0.98 |
| 228.0 | 0.55 | 0.77 | 0.87 | 0.54 | 0.75 | 0.85 | 0.57 | 0.80 | 0.91 | 0.55 | 0.77 | 0.87 | 0.62 | 0.86 | 0.97 |
| 230.0 | 0.55 | 0.76 | 0.86 | 0.53 | 0.75 | 0.85 | 0.56 | 0.80 | 0.90 | 0.54 | 0.76 | 0.87 | 0.61 | 0.85 | 0.97 |
| 232.0 | 0.54 | 0.76 | 0.86 | 0.53 | 0.74 | 0.84 | 0.56 | 0.79 | 0.90 | 0.54 | 0.76 | 0.86 | 0.61 | 0.85 | 0.96 |
| 234.0 | 0.54 | 0.75 | 0.85 | 0.52 | 0.74 | 0.84 | 0.56 | 0.79 | 0.89 | 0.54 | 0.75 | 0.85 | 0.60 | 0.84 | 0.95 |
| 236.0 | 0.53 | 0.74 | 0.84 | 0.52 | 0.73 | 0.83 | 0.55 | 0.78 | 0.89 | 0.53 | 0.75 | 0.85 | 0.60 | 0.84 | 0.95 |
| 238.0 | 0.53 | 0.74 | 0.84 | 0.52 | 0.73 | 0.83 | 0.55 | 0.78 | 0.88 | 0.53 | 0.74 | 0.84 | 0.60 | 0.83 | 0.94 |
| 240.0 | 0.53 | 0.74 | 0.83 | 0.51 | 0.72 | 0.82 | 0.55 | 0.77 | 0.87 | 0.53 | 0.74 | 0.84 | 0.59 | 0.83 | 0.94 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.1 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 6 | | | Zone 7 | | | Zone 8 | | | Zone 9 | | | Zone 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 10.0 | 4.26 | 5.37 | 5.82 | 4.09 | 5.16 | 5.58 | 4.42 | 5.58 | 6.06 | 4.40 | 5.54 | 6.00 | 4.19 | 5.28 | 5.76 |
| 10.1 | 4.24 | 5.35 | 5.79 | 4.07 | 5.13 | 5.55 | 4.40 | 5.55 | 6.03 | 4.37 | 5.52 | 5.97 | 4.17 | 5.26 | 5.73 |
| 10.2 | 4.22 | 5.32 | 5.76 | 4.05 | 5.11 | 5.53 | 4.38 | 5.52 | 6.00 | 4.35 | 5.49 | 5.94 | 4.15 | 5.23 | 5.70 |
| 10.3 | 4.19 | 5.29 | 5.74 | 4.03 | 5.08 | 5.50 | 4.36 | 5.50 | 5.97 | 4.33 | 5.46 | 5.91 | 4.12 | 5.21 | 5.67 |
| 10.4 | 4.17 | 5.27 | 5.71 | 4.00 | 5.06 | 5.48 | 4.33 | 5.47 | 5.94 | 4.30 | 5.43 | 5.89 | 4.10 | 5.18 | 5.65 |
| 10.5 | 4.15 | 5.24 | 5.68 | 3.98 | 5.03 | 5.45 | 4.31 | 5.45 | 5.92 | 4.28 | 5.41 | 5.86 | 4.08 | 5.15 | 5.62 |
| 10.6 | 4.13 | 5.22 | 5.65 | 3.96 | 5.01 | 5.43 | 4.29 | 5.42 | 5.89 | 4.26 | 5.38 | 5.83 | 4.06 | 5.13 | 5.59 |
| 10.7 | 4.11 | 5.19 | 5.63 | 3.95 | 4.99 | 5.40 | 4.27 | 5.39 | 5.86 | 4.24 | 5.36 | 5.80 | 4.04 | 5.11 | 5.56 |
| 10.8 | 4.09 | 5.17 | 5.60 | 3.93 | 4.96 | 5.38 | 4.25 | 5.37 | 5.83 | 4.22 | 5.33 | 5.78 | 4.02 | 5.08 | 5.54 |
| 10.9 | 4.07 | 5.15 | 5.58 | 3.91 | 4.94 | 5.36 | 4.23 | 5.34 | 5.81 | 4.20 | 5.31 | 5.75 | 4.00 | 5.06 | 5.51 |
| 11.0 | 4.05 | 5.12 | 5.55 | 3.89 | 4.92 | 5.33 | 4.21 | 5.32 | 5.78 | 4.18 | 5.28 | 5.73 | 3.98 | 5.04 | 5.49 |
| 11.1 | 4.03 | 5.10 | 5.53 | 3.87 | 4.89 | 5.31 | 4.19 | 5.30 | 5.76 | 4.16 | 5.26 | 5.70 | 3.96 | 5.01 | 5.46 |
| 11.2 | 4.01 | 5.08 | 5.50 | 3.85 | 4.87 | 5.29 | 4.17 | 5.27 | 5.73 | 4.14 | 5.24 | 5.68 | 3.94 | 4.99 | 5.44 |
| 11.3 | 3.99 | 5.05 | 5.48 | 3.83 | 4.85 | 5.26 | 4.15 | 5.25 | 5.70 | 4.12 | 5.21 | 5.65 | 3.93 | 4.97 | 5.41 |
| 11.4 | 3.97 | 5.03 | 5.45 | 3.82 | 4.83 | 5.24 | 4.13 | 5.23 | 5.68 | 4.10 | 5.19 | 5.63 | 3.91 | 4.95 | 5.39 |
| 11.5 | 3.96 | 5.01 | 5.43 | 3.80 | 4.81 | 5.22 | 4.11 | 5.20 | 5.66 | 4.08 | 5.17 | 5.60 | 3.89 | 4.92 | 5.36 |
| 11.6 | 3.94 | 4.99 | 5.41 | 3.78 | 4.79 | 5.20 | 4.09 | 5.18 | 5.63 | 4.06 | 5.14 | 5.58 | 3.87 | 4.90 | 5.34 |
| 11.7 | 3.92 | 4.97 | 5.38 | 3.76 | 4.77 | 5.18 | 4.07 | 5.16 | 5.61 | 4.04 | 5.12 | 5.56 | 3.85 | 4.88 | 5.32 |
| 11.8 | 3.90 | 4.94 | 5.36 | 3.75 | 4.75 | 5.16 | 4.05 | 5.14 | 5.58 | 4.03 | 5.10 | 5.53 | 3.84 | 4.86 | 5.29 |
| 11.9 | 3.88 | 4.92 | 5.34 | 3.73 | 4.73 | 5.14 | 4.03 | 5.11 | 5.56 | 4.01 | 5.08 | 5.51 | 3.82 | 4.84 | 5.27 |
| 12.0 | 3.87 | 4.90 | 5.32 | 3.71 | 4.71 | 5.12 | 4.02 | 5.09 | 5.54 | 3.99 | 5.06 | 5.49 | 3.80 | 4.82 | 5.25 |
| 12.1 | 3.85 | 4.88 | 5.30 | 3.70 | 4.69 | 5.10 | 4.00 | 5.07 | 5.52 | 3.97 | 5.04 | 5.47 | 3.79 | 4.80 | 5.22 |
| 12.2 | 3.83 | 4.86 | 5.27 | 3.68 | 4.67 | 5.08 | 3.98 | 5.05 | 5.49 | 3.95 | 5.02 | 5.44 | 3.77 | 4.78 | 5.20 |
| 12.3 | 3.82 | 4.84 | 5.25 | 3.66 | 4.65 | 5.06 | 3.96 | 5.03 | 5.47 | 3.94 | 5.00 | 5.42 | 3.75 | 4.76 | 5.18 |
| 12.4 | 3.80 | 4.82 | 5.23 | 3.65 | 4.63 | 5.04 | 3.95 | 5.01 | 5.45 | 3.92 | 4.98 | 5.40 | 3.74 | 4.74 | 5.16 |
| 12.5 | 3.78 | 4.80 | 5.21 | 3.63 | 4.61 | 5.02 | 3.93 | 4.99 | 5.43 | 3.90 | 4.96 | 5.38 | 3.72 | 4.72 | 5.14 |
| 12.6 | 3.77 | 4.78 | 5.19 | 3.62 | 4.59 | 5.00 | 3.91 | 4.97 | 5.41 | 3.89 | 4.94 | 5.36 | 3.70 | 4.70 | 5.12 |
| 12.7 | 3.75 | 4.77 | 5.17 | 3.60 | 4.58 | 4.98 | 3.90 | 4.95 | 5.39 | 3.87 | 4.92 | 5.34 | 3.69 | 4.69 | 5.10 |
| 12.8 | 3.74 | 4.75 | 5.15 | 3.59 | 4.56 | 4.96 | 3.88 | 4.93 | 5.36 | 3.85 | 4.90 | 5.32 | 3.67 | 4.67 | 5.08 |
| 12.9 | 3.72 | 4.73 | 5.13 | 3.57 | 4.54 | 4.94 | 3.87 | 4.91 | 5.34 | 3.84 | 4.88 | 5.30 | 3.66 | 4.65 | 5.06 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.1 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 6 | | | Zone 7 | | | Zone 8 | | | Zone 9 | | | Zone 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 13.0 | 3.71 | 4.71 | 5.11 | 3.56 | 4.52 | 4.92 | 3.85 | 4.89 | 5.32 | 3.82 | 4.86 | 5.28 | 3.64 | 4.63 | 5.04 |
| 13.1 | 3.69 | 4.69 | 5.09 | 3.54 | 4.51 | 4.91 | 3.83 | 4.87 | 5.30 | 3.81 | 4.84 | 5.26 | 3.63 | 4.61 | 5.02 |
| 13.2 | 3.68 | 4.67 | 5.07 | 3.53 | 4.49 | 4.89 | 3.82 | 4.85 | 5.28 | 3.79 | 4.82 | 5.24 | 3.61 | 4.60 | 5.00 |
| 13.3 | 3.66 | 4.66 | 5.05 | 3.52 | 4.47 | 4.87 | 3.80 | 4.84 | 5.26 | 3.78 | 4.80 | 5.22 | 3.60 | 4.58 | 4.98 |
| 13.4 | 3.65 | 4.64 | 5.03 | 3.50 | 4.46 | 4.85 | 3.79 | 4.82 | 5.24 | 3.76 | 4.79 | 5.20 | 3.59 | 4.56 | 4.96 |
| 13.5 | 3.63 | 4.62 | 5.02 | 3.49 | 4.44 | 4.84 | 3.77 | 4.80 | 5.23 | 3.75 | 4.77 | 5.18 | 3.57 | 4.54 | 4.94 |
| 13.6 | 3.62 | 4.61 | 5.00 | 3.48 | 4.42 | 4.82 | 3.76 | 4.78 | 5.21 | 3.73 | 4.75 | 5.16 | 3.56 | 4.53 | 4.92 |
| 13.7 | 3.61 | 4.59 | 4.98 | 3.46 | 4.41 | 4.80 | 3.74 | 4.77 | 5.19 | 3.72 | 4.73 | 5.14 | 3.54 | 4.51 | 4.90 |
| 13.8 | 3.59 | 4.57 | 4.96 | 3.45 | 4.39 | 4.79 | 3.73 | 4.75 | 5.17 | 3.70 | 4.72 | 5.12 | 3.53 | 4.49 | 4.88 |
| 13.9 | 3.58 | 4.56 | 4.94 | 3.44 | 4.37 | 4.77 | 3.72 | 4.73 | 5.15 | 3.69 | 4.70 | 5.11 | 3.52 | 4.48 | 4.87 |
| 14.0 | 3.56 | 4.54 | 4.93 | 3.42 | 4.36 | 4.75 | 3.70 | 4.71 | 5.13 | 3.68 | 4.68 | 5.09 | 3.50 | 4.46 | 4.85 |
| 14.1 | 3.55 | 4.52 | 4.91 | 3.41 | 4.34 | 4.74 | 3.69 | 4.70 | 5.11 | 3.66 | 4.66 | 5.07 | 3.49 | 4.45 | 4.83 |
| 14.2 | 3.54 | 4.51 | 4.89 | 3.40 | 4.33 | 4.72 | 3.67 | 4.68 | 5.10 | 3.65 | 4.65 | 5.05 | 3.48 | 4.43 | 4.81 |
| 14.3 | 3.52 | 4.49 | 4.87 | 3.38 | 4.31 | 4.71 | 3.66 | 4.66 | 5.08 | 3.63 | 4.63 | 5.04 | 3.46 | 4.41 | 4.80 |
| 14.4 | 3.51 | 4.48 | 4.86 | 3.37 | 4.30 | 4.69 | 3.65 | 4.65 | 5.06 | 3.62 | 4.62 | 5.02 | 3.45 | 4.40 | 4.78 |
| 14.5 | 3.50 | 4.46 | 4.84 | 3.36 | 4.28 | 4.67 | 3.63 | 4.63 | 5.04 | 3.61 | 4.60 | 5.00 | 3.44 | 4.38 | 4.76 |
| 14.6 | 3.49 | 4.44 | 4.82 | 3.35 | 4.27 | 4.66 | 3.62 | 4.62 | 5.03 | 3.59 | 4.58 | 4.99 | 3.43 | 4.37 | 4.75 |
| 14.7 | 3.47 | 4.43 | 4.81 | 3.34 | 4.25 | 4.64 | 3.61 | 4.60 | 5.01 | 3.58 | 4.57 | 4.97 | 3.41 | 4.35 | 4.73 |
| 14.8 | 3.46 | 4.41 | 4.79 | 3.32 | 4.24 | 4.63 | 3.59 | 4.58 | 4.99 | 3.57 | 4.55 | 4.95 | 3.40 | 4.34 | 4.71 |
| 14.9 | 3.45 | 4.40 | 4.78 | 3.31 | 4.23 | 4.61 | 3.58 | 4.57 | 4.98 | 3.56 | 4.54 | 4.94 | 3.39 | 4.32 | 4.70 |
| 15.0 | 3.44 | 4.38 | 4.76 | 3.30 | 4.21 | 4.60 | 3.57 | 4.55 | 4.96 | 3.54 | 4.52 | 4.92 | 3.38 | 4.31 | 4.68 |
| 15.1 | 3.42 | 4.37 | 4.74 | 3.29 | 4.20 | 4.58 | 3.56 | 4.54 | 4.94 | 3.53 | 4.51 | 4.90 | 3.36 | 4.30 | 4.66 |
| 15.2 | 3.41 | 4.36 | 4.73 | 3.28 | 4.18 | 4.57 | 3.54 | 4.52 | 4.93 | 3.52 | 4.49 | 4.89 | 3.35 | 4.28 | 4.65 |
| 15.3 | 3.40 | 4.34 | 4.71 | 3.27 | 4.17 | 4.55 | 3.53 | 4.51 | 4.91 | 3.51 | 4.48 | 4.87 | 3.34 | 4.27 | 4.64 |
| 15.4 | 3.39 | 4.33 | 4.70 | 3.25 | 4.16 | 4.54 | 3.52 | 4.49 | 4.90 | 3.49 | 4.46 | 4.86 | 3.33 | 4.25 | 4.62 |
| 15.5 | 3.38 | 4.31 | 4.68 | 3.24 | 4.14 | 4.53 | 3.51 | 4.48 | 4.88 | 3.48 | 4.45 | 4.84 | 3.32 | 4.24 | 4.61 |
| 15.6 | 3.37 | 4.30 | 4.67 | 3.23 | 4.13 | 4.51 | 3.49 | 4.46 | 4.87 | 3.47 | 4.43 | 4.83 | 3.31 | 4.23 | 4.59 |
| 15.7 | 3.35 | 4.29 | 4.66 | 3.22 | 4.12 | 4.50 | 3.48 | 4.45 | 4.85 | 3.46 | 4.42 | 4.81 | 3.30 | 4.21 | 4.58 |
| 15.8 | 3.34 | 4.27 | 4.64 | 3.21 | 4.10 | 4.48 | 3.47 | 4.44 | 4.84 | 3.45 | 4.41 | 4.80 | 3.29 | 4.20 | 4.56 |
| 15.9 | 3.33 | 4.26 | 4.63 | 3.20 | 4.09 | 4.47 | 3.46 | 4.42 | 4.82 | 3.44 | 4.39 | 4.78 | 3.27 | 4.19 | 4.55 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.1 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 6 | | | Zone 7 | | | Zone 8 | | | Zone 9 | | | Zone 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 16.0 | 3.32 | 4.25 | 4.61 | 3.19 | 4.08 | 4.45 | 3.45 | 4.41 | 4.81 | 3.42 | 4.38 | 4.77 | 3.26 | 4.17 | 4.54 |
| 16.1 | 3.31 | 4.23 | 4.60 | 3.18 | 4.06 | 4.44 | 3.44 | 4.39 | 4.79 | 3.41 | 4.36 | 4.75 | 3.25 | 4.16 | 4.52 |
| 16.2 | 3.30 | 4.22 | 4.59 | 3.17 | 4.05 | 4.43 | 3.43 | 4.38 | 4.78 | 3.40 | 4.35 | 4.74 | 3.24 | 4.15 | 4.51 |
| 16.3 | 3.29 | 4.21 | 4.57 | 3.16 | 4.04 | 4.41 | 3.41 | 4.37 | 4.76 | 3.39 | 4.34 | 4.72 | 3.23 | 4.13 | 4.49 |
| 16.4 | 3.28 | 4.19 | 4.56 | 3.15 | 4.03 | 4.40 | 3.40 | 4.35 | 4.75 | 3.38 | 4.32 | 4.71 | 3.22 | 4.12 | 4.48 |
| 16.5 | 3.27 | 4.18 | 4.54 | 3.14 | 4.01 | 4.39 | 3.39 | 4.34 | 4.74 | 3.37 | 4.31 | 4.69 | 3.21 | 4.11 | 4.47 |
| 16.6 | 3.26 | 4.17 | 4.53 | 3.13 | 4.00 | 4.37 | 3.38 | 4.33 | 4.72 | 3.36 | 4.30 | 4.68 | 3.20 | 4.10 | 4.45 |
| 16.7 | 3.25 | 4.16 | 4.52 | 3.12 | 3.99 | 4.36 | 3.37 | 4.32 | 4.71 | 3.35 | 4.29 | 4.67 | 3.19 | 4.08 | 4.44 |
| 16.8 | 3.24 | 4.14 | 4.51 | 3.11 | 3.98 | 4.35 | 3.36 | 4.30 | 4.69 | 3.34 | 4.27 | 4.65 | 3.18 | 4.07 | 4.43 |
| 16.9 | 3.23 | 4.13 | 4.49 | 3.10 | 3.97 | 4.34 | 3.35 | 4.29 | 4.68 | 3.33 | 4.26 | 4.64 | 3.17 | 4.06 | 4.42 |
| 17.0 | 3.22 | 4.12 | 4.48 | 3.09 | 3.95 | 4.32 | 3.34 | 4.28 | 4.67 | 3.32 | 4.25 | 4.63 | 3.16 | 4.05 | 4.40 |
| 17.1 | 3.21 | 4.11 | 4.47 | 3.08 | 3.94 | 4.31 | 3.33 | 4.26 | 4.65 | 3.31 | 4.24 | 4.61 | 3.15 | 4.04 | 4.39 |
| 17.2 | 3.20 | 4.09 | 4.45 | 3.07 | 3.93 | 4.30 | 3.32 | 4.25 | 4.64 | 3.30 | 4.22 | 4.60 | 3.14 | 4.02 | 4.38 |
| 17.3 | 3.19 | 4.08 | 4.44 | 3.06 | 3.92 | 4.29 | 3.31 | 4.24 | 4.63 | 3.29 | 4.21 | 4.59 | 3.13 | 4.01 | 4.37 |
| 17.4 | 3.18 | 4.07 | 4.43 | 3.05 | 3.91 | 4.27 | 3.30 | 4.23 | 4.61 | 3.28 | 4.20 | 4.57 | 3.12 | 4.00 | 4.35 |
| 17.5 | 3.17 | 4.06 | 4.42 | 3.04 | 3.90 | 4.26 | 3.29 | 4.22 | 4.60 | 3.27 | 4.19 | 4.56 | 3.11 | 3.99 | 4.34 |
| 17.6 | 3.16 | 4.05 | 4.40 | 3.03 | 3.89 | 4.25 | 3.28 | 4.20 | 4.59 | 3.26 | 4.17 | 4.55 | 3.10 | 3.98 | 4.33 |
| 17.7 | 3.15 | 4.04 | 4.39 | 3.02 | 3.87 | 4.24 | 3.27 | 4.19 | 4.58 | 3.25 | 4.16 | 4.54 | 3.09 | 3.97 | 4.32 |
| 17.8 | 3.14 | 4.02 | 4.38 | 3.01 | 3.86 | 4.23 | 3.26 | 4.18 | 4.56 | 3.24 | 4.15 | 4.52 | 3.09 | 3.96 | 4.31 |
| 17.9 | 3.13 | 4.01 | 4.37 | 3.00 | 3.85 | 4.21 | 3.25 | 4.17 | 4.55 | 3.23 | 4.14 | 4.51 | 3.08 | 3.95 | 4.29 |
| 18.0 | 3.12 | 4.00 | 4.36 | 2.99 | 3.84 | 4.20 | 3.24 | 4.16 | 4.54 | 3.22 | 4.13 | 4.50 | 3.07 | 3.93 | 4.28 |
| 18.1 | 3.11 | 3.99 | 4.35 | 2.99 | 3.83 | 4.19 | 3.23 | 4.14 | 4.53 | 3.21 | 4.12 | 4.49 | 3.06 | 3.92 | 4.27 |
| 18.2 | 3.10 | 3.98 | 4.33 | 2.98 | 3.82 | 4.18 | 3.22 | 4.13 | 4.51 | 3.20 | 4.11 | 4.47 | 3.05 | 3.91 | 4.26 |
| 18.3 | 3.09 | 3.97 | 4.32 | 2.97 | 3.81 | 4.17 | 3.21 | 4.12 | 4.50 | 3.19 | 4.09 | 4.46 | 3.04 | 3.90 | 4.25 |
| 18.4 | 3.08 | 3.96 | 4.31 | 2.96 | 3.80 | 4.16 | 3.20 | 4.11 | 4.49 | 3.18 | 4.08 | 4.45 | 3.03 | 3.89 | 4.24 |
| 18.5 | 3.08 | 3.95 | 4.30 | 2.95 | 3.79 | 4.14 | 3.19 | 4.10 | 4.48 | 3.17 | 4.07 | 4.44 | 3.02 | 3.88 | 4.23 |
| 18.6 | 3.07 | 3.94 | 4.29 | 2.94 | 3.78 | 4.13 | 3.18 | 4.09 | 4.47 | 3.16 | 4.06 | 4.43 | 3.01 | 3.87 | 4.21 |
| 18.7 | 3.06 | 3.93 | 4.28 | 2.93 | 3.77 | 4.12 | 3.18 | 4.08 | 4.46 | 3.15 | 4.05 | 4.41 | 3.01 | 3.86 | 4.20 |
| 18.8 | 3.05 | 3.92 | 4.27 | 2.93 | 3.76 | 4.11 | 3.17 | 4.07 | 4.44 | 3.14 | 4.04 | 4.40 | 3.00 | 3.85 | 4.19 |
| 18.9 | 3.04 | 3.91 | 4.25 | 2.92 | 3.75 | 4.10 | 3.16 | 4.06 | 4.43 | 3.14 | 4.03 | 4.39 | 2.99 | 3.84 | 4.18 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.1 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 6 | | | Zone 7 | | | Zone 8 | | | Zone 9 | | | Zone 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 19.0 | 3.03 | 3.90 | 4.24 | 2.91 | 3.74 | 4.09 | 3.15 | 4.05 | 4.42 | 3.13 | 4.02 | 4.38 | 2.98 | 3.83 | 4.17 |
| 19.1 | 3.02 | 3.89 | 4.23 | 2.90 | 3.73 | 4.08 | 3.14 | 4.03 | 4.41 | 3.12 | 4.01 | 4.37 | 2.97 | 3.82 | 4.16 |
| 19.2 | 3.02 | 3.88 | 4.22 | 2.89 | 3.72 | 4.07 | 3.13 | 4.02 | 4.40 | 3.11 | 4.00 | 4.36 | 2.96 | 3.81 | 4.15 |
| 19.3 | 3.01 | 3.87 | 4.21 | 2.89 | 3.71 | 4.06 | 3.12 | 4.01 | 4.39 | 3.10 | 3.99 | 4.35 | 2.96 | 3.80 | 4.14 |
| 19.4 | 3.00 | 3.86 | 4.20 | 2.88 | 3.70 | 4.05 | 3.11 | 4.00 | 4.38 | 3.09 | 3.98 | 4.34 | 2.95 | 3.79 | 4.13 |
| 19.5 | 2.99 | 3.85 | 4.19 | 2.87 | 3.69 | 4.04 | 3.11 | 3.99 | 4.37 | 3.08 | 3.97 | 4.32 | 2.94 | 3.78 | 4.12 |
| 19.6 | 2.98 | 3.84 | 4.18 | 2.86 | 3.68 | 4.03 | 3.10 | 3.98 | 4.35 | 3.08 | 3.96 | 4.31 | 2.93 | 3.77 | 4.11 |
| 19.7 | 2.97 | 3.83 | 4.17 | 2.85 | 3.67 | 4.02 | 3.09 | 3.97 | 4.34 | 3.07 | 3.95 | 4.30 | 2.92 | 3.76 | 4.10 |
| 19.8 | 2.97 | 3.82 | 4.16 | 2.85 | 3.66 | 4.01 | 3.08 | 3.96 | 4.33 | 3.06 | 3.94 | 4.29 | 2.92 | 3.75 | 4.09 |
| 19.9 | 2.96 | 3.81 | 4.15 | 2.84 | 3.65 | 4.00 | 3.07 | 3.95 | 4.32 | 3.05 | 3.93 | 4.28 | 2.91 | 3.74 | 4.08 |
| 20.0 | 2.95 | 3.80 | 4.14 | 2.83 | 3.64 | 3.99 | 3.06 | 3.94 | 4.31 | 3.04 | 3.92 | 4.27 | 2.90 | 3.73 | 4.07 |
| 20.1 | 2.94 | 3.79 | 4.13 | 2.82 | 3.63 | 3.98 | 3.06 | 3.93 | 4.30 | 3.04 | 3.91 | 4.26 | 2.89 | 3.72 | 4.06 |
| 20.2 | 2.94 | 3.78 | 4.12 | 2.82 | 3.63 | 3.97 | 3.05 | 3.92 | 4.29 | 3.03 | 3.90 | 4.25 | 2.89 | 3.71 | 4.05 |
| 20.3 | 2.93 | 3.77 | 4.11 | 2.81 | 3.62 | 3.96 | 3.04 | 3.91 | 4.28 | 3.02 | 3.89 | 4.24 | 2.88 | 3.70 | 4.04 |
| 20.4 | 2.92 | 3.76 | 4.10 | 2.80 | 3.61 | 3.95 | 3.03 | 3.90 | 4.27 | 3.01 | 3.88 | 4.23 | 2.87 | 3.70 | 4.03 |
| 20.5 | 2.91 | 3.75 | 4.09 | 2.79 | 3.60 | 3.94 | 3.02 | 3.89 | 4.26 | 3.00 | 3.87 | 4.22 | 2.86 | 3.69 | 4.02 |
| 20.6 | 2.91 | 3.74 | 4.08 | 2.79 | 3.59 | 3.93 | 3.02 | 3.89 | 4.25 | 3.00 | 3.86 | 4.21 | 2.86 | 3.68 | 4.01 |
| 20.7 | 2.90 | 3.73 | 4.07 | 2.78 | 3.58 | 3.92 | 3.01 | 3.88 | 4.24 | 2.99 | 3.85 | 4.20 | 2.85 | 3.67 | 4.00 |
| 20.8 | 2.89 | 3.72 | 4.06 | 2.77 | 3.57 | 3.91 | 3.00 | 3.87 | 4.23 | 2.98 | 3.84 | 4.19 | 2.84 | 3.66 | 3.99 |
| 20.9 | 2.88 | 3.71 | 4.05 | 2.77 | 3.56 | 3.90 | 2.99 | 3.86 | 4.22 | 2.97 | 3.83 | 4.18 | 2.83 | 3.65 | 3.98 |
| 21.0 | 2.88 | 3.71 | 4.04 | 2.76 | 3.56 | 3.89 | 2.99 | 3.85 | 4.21 | 2.97 | 3.82 | 4.17 | 2.83 | 3.64 | 3.97 |
| 21.1 | 2.87 | 3.70 | 4.03 | 2.75 | 3.55 | 3.88 | 2.98 | 3.84 | 4.20 | 2.96 | 3.81 | 4.16 | 2.82 | 3.63 | 3.96 |
| 21.2 | 2.86 | 3.69 | 4.02 | 2.75 | 3.54 | 3.87 | 2.97 | 3.83 | 4.19 | 2.95 | 3.80 | 4.15 | 2.81 | 3.63 | 3.95 |
| 21.3 | 2.85 | 3.68 | 4.01 | 2.74 | 3.53 | 3.86 | 2.96 | 3.82 | 4.18 | 2.94 | 3.79 | 4.14 | 2.81 | 3.62 | 3.95 |
| 21.4 | 2.85 | 3.67 | 4.01 | 2.73 | 3.52 | 3.86 | 2.96 | 3.81 | 4.17 | 2.94 | 3.79 | 4.13 | 2.80 | 3.61 | 3.94 |
| 21.5 | 2.84 | 3.66 | 4.00 | 2.72 | 3.51 | 3.85 | 2.95 | 3.80 | 4.16 | 2.93 | 3.78 | 4.12 | 2.79 | 3.60 | 3.93 |
| 21.6 | 2.83 | 3.65 | 3.99 | 2.72 | 3.50 | 3.84 | 2.94 | 3.79 | 4.15 | 2.92 | 3.77 | 4.11 | 2.79 | 3.59 | 3.92 |
| 21.7 | 2.83 | 3.64 | 3.98 | 2.71 | 3.50 | 3.83 | 2.94 | 3.79 | 4.14 | 2.92 | 3.76 | 4.10 | 2.78 | 3.58 | 3.91 |
| 21.8 | 2.82 | 3.64 | 3.97 | 2.70 | 3.49 | 3.82 | 2.93 | 3.78 | 4.14 | 2.91 | 3.75 | 4.09 | 2.77 | 3.58 | 3.90 |
| 21.9 | 2.81 | 3.63 | 3.96 | 2.70 | 3.48 | 3.81 | 2.92 | 3.77 | 4.13 | 2.90 | 3.74 | 4.09 | 2.77 | 3.57 | 3.89 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.1 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 6 | | | Zone 7 | | | Zone 8 | | | Zone 9 | | | Zone 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 22.0 | 2.81 | 3.62 | 3.95 | 2.69 | 3.47 | 3.80 | 2.91 | 3.76 | 4.12 | 2.89 | 3.73 | 4.08 | 2.76 | 3.56 | 3.88 |
| 22.1 | 2.80 | 3.61 | 3.94 | 2.69 | 3.46 | 3.79 | 2.91 | 3.75 | 4.11 | 2.89 | 3.73 | 4.07 | 2.75 | 3.55 | 3.88 |
| 22.2 | 2.79 | 3.60 | 3.94 | 2.68 | 3.46 | 3.79 | 2.90 | 3.74 | 4.10 | 2.88 | 3.72 | 4.06 | 2.75 | 3.54 | 3.87 |
| 22.3 | 2.79 | 3.60 | 3.93 | 2.67 | 3.45 | 3.78 | 2.89 | 3.73 | 4.09 | 2.87 | 3.71 | 4.05 | 2.74 | 3.53 | 3.86 |
| 22.4 | 2.78 | 3.59 | 3.92 | 2.67 | 3.44 | 3.77 | 2.89 | 3.73 | 4.08 | 2.87 | 3.70 | 4.04 | 2.73 | 3.53 | 3.85 |
| 22.5 | 2.77 | 3.58 | 3.91 | 2.66 | 3.43 | 3.76 | 2.88 | 3.72 | 4.07 | 2.86 | 3.69 | 4.03 | 2.73 | 3.52 | 3.84 |
| 22.6 | 2.77 | 3.57 | 3.90 | 2.65 | 3.43 | 3.75 | 2.87 | 3.71 | 4.06 | 2.85 | 3.68 | 4.02 | 2.72 | 3.51 | 3.83 |
| 22.7 | 2.76 | 3.56 | 3.89 | 2.65 | 3.42 | 3.74 | 2.87 | 3.70 | 4.05 | 2.85 | 3.68 | 4.01 | 2.71 | 3.50 | 3.83 |
| 22.8 | 2.75 | 3.56 | 3.88 | 2.64 | 3.41 | 3.74 | 2.86 | 3.69 | 4.05 | 2.84 | 3.67 | 4.01 | 2.71 | 3.50 | 3.82 |
| 22.9 | 2.75 | 3.55 | 3.88 | 2.64 | 3.40 | 3.73 | 2.85 | 3.68 | 4.04 | 2.83 | 3.66 | 4.00 | 2.70 | 3.49 | 3.81 |
| 23.0 | 2.74 | 3.54 | 3.87 | 2.63 | 3.40 | 3.72 | 2.85 | 3.68 | 4.03 | 2.83 | 3.65 | 3.99 | 2.69 | 3.48 | 3.80 |
| 23.1 | 2.73 | 3.53 | 3.86 | 2.62 | 3.39 | 3.71 | 2.84 | 3.67 | 4.02 | 2.82 | 3.64 | 3.98 | 2.69 | 3.47 | 3.79 |
| 23.2 | 2.73 | 3.52 | 3.85 | 2.62 | 3.38 | 3.70 | 2.83 | 3.66 | 4.01 | 2.81 | 3.64 | 3.97 | 2.68 | 3.47 | 3.79 |
| 23.3 | 2.72 | 3.52 | 3.84 | 2.61 | 3.37 | 3.70 | 2.83 | 3.65 | 4.00 | 2.81 | 3.63 | 3.96 | 2.68 | 3.46 | 3.78 |
| 23.4 | 2.72 | 3.51 | 3.84 | 2.60 | 3.37 | 3.69 | 2.82 | 3.65 | 3.99 | 2.80 | 3.62 | 3.95 | 2.67 | 3.45 | 3.77 |
| 23.5 | 2.71 | 3.50 | 3.83 | 2.60 | 3.36 | 3.68 | 2.81 | 3.64 | 3.99 | 2.80 | 3.61 | 3.95 | 2.66 | 3.44 | 3.76 |
| 23.6 | 2.70 | 3.49 | 3.82 | 2.59 | 3.35 | 3.67 | 2.81 | 3.63 | 3.98 | 2.79 | 3.61 | 3.94 | 2.66 | 3.44 | 3.75 |
| 23.7 | 2.70 | 3.49 | 3.81 | 2.59 | 3.35 | 3.66 | 2.80 | 3.62 | 3.97 | 2.78 | 3.60 | 3.93 | 2.65 | 3.43 | 3.75 |
| 23.8 | 2.69 | 3.48 | 3.80 | 2.58 | 3.34 | 3.66 | 2.80 | 3.61 | 3.96 | 2.78 | 3.59 | 3.92 | 2.65 | 3.42 | 3.74 |
| 23.9 | 2.69 | 3.47 | 3.80 | 2.58 | 3.33 | 3.65 | 2.79 | 3.61 | 3.95 | 2.77 | 3.58 | 3.91 | 2.64 | 3.41 | 3.73 |
| 24.0 | 2.68 | 3.47 | 3.79 | 2.57 | 3.32 | 3.64 | 2.78 | 3.60 | 3.95 | 2.76 | 3.57 | 3.91 | 2.63 | 3.41 | 3.72 |
| 24.1 | 2.67 | 3.46 | 3.78 | 2.56 | 3.32 | 3.63 | 2.78 | 3.59 | 3.94 | 2.76 | 3.57 | 3.90 | 2.63 | 3.40 | 3.72 |
| 24.2 | 2.67 | 3.45 | 3.77 | 2.56 | 3.31 | 3.63 | 2.77 | 3.58 | 3.93 | 2.75 | 3.56 | 3.89 | 2.62 | 3.39 | 3.71 |
| 24.3 | 2.66 | 3.44 | 3.77 | 2.55 | 3.30 | 3.62 | 2.76 | 3.58 | 3.92 | 2.75 | 3.55 | 3.88 | 2.62 | 3.39 | 3.70 |
| 24.4 | 2.66 | 3.44 | 3.76 | 2.55 | 3.30 | 3.61 | 2.76 | 3.57 | 3.91 | 2.74 | 3.55 | 3.87 | 2.61 | 3.38 | 3.69 |
| 24.5 | 2.65 | 3.43 | 3.75 | 2.54 | 3.29 | 3.61 | 2.75 | 3.56 | 3.91 | 2.73 | 3.54 | 3.87 | 2.61 | 3.37 | 3.69 |
| 24.6 | 2.64 | 3.42 | 3.74 | 2.54 | 3.28 | 3.60 | 2.75 | 3.56 | 3.90 | 2.73 | 3.53 | 3.86 | 2.60 | 3.37 | 3.68 |
| 24.7 | 2.64 | 3.42 | 3.74 | 2.53 | 3.28 | 3.59 | 2.74 | 3.55 | 3.89 | 2.72 | 3.52 | 3.85 | 2.60 | 3.36 | 3.67 |
| 24.8 | 2.63 | 3.41 | 3.73 | 2.53 | 3.27 | 3.58 | 2.74 | 3.54 | 3.88 | 2.72 | 3.52 | 3.84 | 2.59 | 3.35 | 3.66 |
| 24.9 | 2.63 | 3.40 | 3.72 | 2.52 | 3.26 | 3.58 | 2.73 | 3.53 | 3.88 | 2.71 | 3.51 | 3.84 | 2.58 | 3.35 | 3.66 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.1 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 6 | | | Zone 7 | | | Zone 8 | | | Zone 9 | | | Zone 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 25.0 | 2.62 | 3.40 | 3.71 | 2.51 | 3.26 | 3.57 | 2.72 | 3.53 | 3.87 | 2.71 | 3.50 | 3.83 | 2.58 | 3.34 | 3.65 |
| 25.1 | 2.62 | 3.39 | 3.71 | 2.51 | 3.25 | 3.56 | 2.72 | 3.52 | 3.86 | 2.70 | 3.50 | 3.82 | 2.57 | 3.33 | 3.64 |
| 25.2 | 2.61 | 3.38 | 3.70 | 2.50 | 3.24 | 3.55 | 2.71 | 3.51 | 3.85 | 2.69 | 3.49 | 3.81 | 2.57 | 3.33 | 3.64 |
| 25.3 | 2.61 | 3.38 | 3.69 | 2.50 | 3.24 | 3.55 | 2.71 | 3.51 | 3.85 | 2.69 | 3.48 | 3.81 | 2.56 | 3.32 | 3.63 |
| 25.4 | 2.60 | 3.37 | 3.69 | 2.49 | 3.23 | 3.54 | 2.70 | 3.50 | 3.84 | 2.68 | 3.47 | 3.80 | 2.56 | 3.31 | 3.62 |
| 25.5 | 2.60 | 3.36 | 3.68 | 2.49 | 3.22 | 3.53 | 2.70 | 3.49 | 3.83 | 2.68 | 3.47 | 3.79 | 2.55 | 3.31 | 3.61 |
| 25.6 | 2.59 | 3.36 | 3.67 | 2.48 | 3.22 | 3.53 | 2.69 | 3.48 | 3.82 | 2.67 | 3.46 | 3.78 | 2.55 | 3.30 | 3.61 |
| 25.7 | 2.58 | 3.35 | 3.67 | 2.48 | 3.21 | 3.52 | 2.68 | 3.48 | 3.82 | 2.67 | 3.45 | 3.78 | 2.54 | 3.29 | 3.60 |
| 25.8 | 2.58 | 3.34 | 3.66 | 2.47 | 3.21 | 3.51 | 2.68 | 3.47 | 3.81 | 2.66 | 3.45 | 3.77 | 2.54 | 3.29 | 3.59 |
| 25.9 | 2.57 | 3.34 | 3.65 | 2.47 | 3.20 | 3.51 | 2.67 | 3.46 | 3.80 | 2.66 | 3.44 | 3.76 | 2.53 | 3.28 | 3.59 |
| 26.0 | 2.57 | 3.33 | 3.64 | 2.46 | 3.19 | 3.50 | 2.67 | 3.46 | 3.80 | 2.65 | 3.43 | 3.75 | 2.53 | 3.27 | 3.58 |
| 26.1 | 2.56 | 3.32 | 3.64 | 2.46 | 3.19 | 3.49 | 2.66 | 3.45 | 3.79 | 2.64 | 3.43 | 3.75 | 2.52 | 3.27 | 3.57 |
| 26.2 | 2.56 | 3.32 | 3.63 | 2.45 | 3.18 | 3.49 | 2.66 | 3.44 | 3.78 | 2.64 | 3.42 | 3.74 | 2.52 | 3.26 | 3.57 |
| 26.3 | 2.55 | 3.31 | 3.62 | 2.45 | 3.17 | 3.48 | 2.65 | 3.44 | 3.77 | 2.63 | 3.41 | 3.73 | 2.51 | 3.26 | 3.56 |
| 26.4 | 2.55 | 3.30 | 3.62 | 2.44 | 3.17 | 3.47 | 2.65 | 3.43 | 3.77 | 2.63 | 3.41 | 3.73 | 2.51 | 3.25 | 3.55 |
| 26.5 | 2.54 | 3.30 | 3.61 | 2.44 | 3.16 | 3.47 | 2.64 | 3.43 | 3.76 | 2.62 | 3.40 | 3.72 | 2.50 | 3.24 | 3.55 |
| 26.6 | 2.54 | 3.29 | 3.60 | 2.43 | 3.16 | 3.46 | 2.64 | 3.42 | 3.75 | 2.62 | 3.40 | 3.71 | 2.50 | 3.24 | 3.54 |
| 26.7 | 2.53 | 3.29 | 3.60 | 2.43 | 3.15 | 3.45 | 2.63 | 3.41 | 3.75 | 2.61 | 3.39 | 3.71 | 2.49 | 3.23 | 3.53 |
| 26.8 | 2.53 | 3.28 | 3.59 | 2.42 | 3.14 | 3.45 | 2.63 | 3.41 | 3.74 | 2.61 | 3.38 | 3.70 | 2.49 | 3.22 | 3.53 |
| 26.9 | 2.52 | 3.27 | 3.58 | 2.42 | 3.14 | 3.44 | 2.62 | 3.40 | 3.73 | 2.60 | 3.38 | 3.69 | 2.48 | 3.22 | 3.52 |
| 27.0 | 2.52 | 3.27 | 3.58 | 2.41 | 3.13 | 3.44 | 2.62 | 3.39 | 3.73 | 2.60 | 3.37 | 3.69 | 2.48 | 3.21 | 3.52 |
| 27.1 | 2.51 | 3.26 | 3.57 | 2.41 | 3.13 | 3.43 | 2.61 | 3.39 | 3.72 | 2.59 | 3.36 | 3.68 | 2.47 | 3.21 | 3.51 |
| 27.2 | 2.51 | 3.25 | 3.57 | 2.40 | 3.12 | 3.42 | 2.60 | 3.38 | 3.71 | 2.59 | 3.36 | 3.67 | 2.47 | 3.20 | 3.50 |
| 27.3 | 2.50 | 3.25 | 3.56 | 2.40 | 3.12 | 3.42 | 2.60 | 3.37 | 3.71 | 2.58 | 3.35 | 3.67 | 2.46 | 3.20 | 3.50 |
| 27.4 | 2.50 | 3.24 | 3.55 | 2.40 | 3.11 | 3.41 | 2.59 | 3.37 | 3.70 | 2.58 | 3.35 | 3.66 | 2.46 | 3.19 | 3.49 |
| 27.5 | 2.49 | 3.24 | 3.55 | 2.39 | 3.10 | 3.40 | 2.59 | 3.36 | 3.69 | 2.57 | 3.34 | 3.65 | 2.45 | 3.18 | 3.48 |
| 27.6 | 2.49 | 3.23 | 3.54 | 2.39 | 3.10 | 3.40 | 2.58 | 3.36 | 3.69 | 2.57 | 3.33 | 3.65 | 2.45 | 3.18 | 3.48 |
| 27.7 | 2.48 | 3.23 | 3.53 | 2.38 | 3.09 | 3.39 | 2.58 | 3.35 | 3.68 | 2.56 | 3.33 | 3.64 | 2.44 | 3.17 | 3.47 |
| 27.8 | 2.48 | 3.22 | 3.53 | 2.38 | 3.09 | 3.39 | 2.58 | 3.34 | 3.67 | 2.56 | 3.32 | 3.63 | 2.44 | 3.17 | 3.47 |
| 27.9 | 2.47 | 3.21 | 3.52 | 2.37 | 3.08 | 3.38 | 2.57 | 3.34 | 3.67 | 2.55 | 3.32 | 3.63 | 2.43 | 3.16 | 3.46 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.1 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 6 | | | Zone 7 | | | Zone 8 | | | Zone 9 | | | Zone 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 28.0 | 2.47 | 3.21 | 3.52 | 2.37 | 3.08 | 3.37 | 2.57 | 3.33 | 3.66 | 2.55 | 3.31 | 3.62 | 2.43 | 3.15 | 3.45 |
| 28.1 | 2.47 | 3.20 | 3.51 | 2.36 | 3.07 | 3.37 | 2.56 | 3.33 | 3.65 | 2.54 | 3.30 | 3.61 | 2.42 | 3.15 | 3.45 |
| 28.2 | 2.46 | 3.20 | 3.50 | 2.36 | 3.06 | 3.36 | 2.56 | 3.32 | 3.65 | 2.54 | 3.30 | 3.61 | 2.42 | 3.14 | 3.44 |
| 28.3 | 2.46 | 3.19 | 3.50 | 2.35 | 3.06 | 3.36 | 2.55 | 3.31 | 3.64 | 2.53 | 3.29 | 3.60 | 2.42 | 3.14 | 3.44 |
| 28.4 | 2.45 | 3.19 | 3.49 | 2.35 | 3.05 | 3.35 | 2.55 | 3.31 | 3.64 | 2.53 | 3.29 | 3.60 | 2.41 | 3.13 | 3.43 |
| 28.5 | 2.45 | 3.18 | 3.49 | 2.35 | 3.05 | 3.34 | 2.54 | 3.30 | 3.63 | 2.52 | 3.28 | 3.59 | 2.41 | 3.13 | 3.42 |
| 28.6 | 2.44 | 3.17 | 3.48 | 2.34 | 3.04 | 3.34 | 2.54 | 3.30 | 3.62 | 2.52 | 3.27 | 3.58 | 2.40 | 3.12 | 3.42 |
| 28.7 | 2.44 | 3.17 | 3.47 | 2.34 | 3.04 | 3.33 | 2.53 | 3.29 | 3.62 | 2.52 | 3.27 | 3.58 | 2.40 | 3.12 | 3.41 |
| 28.8 | 2.43 | 3.16 | 3.47 | 2.33 | 3.03 | 3.33 | 2.53 | 3.29 | 3.61 | 2.51 | 3.26 | 3.57 | 2.39 | 3.11 | 3.41 |
| 28.9 | 2.43 | 3.16 | 3.46 | 2.33 | 3.03 | 3.32 | 2.52 | 3.28 | 3.60 | 2.51 | 3.26 | 3.56 | 2.39 | 3.11 | 3.40 |
| 29.0 | 2.42 | 3.15 | 3.46 | 2.32 | 3.02 | 3.32 | 2.52 | 3.27 | 3.60 | 2.50 | 3.25 | 3.56 | 2.38 | 3.10 | 3.40 |
| 29.1 | 2.42 | 3.15 | 3.45 | 2.32 | 3.02 | 3.31 | 2.51 | 3.27 | 3.59 | 2.50 | 3.25 | 3.55 | 2.38 | 3.09 | 3.39 |
| 29.2 | 2.42 | 3.14 | 3.44 | 2.32 | 3.01 | 3.30 | 2.51 | 3.26 | 3.59 | 2.49 | 3.24 | 3.55 | 2.38 | 3.09 | 3.38 |
| 29.3 | 2.41 | 3.14 | 3.44 | 2.31 | 3.01 | 3.30 | 2.50 | 3.26 | 3.58 | 2.49 | 3.24 | 3.54 | 2.37 | 3.08 | 3.38 |
| 29.4 | 2.41 | 3.13 | 3.43 | 2.31 | 3.00 | 3.29 | 2.50 | 3.25 | 3.57 | 2.48 | 3.23 | 3.53 | 2.37 | 3.08 | 3.37 |
| 29.5 | 2.40 | 3.13 | 3.43 | 2.30 | 3.00 | 3.29 | 2.50 | 3.25 | 3.57 | 2.48 | 3.22 | 3.53 | 2.36 | 3.07 | 3.37 |
| 29.6 | 2.40 | 3.12 | 3.42 | 2.30 | 2.99 | 3.28 | 2.49 | 3.24 | 3.56 | 2.47 | 3.22 | 3.52 | 2.36 | 3.07 | 3.36 |
| 29.7 | 2.39 | 3.11 | 3.42 | 2.29 | 2.99 | 3.28 | 2.49 | 3.24 | 3.56 | 2.47 | 3.21 | 3.52 | 2.35 | 3.06 | 3.36 |
| 29.8 | 2.39 | 3.11 | 3.41 | 2.29 | 2.98 | 3.27 | 2.48 | 3.23 | 3.55 | 2.47 | 3.21 | 3.51 | 2.35 | 3.06 | 3.35 |
| 29.9 | 2.39 | 3.10 | 3.41 | 2.29 | 2.98 | 3.27 | 2.48 | 3.22 | 3.55 | 2.46 | 3.20 | 3.51 | 2.35 | 3.05 | 3.35 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.2 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 6 | | | Zone 7 | | | Zone 8 | | | Zone 9 | | | Zone 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 30.0 | 2.38 | 3.10 | 3.40 | 2.28 | 2.97 | 3.26 | 2.47 | 3.22 | 3.54 | 2.46 | 3.20 | 3.50 | 2.34 | 3.05 | 3.34 |
| 30.2 | 2.37 | 3.09 | 3.39 | 2.27 | 2.96 | 3.25 | 2.47 | 3.21 | 3.53 | 2.45 | 3.19 | 3.49 | 2.33 | 3.04 | 3.33 |
| 30.4 | 2.37 | 3.08 | 3.38 | 2.27 | 2.95 | 3.24 | 2.46 | 3.20 | 3.52 | 2.44 | 3.18 | 3.48 | 2.33 | 3.03 | 3.32 |
| 30.6 | 2.36 | 3.07 | 3.37 | 2.26 | 2.95 | 3.23 | 2.45 | 3.19 | 3.51 | 2.43 | 3.17 | 3.47 | 2.32 | 3.02 | 3.31 |
| 30.8 | 2.35 | 3.07 | 3.37 | 2.25 | 2.94 | 3.23 | 2.44 | 3.18 | 3.50 | 2.42 | 3.16 | 3.46 | 2.31 | 3.01 | 3.30 |
| 31.0 | 2.34 | 3.06 | 3.36 | 2.24 | 2.93 | 3.22 | 2.43 | 3.17 | 3.49 | 2.42 | 3.15 | 3.45 | 2.30 | 3.00 | 3.29 |
| 31.2 | 2.33 | 3.05 | 3.35 | 2.24 | 2.92 | 3.21 | 2.42 | 3.16 | 3.48 | 2.41 | 3.14 | 3.44 | 2.30 | 2.99 | 3.28 |
| 31.4 | 2.33 | 3.04 | 3.34 | 2.23 | 2.91 | 3.20 | 2.42 | 3.15 | 3.47 | 2.40 | 3.13 | 3.43 | 2.29 | 2.99 | 3.28 |
| 31.6 | 2.32 | 3.04 | 3.33 | 2.22 | 2.91 | 3.19 | 2.41 | 3.15 | 3.46 | 2.39 | 3.12 | 3.42 | 2.28 | 2.98 | 3.27 |
| 31.8 | 2.31 | 3.03 | 3.33 | 2.21 | 2.90 | 3.18 | 2.40 | 3.14 | 3.45 | 2.39 | 3.12 | 3.42 | 2.28 | 2.97 | 3.26 |
| 32.0 | 2.30 | 3.02 | 3.32 | 2.20 | 2.89 | 3.18 | 2.39 | 3.13 | 3.44 | 2.38 | 3.11 | 3.41 | 2.27 | 2.96 | 3.25 |
| 32.2 | 2.30 | 3.01 | 3.31 | 2.20 | 2.88 | 3.17 | 2.39 | 3.12 | 3.44 | 2.37 | 3.10 | 3.40 | 2.26 | 2.95 | 3.24 |
| 32.4 | 2.29 | 3.01 | 3.30 | 2.19 | 2.88 | 3.16 | 2.38 | 3.11 | 3.43 | 2.36 | 3.09 | 3.39 | 2.25 | 2.94 | 3.23 |
| 32.6 | 2.28 | 3.00 | 3.30 | 2.18 | 2.87 | 3.15 | 2.37 | 3.10 | 3.42 | 2.36 | 3.08 | 3.38 | 2.25 | 2.94 | 3.22 |
| 32.8 | 2.27 | 2.99 | 3.29 | 2.18 | 2.86 | 3.15 | 2.36 | 3.09 | 3.41 | 2.35 | 3.07 | 3.37 | 2.24 | 2.93 | 3.21 |
| 33.0 | 2.27 | 2.98 | 3.28 | 2.17 | 2.85 | 3.14 | 2.36 | 3.09 | 3.40 | 2.34 | 3.07 | 3.36 | 2.23 | 2.92 | 3.21 |
| 33.2 | 2.26 | 2.98 | 3.27 | 2.16 | 2.85 | 3.13 | 2.35 | 3.08 | 3.39 | 2.34 | 3.06 | 3.35 | 2.23 | 2.91 | 3.20 |
| 33.4 | 2.25 | 2.97 | 3.27 | 2.15 | 2.84 | 3.12 | 2.34 | 3.07 | 3.38 | 2.33 | 3.05 | 3.35 | 2.22 | 2.90 | 3.19 |
| 33.6 | 2.25 | 2.96 | 3.26 | 2.15 | 2.83 | 3.12 | 2.33 | 3.06 | 3.37 | 2.32 | 3.04 | 3.34 | 2.21 | 2.90 | 3.18 |
| 33.8 | 2.24 | 2.96 | 3.25 | 2.14 | 2.82 | 3.11 | 2.33 | 3.05 | 3.37 | 2.31 | 3.03 | 3.33 | 2.21 | 2.89 | 3.17 |
| 34.0 | 2.23 | 2.95 | 3.24 | 2.13 | 2.82 | 3.10 | 2.32 | 3.05 | 3.36 | 2.31 | 3.03 | 3.32 | 2.20 | 2.88 | 3.17 |
| 34.2 | 2.23 | 2.94 | 3.24 | 2.13 | 2.81 | 3.09 | 2.31 | 3.04 | 3.35 | 2.30 | 3.02 | 3.31 | 2.19 | 2.87 | 3.16 |
| 34.4 | 2.22 | 2.94 | 3.23 | 2.12 | 2.80 | 3.09 | 2.31 | 3.03 | 3.34 | 2.29 | 3.01 | 3.31 | 2.19 | 2.86 | 3.15 |
| 34.6 | 2.21 | 2.93 | 3.22 | 2.11 | 2.80 | 3.08 | 2.30 | 3.02 | 3.33 | 2.29 | 3.00 | 3.30 | 2.18 | 2.86 | 3.14 |
| 34.8 | 2.21 | 2.92 | 3.22 | 2.11 | 2.79 | 3.07 | 2.29 | 3.01 | 3.32 | 2.28 | 2.99 | 3.29 | 2.18 | 2.85 | 3.13 |
| 35.0 | 2.20 | 2.92 | 3.21 | 2.10 | 2.78 | 3.06 | 2.29 | 3.01 | 3.32 | 2.27 | 2.99 | 3.28 | 2.17 | 2.84 | 3.13 |
| 35.2 | 2.19 | 2.91 | 3.20 | 2.09 | 2.78 | 3.06 | 2.28 | 3.00 | 3.31 | 2.27 | 2.98 | 3.27 | 2.16 | 2.83 | 3.12 |
| 35.4 | 2.19 | 2.90 | 3.19 | 2.09 | 2.77 | 3.05 | 2.27 | 2.99 | 3.30 | 2.26 | 2.97 | 3.27 | 2.16 | 2.83 | 3.11 |
| 35.6 | 2.18 | 2.90 | 3.19 | 2.08 | 2.76 | 3.04 | 2.27 | 2.98 | 3.29 | 2.25 | 2.96 | 3.26 | 2.15 | 2.82 | 3.10 |
| 35.8 | 2.17 | 2.89 | 3.18 | 2.08 | 2.76 | 3.04 | 2.26 | 2.98 | 3.28 | 2.25 | 2.96 | 3.25 | 2.15 | 2.81 | 3.10 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.2 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 6 | | | Zone 7 | | | Zone 8 | | | Zone 9 | | | Zone 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 36.0 | 2.17 | 2.88 | 3.17 | 2.07 | 2.75 | 3.03 | 2.25 | 2.97 | 3.28 | 2.24 | 2.95 | 3.24 | 2.14 | 2.81 | 3.09 |
| 36.2 | 2.16 | 2.88 | 3.17 | 2.06 | 2.74 | 3.02 | 2.25 | 2.96 | 3.27 | 2.24 | 2.94 | 3.24 | 2.13 | 2.80 | 3.08 |
| 36.4 | 2.16 | 2.87 | 3.16 | 2.06 | 2.74 | 3.02 | 2.24 | 2.96 | 3.26 | 2.23 | 2.94 | 3.23 | 2.13 | 2.79 | 3.07 |
| 36.6 | 2.15 | 2.86 | 3.16 | 2.05 | 2.73 | 3.01 | 2.24 | 2.95 | 3.25 | 2.22 | 2.93 | 3.22 | 2.12 | 2.78 | 3.07 |
| 36.8 | 2.14 | 2.86 | 3.15 | 2.05 | 2.72 | 3.00 | 2.23 | 2.94 | 3.25 | 2.22 | 2.92 | 3.21 | 2.12 | 2.78 | 3.06 |
| 37.0 | 2.14 | 2.85 | 3.14 | 2.04 | 2.72 | 3.00 | 2.22 | 2.93 | 3.24 | 2.21 | 2.91 | 3.21 | 2.11 | 2.77 | 3.05 |
| 37.2 | 2.13 | 2.85 | 3.14 | 2.03 | 2.71 | 2.99 | 2.22 | 2.93 | 3.23 | 2.21 | 2.91 | 3.20 | 2.10 | 2.76 | 3.05 |
| 37.4 | 2.13 | 2.84 | 3.13 | 2.03 | 2.71 | 2.98 | 2.21 | 2.92 | 3.22 | 2.20 | 2.90 | 3.19 | 2.10 | 2.76 | 3.04 |
| 37.6 | 2.12 | 2.83 | 3.12 | 2.02 | 2.70 | 2.98 | 2.21 | 2.91 | 3.22 | 2.19 | 2.89 | 3.18 | 2.09 | 2.75 | 3.03 |
| 37.8 | 2.11 | 2.83 | 3.12 | 2.02 | 2.69 | 2.97 | 2.20 | 2.91 | 3.21 | 2.19 | 2.89 | 3.18 | 2.09 | 2.74 | 3.02 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.5 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 6 | | | Zone 7 | | | Zone 8 | | | Zone 9 | | | Zone 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 38.0 | 2.11 | 2.82 | 3.11 | 2.01 | 2.69 | 2.97 | 2.19 | 2.90 | 3.20 | 2.18 | 2.88 | 3.17 | 2.08 | 2.74 | 3.02 |
| 38.5 | 2.09 | 2.81 | 3.10 | 2.00 | 2.67 | 2.95 | 2.18 | 2.88 | 3.19 | 2.17 | 2.86 | 3.15 | 2.07 | 2.72 | 3.00 |
| 39.0 | 2.08 | 2.79 | 3.08 | 1.98 | 2.66 | 2.93 | 2.16 | 2.87 | 3.17 | 2.15 | 2.85 | 3.14 | 2.06 | 2.71 | 2.98 |
| 39.5 | 2.07 | 2.78 | 3.07 | 1.97 | 2.64 | 2.92 | 2.15 | 2.85 | 3.15 | 2.14 | 2.83 | 3.12 | 2.04 | 2.69 | 2.97 |
| 40.0 | 2.05 | 2.77 | 3.05 | 1.96 | 2.63 | 2.91 | 2.14 | 2.84 | 3.13 | 2.13 | 2.82 | 3.10 | 2.03 | 2.67 | 2.95 |
| 40.5 | 2.04 | 2.75 | 3.04 | 1.94 | 2.62 | 2.89 | 2.12 | 2.82 | 3.12 | 2.11 | 2.80 | 3.09 | 2.02 | 2.66 | 2.94 |
| 41.0 | 2.03 | 2.74 | 3.02 | 1.93 | 2.60 | 2.88 | 2.11 | 2.80 | 3.10 | 2.10 | 2.78 | 3.07 | 2.01 | 2.65 | 2.92 |
| 41.5 | 2.01 | 2.73 | 3.01 | 1.92 | 2.59 | 2.86 | 2.10 | 2.79 | 3.09 | 2.09 | 2.77 | 3.06 | 1.99 | 2.63 | 2.91 |
| 42.0 | 2.00 | 2.71 | 3.00 | 1.91 | 2.58 | 2.85 | 2.08 | 2.77 | 3.07 | 2.08 | 2.76 | 3.04 | 1.98 | 2.62 | 2.89 |
| 42.5 | 1.99 | 2.70 | 2.98 | 1.89 | 2.56 | 2.84 | 2.07 | 2.76 | 3.05 | 2.06 | 2.74 | 3.03 | 1.97 | 2.60 | 2.88 |
| 43.0 | 1.98 | 2.69 | 2.97 | 1.88 | 2.55 | 2.82 | 2.06 | 2.75 | 3.04 | 2.05 | 2.73 | 3.01 | 1.96 | 2.59 | 2.86 |
| 43.5 | 1.97 | 2.67 | 2.96 | 1.87 | 2.54 | 2.81 | 2.05 | 2.73 | 3.02 | 2.04 | 2.71 | 3.00 | 1.95 | 2.57 | 2.85 |
| 44.0 | 1.95 | 2.66 | 2.94 | 1.86 | 2.53 | 2.80 | 2.04 | 2.72 | 3.01 | 2.03 | 2.70 | 2.98 | 1.94 | 2.56 | 2.83 |
| 44.5 | 1.94 | 2.65 | 2.93 | 1.85 | 2.51 | 2.78 | 2.02 | 2.70 | 3.00 | 2.02 | 2.69 | 2.97 | 1.93 | 2.55 | 2.82 |
| 45.0 | 1.93 | 2.64 | 2.92 | 1.84 | 2.50 | 2.77 | 2.01 | 2.69 | 2.98 | 2.00 | 2.67 | 2.95 | 1.91 | 2.54 | 2.81 |
| 45.5 | 1.92 | 2.63 | 2.91 | 1.83 | 2.49 | 2.76 | 2.00 | 2.68 | 2.97 | 1.99 | 2.66 | 2.94 | 1.90 | 2.52 | 2.79 |
| 46.0 | 1.91 | 2.62 | 2.90 | 1.81 | 2.48 | 2.75 | 1.99 | 2.67 | 2.95 | 1.98 | 2.65 | 2.93 | 1.89 | 2.51 | 2.78 |
| 46.5 | 1.90 | 2.61 | 2.88 | 1.80 | 2.47 | 2.74 | 1.98 | 2.65 | 2.94 | 1.97 | 2.63 | 2.91 | 1.88 | 2.50 | 2.77 |
| 47.0 | 1.89 | 2.59 | 2.87 | 1.79 | 2.46 | 2.72 | 1.97 | 2.64 | 2.93 | 1.96 | 2.62 | 2.90 | 1.87 | 2.49 | 2.75 |
| 47.5 | 1.88 | 2.58 | 2.86 | 1.78 | 2.45 | 2.71 | 1.96 | 2.63 | 2.91 | 1.95 | 2.61 | 2.89 | 1.86 | 2.47 | 2.74 |
| 48.0 | 1.87 | 2.57 | 2.85 | 1.77 | 2.44 | 2.70 | 1.95 | 2.62 | 2.90 | 1.94 | 2.60 | 2.88 | 1.85 | 2.46 | 2.73 |
| 48.5 | 1.86 | 2.56 | 2.84 | 1.76 | 2.42 | 2.69 | 1.94 | 2.60 | 2.89 | 1.93 | 2.59 | 2.86 | 1.85 | 2.45 | 2.72 |
| 49.0 | 1.85 | 2.55 | 2.83 | 1.75 | 2.41 | 2.68 | 1.93 | 2.59 | 2.88 | 1.92 | 2.57 | 2.85 | 1.84 | 2.44 | 2.71 |
| 49.5 | 1.84 | 2.54 | 2.82 | 1.74 | 2.40 | 2.67 | 1.92 | 2.58 | 2.86 | 1.91 | 2.56 | 2.84 | 1.83 | 2.43 | 2.69 |
| 50.0 | 1.83 | 2.53 | 2.81 | 1.74 | 2.39 | 2.66 | 1.91 | 2.57 | 2.85 | 1.90 | 2.55 | 2.83 | 1.82 | 2.42 | 2.68 |
| 50.5 | 1.82 | 2.52 | 2.80 | 1.73 | 2.38 | 2.65 | 1.90 | 2.56 | 2.84 | 1.89 | 2.54 | 2.82 | 1.81 | 2.41 | 2.67 |
| 51.0 | 1.81 | 2.51 | 2.79 | 1.72 | 2.37 | 2.64 | 1.89 | 2.55 | 2.83 | 1.88 | 2.53 | 2.80 | 1.80 | 2.40 | 2.66 |
| 51.5 | 1.80 | 2.50 | 2.77 | 1.71 | 2.36 | 2.63 | 1.88 | 2.54 | 2.82 | 1.87 | 2.52 | 2.79 | 1.79 | 2.38 | 2.65 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 0.5 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 6 | | | Zone 7 | | | Zone 8 | | | Zone 9 | | | Zone 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 52.0 | 1.79 | 2.49 | 2.76 | 1.70 | 2.35 | 2.62 | 1.87 | 2.53 | 2.80 | 1.86 | 2.51 | 2.78 | 1.78 | 2.37 | 2.64 |
| 52.5 | 1.78 | 2.48 | 2.75 | 1.69 | 2.35 | 2.61 | 1.86 | 2.51 | 2.79 | 1.86 | 2.50 | 2.77 | 1.77 | 2.36 | 2.63 |
| 53.0 | 1.77 | 2.47 | 2.75 | 1.68 | 2.34 | 2.60 | 1.85 | 2.50 | 2.78 | 1.85 | 2.49 | 2.76 | 1.77 | 2.35 | 2.62 |
| 53.5 | 1.77 | 2.46 | 2.74 | 1.67 | 2.33 | 2.59 | 1.84 | 2.49 | 2.77 | 1.84 | 2.48 | 2.75 | 1.76 | 2.34 | 2.61 |
| 54.0 | 1.76 | 2.46 | 2.73 | 1.67 | 2.32 | 2.58 | 1.83 | 2.48 | 2.76 | 1.83 | 2.47 | 2.74 | 1.75 | 2.33 | 2.59 |
| 54.5 | 1.75 | 2.45 | 2.72 | 1.66 | 2.31 | 2.57 | 1.83 | 2.47 | 2.75 | 1.82 | 2.46 | 2.73 | 1.74 | 2.32 | 2.58 |
| 55.0 | 1.74 | 2.44 | 2.71 | 1.65 | 2.30 | 2.56 | 1.82 | 2.46 | 2.74 | 1.81 | 2.45 | 2.72 | 1.73 | 2.31 | 2.57 |
| 55.5 | 1.73 | 2.43 | 2.70 | 1.64 | 2.29 | 2.55 | 1.81 | 2.45 | 2.73 | 1.80 | 2.44 | 2.71 | 1.73 | 2.31 | 2.56 |
| 56.0 | 1.73 | 2.42 | 2.69 | 1.63 | 2.28 | 2.54 | 1.80 | 2.44 | 2.72 | 1.80 | 2.43 | 2.70 | 1.72 | 2.30 | 2.55 |
| 56.5 | 1.72 | 2.41 | 2.68 | 1.63 | 2.27 | 2.53 | 1.79 | 2.43 | 2.71 | 1.79 | 2.42 | 2.69 | 1.71 | 2.29 | 2.54 |
| 57.0 | 1.71 | 2.40 | 2.67 | 1.62 | 2.27 | 2.52 | 1.78 | 2.42 | 2.70 | 1.78 | 2.41 | 2.68 | 1.70 | 2.28 | 2.54 |
| 57.5 | 1.70 | 2.40 | 2.66 | 1.61 | 2.26 | 2.51 | 1.78 | 2.42 | 2.69 | 1.77 | 2.40 | 2.67 | 1.70 | 2.27 | 2.53 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 1 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 6 | | | Zone 7 | | | Zone 8 | | | Zone 9 | | | Zone 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 58.0 | 1.69 | 2.39 | 2.65 | 1.60 | 2.25 | 2.50 | 1.77 | 2.41 | 2.68 | 1.77 | 2.39 | 2.66 | 1.69 | 2.26 | 2.52 |
| 59.0 | 1.68 | 2.37 | 2.64 | 1.59 | 2.23 | 2.49 | 1.75 | 2.39 | 2.66 | 1.75 | 2.37 | 2.64 | 1.67 | 2.24 | 2.50 |
| 60.0 | 1.66 | 2.36 | 2.62 | 1.57 | 2.22 | 2.47 | 1.74 | 2.37 | 2.64 | 1.74 | 2.35 | 2.62 | 1.66 | 2.23 | 2.48 |
| 61.0 | 1.64 | 2.33 | 2.59 | 1.55 | 2.19 | 2.44 | 1.72 | 2.34 | 2.61 | 1.71 | 2.33 | 2.59 | 1.64 | 2.20 | 2.45 |
| 62.0 | 1.62 | 2.30 | 2.56 | 1.54 | 2.16 | 2.41 | 1.70 | 2.31 | 2.58 | 1.69 | 2.30 | 2.56 | 1.62 | 2.17 | 2.42 |
| 63.0 | 1.61 | 2.27 | 2.53 | 1.52 | 2.14 | 2.39 | 1.68 | 2.29 | 2.55 | 1.67 | 2.27 | 2.53 | 1.60 | 2.15 | 2.40 |
| 64.0 | 1.59 | 2.24 | 2.50 | 1.50 | 2.12 | 2.36 | 1.66 | 2.26 | 2.52 | 1.65 | 2.25 | 2.50 | 1.58 | 2.12 | 2.37 |
| 65.0 | 1.57 | 2.22 | 2.47 | 1.48 | 2.09 | 2.34 | 1.64 | 2.24 | 2.49 | 1.63 | 2.22 | 2.47 | 1.56 | 2.10 | 2.34 |
| 66.0 | 1.55 | 2.19 | 2.44 | 1.47 | 2.07 | 2.31 | 1.62 | 2.21 | 2.47 | 1.61 | 2.20 | 2.45 | 1.54 | 2.08 | 2.32 |
| 67.0 | 1.53 | 2.17 | 2.42 | 1.45 | 2.05 | 2.29 | 1.60 | 2.19 | 2.44 | 1.60 | 2.17 | 2.42 | 1.53 | 2.05 | 2.29 |
| 68.0 | 1.52 | 2.14 | 2.39 | 1.44 | 2.03 | 2.26 | 1.58 | 2.17 | 2.42 | 1.58 | 2.15 | 2.40 | 1.51 | 2.03 | 2.27 |
| 69.0 | 1.50 | 2.12 | 2.37 | 1.42 | 2.01 | 2.24 | 1.57 | 2.14 | 2.39 | 1.56 | 2.13 | 2.37 | 1.49 | 2.01 | 2.25 |
| 70.0 | 1.48 | 2.10 | 2.34 | 1.41 | 1.98 | 2.22 | 1.55 | 2.12 | 2.37 | 1.54 | 2.10 | 2.35 | 1.48 | 1.99 | 2.22 |
| 71.0 | 1.47 | 2.08 | 2.32 | 1.39 | 1.96 | 2.20 | 1.54 | 2.10 | 2.34 | 1.53 | 2.08 | 2.32 | 1.46 | 1.97 | 2.20 |
| 72.0 | 1.45 | 2.06 | 2.29 | 1.38 | 1.94 | 2.17 | 1.52 | 2.08 | 2.32 | 1.51 | 2.06 | 2.30 | 1.44 | 1.95 | 2.18 |
| 73.0 | 1.44 | 2.03 | 2.27 | 1.36 | 1.93 | 2.15 | 1.50 | 2.06 | 2.30 | 1.50 | 2.04 | 2.28 | 1.43 | 1.93 | 2.16 |
| 74.0 | 1.42 | 2.01 | 2.25 | 1.35 | 1.91 | 2.13 | 1.49 | 2.04 | 2.28 | 1.48 | 2.02 | 2.26 | 1.41 | 1.91 | 2.14 |
| 75.0 | 1.41 | 1.99 | 2.23 | 1.34 | 1.89 | 2.11 | 1.47 | 2.02 | 2.25 | 1.47 | 2.00 | 2.24 | 1.40 | 1.89 | 2.12 |
| 76.0 | 1.40 | 1.97 | 2.20 | 1.33 | 1.87 | 2.09 | 1.46 | 2.00 | 2.23 | 1.45 | 1.98 | 2.21 | 1.39 | 1.88 | 2.10 |
| 77.0 | 1.38 | 1.95 | 2.18 | 1.31 | 1.85 | 2.07 | 1.45 | 1.98 | 2.21 | 1.44 | 1.96 | 2.19 | 1.37 | 1.86 | 2.08 |
| 78.0 | 1.37 | 1.94 | 2.16 | 1.30 | 1.84 | 2.06 | 1.43 | 1.96 | 2.19 | 1.42 | 1.94 | 2.17 | 1.36 | 1.84 | 2.06 |
| 79.0 | 1.36 | 1.92 | 2.14 | 1.29 | 1.82 | 2.04 | 1.42 | 1.94 | 2.17 | 1.41 | 1.93 | 2.15 | 1.35 | 1.82 | 2.04 |
| 80.0 | 1.34 | 1.90 | 2.12 | 1.28 | 1.80 | 2.02 | 1.41 | 1.92 | 2.15 | 1.40 | 1.91 | 2.14 | 1.33 | 1.81 | 2.02 |
| 81.0 | 1.33 | 1.88 | 2.10 | 1.27 | 1.79 | 2.00 | 1.39 | 1.91 | 2.13 | 1.38 | 1.89 | 2.12 | 1.32 | 1.79 | 2.00 |
| 82.0 | 1.32 | 1.86 | 2.09 | 1.25 | 1.77 | 1.98 | 1.38 | 1.89 | 2.12 | 1.37 | 1.87 | 2.10 | 1.31 | 1.77 | 1.99 |
| 83.0 | 1.31 | 1.85 | 2.07 | 1.24 | 1.76 | 1.97 | 1.37 | 1.87 | 2.10 | 1.36 | 1.86 | 2.08 | 1.30 | 1.76 | 1.97 |
| 84.0 | 1.30 | 1.83 | 2.05 | 1.23 | 1.74 | 1.95 | 1.36 | 1.86 | 2.08 | 1.34 | 1.84 | 2.06 | 1.28 | 1.74 | 1.95 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 1 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 6 | | | Zone 7 | | | Zone 8 | | | Zone 9 | | | Zone 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 85.0 | 1.28 | 1.82 | 2.03 | 1.22 | 1.73 | 1.94 | 1.34 | 1.84 | 2.06 | 1.33 | 1.83 | 2.04 | 1.27 | 1.73 | 1.94 |
| 86.0 | 1.27 | 1.80 | 2.01 | 1.21 | 1.71 | 1.92 | 1.33 | 1.83 | 2.05 | 1.32 | 1.81 | 2.03 | 1.26 | 1.71 | 1.92 |
| 87.0 | 1.26 | 1.78 | 2.00 | 1.20 | 1.70 | 1.90 | 1.32 | 1.81 | 2.03 | 1.31 | 1.80 | 2.01 | 1.25 | 1.70 | 1.90 |
| 88.0 | 1.25 | 1.77 | 1.98 | 1.19 | 1.68 | 1.89 | 1.31 | 1.80 | 2.01 | 1.30 | 1.78 | 2.00 | 1.24 | 1.69 | 1.89 |
| 89.0 | 1.24 | 1.75 | 1.96 | 1.18 | 1.67 | 1.87 | 1.30 | 1.78 | 2.00 | 1.29 | 1.77 | 1.98 | 1.23 | 1.67 | 1.87 |
| 90.0 | 1.23 | 1.74 | 1.95 | 1.17 | 1.66 | 1.86 | 1.29 | 1.77 | 1.98 | 1.28 | 1.75 | 1.96 | 1.22 | 1.66 | 1.86 |
| 91.0 | 1.22 | 1.72 | 1.93 | 1.16 | 1.64 | 1.84 | 1.28 | 1.75 | 1.96 | 1.27 | 1.74 | 1.95 | 1.21 | 1.65 | 1.84 |
| 92.0 | 1.21 | 1.71 | 1.92 | 1.15 | 1.63 | 1.83 | 1.27 | 1.74 | 1.95 | 1.26 | 1.72 | 1.93 | 1.20 | 1.63 | 1.83 |
| 93.0 | 1.20 | 1.70 | 1.90 | 1.14 | 1.62 | 1.82 | 1.26 | 1.73 | 1.93 | 1.25 | 1.71 | 1.92 | 1.19 | 1.62 | 1.82 |
| 94.0 | 1.19 | 1.68 | 1.89 | 1.14 | 1.61 | 1.80 | 1.25 | 1.71 | 1.92 | 1.24 | 1.70 | 1.90 | 1.18 | 1.61 | 1.80 |
| 95.0 | 1.18 | 1.67 | 1.87 | 1.13 | 1.59 | 1.79 | 1.24 | 1.70 | 1.91 | 1.23 | 1.68 | 1.89 | 1.17 | 1.60 | 1.79 |
| 96.0 | 1.17 | 1.66 | 1.86 | 1.12 | 1.58 | 1.78 | 1.23 | 1.69 | 1.89 | 1.22 | 1.67 | 1.88 | 1.16 | 1.58 | 1.78 |
| 97.0 | 1.16 | 1.64 | 1.85 | 1.11 | 1.57 | 1.76 | 1.22 | 1.67 | 1.88 | 1.21 | 1.66 | 1.86 | 1.15 | 1.57 | 1.76 |
| 98.0 | 1.16 | 1.63 | 1.83 | 1.10 | 1.56 | 1.75 | 1.21 | 1.66 | 1.86 | 1.20 | 1.65 | 1.85 | 1.14 | 1.56 | 1.75 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 2 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 6 | | | Zone 7 | | | Zone 8 | | | Zone 9 | | | Zone 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 100.0 | 1.14 | 1.61 | 1.80 | 1.09 | 1.54 | 1.73 | 1.19 | 1.64 | 1.84 | 1.18 | 1.62 | 1.82 | 1.12 | 1.54 | 1.72 |
| 102.0 | 1.12 | 1.58 | 1.78 | 1.07 | 1.51 | 1.70 | 1.17 | 1.61 | 1.81 | 1.16 | 1.60 | 1.80 | 1.11 | 1.52 | 1.70 |
| 104.0 | 1.11 | 1.56 | 1.75 | 1.05 | 1.49 | 1.68 | 1.16 | 1.59 | 1.79 | 1.14 | 1.58 | 1.77 | 1.09 | 1.49 | 1.68 |
| 106.0 | 1.09 | 1.54 | 1.73 | 1.04 | 1.47 | 1.66 | 1.14 | 1.57 | 1.76 | 1.13 | 1.56 | 1.75 | 1.08 | 1.47 | 1.65 |
| 108.0 | 1.07 | 1.52 | 1.71 | 1.03 | 1.45 | 1.64 | 1.13 | 1.55 | 1.74 | 1.11 | 1.53 | 1.72 | 1.06 | 1.45 | 1.63 |
| 110.0 | 1.06 | 1.50 | 1.68 | 1.01 | 1.43 | 1.62 | 1.11 | 1.53 | 1.72 | 1.10 | 1.51 | 1.70 | 1.05 | 1.43 | 1.61 |
| 112.0 | 1.05 | 1.48 | 1.66 | 1.00 | 1.42 | 1.60 | 1.10 | 1.51 | 1.70 | 1.08 | 1.49 | 1.68 | 1.03 | 1.42 | 1.59 |
| 114.0 | 1.03 | 1.46 | 1.64 | 0.99 | 1.40 | 1.58 | 1.08 | 1.49 | 1.67 | 1.07 | 1.47 | 1.66 | 1.02 | 1.40 | 1.57 |
| 116.0 | 1.02 | 1.44 | 1.62 | 0.97 | 1.38 | 1.56 | 1.07 | 1.47 | 1.65 | 1.05 | 1.46 | 1.64 | 1.00 | 1.38 | 1.55 |
| 118.0 | 1.01 | 1.42 | 1.60 | 0.96 | 1.36 | 1.54 | 1.05 | 1.45 | 1.63 | 1.04 | 1.44 | 1.62 | 0.99 | 1.36 | 1.53 |
| 120.0 | 0.99 | 1.40 | 1.58 | 0.95 | 1.35 | 1.52 | 1.04 | 1.44 | 1.62 | 1.03 | 1.42 | 1.60 | 0.98 | 1.35 | 1.52 |
| 122.0 | 0.98 | 1.38 | 1.56 | 0.94 | 1.33 | 1.50 | 1.03 | 1.42 | 1.60 | 1.01 | 1.40 | 1.58 | 0.97 | 1.33 | 1.50 |
| 124.0 | 0.97 | 1.37 | 1.54 | 0.93 | 1.31 | 1.48 | 1.02 | 1.40 | 1.58 | 1.00 | 1.39 | 1.56 | 0.95 | 1.32 | 1.48 |
| 126.0 | 0.96 | 1.35 | 1.52 | 0.92 | 1.30 | 1.46 | 1.00 | 1.39 | 1.56 | 0.99 | 1.37 | 1.54 | 0.94 | 1.30 | 1.46 |
| 128.0 | 0.95 | 1.33 | 1.50 | 0.90 | 1.28 | 1.45 | 0.99 | 1.37 | 1.54 | 0.98 | 1.35 | 1.53 | 0.93 | 1.29 | 1.45 |
| 130.0 | 0.93 | 1.32 | 1.49 | 0.89 | 1.27 | 1.43 | 0.98 | 1.35 | 1.53 | 0.97 | 1.34 | 1.51 | 0.92 | 1.27 | 1.43 |
| 132.0 | 0.92 | 1.30 | 1.47 | 0.88 | 1.25 | 1.41 | 0.97 | 1.34 | 1.51 | 0.95 | 1.32 | 1.49 | 0.91 | 1.26 | 1.42 |
| 134.0 | 0.91 | 1.29 | 1.45 | 0.87 | 1.24 | 1.39 | 0.96 | 1.32 | 1.49 | 0.94 | 1.31 | 1.48 | 0.90 | 1.24 | 1.40 |
| 136.0 | 0.90 | 1.27 | 1.43 | 0.86 | 1.22 | 1.38 | 0.95 | 1.31 | 1.48 | 0.93 | 1.30 | 1.46 | 0.89 | 1.23 | 1.39 |
| 138.0 | 0.89 | 1.26 | 1.42 | 0.85 | 1.21 | 1.36 | 0.94 | 1.30 | 1.46 | 0.92 | 1.28 | 1.45 | 0.88 | 1.22 | 1.37 |
| 140.0 | 0.88 | 1.24 | 1.40 | 0.84 | 1.19 | 1.35 | 0.93 | 1.28 | 1.45 | 0.91 | 1.27 | 1.43 | 0.87 | 1.20 | 1.36 |
| 142.0 | 0.87 | 1.23 | 1.39 | 0.83 | 1.18 | 1.33 | 0.92 | 1.27 | 1.43 | 0.90 | 1.26 | 1.42 | 0.86 | 1.19 | 1.34 |
| 144.0 | 0.86 | 1.22 | 1.37 | 0.82 | 1.17 | 1.32 | 0.91 | 1.26 | 1.42 | 0.89 | 1.24 | 1.40 | 0.85 | 1.18 | 1.33 |
| 146.0 | 0.86 | 1.20 | 1.36 | 0.82 | 1.15 | 1.30 | 0.90 | 1.24 | 1.40 | 0.88 | 1.23 | 1.39 | 0.84 | 1.17 | 1.32 |
| 148.0 | 0.85 | 1.19 | 1.34 | 0.81 | 1.14 | 1.29 | 0.89 | 1.23 | 1.39 | 0.87 | 1.22 | 1.37 | 0.83 | 1.16 | 1.30 |
| 150.0 | 0.84 | 1.18 | 1.33 | 0.80 | 1.13 | 1.28 | 0.88 | 1.22 | 1.38 | 0.86 | 1.21 | 1.36 | 0.82 | 1.15 | 1.29 |
| 152.0 | 0.83 | 1.17 | 1.32 | 0.79 | 1.12 | 1.26 | 0.87 | 1.21 | 1.36 | 0.86 | 1.19 | 1.35 | 0.82 | 1.13 | 1.28 |
| 154.0 | 0.82 | 1.15 | 1.30 | 0.78 | 1.11 | 1.25 | 0.86 | 1.20 | 1.35 | 0.85 | 1.18 | 1.33 | 0.81 | 1.12 | 1.27 |
| 156.0 | 0.81 | 1.14 | 1.29 | 0.77 | 1.10 | 1.24 | 0.85 | 1.19 | 1.34 | 0.84 | 1.17 | 1.32 | 0.80 | 1.11 | 1.26 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 2 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 6 | | | Zone 7 | | | Zone 8 | | | Zone 9 | | | Zone 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 158.0 | 0.81 | 1.13 | 1.28 | 0.77 | 1.08 | 1.23 | 0.84 | 1.18 | 1.33 | 0.83 | 1.16 | 1.31 | 0.79 | 1.10 | 1.24 |
| 160.0 | 0.80 | 1.12 | 1.27 | 0.76 | 1.07 | 1.21 | 0.84 | 1.16 | 1.32 | 0.82 | 1.15 | 1.30 | 0.78 | 1.09 | 1.23 |
| 162.0 | 0.79 | 1.11 | 1.25 | 0.75 | 1.06 | 1.20 | 0.83 | 1.15 | 1.30 | 0.82 | 1.14 | 1.29 | 0.78 | 1.08 | 1.22 |
| 164.0 | 0.78 | 1.10 | 1.24 | 0.75 | 1.05 | 1.19 | 0.82 | 1.14 | 1.29 | 0.81 | 1.13 | 1.27 | 0.77 | 1.07 | 1.21 |
| 166.0 | 0.78 | 1.09 | 1.23 | 0.74 | 1.04 | 1.18 | 0.81 | 1.13 | 1.28 | 0.80 | 1.12 | 1.26 | 0.76 | 1.06 | 1.20 |
| 168.0 | 0.77 | 1.08 | 1.22 | 0.73 | 1.03 | 1.17 | 0.81 | 1.12 | 1.27 | 0.79 | 1.11 | 1.25 | 0.76 | 1.05 | 1.19 |
| 170.0 | 0.76 | 1.07 | 1.21 | 0.72 | 1.02 | 1.16 | 0.80 | 1.11 | 1.26 | 0.79 | 1.10 | 1.24 | 0.75 | 1.05 | 1.18 |
| 172.0 | 0.76 | 1.06 | 1.20 | 0.72 | 1.01 | 1.15 | 0.79 | 1.11 | 1.25 | 0.78 | 1.09 | 1.23 | 0.74 | 1.04 | 1.17 |
| 174.0 | 0.75 | 1.05 | 1.19 | 0.71 | 1.01 | 1.14 | 0.78 | 1.10 | 1.24 | 0.77 | 1.08 | 1.22 | 0.74 | 1.03 | 1.16 |
| 176.0 | 0.74 | 1.04 | 1.18 | 0.71 | 1.00 | 1.13 | 0.78 | 1.09 | 1.23 | 0.77 | 1.07 | 1.21 | 0.73 | 1.02 | 1.15 |
| 178.0 | 0.74 | 1.03 | 1.17 | 0.70 | 0.99 | 1.12 | 0.77 | 1.08 | 1.22 | 0.76 | 1.06 | 1.20 | 0.72 | 1.01 | 1.14 |
| 180.0 | 0.73 | 1.02 | 1.16 | 0.69 | 0.98 | 1.11 | 0.76 | 1.07 | 1.21 | 0.75 | 1.05 | 1.19 | 0.72 | 1.00 | 1.13 |
| 182.0 | 0.72 | 1.01 | 1.15 | 0.69 | 0.97 | 1.10 | 0.76 | 1.06 | 1.20 | 0.75 | 1.04 | 1.18 | 0.71 | 0.99 | 1.12 |
| 184.0 | 0.72 | 1.00 | 1.14 | 0.68 | 0.96 | 1.09 | 0.75 | 1.05 | 1.19 | 0.74 | 1.04 | 1.17 | 0.70 | 0.98 | 1.11 |
| 186.0 | 0.71 | 0.99 | 1.13 | 0.67 | 0.95 | 1.08 | 0.75 | 1.04 | 1.18 | 0.73 | 1.03 | 1.16 | 0.70 | 0.98 | 1.10 |
| 188.0 | 0.70 | 0.99 | 1.12 | 0.67 | 0.94 | 1.07 | 0.74 | 1.03 | 1.17 | 0.73 | 1.02 | 1.15 | 0.69 | 0.97 | 1.09 |
| 190.0 | 0.70 | 0.98 | 1.11 | 0.66 | 0.94 | 1.06 | 0.73 | 1.02 | 1.16 | 0.72 | 1.01 | 1.14 | 0.69 | 0.96 | 1.08 |
| 192.0 | 0.69 | 0.97 | 1.10 | 0.66 | 0.93 | 1.05 | 0.73 | 1.02 | 1.15 | 0.71 | 1.00 | 1.13 | 0.68 | 0.95 | 1.08 |
| 194.0 | 0.69 | 0.96 | 1.09 | 0.65 | 0.92 | 1.04 | 0.72 | 1.01 | 1.14 | 0.71 | 0.99 | 1.12 | 0.67 | 0.94 | 1.07 |
| 196.0 | 0.68 | 0.95 | 1.08 | 0.65 | 0.91 | 1.04 | 0.72 | 1.00 | 1.13 | 0.70 | 0.98 | 1.11 | 0.67 | 0.94 | 1.06 |
| 198.0 | 0.68 | 0.95 | 1.07 | 0.64 | 0.91 | 1.03 | 0.71 | 0.99 | 1.12 | 0.70 | 0.98 | 1.10 | 0.66 | 0.93 | 1.05 |
| 200.0 | 0.67 | 0.94 | 1.06 | 0.64 | 0.90 | 1.02 | 0.70 | 0.98 | 1.11 | 0.69 | 0.97 | 1.09 | 0.66 | 0.92 | 1.04 |
| 202.0 | 0.66 | 0.93 | 1.06 | 0.63 | 0.89 | 1.01 | 0.70 | 0.98 | 1.11 | 0.69 | 0.96 | 1.09 | 0.65 | 0.91 | 1.03 |
| 204.0 | 0.66 | 0.92 | 1.05 | 0.62 | 0.88 | 1.00 | 0.69 | 0.97 | 1.10 | 0.68 | 0.95 | 1.08 | 0.65 | 0.90 | 1.02 |
| 206.0 | 0.65 | 0.92 | 1.04 | 0.62 | 0.88 | 0.99 | 0.69 | 0.96 | 1.09 | 0.67 | 0.94 | 1.07 | 0.64 | 0.90 | 1.02 |
| 208.0 | 0.65 | 0.91 | 1.03 | 0.62 | 0.87 | 0.99 | 0.68 | 0.95 | 1.08 | 0.67 | 0.94 | 1.06 | 0.64 | 0.89 | 1.01 |
| 210.0 | 0.64 | 0.90 | 1.02 | 0.61 | 0.86 | 0.98 | 0.68 | 0.95 | 1.07 | 0.66 | 0.93 | 1.05 | 0.63 | 0.88 | 1.00 |
| 212.0 | 0.64 | 0.90 | 1.02 | 0.61 | 0.86 | 0.97 | 0.67 | 0.94 | 1.06 | 0.66 | 0.92 | 1.04 | 0.63 | 0.88 | 0.99 |
| 214.0 | 0.63 | 0.89 | 1.01 | 0.60 | 0.85 | 0.97 | 0.67 | 0.93 | 1.06 | 0.65 | 0.92 | 1.04 | 0.62 | 0.87 | 0.98 |

# MDOT DRAINAGE MANUAL
# RAINFALL INTENSITY – DURATION TABLE

TIME INTERVAL ON THIS SHEET = 2 MINUTES
Rainfall Intensity given in inches per hour.

| Time in Minutes | Zone 6 | | | Zone 7 | | | Zone 8 | | | Zone 9 | | | Zone 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year | 10 year | 50 year | 100 year |
| 216.0 | 0.63 | 0.88 | 1.00 | 0.60 | 0.85 | 0.96 | 0.66 | 0.93 | 1.05 | 0.65 | 0.91 | 1.03 | 0.62 | 0.86 | 0.98 |
| 218.0 | 0.63 | 0.88 | 0.99 | 0.59 | 0.84 | 0.95 | 0.66 | 0.92 | 1.04 | 0.64 | 0.90 | 1.02 | 0.61 | 0.86 | 0.97 |
| 220.0 | 0.62 | 0.87 | 0.99 | 0.59 | 0.83 | 0.94 | 0.65 | 0.91 | 1.03 | 0.64 | 0.90 | 1.01 | 0.61 | 0.85 | 0.96 |
| 222.0 | 0.62 | 0.86 | 0.98 | 0.58 | 0.83 | 0.94 | 0.65 | 0.91 | 1.03 | 0.64 | 0.89 | 1.01 | 0.60 | 0.84 | 0.96 |
| 224.0 | 0.61 | 0.86 | 0.97 | 0.58 | 0.82 | 0.93 | 0.65 | 0.90 | 1.02 | 0.63 | 0.88 | 1.00 | 0.60 | 0.84 | 0.95 |
| 226.0 | 0.61 | 0.85 | 0.97 | 0.57 | 0.81 | 0.92 | 0.64 | 0.89 | 1.01 | 0.63 | 0.88 | 0.99 | 0.60 | 0.83 | 0.94 |
| 228.0 | 0.60 | 0.85 | 0.96 | 0.57 | 0.81 | 0.92 | 0.64 | 0.89 | 1.01 | 0.62 | 0.87 | 0.99 | 0.59 | 0.83 | 0.94 |
| 230.0 | 0.60 | 0.84 | 0.95 | 0.57 | 0.80 | 0.91 | 0.63 | 0.88 | 1.00 | 0.62 | 0.86 | 0.98 | 0.59 | 0.82 | 0.93 |
| 232.0 | 0.59 | 0.84 | 0.95 | 0.56 | 0.80 | 0.90 | 0.63 | 0.88 | 0.99 | 0.61 | 0.86 | 0.97 | 0.58 | 0.81 | 0.92 |
| 234.0 | 0.59 | 0.83 | 0.94 | 0.56 | 0.79 | 0.90 | 0.62 | 0.87 | 0.99 | 0.61 | 0.85 | 0.97 | 0.58 | 0.81 | 0.92 |
| 236.0 | 0.59 | 0.82 | 0.93 | 0.55 | 0.79 | 0.89 | 0.62 | 0.86 | 0.98 | 0.60 | 0.85 | 0.96 | 0.58 | 0.80 | 0.91 |
| 238.0 | 0.58 | 0.82 | 0.93 | 0.55 | 0.78 | 0.89 | 0.62 | 0.86 | 0.97 | 0.60 | 0.84 | 0.95 | 0.57 | 0.80 | 0.90 |
| 240.0 | 0.58 | 0.81 | 0.92 | 0.55 | 0.78 | 0.88 | 0.61 | 0.85 | 0.97 | 0.60 | 0.83 | 0.95 | 0.57 | 0.79 | 0.90 |

# ATTACHMENT C

## Overburden Stockpile Laboratory Testing Results

| Sample ID | As Rec'd Moisture | Modified Proctor | | Limits | | | Gradation | | | | USCS | Permeability (cm/sec) | % Above OMC | % of Max. Dry Density | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Moisture Content (%) | Max. Dry Unit Wt. (PCF) | OMC (%) | Liquid Limit (%) | Plastic Limit (%) | Plasticity Index (%) | % Finer 2" Sieve | % Finer 3/4" Sieve | % Finer No. 200 Sieve | % Finer 0.005 mm | | | | | |
| | | | | | | | | | | | | | | | |
| Bucket 1 | 9.2 | 137.7 | 6.5 | 20 | 9 | 11 | 100 | 99.22 | 54.26 | 28 | CL | 6.10E-07 | 0.2 | 89.5% | Gray lean clay |
| Bucket 2 | 14.6 | 134.8 | 7.1 | 21 | 9 | 12 | 100 | 99.28 | 55.9 | 29 | CL | 4.20E-08 | 3.2 | 90.4% | Gray lean clay |
| Bucket 3 | 6.7 | 138.6 | 6.2 | 18 | 7 | 11 | 100 | 98.68 | 48.17 | 24 | CL | 2.00E-08 | 6.0 | 89.0% | Gray lean clay |
| Bucket 4 | ~~19.8~~ | ~~125.3~~ | ~~10.8~~ | ~~25~~ | ~~9~~ | ~~16~~ | ~~100~~ | ~~100~~ | ~~77.94~~ | ~~44~~ | ~~CL~~ | | | | Brown clay (not considered in averages) |
| Bucket 5 | 7.5 | 138.6 | 6.5 | 19 | 9 | 10 | 100 | 99.14 | 53.4 | 27 | CL | 4.90E-07 | 0 | 92.4% | Gray lean clay |
| Bucket 6 | 7.5 | 137.9 | 7.3 | 18 | 10 | 8 | 100 | 99.38 | 49.78 | 27 | CL | 1.50E-08 | 3.1 | 92.6% | Gray lean clay |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| AVERAGE | 9.10 | 137.52 | 6.72 | 19.20 | 8.80 | 10.40 | 100.00 | 99.14 | 52.30 | 27.00 | | 5.50E-07 | | | Highest two permeability results used for average |
| MIN | 6.7 | 134.8 | 6.2 | 18 | 7 | 8 | 100 | 98.68 | 48.17 | 24 | | | | | |
| MAX | 14.6 | 138.6 | 7.3 | 21 | 10 | 12 | 100 | 99.38 | 55.9 | 29 | | | | | |

August 24, 2015

Project No. 2015-437-001

Thomas Roberts
AECOM
564 White Pond Drive
Akron, OH 44320

**Transmittal**
**Laboratory Test Results**
**Dow Salzburg LF 60395549**

Please find attached the laboratory test results for the above referenced project. The tests were outlined on the Project Verification Form that was transmitted to your firm prior to the testing. The testing was performed in general accordance with the methods listed on the enclosed data sheets. The test results are believed to be representative of the samples that were submitted for testing and are indicative only of the specimens that were evaluated. We have no direct knowledge of the origin of the samples and imply no position with regard to the nature of the test results, i.e. pass/fail and no claims as to the suitability of the material for its intended use.

The test data and all associated project information provided shall be held in strict confidence and disclosed to other parties only with authorization by our Client. The test data submitted herein is considered integral with this report and is not to be reproduced except in whole and only with the authorization of the Client and Geotechnics. The remaining sample materials for this project will be retained for a minimum of 90 days as directed by the Geotechnics' Quality Program.

We are pleased to provide these testing services. Should you have any questions or if we may be of further assistance, please contact our office.

Respectively submitted,
***Geotechnics, Inc***.

David R. Backstrom
Laboratory Director

***We understand that you have a choice in your laboratory services and we thank you for choosing Geotechnics.***

*DCN: Data Transmittal Letter Date: 1/28/05 Rev.: 1*

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# MOISTURE CONTENT

ASTM D 2216-10

| | |
|---|---|
| Client: | AECOM |
| Client Reference: | Dow Salzburg LF 60395549 |
| Project No.: | 2015-437-001 |

| Lab ID: | 001 | 002 | 003 | 004 | 005 |
|---|---|---|---|---|---|
| Boring No.: | Bucket 1 | Bucket 2 | Bucket 3 | Bucket 4 | Bucket 5 |
| Depth (ft): | NA | NA | NA | NA | NA |
| Sample No.: | 1 | 2 | 3 | 4 | 5 |
| Tare Number | 537 | 580 | 592 | 886 | 894 |
| Wt. of Tare & Wet Sample (g) | 541.80 | 542.10 | 728.00 | 596.00 | 580.20 |
| Wt. of Tare & Dry Sample (g) | 503.00 | 483.90 | 687.60 | 515.60 | 547.40 |
| Weight of Tare (g) | 82.23 | 84.35 | 81.40 | 109.82 | 110.25 |
| Weight of Water (g) | 38.80 | 58.20 | 40.40 | 80.40 | 32.80 |
| Weight of Dry Sample (g) | 420.77 | 399.55 | 606.20 | 405.78 | 437.15 |
| **Water Content (%)** | **9.2** | **14.6** | **6.7** | **19.8** | **7.5** |

| Lab ID | 006 |
|---|---|
| Boring No. | Bucket 6 |
| Depth (ft) | NA |
| Sample No. | 6 |
| Tare Number | 1692 |
| Wt. of Tare & Wet Sample (g) | 723.80 |
| Wt. of Tare & Dry Sample (g) | 679.30 |
| Weight of Tare (g) | 82.51 |
| Weight of Water (g) | 44.50 |
| Weight of Dry Sample (g) | 596.79 |
| **Water Content (%)** | **7.5** |

*Notes :*

*Tested By* *PC* *Date* *8/14/15* *Checked By* *KC* *Date* *8/17/15*



DCN: CT-S1 DATE: 3/18/13 REVISION: 4

S:\Excel\Excel Qa\Spreadsheets\Water Content.xls

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# SIEVE AND HYDROMETER ANALYSIS

ASTM D 422-63 (2007)/AASHTO T88-00 SOP-S3

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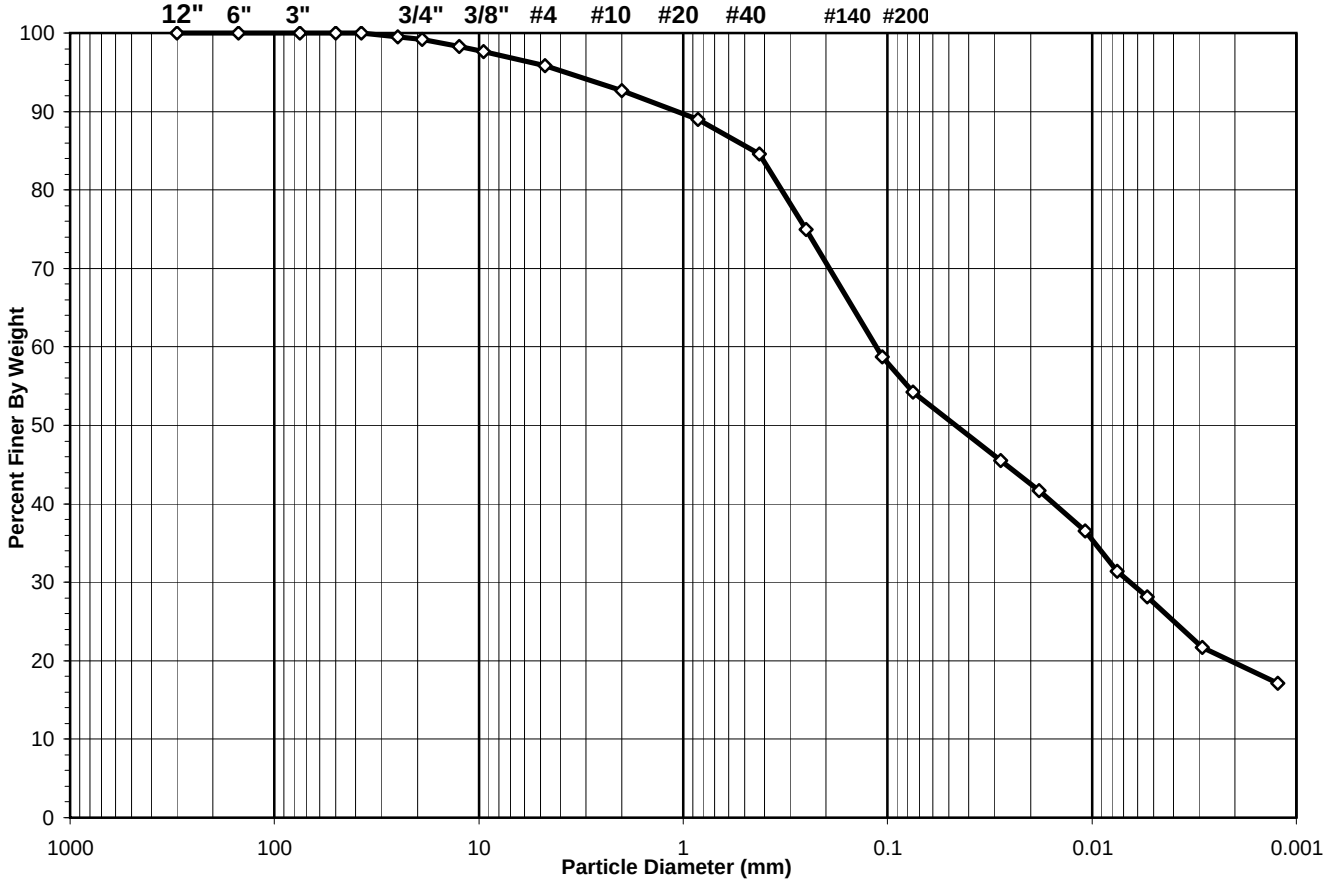
| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 1 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 1 |
| Lab ID: | 2015-437-001-001 | Soil Color: | Gray |

| | SIEVE ANALYSIS | | | HYDROMETER | |
|---|---|---|---|---|---|
| USCS | cobbles | gravel | sand | silt and clay fraction | |
| USDA | cobbles | gravel | sand | silt | clay |




**USCS Summary**

| Sieve Sizes (mm) | | Percentage |
|---|---|---|
| Greater Than #4 | *Gravel* | 4.15 |
| #4 To #200 | *Sand* | 41.59 |
| Finer Than #200 | *Silt & Clay* | 54.26 |

**USCS Symbol:**
***CL, TESTED***

**USCS Classification:**
***SANDY LEAN CLAY***





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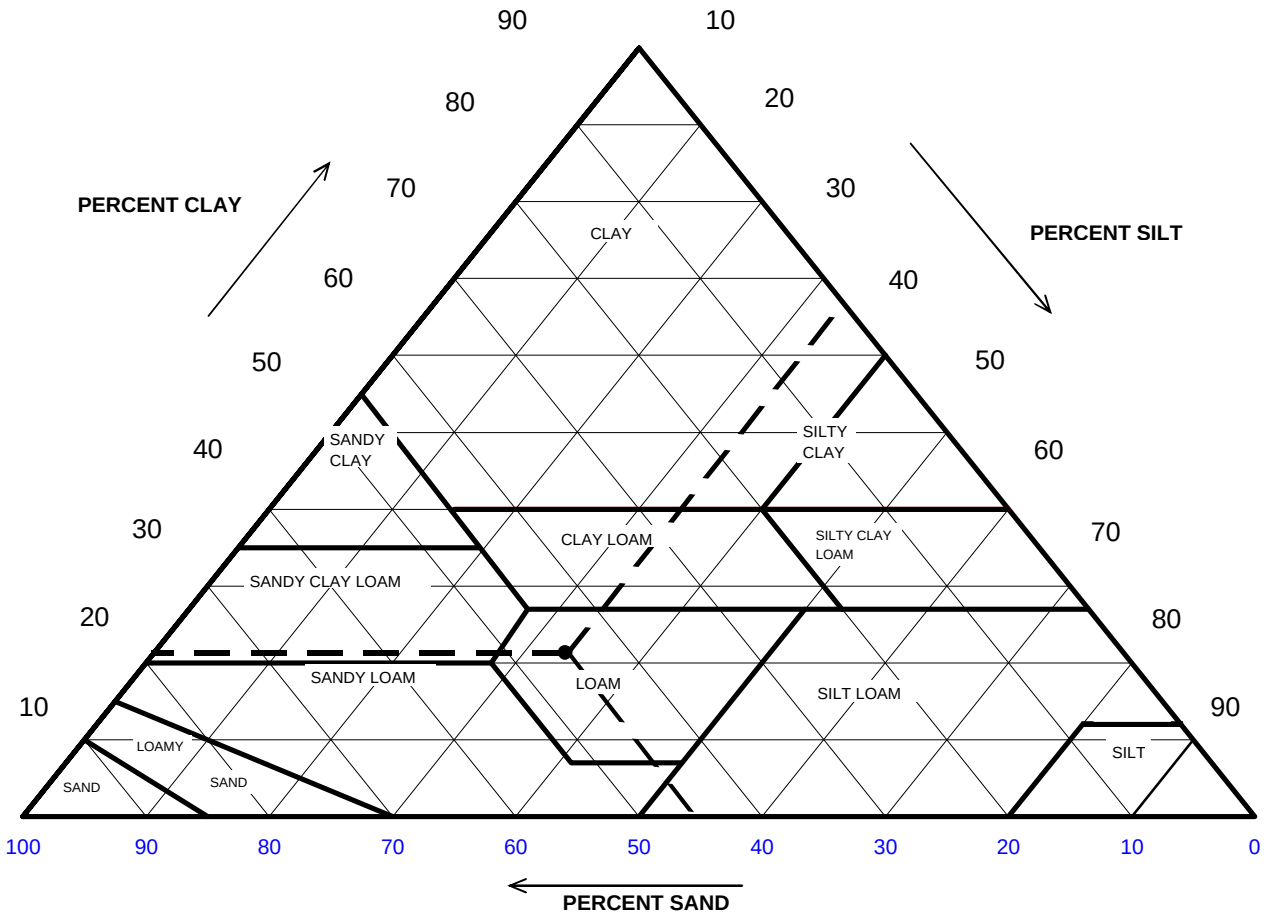
# USDA CLASSIFICATION CHART

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 1 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 1 |
| Lab ID: | 2015-437-001-001 | Soil Color: | Gray |




| Particle Size (mm) | Percent Finer | USDA SUMMARY | Actual Percentage | Corrected % of Minus 2.0 mm material for USDA Classificat. |
|---|---|---|---|---|
| | | *Gravel* | 7.38 | **0.00** |
| 2 | 92.62 | *Sand* | 41.95 | **45.29** |
| 0.05 | 50.67 | *Silt* | 30.93 | **33.39** |
| 0.002 | 19.74 | *Clay* | 19.74 | **21.32** |

**USDA Classification**: ***LOAM***





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# WASH SIEVE ANALYSIS

ASTM D 422-63 (2007)/AASHTO T88-00 SOP-S3

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| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 1 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 1 |
| Lab ID: | 2015-437-001-001 | Soil Color: | Gray |

| Moisture Content of Passing 3/4" Material | | Water Content of Retained 3/4" Material | |
|---|---|---|---|
| Tare No.: | 33 | Tare No.: | 2992 |
| Wt. of Tare & Wet Sample (g): | 1054.40 | Weight of Tare & Wet Sample (g): | 151.66 |
| Wt. of Tare & Dry Sample (g): | 1046.00 | Weight of Tare & Dry Sample (g): | 150.48 |
| Weight of Tare (g): | 201.89 | Weight of Tare (g): | 6.43 |
| Weight of Water (g): | 8.40 | Weight of Water (g): | 1.18 |
| Weight of Dry Soil (g): | 844.11 | Weight of Dry Soil (g): | 144.05 |
| **Moisture Content (%):** | **1.0** | **Moisture Content (%):** | **0.8** |

| | | | |
|---|---|---|---|
| Wet Weight of -3/4" Sample (g): | 18473 | Weight of the Dry Sample (g): | 844.11 |
| Dry Weight of - 3/4" Sample (g): | 18291.0 | Weight of Minus #200 Material (g): | 461.64 |
| Wet Weight of +3/4" Sample (g): | 145.23 | Weight of Plus #200 Material (g): | 382.47 |
| Dry Weight of + 3/4" Sample (g): | 144.05 | | |
| Total Dry Weight of Sample (g): | 18435.0 | **J - Factor (Percent Finer than 3/4"):** | **0.9922** |

| Sieve Size | Sieve Opening (mm) | Weight of Soil Retained (g) | | Percent Retained (%) | Accumulated Percent Retained (%) | Percent Finer (%) | **Accumulated Percent Finer (%)** |
|---|---|---|---|---|---|---|---|
| 12" | 300 | 0.00 | | 0.00 | 0.00 | 100.00 | **100.00** |
| 6" | 150 | 0.00 | | 0.00 | 0.00 | 100.00 | **100.00** |
| 3" | 75 | 0.00 | | 0.00 | 0.00 | 100.00 | **100.00** |
| 2" | 50 | 0.00 | ( * ) | 0.00 | 0.00 | 100.00 | **100.00** |
| 1 1/2" | 37.5 | 0.00 | | 0.00 | 0.00 | 100.00 | **100.00** |
| 1" | 25.0 | 92.41 | | 0.50 | 0.50 | 99.50 | **99.50** |
| 3/4" | 19.0 | 52.82 | | 0.28 | 0.78 | 99.22 | **99.22** |
| 1/2" | 12.5 | 7.89 | | 0.93 | 0.93 | 99.07 | **98.29** |
| 3/8" | 9.50 | 5.56 | | 0.66 | 1.59 | 98.41 | **97.64** |
| #4 | 4.75 | 15.23 | | 1.80 | 3.40 | 96.60 | **95.85** |
| #10 | 2.00 | 27.47 | | 3.25 | 6.65 | 93.35 | **92.62** |
| #20 | 0.85 | 30.63 | ( ** ) | 3.63 | 10.28 | 89.72 | **89.02** |
| #40 | 0.425 | 37.48 | | 4.44 | 14.72 | 85.28 | **84.61** |
| #60 | 0.250 | 82.25 | | 9.74 | 24.46 | 75.54 | **74.94** |
| #140 | 0.106 | 137.97 | | 16.35 | 40.81 | 59.19 | **58.73** |
| #200 | 0.075 | 37.99 | | 4.50 | 45.31 | 54.69 | **54.26** |
| Pan | - | 461.64 | | 54.69 | 100.00 | - | **-** |

***Notes :*** *( * ) The + 3/4" sieve analysis is based on the Total Dry Weight of the Sample*
*( ** ) The - 3/4" sieve analysis is based on the Weight of the Dry Sample*

| Tested By | RAL | Date | 8/19/15 | Checked By | KC | Date | 8/22/15 |
|---|---|---|---|---|---|---|---|



DCN: CT-S3B DATE: 2/09/10 REVISION: 0 *E:\2015\PROJECTS\AECOM\2015-437-001 Dow Salzburg\[2015-437-001-001 Grain JSieveHyd.xls]Print Sheet*

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# HYDROMETER ANALYSIS

ASTM D 422-63 (2007)/AASHTO T88-00 SOP-S3

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 1 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 1 |
| Lab ID: | 2015-437-001-001 | Soil Color: | Gray |

| Elapsed Time | | R Measured | Temp. | Composite Correction | R Corrected | N | K Factor | Diameter | N' |
|---|---|---|---|---|---|---|---|---|---|
| (min) | | | (°C) | | | (%) | | (mm) | (%) |
| 0 | | NA | NA | NA | NA | NA | NA | NA | NA |
| 2 | | 41.0 | 24.1 | 5.55 | 35.4 | 83.9 | 0.01281 | 0.0280 | **45.5** |
| 5 | | 38.0 | 24.1 | 5.55 | 32.4 | 76.8 | 0.01281 | 0.0182 | **41.7** |
| 15 | | 34.0 | 24.1 | 5.55 | 28.4 | 67.3 | 0.01281 | 0.0108 | **36.5** |
| 33 | | 30.0 | 24.1 | 5.55 | 24.4 | 57.9 | 0.01281 | 0.0075 | **31.4** |
| 67 | | 27.5 | 23.9 | 5.62 | 21.9 | 51.8 | 0.01284 | 0.0054 | **28.1** |
| 250 | | 22.5 | 24 | 5.59 | 16.9 | 40.0 | 0.01282 | 0.0029 | **21.7** |
| 1440 | | 19.0 | 23.7 | 5.69 | 13.3 | 31.5 | 0.01287 | 0.0012 | **17.1** |

| **Soil Specimen Data** | | **Other Corrections** | |
|---|---|---|---|
| Tare No.: | 932 | | |
| Wt. of Tare & Dry Material (g): | 144.69 | a - Factor: | 0.99 |
| Weight of Tare (g): | 97.87 | | |
| Weight of Deflocculant (g): | 5.0 | Percent Finer than # 200: | 54.26 |
| Weight of Dry Material (g): | 41.82 | | |
| | | Specific Gravity: | 2.7 Assumed |

***Note:*** *Hydrometer test is performed on - # 200 sieve material.*

Tested By TO Date 8/20/15 Checked By KC Date 8/22/15



DCN: CT-S3B DATE: 2/09/10 REVISION: 0 *E:\PROJECTS\AECOM\2015-437-001 Dow Salzburg\[2015-437-001-001 Grain JSieveHyd.xls]Print Sheet*

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# ATTERBERG LIMITS

ASTM D 4318-10

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 1 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 1 |
| Lab ID: | 2015-437-001-001 | Soil Description: | GRAY LEAN CLAY |

***Note: The USCS symbol used with this test refers only to the minus No. 40 sieve material. See the "Sieve and Hydrometer Analysis" graph page for the complete material description .***

( Minus No. 40 sieve material, Airdried)

| **Liquid Limit Test** | **1** | **2** | **3** | |
|---|---|---|---|---|
| Tare Number: | 1101 | 144 | 2289 | **MULTIPOINT** |
| Wt. of Tare & Wet Sample (g): | 38.57 | 38.11 | 40.66 | |
| Wt. of Tare & Dry Sample (g): | 34.95 | 34.86 | 37.44 | |
| Weight of Tare (g): | 18.19 | 17.98 | 20.43 | |
| Weight of Water (g): | 3.6 | 3.3 | 3.2 | |
| Weight of Dry Sample (g): | 16.8 | 16.9 | 17.0 | |
| **Moisture Content (%):** | **21.6** | **19.3** | **18.9** | |
| **Number of Blows:** | **15** | **26** | **32** | |

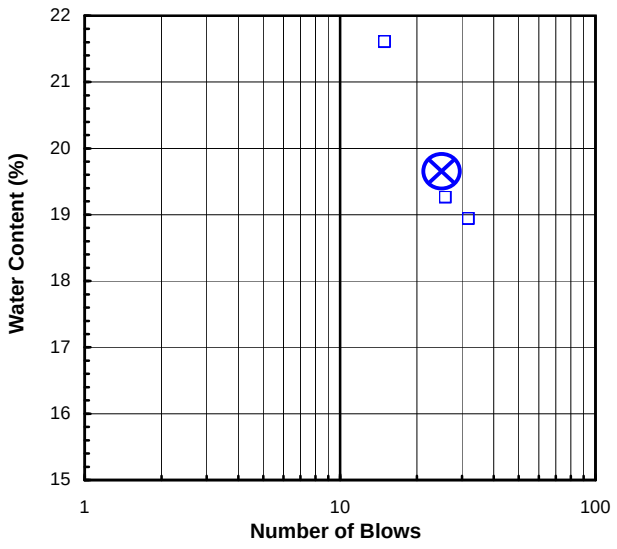
| **Plastic Limit Test** | **1** | **2** | **Range** |
|---|---|---|---|
| Tare Number: | 215 | 182 | |
| Wt. of Tare & Wet Sample (g): | 24.85 | 25.47 | |
| Wt. of Tare & Dry Sample (g): | 24.34 | 24.99 | |
| Weight of Tare (g): | 18.36 | 19.39 | |
| Weight of Water (g): | 0.5 | 0.5 | |
| Weight of Dry Sample (g): | 6.0 | 5.6 | |
| **Moisture Content (%):** | **8.5** | **8.6** | **0.0** |

*Note: The acceptable range of the two Moisture contents is ± 2.6*

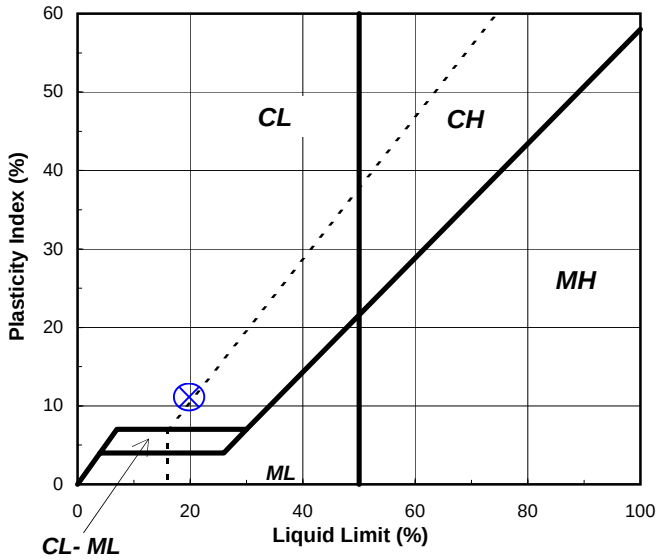
## Test Results

| | |
|---|---|
| **Liquid Limit (%):** | **20** |
| **Plastic Limit (%):** | **9** |
| **Plasticity Index (%):** | **11** |
| **USCS Symbol:** | **CL** |

**Flow Curve**




**Plasticity Chart**




*Tested By* *RAL* *Date* *8/20/15* *Checked By* *KC* *Date* 8/22/15



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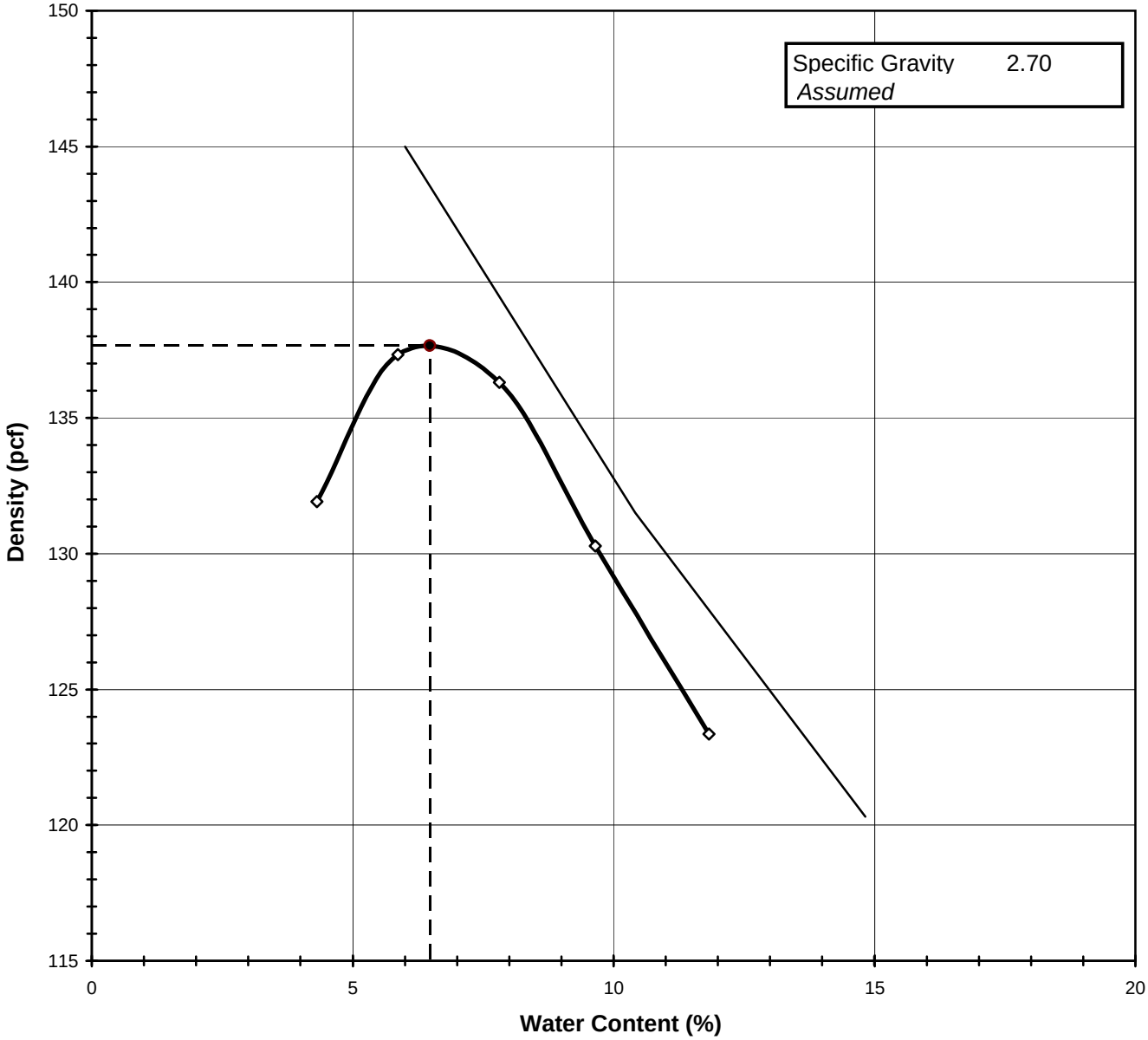
# MOISTURE DENSITY RELATIONSHIP

*ASTM D1557-12*

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 1 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 1 |
| Lab ID: | 2015-437-001-001 | Test Method | **MODIFIED** |

Visual Description: Gray Clay with small amount of Rock Fragments

**Optimum Water Content** **6.5**
**Maximum Dry Density** **137.7**




*Tested By* *BS* *Date* *8/20/15* *Checked By* *KC* *Date* 8/21/15



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# MOISTURE - DENSITY RELATIONSHIP

*ASTM D1557-12*

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 1 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 1 |
| Lab ID: | 2015-437-001-001 | | |

Visual Description: Gray Clay with small amount of Rock Fragments

| | |
|---|---|
| Total Weight of the Sample (g): | NA |
| As Received Water Content (%): | NA |
| *Assumed* Specific Gravity: | 2.70 |
| Percent Retained on 3/4": | NA |
| Percent Retained on 3/8": | NA |
| Percent Retained on #4: | NA |
| Oversize Material: | Not included |
| Procedure Used: | B |

| | | |
|---|---|---|
| Test Type: | | **MODIFIED** |
| Rammer Weight (lb): | | 10.0 |
| Rammer Drop (in): | | 18 |
| Rammer Type: | | MECHANICAL |
| Machine ID: | G | 774 |
| Mold ID: | G | 1499 |
| Mold diameter: | | 4" |
| Weight of the Mold (g): | | 4389 |
| Volume of the Mold ($cm^3$): | | 940 |

## Mold / Specimen

| **Point No.** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| Weight of Mold & Wet Sample (g): | 6462 | 6579 | 6603 | 6541 | 6467 |
| Weight of Mold (g): | 4389 | 4389 | 4389 | 4389 | 4389 |
| Weight of Wet Sample (g): | 2073 | 2190 | 2214 | 2152 | 2078 |
| Mold Volume ($cm^3$): | 940 | 940 | 940 | 940 | 940 |

## Moisture Content / Density

| | | | | | |
|---|---|---|---|---|---|
| Tare Number: | 1459 | 582 | 887 | 1719 | 630 |
| Weight of Tare & Wet Sample (g): | 460.80 | 491.80 | 454.70 | 412.70 | 428.30 |
| Weight of Tare & Dry Sample (g): | 445.00 | 469.20 | 429.70 | 383.78 | 391.69 |
| Weight of Tare (g): | 79.00 | 83.88 | 109.74 | 84.07 | 82.19 |
| Weight of Water (g): | 15.80 | 22.60 | 25.00 | 28.92 | 36.61 |
| Weight of Dry Sample (g): | 366.00 | 385.32 | 319.96 | 299.71 | 309.50 |

| | | | | | |
|---|---|---|---|---|---|
| Wet Density ($g/cm^3$): | 2.21 | 2.33 | 2.36 | 2.29 | 2.21 |
| Wet Density (pcf): | 137.6 | 145.4 | 147.0 | 142.9 | 137.9 |
| **Moisture Content (%):** | **4.3** | **5.9** | **7.8** | **9.6** | **11.8** |
| **Dry Density (pcf):** | **131.9** | **137.3** | **136.3** | **130.3** | **123.4** |

## Zero Air Voids

| | | | |
|---|---|---|---|
| **Moisture Content (%):** | 6.0 | 10.4 | 14.8 |
| **Dry Unit Weight (pcf):** | 145.0 | 131.5 | 120.3 |

*Tested By* *BS* *Date* *8/20/15* *Checked By* *KC* *Date* 8/21/15



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# SIEVE AND HYDROMETER ANALYSIS

ASTM D 422-63 (2007)/AASHTO T88-00 SOP-S3

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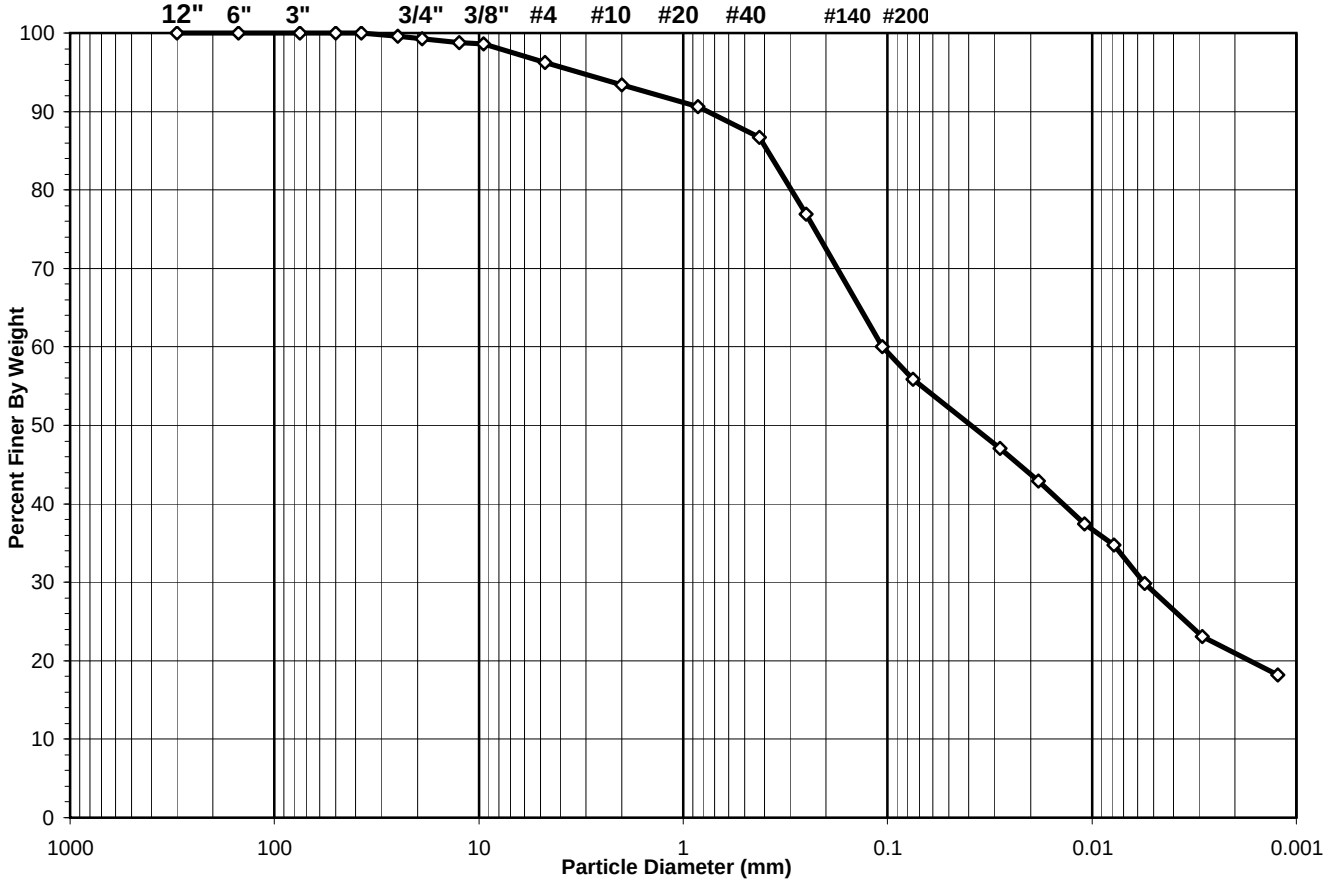
| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 2 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 2 |
| Lab ID: | 2015-437-001-002 | Soil Color: | Gray |

| | SIEVE ANALYSIS | | | HYDROMETER | |
|---|---|---|---|---|---|
| USCS | cobbles | gravel | sand | silt and clay fraction | |
| USDA | cobbles | gravel | sand | silt | clay |




**USCS Summary**

| Sieve Sizes (mm) | | Percentage |
|---|---|---|
| Greater Than #4 | *Gravel* | 3.74 |
| #4 To #200 | *Sand* | 40.36 |
| Finer Than #200 | *Silt & Clay* | 55.90 |

**USCS Symbol:**
***CL, TESTED***

**USCS Classification:**
***SANDY LEAN CLAY***





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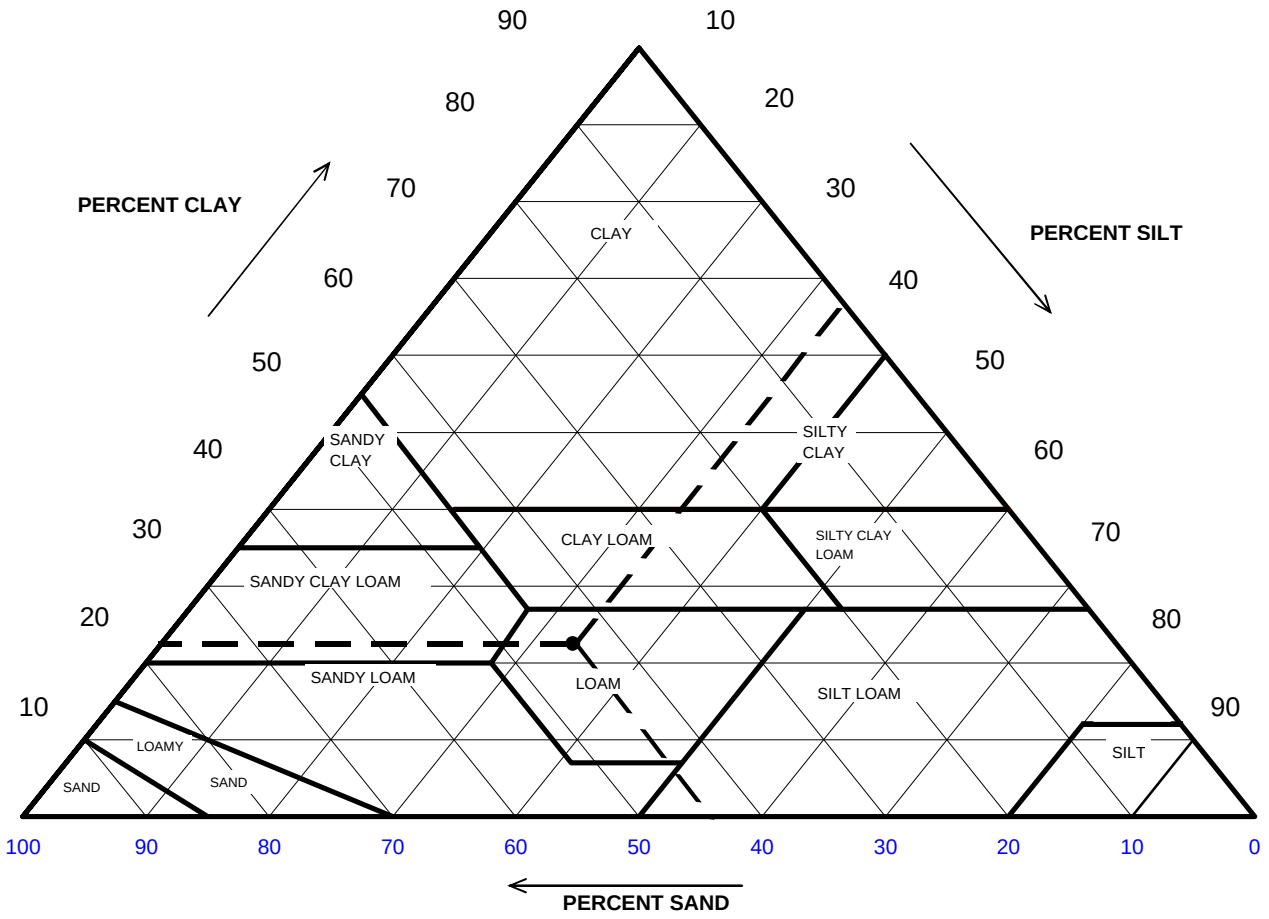
# USDA CLASSIFICATION CHART

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 2 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 2 |
| Lab ID: | 2015-437-001-002 | Soil Color: | Gray |




| Particle Size (mm) | Percent Finer | USDA SUMMARY | Actual Percentage | Corrected % of Minus 2.0 mm material for USDA Classificat. |
|---|---|---|---|---|
| | | *Gravel* | 6.63 | **0.00** |
| 2 | 93.37 | *Sand* | 41.15 | **44.08** |
| 0.05 | 52.21 | *Silt* | 31.23 | **33.45** |
| 0.002 | 20.98 | *Clay* | 20.98 | **22.47** |

**USDA Classification**: ***LOAM***





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# WASH SIEVE ANALYSIS

ASTM D 422-63 (2007)/AASHTO T88-00 SOP-S3

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| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 2 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 2 |
| Lab ID: | 2015-437-001-002 | Soil Color: | Gray |

| Moisture Content of Passing 3/4" Material | | Water Content of Retained 3/4" Material | |
|---|---|---|---|
| Tare No.: | 53 | Tare No.: | 2898 |
| Wt. of Tare & Wet Sample (g): | 1130.10 | Weight of Tare & Wet Sample (g): | 145.47 |
| Wt. of Tare & Dry Sample (g): | 1118.60 | Weight of Tare & Dry Sample (g): | 145.24 |
| Weight of Tare (g): | 202.25 | Weight of Tare (g): | 6.67 |
| Weight of Water (g): | 11.50 | Weight of Water (g): | 0.23 |
| Weight of Dry Soil (g): | 916.35 | Weight of Dry Soil (g): | 138.57 |
| **Moisture Content (%):** | **1.3** | **Moisture Content (%):** | **0.2** |

| | | | |
|---|---|---|---|
| Wet Weight of -3/4" Sample (g): | 19464 | Weight of the Dry Sample (g): | 916.35 |
| Dry Weight of - 3/4" Sample (g): | 19222.8 | Weight of Minus #200 Material (g): | 515.89 |
| Wet Weight of +3/4" Sample (g): | 138.80 | Weight of Plus #200 Material (g): | 400.46 |
| Dry Weight of + 3/4" Sample (g): | 138.57 | | |
| Total Dry Weight of Sample (g): | 19361.3 | **J - Factor (Percent Finer than 3/4"):** | **0.9928** |

| Sieve Size | Sieve Opening (mm) | Weight of Soil Retained (g) | | Percent Retained (%) | Accumulated Percent Retained (%) | Percent Finer (%) | **Accumulated Percent Finer (%)** |
|---|---|---|---|---|---|---|---|
| 12" | 300 | 0.00 | | 0.00 | 0.00 | 100.00 | **100.00** |
| 6" | 150 | 0.00 | | 0.00 | 0.00 | 100.00 | **100.00** |
| 3" | 75 | 0.00 | | 0.00 | 0.00 | 100.00 | **100.00** |
| 2" | 50 | 0.00 | ( * ) | 0.00 | 0.00 | 100.00 | **100.00** |
| 1 1/2" | 37.5 | 0.00 | | 0.00 | 0.00 | 100.00 | **100.00** |
| 1" | 25.0 | 82.67 | | 0.43 | 0.43 | 99.57 | **99.57** |
| 3/4" | 19.0 | 56.13 | | 0.29 | 0.72 | 99.28 | **99.28** |
| 1/2" | 12.5 | 4.40 | | 0.48 | 0.48 | 99.52 | **98.81** |
| 3/8" | 9.50 | 1.63 | | 0.18 | 0.66 | 99.34 | **98.63** |
| #4 | 4.75 | 21.89 | | 2.39 | 3.05 | 96.95 | **96.26** |
| #10 | 2.00 | 26.71 | | 2.91 | 5.96 | 94.04 | **93.37** |
| #20 | 0.85 | 25.27 | ( ** ) | 2.76 | 8.72 | 91.28 | **90.63** |
| #40 | 0.425 | 36.11 | | 3.94 | 12.66 | 87.34 | **86.71** |
| #60 | 0.250 | 90.29 | | 9.85 | 22.51 | 77.49 | **76.93** |
| #140 | 0.106 | 156.05 | | 17.03 | 39.54 | 60.46 | **60.02** |
| #200 | 0.075 | 38.11 | | 4.16 | 43.70 | 56.30 | **55.90** |
| Pan | - | 515.89 | | 56.30 | 100.00 | - | **-** |

***Notes :*** *( * ) The + 3/4" sieve analysis is based on the Total Dry Weight of the Sample*
*( ** ) The - 3/4" sieve analysis is based on the Weight of the Dry Sample*

| Tested By | RAL | Date | 8/19/15 | Checked By | KC | Date | 8/22/15 |
|---|---|---|---|---|---|---|---|



DCN: CT-S3B DATE: 2/09/10 REVISION: 0 *E:\PROJECTS\AECOM\2015-437-001 Dow Salzburg\[2015-437-001-002 Grain JSieveHyd.xls]Print Sheet*

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# HYDROMETER ANALYSIS

ASTM D 422-63 (2007)/AASHTO T88-00 SOP-S3

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| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 2 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 2 |
| Lab ID: | 2015-437-001-002 | Soil Color: | Gray |

| Elapsed Time | | R Measured | Temp. | Composite Correction | R Corrected | N | K Factor | Diameter | N' |
|---|---|---|---|---|---|---|---|---|---|
| (min) | | | (°C) | | | (%) | | (mm) | (%) |
| 0 | | NA | NA | NA | NA | NA | NA | NA | NA |
| 2 | | 40.0 | 24.1 | 5.55 | 34.4 | 84.1 | 0.01281 | 0.0283 | **47.0** |
| 5 | | 37.0 | 24.1 | 5.55 | 31.4 | 76.8 | 0.01281 | 0.0183 | **42.9** |
| 15 | | 33.0 | 24.1 | 5.55 | 27.4 | 67.0 | 0.01281 | 0.0109 | **37.5** |
| 30 | | 31.0 | 24.1 | 5.55 | 25.4 | 62.2 | 0.01281 | 0.0078 | **34.7** |
| 64 | | 27.5 | 23.9 | 5.62 | 21.9 | 53.4 | 0.01284 | 0.0055 | **29.9** |
| 250 | | 22.5 | 24 | 5.59 | 16.9 | 41.3 | 0.01282 | 0.0029 | **23.1** |
| 1440 | | 19.0 | 23.7 | 5.69 | 13.3 | 32.5 | 0.01287 | 0.0012 | **18.2** |

| **Soil Specimen Data** | | **Other Corrections** | |
|---|---|---|---|
| Tare No.: | 1681 | | |
| Wt. of Tare & Dry Material (g): | 143.78 | a - Factor: | 0.99 |
| Weight of Tare (g): | 98.25 | | |
| Weight of Deflocculant (g): | 5.0 | Percent Finer than # 200: | 55.90 |
| Weight of Dry Material (g): | 40.53 | | |
| | | Specific Gravity: | 2.7 Assumed |

***Note:*** *Hydrometer test is performed on - # 200 sieve material.*

| Tested By | TO | Date | 8/20/15 | Checked By | KC | Date | 8/22/15 |
|---|---|---|---|---|---|---|---|



DCN: CT-S3B DATE: 2/09/10 REVISION: 0 *E:\PROJECTS\AECOM\2015-437-001 Dow Salzburg\[2015-437-001-002 Grain JSieveHyd.xls]Print Sheet*

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# ATTERBERG LIMITS

ASTM D 4318-10

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 2 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 2 |
| Lab ID: | 2015-437-001-002 | Soil Description: | GRAY LEAN CLAY |

***Note: The USCS symbol used with this test refers only to the minus No. 40 sieve material. See the "Sieve and Hydrometer Analysis" graph page for the complete material description .***

( Minus No. 40 sieve material, Airdried)

| **Liquid Limit Test** | **1** | **2** | **3** | |
|---|---|---|---|---|
| Tare Number: | 241 | 197 | 195 | **MULTIPOINT** |
| Wt. of Tare & Wet Sample (g): | 39.12 | 38.35 | 38.44 | |
| Wt. of Tare & Dry Sample (g): | 35.38 | 34.77 | 34.88 | |
| Weight of Tare (g): | 18.52 | 17.45 | 17.26 | |
| Weight of Water (g): | 3.7 | 3.6 | 3.6 | |
| Weight of Dry Sample (g): | 16.9 | 17.3 | 17.6 | |
| **Moisture Content (%):** | **22.2** | **20.7** | **20.2** | |
| **Number of Blows:** | **19** | **24** | **33** | |

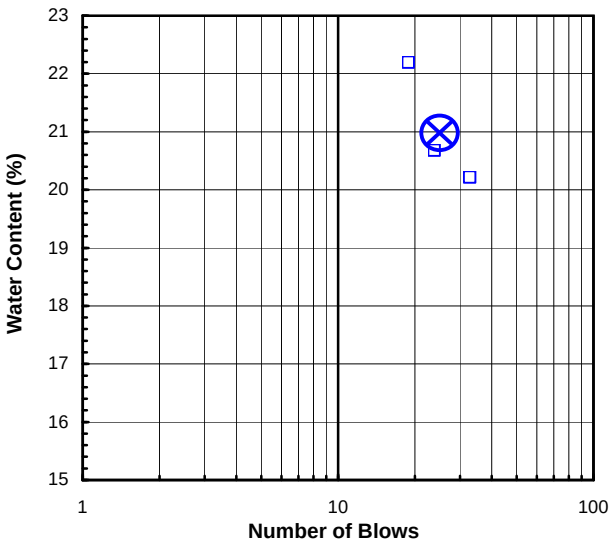
| **Plastic Limit Test** | **1** | **2** | **Range** |
|---|---|---|---|
| Tare Number: | 333 | 2 | |
| Wt. of Tare & Wet Sample (g): | 26.26 | 25.49 | |
| Wt. of Tare & Dry Sample (g): | 25.77 | 25.00 | |
| Weight of Tare (g): | 19.86 | 19.46 | |
| Weight of Water (g): | 0.5 | 0.5 | |
| Weight of Dry Sample (g): | 5.9 | 5.5 | |
| **Moisture Content (%):** | **8.3** | **8.8** | **-0.6** |

*Note: The acceptable range of the two Moisture contents is ± 2.6*

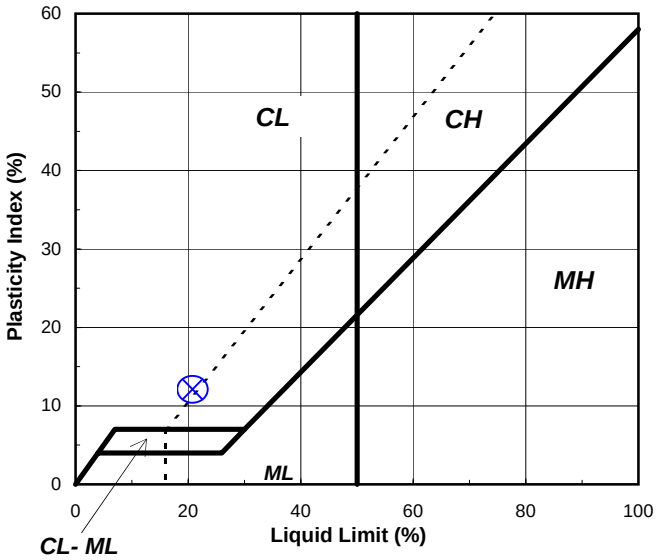
## Test Results

| | |
|---|---|
| **Liquid Limit (%):** | **21** |
| **Plastic Limit (%):** | **9** |
| **Plasticity Index (%):** | **12** |
| **USCS Symbol:** | **CL** |

**Flow Curve**




**Plasticity Chart**




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Tested By* | *RAL* | *Date* | *8/20/15* | *Checked By* | *KC* | *Date* | 8/22/15 |



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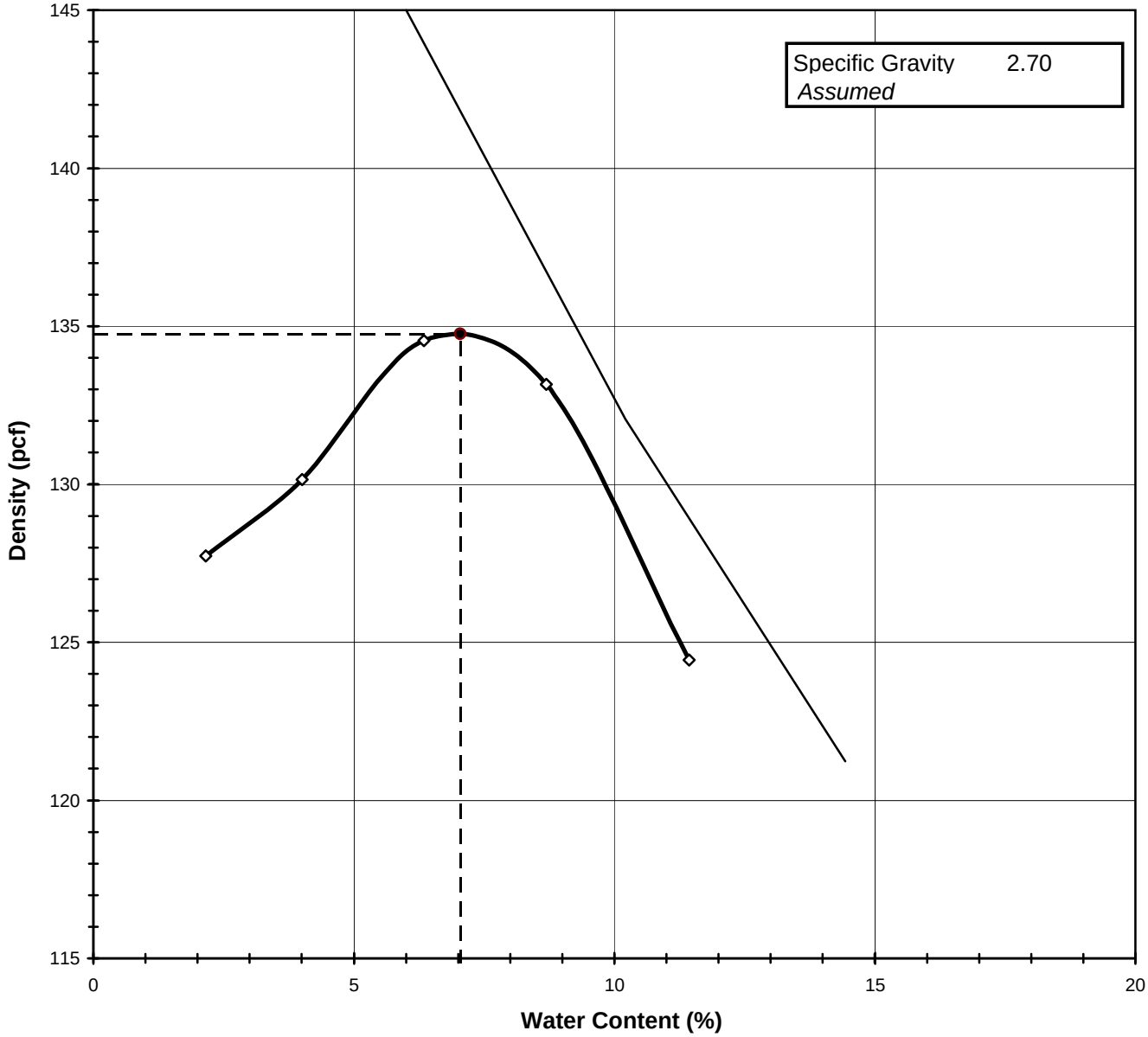
# MOISTURE DENSITY RELATIONSHIP

*ASTM D1557-12*

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 2 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 2 |
| Lab ID: | 2015-437-001-002 | Test Method | **MODIFIED** |

Visual Description: Gray Clay with small amount of Rock Fragments

**Optimum Water Content** **7.1**
**Maximum Dry Density** **134.8**




*Tested By* *AMC* *Date* *8/20/15* *Checked By* *KC* *Date* 8/21/15



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# MOISTURE - DENSITY RELATIONSHIP

*ASTM D1557-12*

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 2 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 2 |
| Lab ID: | 2015-437-001-002 | | |

Visual Description: Gray Clay with small amount of Rock Fragments

| | |
|---|---|
| Total Weight of the Sample (g): | NA |
| As Received Water Content (%): | NA |
| *Assumed* Specific Gravity: | 2.70 |
| Percent Retained on 3/4": | NA |
| Percent Retained on 3/8": | NA |
| Percent Retained on #4: | NA |
| Oversize Material: | Not included |
| Procedure Used: | B |

| | | |
|---|---|---|
| Test Type: | | **MODIFIED** |
| Rammer Weight (lb): | | 10.0 |
| Rammer Drop (in): | | 18 |
| Rammer Type: | | MECHANICAL |
| Machine ID: | G | 774 |
| Mold ID: | G | 1192 |
| Mold diameter: | | 4" |
| Weight of the Mold (g): | | 4170 |
| Volume of the Mold ($cm^3$): | | 945 |

## Mold / Specimen

| **Point No.** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| Weight of Mold & Wet Sample (g): | 6146 | 6220 | 6337 | 6362 | 6270 |
| Weight of Mold (g): | 4170 | 4170 | 4170 | 4170 | 4170 |
| Weight of Wet Sample (g): | 1976 | 2050 | 2167 | 2192 | 2100 |
| Mold Volume ($cm^3$): | 945 | 945 | 945 | 945 | 945 |

## Moisture Content / Density

| | | | | | |
|---|---|---|---|---|---|
| Tare Number: | 578 | 606 | 1705 | 589 | 890 |
| Weight of Tare & Wet Sample (g): | 667.30 | 602.40 | 637.80 | 660.50 | 639.20 |
| Weight of Tare & Dry Sample (g): | 655.00 | 582.50 | 604.70 | 614.30 | 584.90 |
| Weight of Tare (g): | 84.20 | 85.30 | 83.10 | 82.90 | 110.00 |
| Weight of Water (g): | 12.30 | 19.90 | 33.10 | 46.20 | 54.30 |
| Weight of Dry Sample (g): | 570.80 | 497.20 | 521.60 | 531.40 | 474.90 |

| | | | | | |
|---|---|---|---|---|---|
| Wet Density ($g/cm^3$): | 2.09 | 2.17 | 2.29 | 2.32 | 2.22 |
| Wet Density (pcf): | 130.5 | 135.4 | 143.1 | 144.7 | 138.7 |
| **Moisture Content (%):** | **2.2** | **4.0** | **6.3** | **8.7** | **11.4** |
| **Dry Density (pcf):** | **127.7** | **130.2** | **134.6** | **133.2** | **124.4** |

## Zero Air Voids

| | | | |
|---|---|---|---|
| **Moisture Content (%):** | 6.0 | 10.2 | 14.4 |
| **Dry Unit Weight (pcf):** | 145.0 | 132.1 | 121.2 |

*Tested By* *AMC* *Date* *8/20/15* *Checked By* *KC* *Date* 8/21/15



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# SIEVE AND HYDROMETER ANALYSIS

ASTM D 422-63 (2007)/AASHTO T88-00 SOP-S3

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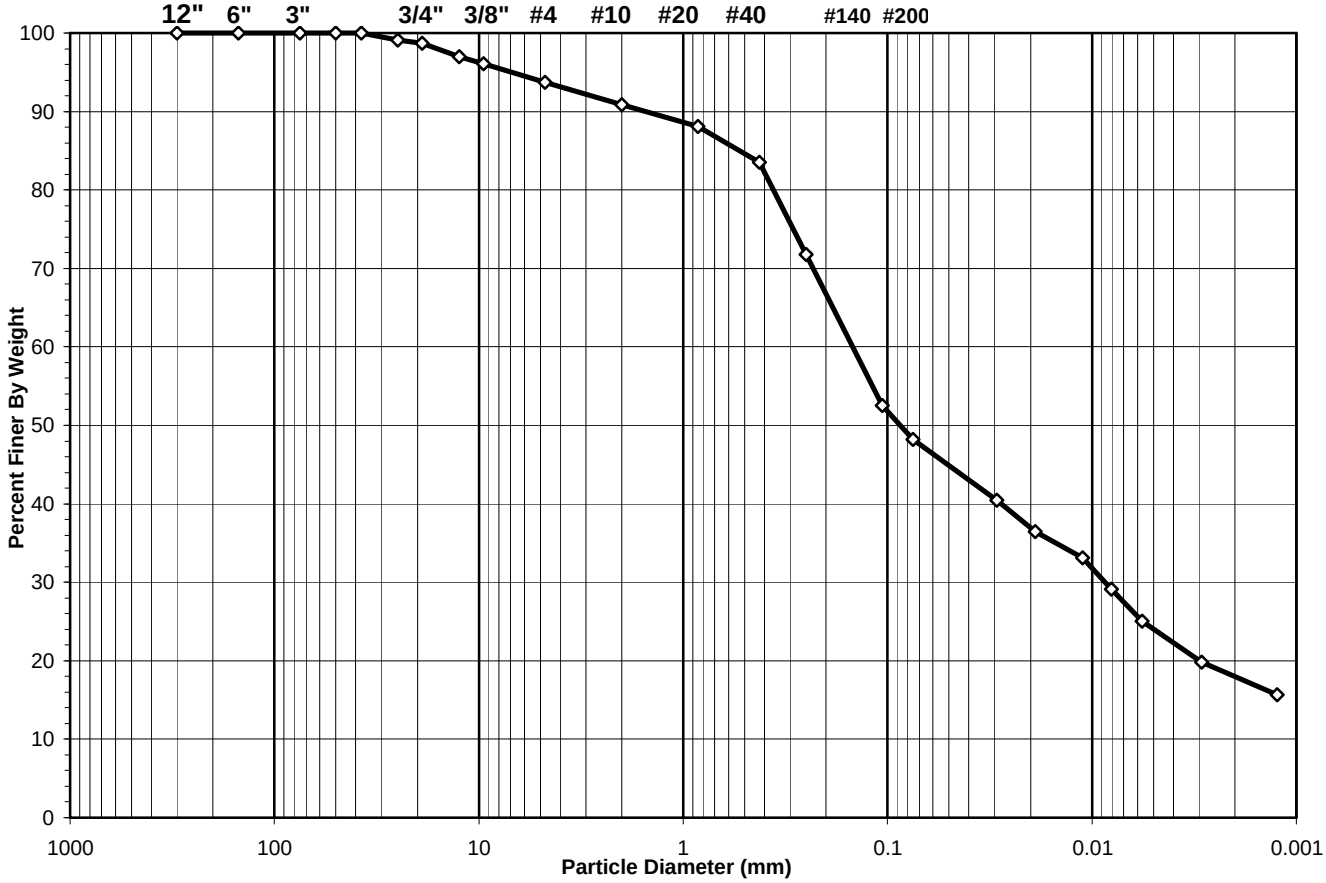
| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 3 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 3 |
| Lab ID: | 2015-437-001-003 | Soil Color: | Gray |

| | SIEVE ANALYSIS | | | HYDROMETER | |
|---|---|---|---|---|---|
| USCS | cobbles | gravel | sand | silt and clay fraction | |
| USDA | cobbles | gravel | sand | silt | clay |




**USCS Summary**

| Sieve Sizes (mm) | | Percentage |
|---|---|---|
| Greater Than #4 | *Gravel* | 6.29 |
| #4 To #200 | *Sand* | 45.54 |
| Finer Than #200 | *Silt & Clay* | 48.17 |

**USCS Symbol:**
***SC, TESTED***

**USCS Classification:**
***CLAYEY SAND***





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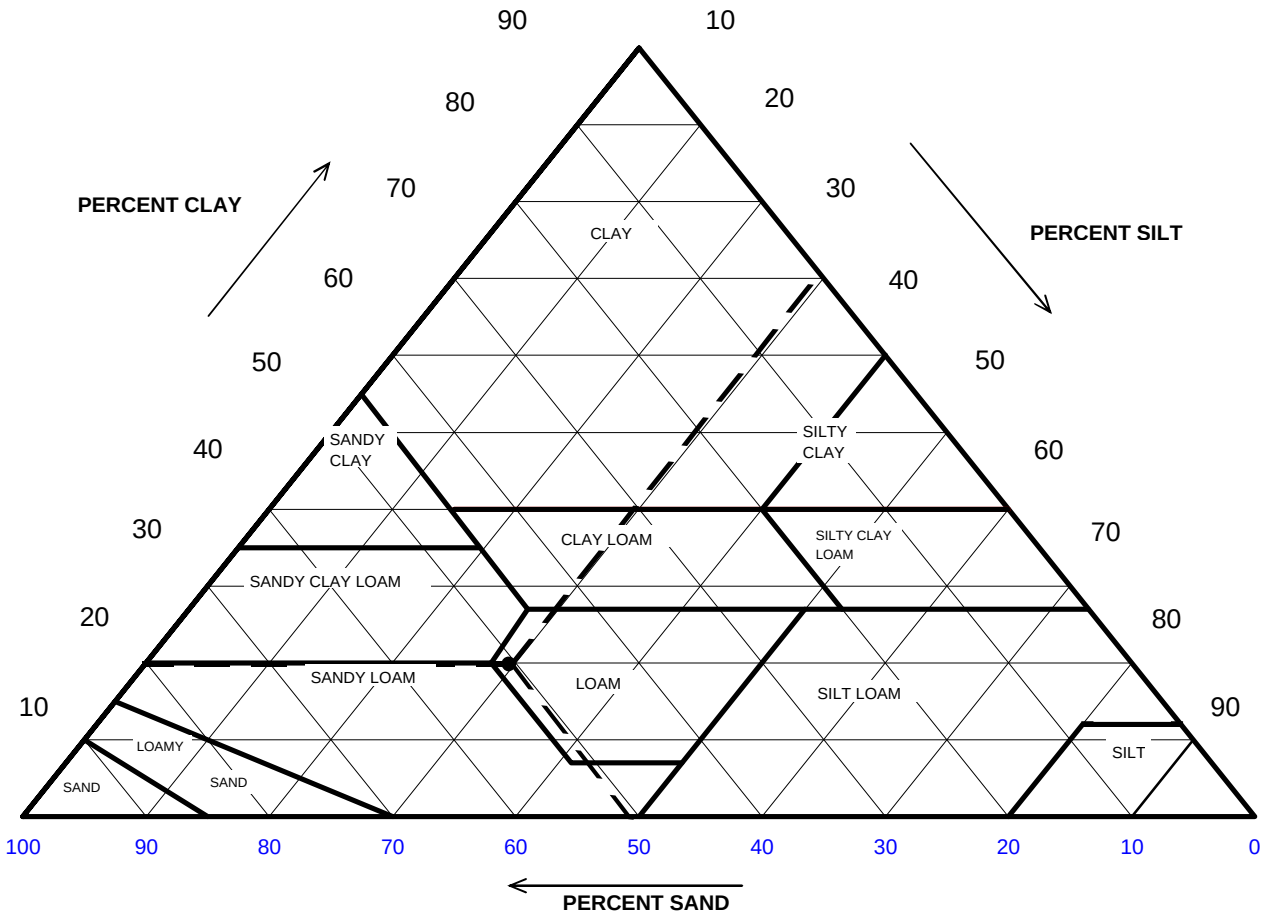
# USDA CLASSIFICATION CHART

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 3 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 3 |
| Lab ID: | 2015-437-001-003 | Soil Color: | Gray |




| Particle Size (mm) | Percent Finer | USDA SUMMARY | Actual Percentage | Corrected % of Minus 2.0 mm material for USDA Classificat. |
|---|---|---|---|---|
| | | *Gravel* | 9.13 | **0.00** |
| 2 | 90.87 | *Sand* | 46.02 | **50.65** |
| 0.05 | 44.85 | *Silt* | 26.86 | **29.56** |
| 0.002 | 17.98 | *Clay* | 17.98 | **19.79** |

**USDA Classification**: ***LOAM***





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# WASH SIEVE ANALYSIS

ASTM D 422-63 (2007)/AASHTO T88-00 SOP-S3

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| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 3 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 3 |
| Lab ID: | 2015-437-001-003 | Soil Color: | Gray |

| Moisture Content of Passing 3/4" Material | | Water Content of Retained 3/4" Material | |
|---|---|---|---|
| Tare No.: | 10 | Tare No.: | 544 |
| Wt. of Tare & Wet Sample (g): | 1159.30 | Weight of Tare & Wet Sample (g): | 384.05 |
| Wt. of Tare & Dry Sample (g): | 1146.60 | Weight of Tare & Dry Sample (g): | 383.22 |
| Weight of Tare (g): | 202.34 | Weight of Tare (g): | 84.42 |
| Weight of Water (g): | 12.70 | Weight of Water (g): | 0.83 |
| Weight of Dry Soil (g): | 944.26 | Weight of Dry Soil (g): | 298.80 |
| **Moisture Content (%):** | **1.3** | **Moisture Content (%):** | **0.3** |

| | | | |
|---|---|---|---|
| Wet Weight of -3/4" Sample (g): | 22624 | Weight of the Dry Sample (g): | 944.26 |
| Dry Weight of - 3/4" Sample (g): | 22323.8 | Weight of Minus #200 Material (g): | 460.96 |
| Wet Weight of +3/4" Sample (g): | 299.63 | Weight of Plus #200 Material (g): | 483.30 |
| Dry Weight of + 3/4" Sample (g): | 298.80 | | |
| Total Dry Weight of Sample (g): | 22622.6 | **J - Factor (Percent Finer than 3/4"):** | **0.9868** |

| Sieve Size | Sieve Opening (mm) | Weight of Soil Retained (g) | | Percent Retained (%) | Accumulated Percent Retained (%) | Percent Finer (%) | **Accumulated Percent Finer (%)** |
|---|---|---|---|---|---|---|---|
| 12" | 300 | 0.00 | | 0.00 | 0.00 | 100.00 | **100.00** |
| 6" | 150 | 0.00 | | 0.00 | 0.00 | 100.00 | **100.00** |
| 3" | 75 | 0.00 | | 0.00 | 0.00 | 100.00 | **100.00** |
| 2" | 50 | 0.00 | ( * ) | 0.00 | 0.00 | 100.00 | **100.00** |
| 1 1/2" | 37.5 | 0.00 | | 0.00 | 0.00 | 100.00 | **100.00** |
| 1" | 25.0 | 198.64 | | 0.88 | 0.88 | 99.12 | **99.12** |
| 3/4" | 19.0 | 100.99 | | 0.45 | 1.32 | 98.68 | **98.68** |
| 1/2" | 12.5 | 15.99 | | 1.69 | 1.69 | 98.31 | **97.01** |
| 3/8" | 9.50 | 8.57 | | 0.91 | 2.60 | 97.40 | **96.11** |
| #4 | 4.75 | 22.99 | | 2.43 | 5.04 | 94.96 | **93.71** |
| #10 | 2.00 | 27.18 | | 2.88 | 7.91 | 92.09 | **90.87** |
| #20 | 0.85 | 26.86 | ( ** ) | 2.84 | 10.76 | 89.24 | **88.06** |
| #40 | 0.425 | 43.24 | | 4.58 | 15.34 | 84.66 | **83.54** |
| #60 | 0.250 | 112.82 | | 11.95 | 27.29 | 72.71 | **71.75** |
| #140 | 0.106 | 184.11 | | 19.50 | 46.78 | 53.22 | **52.51** |
| #200 | 0.075 | 41.54 | | 4.40 | 51.18 | 48.82 | **48.17** |
| Pan | - | 460.96 | | 48.82 | 100.00 | - | **-** |

***Notes :*** *( * ) The + 3/4" sieve analysis is based on the Total Dry Weight of the Sample*
*( ** ) The - 3/4" sieve analysis is based on the Weight of the Dry Sample*

| Tested By | RAL | Date | 8/19/15 | Checked By | KC | Date | 8/22/15 |
|---|---|---|---|---|---|---|---|



DCN: CT-S3B DATE: 2/09/10 REVISION: 0 *E:\GTI\PROJECTS\AECOM\2015-437-001 Dow Salzburg\[2015-437-001-003 Grain JSieveHyd.xls]Print Sheet*

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# HYDROMETER ANALYSIS

ASTM D 422-63 (2007)/AASHTO T88-00 SOP-S3

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| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 3 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 3 |
| Lab ID: | 2015-437-001-003 | Soil Color: | Gray |

| Elapsed Time | | R Measured | Temp. | Composite Correction | R Corrected | N | K Factor | Diameter | N' |
|---|---|---|---|---|---|---|---|---|---|
| (min) | | | (°C) | | | (%) | | (mm) | (%) |
| 0 | | NA | NA | NA | NA | NA | NA | NA | NA |
| 2 | | 36.0 | 24.1 | 5.55 | 30.4 | 83.9 | 0.01281 | 0.0292 | **40.4** |
| 5 | | 33.0 | 24.1 | 5.55 | 27.4 | 75.7 | 0.01281 | 0.0189 | **36.5** |
| 15 | | 30.5 | 24.1 | 5.55 | 24.9 | 68.8 | 0.01281 | 0.0111 | **33.1** |
| 30 | | 27.5 | 24.1 | 5.55 | 21.9 | 60.5 | 0.01281 | 0.0080 | **29.1** |
| 63 | | 24.5 | 23.9 | 5.62 | 18.9 | 52.0 | 0.01284 | 0.0057 | **25.1** |
| 250 | | 20.5 | 24 | 5.59 | 14.9 | 41.1 | 0.01282 | 0.0029 | **19.8** |
| 1440 | | 17.5 | 23.7 | 5.69 | 11.8 | 32.6 | 0.01287 | 0.0012 | **15.7** |

| **Soil Specimen Data** | | **Other Corrections** | |
|---|---|---|---|
| Tare No.: | 960 | | |
| Wt. of Tare & Dry Material (g): | 136.53 | a - Factor: | 0.99 |
| Weight of Tare (g): | 95.62 | | |
| Weight of Deflocculant (g): | 5.0 | Percent Finer than # 200: | 48.17 |
| Weight of Dry Material (g): | 35.91 | | |
| | | Specific Gravity: | 2.7 Assumed |

***Note:*** *Hydrometer test is performed on - # 200 sieve material.*

Tested By TO Date 8/20/15 Checked By KC Date 8/22/15



DCN: CT-S3B DATE: 2/09/10 REVISION: 0 *E:\PROJECTS\AECOM\2015-437-001 Dow Salzburg\[2015-437-001-003 Grain JSieveHyd.xls]Print Sheet*

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# ATTERBERG LIMITS

ASTM D 4318-10

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 3 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 3 |
| Lab ID: | 2015-437-001-003 | Soil Description: | GRAY LEAN CLAY |

***Note: The USCS symbol used with this test refers only to the minus No. 40 sieve material. See the "Sieve and Hydrometer Analysis" graph page for the complete material description .***

( Minus No. 40 sieve material, Airdried)

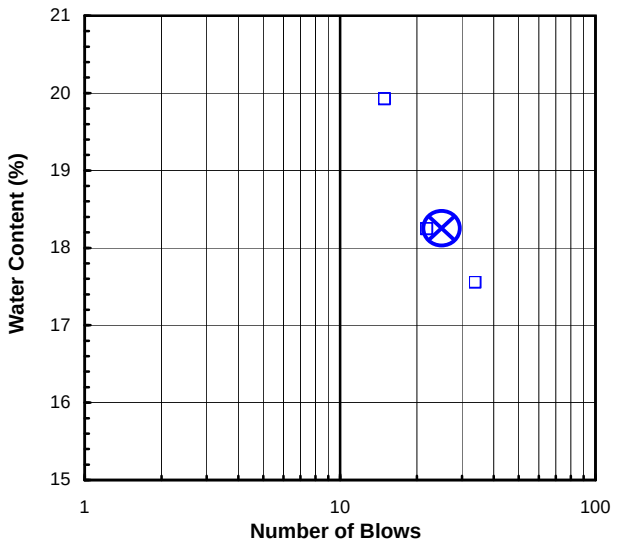
| **Liquid Limit Test** | **1** | **2** | **3** | |
|---|---|---|---|---|
| Tare Number: | 208 | 249 | 196 | **MULTIPOINT** |
| Wt. of Tare & Wet Sample (g): | 39.56 | 38.25 | 38.87 | |
| Wt. of Tare & Dry Sample (g): | 36.16 | 35.04 | 35.71 | |
| Weight of Tare (g): | 19.09 | 17.44 | 17.70 | |
| Weight of Water (g): | 3.4 | 3.2 | 3.2 | |
| Weight of Dry Sample (g): | 17.1 | 17.6 | 18.0 | |
| **Moisture Content (%):** | **19.9** | **18.2** | **17.5** | |
| **Number of Blows:** | **15** | **22** | **34** | |

| **Plastic Limit Test** | **1** | **2** | **Range** |
|---|---|---|---|
| Tare Number: | 169 | 3 | |
| Wt. of Tare & Wet Sample (g): | 25.81 | 25.02 | |
| Wt. of Tare & Dry Sample (g): | 25.37 | 24.59 | |
| Weight of Tare (g): | 19.28 | 18.89 | |
| Weight of Water (g): | 0.4 | 0.4 | |
| Weight of Dry Sample (g): | 6.1 | 5.7 | |
| **Moisture Content (%):** | **7.2** | **7.5** | **-0.3** |

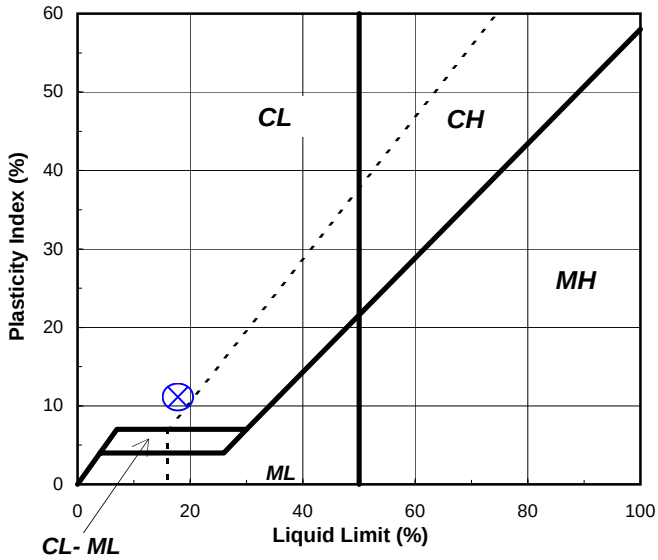
*Note: The acceptable range of the two Moisture contents is ± 2.6*

| **Test Results** | |
|---|---|
| **Liquid Limit (%):** | **18** |
| **Plastic Limit (%):** | **7** |
| **Plasticity Index (%):** | **11** |
| **USCS Symbol:** | **CL** |

**Flow Curve**




**Plasticity Chart**




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Tested By* | *RAL* | *Date* | *8/20/15* | *Checked By* | *KC* | *Date* | 8/22/15 |



*S:\Excel\Excel QA\Spreadsheets\Limit 3Pt.xls*

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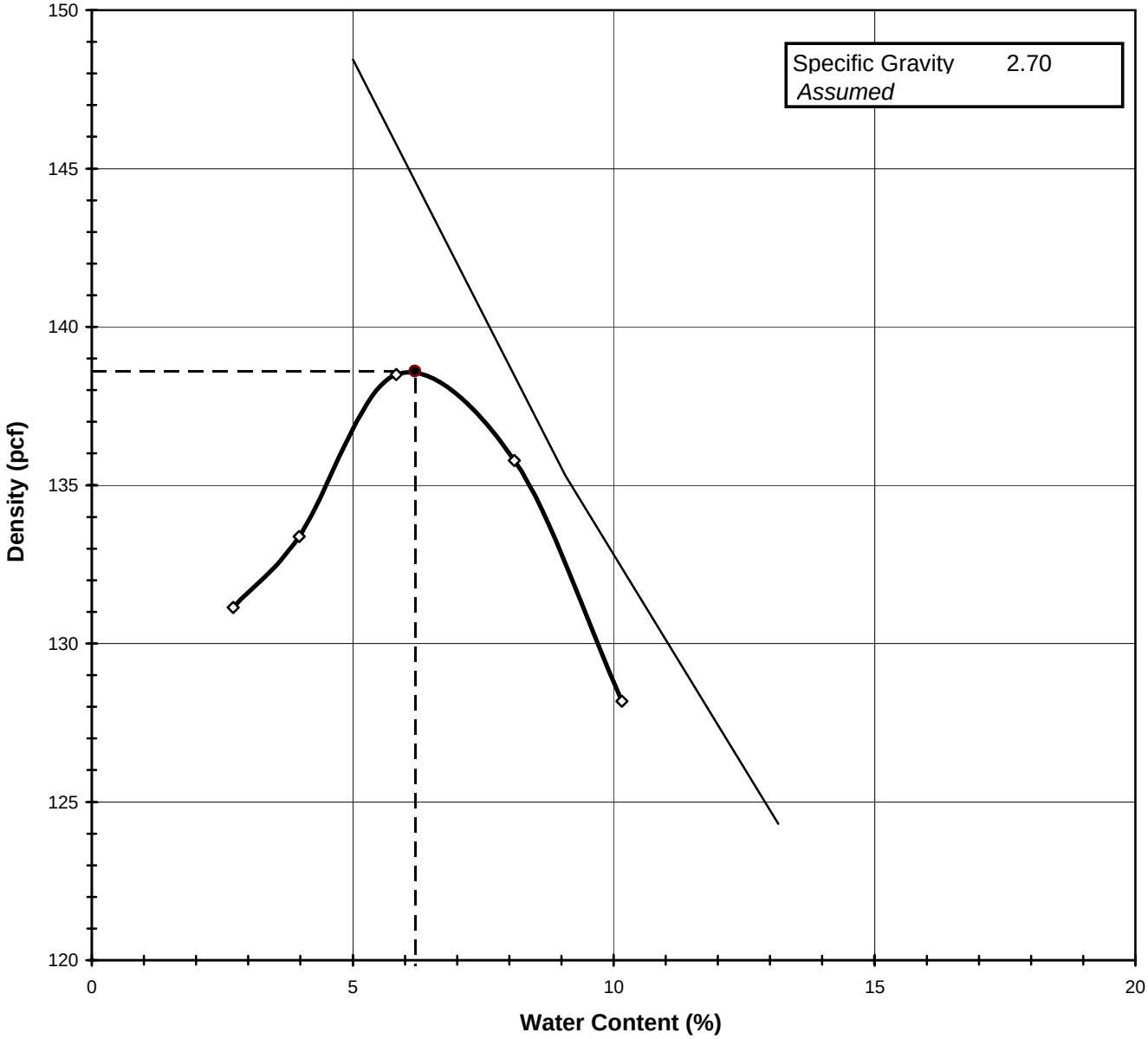
# MOISTURE DENSITY RELATIONSHIP

*ASTM D1557-12*

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 3 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 3 |
| Lab ID: | 2015-437-001-003 | Test Method | **MODIFIED** |

Visual Description: Gray Clay with small amount of Rock Fragments

| | |
|---|---|
| **Optimum Water Content** | **6.2** |
| **Maximum Dry Density** | **138.6** |




*Tested By* *MF* *Date* *8/20/15* *Checked By* *KC* *Date* 8/21/15



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# MOISTURE - DENSITY RELATIONSHIP

*ASTM D1557-12*

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 3 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 3 |
| Lab ID: | 2015-437-001-003 | | |

Visual Description: Gray Clay with small amount of Rock Fragments

| | |
|---|---|
| Total Weight of the Sample (g): | NA |
| As Received Water Content (%): | NA |
| *Assumed* Specific Gravity: | 2.70 |
| Percent Retained on 3/4": | NA |
| Percent Retained on 3/8": | NA |
| Percent Retained on #4: | NA |
| Oversize Material: | Not included |
| Procedure Used: | B |

| | | |
|---|---|---|
| Test Type: | | **MODIFIED** |
| Rammer Weight (lb): | | 10.0 |
| Rammer Drop (in): | | 18 |
| Rammer Type: | | MECHANICAL |
| Machine ID: | G | 774 |
| Mold ID: | G | 1499 |
| Mold diameter: | | 4" |
| Weight of the Mold (g): | | 4389 |
| Volume of the Mold ($cm^3$): | | 940 |

## Mold / Specimen

| **Point No.** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| Weight of Mold & Wet Sample (g): | 6418 | 6478 | 6597 | 6600 | 6516 |
| Weight of Mold (g): | 4389 | 4389 | 4389 | 4389 | 4389 |
| Weight of Wet Sample (g): | 2029 | 2089 | 2208 | 2211 | 2127 |
| Mold Volume ($cm^3$): | 940 | 940 | 940 | 940 | 940 |

## Moisture Content / Density

| | | | | | |
|---|---|---|---|---|---|
| Tare Number: | 587 | 203 | 2728 | 884 | 1696 |
| Weight of Tare & Wet Sample (g): | 395.17 | 410.40 | 393.14 | 421.30 | 405.50 |
| Weight of Tare & Dry Sample (g): | 386.90 | 398.50 | 376.17 | 397.96 | 375.76 |
| Weight of Tare (g): | 82.25 | 98.85 | 85.12 | 109.62 | 83.04 |
| Weight of Water (g): | 8.27 | 11.90 | 16.97 | 23.34 | 29.74 |
| Weight of Dry Sample (g): | 304.65 | 299.65 | 291.05 | 288.34 | 292.72 |

| | | | | | |
|---|---|---|---|---|---|
| Wet Density ($g/cm^3$): | 2.16 | 2.22 | 2.35 | 2.35 | 2.26 |
| Wet Density (pcf): | 134.7 | 138.7 | 146.6 | 146.8 | 141.2 |
| **Moisture Content (%):** | **2.7** | **4.0** | **5.8** | **8.1** | **10.2** |
| **Dry Density (pcf):** | **131.1** | **133.4** | **138.5** | **135.8** | **128.2** |

## Zero Air Voids

| | | | |
|---|---|---|---|
| **Moisture Content (%):** | 5.0 | 9.1 | 13.2 |
| **Dry Unit Weight (pcf):** | 148.4 | 135.3 | 124.3 |

*Tested By* *MF* *Date* *8/20/15* *Checked By* *KC* *Date* 8/21/15



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# SIEVE AND HYDROMETER ANALYSIS

ASTM D 422-63 (2007)

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| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 4 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 4 |
| Lab ID: | 2015-437-001-004 | Soil Color: | Brown |

| | SIEVE ANALYSIS | | | HYDROMETER | |
|---|---|---|---|---|---|
| USCS | cobbles | gravel | sand | silt and clay fraction | |
| USDA | cobbles | gravel | sand | silt | clay |

**USCS Summary**

| Sieve Sizes (mm) | | Percentage |
|---|---|---|
| Greater Than #4 | *Gravel* | 1.40 |
| #4 To #200 | *Sand* | 20.66 |
| Finer Than #200 | *Silt & Clay* | 77.94 |

**USCS Symbol:**

***CL, TESTED***

**USCS Classification:**

***LEAN CLAY WITH SAND***



DCN: CT-S3A DATE: 3/18/13 REVISION: 11

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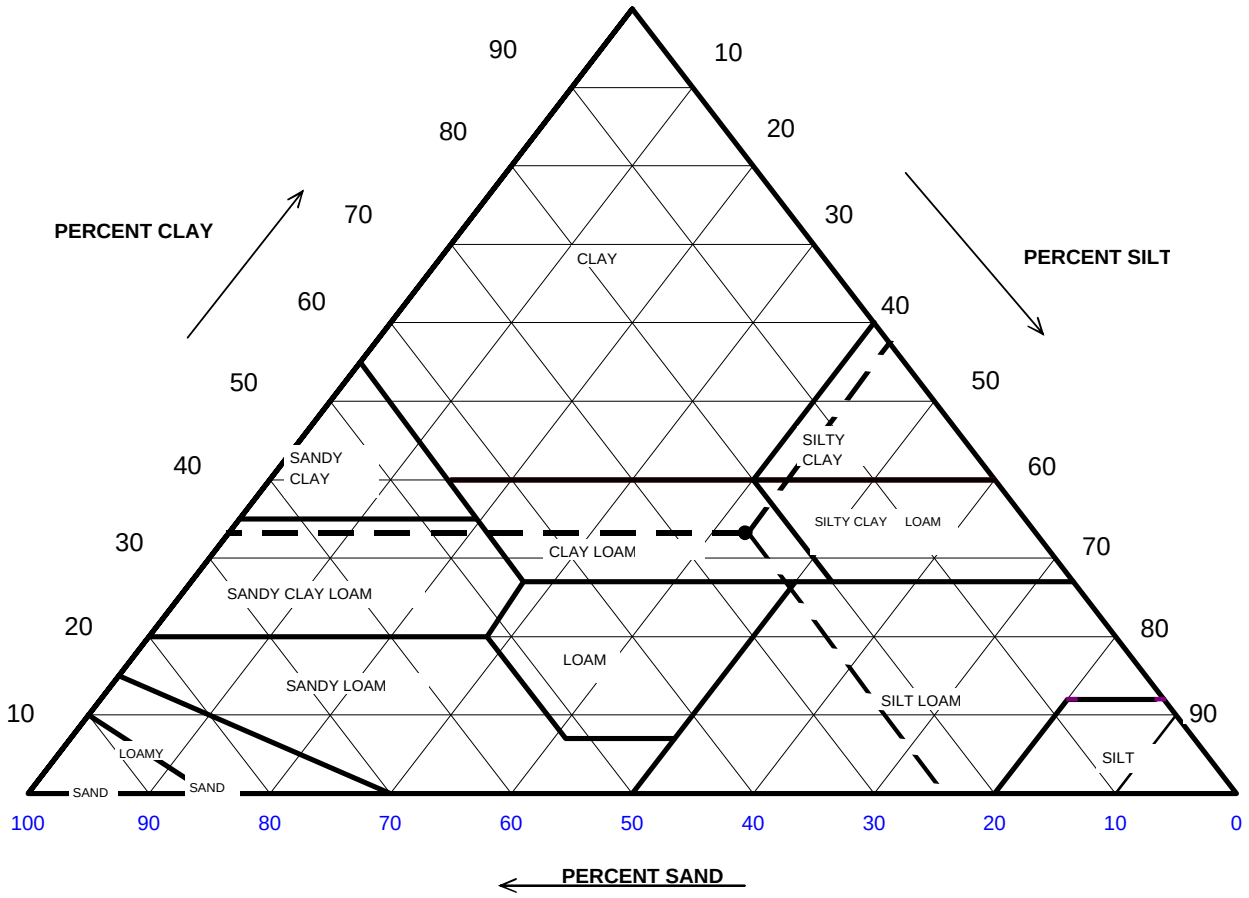
# USDA CLASSIFICATION CHART

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 4 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 4 |
| Lab ID: | 2015-437-001-004 | Soil Color: | Brown |




| Particle Size (mm) | Percent Finer (%) | USDA SUMMARY | Actual Percentage (%) | Corrected % of Minus 2.0 mm material for USDA Classificat. (%) |
|---|---|---|---|---|
| | | *Gravel* | 2.22 | **0.00** |
| 2 | 97.78 | *Sand* | 23.52 | **24.05** |
| 0.05 | 74.26 | *Silt* | 41.82 | **42.77** |
| 0.002 | 32.44 | *Clay* | 32.44 | **33.18** |

**USDA Classification:** ***CLAY LOAM***



DCN: CT-S3A DATE: 3/18/13 REVISION: 11

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# WASH SIEVE ANALYSIS

ASTM D 422-63 (2007)

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 4 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 4 |
| Lab ID: | 2015-437-001-004 | Soil Color: | Brown |

| Moisture Content of Passing 3/4" Materia | | Water Content of Retained 3/4" Material | |
|---|---|---|---|
| Tare No. | 20 | Tare No. | NA |
| Weight of Tare & Wet Sample (g) | 1156.70 | Weight of Tare & Wet Sample (g) | NA |
| Weight of Tare & Dry Sample (g) | 1116.60 | Weight of Tare & Dry Sample (g) | NA |
| Weight of Tare (g) | 205.06 | Weight of Tare (g) | NA |
| Weight of Water (g) | 40.10 | Weight of Water (g) | NA |
| Weight of Dry Sample (g) | 911.54 | Weight of Dry Sample (g) | NA |
| **Moisture Content (%)** | **4.4** | **Moisture Content (%)** | **NA** |

| | | | |
|---|---|---|---|
| Wet Weight of -3/4" Sample (g) | NA | Weight of the Dry Sample (g) | 911.54 |
| Dry Weight of -3/4" Sample (g) | 201.07 | Weight of - #200 Material (g) | 710.47 |
| Wet Weight of +3/4" Sample (g) | NA | Weight of + #200 Material (g) | 201.07 |
| Dry Weight of +3/4" Sample (g) | 0.00 | | |
| Total Dry Weight of Sample (g) | NA | | |

| Sieve Size | Sieve Opening | Weight of Soil Retained | Percent Retained | Accumulated Percent Retained | | Percent Finer | Accumulated Percent Finer |
|---|---|---|---|---|---|---|---|
| | (mm) | (g) | (%) | (%) | | (%) | (%) |
| 12" | 300 | 0.00 | 0.00 | 0.00 | | 100.00 | **100.00** |
| 6" | 150 | 0.00 | 0.00 | 0.00 | | 100.00 | **100.00** |
| 3" | 75 | 0.00 | 0.00 | 0.00 | | 100.00 | **100.00** |
| 2" | 50 | 0.00 | 0.00 | 0.00 | | 100.00 | **100.00** |
| 1 1/2" | 37.5 | 0.00 | 0.00 | 0.00 | | 100.00 | **100.00** |
| 1" | 25.0 | 0.00 | 0.00 | 0.00 | | 100.00 | **100.00** |
| 3/4" | 19.0 | 0.00 | 0.00 | 0.00 | | 100.00 | **100.00** |
| 1/2" | 12.5 | 6.83 | 0.75 | 0.75 | | 99.25 | **99.25** |
| 3/8" | 9.50 | 0.00 | 0.00 | 0.75 | | 99.25 | **99.25** |
| #4 | 4.75 | 5.95 | 0.65 | 1.40 | | 98.60 | **98.60** |
| #10 | 2.00 | 7.49 | 0.82 | 2.22 | | 97.78 | **97.78** |
| #20 | 0.85 | 6.49 | 0.71 | 2.94 | | 97.06 | **97.06** |
| #40 | 0.425 | 14.65 | 1.61 | 4.54 | | 95.46 | **95.46** |
| #60 | 0.250 | 36.98 | 4.06 | 8.60 | | 91.40 | **91.40** |
| #140 | 0.106 | 85.66 | 9.40 | 18.00 | | 82.00 | **82.00** |
| #200 | 0.075 | 37.02 | 4.06 | 22.06 | | 77.94 | **77.94** |
| Pan | - | 710.47 | 77.94 | 100.00 | | - | **-** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Tested By | RAL | Date | 8/19/15 | Checked By | KC | Date | 8/22/15 |



DCN: CT-S3A DATE: 3/18/13 REVISION: 11

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# HYDROMETER ANALYSIS

ASTM D 422-63 (2007)

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 4 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 4 |
| Lab ID: | 2015-437-001-004 | Soil Color: | Brown |

| Elapsed Time | | R Measured | Temp. | Composite Correction | R Corrected | N | K Factor | Diameter | N' |
|---|---|---|---|---|---|---|---|---|---|
| (min) | | | (°C) | | | ( % ) | | ( mm ) | ( % ) |
| 0 | | NA | NA | NA | NA | NA | NA | NA | NA |
| 2 | | 46.5 | 24.1 | 5.55 | 40.9 | 88.0 | 0.01281 | 0.0267 | **68.6** |
| 5 | | 43.0 | 24.1 | 5.55 | 37.4 | 80.4 | 0.01281 | 0.0174 | **62.7** |
| 15 | | 38.5 | 24.1 | 5.55 | 32.9 | 70.8 | 0.01281 | 0.0104 | **55.2** |
| 30 | | 35.5 | 24.1 | 5.55 | 29.9 | 64.3 | 0.01281 | 0.0076 | **50.1** |
| 60 | | 32.0 | 23.9 | 5.62 | 26.4 | 56.7 | 0.01284 | 0.0055 | **44.2** |
| 250 | | 27.0 | 24 | 5.59 | 21.4 | 46.0 | 0.01282 | 0.0028 | **35.9** |
| 1440 | | 22.0 | 23.7 | 5.69 | 16.3 | 35.0 | 0.01287 | 0.0012 | **27.3** |

| **Soil Specimen Data** | | **Other Corrections** | | |
|---|---|---|---|---|
| Tare No. | 637 | | | |
| Weight of Tare & Dry Material (g) | 148.06 | a - Factor | 0.99 | |
| Weight of Tare (g) | 96.97 | | | |
| Weight of Deflocculant (g) | 5.0 | Percent Finer than # 200 | 77.94 | |
| Weight of Dry Material (g) | 46.1 | | | |
| | | Specific Gravity | 2.7 | Assumed |

***Note:*** *Hydrometer test is performed on - # 200 sieve material.*

Tested By TO Date 8/20/15 Checked By KC Date 8/22/15



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# ATTERBERG LIMITS

ASTM D 4318-10

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 4 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 4 |
| Lab ID: | 2015-437-001-004 | Soil Description: | BROWN LEAN CLAY |

***Note: The USCS symbol used with this test refers only to the minus No. 40 sieve material. See the "Sieve and Hydrometer Analysis" graph page for the complete material description .***

( Minus No. 40 sieve material, Airdried)

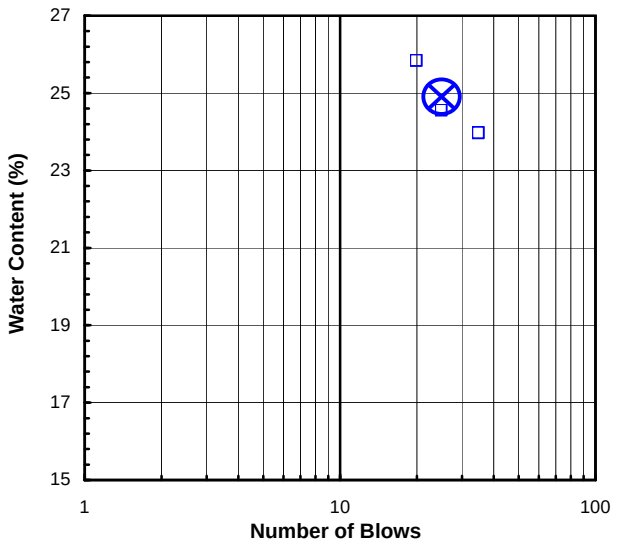
| **Liquid Limit Test** | **1** | **2** | **3** | |
|---|---|---|---|---|
| Tare Number: | 115 | 110 | 2234 | **MULTIPOINT** |
| Wt. of Tare & Wet Sample (g): | 49.22 | 49.48 | 46.11 | |
| Wt. of Tare & Dry Sample (g): | 43.31 | 43.60 | 39.95 | |
| Weight of Tare (g): | 18.64 | 19.64 | 16.10 | |
| Weight of Water (g): | 5.9 | 5.9 | 6.2 | |
| Weight of Dry Sample (g): | 24.7 | 24.0 | 23.9 | |
| **Moisture Content (%):** | **24.0** | **24.5** | **25.8** | |
| **Number of Blows:** | **35** | **25** | **20** | |

| **Plastic Limit Test** | **1** | **2** | **Range** |
|---|---|---|---|
| Tare Number: | 315 | 5 | |
| Wt. of Tare & Wet Sample (g): | 24.95 | 23.36 | |
| Wt. of Tare & Dry Sample (g): | 24.40 | 22.83 | |
| Weight of Tare (g): | 18.59 | 17.14 | |
| Weight of Water (g): | 0.6 | 0.5 | |
| Weight of Dry Sample (g): | 5.8 | 5.7 | |
| **Moisture Content (%):** | **9.5** | **9.3** | **0.2** |

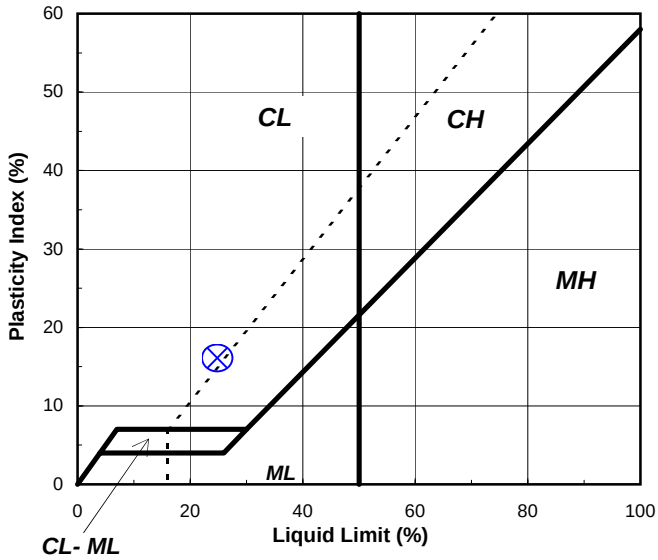
*Note: The acceptable range of the two Moisture contents is ± 2.6*

| **Test Results** | |
|---|---|
| **Liquid Limit (%):** | **25** |
| **Plastic Limit (%):** | **9** |
| **Plasticity Index (%):** | **16** |
| **USCS Symbol:** | **CL** |

**Flow Curve**




**Plasticity Chart**




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Tested By* | *TO* | *Date* | *8/21/15* | *Checked By* | *KC* | *Date* | 8/22/15 |



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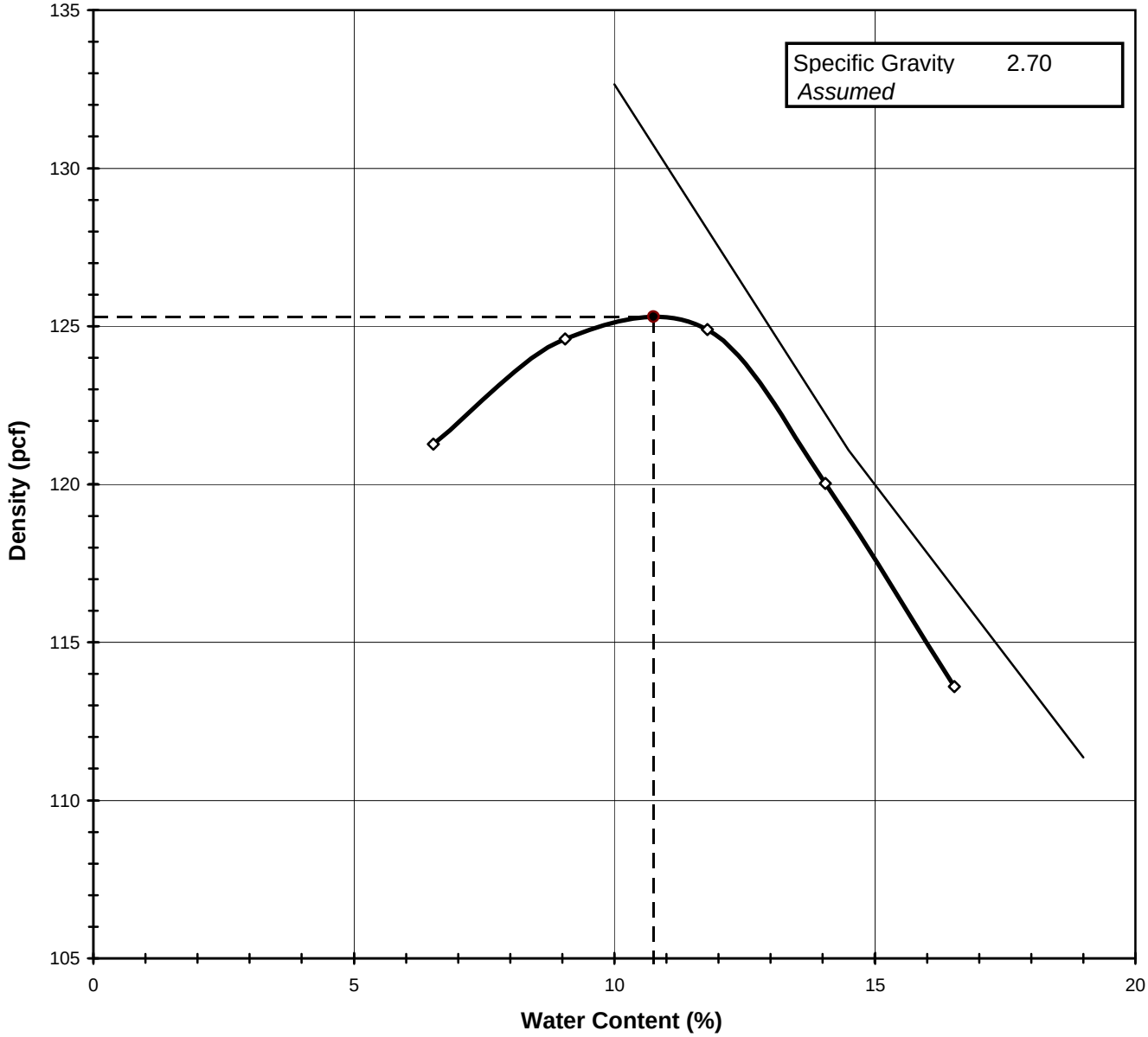
# MOISTURE DENSITY RELATIONSHIP

*ASTM D1557-12*

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 4 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 4 |
| Lab ID: | 2015-437-001-004 | Test Method | **MODIFIED** |

Visual Description: Brown Clay

**Optimum Water Content** **10.8**
**Maximum Dry Density** **125.3**




*Tested By* *MF* *Date* *8/20/15* *Checked By* *KC* *Date* 8/21/15



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# MOISTURE - DENSITY RELATIONSHIP

*ASTM D1557-12*

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 4 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 4 |
| Lab ID: | 2015-437-001-004 | | |

Visual Description: Brown Clay

| | |
|---|---|
| Total Weight of the Sample (g): | NA |
| As Received Water Content (%): | NA |
| *Assumed* Specific Gravity: | 2.70 |
| Percent Retained on 3/4": | NA |
| Percent Retained on 3/8": | NA |
| Percent Retained on #4: | NA |
| Oversize Material: | Not included |
| Procedure Used: | B |

| | | |
|---|---|---|
| Test Type: | | **MODIFIED** |
| Rammer Weight (lb): | | 10.0 |
| Rammer Drop (in): | | 18 |
| Rammer Type: | | MECHANICAL |
| Machine ID: | G | 774 |
| Mold ID: | G | 1499 |
| Mold diameter: | | 4" |
| Weight of the Mold (g): | | 4389 |
| Volume of the Mold ($cm^3$): | | 940 |

## Mold / Specimen

| **Point No.** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| Weight of Mold & Wet Sample (g): | 6335 | 6436 | 6492 | 6451 | 6383 |
| Weight of Mold (g): | 4389 | 4389 | 4389 | 4389 | 4389 |
| Weight of Wet Sample (g): | 1946 | 2047 | 2103 | 2062 | 1994 |
| Mold Volume ($cm^3$): | 940 | 940 | 940 | 940 | 940 |

## Moisture Content / Density

| | | | | | |
|---|---|---|---|---|---|
| Tare Number: | 903 | 598 | 596 | 891 | 569 |
| Weight of Tare & Wet Sample (g): | 437.80 | 404.20 | 410.60 | 415.90 | 408.10 |
| Weight of Tare & Dry Sample (g): | 417.70 | 377.67 | 376.30 | 378.31 | 362.00 |
| Weight of Tare (g): | 109.67 | 84.62 | 85.24 | 110.72 | 83.06 |
| Weight of Water (g): | 20.10 | 26.53 | 34.30 | 37.59 | 46.10 |
| Weight of Dry Sample (g): | 308.03 | 293.05 | 291.06 | 267.59 | 278.94 |

| | | | | | |
|---|---|---|---|---|---|
| Wet Density ($g/cm^3$): | 2.07 | 2.18 | 2.24 | 2.19 | 2.12 |
| Wet Density (pcf): | 129.2 | 135.9 | 139.6 | 136.9 | 132.4 |
| **Moisture Content (%):** | **6.5** | **9.1** | **11.8** | **14.0** | **16.5** |
| **Dry Density (pcf):** | **121.3** | **124.6** | **124.9** | **120.0** | **113.6** |

## Zero Air Voids

| | | | |
|---|---|---|---|
| **Moisture Content (%):** | 10.0 | 14.5 | 19.0 |
| **Dry Unit Weight (pcf):** | 132.7 | 121.1 | 111.4 |

*Tested By* *MF* *Date* *8/20/15* *Checked By* *KC* *Date* 8/21/15



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# SIEVE AND HYDROMETER ANALYSIS

ASTM D 422-63 (2007)/AASHTO T88-00 SOP-S3

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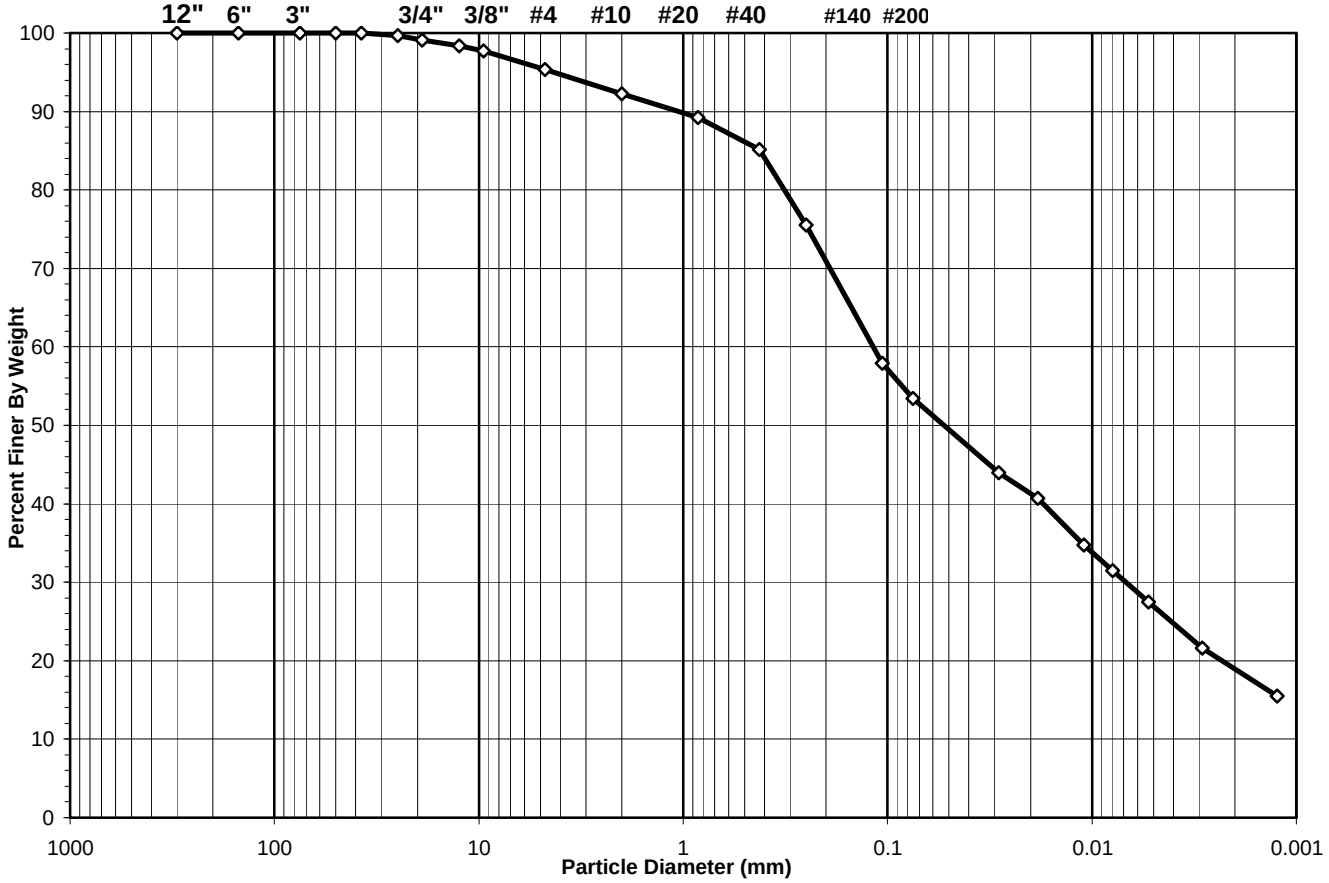
| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 5 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 5 |
| Lab ID: | 2015-437-001-005 | Soil Color: | Gray |

| | SIEVE ANALYSIS | | | HYDROMETER | |
|---|---|---|---|---|---|
| USCS | cobbles | gravel | sand | silt and clay fraction | |
| USDA | cobbles | gravel | sand | silt | clay |




**USCS Summary**

| Sieve Sizes (mm) | | Percentage |
|---|---|---|
| Greater Than #4 | *Gravel* | 4.64 |
| #4 To #200 | *Sand* | 41.96 |
| Finer Than #200 | *Silt & Clay* | 53.40 |

**USCS Symbol:**
***CL, TESTED***

**USCS Classification:**
***SANDY LEAN CLAY***





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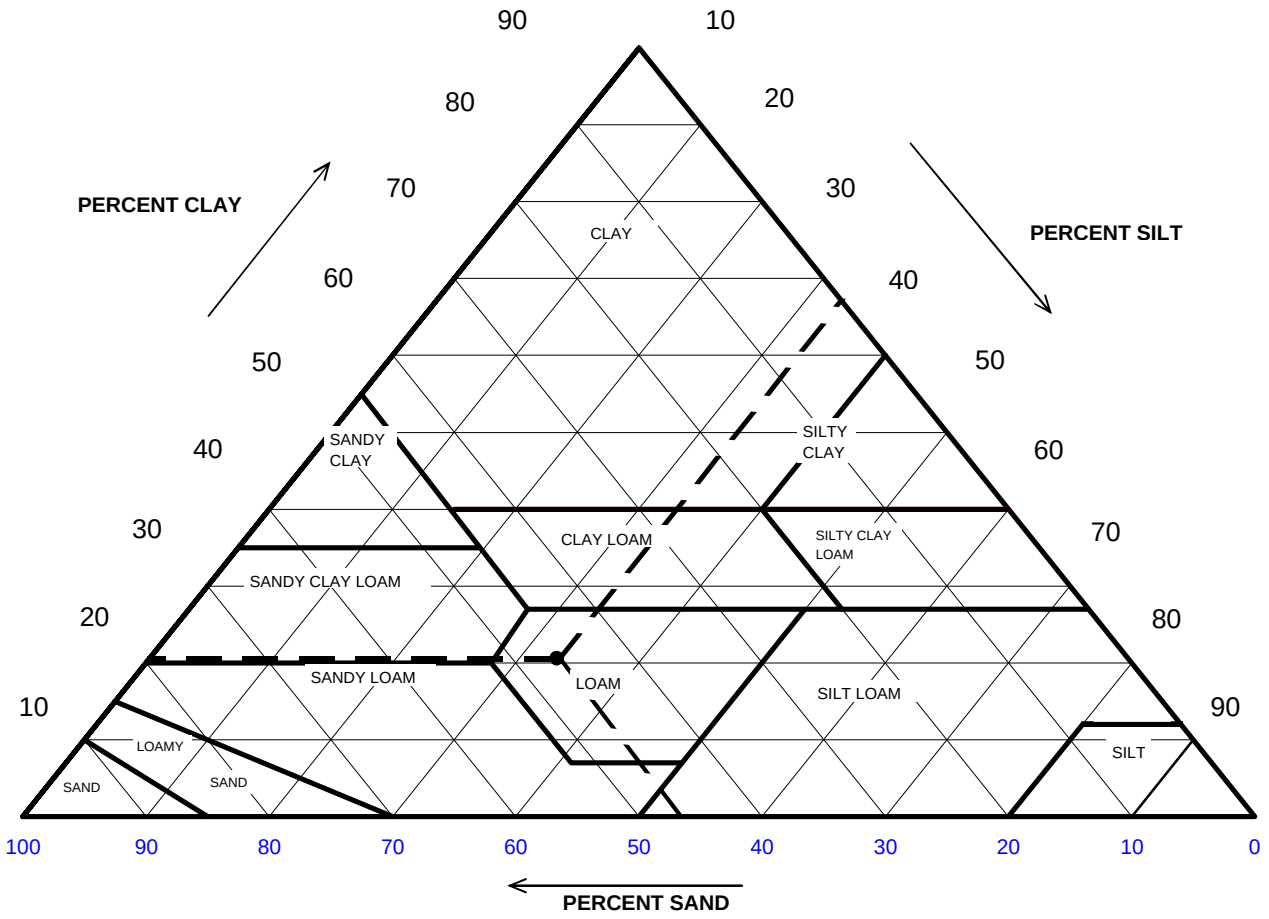
# USDA CLASSIFICATION CHART

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 5 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 5 |
| Lab ID: | 2015-437-001-005 | Soil Color: | Gray |




| Particle Size (mm) | Percent Finer | USDA SUMMARY | Actual Percentage | Corrected % of Minus 2.0 mm material for USDA Classificat. |
|---|---|---|---|---|
| | | *Gravel* | 7.79 | **0.00** |
| 2 | 92.21 | *Sand* | 42.75 | **46.36** |
| 0.05 | 49.46 | *Silt* | 30.51 | **33.09** |
| 0.002 | 18.95 | *Clay* | 18.95 | **20.55** |

**USDA Classification**: ***LOAM***





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# WASH SIEVE ANALYSIS

ASTM D 422-63 (2007)/AASHTO T88-00 SOP-S3

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| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 5 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 5 |
| Lab ID: | 2015-437-001-005 | Soil Color: | Gray |

| Moisture Content of Passing 3/4" Material | | Water Content of Retained 3/4" Material | |
|---|---|---|---|
| Tare No.: | 9 | Tare No.: | 542 |
| Wt. of Tare & Wet Sample (g): | 1141.20 | Weight of Tare & Wet Sample (g): | 273.09 |
| Wt. of Tare & Dry Sample (g): | 1126.70 | Weight of Tare & Dry Sample (g): | 272.56 |
| Weight of Tare (g): | 201.69 | Weight of Tare (g): | 82.14 |
| Weight of Water (g): | 14.50 | Weight of Water (g): | 0.53 |
| Weight of Dry Soil (g): | 925.01 | Weight of Dry Soil (g): | 190.42 |
| **Moisture Content (%):** | **1.6** | **Moisture Content (%):** | **0.3** |

| | | | |
|---|---|---|---|
| Wet Weight of -3/4" Sample (g): | 22294 | Weight of the Dry Sample (g): | 925.01 |
| Dry Weight of - 3/4" Sample (g): | 21949.9 | Weight of Minus #200 Material (g): | 498.27 |
| Wet Weight of +3/4" Sample (g): | 190.95 | Weight of Plus #200 Material (g): | 426.74 |
| Dry Weight of + 3/4" Sample (g): | 190.42 | | |
| Total Dry Weight of Sample (g): | 22140.3 | **J - Factor (Percent Finer than 3/4"):** | **0.9914** |

| Sieve Size | Sieve Opening (mm) | Weight of Soil Retained (g) | | Percent Retained (%) | Accumulated Percent Retained (%) | Percent Finer (%) | **Accumulated Percent Finer (%)** |
|---|---|---|---|---|---|---|---|
| 12" | 300 | 0.00 | | 0.00 | 0.00 | 100.00 | **100.00** |
| 6" | 150 | 0.00 | | 0.00 | 0.00 | 100.00 | **100.00** |
| 3" | 75 | 0.00 | | 0.00 | 0.00 | 100.00 | **100.00** |
| 2" | 50 | 0.00 | ( * ) | 0.00 | 0.00 | 100.00 | **100.00** |
| 1 1/2" | 37.5 | 0.00 | | 0.00 | 0.00 | 100.00 | **100.00** |
| 1" | 25.0 | 74.68 | | 0.34 | 0.34 | 99.66 | **99.66** |
| 3/4" | 19.0 | 116.27 | | 0.52 | 0.86 | 99.14 | **99.14** |
| 1/2" | 12.5 | 7.31 | | 0.79 | 0.79 | 99.21 | **98.36** |
| 3/8" | 9.50 | 5.95 | | 0.64 | 1.43 | 98.57 | **97.72** |
| #4 | 4.75 | 22.01 | | 2.38 | 3.81 | 96.19 | **95.36** |
| #10 | 2.00 | 29.37 | | 3.18 | 6.99 | 93.01 | **92.21** |
| #20 | 0.85 | 27.88 | ( ** ) | 3.01 | 10.00 | 90.00 | **89.22** |
| #40 | 0.425 | 37.84 | | 4.09 | 14.09 | 85.91 | **85.17** |
| #60 | 0.250 | 89.93 | | 9.72 | 23.81 | 76.19 | **75.53** |
| #140 | 0.106 | 164.01 | | 17.73 | 41.55 | 58.45 | **57.95** |
| #200 | 0.075 | 42.44 | | 4.59 | 46.13 | 53.87 | **53.40** |
| Pan | - | 498.27 | | 53.87 | 100.00 | - | **-** |

***Notes :*** *( * ) The + 3/4" sieve analysis is based on the Total Dry Weight of the Sample*
*( ** ) The - 3/4" sieve analysis is based on the Weight of the Dry Sample*

| Tested By | RAL | Date | 8/19/15 | Checked By | KC | Date | 8/22/15 |
|---|---|---|---|---|---|---|---|



DCN: CT-S3B DATE: 2/09/10 REVISION: 0 *E:\PROJECTS\AECOM\2015-437-001 Dow Salzburg\[2015-437-001-005 Grain JSieveHyd.xls]Print Sheet*

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# HYDROMETER ANALYSIS

ASTM D 422-63 (2007)/AASHTO T88-00 SOP-S3

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| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 5 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 5 |
| Lab ID: | 2015-437-001-005 | Soil Color: | Gray |

| Elapsed Time | | R Measured | Temp. | Composite Correction | R Corrected | N | K Factor | Diameter | N' |
|---|---|---|---|---|---|---|---|---|---|
| (min) | | | (°C) | | | (%) | | (mm) | (%) |
| 0 | | NA | NA | NA | NA | NA | NA | NA | NA |
| 2 | | 39.0 | 24.1 | 5.55 | 33.4 | 82.4 | 0.01281 | 0.0285 | **44.0** |
| 5 | | 36.5 | 24.1 | 5.55 | 30.9 | 76.2 | 0.01281 | 0.0184 | **40.7** |
| 15 | | 32.0 | 24.1 | 5.55 | 26.4 | 65.1 | 0.01281 | 0.0110 | **34.8** |
| 30 | | 29.5 | 24.1 | 5.55 | 23.9 | 59.0 | 0.01281 | 0.0079 | **31.5** |
| 70 | | 26.5 | 23.9 | 5.62 | 20.9 | 51.4 | 0.01284 | 0.0053 | **27.5** |
| 250 | | 22.0 | 24 | 5.59 | 16.4 | 40.4 | 0.01282 | 0.0029 | **21.6** |
| 1440 | | 17.5 | 23.7 | 5.69 | 11.8 | 29.1 | 0.01287 | 0.0012 | **15.5** |

| **Soil Specimen Data** | | **Other Corrections** | |
|---|---|---|---|
| Tare No.: | 503 | | |
| Wt. of Tare & Dry Material (g): | 138.91 | a - Factor: | 0.99 |
| Weight of Tare (g): | 93.71 | | |
| Weight of Deflocculant (g): | 5.0 | Percent Finer than # 200: | 53.40 |
| Weight of Dry Material (g): | 40.2 | | |
| | | Specific Gravity: | 2.7 Assumed |

***Note:*** *Hydrometer test is performed on - # 200 sieve material.*

| Tested By | TO | Date | 8/20/15 | Checked By | KC | Date | 8/22/15 |
|---|---|---|---|---|---|---|---|



DCN: CT-S3B DATE: 2/09/10 REVISION: 0 *E:\PROJECTS\AECOM\2015-437-001 Dow Salzburg\[2015-437-001-005 Grain JSieveHyd.xls]Print Sheet*

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# ATTERBERG LIMITS

ASTM D 4318-10

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 5 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 5 |
| Lab ID: | 2015-437-001-005 | Soil Description: | BROWN LEAN CLAY |

***Note: The USCS symbol used with this test refers only to the minus No. 40 sieve material. See the "Sieve and Hydrometer Analysis" graph page for the complete material description .***

( Minus No. 40 sieve material, Airdried)

| **Liquid Limit Test** | **1** | **2** | **3** | |
|---|---|---|---|---|
| Tare Number: | 190 | 211 | 193 | **MULTIPOINT** |
| Wt. of Tare & Wet Sample (g): | 38.46 | 39.29 | 38.52 | |
| Wt. of Tare & Dry Sample (g): | 35.13 | 35.86 | 35.32 | |
| Weight of Tare (g): | 18.08 | 18.15 | 18.00 | |
| Weight of Water (g): | 3.3 | 3.4 | 3.2 | |
| Weight of Dry Sample (g): | 17.1 | 17.7 | 17.3 | |
| **Moisture Content (%):** | **19.5** | **19.4** | **18.5** | |
| **Number of Blows:** | **19** | **24** | **30** | |

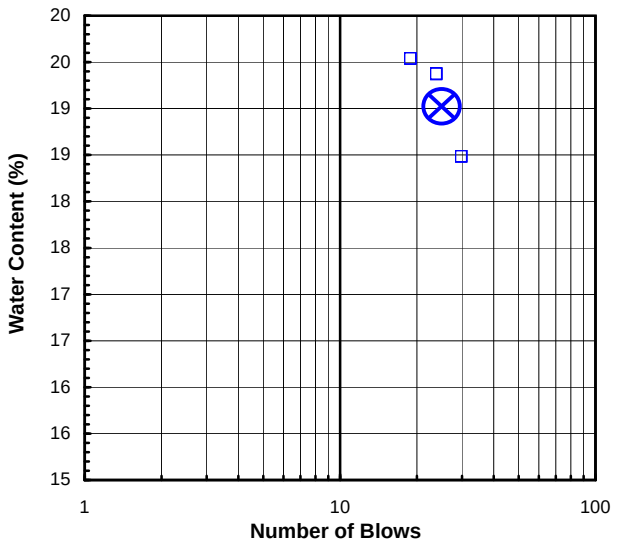
| **Plastic Limit Test** | **1** | **2** | **Range** |
|---|---|---|---|
| Tare Number: | 216 | 228 | |
| Wt. of Tare & Wet Sample (g): | 25.34 | 24.99 | |
| Wt. of Tare & Dry Sample (g): | 24.85 | 24.49 | |
| Weight of Tare (g): | 19.22 | 18.69 | |
| Weight of Water (g): | 0.5 | 0.5 | |
| Weight of Dry Sample (g): | 5.6 | 5.8 | |
| **Moisture Content (%):** | **8.7** | **8.6** | **0.1** |

*Note: The acceptable range of the two Moisture contents is ± 2.6*

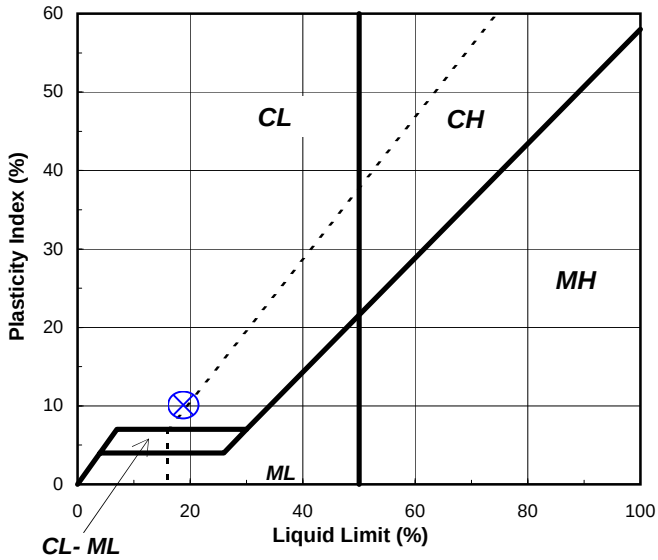
## Test Results

| | |
|---|---|
| **Liquid Limit (%):** | **19** |
| **Plastic Limit (%):** | **9** |
| **Plasticity Index (%):** | **10** |
| **USCS Symbol:** | **CL** |

**Flow Curve**




**Plasticity Chart**




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Tested By* | *RAL* | *Date* | *8/20/15* | *Checked By* | *KC* | *Date* | 8/22/15 |



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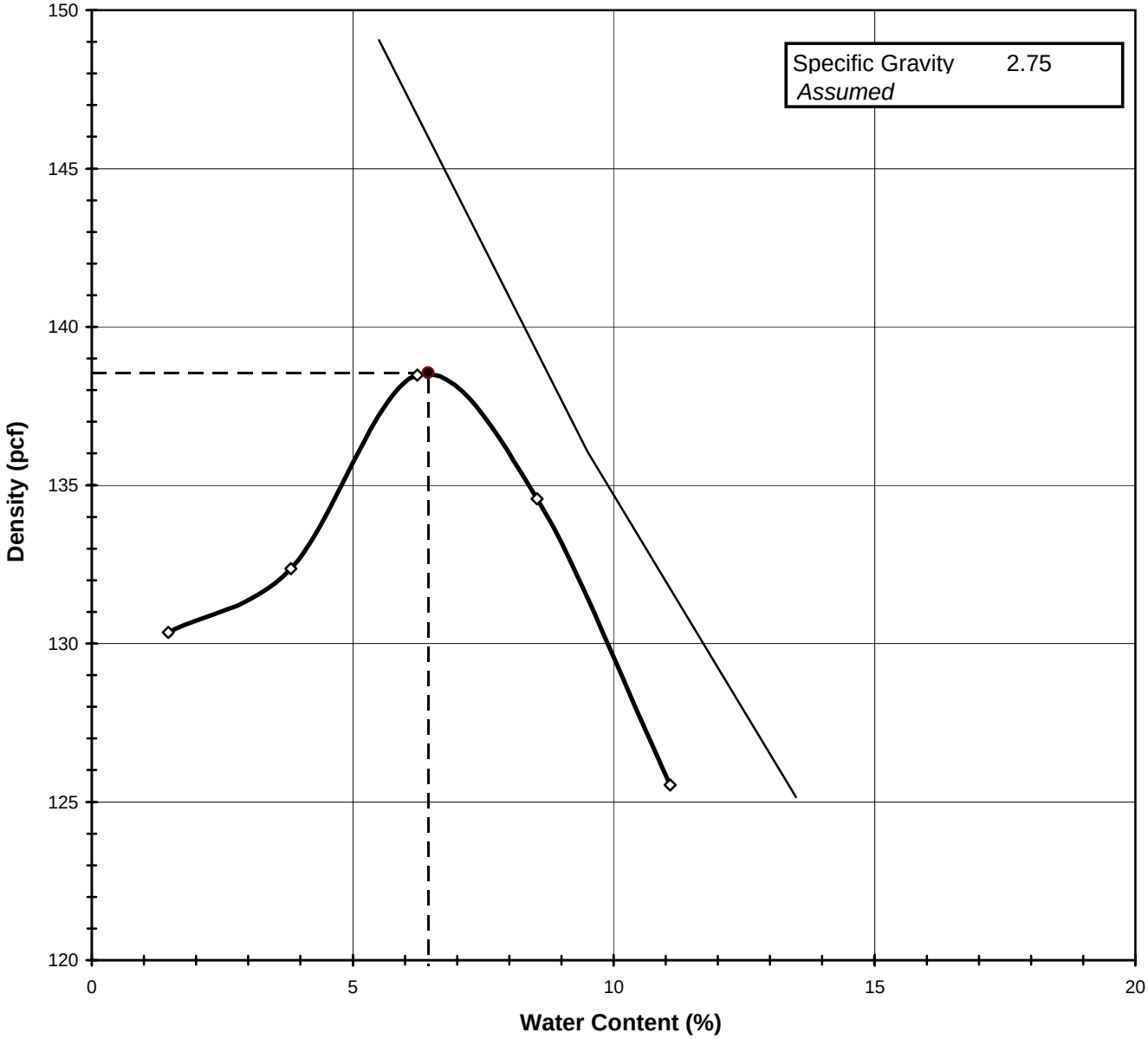
# MOISTURE DENSITY RELATIONSHIP

*ASTM D1557-12*

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 5 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 5 |
| Lab ID: | 2015-437-001-005 | Test Method | **MODIFIED** |

Visual Description: Gray Clay with small amount of Rock Fragments

| | |
|---|---|
| **Optimum Water Content** | **6.5** |
| **Maximum Dry Density** | **138.6** |




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Tested By* | *AMC* | *Date* | *8/20/15* | *Checked By* | *KC* | *Date* | 8/21/15 |



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# MOISTURE - DENSITY RELATIONSHIP

*ASTM D1557-12*

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 5 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 5 |
| Lab ID: | 2015-437-001-005 | | |

Visual Description: Gray Clay with small amount of Rock Fragments

| | |
|---|---|
| Total Weight of the Sample (g): | NA |
| As Received Water Content (%): | NA |
| *Assumed* Specific Gravity: | 2.75 |
| Percent Retained on 3/4": | NA |
| Percent Retained on 3/8": | NA |
| Percent Retained on #4: | NA |
| Oversize Material: | Not included |
| Procedure Used: | B |

| | | |
|---|---|---|
| Test Type: | | **MODIFIED** |
| Rammer Weight (lb): | | 10.0 |
| Rammer Drop (in): | | 18 |
| Rammer Type: | | MECHANICAL |
| Machine ID: | G | 774 |
| Mold ID: | G | 1192 |
| Mold diameter: | | 4" |
| Weight of the Mold (g): | | 4169 |
| Volume of the Mold ($cm^3$): | | 945 |

## Mold / Specimen

| **Point No.** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| Weight of Mold & Wet Sample (g): | 6172 | 6250 | 6397 | 6381 | 6281 |
| Weight of Mold (g): | 4169 | 4169 | 4169 | 4169 | 4169 |
| Weight of Wet Sample (g): | 2003 | 2081 | 2228 | 2212 | 2112 |
| Mold Volume ($cm^3$): | 945 | 945 | 945 | 945 | 945 |

## Moisture Content / Density

| | | | | | |
|---|---|---|---|---|---|
| Tare Number: | 914 | 579 | 590 | 1717 | 899 |
| Weight of Tare & Wet Sample (g): | 650.30 | 499.60 | 528.10 | 511.50 | 566.00 |
| Weight of Tare & Dry Sample (g): | 642.50 | 484.30 | 501.90 | 477.80 | 520.50 |
| Weight of Tare (g): | 110.30 | 83.07 | 81.90 | 83.10 | 110.10 |
| Weight of Water (g): | 7.80 | 15.30 | 26.20 | 33.70 | 45.50 |
| Weight of Dry Sample (g): | 532.20 | 401.23 | 420.00 | 394.70 | 410.40 |

| | | | | | |
|---|---|---|---|---|---|
| Wet Density ($g/cm^3$): | 2.12 | 2.20 | 2.36 | 2.34 | 2.23 |
| Wet Density (pcf): | 132.3 | 137.4 | 147.1 | 146.1 | 139.5 |
| **Moisture Content (%):** | **1.5** | **3.8** | **6.2** | **8.5** | **11.1** |
| **Dry Density (pcf):** | **130.4** | **132.4** | **138.5** | **134.6** | **125.5** |

## Zero Air Voids

| | | | |
|---|---|---|---|
| **Moisture Content (%):** | 5.5 | 9.5 | 13.5 |
| **Dry Unit Weight (pcf):** | 149.1 | 136.1 | 125.1 |

*Tested By* *AMC* *Date* *8/20/15* *Checked By* *KC* *Date* 8/21/15



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# SIEVE AND HYDROMETER ANALYSIS

ASTM D 422-63 (2007)/AASHTO T88-00 SOP-S3

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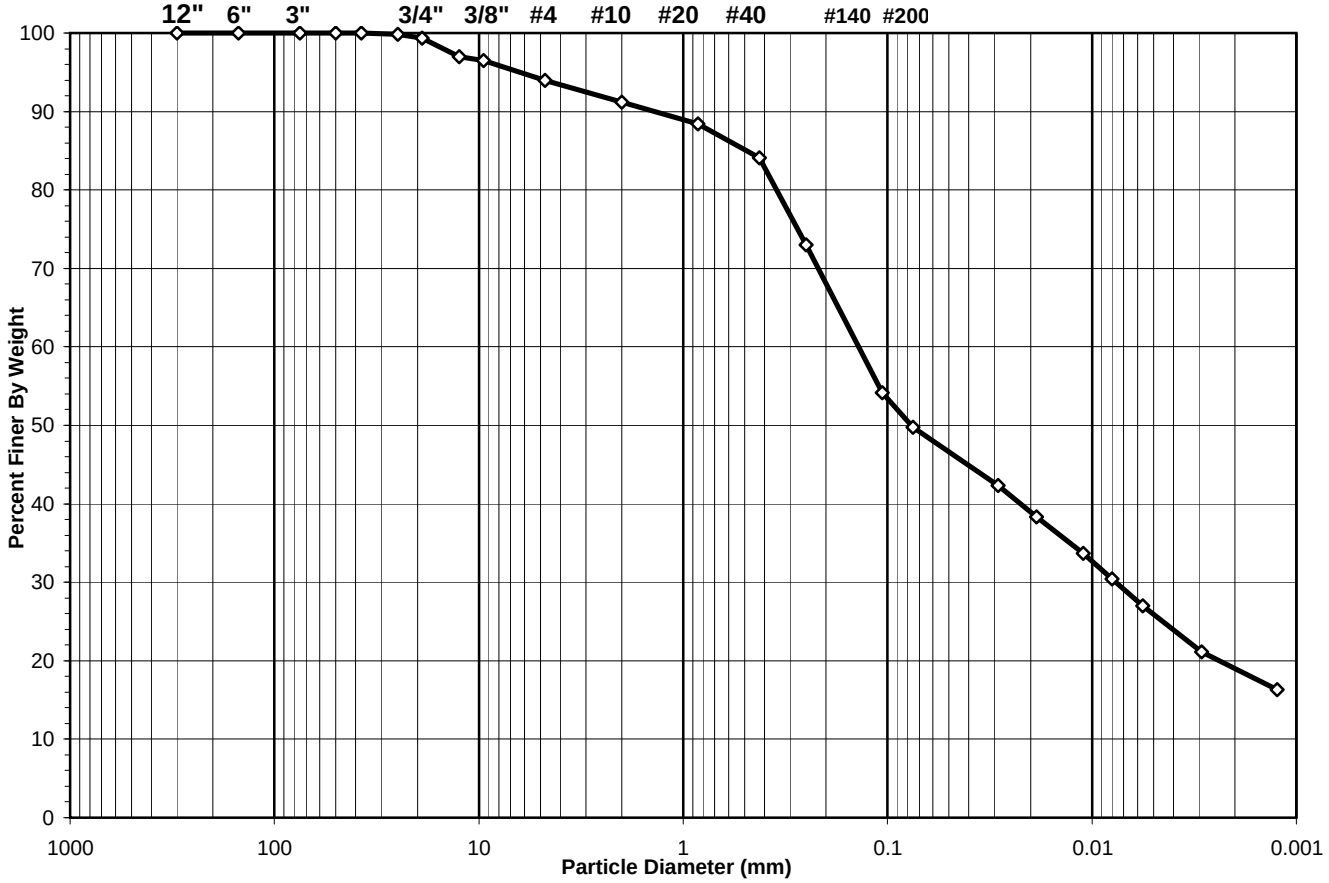
| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 6 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 6 |
| Lab ID: | 2015-437-001-006 | Soil Color: | Gray |

| | SIEVE ANALYSIS | | | HYDROMETER | |
|---|---|---|---|---|---|
| USCS | cobbles | gravel | sand | silt and clay fraction | |
| USDA | cobbles | gravel | sand | silt | clay |




**USCS Summary**

| Sieve Sizes (mm) | | Percentage |
|---|---|---|
| Greater Than #4 | *Gravel* | 6.03 |
| #4 To #200 | *Sand* | 44.18 |
| Finer Than #200 | *Silt & Clay* | 49.78 |

**USCS Symbol:**
***SC, TESTED***

**USCS Classification:**
***CLAYEY SAND***





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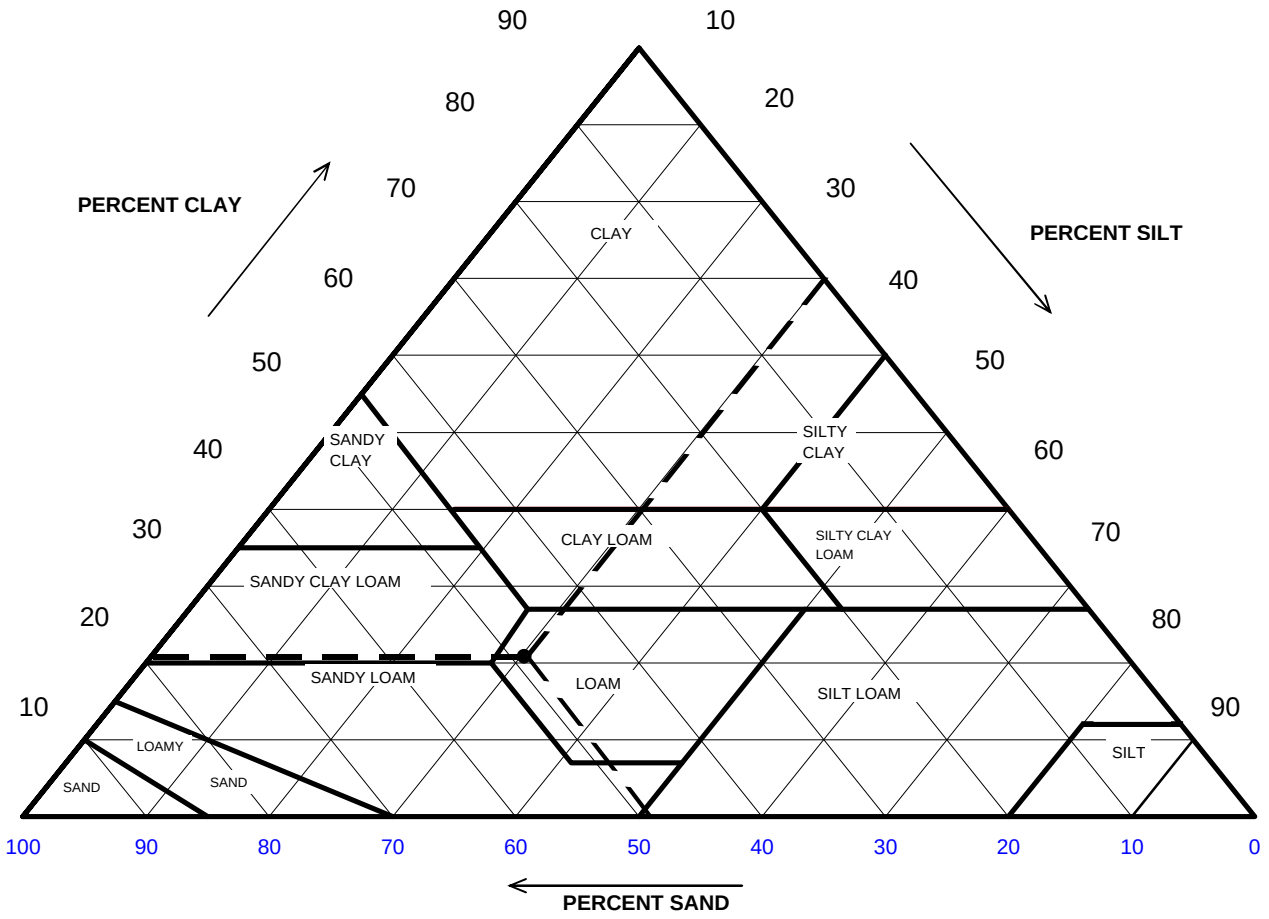
# USDA CLASSIFICATION CHART

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 6 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 6 |
| Lab ID: | 2015-437-001-006 | Soil Color: | Gray |




| Particle Size (mm) | Percent Finer | USDA SUMMARY | Actual Percentage | Corrected % of Minus 2.0 mm material for USDA Classificat. |
|---|---|---|---|---|
| | | *Gravel* | 8.81 | **0.00** |
| 2 | 91.19 | *Sand* | 44.57 | **48.87** |
| 0.05 | 46.63 | *Silt* | 27.62 | **30.29** |
| 0.002 | 19.01 | *Clay* | 19.01 | **20.84** |

**USDA Classification**: ***LOAM***





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# WASH SIEVE ANALYSIS

ASTM D 422-63 (2007)/AASHTO T88-00 SOP-S3

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| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 6 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 6 |
| Lab ID: | 2015-437-001-006 | Soil Color: | Gray |

| Moisture Content of Passing 3/4" Material | | Water Content of Retained 3/4" Material | |
|---|---|---|---|
| Tare No.: | 46 | Tare No.: | 2868 |
| Wt. of Tare & Wet Sample (g): | 1230.60 | Weight of Tare & Wet Sample (g): | 138.36 |
| Wt. of Tare & Dry Sample (g): | 1218.30 | Weight of Tare & Dry Sample (g): | 138.12 |
| Weight of Tare (g): | 204.55 | Weight of Tare (g): | 6.70 |
| Weight of Water (g): | 12.30 | Weight of Water (g): | 0.24 |
| Weight of Dry Soil (g): | 1013.75 | Weight of Dry Soil (g): | 131.42 |
| **Moisture Content (%):** | **1.2** | **Moisture Content (%):** | **0.2** |

| | | | |
|---|---|---|---|
| Wet Weight of -3/4" Sample (g): | 21251 | Weight of the Dry Sample (g): | 1013.75 |
| Dry Weight of - 3/4" Sample (g): | 20996.2 | Weight of Minus #200 Material (g): | 507.85 |
| Wet Weight of +3/4" Sample (g): | 131.66 | Weight of Plus #200 Material (g): | 505.90 |
| Dry Weight of + 3/4" Sample (g): | 131.42 | | |
| Total Dry Weight of Sample (g): | 21127.7 | **J - Factor (Percent Finer than 3/4"):** | **0.9938** |

| Sieve Size | Sieve Opening (mm) | Weight of Soil Retained (g) | | Percent Retained (%) | Accumulated Percent Retained (%) | Percent Finer (%) | **Accumulated Percent Finer (%)** |
|---|---|---|---|---|---|---|---|
| 12" | 300 | 0.00 | | 0.00 | 0.00 | 100.00 | **100.00** |
| 6" | 150 | 0.00 | | 0.00 | 0.00 | 100.00 | **100.00** |
| 3" | 75 | 0.00 | | 0.00 | 0.00 | 100.00 | **100.00** |
| 2" | 50 | 0.00 | ( * ) | 0.00 | 0.00 | 100.00 | **100.00** |
| 1 1/2" | 37.5 | 0.00 | | 0.00 | 0.00 | 100.00 | **100.00** |
| 1" | 25.0 | 34.65 | | 0.16 | 0.16 | 99.84 | **99.84** |
| 3/4" | 19.0 | 97.01 | | 0.46 | 0.62 | 99.38 | **99.38** |
| 1/2" | 12.5 | 24.42 | | 2.41 | 2.41 | 97.59 | **96.98** |
| 3/8" | 9.50 | 5.37 | | 0.53 | 2.94 | 97.06 | **96.46** |
| #4 | 4.75 | 25.41 | | 2.51 | 5.45 | 94.55 | **93.97** |
| #10 | 2.00 | 28.29 | | 2.79 | 8.24 | 91.76 | **91.19** |
| #20 | 0.85 | 28.06 | ( ** ) | 2.77 | 11.00 | 89.00 | **88.44** |
| #40 | 0.425 | 44.48 | | 4.39 | 15.39 | 84.61 | **84.08** |
| #60 | 0.250 | 112.67 | | 11.11 | 26.51 | 73.49 | **73.04** |
| #140 | 0.106 | 192.19 | | 18.96 | 45.46 | 54.54 | **54.20** |
| #200 | 0.075 | 45.01 | | 4.44 | 49.90 | 50.10 | **49.78** |
| Pan | - | 507.85 | | 50.10 | 100.00 | - | **-** |

***Notes :*** *( * ) The + 3/4" sieve analysis is based on the Total Dry Weight of the Sample*
*( ** ) The - 3/4" sieve analysis is based on the Weight of the Dry Sample*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Tested By | RAL | Date | 8/19/15 | Checked By | KC | Date | 8/22/15 |



DCN: CT-S3B DATE: 2/09/10 REVISION: 0 *E:\2015\PROJECTS\AECOM\2015-437-001 Dow Salzburg\[2015-437-001-006 Grain JSieveHyd.xls]Print Sheet*

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# HYDROMETER ANALYSIS

ASTM D 422-63 (2007)/AASHTO T88-00 SOP-S3

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| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 6 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 6 |
| Lab ID: | 2015-437-001-006 | Soil Color: | Gray |

| Elapsed Time | | R Measured | Temp. | Composite Correction | R Corrected | N | K Factor | Diameter | N' |
|---|---|---|---|---|---|---|---|---|---|
| (min) | | | (°C) | | | (%) | | (mm) | (%) |
| 0 | | NA | NA | NA | NA | NA | NA | NA | NA |
| 2 | | 37.5 | 24.1 | 5.55 | 31.9 | 85.0 | 0.01281 | 0.0289 | **42.3** |
| 5 | | 34.5 | 24.1 | 5.55 | 28.9 | 77.1 | 0.01281 | 0.0187 | **38.4** |
| 15 | | 31.0 | 24.1 | 5.55 | 25.4 | 67.7 | 0.01281 | 0.0111 | **33.7** |
| 30 | | 28.5 | 24.1 | 5.55 | 22.9 | 61.1 | 0.01281 | 0.0080 | **30.4** |
| 62 | | 26.0 | 23.9 | 5.62 | 20.4 | 54.3 | 0.01284 | 0.0057 | **27.0** |
| 250 | | 21.5 | 24 | 5.59 | 15.9 | 42.4 | 0.01282 | 0.0029 | **21.1** |
| 1440 | | 18.0 | 23.7 | 5.69 | 12.3 | 32.8 | 0.01287 | 0.0012 | **16.3** |

| **Soil Specimen Data** | | **Other Corrections** | |
|---|---|---|---|
| Tare No.: | 1463 | | |
| Wt. of Tare & Dry Material (g): | 144.34 | a - Factor: | 0.99 |
| Weight of Tare (g): | 102.15 | | |
| Weight of Deflocculant (g): | 5.0 | Percent Finer than # 200: | 49.78 |
| Weight of Dry Material (g): | 37.19 | | |
| | | Specific Gravity: | 2.7 Assumed |

***Note:*** *Hydrometer test is performed on - # 200 sieve material.*

| Tested By | TO | Date | 8/20/15 | Checked By | KC | Date | 8/22/15 |
|---|---|---|---|---|---|---|---|



DCN: CT-S3B DATE: 2/09/10 REVISION: 0 *E:\PROJECTS\AECOM\2015-437-001 Dow Salzburg\[2015-437-001-006 Grain JSieveHyd.xls]Print Sheet*

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# ATTERBERG LIMITS

ASTM D 4318-10

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 6 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 6 |
| Lab ID: | 2015-437-001-006 | Soil Description: | BROWN LEAN CLAY |

***Note: The USCS symbol used with this test refers only to the minus No. 40 sieve material. See the "Sieve and Hydrometer Analysis" graph page for the complete material description .***

( Minus No. 40 sieve material, Airdried)

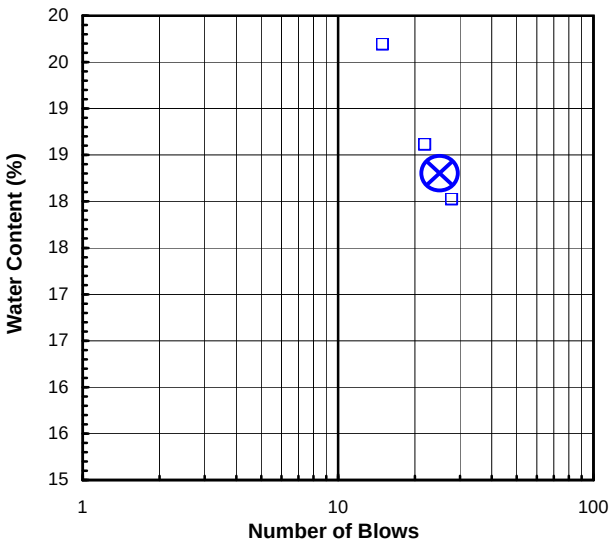
| **Liquid Limit Test** | **1** | **2** | **3** | |
|---|---|---|---|---|
| Tare Number: | 327 | 32 | 154 | **MULTIPOINT** |
| Wt. of Tare & Wet Sample (g): | 46.37 | 47.50 | 46.46 | |
| Wt. of Tare & Dry Sample (g): | 42.35 | 43.17 | 42.07 | |
| Weight of Tare (g): | 20.04 | 19.90 | 19.77 | |
| Weight of Water (g): | 4.0 | 4.3 | 4.4 | |
| Weight of Dry Sample (g): | 22.3 | 23.3 | 22.3 | |
| **Moisture Content (%):** | **18.0** | **18.6** | **19.7** | |
| **Number of Blows:** | **28** | **22** | **15** | |

| **Plastic Limit Test** | **1** | **2** | **Range** |
|---|---|---|---|
| Tare Number: | 2224 | 116 | |
| Wt. of Tare & Wet Sample (g): | 25.82 | 24.62 | |
| Wt. of Tare & Dry Sample (g): | 25.26 | 24.06 | |
| Weight of Tare (g): | 19.48 | 18.24 | |
| Weight of Water (g): | 0.6 | 0.6 | |
| Weight of Dry Sample (g): | 5.8 | 5.8 | |
| **Moisture Content (%):** | **9.7** | **9.6** | **0.1** |

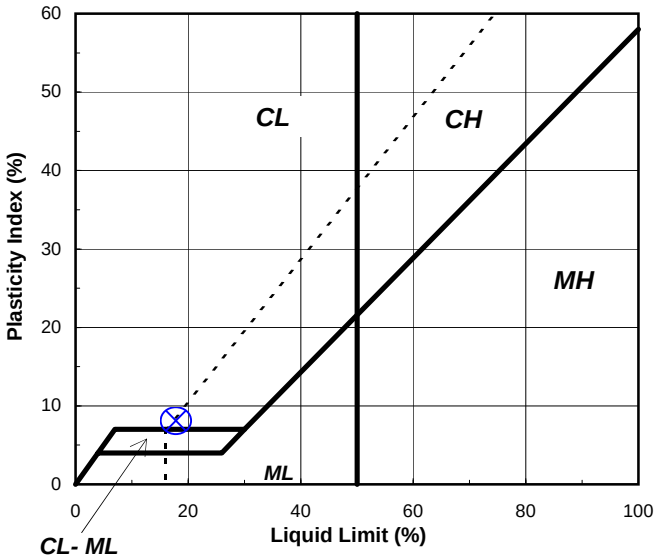
*Note: The acceptable range of the two Moisture contents is ± 2.6*

| **Test Results** | |
|---|---|
| **Liquid Limit (%):** | **18** |
| **Plastic Limit (%):** | **10** |
| **Plasticity Index (%):** | **8** |
| **USCS Symbol:** | **CL** |

**Flow Curve**




**Plasticity Chart**




*Tested By* *TO* *Date* *8/19/15* *Checked By* *KC* *Date* 8/22/15



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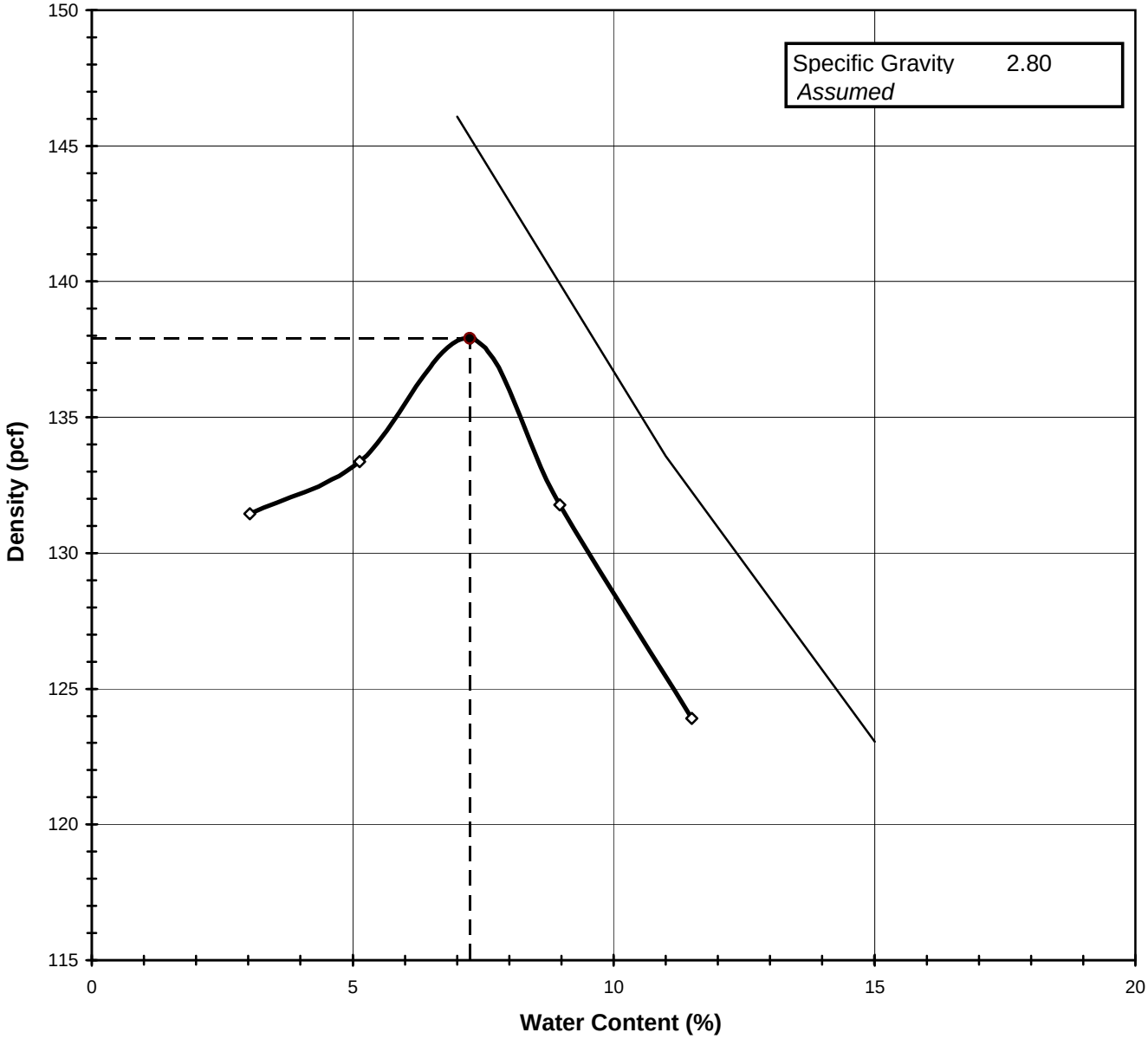
# MOISTURE DENSITY RELATIONSHIP

*ASTM D1557-12*

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 6 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 6 |
| Lab ID: | 2015-437-001-006 | Test Method | **MODIFIED** |

Visual Description: Gray Clay with small amount of Rock Fragments

| | |
|---|---|
| **Optimum Water Content** | **7.3** |
| **Maximum Dry Density** | **137.9** |




*Tested By* BS *Date* *8/20/15* *Checked By* KC *Date* 8/21/15



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# MOISTURE - DENSITY RELATIONSHIP

*ASTM D1557-12*

| | | | |
|---|---|---|---|
| Client: | AECOM | Boring No.: | Bucket 6 |
| Client Reference: | Dow Salzburg LF 60395549 | Depth (ft): | NA |
| Project No.: | 2015-437-001 | Sample No.: | 6 |
| Lab ID: | 2015-437-001-006 | | |

Visual Description: Gray Clay with small amount of Rock Fragments

| | |
|---|---|
| Total Weight of the Sample (g): | NA |
| As Received Water Content (%): | NA |
| *Assumed* Specific Gravity: | 2.80 |
| Percent Retained on 3/4": | NA |
| Percent Retained on 3/8": | NA |
| Percent Retained on #4: | NA |
| Oversize Material: | Not included |
| Procedure Used: | B |

| | | |
|---|---|---|
| Test Type: | | **MODIFIED** |
| Rammer Weight (lb): | | 10.0 |
| Rammer Drop (in): | | 18 |
| Rammer Type: | | MECHANICAL |
| Machine ID: | G | 774 |
| Mold ID: | G | 1499 |
| Mold diameter: | | 4" |
| Weight of the Mold (g): | | 4389 |
| Volume of the Mold ($cm^3$): | | 940 |

## Mold / Specimen

| **Point No.** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| Weight of Mold & Wet Sample (g): | 6429 | 6501 | 6617 | 6552 | 6470 |
| Weight of Mold (g): | 4389 | 4389 | 4389 | 4389 | 4389 |
| Weight of Wet Sample (g): | 2040 | 2112 | 2228 | 2163 | 2081 |
| Mold Volume ($cm^3$): | 940 | 940 | 940 | 940 | 940 |

## Moisture Content / Density

| | | | | | |
|---|---|---|---|---|---|
| Tare Number: | 545 | 901 | 623 | 881 | 870 |
| Weight of Tare & Wet Sample (g): | 494.90 | 540.80 | 527.00 | 527.10 | 547.30 |
| Weight of Tare & Dry Sample (g): | 482.80 | 519.80 | 497.00 | 492.80 | 502.20 |
| Weight of Tare (g): | 82.92 | 110.39 | 83.49 | 110.42 | 109.83 |
| Weight of Water (g): | 12.10 | 21.00 | 30.00 | 34.30 | 45.10 |
| Weight of Dry Sample (g): | 399.88 | 409.41 | 413.51 | 382.38 | 392.37 |

| | | | | | |
|---|---|---|---|---|---|
| Wet Density ($g/cm^3$): | 2.17 | 2.25 | 2.37 | 2.30 | 2.21 |
| Wet Density (pcf): | 135.4 | 140.2 | 147.9 | 143.6 | 138.1 |
| **Moisture Content (%):** | **3.0** | **5.1** | **7.3** | **9.0** | **11.5** |
| **Dry Density (pcf):** | **131.4** | **133.4** | **137.9** | **131.8** | **123.9** |

## Zero Air Voids

| | | | |
|---|---|---|---|
| **Moisture Content (%):** | 7.0 | 11.0 | 15.0 |
| **Dry Unit Weight (pcf):** | 146.1 | 133.6 | 123.0 |

*Tested By* BS *Date* 8/20/15 *Checked By* KC *Date* 8/21/15



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