

**Summary of Results:
Slope Stability analysis of Reinforced Berm
Design for Crow Lane Landfill**

by

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for

Sitec Environmental

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Crow Lane Landfill : Summary of Reinforced Berm Analysis

Table 1. Minimum Factors of Safety A-A'

Case	Geogrid Strength, T_{ult} lbf (lb per lin. ft)	Global Stability		Translational	Internal
		Rotational	3-Part Wedge	Sliding 2-part Wedge	Rotational
Static	$T_{ult} = 2500$	1.34	1.75	1.72	2.14
Seismic	$T_{ult} = 2500$	1.15	1.45	1.52	1.83

Section A-A' Quantity . of Reinf. (ft² per lin. ft. of MSE Berm) : 125 ft²

Table 2. Minimum Factors of Safety B-B'

Case	Geogrid Strength, T_{ult} lbf (lb per lin. ft)	Global Stability		Translational	Internal
		Rotational	3-Part Wedge	Sliding 2-part Wedge	Rotational
Static	$T_{ult} = 2500$	1.36	2.08	1.98	2.33
Seismic	$T_{ult} = 2500$	1.16	1.76	1.74	2.03

Section B-B' Quantity . of Reinf. (ft² per lin. ft. of MSE Berm) : 48 ft²

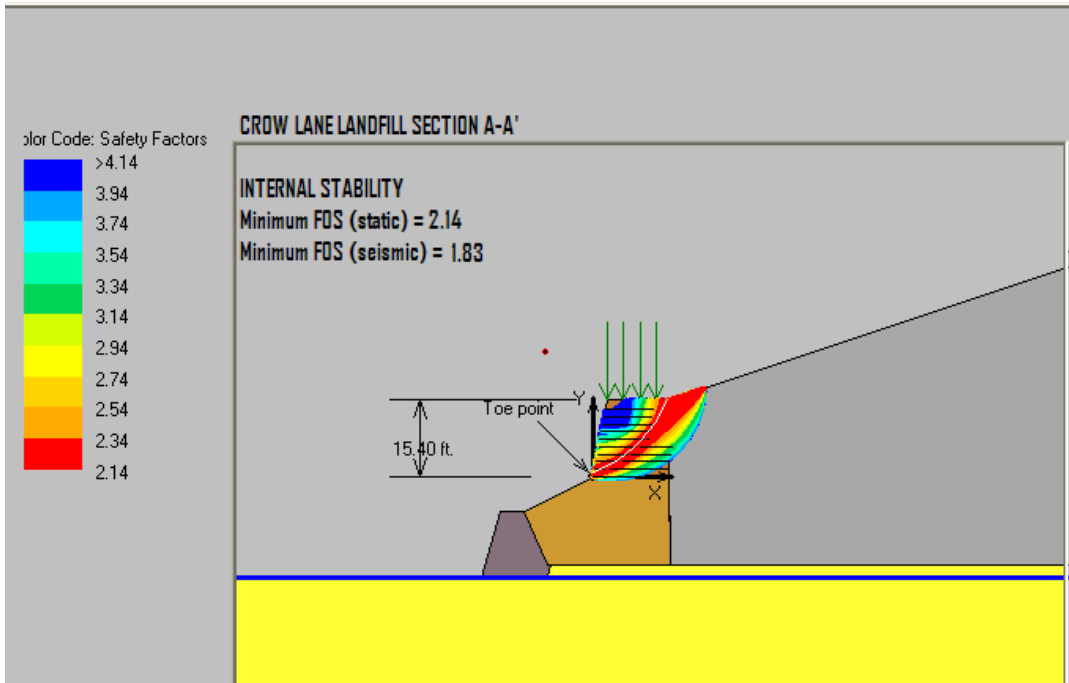
Table 3. Minimum Factors of Safety C-C'

Case	Geogrid Strength, T_{ult} lbf (lb per lin. ft)	Global Stability		Translational	Internal
		Rotational	3-Part Wedge	Sliding 2-part Wedge	Rotational
Static	$T_{ult} = 2500$	1.35	1.72	1.88	2.62
Seismic	$T_{ult} = 2500$	1.16	1.48	1.68	2.22

Section C-C' Quantity . of Reinf. (ft² per lin. ft. of MSE Berm) : 86 ft²

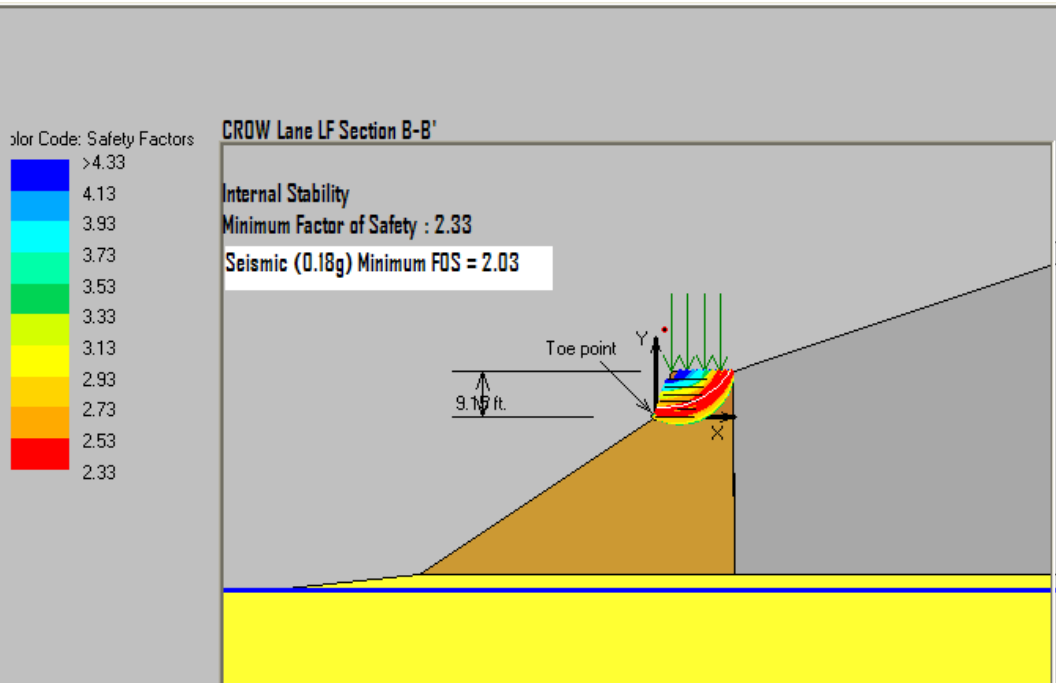
Appendix A

ReSSA calculations and results for Section A-A'



Appendix B

ReSSA calculations and results for Section B-B'



Appendix C

ReSSA calculations and results for Section C-C'

MECHANICALLY STABILIZED EARTH (MSE) BERM

PART 1 - GENERAL

1.01 DESCRIPTION

- A. Provide the perimeter berm shown on the drawings by constructing Mechanically Stabilized Earth (MSE) berms in accordance with these specifications and the drawings:
1. Coordinate the installation of the indicated geosynthetic materials with the placement and compaction of the reinforced backfill, and the Landfill Waste, and landfill cover materials to create the MSE berms indicated on the drawings.
 2. Place the geosynthetic reinforcement materials as indicated in section 3.03.
 3. The Engineer must observe and approve the placement of each primary geosynthetic reinforcement layer prior to covering with a lift of reinforced backfill material.
 4. Construct the MSE berm facing using welded wire mesh basket face forms and the specified face wrap materials to construct the wall face configuration shown on the drawings.
- B. The work of this section includes, but is not limited to:
1. Furnishing all labor, materials, equipment, and incidentals required to perform all work necessary for the construction of the MSE berms as indicated on the drawings. Work includes furnishing and installing: (a) geosynthetic reinforcing materials; (b) welded wire mesh face forms and geosynthetic face wrap materials; (c) reinforced backfill materials.
 2. As indicated on the project drawings, the MSE berm facing extends from the bottom of the first wrapped lift to the top of the berm.

1.02 REFERENCE STANDARDS

Reference standards for geosynthetic reinforcement materials include:

ASTM D 4354 - Practice of Sampling Geosynthetic Materials for Testing

ASTM D 4595 - Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method (modified for geogrids)

ASTM D 5262 - Test Method for Evaluating the Unconfined Creep Behavior of Geosynthetics

ASTM D 1505 - Specific gravity (HDPE only)

ASTM D 1238 - Melt Flow Index (PP&HDPE)

ASTM D 4603 - Intrinsic Viscosity (PET only)

ASTM D4355 - Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water

ASTM D2455 – Carboxyl End Group (PET Only)

GRI GG-1: Single Rib Geogrid Tensile Strength (Quality Control only)

GRI GG-4 (a): Determination of the Long-Term Design Strength of Stiff Geogrids

GRI GG-4 (b): Determination of the Long-Term Design Strength of Flexible Geogrids

GRI GG-5: Geogrid Pullout

GRI GT-6: Geotextile Pullout

GRI GG-7: Determining Carboxyl End Groups in Polyethylene Terephthalate (PET) Geotextiles and Geogrids

GRI GG-8: Determining the Average Molecular Weight Based on a Relative Viscosity Value.

1.03 DEFINITIONS

- A. ASTM: American Society for Testing and Materials.
- B. GRI: Geosynthetics Research Institute.

1.04 SUBMITTALS

- A. Within thirty (30) days after receiving Notice to Proceed, Contractor shall submit to the Engineer for review a plan that describes the following:
 - 1. A detailed construction sequence plan for installing the MSE berms indicating the limits of work, sequence of work, and procedures.
- B. All manufacturer's QC data and certifications for geosynthetic reinforcement, to confirm that the proposed materials meet all the requirements of Section 2.0 of this specification.

PART 2 - PRODUCTS

2.01 WELDED WIRE (FACE FORM)

Welded wire basket face forms shall consist of prefabricated steel wire forms comprised of a minimum of W4.0 size standard wire welded orthogonally 4 inches on center, and conforming to ASTM A497. All forms and struts will be fabricated with No. 4 black wire. Strut length and cross-section of the form shall be as noted on the drawings.

2.02 Separation Fabric .

Shall be a non-woven geotextile fabric, AMOCO 4551 or equivalent, Separation fabric shall be placed between the Reinforced Backfill and Rock Facing Backfill as shown on the Plans.

2.03 PRIMARY GEOSYNTHETIC REINFORCEMENT MATERIAL

- A. Geosynthetic Reinforcement Material shall consist of geogrids manufactured for soil reinforcement applications, and shall be manufactured from high density polyethylene or high tenacity polyester yarn.

High density polyethylene material shall conform to the requirements of ASTM Designation: D 1248. High tenacity polyester yarn material shall be manufactured from high tenacity polyester yarn as determined by the requirements of ASTM Designation: D 629, and shall be encapsulated in an acrylic latex or polyvinyl chloride material.

All geosynthetic reinforcements shall be from the same manufacturer and of the same type, manufacturing process, and polymer.

The type, properties and placement location requirements of the reinforcing geosynthetic shall be as shown on the plans and stated in this Section.

- B. Required Properties: Test data and reports by the manufacturer’s QC laboratory and project conformance testing shall demonstrate that the selected geosynthetic reinforcement(s) have the following minimum properties for backfill materials similar to the Low Permeability Soil specified in Section 2.04:

Strength Properties	Units	Test Method	Min. Required Value
Ultimate Reinforcement Tensile Strength – T_U	lbs/ft	ASTM D4595	Polyester grids = 2500 Polyethylene grids = 4500
Geogrid Junction Strength	lbs.	GRI GG-1	25

The manufacturer of each geosynthetic reinforcement material shall provide the minimum ultimate strength (T_u) based on ASTM D 4595 (modified for geogrid) and minimum average roll values.

Interaction Properties	Test Method	Min. Required Value
Coefficient of Interaction - C_1	GRI GG-5 & GG-6	0.7
Coefficient of Interface Friction between Soil and Geosynthetic Reinforcement - ϕ_p , where peak soil friction angle is greater than 36 degrees	ASTM D 5321	0.5

C. Minimum Durability Requirements:

Geosynthetic	Property	Test Method	Requirement
Polyethylene	UV Oxidation Resistance	ASTM D 4355	Min. 70% strength retained after 500 hrs.
Polyester	Hydrolysis Resistance	Intrinsic Viscosity Method (ASTM D 4603) with Correlation or Determine Directly Using Gel permeation Chromatography	Min. Number (Mn) Molecular weight of 25,000
Polyester	Hydrolysis Resistance	GRI GG-7	Max. Carboxyl End Group Number of 30
All	Survivability	Weight per Unit Area ASTM D 5261	Min. 270 g/m ² (8 oz/sy)
All	% Post Consumer Recycled Material by Weight	Certification of material used	Maximum 0%

D. Certification:

1. The contractor shall submit a manufacturer's certification that the geosynthetics supplied meet the respective criteria in this specification, measured in full accordance with all test methods and standards specified and as set forth in these specifications.
2. The manufacturer's certificate shall state that the furnished geosynthetic meets the requirements of the specifications as evaluated by the manufacturer's quality control program. The certificates shall be attested to by a person having legal authority to bond the manufacturer. In case of dispute over validity of values, the Owner's Engineer can require the Contractor to supply test data from a laboratory accredited by the Geosynthetic Accreditation Institute (GAI) to support the certified values submitted.
3. The quality control certificate shall include:
 - a. Roll numbers and identification.
 - b. Sampling procedures.

c. Result of quality control tests, including a description of test methods used.

E. Manufacturing Quality Control:

The geosynthetic reinforcement shall be manufactured with a high degree of quality control. The Manufacturer is responsible for establishing and maintaining a quality control program to ensure compliance with the requirements of the specification.

Conformance testing shall be performed as part of the manufacturing process and may vary for each type of product. As a minimum the following index tests shall be considered as applicable for an acceptable QA/QC program.

Property	Test Procedure
Specific Gravity (HDPE only)	ASTM D 1505
Wide Width Tensile	ASTM D 4595; GRI:GG1
Melt Flow (HDPE and PP only)	ASTM D 1238
Intrinsic Viscosity (PET only)	GRI GG8
Carboxyl End Group (PET only)	GRI GG7

F. Sampling, Testing and Acceptance:

Sampling and conformance testing shall be in accordance with ASTM D 4354. The Owner's Engineer will sample the geosynthetic reinforcement at selected intervals during construction and test samples for verification of the manufacturer's factor for installation damage.

Geosynthetic product acceptance shall be based on ASTM D 4759.

2.04 REINFORCED BACKFILL –

A. All reinforced backfill material used in the MSE berm shall consist of materials, which are free from organic or other unsuitable or deleterious material. The material shall be non-plastic. The material shall conform to the gradation requirements listed below:

- 100 percent passing a 6-in. sieve
- 100 to 75 percent passing a 3-in sieve
- 0 to 60 percent passing a No. 40 sieve
- 25 percent passing a No. 200 sieve

B. The material shall exhibit an angle of internal friction of not less than 40 degrees, as determined by the direct shear test ASTM D3080, utilizing as sample of the material compacted to 90% of ASTM D1557, at optimum moisture content.

C. The frequency of sampling the reinforced backfill necessary to assure the above –mentioned requirement shall be directed by the Owner's Engineer

2.05 Rock Facing Backfill:

A. Rock facing backfill shall be placed behind the wall face as shown on the Plans.

- B. The material shall consist of sound, durable, angular or sub-angular, crushed stone, and reasonably free from organic material or other deleterious materials.
- C. The material shall conform to the following gradation limits as determined by ASTM D 422:

<u>Sieve Size</u>	<u>Percent Passing</u>
3 inch (160 mm)	100
2 inch (75 mm)	0 – 5

PART 3 – EXECUTION

3.01 GENERAL REQUIREMENTS

The Contractor shall determine exact configurations, lengths, sizes and quantities of all geosynthetic materials, reinforced backfill, and associated and ancillary construction items required by this section. The Contractor shall be responsible for layout, elevation, length, quantity and quality of each work item required by this section and request Engineer approval of underlying materials before proceeding with construction of succeeding MSF wall activities. The Engineer will monitor the Contractor’s MSE berm construction operations and installation of all geosynthetic materials.

3.02 FOUNDATION PREPARATION

All areas immediately beneath the installation area for the MSE berms shall be properly prepared, as detailed on the contract drawings, specified elsewhere within the specifications, or as directed by the Engineer. Specifically, this will include removal of unsuitable, soft organic soils (peat).

3.03 MSE BERM CONSTRUCTION

- A. The Contractor shall use welded wire basket forms to develop the specified wall face and batter. The welded wire forms, soil retention layer, primary geosynthetic reinforcement, and reinforced backfill materials shall be placed in successive lifts.
- B. Wall Face Construction
 - 1. The primary geosynthetic reinforcement shall be connected to the welded wire forms. A Bodkin connection shall be provided if HDPE geogrids are used. Regularly spaced hog rings shall be employed if polyester geogrids are used.
 - 2. Welded wire facing will be monitored by the Engineer during fill placement and compaction. The Contractor shall employ compaction equipment and procedures that will not result in excessive deformation of the welded wire facing.
 - 3. Adjacent welded wire forms shall be connected along vertical and horizontal seams with galvanized interlocking fasteners placed 8 inches on center.
- C. Primary Geosynthetic Reinforcement

1. All materials shall be installed at the proper elevation and orientation as shown in the wall details on the drawings or as directed by the Engineer. The primary reinforcement lengths are as shown on the design drawings.
2. The primary geosynthetic reinforcement shall be installed in general accordance with the manufacturer's recommendations, unless otherwise modified by these specifications. The contract drawings shall govern in any conflict between the two requirements.
3. Overlap of the geosynthetic reinforcement in the design strength direction shall not be permitted, except where indicated on the drawings. The design strength direction is that length of geosynthetic reinforcement perpendicular to the wall face and shall consist of one continuous piece of material. Adjacent sections of geosynthetic shall be placed in a manner to assure that the horizontal coverage shown on the drawings is provided.
4. Place only that amount of primary geosynthetic reinforcement required for immediately pending work to prevent undue damage. After a layer of geosynthetic reinforcement has been placed and the next succeeding layer of soil has been placed, the next geosynthetic reinforcement layer shall be installed. The process shall be repeated for each subsequent layer of geosynthetic reinforcement and soil.
5. Geosynthetic reinforcement shall be placed to lay flat and be pulled tight prior to backfilling. After a layer of geosynthetic reinforcement has been placed, suitable means, such as pins or small piles of soil, shall be used to hold the geosynthetic reinforcement in position until the subsequent soil layer can be placed. Under no circumstances shall a track-type vehicle be allowed on the geosynthetic reinforcement before at least 6.0 in. of soil has been placed.
6. During construction, the surface of the backfill should be kept approximately horizontal. Primary geosynthetic reinforcement shall be placed directly on the compacted horizontal fill surface. Primary geosynthetic reinforcements are to be placed within 3.0 in. of the design elevations and extend the length shown on schedule unless otherwise directed by the Engineer. Correct orientation of the primary geosynthetic reinforcement shall be verified by the Contractor.

D. Reinforced Backfill Placement

1. The reinforced backfill shall be placed as shown on the contract drawings in maximum compacted lift thicknesses of 10 inches and each lift shall be compacted to a minimum of 90% of the maximum dry density (ASTM D 1557) and at a moisture content within 4% of optimum. Reinforced Backfill shall be placed, spread, and compacted in such a manner that eliminates the development of wrinkles or movement of the primary geosynthetic reinforcement and the welded wire face. Any welded wire face forms or geosynthetic reinforcement that become damaged during backfill placement shall be removed and replaced at the contractor's expense. Any misalignment or distortion of the wall facing units outside the limits of these specifications shall be corrected at the contractor's expense. Backfill placement methods near the facing shall assure that no voids exist directly beneath the reinforcing elements.

2. Tracked construction equipment shall not be operated directly on the geosynthetic reinforcement. A minimum backfill thickness of 6 inches is required, prior to operation of tracked vehicles over the geosynthetic reinforcement. Turning of tracked vehicles should be kept to a minimum to prevent displacing the fill and damaging or moving the geosynthetic reinforcement.
3. Rubber-tired equipment will not be allowed to pass over the geosynthetic reinforcement, unless it is performed in accordance with the manufacturer's recommendations and field tests are performed to demonstrate the geosynthetic reinforcement will not be damaged more than the geosynthetic manufacturer's installation damage reduction factor would indicate. If allowed, all equipment shall operate at speeds less than 10 mph. Sudden braking and sharp turning is prohibited.
4. At the end of each day's operation, the Contractor shall slope the last lift of reinforced backfill away from the wall facing, to direct runoff of rainwater away from the wall face. In addition, the Contractor shall not allow surface runoff from adjacent areas to enter the wall construction site.

END OF SECTION