Guidelines for the Use of Fiber Reinforced Soil (FRS) in Highway Construction

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16. ABSTRACT

Fiber Reinforced Soil (FRS) is essentially polypropylene fibers mixed with soil to reinforce the soil mass against shear or tensile failure. This concept has been in use in one form or another throughout history such as clay bricks and mud roofs reinforced with straw in traditional construction in many parts of the world. However, despite its proven record, long history, affordability and ease of construction, this technology has been underutilized, primarily because until relatively recently, extensive laboratory testing, usually in the form of time-consuming and complex triaxial and direct shear tests, was required in order to determine an appropriate application rate. In other words, if an engineer was interested in using FRS, extensive testing was required for each fiber type and range of concentrations of possible interest. However, with significant developments in theoretical models, laboratory testing and field application and verification in the recent years, soil and fiber properties can be used as input values in mathematical models to predict the magnitude of increase in shear strength of the FRS relative to the unreinforced (i.e. raw) soil, and use the resulting data in stability analysis programs to obtain the desired factors of safety in the earthwork project at hand. When the engineer is satisfied with a potential fiber type and application rate, targeted verification tests can be performed as necessary to improve confidence in design. FRS is applicable to a wide range of projects (e.g. retaining walls, slopes, foundations, and pavement subgrades). However, the focus of this study was on its application in repairing shallow slope failures. This report contains a brief review of different slope stabilization techniques beyond soil reinforcement, followed by descriptions of major discrete models developed for FRS, sample preparation and testing procedures in the laboratory, important concepts, and field implementation. Two case studies are also provided together with detailed slope stability calculations, which illustrate alternative methods of using commonly available slope stability analysis programs in combination with FRS data from spreadsheet calculations vs. special programs which can accept fiber properties and application rate as input values in their algorithms. The case study projects included in this report constitute the largest applications of FRS in the United States.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl	fluid ounces	29.57	milliliters	m
oz	gallons	3.785	liters	L
gal	cubic feet	0.028	cubic meters	L
ft^3	cubic yards	0.765	cubic	m^3
yd^3		meters NOTE: volumes greater than 1000 L shall be		m^3
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 Celsius or (F-32)/1.8		°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square h	lbf/in^2

***SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. Rev. March 2003.**

Acknowledgements

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Draft Final Report

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Executive Summary

Fiber Reinforced Soil (FRS) is essentially polypropylene fibers mixed with soil to reinforce the soil mass against shear or tensile failure. This concept has been in use in one form or another throughout history such as clay bricks and mud roofs reinforced with straw in traditional construction in many parts of the world. However, despite its proven record, long history, affordability and ease of construction, this technology has been underutilized.

The underutilization of FRS, in modern times, is because until relatively recently, extensive laboratory testing, usually in the form of time-consuming and complex triaxial and direct shear tests, was required in order to determine an appropriate application rate. Based on one's experience with a given fiber or soil one could choose a reasonable starting point. However, laboratory testing was required to test each proposed fiber concentration for a given soil. This would be especially problematic if a given fiber was deemed not applicable for a project and as a result, the testing regiment had to start anew with a new fiber type. That is to say, if an engineer was interested in using FRS, extensive testing was required for each fiber type and range of concentrations of possible interest.

However, thankfully this is no longer the case. With significant developments in theoretical models, laboratory testing and field application and verification in the recent years, soil and fiber properties can be used as input values in mathematical models to predict the magnitude of increase in shear strength of the FRS relative to the unreinforced (i.e. raw) soil, and use the resulting data in stability analysis programs to obtain the desired factors of safety in the earthwork project at hand. When the engineer is satisfied with a potential fiber type and application rate, targeted verification tests can be performed as necessary to improve confidence in design.

Although in principle, FRS is applicable to a wide range of reinforced soil projects (e.g. retaining walls, slopes, foundations, and pavement subgrades), the focus of this study was on its application in repairing shallow slope failures. This report begins with a brief review of different slope stabilization techniques beyond soil reinforcement. It then continues with a summary description of major discrete models developed for FRS, laboratory testing procedures (including sample preparation), important concepts, and field implementation. Two case studies with detailed slope stability calculations are also provided which illustrate alternative methods of using commonly available slope stability analysis programs in combination with FRS data from spreadsheet calculations vs. special programs which can accept fiber properties and application rate as input values in their algorithms. The case study projects included in this report constitute the largest applications of FRS in the United States.

1.0 – Scope and Overview

1.1 - Background

Shallow slope failures are a common occurrence in the state of Oklahoma and across other parts of the country. Often, the repair of these shallow failures involves extensive excavations in the forms of benching in order to provide adequate anchorage length (embedment) of planar reinforcement. These reinforcements require anchorage zones which often necessitate excavations that would impact the roadway shoulder and perhaps even the pavement. These excavations are not always feasible when obstructions are present such as paved roadway shoulders, guard rails, and utilities. When planar reinforcements are not practical, usually more expensive alternatives have been required previously. However, there is a technology called Fiber Reinforced Soil (FRS) which utilizes synthetic fibers as a soil admixture to increase the shear strength of the soil. The ideal length of the individual fibers is approximately 3- to 4-inches (75 – 100 mm). This means that the reinforced zone is fully effective only 2-inches (50 mm) or less from the limits of the excavated zone. Accordingly, in the case of a roadway, the excavation can be extended only to the shoulder or pavement edge which is typically beyond the failure zone. FRS can reinforce and repair a shallow slope failure using common, non-proprietary heavy earthwork equipment while limiting the required excavation beyond the slip surface (Gregory and Chill 1998a).

1.2 – Scope

This report provides a brief review of alternative slope stabilization techniques with a focus on the FRS technology. Major studies contributing to the development of FRS are reviewed, and a long term, in-depth study by Dr. Garry Gregory (a co-author of this report) is used as a basis to describe recommended methodologies for laboratory testing, analysis, and field implementation of FRS through a review of selected major field case studies and related stability analyses. FRS is typically intended for application in situations where shallow slope failures have occurred. In contrast to planar reinforcement that would typically require large anchorage zones, FRS is ideal for use especially in areas where constraints such as underground utilities or other obstructions exist, or scenarios where it is not feasible to excavate extensively. However, FRS may also be used as secondary reinforcement in conjunction with other means of reinforcement, or even as primary reinforcement in the construction of new slopes.

1.3 – Causes of Shallow Slope Failures

The presence of water is typically a factor involved in many instances of slope failure. Duncan et al. (2014) summarize a variety of ways that water content in soil can adversely affect the stability of slopes. Depending on factors such as the soil type and hydraulic conductivity, water may result in a decrease in shear strength by increasing pore pressure, and consequently cause cracking near the crest of the slope, swelling and increasing of the soil void ratio, weathering of the soil or rock, or leaching of chemicals (e.g. salt from pore water of marine clays) leading to potential instability and/or significant slope deformations. Additionally, water can destabilize a slope in rapid drawdown conditions. For example, water can increase the weight of the overlying soils and simultaneously decrease the effective stress. These effects or combinations thereof have been the cause of many slope failures. Other shallow slope failures related to water may be more related to erosion or wetting-induced creep. Cycles of wetting and drying may also result in high-plasticity soils degrading to the fully-softened condition over time (Duncan et al. 2014).

The focus and scope of this report is on the use of FRS as a viable and cost-effective remedial technology for repair of shallow slope failures, and a preventive measure in the construction of new embankments and slopes. FRS is especially useful in situations where proximity of underground utilities, roadway shoulders, pavements, and similar facilities to the slope failure is a concern.

2.0 – Available Techniques and Technologies

2.1 – Selected Stabilization Techniques for Slopes and Embankments

Many techniques and technologies are currently available for the repair of shallow slope failures. This section will provide a brief overview of these technologies including their advantages and disadvantages. Technologies outlined include:

Micropiles

Launched Soil Nails

Rammed Aggregate Piers

Rock Buttress

Terracing/Benching

Aggregate Drains and Horizontal Drains

Planar Reinforcement

Biotechnical

Fiber Reinforced Soils (FRS)

2.2 – Micropiles

Micropiles are typically less than twelve inches in diameter and can be installed at any angle with respect to the failure face. Micro piles can be reinforced or unreinforced, and are created by drilling a hole to a predetermined depth beyond the slip surface, inserting a steel mircopile (pipe) and grouting it. (**Figure 1**).

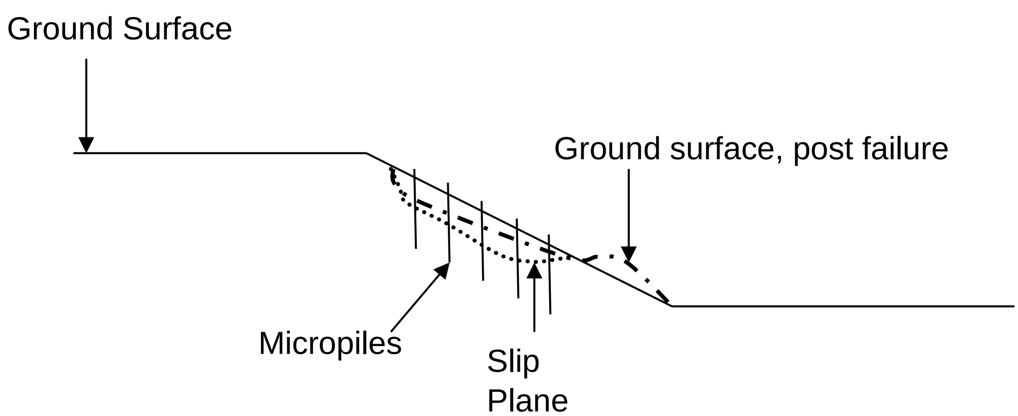

Figure 1. *Schematic of Micropile Repair of a Slope*

Applicability

When used for shallow slope failure repair, it is typically used for failures not exceeding ten feet in depth, although deeper failures have been successfully repaired with micropiles.

Advantages

One notable advantage of micropiles is that they do not typically require excavations if the slope is in creep distress but has not failed with resulting significant displacement. This should typically translate to cost savings related to equipment mobilization, excavation, and labor. Micropiles have been used extensively, and therefore many rules of thumb have been developed for their use. Therefore, a site-specific detailed design may not always be necessary for their implementation, which could be useful in an emergency.

Limitations

Limitations of micro piles are typically related to the need for specialized equipment and experienced labor. If the depth to the slip surface is underestimated and the micropiles are not installed deep enough as a result, little benefit would be realized from their installation. If slope failure is due to water, this should still be addressed even after micropile installation. Also, since the typical application is to repair failed slopes ten feet or shallower in depth, this too can be a limitation in some cases if the failure is significantly deeper.

2.3 – Launched (Ballistic) Soil Nails

The mechanism by which soil nailing works is similar to that for micro piles. Long steel rods (i.e. nails) are launched at high speeds (300+ km/h) by means of high pressure air (**Figure 2**). Much like micropiles, they are installed in groups and the aim is to intercept the slip surface in order to resist the soil mass' movement.

Applicability

Figure 2. *Launched Soil Nails at Pebble Beach Dr., Crescent City, CA (Landslide Solutions, Inc. 2017)*

This technology is applicable for slope failures where the slip surface is within 10 ft (3 m) (shallow failures). Fifteen to 18 feet is the typical maximum launched soil nail embedment depth.

Advantages

One advantage of this process is that it is relatively fast. Based on experience obtained, the New York DOT's Geotechnical Design Procedure GDP-14 (NYDOT 2015) states that approximately eighty linear feet of roadway can be treated per day for a two-row installation procedure. This technology has been used throughout the world and has a proven track record. Other advantages include minimal disturbance to traffic, and since the nail launcher is typically attached to an articulating arm, it can be used on relatively steep slopes where site access may not be feasible for traditional roadway construction equipment.

2.4 – Rammed Aggregate Piers

Similar to micro piles and launched soil nails, the objective of rammed aggregate piers in shallow slope failure repair is to intersect the slip plane. With rammed aggregate piers (e.g. Geopiers®), this objective is accomplished with piers/columns of crushed aggregate (**Figure 3**). In addition to the presence of rammed aggregate piers intercepting the slip plane, ramming of the stone into the soil may also densify the surrounding soils, although this may be limited in high-plasticity soils due to pore pressure build up during ramming.

Applicability

This method can be used for the repair of shallow or medium-depth failures.

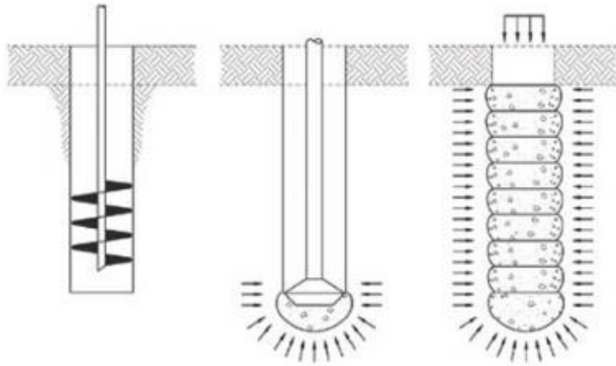

Figure 3. *Schematic Details of Rammed Aggregate Piers (www.csengineermag.com)*

<u>Advantages</u>

Some advantages are that dewatering and excavation are not typically required (if the slope has not experienced significant displacements), and the repair time is relatively short. The application of rammed aggregate piers as a proven technology also extends to foundations and general ground improvement projects.

<u>Limitations</u>

Specialized contractors, labor, and equipment are necessary. Because the densification is brought about by dynamic effects occurring during installation, this method is best suited for sandy soils. Noise and vibrations could be undesirable for projects in residential areas. Also, the dynamic effects may not be desirable for marginally stable slopes. Due to the nature of the equipment involved, this option may not be suitable for areas with limited site access.

2.5 – Rock Buttressing

Some slope failures are simply due to significant destabilizing weight acting on the slope with insufficient counter weight to resist the instability. Rock buttress is simply a large mass/overburden (typically in the form of aggregate) which is applied at the base of the slope to resist the sliding mass on the slope (**Figure 4**).

<u>Applicability</u>

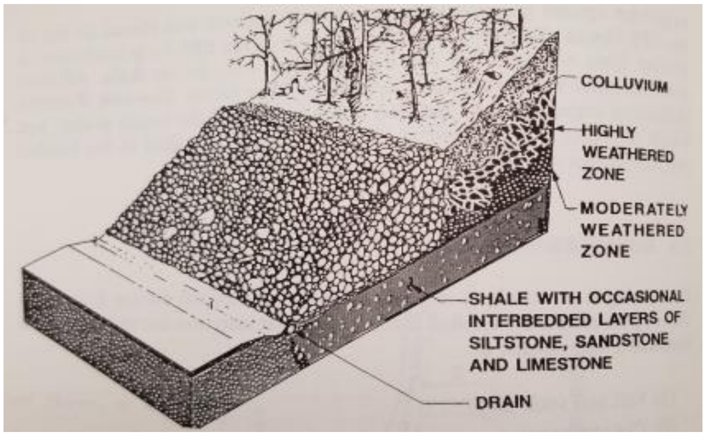

Figure 4. *Example Schematic of Rock Buttress to Stabilize a Slope (Schuster and Krizek 1978)*

This method is applicable to both shallow and deep slope failures, depending on the geometry of the slope and slip surface.

Advantages

This method is simple and can be fast. It does not require specialized equipment or labor to complete, and many rules of thumb exist which can be applied to minimize design effort/time.

Limitations

Site access is a concern, as haul-trucks need to have access to unload the aggregate. It also involves large volumes of aggregate which may not be a cost-effective option for shallow failures. The base of the rock buttress is typically at least half as wide as the slope is tall; these large dimensions may not be acceptable or even feasible depending on limitations such as right of way, and the geometries of the slope to be repaired.

2.6 – Terracing/Benching

Similar to a rock buttress, the option of terracing/benching seeks to fundamentally change the forces applied to the slope. Benching typically involves extensive earthwork. The basic concept behind its applicability is to remove soil/mass from the slope which is driving the movement of the slope (**Figure 5**).

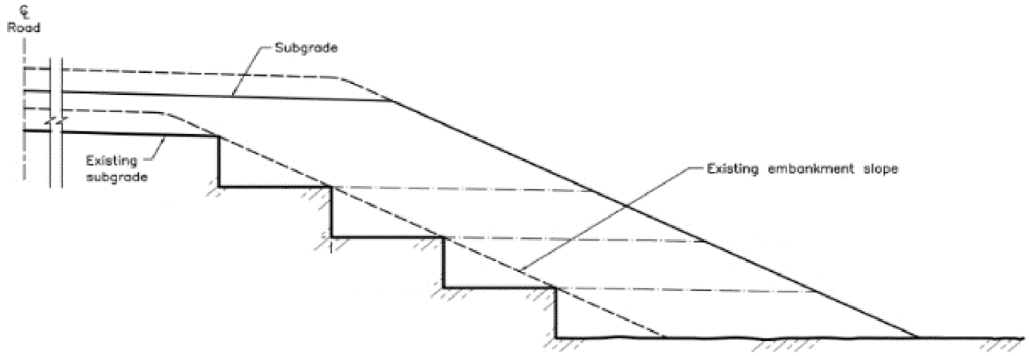

Figure 5. *Typical Section for Terracing/Benching (After Ontario Provincial Standard Drawing - OPSD 208.010)*

Applicability

Terracing can be applied to both deep and shallow failures. This method has been applied worldwide throughout history. Many modern examples exist that are also aesthetically pleasing as they involve landscaping as well.

Advantages

Terracing/benching is a very basic concept to design for and it has been proven around the world. In areas where the scenic views are of concern, landscaping can be applied to make the repair less visually obtrusive.

Limitations

The obvious limitation to this option is that it requires extensive earth work and may not be cost effective for shallow failures. If the project involves geometries that are constraining, this method may not be feasible, as it typically requires extensive modifications to the geometry of the slope and additional right-of-way in many cases.

2.7 - Aggregate Drains or Horizontal Drains

A common cause of slope failures is lack of adequate drainage either on surface or internally. This can cause increased pore pressures in the soils, reduce the effective stress and increase the overall weight of the soil mass. Adding or improving drainage has the potential to greatly reduce pore pressures and improve the stability of the slope.

To this end, options such as aggregate drains or horizontal drains are available (**Figure 6**).

Figure 6. *Horizontal Drains Protruding from Slope (www.geonusa.com)*

<u>Applicability</u>

These methods are applicable in instances where drainage within the slope is the main cause of slope failure. These drains are installed in predetermined patterns to accelerate and improve drainage. It is common for some drains to produce significant drainage, while others are less productive. Eventually, drainage will reduce in all drains and fluctuate with seasonal changes in moisture. Aggregate drains (sometimes called "Finger Drains") are similar in concept to French Drains. They are essentially a sloped trench dug perpendicular to the slope and backfilled with aggregate. These perpendicular trenches (or "fingers") tie in to another aggregate-filled trench typically dug parallel to the toe of the slope.

<u>Advantages</u>

Methods which improve the drainage of a slope, such as the examples provided earlier, are usually cheaper than methods involving significant earth work or construction activity (e.g. buttress fills or soil nailing). Drainage methods are based on relatively simple concepts.

Limitations

Limitations relating to drainage methods typically involve accessibility issues for specialized horizontal drilling equipment to install horizontal drains and dozers, excavators, and tandem-axel, dump-trucks for finger drains. Also, if the cause of slope failure is not drainage, then little or no improvement would be expected. Therefore, it is critical to definitively assess the cause(s) of the slope failure ahead of the repair work.

2.8 - Planar Reinforcement

Planar reinforcement in the form of geogrids and geotextiles is another commonly used method of soil improvement. Geogrids and geotextiles are used extensively in projects involving slope stability, retaining wall construction, road base improvement, or even ground improvement for foundations. The concept behind how they work is similar to reinforced concrete construction/design. Concrete is weak in tension and the addition of reinforcing steel creates a composite material which is more capable of resisting compressive and tensile forces. Similarly, soils are relatively weak under the influence of tensile forces, while geogrids and geotextiles are comparatively strong. Therefore, using these materials in ground improvement projects creates a composite material with improved mechanical properties for the intended application.

Applicability

With regards to slope stability, geogrids and geotextiles can be used for construction of new slopes or repair of existing slopes (**Figure 7**). They may also be used in conjunction with Fiber Reinforced Soil (FRS), especially during new construction. The use of planar reinforcement involves excavation beyond the failure surface and laying the geogrid or geotextile material down, then rebuilding the slope in controlled lifts. This has the effect of stabilizing the soil and improving factor of safety against failure.

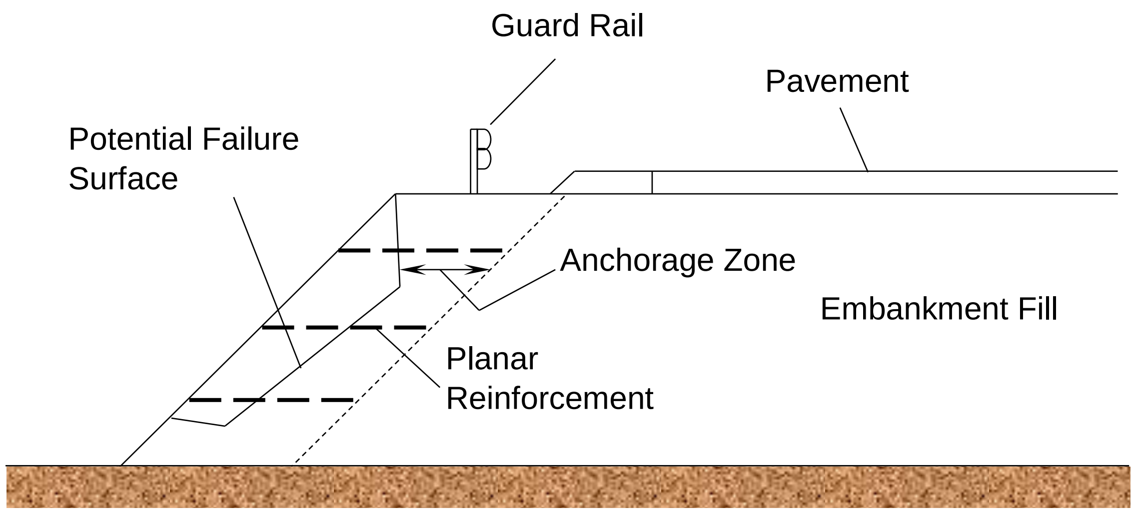

Figure 7.*Example of Obstructions Limiting the Use of Planar reinforcement (After Gregory and Chill 1998a)*

<u>Advantages</u>

Because of the extensive use of planar reinforcement in a broad variety of applications, the use of planar reinforcement is commonplace and therefore, engineers and construction crews are familiar and confident with both its design and installation. Also, many textbooks, guidelines, and rules of thumb exist regarding designing and using planar reinforcement; therefore, for the unfamiliar engineer many resources exist which will help in confidently performing the design.

<u>Limitations</u>

Planar reinforcement, although commonplace, is not without its limitations. With regards to slope repair, one limitation involves obstructions. Obstructions in the form of utilities or existing pavements may exist which prevent the excavations necessary to provide proper anchorage of the geogrid/geotextile.

2.9 – Biotechnical Reinforcement

Gray and Sotir (1995) describe biotechnical reinforcement as:

> *"Live cuttings and stems are purposely imbedded and arranged in the ground where they serve as soil reinforcements, horizontal drains, barriers to earth movement, and hydraulic pumps or wicks. Live plants and plant parts can be used alone or in conjunction with*

geotextiles or geogrids. The live cut stems and branches provide immediate reinforcement; secondary stabilization occurs as a result of adventitious rooting that occurs along the length of buried stems."

<u>Applicability</u>

Biotechnical reinforcement can be used for new construction or slope repair (**Figure 8**). It is commonly considered in areas that involve scenic routes because the foliage associated with it provides an unobtrusive, and natural aesthetic appearance. Additionally, this application is typically for the construction of new slopes as opposed to their repair.

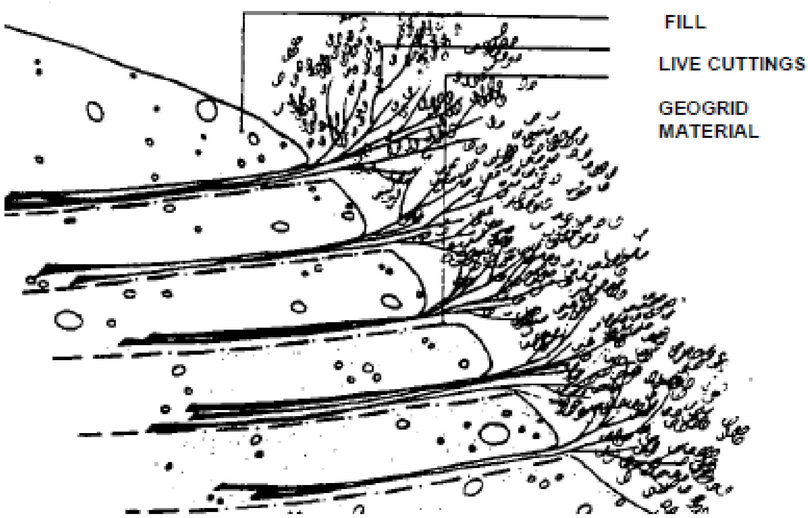

Figure 8. *Example Biotechnical Cut Section (Gray and Sotir 1995)*

<u>Advantages</u>

Biotechnical reinforcement may be used in conjunction with other improvements such as drainage modifications, rock buttresses, or planar reinforcement. Because it consists of planting live vegetation, it has a natural aesthetic, it is considered environmentally friendly, and it also serves as planar reinforcement and drainage improvement.

Limitations

Biotechnical reinforcement is typically performed in conjunction with other improvements such as rock buttresses or drainage. Therefore, associated costs may be relatively high. It can be a labor-intensive process as well. Additionally, although this system has been in use since the mid-1930s, its use is typically considered for areas where the natural, scenic views are desired to be maintained.

2.10 – Fiber Reinforced Soil (FRS)

Fiber Reinforced Soil (FRS) is a type of geosynthetic reinforcement that consists of thin fibers (approximately two to four inches long), which are typically made of polypropylene. Natural fibers such as coir, reed and straw have long been used for reinforcement applications in different parts of the world. In FRS, fibers are mixed with the existing soil using traditionally available equipment and methods to improve its strength characteristics. The strength improvement is typically described as an increase in the soil shear strength parameters cohesion and friction angle (Δc and $\Delta\phi$). However, FRS will not increase cohesion in sandy soils that exhibit zero cohesion in the non-reinforced case. The concept is like that in ancient adobe bricks where fibrous plant material was added to clay to increase the brick's strength.

Applicability

FRS technology may be applied as the secondary reinforcement in conjunction with conventional planar reinforcement, a preventative measure, or as reinforcing material for the repair of shallow failures especially where existing geometries or obstructions prevent excessive excavations. After examination of the site's features or constraints such as existing soil properties, slope geometry, cause of slope failure (i.e. cycles of wetting and drying, creep, excess pore pressure, etc.), presence of underground utilities and other factors, applicability of FRS can be determined. After the slope has been cut back beyond its failure surface, the fibers are mixed with the soil in a similar fashion as with the chemical (e.g. lime) stabilization of soils. The reinforced soil is placed and compacted in lifts, maintaining careful control of moisture and density. As compared to methods such as planar reinforcement, the anchorage zone and required excavation are minimal, as demonstrated in **Figure 9**.

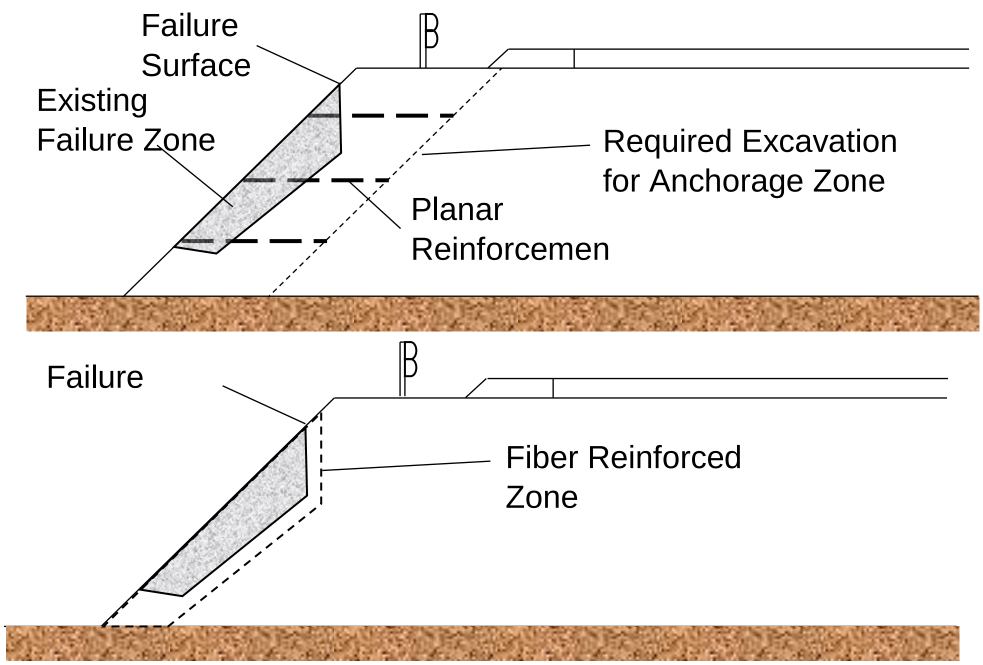

Figure 9.*Example of Reduced Anchorage Zone with FRS Relative to Planar Reinforcement (After Gregory and Chill 1998a)*

Advantages

The minimized anchorage zone is a major benefit with FRS. With options such as soil nailing, micro piles, and planar reinforcement, avoiding underground obstructions such as buried utilities could be a major concern as many utilities companies require some minimum offset/safe zone from their utility. Similarly, a scenario such as when a structure or pavement is at the crest of the slope, large excavations to develop proper anchorage for planar reinforcement may not be feasible without impacting the shoulder and/or pavement.

Finally, FRS does not require highly specialized equipment or labor. The method by which the fibers are added and mixed with the soils is not unlike traditional earthwork methods used for the chemical stabilization of soils. This similarity means that all parties who are involved in the construction, quality control, quality assurance, and design of chemical soil stabilization projects should have no difficulty implementing the FRS technology in slope repair and construction projects. Additionally, no proprietary equipment and specialized expertise is needed to apply FRS in the field. All this translates to keeping local labor and professionals (engineers, technicians, laborers, etc.) employed and avoiding the costs and logistical difficulties associated with bringing in outside expertise.

Limitations

The use of FRS does have its limitations. Due to the nature of how FRS is applied to the soils, typical equipment such as excavators, dozers, and tamping foot (sheep's foot) compactors are necessary. For slopes which are showing significant signs of distress and perhaps tension cracks in the crest area, but which have not experienced significant sliding displacement, FRS may not be as cost effective as other methods. FRS requires excavating the entire soil mass from the failure zone and recompacting in lifts as the fibers are added. Accordingly, for slopes that have not had catastrophic failures with large movements requiring excavation to repair, other methods such as micro piles or launched soil nails may be more appropriate since large excavations may not be required.

Properties such as interaction coefficients have not been researched thoroughly as they relate to FRS. Laboratory testing should be performed including large direct shear interface testing to verify interaction coefficients for the site specific soils and fiber material involved. In the absence of such site specific testing, interaction coefficients larger than 0.5 should not be used (Gregory 2006).

Comparison of Slope Repair Methods

The application of fibers increases the composite shear strength of soils. The strength increase, in discrete models, is typically reported as an increase/change in cohesion and/or friction angle, Δc and $\Delta\phi$, respectively. The way in which these fibers improve the soil behavior as it relates to slope stability is distinctly different from methods such as micro piles, soil nails, rammed aggregate piers, rock buttresses, and arguably even planar reinforcement. While these methods tend to arrest movement of the soil by intersecting failure planes and behave as discrete elements within the soil mass, FRS is more similar to chemical stabilization of soil in that it improves the strength characteristics of the fiber-soil composite. It does so by creating a 'homogenous' soil-fiber composite mass which has higher shear strength relative to the unreinforced soil.

Aggregate drains and horizontal drains seek to remedy the negative effects of water caused by lack of drainage in the slope. If, however, the failure of the slope is not due to water or drainage issues alone, these options do not achieve full stability. If the slope's failure is because of moisture, in the case of aggregate drains, the repair will require extensive excavations and hauling in of aggregates. The horizontal drain option uses technology and techniques that require specialized equipment and a complex array of drains.

Sometimes, there is either too much load at the crest of the slope, or not enough weight at the toe resisting the weight above. Terracing and rock buttresses seek to remedy this type of imbalance by physically adding or removing loads on the slope. Terracing, in conjunction with reducing the overall grade of the slope can reduce the weight being resisted by the soils at the toe. A rock buttress simply places a very large load at the toe of the slope to resist the weight from above. Both options essentially seek to tip the balance by modifying the geometry of the slope itself and are not always feasible or practical. Occasionally, situations occur where reducing the grade of the slope or adding material to the toe would require land acquisition or additional right-of-way. Because of the mechanism by which FRS works, it is not always necessary to change the physical shape of the slope to repair or improve it and issues such as land acquisition can be avoided. Therefore, less excavation is required, and less disturbance occurs to surrounding structures and traffic flow.

Lastly, the biotechnical option is similar in that the fibrous roots of the plants act as a fiber reinforcement of sorts. However, it takes years for the vegetation to fully take root, and the depth to which those roots penetrate and reinforce the soil is limited compared to the FRS option. The biotechnical option does improve the drainage of the slope by essentially serving as horizontal drains and is aesthetically pleasing, especially in scenic areas. The repair of slope failures can be an urgent need and therefore FRS has a distinct advantage over the biotechnical option. As with most slopes, FRS slopes can be seeded/hydro mulched to provide a grass cover to limit erosion.

3.0 – Literature Survey

3.1 - Studies by Gregory et al.

Gregory and Chill (1998a) presented a case study of a slope consisting of fat clays in Beaumont, TX which failed repeatedly over the years. The previous repairs had consisted of simply excavating the failed materials and replacing them in compacted lifts. The slope was finally repaired using FRS, and the FRS zone has not failed subsequently. This paper also included the results of a series of 86 direct shear specimens and 32 triaxial specimens which were tested in the laboratory. Some of the specimens were from the case study slope, and others were soils obtained from other locations in Texas. The laboratory tests included non-reinforced and fiber-reinforced specimens on the same soils for comparison purposes. Average shear strength increased in all cases. The percent strength increase in direct shear specimens and triaxial specimens depended on the length of the fiber used (i.e. 25mm vs. 50mm). In some individual tests, one parameter may have decreased slightly while the other increased significantly (e.g. c' may have slightly decreased while ϕ' increased significantly).

Gregory (1999, 2006) presented a discrete model (1999) which allows prediction of shear strength increase of an FRS soil knowing the unreinforced soil and fiber properties. The 1999 model was based on extensive laboratory testing of FRS and field observations of actual FRS slope repair applications. The 1999 paper included the first known important recognition that the stress regime on fibers in a soil mass is a combination of vertical and horizontal stresses. This is significantly different from the vertical (only) stress regime that applies to planar reinforcement. Prior to this work, engineers who may have considered using FRS to stabilize or repair slopes had to perform extensive and time-consuming laboratory testing to obtain equivalent shear strength values to use in their analysis, or had to use rules of thumb and experience to estimate slope stability improvement with addition of fibers. Gregory extended this model (2006) to include a decay (cap) function on shear strength gain due to fibers as the fiber content reaches a relatively large value, and made a correction in the cohesive component of strength gain. The 2006 study also included the first known laboratory testing of creep resistance of FRS. The study showed that FRS specimens were able to sustain a much larger percent of the FRS peak shear strength under sustained loading than non-reinforced specimens of the same soil compared to the peak shear strength of the non-reinforced soil, even after 16 days of sustained load. The 2006 study included an extensive program of laboratory testing of high-plasticity clay soils and sandy soils, utilizing triaxial shear and specialized direct shear devices. Additionally, Gregory (2006) presented extensive descriptions and figures relating to the preparation of laboratory FRS specimens for direct shear, triaxial, and creep testing, which is very useful, as there is currently no widely accepted standard for preparation of such specimens. The laboratory testing also included large-scale direct shear interface testing of the polypropylene sheet material from which the fibers are cut, and fully-saturated soils used in this study. This study also contained two extensive case histories which included the largest known FRS projects to date.

3.2 - Studies by Zornberg et al.

Zornberg (2002) published a discrete model, similar to the Gregory (1999) model, which, given soil and fiber properties, allowed one to predict the increase in cohesion and friction angle due to addition of fibers. This study further contributed to the knowledge of FRS application to slope stability initially proposed by Gregory (1999)

Heineck and Consoli (2004) discussed the accuracy of Zornberg's (2002) model predictions, stating that Zornberg's model would overestimate cohesive and frictional strength increases. Zornberg (2004), argued that the aspect ratio of the fibers used in Heineck and Consoli's paper (η = 1128, i.e. hair-like fibers) was extremely high, which resulted in tangled webs of reinforcement which were not fully engaged with the soil. This discussion showed that there are practical limits which pertain to the dimensions of the fibers and the equations used to predict the strength increase. Although the equation seemingly shows a linear and infinite increase in shear strength as aspect ratio increases, these infinitely thin and long fibers result in tangled webs of reinforcement which are never fully engaged. Additionally, the reinforcing fibers examined in the

Heineck and Consoli's paper may have been even thinner than the smallest particle sizes of the soil mass being reinforced.

Li and Zornberg (2005a) carried out a triaxial testing program to validate their earlier discrete methodology in predicting equivalent shear strength of FRS (Zornberg 2002). One important observation was that the initial density of the specimen did not have a significant influence on shear strength of the reinforced soil when high fiber contents were used. Additionally, it was found that the residual shear strength of the unreinforced soil should be used to predict the equivalent shear strength and conversely, for soils placed using relatively low fiber content, the peak shear strength of the unreinforced soil is recommended (if the stress-strain curve shows a peak) to predict the equivalent shear strength using the discrete framework developed in Zornberg (2002) study.

Li and Zornberg (2005b) studied the effects of soil density and confining pressure on the coefficient of interaction between sand and reinforcing fibers. A series of interface tests were performed on a single strand of fiber as opposed to an entire sheet of the reinforcing material. Their findings showed that the interaction coefficient decreases with increasing confining stress and that, for confining stresses less than approximately 200kPa, an interaction coefficient of 0.8 is appropriate. However, based on large scale interface tests on sheet material with saturated soils, an interaction coefficient greater than 0.5 should not be used in the absence of large scale interface testing on site specific soils and fiber material (Gregory 2006)

Zornberg et al. (2007) studied the benefits of fiber reinforced soil in blast protection applications. The ability of soil berms built around structures, such as bunkers, to resist blast loadings is related to the post-peak shear strength of the soil. It was found that there was little or no post-peak shear strength loss in soils that were reinforced with fibers (i.e. the reinforced soil mass exhibited ductile behavior) even at axial strains as high as 15%.

3.3 - Studies by Michalowski et al.

Michalowski's studies on the effect of reinforcing fibers on soil shear strength have been focused on sand. For example, Michalowski et al (2003) presented a model to predict failure stress in triaxial compression for fiber reinforced sands where fiber distribution is isotropic. In that study, he also showed that for a given aspect ratio, the length of the fiber is the most critical aspect of the reinforcing fiber (e.g. keeping aspect ratio constant, and varying length, the longer fiber will be most effective). Additionally, he observed scaling effects between coarser and finer sands with a given type of fiber. For example, for a given fiber, in a coarser sand, 1.5% fiber addition (by volume) produced the same strength gain as 2.0% fiber in a finer sand.

Michalowski (2008) proposed a kinematic approach of limit analysis for FRS sands with anisotropic fiber orientation (i.e. a preferred bedding plane), which he argued, is a more realistic assumption than the isotropic assumption made by Maher and Gray (1990), Zornberg (2002), Gregory (2006), and others, due to the mixing and compaction equipment used to incorporate fibers into the soil. Additionally, he showed the anisotropic internal friction angle to be a function of the major principal strain rate direction and not merely a function of the orientation of the shear surface. However, the field and laboratory mixing techniques proposed and utilized by Gregory (1999, 2006) and extensive field observation and testing by Gregory on more than 25 major FRS projects, including the two largest known FRS projects to date, has strongly illustrated that the fibers are uniformly distributed and randomly oriented and are not anisotropic in preferential bedding planes.

4.0 – Theoretical Background and Development

4.1 – Development of Discrete Analysis of FRS

Until the early 2000's FRS designs typically assumed a homogenized material where the fibers in the reinforced soil mass behaved as part of a composite material whose contribution to stability of the mass was quantified as an increase in shear strength. Treating FRS in this manner without the ability to quantify the increase in cohesion and friction angle using discrete methods resulted in the need for extensive laboratory testing of the reinforced specimens to quantify properties needed in design. For a given project, tests on soil needed to be performed for different types of soil and fibers being considered for use in a project. The result was an expensive and time-consuming laboratory testing schedule. This need for extensive laboratory testing has potentially discouraged widespread use of FRS in practice (Zornberg 2002).

Eventually, researchers and practitioners such as Gregory (1999, 2006) and Zornberg (2002) developed discrete models which aid in the design of FRS slopes and slope repairs and other geotechnical projects by allowing the engineer to easily predict FRS strength without extensive testing. These models, given the unreinforced soil properties and fiber properties, allow the engineer to predict increases in cohesion and friction angle (Δc and $\Delta\phi$) within reasonable and practical accuracy and thus calculate the improved shear strength without the need for extensive testing. This is a powerful tool, which affords an engineer the ability to quickly determine if a certain fiber is more advantageous or efficient than another, or if FRS is a viable option for any specific site. Researchers such as Gregory, Zornberg, and Michalowski have all provided significant contributions to this end. In the following sections the studies by Gregory and Zornberg are discussed in more detail.

4.2 – Concepts and Terminology

Some of the FRS concepts and terminologies are common among the three methods discussed here (see end of **Section 4.1**), while others are either slightly different or they are unique to a specific model under consideration.

4.2.a Critical Stress

For most geotechnical applications, the anticipated failure mechanism of the fibers in the matrix is pullout of the fibers. Unrealistically high confining pressures would be required for the failure mechanism to be fiber breakage. Zornberg (2002) provides an example that shows that a soil column nearly 0.5 miles (790 m) tall would be required to provide the necessary confining pressure to allow fiber breakage to be the failure mechanism. This confining stress, $\sigma_{n,crit}$, is called the critical normal stress and is the point which defines the change in the governing failure mode.

Although different variables are used, all three models recognize and accept the existence of this stress level. Additionally, all recognize and state that such a high level of stress is unlikely to be encountered in typical geotechnical work.

4.2.b Embedment Depth

The embedment depth of the fiber across the failure plane is directly related to the pullout resistance of the reinforced soil. The embedment depth could vary from zero to half of the fiber's length. (l_f = length of fiber). Per Zornberg (2002), statistically, the average embedment length of randomly distributed fibers, $l_{e,ave}$ can analytically be assumed as:

$$l_{e,ave} = \frac{l_f}{4} \qquad [1]$$

Gregory (1999, 2006) refers to this as the effective fiber length, $l_{e(ave)}$. Although Michalowski (2008) does not explicitly derive or explain this concept, based on his explanations and diagrams of stress distribution, it is clearly seen that he has utilized this concept to develop his model.

4.2.c Isotropy/anisotropy of Fiber Distribution and Orientation

Pullout resistance also depends on the distribution and orientation of the fibers within the soil mass. Zornberg (2002) assumes that a fiber has an equal chance of being oriented in any plane (i.e. isotropy/random fiber orientation). However, he suggests anisotropy may reduce the fiber's efficiency, and therefore reduce the potential maximum gain in the equivalent shear strength by the addition of fibers. Therefore, a term, α, is introduced to account for anisotropy of the fibers and the perceived resulting reduction in efficiency (i.e. $\alpha < 1$ equates to anisotropy, or less than 100% efficiency). Zornberg (2002) assumed isotropic fiber orientation ($\alpha = 1$) which was shown to accurately predict strength gains due to the addition of fibers in his testing.

Similarly, Gregory (2006) assumes random fiber orientation and sites Gregory (1999) to support the argument that an individual fiber with a rectangular cross section should have an equal probability of any orientation between vertical and horizontal axes with respect to the fiber's cross-sectional axes.

On the other hand, Michalowski (2008) suggested that due to the existence of preferred bedding plane, anisotropy would be a more realistic assumption. He argues that anisotropy is brought about by the limitations of the construction equipment and the method by which the fibers are incorporated into the soil and then compacted. Additionally, his research suggests that for many cases, anisotropy actually improves the equivalent shear strength. His paper shows, for example, the variation of ϕ could be anywhere between a loss of approximately 4 degrees and a gain of approximately 11 degrees depending on the distribution of fibers and their orientation. However, the authors are of the opinion that Michalowski's observations were very likely a result of the mixing methods employed in the laboratory and are not consistent with those observed in other research studies or in the field using recommended mixing methods (e.g. Gregory 2006).

4.2.d Interaction Coefficients

There are two interaction coefficients in Zornberg's (2002) model, $c_{i,c}$ and $c_{i,\phi}$. The cohesion interaction coefficient is simply the ratio of the adhesive component of interface shear strength and cohesion of the unreinforced soil. Similarly, the friction interaction coefficient is the ratio of the frictional component of the interface shear strength and the frictional component of the soil shear strength. The interface shear resistance of individual fibers f_f is given by:

$$f_f = a + tan\,\delta \cdot \sigma_{n,ave} \qquad [2]$$

where *a* and tan δ are the adhesive and frictional components of the interface shear strength between soil and the fiber, respectively. The soil-fiber interaction coefficients are given by:

$$c_{i,c} = \frac{a}{c} \qquad [3]$$

and

$$c_{i,\phi} = \frac{tan\,\delta}{tan\,\phi} \qquad [4]$$

where c and ϕ are the cohesion and friction angle of unreinforced soil, respectively.

Zornberg (2002, 2003, 2005a, 2005b, and 2013) used $c_{i,c}$ and $c_{i,\phi}$ values equal to 0.8 based on widely reported values in literature for planar reinforcement. Zornberg et al. (2005) published a study specifically addressing interface shear strength in fiber-reinforced sands. In this paper, although the interaction coefficient varies with relative density, the value of 0.8 was recommended as a reasonable value so long as the confining pressures are less than 200 kPa. Additionally, it was found that the interaction coefficients gradually decrease with increasing confining pressure.

Gregory (1999, 2006) also utilizes the concept of interaction coefficient. Similar to Zornberg (2002) there is an interaction coefficient related to the frictional component of the shear strength, f_ϕ, and an interaction coefficient related to the cohesive component of the shear strength, f_c. Based on large scale direct shear interface testing of the fiber sheet material and saturated soil, Gregory (2006) recommends that a maximum value of 0.5 for both interaction coefficients should be used, unless large scale interface shear testing of the fiber sheet material and site specific saturated soil is performed which would indicate higher values.

Sadek et al. (2010) also determined these interaction coefficients using similar tests for various types of sand which ranged between 0.44 and 0.55. This value agrees well with the findings of Gregory (2006).

Michalowski et al. (2003) and Michalowski (2008) utilize the concept of interface friction angle, ϕ_w, determined by performing pullout tests on individual fibers of reinforcing material. In sands, it was determined that the grain size did not affect the interface friction angle, but instead, this value depended on fiber type and normal stress.

Interaction coefficients may be obtained experimentally either by pulling an individual fiber through a modified shear box (Zornberg et al. 2005), or by performing a direct shear test over a sheet of the reinforcing material in the direct shear box. Gregory (2006) determined interaction coefficients by performing testing over sheets of reinforcing material and saturated soils as opposed to individual fibers. In sands, at least, there is evidence that a higher interaction coefficient would be obtained if testing is performed on individual strands (e.g. Michalowski 2008).

4.2.e Aspect Ratio

The traditional definition of aspect ratio, η, of a fiber is the ratio of its length, l_f, to its diameter, or equivalent diameter, d_{eq}. Zornberg (2002) and Michalowski (2003, 2008) used this definition in their studies:

$$\eta = \frac{l_f}{d_{eq}} \qquad [5]$$

However, Gregory (1999, 2006) used a variation of this definition he termed as the effective aspect ratio, a_{re}:

$$a_{re} = \frac{l_f}{2d_{eq}} \qquad [6]$$

One design constraint in the use of FRS regarding the fiber aspect ratio is that its value needs to be within a reasonable range to prevent premature pullout (i.e. $\square > \square_{min}$) or excessive entanglement and inefficient mixing with the soil (i.e. $\square < \square_{max}$). For example, Zornberg (2004) showed that the number of fibers in a 147 mm diameter triaxial specimen reinforced with 24 mm long, 3620 denier ($\eta = 32$) fibers, at 0.5%wt concentration would equate to approximately 5,000 fibers. However, if the same size specimen were reinforced with 3 denier ($\eta = 1128$) fibers of the same length and concentration, the specimen would need to contain over six million fibers. Additionally, high aspect ratio implies a very thin diameter relative to the length of the fiber (i.e. hair-like, very thin fibers), which may be too thin to effectively engage with the soil particles for proper reinforcement.

4.2.f Comparison of Discrete Models

A summary comparison between discrete models proposed by Zornberg (2002), Gregory (1999, 2006), and Michalowski (2008) is given in **Table 1**.

Table 1. *Comparison of Zornberg (2002), Gregory (1999, 2006), and Michalowski (2008) FRS Models*

	Zornberg (2002)	**Gregory (1999, 2006)**	**Michalowski (2008)**
Embedment Depth	$l_{e,ave} = \frac{l_f}{4}$	$l_{e,ave} = \frac{l_f}{4}$	-
Fiber Orientation	Isotropic	Isotropic	Anisotropy
Suggested Coefficient of Interaction	0.8	0.5	-
Aspect Ratio	$\eta = \frac{l_f}{d}$	$a_{re} = \frac{l_f}{2d}$	$\eta = \frac{l_f}{d}$
Equivalent Cohesion	$c_{eq,p} = (1 + \alpha \cdot \eta \cdot \chi \cdot c_{i,c}) \cdot c$	-	NA
Equivalent Friction Angle	$c_{eq,p} = (1 + \alpha \cdot \eta \cdot \chi \cdot c_{i,\phi}) \cdot \tan\phi$	-	$\sin\phi_a = \frac{R_0}{p} - \frac{Q}{p} cos2\xi$
Change in Cohesion	-	$\Delta\phi_{frs} = \tan^{-1}[a_{re} K_e f_\phi V_r \tan\phi]$	NA
Change in Friction Angle	-	$\Delta c_{frsc} = \tau_{frsc} - \sigma_r(\tan\phi_{frs} - \tan\phi)$	-
Model Type	Discrete	Discrete	Kinematic Limit Analysis
Provision not to run Interface shear tests	□	□	-
Suggested to perform interface shear tests	□	□	-
Applicable to clay soils	□	□	-
Applicable to sandy soils	□	□	□

5.0 – Gregory (1999, 2006) Discrete Model

This section describes the discrete model proposed by Gregory (1999, 2006), and provides some background in order to provide the reader a better understanding of its fundamental assumptions and concepts.

5.1 - Stress on Fibers

According to Gregory (1999, 2006), because a fiber is expected to be randomly oriented with respect to its longitudinal axis, the average normal stress with respect to the longitudinal axis is a combination of the vertical and horizontal stresses. If the fiber has an equal probability of being oriented in any direction, the effective normal stress, with respect to the longitudinal axis, will be the average of the vertical and horizontal stresses (**Figure 10**). Similarly, fibers will be under normal stress conditions with respect to their cross-sectional axis that are an average of the vertical and horizontal stresses.

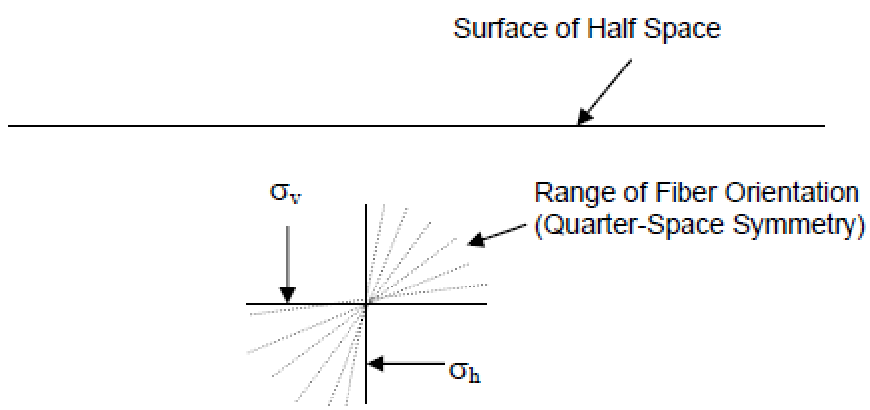

Figure 10. *Range of Potential Fiber Orientations about Fiber's Longitudinal Axis (Gregory 2006)*

Therefore, the combined average stress on an individual fiber with respect to the longitudinal and cross-sectional axes can be expressed as follows:

$$\sigma_{ave} = \frac{\sigma_h + \frac{\sigma_h + \sigma_v}{2}}{2} = \frac{3\sigma_h + \sigma_v}{4} \quad [7]$$

For geostatic stress conditions, where K_o is the at-rest earth pressure:

$$\sigma_h = K_0\sigma_v \qquad [8]$$

substitution yields:

$$\sigma_{ave} = \left(\frac{3K_0\sigma_v+\sigma_v}{4}\right) = \frac{\sigma_v(3K_0+1)}{4} = \sigma_v(0.75K_0 + 0.25) = \sigma_v K_e \qquad [9]$$

where K_e is the stress variable for fibers:

$$K_e = 0.75K_0 + 0.25 \qquad [10]$$

As discussed in **Section 4.2a**, a critical confining stress exists below which fibers slip during deformation of the soil mass and beyond which the fibers will yield or break. Considering practical fiber lengths, cross sectional areas, and tensile strength, an extremely tall embankment would be required to reach the critical confining stress. As a result, the failure mechanism for FRS will be pullout of the fibers under most practical conditions (Maher and Gray 1990, Zornberg 2002, Gregory 1999, 2006, Michlowski 2008).

5.2 - Increase in Frictional Shear Strength Due to Fibers ($\Delta\phi_{frs}$)

Gregory (1999, 2006) proposed the following equations to calculate the anticipated increase in frictional ($\Delta\phi_{frs}$) and cohesive (Δc_{frs}) shear strength components due to the addition of fibers:

$$\Delta\phi_{frs} = tan^{-1}(a_{re}K_e f_\phi V_r tan\phi) \qquad [11]$$

where:

f_ϕ = interaction coefficient related to frictional component of shear strength

V_r = ratio of fiber volume to total volume of unit mass of FRS

and

$$\tau_{frsc} = a_{re} f_c V_r c \quad [12]$$

where:

τ_{frsc} = Apparent increase in cohesive shear strength due to fiber when $\Delta\phi_{frs} = 0$

f_c = interaction coefficient related to the cohesive component of the shear strength

c = cohesion of raw soil

In Equation 11, it is assumed that there is no increase in ϕ due to the addition of fibers. Based on laboratory research by Gregory (2006) this is not the case for the vast majority of shear test results. Therefore, the increase in cohesion calculated by the above equation should be reduced by the magnitude implied by the increase in ϕ for the fiber reinforced case. So, the above equation may be referred to as the “uncorrected cohesion”. The corrected increase in cohesion due to fibers may be calculated by (**Figure 11**):

$$\Delta c_{frs} = \tau_{frs} - \sigma_r(tan\phi_{frs} - tan\phi) \quad [13]$$

where:

σ_r = Normal stress value at which the cohesion correction factor is calculated

tan ϕ = tangent of the non-reinforced ϕ value

c = non-reinforced cohesion value

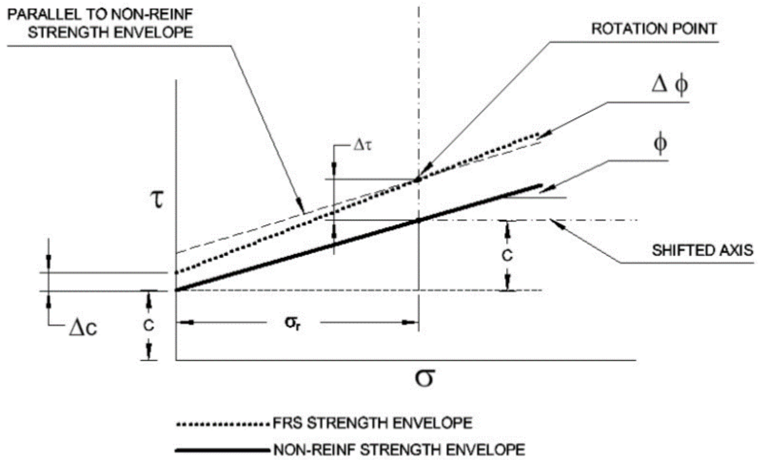

Figure 11. *Rotation Point in FRS Strength Envelope (Gregory 2006)*

5.3 - Decay Functions

Based on the equations presented in the preceding sections it can be seen that it appears mathematically as though the strength can increase infinitely with increasing fiber content. However, this is not the case. As the fiber content increases there is increasing contact of fiber to fiber rather than fiber to soil. Therefore, since the interaction coefficient of fiber to fiber is much less than fiber to soil, a decay function is necessary. Based on the testing of a fat clay and silty sand, Gregory (2006) suggested the following:

Observing **Figure 12**, the percent decrease in interaction between fibers and soil particles decreases with increasing fiber content. Therefore, the reduction factors are a critical aspect of calculating accurate values of Δc_{frs} and $\Delta \phi_{frs}$ at higher fiber contents.

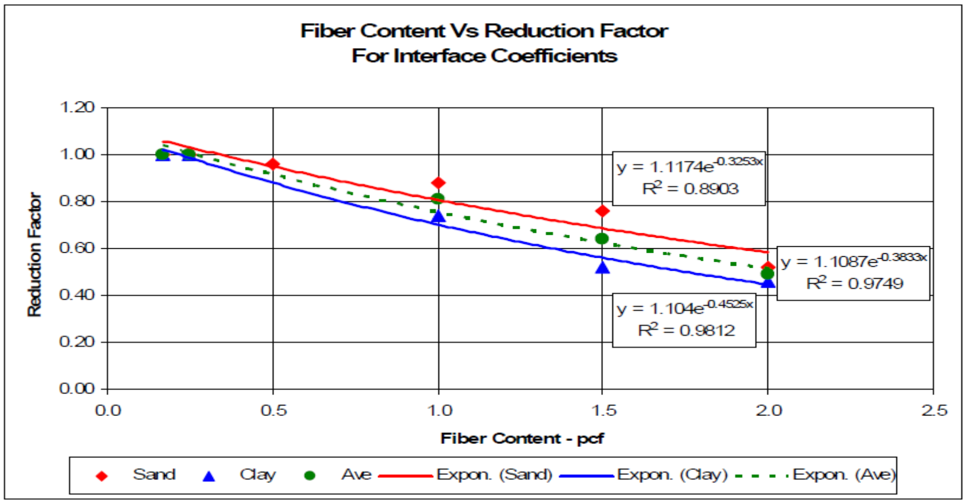

Figure 12. *Fiber Content vs. Reduction Factor for Interface Coefficients (Gregory 2006)*

6.0 Design Charts & Practical Application of Discrete Models

In the past, before discrete models were developed for FRS, extensive testing was required to determine application rates of FRS to a soil or if it was even practical. Tests typically involved time-consuming triaxial testing, however direct shear was also used extensively for the same purpose. These time-consuming and expensive tests potentially discouraged the use of FRS (Zornberg 2002). Now, however, discrete models exist for the application of FRS just as for planar reinforcement such as geotextiles and geogrids.

With these discrete models, an engineer can create spreadsheets to easily calculate different properties of interest and create design charts, examples of which are given in the following section.

6.1 – Design Charts and Graphs

Based on the available discrete models, a series of design charts can be developed to help determine a starting point/application rate for fibers (lb/yd^3) for use in slope stability analysis. **Figure 13** and **Figure 14** show example design charts and graphs for 2-inch long, 360-denier fibrillated polypropylene fibers developed by Gregory (2000) (note that longer fibers are now recommended to achieve larger aspect ratio):

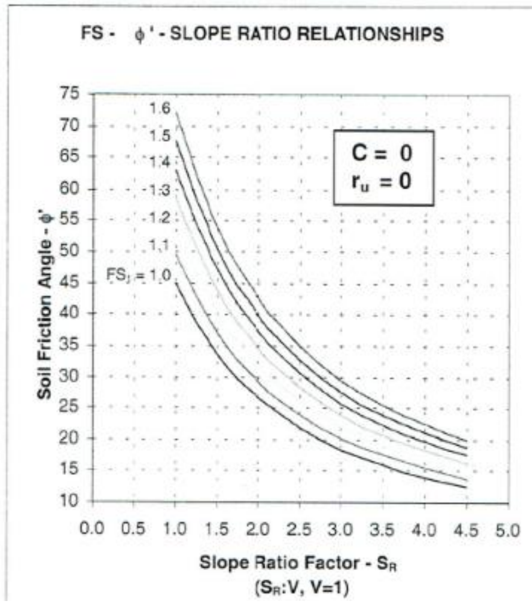

Figure 13. *Slope Ratio Factor vs. Effective Soil Friction Angle - No Pore Pressure (Gregory 2000)*

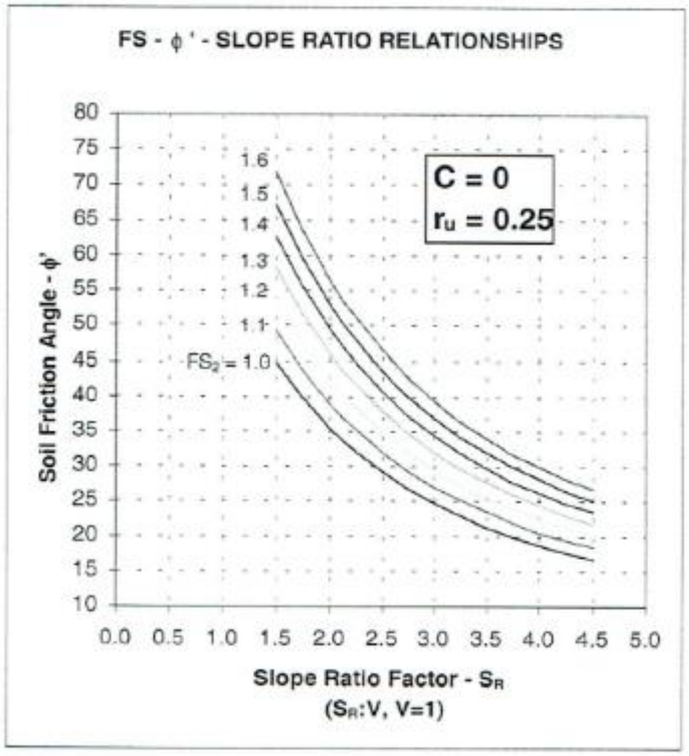

Figure 14. *Slope Ratio Factor vs. Friction Angle - 50% Saturation (Gregory 2000)*

The above charts were meant to be used as an easy guide to aid in the preliminary design of FRS slopes. They are, however, considered somewhat outdated in light of more recent analysis (Gregory 2006), and are only provided herein as an example of the potential ease of use the discrete models provide a design engineer. The above graphs were used in a simple three-step process as described below:

Step 1, determine the effective friction angle of the non-reinforced fill soil, its moist unit weight, slope ratio factor (defined below), slope height, average thickness of the FRS zone, length of the slope face in height and parallel to the crest, required factors of safety in dry condition and for 50% saturation (r_u = 0.25). The slope ratio factor is essentially a normalized way of describing the slope. For example, 2:1, or 3.3:1 (i.e. the vertical component is set at 1).

Step 2 involves determining the required ϕ' of the FRS. This is accomplished by using **Figure 13** for the case when saturation is 0 (r_u = 0). Select the slope ratio factor on the graph's x-axis and project upward until the desired/required factor of safety is intercepted. Then, project horizontally to the y-axis and read the corresponding value. Record this value as FS1. Next use **Figure 14** do the same for the 50% saturation case (r_u = 0.25), and record this value as FS2. The larger corresponding ϕ' for the two values, FS1 or FS2 is the required ϕ' for FRS.

Step 3 is the final step to determine the application rate. Find the ϕ' of the unreinforced fill on the y-axis of **Figure 15**. Then, follow the line outwards from the y-axis until it crosses the horizontal axis corresponding to the ϕ' of the FRS determined in Step 2. From here, project downward to the x-axis for an application rate.

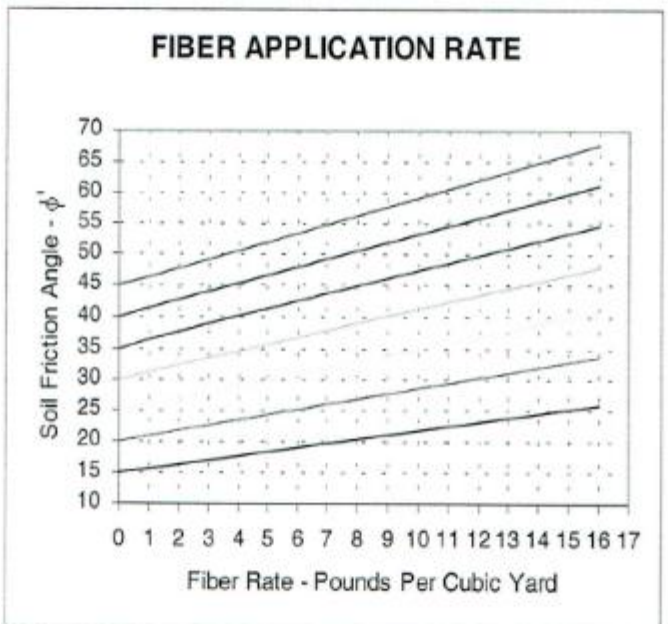

Figure 15. *Fiber Rate vs. Friction Angle (Gregory 2000)*

Similar charts to those shown in **Figure 13** through **Figure 15** can easily be developed by an engineer to aid in the analysis or design of an FRS slope. For example, these types of graphs can be created in a spreadsheet for a variety of fiber types available to the engineer in his/her specific market or region. Then, instead of blindly starting with a ‘best guess’ as to an application rate, these types of graphs can be used to determine an accurate starting point for use in slope stability analysis. If the factor of safety was determined to be too high or low, it can be adjusted accordingly. Given enough experience, such graphs can be useful in emergency situations where there is not enough time to perform laboratory testing and extensive analysis. An engineer may then be able to make a fast decision, using these graphs, based on their experience of the geology, soil types, and use of FRS.

6.2 – Parametric Graphs and Tables

Using Gregory's 2006 model, the authors have created a series of parametric charts and graphs comparing a variety of combinations of soil and fiber parameters. A sample is provided below (Note that the application rate used in **Figure 16** through **Figure 19** is 2.82 kg/m^3 or equivalently, 0.176 pcf, which is on the lower limit of practical application rates):

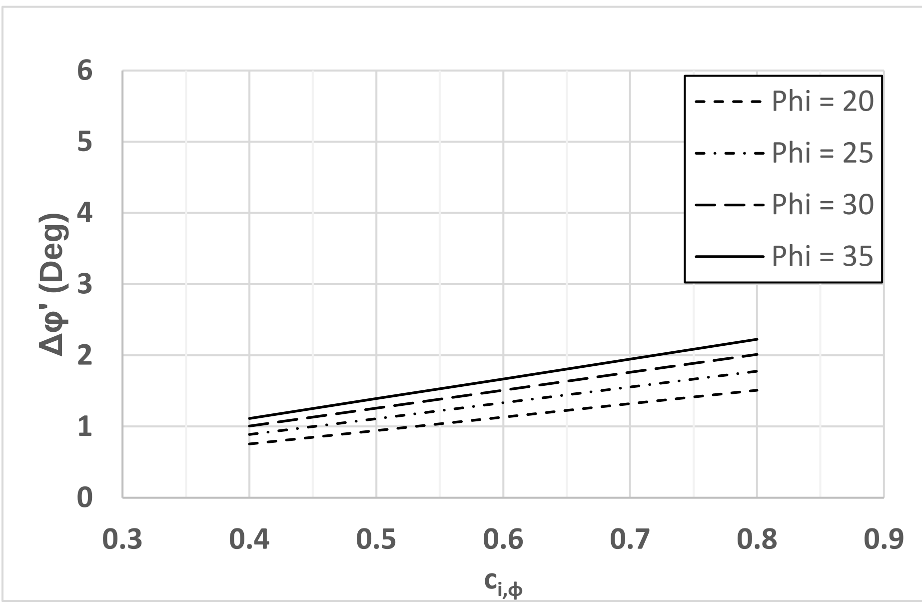

Figure 16. *Friction Interaction Coefficient vs. Change in Friction Angle for a Range of Practical Phi Values*

The value of such parametric graphs should be apparent. For example, a failed slope may need to be repaired back to its original dimensions due to right-of-way acquisition costs. After analyzing the previous slope's failure mechanisms and determining necessary information such as slip plane, one may back calculate a necessary friction angle and/or cohesion required for a desired factor of safety.

Knowing the types of FRS fiber products that are available on the market, the engineer can use **Figure 17** or **Figure 18** and easily determine candidate products that can provide the required increase in friction and/or cohesion for a desired level of stability.

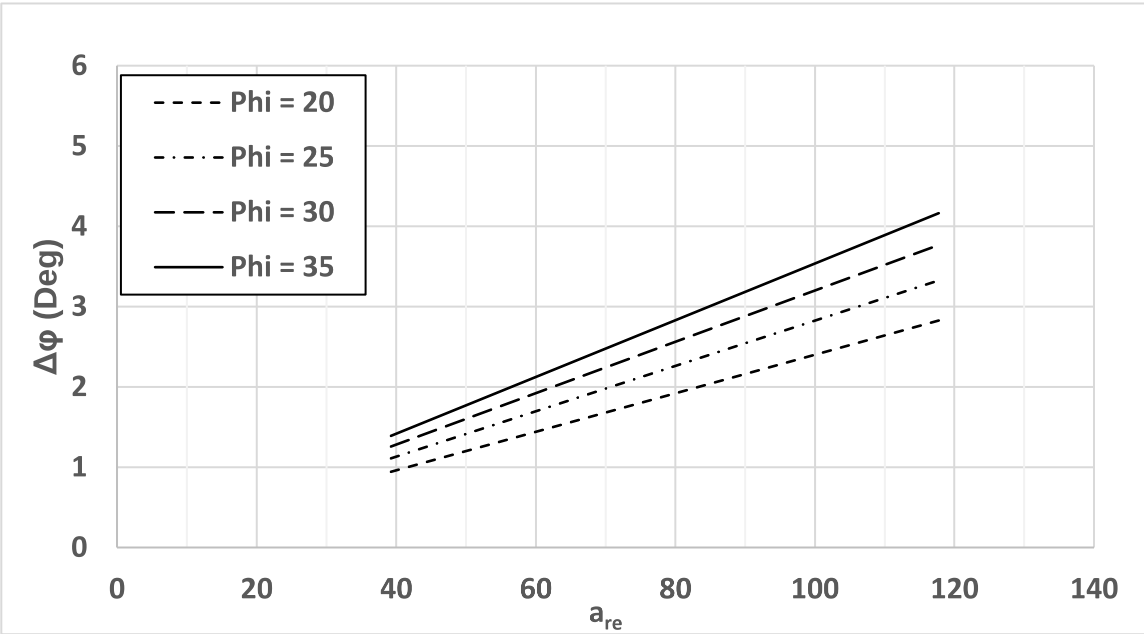

Figure 17. *Effective Aspect Ratio vs. Change in Friction Angle*

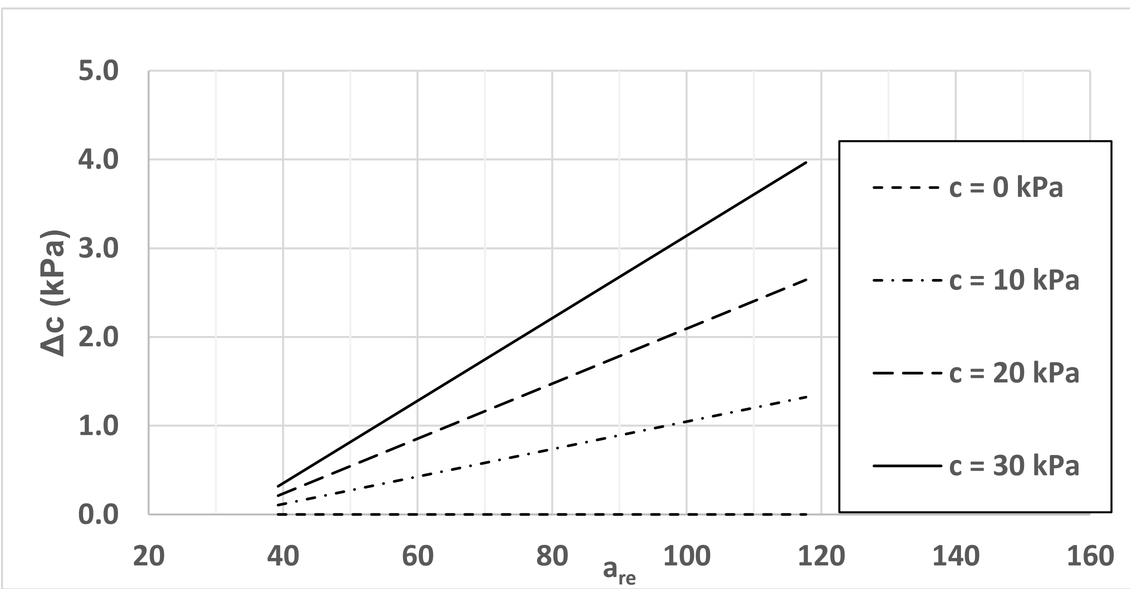

Figure 18. *Change in Cohesion vs. Effective Aspect Ratio*

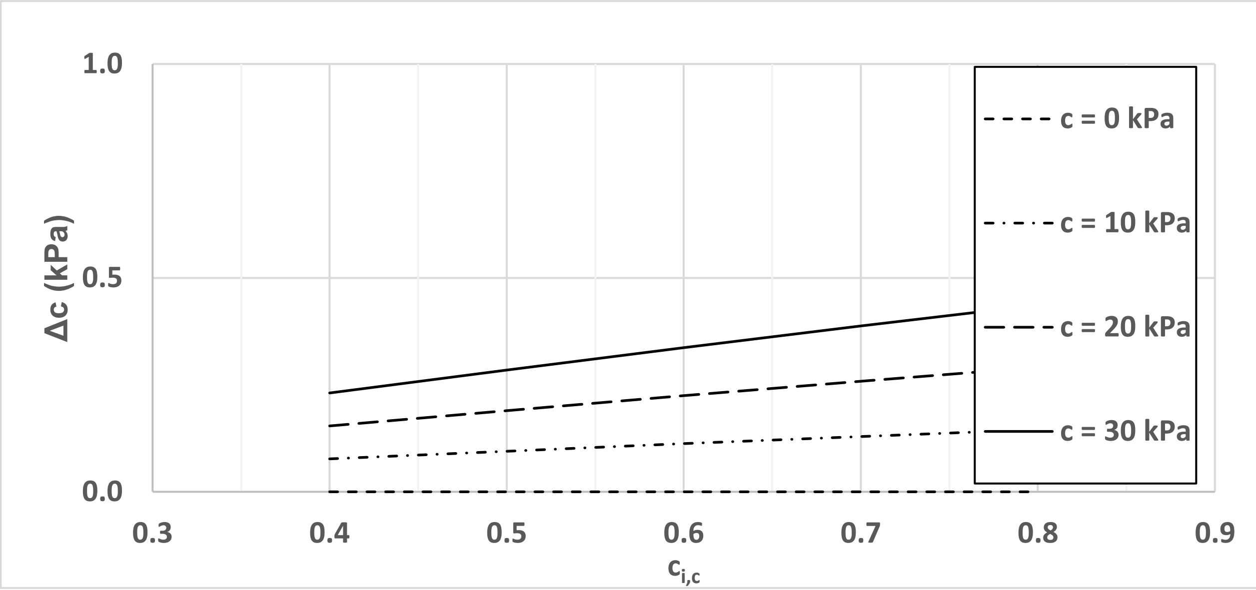

Figure 19. *Cohesion Interaction Coefficient vs. Change in Cohesion (For Phi'=30)*

7.0 Slope Stability Analysis Programs

7.1 – Slope Stability Analysis Using Existing Computer Programs

Analysis of FRS slopes can be accomplished using readily available slope stability computer software for limit equilibrium analysis. A relatively simple spreadsheet can be developed for calculating the FRS ϕ. and c using the equations previously presented. The FRS φ and c values can then be input into the slope stability program's model representing the areas stabilized with FRS, and the analysis can proceed as usual. In other words, the FRS region in the model would be assumed as an individual soil type with enhanced strength properties relative to those of unreinforced soil. Since the unreinforced soil parameters need to be determined by laboratory testing or estimating from previous experience with the same soils, there is no difference in requirements for the slope stability analysis, except for calculating the FRS strength parameters using the conceptual model. With the conceptual models, several different fiber contents and fiber types can be evaluated with slope stability software until the required factor of safety (FS) is achieved in the analysis.

7.2 – Slope Stability Analysis Using Computer Programs with FRS Options

As an alternative to the use of commonly available slope stability programs in conjunction with separate spreadsheet calculations of FRS properties, computer programs with built-in FRS models can be used to obtain the required fiber content and other FRS properties to obtain a desired FS value more directly and in reduced time. Gregory (2005-2018) developed a general slope stability analysis computer program GEOSTASE®, which includes an FRS model. The program also includes a user-friendly GUI (graphical user interface) that allows all the input values to be entered in an interactive manner using dialog menus for all input items. The FRS and unreinforced soil properties for the various zones in the slope are directly entered as input into the program, and the program internally calculates the FRS properties and uses them in the stability analysis. The program can also accommodate FRS in combination with fully-softened shear strengths using a power-curve function. Examples of the program output are included in **Appendix C** for the case history projects discussed in **Section 8.0**.

8.0 Case Studies

In this section, two different case studies are described in detail that demonstrate the use of FRS and corresponding slope stability analyses in both repair (Section 8.1) and preventive (Section 8.2) applications in highway projects. Further details related to these projects are reported by Gregory (2006).

8.1 - Lake Ridge Parkway Slope Repair Project (Case Study #1)

8.1.a - Project Description

This project is located along Joe Pool Lake in the city of Grand Prairie, Texas. The existing embankment slopes had been constructed by the US Army Corps of Engineers in about 1980 to raise the roadway level above the proposed normal pool level of Joe Pool Lake, which was under construction. This project is also located within residual soils of the Eagle Ford Shale geologic formation. The slopes were constructed using a fat clay soil with a side slope ratio of 3, and heights ranging from about 10 to 25 feet (3 to 7.6 m). Within about 5 to 8 years after construction, the embankment slopes began to experience shallow slope failures.

The City of Grand Prairie (owner of the roadway) began performing minor slope repair maintenance on the roadway slopes. By 2003, the slope failures had become progressive and had slightly damaged a portion of the roadway pavement. Approximately 2,000 linear feet (600 m) of one lane adjacent to the slope had to be shut down and barricaded to traffic. Dr. Gregory was retained to perform a geotechnical study and work with the project design team to develop a repair method for the slopes. The total length of distressed slope was in excess of 6,700 linear feet (2,000 m).

8.1.b - FRS Application in the Project

After evaluating several alternatives, FRS was selected as the repair method for the slopes. Eight soil borings were performed and 4 inclinometers were installed to help locate the depth to the failure surface. The borings were sampled continuously, and all soil samples were retained following laboratory testing for the geotechnical study. The City elected to repair about 3,700 linear feet of the most distressed slopes in the first phase of the repairs, and to follow with another phase within one or two years. An application rate of 6.75 pounds per cubic yard (4 kg/m^3) was used on the project. Approximately 365,000 pounds (166,000 kilograms) of fibers were used on the project, making it the second largest volume of FRS used on an earthwork project at that time. Considering both Phases I and II, this project was the largest application of FRS known to date.

8.1.c - Laboratory and In-Situ Testing of Soils and FRS

A series of laboratory tests was performed during the design phase of the project to establish shear strength and index properties of the project soils. During construction, fiber content testing was performed as is described later for the PGBT project (Case Study #2). The clay soil for laboratory testing was taken from the unused soil from the borings. Additionally, six Shelby tube samples were obtained of the FRS during construction to determine their material properties. The Shelby tube samples were obtained from FRS after compaction in the embankment. The samples were brought to the laboratory and six specimens were trimmed from the samples for triaxial shear testing. These tests were performed as a means to illustrate that FRS can be tested for shear strength during construction in the same general manner that the other triaxial

Figure 20. *Dissected Field Specimen Following Triaxial Test (Gregory2006)*

tests were performed for this study. The test results on the field specimens are included in **Appendix A**. One of the dissected field specimens following testing is shown in **Figure 20**. **Figure 21** and **Figure 22** show photographs of the mixer (custom fabricated from a drill press) used to process the FRS field specimens into slurry prior to sieving, and of the sieving process to determine fiber content, respectively.

Note that the fibers in the field samples are black in color due to their carbon black content for ultra violet protection during construction. However, the fibers used in the laboratory testing were opaque without the carbon black additive. The carbon black does not change the fiber strength properties as demonstrated by fiber material properties tests performed by the manufacturers on both carbon-black treated and non-treated polypropylene material (Gregory 2006).

Figure 21. *Mixer for Processing Fiber-Soil Specimen into Slurry (Gregory 2006)*

Figure 22. *Sieving of Slurry to Extract Fibers (Gregory 2006)*

<u>8.1.d - Slope Stability Analyses</u>

Gregory (2006) carried out a series of slope stability analyses during the design of Phase I of the project, and later for Phase II. Selected slope stability analysis results for the tallest section in Phase II are included for illustration purposes in this report. The analyses were performed for the initial condition of the slope profile without any reinforcement, and with FRS in the appropriate zones for the repaired slope to illustrate how the use of FRS significantly increased the FS. These analyses include a wide range of conditions and illustrate the practical use of FRS in embankment stabilization for previously-failing slopes. The results of the analyses are presented on **Plates C.1** through **C.10** in **Appendix C**, and a summary table of various conditions analyzed is presented on **Plate CS.1**. The analyses show unacceptable factors of safety (FS) for all conditions for the cases of non-reinforced slopes. The analyses also show acceptable FS values for all repaired conditions using FRS.

8.1.e Project Performance

Construction of the slope repairs with FRS was completed in September 2005 for Phase I, and in early 2008 for Phase II. The slopes have performed well to date, including during a 100-year flood event and subsequent rapid drawdown conditions. Photographs of the initial slope failure along the roadway are presented in **Figure 23** through **Figure 25**. Photographs of the FRS construction and the completed embankment are presented in **Figure 26** through **Figure 30**.

Figure 23. *Slope Failure on Lake Ridge Parkway (Gregory 2006)*

Figure 24. *Slope Failure at Roadway Edge - Lake Ridge Parkway (Gregory 2006)*

Figure 25. *Slope Failure Scarp at Roadway's Edge - Lake Ridge Parkway (Gregory 2006)*

Figure 26. *Partially Used Fiber Supply Bag - Lake Ridge Parkway (Gregory 2006)*

Figure 27. *Initial Excavation for FRS Slope Repair - Lake Ridge Parkway (Gregory 2006)*

Figure 28. *View of FRS Being Installed In Lifts - Lake Ridge Parkway (Gregory 2006)*

Figure 29. *Down-Slope View of Completed FRS Embankment Prior to Grass Establishment - Lake Ridge Parkway (Gregory 2006)*

Figure 30. *Up-Slope View of Completed FRS Slope Prior to Grass Establishment (Existing Soil-Cement in Foreground) - Lake Ridge Parkway (Gregory 2006)*

8.1.f – FRS Slope Analysis Using Curved Strength Envelopes

Current practice for stability analysis of slopes typically involves soil shear strength properties based on a linear Mohr-Coulomb failure surface. However, more accurate slope stability analysis involving fully-softened clay soils (e.g. as a result of repeated wetting and drying cycles) needs to include a stress-dependent (curved) strength envelope. One common nonlinear model is the power-curve equation in the form:

$$\tau = aP_a\left(\frac{\sigma'}{P_a}\right)^b$$

Where: τ = Shear strength

a and b = Power curve coefficients

σ' = Effective normal stress

P_a = Atmospheric pressure in the same units as the stress

The atmospheric pressure has been included to make the power curve coefficients non-dimensional. Note that when the power curve coefficients are dimensional, the P_a value should be set equal to 1.

When using a slope stability software program that does not include an FRS model, but does include a power curve strength envelope, the FRS can be included by modifying the power curve coefficients as explained below:

- Calculate the increase in the frictional shear strength parameter ($\Delta\phi_{frs}$) using the FRS calculation spreadsheet provided as part of this study (**Appendix B**). Then, obtain the value tan $\square_{rs}$ and multiply it by the normal stress for each point. Only the frictional component (not cohesion) is required when using the power curves since the function curves through zero at the origin (cohesion = 0 at the origin).
- Use a spreadsheet to generate a power curve fit to points calculated from correlations based on the soil index properties (i.e. liquid limit and clay-size fraction), or from laboratory test points on fully-softened soil specimens. This is illustrated as “Non-FRS Power Curve” in the spreadsheet graph presented in **Figure 31**. The power curve incorporating the FRS strength is denoted as “+FRS” in the same figure. The equations displayed on the graph contain the “a” and “b” coefficients in the power curve. In this example, the non-FRS coefficients are a = 0.7741 and b = 0.8852, and the +FRS coefficients are a = 0.8059 and b = 0.9033. Use the +FRS coefficients in the slope stability instead of the non-FRS points and the effect of the FRS will be included in the power curve representation of the soil shear strength.

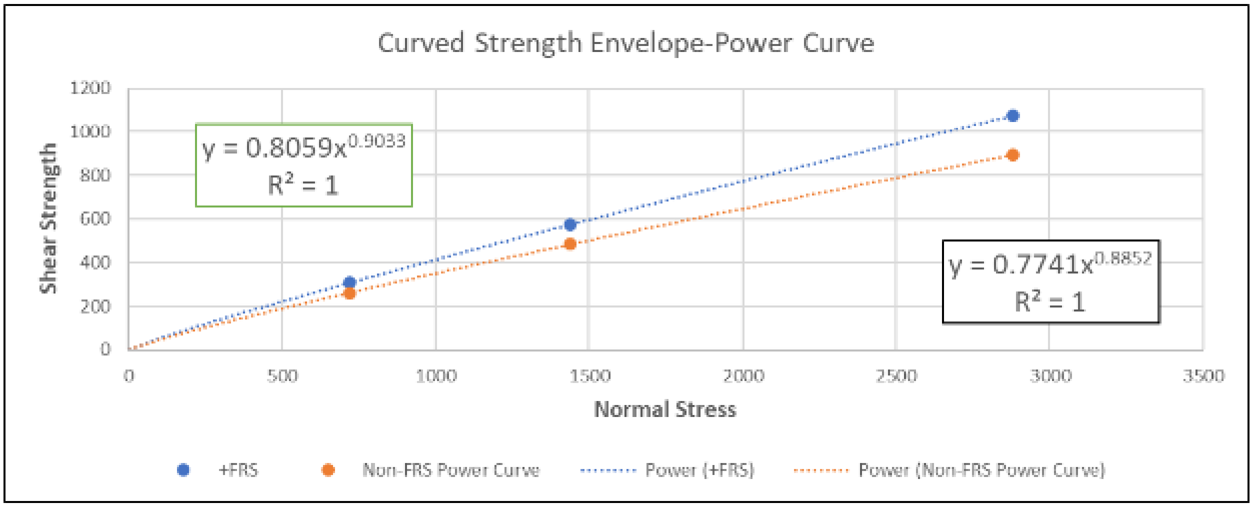

Figure 31. *Illustration of Graph to Calculate Power Curve Coefficients (Gregory 2006)*

Use of this method of incorporating a curved strength envelope in FRS slope stability analyses is illustrated on slope stability analysis **Plates C.2** and **C.2A** in **Appendix C**. The slope stability software program GEOSTASE® (Gregory 2017) includes both the curved strength envelope and the FRS model, and hence, the user can select these options in combination in the analysis. The analysis on **Plate C.2** was produced using these options. The method of calculating revised power curve coefficients described above was then used and implemented in the analyses shown on **Plate C.2A**. Note that the two analyses produce identical results for FS to 3 decimal places. This demonstrates that a slope stability program that has the option of representing a curve strength envelope with a power curve, but does not have an FRS function can still be efficiently used to include a curved strength envelope for FRS regions of the slope model.

8.2 – President George Bush Turnpike (Case Study #2)

8.2.a – Project Description

The PGBT (President George Bush Turnpike) project is named after the first President Bush and is located in the Dallas/Fort Worth (DFW), Texas area. It is a multi-segment, 6-lane toll road that was constructed during the 2002-2005 period. The project was intended to help relieve some of the ever-increasing vehicle traffic in the DFW area. Gregory (2006) was involved as a consultant for a 6-mile long north-south segment that is in the Farmers-Branch and Carrollton, Texas areas during the 2002 – 2005 period. The project involved a large element of subsurface stabilization of problematic soil areas on which Gregory performed the geotechnical design. The project also involved a large amount of soil embankment construction with embankment heights ranging from approximately 15 feet to over 35 feet. The project is located within the Eagle Ford Shale geologic formation, with residual soils consisting largely of highly expansive fat clays. These clay soils were essentially the only earth fill material available at affordable cost for construction of the embankments. These soils are known to experience widespread shallow slope failures within a few years after embankment construction for slopes about 15 feet (4.6 m) or more in height with slope ratios of 4 (4-horizontal to 1-vertical) or steeper. Once these shallow failures begin, they are very expensive and inconvenient to repair on an active highway. If not repaired in a timely manner, the failures become progressive and soon impact the shoulder and roadway pavements.

8.2.b – FRS Application in the PGBT Project

Gregory recommended the use of FRS in the top 6 feet (1.8 m) of the side slopes as a preventive maintenance measure to significantly reduce the potential for the shallow slope failures following construction of the embankments. The recommendation included all slopes that were 15.5 feet (4.7 m) in height or taller and that had slope ratios of 4 or steeper. A portion of the project also included geogrid reinforcement of an embankment area that had to be constructed with a slope ratio of approximately 2 to prevent encroachment onto an adjacent closed landfill site. Gregory also recommended FRS as secondary reinforcement between the geogrid layers in that area. The Owner accepted these recommendations. The portion of the project that included FRS as secondary reinforcement between the geogrid layers is not included as part of this case study.

Gregory originally (circa 2000) performed slope stability analyses to determine the fiber application rate based on an earlier, less complete conceptual model. However, since he was aware that the model was not fully developed, he adopted a conservative approach in his design. The slope stability was re-evaluated as part of the current case study using a newly developed model and a significantly updated version of the slope stability software, as discussed in the next section. The FRS volume in this project was originally the largest known use of FRS in an earthwork project. However, the Lakeridge Parkway Case Study-1 Project (including Phases I and II) later became the largest project at approximately 530,000 pounds (240,400 kilograms) of fiber used in the project. In comparison, approximately 520,000 pounds (236,000 kilograms) of fibers were used in the PGBT project at an application rate of 6 pounds per cubic yard (3.6 kilograms per m^3). Photographs of the FRS construction on the PGBT project are included in **Figure 32** and **Figure 33**.

Figure 32. *Spreading FRS Fibers in PGBT Project (Gregory 2006)*

Figure 33. *Mixing FRS on PGBT Project (Gregory 2006)*

8.2.c – Slope Stability Analyses

Gregory performed extensive slope stability analyses as part of the original design of the PGBT project. As part of the current study, Gregory (2017b) used a modified version of the slope stability computer program that includes the new model for FRS and is also capable of performing analyses with curved strength envelopes and FRS combined. The slope stability analysis output for the PGBT project is included in **Appendix C**, on **Plates C.11** through **C.13**. The output includes graphics of the slope profile and text data and description. The current analyses show that the slopes as designed meet or exceed the target FS values. The analyses were performed for the new slope profile both without any reinforcement, and with FRS in the appropriate zones to illustrate how the use of FRS significantly increased the FS. The actual analyses originally performed for the project included numerous other computer runs for various conditions. However, since the analyses performed in the current study were to illustrate the use of FRS, only comparative analyses with and without FRS are included. The analyses are for the shallow slope zone (veneer) as shown on **Plates C.11** through **C.13**. The calculated FS for the veneer without the FRS is approximately 1.066 (**Plate C.11**), which equates to a stress ratio of approximately 0.94 (reciprocal of the FS). This stress ratio is well above the potential creep failure threshold of about 0.7 for clay slopes (Sowers 1974, 1984). The FRS veneer has a calculated FS of approximately

1.546 (**Plate C.12**), which equates to a stress ratio of approximately 0.65, comfortably below the 0.7 threshold. Project criteria for FS values and conditions are shown on summary **Plate CS.2**.

8.2.d – Project Related Testing

An extensive laboratory testing program was carried out during the design phase of the project to establish the standard properties of site soils. This information was used during design of the FRS portion of the project. During construction of the FRS, Gregory performed periodic testing of FRS to help verify compliance with respect to the fiber application rate. The test procedure involved processing the FRS specimens obtained from the field through a sieve to determine the fiber content of each specimen. This process was discussed in more detail in **Section 8.1**.

8.2.e – Project Performance

Embankment construction in the FRS areas was completed in late 2004. To the best of the authors' knowledge, the embankments have performed well since, covering a period of more than 13 years after construction.

9.0 Laboratory Procedures and Testing

In laboratory testing of FRS samples, specimen preparation is of utmost importance. Gregory (2006) reported that taking specimens for testing from a large batch of FRS resulted in considerable variation in the amount of fibers in each specimen and the test results. Therefore, it is recommended that each of the FRS specimens with a target fiber content should be prepared individually before testing, as described in the following sections.

9.1 - Specimen Preparation Prior to Compaction

9.1.a – General methodology

Previous research and project testing of FRS has consisted of specimen preparation by mixing "batches" of soil from the bulk sample in sufficient quantity to produce 4 to 6 individual specimens (AGT Laboratory 1999; Fugro McClelland

1997a,b). The fiber content was added to the batch based on the weight of the entire batch and then mixed in a large mixer. Individual specimens were then hand grabbed from the batch. This procedure, although carefully controlled, was later found to produce considerable variation in the amount of fibers actually contained in each individual specimen, and in its moisture content. As a result, a different method of specimen preparation was developed for Gregory's study (2006) as described below.

9.1.b - Moisture and Weight Preparation

Each specimen should be prepared individually rather than by the batch method. Each specimen should be weighed to determine a target moisture content and a small additional amount over the exact required weight for an anticipated moisture loss. The specimens should be placed in individual sealed bags and the hydroscopic moisture content determined from specimens taken from each bag by obtaining a composite mixture from three places in the bag. Typical specimens are shown in **Figure 34**.

Figure 34. *Clay Specimens Prior to Hydration (Gregory 2006)*

Moisture contents should be determined in general accordance with ASTM D 2216. Once hydroscopic moisture contents have been determined for each bag, the specimens should be individually mixed with the exact amount of water required to bring the specimen to the target moisture content (optimum per ASTM D 698). The specimens should be hydrated in the sealed bags for a minimum of 36 hours to allow for uniform distribution of the moisture. Following hydration, the final specimen quantity can be obtained by carefully weighing the exact amount of moist soil required for the compacted specimen size. For non-reinforced specimens, the soil can be sealed in a new plastic bag and labeled with the specimen number. For FRS specimens, the fibers can be mixed into the specimen prior to placing in the new bag as described in the following section.

9.1.c -FRS Mixing

The fibers should be weighed to the exact amount for each specimen and placed in labeled plastic bags for each specimen prior to the mixing stage. The fibers can be mixed into each individual specimen by hand. The small quantity involved in mixing individual specimens makes it impractical to use a mixer. The soil may be spread into a flat mixing pan and the fibers evenly spread over the soil and thoroughly mixed into the soil by hand as illustrated in **Figure 35** through **Figure 38**.

The fibers should be weighed to the exact required amount and placed in labeled

Figure 35. *Spreading Fibers Over Hydrated Clay Soil Specimen (Gregory 2006)*

plastic zip-lock bags prior to the mixing operation. The soil specimen should be spread out over the bottom of the pan to a thickness of approximately 0.75 inches. The fibers can then be spread uniformly over the soil based on visual observation. The fibers can be blended into the soil by hand by repeatedly kneading the soil and fibers as illustrated in **Figure 36** and **Figure 37**. A fine water mist can be applied one or two times during mixing to facilitate bonding of the fibers into the mix. The final FRS mixture is illustrated in **Figure 38**.

Figure 36. *Initial Hand Mixing of FRS Specimen (Gregory 2006)*

Immediately following mixing, the specimen should be carefully placed into a labeled zip-lock bag with the air being pushed out by hand prior to zipping the bag. The specimen should then be placed in storage until the compaction process. Due to the cohesion (stickiness) of the clay soil, segregation of the fibers from the soil should not be a problem during subsequent handling.

Figure 37. *Final Hand Mixing of FRS Specimen (Gregory 2006)*

Figure 38. *Mixed FRS Specimen Ready for Storage or Compaction (Gregory 2006)*

9.2 Compaction of Clay Specimens

9.2.a – Triaxial Shear Specimens

Clay specimens for triaxial shear tests can be compacted in a standard-sized steel mold such as a 2.875-inch (73 mm) diameter by 5.8- inch (147 mm) tall mold. This mold size is one of the standard sizes for triaxial testing and can be selected so that the specimen would be greater in all dimensions than a fiber length of 2 inches (50 mm). The mold and compaction process are illustrated in **Figure 39** through **Figure 42**. The mold should be fitted with a temporary plastic collar mounted on top of the steel collar. The entire loose specimen can then be placed in the mold with a small scoop prior to compaction as illustrated in **Figure 39**. The same procedure may be used for raw soil and FRS.

Figure 39. *Placement of Loose Specimen into Mold (Gregory 2006)*

Figure 40. *Compaction with a Metal Rod (Gregory 2006)*

Figure 41. *Rod Plunged to Near Bottom of Mold during Initial Compaction (Gregory 2006)*

Figure 42. *Finishing Compaction with Piston and Guide Ring (Gregory 2006)*

The plastic collar can be removed and the specimen should then be compacted with multiple strokes of a 0.5-inch (13 mm) diameter metal rod with a rounded tip as illustrated in **Figure 40** and **Figure 41**. The rod is used as a miniature simulation of a tamping-foot (sheep-foot) compaction roller typically used for embankment construction.

The rod also causes the fibers to be randomly oriented in the compacted specimen, rather than being horizontally oriented as would occur if a flat piston or hammer were used for compaction. The rod can be initially plunged numerous times to a depth almost to the bottom of the mold. This is initially possible with a loose specimen. As the specimen becomes partially compacted, the depth of plunge for the rod decreases. This process is repeated until all the soil is well compacted and is below the top of the steel collar. The process is completed by compacting and smoothing the top of the specimen with a steel piston just slightly smaller in diameter than the mold. The piston can be tapped or pressed into the mold until it bottoms out on a guide ring on the piston as illustrated in **Figure 42**. The piston extension below the guide ring should be set to result in a finished specimen height of 5.8 inches (147 mm). These dimensions are chosen due to the fibers being used for the soil. If larger fibers are used, a specimen size should be chosen such that the specimen is larger in all dimensions than the fibers.

Immediately following compaction, the specimen should be carefully extruded from the mold. The dimensional integrity of each specimen should be checked following extrusion with a caliper. The weight of each specimen should have been prepared so that exactly the desired percent of maximum dry density as determined in the Proctor test (ASTM D 698) will be achieved when the entire soil specimen is compacted into the mold to the dimensions discussed above. Accordingly, all specimens should be at exactly the same moisture content and dry density. The variation from the target weight in the compacted specimens should be minimized as much as possible.

9.2.b - Direct Shear Specimens

Clay specimens for the direct shear tests should be prepared in a very similar manner to that described for triaxial specimens. The mold can be configured, for example, to produce a final specimen size of 2.5-inches (64 mm) in diameter by 2.25-inches (57 mm) in height (custom shear box is required). This specimen size, for example, is larger in all dimensions than a 2-inch long fiber. The 2.5-inch (64 mm) diameter is one of the standard sizes for a direct shear box.

Placement in the mold and compaction of the direct shear specimens may be performed in exactly the same manner as for the triaxial specimens except that a different diameter piston may be required for final compaction and smoothing of the specimen's top. The process is shown in **Figure 43** and **Figure 44**.

Figure 43. *Preparation for Compaction of Direct Shear Specimen (Gregory 2006)*

Following compaction, the specimens should be extruded as previously described for the triaxial specimens and dimensional integrity verified with a caliper.

9.2.c - Creep Specimens

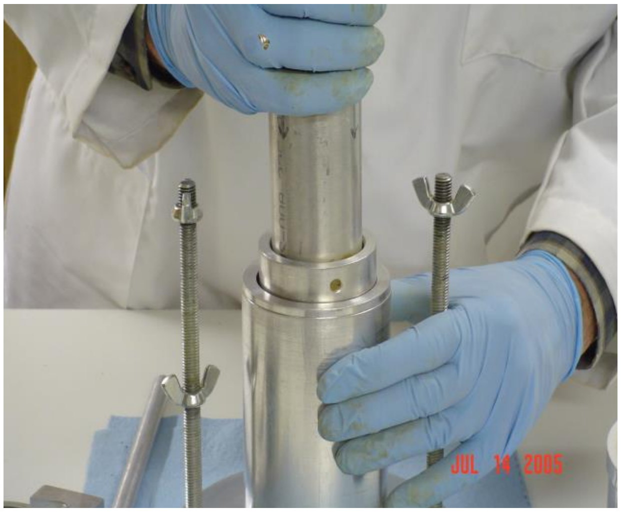

Figure 44. *Completing Compaction of Direct Shear Specimen (Gregory 2006)*

The clay specimens for creep tests may be prepared in exactly the same manner and with the same equipment as described for the direct shear specimens, depending on the size of the specimen. If the same size specimens are used, no modifications should be required in the procedure since the direct shear specimens and creep specimens are the same size.

9.2.d -Storage of Specimens

Following compaction and extrusion, each clay specimen should be double wrapped in plastic cling wrap. Each specimen can then be labeled and placed in a portable cooler or moisture room to maintain uniform moisture. If a portable cooler is used, specimens should be covered with heavy duty paper lab towels, and the towels and inside of the cooler should be sprayed with a water mist sprayer each day. The storage cooler is illustrated in **Figure 45**.

Figure 45. *Clay Specimen Storage Cooler (Gregory 2006)*

9.2.e - Moisture Content Stability during Storage

Moisture content stability of the specimens during storage may be periodically verified by weighing selected specimens. The specimens that have been in storage the longest period of time may be selected for moisture checking each time the verifications are performed. The verification specimens should be removed from the storage cooler, temporarily unwrapped and quickly weighed. The specimen should be sprayed with a light mist of water, rewrapped and immediately placed back in the storage cooler. All specimens should be very stable with respect to moisture content if the procedure is carefully followed. All specimens should be individually checked for moisture content stability by weighing the unwrapped specimen just prior to testing.

9.3 Compaction of Sand Specimens

9.3.a – Triaxial shear Specimens

It is necessary to prepare the sand specimens for the triaxial tests inside the triaxial test membrane just prior to shear testing since the sand will not mold into a specimen that will hold together after compaction without confinement. Therefore, the sand specimens should be compacted inside the membrane in a split mold that also serves as a membrane stretcher. The mold and the compaction operation are shown in **Figure 46**.

Figure 46. *Preparation of Sand Specimen in Split Mold (Gregory 2006)*

For the FRS specimens, the fibers should be added along with the sand during the compaction stage. The entire specimen may be placed in the mold by inserting the fibers as the sand is placed as shown in **Figure 47**. After the entire loose specimen (and fibers for FRS specimens) is placed in the mold, the specimen may be compacted with the metal rod as described for the clay specimens. The mold should be periodically tapped on the sides to help with consolidating the sand by vibration. The top of each specimen should be smoothed and final compaction performed with the steel piston as previously described for the clay. A typical compacted specimen after removal of the split mold is shown in **Figure 48**.

Figure 47. *Addition of Fibers to Sand Specimen during Compaction (Gregory 2006)*

Figure 48. *Compacted Sand Specimen after Removal of Split Mold (Gregory 2006)*

As illustrated in **Figure 47**, the specimens may be prepared directly on the base of the triaxial cell, with the split mold being fitted around the bottom platen of the cell.

This procedure eliminates the need to handle the specimen following compaction and allows the triaxial cell to be assembled around the prepared specimen.

9.3.b - Direct Shear Specimens

The sand specimens for the direct shear tests may also be prepared directly in the assembled shear box as illustrated in **Figure 49**. The fibers should be added as the sand is placed for the FRS specimens as described for the triaxial specimen preparation. This procedure allows the sand specimens to be prepared without subsequent handling outside the shear box.

Figure 49. *Preparation of FRS Sand Specimen in Direct Shear Box (Gregory 2006)*

9.4 - Triaxial Shear Testing – Clay

The triaxial tests on the clay specimens should be performed according to the appropriate standards (e.g. ASTM D2850, D4767, etc.). The choice of whether it should be isotropically consolidated/unconsolidated and/or drained/undrained is based on loading conditions to be experienced in the field. This should be determined by an engineer. Shearing rates, saturation, and all other details are governed by appropriate ASTM standards which should be followed.

9.4.a - Mounting in Triaxial Cell

For each test, the clay specimen may be removed from the storage cooler and the cling wrap should be removed prior to mounting the specimen. Filter papers can be placed between the specimen and the porous stones on each end of the specimen to prevent intrusion of the clay soil into the porous stones. A filter paper “skirt” may be provided on the perimeter of the specimen to facilitate saturation. The membrane can then be placed over the specimen with a membrane stretcher by applying vacuum to hold the membrane to the stretcher tube during placement. An FRS specimen prior to placement of the membrane is shown in **Figure 50**, and a specimen with the membrane and top cap in place is shown in **Figure 51**. Note that two different models of triaxial cells are pictured. However, both cells function basically the same. Following placement of the membrane and top cap, the remainder of the cell may be mounted around the specimen and the cell can be filled with water and the back-pressure lines should be purged of air.

Figure 50. *FRS Specimen Mounted on Base of Triaxial Cell (Gregory 2006)*

Figure 51. *Specimen with Membrane and Top Cap in Place (Gregory 2006)*

9.4.b - Saturation and Consolidation

Saturation and saturation verification of the specimens should be performed in accordance with the applicable ASTM standards. The Skempton "B" parameter is used to check saturation. Typically, a specimen is considered saturated if the B value does not change with increasing the back pressure and the B parameter is greater than or equal to 0.95. A plot of back pressure vs. B value may be made to verify saturation. An example chart with typical sample responses is provided in **Figure 52** (Chaney et al. 1980).

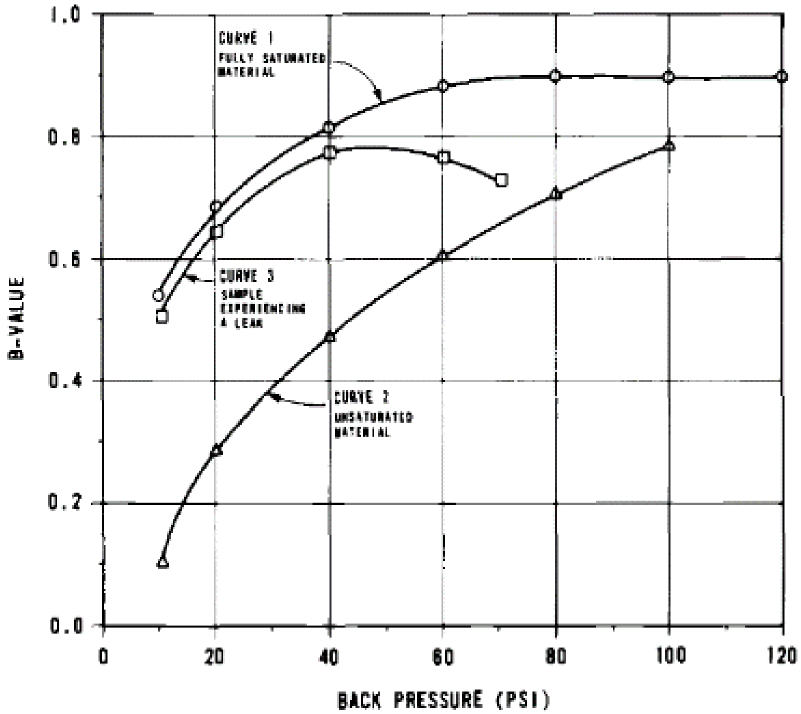

Figure 52. *Back Pressure vs. B Value & Typical Sample Responses (Chaney et al 1979)*

Following saturation the specimen should be consolidated with the desired cell pressure. It is preferable to use a different specimen for each desired consolidating pressure (i.e. not to run a staged test on one specimen). The end of primary consolidation should be verified by monitoring specimen height and change in the panel burette water height until both were stabilized with no additional change. An illustration of the saturation/consolidation stage is presented in **Figure 53**.

Figure 53. *Saturation/Consolidation Stage (Gregory 2006)*

9.4.c - Shear Stage

The specimens should be sheared in a triaxial compression machine that is capable of a very slow shear rate. For example, Gregory (2006) sheared the specimens at a rate of 0.00049 inches (.0125 mm) per minute. A triaxial test on clay during the shear stage is illustrated in **Figure 54**.

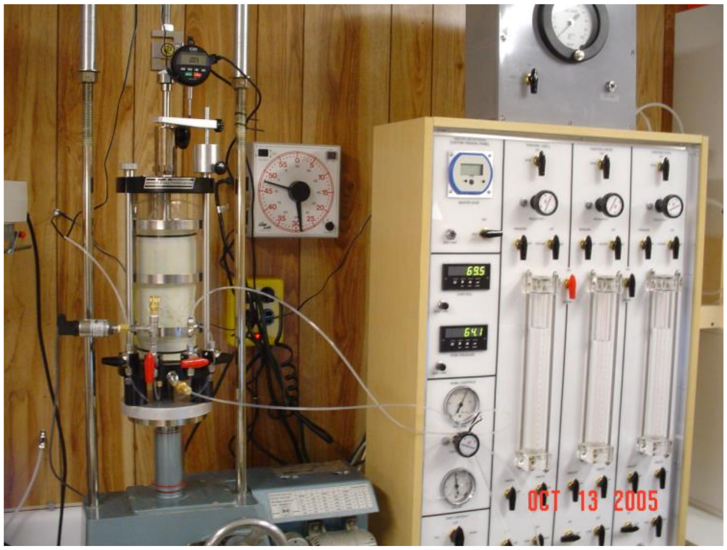

Figure 54. *Shear Stage of Triaxial Test on Clay Specimen (Gregory 2006)*

Upon completion of the shear stage, each specimen should be removed from the cell and membrane and visually examined for failure mode and then dissected to visually observe the interior of the specimen. Typical post-test specimens are shown in **Figure 55** and **Figure 56**. Final moisture contents can be obtained on cuttings from each specimen following completion of the test.

Figure 55. *Clay Triaxial Specimen Following Test (Gregory 2006)*

Figure 56. *Dissected Triaxial Clay Specimen with Exposed Fibers (Gregory 2006)*

9.5 - Direct Shear Tests – Clay

During the study by Gregory (2006), specimens were sheared at a rate of 0.0003 inches (0.0076 mm) per minute to a total deformation of approximately 0.4 inches (10 mm).

<u>9.5.a - Mounting in Direct Shear Box</u>

Each clay specimen should be taken from the storage cooler/moisture room and the cling wrap should be removed prior to mounting. The specimen should be fitted with a filter paper on each end to separate the clay soil from the bronze porous stones. The specimen should be carefully pushed into the shear box with a metal piston with an end cap slightly smaller than the inside diameter of the shear box. The bottom porous stone and filter paper should have already been placed in the bottom of the box. The top filter paper can be in place during placement of the specimen in the box, but the top porous stone should not be placed until the specimen has been pushed into final place. An illustration of mounting a clay specimen in the shear box is presented in **Figure 57**.

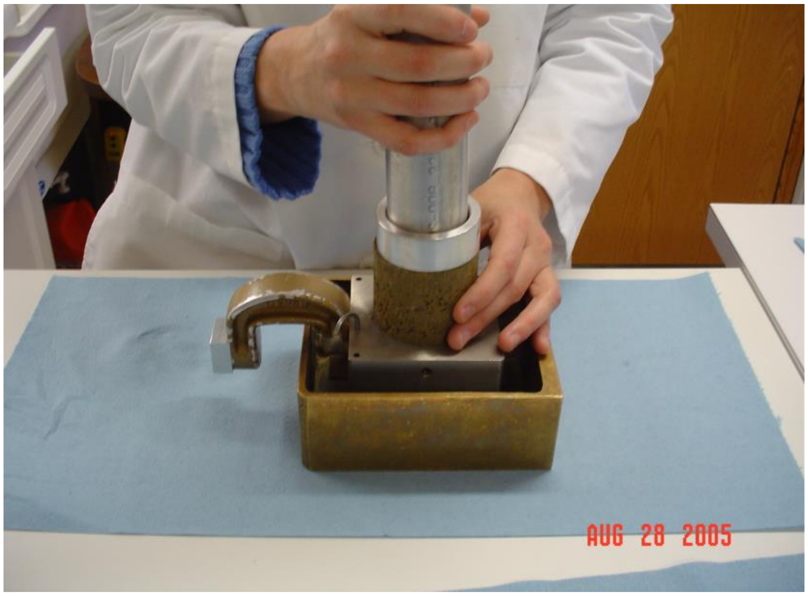

Figure 57. *Mounting Direct Shear Specimen (Gregory 2006)*

After placement of the specimen in the direct shear box, the box can be mounted into the direct shear machine and a seating load applied to the specimen. Distilled water can then be added to the water reservoir around the shear box.

9.5.b - Saturation and Consolidation

In Gregory's tests (2006), specimens were saturated and consolidated at the same time by applying the required normal load while maintaining the water level in the reservoir by adding water several times a day. During a direct shear test full saturation of the specimen cannot be verified because it is not possible to measure pore pressures in the device. Saturation is assumed to have occurred along the shear surface between the top and bottom halves of the shear box by the time the specimen has reached the end of primary consolidation. The end of primary consolidation can be verified by recording readings of the vertical dial indicator until the deformation essentially levels out and becomes stable. The consolidation stage typically requires approximately 24 to 36 hours for the clay specimens. As with triaxial testing, it is recommended to use a separate specimen for each desired normal stress. Normal stress can be applied with a dead weight hanger. This method provides a constant and positive normal loading arrangement and does not have the potential variability or "drift" of an air-applied normal load system.

9.5.c - Shear Stage

It is preferable to shear specimens in a computer-controlled direct shear machine. The shear rate and total deformation values can be entered into the computer interface program that controls the shear machine. The shear rate can be set over a large range of values from very fast to extremely slow. As previously stated, Gregory (2006) performed direct shear testing at the shear rate of 0.0003 inches (0.0076 mm) per minute. Additionally, he programmed the shear machine to shear the specimen to a deformation value of 0.4 inches (10 mm), hold the shear load at that location for 30 seconds, then release the load and return to the zero position at a faster rate.

As discussed, it is preferable to electronically record the shear load using a load cell while the displacement is recorded through the time-displacement rate by the computer. These readings are very precise in the apparatus used for the direct shear testing. During the shear stage, the data can also be displayed in real time on the computer screen as previously described for the triaxial shear data and shown in **Figure 58**. The direct shear test machine is shown in **Figure 59**.

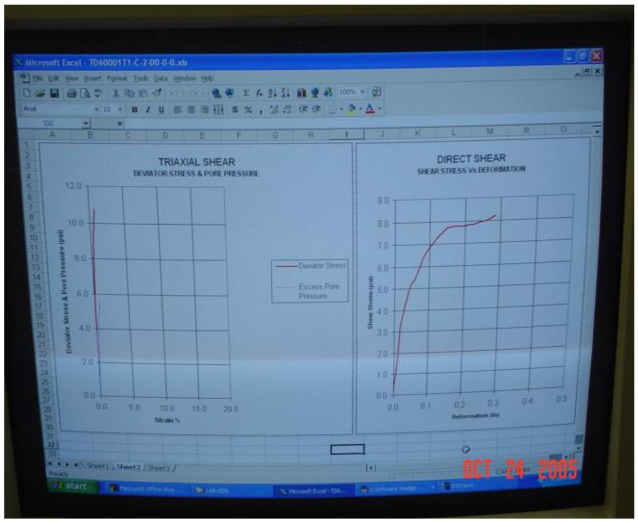

Figure 58. *Test Data Display in Real Time on Computer Screen (Gregory 2006)*

Figure 59. *Computer Controlled Direct Shear Test Machine (Gregory 2006)*

Upon completion of the shear stage, each specimen should be removed from the shear box and the shear plane visually examined. The specimen can then be dissected to visually observe the interior of the specimen. Typical post-test specimens are shown in **Figure 60**. Final moisture contents can then be obtained on cuttings from each specimen following completion of the test.

Figure 60. *Dissected Direct Shear Clay Specimen with Exposed Fibers (Gregory 2006)*

9.6 - Creep Tests – Clay

If desired, creep tests may be performed as well. The creep tests on clay specimens may be performed as constant-load direct shear creep tests. In this test, a constant shear load is applied with dead load weights and a lever-advantage hanger system. This differs from the standard direct shear test in which a constant rate of shear is applied. In Gregory's tests (2006), the normal load was applied in the creep tests with a dead load hanger in a special test device that was designed for creep tests. The laboratory research program described by Gregory (2006) included six creep tests which were performed simultaneously and required fabrication of six creep devices. Schematic design drawings of a direct shear creep test device are given by Gregory (2006).

9.6.a - Mounting in Creep Device

The specimens can be mounted in the creep devices (**Figure 61**) in the same manner as described previously for the standard direct shear tests. This procedure is illustrated in **Figure 62,** and one of the devices with the specimen fully in place is shown in **Figure 63**.

Figure 61. *Direct Shear Creep Devices (Gregory 2006)*

Figure 62. *Mounting Clay Specimen in Creep Device (Gregory 2006)*

Figure 63. *Fully Mounted Creep Specimens with Water in Reservoir (Gregory 2006)*

9.6.b - Saturation and Consolidation

The creep specimens can be saturated and consolidated in the same manner as previously described for the standard direct shear tests. The specimens can be consolidated to any desired normal stress, which simulates the desired overburden pressure. Five to eight feet (1.5 to 2.4 m) overburden pressure is a common depth range for shallow slope failure surfaces in clay slopes. Specimens may reach the end of primary consolidation under the relatively light normal load in about 24 hours.

9.6.c - Creep Shear Stage

Specimens were initially loaded to produce a shear stress of approximately 70 percent of the peak shear strength of the raw soil as determined in the standard direct shear tests. The load can be applied by hanging the appropriate weights on the lever arm of each device. The lever arm of the depicted creep devices has a maximum lever ratio of 17.5 to 1.0. The lever arms can be adjusted to a lever ratio in order to apply the desired stress with the available weights. The 70-percent stress ratio is in the range known to likely cause creep failure in clay slopes if sustained over the long term (Sowers 1979, 1984). The creep tests performed by Gregory (2006) were performed for approximately 23,000 minutes (~16 days) to obtain an indication of the creep behavior of the raw soil compared to the FRS specimens. Additionally, if its desired to determine the shear stress required to fail each specimen, individual specimens may be chosen to load incrementally to failure in small increments.

9.7 - Triaxial Shear Tests – Sand

Triaxial tests on sand specimens should be performed according to appropriate standards. Sand specimens are typically tested in drained condition. The descriptions in the following sections are on Consolidated Drained (CD) tests. Nevertheless, an engineer should be involved in determining the appropriate test type and procedures.

9.7.a - Consolidation and Saturation

The triaxial sand specimens are compacted and mounted in the triaxial cell as discussed in **Section 9.4**. Saturation can be accomplished by connecting a distilled water tank to the bottom drain line of the triaxial cell and applying a vacuum to the top drain line. Saturation may be accomplished while maintaining a cell pressure of 10 psi (67 kPa). Saturation can be confirmed by visual observation of flow of water out the top of the specimen, and by monitoring the volume of water transferred into the specimen. Following saturation, the specimens can be consolidated under the desired cell pressure. Consolidation of the specimens may be achieved almost immediately upon applying the cell pressure.

9.7.b - Shear Stage

The sand specimens may be sheared in a multi-purpose compression machine with digital indicators. The readings can be recorded manually from the digital indicators, which is practical and efficient for short duration tests. A triaxial test setup on sand is shown in **Figure 64**.

Figure 64. *Triaxial Test on Sand Specimen (Gregory 2006)*

Upon completion of the shear stage, each sand specimen should be removed from the cell and membrane, and dissected to visually observe the interior of the specimen. Final moisture contents may be obtained on each specimen following completion of the test.

9.8 - Direct Shear Tests – Sand

Direct shear tests on sand may be performed as the CD tests in the direct shear test machine described for the clay specimens, and shown in **Figure 59**. However, an engineer should make the final decision on the test type. The test data should be recorded electronically in a computer file and displayed in real time on the computer screen as described in **Section 9.5**.

The tests performed by Gregory (2006) were sheared at a rate of 0.03 inches (0.76 mm) per minute. Upon completion of the shear stage, each sand specimen was removed from the shear box and dissected to visually observe the interior of the specimen. Final moisture contents were obtained on each specimen following completion of the test.

9.9 - Interface Shear Tests

The large-scale equipment necessary for the interface test is not commonly available. However, it is available at the University of Oklahoma. For instance, Gregory (2006) had to retain the services of an out of state laboratory to carry out large-scale direct shear tests on his FRS samples. The interface tests were performed using the soil shearing against a sheet of the material from which the fibers were made.

The large-scale direct shear machine has a 16-inch (400 mm) bottom shear box and a 12-inch (300 mm) top shear box. The sheet material is anchored to the bottom shear box with an Emory-board backing to prevent slippage. The soil specimen is placed in 2-inch (50 mm)-thick, as-compacted lifts in the upper shear box and protrudes slightly from the bottom of the box. The soil is saturated prior to shearing. This arrangement allows the top box to move horizontally and shear the soil across the sheet material on the bottom box. This test measures the interaction coefficient (interface friction-adhesion coefficient) between the polypropylene sheet material and the particular soil being tested. This interaction coefficient is a necessary input for the FRS models discussed in this report.

In the tests reported by Gregory (2016), soil specimens from bulk clay and sand samples were hydrated to the target moisture content, sealed in plastic bags, placed inside sealed plastic buckets along with the sheet material, and shipped to a commercial laboratory with instructions for setting up the tests. The laboratory prepared the specimens in two different shear machines and placed them in a water bath under 20 psi (138 kPa) normal stress and allowed the specimens to saturate and consolidate for 24 hours. The interface shear tests were performed at a shear rate of 0.04 inches (1 mm) per minute. The test data were recorded automatically in a computer file and the real-time data were displayed on the computer screen during the shearing stage of the tests. The test results are presented in **Appendix A**.

10.0 Remarks on Best Practices in FRS Construction

A major benefit of the use and application of FRS at a project site is that the practices associated with its application are similar to those of adding any chemical additive (such as lime, cement, CKD, Fly Ash, etc.) to soil. This has the unique advantage of a very short learning curve for those involved in FRS construction. For example, practically all machinery and equipment associated with the use of chemical stabilization of soil is applicable to FRS- no specialized or proprietary equipment is necessary. Equipment such as tamping foot (sheep’s foot) rollers, rotary tilling machines (i.e. ‘Bomag’), excavators, motor graders, dozers, etc. are all common types of equipment at jobs sites which are also used for FRS construction.

Although, theoretically, the amount of embedment for a fiber to achieve full anchorage is on the order of magnitude of inches, best practice dictates to excavate a minimum of two feet beyond the slip surface of a failed slope, if space permits. All excavations should be benched approximately horizontally in an effort to allow the FRS fill to be placed in essentially horizontal lifts. Additionally, the lifts should not exceed six inches in compacted thickness. Common moisture and density control conditions still apply such as maintaining moisture, for example, within 2% of optimum moisture and compacting to 95% of maximum dry density as determined by ASTM D 698.

All QA and QC protocols germane to the FRS construction are nearly identical to those for other earthwork and stabilized soil projects. One addition being that samples of soil should be randomly collected, mixed into a slurry, and washed over a sieve to weigh the amount of fiber per unit mass of soil. Also, fibers need to be spread over the prepared subgrade of each lift. The reader is referred to a guide that is attached as an appendix to this report for more details.

11.0 Concluding Remarks

FRS is an underutilized technology due to past limitations in terms of extensive testing required to determine reliable values for enhanced shear strength properties relative to those of the baseline (raw) soil. However, extensive work by Gregory (2006) and others involving theoretical development, laboratory testing and field implementation in the past two decades has made it possible to implement the FRS technology in transportation projects cost-effectively and with confidence.

Implementation of the FRS technology in preliminary design requires merely knowing the mechanical properties of unreinforced soil and the fibers to predict the properties of the FRS composite for analysis and design. Nevertheless, it is recommended to carry out targeted laboratory tests as good practice to confirm the predicted FRS properties, and to increase confidence in design in larger projects. When FRS properties are confirmed, further modeling and analysis can be performed as deemed necessary. After analysis is performed and satisfactory results are obtained, field implementation can be carried out using recommendations provided, for instance, by Gregory (2006).

Field implementation of FRS related to mixing with soil and construction procedure is similar to that of related technologies such as chemical stabilization and therefore, fairly straightforward requiring minimal "learning curve" by all involved. This is due to the fact that construction involving FRS technology requires no proprietary equipment; rather it involves commonly used construction equipment and field practices. This can result in cost savings and the use of local workforce and equipment with successful outcome, as is demonstrated in the case studies reviewed in this report.

Lastly, some useful material has been provided in the appendices to this report, which include slope stability analyses for the referenced case studies, test results on field specimens from the case studies, and a snapshot of the spreadsheet that is set up to calculate fiber reinforced soil properties using Gregory's (2006) model.

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Appendix B – FRS Calculation Spreadsheet

	Input in Blue Cells Only.				PI/180		
Length of Fibers	l	2.75	inches		0.017453		
Width of Fibers	w	0.0470	inches				
Thickness of Fibers	t	0.00149	inches				
Equivalent Diameter	d	0.00944	inches				
Effective Aspect Ratio	a_{re}	145.61					
Friction angle (effective)	ϕ	16					
Cohesion (effective)	c	1.2	lb/sq in	172.80	lb/sq ft		
For NC Clay							
$K_o = 1 - \sin\phi$	K_o	0.724363		σ_r =	4.18	psi	
Constant, K_e							
$K_e = (0.75 K_o + 0.25)$	K_e	0.793272					
Friction factor	f_ϕ	0.5	(0.5 maximum unless based on actual interface tests)				
Cohesion factor	f_c	0.5	(0.5 maximum unless based on actual interface tests)				
Weight of fibers	w	0.2500	lb/cu ft				
Unit weight of water	γ_w	62.4	lb/cu ft				
Specific gravity of fibers	G_s	0.91					
Volume ratio factor	$1/G_s\gamma_w$	0.0176					
Volume ratio	V_r	0.0044					
Change in Friction Angle Due to Fibers	$\Delta\phi_{gm}$	4.2	degrees				
Reinforced Friction Angle	ϕ_{gm}	**20.17**	**degrees**				
Uncorrected Increase in Cohesion Due to Fibers	Δc_{gm}	0.38	lb/sq in	55.39	lb/sq ft		
Reduction in Δc_{gm}		0.337	lb/sq in	48.57	lb/sq ft		
Reinforced Cohesion	c_{gm}	**1.25**	**lb/sq in**	**179.62**	**lb/sq ft**		
Note: Large fiber content may result in C_{gm} being negative. Set C_{gm} = 0.0 in this case.							

Figure B1. Spreadsheet to determine shear strength of FRS using the properties of fiber and soil

APPENDIX C

CASE STUDY-1
SUMMARY OF SLOPE STABILITY ANALYSES
Lake Ridge Pkwy – Embankment Repairs – Phase II
Grand Prairie, Texas

Analysis Plate Number	Condition Analyzed	Calculated Factor of Safety	Minimum Recommended Factor of Safety
Plate C.1	Initial Condition – Long Term – Normal Rainfall	1.151 (NG)	1.5
Plate C.2	Long-Term Repaired – Normal Rainfall - FRS	1.549 (OK)	1.5
Plate C.2A	Same as Plate C.2 w/ FRS Modeled with Power Curve	1.549 (OK)	1.5
Plate C.3	Initial Condition – Long Term – Heavy Rainfall	1.004 (NG)	1.2
Plate C.4	Repaired – Heavy Rainfall - FRS	1.207 (OK)	1.2
Plate C.5	Rapid Drawdown - Drained – Initial Condition	0.901 (NG)	1.2
Plate C.6	Rapid Drawdown – Drained – Repaired - FRS	1.322 (OK)	1.2
Plate C.7	3-Stage Rapid Drawdown – Initial condition	1.038 (NG)	1.2
Plate C.8	3-Stage Rapid Drawdown – Repaired - FRS	1.307 (OK)	1.2
Plate C.9	Long-Term Repaired – FRS - ZRSAUTO Search	1.464 (OK)	1.35
Plate C.10	3-Stage Rapid Drawdown – Repaired FRS ZRSAUTO Search	1.264 (OK)	1.2

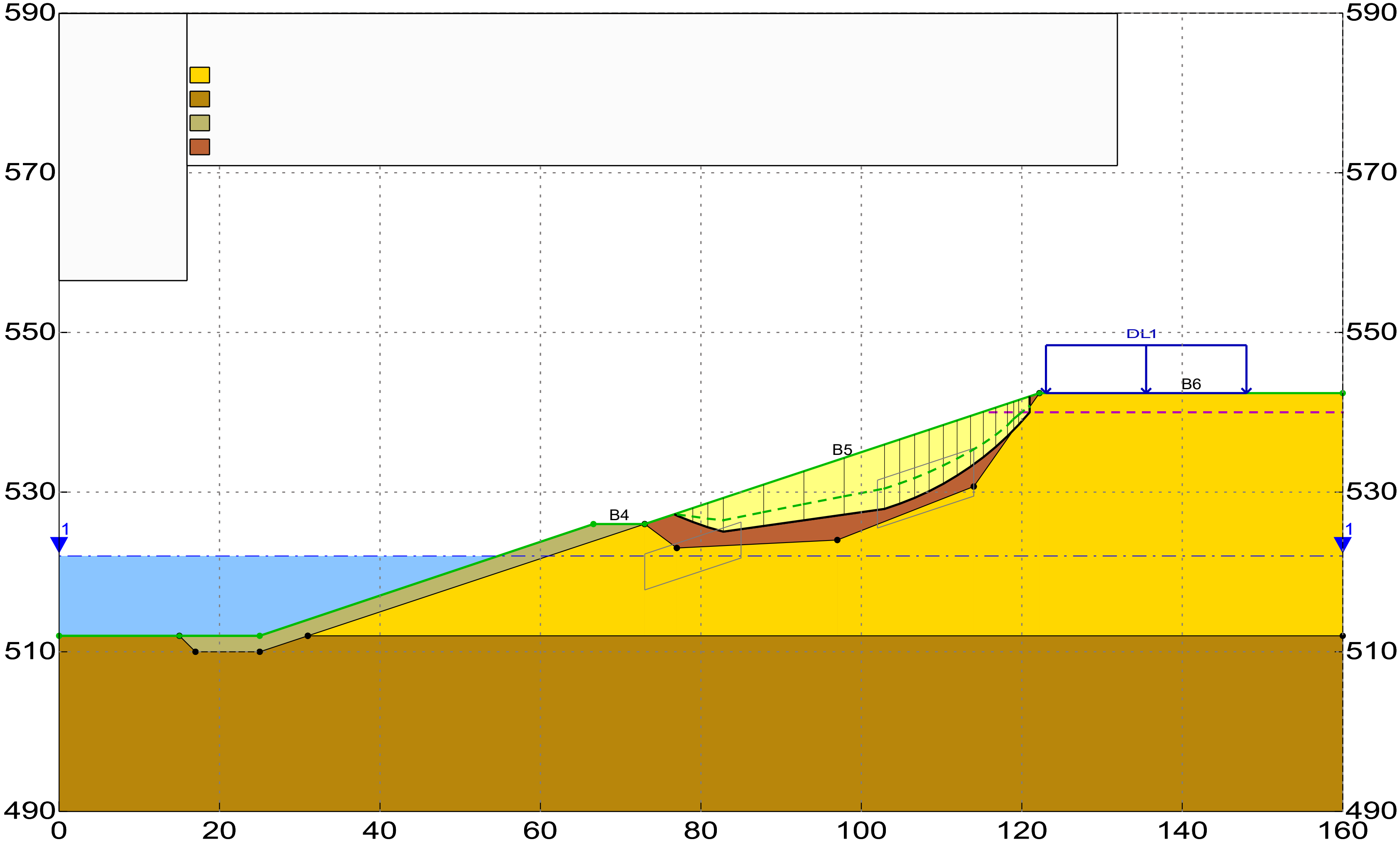
FRS content = 6.75 lb/yd^3

Note: Factor of Safety values are expressed to 3 decimal places to provide relative comparisons among the various analyses. This does not imply actual accuracy to 3 decimal places. Factor of safety values rounded to one decimal place should be considered as the typical actual level of accuracy for the analyses. **FS = Calculated Factor of Safety Value, NG= No Good, OK = Acceptable Value of Calculated FS**

LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II
Long-Term-Initial Condition

GREGORY GEOTECHNICAL - GHG

\lakeridge-Initial.gsd



GEOSTASE FS = 1.151

Spencer Method

GEOSTASE Slope Stability Analysis

GREGORY GEOTECHNICAL

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

PLATE C.1

*** GEOSTASE ***

****
SLOPE STABILITY ANALYSIS SOFTWARE
Simplified Bishop, Simplified Janbu, or General Equilibrium (GE) Options.
(Spencer, Morgenstern-Price, USACE, and Lowe & Karafiath)
Including Pier/Pile, Planar Reinf, Nail, Tieback, Line Loads
Nonlinear Undrained Shear Strength, Curved Strength Envelope,
Anisotropic , Fiber-Reinforced , Distributed Loads, Water
Surfaces, Pseudo-Static & Newmark Earthquake, and Applied Forces.
****

Analysis Date:
Analysis Time:
Analysis By: GREGORY GEOTECHNICAL - GHG

Input File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Initial.gsd

Output File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Initial.OUT

Unit System: English

PROJECT: LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II

DESCRIPTION: Long-Term-Initial Condition

BOUNDARY DATA

6 Surface Boundaries
15 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	512.000	15.000	512.000	2
2	15.000	512.000	25.000	512.000	3
3	25.000	512.000	66.600	526.000	3

4	66.600	526.000	73.000	526.000	3
5	73.000	526.000	122.200	542.400	4
6	122.200	542.400	160.000	542.400	1
7	15.000	512.000	17.000	510.000	2
8	17.000	510.000	25.000	510.000	2
9	25.000	510.000	31.000	512.000	2
10	31.000	512.000	73.000	526.000	1
11	73.000	526.000	77.000	523.000	1
12	77.000	523.000	97.000	524.000	1
13	97.000	524.000	114.000	530.700	1
14	114.000	530.700	122.200	542.400	1
15	31.000	512.000	160.000	512.000	2

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 490.000(ft)

MOHR-COULOMB SOIL PARAMETERS

4 Type(s) of Soil Defined

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Ratio(ru)	Pressure Constant (psf)	Water Surface No.	Water Option
1 Fill-Clay	120.0	132.0	40.00	25.00	0.000	0.0	1	0
2 In-Situ	120.0	132.0	1000.00	20.00	0.000	0.0	1	0
3 Soil Cement	130.0	135.0	1000.00	40.00	0.000	0.0	1	0
4 Weak Clay	120.0	132.0	70.00	13.00	0.000	0.0	1	0

FIBER-REINFORCED SOIL PROPERTIES

1 Soil Type(s) With Fiber Reinforcement

Soil Type 4:

Fiber Length = 3.00(in) Fiber Width = 0.05300(in)
Fiber Thickness = 0.00150(in) Fiber Equivalent Dia. = 0.01006(in)
Friction Coefficient = 0.50 Cohesion Coefficient = 0.50
Specific Gravity of Fiber = 0.910 Application Rate = 0.250 (pcf)

Fiber-Reinforced Shear-Strength Properties

Soil Type 4: FRS c = 72.56 (psf) FRS Phi = 16.60 Deg.
Delta(c) = 2.559(psf) Tan(DeltaPhi) = 0.062926

FIBER-REINFORCED SOIL DATA HAS BEEN SUPPRESSED

CURVED STRENGTH PARAMETERS

1 Soil Type(s) Assigned Curved Strength Envelope Properties

Pa = 2116.800(psf)
A Value of 1.0 indicates Dimensional Coefficients

Soil Type 4:

Curve Coefficients a, b, and T are User Input Values

Coefficient a = 0.2723 Coefficient b = 0.8691
Cohesion(c) = 0.00000(psf) Coefficient T = 0.00000

A Power Curve Function Has Been Selected to Model
Stress-Dependent Shear Strength (C = 0).

WATER SURFACE DATA

1 Water Surface(s) Defined

Unit Weight of Water = 62.400 (pcf)

Water Surface No. 1 Specified by 2 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	522.00
2	160.00	522.00

DISTRIBUTED LOAD(S)

1 Load(s) Specified

Load No.	BND No.	X - 1 (ft)	Y - 1 (ft)	Stress (psf)	X - 2 (ft)	Y - 2 (ft)	Stress (psf)	Deflection (deg from Vert)
1	6	123.000	542.400	250.000	148.000	542.400	250.000	0.00

NOTE - Load Stress Varies Linearly Within Specified Range.

TENSION CRACK DATA

Tension Crack Zones Have Been Defined By 1 Tension Crack Line(s)

TC-Line No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)
1	116.00	540.00	160.00	540.00

Specified Tension Crack Water Depth Factor = 1.0000

Specified Tension Crack Fluid Weight = 62.400 (pcf)

SEISMIC (EARTHQUAKE) DATA

Specified Peak Ground Acceleration Coefficient (PGA) = 0.070(g)
Default Velocity = 0.175(ft) per second
Specified Horizontal Earthquake Coefficient (kh) = 0.0300(g)
Specified Vertical Earthquake Coefficient (kv) = 0.000(g)
(NOTE:Input Velocity = 0.0 will result in default Peak
Velocity = 2 times(PGA) times 2.5 fps or 0.762 mps)
Specified Seismic Pore-Pressure Factor = 0.000
Horizontal Seismic Force is Applied at Center of Gravity of Slices

EARTHQUAKE DATA HAS BEEN SUPPRESSED

A Non-Circular Zone Search Has Been Selected For Analysis
Using Random Generation Within Specified Zones.

2 Zones Defined For Generation Of Non-Circular Surfaces

1000 Trial Surfaces Have Been Generated.

Length Of Line Segments For Active And Passive Portions Of
Non-Circular Zone Search = 2.00(ft)

Zone No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Height (ft)
1	73.00	520.00	85.00	524.00	4.50
2	102.00	528.50	114.00	532.50	6.00

The Spencer Method Was Selected for FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR SPENCER METHOD:
Initial estimate of FS = 1.500

```
FS tolerance =  0.00000100
Initial estimate of theta(deg) =  8.00
Theta tolerance(radians) =  0.0001000
Minimum theta(deg) = -45.00 ; Maximum theta(deg) =  45.00
Theta convergence Step Factor = 5000.00
Maximum number of iterations = 50
Maximum force imbalance  = 100.000000(lbs)
Maximum moment imbalance = 100.000000 (ft/lbs)

Selected Lambda Coefficient =  1.00

The option of using a different convergence method
during the first 25% of iterations has been selected.

Specified Tension Crack Water Depth Factor =   1.000

Total Number of Trial Surfaces Attempted = 1000

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence =    171
Maximum Normal Stress Difference (%) =   0.005000


Warning: Convergence not achieved on  152
surfaces during curved strength envelope calculations.
Maximum Normal Stress Difference (%) =     Infinity


WARNING! The Factor of Safety Calculation for one or More Trial Surfaces
Did Not Converge in 50 Iterations.


Number of Trial Surfaces with Non-Converged FS = 196

Number of Trial Surfaces With Valid FS = 804


Percentage of Trial Surfaces With Non-Converged and/or
Non-Valid FS Solutions of the Total Attempted =  19.6 %

Statistical Data On All Valid FS Values:
   FS Max =   3.739   FS Min =   1.151   FS Ave =   1.783
   Standard Deviation =    0.417   Coefficient of Variation =   23.38 %


Critical Surface is Sequence Number      17 of Those Analyzed.


*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****
```

Iter. No.	Theta (deg) (fx=1.0)	FS (Moment)	FS (Force)	Lambda	Delta FS
1	8.0000	1.336440	1.107261	0.141	0.2291791E+00
2	10.6400	1.291595	1.121286	0.188	0.1703098E+00
3	12.2561	1.256443	1.130228	0.217	0.1262148E+00
4	13.6248	1.220816	1.138043	0.242	0.8277316E-01
5	14.6157	1.190970	1.143854	0.261	0.4711613E-01
6	15.2177	1.170908	1.147450	0.272	0.2345729E-01
7	15.5288	1.159909	1.149330	0.278	0.1057883E-01
8	15.6718	1.154702	1.150198	0.281	0.4503939E-02
9	15.7331	1.152436	1.150572	0.282	0.1864339E-02
10	15.7586	1.151489	1.150727	0.282	0.7621795E-03
11	15.7691	1.151101	1.150791	0.282	0.3099694E-03
12	15.7733	1.150943	1.150817	0.282	0.1257445E-03
13	15.7750	1.150878	1.150827	0.283	0.5101096E-04
14	15.7762	1.150835	1.150835	0.283	0.1732496E-08

Factor Of Safety For The Preceding Specified Surface = 1.151
Theta (fx = 1.0) = 15.78 Deg   Lambda =   0.283

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence =   171
Maximum Normal Stress Difference (%) =   0.005000

The Spencer Method Has Been Selected For FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR ANALYSIS METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 8.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = -45.00 ; Maximum theta(deg) = 45.00
Theta convergence Step Factor = 5000.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance(if Applicable) = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

The option of using a different convergence method
during the first 25% of iterations has been selected.

Tension Crack Water Force = 123.15(lbs)

Specified Tension Crack Water Depth Factor = 1.000

Depth of Tension Crack (zo) at Side of Last Slice = 1.987(ft)

Depth of Water in Tension Crack = 1.987(ft)

Theoretical Tension Crack Depth = 1.046(ft)

NOTE: In Table 1 following, when a tension crack with water is present on the first slice (right facing slope) or on the last slice (left facing slope), the "side force" in the tension crack is set equal to the water pressure resultant.

*** Table 1 - Line of Thrust(if applicable) and Slice Force Data ***

Slice No.	X Coord.	Y Coord.	h/H	Side Force (lbs)	fx	Force Angle (Deg)	Vert. Shear Force(lbs)
1	77.13	527.18	0.468	15.57	1.000	15.78	4.2
2	78.98	526.94	0.394	283.21	1.000	15.78	77.0
3	80.87	526.66	0.350	784.80	1.000	15.78	213.4
4	82.79	526.47	0.338	1437.44	1.000	15.78	390.8
5	87.82	527.50	0.336	1847.31	1.000	15.78	502.2
6	92.84	528.49	0.329	2316.74	1.000	15.78	629.9
7	97.86	529.47	0.322	2842.51	1.000	15.78	772.8
8	102.88	530.45	0.316	3421.93	1.000	15.78	930.4
9	104.77	531.08	0.315	3295.95	1.000	15.78	896.1
10	106.63	531.77	0.313	3082.76	1.000	15.78	838.1
11	108.45	532.52	0.312	2794.45	1.000	15.78	759.8
12	110.22	533.33	0.310	2446.18	1.000	15.78	665.1
13	111.94	534.20	0.308	2055.58	1.000	15.78	558.9
14	113.60	535.12	0.306	1642.24	1.000	15.78	446.5
15	115.20	536.11	0.304	1227.00	1.000	15.78	333.6
16	116.74	537.16	0.305	831.31	1.000	15.78	226.0
17	118.21	538.35	0.328	476.50	1.000	15.78	129.6
18	118.99	539.16	0.384	302.20	1.000	15.78	82.2
19	119.61	539.68	0.398	231.83	1.000	15.78	63.0
20	120.92	540.75	0.394	112.69	1.000	15.78	30.6
21	120.96	540.66	0.662	123.15	1.000	15.78	-0.0

NOTE: A value of 0.000- for h/H indicates that the line of thrust is at or below the lower boundary of the sliding mass. A value of 1.000+ for h/H indicates that the line of thrust is at or above the upper boundary of the sliding mass.

Table 2 - Geometry Data on the 21 Slices

Slice No.	Width (ft)	Height (ft)	X-Cntr (ft)	Y-Cntr-Base (ft)	Y-Cntr-Top (ft)	Alpha (deg)	Beta (deg)	Base Length (ft)
1	0.45	0.18	76.91	527.12	527.30	-25.16	18.43	0.50
2	1.85	1.05	78.06	526.64	527.69	-22.16	18.43	2.00
3	1.89	2.38	79.93	525.93	528.31	-19.16	18.43	2.00
4	1.92	3.62	81.83	525.33	528.94	-16.16	18.43	2.00
5	5.02	4.70	85.30	525.40	530.10	8.08	18.43	5.07
6	5.02	5.66	90.33	526.12	531.78	8.08	18.43	5.07
7	5.02	6.62	95.35	526.83	533.45	8.08	18.43	5.07
8	5.02	7.58	100.37	527.54	535.12	8.08	18.43	5.07
9	1.89	8.05	103.83	528.22	536.28	18.75	18.43	2.00
10	1.86	7.99	105.70	528.91	536.90	21.75	18.43	2.00
11	1.82	7.81	107.54	529.70	537.51	24.75	18.43	2.00
12	1.77	7.52	109.33	530.59	538.11	27.75	18.43	2.00
13	1.72	7.13	111.08	531.56	538.69	30.75	18.43	2.00
14	1.66	6.63	112.77	532.63	539.26	33.75	18.43	2.00
15	1.60	6.02	114.40	533.78	539.80	36.75	18.43	2.00
16	1.54	5.30	115.97	535.02	540.32	39.75	18.43	2.00
17	1.47	4.49	117.48	536.34	540.83	42.75	18.43	2.00
18	0.78	3.78	118.60	537.42	541.20	45.75	18.43	1.12
19	0.62	3.30	119.30	538.13	541.43	45.75	18.43	0.88
20	1.32	2.55	120.26	539.20	541.75	48.75	18.43	2.00
21	0.04	2.00	120.94	539.98	541.98	51.75	18.43	0.06

Table 2A - Coordinates of Slice Points Defining the Slip Surface

Point No.	X-Pt (ft)	Y-Pt (ft)
1	76.680747	527.226916
2	77.130698	527.015585
3	78.982989	526.261251
4	80.872220	525.604893
5	82.793213	525.048309
6	87.815186	525.761177
7	92.837158	526.474045
8	97.859131	527.186913
9	102.881104	527.899780
10	104.774998	528.542562
11	106.632656	529.283582
12	108.448986	530.120809
13	110.219010	531.051947
14	111.937876	532.074446
15	113.600873	533.185501
16	115.203443	534.382068
17	116.741193	535.660868

18	118.209908	537.018394
19	118.988052	537.817098
20	119.605563	538.450926
21	120.924333	539.954539
22	120.960176	540.000000

Table 3 - Force and Pore Pressure Data On The 21 Slices (Excluding Reinforcement)

Slice No.	Weight (lbs)	Ubeta Force Top (lbs)	Ubeta Stress Top (psf)	Ualpha Force Bot (lbs)	Pore Pressure (psf)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Distributed Load (lbs)
1	9.8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
2	232.8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
3	538.7	0.0	0.0	0.0	0.0	0.0	0.0	0.00
4	833.9	0.0	0.0	0.0	0.0	0.0	0.0	0.00
5	2830.4	0.0	0.0	0.0	0.0	0.0	0.0	0.00
6	3409.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
7	3988.8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
8	4568.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
9	1830.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
10	1780.7	0.0	0.0	0.0	0.0	0.0	0.0	0.00
11	1702.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
12	1598.3	0.0	0.0	0.0	0.0	0.0	0.0	0.00
13	1470.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
14	1322.4	0.0	0.0	0.0	0.0	0.0	0.0	0.00
15	1157.1	0.0	0.0	0.0	0.0	0.0	0.0	0.00
16	978.5	0.0	0.0	0.0	0.0	0.0	0.0	0.00
17	790.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
18	353.1	0.0	0.0	0.0	0.0	0.0	0.0	0.00
19	244.4	0.0	0.0	0.0	0.0	0.0	0.0	0.00
20	403.9	0.0	0.0	0.0	0.0	0.0	0.0	0.00
21	8.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00

Table 3A - Center of Pressure of Water Loads On the 21 Slices
Only Applicable Slices Listed

Slice No.	X-Ubeta (ft)	Y-Ubeta (ft)	Ubeta-Moment (ft/lbs)

Table 3B - Center of Pressure of Distributed Loads On the 21 Slices
Only Applicable Slices Listed

Slice No.	X-Dload (ft)	Y-Dload (ft)	Dist-Load (lbs)	Dload-Moment (ft/lbs)
18	123.39	542.40	0.197351E+03	0.000000E+00

19	123.17	542.40	0.829042E+02	0.000000E+00
20	124.14	542.40	0.402400E+03	0.000000E+00
21	125.71	542.40	0.386317E+03	0.000000E+00

TOTAL WEIGHT OF SLIDING MASS = 30053.31(lbs)

EFFECTIVE WEIGHT OF SLIDING MASS = 30053.31(lbs)

TOTAL AREA OF SLIDING MASS = 250.44(ft2)

TABLE 4 - SOIL STRENGTH & SOIL OPTIONS DATA ON THE 21 SLICES

Slice No.	Soil Type	Cohesion (psf)	Phi(Deg)	Options
1	4	2.31	21.81	C
2	4	9.29	17.98	C
3	4	17.66	16.41	C
4	4	24.24	15.68	C
5	4	23.88	15.72	C
6	4	28.05	15.36	C
7	4	32.12	15.06	C
8	4	36.12	14.81	C
9	4	34.84	14.89	C
10	4	33.72	14.96	C
11	4	32.23	15.06	C
12	4	30.39	15.18	C
13	4	28.21	15.35	C
14	4	25.72	15.55	C
15	4	22.94	15.81	C
16	4	19.89	16.13	C
17	4	16.60	16.56	C
18	4	13.77	17.00	C
19	1	40.00	25.00	
20	1	40.00	25.00	
21	1	40.00	25.00	

SOIL OPTIONS: A = ANISOTROPIC, C = CURVED STRENGTH ENVELOPE (TANGENT PHI),
F = FIBER-REINFORCED SOIL (FRS), N = NONLINEAR UNDRAINED SHEAR STRENGTH,
R = RAPID DRAWDOWN SHEAR STRENGTH
NOTE: Phi and C in Table 4 are modified values based on specified
Soil Options (if any). Zero values indicate that the normal stress = 0.0

Calculated Secant Phi Values

Slice No.	Phi(Deg)
1	24.72
2	20.47
3	18.72

4	17.91
5	17.94
6	17.54
7	17.21
8	16.92
9	17.01
10	17.09
11	17.20
12	17.34
13	17.53
14	17.76
15	18.04
16	18.41
17	18.88
18	19.38
19	17.06
20	17.25
21	17.49

NOTE: The slices in the table above with phi marked
with an * are unmodified phi values for soil type(s) not
specified to have curved strength envelope (if any).

TABLE 5 - Total Base Stress Data on the 21 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Stress (psf)	Total Vert. Stress (psf)	Total Normal/Vert. Stress Ratio
1	-25.16	76.91	0.50	38.28	21.68	1.766
2	-22.16	78.06	2.00	190.06	125.66	1.512
3	-19.16	79.93	2.00	398.04	285.14	1.396
4	-16.16	81.83	2.00	573.10	434.12	1.320
5	8.08	85.30	5.07	563.29	563.60	0.999
6	8.08	90.33	5.07	677.92	678.93	0.999
7	8.08	95.35	5.07	792.46	794.27	0.998
8	8.08	100.37	5.07	906.94	909.60	0.997
9	18.75	103.83	2.00	870.01	966.58	0.900
10	21.75	105.70	2.00	838.08	958.58	0.874
11	24.75	107.54	2.00	795.59	937.37	0.849
12	27.75	109.33	2.00	743.38	902.99	0.823
13	30.75	111.08	2.00	682.38	855.55	0.798
14	33.75	112.77	2.00	613.54	795.18	0.772
15	36.75	114.40	2.00	537.89	722.03	0.745
16	39.75	115.97	2.00	456.55	636.32	0.717
17	42.75	117.48	2.00	370.74	538.27	0.689
18	45.75	118.60	1.12	299.09	453.83	0.659
19	45.75	119.30	0.88	232.46	395.79	0.587
20	48.75	120.26	2.00	165.58	306.27	0.541

21	51.75	120.94	0.06	-434.95	240.42	-1.809

TABLE 5A - Total Base Force Data on the 21 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Force (lbs)	Total Vert. Force (lbs)	Total Normal/Vert. Force Ratio
1	-25.16	76.91	0.50	19.03	9.75	1.951
2	-22.16	78.06	2.00	380.11	232.77	1.633
3	-19.16	79.93	2.00	796.08	538.69	1.478
4	-16.16	81.83	2.00	1146.21	833.93	1.374
5	8.08	85.30	5.07	2857.18	2830.38	1.009
6	8.08	90.33	5.07	3438.62	3409.59	1.009
7	8.08	95.35	5.07	4019.62	3988.79	1.008
8	8.08	100.37	5.07	4600.27	4568.00	1.007
9	18.75	103.83	2.00	1740.01	1830.60	0.951
10	21.75	105.70	2.00	1676.16	1780.72	0.941
11	24.75	107.54	2.00	1591.17	1702.57	0.935
12	27.75	109.33	2.00	1486.77	1598.32	0.930
13	30.75	111.08	2.00	1364.77	1470.58	0.928
14	33.75	112.77	2.00	1227.09	1322.38	0.928
15	36.75	114.40	2.00	1075.78	1157.11	0.930
16	39.75	115.97	2.00	913.10	978.50	0.933
17	42.75	117.48	2.00	741.47	790.56	0.938
18	45.75	118.60	1.12	333.51	353.14	0.944
19	45.75	119.30	0.88	205.70	244.41	0.842
20	48.75	120.26	2.00	331.16	403.90	0.820
21	51.75	120.94	0.06	-25.18	8.62	-2.922

TABLE 6 - Effective and Base Shear Stress Data on the 21 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Stress (psf)	Available Shear Strength (psf)	Mobilized Shear Stress (psf)
1	-25.16	76.91	0.50	38.28	17.62	15.31
2	-22.16	78.06	2.00	190.06	70.95	61.65
3	-19.16	79.93	2.00	398.04	134.89	117.21
4	-16.16	81.83	2.00	573.10	185.17	160.90
5	8.08	85.30	5.07	563.29	182.41	158.50
6	8.08	90.33	5.07	677.92	214.27	186.18
7	8.08	95.35	5.07	792.46	245.40	213.24
8	8.08	100.37	5.07	906.94	275.94	239.77
9	18.75	103.83	2.00	870.01	266.14	231.26
10	21.75	105.70	2.00	838.08	257.64	223.87
11	24.75	107.54	2.00	795.59	246.24	213.97
12	27.75	109.33	2.00	743.38	232.14	201.71

13	30.75	111.08	2.00	682.38	215.49	187.25
14	33.75	112.77	2.00	613.54	196.47	170.72
15	36.75	114.40	2.00	537.89	175.24	152.27
16	39.75	115.97	2.00	456.55	151.96	132.05
17	42.75	117.48	2.00	370.74	126.81	110.19
18	45.75	118.60	1.12	299.09	105.22	91.43
19	45.75	119.30	0.88	232.46	148.40	128.95
20	48.75	120.26	2.00	165.58	117.21	101.85
21	51.75	120.94	0.06	0.00	40.00	-141.48

TABLE 6A - Effective and Base Shear Force Data on the 21 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Force (lbs)	Available Shear Force (lbs)	Mobilized Shear Force (lbs)
1	-25.16	76.91	0.50	19.03	8.76	7.61
2	-22.16	78.06	2.00	380.11	141.90	123.30
3	-19.16	79.93	2.00	796.08	269.78	234.42
4	-16.16	81.83	2.00	1146.21	370.33	321.79
5	8.08	85.30	5.07	2857.18	925.22	803.96
6	8.08	90.33	5.07	3438.62	1086.83	944.38
7	8.08	95.35	5.07	4019.62	1244.77	1081.62
8	8.08	100.37	5.07	4600.27	1399.64	1216.19
9	18.75	103.83	2.00	1740.01	532.29	462.52
10	21.75	105.70	2.00	1676.16	515.27	447.74
11	24.75	107.54	2.00	1591.17	492.49	427.94
12	27.75	109.33	2.00	1486.77	464.28	403.43
13	30.75	111.08	2.00	1364.77	430.99	374.50
14	33.75	112.77	2.00	1227.09	392.94	341.44
15	36.75	114.40	2.00	1075.78	350.47	304.54
16	39.75	115.97	2.00	913.10	303.93	264.09
17	42.75	117.48	2.00	741.47	253.62	220.38
18	45.75	118.60	1.12	333.51	117.33	101.95
19	45.75	119.30	0.88	205.70	131.32	114.11
20	48.75	120.26	2.00	331.16	234.42	203.70
21	51.75	120.94	0.06	0.00	2.32	-8.19

SUM OF MOMENTS = -0.580529E-06 (ft/lbs);Imbalance (Fraction of Total Weight) = -0.1931665E-10
SUM OF FORCES = -.553922E-06 (lbs);Imbalance (Fraction of Total Weight) = -0.1843131E-10

Sum of Available Shear Forces = 9657.15(lbs)

Sum of Mobilized Shear Forces = 8391.43(lbs)

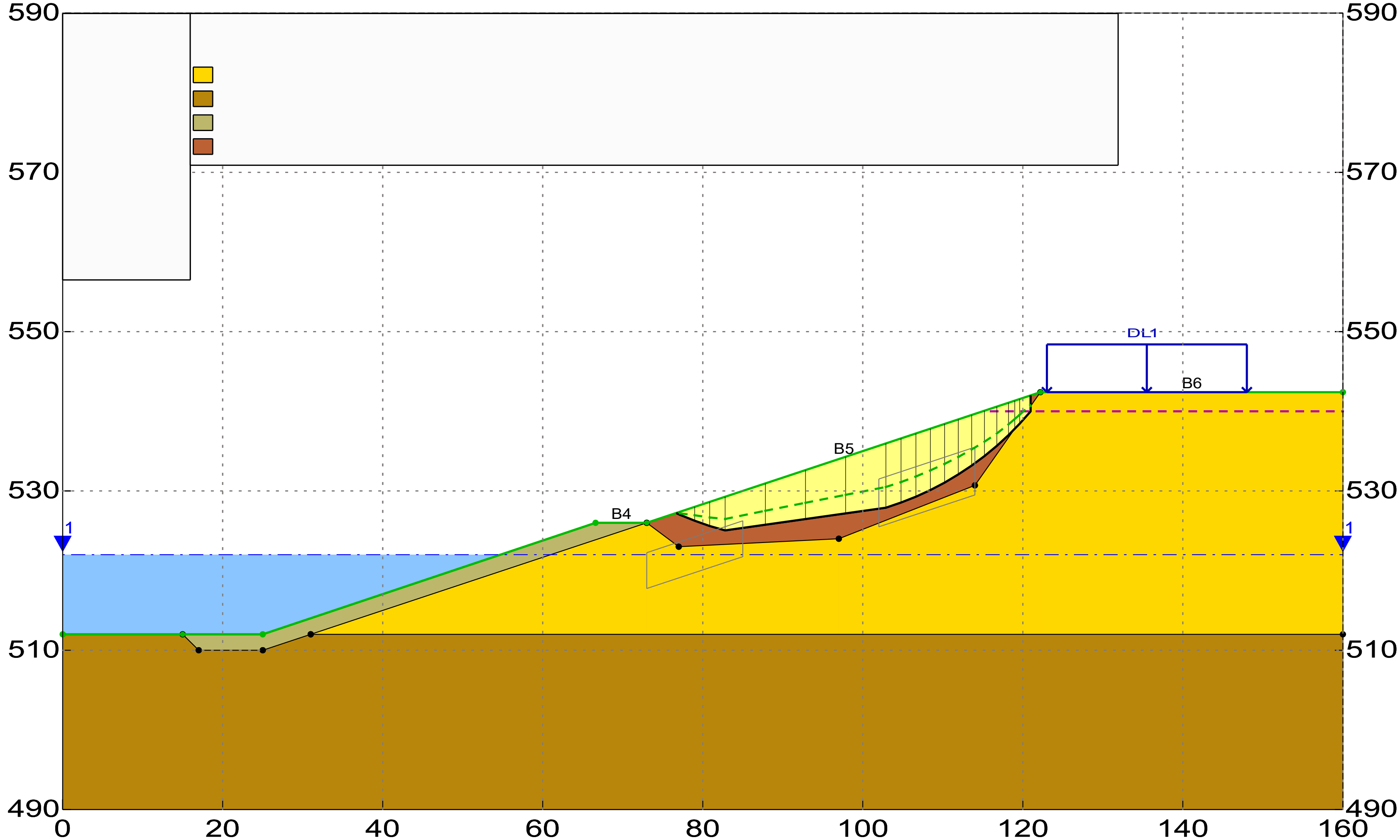
FS Balance Check: FS = 1.150835

**** END OF GEOSTASE OUTPUT ****

LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II
Long-Term-Repaired Condition - FRS

GREGORY GEOTECHNICAL - GHG

\lakeridge-Repaired-A.gsd



GEOSTASE FS = 1.549

Spencer Method

GEOSTASE Slope Stability Analysis

GREGORY GEOTECHNICAL

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

PLATE C.2A

*** GEOSTASE ***

****
SLOPE STABILITY ANALYSIS SOFTWARE
Simplified Bishop, Simplified Janbu, or General Equilibrium (GE) Options.
(Spencer, Morgenstern-Price, USACE, and Lowe & Karafiath)
Including Pier/Pile, Planar Reinf, Nail, Tieback, Line Loads
Nonlinear Undrained Shear Strength, Curved Strength Envelope,
Anisotropic , Fiber-Reinforced , Distributed Loads, Water
Surfaces, Pseudo-Static & Newmark Earthquake, and Applied Forces.
****

Analysis Date:
Analysis Time:
Analysis By: GREGORY GEOTECHNICAL - GHG

Input File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Repaired-A.gsd

Output File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Repaired-A.OUT

Unit System: English

PROJECT: LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II

DESCRIPTION: Long-Term-Repaired Condition - FRS

BOUNDARY DATA

6 Surface Boundaries
15 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	512.000	15.000	512.000	2
2	15.000	512.000	25.000	512.000	3
3	25.000	512.000	66.600	526.000	3

4	66.600	526.000	73.000	526.000	3
5	73.000	526.000	122.200	542.400	4
6	122.200	542.400	160.000	542.400	1
7	15.000	512.000	17.000	510.000	2
8	17.000	510.000	25.000	510.000	2
9	25.000	510.000	31.000	512.000	2
10	31.000	512.000	73.000	526.000	1
11	73.000	526.000	77.000	523.000	1
12	77.000	523.000	97.000	524.000	1
13	97.000	524.000	114.000	530.700	1
14	114.000	530.700	122.200	542.400	1
15	31.000	512.000	160.000	512.000	2

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 490.000(ft)

MOHR-COULOMB SOIL PARAMETERS

4 Type(s) of Soil Defined

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Ratio(ru)	Pressure Constant (psf)	Water Surface No.	Water Option
1 Fill-Clay	120.0	132.0	40.00	25.00	0.000	0.0	1	0
2 In-Situ	120.0	132.0	1000.00	20.00	0.000	0.0	1	0
3 Soil Cement	130.0	135.0	1000.00	40.00	0.000	0.0	1	0
4 Weak Clay	120.0	132.0	70.00	13.00	0.000	0.0	1	0

FIBER-REINFORCED SOIL PROPERTIES
1 Soil Type(s) With Fiber Reinforcement

Soil Type 4:

Fiber Length = 3.00(in) Fiber Width = 0.05300(in)
Fiber Thickness = 0.00150(in) Fiber Equivalent Dia. = 0.01006(in)
Friction Coefficient = 0.50 Cohesion Coefficient = 0.50
Specific Gravity of Fiber = 0.910 Application Rate = 0.250 (pcf)

Fiber-Reinforced Shear-Strength Properties

Soil Type 4: FRS c = 72.56 (psf) FRS Phi = 16.60 Deg.
Delta(c) = 2.559(psf) Tan(DeltaPhi) = 0.062926

FIBER-REINFORCED SOIL DATA HAS BEEN SUPPRESSED

CURVED STRENGTH PARAMETERS

1 Soil Type(s) Assigned Curved Strength Envelope Properties

Pa = 1.000

Soil Type 4:

Curve Coefficients a, b, and T are User Input Values

Coefficient a = 0.8059 Coefficient b = 0.9033
Cohesion(c) = 0.00000(psf) Coefficient T = 0.00000

A Power Curve Function Has Been Selected to Model
Stress-Dependent Shear Strength (C = 0).

WATER SURFACE DATA

1 Water Surface(s) Defined

Unit Weight of Water = 62.400 (pcf)

Water Surface No. 1 Specified by 2 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	522.00
2	160.00	522.00

DISTRIBUTED LOAD(S)

1 Load(s) Specified

Load No.	BND No.	X - 1 (ft)	Y - 1 (ft)	Stress (psf)	X - 2 (ft)	Y - 2 (ft)	Stress (psf)	Deflection (deg from Vert)
1	6	123.000	542.400	250.000	148.000	542.400	250.000	0.00

NOTE - Load Stress Varies Linearly Within Specified Range.

TENSION CRACK DATA

Tension Crack Zones Have Been Defined By 1 Tension Crack Line(s)

TC-Line No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)
1	116.00	540.00	160.00	540.00

Specified Tension Crack Water Depth Factor = 1.0000

Specified Tension Crack Fluid Weight = 62.400 (pcf)

SEISMIC (EARTHQUAKE) DATA

Specified Peak Ground Acceleration Coefficient (PGA) = 0.070(g)
Default Velocity = 0.175(ft) per second
Specified Horizontal Earthquake Coefficient (kh) = 0.0300(g)
Specified Vertical Earthquake Coefficient (kv) = 0.000(g)
(NOTE:Input Velocity = 0.0 will result in default Peak
Velocity = 2 times(PGA) times 2.5 fps or 0.762 mps)
Specified Seismic Pore-Pressure Factor = 0.000
Horizontal Seismic Force is Applied at Center of Gravity of Slices

EARTHQUAKE DATA HAS BEEN SUPPRESSED

A Non-Circular Zone Search Has Been Selected For Analysis
Using Random Generation Within Specified Zones.

2 Zones Defined For Generation Of Non-Circular Surfaces

1000 Trial Surfaces Have Been Generated.

Length Of Line Segments For Active And Passive Portions Of
Non-Circular Zone Search = 2.00(ft)

Zone No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Height (ft)
1	73.00	520.00	85.00	524.00	4.50
2	102.00	528.50	114.00	532.50	6.00

The Spencer Method Was Selected for FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR SPENCER METHOD:
Initial estimate of FS = 1.600
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 8.00

```
Theta tolerance(radians) =  0.0001000
Minimum theta(deg) = -45.00 ; Maximum theta(deg) =  45.00
Theta convergence Step Factor = 1000.00
Maximum number of iterations = 50
Maximum force imbalance  = 100.000000(lbs)
Maximum moment imbalance = 100.000000 (ft/lbs)

Selected Lambda Coefficient =  1.00

The option of using a different convergence method
during the first 25% of iterations has been selected.

Specified Tension Crack Water Depth Factor =   1.000

Total Number of Trial Surfaces Attempted = 1000

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence =    145
Maximum Normal Stress Difference (%) =   0.005000


Warning: Convergence not achieved on   96
surfaces during curved strength envelope calculations.
Maximum Normal Stress Difference (%) =     Infinity


WARNING! The Factor of Safety Calculation for one or More Trial Surfaces
Did Not Converge in 50 Iterations.


Number of Trial Surfaces with Non-Converged FS = 143

Number of Trial Surfaces With Valid FS = 857


Percentage of Trial Surfaces With Non-Converged and/or
Non-Valid FS Solutions of the Total Attempted =  14.3 %

Statistical Data On All Valid FS Values:
   FS Max =   3.968   FS Min =   1.549   FS Ave =   2.104
   Standard Deviation =    0.381   Coefficient of Variation =   18.11 %


Critical Surface is Sequence Number      15 of Those Analyzed.


*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****


  Iter.     Theta         FS         FS
```

No.	(deg) (fx=1.0)	(Moment)	(Force)	Lambda	Delta FS
1	8.0000	1.812416	1.486111	0.141	0.3263050E+00
2	10.6400	1.752059	1.505515	0.188	0.2465432E+00
3	12.3824	1.700666	1.518862	0.220	0.1818047E+00
4	13.8646	1.647579	1.530603	0.247	0.1169769E+00
5	14.9242	1.603139	1.539238	0.267	0.6390056E-01
6	15.5437	1.574208	1.544388	0.278	0.2981931E-01
7	15.8438	1.559324	1.546911	0.284	0.1241275E-01
8	15.9710	1.552838	1.547986	0.286	0.4852069E-02
9	16.0210	1.550253	1.548410	0.287	0.1843619E-02
10	16.0401	1.549264	1.548571	0.288	0.6925249E-03
11	16.0473	1.548891	1.548632	0.288	0.2589894E-03
12	16.0500	1.548752	1.548655	0.288	0.9666003E-04
13	16.0510	1.548699	1.548663	0.288	0.3608793E-04
14	16.0516	1.548668	1.548668	0.288	0.3276892E-07

Factor Of Safety For The Preceding Specified Surface = 1.549
Theta (fx = 1.0) = 16.05 Deg   Lambda =   0.288

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence =   145
Maximum Normal Stress Difference (%) =   0.005000

The Spencer Method Has Been Selected For FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR ANALYSIS METHOD:
Initial estimate of FS = 1.600
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 8.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = -45.00 ; Maximum theta(deg) = 45.00
Theta convergence Step Factor = 1000.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance(if Applicable) = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

The option of using a different convergence method
during the first 25% of iterations has been selected.

Tension Crack Water Force =   123.15(lbs)

Specified Tension Crack Water Depth Factor = 1.000

Depth of Tension Crack (zo) at Side of Last Slice = 1.987(ft)

Depth of Water in Tension Crack = 1.987(ft)

Theoretical Tension Crack Depth = 1.046(ft)

NOTE: In Table 1 following, when a tension crack with water is present on the first slice (right facing slope) or on the last slice (left facing slope), the "side force" in the tension crack is set equal to the water pressure resultant.

*** Table 1 - Line of Thrust(if applicable) and Slice Force Data ***

Slice No.	X Coord.	Y Coord.	h/H	Side Force (lbs)	fx	Force Angle (Deg)	Vert. Shear Force(lbs)
1	77.13	527.19	0.472	14.47	1.000	16.05	4.0
2	78.98	526.95	0.396	276.98	1.000	16.05	76.6
3	80.87	526.66	0.350	778.10	1.000	16.05	215.1
4	82.79	526.48	0.339	1435.39	1.000	16.05	396.9
5	87.82	527.52	0.340	1848.06	1.000	16.05	511.0
6	92.84	528.53	0.335	2327.04	1.000	16.05	643.4
7	97.86	529.52	0.328	2869.82	1.000	16.05	793.5
8	102.88	530.49	0.322	3474.29	1.000	16.05	960.7
9	104.77	531.13	0.321	3356.15	1.000	16.05	928.0
10	106.63	531.82	0.320	3149.88	1.000	16.05	871.0
11	108.45	532.58	0.320	2867.42	1.000	16.05	792.8
12	110.22	533.40	0.319	2523.76	1.000	16.05	697.8
13	111.94	534.27	0.318	2136.45	1.000	16.05	590.7
14	113.60	535.19	0.316	1725.00	1.000	16.05	477.0
15	115.20	536.17	0.315	1310.22	1.000	16.05	362.3
16	116.74	537.21	0.315	913.60	1.000	16.05	252.6
17	118.21	538.33	0.324	556.57	1.000	16.05	153.9
18	118.99	539.03	0.345	380.54	1.000	16.05	105.2
19	119.61	539.55	0.357	281.46	1.000	16.05	77.8
20	120.92	540.77	0.402	110.37	1.000	16.05	30.5
21	120.96	540.66	0.662	123.15	1.000	16.05	-0.0

NOTE: A value of 0.000- for h/H indicates that the line of thrust is at or below the lower boundary of the sliding mass. A value of 1.000+ for h/H indicates that the line of thrust is at or above the upper boundary of the sliding mass.

Table 2 - Geometry Data on the 21 Slices

Slice	Width	Height	X-Cntr	Y-Cntr-Base	Y-Cntr-Top	Alpha	Beta	Base Length

No.	(ft)	(ft)	(ft)	(ft)	(ft)	(deg)	(deg)	(ft)
1	0.45	0.18	76.91	527.12	527.30	-25.16	18.43	0.50
2	1.85	1.05	78.06	526.64	527.69	-22.16	18.43	2.00
3	1.89	2.38	79.93	525.93	528.31	-19.16	18.43	2.00
4	1.92	3.62	81.83	525.33	528.94	-16.16	18.43	2.00
5	5.02	4.70	85.30	525.40	530.10	8.08	18.43	5.07
6	5.02	5.66	90.33	526.12	531.78	8.08	18.43	5.07
7	5.02	6.62	95.35	526.83	533.45	8.08	18.43	5.07
8	5.02	7.58	100.37	527.54	535.12	8.08	18.43	5.07
9	1.89	8.05	103.83	528.22	536.28	18.75	18.43	2.00
10	1.86	7.99	105.70	528.91	536.90	21.75	18.43	2.00
11	1.82	7.81	107.54	529.70	537.51	24.75	18.43	2.00
12	1.77	7.52	109.33	530.59	538.11	27.75	18.43	2.00
13	1.72	7.13	111.08	531.56	538.69	30.75	18.43	2.00
14	1.66	6.63	112.77	532.63	539.26	33.75	18.43	2.00
15	1.60	6.02	114.40	533.78	539.80	36.75	18.43	2.00
16	1.54	5.30	115.97	535.02	540.32	39.75	18.43	2.00
17	1.47	4.49	117.48	536.34	540.83	42.75	18.43	2.00
18	0.78	3.78	118.60	537.42	541.20	45.75	18.43	1.12
19	0.62	3.30	119.30	538.13	541.43	45.75	18.43	0.88
20	1.32	2.55	120.26	539.20	541.75	48.75	18.43	2.00
21	0.04	2.00	120.94	539.98	541.98	51.75	18.43	0.06

Table 2A - Coordinates of Slice Points Defining the Slip Surface

Point No.	X-Pt (ft)	Y-Pt (ft)
1	76.680747	527.226916
2	77.130698	527.015585
3	78.982989	526.261251
4	80.872220	525.604893
5	82.793213	525.048309
6	87.815186	525.761177
7	92.837158	526.474045
8	97.859131	527.186913
9	102.881104	527.899780
10	104.774998	528.542562
11	106.632656	529.283582
12	108.448986	530.120809
13	110.219010	531.051947
14	111.937876	532.074446
15	113.600873	533.185501
16	115.203443	534.382068
17	116.741193	535.660868
18	118.209908	537.018394
19	118.988052	537.817098

20	119.605563	538.450926
21	120.924333	539.954539
22	120.960176	540.000000

Table 3 - Force and Pore Pressure Data On The 21 Slices (Excluding Reinforcement)

Slice No.	Weight (lbs)	Ubeta Force Top (lbs)	Ubeta Stress Top (psf)	Ualpha Force Bot (lbs)	Pore Pressure (psf)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Distributed Load (lbs)
1	9.8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
2	232.8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
3	538.7	0.0	0.0	0.0	0.0	0.0	0.0	0.00
4	833.9	0.0	0.0	0.0	0.0	0.0	0.0	0.00
5	2830.4	0.0	0.0	0.0	0.0	0.0	0.0	0.00
6	3409.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
7	3988.8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
8	4568.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
9	1830.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
10	1780.7	0.0	0.0	0.0	0.0	0.0	0.0	0.00
11	1702.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
12	1598.3	0.0	0.0	0.0	0.0	0.0	0.0	0.00
13	1470.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
14	1322.4	0.0	0.0	0.0	0.0	0.0	0.0	0.00
15	1157.1	0.0	0.0	0.0	0.0	0.0	0.0	0.00
16	978.5	0.0	0.0	0.0	0.0	0.0	0.0	0.00
17	790.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
18	353.1	0.0	0.0	0.0	0.0	0.0	0.0	0.00
19	244.4	0.0	0.0	0.0	0.0	0.0	0.0	0.00
20	403.9	0.0	0.0	0.0	0.0	0.0	0.0	0.00
21	8.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00

Table 3A - Center of Pressure of Water Loads On the 21 Slices
Only Applicable Slices Listed

Slice No.	X-Ubeta (ft)	Y-Ubeta (ft)	Ubeta-Moment (ft/lbs)

Table 3B - Center of Pressure of Distributed Loads On the 21 Slices
Only Applicable Slices Listed

Slice No.	X-Dload (ft)	Y-Dload (ft)	Dist-Load (lbs)	Dload-Moment (ft/lbs)
18	123.39	542.40	0.197351E+03	0.000000E+00
19	123.17	542.40	0.829042E+02	0.000000E+00
20	124.14	542.40	0.402400E+03	0.000000E+00

```
 21        125.71    542.40     0.386317E+03     0.000000E+00
```

TOTAL WEIGHT OF SLIDING MASS =   30053.31(lbs)

EFFECTIVE WEIGHT OF SLIDING MASS =   30053.31(lbs)

TOTAL AREA OF SLIDING MASS =   250.44(ft2)

TABLE 4 - SOIL STRENGTH & SOIL OPTIONS DATA ON THE   21 SLICES

Slice No.	Soil Type	Cohesion (psf)	Phi(Deg)	Options
1	4	2.03	27.18	C
2	4	8.87	23.68	C
3	4	17.42	22.19	C
4	4	24.26	21.49	C
5	4	23.81	21.53	C
6	4	28.15	21.18	C
7	4	32.42	20.89	C
8	4	36.63	20.64	C
9	4	35.22	20.72	C
10	4	34.03	20.79	C
11	4	32.46	20.89	C
12	4	30.52	21.02	C
13	4	28.24	21.18	C
14	4	25.65	21.38	C
15	4	22.78	21.62	C
16	4	19.65	21.94	C
17	4	16.30	22.34	C
18	4	13.43	22.76	C
19	1	40.00	25.00	
20	1	40.00	25.00	
21	1	40.00	25.00	

SOIL OPTIONS: A = ANISOTROPIC, C = CURVED STRENGTH ENVELOPE (TANGENT PHI),
F = FIBER-REINFORCED SOIL (FRS), N = NONLINEAR UNDRAINED SHEAR STRENGTH,
R = RAPID DRAWDOWN SHEAR STRENGTH
NOTE: Phi and C in Table 4 are modified values based on specified
Soil Options (if any). Zero values indicate that the normal stress = 0.0

Calculated Secant Phi Values

Slice No.	Phi(Deg)
1	29.62
2	25.89
3	24.31
4	23.55
5	23.59

6	23.22
7	22.91
8	22.64
9	22.73
10	22.80
11	22.90
12	23.04
13	23.21
14	23.43
15	23.69
16	24.03
17	24.46
18	24.91
19	22.80
20	22.99
21	23.21

NOTE: The slices in the table above with phi marked
with an * are unmodified phi values for soil type(s) not
specified to have curved strength envelope (if any).

TABLE 5 - Total Base Stress Data on the 21 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Stress (psf)	Total Vert. Stress (psf)	Total Normal/Vert. Stress Ratio
1	-25.16	76.91	0.50	36.94	21.68	1.704
2	-22.16	78.06	2.00	188.97	125.66	1.504
3	-19.16	79.93	2.00	398.89	285.14	1.399
4	-16.16	81.83	2.00	575.67	434.12	1.326
5	8.08	85.30	5.07	563.75	563.60	1.000
6	8.08	90.33	5.07	678.62	678.93	1.000
7	8.08	95.35	5.07	793.42	794.27	0.999
8	8.08	100.37	5.07	908.17	909.60	0.998
9	18.75	103.83	2.00	869.52	966.58	0.900
10	21.75	105.70	2.00	837.23	958.58	0.873
11	24.75	107.54	2.00	794.46	937.37	0.848
12	27.75	109.33	2.00	742.10	902.99	0.822
13	30.75	111.08	2.00	681.06	855.55	0.796
14	33.75	112.77	2.00	612.31	795.18	0.770
15	36.75	114.40	2.00	536.88	722.03	0.744
16	39.75	115.97	2.00	455.87	636.32	0.716
17	42.75	117.48	2.00	370.48	538.27	0.688
18	45.75	118.60	1.12	299.20	453.83	0.659
19	45.75	119.30	0.88	248.20	395.79	0.627
20	48.75	120.26	2.00	179.37	306.27	0.586
21	51.75	120.94	0.06	-465.88	240.42	-1.938

TABLE 5A - Total Base Force Data on the 21 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Force (lbs)	Total Vert. Force (lbs)	Total Normal/Vert. Force Ratio
1	-25.16	76.91	0.50	18.36	9.75	1.883
2	-22.16	78.06	2.00	377.95	232.77	1.624
3	-19.16	79.93	2.00	797.78	538.69	1.481
4	-16.16	81.83	2.00	1151.34	833.93	1.381
5	8.08	85.30	5.07	2859.52	2830.38	1.010
6	8.08	90.33	5.07	3442.18	3409.59	1.010
7	8.08	95.35	5.07	4024.49	3988.79	1.009
8	8.08	100.37	5.07	4606.50	4568.00	1.008
9	18.75	103.83	2.00	1739.04	1830.60	0.950
10	21.75	105.70	2.00	1674.46	1780.72	0.940
11	24.75	107.54	2.00	1588.92	1702.57	0.933
12	27.75	109.33	2.00	1484.20	1598.32	0.929
13	30.75	111.08	2.00	1362.12	1470.58	0.926
14	33.75	112.77	2.00	1224.62	1322.38	0.926
15	36.75	114.40	2.00	1073.76	1157.11	0.928
16	39.75	115.97	2.00	911.73	978.50	0.932
17	42.75	117.48	2.00	740.95	790.56	0.937
18	45.75	118.60	1.12	333.63	353.14	0.945
19	45.75	119.30	0.88	219.64	244.41	0.899
20	48.75	120.26	2.00	358.74	403.90	0.888
21	51.75	120.94	0.06	-26.97	8.62	-3.130

TABLE 6 - Effective and Base Shear Stress Data on the 21 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Stress (psf)	Available Shear Strength (psf)	Mobilized Shear Stress (psf)
1	-25.16	76.91	0.50	36.94	21.00	13.56
2	-22.16	78.06	2.00	188.97	91.74	59.24
3	-19.16	79.93	2.00	398.89	180.15	116.33
4	-16.16	81.83	2.00	575.67	250.93	162.03
5	8.08	85.30	5.07	563.75	246.23	158.99
6	8.08	90.33	5.07	678.62	291.13	187.99
7	8.08	95.35	5.07	793.42	335.28	216.49
8	8.08	100.37	5.07	908.17	378.78	244.59
9	18.75	103.83	2.00	869.52	364.19	235.17
10	21.75	105.70	2.00	837.23	351.95	227.26
11	24.75	107.54	2.00	794.46	335.67	216.75
12	27.75	109.33	2.00	742.10	315.62	203.80
13	30.75	111.08	2.00	681.06	292.08	188.60
14	33.75	112.77	2.00	612.31	265.31	171.31

15	36.75	114.40	2.00	536.88	235.60	152.13
16	39.75	115.97	2.00	455.87	203.24	131.24
17	42.75	117.48	2.00	370.48	168.52	108.81
18	45.75	118.60	1.12	299.20	138.94	89.71
19	45.75	119.30	0.88	248.20	155.74	100.56
20	48.75	120.26	2.00	179.37	123.64	79.84
21	51.75	120.94	0.06	0.00	40.00	-114.45

TABLE 6A - Effective and Base Shear Force Data on the 21 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Force (lbs)	Available Shear Force (lbs)	Mobilized Shear Force (lbs)
1	-25.16	76.91	0.50	18.36	10.44	6.74
2	-22.16	78.06	2.00	377.95	183.48	118.47
3	-19.16	79.93	2.00	797.78	360.30	232.65
4	-16.16	81.83	2.00	1151.34	501.85	324.05
5	8.08	85.30	5.07	2859.52	1248.95	806.47
6	8.08	90.33	5.07	3442.18	1476.71	953.54
7	8.08	95.35	5.07	4024.49	1700.63	1098.12
8	8.08	100.37	5.07	4606.50	1921.31	1240.62
9	18.75	103.83	2.00	1739.04	728.39	470.33
10	21.75	105.70	2.00	1674.46	703.91	454.52
11	24.75	107.54	2.00	1588.92	671.35	433.50
12	27.75	109.33	2.00	1484.20	631.25	407.61
13	30.75	111.08	2.00	1362.12	584.15	377.20
14	33.75	112.77	2.00	1224.62	530.62	342.63
15	36.75	114.40	2.00	1073.76	471.20	304.26
16	39.75	115.97	2.00	911.73	406.48	262.47
17	42.75	117.48	2.00	740.95	337.03	217.63
18	45.75	118.60	1.12	333.63	154.93	100.04
19	45.75	119.30	0.88	219.64	137.81	88.99
20	48.75	120.26	2.00	358.74	247.28	159.68
21	51.75	120.94	0.06	0.00	2.32	-6.63

SUM OF MOMENTS = -0.385727E-04 (ft/lbs);Imbalance (Fraction of Total Weight) = -0.1283475E-08
SUM OF FORCES = -.149351E-05 (lbs);Imbalance (Fraction of Total Weight) = -0.4969547E-10

Sum of Available Shear Forces = 12997.81(lbs)

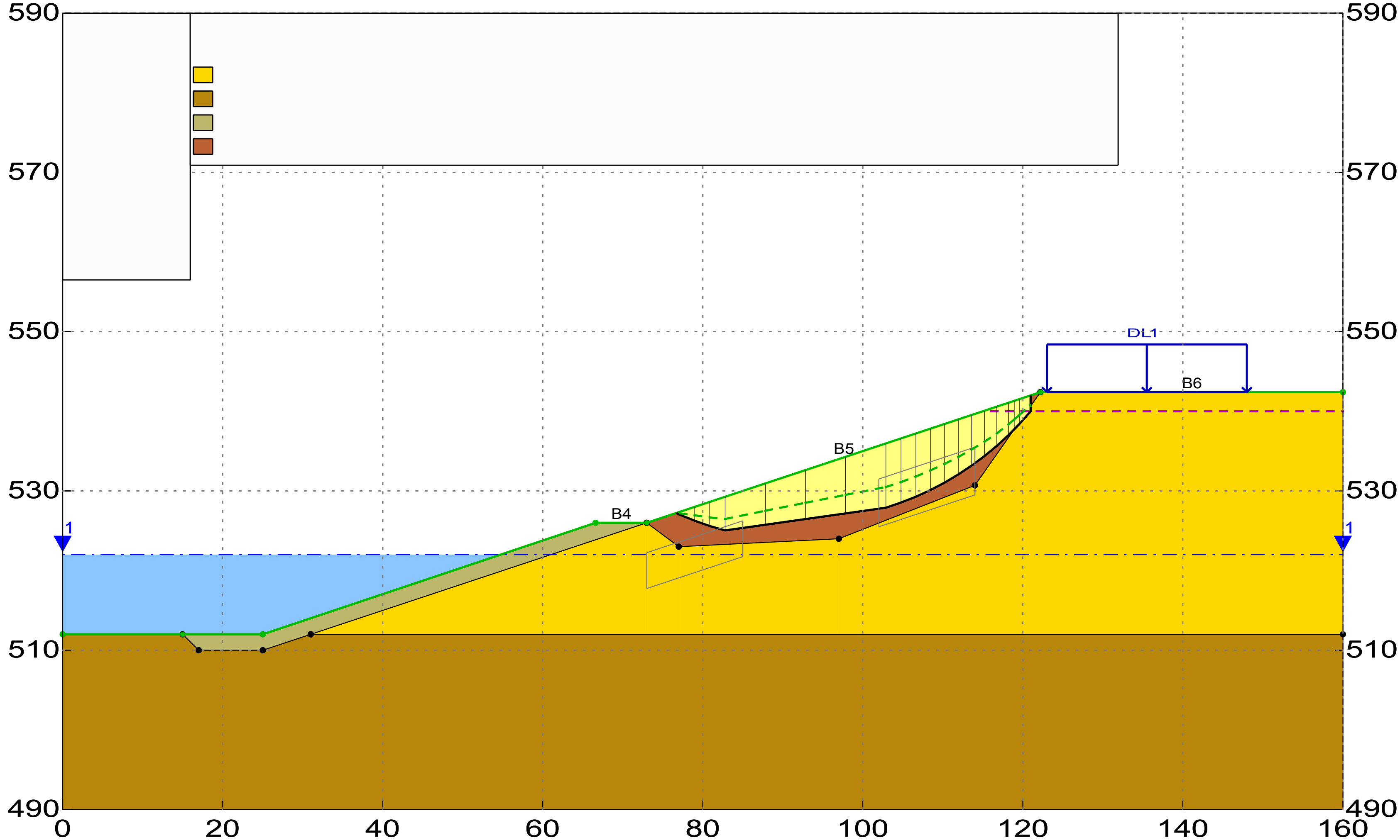
Sum of Mobilized Shear Forces = 8392.89(lbs)

FS Balance Check: FS = 1.548668

**** END OF GEOSTASE OUTPUT ****

LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II
Long-Term-Repaired Condition - FRS

GREGORY GEOTECHNICAL - GHG \lakeridge-Repaired.gsd



GEOSTASE FS = 1.549

Spencer Method

GEOSTASE Slope Stability Analysis

GREGORY GEOTECHNICAL

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

PLATE C.2

*** GEOSTASE ***

** Current Version 4.20.0000-Double Precision, Dec. 2016 **

****
SLOPE STABILITY ANALYSIS SOFTWARE
Simplified Bishop, Simplified Janbu, or General Equilibrium (GE) Options.
(Spencer, Morgenstern-Price, USACE, and Lowe & Karafiath)
Including Pier/Pile, Planar Reinf, Nail, Tieback, Line Loads
Nonlinear Undrained Shear Strength, Curved Strength Envelope,
Anisotropic , Fiber-Reinforced , Distributed Loads, Water
Surfaces, Pseudo-Static & Newmark Earthquake, and Applied Forces.
****

Analysis Date:
Analysis Time:
Analysis By: GREGORY GEOTECHNICAL - GHG

Input File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Repaired.gsd

Output File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Repaired.OUT

Unit System: English

PROJECT: LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II

DESCRIPTION: Long-Term-Repaired Condition - FRS

BOUNDARY DATA

6 Surface Boundaries
15 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	512.000	15.000	512.000	2
2	15.000	512.000	25.000	512.000	3
3	25.000	512.000	66.600	526.000	3

4	66.600	526.000	73.000	526.000	3
5	73.000	526.000	122.200	542.400	4
6	122.200	542.400	160.000	542.400	1
7	15.000	512.000	17.000	510.000	2
8	17.000	510.000	25.000	510.000	2
9	25.000	510.000	31.000	512.000	2
10	31.000	512.000	73.000	526.000	1
11	73.000	526.000	77.000	523.000	1
12	77.000	523.000	97.000	524.000	1
13	97.000	524.000	114.000	530.700	1
14	114.000	530.700	122.200	542.400	1
15	31.000	512.000	160.000	512.000	2

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 490.000(ft)

MOHR-COULOMB SOIL PARAMETERS

4 Type(s) of Soil Defined

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Ratio(ru)	Pressure Constant (psf)	Water Surface No.	Water Option
1 Fill-Clay	120.0	132.0	40.00	25.00	0.000	0.0	1	0
2 In-Situ	120.0	132.0	1000.00	20.00	0.000	0.0	1	0
3 Soil Cement	130.0	135.0	1000.00	40.00	0.000	0.0	1	0
4 Weak Clay	120.0	132.0	70.00	13.00	0.000	0.0	1	0

FIBER-REINFORCED SOIL PROPERTIES
1 Soil Type(s) With Fiber Reinforcement

Soil Type 4:

Fiber Length = 3.00(in) Fiber Width = 0.05300(in)
Fiber Thickness = 0.00150(in) Fiber Equivalent Dia. = 0.01006(in)
Friction Coefficient = 0.50 Cohesion Coefficient = 0.50
Specific Gravity of Fiber = 0.910 Application Rate = 0.250 (pcf)

Fiber-Reinforced Shear-Strength Properties

Soil Type 4: FRS c = 72.56 (psf) FRS Phi = 16.60 Deg.
Delta(c) = 2.559(psf) Tan(DeltaPhi) = 0.062926

CURVED STRENGTH PARAMETERS
1 Soil Type(s) Assigned Curved Strength Envelope Properties

Pa = 1.000

Soil Type 4:

Curve Coefficients a, b, and T are User Input Values

Coefficient a = 0.7741 Coefficient b = 0.8852
Cohesion(c) = 0.00000(psf) Coefficient T = 0.00000

A Power Curve Function Has Been Selected to Model
Stress-Dependent Shear Strength (C = 0).

WATER SURFACE DATA

1 Water Surface(s) Defined

Unit Weight of Water = 62.400 (pcf)

Water Surface No. 1 Specified by 2 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	522.00
2	160.00	522.00

DISTRIBUTED LOAD(S)

1 Load(s) Specified

Load No.	BND No.	X - 1 (ft)	Y - 1 (ft)	Stress (psf)	X - 2 (ft)	Y - 2 (ft)	Stress (psf)	Deflection (deg from Vert)
1	6	123.000	542.400	250.000	148.000	542.400	250.000	0.00

NOTE - Load Stress Varies Linearly Within Specified Range.

TENSION CRACK DATA

Tension Crack Zones Have Been Defined By 1 Tension Crack Line(s)

TC-Line No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)

1	116.00	540.00	160.00	540.00

Specified Tension Crack Water Depth Factor = 1.0000

Specified Tension Crack Fluid Weight = 62.400 (pcf)

SEISMIC (EARTHQUAKE) DATA

Specified Peak Ground Acceleration Coefficient (PGA) = 0.070(g)
Default Velocity = 0.175(ft) per second
Specified Horizontal Earthquake Coefficient (kh) = 0.0300(g)
Specified Vertical Earthquake Coefficient (kv) = 0.000(g)
(NOTE:Input Velocity = 0.0 will result in default Peak
Velocity = 2 times(PGA) times 2.5 fps or 0.762 mps)
Specified Seismic Pore-Pressure Factor = 0.000
Horizontal Seismic Force is Applied at Center of Gravity of Slices

EARTHQUAKE DATA HAS BEEN SUPPRESSED

A Non-Circular Zone Search Has Been Selected For Analysis
Using Random Generation Within Specified Zones.

2 Zones Defined For Generation Of Non-Circular Surfaces

1000 Trial Surfaces Have Been Generated.

Length Of Line Segments For Active And Passive Portions Of
Non-Circular Zone Search = 2.00(ft)

Zone No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Height (ft)
1	73.00	520.00	85.00	524.00	4.50
2	102.00	528.50	114.00	532.50	6.00

The Spencer Method Was Selected for FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR SPENCER METHOD:
Initial estimate of FS = 1.600
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 8.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = -45.00 ; Maximum theta(deg) = 45.00
Theta convergence Step Factor = 1000.00

```
Maximum number of iterations = 50
Maximum force imbalance  = 100.000000(lbs)
Maximum moment imbalance = 100.000000 (ft/lbs)

Selected Lambda Coefficient =  1.00

The option of using a different convergence method
during the first 25% of iterations has been selected.

Specified Tension Crack Water Depth Factor =   1.000

Total Number of Trial Surfaces Attempted = 1000

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence =     33
Maximum Normal Stress Difference (%) =   0.005000


Warning: Convergence not achieved on  107
surfaces during curved strength envelope calculations.
Maximum Normal Stress Difference (%) =     Infinity


WARNING! The Factor of Safety Calculation for one or More Trial Surfaces
Did Not Converge in 50 Iterations.


Number of Trial Surfaces with Non-Converged FS = 143

Number of Trial Surfaces With Valid FS = 857


Percentage of Trial Surfaces With Non-Converged and/or
Non-Valid FS Solutions of the Total Attempted =  14.3 %

Statistical Data On All Valid FS Values:
   FS Max =   4.604   FS Min =   1.549   FS Ave =   2.109
   Standard Deviation =    0.392   Coefficient of Variation =   18.58 %


Critical Surface is Sequence Number      16 of Those Analyzed.


*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****


  Iter.     Theta         FS         FS
   No.      (deg)      (Moment)   (Force)
          (fx=1.0)                          Lambda        Delta FS
```

1	8.0000	1.813057	1.486719	0.141	0.3263378E+00
2	10.6400	1.752648	1.506133	0.188	0.2465142E+00
3	12.3815	1.701241	1.519479	0.220	0.1817620E+00
4	13.8626	1.648156	1.531217	0.247	0.1169391E+00
5	14.9213	1.603729	1.539848	0.266	0.6388069E-01
6	15.5403	1.574811	1.544996	0.278	0.2981522E-01
7	15.8402	1.559933	1.547518	0.284	0.1241503E-01
8	15.9672	1.553447	1.548592	0.286	0.4854913E-02
9	16.0173	1.550862	1.549016	0.287	0.1845495E-02
10	16.0364	1.549871	1.549178	0.287	0.6935343E-03
11	16.0436	1.549498	1.549239	0.288	0.2594811E-03
12	16.0463	1.549359	1.549262	0.288	0.9688612E-04
13	16.0473	1.549306	1.549270	0.288	0.3618822E-04
14	16.0479	1.549275	1.549275	0.288	0.3285373E-07

Factor Of Safety For The Preceding Specified Surface = 1.549
Theta (fx = 1.0) = 16.05 Deg   Lambda =   0.288

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence =   33
Maximum Normal Stress Difference (%) =   0.005000

The Spencer Method Has Been Selected For FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR ANALYSIS METHOD:
Initial estimate of FS = 1.600
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 8.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = -45.00 ; Maximum theta(deg) = 45.00
Theta convergence Step Factor = 1000.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance(if Applicable) = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

The option of using a different convergence method
during the first 25% of iterations has been selected.

Tension Crack Water Force =   123.15(lbs)

Specified Tension Crack Water Depth Factor = 1.000

Depth of Tension Crack (zo) at Side of Last Slice =   1.987(ft)

Depth of Water in Tension Crack =   1.987(ft)

Theoretical Tension Crack Depth =   1.046(ft)

NOTE: In Table 1 following, when a tension crack with water is present on the first slice (right facing slope) or on the last slice (left facing slope), the "side force" in the tension crack is set equal to the water pressure resultant.

*** Table 1 - Line of Thrust(if applicable) and Slice Force Data ***

Slice No.	X Coord.	Y Coord.	h/H	Side Force (lbs)	fx	Force Angle (Deg)	Vert. Shear Force(lbs)
1	77.13	527.19	0.472	14.60	1.000	16.05	4.0
2	78.98	526.95	0.396	277.63	1.000	16.05	76.7
3	80.87	526.66	0.351	778.99	1.000	16.05	215.3
4	82.79	526.48	0.339	1436.30	1.000	16.05	397.1
5	87.82	527.52	0.340	1849.10	1.000	16.05	511.2
6	92.84	528.53	0.335	2327.97	1.000	16.05	643.5
7	97.86	529.52	0.328	2870.42	1.000	16.05	793.5
8	102.88	530.49	0.322	3474.37	1.000	16.05	960.5
9	104.77	531.13	0.321	3356.06	1.000	16.05	927.8
10	106.63	531.82	0.320	3149.65	1.000	16.05	870.7
11	108.45	532.58	0.320	2867.07	1.000	16.05	792.6
12	110.22	533.40	0.319	2523.33	1.000	16.05	697.6
13	111.94	534.27	0.318	2135.99	1.000	16.05	590.5
14	113.60	535.19	0.316	1724.55	1.000	16.05	476.7
15	115.20	536.17	0.315	1309.84	1.000	16.05	362.1
16	116.74	537.21	0.316	913.35	1.000	16.05	252.5
17	118.21	538.33	0.324	556.52	1.000	16.05	153.8
18	118.99	539.03	0.345	380.64	1.000	16.05	105.2
19	119.61	539.55	0.357	281.53	1.000	16.05	77.8
20	120.92	540.77	0.402	110.37	1.000	16.05	30.5
21	120.96	540.66	0.662	123.15	1.000	16.05	-0.0

NOTE: A value of 0.000- for h/H indicates that the line of thrust is at or below the lower boundary of the sliding mass. A value of 1.000+ for h/H indicates that the line of thrust is at or above the upper boundary of the sliding mass.

Table 2 - Geometry Data on the   21 Slices

Slice No.	Width (ft)	Height (ft)	X-Cntr (ft)	Y-Cntr-Base (ft)	Y-Cntr-Top (ft)	Alpha (deg)	Beta (deg)	Base Length (ft)
1	0.45	0.18	76.91	527.12	527.30	-25.16	18.43	0.50

2	1.85	1.05	78.06	526.64	527.69	-22.16	18.43	2.00
3	1.89	2.38	79.93	525.93	528.31	-19.16	18.43	2.00
4	1.92	3.62	81.83	525.33	528.94	-16.16	18.43	2.00
5	5.02	4.70	85.30	525.40	530.10	8.08	18.43	5.07
6	5.02	5.66	90.33	526.12	531.78	8.08	18.43	5.07
7	5.02	6.62	95.35	526.83	533.45	8.08	18.43	5.07
8	5.02	7.58	100.37	527.54	535.12	8.08	18.43	5.07
9	1.89	8.05	103.83	528.22	536.28	18.75	18.43	2.00
10	1.86	7.99	105.70	528.91	536.90	21.75	18.43	2.00
11	1.82	7.81	107.54	529.70	537.51	24.75	18.43	2.00
12	1.77	7.52	109.33	530.59	538.11	27.75	18.43	2.00
13	1.72	7.13	111.08	531.56	538.69	30.75	18.43	2.00
14	1.66	6.63	112.77	532.63	539.26	33.75	18.43	2.00
15	1.60	6.02	114.40	533.78	539.80	36.75	18.43	2.00
16	1.54	5.30	115.97	535.02	540.32	39.75	18.43	2.00
17	1.47	4.49	117.48	536.34	540.83	42.75	18.43	2.00
18	0.78	3.78	118.60	537.42	541.20	45.75	18.43	1.12
19	0.62	3.30	119.30	538.13	541.43	45.75	18.43	0.88
20	1.32	2.55	120.26	539.20	541.75	48.75	18.43	2.00
21	0.04	2.00	120.94	539.98	541.98	51.75	18.43	0.06

Table 2A - Coordinates of Slice Points Defining the Slip Surface

Point No.	X-Pt (ft)	Y-Pt (ft)
1	76.680747	527.226916
2	77.130698	527.015585
3	78.982989	526.261251
4	80.872220	525.604893
5	82.793213	525.048309
6	87.815186	525.761177
7	92.837158	526.474045
8	97.859131	527.186913
9	102.881104	527.899780
10	104.774998	528.542562
11	106.632656	529.283582
12	108.448986	530.120809
13	110.219010	531.051947
14	111.937876	532.074446
15	113.600873	533.185501
16	115.203443	534.382068
17	116.741193	535.660868
18	118.209908	537.018394
19	118.988052	537.817098
20	119.605563	538.450926
21	120.924333	539.954539
22	120.960176	540.000000

Table 3 - Force and Pore Pressure Data On The 21 Slices (Excluding Reinforcement)

Slice No.	Weight (lbs)	Ubeta Force Top (lbs)	Ubeta Stress Top (psf)	Ualpha Force Bot (lbs)	Pore Pressure (psf)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Distributed Load (lbs)
1	9.8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
2	232.8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
3	538.7	0.0	0.0	0.0	0.0	0.0	0.0	0.00
4	833.9	0.0	0.0	0.0	0.0	0.0	0.0	0.00
5	2830.4	0.0	0.0	0.0	0.0	0.0	0.0	0.00
6	3409.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
7	3988.8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
8	4568.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
9	1830.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
10	1780.7	0.0	0.0	0.0	0.0	0.0	0.0	0.00
11	1702.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
12	1598.3	0.0	0.0	0.0	0.0	0.0	0.0	0.00
13	1470.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
14	1322.4	0.0	0.0	0.0	0.0	0.0	0.0	0.00
15	1157.1	0.0	0.0	0.0	0.0	0.0	0.0	0.00
16	978.5	0.0	0.0	0.0	0.0	0.0	0.0	0.00
17	790.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
18	353.1	0.0	0.0	0.0	0.0	0.0	0.0	0.00
19	244.4	0.0	0.0	0.0	0.0	0.0	0.0	0.00
20	403.9	0.0	0.0	0.0	0.0	0.0	0.0	0.00
21	8.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00

Table 3A - Center of Pressure of Water Loads On the 21 Slices
Only Applicable Slices Listed

Slice No.	X-Ubeta (ft)	Y-Ubeta (ft)	Ubeta-Moment (ft/lbs)

Table 3B - Center of Pressure of Distributed Loads On the 21 Slices
Only Applicable Slices Listed

Slice No.	X-Dload (ft)	Y-Dload (ft)	Dist-Load (lbs)	Dload-Moment (ft/lbs)
18	123.39	542.40	0.197351E+03	0.000000E+00
19	123.17	542.40	0.829042E+02	0.000000E+00
20	124.14	542.40	0.402400E+03	0.000000E+00
21	125.71	542.40	0.386317E+03	0.000000E+00

TOTAL WEIGHT OF SLIDING MASS = 30053.31(lbs)

EFFECTIVE WEIGHT OF SLIDING MASS = 30053.31(lbs)

TOTAL AREA OF SLIDING MASS = 250.44(ft2)

TABLE 4 - SOIL STRENGTH & SOIL OPTIONS DATA ON THE 21 SLICES

Slice No.	Soil Type	Cohesion (psf)	Phi(Deg)	Options
1	4	2.18	27.27	C F
2	4	9.21	23.67	C F
3	4	17.83	22.17	C F
4	4	24.66	21.47	C F
5	4	24.21	21.51	C F
6	4	28.53	21.16	C F
7	4	32.76	20.87	C F
8	4	36.92	20.63	C F
9	4	35.53	20.71	C F
10	4	34.36	20.78	C F
11	4	32.80	20.87	C F
12	4	30.88	21.00	C F
13	4	28.62	21.15	C F
14	4	26.05	21.35	C F
15	4	23.19	21.60	C F
16	4	20.06	21.91	C F
17	4	16.69	22.31	C F
18	4	13.82	22.74	C F
19	1	40.00	25.00	
20	1	40.00	25.00	
21	1	40.00	25.00	

SOIL OPTIONS: A = ANISOTROPIC, C = CURVED STRENGTH ENVELOPE (TANGENT PHI),
F = FIBER-REINFORCED SOIL (FRS), N = NONLINEAR UNDRAINED SHEAR STRENGTH,
R = RAPID DRAWDOWN SHEAR STRENGTH
NOTE: Phi and C in Table 4 are modified values based on specified
Soil Options (if any). Zero values indicate that the normal stress = 0.0

Calculated Secant Phi Values

Slice No.	Phi(Deg)
1	29.86
2	25.97
3	24.33
4	23.56
5	23.61
6	23.23
7	22.91
8	22.64

9	22.73
10	22.80
11	22.91
12	23.04
13	23.22
14	23.44
15	23.71
16	24.05
17	24.49
18	24.95
19	22.80
20	22.99
21	23.22

NOTE: The slices in the table above with phi marked with an * are unmodified phi values for soil type(s) not specified to have curved strength envelope (if any).

TABLE 5 - Total Base Stress Data on the 21 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Stress (psf)	Total Vert. Stress (psf)	Total Normal/Vert. Stress Ratio
1	-25.16	76.91	0.50	37.11	21.68	1.712
2	-22.16	78.06	2.00	189.13	125.66	1.505
3	-19.16	79.93	2.00	398.95	285.14	1.399
4	-16.16	81.83	2.00	575.66	434.12	1.326
5	8.08	85.30	5.07	563.75	563.60	1.000
6	8.08	90.33	5.07	678.61	678.93	1.000
7	8.08	95.35	5.07	793.41	794.27	0.999
8	8.08	100.37	5.07	908.14	909.60	0.998
9	18.75	103.83	2.00	869.53	966.58	0.900
10	21.75	105.70	2.00	837.24	958.58	0.873
11	24.75	107.54	2.00	794.48	937.37	0.848
12	27.75	109.33	2.00	742.12	902.99	0.822
13	30.75	111.08	2.00	681.08	855.55	0.796
14	33.75	112.77	2.00	612.32	795.18	0.770
15	36.75	114.40	2.00	536.88	722.03	0.744
16	39.75	115.97	2.00	455.85	636.32	0.716
17	42.75	117.48	2.00	370.44	538.27	0.688
18	45.75	118.60	1.12	299.14	453.83	0.659
19	45.75	119.30	0.88	248.23	395.79	0.627
20	48.75	120.26	2.00	179.39	306.27	0.586
21	51.75	120.94	0.06	-465.78	240.42	-1.937

TABLE 5A - Total Base Force Data on the 21 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Force (lbs)	Total Vert. Force (lbs)	Total Normal/Vert. Force Ratio
1	-25.16	76.91	0.50	18.45	9.75	1.891
2	-22.16	78.06	2.00	378.26	232.77	1.625
3	-19.16	79.93	2.00	797.90	538.69	1.481
4	-16.16	81.83	2.00	1151.31	833.93	1.381
5	8.08	85.30	5.07	2859.51	2830.38	1.010
6	8.08	90.33	5.07	3442.13	3409.59	1.010
7	8.08	95.35	5.07	4024.41	3988.79	1.009
8	8.08	100.37	5.07	4606.39	4568.00	1.008
9	18.75	103.83	2.00	1739.05	1830.60	0.950
10	21.75	105.70	2.00	1674.48	1780.72	0.940
11	24.75	107.54	2.00	1588.96	1702.57	0.933
12	27.75	109.33	2.00	1484.23	1598.32	0.929
13	30.75	111.08	2.00	1362.15	1470.58	0.926
14	33.75	112.77	2.00	1224.64	1322.38	0.926
15	36.75	114.40	2.00	1073.76	1157.11	0.928
16	39.75	115.97	2.00	911.70	978.50	0.932
17	42.75	117.48	2.00	740.88	790.56	0.937
18	45.75	118.60	1.12	333.57	353.14	0.945
19	45.75	119.30	0.88	219.66	244.41	0.899
20	48.75	120.26	2.00	358.79	403.90	0.888
21	51.75	120.94	0.06	-26.97	8.62	-3.129

TABLE 6 - Effective and Base Shear Stress Data on the 21 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Stress (psf)	Available Shear Strength (psf)	Mobilized Shear Stress (psf)
1	-25.16	76.91	0.50	37.11	21.31	13.75
2	-22.16	78.06	2.00	189.13	92.10	59.45
3	-19.16	79.93	2.00	398.95	180.39	116.43
4	-16.16	81.83	2.00	575.66	251.05	162.05
5	8.08	85.30	5.07	563.75	246.37	159.02
6	8.08	90.33	5.07	678.61	291.21	187.97
7	8.08	95.35	5.07	793.41	335.31	216.43
8	8.08	100.37	5.07	908.14	378.77	244.49
9	18.75	103.83	2.00	869.53	364.21	235.08
10	21.75	105.70	2.00	837.24	351.98	227.19
11	24.75	107.54	2.00	794.48	335.72	216.69
12	27.75	109.33	2.00	742.12	315.69	203.77
13	30.75	111.08	2.00	681.08	292.17	188.58
14	33.75	112.77	2.00	612.32	265.43	171.32
15	36.75	114.40	2.00	536.88	235.75	152.17
16	39.75	115.97	2.00	455.85	203.42	131.30
17	42.75	117.48	2.00	370.44	168.73	108.91

18	45.75	118.60	1.12	299.14	139.17	89.83
19	45.75	119.30	0.88	248.23	155.75	100.53
20	48.75	120.26	2.00	179.39	123.65	79.81
21	51.75	120.94	0.06	0.00	40.00	-114.38

TABLE 6A - Effective and Base Shear Force Data on the 21 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Force (lbs)	Available Shear Force (lbs)	Mobilized Shear Force (lbs)
1	-25.16	76.91	0.50	18.45	10.59	6.84
2	-22.16	78.06	2.00	378.26	184.21	118.90
3	-19.16	79.93	2.00	797.90	360.78	232.87
4	-16.16	81.83	2.00	1151.31	502.11	324.09
5	8.08	85.30	5.07	2859.51	1249.64	806.60
6	8.08	90.33	5.07	3442.13	1477.13	953.43
7	8.08	95.35	5.07	4024.41	1700.80	1097.80
8	8.08	100.37	5.07	4606.39	1921.26	1240.11
9	18.75	103.83	2.00	1739.05	728.42	470.17
10	21.75	105.70	2.00	1674.48	703.97	454.38
11	24.75	107.54	2.00	1588.96	671.44	433.39
12	27.75	109.33	2.00	1484.23	631.38	407.53
13	30.75	111.08	2.00	1362.15	584.34	377.17
14	33.75	112.77	2.00	1224.64	530.86	342.65
15	36.75	114.40	2.00	1073.76	471.50	304.34
16	39.75	115.97	2.00	911.70	406.84	262.60
17	42.75	117.48	2.00	740.88	337.46	217.82
18	45.75	118.60	1.12	333.57	155.19	100.17
19	45.75	119.30	0.88	219.66	137.83	88.96
20	48.75	120.26	2.00	358.79	247.30	159.63
21	51.75	120.94	0.06	0.00	2.32	-6.62

SUM OF MOMENTS = -0.386625E-04 (ft/lbs);Imbalance (Fraction of Total Weight) = -0.1286463E-08
SUM OF FORCES = -.149697E-05 (lbs);Imbalance (Fraction of Total Weight) = -0.4981044E-10

Sum of Available Shear Forces = 13002.79(lbs)

Sum of Mobilized Shear Forces = 8392.82(lbs)

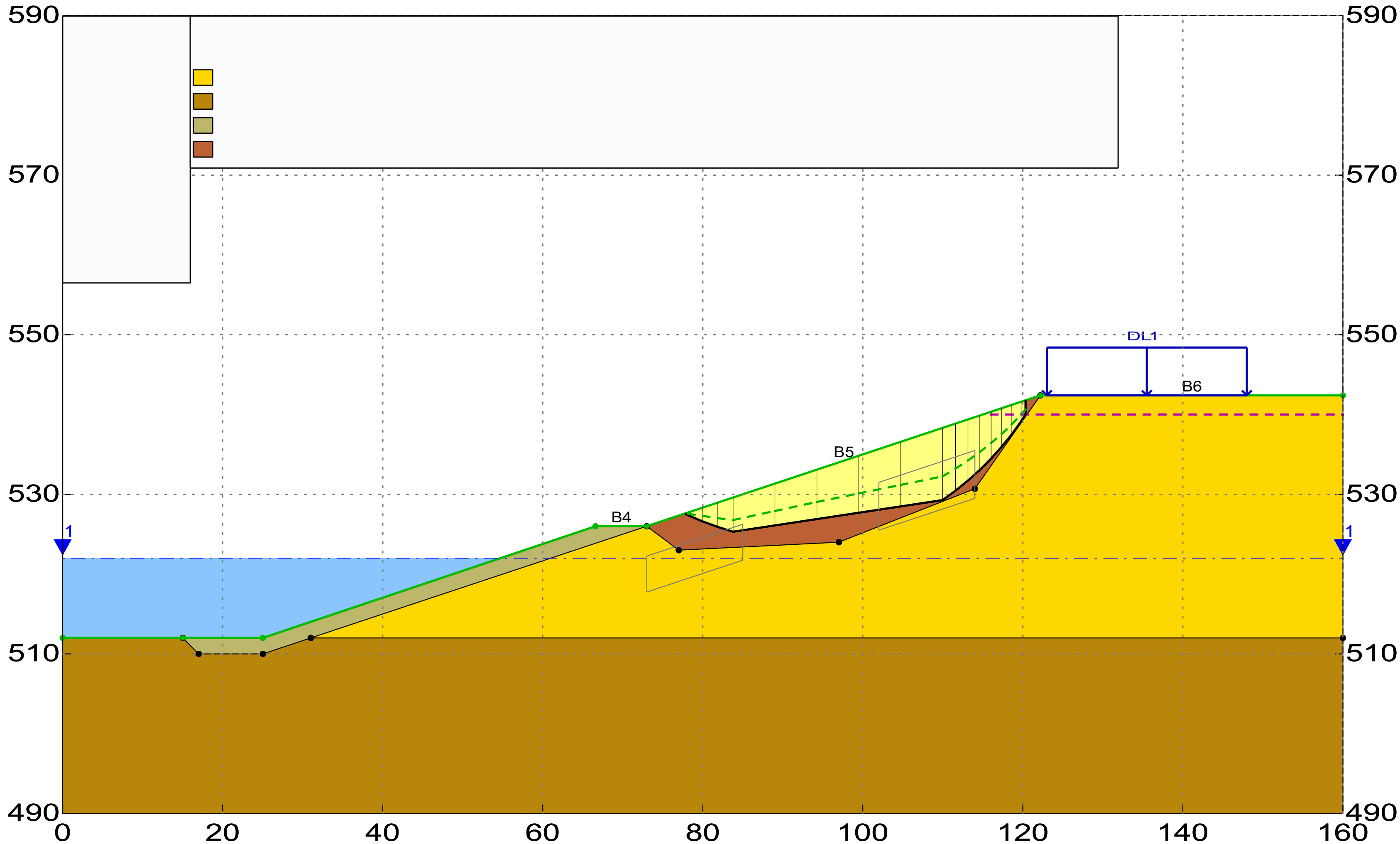
FS Balance Check: FS = 1.549275

**** END OF GEOSTASE OUTPUT ****

LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II
Long-Term - Intital Condition Following Heavy Rainfall

GREGORY GEOTECHNICAL - GHG

\lakeridge-Initial-HRF.gsd



GEOSTASE FS = 0.894

Spencer Method

GEOSTASE Slope Stability Analysis

GREGORY GEOTECHNICAL

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

PLATE C.3

*** GEOSTASE ***

** Current Version 4.20.0000-Double Precision, Dec. 2016 **

****
SLOPE STABILITY ANALYSIS SOFTWARE
Simplified Bishop, Simplified Janbu, or General Equilibrium (GE) Options.
(Spencer, Morgenstern-Price, USACE, and Lowe & Karafiath)
Including Pier/Pile, Planar Reinf, Nail, Tieback, Line Loads
Nonlinear Undrained Shear Strength, Curved Strength Envelope,
Anisotropic , Fiber-Reinforced , Distributed Loads, Water
Surfaces, Pseudo-Static & Newmark Earthquake, and Applied Forces.
****

Analysis Date:
Analysis Time:
Analysis By: GREGORY GEOTECHNICAL - GHG

Input File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Initial-HRF.gsd

Output File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Initial-HRF.OUT

Unit System: English

PROJECT: LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II

DESCRIPTION: Long-Term - Intital Condition Following Heavy Rainfall

BOUNDARY DATA

6 Surface Boundaries
15 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	512.000	15.000	512.000	2
2	15.000	512.000	25.000	512.000	3
3	25.000	512.000	66.600	526.000	3

4	66.600	526.000	73.000	526.000	3
5	73.000	526.000	122.200	542.400	4
6	122.200	542.400	160.000	542.400	1
7	15.000	512.000	17.000	510.000	2
8	17.000	510.000	25.000	510.000	2
9	25.000	510.000	31.000	512.000	2
10	31.000	512.000	73.000	526.000	1
11	73.000	526.000	77.000	523.000	1
12	77.000	523.000	97.000	524.000	1
13	97.000	524.000	114.000	530.700	1
14	114.000	530.700	122.200	542.400	1
15	31.000	512.000	160.000	512.000	2

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 490.000(ft)

MOHR-COULOMB SOIL PARAMETERS

4 Type(s) of Soil Defined

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Ratio(ru)	Pressure Constant (psf)	Water Surface No.	Water Option
1 Fill-Clay	120.0	132.0	40.00	25.00	0.000	0.0	1	0
2 In-Situ	120.0	132.0	1000.00	20.00	0.000	0.0	1	0
3 Soil Cement	130.0	135.0	1000.00	40.00	0.000	0.0	1	0
4 Weak Clay	120.0	132.0	70.00	13.00	0.270	0.0	1	0

CURVED STRENGTH PARAMETERS

1 Soil Type(s) Assigned Curved Strength Envelope Properties

Pa = 2116.800(psf)
A Value of 1.0 indicates Dimensional Coefficients

Soil Type 4:

Curve Coefficients a, b, and T are User Input Values

Coefficient a = 0.2723 Coefficient b = 0.8691
Cohesion(c) = 0.00000(psf) Coefficient T = 0.00000

A Power Curve Function Has Been Selected to Model
Stress-Dependent Shear Strength (C = 0).

WATER SURFACE DATA

1 Water Surface(s) Defined

Unit Weight of Water = 62.400 (pcf)

Water Surface No. 1 Specified by 2 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	522.00
2	160.00	522.00

DISTRIBUTED LOAD(S)

1 Load(s) Specified

Load No.	BND No.	X - 1 (ft)	Y - 1 (ft)	Stress (psf)	X - 2 (ft)	Y - 2 (ft)	Stress (psf)	Deflection (deg from Vert)
1	6	123.000	542.400	250.000	148.000	542.400	250.000	0.00

NOTE - Load Stress Varies Linearly Within Specified Range.

TENSION CRACK DATA

Tension Crack Zones Have Been Defined By 1 Tension Crack Line(s)

TC-Line No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)
1	116.00	540.00	160.00	540.00

Specified Tension Crack Water Depth Factor = 1.0000

Specified Tension Crack Fluid Weight = 62.400 (pcf)

SEISMIC (EARTHQUAKE) DATA

Specified Peak Ground Acceleration Coefficient (PGA) = 0.070(g)
Default Velocity = 0.175(ft) per second

Specified Horizontal Earthquake Coefficient (kh) = 0.0300(g)
Specified Vertical Earthquake Coefficient (kv) = 0.000(g)
(NOTE:Input Velocity = 0.0 will result in default Peak
Velocity = 2 times(PGA) times 2.5 fps or 0.762 mps)
Specified Seismic Pore-Pressure Factor = 0.000
Horizontal Seismic Force is Applied at Center of Gravity of Slices

EARTHQUAKE DATA HAS BEEN SUPPRESSED

A Non-Circular Zone Search Has Been Selected For Analysis
Using Random Generation Within Specified Zones.

2 Zones Defined For Generation Of Non-Circular Surfaces

1000 Trial Surfaces Have Been Generated.

Length Of Line Segments For Active And Passive Portions Of
Non-Circular Zone Search = 2.00(ft)

Zone No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Height (ft)
1	73.00	520.00	85.00	524.00	4.50
2	102.00	528.50	114.00	532.50	6.00

The Spencer Method Was Selected for FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR SPENCER METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 8.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = -45.00 ; Maximum theta(deg) = 90.00
Theta convergence Step Factor = 5000.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

Specified Tension Crack Water Depth Factor = 1.000

Total Number of Trial Surfaces Attempted = 1000

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence = 32
Maximum Normal Stress Difference (%) = 0.005000

Warning: Convergence not achieved on 404
surfaces during curved strength envelope calculations.
Maximum Normal Stress Difference (%) = Infinity

WARNING! The Factor of Safety Calculation for one or More Trial Surfaces
Did Not Converge in 50 Iterations.

Number of Trial Surfaces with Non-Converged FS = 538

Number of Trial Surfaces With Valid FS = 462

Percentage of Trial Surfaces With Non-Converged and/or
Non-Valid FS Solutions of the Total Attempted = 53.8 %

Statistical Data On All Valid FS Values:
FS Max = 3.034 FS Min = 0.894 FS Ave = 1.627
Standard Deviation = 0.419 Coefficient of Variation = 25.74 %

Critical Surface is Sequence Number 323 of Those Analyzed.

*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****

Iter. No.	Theta (deg) (fx=1.0)	FS (Moment)	FS (Force)	Lambda	Delta FS
1	8.0000	1.050197	0.841847	0.141	0.2083506E+00
2	10.6400	1.013313	0.858264	0.188	0.1550492E+00
3	18.3180	0.806265	0.911585	0.331	0.1053206E+00
4	15.2128	0.914552	0.888840	0.272	0.2571210E-01
5	15.8226	0.896671	0.893164	0.283	0.3506739E-02
6	15.9189	0.893717	0.893853	0.285	0.1356386E-03
7	15.9153	0.893828	0.893827	0.285	0.6477883E-06

Factor Of Safety For The Preceding Specified Surface = 0.894
Theta (fx = 1.0) = 15.92 Deg Lambda = 0.285

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence = 32
Maximum Normal Stress Difference (%) = 0.005000

The Spencer Method Has Been Selected For FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR ANALYSIS METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 8.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = -45.00 ; Maximum theta(deg) = 90.00
Theta convergence Step Factor = 5000.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance(if Applicable) = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

Tension Crack Water Force =   98.57(lbs)

Specified Tension Crack Water Depth Factor = 1.000

Depth of Tension Crack (zo) at Side of Last Slice =   1.777(ft)

Depth of Water in Tension Crack =   1.777(ft)

Theoretical Tension Crack Depth =   2.332(ft)

NOTE: In Table 1 following, when a tension crack with water is present on the first slice (right facing slope) or on the last slice (left facing slope), the "side force" in the tension crack is set equal to the water pressure resultant.

*** Table 1 - Line of Thrust(if applicable) and Slice Force Data ***

Slice No.	X Coord.	Y Coord.	h/H	Side Force (lbs)	fx	Force Angle (Deg)	Vert. Shear Force(lbs)
1	78.17	527.55	0.471	15.56	1.000	15.92	4.3
2	80.00	527.30	0.402	312.77	1.000	15.92	85.8
3	81.88	526.99	0.356	869.32	1.000	15.92	238.4
4	83.79	526.79	0.344	1591.26	1.000	15.92	436.3
5	89.03	527.93	0.348	1971.52	1.000	15.92	540.6
6	94.26	529.03	0.344	2403.29	1.000	15.92	659.0
7	99.50	530.11	0.339	2883.35	1.000	15.92	790.7
8	104.73	531.18	0.332	3409.06	1.000	15.92	934.8
9	109.97	532.24	0.327	3978.11	1.000	15.92	1090.9
10	111.59	533.21	0.327	3317.31	1.000	15.92	909.7

11	113.14	534.24	0.328	2656.06	1.000	15.92	728.3
12	114.62	535.31	0.329	2019.42	1.000	15.92	553.8
13	116.03	536.42	0.330	1432.08	1.000	15.92	392.7
14	117.36	537.57	0.332	917.66	1.000	15.92	251.6
15	118.62	538.77	0.336	497.92	1.000	15.92	136.5
16	119.79	540.04	0.363	191.85	1.000	15.92	52.6
17	120.33	540.59	0.592	98.57	1.000	15.92	-0.0

NOTE: A value of 0.000- for h/H indicates that the line of thrust is at or below the lower boundary of the sliding mass. A value of 1.000+ for h/H indicates that the line of thrust is at or above the upper boundary of the sliding mass.

Table 2 - Geometry Data on the 17 Slices

Slice No.	Width (ft)	Height (ft)	X-Cntr (ft)	Y-Cntr-Base (ft)	Y-Cntr-Top (ft)	Alpha (deg)	Beta (deg)	Base Length (ft)
1	0.40	0.17	77.96	527.49	527.65	-26.25	18.43	0.45
2	1.84	1.03	79.08	526.99	528.03	-23.25	18.43	2.00
3	1.88	2.39	80.94	526.25	528.65	-20.25	18.43	2.00
4	1.91	3.67	82.83	525.61	529.28	-17.25	18.43	2.00
5	5.24	4.76	86.41	525.71	530.47	8.62	18.43	5.30
6	5.24	5.71	91.64	526.51	532.21	8.62	18.43	5.30
7	5.24	6.66	96.88	527.30	533.96	8.62	18.43	5.30
8	5.24	7.61	102.12	528.09	535.71	8.62	18.43	5.30
9	5.24	8.56	107.35	528.89	537.45	8.62	18.43	5.30
10	1.61	8.72	110.78	529.87	538.59	36.16	18.43	2.00
11	1.55	8.02	112.36	531.10	539.12	39.16	18.43	2.00
12	1.48	7.23	113.88	532.40	539.63	42.16	18.43	2.00
13	1.41	6.33	115.32	533.78	540.11	45.16	18.43	2.00
14	1.33	5.33	116.70	535.23	540.57	48.16	18.43	2.00
15	1.25	4.24	117.99	536.76	541.00	51.16	18.43	2.00
16	1.17	3.05	119.20	538.35	541.40	54.16	18.43	2.00
17	0.54	2.11	120.06	539.58	541.69	57.16	18.43	1.00

Table 2A - Coordinates of Slice Points Defining the Slip Surface

Point No.	X-Pt (ft)	Y-Pt (ft)
1	77.762193	527.587398
2	78.165121	527.388739
3	80.002772	526.599411
4	81.879215	525.907340
5	83.789307	525.314423
6	89.025635	526.108447

7	94.261963	526.902472
8	99.498291	527.696497
9	104.734619	528.490521
10	109.970947	529.284546
11	111.585675	530.464655
12	113.136428	531.727654
13	114.618956	533.070083
14	116.029194	534.488262
15	117.363278	535.978303
16	118.617551	537.536123
17	119.788575	539.157451
18	120.332376	540.000000

Table 3 - Force and Pore Pressure Data On The 17 Slices (Excluding Reinforcement)

Slice No.	Weight (lbs)	Ubeta Force Top (lbs)	Ubeta Stress Top (psf)	Ualpha Force Bot (lbs)	Pore Pressure (psf)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Distributed Load (lbs)
1	8.0	0.0	0.0	2.4	5.4	0.0	0.0	0.00
2	228.0	0.0	0.0	67.0	33.5	0.0	0.0	0.00
3	539.0	0.0	0.0	155.1	77.6	0.0	0.0	0.00
4	840.6	0.0	0.0	237.6	118.8	0.0	0.0	0.00
5	2989.6	0.0	0.0	816.4	154.2	0.0	0.0	0.00
6	3587.4	0.0	0.0	979.7	185.0	0.0	0.0	0.00
7	4185.2	0.0	0.0	1142.9	215.8	0.0	0.0	0.00
8	4783.1	0.0	0.0	1306.2	246.6	0.0	0.0	0.00
9	5380.9	0.0	0.0	1469.4	277.5	0.0	0.0	0.00
10	1689.3	0.0	0.0	564.9	282.5	0.0	0.0	0.00
11	1493.2	0.0	0.0	520.0	260.0	0.0	0.0	0.00
12	1285.7	0.0	0.0	468.3	234.2	0.0	0.0	0.00
13	1071.0	0.0	0.0	410.1	205.1	0.0	0.0	0.00
14	853.6	0.0	0.0	345.5	172.8	0.0	0.0	0.00
15	638.1	0.0	0.0	274.7	137.4	0.0	0.0	0.00
16	429.2	0.0	0.0	197.9	99.0	0.0	0.0	0.00
17	137.6	0.0	0.0	68.5	68.3	0.0	0.0	0.00

Table 3A - Center of Pressure of Water Loads On the 17 Slices
Only Applicable Slices Listed

Slice No.	X-Ubeta (ft)	Y-Ubeta (ft)	Ubeta-Moment (ft/lbs)

Table 3B - Center of Pressure of Distributed Loads On the 17 Slices
Only Applicable Slices Listed

Slice No.	X-Dload (ft)	Y-Dload (ft)	Dist-Load (lbs)	Dload-Moment (ft/lbs)

TOTAL WEIGHT OF SLIDING MASS = 30139.46(lbs)

EFFECTIVE WEIGHT OF SLIDING MASS = 22001.80(lbs)

TOTAL AREA OF SLIDING MASS = 251.16(ft2)

TABLE 4 - SOIL STRENGTH & SOIL OPTIONS DATA ON THE 17 SLICES

Slice No.	Soil Type	Cohesion (psf)	Phi(Deg)	Options
1	4	2.08	22.12	C
2	4	8.22	18.29	C
3	4	15.38	16.74	C
4	4	20.78	16.03	C
5	4	18.23	16.34	C
6	4	21.34	15.97	C
7	4	24.38	15.67	C
8	4	27.36	15.41	C
9	4	30.29	15.19	C
10	4	22.04	15.90	C
11	4	19.62	16.17	C
12	4	17.08	16.49	C
13	4	14.45	16.89	C
14	4	11.75	17.39	C
15	4	9.02	18.05	C
16	4	6.29	18.99	C
17	4	2.89	21.15	C

SOIL OPTIONS: A = ANISOTROPIC, C = CURVED STRENGTH ENVELOPE (TANGENT PHI),
F = FIBER-REINFORCED SOIL (FRS), N = NONLINEAR UNDRAINED SHEAR STRENGTH,
R = RAPID DRAWDOWN SHEAR STRENGTH
NOTE: Phi and C in Table 4 are modified values based on specified
Soil Options (if any). Zero values indicate that the normal stress = 0.0

Calculated Secant Phi Values

Slice No.	Phi(Deg)
1	25.07
2	20.82
3	19.09
4	18.30
5	18.64
6	18.23
7	17.89
8	17.60

9	17.35
10	18.15
11	18.45
12	18.81
13	19.25
14	19.81
15	20.55
16	21.60
17	23.99

NOTE: The slices in the table above with phi marked with an * are unmodified phi values for soil type(s) not specified to have curved strength envelope (if any).

TABLE 5 - Total Base Stress Data on the 17 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Stress (psf)	Total Vert. Stress (psf)	Total Normal/Vert. Stress Ratio
1	-26.25	77.96	0.45	39.32	19.98	1.968
2	-23.25	79.08	2.00	198.59	124.07	1.601
3	-20.25	80.94	2.00	417.04	287.23	1.452
4	-17.25	82.83	2.00	598.83	440.06	1.361
5	8.62	86.41	5.30	567.21	570.93	0.993
6	8.62	91.64	5.30	680.05	685.10	0.993
7	8.62	96.88	5.30	792.81	799.27	0.992
8	8.62	102.12	5.30	905.51	913.44	0.991
9	8.62	107.35	5.30	1018.15	1027.61	0.991
10	36.16	110.78	2.00	796.27	1046.18	0.761
11	39.16	112.36	2.00	709.39	962.90	0.737
12	42.16	113.88	2.00	617.29	867.24	0.712
13	45.16	115.32	2.00	521.07	759.46	0.686
14	48.16	116.70	2.00	421.93	639.86	0.659
15	51.16	117.99	2.00	321.20	508.75	0.631
16	54.16	119.20	2.00	220.38	366.51	0.601
17	57.16	120.06	1.00	117.94	252.97	0.466

TABLE 5A - Total Base Force Data on the 17 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Force (lbs)	Total Vert. Force (lbs)	Total Normal/Vert. Force Ratio
1	-26.25	77.96	0.45	17.67	8.05	2.195
2	-23.25	79.08	2.00	397.17	228.00	1.742
3	-20.25	80.94	2.00	834.08	538.98	1.548
4	-17.25	82.83	2.00	1197.66	840.56	1.425

5	8.62	86.41	5.30	3004.04	2989.56	1.005
6	8.62	91.64	5.30	3601.65	3587.39	1.004
7	8.62	96.88	5.30	4198.86	4185.22	1.003
8	8.62	102.12	5.30	4795.73	4783.06	1.003
9	8.62	107.35	5.30	5392.31	5380.89	1.002
10	36.16	110.78	2.00	1592.54	1689.30	0.943
11	39.16	112.36	2.00	1418.79	1493.23	0.950
12	42.16	113.88	2.00	1234.59	1285.71	0.960
13	45.16	115.32	2.00	1042.15	1071.02	0.973
14	48.16	116.70	2.00	843.87	853.62	0.989
15	51.16	117.99	2.00	642.41	638.11	1.007
16	54.16	119.20	2.00	440.76	429.19	1.027
17	57.16	120.06	1.00	118.27	137.57	0.860

TABLE 6 - Effective and Base Shear Stress Data on the 17 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Stress (psf)	Available Shear Strength (psf)	Mobilized Shear Stress (psf)
1	-26.25	77.96	0.45	33.93	15.87	17.76
2	-23.25	79.08	2.00	165.09	62.78	70.23
3	-20.25	80.94	2.00	339.48	117.47	131.42
4	-17.25	82.83	2.00	480.01	158.73	177.58
5	8.62	86.41	5.30	413.06	139.30	155.85
6	8.62	91.64	5.30	495.07	163.05	182.41
7	8.62	96.88	5.30	577.01	186.26	208.39
8	8.62	102.12	5.30	658.88	209.03	233.86
9	8.62	107.35	5.30	740.69	231.41	258.90
10	36.16	110.78	2.00	513.80	168.40	188.40
11	39.16	112.36	2.00	449.41	149.90	167.70
12	42.16	113.88	2.00	383.14	130.49	145.99
13	45.16	115.32	2.00	316.02	110.38	123.49
14	48.16	116.70	2.00	249.17	89.78	100.44
15	51.16	117.99	2.00	183.84	68.93	77.12
16	54.16	119.20	2.00	121.42	48.07	53.78
17	57.16	120.06	1.00	49.63	22.09	24.71

TABLE 6A - Effective and Base Shear Force Data on the 17 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Force (lbs)	Available Shear Force (lbs)	Mobilized Shear Force (lbs)
1	-26.25	77.96	0.45	15.24	7.13	7.98
2	-23.25	79.08	2.00	330.17	125.55	140.47
3	-20.25	80.94	2.00	678.97	234.93	262.84
4	-17.25	82.83	2.00	960.03	317.46	355.17

5	8.62	86.41	5.30	2187.63	737.76	825.40
6	8.62	91.64	5.30	2621.98	863.53	966.10
7	8.62	96.88	5.30	3055.93	986.47	1103.65
8	8.62	102.12	5.30	3489.54	1107.05	1238.55
9	8.62	107.35	5.30	3922.86	1225.59	1371.17
10	36.16	110.78	2.00	1027.61	336.79	376.80
11	39.16	112.36	2.00	898.82	299.79	335.40
12	42.16	113.88	2.00	766.28	260.98	291.98
13	45.16	115.32	2.00	632.04	220.75	246.98
14	48.16	116.70	2.00	498.34	179.56	200.89
15	51.16	117.99	2.00	367.68	137.86	154.24
16	54.16	119.20	2.00	242.85	96.13	107.55
17	57.16	120.06	1.00	49.77	22.15	24.78

SUM OF MOMENTS = -0.156455E-02 (ft/lbs);Imbalance (Fraction of Total Weight) = -0.5191030E-07
SUM OF FORCES = -.476113E-05 (lbs);Imbalance (Fraction of Total Weight) = -0.1579699E-09

Sum of Available Shear Forces = 7159.50(lbs)

Sum of Mobilized Shear Forces = 8009.93(lbs)

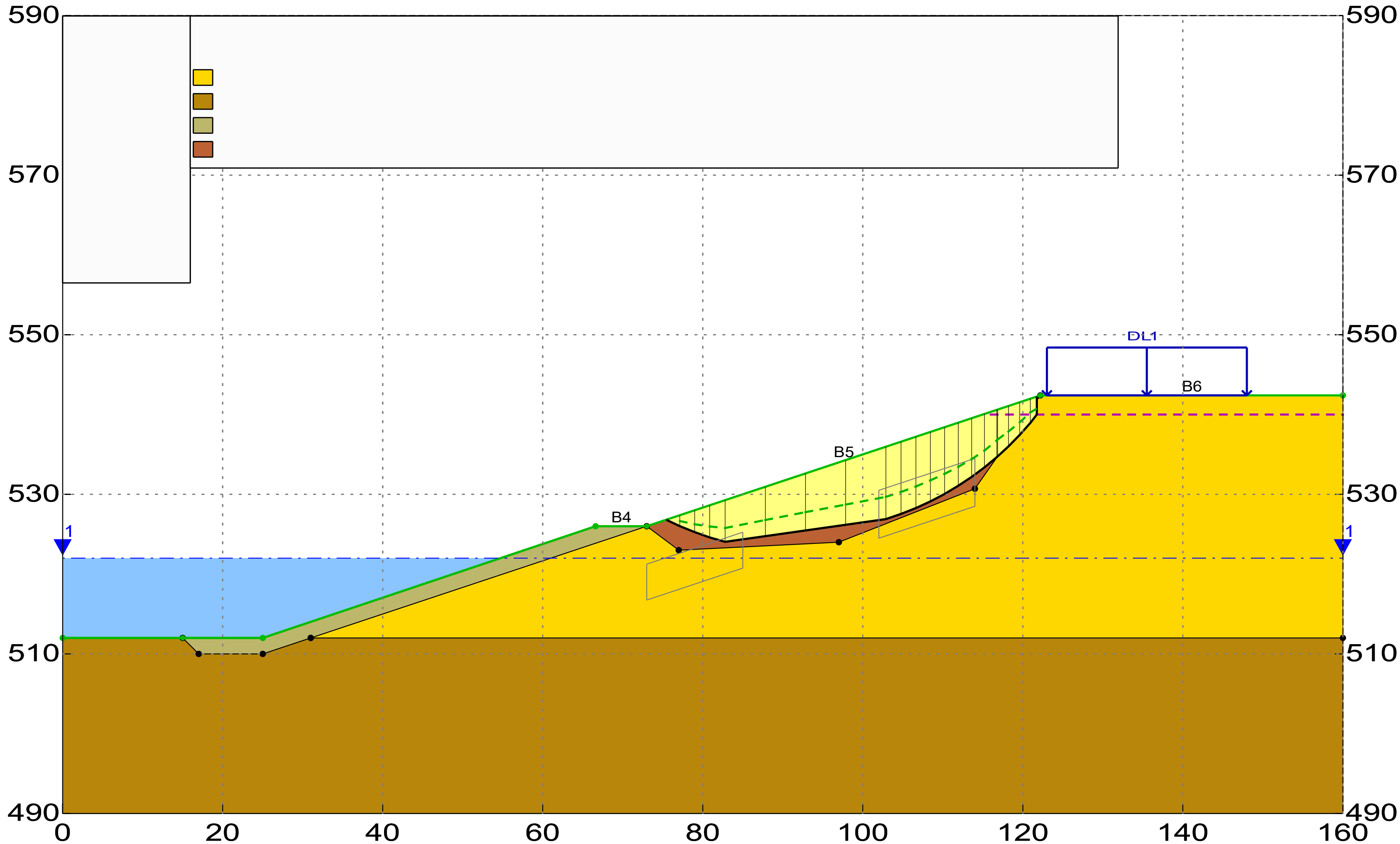
FS Balance Check: FS = 0.893827

**** END OF GEOSTASE OUTPUT ****

LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II
Long-Term-Repaired Condition Following Heavy Rainfall - FRS

GREGORY GEOTECHNICAL - GHG

\lakeridge-Repaired-HRF.gsd



GEOSTASE FS = 1.207

Spencer Method

GEOSTASE Slope Stability Analysis

GREGORY GEOTECHNICAL

PLATE C.4

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

*** GEOSTASE ***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*********************************************************************************
                   SLOPE STABILITY ANALYSIS SOFTWARE
Simplified Bishop, Simplified Janbu, or General Equilibrium (GE) Options.
       (Spencer, Morgenstern-Price, USACE, and Lowe & Karafiath)
       Including Pier/Pile, Planar Reinf,  Nail, Tieback, Line Loads
       Nonlinear Undrained Shear Strength, Curved Strength Envelope,
       Anisotropic , Fiber-Reinforced , Distributed Loads, Water
       Surfaces, Pseudo-Static & Newmark Earthquake, and Applied Forces.
*********************************************************************************
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Analysis Date:
Analysis Time:
Analysis By: GREGORY GEOTECHNICAL - GHG

Input File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Repaired-HRF.gsd

Output File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Repaired-HRF.OUT

Unit System: English

PROJECT: LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II

DESCRIPTION: Long-Term-Repaired Condition Following Heavy Rainfall - FRS

BOUNDARY DATA

6 Surface Boundaries
15 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	512.000	15.000	512.000	2
2	15.000	512.000	25.000	512.000	3
3	25.000	512.000	66.600	526.000	3

4	66.600	526.000	73.000	526.000	3
5	73.000	526.000	122.200	542.400	4
6	122.200	542.400	160.000	542.400	1
7	15.000	512.000	17.000	510.000	2
8	17.000	510.000	25.000	510.000	2
9	25.000	510.000	31.000	512.000	2
10	31.000	512.000	73.000	526.000	1
11	73.000	526.000	77.000	523.000	1
12	77.000	523.000	97.000	524.000	1
13	97.000	524.000	114.000	530.700	1
14	114.000	530.700	122.200	542.400	1
15	31.000	512.000	160.000	512.000	2

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 490.000(ft)

MOHR-COULOMB SOIL PARAMETERS

4 Type(s) of Soil Defined

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Ratio(ru)	Pressure Constant (psf)	Water Surface No.	Water Option
1 Fill-Clay	120.0	132.0	40.00	25.00	0.000	0.0	1	0
2 In-Situ	120.0	132.0	1000.00	20.00	0.000	0.0	1	0
3 Soil Cement	130.0	135.0	1000.00	40.00	0.000	0.0	1	0
4 Weak Clay	120.0	132.0	70.00	13.00	0.270	0.0	1	0

FIBER-REINFORCED SOIL PROPERTIES
1 Soil Type(s) With Fiber Reinforcement

Soil Type 4:

Fiber Length = 3.00(in) Fiber Width = 0.05300(in)
Fiber Thickness = 0.00150(in) Fiber Equivalent Dia. = 0.01006(in)
Friction Coefficient = 0.50 Cohesion Coefficient = 0.50
Specific Gravity of Fiber = 0.910 Application Rate = 0.250 (pcf)

Fiber-Reinforced Shear-Strength Properties

Soil Type 4: FRS c = 72.56 (psf) FRS Phi = 16.60 Deg.
Delta(c) = 2.559(psf) Tan(DeltaPhi) = 0.062926

CURVED STRENGTH PARAMETERS
1 Soil Type(s) Assigned Curved Strength Envelope Properties

Pa = 2116.800(psf)

A Value of 1.0 indicates Dimensional Coefficients

Soil Type 4:

Curve Coefficients a, b, and T are User Input Values

Coefficient a = 0.3214 Coefficient b = 0.8852
Cohesion(c) = 0.00000(psf) Coefficient T = 0.00000

A Power Curve Function Has Been Selected to Model
Stress-Dependent Shear Strength (C = 0).

WATER SURFACE DATA

1 Water Surface(s) Defined

Unit Weight of Water = 62.400 (pcf)

Water Surface No. 1 Specified by 2 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	522.00
2	160.00	522.00

DISTRIBUTED LOAD(S)

1 Load(s) Specified

Load No.	BND No.	X - 1 (ft)	Y - 1 (ft)	Stress (psf)	X - 2 (ft)	Y - 2 (ft)	Stress (psf)	Deflection (deg from Vert)
1	6	123.000	542.400	250.000	148.000	542.400	250.000	0.00

NOTE - Load Stress Varies Linearly Within Specified Range.

TENSION CRACK DATA

Tension Crack Zones Have Been Defined By 1 Tension Crack Line(s)

TC-Line X - 1 Y - 1 X - 2 Y - 2

No.	(ft)	(ft)	(ft)	(ft)
1	116.00	540.00	160.00	540.00

Specified Tension Crack Water Depth Factor = 1.0000

Specified Tension Crack Fluid Weight = 62.400 (pcf)

SEISMIC (EARTHQUAKE) DATA

Specified Peak Ground Acceleration Coefficient (PGA) = 0.070(g)
Default Velocity = 0.175(ft) per second
Specified Horizontal Earthquake Coefficient (kh) = 0.0300(g)
Specified Vertical Earthquake Coefficient (kv) = 0.000(g)
(NOTE:Input Velocity = 0.0 will result in default Peak
Velocity = 2 times(PGA) times 2.5 fps or 0.762 mps)
Specified Seismic Pore-Pressure Factor = 0.000
Horizontal Seismic Force is Applied at Center of Gravity of Slices

EARTHQUAKE DATA HAS BEEN SUPPRESSED

A Non-Circular Zone Search Has Been Selected For Analysis
Using Random Generation Within Specified Zones.

2 Zones Defined For Generation Of Non-Circular Surfaces

1000 Trial Surfaces Have Been Generated.

Length Of Line Segments For Active And Passive Portions Of
Non-Circular Zone Search = 2.00(ft)

Zone No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Height (ft)
1	73.00	519.00	85.00	523.00	4.50
2	102.00	527.50	114.00	531.50	6.00

The Spencer Method Was Selected for FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR SPENCER METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 10.00
Theta tolerance(radians) = 0.0001000

```
Minimum theta(deg) =   0.00 ; Maximum theta(deg) =  90.00
Theta convergence Step Factor = 5000.00
Maximum number of iterations = 50
Maximum force imbalance  = 100.000000(lbs)
Maximum moment imbalance = 100.000000 (ft/lbs)

Selected Lambda Coefficient =  1.00

The option of using a different convergence method
during the first 25% of iterations has been selected.

Specified Tension Crack Water Depth Factor =   1.000

Total Number of Trial Surfaces Attempted = 1000

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence =     41
Maximum Normal Stress Difference (%) =   0.005000


Warning: Convergence not achieved on  364
surfaces during curved strength envelope calculations.
Maximum Normal Stress Difference (%) =     Infinity


WARNING! The Factor of Safety Calculation for one or More Trial Surfaces
Did Not Converge in 50 Iterations.


Number of Trial Surfaces with Non-Converged FS = 429

Number of Trial Surfaces With Valid FS = 571


Percentage of Trial Surfaces With Non-Converged and/or
Non-Valid FS Solutions of the Total Attempted =  42.9 %

Statistical Data On All Valid FS Values:
   FS Max =   3.374   FS Min =   1.207   FS Ave =   1.879
   Standard Deviation =    0.343   Coefficient of Variation =   18.26 %


Critical Surface is Sequence Number       7 of Those Analyzed.


*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****


  Iter.     Theta         FS         FS
   No.      (deg)      (Moment)   (Force)
```

	(fx=1.0)			Lambda	Delta FS
1	10.0000	1.360432	1.168929	0.176	0.1915034E+00
2	13.3000	1.271899	1.193312	0.236	0.7858680E-01
3	14.1759	1.241534	1.200181	0.253	0.4135349E-01
4	14.6643	1.223029	1.204092	0.262	0.1893733E-01
5	14.8950	1.213865	1.205960	0.266	0.7905422E-02
6	14.9926	1.209899	1.206754	0.268	0.3144496E-02
7	15.0317	1.208297	1.207073	0.269	0.1224226E-02
8	15.0469	1.207670	1.207198	0.269	0.4724638E-03
9	15.0528	1.207427	1.207246	0.269	0.1817101E-03
10	15.0551	1.207334	1.207264	0.269	0.6976203E-04
11	15.0559	1.207298	1.207271	0.269	0.2679977E-04
12	15.0563	1.207284	1.207274	0.269	0.1027106E-04
13	15.0564	1.207275	1.207275	0.269	0.0000000E+00

Factor Of Safety For The Preceding Specified Surface = 1.207
Theta (fx = 1.0) = 15.06 Deg   Lambda =   0.269

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence =   41
Maximum Normal Stress Difference (%) =   0.005000

The Spencer Method Has Been Selected For FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR ANALYSIS METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 10.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) =   0.00 ; Maximum theta(deg) = 90.00
Theta convergence Step Factor = 5000.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance(if Applicable) = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

The option of using a different convergence method
during the first 25% of iterations has been selected.

Tension Crack Water Force =   157.88(lbs)

Specified Tension Crack Water Depth Factor = 1.000

Depth of Tension Crack (zo) at Side of Last Slice = 2.250(ft)

Depth of Water in Tension Crack = 2.250(ft)

Theoretical Tension Crack Depth = 1.046(ft)

NOTE: In Table 1 following, when a tension crack with water is present on the first slice (right facing slope) or on the last slice (left facing slope), the "side force" in the tension crack is set equal to the water pressure resultant.

*** Table 1 - Line of Thrust(if applicable) and Slice Force Data ***

Slice No.	X Coord.	Y Coord.	h/H	Side Force (lbs)	fx	Force Angle (Deg)	Vert. Shear Force(lbs)
1	77.13	526.64	0.460	193.47	1.000	15.06	50.3
2	78.98	526.24	0.357	696.10	1.000	15.06	180.8
3	80.87	525.96	0.337	1403.50	1.000	15.06	364.6
4	82.79	525.77	0.330	2237.83	1.000	15.06	581.3
5	87.82	526.78	0.328	2681.18	1.000	15.06	696.5
6	92.84	527.77	0.321	3182.12	1.000	15.06	826.6
7	97.86	528.73	0.314	3738.64	1.000	15.06	971.2
8	102.88	529.68	0.307	4349.01	1.000	15.06	1129.7
9	104.77	530.30	0.305	4174.84	1.000	15.06	1084.5
10	106.63	530.99	0.303	3898.16	1.000	15.06	1012.6
11	108.45	531.74	0.301	3532.02	1.000	15.06	917.5
12	110.22	532.55	0.300	3092.67	1.000	15.06	803.4
13	111.94	533.44	0.299	2599.05	1.000	15.06	675.2
14	113.60	534.40	0.302	2072.26	1.000	15.06	538.3
15	115.20	535.48	0.313	1534.93	1.000	15.06	398.7
16	116.74	536.75	0.353	1010.61	1.000	15.06	262.5
17	116.84	536.85	0.358	975.29	1.000	15.06	253.4
18	118.21	537.87	0.366	700.54	1.000	15.06	182.0
19	119.61	539.03	0.386	439.91	1.000	15.06	114.3
20	120.92	540.25	0.428	236.16	1.000	15.06	61.3
21	121.75	540.75	0.750	157.88	1.000	15.06	-0.0

NOTE: A value of 0.000- for h/H indicates that the line of thrust is at or below the lower boundary of the sliding mass. A value of 1.000+ for h/H indicates that the line of thrust is at or above the upper boundary of the sliding mass.

Table 2 - Geometry Data on the 21 Slices

Slice No.	Width (ft)	Height (ft)	X-Cntr (ft)	Y-Cntr-Base (ft)	Y-Cntr-Top (ft)	Alpha (deg)	Beta (deg)	Base Length (ft)

1	1.70	0.68	76.28	526.41	527.09	-25.16	18.43	1.87
2	1.85	2.05	78.06	525.64	527.69	-22.16	18.43	2.00
3	1.89	3.38	79.93	524.93	528.31	-19.16	18.43	2.00
4	1.92	4.62	81.83	524.33	528.94	-16.16	18.43	2.00
5	5.02	5.70	85.30	524.40	530.10	8.08	18.43	5.07
6	5.02	6.66	90.33	525.12	531.78	8.08	18.43	5.07
7	5.02	7.62	95.35	525.83	533.45	8.08	18.43	5.07
8	5.02	8.58	100.37	526.54	535.12	8.08	18.43	5.07
9	1.89	9.05	103.83	527.22	536.28	18.75	18.43	2.00
10	1.86	8.99	105.70	527.91	536.90	21.75	18.43	2.00
11	1.82	8.81	107.54	528.70	537.51	24.75	18.43	2.00
12	1.77	8.52	109.33	529.59	538.11	27.75	18.43	2.00
13	1.72	8.13	111.08	530.56	538.69	30.75	18.43	2.00
14	1.66	7.63	112.77	531.63	539.26	33.75	18.43	2.00
15	1.60	7.02	114.40	532.78	539.80	36.75	18.43	2.00
16	1.54	6.30	115.97	534.02	540.32	39.75	18.43	2.00
17	0.10	5.89	116.79	534.71	540.60	42.75	18.43	0.13
18	1.37	5.46	117.52	535.39	540.84	42.75	18.43	1.87
19	1.40	4.57	118.91	536.73	541.30	45.75	18.43	2.00
20	1.32	3.55	120.26	538.20	541.75	48.75	18.43	2.00
21	0.82	2.63	121.34	539.48	542.11	51.75	18.43	1.33

Table 2A - Coordinates of Slice Points Defining the Slip Surface

Point No.	X-Pt (ft)	Y-Pt (ft)
1	75.435431	526.811810
2	77.130698	526.015585
3	78.982989	525.261251
4	80.872220	524.604893
5	82.793213	524.048309
6	87.815186	524.761177
7	92.837158	525.474045
8	97.859131	526.186913
9	102.881104	526.899780
10	104.774998	527.542562
11	106.632656	528.283582
12	108.448986	529.120809
13	110.219010	530.051947
14	111.937876	531.074446
15	113.600873	532.185501
16	115.203443	533.382068
17	116.741193	534.660868
18	116.839999	534.752193
19	118.209908	536.018394
20	119.605563	537.450926
21	120.924333	538.954539

22	121.748596	540.000000

Table 3 - Force and Pore Pressure Data On The 21 Slices (Excluding Reinforcement)

Slice No.	Weight (lbs)	Ubeta Force Top (lbs)	Ubeta Stress Top (psf)	Ualpha Force Bot (lbs)	Pore Pressure (psf)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Distributed Load (lbs)
1	138.5	0.0	0.0	41.3	22.1	0.0	0.0	0.00
2	455.0	0.0	0.0	132.7	66.3	0.0	0.0	0.00
3	765.4	0.0	0.0	218.8	109.4	0.0	0.0	0.00
4	1064.5	0.0	0.0	299.2	149.6	0.0	0.0	0.00
5	3433.0	0.0	0.0	936.2	184.6	0.0	0.0	0.00
6	4012.2	0.0	0.0	1094.2	215.7	0.0	0.0	0.00
7	4591.4	0.0	0.0	1252.1	246.9	0.0	0.0	0.00
8	5170.6	0.0	0.0	1410.1	278.0	0.0	0.0	0.00
9	2057.9	0.0	0.0	586.8	293.4	0.0	0.0	0.00
10	2003.6	0.0	0.0	582.4	291.2	0.0	0.0	0.00
11	1920.5	0.0	0.0	571.0	285.5	0.0	0.0	0.00
12	1810.7	0.0	0.0	552.4	276.2	0.0	0.0	0.00
13	1676.8	0.0	0.0	526.8	263.4	0.0	0.0	0.00
14	1521.9	0.0	0.0	494.2	247.1	0.0	0.0	0.00
15	1349.4	0.0	0.0	454.7	227.3	0.0	0.0	0.00
16	1163.0	0.0	0.0	408.4	204.2	0.0	0.0	0.00
17	69.8	0.0	0.0	25.7	190.8	0.0	0.0	0.00
18	897.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
19	765.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
20	562.2	0.0	0.0	0.0	0.0	0.0	0.0	0.00
21	260.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00

Table 3A - Center of Pressure of Water Loads On the 21 Slices
Only Applicable Slices Listed

Slice No.	X-Ubeta (ft)	Y-Ubeta (ft)	Ubeta-Moment (ft/lbs)

Table 3B - Center of Pressure of Distributed Loads On the 21 Slices
Only Applicable Slices Listed

Slice No.	X-Dload (ft)	Y-Dload (ft)	Dist-Load (lbs)	Dload-Moment (ft/lbs)
18	123.11	542.40	0.554021E+02	0.000000E+00
19	123.39	542.40	0.197351E+03	0.000000E+00
20	124.62	542.40	0.417527E+03	0.000000E+00
21	123.67	542.40	0.333473E+03	0.000000E+00

TOTAL WEIGHT OF SLIDING MASS = 35689.26(lbs)

EFFECTIVE WEIGHT OF SLIDING MASS = 26724.05(lbs)

TOTAL AREA OF SLIDING MASS = 297.41(ft2)

TABLE 4 - SOIL STRENGTH & SOIL OPTIONS DATA ON THE 21 SLICES

Slice No.	Soil Type	Cohesion (psf)	Phi(Deg)	Options
1	4	5.77	24.79	C F
2	4	13.70	22.76	C F
3	4	19.87	21.93	C F
4	4	24.74	21.46	C F
5	4	21.62	21.75	C F
6	4	24.81	21.46	C F
7	4	27.94	21.21	C F
8	4	31.02	20.99	C F
9	4	28.83	21.14	C F
10	4	27.67	21.23	C F
11	4	26.24	21.34	C F
12	4	24.57	21.48	C F
13	4	22.69	21.65	C F
14	4	20.61	21.85	C F
15	4	18.37	22.11	C F
16	4	15.97	22.41	C F
17	4	14.35	22.65	C F
18	1	40.00	25.00	
19	1	40.00	25.00	
20	1	40.00	25.00	
21	1	40.00	25.00	

SOIL OPTIONS: A = ANISOTROPIC, C = CURVED STRENGTH ENVELOPE (TANGENT PHI),
F = FIBER-REINFORCED SOIL (FRS), N = NONLINEAR UNDRAINED SHEAR STRENGTH,
R = RAPID DRAWDOWN SHEAR STRENGTH
NOTE: Phi and C in Table 4 are modified values based on specified
Soil Options (if any). Zero values indicate that the normal stress = 0.0

Calculated Secant Phi Values

Slice No.	Phi(Deg)
1	27.18
2	24.97
3	24.07
4	23.56
5	23.87
6	23.55
7	23.28

8	23.04
9	23.20
10	23.30
11	23.42
12	23.57
13	23.76
14	23.99
15	24.26
16	24.60
17	24.86
18	23.61
19	23.66
20	23.33
21	23.48

NOTE: The slices in the table above with phi marked
with an * are unmodified phi values for soil type(s) not
specified to have curved strength envelope (if any).

TABLE 5 - Total Base Stress Data on the 21 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Stress (psf)	Total Vert. Stress (psf)	Total Normal/Vert. Stress Ratio
1	-25.16	76.28	1.87	133.61	81.68	1.636
2	-22.16	78.06	2.00	362.71	245.66	1.476
3	-19.16	79.93	2.00	560.38	405.14	1.383
4	-16.16	81.83	2.00	727.40	554.12	1.313
5	8.08	85.30	5.07	680.71	683.60	0.996
6	8.08	90.33	5.07	795.15	798.93	0.995
7	8.08	95.35	5.07	909.54	914.27	0.995
8	8.08	100.37	5.07	1023.88	1029.60	0.994
9	18.75	103.83	2.00	979.95	1086.58	0.902
10	21.75	105.70	2.00	946.64	1078.58	0.878
11	24.75	107.54	2.00	902.90	1057.37	0.854
12	27.75	109.33	2.00	849.52	1022.99	0.830
13	30.75	111.08	2.00	787.32	975.55	0.807
14	33.75	112.77	2.00	717.15	915.18	0.784
15	36.75	114.40	2.00	639.93	842.03	0.760
16	39.75	115.97	2.00	556.62	756.32	0.736
17	42.75	116.79	0.13	503.19	706.84	0.712
18	42.75	117.52	1.87	421.54	654.76	0.644
19	45.75	118.91	2.00	333.44	548.15	0.608
20	48.75	120.26	2.00	241.85	426.27	0.567
21	51.75	121.34	1.33	134.06	316.19	0.424

TABLE 5A - Total Base Force Data on the 21 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Force (lbs)	Total Vert. Force (lbs)	Total Normal/Vert. Force Ratio
1	-25.16	76.28	1.87	250.25	138.47	1.807
2	-22.16	78.06	2.00	725.43	455.04	1.594
3	-19.16	79.93	2.00	1120.77	765.39	1.464
4	-16.16	81.83	2.00	1454.79	1064.45	1.367
5	8.08	85.30	5.07	3452.80	3433.01	1.006
6	8.08	90.33	5.07	4033.25	4012.22	1.005
7	8.08	95.35	5.07	4613.46	4591.43	1.005
8	8.08	100.37	5.07	5193.46	5170.64	1.004
9	18.75	103.83	2.00	1959.90	2057.87	0.952
10	21.75	105.70	2.00	1893.27	2003.64	0.945
11	24.75	107.54	2.00	1805.79	1920.53	0.940
12	27.75	109.33	2.00	1699.03	1810.72	0.938
13	30.75	111.08	2.00	1574.63	1676.85	0.939
14	33.75	112.77	2.00	1434.30	1521.94	0.942
15	36.75	114.40	2.00	1279.86	1349.42	0.948
16	39.75	115.97	2.00	1113.24	1163.03	0.957
17	42.75	116.79	0.13	67.70	69.84	0.969
18	42.75	117.52	1.87	786.37	896.97	0.877
19	45.75	118.91	2.00	666.88	765.03	0.872
20	48.75	120.26	2.00	483.70	562.15	0.860
21	51.75	121.34	1.33	178.48	260.62	0.685

TABLE 6 - Effective and Base Shear Stress Data on the 21 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Stress (psf)	Available Shear Strength (psf)	Mobilized Shear Stress (psf)
1	-25.16	76.28	1.87	111.56	57.29	47.45
2	-22.16	78.06	2.00	296.39	138.03	114.33
3	-19.16	79.93	2.00	451.00	201.48	166.89
4	-16.16	81.83	2.00	577.79	251.91	208.66
5	8.08	85.30	5.07	496.14	219.58	181.88
6	8.08	90.33	5.07	579.44	252.56	209.20
7	8.08	95.35	5.07	662.69	285.06	236.12
8	8.08	100.37	5.07	745.89	317.16	262.71
9	18.75	103.83	2.00	686.57	294.32	243.79
10	21.75	105.70	2.00	655.42	282.24	233.78
11	24.75	107.54	2.00	617.41	267.44	221.52
12	27.75	109.33	2.00	573.31	250.15	207.20
13	30.75	111.08	2.00	523.92	230.63	191.03
14	33.75	112.77	2.00	470.05	209.14	173.23
15	36.75	114.40	2.00	412.58	185.95	154.02
16	39.75	115.97	2.00	352.41	161.33	133.63

17	42.75	116.79	0.13	312.34	144.70	119.86
18	42.75	117.52	1.87	421.54	236.57	195.95
19	45.75	118.91	2.00	333.44	195.49	161.92
20	48.75	120.26	2.00	241.85	152.78	126.55
21	51.75	121.34	1.33	134.06	102.51	84.91

TABLE 6A - Effective and Base Shear Force Data on the 21 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Force (lbs)	Available Shear Force (lbs)	Mobilized Shear Force (lbs)
1	-25.16	76.28	1.87	208.94	107.29	88.87
2	-22.16	78.06	2.00	592.77	276.05	228.66
3	-19.16	79.93	2.00	901.99	402.97	333.78
4	-16.16	81.83	2.00	1155.57	503.82	417.32
5	8.08	85.30	5.07	2516.59	1113.77	922.55
6	8.08	90.33	5.07	2939.09	1281.05	1061.11
7	8.08	95.35	5.07	3361.35	1445.93	1197.68
8	8.08	100.37	5.07	3783.40	1608.74	1332.54
9	18.75	103.83	2.00	1373.15	588.63	487.57
10	21.75	105.70	2.00	1310.84	564.49	467.57
11	24.75	107.54	2.00	1234.81	534.87	443.04
12	27.75	109.33	2.00	1146.61	500.29	414.40
13	30.75	111.08	2.00	1047.83	461.26	382.07
14	33.75	112.77	2.00	940.11	418.28	346.47
15	36.75	114.40	2.00	825.16	371.90	308.05
16	39.75	115.97	2.00	704.83	322.65	267.26
17	42.75	116.79	0.13	42.02	19.47	16.13
18	42.75	117.52	1.87	786.37	441.31	365.54
19	45.75	118.91	2.00	666.88	390.97	323.85
20	48.75	120.26	2.00	483.70	305.55	253.09
21	51.75	121.34	1.33	178.48	136.48	113.05

SUM OF MOMENTS = -0.177413E+00 (ft/lbs);Imbalance (Fraction of Total Weight) = -0.4971051E-05
SUM OF FORCES = -.217349E-04 (lbs);Imbalance (Fraction of Total Weight) = -0.6090042E-09

Sum of Available Shear Forces = 11795.79(lbs)

Sum of Mobilized Shear Forces = 9770.59(lbs)

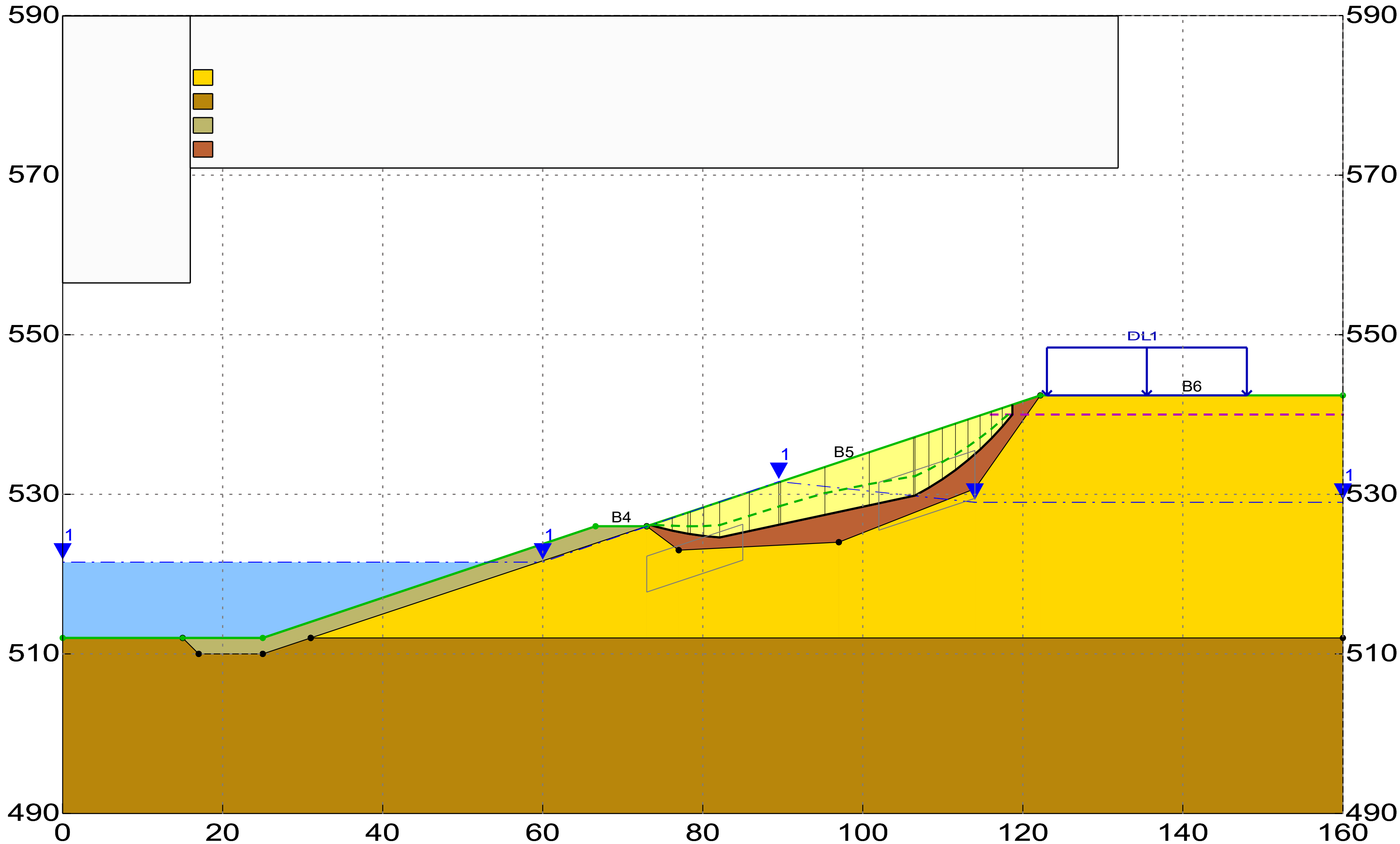
FS Balance Check: FS = 1.207275

**** END OF GEOSTASE OUTPUT ****

LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II
Rapid Drawdown - Initial - Assuming Drained Strength Conditions After Drawdown

GREGORY GEOTECHNICAL - GHG

\lakeridge-Initial-RD.gsd



GEOSTASE FS = 0.901

Spencer Method

GEOSTASE Slope Stability Analysis

GREGORY GEOTECHNICAL

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

PLATE C.5

*** GEOSTASE ***

****
SLOPE STABILITY ANALYSIS SOFTWARE
Simplified Bishop, Simplified Janbu, or General Equilibrium (GE) Options.
(Spencer, Morgenstern-Price, USACE, and Lowe & Karafiath)
Including Pier/Pile, Planar Reinf, Nail, Tieback, Line Loads
Nonlinear Undrained Shear Strength, Curved Strength Envelope,
Anisotropic , Fiber-Reinforced , Distributed Loads, Water
Surfaces, Pseudo-Static & Newmark Earthquake, and Applied Forces.
****

Analysis Date:
Analysis Time:
Analysis By: GREGORY GEOTECHNICAL - GHG

Input File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Initial-RD.gsd

Output File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Initial-RD.OUT

Unit System: English

PROJECT: LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II

DESCRIPTION: Rapid Drawdown - Initial - Assuming Drained Strength Conditions After Drawdown

BOUNDARY DATA

6 Surface Boundaries
15 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	512.000	15.000	512.000	2
2	15.000	512.000	25.000	512.000	3
3	25.000	512.000	66.600	526.000	3

4	66.600	526.000	73.000	526.000	3
5	73.000	526.000	122.200	542.400	4
6	122.200	542.400	160.000	542.400	1
7	15.000	512.000	17.000	510.000	2
8	17.000	510.000	25.000	510.000	2
9	25.000	510.000	31.000	512.000	2
10	31.000	512.000	73.000	526.000	1
11	73.000	526.000	77.000	523.000	1
12	77.000	523.000	97.000	524.000	1
13	97.000	524.000	114.000	530.700	1
14	114.000	530.700	122.200	542.400	1
15	31.000	512.000	160.000	512.000	2

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 490.000(ft)

MOHR-COULOMB SOIL PARAMETERS

4 Type(s) of Soil Defined

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Ratio(ru)	Pressure Constant (psf)	Water Surface No.	Water Option
1 Fill-Clay	120.0	132.0	40.00	25.00	0.000	0.0	1	0
2 In-Situ	120.0	132.0	1000.00	20.00	0.000	0.0	1	0
3 Soil Cement	130.0	135.0	1000.00	40.00	0.000	0.0	1	0
4 Weak Clay	120.0	132.0	70.00	13.00	0.000	0.0	1	0

FIBER-REINFORCED SOIL PROPERTIES
1 Soil Type(s) With Fiber Reinforcement

Soil Type 4:

Fiber Length = 3.00(in) Fiber Width = 0.05300(in)
Fiber Thickness = 0.00150(in) Fiber Equivalent Dia. = 0.01006(in)
Friction Coefficient = 0.50 Cohesion Coefficient = 0.50
Specific Gravity of Fiber = 0.910 Application Rate = 0.250 (pcf)

Fiber-Reinforced Shear-Strength Properties

Soil Type 4: FRS c = 72.56 (psf) FRS Phi = 16.60 Deg.
Delta(c) = 2.559(psf) Tan(DeltaPhi) = 0.062926

FIBER-REINFORCED SOIL DATA HAS BEEN SUPPRESSED

CURVED STRENGTH PARAMETERS

1 Soil Type(s) Assigned Curved Strength Envelope Properties

Pa = 2116.800(psf)
A Value of 1.0 indicates Dimensional Coefficients

Soil Type 4:

Curve Coefficients a, b, and T are User Input Values

Coefficient a = 0.2723 Coefficient b = 0.8691
Cohesion(c) = 0.00000(psf) Coefficient T = 0.00000

A Power Curve Function Has Been Selected to Model
Stress-Dependent Shear Strength (C = 0).

WATER SURFACE DATA

1 Water Surface(s) Defined

Unit Weight of Water = 62.400 (pcf)

Water Surface No. 1 Specified by 5 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	521.50
2	60.00	521.50
3	89.50	531.60
4	114.00	529.00
5	160.00	529.00

DISTRIBUTED LOAD(S)

1 Load(s) Specified

Load No.	BND No.	X - 1 (ft)	Y - 1 (ft)	Stress (psf)	X - 2 (ft)	Y - 2 (ft)	Stress (psf)	Deflection (deg from Vert)
1	6	123.000	542.400	250.000	148.000	542.400	250.000	0.00

NOTE - Load Stress Varies Linearly Within Specified Range.

TENSION CRACK DATA

Tension Crack Zones Have Been Defined By 1 Tension Crack Line(s)

TC-Line No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)
1	116.00	540.00	160.00	540.00

Specified Tension Crack Water Depth Factor = 1.0000

Specified Tension Crack Fluid Weight = 62.400 (pcf)

SEISMIC (EARTHQUAKE) DATA

Specified Peak Ground Acceleration Coefficient (PGA) = 0.070(g)
Default Velocity = 0.175(ft) per second
Specified Horizontal Earthquake Coefficient (kh) = 0.0300(g)
Specified Vertical Earthquake Coefficient (kv) = 0.000(g)
(NOTE:Input Velocity = 0.0 will result in default Peak
Velocity = 2 times(PGA) times 2.5 fps or 0.762 mps)
Specified Seismic Pore-Pressure Factor = 0.000
Horizontal Seismic Force is Applied at Center of Gravity of Slices

EARTHQUAKE DATA HAS BEEN SUPPRESSED

A Non-Circular Zone Search Has Been Selected For Analysis
Using Random Generation Within Specified Zones.

2 Zones Defined For Generation Of Non-Circular Surfaces

1000 Trial Surfaces Have Been Generated.

Length Of Line Segments For Active And Passive Portions Of
Non-Circular Zone Search = 2.00(ft)

Zone No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Height (ft)
1	73.00	520.00	85.00	524.00	4.50
2	102.00	528.50	114.00	532.50	6.00

The Spencer Method Was Selected for FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR SPENCER METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 7.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) =   0.00 ; Maximum theta(deg) = 90.00
Theta convergence Step Factor = 5000.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

The option of using a different convergence method
during the first 25% of iterations has been selected.

Specified Tension Crack Water Depth Factor =   1.000

Total Number of Trial Surfaces Attempted = 1000

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence =   180
Maximum Normal Stress Difference (%) =   0.005000

Warning: Convergence not achieved on 198
surfaces during curved strength envelope calculations.
Maximum Normal Stress Difference (%) =   Infinity

WARNING! The Factor of Safety Calculation for one or More Trial Surfaces
Did Not Converge in 50 Iterations.

Number of Trial Surfaces with Non-Converged FS = 209

Number of Trial Surfaces With Valid FS = 791

Percentage of Trial Surfaces With Non-Converged and/or
Non-Valid FS Solutions of the Total Attempted = 20.9 %

Statistical Data On All Valid FS Values:
   FS Max =   2.930   FS Min =   0.901   FS Ave =   1.608
   Standard Deviation =   0.404   Coefficient of Variation =   25.13 %

Critical Surface is Sequence Number   703 of Those Analyzed.

*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****

Iter. No.	Theta (deg) (fx=1.0)	FS (Moment)	FS (Force)	Lambda	Delta FS
1	7.0000	1.027191	0.869596	0.123	0.1575954E+00
2	9.3100	1.011110	0.876519	0.164	0.1345919E+00
3	10.7396	0.998309	0.880914	0.190	0.1173952E+00
4	12.1708	0.982680	0.885411	0.216	0.9726844E-01
5	13.5078	0.964892	0.889710	0.240	0.7518196E-01
6	14.6493	0.946655	0.893461	0.261	0.5319390E-01
7	15.5214	0.930391	0.896382	0.278	0.3400897E-01
8	16.1103	0.918055	0.898382	0.289	0.1967335E-01
9	16.4631	0.910073	0.899592	0.296	0.1048118E-01
10	16.6549	0.905531	0.900253	0.299	0.5277636E-02
11	16.7526	0.903162	0.900591	0.301	0.2570540E-02
12	16.8004	0.901987	0.900757	0.302	0.1230058E-02
13	16.8233	0.901420	0.900836	0.302	0.5834159E-03
14	16.8440	0.900906	0.900908	0.303	0.1828180E-05
15	16.8440	0.900908	0.900908	0.303	0.2091591E-08

Factor Of Safety For The Preceding Specified Surface = 0.901
Theta (fx = 1.0) = 16.84 Deg   Lambda =   0.303

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence =   180
Maximum Normal Stress Difference (%) =   0.005000

The Spencer Method Has Been Selected For FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR ANALYSIS METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 7.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) =   0.00 ; Maximum theta(deg) = 90.00
Theta convergence Step Factor = 5000.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance(if Applicable) = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

The option of using a different convergence method during the first 25% of iterations has been selected.

Tension Crack Water Force = 47.25(lbs)

Specified Tension Crack Water Depth Factor = 1.000

Depth of Tension Crack (zo) at Side of Last Slice = 1.231(ft)

Depth of Water in Tension Crack = 1.231(ft)

Theoretical Tension Crack Depth = 1.639(ft)

NOTE: In Table 1 following, when a tension crack with water is present on the first slice (right facing slope) or on the last slice (left facing slope), the "side force" in the tension crack is set equal to the water pressure resultant.

*** Table 1 - Line of Thrust(if applicable) and Slice Force Data ***

Slice No.	X Coord.	Y Coord.	h/H	Side Force (lbs)	fx	Force Angle (Deg)	Vert. Shear Force(lbs)
1	73.55	526.16	0.476	0.37	1.000	16.84	0.1
2	74.24	526.14	0.440	25.30	1.000	16.84	7.3
3	76.18	526.06	0.384	224.25	1.000	16.84	65.0
4	78.14	526.00	0.356	546.02	1.000	16.84	158.2
5	78.44	526.01	0.354	596.69	1.000	16.84	172.9
6	80.12	526.03	0.348	928.34	1.000	16.84	269.0
7	82.11	526.14	0.348	1323.01	1.000	16.84	383.4
8	85.81	527.29	0.390	1298.14	1.000	16.84	376.2
9	89.50	528.47	0.429	1262.94	1.000	16.84	366.0
10	89.73	528.55	0.432	1259.60	1.000	16.84	365.0
11	95.27	530.13	0.451	1304.62	1.000	16.84	378.0
12	100.81	531.29	0.401	1586.27	1.000	16.84	459.6
13	106.34	532.26	0.335	2093.04	1.000	16.84	606.5
14	106.51	532.29	0.333	2111.95	1.000	16.84	612.0
15	108.26	533.13	0.332	1851.28	1.000	16.84	536.4
16	109.95	534.03	0.332	1551.79	1.000	16.84	449.7
17	111.58	534.99	0.334	1232.84	1.000	16.84	357.2
18	113.15	536.01	0.336	914.66	1.000	16.84	265.0
19	114.65	537.08	0.342	617.60	1.000	16.84	179.0
20	116.08	538.20	0.355	361.37	1.000	16.84	104.7
21	117.44	539.40	0.395	164.06	1.000	16.84	47.5
22	118.69	540.41	0.410	47.25	1.000	16.84	0.0

NOTE: A value of 0.000- for h/H indicates that the line of thrust is at or below the lower boundary of the sliding mass. A value of 1.000+ for h/H indicates that the line of thrust is at or above the upper boundary of the sliding mass.

Table 2 - Geometry Data on the 22 Slices

Slice No.	Width (ft)	Height (ft)	X-Cntr (ft)	Y-Cntr-Base (ft)	Y-Cntr-Top (ft)	Alpha (deg)	Beta (deg)	Base Length (ft)
1	0.07	0.02	73.52	526.15	526.17	-17.06	18.43	0.07
2	0.69	0.26	73.89	526.03	526.30	-17.06	18.43	0.72
3	1.94	1.05	75.21	525.69	526.74	-14.06	18.43	2.00
4	1.96	2.14	77.16	525.25	527.39	-11.06	18.43	2.00
5	0.30	2.73	78.29	525.04	527.76	-8.06	18.43	0.30
6	1.68	3.20	79.28	524.90	528.09	-8.06	18.43	1.70
7	1.99	4.02	81.12	524.69	528.71	-5.06	18.43	2.00
8	3.69	4.65	83.96	525.00	529.65	12.14	18.43	3.78
9	3.69	5.09	87.65	525.79	530.88	12.14	18.43	3.78
10	0.23	5.32	89.61	526.21	531.54	12.14	18.43	0.23
11	5.54	5.66	92.50	526.83	532.50	12.14	18.43	5.67
12	5.54	6.32	98.04	528.03	534.35	12.14	18.43	5.67
13	5.54	6.97	103.57	529.22	536.19	12.14	18.43	5.67
14	0.17	7.31	106.43	529.83	537.14	12.14	18.43	0.17
15	1.74	7.12	107.39	530.34	537.46	29.33	18.43	2.00
16	1.69	6.67	109.10	531.36	538.03	32.33	18.43	2.00
17	1.63	6.11	110.76	532.48	538.59	35.33	18.43	2.00
18	1.57	5.45	112.36	533.68	539.12	38.33	18.43	2.00
19	1.50	4.68	113.90	534.96	539.63	41.33	18.43	2.00
20	1.43	3.81	115.36	536.32	540.12	44.33	18.43	2.00
21	1.36	2.84	116.76	537.75	540.59	47.33	18.43	2.00
22	1.26	1.78	118.06	539.24	541.02	50.33	18.43	1.97

Table 2A - Coordinates of Slice Points Defining the Slip Surface

Point No.	X-Pt (ft)	Y-Pt (ft)
1	73.482134	526.160711
2	73.551124	526.139537
3	74.238186	525.928668
4	76.178252	525.442723
5	78.141092	525.058979
6	78.437500	525.016995
7	80.121326	524.778489
8	82.113525	524.602020
9	85.806763	525.396202
10	89.500000	526.190383
11	89.727554	526.239316

12	95.266383	527.430367
13	100.805211	528.621418
14	106.344039	529.812469
15	106.513916	529.848999
16	108.257478	530.828793
17	109.947371	531.898495
18	111.578965	533.055174
19	113.147787	534.295658
20	114.649537	535.616548
21	116.080099	537.014223
22	117.435551	538.484852
23	118.691943	540.000000

Table 3 - Force and Pore Pressure Data On The 22 Slices (Excluding Reinforcement)

Slice No.	Weight (lbs)	Ubeta Force Top (lbs)	Ubeta Stress Top (psf)	Ualpha Force Bot (lbs)	Pore Pressure (psf)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Distributed Load (lbs)
1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.00
2	23.5	0.0	0.0	9.5	13.2	0.0	0.0	0.00
3	267.1	0.0	0.0	120.8	60.4	0.0	0.0	0.00
4	550.5	0.0	0.0	251.2	125.6	0.0	0.0	0.00
5	106.1	0.0	0.0	48.2	161.0	0.0	0.0	0.00
6	707.0	0.0	0.0	322.1	189.4	0.0	0.0	0.00
7	1051.5	0.0	0.0	477.7	238.9	0.0	0.0	0.00
8	2260.3	0.0	0.0	1050.7	278.1	0.0	0.0	0.00
9	2473.6	0.0	0.0	1155.8	305.9	0.0	0.0	0.00
10	159.9	0.3	1.3	77.6	333.4	0.0	0.0	0.00
11	4058.7	0.0	0.0	1563.4	276.0	0.0	0.0	0.00
12	4376.6	0.0	0.0	938.0	165.6	0.0	0.0	0.00
13	4694.5	0.0	0.0	312.7	55.2	0.0	0.0	0.00
14	149.1	0.0	0.0	0.0	0.0	0.0	0.0	0.00
15	1490.3	0.0	0.0	0.0	0.0	0.0	0.0	0.00
16	1352.7	0.0	0.0	0.0	0.0	0.0	0.0	0.00
17	1196.5	0.0	0.0	0.0	0.0	0.0	0.0	0.00
18	1025.2	0.0	0.0	0.0	0.0	0.0	0.0	0.00
19	842.8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
20	653.4	0.0	0.0	0.0	0.0	0.0	0.0	0.00
21	461.4	0.0	0.0	0.0	0.0	0.0	0.0	0.00
22	268.2	0.0	0.0	0.0	0.0	0.0	0.0	0.00

Table 3A - Center of Pressure of Water Loads On the 22 Slices
Only Applicable Slices Listed

Slice No.	X-Ubeta (ft)	Y-Ubeta (ft)	Ubeta-Moment (ft/lbs)

10	89.54	531.51		-0.48

Table 3B - Center of Pressure of Distributed Loads On the 22 Slices
Only Applicable Slices Listed

Slice No.	X-Dload (ft)	Y-Dload (ft)	Dist-Load (lbs)	Dload-Moment (ft/lbs)

TOTAL WEIGHT OF SLIDING MASS = 28168.86(lbs)

EFFECTIVE WEIGHT OF SLIDING MASS = 21969.37(lbs)

TOTAL AREA OF SLIDING MASS = 224.81(ft2)

TABLE 4 - SOIL STRENGTH & SOIL OPTIONS DATA ON THE 22 SLICES

Slice No.	Soil Type	Cohesion (psf)	Phi(Deg)	Options
1	4	0.41	27.42	C
2	4	2.26	21.87	C
3	4	6.24	19.01	C
4	4	10.54	17.66	C
5	4	12.24	17.29	C
6	4	13.98	16.96	C
7	4	16.12	16.63	C
8	4	14.06	16.95	C
9	4	15.14	16.77	C
10	4	15.33	16.74	C
11	4	18.69	16.28	C
12	4	24.99	15.62	C
13	4	31.06	15.14	C
14	4	34.06	14.94	C
15	4	28.04	15.36	C
16	4	25.64	15.56	C
17	4	22.96	15.81	C
18	4	20.04	16.12	C
19	4	16.88	16.52	C
20	4	13.52	17.05	C
21	4	9.98	17.79	C
22	4	5.98	19.12	C

SOIL OPTIONS: A = ANISOTROPIC, C = CURVED STRENGTH ENVELOPE (TANGENT PHI),
F = FIBER-REINFORCED SOIL (FRS), N = NONLINEAR UNDRAINED SHEAR STRENGTH,
R = RAPID DRAWDOWN SHEAR STRENGTH
NOTE: Phi and C in Table 4 are modified values based on specified
Soil Options (if any). Zero values indicate that the normal stress = 0.0

Calculated Secant Phi Values

Slice No.	Phi(Deg)
1	30.83
2	24.79
3	21.62
4	20.12
5	19.70
6	19.34
7	18.96
8	19.33
9	19.13
10	19.09
11	18.57
12	17.83
13	17.29
14	17.06
15	17.54
16	17.76
17	18.04
18	18.39
19	18.84
20	19.43
21	20.27
22	21.75

NOTE: The slices in the table above with phi marked
with an * are unmodified phi values for soil type(s) not
specified to have curved strength envelope (if any).

TABLE 5 - Total Base Stress Data on the 22 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Stress (psf)	Total Vert. Stress (psf)	Total Normal/Vert. Stress Ratio
1	-17.06	73.52	0.07	5.27	2.65	1.988
2	-17.06	73.89	0.72	50.64	34.23	1.479
3	-14.06	75.21	2.00	180.62	137.66	1.312
4	-11.06	77.16	2.00	345.41	280.44	1.232
5	-8.06	78.29	0.30	422.23	357.98	1.179
6	-8.06	79.28	1.70	493.74	419.87	1.176
7	-5.06	81.12	2.00	597.31	527.80	1.132
8	12.14	83.96	3.78	584.41	612.00	0.955
9	12.14	87.65	3.78	639.41	669.78	0.955
10	12.14	89.61	0.23	671.70	703.90	0.954
11	12.14	92.50	5.67	701.03	732.77	0.957
12	12.14	98.04	5.67	759.32	790.17	0.961
13	12.14	103.57	5.67	817.45	847.57	0.964

14	12.14	106.43	0.17	847.62	877.47	0.966
15	29.33	107.39	2.00	677.81	854.76	0.793
16	32.33	109.10	2.00	611.47	800.46	0.764
17	35.33	110.76	2.00	538.61	733.31	0.734
18	38.33	112.36	2.00	460.37	653.49	0.704
19	41.33	113.90	2.00	377.99	561.21	0.674
20	44.33	115.36	2.00	292.82	456.75	0.641
21	47.33	116.76	2.00	206.39	340.37	0.606
22	50.33	118.06	1.97	114.49	213.46	0.536

TABLE 5A - Total Base Force Data on the 22 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Force (lbs)	Total Vert. Force (lbs)	Total Normal/Vert. Force Ratio
1	-17.06	73.52	0.07	0.38	0.18	2.079
2	-17.06	73.89	0.72	36.39	23.52	1.547
3	-14.06	75.21	2.00	361.24	267.06	1.353
4	-11.06	77.16	2.00	690.82	550.45	1.255
5	-8.06	78.29	0.30	126.40	106.11	1.191
6	-8.06	79.28	1.70	839.66	706.98	1.188
7	-5.06	81.12	2.00	1194.63	1051.48	1.136
8	12.14	83.96	3.78	2207.71	2260.27	0.977
9	12.14	87.65	3.78	2415.47	2473.64	0.976
10	12.14	89.61	0.23	156.34	160.18	0.976
11	12.14	92.50	5.67	3971.66	4058.67	0.979
12	12.14	98.04	5.67	4301.90	4376.59	0.983
13	12.14	103.57	5.67	4631.20	4694.52	0.987
14	12.14	106.43	0.17	147.28	149.06	0.988
15	29.33	107.39	2.00	1355.61	1490.33	0.910
16	32.33	109.10	2.00	1222.94	1352.69	0.904
17	35.33	110.76	2.00	1077.22	1196.46	0.900
18	38.33	112.36	2.00	920.74	1025.20	0.898
19	41.33	113.90	2.00	755.98	842.80	0.897
20	44.33	115.36	2.00	585.64	653.40	0.896
21	47.33	116.76	2.00	412.79	461.35	0.895
22	50.33	118.06	1.97	225.34	268.19	0.840

TABLE 6 - Effective and Base Shear Stress Data on the 22 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Stress (psf)	Available Shear Strength (psf)	Mobilized Shear Stress (psf)
1	-17.06	73.52	0.07	5.27	3.14	3.49
2	-17.06	73.89	0.72	37.45	17.29	19.19
3	-14.06	75.21	2.00	120.24	47.66	52.90

4	-11.06	77.16	2.00	219.82	80.51	89.37
5	-8.06	78.29	0.30	261.18	93.53	103.81
6	-8.06	79.28	1.70	304.35	106.83	118.58
7	-5.06	81.12	2.00	358.46	123.15	136.70
8	12.14	83.96	3.78	306.27	107.41	119.23
9	12.14	87.65	3.78	333.46	115.65	128.37
10	12.14	89.61	0.23	338.28	117.11	129.99
11	12.14	92.50	5.67	425.08	142.82	158.53
12	12.14	98.04	5.67	593.75	190.95	211.95
13	12.14	103.57	5.67	762.26	237.25	263.35
14	12.14	106.43	0.17	847.62	260.18	288.80
15	29.33	107.39	2.00	677.81	214.24	237.80
16	32.33	109.10	2.00	611.47	195.89	217.44
17	35.33	110.76	2.00	538.61	175.44	194.74
18	38.33	112.36	2.00	460.37	153.07	169.90
19	41.33	113.90	2.00	377.99	128.96	143.15
20	44.33	115.36	2.00	292.82	103.30	114.66
21	47.33	116.76	2.00	206.39	76.22	84.61
22	50.33	118.06	1.97	114.49	45.67	50.69

TABLE 6A - Effective and Base Shear Force Data on the 22 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Force (lbs)	Available Shear Force (lbs)	Mobilized Shear Force (lbs)
1	-17.06	73.52	0.07	0.38	0.23	0.25
2	-17.06	73.89	0.72	26.91	12.43	13.80
3	-14.06	75.21	2.00	240.48	95.32	105.80
4	-11.06	77.16	2.00	439.63	161.03	178.74
5	-8.06	78.29	0.30	78.19	28.00	31.08
6	-8.06	79.28	1.70	517.59	181.67	201.66
7	-5.06	81.12	2.00	716.91	246.30	273.39
8	12.14	83.96	3.78	1156.98	405.77	450.40
9	12.14	87.65	3.78	1259.70	436.90	484.95
10	12.14	89.61	0.23	78.74	27.26	30.26
11	12.14	92.50	5.67	2408.25	809.12	898.12
12	12.14	98.04	5.67	3363.86	1081.81	1200.80
13	12.14	103.57	5.67	4318.52	1344.15	1491.99
14	12.14	106.43	0.17	147.28	45.21	50.18
15	29.33	107.39	2.00	1355.61	428.47	475.60
16	32.33	109.10	2.00	1222.94	391.78	434.88
17	35.33	110.76	2.00	1077.22	350.88	389.47
18	38.33	112.36	2.00	920.74	306.14	339.81
19	41.33	113.90	2.00	755.98	257.93	286.30
20	44.33	115.36	2.00	585.64	206.60	229.33
21	47.33	116.76	2.00	412.79	152.44	169.21
22	50.33	118.06	1.97	225.34	89.89	99.78

```
SUM OF MOMENTS =  -0.369983E-05 (ft/lbs);Imbalance (Fraction of Total Weight) =  -0.1313446E-09
SUM OF FORCES = -.198473E-07 (lbs);Imbalance (Fraction of Total Weight) =   -0.7045842E-12

Sum of Available Shear Forces =    7059.33(lbs)

Sum of Mobilized Shear Forces =    7835.80(lbs)

FS Balance Check: FS =  0.900908

                    **** END OF GEOSTASE OUTPUT ****
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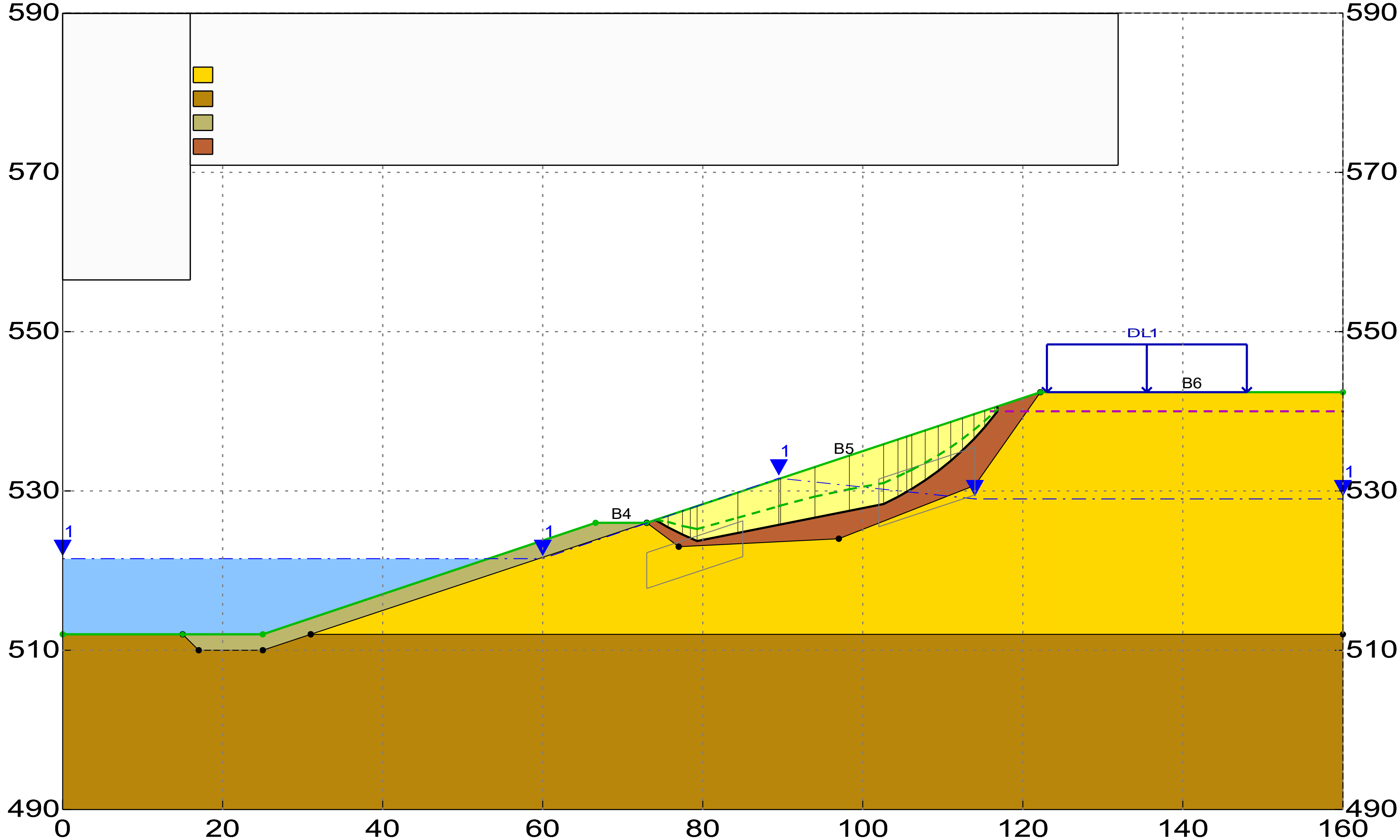
LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II
Rapid Drawdown -Repaired - FRS- Assuming Drained Strength After Drawdown

GREGORY GEOTECHNICAL - GHG

\lakeridge-Repaired-RD.gsd



GEOSTASE FS = 1.322

Spencer Method

GEOSTASE Slope Stability Analysis

GREGORY GEOTECHNICAL

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

PLATE C.6

*** GEOSTASE ***

****
SLOPE STABILITY ANALYSIS SOFTWARE
Simplified Bishop, Simplified Janbu, or General Equilibrium (GE) Options.
(Spencer, Morgenstern-Price, USACE, and Lowe & Karafiath)
Including Pier/Pile, Planar Reinf, Nail, Tieback, Line Loads
Nonlinear Undrained Shear Strength, Curved Strength Envelope,
Anisotropic , Fiber-Reinforced , Distributed Loads, Water
Surfaces, Pseudo-Static & Newmark Earthquake, and Applied Forces.
****

Analysis Date:
Analysis Time:
Analysis By: GREGORY GEOTECHNICAL - GHG

Input File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Repaired-RD.gsd

Output File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Repaired-RD.OUT

Unit System: English

PROJECT: LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II

DESCRIPTION: Rapid Drawdown -Repaired - FRS- Assuming Drained Strength After Drawdown

BOUNDARY DATA

6 Surface Boundaries
15 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	512.000	15.000	512.000	2
2	15.000	512.000	25.000	512.000	3
3	25.000	512.000	66.600	526.000	3

4	66.600	526.000	73.000	526.000	3
5	73.000	526.000	122.200	542.400	4
6	122.200	542.400	160.000	542.400	1
7	15.000	512.000	17.000	510.000	2
8	17.000	510.000	25.000	510.000	2
9	25.000	510.000	31.000	512.000	2
10	31.000	512.000	73.000	526.000	1
11	73.000	526.000	77.000	523.000	1
12	77.000	523.000	97.000	524.000	1
13	97.000	524.000	114.000	530.700	1
14	114.000	530.700	122.200	542.400	1
15	31.000	512.000	160.000	512.000	2

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 490.000(ft)

MOHR-COULOMB SOIL PARAMETERS

4 Type(s) of Soil Defined

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Ratio(ru)	Pressure Constant (psf)	Water Surface No.	Water Option
1 Fill-Clay	120.0	132.0	40.00	25.00	0.000	0.0	1	0
2 In-Situ	120.0	132.0	1000.00	20.00	0.000	0.0	1	0
3 Soil Cement	130.0	135.0	1000.00	40.00	0.000	0.0	1	0
4 Weak Clay	120.0	132.0	90.85	22.54	0.000	0.0	1	0

FIBER-REINFORCED SOIL PROPERTIES
1 Soil Type(s) With Fiber Reinforcement

Soil Type 4:

Fiber Length = 3.00(in) Fiber Width = 0.05300(in)
Fiber Thickness = 0.00150(in) Fiber Equivalent Dia. = 0.01006(in)
Friction Coefficient = 0.50 Cohesion Coefficient = 0.50
Specific Gravity of Fiber = 0.910 Application Rate = 0.250 (pcf)

Fiber-Reinforced Shear-Strength Properties

Soil Type 4: FRS c = 94.71 (psf) FRS Phi = 28.08 Deg.
Delta(c) = 3.865(psf) Tan(DeltaPhi) = 0.096957

CURVED STRENGTH PARAMETERS
1 Soil Type(s) Assigned Curved Strength Envelope Properties

Pa = 2116.800(psf)

A Value of 1.0 indicates Dimensional Coefficients

Soil Type 4:

Curve Coefficients a, b, and T are User Input Values

Coefficient a = 0.3214 Coefficient b = 0.8852
Cohesion(c) = 0.00000(psf) Coefficient T = 0.00000

A Power Curve Function Has Been Selected to Model
Stress-Dependent Shear Strength (C = 0).

WATER SURFACE DATA

1 Water Surface(s) Defined

Unit Weight of Water = 62.400 (pcf)

Water Surface No. 1 Specified by 5 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	521.50
2	60.00	521.50
3	89.50	531.60
4	114.00	529.00
5	160.00	529.00

DISTRIBUTED LOAD(S)

1 Load(s) Specified

Load No.	BND No.	X - 1 (ft)	Y - 1 (ft)	Stress (psf)	X - 2 (ft)	Y - 2 (ft)	Stress (psf)	Deflection (deg from Vert)
1	6	123.000	542.400	250.000	148.000	542.400	250.000	0.00

NOTE - Load Stress Varies Linearly Within Specified Range.

TENSION CRACK DATA

Tension Crack Zones Have Been Defined By 1 Tension Crack Line(s)

TC-Line No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)
1	116.00	540.00	160.00	540.00

Specified Tension Crack Water Depth Factor = 1.0000

Specified Tension Crack Fluid Weight = 62.400 (pcf)

SEISMIC (EARTHQUAKE) DATA

Specified Peak Ground Acceleration Coefficient (PGA) = 0.070(g)
Default Velocity = 0.175(ft) per second
Specified Horizontal Earthquake Coefficient (kh) = 0.0300(g)
Specified Vertical Earthquake Coefficient (kv) = 0.000(g)
(NOTE:Input Velocity = 0.0 will result in default Peak
Velocity = 2 times(PGA) times 2.5 fps or 0.762 mps)
Specified Seismic Pore-Pressure Factor = 0.000
Horizontal Seismic Force is Applied at Center of Gravity of Slices

EARTHQUAKE DATA HAS BEEN SUPPRESSED

A Non-Circular Zone Search Has Been Selected For Analysis
Using Random Generation Within Specified Zones.

2 Zones Defined For Generation Of Non-Circular Surfaces

1000 Trial Surfaces Have Been Generated.

Length Of Line Segments For Active And Passive Portions Of
Non-Circular Zone Search = 2.00(ft)

Zone No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Height (ft)
1	73.00	520.00	85.00	524.00	4.50
2	102.00	528.50	114.00	532.50	6.00

The Spencer Method Was Selected for FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR SPENCER METHOD:
Initial estimate of FS = 1.500

```
FS tolerance =  0.00000100
Initial estimate of theta(deg) =  8.00
Theta tolerance(radians) =  0.0001000
Minimum theta(deg) = -45.00 ; Maximum theta(deg) =  45.00
Theta convergence Step Factor = 1000.00
Maximum number of iterations = 50
Maximum force imbalance  = 100.000000(lbs)
Maximum moment imbalance = 100.000000 (ft/lbs)

Selected Lambda Coefficient =  1.00

The option of using a different convergence method
during the first 25% of iterations has been selected.

Specified Tension Crack Water Depth Factor =   1.000

Total Number of Trial Surfaces Attempted = 1000

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence =    195
Maximum Normal Stress Difference (%) =   0.005000


Warning: Convergence not achieved on  348
surfaces during curved strength envelope calculations.
Maximum Normal Stress Difference (%) =     Infinity


WARNING! The Factor of Safety Calculation for one or More Trial Surfaces
Did Not Converge in 50 Iterations.


Number of Trial Surfaces with Non-Converged FS = 442

Number of Trial Surfaces With Valid FS = 558


Percentage of Trial Surfaces With Non-Converged and/or
Non-Valid FS Solutions of the Total Attempted =  44.2 %

Statistical Data On All Valid FS Values:
   FS Max =   3.082   FS Min =   1.322   FS Ave =   1.773
   Standard Deviation =    0.302   Coefficient of Variation =   17.03 %


Critical Surface is Sequence Number      37 of Those Analyzed.


*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****
```

Iter. No.	Theta (deg) (fx=1.0)	FS (Moment)	FS (Force)	Lambda	Delta FS
1	8.0000	1.437446	1.255779	0.141	0.1816671E+00
2	10.6400	1.411946	1.276462	0.188	0.1354836E+00
3	11.7693	1.397163	1.285949	0.208	0.1112141E+00
4	12.7872	1.381323	1.294871	0.227	0.8645193E-01
5	13.6409	1.365881	1.302649	0.243	0.6323259E-01
6	14.3031	1.352349	1.308879	0.255	0.4346957E-01
7	14.7781	1.341703	1.313462	0.264	0.2824103E-01
8	15.0958	1.334105	1.316582	0.270	0.1752334E-01
9	15.2968	1.329091	1.318578	0.274	0.1051362E-01
10	15.4187	1.325965	1.319798	0.276	0.6167186E-02
11	15.4908	1.324089	1.320523	0.277	0.3566512E-02
12	15.5326	1.322989	1.320944	0.278	0.2044873E-02
13	15.5567	1.322353	1.321187	0.278	0.1166518E-02
14	15.5886	1.321506	1.321509	0.279	0.3177883E-05
15	15.5885	1.321509	1.321509	0.279	0.4875084E-08

Factor Of Safety For The Preceding Specified Surface = 1.322
Theta (fx = 1.0) = 15.59 Deg   Lambda =   0.279

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence =   195
Maximum Normal Stress Difference (%) =   0.005000

The Spencer Method Has Been Selected For FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR ANALYSIS METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 8.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = -45.00 ; Maximum theta(deg) = 45.00
Theta convergence Step Factor = 1000.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance(if Applicable) = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

The option of using a different convergence method during the first 25% of iterations has been selected.

Tension Crack Water Force = 11.40(lbs)

Specified Tension Crack Water Depth Factor = 1.000

Depth of Tension Crack (zo) at Side of Last Slice = 0.604(ft)

Depth of Water in Tension Crack = 0.604(ft)

Theoretical Tension Crack Depth = 2.648(ft)

NOTE: In Table 1 following, when a tension crack with water is present on the first slice (right facing slope) or on the last slice (left facing slope), the "side force" in the tension crack is set equal to the water pressure resultant.

*** Table 1 - Line of Thrust(if applicable) and Slice Force Data ***

Slice No.	X Coord.	Y Coord.	h/H	Side Force (lbs)	fx	Force Angle (Deg)	Vert. Shear Force(lbs)
1	74.12	526.35	0.470	0.32	1.000	15.59	0.1
2	75.67	526.10	0.458	243.04	1.000	15.59	65.3
3	77.46	525.61	0.365	886.51	1.000	15.59	238.2
4	78.44	525.40	0.351	1335.32	1.000	15.59	358.8
5	79.28	525.22	0.343	1799.11	1.000	15.59	483.5
6	84.39	526.64	0.378	1798.03	1.000	15.59	483.2
7	89.50	528.09	0.406	1783.62	1.000	15.59	479.3
8	89.73	528.15	0.408	1781.73	1.000	15.59	478.8
9	94.02	529.29	0.415	1824.60	1.000	15.59	490.3
10	98.31	530.22	0.392	2016.72	1.000	15.59	541.9
11	102.61	531.00	0.352	2353.94	1.000	15.59	632.6
12	104.39	531.81	0.354	2088.23	1.000	15.59	561.2
13	105.50	532.35	0.353	1905.59	1.000	15.59	512.1
14	106.12	532.65	0.352	1811.32	1.000	15.59	486.7
15	107.80	533.53	0.350	1507.75	1.000	15.59	405.2
16	109.42	534.48	0.349	1186.84	1.000	15.59	318.9
17	110.98	535.48	0.349	869.00	1.000	15.59	233.5
18	112.47	536.53	0.352	574.83	1.000	15.59	154.5
19	113.89	537.64	0.359	324.29	1.000	15.59	87.1
20	115.23	538.79	0.378	135.89	1.000	15.59	36.5
21	116.49	539.93	0.397	25.41	1.000	15.59	6.8
22	116.81	540.20	0.201	11.40	1.000	15.59	0.0

NOTE: A value of 0.000- for h/H indicates that the line of thrust is at or below the lower boundary of the sliding mass. A value of 1.000+ for h/H indicates that the line of thrust is at or above the upper boundary of the sliding mass.

Table 2 - Geometry Data on the 22 Slices

Slice No.	Width (ft)	Height (ft)	X-Cntr (ft)	Y-Cntr-Base (ft)	Y-Cntr-Top (ft)	Alpha (deg)	Beta (deg)	Base Length (ft)
1	0.04	0.02	74.10	526.35	526.37	-30.02	18.43	0.05
2	1.55	0.75	74.90	525.89	526.63	-30.02	18.43	1.80
3	1.78	2.21	76.57	524.98	527.19	-27.02	18.43	2.00
4	0.98	3.34	77.95	524.31	527.65	-24.02	18.43	1.07
5	0.85	4.05	78.86	523.90	527.95	-24.02	18.43	0.93
6	5.11	4.72	81.84	524.22	528.95	11.27	18.43	5.21
7	5.11	5.41	86.95	525.24	530.65	11.27	18.43	5.21
8	0.23	5.77	89.61	525.77	531.54	11.27	18.43	0.23
9	4.29	6.07	91.87	526.22	532.29	11.27	18.43	4.38
10	4.29	6.64	96.17	527.08	533.72	11.27	18.43	4.38
11	4.29	7.22	100.46	527.93	535.15	11.27	18.43	4.38
12	1.78	7.35	103.50	528.81	536.17	26.88	18.43	2.00
13	1.11	7.06	104.94	529.58	536.65	29.88	18.43	1.28
14	0.63	6.85	105.81	530.08	536.94	29.88	18.43	0.72
15	1.68	6.52	106.96	530.81	537.32	32.88	18.43	2.00
16	1.62	5.94	108.61	531.93	537.87	35.88	18.43	2.00
17	1.56	5.25	110.20	533.15	538.40	38.88	18.43	2.00
18	1.49	4.47	111.73	534.44	538.91	41.88	18.43	2.00
19	1.42	3.58	113.18	535.82	539.39	44.88	18.43	2.00
20	1.34	2.59	114.56	537.26	539.85	47.88	18.43	2.00
21	1.26	1.50	115.86	538.78	540.29	50.88	18.43	2.00
22	0.32	0.77	116.65	539.78	540.55	53.88	18.43	0.55

Table 2A - Coordinates of Slice Points Defining the Slip Surface

Point No.	X-Pt (ft)	Y-Pt (ft)
1	74.077720	526.359240
2	74.120548	526.334493
3	75.674953	525.436323
4	77.456644	524.527712
5	78.437500	524.090591
6	79.283447	523.713593
7	84.391724	524.731666
8	89.500000	525.749740
9	89.727554	525.795092
10	94.020274	526.650626
11	98.312993	527.506160
12	102.605713	528.361694
13	104.389608	529.265973
14	105.497141	529.902344

15	106.123733	530.262374
16	107.803333	531.348167
17	109.423806	532.520375
18	110.980709	533.775786
19	112.469775	535.110958
20	113.886924	536.522232
21	115.228269	538.005739
22	116.490136	539.557414
23	116.813099	540.000000

Table 3 - Force and Pore Pressure Data On The 22 Slices (Excluding Reinforcement)

Slice No.	Weight (lbs)	Ubeta Force Top (lbs)	Ubeta Stress Top (psf)	Ualpha Force Bot (lbs)	Pore Pressure (psf)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Distributed Load (lbs)
1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.00
2	152.0	0.0	0.0	75.9	42.3	0.0	0.0	0.00
3	516.1	0.0	0.0	258.9	129.5	0.0	0.0	0.00
4	430.3	0.0	0.0	211.8	197.2	0.0	0.0	0.00
5	450.3	0.0	0.0	222.1	239.8	0.0	0.0	0.00
6	3171.4	0.0	0.0	1464.1	281.1	0.0	0.0	0.00
7	3633.6	0.0	0.0	1689.2	324.3	0.0	0.0	0.00
8	173.2	0.3	1.1	83.7	360.9	0.0	0.0	0.00
9	3388.6	0.0	0.0	1392.1	318.0	0.0	0.0	0.00
10	3617.8	0.0	0.0	1036.0	236.7	0.0	0.0	0.00
11	3847.0	0.0	0.0	679.9	155.3	0.0	0.0	0.00
12	1601.5	0.0	0.0	161.4	80.7	0.0	0.0	0.00
13	943.8	0.0	0.0	29.9	23.4	0.0	0.0	0.00
14	515.4	0.0	0.0	0.0	0.0	0.0	0.0	0.00
15	1313.3	0.0	0.0	0.0	0.0	0.0	0.0	0.00
16	1154.5	0.0	0.0	0.0	0.0	0.0	0.0	0.00
17	981.3	0.0	0.0	0.0	0.0	0.0	0.0	0.00
18	797.8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
19	608.2	0.0	0.0	0.0	0.0	0.0	0.0	0.00
20	416.7	0.0	0.0	0.0	0.0	0.0	0.0	0.00
21	227.9	0.0	0.0	0.0	0.0	0.0	0.0	0.00
22	29.9	0.0	0.0	0.0	0.0	0.0	0.0	0.00

Table 3A - Center of Pressure of Water Loads On the 22 Slices
Only Applicable Slices Listed

Slice No.	X-Ubeta (ft)	Y-Ubeta (ft)	Ubeta-Moment (ft/lbs)
8	89.53	531.51	-0.46

Table 3B - Center of Pressure of Distributed Loads On the 22 Slices
Only Applicable Slices Listed

Slice No.	X-Dload (ft)	Y-Dload (ft)	Dist-Load (lbs)	Dload-Moment (ft/lbs)
18	123.27	542.40	0.135488E+03	0.000000E+00
19	123.39	542.40	0.197351E+03	0.000000E+00
20	124.62	542.40	0.417527E+03	0.000000E+00
21	126.26	542.40	0.402558E+03	0.000000E+00
22	127.34	542.40	0.136204E+03	0.000000E+00

TOTAL WEIGHT OF SLIDING MASS = 27970.65(lbs)

EFFECTIVE WEIGHT OF SLIDING MASS = 20885.55(lbs)

TOTAL AREA OF SLIDING MASS = 221.73(ft2)

TABLE 4 - SOIL STRENGTH & SOIL OPTIONS DATA ON THE 22 SLICES

Slice No.	Soil Type	Cohesion (psf)	Phi(Deg)	Options
1	4	0.46	33.08	C F
2	4	6.50	26.09	C F
3	4	14.59	24.26	C F
4	4	19.26	23.66	C F
5	4	22.68	23.31	C F
6	4	14.51	24.27	C F
7	4	16.26	24.02	C F
8	4	16.74	23.96	C F
9	4	19.52	23.63	C F
10	4	24.72	23.13	C F
11	4	29.79	22.75	C F
12	4	27.82	22.89	C F
13	4	27.56	22.91	C F
14	4	27.48	22.92	C F
15	4	25.46	23.07	C F
16	4	22.67	23.31	C F
17	4	19.63	23.62	C F
18	4	16.36	24.01	C F
19	4	12.90	24.53	C F
20	4	9.25	25.27	C F
21	4	5.41	26.53	C F
22	4	2.54	28.40	C F

SOIL OPTIONS: A = ANISOTROPIC, C = CURVED STRENGTH ENVELOPE (TANGENT PHI),
F = FIBER-REINFORCED SOIL (FRS), N = NONLINEAR UNDRAINED SHEAR STRENGTH,
R = RAPID DRAWDOWN SHEAR STRENGTH
NOTE: Phi and C in Table 4 are modified values based on specified
Soil Options (if any). Zero values indicate that the normal stress = 0.0

Calculated Secant Phi Values

Slice No.	Phi(Deg)
1	35.88
2	28.40
3	26.40
4	25.75
5	25.37
6	26.42
7	26.15
8	26.08
9	25.72
10	25.18
11	24.76
12	24.91
13	24.93
14	24.94
15	25.11
16	25.37
17	25.71
18	26.13
19	26.70
20	27.51
21	28.87
22	30.89

NOTE: The slices in the table above with phi marked
with an * are unmodified phi values for soil type(s) not
specified to have curved strength envelope (if any).

TABLE 5 - Total Base Stress Data on the 22 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Stress (psf)	Total Vert. Stress (psf)	Total Normal/Vert. Stress Ratio
1	-30.02	74.10	0.05	6.33	2.34	2.704
2	-30.02	74.90	1.80	169.93	97.79	1.738
3	-27.02	76.57	2.00	447.71	289.69	1.545
4	-24.02	77.95	1.07	632.47	438.71	1.442
5	-24.02	78.86	0.93	763.35	532.28	1.434
6	11.27	81.84	5.21	597.11	620.84	0.962
7	11.27	86.95	5.21	683.93	711.32	0.962
8	11.27	89.61	0.23	732.49	762.15	0.961
9	11.27	91.87	4.38	759.95	789.37	0.963
10	11.27	96.17	4.38	813.88	842.77	0.966
11	11.27	100.46	4.38	867.74	896.17	0.968

12	26.88	103.50	2.00	740.25	897.77	0.825
13	29.88	104.94	1.28	675.93	852.13	0.793
14	29.88	105.81	0.72	650.58	822.53	0.791
15	32.88	106.96	2.00	596.57	781.91	0.763
16	35.88	108.61	2.00	523.35	712.43	0.735
17	38.88	110.20	2.00	444.81	630.32	0.706
18	41.88	111.73	2.00	362.17	535.81	0.676
19	44.88	113.18	2.00	276.75	429.14	0.645
20	47.88	114.56	2.00	190.05	310.63	0.612
21	50.88	115.86	2.00	103.80	180.58	0.575
22	53.88	116.65	0.55	44.12	92.62	0.476

TABLE 5A - Total Base Force Data on the 22 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Force (lbs)	Total Vert. Force (lbs)	Total Normal/Vert. Force Ratio
1	-30.02	74.10	0.05	0.31	0.10	3.123
2	-30.02	74.90	1.80	305.06	152.01	2.007
3	-27.02	76.57	2.00	895.42	516.13	1.735
4	-24.02	77.95	1.07	679.18	430.31	1.578
5	-24.02	78.86	0.93	706.97	450.28	1.570
6	11.27	81.84	5.21	3110.19	3171.44	0.981
7	11.27	86.95	5.21	3562.43	3633.59	0.980
8	11.27	89.61	0.23	169.96	173.43	0.980
9	11.27	91.87	4.38	3326.43	3388.56	0.982
10	11.27	96.17	4.38	3562.47	3617.79	0.985
11	11.27	100.46	4.38	3798.20	3847.02	0.987
12	26.88	103.50	2.00	1480.51	1601.52	0.924
13	29.88	104.94	1.28	863.39	943.77	0.915
14	29.88	105.81	0.72	470.15	515.39	0.912
15	32.88	106.96	2.00	1193.14	1313.29	0.909
16	35.88	108.61	2.00	1046.69	1154.47	0.907
17	38.88	110.20	2.00	889.61	981.35	0.907
18	41.88	111.73	2.00	724.33	797.85	0.908
19	44.88	113.18	2.00	553.50	608.16	0.910
20	47.88	114.56	2.00	380.09	416.66	0.912
21	50.88	115.86	2.00	207.60	227.87	0.911
22	53.88	116.65	0.55	24.17	29.91	0.808

TABLE 6 - Effective and Base Shear Stress Data on the 22 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Stress (psf)	Available Shear Strength (psf)	Mobilized Shear Stress (psf)
1	-30.02	74.10	0.05	6.33	4.58	3.47

2	-30.02	74.90	1.80	127.64	69.01	52.22
3	-27.02	76.57	2.00	318.24	157.99	119.56
4	-24.02	77.95	1.07	435.26	209.95	158.87
5	-24.02	78.86	0.93	523.58	248.31	187.90
6	11.27	81.84	5.21	316.02	156.99	118.80
7	11.27	86.95	5.21	359.63	176.54	133.59
8	11.27	89.61	0.23	371.62	181.87	137.63
9	11.27	91.87	4.38	441.92	212.87	161.08
10	11.27	96.17	4.38	577.20	271.32	205.31
11	11.27	100.46	4.38	712.42	328.54	248.61
12	26.88	103.50	2.00	659.54	306.29	231.77
13	29.88	104.94	1.28	652.54	303.33	229.53
14	29.88	105.81	0.72	650.58	302.50	228.91
15	32.88	106.96	2.00	596.57	279.58	211.56
16	35.88	108.61	2.00	523.35	248.21	187.83
17	38.88	110.20	2.00	444.81	214.13	162.03
18	41.88	111.73	2.00	362.17	177.67	134.44
19	44.88	113.18	2.00	276.75	139.18	105.32
20	47.88	114.56	2.00	190.05	98.98	74.90
21	50.88	115.86	2.00	103.80	57.22	43.30
22	53.88	116.65	0.55	44.12	26.39	19.97

TABLE 6A - Effective and Base Shear Force Data on the 22 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Force (lbs)	Available Shear Force (lbs)	Mobilized Shear Force (lbs)
1	-30.02	74.10	0.05	0.31	0.23	0.17
2	-30.02	74.90	1.80	229.15	123.88	93.74
3	-27.02	76.57	2.00	636.49	315.99	239.11
4	-24.02	77.95	1.07	467.40	225.45	170.60
5	-24.02	78.86	0.93	484.91	229.98	174.03
6	11.27	81.84	5.21	1646.09	817.74	618.79
7	11.27	86.95	5.21	1873.24	919.55	695.84
8	11.27	89.61	0.23	86.23	42.20	31.93
9	11.27	91.87	4.38	1934.36	931.74	705.06
10	11.27	96.17	4.38	2526.51	1187.62	898.69
11	11.27	100.46	4.38	3118.34	1438.05	1088.19
12	26.88	103.50	2.00	1319.08	612.58	463.54
13	29.88	104.94	1.28	833.52	387.46	293.19
14	29.88	105.81	0.72	470.15	218.61	165.42
15	32.88	106.96	2.00	1193.14	559.17	423.13
16	35.88	108.61	2.00	1046.69	496.43	375.65
17	38.88	110.20	2.00	889.61	428.25	324.06
18	41.88	111.73	2.00	724.33	355.34	268.89
19	44.88	113.18	2.00	553.50	278.37	210.64
20	47.88	114.56	2.00	380.09	197.96	149.80
21	50.88	115.86	2.00	207.60	114.45	86.61

22	53.88	116.65	0.55	24.17	14.46	10.94

SUM OF MOMENTS = -0.776967E-05 (ft/lbs);Imbalance (Fraction of Total Weight) = -0.2777795E-09
SUM OF FORCES = -.156414E-06 (lbs);Imbalance (Fraction of Total Weight) = -0.5592082E-11

Sum of Available Shear Forces = 9895.49(lbs)

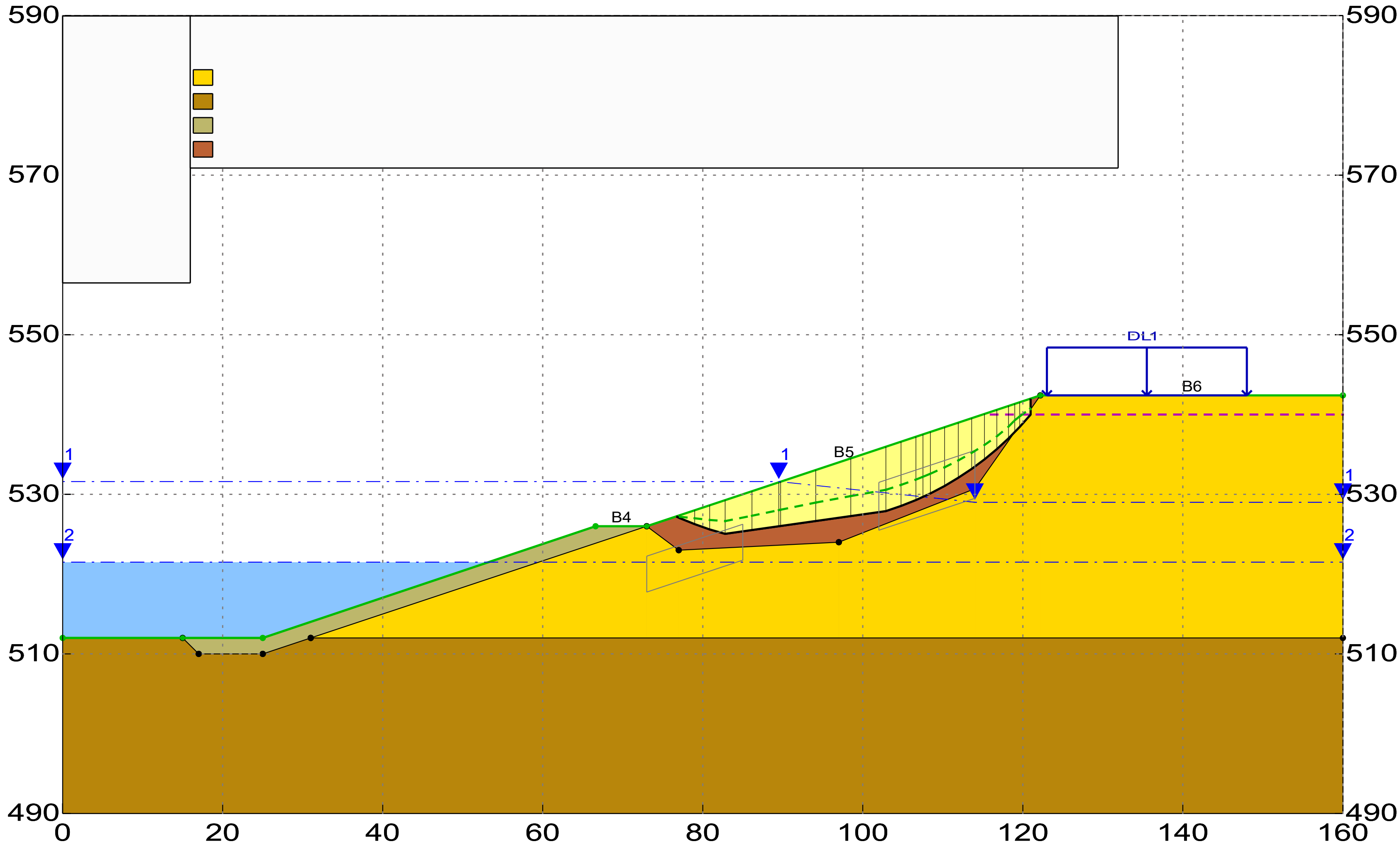
Sum of Mobilized Shear Forces = 7488.03(lbs)

FS Balance Check: FS = 1.321509

**** END OF GEOSTASE OUTPUT ****

LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II
3-Stage Rapid Drawdown - Initial Condition

GREGORY GEOTECHNICAL - GHG \lakeridge-Initial-3RD.gsd



GEOSTASE FS = 1.038

Spencer Method

GEOSTASE Slope Stability Analysis

GREGORY GEOTECHNICAL

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

PLATE C.7

*** GEOSTASE ***

****
SLOPE STABILITY ANALYSIS SOFTWARE
Simplified Bishop, Simplified Janbu, or General Equilibrium (GE) Options.
(Spencer, Morgenstern-Price, USACE, and Lowe & Karafiath)
Including Pier/Pile, Planar Reinf, Nail, Tieback, Line Loads
Nonlinear Undrained Shear Strength, Curved Strength Envelope,
Anisotropic , Fiber-Reinforced , Distributed Loads, Water
Surfaces, Pseudo-Static & Newmark Earthquake, and Applied Forces.
****

Analysis Date:
Analysis Time:
Analysis By: GREGORY GEOTECHNICAL - GHG

Input File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Initial-3RD.gsd

Output File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Initial-3RD.OUT

Unit System: English

PROJECT: LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II

DESCRIPTION: 3-Stage Rapid Drawdown - Initial Condition

BOUNDARY DATA

6 Surface Boundaries
15 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	512.000	15.000	512.000	2
2	15.000	512.000	25.000	512.000	3
3	25.000	512.000	66.600	526.000	3

4	66.600	526.000	73.000	526.000	3
5	73.000	526.000	122.200	542.400	4
6	122.200	542.400	160.000	542.400	1
7	15.000	512.000	17.000	510.000	2
8	17.000	510.000	25.000	510.000	2
9	25.000	510.000	31.000	512.000	2
10	31.000	512.000	73.000	526.000	1
11	73.000	526.000	77.000	523.000	1
12	77.000	523.000	97.000	524.000	1
13	97.000	524.000	114.000	530.700	1
14	114.000	530.700	122.200	542.400	1
15	31.000	512.000	160.000	512.000	2

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 490.000(ft)

MOHR-COULOMB SOIL PARAMETERS

4 Type(s) of Soil Defined

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Ratio(ru)	Pressure Constant (psf)	Water Surface No.	Water Option
1 Fill-Clay	120.0	132.0	40.00	25.00	0.000	0.0	1	0
2 In-Situ	120.0	132.0	1000.00	20.00	0.000	0.0	1	0
3 Soil Cement	130.0	135.0	1000.00	40.00	0.000	0.0	1	0
4 Weak Clay	120.0	132.0	70.00	13.00	0.100	0.0	1	0

FIBER-REINFORCED SOIL PROPERTIES
1 Soil Type(s) With Fiber Reinforcement

Soil Type 4:

Fiber Length = 3.00(in) Fiber Width = 0.05300(in)
Fiber Thickness = 0.00150(in) Fiber Equivalent Dia. = 0.01006(in)
Friction Coefficient = 0.50 Cohesion Coefficient = 0.50
Specific Gravity of Fiber = 0.910 Application Rate = 0.250 (pcf)

Fiber-Reinforced Shear-Strength Properties

Soil Type 4: FRS c = 72.56 (psf) FRS Phi = 16.60 Deg.
Delta(c) = 2.559(psf) Tan(DeltaPhi) = 0.062926

FIBER-REINFORCED SOIL DATA HAS BEEN SUPPRESSED

CURVED STRENGTH PARAMETERS

1 Soil Type(s) Assigned Curved Strength Envelope Properties

Pa = 2116.800(psf)
A Value of 1.0 indicates Dimensional Coefficients

Soil Type 4:

Curve Coefficients a, b, and T are User Input Values

Coefficient a = 0.2723 Coefficient b = 0.8691
Cohesion(c) = 0.00000(psf) Coefficient T = 0.00000

A Power Curve Function Has Been Selected to Model
Stress-Dependent Shear Strength (C = 0).

CURVED STRENGTH ENVELOPE DATA HAS BEEN SUPPRESSED

WATER SURFACE DATA

2 Water Surface(s) Defined for 3-Stage Rapid Drawdown Analysis.
Water Surface No. 1 is Prior to Drawdown.
Water Surface No. 2 is After Drawdown.

Unit Weight of Water = 62.400 (pcf)

Water Surface No. 1 Specified by 4 Coordinate Points
Pore Pressure Inclination Factor = 1.00

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	531.60
2	89.50	531.60
3	114.00	529.00
4	160.00	529.00

Water Surface No. 2 Specified by 2 Coordinate Points
Pore Pressure Inclination Factor = 1.00

Point No.	X-Water (ft)	Y-Water (ft)

1	0.00	521.50
2	160.00	521.50

SOIL PARAMETERS FOR 3-STAGE RAPID DRAWDOWN

3-Stage Rapid Drawdown Method = Duncan, Wright, and Wong (1990)

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	CR (psf)	PhiR (deg)	dk (psf)	PSIk (deg)
1 Fill-Clay	120.00	132.00	40.00	25.00	0.00	0.00	0.00	0.00
2 In-Situ	120.00	132.00	1000.00	20.00	0.00	0.00	0.00	0.00
3 Soil Cement	130.00	135.00	1000.00	40.00	0.00	0.00	0.00	0.00
4 Weak Clay	120.00	132.00	70.00	13.00	146.00	9.00	166.56	10.24

DISTRIBUTED LOAD(S)

1 Load(s) Specified

Load No.	BND No.	X - 1 (ft)	Y - 1 (ft)	Stress (psf)	X - 2 (ft)	Y - 2 (ft)	Stress (psf)	Deflection (deg from Vert)
1	6	123.000	542.400	250.000	148.000	542.400	250.000	0.00

NOTE - Load Stress Varies Linearly Within Specified Range.

TENSION CRACK DATA

Tension Crack Zones Have Been Defined By 1 Tension Crack Line(s)

TC-Line No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)
1	116.00	540.00	160.00	540.00

Specified Tension Crack Water Depth Factor = 1.0000

Specified Tension Crack Fluid Weight = 62.400 (pcf)

SEISMIC (EARTHQUAKE) DATA

Specified Peak Ground Acceleration Coefficient (PGA) = 0.070(g)

Default Velocity = 0.175(ft) per second
Specified Horizontal Earthquake Coefficient (kh) = 0.0300(g)
Specified Vertical Earthquake Coefficient (kv) = 0.000(g)
(NOTE:Input Velocity = 0.0 will result in default Peak
Velocity = 2 times(PGA) times 2.5 fps or 0.762 mps)
Specified Seismic Pore-Pressure Factor = 0.000
Horizontal Seismic Force is Applied at Center of Gravity of Slices

EARTHQUAKE DATA HAS BEEN SUPPRESSED

A Non-Circular Zone Search Has Been Selected For Analysis
Using Random Generation Within Specified Zones.

2 Zones Defined For Generation Of Non-Circular Surfaces

1000 Trial Surfaces Have Been Generated.

Length Of Line Segments For Active And Passive Portions Of
Non-Circular Zone Search = 2.00(ft)

Zone No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Height (ft)
1	73.00	520.00	85.00	524.00	4.50
2	102.00	528.50	114.00	532.50	6.00

The Spencer Method Was Selected for FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR SPENCER METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 10.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = -45.00 ; Maximum theta(deg) = 45.00
Theta convergence Step Factor = 5000.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

Specified Tension Crack Water Depth Factor = 1.000

Total Number of Trial Surfaces Attempted = 1000

WARNING! The Factor of Safety Calculation for one or More Trial Surfaces
Did Not Converge in 50 Iterations.

Number of Trial Surfaces with Non-Converged FS = 275

Number of Trial Surfaces With Valid FS = 725

Percentage of Trial Surfaces With Non-Converged and/or
Non-Valid FS Solutions of the Total Attempted = 27.5 %

Statistical Data On All Valid FS Values:
FS Max = 3.939 FS Min = 1.038 FS Ave = 1.698
Standard Deviation = 0.397 Coefficient of Variation = 23.37 %

Critical Surface is Sequence Number 46 of Those Analyzed.

**** END OF GEOSTASE OUTPUT FOR RAPID DRAWDOWN STAGE 3 ****

*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****

Iter. No.	Theta (deg) (fx=1.0)	FS (Moment)	FS (Force)	Lambda	Delta FS
1	10.0000	1.200868	1.098552	0.176	0.1023166E+00
2	13.3000	1.088833	1.124676	0.236	0.3584287E-01
3	12.4440	1.121429	1.117650	0.221	0.3779368E-02
4	12.5258	1.118430	1.118313	0.222	0.1167669E-03
5	12.5285	1.118334	1.118335	0.222	0.3787015E-06

Factor Of Safety For The Preceding Specified Surface = 1.118
Theta (fx = 1.0) = 12.53 Deg Lambda = 0.222

The Spencer Method Has Been Selected For FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR ANALYSIS METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 10.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = -45.00 ; Maximum theta(deg) = 45.00
Theta convergence Step Factor = 5000.00
Maximum number of iterations = 50

Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance(if Applicable) = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

Tension Crack Water Force = 123.15(lbs)

Specified Tension Crack Water Depth Factor = 1.000

Depth of Tension Crack (zo) at Side of Last Slice = 1.987(ft)

Depth of Water in Tension Crack = 1.987(ft)

Theoretical Tension Crack Depth = 1.046(ft)

NOTE: In Table 1 following, when a tension crack with water is present on the first slice (right facing slope) or on the last slice (left facing slope), the "side force" in the tension crack is set equal to the water pressure resultant.

*** Table 1 - Line of Thrust(if applicable) and Slice Force Data ***

Slice No.	X Coord.	Y Coord.	h/H	Side Force (lbs)	fx	Force Angle (Deg)	Vert. Shear Force(lbs)
1	77.13	527.17	0.431	223.71	1.000	12.53	48.5
2	78.98	527.11	0.490	1182.58	1.000	12.53	256.5
3	80.87	527.12	0.503	1980.71	1.000	12.53	429.7
4	82.79	526.99	0.460	3008.51	1.000	12.53	652.6
5	86.15	527.67	0.442	3349.47	1.000	12.53	726.6
6	89.50	528.30	0.419	3602.74	1.000	12.53	781.5
7	89.73	528.35	0.417	3616.71	1.000	12.53	784.6
8	94.11	529.17	0.394	3853.59	1.000	12.53	835.9
9	98.50	530.02	0.380	4035.93	1.000	12.53	875.5
10	102.88	530.88	0.370	4203.11	1.000	12.53	911.8
11	104.77	531.46	0.363	3976.43	1.000	12.53	862.6
12	106.63	532.07	0.351	3719.56	1.000	12.53	806.9
13	107.51	532.37	0.343	3577.05	1.000	12.53	775.9
14	108.45	532.69	0.333	3430.98	1.000	12.53	744.3
15	110.22	533.32	0.308	3105.47	1.000	12.53	673.7
16	111.94	534.30	0.322	2377.48	1.000	12.53	515.7
17	113.60	534.99	0.285	2023.90	1.000	12.53	439.0
18	115.20	535.56	0.207	1759.76	1.000	12.53	381.7
19	116.74	536.09	0.087	1382.18	1.000	12.53	299.8
20	118.21	536.39	0.000-	1058.02	1.000	12.53	229.5
21	118.99	536.41	0.000-	907.74	1.000	12.53	196.9
22	119.61	536.41	0.000-	839.86	1.000	12.53	182.2
23	120.92	536.29	0.000-	724.90	1.000	12.53	157.2
24	120.96	540.66	0.662	123.15	1.000	12.53	132.4

NOTE: A value of 0.000- for h/H indicates that the line of thrust is at or below the lower boundary of the sliding mass. A value of 1.000+ for h/H indicates that the line of thrust is at or above the upper boundary of the sliding mass.

Table 2 - Geometry Data on the 24 Slices

Slice No.	Width (ft)	Height (ft)	X-Cntr (ft)	Y-Cntr-Base (ft)	Y-Cntr-Top (ft)	Alpha (deg)	Beta (deg)	Base Length (ft)
1	0.45	0.18	76.91	527.12	527.30	-25.16	18.43	0.50
2	1.85	1.05	78.06	526.64	527.69	-22.16	18.43	2.00
3	1.89	2.38	79.93	525.93	528.31	-19.16	18.43	2.00
4	1.92	3.62	81.83	525.33	528.94	-16.16	18.43	2.00
5	3.35	4.54	84.47	525.29	529.82	8.08	18.43	3.39
6	3.35	5.18	87.82	525.76	530.94	8.08	18.43	3.39
7	0.23	5.52	89.61	526.02	531.54	8.08	18.43	0.23
8	4.38	5.96	91.92	526.34	532.31	8.08	18.43	4.43
9	4.38	6.80	96.30	526.97	533.77	8.08	18.43	4.43
10	4.38	7.64	100.69	527.59	535.23	8.08	18.43	4.43
11	1.89	8.05	103.83	528.22	536.28	18.75	18.43	2.00
12	1.86	7.99	105.70	528.91	536.90	21.75	18.43	2.00
13	0.88	7.87	107.07	529.49	537.36	24.75	18.43	0.97
14	0.94	7.76	107.98	529.90	537.66	24.75	18.43	1.03
15	1.77	7.52	109.33	530.59	538.11	27.75	18.43	2.00
16	1.72	7.13	111.08	531.56	538.69	30.75	18.43	2.00
17	1.66	6.63	112.77	532.63	539.26	33.75	18.43	2.00
18	1.60	6.02	114.40	533.78	539.80	36.75	18.43	2.00
19	1.54	5.30	115.97	535.02	540.32	39.75	18.43	2.00
20	1.47	4.49	117.48	536.34	540.83	42.75	18.43	2.00
21	0.78	3.78	118.60	537.42	541.20	45.75	18.43	1.12
22	0.62	3.30	119.30	538.13	541.43	45.75	18.43	0.88
23	1.32	2.55	120.26	539.20	541.75	48.75	18.43	2.00
24	0.04	2.00	120.94	539.98	541.98	51.75	18.43	0.06

Table 2A - Coordinates of Slice Points Defining the Slip Surface

Point No.	X-Pt (ft)	Y-Pt (ft)
1	76.680747	527.226916
2	77.130698	527.015585
3	78.982989	526.261251
4	80.872220	525.604893
5	82.793213	525.048309
6	86.146606	525.524323

7	89.500000	526.000336
8	89.727554	526.032637
9	94.112071	526.655018
10	98.496587	527.277399
11	102.881104	527.899780
12	104.774998	528.542562
13	106.632656	529.283582
14	107.511315	529.688595
15	108.448986	530.120809
16	110.219010	531.051947
17	111.937876	532.074446
18	113.600873	533.185501
19	115.203443	534.382068
20	116.741193	535.660868
21	118.209908	537.018394
22	118.988052	537.817098
23	119.605563	538.450926
24	120.924333	539.954539
25	120.960176	540.000000

Table 3 - Force and Pore Pressure Data On The 24 Slices (Excluding Reinforcement)

Slice No.	Weight (lbs)	Ubeta Force Top (lbs)	Ubeta Stress Top (psf)	Ualpha Force Bot (lbs)	Pore Pressure (psf)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Distributed Load (lbs)
1	10.7	127.2	268.2	140.1	281.9	0.0	0.0	0.00
2	256.0	476.9	244.3	646.9	323.4	0.0	0.0	0.00
3	592.6	408.9	205.3	770.0	385.0	0.0	0.0	0.00
4	917.3	335.6	165.7	878.4	439.2	0.0	0.0	0.00
5	2008.3	391.9	110.9	1537.2	453.9	0.0	0.0	0.00
6	2292.4	145.3	41.1	1465.3	432.6	0.0	0.0	0.00
7	165.8	0.7	3.1	96.7	420.5	0.0	0.0	0.00
8	3400.3	0.0	0.0	1724.9	389.5	0.0	0.0	0.00
9	3784.6	0.0	0.0	1463.2	330.4	0.0	0.0	0.00
10	4168.8	0.0	0.0	1201.4	271.3	0.0	0.0	0.00
11	1872.8	0.0	0.0	429.7	214.8	0.0	0.0	0.00
12	1802.3	0.0	0.0	314.8	157.4	0.0	0.0	0.00
13	832.6	0.0	0.0	106.7	110.3	0.0	0.0	0.00
14	872.6	0.0	0.0	96.1	93.1	0.0	0.0	0.00
15	1598.3	0.0	0.0	180.6	90.3	0.0	0.0	0.00
16	1470.6	0.0	0.0	171.1	85.6	0.0	0.0	0.00
17	1322.4	0.0	0.0	159.0	79.5	0.0	0.0	0.00
18	1157.1	0.0	0.0	144.4	72.2	0.0	0.0	0.00
19	978.5	0.0	0.0	127.3	63.6	0.0	0.0	0.00
20	790.6	0.0	0.0	107.7	53.8	0.0	0.0	0.00
21	353.1	0.0	0.0	50.6	45.4	0.0	0.0	0.00
22	244.4	0.0	0.0	0.0	0.0	0.0	0.0	0.00

23	403.9	0.0	0.0	0.0	0.0	0.0	0.0	0.00
24	8.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00

Table 3A - Center of Pressure of Water Loads On the 24 Slices
Only Applicable Slices Listed

Slice No.	X-Ubeta (ft)	Y-Ubeta (ft)	Ubeta-Moment (ft/lbs)
1	76.90	527.30	-7.09
2	78.03	527.68	-145.69
3	79.90	528.30	-294.28
4	81.79	528.93	-370.23
5	84.29	529.76	-489.62
6	87.35	530.78	-165.38
7	89.59	531.53	-1.28

Table 3B - Center of Pressure of Distributed Loads On the 24 Slices
Only Applicable Slices Listed

Slice No.	X-Dload (ft)	Y-Dload (ft)	Dist-Load (lbs)	Dload-Moment (ft/lbs)
18	123.27	542.40	0.135488E+03	0.000000E+00
19	123.39	542.40	0.197351E+03	0.000000E+00
20	124.62	542.40	0.417527E+03	0.000000E+00
21	126.26	542.40	0.402558E+03	0.000000E+00
22	123.17	542.40	0.829042E+02	0.000000E+00
23	123.40	542.40	0.201540E+03	0.000000E+00
24	124.61	542.40	0.399881E+03	0.000000E+00

TOTAL WEIGHT OF SLIDING MASS = 31304.73(lbs)

EFFECTIVE WEIGHT OF SLIDING MASS = 19942.81(lbs)

TOTAL AREA OF SLIDING MASS = 250.44(ft2)

TABLE 4 - SOIL STRENGTH & SOIL OPTIONS DATA ON THE 24 SLICES

Slice No.	Soil Type	Cohesion (psf)	Phi(Deg)	Options
1	4	70.00	13.00	R
2	4	70.00	13.00	R
3	4	70.00	13.00	R
4	4	70.00	13.00	R
5	4	70.00	13.00	R
6	4	70.00	13.00	R
7	4	70.00	13.00	R
8	4	70.00	13.00	R

9	4	70.00	13.00	R
10	4	70.00	13.00	R
11	4	70.00	13.00	R
12	4	70.00	13.00	R
13	4	70.00	13.00	R
14	4	70.00	13.00	R
15	4	70.00	13.00	R
16	4	70.00	13.00	R
17	4	70.00	13.00	R
18	4	70.00	13.00	R
19	4	70.00	13.00	R
20	4	70.00	13.00	R
21	4	70.00	13.00	R
22	1	40.00	25.00	
23	1	40.00	25.00	
24	1	40.00	25.00	

SOIL OPTIONS: A = ANISOTROPIC, C = CURVED STRENGTH ENVELOPE (TANGENT PHI),
F = FIBER-REINFORCED SOIL (FRS), N = NONLINEAR UNDRAINED SHEAR STRENGTH,
R = RAPID DRAWDOWN SHEAR STRENGTH
NOTE: Phi and C in Table 4 are modified values based on specified
Soil Options (if any). Zero values indicate that the normal stress = 0.0

TABLE 5 - Total Base Stress Data on the 24 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Stress (psf)	Total Vert. Stress (psf)	Total Normal/Vert. Stress Ratio
1	-25.16	76.91	0.50	479.99	292.05	1.644
2	-22.16	78.06	2.00	572.48	382.49	1.497
3	-19.16	79.93	2.00	651.50	518.99	1.255
4	-16.16	81.83	2.00	825.35	643.25	1.283
5	8.08	84.47	3.39	708.68	709.75	0.998
6	8.08	87.82	3.39	718.11	724.71	0.991
7	8.08	89.61	0.23	722.35	731.95	0.987
8	8.08	91.92	4.43	764.36	775.53	0.986
9	8.08	96.30	4.43	849.31	863.17	0.984
10	8.08	100.69	4.43	934.96	950.81	0.983
11	18.75	103.83	2.00	899.02	988.88	0.909
12	21.75	105.70	2.00	857.58	970.19	0.884
13	24.75	107.07	0.97	812.67	947.54	0.858
14	24.75	107.98	1.03	797.50	930.64	0.857
15	27.75	109.33	2.00	749.99	902.99	0.831
16	30.75	111.08	2.00	745.73	855.55	0.872
17	33.75	112.77	2.00	613.76	795.18	0.772
18	36.75	114.40	2.00	517.76	722.03	0.717
19	39.75	115.97	2.00	462.52	636.32	0.727

20	42.75	117.48	2.00	371.85	538.27	0.691
21	45.75	118.60	1.12	294.83	453.83	0.650
22	45.75	119.30	0.88	234.76	395.79	0.593
23	48.75	120.26	2.00	167.13	306.27	0.546
24	51.75	120.94	0.06	-326.24	240.42	-1.357

TABLE 5A - Total Base Force Data on the 24 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Force (lbs)	Total Vert. Force (lbs)	Total Normal/Vert. Force Ratio
1	-25.16	76.91	0.50	238.60	131.41	1.816
2	-22.16	78.06	2.00	1144.95	708.48	1.616
3	-19.16	79.93	2.00	1303.00	980.50	1.329
4	-16.16	81.83	2.00	1650.69	1235.67	1.336
5	8.08	84.47	3.39	2400.31	2380.07	1.009
6	8.08	87.82	3.39	2432.24	2430.25	1.001
7	8.08	89.61	0.23	166.02	166.56	0.997
8	8.08	91.92	4.43	3384.93	3400.31	0.995
9	8.08	96.30	4.43	3761.16	3784.58	0.994
10	8.08	100.69	4.43	4140.44	4168.85	0.993
11	18.75	103.83	2.00	1798.03	1872.84	0.960
12	21.75	105.70	2.00	1715.16	1802.29	0.952
13	24.75	107.07	0.97	786.27	832.56	0.944
14	24.75	107.98	1.03	823.41	872.64	0.944
15	27.75	109.33	2.00	1499.98	1598.32	0.938
16	30.75	111.08	2.00	1491.47	1470.58	1.014
17	33.75	112.77	2.00	1227.52	1322.38	0.928
18	36.75	114.40	2.00	1035.53	1157.11	0.895
19	39.75	115.97	2.00	925.04	978.50	0.945
20	42.75	117.48	2.00	743.70	790.56	0.941
21	45.75	118.60	1.12	328.76	353.14	0.931
22	45.75	119.30	0.88	207.74	244.41	0.850
23	48.75	120.26	2.00	334.25	403.90	0.828
24	51.75	120.94	0.06	-18.89	8.62	-2.192

TABLE 6 - Effective and Base Shear Stress Data on the 24 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Stress (psf)	Available Shear Strength (psf)	Mobilized Shear Stress (psf)	Rapid Drawdown Strength Type
1	-25.16	76.91	0.50	136.53	101.52	90.78	Drained
2	-22.16	78.06	2.00	187.06	113.19	101.21	Drained
3	-19.16	79.93	2.00	266.52	131.53	117.61	Drained
4	-16.16	81.83	2.00	333.32	146.95	131.40	Drained
5	8.08	84.47	3.39	251.05	127.96	114.42	Drained

6	8.08	87.82	3.39	282.28	135.17	120.87	Drained
7	8.08	89.61	0.23	298.92	139.01	124.30	Drained
8	8.08	91.92	4.43	373.16	156.15	139.63	Drained
9	8.08	96.30	4.43	519.58	189.96	169.86	Drained
10	8.08	100.69	4.43	666.01	223.76	200.08	Drained
11	18.75	103.83	2.00	682.51	227.57	203.49	Drained
12	21.75	105.70	2.00	700.20	231.65	207.14	Drained
13	24.75	107.07	0.97	704.17	232.57	207.96	Drained
14	24.75	107.98	1.03	705.99	232.99	208.34	Drained
15	27.75	109.33	2.00	663.87	223.27	199.64	Drained
16	30.75	111.08	2.00	608.18	210.41	188.15	Drained
17	33.75	112.77	2.00	544.89	195.80	175.08	Drained
18	36.75	114.40	2.00	474.83	179.62	160.62	Drained
19	39.75	115.97	2.00	398.89	162.09	144.94	Drained
20	42.75	117.48	2.00	318.03	143.42	128.25	Drained
21	45.75	118.60	1.12	249.45	127.59	114.09	Drained
22	45.75	119.30	0.88	234.76	243.02	217.30	Drained
23	48.75	120.26	2.00	167.13	231.16	206.70	Drained
24	51.75	120.94	0.06	0.00	213.83	191.20	Drained

TABLE 6A - Effective and Base Shear Force Data on the 24 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Force (lbs)	Available Shear Force (lbs)	Mobilized Shear Force (lbs)
1	-25.16	76.91	0.50	98.49	94.79	84.76
2	-22.16	78.06	2.00	498.10	426.72	381.57
3	-19.16	79.93	2.00	533.04	263.06	235.23
4	-16.16	81.83	2.00	772.27	509.78	455.84
5	8.08	84.47	3.39	863.07	617.02	551.73
6	8.08	87.82	3.39	966.91	613.47	548.56
7	8.08	89.61	0.23	69.37	41.49	37.10
8	8.08	91.92	4.43	1659.98	798.55	714.05
9	8.08	96.30	4.43	2297.96	798.12	713.67
10	8.08	100.69	4.43	2939.00	841.63	752.58
11	18.75	103.83	2.00	1368.34	421.12	376.56
12	21.75	105.70	2.00	1400.40	463.24	414.22
13	24.75	107.07	0.97	679.55	233.99	209.23
14	24.75	107.98	1.03	727.32	248.87	222.53
15	27.75	109.33	2.00	1319.38	480.93	430.04
16	30.75	111.08	2.00	1320.36	67.47	60.33
17	33.75	112.77	2.00	1068.49	452.94	405.01
18	36.75	114.40	2.00	891.12	504.80	451.39
19	39.75	115.97	2.00	797.78	324.18	289.88
20	42.75	117.48	2.00	636.05	286.84	256.49
21	45.75	118.60	1.12	278.16	142.27	127.22
22	45.75	119.30	0.88	207.74	132.27	118.27
23	48.75	120.26	2.00	334.25	235.86	210.91

24	51.75	120.94	0.06	0.00	2.32	-5.80

SUM OF MOMENTS = -0.783218E-03 (ft/lbs);Imbalance (Fraction of Total Weight) = -0.2501917E-07
SUM OF FORCES = -.208924E-05 (lbs);Imbalance (Fraction of Total Weight) = -0.6673893E-10

Sum of Available Shear Forces = 13365.61(lbs)

Sum of Mobilized Shear Forces = 11951.35(lbs)

FS Balance Check: FS = 1.118334

**** END OF GEOSTASE OUTPUT FOR RAPID DRAWDOWN STAGE 1 ****

Iter. No.	Theta (deg) (fx=1.0)	FS (Moment)	FS (Force)	Lambda	Delta FS
1	10.0000	1.173992	1.044188	0.176	0.1298043E+00
2	13.3000	1.102913	1.059218	0.236	0.4369531E-01
3	14.9742	1.054761	1.067112	0.267	0.1235051E-01
4	14.6054	1.066221	1.065355	0.261	0.8663114E-03
5	14.6296	1.065484	1.065470	0.261	0.1354823E-04
6	14.6300	1.065472	1.065472	0.261	0.1856260E-07

Factor Of Safety For The Preceding Specified Surface = 1.065
Theta (fx = 1.0) = 14.63 Deg   Lambda = 0.261

The Spencer Method Has Been Selected For FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR ANALYSIS METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 10.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = -45.00 ; Maximum theta(deg) = 45.00
Theta convergence Step Factor = 5000.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance(if Applicable) = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

Tension Crack Water Force = 123.15(lbs)

Specified Tension Crack Water Depth Factor = 1.000

Depth of Tension Crack (zo) at Side of Last Slice = 1.987(ft)

Depth of Water in Tension Crack = 1.987(ft)

Theoretical Tension Crack Depth = 1.046(ft)

NOTE: In Table 1 following, when a tension crack with water is present on the first slice (right facing slope) or on the last slice (left facing slope), the "side force" in the tension crack is set equal to the water pressure resultant.

*** Table 1 - Line of Thrust(if applicable) and Slice Force Data ***

Slice No.	X Coord.	Y Coord.	h/H	Side Force (lbs)	fx	Force Angle (Deg)	Vert. Shear Force(lbs)
1	77.13	527.18	0.455	61.11	1.000	14.63	15.4
2	78.98	526.99	0.419	449.22	1.000	14.63	113.5
3	80.87	526.77	0.386	989.64	1.000	14.63	250.0
4	82.79	526.62	0.373	1607.78	1.000	14.63	406.1
5	86.15	527.30	0.366	1803.54	1.000	14.63	455.5
6	89.50	528.00	0.363	1983.55	1.000	14.63	501.0
7	89.73	528.05	0.363	1995.21	1.000	14.63	503.9
8	94.11	528.93	0.356	2253.74	1.000	14.63	569.2
9	98.50	529.75	0.342	2584.35	1.000	14.63	652.7
10	102.88	530.53	0.326	2988.49	1.000	14.63	754.8
11	104.77	531.15	0.324	2843.18	1.000	14.63	718.1
12	106.63	531.83	0.322	2632.57	1.000	14.63	664.9
13	107.51	532.20	0.321	2495.32	1.000	14.63	630.3
14	108.45	532.59	0.321	2351.98	1.000	14.63	594.1
15	110.22	533.43	0.323	2014.41	1.000	14.63	508.8
16	111.94	534.35	0.330	1638.59	1.000	14.63	413.9
17	113.60	535.40	0.349	1245.38	1.000	14.63	314.6
18	115.20	536.65	0.398	857.22	1.000	14.63	216.5
19	116.74	538.37	0.550	497.48	1.000	14.63	125.7
20	118.21	542.35	1.000+	189.85	1.000	14.63	48.0
21	118.99	557.38	1.000+	48.07	1.000	14.63	12.1
22	119.61	471.90	0.000-	-14.01	1.000	14.63	-3.5
23	120.92	531.43	0.000-	-118.37	1.000	14.63	-29.9
24	120.96	540.66	0.662	123.15	1.000	14.63	-58.6

NOTE: A value of 0.000- for h/H indicates that the line of thrust is at or below the lower boundary of the sliding mass. A value of 1.000+ for h/H indicates that the line of thrust is at or above the upper boundary of the sliding mass.

Table 2 - Geometry Data on the 24 Slices

Slice No.	Width (ft)	Height (ft)	X-Cntr (ft)	Y-Cntr-Base (ft)	Y-Cntr-Top (ft)	Alpha (deg)	Beta (deg)	Base Length (ft)
1	0.45	0.18	76.91	527.12	527.30	-25.16	18.43	0.50
2	1.85	1.05	78.06	526.64	527.69	-22.16	18.43	2.00
3	1.89	2.38	79.93	525.93	528.31	-19.16	18.43	2.00
4	1.92	3.62	81.83	525.33	528.94	-16.16	18.43	2.00
5	3.35	4.54	84.47	525.29	529.82	8.08	18.43	3.39
6	3.35	5.18	87.82	525.76	530.94	8.08	18.43	3.39
7	0.23	5.52	89.61	526.02	531.54	8.08	18.43	0.23
8	4.38	5.96	91.92	526.34	532.31	8.08	18.43	4.43
9	4.38	6.80	96.30	526.97	533.77	8.08	18.43	4.43
10	4.38	7.64	100.69	527.59	535.23	8.08	18.43	4.43
11	1.89	8.05	103.83	528.22	536.28	18.75	18.43	2.00
12	1.86	7.99	105.70	528.91	536.90	21.75	18.43	2.00
13	0.88	7.87	107.07	529.49	537.36	24.75	18.43	0.97
14	0.94	7.76	107.98	529.90	537.66	24.75	18.43	1.03
15	1.77	7.52	109.33	530.59	538.11	27.75	18.43	2.00
16	1.72	7.13	111.08	531.56	538.69	30.75	18.43	2.00
17	1.66	6.63	112.77	532.63	539.26	33.75	18.43	2.00
18	1.60	6.02	114.40	533.78	539.80	36.75	18.43	2.00
19	1.54	5.30	115.97	535.02	540.32	39.75	18.43	2.00
20	1.47	4.49	117.48	536.34	540.83	42.75	18.43	2.00
21	0.78	3.78	118.60	537.42	541.20	45.75	18.43	1.12
22	0.62	3.30	119.30	538.13	541.43	45.75	18.43	0.88
23	1.32	2.55	120.26	539.20	541.75	48.75	18.43	2.00
24	0.04	2.00	120.94	539.98	541.98	51.75	18.43	0.06

Table 2A - Coordinates of Slice Points Defining the Slip Surface

Point No.	X-Pt (ft)	Y-Pt (ft)
1	76.680747	527.226916
2	77.130698	527.015585
3	78.982989	526.261251
4	80.872220	525.604893
5	82.793213	525.048309
6	86.146606	525.524323
7	89.500000	526.000336
8	89.727554	526.032637
9	94.112071	526.655018
10	98.496587	527.277399
11	102.881104	527.899780
12	104.774998	528.542562
13	106.632656	529.283582
14	107.511315	529.688595

15	108.448986	530.120809
16	110.219010	531.051947
17	111.937876	532.074446
18	113.600873	533.185501
19	115.203443	534.382068
20	116.741193	535.660868
21	118.209908	537.018394
22	118.988052	537.817098
23	119.605563	538.450926
24	120.924333	539.954539
25	120.960176	540.000000

Table 3 - Force and Pore Pressure Data On The 24 Slices (Excluding Reinforcement)

Slice No.	Weight (lbs)	Ubeta Force Top (lbs)	Ubeta Stress Top (psf)	Ualpha Force Bot (lbs)	Pore Pressure (psf)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Distributed Load (lbs)
1	9.8	0.0	0.0	1.1	2.2	0.0	0.0	0.00
2	232.8	0.0	0.0	25.1	12.6	0.0	0.0	0.00
3	538.7	0.0	0.0	57.0	28.5	0.0	0.0	0.00
4	833.9	0.0	0.0	86.8	43.4	0.0	0.0	0.00
5	1825.7	0.0	0.0	184.4	54.4	0.0	0.0	0.00
6	2084.0	0.0	0.0	210.5	62.1	0.0	0.0	0.00
7	150.8	0.0	0.0	15.2	66.3	0.0	0.0	0.00
8	3137.3	0.0	0.0	316.9	71.6	0.0	0.0	0.00
9	3578.8	0.0	0.0	361.5	81.6	0.0	0.0	0.00
10	4020.3	0.0	0.0	406.1	91.7	0.0	0.0	0.00
11	1830.6	0.0	0.0	193.3	96.7	0.0	0.0	0.00
12	1780.7	0.0	0.0	191.7	95.9	0.0	0.0	0.00
13	829.9	0.0	0.0	91.4	94.5	0.0	0.0	0.00
14	872.6	0.0	0.0	96.1	93.1	0.0	0.0	0.00
15	1598.3	0.0	0.0	180.6	90.3	0.0	0.0	0.00
16	1470.6	0.0	0.0	171.1	85.6	0.0	0.0	0.00
17	1322.4	0.0	0.0	159.0	79.5	0.0	0.0	0.00
18	1157.1	0.0	0.0	144.4	72.2	0.0	0.0	0.00
19	978.5	0.0	0.0	127.3	63.6	0.0	0.0	0.00
20	790.6	0.0	0.0	107.7	53.8	0.0	0.0	0.00
21	353.1	0.0	0.0	50.6	45.4	0.0	0.0	0.00
22	244.4	0.0	0.0	0.0	0.0	0.0	0.0	0.00
23	403.9	0.0	0.0	0.0	0.0	0.0	0.0	0.00
24	8.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00

Table 3A - Center of Pressure of Water Loads On the 24 Slices
Only Applicable Slices Listed

Slice	X-Ubeta	Y-Ubeta	Ubeta-Moment

No. (ft) (ft) (ft/lbs)

Table 3B - Center of Pressure of Distributed Loads On the 24 Slices
Only Applicable Slices Listed

Slice No.	X-Dload (ft)	Y-Dload (ft)	Dist-Load (lbs)	Dload-Moment (ft/lbs)
18	123.27	542.40	0.135488E+03	0.000000E+00
19	123.39	542.40	0.197351E+03	0.000000E+00
20	124.62	542.40	0.417527E+03	0.000000E+00
21	126.26	542.40	0.402558E+03	0.000000E+00
22	123.17	542.40	0.829042E+02	0.000000E+00
23	123.40	542.40	0.201540E+03	0.000000E+00
24	124.61	542.40	0.399881E+03	0.000000E+00

TOTAL WEIGHT OF SLIDING MASS = 30053.31(lbs)

EFFECTIVE WEIGHT OF SLIDING MASS = 27113.67(lbs)

TOTAL AREA OF SLIDING MASS = 250.44(ft2)

TABLE 4 - SOIL STRENGTH & SOIL OPTIONS DATA ON THE 24 SLICES

Slice No.	Soil Type	Cohesion (psf)	Phi(Deg)	Options
1	4	97.16	0.00	R
2	4	120.52	0.00	R
3	4	145.09	0.00	R
4	4	159.26	0.00	R
5	4	141.90	0.00	R
6	4	148.39	0.00	R
7	4	151.91	0.00	R
8	4	167.88	0.00	R
9	4	200.04	0.00	R
10	4	232.54	0.00	R
11	4	236.21	0.00	R
12	4	240.15	0.00	R
13	4	233.52	0.00	R
14	4	230.96	0.00	R
15	4	220.74	0.00	R
16	4	207.46	0.00	R
17	4	192.52	0.00	R
18	4	176.09	0.00	R
19	4	158.39	0.00	R
20	4	139.63	0.00	R
21	4	123.64	0.00	R
22	1	40.00	25.00	
23	1	40.00	25.00	

24	1	40.00	25.00

SOIL OPTIONS: A = ANISOTROPIC, C = CURVED STRENGTH ENVELOPE (TANGENT PHI),
F = FIBER-REINFORCED SOIL (FRS), N = NONLINEAR UNDRAINED SHEAR STRENGTH,
R = RAPID DRAWDOWN SHEAR STRENGTH
NOTE: Phi and C in Table 4 are modified values based on specified
Soil Options (if any). Zero values indicate that the normal stress = 0.0

TABLE 5 - Total Base Stress Data on the 24 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Stress (psf)	Total Vert. Stress (psf)	Total Normal/Vert. Stress Ratio
1	-25.16	76.91	0.50	96.43	21.68	4.448
2	-22.16	78.06	2.00	224.00	125.66	1.783
3	-19.16	79.93	2.00	404.70	285.14	1.419
4	-16.16	81.83	2.00	558.70	434.12	1.287
5	8.08	84.47	3.39	540.28	544.44	0.992
6	8.08	87.82	3.39	615.24	621.45	0.990
7	8.08	89.61	0.23	655.27	662.57	0.989
8	8.08	91.92	4.43	708.06	715.53	0.990
9	8.08	96.30	4.43	808.62	816.23	0.991
10	8.08	100.69	4.43	909.22	916.92	0.992
11	18.75	103.83	2.00	871.96	966.58	0.902
12	21.75	105.70	2.00	840.04	958.58	0.876
13	24.75	107.07	0.97	803.95	944.55	0.851
14	24.75	107.98	1.03	791.95	930.64	0.851
15	27.75	109.33	2.00	745.57	902.99	0.826
16	30.75	111.08	2.00	684.10	855.55	0.800
17	33.75	112.77	2.00	614.17	795.18	0.772
18	36.75	114.40	2.00	536.66	722.03	0.743
19	39.75	115.97	2.00	452.52	636.32	0.711
20	42.75	117.48	2.00	362.77	538.27	0.674
21	45.75	118.60	1.12	286.70	453.83	0.632
22	45.75	119.30	0.88	228.99	395.79	0.579
23	48.75	120.26	2.00	162.43	306.27	0.530
24	51.75	120.94	0.06	-391.82	240.42	-1.630

TABLE 5A - Total Base Force Data on the 24 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Force (lbs)	Total Vert. Force (lbs)	Total Normal/Vert. Force Ratio
1	-25.16	76.91	0.50	47.94	9.75	4.915
2	-22.16	78.06	2.00	447.99	232.77	1.925

3	-19.16	79.93	2.00	809.39	538.69	1.503
4	-16.16	81.83	2.00	1117.40	833.93	1.340
5	8.08	84.47	3.39	1829.93	1825.72	1.002
6	8.08	87.82	3.39	2083.83	2083.98	1.000
7	8.08	89.61	0.23	150.60	150.77	0.999
8	8.08	91.92	4.43	3135.62	3137.27	0.999
9	8.08	96.30	4.43	3580.96	3578.77	1.001
10	8.08	100.69	4.43	4026.47	4020.26	1.002
11	18.75	103.83	2.00	1743.92	1830.60	0.953
12	21.75	105.70	2.00	1680.08	1780.72	0.943
13	24.75	107.07	0.97	777.83	829.94	0.937
14	24.75	107.98	1.03	817.68	872.64	0.937
15	27.75	109.33	2.00	1491.14	1598.32	0.933
16	30.75	111.08	2.00	1368.20	1470.58	0.930
17	33.75	112.77	2.00	1228.33	1322.38	0.929
18	36.75	114.40	2.00	1073.32	1157.11	0.928
19	39.75	115.97	2.00	905.04	978.50	0.925
20	42.75	117.48	2.00	725.53	790.56	0.918
21	45.75	118.60	1.12	319.70	353.14	0.905
22	45.75	119.30	0.88	202.64	244.41	0.829
23	48.75	120.26	2.00	324.86	403.90	0.804
24	51.75	120.94	0.06	-22.68	8.62	-2.632

TABLE 6 - Effective and Base Shear Stress Data on the 24 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Stress (psf)	Available Shear Strength (psf)	Mobilized Shear Stress (psf)	Rapid Drawdown Strength Type
1	-25.16	76.91	0.50	136.53	121.67	114.19	Undrained
2	-22.16	78.06	2.00	187.06	129.38	121.43	Undrained
3	-19.16	79.93	2.00	266.52	145.09	136.18	Undrained
4	-16.16	81.83	2.00	333.32	159.26	149.47	Undrained
5	8.08	84.47	3.39	251.05	141.90	133.18	Undrained
6	8.08	87.82	3.39	282.28	148.39	139.27	Undrained
7	8.08	89.61	0.23	298.92	151.91	142.57	Undrained
8	8.08	91.92	4.43	373.16	167.88	157.56	Undrained
9	8.08	96.30	4.43	519.58	200.04	187.74	Undrained
10	8.08	100.69	4.43	666.01	232.54	218.25	Undrained
11	18.75	103.83	2.00	682.51	236.21	221.70	Undrained
12	21.75	105.70	2.00	700.20	240.15	225.40	Undrained
13	24.75	107.07	0.97	704.17	241.04	226.23	Undrained
14	24.75	107.98	1.03	705.99	241.45	226.61	Undrained
15	27.75	109.33	2.00	663.87	232.06	217.80	Undrained
16	30.75	111.08	2.00	608.18	219.68	206.18	Undrained
17	33.75	112.77	2.00	544.89	205.64	193.00	Undrained
18	36.75	114.40	2.00	474.83	190.15	178.47	Undrained
19	39.75	115.97	2.00	398.89	173.48	162.82	Undrained
20	42.75	117.48	2.00	318.03	155.98	146.39	Undrained

21	45.75	118.60	1.12	249.45	141.57	132.87	Undrained
22	45.75	119.30	0.88	234.76	279.25	262.09	Undrained
23	48.75	120.26	2.00	167.13	269.09	252.55	Undrained
24	51.75	120.94	0.06	0.00	254.28	238.65	Undrained

TABLE 6A - Effective and Base Shear Force Data on the 24 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Force (lbs)	Available Shear Force (lbs)	Mobilized Shear Force (lbs)
1	-25.16	76.91	0.50	46.86	45.62	42.81
2	-22.16	78.06	2.00	422.86	237.63	223.02
3	-19.16	79.93	2.00	752.37	290.19	272.36
4	-16.16	81.83	2.00	1030.58	318.52	298.95
5	8.08	84.47	3.39	1645.53	480.60	451.07
6	8.08	87.82	3.39	1873.34	502.60	471.72
7	8.08	89.61	0.23	135.38	34.91	32.77
8	8.08	91.92	4.43	2818.75	743.44	697.76
9	8.08	96.30	4.43	3219.50	885.85	831.42
10	8.08	100.69	4.43	3620.41	1029.79	966.51
11	18.75	103.83	2.00	1550.60	472.43	443.40
12	21.75	105.70	2.00	1488.36	480.31	450.79
13	24.75	107.07	0.97	686.44	226.20	212.30
14	24.75	107.98	1.03	721.59	238.87	224.19
15	27.75	109.33	2.00	1310.54	442.56	415.37
16	30.75	111.08	2.00	1197.08	416.37	390.78
17	33.75	112.77	2.00	1069.30	386.87	363.09
18	36.75	114.40	2.00	928.91	354.46	332.67
19	39.75	115.97	2.00	777.78	319.56	299.93
20	42.75	117.48	2.00	617.88	282.65	265.28
21	45.75	118.60	1.12	269.10	140.18	131.57
22	45.75	119.30	0.88	202.64	129.89	121.91
23	48.75	120.26	2.00	324.86	231.48	217.26
24	51.75	120.94	0.06	0.00	2.32	-7.75

SUM OF MOMENTS = -0.162787E-04 (ft/lbs);Imbalance (Fraction of Total Weight) = -0.5416603E-09
SUM OF FORCES = 0.966896E-07 (lbs);Imbalance (Fraction of Total Weight) = 0.3217268E-11

Sum of Available Shear Forces = 12869.47(lbs)

Sum of Mobilized Shear Forces = 12078.66(lbs)

FS Balance Check: FS = 1.065472

**** END OF GEOSTASE OUTPUT FOR RAPID DRAWDOWN STAGE 2 ****

Iter.	Theta	FS	FS

No.	(deg) (fx=1.0)	(Moment)	(Force)	Lambda	Delta FS
1	10.0000	1.156342	1.019380	0.176	0.1369619E+00
2	13.3000	1.082703	1.031524	0.236	0.5117955E-01
3	15.2685	1.023273	1.039220	0.273	0.1594674E-01
4	14.8009	1.038695	1.037358	0.264	0.1337684E-02
5	14.8372	1.037530	1.037501	0.265	0.2902621E-04
6	14.8380	1.037504	1.037505	0.265	0.5315377E-07

Factor Of Safety For The Preceding Specified Surface = 1.038
Theta (fx = 1.0) = 14.84 Deg   Lambda = 0.265

The Spencer Method Has Been Selected For FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR ANALYSIS METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 10.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = -45.00 ; Maximum theta(deg) = 45.00
Theta convergence Step Factor = 5000.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance(if Applicable) = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

Tension Crack Water Force = 123.15(lbs)

Specified Tension Crack Water Depth Factor = 1.000

Depth of Tension Crack (zo) at Side of Last Slice = 1.987(ft)

Depth of Water in Tension Crack = 1.987(ft)

Theoretical Tension Crack Depth = 1.046(ft)

NOTE: In Table 1 following, when a tension crack with water is present on the first slice (right facing slope) or on the last slice (left facing slope), the "side force" in the tension crack is set equal to the water pressure resultant.

*** Table 1 - Line of Thrust(if applicable) and Slice Force Data ***

Slice No.	X Coord.	Y Coord.	h/H	Side Force (lbs)	fx	Force Angle (Deg)	Vert. Shear Force(lbs)
1	77.13	527.18	0.457	63.25	1.000	14.84	16.2
2	78.98	526.99	0.421	462.05	1.000	14.84	118.3
3	80.87	526.78	0.389	1012.65	1.000	14.84	259.3
4	82.79	526.63	0.376	1641.54	1.000	14.84	420.4
5	86.15	527.32	0.370	1849.63	1.000	14.84	473.7
6	89.50	528.02	0.367	2042.52	1.000	14.84	523.1
7	89.73	528.07	0.367	2055.07	1.000	14.84	526.3
8	94.11	528.96	0.360	2332.65	1.000	14.84	597.4
9	98.50	529.78	0.346	2685.97	1.000	14.84	687.8
10	102.88	530.56	0.330	3116.52	1.000	14.84	798.1
11	104.77	531.18	0.327	2983.22	1.000	14.84	764.0
12	106.63	531.85	0.323	2784.95	1.000	14.84	713.2
13	107.51	532.20	0.322	2653.26	1.000	14.84	679.5
14	108.45	532.58	0.320	2515.81	1.000	14.84	644.3
15	110.22	533.38	0.317	2189.18	1.000	14.84	560.6
16	111.94	534.25	0.315	1823.74	1.000	14.84	467.0
17	113.60	535.18	0.314	1440.31	1.000	14.84	368.8
18	115.20	536.18	0.316	1061.25	1.000	14.84	271.8
19	116.74	537.26	0.325	709.88	1.000	14.84	181.8
20	118.21	538.47	0.358	409.80	1.000	14.84	104.9
21	118.99	539.26	0.410	271.84	1.000	14.84	69.6
22	119.61	539.76	0.423	212.80	1.000	14.84	54.5
23	120.92	540.74	0.388	113.93	1.000	14.84	29.2
24	120.96	540.66	0.662	123.15	1.000	14.84	0.0

NOTE: A value of 0.000- for h/H indicates that the line of thrust is at or below the lower boundary of the sliding mass. A value of 1.000+ for h/H indicates that the line of thrust is at or above the upper boundary of the sliding mass.

Table 2 - Geometry Data on the 24 Slices

Slice No.	Width (ft)	Height (ft)	X-Cntr (ft)	Y-Cntr-Base (ft)	Y-Cntr-Top (ft)	Alpha (deg)	Beta (deg)	Base Length (ft)
1	0.45	0.18	76.91	527.12	527.30	-25.16	18.43	0.50
2	1.85	1.05	78.06	526.64	527.69	-22.16	18.43	2.00
3	1.89	2.38	79.93	525.93	528.31	-19.16	18.43	2.00
4	1.92	3.62	81.83	525.33	528.94	-16.16	18.43	2.00
5	3.35	4.54	84.47	525.29	529.82	8.08	18.43	3.39
6	3.35	5.18	87.82	525.76	530.94	8.08	18.43	3.39
7	0.23	5.52	89.61	526.02	531.54	8.08	18.43	0.23
8	4.38	5.96	91.92	526.34	532.31	8.08	18.43	4.43
9	4.38	6.80	96.30	526.97	533.77	8.08	18.43	4.43
10	4.38	7.64	100.69	527.59	535.23	8.08	18.43	4.43
11	1.89	8.05	103.83	528.22	536.28	18.75	18.43	2.00

12	1.86	7.99	105.70	528.91	536.90	21.75	18.43	2.00
13	0.88	7.87	107.07	529.49	537.36	24.75	18.43	0.97
14	0.94	7.76	107.98	529.90	537.66	24.75	18.43	1.03
15	1.77	7.52	109.33	530.59	538.11	27.75	18.43	2.00
16	1.72	7.13	111.08	531.56	538.69	30.75	18.43	2.00
17	1.66	6.63	112.77	532.63	539.26	33.75	18.43	2.00
18	1.60	6.02	114.40	533.78	539.80	36.75	18.43	2.00
19	1.54	5.30	115.97	535.02	540.32	39.75	18.43	2.00
20	1.47	4.49	117.48	536.34	540.83	42.75	18.43	2.00
21	0.78	3.78	118.60	537.42	541.20	45.75	18.43	1.12
22	0.62	3.30	119.30	538.13	541.43	45.75	18.43	0.88
23	1.32	2.55	120.26	539.20	541.75	48.75	18.43	2.00
24	0.04	2.00	120.94	539.98	541.98	51.75	18.43	0.06

Table 2A - Coordinates of Slice Points Defining the Slip Surface

Point No.	X-Pt (ft)	Y-Pt (ft)
1	76.680747	527.226916
2	77.130698	527.015585
3	78.982989	526.261251
4	80.872220	525.604893
5	82.793213	525.048309
6	86.146606	525.524323
7	89.500000	526.000336
8	89.727554	526.032637
9	94.112071	526.655018
10	98.496587	527.277399
11	102.881104	527.899780
12	104.774998	528.542562
13	106.632656	529.283582
14	107.511315	529.688595
15	108.448986	530.120809
16	110.219010	531.051947
17	111.937876	532.074446
18	113.600873	533.185501
19	115.203443	534.382068
20	116.741193	535.660868
21	118.209908	537.018394
22	118.988052	537.817098
23	119.605563	538.450926
24	120.924333	539.954539
25	120.960176	540.000000

Table 3 - Force and Pore Pressure Data On The 24 Slices (Excluding Reinforcement)

Slice No.	Weight (lbs)	Ubeta Force Top (lbs)	Ubeta Stress Top (psf)	Ualpha Force Bot (lbs)	Pore Pressure (psf)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Distributed Load (lbs)
1	9.8	0.0	0.0	1.1	2.2	0.0	0.0	0.00
2	232.8	0.0	0.0	25.1	12.6	0.0	0.0	0.00
3	538.7	0.0	0.0	57.0	28.5	0.0	0.0	0.00
4	833.9	0.0	0.0	86.8	43.4	0.0	0.0	0.00
5	1825.7	0.0	0.0	184.4	54.4	0.0	0.0	0.00
6	2084.0	0.0	0.0	210.5	62.1	0.0	0.0	0.00
7	150.8	0.0	0.0	15.2	66.3	0.0	0.0	0.00
8	3137.3	0.0	0.0	316.9	71.6	0.0	0.0	0.00
9	3578.8	0.0	0.0	361.5	81.6	0.0	0.0	0.00
10	4020.3	0.0	0.0	406.1	91.7	0.0	0.0	0.00
11	1830.6	0.0	0.0	193.3	96.7	0.0	0.0	0.00
12	1780.7	0.0	0.0	191.7	95.9	0.0	0.0	0.00
13	829.9	0.0	0.0	91.4	94.5	0.0	0.0	0.00
14	872.6	0.0	0.0	96.1	93.1	0.0	0.0	0.00
15	1598.3	0.0	0.0	180.6	90.3	0.0	0.0	0.00
16	1470.6	0.0	0.0	171.1	85.6	0.0	0.0	0.00
17	1322.4	0.0	0.0	159.0	79.5	0.0	0.0	0.00
18	1157.1	0.0	0.0	144.4	72.2	0.0	0.0	0.00
19	978.5	0.0	0.0	127.3	63.6	0.0	0.0	0.00
20	790.6	0.0	0.0	107.7	53.8	0.0	0.0	0.00
21	353.1	0.0	0.0	50.6	45.4	0.0	0.0	0.00
22	244.4	0.0	0.0	0.0	0.0	0.0	0.0	0.00
23	403.9	0.0	0.0	0.0	0.0	0.0	0.0	0.00
24	8.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00

Table 3A - Center of Pressure of Water Loads On the 24 Slices
Only Applicable Slices Listed

Slice No.	X-Ubeta (ft)	Y-Ubeta (ft)	Ubeta-Moment (ft/lbs)

Table 3B - Center of Pressure of Distributed Loads On the 24 Slices
Only Applicable Slices Listed

Slice No.	X-Dload (ft)	Y-Dload (ft)	Dist-Load (lbs)	Dload-Moment (ft/lbs)
18	123.27	542.40	0.135488E+03	0.000000E+00
19	123.39	542.40	0.197351E+03	0.000000E+00
20	124.62	542.40	0.417527E+03	0.000000E+00
21	126.26	542.40	0.402558E+03	0.000000E+00
22	123.17	542.40	0.829042E+02	0.000000E+00
23	123.40	542.40	0.201540E+03	0.000000E+00
24	124.61	542.40	0.399881E+03	0.000000E+00

TOTAL WEIGHT OF SLIDING MASS = 30053.31(lbs)

EFFECTIVE WEIGHT OF SLIDING MASS = 27113.67(lbs)

TOTAL AREA OF SLIDING MASS = 250.44(ft2)

TABLE 4 - SOIL STRENGTH & SOIL OPTIONS DATA ON THE 24 SLICES

Slice No.	Soil Type	Cohesion (psf)	Phi(Deg)	Options
1	4	70.00	13.00	R
2	4	70.00	13.00	R
3	4	145.09	0.00	R
4	4	159.26	0.00	R
5	4	141.90	0.00	R
6	4	148.39	0.00	R
7	4	151.91	0.00	R
8	4	167.88	0.00	R
9	4	200.04	0.00	R
10	4	232.54	0.00	R
11	4	236.21	0.00	R
12	4	240.15	0.00	R
13	4	70.00	13.00	R
14	4	70.00	13.00	R
15	4	70.00	13.00	R
16	4	70.00	13.00	R
17	4	70.00	13.00	R
18	4	70.00	13.00	R
19	4	70.00	13.00	R
20	4	70.00	13.00	R
21	4	70.00	13.00	R
22	1	40.00	25.00	
23	1	40.00	25.00	
24	1	40.00	25.00	

SOIL OPTIONS: A = ANISOTROPIC, C = CURVED STRENGTH ENVELOPE (TANGENT PHI),
F = FIBER-REINFORCED SOIL (FRS), N = NONLINEAR UNDRAINED SHEAR STRENGTH,
R = RAPID DRAWDOWN SHEAR STRENGTH
NOTE: Phi and C in Table 4 are modified values based on specified
Soil Options (if any). Zero values indicate that the normal stress = 0.0

TABLE 5 - Total Base Stress Data on the 24 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Stress (psf)	Total Vert. Stress (psf)	Total Normal/Vert. Stress Ratio

1	-25.16	76.91	0.50	99.55	21.68	4.592
2	-22.16	78.06	2.00	227.78	125.66	1.813
3	-19.16	79.93	2.00	408.36	285.14	1.432
4	-16.16	81.83	2.00	562.43	434.12	1.296
5	8.08	84.47	3.39	540.92	544.44	0.994
6	8.08	87.82	3.39	615.88	621.45	0.991
7	8.08	89.61	0.23	655.91	662.57	0.990
8	8.08	91.92	4.43	708.78	715.53	0.991
9	8.08	96.30	4.43	809.50	816.23	0.992
10	8.08	100.69	4.43	910.25	916.92	0.993
11	18.75	103.83	2.00	871.28	966.58	0.901
12	21.75	105.70	2.00	838.92	958.58	0.875
13	24.75	107.07	0.97	802.45	944.55	0.850
14	24.75	107.98	1.03	790.47	930.64	0.849
15	27.75	109.33	2.00	743.75	902.99	0.824
16	30.75	111.08	2.00	682.02	855.55	0.797
17	33.75	112.77	2.00	611.91	795.18	0.770
18	36.75	114.40	2.00	534.31	722.03	0.740
19	39.75	115.97	2.00	450.17	636.32	0.707
20	42.75	117.48	2.00	360.51	538.27	0.670
21	45.75	118.60	1.12	284.55	453.83	0.627
22	45.75	119.30	0.88	227.01	395.79	0.574
23	48.75	120.26	2.00	160.74	306.27	0.525
24	51.75	120.94	0.06	-396.46	240.42	-1.649

TABLE 5A - Total Base Force Data on the 24 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Force (lbs)	Total Vert. Force (lbs)	Total Normal/Vert. Force Ratio
1	-25.16	76.91	0.50	49.48	9.75	5.073
2	-22.16	78.06	2.00	455.56	232.77	1.957
3	-19.16	79.93	2.00	816.71	538.69	1.516
4	-16.16	81.83	2.00	1124.86	833.93	1.349
5	8.08	84.47	3.39	1832.09	1825.72	1.003
6	8.08	87.82	3.39	2085.99	2083.98	1.001
7	8.08	89.61	0.23	150.75	150.77	1.000
8	8.08	91.92	4.43	3138.80	3137.27	1.000
9	8.08	96.30	4.43	3584.83	3578.77	1.002
10	8.08	100.69	4.43	4031.03	4020.26	1.003
11	18.75	103.83	2.00	1742.57	1830.60	0.952
12	21.75	105.70	2.00	1677.84	1780.72	0.942
13	24.75	107.07	0.97	776.38	829.94	0.935
14	24.75	107.98	1.03	816.15	872.64	0.935
15	27.75	109.33	2.00	1487.50	1598.32	0.931
16	30.75	111.08	2.00	1364.04	1470.58	0.928
17	33.75	112.77	2.00	1223.81	1322.38	0.925

18	36.75	114.40	2.00	1068.61	1157.11	0.924
19	39.75	115.97	2.00	900.33	978.50	0.920
20	42.75	117.48	2.00	721.01	790.56	0.912
21	45.75	118.60	1.12	317.30	353.14	0.898
22	45.75	119.30	0.88	200.88	244.41	0.822
23	48.75	120.26	2.00	321.48	403.90	0.796
24	51.75	120.94	0.06	-22.95	8.62	-2.664

TABLE 6 - Effective and Base Shear Stress Data on the 24 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Stress (psf)	Available Shear Strength (psf)	Mobilized Shear Stress (psf)	Rapid Drawdown Strength Type
1	-25.16	76.91	0.50	117.64	97.16	93.65	Drained
2	-22.16	78.06	2.00	218.85	120.52	116.17	Drained
3	-19.16	79.93	2.00	376.18	145.09	139.85	Undrained
4	-16.16	81.83	2.00	515.29	159.26	153.50	Undrained
5	8.08	84.47	3.39	485.83	141.90	136.77	Undrained
6	8.08	87.82	3.39	553.10	148.39	143.03	Undrained
7	8.08	89.61	0.23	589.01	151.91	146.42	Undrained
8	8.08	91.92	4.43	636.51	167.88	161.81	Undrained
9	8.08	96.30	4.43	727.00	200.04	192.80	Undrained
10	8.08	100.69	4.43	817.53	232.54	224.13	Undrained
11	18.75	103.83	2.00	775.30	236.21	227.68	Undrained
12	21.75	105.70	2.00	744.18	240.15	231.47	Undrained
13	24.75	107.07	0.97	708.28	233.52	225.08	Drained
14	24.75	107.98	1.03	697.19	230.96	222.61	Drained
15	27.75	109.33	2.00	652.91	220.74	212.76	Drained
16	30.75	111.08	2.00	595.42	207.46	199.97	Drained
17	33.75	112.77	2.00	530.68	192.52	185.56	Drained
18	36.75	114.40	2.00	459.52	176.09	169.72	Drained
19	39.75	115.97	2.00	382.86	158.39	152.66	Drained
20	42.75	117.48	2.00	301.59	139.63	134.58	Drained
21	45.75	118.60	1.12	232.34	123.64	119.17	Drained
22	45.75	119.30	0.88	228.99	146.78	141.48	Drained
23	48.75	120.26	2.00	162.43	115.74	111.56	Drained
24	51.75	120.94	0.06	0.00	40.00	38.55	Drained

TABLE 6A - Effective and Base Shear Force Data on the 24 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Force (lbs)	Available Shear Force (lbs)	Mobilized Shear Force (lbs)
1	-25.16	76.91	0.50	48.41	45.97	44.31
2	-22.16	78.06	2.00	430.42	239.37	230.72
3	-19.16	79.93	2.00	759.68	290.19	279.70

4	-16.16	81.83	2.00	1038.04	318.52	307.01
5	8.08	84.47	3.39	1647.68	480.60	463.23
6	8.08	87.82	3.39	1875.51	502.60	484.43
7	8.08	89.61	0.23	135.52	34.91	33.65
8	8.08	91.92	4.43	2821.93	743.44	716.57
9	8.08	96.30	4.43	3223.36	885.85	853.83
10	8.08	100.69	4.43	3624.98	1029.79	992.57
11	18.75	103.83	2.00	1549.25	472.43	455.35
12	21.75	105.70	2.00	1486.12	480.31	462.94
13	24.75	107.07	0.97	684.99	225.87	217.70
14	24.75	107.98	1.03	720.06	238.51	229.89
15	27.75	109.33	2.00	1306.90	441.72	425.76
16	30.75	111.08	2.00	1192.93	415.41	400.39
17	33.75	112.77	2.00	1064.78	385.82	371.88
18	36.75	114.40	2.00	924.21	353.37	340.60
19	39.75	115.97	2.00	773.07	318.48	306.96
20	42.75	117.48	2.00	613.36	281.60	271.43
21	45.75	118.60	1.12	266.69	139.63	134.58
22	45.75	119.30	0.88	200.88	129.07	124.40
23	48.75	120.26	2.00	321.48	229.91	221.60
24	51.75	120.94	0.06	0.00	2.32	-8.08

SUM OF MOMENTS = -0.446778E-04 (ft/lbs);Imbalance (Fraction of Total Weight) = -0.1486618E-08
SUM OF FORCES = 0.393283E-07 (lbs);Imbalance (Fraction of Total Weight) = 0.1308619E-11

Sum of Available Shear Forces = 12868.05(lbs)

Sum of Mobilized Shear Forces = 12402.88(lbs)

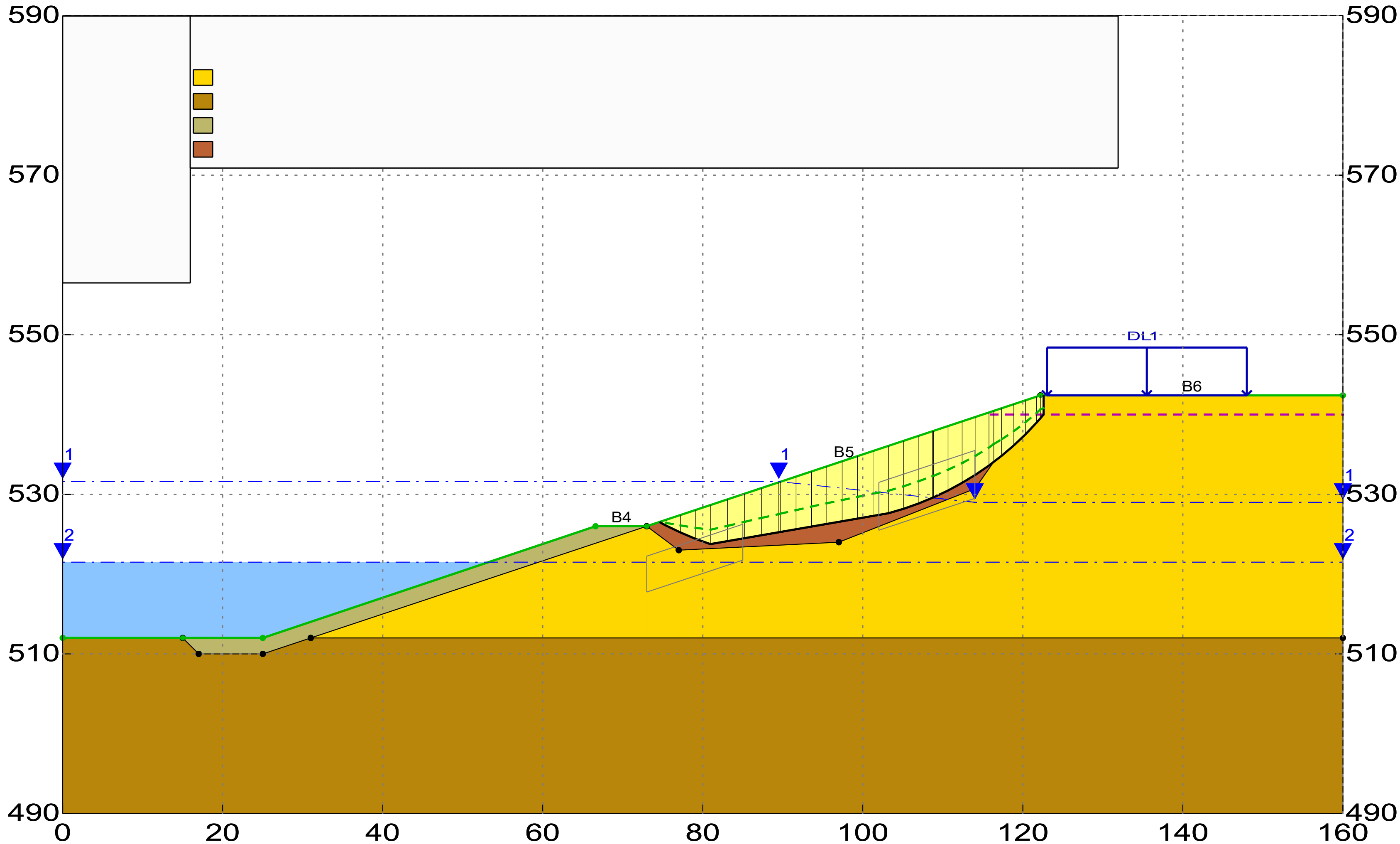
FS Balance Check: FS = 1.037505

**** END OF GEOSTASE OUTPUT FOR RAPID DRAWDOWN STAGE 3 ****

LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II
3-Stage Rapid Drawdown - Repaired - FRS

GREGORY GEOTECHNICAL - GHG

\lakeridge-Repaired-3RD.gsd



GEOSTASE FS = 1.307

Spencer Method

GEOSTASE Slope Stability Analysis

GREGORY GEOTECHNICAL

PLATE C.8

*** GEOSTASE ***

** Current Version 4.20.0000-Double Precision, Dec. 2016 **

****
SLOPE STABILITY ANALYSIS SOFTWARE
Simplified Bishop, Simplified Janbu, or General Equilibrium (GE) Options.
(Spencer, Morgenstern-Price, USACE, and Lowe & Karafiath)
Including Pier/Pile, Planar Reinf, Nail, Tieback, Line Loads
Nonlinear Undrained Shear Strength, Curved Strength Envelope,
Anisotropic , Fiber-Reinforced , Distributed Loads, Water
Surfaces, Pseudo-Static & Newmark Earthquake, and Applied Forces.
****

Analysis Date:
Analysis Time:
Analysis By: GREGORY GEOTECHNICAL - GHG

Input File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Repaired-3RD.gsd

Output File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Repaired-3RD.OUT

Unit System: English

PROJECT: LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II

DESCRIPTION: 3-Stage Rapid Drawdown - Repaired - FRS

BOUNDARY DATA

6 Surface Boundaries
15 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	512.000	15.000	512.000	2
2	15.000	512.000	25.000	512.000	3
3	25.000	512.000	66.600	526.000	3

4	66.600	526.000	73.000	526.000	3
5	73.000	526.000	122.200	542.400	4
6	122.200	542.400	160.000	542.400	1
7	15.000	512.000	17.000	510.000	2
8	17.000	510.000	25.000	510.000	2
9	25.000	510.000	31.000	512.000	2
10	31.000	512.000	73.000	526.000	1
11	73.000	526.000	77.000	523.000	1
12	77.000	523.000	97.000	524.000	1
13	97.000	524.000	114.000	530.700	1
14	114.000	530.700	122.200	542.400	1
15	31.000	512.000	160.000	512.000	2

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 490.000(ft)

MOHR-COULOMB SOIL PARAMETERS

4 Type(s) of Soil Defined

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Ratio(ru)	Pressure Constant (psf)	Water Surface No.	Water Option
1 Fill-Clay	120.0	132.0	40.00	25.00	0.000	0.0	1	0
2 In-Situ	120.0	132.0	1000.00	20.00	0.000	0.0	1	0
3 Soil Cement	130.0	135.0	1000.00	40.00	0.000	0.0	1	0
4 Weak Clay	120.0	132.0	73.00	17.83	0.100	0.0	1	0

FIBER-REINFORCED SOIL PROPERTIES
1 Soil Type(s) With Fiber Reinforcement

Soil Type 4:

Fiber Length = 3.00(in) Fiber Width = 0.05300(in)
Fiber Thickness = 0.00150(in) Fiber Equivalent Dia. = 0.01006(in)
Friction Coefficient = 0.50 Cohesion Coefficient = 0.50
Specific Gravity of Fiber = 0.910 Application Rate = 0.250 (pcf)

Fiber-Reinforced Shear-Strength Properties

Soil Type 4: FRS c = 76.04 (psf) FRS Phi = 22.47 Deg.
Delta(c) = 3.043(psf) Tan(DeltaPhi) = 0.081241

FIBER-REINFORCED SOIL DATA HAS BEEN SUPPRESSED

CURVED STRENGTH PARAMETERS

1 Soil Type(s) Assigned Curved Strength Envelope Properties

Pa = 2116.800(psf)
A Value of 1.0 indicates Dimensional Coefficients

Soil Type 4:

Curve Coefficients a, b, and T are User Input Values

Coefficient a = 0.2723 Coefficient b = 0.8691
Cohesion(c) = 0.00000(psf) Coefficient T = 0.00000

A Power Curve Function Has Been Selected to Model
Stress-Dependent Shear Strength (C = 0).

CURVED STRENGTH ENVELOPE DATA HAS BEEN SUPPRESSED

WATER SURFACE DATA

2 Water Surface(s) Defined for 3-Stage Rapid Drawdown Analysis.
Water Surface No. 1 is Prior to Drawdown.
Water Surface No. 2 is After Drawdown.

Unit Weight of Water = 62.400 (pcf)

Water Surface No. 1 Specified by 4 Coordinate Points
Pore Pressure Inclination Factor = 1.00

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	531.60
2	89.50	531.60
3	114.00	529.00
4	160.00	529.00

Water Surface No. 2 Specified by 2 Coordinate Points
Pore Pressure Inclination Factor = 1.00

Point No.	X-Water (ft)	Y-Water (ft)

1	0.00	521.50
2	160.00	521.50

SOIL PARAMETERS FOR 3-STAGE RAPID DRAWDOWN

3-Stage Rapid Drawdown Method = Duncan, Wright, and Wong (1990)

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	CR (psf)	PhiR (deg)	dk (psf)	PSIk (deg)
1 Fill-Clay	120.00	132.00	40.00	25.00	0.00	0.00	0.00	0.00
2 In-Situ	120.00	132.00	1000.00	20.00	0.00	0.00	0.00	0.00
3 Soil Cement	130.00	135.00	1000.00	40.00	0.00	0.00	0.00	0.00
4 Weak Clay	120.00	132.00	73.00	17.83	152.00	11.46	176.98	13.28

DISTRIBUTED LOAD(S)

1 Load(s) Specified

Load No.	BND No.	X - 1 (ft)	Y - 1 (ft)	Stress (psf)	X - 2 (ft)	Y - 2 (ft)	Stress (psf)	Deflection (deg from Vert)
1	6	123.000	542.400	250.000	148.000	542.400	250.000	0.00

NOTE - Load Stress Varies Linearly Within Specified Range.

TENSION CRACK DATA

Tension Crack Zones Have Been Defined By 1 Tension Crack Line(s)

TC-Line No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)
1	116.00	540.00	160.00	540.00

Specified Tension Crack Water Depth Factor = 1.0000

Specified Tension Crack Fluid Weight = 62.400 (pcf)

SEISMIC (EARTHQUAKE) DATA

Specified Peak Ground Acceleration Coefficient (PGA) = 0.070(g)

Default Velocity = 0.175(ft) per second
Specified Horizontal Earthquake Coefficient (kh) = 0.0300(g)
Specified Vertical Earthquake Coefficient (kv) = 0.000(g)
(NOTE:Input Velocity = 0.0 will result in default Peak
Velocity = 2 times(PGA) times 2.5 fps or 0.762 mps)
Specified Seismic Pore-Pressure Factor = 0.000
Horizontal Seismic Force is Applied at Center of Gravity of Slices

EARTHQUAKE DATA HAS BEEN SUPPRESSED

A Non-Circular Zone Search Has Been Selected For Analysis
Using Random Generation Within Specified Zones.

2 Zones Defined For Generation Of Non-Circular Surfaces

1000 Trial Surfaces Have Been Generated.

Length Of Line Segments For Active And Passive Portions Of
Non-Circular Zone Search = 2.00(ft)

Zone No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Height (ft)
1	73.00	520.00	85.00	524.00	4.50
2	102.00	528.50	114.00	532.50	6.00

The Spencer Method Was Selected for FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR SPENCER METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 10.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = 0.00 ; Maximum theta(deg) = 90.00
Theta convergence Step Factor = 500.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

Specified Tension Crack Water Depth Factor = 1.000

Total Number of Trial Surfaces Attempted = 1000

WARNING! The Factor of Safety Calculation for one or More Trial Surfaces
Did Not Converge in 50 Iterations.

Number of Trial Surfaces with Non-Converged FS = 280

Number of Trial Surfaces With Valid FS = 720

Percentage of Trial Surfaces With Non-Converged and/or
Non-Valid FS Solutions of the Total Attempted = 28.0 %

Statistical Data On All Valid FS Values:
FS Max = 4.318 FS Min = 1.307 FS Ave = 1.905
Standard Deviation = 0.394 Coefficient of Variation = 20.69 %

Critical Surface is Sequence Number 1085 of Those Analyzed.

**** END OF GEOSTASE OUTPUT FOR RAPID DRAWDOWN STAGE 3 ****

*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****

Iter. No.	Theta (deg) (fx=1.0)	FS (Moment)	FS (Force)	Lambda	Delta FS
1	10.0000	1.496290	1.378828	0.176	0.1174622E+00
2	13.3000	1.337807	1.417554	0.236	0.7974716E-01
3	11.9682	1.408408	1.401316	0.212	0.7092206E-02
4	12.0794	1.402881	1.402639	0.214	0.2418812E-03
5	12.0834	1.402685	1.402686	0.214	0.7859577E-06

Factor Of Safety For The Preceding Specified Surface = 1.403
Theta (fx = 1.0) = 12.08 Deg Lambda = 0.214

The Spencer Method Has Been Selected For FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR ANALYSIS METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 10.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = 0.00 ; Maximum theta(deg) = 90.00
Theta convergence Step Factor = 500.00
Maximum number of iterations = 50

Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance(if Applicable) = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

Tension Crack Water Force = 179.71(lbs)

Specified Tension Crack Water Depth Factor = 1.000

Depth of Tension Crack (zo) at Side of Last Slice = 2.400(ft)

Depth of Water in Tension Crack = 2.400(ft)

Theoretical Tension Crack Depth = 1.046(ft)

NOTE: In Table 1 following, when a tension crack with water is present on the first slice (right facing slope) or on the last slice (left facing slope), the "side force" in the tension crack is set equal to the water pressure resultant.

*** Table 1 - Line of Thrust(if applicable) and Slice Force Data ***

Slice No.	X Coord.	Y Coord.	h/H	Side Force (lbs)	fx	Force Angle (Deg)	Vert. Shear Force(lbs)
1	75.42	526.39	0.432	494.59	1.000	12.08	103.5
2	77.23	526.27	0.482	1633.45	1.000	12.08	341.9
3	79.07	526.19	0.490	2654.53	1.000	12.08	555.7
4	80.95	526.09	0.476	3708.41	1.000	12.08	776.3
5	83.09	526.61	0.473	3856.36	1.000	12.08	807.3
6	85.23	527.10	0.466	3970.78	1.000	12.08	831.2
7	87.36	527.58	0.457	4052.61	1.000	12.08	848.4
8	89.50	528.03	0.445	4102.24	1.000	12.08	858.7
9	89.73	528.07	0.443	4105.61	1.000	12.08	859.4
10	91.65	528.47	0.432	4127.22	1.000	12.08	864.0
11	93.58	528.87	0.423	4138.68	1.000	12.08	866.4
12	95.50	529.28	0.415	4147.94	1.000	12.08	868.3
13	97.42	529.68	0.407	4163.15	1.000	12.08	871.5
14	99.35	530.08	0.399	4184.60	1.000	12.08	876.0
15	101.27	530.47	0.391	4212.50	1.000	12.08	881.8
16	103.20	530.85	0.383	4246.97	1.000	12.08	889.0
17	105.12	531.40	0.376	4077.54	1.000	12.08	853.6
18	107.00	531.99	0.369	3840.42	1.000	12.08	803.9
19	108.70	533.22	0.439	2968.05	1.000	12.08	621.3
20	108.85	533.29	0.440	2940.16	1.000	12.08	615.5
21	110.65	534.19	0.460	2552.58	1.000	12.08	534.3
22	112.41	535.21	0.490	2148.56	1.000	12.08	449.8
23	114.12	536.36	0.536	1752.63	1.000	12.08	366.9
24	115.77	537.61	0.602	1391.73	1.000	12.08	291.3

25	116.37	538.11	0.632	1268.30	1.000	12.08	265.5
26	117.35	539.05	0.709	1062.37	1.000	12.08	222.4
27	118.87	541.08	0.958	729.99	1.000	12.08	152.8
28	120.32	544.49	1.000+	428.32	1.000	12.08	89.7
29	121.70	553.68	1.000+	179.40	1.000	12.08	37.6
30	122.20	565.00	1.000+	101.10	1.000	12.08	21.2
31	122.59	540.80	0.800	179.71	1.000	12.08	-23.4

NOTE: A value of 0.000- for h/H indicates that the line of thrust is at or below the lower boundary of the sliding mass. A value of 1.000+ for h/H indicates that the line of thrust is at or above the upper boundary of the sliding mass.

Table 2 - Geometry Data on the 31 Slices

Slice No.	Width (ft)	Height (ft)	X-Cntr (ft)	Y-Cntr-Base (ft)	Y-Cntr-Top (ft)	Alpha (deg)	Beta (deg)	Base Length (ft)
1	0.83	0.37	75.01	526.30	526.67	-28.70	18.43	0.95
2	1.80	1.47	76.32	525.64	527.11	-25.70	18.43	2.00
3	1.85	2.89	78.15	524.82	527.72	-22.70	18.43	2.00
4	1.88	4.24	80.01	524.10	528.34	-19.70	18.43	2.00
5	2.14	5.06	82.02	523.95	529.01	9.85	18.43	2.17
6	2.14	5.40	84.16	524.32	529.72	9.85	18.43	2.17
7	2.14	5.74	86.30	524.69	530.43	9.85	18.43	2.17
8	2.14	6.08	88.43	525.06	531.14	9.85	18.43	2.17
9	0.23	6.27	89.61	525.27	531.54	9.85	18.43	0.23
10	1.92	6.44	90.69	525.45	531.90	9.85	18.43	1.95
11	1.92	6.75	92.61	525.79	532.54	9.85	18.43	1.95
12	1.92	7.06	94.54	526.12	533.18	9.85	18.43	1.95
13	1.92	7.37	96.46	526.46	533.82	9.85	18.43	1.95
14	1.92	7.67	98.39	526.79	534.46	9.85	18.43	1.95
15	1.92	7.98	100.31	527.12	535.10	9.85	18.43	1.95
16	1.92	8.29	102.24	527.46	535.75	9.85	18.43	1.95
17	1.92	8.48	104.16	527.91	536.39	16.49	18.43	2.00
18	1.89	8.49	106.06	528.53	537.02	19.49	18.43	2.00
19	1.70	8.41	107.85	529.21	537.62	22.49	18.43	1.84
20	0.15	8.33	108.77	529.59	537.92	22.49	18.43	0.16
21	1.81	8.20	109.75	530.06	538.25	25.49	18.43	2.00
22	1.76	7.88	111.53	530.96	538.84	28.49	18.43	2.00
23	1.71	7.46	113.26	531.96	539.42	31.49	18.43	2.00
24	1.65	6.93	114.94	533.05	539.98	34.49	18.43	2.00
25	0.60	6.51	116.07	533.85	540.36	37.49	18.43	0.76
26	0.98	6.16	116.86	534.46	540.62	37.49	18.43	1.24
27	1.52	5.55	118.11	535.48	541.04	40.49	18.43	2.00
28	1.45	4.71	119.60	536.82	541.53	43.49	18.43	2.00
29	1.38	3.77	121.01	538.23	542.00	46.49	18.43	2.00
30	0.50	3.06	121.95	539.25	542.32	49.49	18.43	0.77
31	0.39	2.63	122.39	539.77	542.40	49.49	0.00	0.60

Table 2A - Coordinates of Slice Points Defining the Slip Surface

Point No.	X-Pt (ft)	Y-Pt (ft)
1	74.592049	526.530683
2	75.423097	526.075745
3	77.225289	525.208505
4	79.070399	524.436773
5	80.953369	523.762665
6	83.090027	524.133602
7	85.226685	524.504540
8	87.363342	524.875477
9	89.500000	525.246414
10	89.727554	525.285919
11	91.651834	525.619987
12	93.576113	525.954054
13	95.500392	526.288121
14	97.424672	526.622188
15	99.348951	526.956255
16	101.273230	527.290322
17	103.197510	527.624390
18	105.115216	528.192197
19	107.000578	528.859592
20	108.698397	529.562619
21	108.848427	529.624743
22	110.653699	530.485555
23	112.411445	531.439668
24	114.116848	532.484467
25	115.765233	533.617088
26	116.369157	534.080383
27	117.352083	534.834426
28	118.873047	536.133145
29	120.323957	537.509685
30	121.700836	538.960274
31	122.200000	539.544582
32	122.589055	540.000000

Table 3 - Force and Pore Pressure Data On The 31 Slices (Excluding Reinforcement)

Slice No.	Weight (lbs)	Ubeta Force Top (lbs)	Ubeta Stress Top (psf)	Ualpha Force Bot (lbs)	Pore Pressure (psf)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Distributed Load (lbs)
1	40.1	269.5	307.7	317.7	335.4	0.0	0.0	0.00

2	348.7	532.5	280.3	782.2	391.1	0.0	0.0	0.00
3	704.7	471.4	242.4	922.2	461.1	0.0	0.0	0.00
4	1053.3	404.1	203.6	1047.9	524.0	0.0	0.0	0.00
5	1426.9	364.4	161.8	1180.3	544.3	0.0	0.0	0.00
6	1523.1	264.3	117.3	1139.9	525.6	0.0	0.0	0.00
7	1619.4	164.2	72.9	1099.4	507.0	0.0	0.0	0.00
8	1715.6	64.1	28.5	1059.0	488.3	0.0	0.0	0.00
9	188.4	0.7	3.1	110.2	477.3	0.0	0.0	0.00
10	1626.9	0.0	0.0	898.9	460.2	0.0	0.0	0.00
11	1685.5	0.0	0.0	839.2	429.7	0.0	0.0	0.00
12	1744.0	0.0	0.0	779.6	399.2	0.0	0.0	0.00
13	1802.6	0.0	0.0	719.9	368.6	0.0	0.0	0.00
14	1861.1	0.0	0.0	660.3	338.1	0.0	0.0	0.00
15	1919.7	0.0	0.0	600.6	307.5	0.0	0.0	0.00
16	1978.2	0.0	0.0	540.9	277.0	0.0	0.0	0.00
17	2000.0	0.0	0.0	475.2	237.6	0.0	0.0	0.00
18	1951.4	0.0	0.0	371.4	185.7	0.0	0.0	0.00
19	1721.5	0.0	0.0	237.0	129.0	0.0	0.0	0.00
20	150.0	0.0	0.0	16.2	100.0	0.0	0.0	0.00
21	1775.3	0.0	0.0	196.7	98.3	0.0	0.0	0.00
22	1662.5	0.0	0.0	189.2	94.6	0.0	0.0	0.00
23	1526.5	0.0	0.0	179.0	89.5	0.0	0.0	0.00
24	1370.7	0.0	0.0	166.3	83.2	0.0	0.0	0.00
25	471.6	0.0	0.0	59.4	78.1	0.0	0.0	0.00
26	726.9	0.0	0.0	0.0	0.0	0.0	0.0	0.00
27	1013.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
28	820.3	0.0	0.0	0.0	0.0	0.0	0.0	0.00
29	622.8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
30	183.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
31	122.7	0.0	0.0	0.0	0.0	0.0	0.0	0.00

Table 3A - Center of Pressure of Water Loads On the 31 Slices
Only Applicable Slices Listed

Slice No.	X-Ubeta (ft)	Y-Ubeta (ft)	Ubeta-Moment (ft/lbs)
1	75.00	526.67	-30.09
2	76.30	527.10	-235.57
3	78.12	527.71	-419.19
4	79.98	528.33	-528.65
5	81.97	528.99	-564.17
6	84.09	529.70	-432.56
7	86.19	530.40	-279.34
8	88.15	531.05	-104.52
9	89.59	531.53	-1.46

Table 3B - Center of Pressure of Distributed Loads On the 31 Slices
Only Applicable Slices Listed

Slice No.	X-Dload (ft)	Y-Dload (ft)	Dist-Load (lbs)	Dload-Moment (ft/lbs)
27	123.39	542.40	0.197351E+03	0.000000E+00
28	124.62	542.40	0.417527E+03	0.000000E+00
29	123.17	542.40	0.829042E+02	0.000000E+00
30	124.14	542.40	0.402400E+03	0.000000E+00
31	125.71	542.40	0.386317E+03	0.000000E+00

TOTAL WEIGHT OF SLIDING MASS = 37357.51(lbs)

EFFECTIVE WEIGHT OF SLIDING MASS = 23329.96(lbs)

TOTAL AREA OF SLIDING MASS = 298.11(ft2)

TABLE 4 - SOIL STRENGTH & SOIL OPTIONS DATA ON THE 31 SLICES

Slice No.	Soil Type	Cohesion (psf)	Phi(Deg)	Options
1	4	73.00	17.83	R
2	4	73.00	17.83	R
3	4	73.00	17.83	R
4	4	73.00	17.83	R
5	4	73.00	17.83	R
6	4	73.00	17.83	R
7	4	73.00	17.83	R
8	4	73.00	17.83	R
9	4	73.00	17.83	R
10	4	73.00	17.83	R
11	4	73.00	17.83	R
12	4	73.00	17.83	R
13	4	73.00	17.83	R
14	4	73.00	17.83	R
15	4	73.00	17.83	R
16	4	73.00	17.83	R
17	4	73.00	17.83	R
18	4	73.00	17.83	R
19	4	73.00	17.83	R
20	4	73.00	17.83	R
21	4	73.00	17.83	R
22	4	73.00	17.83	R
23	4	73.00	17.83	R
24	4	73.00	17.83	R
25	4	73.00	17.83	R
26	1	40.00	25.00	
27	1	40.00	25.00	
28	1	40.00	25.00	
29	1	40.00	25.00	
30	1	40.00	25.00	

31 1 40.00 25.00

SOIL OPTIONS: A = ANISOTROPIC, C = CURVED STRENGTH ENVELOPE (TANGENT PHI),
F = FIBER-REINFORCED SOIL (FRS), N = NONLINEAR UNDRAINED SHEAR STRENGTH,
R = RAPID DRAWDOWN SHEAR STRENGTH
NOTE: Phi and C in Table 4 are modified values based on specified
Soil Options (if any). Zero values indicate that the normal stress = 0.0

TABLE 5 - Total Base Stress Data on the 31 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Stress (psf)	Total Vert. Stress (psf)	Total Normal/Vert. Stress Ratio
1	-28.70	75.01	0.95	571.69	355.99	1.606
2	-25.70	76.32	2.00	697.06	473.80	1.471
3	-22.70	78.15	2.00	793.80	624.28	1.272
4	-19.70	80.01	2.00	932.27	762.95	1.222
5	9.85	82.02	2.17	817.07	829.59	0.985
6	9.85	84.16	2.17	814.56	830.20	0.981
7	9.85	86.30	2.17	812.06	830.80	0.977
8	9.85	88.43	2.17	809.58	831.41	0.974
9	9.85	89.61	0.23	807.43	830.99	0.972
10	9.85	90.69	1.95	821.18	845.48	0.971
11	9.85	92.61	1.95	850.51	875.91	0.971
12	9.85	94.54	1.95	880.00	906.33	0.971
13	9.85	96.46	1.95	909.65	936.75	0.971
14	9.85	98.39	1.95	939.31	967.18	0.971
15	9.85	100.31	1.95	968.97	997.60	0.971
16	9.85	102.24	1.95	998.64	1028.03	0.971
17	16.49	104.16	2.00	965.35	1042.90	0.926
18	19.49	106.06	2.00	935.05	1035.01	0.903
19	22.49	107.85	1.84	951.32	1013.95	0.938
20	22.49	108.77	0.16	884.42	999.69	0.885
21	25.49	109.75	2.00	846.19	983.42	0.860
22	28.49	111.53	2.00	787.61	945.79	0.833
23	31.49	113.26	2.00	716.63	895.12	0.801
24	34.49	114.94	2.00	633.66	831.55	0.762
25	37.49	116.07	0.76	561.14	780.84	0.719
26	37.49	116.86	1.24	536.88	739.54	0.726
27	40.49	118.11	2.00	464.50	666.45	0.697
28	43.49	119.60	2.00	376.15	565.37	0.665
29	46.49	121.01	2.00	284.70	452.30	0.629
30	49.49	121.95	0.77	217.04	367.73	0.590
31	49.49	122.39	0.60	120.60	315.33	0.382

TABLE 5A - Total Base Force Data on the 31 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Force (lbs)	Total Vert. Force (lbs)	Total Normal/Vert. Force Ratio
1	-28.70	75.01	0.95	541.63	295.85	1.831
2	-25.70	76.32	2.00	1394.13	853.88	1.633
3	-22.70	78.15	2.00	1587.61	1151.87	1.378
4	-19.70	80.01	2.00	1864.53	1436.62	1.298
5	9.85	82.02	2.17	1771.91	1772.55	1.000
6	9.85	84.16	2.17	1766.46	1773.85	0.996
7	9.85	86.30	2.17	1761.05	1775.14	0.992
8	9.85	88.43	2.17	1755.66	1776.44	0.988
9	9.85	89.61	0.23	186.48	189.10	0.986
10	9.85	90.69	1.95	1603.81	1626.95	0.986
11	9.85	92.61	1.95	1661.10	1685.49	0.986
12	9.85	94.54	1.95	1718.69	1744.03	0.985
13	9.85	96.46	1.95	1776.61	1802.58	0.986
14	9.85	98.39	1.95	1834.53	1861.12	0.986
15	9.85	100.31	1.95	1892.46	1919.66	0.986
16	9.85	102.24	1.95	1950.40	1978.21	0.986
17	16.49	104.16	2.00	1930.70	1999.97	0.965
18	19.49	106.06	2.00	1870.10	1951.37	0.958
19	22.49	107.85	1.84	1748.16	1721.50	1.015
20	22.49	108.77	0.16	143.61	149.98	0.958
21	25.49	109.75	2.00	1692.38	1775.35	0.953
22	28.49	111.53	2.00	1575.23	1662.46	0.948
23	31.49	113.26	2.00	1433.26	1526.54	0.939
24	34.49	114.94	2.00	1267.32	1370.71	0.925
25	37.49	116.07	0.76	427.12	471.57	0.906
26	37.49	116.86	1.24	665.11	726.91	0.915
27	40.49	118.11	2.00	929.00	1013.64	0.916
28	43.49	119.60	2.00	752.31	820.30	0.917
29	46.49	121.01	2.00	569.40	622.76	0.914
30	49.49	121.95	0.77	166.80	183.56	0.909
31	49.49	122.39	0.60	72.23	122.68	0.589

TABLE 6 - Effective and Base Shear Stress Data on the 31 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Stress (psf)	Available Shear Strength (psf)	Mobilized Shear Stress (psf)	Rapid Drawdown Strength Type
1	-28.70	75.01	0.95	171.60	128.20	91.39	Drained
2	-25.70	76.32	2.00	242.91	151.13	107.74	Drained
3	-22.70	78.15	2.00	332.70	180.01	128.33	Drained
4	-19.70	80.01	2.00	408.31	204.33	145.67	Drained
5	9.85	82.02	2.17	271.19	160.23	114.23	Drained
6	9.85	84.16	2.17	287.51	165.48	117.97	Drained

7	9.85	86.30	2.17	303.82	170.72	121.71	Drained
8	9.85	88.43	2.17	320.14	175.97	125.45	Drained
9	9.85	89.61	0.23	329.14	178.87	127.52	Drained
10	9.85	90.69	1.95	360.19	188.85	134.64	Drained
11	9.85	92.61	1.95	420.61	208.29	148.49	Drained
12	9.85	94.54	1.95	481.03	227.72	162.35	Drained
13	9.85	96.46	1.95	541.46	247.15	176.20	Drained
14	9.85	98.39	1.95	601.88	266.59	190.06	Drained
15	9.85	100.31	1.95	662.30	286.02	203.91	Drained
16	9.85	102.24	1.95	722.72	305.46	217.77	Drained
17	16.49	104.16	2.00	726.28	306.60	218.58	Drained
18	19.49	106.06	2.00	747.37	313.39	223.42	Drained
19	22.49	107.85	1.84	760.82	317.71	226.50	Drained
20	22.49	108.77	0.16	776.07	322.62	230.00	Drained
21	25.49	109.75	2.00	741.07	311.36	221.97	Drained
22	28.49	111.53	2.00	690.77	295.18	210.44	Drained
23	31.49	113.26	2.00	632.39	276.40	197.05	Drained
24	34.49	114.94	2.00	566.71	255.28	181.99	Drained
25	37.49	116.07	0.76	512.10	237.71	169.47	Drained
26	37.49	116.86	1.24	536.88	309.56	220.69	Drained
27	40.49	118.11	2.00	464.50	325.53	232.07	Drained
28	43.49	119.60	2.00	376.15	312.20	222.57	Drained
29	46.49	121.01	2.00	284.70	311.84	222.32	Drained
30	49.49	121.95	0.77	217.04	311.04	221.74	Drained
31	49.49	122.39	0.60	120.60	294.35	209.85	Drained

TABLE 6A - Effective and Base Shear Force Data on the 31 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Force (lbs)	Available Shear Force (lbs)	Mobilized Shear Force (lbs)
1	-28.70	75.01	0.95	223.91	221.18	157.69
2	-25.70	76.32	2.00	611.88	530.38	378.12
3	-22.70	78.15	2.00	665.41	360.02	256.67
4	-19.70	80.01	2.00	816.62	408.66	291.34
5	9.85	82.02	2.17	591.62	473.41	337.50
6	9.85	84.16	2.17	626.60	470.45	335.39
7	9.85	86.30	2.17	661.62	468.85	334.25
8	9.85	88.43	2.17	696.66	467.75	333.47
9	9.85	89.61	0.23	76.25	49.78	35.49
10	9.85	90.69	1.95	704.92	420.63	299.88
11	9.85	92.61	1.95	821.87	420.45	299.75
12	9.85	94.54	1.95	939.12	431.41	307.56
13	9.85	96.46	1.95	1056.69	453.81	323.53
14	9.85	98.39	1.95	1174.27	476.60	339.78
15	9.85	100.31	1.95	1291.86	499.68	356.23
16	9.85	102.24	1.95	1409.46	522.94	372.82
17	16.49	104.16	2.00	1455.51	559.48	398.86

18	19.49	106.06	2.00	1498.74	583.56	416.03
19	22.49	107.85	1.84	1511.20	-279.71	-199.41
20	22.49	108.77	0.16	127.38	42.00	29.94
21	25.49	109.75	2.00	1495.69	542.99	387.11
22	28.49	111.53	2.00	1386.07	568.83	405.53
23	31.49	113.26	2.00	1254.23	594.79	424.03
24	34.49	114.94	2.00	1101.01	620.83	442.60
25	37.49	116.07	0.76	367.68	246.22	175.53
26	37.49	116.86	1.24	665.11	359.70	256.44
27	40.49	118.11	2.00	929.00	513.20	365.87
28	43.49	119.60	2.00	752.31	430.81	307.13
29	46.49	121.01	2.00	569.40	345.51	246.32
30	49.49	121.95	0.77	166.80	108.52	77.36
31	49.49	122.39	0.60	72.23	57.64	41.09

SUM OF MOMENTS = -0.154868E-02 (ft/lbs);Imbalance (Fraction of Total Weight) = -0.4145575E-07
SUM OF FORCES = -.159344E-05 (lbs);Imbalance (Fraction of Total Weight) = -0.4265391E-10

Sum of Available Shear Forces = 18752.00(lbs)

Sum of Mobilized Shear Forces = 13368.64(lbs)

FS Balance Check: FS = 1.402685

**** END OF GEOSTASE OUTPUT FOR RAPID DRAWDOWN STAGE 1 ****

Iter. No.	Theta (deg) (fx=1.0)	FS (Moment)	FS (Force)	Lambda	Delta FS
1	10.0000	1.497340	1.314435	0.176	0.1829051E+00
2	13.3000	1.396819	1.332459	0.236	0.6435976E-01
3	15.0880	1.321666	1.342790	0.270	0.2112379E-01
4	14.6471	1.341880	1.340201	0.261	0.1678608E-02
5	14.6804	1.340395	1.340396	0.262	0.1610803E-06

Factor Of Safety For The Preceding Specified Surface = 1.340
Theta (fx = 1.0) = 14.68 Deg Lambda = 0.262

The Spencer Method Has Been Selected For FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR ANALYSIS METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 10.00

Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = 0.00 ; Maximum theta(deg) = 90.00
Theta convergence Step Factor = 500.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance(if Applicable) = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

Tension Crack Water Force = 179.71(lbs)

Specified Tension Crack Water Depth Factor = 1.000

Depth of Tension Crack (zo) at Side of Last Slice = 2.400(ft)

Depth of Water in Tension Crack = 2.400(ft)

Theoretical Tension Crack Depth = 1.046(ft)

NOTE: In Table 1 following, when a tension crack with water is present on the first slice (right facing slope) or on the last slice (left facing slope), the "side force" in the tension crack is set equal to the water pressure resultant.

*** Table 1 - Line of Thrust(if applicable) and Slice Force Data ***

Slice No.	X Coord.	Y Coord.	h/H	Side Force (lbs)	fx	Force Angle (Deg)	Vert. Shear Force(lbs)
1	75.42	526.41	0.459	134.88	1.000	14.68	34.2
2	77.23	526.09	0.401	640.38	1.000	14.68	162.3
3	79.07	525.78	0.375	1346.06	1.000	14.68	341.1
4	80.95	525.55	0.366	2154.91	1.000	14.68	546.1
5	83.09	526.03	0.363	2246.72	1.000	14.68	569.4
6	85.23	526.52	0.362	2330.49	1.000	14.68	590.6
7	87.36	527.02	0.362	2406.31	1.000	14.68	609.8
8	89.50	527.51	0.363	2474.26	1.000	14.68	627.0
9	89.73	527.57	0.363	2481.03	1.000	14.68	628.8
10	91.65	528.01	0.363	2543.97	1.000	14.68	644.7
11	93.58	528.45	0.361	2619.37	1.000	14.68	663.8
12	95.50	528.87	0.357	2707.54	1.000	14.68	686.2
13	97.42	529.27	0.353	2808.70	1.000	14.68	711.8
14	99.35	529.67	0.347	2922.99	1.000	14.68	740.8
15	101.27	530.06	0.340	3050.49	1.000	14.68	773.1
16	103.20	530.44	0.333	3191.29	1.000	14.68	808.8
17	105.12	531.00	0.330	3117.83	1.000	14.68	790.1
18	107.00	531.64	0.328	2965.58	1.000	14.68	751.6
19	108.70	532.29	0.327	2750.71	1.000	14.68	697.1
20	108.85	532.35	0.327	2731.96	1.000	14.68	692.4

21	110.65	533.14	0.330	2422.54	1.000	14.68	613.9
22	112.41	534.04	0.337	2054.05	1.000	14.68	520.5
23	114.12	535.05	0.356	1645.79	1.000	14.68	417.1
24	115.77	536.26	0.399	1219.09	1.000	14.68	309.0
25	116.37	536.82	0.429	1051.52	1.000	14.68	266.5
26	117.35	537.64	0.471	857.67	1.000	14.68	217.4
27	118.87	539.40	0.633	543.55	1.000	14.68	137.7
28	120.32	542.83	1.000+	258.19	1.000	14.68	65.4
29	121.70	591.76	1.000+	23.13	1.000	14.68	5.9
30	122.20	515.27	0.000-	-50.57	1.000	14.68	-12.8
31	122.59	540.80	0.800	179.71	1.000	14.68	-65.5

NOTE: A value of 0.000- for h/H indicates that the line of thrust is at or below the lower boundary of the sliding mass. A value of 1.000+ for h/H indicates that the line of thrust is at or above the upper boundary of the sliding mass.

Table 2 - Geometry Data on the 31 Slices

Slice No.	Width (ft)	Height (ft)	X-Cntr (ft)	Y-Cntr-Base (ft)	Y-Cntr-Top (ft)	Alpha (deg)	Beta (deg)	Base Length (ft)
1	0.83	0.37	75.01	526.30	526.67	-28.70	18.43	0.95
2	1.80	1.47	76.32	525.64	527.11	-25.70	18.43	2.00
3	1.85	2.89	78.15	524.82	527.72	-22.70	18.43	2.00
4	1.88	4.24	80.01	524.10	528.34	-19.70	18.43	2.00
5	2.14	5.06	82.02	523.95	529.01	9.85	18.43	2.17
6	2.14	5.40	84.16	524.32	529.72	9.85	18.43	2.17
7	2.14	5.74	86.30	524.69	530.43	9.85	18.43	2.17
8	2.14	6.08	88.43	525.06	531.14	9.85	18.43	2.17
9	0.23	6.27	89.61	525.27	531.54	9.85	18.43	0.23
10	1.92	6.44	90.69	525.45	531.90	9.85	18.43	1.95
11	1.92	6.75	92.61	525.79	532.54	9.85	18.43	1.95
12	1.92	7.06	94.54	526.12	533.18	9.85	18.43	1.95
13	1.92	7.37	96.46	526.46	533.82	9.85	18.43	1.95
14	1.92	7.67	98.39	526.79	534.46	9.85	18.43	1.95
15	1.92	7.98	100.31	527.12	535.10	9.85	18.43	1.95
16	1.92	8.29	102.24	527.46	535.75	9.85	18.43	1.95
17	1.92	8.48	104.16	527.91	536.39	16.49	18.43	2.00
18	1.89	8.49	106.06	528.53	537.02	19.49	18.43	2.00
19	1.70	8.41	107.85	529.21	537.62	22.49	18.43	1.84
20	0.15	8.33	108.77	529.59	537.92	22.49	18.43	0.16
21	1.81	8.20	109.75	530.06	538.25	25.49	18.43	2.00
22	1.76	7.88	111.53	530.96	538.84	28.49	18.43	2.00
23	1.71	7.46	113.26	531.96	539.42	31.49	18.43	2.00
24	1.65	6.93	114.94	533.05	539.98	34.49	18.43	2.00
25	0.60	6.51	116.07	533.85	540.36	37.49	18.43	0.76
26	0.98	6.16	116.86	534.46	540.62	37.49	18.43	1.24
27	1.52	5.55	118.11	535.48	541.04	40.49	18.43	2.00

28	1.45	4.71	119.60	536.82	541.53	43.49	18.43	2.00
29	1.38	3.77	121.01	538.23	542.00	46.49	18.43	2.00
30	0.50	3.06	121.95	539.25	542.32	49.49	18.43	0.77
31	0.39	2.63	122.39	539.77	542.40	49.49	0.00	0.60

Table 2A - Coordinates of Slice Points Defining the Slip Surface

Point No.	X-Pt (ft)	Y-Pt (ft)
1	74.592049	526.530683
2	75.423097	526.075745
3	77.225289	525.208505
4	79.070399	524.436773
5	80.953369	523.762665
6	83.090027	524.133602
7	85.226685	524.504540
8	87.363342	524.875477
9	89.500000	525.246414
10	89.727554	525.285919
11	91.651834	525.619987
12	93.576113	525.954054
13	95.500392	526.288121
14	97.424672	526.622188
15	99.348951	526.956255
16	101.273230	527.290322
17	103.197510	527.624390
18	105.115216	528.192197
19	107.000578	528.859592
20	108.698397	529.562619
21	108.848427	529.624743
22	110.653699	530.485555
23	112.411445	531.439668
24	114.116848	532.484467
25	115.765233	533.617088
26	116.369157	534.080383
27	117.352083	534.834426
28	118.873047	536.133145
29	120.323957	537.509685
30	121.700836	538.960274
31	122.200000	539.544582
32	122.589055	540.000000

Table 3 - Force and Pore Pressure Data On The 31 Slices (Excluding Reinforcement)

Ubeta Ubeta Ualpha Earthquake

Slice No.	Weight (lbs)	Force Top (lbs)	Stress Top (psf)	Force Bot (lbs)	Pore Pressure (psf)	Force Hor (lbs)	Force Ver (lbs)	Distributed Load (lbs)
1	36.5	0.0	0.0	4.2	4.4	0.0	0.0	0.00
2	317.0	0.0	0.0	35.2	17.6	0.0	0.0	0.00
3	640.6	0.0	0.0	69.4	34.7	0.0	0.0	0.00
4	957.5	0.0	0.0	101.7	50.9	0.0	0.0	0.00
5	1297.1	0.0	0.0	131.7	60.7	0.0	0.0	0.00
6	1384.7	0.0	0.0	140.5	64.8	0.0	0.0	0.00
7	1472.2	0.0	0.0	149.4	68.9	0.0	0.0	0.00
8	1559.7	0.0	0.0	158.3	73.0	0.0	0.0	0.00
9	171.3	0.0	0.0	17.4	75.3	0.0	0.0	0.00
10	1487.9	0.0	0.0	151.0	77.3	0.0	0.0	0.00
11	1558.9	0.0	0.0	158.2	81.0	0.0	0.0	0.00
12	1629.9	0.0	0.0	165.4	84.7	0.0	0.0	0.00
13	1700.8	0.0	0.0	172.6	88.4	0.0	0.0	0.00
14	1771.8	0.0	0.0	179.8	92.1	0.0	0.0	0.00
15	1842.8	0.0	0.0	187.0	95.8	0.0	0.0	0.00
16	1913.8	0.0	0.0	194.2	99.5	0.0	0.0	0.00
17	1950.8	0.0	0.0	203.5	101.7	0.0	0.0	0.00
18	1921.6	0.0	0.0	203.8	101.9	0.0	0.0	0.00
19	1712.5	0.0	0.0	185.4	100.9	0.0	0.0	0.00
20	150.0	0.0	0.0	16.2	100.0	0.0	0.0	0.00
21	1775.3	0.0	0.0	196.7	98.3	0.0	0.0	0.00
22	1662.5	0.0	0.0	189.2	94.6	0.0	0.0	0.00
23	1526.5	0.0	0.0	179.0	89.5	0.0	0.0	0.00
24	1370.7	0.0	0.0	166.3	83.2	0.0	0.0	0.00
25	471.6	0.0	0.0	59.4	78.1	0.0	0.0	0.00
26	726.9	0.0	0.0	0.0	0.0	0.0	0.0	0.00
27	1013.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
28	820.3	0.0	0.0	0.0	0.0	0.0	0.0	0.00
29	622.8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
30	183.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
31	122.7	0.0	0.0	0.0	0.0	0.0	0.0	0.00

Table 3A - Center of Pressure of Water Loads On the 31 Slices
Only Applicable Slices Listed

Slice No.	X-Ubeta (ft)	Y-Ubeta (ft)	Ubeta-Moment (ft/lbs)

Table 3B - Center of Pressure of Distributed Loads On the 31 Slices
Only Applicable Slices Listed

Slice No.	X-Dload (ft)	Y-Dload (ft)	Dist-Load (lbs)	Dload-Moment (ft/lbs)
27	123.39	542.40	0.197351E+03	0.000000E+00
28	124.62	542.40	0.417527E+03	0.000000E+00

29	123.17	542.40	0.829042E+02	0.000000E+00
30	124.14	542.40	0.402400E+03	0.000000E+00
31	125.71	542.40	0.386317E+03	0.000000E+00

TOTAL WEIGHT OF SLIDING MASS = 35773.72(lbs)

EFFECTIVE WEIGHT OF SLIDING MASS = 32545.34(lbs)

TOTAL AREA OF SLIDING MASS = 298.11(ft2)

TABLE 4 - SOIL STRENGTH & SOIL OPTIONS DATA ON THE 31 SLICES

Slice No.	Soil Type	Cohesion (psf)	Phi(Deg)	Options
1	4	126.64	0.00	R
2	4	170.13	0.00	R
3	4	210.16	0.00	R
4	4	231.11	0.00	R
5	4	193.68	0.00	R
6	4	197.98	0.00	R
7	4	202.34	0.00	R
8	4	206.74	0.00	R
9	4	209.19	0.00	R
10	4	217.71	0.00	R
11	4	234.56	0.00	R
12	4	251.63	0.00	R
13	4	268.84	0.00	R
14	4	286.15	0.00	R
15	4	303.52	0.00	R
16	4	320.95	0.00	R
17	4	321.97	0.00	R
18	4	328.07	0.00	R
19	4	322.30	0.00	R
20	4	319.85	0.00	R
21	4	307.60	0.00	R
22	4	290.52	0.00	R
23	4	270.92	0.00	R
24	4	249.05	0.00	R
25	4	230.72	0.00	R
26	1	40.00	25.00	
27	1	40.00	25.00	
28	1	40.00	25.00	
29	1	40.00	25.00	
30	1	40.00	25.00	
31	1	40.00	25.00	

SOIL OPTIONS: A = ANISOTROPIC, C = CURVED STRENGTH ENVELOPE (TANGENT PHI),
F = FIBER-REINFORCED SOIL (FRS), N = NONLINEAR UNDRAINED SHEAR STRENGTH,
R = RAPID DRAWDOWN SHEAR STRENGTH

NOTE: Phi and C in Table 4 are modified values based on specified
Soil Options (if any). Zero values indicate that the normal stress = 0.0

TABLE 5 - Total Base Stress Data on the 31 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Stress (psf)	Total Vert. Stress (psf)	Total Normal/Vert. Stress Ratio
1	-28.70	75.01	0.95	131.57	43.92	2.996
2	-25.70	76.32	2.00	306.57	175.91	1.743
3	-22.70	78.15	2.00	509.70	347.20	1.468
4	-19.70	80.01	2.00	679.10	508.51	1.335
5	9.85	82.02	2.17	592.90	607.09	0.977
6	9.85	84.16	2.17	632.34	648.05	0.976
7	9.85	86.30	2.17	671.79	689.00	0.975
8	9.85	88.43	2.17	711.24	729.95	0.974
9	9.85	89.61	0.23	733.06	752.61	0.974
10	9.85	90.69	1.95	753.33	773.23	0.974
11	9.85	92.61	1.95	789.67	810.12	0.975
12	9.85	94.54	1.95	826.02	847.00	0.975
13	9.85	96.46	1.95	862.39	883.88	0.976
14	9.85	98.39	1.95	898.76	920.77	0.976
15	9.85	100.31	1.95	935.13	957.65	0.976
16	9.85	102.24	1.95	971.51	994.53	0.977
17	16.49	104.16	2.00	936.43	1017.26	0.921
18	19.49	106.06	2.00	912.10	1019.21	0.895
19	22.49	107.85	1.84	876.91	1008.65	0.869
20	22.49	108.77	0.16	869.07	999.69	0.869
21	25.49	109.75	2.00	830.27	983.42	0.844
22	28.49	111.53	2.00	774.53	945.79	0.819
23	31.49	113.26	2.00	709.88	895.12	0.793
24	34.49	114.94	2.00	637.18	831.55	0.766
25	37.49	116.07	0.76	576.91	780.84	0.739
26	37.49	116.86	1.24	526.22	739.54	0.712
27	40.49	118.11	2.00	453.82	666.45	0.681
28	43.49	119.60	2.00	366.31	565.37	0.648
29	46.49	121.01	2.00	276.32	452.30	0.611
30	49.49	121.95	0.77	209.90	367.73	0.571
31	49.49	122.39	0.60	103.03	315.33	0.327

TABLE 5A - Total Base Force Data on the 31 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Force (lbs)	Total Vert. Force (lbs)	Total Normal/Vert. Force Ratio

1	-28.70	75.01	0.95	124.65	36.50	3.415
2	-25.70	76.32	2.00	613.15	317.03	1.934
3	-22.70	78.15	2.00	1019.40	640.62	1.591
4	-19.70	80.01	2.00	1358.19	957.51	1.418
5	9.85	82.02	2.17	1285.76	1297.15	0.991
6	9.85	84.16	2.17	1371.30	1384.65	0.990
7	9.85	86.30	2.17	1456.85	1472.16	0.990
8	9.85	88.43	2.17	1542.40	1559.66	0.989
9	9.85	89.61	0.23	169.31	171.26	0.989
10	9.85	90.69	1.95	1471.29	1487.92	0.989
11	9.85	92.61	1.95	1542.27	1558.89	0.989
12	9.85	94.54	1.95	1613.27	1629.86	0.990
13	9.85	96.46	1.95	1684.29	1700.84	0.990
14	9.85	98.39	1.95	1755.32	1771.81	0.991
15	9.85	100.31	1.95	1826.37	1842.78	0.991
16	9.85	102.24	1.95	1897.41	1913.76	0.991
17	16.49	104.16	2.00	1872.86	1950.80	0.960
18	19.49	106.06	2.00	1824.21	1921.58	0.949
19	22.49	107.85	1.84	1611.43	1712.50	0.941
20	22.49	108.77	0.16	141.12	149.98	0.941
21	25.49	109.75	2.00	1660.54	1775.35	0.935
22	28.49	111.53	2.00	1549.07	1662.46	0.932
23	31.49	113.26	2.00	1419.77	1526.54	0.930
24	34.49	114.94	2.00	1274.36	1370.71	0.930
25	37.49	116.07	0.76	439.13	471.57	0.931
26	37.49	116.86	1.24	651.91	726.91	0.897
27	40.49	118.11	2.00	907.64	1013.64	0.895
28	43.49	119.60	2.00	732.62	820.30	0.893
29	46.49	121.01	2.00	552.64	622.76	0.887
30	49.49	121.95	0.77	161.30	183.56	0.879
31	49.49	122.39	0.60	61.71	122.68	0.503

TABLE 6 - Effective and Base Shear Stress Data on the 31 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Stress (psf)	Available Shear Strength (psf)	Mobilized Shear Stress (psf)	Rapid Drawdown Strength Type
1	-28.70	75.01	0.95	171.60	170.09	126.89	Undrained
2	-25.70	76.32	2.00	242.91	186.42	139.08	Undrained
3	-22.70	78.15	2.00	332.70	210.16	156.79	Undrained
4	-19.70	80.01	2.00	408.31	231.11	172.42	Undrained
5	9.85	82.02	2.17	271.19	193.68	144.50	Undrained
6	9.85	84.16	2.17	287.51	197.98	147.70	Undrained
7	9.85	86.30	2.17	303.82	202.34	150.95	Undrained
8	9.85	88.43	2.17	320.14	206.74	154.24	Undrained
9	9.85	89.61	0.23	329.14	209.19	156.06	Undrained
10	9.85	90.69	1.95	360.19	217.71	162.43	Undrained
11	9.85	92.61	1.95	420.61	234.56	174.99	Undrained

12	9.85	94.54	1.95	481.03	251.63	187.73	Undrained
13	9.85	96.46	1.95	541.46	268.84	200.57	Undrained
14	9.85	98.39	1.95	601.88	286.15	213.48	Undrained
15	9.85	100.31	1.95	662.30	303.52	226.44	Undrained
16	9.85	102.24	1.95	722.72	320.95	239.44	Undrained
17	16.49	104.16	2.00	726.28	321.97	240.21	Undrained
18	19.49	106.06	2.00	747.37	328.07	244.75	Undrained
19	22.49	107.85	1.84	760.82	331.96	247.65	Undrained
20	22.49	108.77	0.16	776.07	336.36	250.94	Undrained
21	25.49	109.75	2.00	741.07	326.25	243.40	Undrained
22	28.49	111.53	2.00	690.77	311.73	232.57	Undrained
23	31.49	113.26	2.00	632.39	294.92	220.02	Undrained
24	34.49	114.94	2.00	566.71	276.07	205.96	Undrained
25	37.49	116.07	0.76	512.10	260.47	194.32	Undrained
26	37.49	116.86	1.24	536.88	336.56	251.09	Undrained
27	40.49	118.11	2.00	464.50	349.67	260.87	Undrained
28	43.49	119.60	2.00	376.15	338.73	252.71	Undrained
29	46.49	121.01	2.00	284.70	338.44	252.49	Undrained
30	49.49	121.95	0.77	217.04	337.77	252.00	Undrained
31	49.49	122.39	0.60	120.60	324.09	241.79	Undrained

TABLE 6A - Effective and Base Shear Force Data on the 31 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Force (lbs)	Available Shear Force (lbs)	Mobilized Shear Force (lbs)
1	-28.70	75.01	0.95	120.49	107.92	80.51
2	-25.70	76.32	2.00	577.96	331.90	247.61
3	-22.70	78.15	2.00	949.96	420.32	313.58
4	-19.70	80.01	2.00	1256.49	462.22	344.84
5	9.85	82.02	2.17	1154.11	420.02	313.36
6	9.85	84.16	2.17	1230.76	429.34	320.31
7	9.85	86.30	2.17	1307.43	438.79	327.36
8	9.85	88.43	2.17	1384.10	448.34	334.48
9	9.85	89.61	0.23	151.92	48.31	36.04
10	9.85	90.69	1.95	1320.27	425.21	317.23
11	9.85	92.61	1.95	1384.05	458.11	341.77
12	9.85	94.54	1.95	1447.85	491.45	366.65
13	9.85	96.46	1.95	1511.66	525.06	391.72
14	9.85	98.39	1.95	1575.49	558.87	416.94
15	9.85	100.31	1.95	1639.33	592.80	442.26
16	9.85	102.24	1.95	1703.17	626.83	467.64
17	16.49	104.16	2.00	1669.41	643.95	480.42
18	19.49	106.06	2.00	1620.37	656.13	489.51
19	22.49	107.85	1.84	1426.08	592.83	442.28
20	22.49	108.77	0.16	124.89	52.02	38.81
21	25.49	109.75	2.00	1463.86	616.84	460.19
22	28.49	111.53	2.00	1359.91	583.41	435.25

23	31.49	113.26	2.00	1240.74	545.08	406.65
24	34.49	114.94	2.00	1108.05	502.40	374.81
25	37.49	116.07	0.76	379.69	177.69	132.56
26	37.49	116.86	1.24	651.91	353.54	263.76
27	40.49	118.11	2.00	907.64	503.24	375.44
28	43.49	119.60	2.00	732.62	421.63	314.55
29	46.49	121.01	2.00	552.64	337.70	251.94
30	49.49	121.95	0.77	161.30	105.96	79.05
31	49.49	122.39	0.60	61.71	52.74	39.34

SUM OF MOMENTS = -0.281899E-02 (ft/lbs);Imbalance (Fraction of Total Weight) = -0.7880055E-07
SUM OF FORCES = 0.571555E-03 (lbs);Imbalance (Fraction of Total Weight) = 0.1597696E-07

Sum of Available Shear Forces = 19783.68(lbs)

Sum of Mobilized Shear Forces = 14759.59(lbs)

FS Balance Check: FS = 1.340395

**** END OF GEOSTASE OUTPUT FOR RAPID DRAWDOWN STAGE 2 ****

Iter. No.	Theta (deg) (fx=1.0)	FS (Moment)	FS (Force)	Lambda	Delta FS
1	10.0000	1.469474	1.282889	0.176	0.1865849E+00
2	13.3000	1.370219	1.299084	0.236	0.7113466E-01
3	15.3292	1.284254	1.309924	0.274	0.2566961E-01
4	14.7922	1.309363	1.306982	0.264	0.2380847E-02
5	14.8388	1.307259	1.307235	0.265	0.2406697E-04
6	14.8393	1.307238	1.307238	0.265	0.1408303E-07

Factor Of Safety For The Preceding Specified Surface = 1.307
Theta (fx = 1.0) = 14.84 Deg   Lambda = 0.265

The Spencer Method Has Been Selected For FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR ANALYSIS METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 10.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = 0.00 ; Maximum theta(deg) = 90.00
Theta convergence Step Factor = 500.00
Maximum number of iterations = 50

Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance(if Applicable) = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

Tension Crack Water Force = 179.71(lbs)

Specified Tension Crack Water Depth Factor = 1.000

Depth of Tension Crack (zo) at Side of Last Slice = 2.400(ft)

Depth of Water in Tension Crack = 2.400(ft)

Theoretical Tension Crack Depth = 1.046(ft)

NOTE: In Table 1 following, when a tension crack with water is present on the first slice (right facing slope) or on the last slice (left facing slope), the "side force" in the tension crack is set equal to the water pressure resultant.

*** Table 1 - Line of Thrust(if applicable) and Slice Force Data ***

Slice No.	X Coord.	Y Coord.	h/H	Side Force (lbs)	fx	Force Angle (Deg)	Vert. Shear Force(lbs)
1	75.42	526.41	0.461	139.14	1.000	14.84	35.6
2	77.23	526.09	0.403	657.06	1.000	14.84	168.3
3	79.07	525.79	0.378	1374.27	1.000	14.84	352.0
4	80.95	525.56	0.369	2195.28	1.000	14.84	562.2
5	83.09	526.05	0.366	2295.09	1.000	14.84	587.8
6	85.23	526.54	0.365	2387.03	1.000	14.84	611.3
7	87.36	527.03	0.364	2471.20	1.000	14.84	632.9
8	89.50	527.53	0.365	2547.69	1.000	14.84	652.5
9	89.73	527.58	0.365	2555.38	1.000	14.84	654.5
10	91.65	528.03	0.365	2626.42	1.000	14.84	672.6
11	93.58	528.46	0.363	2710.53	1.000	14.84	694.2
12	95.50	528.88	0.359	2808.06	1.000	14.84	719.2
13	97.42	529.29	0.354	2919.22	1.000	14.84	747.6
14	99.35	529.68	0.349	3044.15	1.000	14.84	779.6
15	101.27	530.07	0.342	3182.94	1.000	14.84	815.2
16	103.20	530.45	0.335	3335.68	1.000	14.84	854.3
17	105.12	531.01	0.331	3274.42	1.000	14.84	838.6
18	107.00	531.63	0.327	3134.66	1.000	14.84	802.8
19	108.70	532.27	0.324	2930.68	1.000	14.84	750.6
20	108.85	532.32	0.324	2912.89	1.000	14.84	746.0
21	110.65	533.09	0.322	2614.78	1.000	14.84	669.7
22	112.41	533.92	0.323	2257.00	1.000	14.84	578.0
23	114.12	534.85	0.327	1858.83	1.000	14.84	476.1
24	115.77	535.87	0.339	1441.54	1.000	14.84	369.2

25	116.37	536.29	0.347	1277.34	1.000	14.84	327.1
26	117.35	536.89	0.346	1089.83	1.000	14.84	279.1
27	118.87	537.92	0.347	784.82	1.000	14.84	201.0
28	120.32	539.02	0.353	507.19	1.000	14.84	129.9
29	121.70	540.17	0.370	278.43	1.000	14.84	71.3
30	122.20	540.64	0.385	206.74	1.000	14.84	52.9
31	122.59	540.80	0.800	179.71	1.000	14.84	0.0

NOTE: A value of 0.000- for h/H indicates that the line of thrust is at or below the lower boundary of the sliding mass. A value of 1.000+ for h/H indicates that the line of thrust is at or above the upper boundary of the sliding mass.

Table 2 - Geometry Data on the 31 Slices

Slice No.	Width (ft)	Height (ft)	X-Cntr (ft)	Y-Cntr-Base (ft)	Y-Cntr-Top (ft)	Alpha (deg)	Beta (deg)	Base Length (ft)
1	0.83	0.37	75.01	526.30	526.67	-28.70	18.43	0.95
2	1.80	1.47	76.32	525.64	527.11	-25.70	18.43	2.00
3	1.85	2.89	78.15	524.82	527.72	-22.70	18.43	2.00
4	1.88	4.24	80.01	524.10	528.34	-19.70	18.43	2.00
5	2.14	5.06	82.02	523.95	529.01	9.85	18.43	2.17
6	2.14	5.40	84.16	524.32	529.72	9.85	18.43	2.17
7	2.14	5.74	86.30	524.69	530.43	9.85	18.43	2.17
8	2.14	6.08	88.43	525.06	531.14	9.85	18.43	2.17
9	0.23	6.27	89.61	525.27	531.54	9.85	18.43	0.23
10	1.92	6.44	90.69	525.45	531.90	9.85	18.43	1.95
11	1.92	6.75	92.61	525.79	532.54	9.85	18.43	1.95
12	1.92	7.06	94.54	526.12	533.18	9.85	18.43	1.95
13	1.92	7.37	96.46	526.46	533.82	9.85	18.43	1.95
14	1.92	7.67	98.39	526.79	534.46	9.85	18.43	1.95
15	1.92	7.98	100.31	527.12	535.10	9.85	18.43	1.95
16	1.92	8.29	102.24	527.46	535.75	9.85	18.43	1.95
17	1.92	8.48	104.16	527.91	536.39	16.49	18.43	2.00
18	1.89	8.49	106.06	528.53	537.02	19.49	18.43	2.00
19	1.70	8.41	107.85	529.21	537.62	22.49	18.43	1.84
20	0.15	8.33	108.77	529.59	537.92	22.49	18.43	0.16
21	1.81	8.20	109.75	530.06	538.25	25.49	18.43	2.00
22	1.76	7.88	111.53	530.96	538.84	28.49	18.43	2.00
23	1.71	7.46	113.26	531.96	539.42	31.49	18.43	2.00
24	1.65	6.93	114.94	533.05	539.98	34.49	18.43	2.00
25	0.60	6.51	116.07	533.85	540.36	37.49	18.43	0.76
26	0.98	6.16	116.86	534.46	540.62	37.49	18.43	1.24
27	1.52	5.55	118.11	535.48	541.04	40.49	18.43	2.00
28	1.45	4.71	119.60	536.82	541.53	43.49	18.43	2.00
29	1.38	3.77	121.01	538.23	542.00	46.49	18.43	2.00
30	0.50	3.06	121.95	539.25	542.32	49.49	18.43	0.77
31	0.39	2.63	122.39	539.77	542.40	49.49	0.00	0.60

Table 2A - Coordinates of Slice Points Defining the Slip Surface

Point No.	X-Pt (ft)	Y-Pt (ft)
1	74.592049	526.530683
2	75.423097	526.075745
3	77.225289	525.208505
4	79.070399	524.436773
5	80.953369	523.762665
6	83.090027	524.133602
7	85.226685	524.504540
8	87.363342	524.875477
9	89.500000	525.246414
10	89.727554	525.285919
11	91.651834	525.619987
12	93.576113	525.954054
13	95.500392	526.288121
14	97.424672	526.622188
15	99.348951	526.956255
16	101.273230	527.290322
17	103.197510	527.624390
18	105.115216	528.192197
19	107.000578	528.859592
20	108.698397	529.562619
21	108.848427	529.624743
22	110.653699	530.485555
23	112.411445	531.439668
24	114.116848	532.484467
25	115.765233	533.617088
26	116.369157	534.080383
27	117.352083	534.834426
28	118.873047	536.133145
29	120.323957	537.509685
30	121.700836	538.960274
31	122.200000	539.544582
32	122.589055	540.000000

Table 3 - Force and Pore Pressure Data On The 31 Slices (Excluding Reinforcement)

Slice No.	Weight (lbs)	Ubeta Force Top (lbs)	Ubeta Stress Top (psf)	Ualpha Force Bot (lbs)	Pore Pressure (psf)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Distributed Load (lbs)
1	36.5	0.0	0.0	4.2	4.4	0.0	0.0	0.00

2	317.0	0.0	0.0	35.2	17.6	0.0	0.0	0.00
3	640.6	0.0	0.0	69.4	34.7	0.0	0.0	0.00
4	957.5	0.0	0.0	101.7	50.9	0.0	0.0	0.00
5	1297.1	0.0	0.0	131.7	60.7	0.0	0.0	0.00
6	1384.7	0.0	0.0	140.5	64.8	0.0	0.0	0.00
7	1472.2	0.0	0.0	149.4	68.9	0.0	0.0	0.00
8	1559.7	0.0	0.0	158.3	73.0	0.0	0.0	0.00
9	171.3	0.0	0.0	17.4	75.3	0.0	0.0	0.00
10	1487.9	0.0	0.0	151.0	77.3	0.0	0.0	0.00
11	1558.9	0.0	0.0	158.2	81.0	0.0	0.0	0.00
12	1629.9	0.0	0.0	165.4	84.7	0.0	0.0	0.00
13	1700.8	0.0	0.0	172.6	88.4	0.0	0.0	0.00
14	1771.8	0.0	0.0	179.8	92.1	0.0	0.0	0.00
15	1842.8	0.0	0.0	187.0	95.8	0.0	0.0	0.00
16	1913.8	0.0	0.0	194.2	99.5	0.0	0.0	0.00
17	1950.8	0.0	0.0	203.5	101.7	0.0	0.0	0.00
18	1921.6	0.0	0.0	203.8	101.9	0.0	0.0	0.00
19	1712.5	0.0	0.0	185.4	100.9	0.0	0.0	0.00
20	150.0	0.0	0.0	16.2	100.0	0.0	0.0	0.00
21	1775.3	0.0	0.0	196.7	98.3	0.0	0.0	0.00
22	1662.5	0.0	0.0	189.2	94.6	0.0	0.0	0.00
23	1526.5	0.0	0.0	179.0	89.5	0.0	0.0	0.00
24	1370.7	0.0	0.0	166.3	83.2	0.0	0.0	0.00
25	471.6	0.0	0.0	59.4	78.1	0.0	0.0	0.00
26	726.9	0.0	0.0	0.0	0.0	0.0	0.0	0.00
27	1013.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
28	820.3	0.0	0.0	0.0	0.0	0.0	0.0	0.00
29	622.8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
30	183.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
31	122.7	0.0	0.0	0.0	0.0	0.0	0.0	0.00

Table 3A - Center of Pressure of Water Loads On the 31 Slices
Only Applicable Slices Listed

Slice No.	X-Ubeta (ft)	Y-Ubeta (ft)	Ubeta-Moment (ft/lbs)

Table 3B - Center of Pressure of Distributed Loads On the 31 Slices
Only Applicable Slices Listed

Slice No.	X-Dload (ft)	Y-Dload (ft)	Dist-Load (lbs)	Dload-Moment (ft/lbs)
27	123.39	542.40	0.197351E+03	0.000000E+00
28	124.62	542.40	0.417527E+03	0.000000E+00
29	123.17	542.40	0.829042E+02	0.000000E+00
30	124.14	542.40	0.402400E+03	0.000000E+00
31	125.71	542.40	0.386317E+03	0.000000E+00

TOTAL WEIGHT OF SLIDING MASS = 35773.72(lbs)

EFFECTIVE WEIGHT OF SLIDING MASS = 32545.34(lbs)

TOTAL AREA OF SLIDING MASS = 298.11(ft2)

TABLE 4 - SOIL STRENGTH & SOIL OPTIONS DATA ON THE 31 SLICES

Slice No.	Soil Type	Cohesion (psf)	Phi(Deg)	Options
1	4	73.00	17.83	R
2	4	73.00	17.83	R
3	4	210.16	0.00	R
4	4	231.11	0.00	R
5	4	193.68	0.00	R
6	4	197.98	0.00	R
7	4	202.34	0.00	R
8	4	206.74	0.00	R
9	4	209.19	0.00	R
10	4	217.71	0.00	R
11	4	234.56	0.00	R
12	4	251.63	0.00	R
13	4	268.84	0.00	R
14	4	286.15	0.00	R
15	4	303.52	0.00	R
16	4	320.95	0.00	R
17	4	321.97	0.00	R
18	4	328.07	0.00	R
19	4	73.00	17.83	R
20	4	73.00	17.83	R
21	4	73.00	17.83	R
22	4	73.00	17.83	R
23	4	73.00	17.83	R
24	4	73.00	17.83	R
25	4	73.00	17.83	R
26	1	40.00	25.00	
27	1	40.00	25.00	
28	1	40.00	25.00	
29	1	40.00	25.00	
30	1	40.00	25.00	
31	1	40.00	25.00	

SOIL OPTIONS: A = ANISOTROPIC, C = CURVED STRENGTH ENVELOPE (TANGENT PHI),
F = FIBER-REINFORCED SOIL (FRS), N = NONLINEAR UNDRAINED SHEAR STRENGTH,
R = RAPID DRAWDOWN SHEAR STRENGTH
NOTE: Phi and C in Table 4 are modified values based on specified
Soil Options (if any). Zero values indicate that the normal stress = 0.0

TABLE 5 - Total Base Stress Data on the 31 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Stress (psf)	Total Vert. Stress (psf)	Total Normal/Vert. Stress Ratio
1	-28.70	75.01	0.95	134.95	43.92	3.073
2	-25.70	76.32	2.00	311.14	175.91	1.769
3	-22.70	78.15	2.00	513.99	347.20	1.480
4	-19.70	80.01	2.00	683.47	508.51	1.344
5	9.85	82.02	2.17	593.33	607.09	0.977
6	9.85	84.16	2.17	632.77	648.05	0.976
7	9.85	86.30	2.17	672.22	689.00	0.976
8	9.85	88.43	2.17	711.66	729.95	0.975
9	9.85	89.61	0.23	733.49	752.61	0.975
10	9.85	90.69	1.95	753.77	773.23	0.975
11	9.85	92.61	1.95	790.16	810.12	0.975
12	9.85	94.54	1.95	826.56	847.00	0.976
13	9.85	96.46	1.95	862.97	883.88	0.976
14	9.85	98.39	1.95	899.39	920.77	0.977
15	9.85	100.31	1.95	935.81	957.65	0.977
16	9.85	102.24	1.95	972.24	994.53	0.978
17	16.49	104.16	2.00	936.15	1017.26	0.920
18	19.49	106.06	2.00	911.39	1019.21	0.894
19	22.49	107.85	1.84	875.80	1008.65	0.868
20	22.49	108.77	0.16	867.96	999.69	0.868
21	25.49	109.75	2.00	828.80	983.42	0.843
22	28.49	111.53	2.00	772.77	945.79	0.817
23	31.49	113.26	2.00	707.90	895.12	0.791
24	34.49	114.94	2.00	635.04	831.55	0.764
25	37.49	116.07	0.76	574.64	780.84	0.736
26	37.49	116.86	1.24	523.85	739.54	0.708
27	40.49	118.11	2.00	451.45	666.45	0.677
28	43.49	119.60	2.00	364.11	565.37	0.644
29	46.49	121.01	2.00	274.39	452.30	0.607
30	49.49	121.95	0.77	208.19	367.73	0.566
31	49.49	122.39	0.60	101.17	315.33	0.321

TABLE 5A - Total Base Force Data on the 31 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Force (lbs)	Total Vert. Force (lbs)	Total Normal/Vert. Force Ratio
1	-28.70	75.01	0.95	127.86	36.50	3.503
2	-25.70	76.32	2.00	622.29	317.03	1.963
3	-22.70	78.15	2.00	1027.98	640.62	1.605
4	-19.70	80.01	2.00	1366.94	957.51	1.428

5	9.85	82.02	2.17	1286.71	1297.15	0.992
6	9.85	84.16	2.17	1372.24	1384.65	0.991
7	9.85	86.30	2.17	1457.78	1472.16	0.990
8	9.85	88.43	2.17	1543.33	1559.66	0.990
9	9.85	89.61	0.23	169.41	171.26	0.989
10	9.85	90.69	1.95	1472.17	1487.92	0.989
11	9.85	92.61	1.95	1543.23	1558.89	0.990
12	9.85	94.54	1.95	1614.33	1629.86	0.990
13	9.85	96.46	1.95	1685.44	1700.84	0.991
14	9.85	98.39	1.95	1756.57	1771.81	0.991
15	9.85	100.31	1.95	1827.70	1842.78	0.992
16	9.85	102.24	1.95	1898.84	1913.76	0.992
17	16.49	104.16	2.00	1872.30	1950.80	0.960
18	19.49	106.06	2.00	1822.77	1921.58	0.949
19	22.49	107.85	1.84	1609.39	1712.50	0.940
20	22.49	108.77	0.16	140.94	149.98	0.940
21	25.49	109.75	2.00	1657.61	1775.35	0.934
22	28.49	111.53	2.00	1545.55	1662.46	0.930
23	31.49	113.26	2.00	1415.79	1526.54	0.927
24	34.49	114.94	2.00	1270.08	1370.71	0.927
25	37.49	116.07	0.76	437.40	471.57	0.928
26	37.49	116.86	1.24	648.97	726.91	0.893
27	40.49	118.11	2.00	902.91	1013.64	0.891
28	43.49	119.60	2.00	728.22	820.30	0.888
29	46.49	121.01	2.00	548.78	622.76	0.881
30	49.49	121.95	0.77	159.99	183.56	0.872
31	49.49	122.39	0.60	60.60	122.68	0.494

TABLE 6 - Effective and Base Shear Stress Data on the 31 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Stress (psf)	Available Shear Strength (psf)	Mobilized Shear Stress (psf)	Rapid Drawdown Strength Type
1	-28.70	75.01	0.95	166.78	126.64	96.88	Drained
2	-25.70	76.32	2.00	301.97	170.13	130.14	Drained
3	-22.70	78.15	2.00	474.98	210.16	160.77	Undrained
4	-19.70	80.01	2.00	628.25	231.11	176.79	Undrained
5	9.85	82.02	2.17	532.19	193.68	148.16	Undrained
6	9.85	84.16	2.17	567.53	197.98	151.45	Undrained
7	9.85	86.30	2.17	602.89	202.34	154.78	Undrained
8	9.85	88.43	2.17	638.24	206.74	158.15	Undrained
9	9.85	89.61	0.23	657.80	209.19	160.02	Undrained
10	9.85	90.69	1.95	676.00	217.71	166.54	Undrained
11	9.85	92.61	1.95	708.65	234.56	179.43	Undrained
12	9.85	94.54	1.95	741.32	251.63	192.49	Undrained
13	9.85	96.46	1.95	774.00	268.84	205.66	Undrained
14	9.85	98.39	1.95	806.68	286.15	218.90	Undrained
15	9.85	100.31	1.95	839.36	303.52	232.19	Undrained

16	9.85	102.24	1.95	872.05	320.95	245.52	Undrained
17	16.49	104.16	2.00	834.70	321.97	246.30	Undrained
18	19.49	106.06	2.00	810.18	328.07	250.96	Undrained
19	22.49	107.85	1.84	775.09	322.30	246.55	Drained
20	22.49	108.77	0.16	767.46	319.85	244.67	Drained
21	25.49	109.75	2.00	729.39	307.60	235.31	Drained
22	28.49	111.53	2.00	676.28	290.52	222.24	Drained
23	31.49	113.26	2.00	615.33	270.92	207.24	Drained
24	34.49	114.94	2.00	547.34	249.05	190.51	Drained
25	37.49	116.07	0.76	490.35	230.72	176.49	Drained
26	37.49	116.86	1.24	526.22	285.38	218.31	Drained
27	40.49	118.11	2.00	453.82	251.62	192.48	Drained
28	43.49	119.60	2.00	366.31	210.81	161.27	Drained
29	46.49	121.01	2.00	276.32	168.85	129.17	Drained
30	49.49	121.95	0.77	209.90	137.88	105.47	Drained
31	49.49	122.39	0.60	103.03	88.05	67.35	Drained

TABLE 6A - Effective and Base Shear Force Data on the 31 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Force (lbs)	Available Shear Force (lbs)	Mobilized Shear Force (lbs)
1	-28.70	75.01	0.95	123.70	108.95	83.34
2	-25.70	76.32	2.00	587.10	334.84	256.14
3	-22.70	78.15	2.00	958.54	420.32	321.53
4	-19.70	80.01	2.00	1265.23	462.22	353.58
5	9.85	82.02	2.17	1155.06	420.02	321.31
6	9.85	84.16	2.17	1231.71	429.34	328.43
7	9.85	86.30	2.17	1308.37	438.79	335.66
8	9.85	88.43	2.17	1385.03	448.34	342.97
9	9.85	89.61	0.23	152.02	48.31	36.96
10	9.85	90.69	1.95	1321.15	425.21	325.27
11	9.85	92.61	1.95	1385.01	458.11	350.44
12	9.85	94.54	1.95	1448.90	491.45	375.95
13	9.85	96.46	1.95	1512.81	525.06	401.66
14	9.85	98.39	1.95	1576.74	558.87	427.52
15	9.85	100.31	1.95	1640.67	592.80	453.47
16	9.85	102.24	1.95	1704.60	626.83	479.51
17	16.49	104.16	2.00	1668.85	643.95	492.60
18	19.49	106.06	2.00	1618.93	656.13	501.92
19	22.49	107.85	1.84	1424.04	592.18	453.00
20	22.49	108.77	0.16	124.71	51.97	39.75
21	25.49	109.75	2.00	1460.92	615.90	471.14
22	28.49	111.53	2.00	1356.39	582.27	445.42
23	31.49	113.26	2.00	1236.77	543.80	415.99
24	34.49	114.94	2.00	1103.77	501.02	383.27
25	37.49	116.07	0.76	377.96	177.13	135.50
26	37.49	116.86	1.24	648.97	352.17	269.40

27	40.49	118.11	2.00	902.91	501.03	383.28
28	43.49	119.60	2.00	728.22	419.57	320.96
29	46.49	121.01	2.00	548.78	335.90	256.96
30	49.49	121.95	0.77	159.99	105.35	80.59
31	49.49	122.39	0.60	60.60	52.22	39.94

SUM OF MOMENTS = -0.121862E-04 (ft/lbs);Imbalance (Fraction of Total Weight) = -0.3406475E-09
SUM OF FORCES = 0.277758E-06 (lbs);Imbalance (Fraction of Total Weight) = 0.7764310E-11

Sum of Available Shear Forces = 19781.86(lbs)

Sum of Mobilized Shear Forces = 15132.56(lbs)

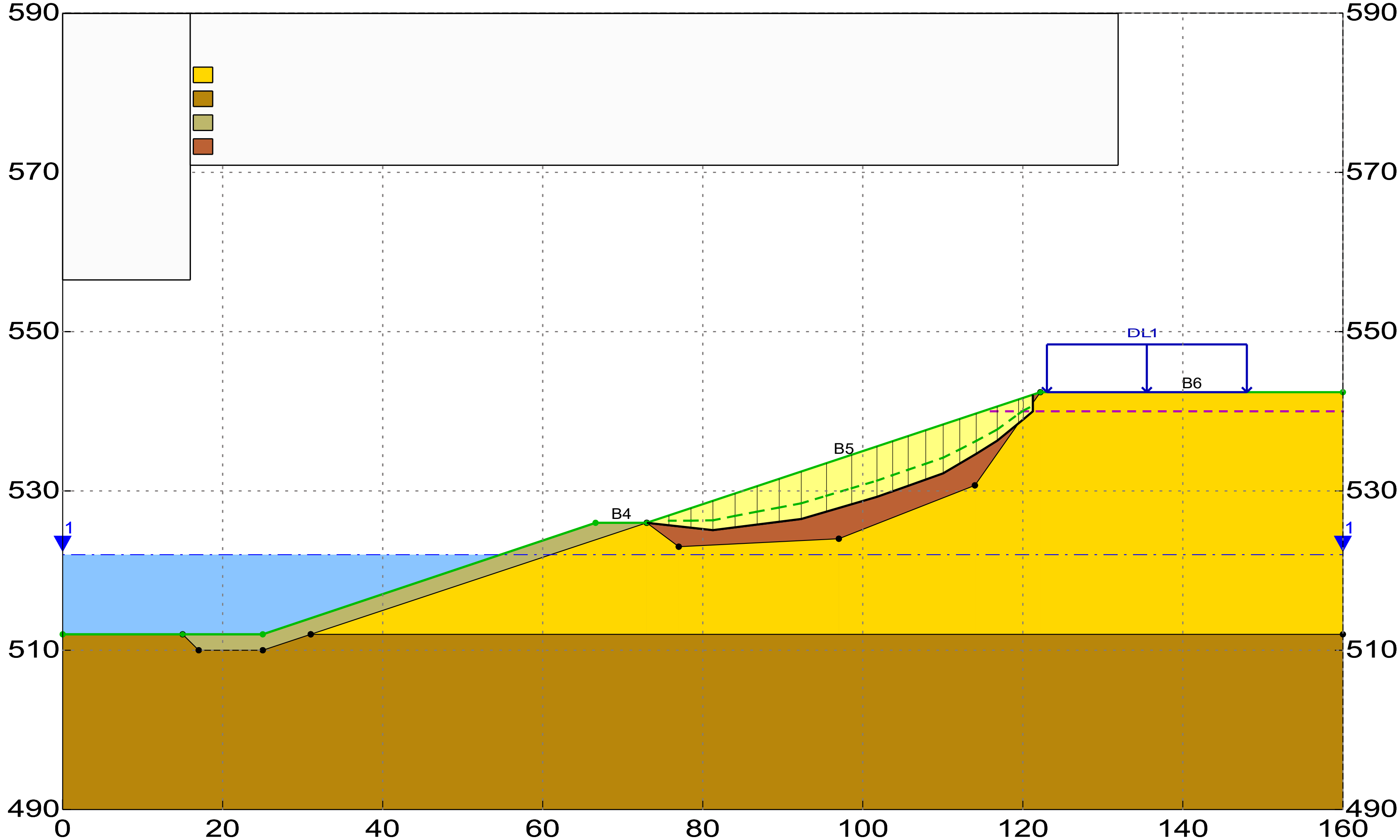
FS Balance Check: FS = 1.307238

**** END OF GEOSTASE OUTPUT FOR RAPID DRAWDOWN STAGE 3 ****

LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II
Long-Term-Repaired Condition - FRS - ZRSAUTO Search

GREGORY GEOTECHNICAL - GHG

\lakeridge-Repaired-ZRSAUTO-I.gsd



GEOSTASE FS = 1.464

Spencer Method

GEOSTASE Slope Stability Analysis

GREGORY GEOTECHNICAL

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

PLATE C.9

*** GEOSTASE ***

****
SLOPE STABILITY ANALYSIS SOFTWARE
Simplified Bishop, Simplified Janbu, or General Equilibrium (GE) Options.
(Spencer, Morgenstern-Price, USACE, and Lowe & Karafiath)
Including Pier/Pile, Planar Reinf, Nail, Tieback, Line Loads
Nonlinear Undrained Shear Strength, Curved Strength Envelope,
Anisotropic , Fiber-Reinforced , Distributed Loads, Water
Surfaces, Pseudo-Static & Newmark Earthquake, and Applied Forces.
****

Analysis Date:
Analysis Time:
Analysis By: GREGORY GEOTECHNICAL - GHG

Input File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Repaired-ZRSAUTO-I.gsd

Output File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Repaired-ZRSAUTO-I.OUT

Unit System: English

PROJECT: LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II

DESCRIPTION: Long-Term-Repaired Condition - FRS - ZRSAUTO Search

BOUNDARY DATA

6 Surface Boundaries
15 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	512.000	15.000	512.000	2
2	15.000	512.000	25.000	512.000	3
3	25.000	512.000	66.600	526.000	3
4	66.600	526.000	73.000	526.000	3
5	73.000	526.000	122.200	542.400	4

6	122.200	542.400	160.000	542.400	1
7	15.000	512.000	17.000	510.000	2
8	17.000	510.000	25.000	510.000	2
9	25.000	510.000	31.000	512.000	2
10	31.000	512.000	73.000	526.000	1
11	73.000	526.000	77.000	523.000	1
12	77.000	523.000	97.000	524.000	1
13	97.000	524.000	114.000	530.700	1
14	114.000	530.700	122.200	542.400	1
15	31.000	512.000	160.000	512.000	2

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 490.000(ft)

MOHR-COULOMB SOIL PARAMETERS

4 Type(s) of Soil Defined

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Ratio(ru)	Pressure Constant (psf)	Water Surface No.	Water Option
1 Fill-Clay	120.0	132.0	40.00	25.00	0.000	0.0	1	0
2 In-Situ	120.0	132.0	1000.00	20.00	0.000	0.0	1	0
3 Soil Cement	130.0	135.0	1000.00	40.00	0.000	0.0	1	0
4 Weak Clay	120.0	132.0	70.00	13.00	0.000	0.0	1	0

FIBER-REINFORCED SOIL PROPERTIES
1 Soil Type(s) With Fiber Reinforcement

Soil Type 4:

Fiber Length = 3.00(in) Fiber Width = 0.05300(in)
Fiber Thickness = 0.00150(in) Fiber Equivalent Dia. = 0.01006(in)
Friction Coefficient = 0.50 Cohesion Coefficient = 0.50
Specific Gravity of Fiber = 0.910 Application Rate = 0.250 (pcf)

Fiber-Reinforced Shear-Strength Properties

Soil Type 4: FRS c = 72.56 (psf) FRS Phi = 16.60 Deg.
Delta(c) = 2.559(psf) Tan(DeltaPhi) = 0.062926

CURVED STRENGTH PARAMETERS
1 Soil Type(s) Assigned Curved Strength Envelope Properties

Pa = 2116.800(psf)
A Value of 1.0 indicates Dimensional Coefficients

Soil Type 4:

Curve Coefficients a, b, and T are User Input Values

Coefficient a = 0.3214 Coefficient b = 0.8852
Cohesion(c) = 0.00000(psf) Coefficient T = 0.00000

A Power Curve Function Has Been Selected to Model
Stress-Dependent Shear Strength (C = 0).

WATER SURFACE DATA

1 Water Surface(s) Defined

Unit Weight of Water = 62.400 (pcf)

Water Surface No. 1 Specified by 2 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	522.00
2	160.00	522.00

DISTRIBUTED LOAD(S)

1 Load(s) Specified

Load No.	BND No.	X - 1 (ft)	Y - 1 (ft)	Stress (psf)	X - 2 (ft)	Y - 2 (ft)	Stress (psf)	Deflection (deg from Vert)
1	6	123.000	542.400	250.000	148.000	542.400	250.000	0.00

NOTE - Load Stress Varies Linearly Within Specified Range.

TENSION CRACK DATA

Tension Crack Zones Have Been Defined By 1 Tension Crack Line(s)

TC-Line No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)
1	116.00	540.00	160.00	540.00

Specified Tension Crack Water Depth Factor = 1.0000

Specified Tension Crack Fluid Weight = 62.400 (pcf)

SEISMIC (EARTHQUAKE) DATA

Specified Peak Ground Acceleration Coefficient (PGA) = 0.070(g)
Default Velocity = 0.175(ft) per second
Specified Horizontal Earthquake Coefficient (kh) = 0.0300(g)
Specified Vertical Earthquake Coefficient (kv) = 0.000(g)
(NOTE:Input Velocity = 0.0 will result in default Peak
Velocity = 2 times(PGA) times 2.5 fps or 0.762 mps)
Specified Seismic Pore-Pressure Factor = 0.000
Horizontal Seismic Force is Applied at Center of Gravity of Slices

EARTHQUAKE DATA HAS BEEN SUPPRESSED

A Non-Circular Zone Search Has Been Selected For Analysis
Using Random Generation Within Specified Zones.

8 Zones Defined For Generation Of Non-Circular Surfaces

Length Of Line Segments For Active And Passive Portions Of
Non-Circular Zone Search = 12.00(ft)

A NON-CIRCULAR ZRSAUTO REFINED SEARCH HAS BEEN SPECIFIED.

ZRS Initial Zone Height = 2.000(ft)
ZRS Initial Zone Width = 2.000(ft)
ZRS Minimum Standard Zone Size = .700(ft)
ZRS Reduction Factor = .950
ZRS SOR Convergence Factor = 1.250
Number of ZRS Cycles = 4
ZRS Final Shift Factor = .700
Number of ZRS Passes Per Cycle = 500
Number of ZRS Increments (Reductions) Per Cycle = 20
Total Number of ZRS Trial Surfaces = 40000

Zone No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Height (ft)
1	79.87	525.61	81.87	525.61	2.00
2	92.40	525.80	94.40	525.80	2.00
3	101.88	527.90	103.88	527.90	2.00
4	105.63	529.28	107.63	529.28	2.00
5	109.22	531.05	111.22	531.05	2.00
6	112.60	533.19	114.60	533.19	2.00

7	115.74	535.66	117.74	535.66	2.00
8	118.61	538.45	120.61	538.45	2.00

The Spencer Method Was Selected for FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR SPENCER METHOD:
Initial estimate of FS = 1.600
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 8.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = -45.00 ; Maximum theta(deg) = 45.00
Theta convergence Step Factor = 1000.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

The option of using a different convergence method
during the first 25% of iterations has been selected.

Specified Tension Crack Water Depth Factor = 1.000

Total Number of Trial Surfaces Attempted = 40000

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence = 35
Maximum Normal Stress Difference (%) = 0.005000

Warning: Convergence not achieved on 6510
surfaces during curved strength envelope calculations.
Maximum Normal Stress Difference (%) = Infinity

WARNING! The Factor of Safety Calculation for one or More Trial Surfaces
Did Not Converge in 50 Iterations.

Number of Trial Surfaces with Non-Converged FS = 6821

Number of Trial Surfaces With Valid FS = 33179

Percentage of Trial Surfaces With Non-Converged and/or
Non-Valid FS Solutions of the Total Attempted = 17.1 %

Statistical Data On All Valid FS Values:
FS Max = 2.636 FS Min = 1.464 FS Ave = 1.712

Standard Deviation = 0.186 Coefficient of Variation = 10.88 %

Critical Surface is Sequence Number 22664 of Those Analyzed.

*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****

Iter. No.	Theta (deg) (fx=1.0)	FS (Moment)	FS (Force)	Lambda	Delta FS
1	8.0000	1.758701	1.430472	0.141	0.3282288E+00
2	10.6400	1.708061	1.440100	0.188	0.2679614E+00
3	12.6198	1.655228	1.447515	0.224	0.2077129E+00
4	14.4307	1.590113	1.454470	0.257	0.1356427E+00
5	15.7765	1.526627	1.459758	0.283	0.6686873E-01
6	16.4992	1.485276	1.462644	0.296	0.2263171E-01
7	16.7545	1.469181	1.463672	0.301	0.5509560E-02
8	16.8175	1.465074	1.463926	0.302	0.1147218E-02
9	16.8307	1.464208	1.463980	0.303	0.2287321E-03
10	16.8333	1.464035	1.463990	0.303	0.4521717E-04
11	16.8339	1.464001	1.463992	0.303	0.8900867E-05
12	16.8340	1.463995	1.463993	0.303	0.1777085E-05
13	16.8340	1.463993	1.463993	0.303	0.3502768E-06

Factor Of Safety For The Preceding Specified Surface = 1.464
Theta (fx = 1.0) = 16.83 Deg Lambda = 0.303

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence = 35
Maximum Normal Stress Difference (%) = 0.005000

The Spencer Method Has Been Selected For FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR ANALYSIS METHOD:
Initial estimate of FS = 1.600
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 8.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = -45.00 ; Maximum theta(deg) = 45.00
Theta convergence Step Factor = 1000.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance(if Applicable) = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

The option of using a different convergence method
during the first 25% of iterations has been selected.

Tension Crack Water Force = 135.03(lbs)

Specified Tension Crack Water Depth Factor = 1.000

Depth of Tension Crack (zo) at Side of Last Slice = 2.080(ft)

Depth of Water in Tension Crack = 2.080(ft)

Theoretical Tension Crack Depth = 1.046(ft)

NOTE: In Table 1 following, when a tension crack with water is present on the first slice (right facing slope) or on the last slice (left facing slope), the "side force" in the tension crack is set equal to the water pressure resultant.

*** Table 1 - Line of Thrust(if applicable) and Slice Force Data ***

Slice No.	X Coord.	Y Coord.	h/H	Side Force (lbs)	fx	Force Angle (Deg)	Vert. Shear Force(lbs)
1	75.76	526.27	0.465	121.16	1.000	16.83	35.1
2	78.52	526.27	0.358	450.01	1.000	16.83	130.3
3	81.27	526.32	0.337	974.20	1.000	16.83	282.1
4	84.03	526.86	0.336	1218.57	1.000	16.83	352.9
5	86.79	527.39	0.333	1491.60	1.000	16.83	432.0
6	89.54	527.92	0.331	1792.63	1.000	16.83	519.1
7	92.30	528.44	0.328	2121.09	1.000	16.83	614.3
8	95.46	529.39	0.326	2121.22	1.000	16.83	614.3
9	98.62	530.35	0.324	2120.03	1.000	16.83	614.0
10	101.77	531.31	0.322	2117.50	1.000	16.83	613.2
11	103.73	531.98	0.321	2035.31	1.000	16.83	589.4
12	105.68	532.65	0.320	1953.87	1.000	16.83	565.8
13	107.86	533.41	0.320	1854.60	1.000	16.83	537.1
14	110.05	534.18	0.320	1756.64	1.000	16.83	508.7
15	112.11	535.22	0.318	1404.53	1.000	16.83	406.8
16	114.18	536.28	0.319	1087.90	1.000	16.83	315.1
17	116.80	537.72	0.327	706.01	1.000	16.83	204.5
18	119.46	539.66	0.388	273.07	1.000	16.83	79.1
19	120.05	540.09	0.410	218.28	1.000	16.83	63.2
20	121.24	540.69	0.693	135.03	1.000	16.83	-0.0

NOTE: A value of 0.000- for h/H indicates that the line of thrust is at or below the lower boundary of the sliding mass. A value of 1.000+ for h/H indicates that the line of thrust is at or above the upper boundary of the sliding mass.

Table 2 - Geometry Data on the 20 Slices

Slice No.	Width (ft)	Height (ft)	X-Cntr (ft)	Y-Cntr-Base (ft)	Y-Cntr-Top (ft)	Alpha (deg)	Beta (deg)	Base Length (ft)
1	2.75	0.61	74.38	525.85	526.46	-6.32	18.43	2.77
2	2.75	1.83	77.14	525.54	527.38	-6.32	18.43	2.77
3	2.75	3.06	79.89	525.24	528.30	-6.32	18.43	2.77
4	2.76	3.95	82.65	525.26	529.22	7.24	18.43	2.78
5	2.76	4.52	85.41	525.61	530.14	7.24	18.43	2.78
6	2.76	5.09	88.16	525.96	531.05	7.24	18.43	2.78
7	2.76	5.66	90.92	526.31	531.97	7.24	18.43	2.78
8	3.16	6.01	93.88	526.95	532.96	16.37	18.43	3.29
9	3.16	6.13	97.04	527.88	534.01	16.37	18.43	3.29
10	3.16	6.26	100.19	528.81	535.06	16.37	18.43	3.29
11	1.95	6.30	102.75	529.62	535.92	19.45	18.43	2.07
12	1.95	6.26	104.70	530.31	536.57	19.45	18.43	2.07
13	2.18	6.21	106.77	531.04	537.26	19.77	18.43	2.32
14	2.18	6.16	108.95	531.83	537.98	19.77	18.43	2.32
15	2.07	5.86	111.08	532.83	538.69	30.64	18.43	2.40
16	2.07	5.33	113.15	534.06	539.38	30.64	18.43	2.40
17	2.62	4.67	115.49	535.49	540.16	32.06	18.43	3.10
18	2.66	3.64	118.13	537.40	541.04	39.37	18.43	3.44
19	0.59	2.85	119.76	538.74	541.59	39.37	18.43	0.76
20	1.19	2.39	120.65	539.49	541.88	40.68	18.43	1.57

Table 2A - Coordinates of Slice Points Defining the Slip Surface

Point No.	X-Pt (ft)	Y-Pt (ft)
1	73.006906	526.002302
2	75.761578	525.697207
3	78.516251	525.392112
4	81.270923	525.087017
5	84.028060	525.437324
6	86.785197	525.787630
7	89.542334	526.137937
8	92.299472	526.488243
9	95.457542	527.415851
10	98.615612	528.343458
11	101.773682	529.271066
12	103.726092	529.960484
13	105.678501	530.649902
14	107.862044	531.434910
15	110.045587	532.219917
16	112.112529	533.444488
17	114.179472	534.669060

18	116.804158	536.312799
19	119.462879	538.494596
20	120.051218	538.977398
21	121.241002	540.000000

Table 3 - Force and Pore Pressure Data On The 20 Slices (Excluding Reinforcement)

Slice No.	Weight (lbs)	Ubeta Force Top (lbs)	Ubeta Stress Top (psf)	Ualpha Force Bot (lbs)	Pore Pressure (psf)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Distributed Load (lbs)
1	202.2	0.0	0.0	0.0	0.0	0.0	0.0	0.00
2	606.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
3	1011.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
4	1308.3	0.0	0.0	0.0	0.0	0.0	0.0	0.00
5	1496.5	0.0	0.0	0.0	0.0	0.0	0.0	0.00
6	1684.7	0.0	0.0	0.0	0.0	0.0	0.0	0.00
7	1872.8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
8	2276.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
9	2324.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
10	2371.4	0.0	0.0	0.0	0.0	0.0	0.0	0.00
11	1476.2	0.0	0.0	0.0	0.0	0.0	0.0	0.00
12	1467.2	0.0	0.0	0.0	0.0	0.0	0.0	0.00
13	1628.3	0.0	0.0	0.0	0.0	0.0	0.0	0.00
14	1613.3	0.0	0.0	0.0	0.0	0.0	0.0	0.00
15	1453.7	0.0	0.0	0.0	0.0	0.0	0.0	0.00
16	1320.8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
17	1471.8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
18	1161.6	0.0	0.0	0.0	0.0	0.0	0.0	0.00
19	201.2	0.0	0.0	0.0	0.0	0.0	0.0	0.00
20	341.7	0.0	0.0	0.0	0.0	0.0	0.0	0.00

Table 3A - Center of Pressure of Water Loads On the 20 Slices
Only Applicable Slices Listed

Slice No.	X-Ubeta (ft)	Y-Ubeta (ft)	Ubeta-Moment (ft/lbs)

Table 3B - Center of Pressure of Distributed Loads On the 20 Slices
Only Applicable Slices Listed

Slice No.	X-Dload (ft)	Y-Dload (ft)	Dist-Load (lbs)	Dload-Moment (ft/lbs)
18	123.76	542.40	0.382374E+03	0.000000E+00
19	123.01	542.40	0.380094E+01	0.000000E+00
20	123.01	542.40	0.367507E+01	0.000000E+00

TOTAL WEIGHT OF SLIDING MASS = 27289.98(lbs)

EFFECTIVE WEIGHT OF SLIDING MASS = 27289.98(lbs)

TOTAL AREA OF SLIDING MASS = 227.42(ft2)

TABLE 4 - SOIL STRENGTH & SOIL OPTIONS DATA ON THE 20 SLICES

Slice No.	Soil Type	Cohesion (psf)	Phi(Deg)	Options
1	4	4.76	25.26	C F
2	4	12.38	22.99	C F
3	4	19.32	22.00	C F
4	4	21.06	21.81	C F
5	4	23.71	21.55	C F
6	4	26.31	21.33	C F
7	4	28.89	21.14	C F
8	4	27.97	21.20	C F
9	4	28.49	21.17	C F
10	4	29.00	21.13	C F
11	4	28.36	21.17	C F
12	4	28.21	21.19	C F
13	4	27.93	21.21	C F
14	4	27.71	21.22	C F
15	4	23.90	21.54	C F
16	4	21.94	21.72	C F
17	4	19.25	22.00	C F
18	4	14.23	22.67	C F
19	1	40.00	25.00	
20	1	40.00	25.00	

SOIL OPTIONS: A = ANISOTROPIC, C = CURVED STRENGTH ENVELOPE (TANGENT PHI),
F = FIBER-REINFORCED SOIL (FRS), N = NONLINEAR UNDRAINED SHEAR STRENGTH,
R = RAPID DRAWDOWN SHEAR STRENGTH
NOTE: Phi and C in Table 4 are modified values based on specified
Soil Options (if any). Zero values indicate that the normal stress = 0.0

Calculated Secant Phi Values

Slice No.	Phi(Deg)
1	27.70
2	25.22
3	24.14
4	23.93
5	23.66
6	23.41
7	23.20

8	23.27
9	23.23
10	23.19
11	23.24
12	23.25
13	23.28
14	23.29
15	23.64
16	23.84
17	24.15
18	24.88
19	36.34
20	90.00

NOTE: The slices in the table above with phi marked with an * are unmodified phi values for soil type(s) not specified to have curved strength envelope (if any).

TABLE 5 - Total Base Stress Data on the 20 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Stress (psf)	Total Vert. Stress (psf)	Total Normal/Vert. Stress Ratio
1	-6.32	74.38	2.77	89.70	73.40	1.222
2	-6.32	77.14	2.77	264.18	220.20	1.200
3	-6.32	79.89	2.77	436.92	367.00	1.191
4	7.24	82.65	2.78	481.63	474.52	1.015
5	7.24	85.41	2.78	550.52	542.77	1.014
6	7.24	88.16	2.78	619.36	611.02	1.014
7	7.24	90.92	2.78	688.17	679.27	1.013
8	16.37	93.88	3.29	663.64	720.89	0.921
9	16.37	97.04	3.29	677.45	735.90	0.921
10	16.37	100.19	3.29	691.27	750.91	0.921
11	19.45	102.75	2.07	674.09	756.10	0.892
12	19.45	104.70	2.07	669.95	751.47	0.892
13	19.77	106.77	2.32	662.56	745.72	0.888
14	19.77	108.95	2.32	656.46	738.86	0.888
15	30.64	111.08	2.40	555.56	703.30	0.790
16	30.64	113.15	2.40	504.46	639.03	0.789
17	32.06	115.49	3.10	435.17	560.76	0.776
18	39.37	118.13	3.44	309.33	436.90	0.708
19	39.37	119.76	0.76	231.94	341.96	0.678
20	40.68	120.65	1.57	165.33	287.20	0.576

TABLE 5A - Total Base Force Data on the 20 Slices

Slice	Alpha	X-Coord.	Base	Total	Total	Total

No. *	(deg)	Slice Cntr (ft)	Leng. (ft)	Normal Force (lbs)	Vert. Force (lbs)	Normal/Vert. Force Ratio
1	-6.32	74.38	2.77	248.60	202.19	1.230
2	-6.32	77.14	2.77	732.19	606.57	1.207
3	-6.32	79.89	2.77	1210.92	1010.95	1.198
4	7.24	82.65	2.78	1338.60	1308.31	1.023
5	7.24	85.41	2.78	1530.05	1496.49	1.022
6	7.24	88.16	2.78	1721.39	1684.66	1.022
7	7.24	90.92	2.78	1912.63	1872.83	1.021
8	16.37	93.88	3.29	2184.36	2276.64	0.959
9	16.37	97.04	3.29	2229.83	2324.04	0.959
10	16.37	100.19	3.29	2275.30	2371.44	0.959
11	19.45	102.75	2.07	1395.74	1476.22	0.945
12	19.45	104.70	2.07	1387.17	1467.17	0.945
13	19.77	106.77	2.32	1537.39	1628.32	0.944
14	19.77	108.95	2.32	1523.23	1613.34	0.944
15	30.64	111.08	2.40	1334.72	1453.68	0.918
16	30.64	113.15	2.40	1211.95	1320.83	0.918
17	32.06	115.49	3.10	1347.67	1471.82	0.916
18	39.37	118.13	3.44	1063.90	1161.59	0.916
19	39.37	119.76	0.76	176.53	201.19	0.877
20	40.68	120.65	1.57	259.37	341.71	0.759

TABLE 6 - Effective and Base Shear Stress Data on the 20 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Stress (psf)	Available Shear Strength (psf)	Mobilized Shear Stress (psf)
1	-6.32	74.38	2.77	89.70	47.09	32.16
2	-6.32	77.14	2.77	264.18	124.45	85.00
3	-6.32	79.89	2.77	436.92	195.81	133.75
4	7.24	82.65	2.78	481.63	213.78	146.03
5	7.24	85.41	2.78	550.52	241.16	164.73
6	7.24	88.16	2.78	619.36	268.20	183.20
7	7.24	90.92	2.78	688.17	294.93	201.46
8	16.37	93.88	3.29	663.64	285.43	194.97
9	16.37	97.04	3.29	677.45	290.79	198.63
10	16.37	100.19	3.29	691.27	296.13	202.28
11	19.45	102.75	2.07	674.09	289.48	197.74
12	19.45	104.70	2.07	669.95	287.88	196.64
13	19.77	106.77	2.32	662.56	285.02	194.68
14	19.77	108.95	2.32	656.46	282.65	193.07
15	30.64	111.08	2.40	555.56	243.15	166.09
16	30.64	113.15	2.40	504.46	222.90	152.25
17	32.06	115.49	3.10	435.17	195.10	133.26
18	39.37	118.13	3.44	309.33	143.45	97.98
19	39.37	119.76	0.76	231.94	148.16	101.20

20	40.68	120.65	1.57	165.33	117.09	79.98

TABLE 6A - Effective and Base Shear Force Data on the 20 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Force (lbs)	Available Shear Force (lbs)	Mobilized Shear Force (lbs)
1	-6.32	74.38	2.77	248.60	130.50	89.14
2	-6.32	77.14	2.77	732.19	344.90	235.59
3	-6.32	79.89	2.77	1210.92	542.68	370.68
4	7.24	82.65	2.78	1338.60	594.16	405.85
5	7.24	85.41	2.78	1530.05	670.26	457.83
6	7.24	88.16	2.78	1721.39	745.40	509.16
7	7.24	90.92	2.78	1912.63	819.71	559.91
8	16.37	93.88	3.29	2184.36	939.50	641.74
9	16.37	97.04	3.29	2229.83	957.12	653.78
10	16.37	100.19	3.29	2275.30	974.71	665.79
11	19.45	102.75	2.07	1395.74	599.39	409.42
12	19.45	104.70	2.07	1387.17	596.07	407.16
13	19.77	106.77	2.32	1537.39	661.34	451.74
14	19.77	108.95	2.32	1523.23	655.85	447.98
15	30.64	111.08	2.40	1334.72	584.17	399.02
16	30.64	113.15	2.40	1211.95	535.50	365.78
17	32.06	115.49	3.10	1347.67	604.20	412.71
18	39.37	118.13	3.44	1063.90	493.36	337.00
19	39.37	119.76	0.76	176.53	112.76	77.02
20	40.68	120.65	1.57	259.37	183.70	125.48

SUM OF MOMENTS = -0.209346E-05 (ft/lbs);Imbalance (Fraction of Total Weight) = -0.7671168E-10
SUM OF FORCES = -.273781E-06 (lbs);Imbalance (Fraction of Total Weight) = -0.1003229E-10

Sum of Available Shear Forces = 11745.30(lbs)

Sum of Mobilized Shear Forces = 8022.78(lbs)

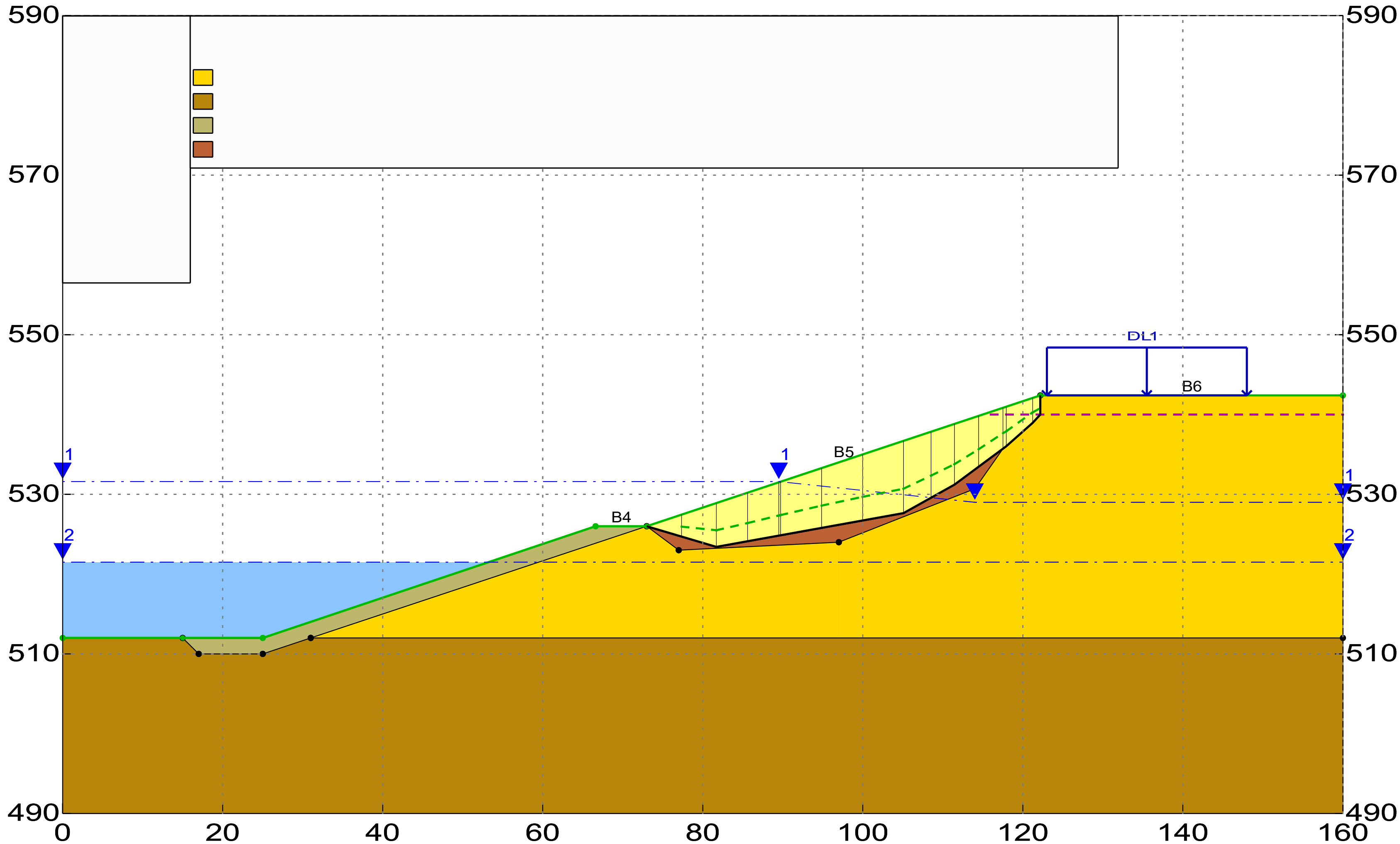
FS Balance Check: FS = 1.463993

**** END OF GEOSTASE OUTPUT ****

LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II
3-Stage Rapid Drawdown - Repaired - FRS - ZRSAUTO Search

GREGORY GEOTECHNICAL - GHG

\lakeridge-Repaired-3RD-ZRSAUTO.gsd



GEOSTASE FS = 1.264

Spencer Method

GEOSTASE Slope Stability Analysis

GREGORY GEOTECHNICAL

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

PLATE C.10

*** GEOSTASE ***

****
SLOPE STABILITY ANALYSIS SOFTWARE
Simplified Bishop, Simplified Janbu, or General Equilibrium (GE) Options.
(Spencer, Morgenstern-Price, USACE, and Lowe & Karafiath)
Including Pier/Pile, Planar Reinf, Nail, Tieback, Line Loads
Nonlinear Undrained Shear Strength, Curved Strength Envelope,
Anisotropic , Fiber-Reinforced , Distributed Loads, Water
Surfaces, Pseudo-Static & Newmark Earthquake, and Applied Forces.
****

Analysis Date:
Analysis Time:
Analysis By: GREGORY GEOTECHNICAL - GHG

Input File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Repaired-3RD-ZRSAUTO.gsd

Output File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Study -1\lakeridge-Repaired-3RD-ZRSAUTO.OUT

Unit System: English

PROJECT: LAKE RIDGE PKWY EMBANKMENT REPAIRS PHASE II

DESCRIPTION: 3-Stage Rapid Drawdown - Repaired - 16 ft Tall Slope - FRS - ZRSAUTO Search

BOUNDARY DATA

6 Surface Boundaries
15 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	512.000	15.000	512.000	2
2	15.000	512.000	25.000	512.000	3
3	25.000	512.000	66.600	526.000	3

4	66.600	526.000	73.000	526.000	3
5	73.000	526.000	122.200	542.400	4
6	122.200	542.400	160.000	542.400	1
7	15.000	512.000	17.000	510.000	2
8	17.000	510.000	25.000	510.000	2
9	25.000	510.000	31.000	512.000	2
10	31.000	512.000	73.000	526.000	1
11	73.000	526.000	77.000	523.000	1
12	77.000	523.000	97.000	524.000	1
13	97.000	524.000	114.000	530.700	1
14	114.000	530.700	122.200	542.400	1
15	31.000	512.000	160.000	512.000	2

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 490.000(ft)

MOHR-COULOMB SOIL PARAMETERS

4 Type(s) of Soil Defined

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Ratio(ru)	Pressure Constant (psf)	Water Surface No.	Water Option
1 Fill-Clay	120.0	132.0	40.00	25.00	0.000	0.0	1	0
2 In-Situ	120.0	132.0	1000.00	20.00	0.000	0.0	1	0
3 Soil Cement	130.0	135.0	1000.00	40.00	0.000	0.0	1	0
4 Weak Clay	120.0	132.0	73.00	17.83	0.100	0.0	1	0

FIBER-REINFORCED SOIL PROPERTIES
1 Soil Type(s) With Fiber Reinforcement

Soil Type 4:

Fiber Length = 3.00(in) Fiber Width = 0.05300(in)
Fiber Thickness = 0.00150(in) Fiber Equivalent Dia. = 0.01006(in)
Friction Coefficient = 0.50 Cohesion Coefficient = 0.50
Specific Gravity of Fiber = 0.910 Application Rate = 0.250 (pcf)

Fiber-Reinforced Shear-Strength Properties

Soil Type 4: FRS c = 76.04 (psf) FRS Phi = 22.47 Deg.
Delta(c) = 3.043(psf) Tan(DeltaPhi) = 0.081241

FIBER-REINFORCED SOIL DATA HAS BEEN SUPPRESSED

CURVED STRENGTH PARAMETERS

1 Soil Type(s) Assigned Curved Strength Envelope Properties

Pa = 2116.800(psf)
A Value of 1.0 indicates Dimensional Coefficients

Soil Type 4:

Curve Coefficients a, b, and T are User Input Values

Coefficient a = 0.2723 Coefficient b = 0.8691
Cohesion(c) = 0.00000(psf) Coefficient T = 0.00000

A Power Curve Function Has Been Selected to Model
Stress-Dependent Shear Strength (C = 0).

CURVED STRENGTH ENVELOPE DATA HAS BEEN SUPPRESSED

WATER SURFACE DATA

2 Water Surface(s) Defined

Unit Weight of Water = 62.400 (pcf)

Water Surface No. 1 Specified by 4 Coordinate Points
Pore Pressure Inclination Factor = 1.00

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	531.60
2	89.50	531.60
3	114.00	529.00
4	160.00	529.00

Water Surface No. 2 Specified by 2 Coordinate Points
Pore Pressure Inclination Factor = 1.00

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	521.50
2	160.00	521.50

SOIL PARAMETERS FOR 3-STAGE RAPID DRAWDOWN

3-Stage Rapid Drawdown Method = Duncan, Wrignt, and Wong (1990)

Soil Number and Description	Moist Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	CR (psf)	PhiR (deg)	dk (psf)	PSIk (deg)
1 Fill-Clay	120.00	132.00	40.00	25.00	0.00	0.00	0.00	0.00
2 In-Situ	120.00	132.00	1000.00	20.00	0.00	0.00	0.00	0.00
3 Soil Cement	130.00	135.00	1000.00	40.00	0.00	0.00	0.00	0.00
4 Weak Clay	120.00	132.00	73.00	17.83	152.00	11.46	176.98	13.28

DISTRIBUTED LOAD(S)

1 Load(s) Specified

Load No.	BND No.	X - 1 (ft)	Y - 1 (ft)	Stress (psf)	X - 2 (ft)	Y - 2 (ft)	Stress (psf)	Deflection (deg from Vert)
1	6	123.000	542.400	250.000	148.000	542.400	250.000	0.00

NOTE - Load Stress Varies Linearly Within Specified Range.

TENSION CRACK DATA

Tension Crack Zones Have Been Defined By 1 Tension Crack Line(s)

TC-Line No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)
1	116.00	540.00	160.00	540.00

Specified Tension Crack Water Depth Factor = 1.0000

Specified Tension Crack Fluid Weight = 62.400 (pcf)

SEISMIC (EARTHQUAKE) DATA

Specified Peak Ground Acceleration Coefficient (PGA) = 0.070(g)
Default Velocity = 0.175(ft) per second
Specified Horizontal Earthquake Coefficient (kh) = 0.0300(g)

Specified Vertical Earthquake Coefficient (kv) =   0.000(g)
(NOTE:Input Velocity = 0.0 will result in default Peak
Velocity = 2 times(PGA) times 2.5 fps or 0.762 mps)
Specified Seismic Pore-Pressure Factor =   0.000
Horizontal Seismic Force is Applied at Center of Gravity of Slices

EARTHQUAKE DATA HAS BEEN SUPPRESSED

A Non-Circular Zone Search Has Been Selected For Analysis
Using Random Generation Within Specified Zones.

5 Zones Defined For Generation Of Non-Circular Surfaces

Length Of Line Segments For Active And Passive Portions Of
Non-Circular Zone Search =   12.00(ft)

A NON-CIRCULAR ZRSAUTO REFINED SEARCH HAS BEEN SPECIFIED.

ZRS Initial Zone Height = 2.000(ft)
ZRS Initial Zone Width = 2.000(ft)
ZRS Minimum Standard Zone Size = .700(ft)
ZRS Reduction Factor = .950
ZRS SOR Convergence Factor = 1.250
Number of ZRS Cycles = 4
ZRS Final Shift Factor = .700
Number of ZRS Passes Per Cycle = 200
Number of ZRS Increments (Reductions) Per Cycle = 20
Total Number of ZRS Trial Surfaces = 16000

Zone No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Height (ft)
1	79.95	523.76	81.95	523.76	2.00
2	106.00	528.86	108.00	528.86	2.00
3	111.41	531.44	113.41	531.44	2.00
4	116.35	534.83	118.35	534.83	2.00
5	120.70	538.96	122.70	538.96	0.00

The Spencer Method Was Selected for FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR SPENCER METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 10.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = -45.00 ; Maximum theta(deg) = 45.00

Theta convergence Step Factor = 1000.00
Maximum number of iterations = 20
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

Specified Tension Crack Water Depth Factor = 1.000

Total Number of Trial Surfaces Attempted = 16000

WARNING! The Factor of Safety Calculation for one or More Trial Surfaces
Did Not Converge in 20 Iterations.

Number of Trial Surfaces with Non-Converged FS = 1068

Number of Trial Surfaces With Valid FS = 14932

Percentage of Trial Surfaces With Non-Converged and/or
Non-Valid FS Solutions of the Total Attempted = 6.7 %

Statistical Data On All Valid FS Values:
FS Max = 2.597 FS Min = 1.264 FS Ave = 1.552
Standard Deviation = 0.199 Coefficient of Variation = 12.81 %

Critical Surface is Sequence Number 27192 of Those Analyzed.

**** END OF GEOSTASE OUTPUT FOR RAPID DRAWDOWN STAGE 3 ****

*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****

Iter. No.	Theta (deg) (fx=1.0)	FS (Moment)	FS (Force)	Lambda	Delta FS
1	10.0000	1.480974	1.343899	0.176	0.1370745E+00
2	13.3000	1.316661	1.378715	0.236	0.6205478E-01
3	12.2726	1.373671	1.367491	0.218	0.6180071E-02
4	12.3666	1.368692	1.368502	0.219	0.1894645E-03
5	12.3696	1.368534	1.368534	0.219	0.5982032E-06

Factor Of Safety For The Preceding Specified Surface = 1.369
Theta (fx = 1.0) = 12.37 Deg Lambda = 0.219

The Spencer Method Has Been Selected For FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR ANALYSIS METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 10.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = -45.00 ; Maximum theta(deg) = 45.00
Theta convergence Step Factor = 1000.00
Maximum number of iterations = 20
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance(if Applicable) = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

Tension Crack Water Force = 178.82(lbs)

Specified Tension Crack Water Depth Factor = 1.000

Depth of Tension Crack (zo) at Side of Last Slice = 2.394(ft)

Depth of Water in Tension Crack = 2.394(ft)

Theoretical Tension Crack Depth = 1.046(ft)

NOTE: In Table 1 following, when a tension crack with water is present on the first slice (right facing slope) or on the last slice (left facing slope), the "side force" in the tension crack is set equal to the water pressure resultant.

*** Table 1 - Line of Thrust(if applicable) and Slice Force Data ***

Slice No.	X Coord.	Y Coord.	h/H	Side Force (lbs)	fx	Force Angle (Deg)	Vert. Shear Force(lbs)
1	77.35	525.83	0.409	2271.29	1.000	12.37	486.5
2	81.70	525.93	0.459	4485.28	1.000	12.37	960.8
3	85.60	526.87	0.452	4669.16	1.000	12.37	1000.2
4	89.50	527.73	0.435	4762.43	1.000	12.37	1020.2
5	89.73	527.78	0.433	4768.27	1.000	12.37	1021.4
6	94.85	528.75	0.394	5023.61	1.000	12.37	1076.1
7	99.97	529.67	0.357	5374.73	1.000	12.37	1151.4
8	105.09	530.68	0.335	5585.25	1.000	12.37	1196.5
9	108.53	531.94	0.286	4624.46	1.000	12.37	990.6
10	111.45	532.90	0.220	3952.87	1.000	12.37	846.8
11	114.48	533.82	0.056	3056.76	1.000	12.37	654.8

12	117.51	534.38	0.000-	2440.40	1.000	12.37	522.8
13	117.92	534.43	0.000-	2379.62	1.000	12.37	509.8
14	121.23	534.42	0.000-	1870.46	1.000	12.37	400.7
15	122.18	540.80	0.798	178.82	1.000	12.37	340.6

NOTE: A value of 0.000- for h/H indicates that the line of thrust is at or below the lower boundary of the sliding mass. A value of 1.000+ for h/H indicates that the line of thrust is at or above the upper boundary of the sliding mass.

Table 2 - Geometry Data on the 15 Slices

Slice No.	Width (ft)	Height (ft)	X-Cntr (ft)	Y-Cntr-Base (ft)	Y-Cntr-Top (ft)	Alpha (deg)	Beta (deg)	Base Length (ft)
1	4.35	1.37	75.18	525.36	526.73	-16.51	18.43	4.54
2	4.35	4.11	79.53	524.07	528.18	-16.51	18.43	4.54
3	3.90	5.78	83.65	523.77	529.55	10.25	18.43	3.96
4	3.90	6.37	87.55	524.48	530.85	10.25	18.43	3.96
5	0.23	6.69	89.61	524.85	531.54	10.25	18.43	0.23
6	5.12	7.09	92.29	525.33	532.43	10.25	18.43	5.20
7	5.12	7.88	97.41	526.26	534.14	10.25	18.43	5.20
8	5.12	8.66	102.53	527.19	535.84	10.25	18.43	5.20
9	3.44	8.65	106.81	528.61	537.27	29.35	18.43	3.94
10	2.92	7.93	109.99	530.40	538.33	29.35	18.43	3.35
11	3.03	6.98	112.96	532.35	539.32	36.50	18.43	3.77
12	3.03	5.74	116.00	534.59	540.33	36.50	18.43	3.77
13	0.41	5.04	117.72	535.86	540.91	36.50	18.43	0.50
14	3.31	4.04	119.57	537.49	541.52	41.70	18.43	4.43
15	0.96	2.75	121.70	539.48	542.23	47.43	18.43	1.41

Table 2A - Coordinates of Slice Points Defining the Slip Surface

Point No.	X-Pt (ft)	Y-Pt (ft)
1	73.000960	526.000320
2	77.351963	524.710560
3	81.702965	523.420801
4	85.601483	524.125648
5	89.500000	524.830495
6	89.727554	524.871636
7	94.848187	525.797440
8	99.968820	526.723243
9	105.089453	527.649047
10	108.525694	529.580947
11	111.445903	531.222726

12	114.479746	533.468009
13	117.513590	535.713292
14	117.918626	536.013052
15	121.226644	538.960000
16	122.182136	540.000000

Table 3 - Force and Pore Pressure Data On The 15 Slices (Excluding Reinforcement)

Slice No.	Weight (lbs)	Ubeta Force Top (lbs)	Ubeta Stress Top (psf)	Ualpha Force Bot (lbs)	Pore Pressure (psf)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Distributed Load (lbs)
1	786.9	1395.0	304.2	1850.4	407.7	0.0	0.0	0.00
2	2360.6	980.0	213.7	2379.8	524.4	0.0	0.0	0.00
3	2973.1	525.5	127.9	2237.0	564.7	0.0	0.0	0.00
4	3279.1	192.3	46.8	2093.9	528.5	0.0	0.0	0.00
5	200.9	0.7	3.1	117.6	508.6	0.0	0.0	0.00
6	4726.4	0.0	0.0	2418.7	464.8	0.0	0.0	0.00
7	5116.0	0.0	0.0	1981.2	380.7	0.0	0.0	0.00
8	5505.7	0.0	0.0	1543.7	296.7	0.0	0.0	0.00
9	3615.9	0.0	0.0	697.3	176.9	0.0	0.0	0.00
10	2777.7	0.0	0.0	318.7	95.1	0.0	0.0	0.00
11	2539.5	0.0	0.0	315.9	83.7	0.0	0.0	0.00
12	2090.3	0.0	0.0	260.0	68.9	0.0	0.0	0.00
13	245.1	0.0	0.0	0.0	0.0	0.0	0.0	0.00
14	1602.8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
15	315.9	0.0	0.0	0.0	0.0	0.0	0.0	0.00

Table 3A - Center of Pressure of Water Loads On the 15 Slices
Only Applicable Slices Listed

Slice No.	X-Ubeta (ft)	Y-Ubeta (ft)	Ubeta-Moment (ft/lbs)
1	75.07	526.69	-445.75
2	79.37	528.12	-1115.06
3	83.45	529.48	-845.95
4	86.99	530.66	-273.29
5	89.59	531.53	-1.56

Table 3B - Center of Pressure of Distributed Loads On the 15 Slices
Only Applicable Slices Listed

Slice No.	X-Dload (ft)	Y-Dload (ft)	Dist-Load (lbs)	Dload-Moment (ft/lbs)
15	123.28	542.40	0.138689E+03	0.000000E+00

TOTAL WEIGHT OF SLIDING MASS = 38135.92(lbs)

EFFECTIVE WEIGHT OF SLIDING MASS = 22505.29(lbs)

TOTAL AREA OF SLIDING MASS = 303.22(ft2)

TABLE 4 - SOIL STRENGTH & SOIL OPTIONS DATA ON THE 15 SLICES

Slice No.	Soil Type	Cohesion (psf)	Phi(Deg)	Options
1	4	73.00	17.83	R
2	4	73.00	17.83	R
3	4	73.00	17.83	R
4	4	73.00	17.83	R
5	4	73.00	17.83	R
6	4	73.00	17.83	R
7	4	73.00	17.83	R
8	4	73.00	17.83	R
9	4	73.00	17.83	R
10	4	73.00	17.83	R
11	4	73.00	17.83	R
12	4	73.00	17.83	R
13	1	40.00	25.00	
14	1	40.00	25.00	
15	1	40.00	25.00	

SOIL OPTIONS: A = ANISOTROPIC, C = CURVED STRENGTH ENVELOPE (TANGENT PHI),
F = FIBER-REINFORCED SOIL (FRS), N = NONLINEAR UNDRAINED SHEAR STRENGTH,
R = RAPID DRAWDOWN SHEAR STRENGTH
NOTE: Phi and C in Table 4 are modified values based on specified
Soil Options (if any). Zero values indicate that the normal stress = 0.0

TABLE 5 - Total Base Stress Data on the 15 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Stress (psf)	Total Vert. Stress (psf)	Total Normal/Vert. Stress Ratio
1	-16.51	75.18	4.54	659.94	485.02	1.361
2	-16.51	79.53	4.54	911.35	756.21	1.205
3	10.25	83.65	3.96	871.50	890.51	0.979
4	10.25	87.55	3.96	863.41	887.91	0.972
5	10.25	89.61	0.23	858.87	885.79	0.970
6	10.25	92.29	5.20	895.61	923.01	0.970
7	10.25	97.41	5.20	969.98	999.10	0.971
8	10.25	102.53	5.20	1042.67	1075.20	0.970
9	29.35	106.81	3.94	870.72	1052.28	0.827

10	29.35	109.99	3.35	781.29	951.21	0.821
11	36.50	112.96	3.77	637.92	837.07	0.762
12	36.50	116.00	3.77	511.94	688.99	0.743
13	36.50	117.72	0.50	440.26	605.06	0.728
14	41.70	119.57	4.43	326.43	484.52	0.674
15	47.43	121.70	1.41	172.09	330.58	0.521

TABLE 5A - Total Base Force Data on the 15 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Force (lbs)	Total Vert. Force (lbs)	Total Normal/Vert. Force Ratio
1	-16.51	75.18	4.54	2994.92	2110.31	1.419
2	-16.51	79.53	4.54	4135.84	3290.26	1.257
3	10.25	83.65	3.96	3452.64	3471.65	0.995
4	10.25	87.55	3.96	3420.58	3461.54	0.988
5	10.25	89.61	0.23	198.61	201.56	0.985
6	10.25	92.29	5.20	4660.42	4726.37	0.986
7	10.25	97.41	5.20	5047.42	5116.04	0.987
8	10.25	102.53	5.20	5425.67	5505.72	0.985
9	29.35	106.81	3.94	3432.43	3615.90	0.949
10	29.35	109.99	3.35	2617.39	2777.74	0.942
11	36.50	112.96	3.77	2407.71	2539.54	0.948
12	36.50	116.00	3.77	1932.21	2090.28	0.924
13	36.50	117.72	0.50	221.85	245.07	0.905
14	41.70	119.57	4.43	1446.17	1602.81	0.902
15	47.43	121.70	1.41	243.04	315.86	0.769

TABLE 6 - Effective and Base Shear Stress Data on the 15 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Stress (psf)	Available Shear Strength (psf)	Mobilized Shear Stress (psf)	Rapid Drawdown Strength Type
1	-16.51	75.18	4.54	188.66	133.68	97.68	Drained
2	-16.51	79.53	4.54	379.75	195.14	142.59	Drained
3	10.25	83.65	3.96	305.52	171.27	125.15	Drained
4	10.25	87.55	3.96	333.70	180.33	131.77	Drained
5	10.25	89.61	0.23	348.59	185.12	135.27	Drained
6	10.25	92.29	5.20	428.71	210.89	154.10	Drained
7	10.25	97.41	5.20	587.35	261.92	191.39	Drained
8	10.25	102.53	5.20	746.00	312.95	228.67	Drained
9	29.35	106.81	3.94	693.84	296.17	216.41	Drained
10	29.35	109.99	3.35	686.17	293.70	214.61	Drained
11	36.50	112.96	3.77	554.21	251.26	183.60	Drained
12	36.50	116.00	3.77	452.35	218.49	159.66	Drained
13	36.50	117.72	0.50	440.26	313.64	229.18	Drained

14	41.70	119.57	4.43	326.43	307.92	225.00	Drained
15	47.43	121.70	1.41	172.09	304.55	222.54	Drained

TABLE 6A - Effective and Base Shear Force Data on the 15 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Force (lbs)	Available Shear Force (lbs)	Mobilized Shear Force (lbs)
1	-16.51	75.18	4.54	1144.52	1322.12	966.09
2	-16.51	79.53	4.54	1756.06	966.73	706.40
3	10.25	83.65	3.96	1215.63	872.98	637.89
4	10.25	87.55	3.96	1326.73	888.50	649.24
5	10.25	89.61	0.23	80.99	56.75	41.47
6	10.25	92.29	5.20	2241.74	1499.98	1096.05
7	10.25	97.41	5.20	3066.21	1725.85	1261.09
8	10.25	102.53	5.20	3881.93	1628.46	1189.93
9	29.35	106.81	3.94	2735.15	1167.51	853.11
10	29.35	109.99	3.35	2298.72	983.92	718.96
11	36.50	112.96	3.77	2091.78	948.33	692.95
12	36.50	116.00	3.77	1672.17	931.97	681.00
13	36.50	117.72	0.50	221.85	123.60	90.32
14	41.70	119.57	4.43	1446.17	851.57	622.25
15	47.43	121.70	1.41	243.04	169.82	124.09

SUM OF MOMENTS = -0.119102E-02 (ft/lbs);Imbalance (Fraction of Total Weight) = -0.3123091E-07
SUM OF FORCES = -.142425E-05 (lbs);Imbalance (Fraction of Total Weight) = -0.3734666E-10

Sum of Available Shear Forces = 18159.94(lbs)

Sum of Mobilized Shear Forces = 13269.63(lbs)

FS Balance Check: FS = 1.368534

**** END OF GEOSTASE OUTPUT FOR RAPID DRAWDOWN STAGE 1 ****

Iter. No.	Theta (deg) (fx=1.0)	FS (Moment)	FS (Force)	Lambda	Delta FS
1	10.0000	1.458106	1.276097	0.176	0.1820090E+00
2	13.3000	1.360494	1.294292	0.236	0.6620182E-01
3	15.1846	1.282455	1.305107	0.271	0.2265248E-01
4	14.7046	1.304254	1.302320	0.262	0.1933626E-02
5	14.7428	1.302571	1.302541	0.263	0.3000050E-04
6	14.7434	1.302544	1.302544	0.263	0.2894012E-07

Factor Of Safety For The Preceding Specified Surface = 1.303
Theta (fx = 1.0) = 14.74 Deg   Lambda = 0.263

The Spencer Method Has Been Selected For FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR ANALYSIS METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 10.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = -45.00 ; Maximum theta(deg) = 45.00
Theta convergence Step Factor = 1000.00
Maximum number of iterations = 20
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance(if Applicable) = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

Tension Crack Water Force = 178.82(lbs)

Specified Tension Crack Water Depth Factor = 1.000

Depth of Tension Crack (zo) at Side of Last Slice = 2.394(ft)

Depth of Water in Tension Crack = 2.394(ft)

Theoretical Tension Crack Depth = 1.046(ft)

NOTE: In Table 1 following, when a tension crack with water is present on the first slice (right facing slope) or on the last slice (left facing slope), the "side force" in the tension crack is set equal to the water pressure resultant.

*** Table 1 - Line of Thrust(if applicable) and Slice Force Data ***

Slice No.	X Coord.	Y Coord.	h/H	Side Force (lbs)	fx	Force Angle (Deg)	Vert. Shear Force(lbs)
1	77.35	525.93	0.444	837.38	1.000	14.74	213.1
2	81.70	525.47	0.374	2454.13	1.000	14.74	624.6
3	85.60	526.38	0.372	2585.44	1.000	14.74	658.0
4	89.50	527.31	0.372	2690.60	1.000	14.74	684.7
5	89.73	527.37	0.373	2695.94	1.000	14.74	686.1
6	94.85	528.56	0.369	2861.40	1.000	14.74	728.2
7	99.97	529.66	0.355	3123.30	1.000	14.74	794.9
8	105.09	530.68	0.335	3483.79	1.000	14.74	886.6

9	108.53	532.38	0.339	2647.95	1.000	14.74	673.9
10	111.45	533.89	0.352	2012.66	1.000	14.74	512.2
11	114.48	536.13	0.419	1156.87	1.000	14.74	294.4
12	117.51	539.58	0.754	489.15	1.000	14.74	124.5
13	117.92	540.17	0.839	432.82	1.000	14.74	110.1
14	121.23	506.70	0.000-	-43.30	1.000	14.74	-11.0
15	122.18	540.80	0.798	178.82	1.000	14.74	-80.1

NOTE: A value of 0.000- for h/H indicates that the line of thrust is at or below the lower boundary of the sliding mass. A value of 1.000+ for h/H indicates that the line of thrust is at or above the upper boundary of the sliding mass.

Table 2 - Geometry Data on the 15 Slices

Slice No.	Width (ft)	Height (ft)	X-Cntr (ft)	Y-Cntr-Base (ft)	Y-Cntr-Top (ft)	Alpha (deg)	Beta (deg)	Base Length (ft)
1	4.35	1.37	75.18	525.36	526.73	-16.51	18.43	4.54
2	4.35	4.11	79.53	524.07	528.18	-16.51	18.43	4.54
3	3.90	5.78	83.65	523.77	529.55	10.25	18.43	3.96
4	3.90	6.37	87.55	524.48	530.85	10.25	18.43	3.96
5	0.23	6.69	89.61	524.85	531.54	10.25	18.43	0.23
6	5.12	7.09	92.29	525.33	532.43	10.25	18.43	5.20
7	5.12	7.88	97.41	526.26	534.14	10.25	18.43	5.20
8	5.12	8.66	102.53	527.19	535.84	10.25	18.43	5.20
9	3.44	8.65	106.81	528.61	537.27	29.35	18.43	3.94
10	2.92	7.93	109.99	530.40	538.33	29.35	18.43	3.35
11	3.03	6.98	112.96	532.35	539.32	36.50	18.43	3.77
12	3.03	5.74	116.00	534.59	540.33	36.50	18.43	3.77
13	0.41	5.04	117.72	535.86	540.91	36.50	18.43	0.50
14	3.31	4.04	119.57	537.49	541.52	41.70	18.43	4.43
15	0.96	2.75	121.70	539.48	542.23	47.43	18.43	1.41

Table 2A - Coordinates of Slice Points Defining the Slip Surface

Point No.	X-Pt (ft)	Y-Pt (ft)
1	73.000960	526.000320
2	77.351963	524.710560
3	81.702965	523.420801
4	85.601483	524.125648
5	89.500000	524.830495
6	89.727554	524.871636
7	94.848187	525.797440
8	99.968820	526.723243

9	105.089453	527.649047
10	108.525694	529.580947
11	111.445903	531.222726
12	114.479746	533.468009
13	117.513590	535.713292
14	117.918626	536.013052
15	121.226644	538.960000
16	122.182136	540.000000

Table 3 - Force and Pore Pressure Data On The 15 Slices (Excluding Reinforcement)

Slice No.	Weight (lbs)	Ubeta Force Top (lbs)	Ubeta Stress Top (psf)	Ualpha Force Bot (lbs)	Pore Pressure (psf)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Distributed Load (lbs)
1	715.3	0.0	0.0	74.6	16.4	0.0	0.0	0.00
2	2146.0	0.0	0.0	223.8	49.3	0.0	0.0	0.00
3	2702.9	0.0	0.0	274.7	69.3	0.0	0.0	0.00
4	2981.0	0.0	0.0	302.9	76.5	0.0	0.0	0.00
5	182.6	0.0	0.0	18.6	80.2	0.0	0.0	0.00
6	4359.6	0.0	0.0	443.0	85.1	0.0	0.0	0.00
7	4839.5	0.0	0.0	491.8	94.5	0.0	0.0	0.00
8	5319.5	0.0	0.0	540.6	103.9	0.0	0.0	0.00
9	3568.5	0.0	0.0	409.4	103.9	0.0	0.0	0.00
10	2777.7	0.0	0.0	318.7	95.1	0.0	0.0	0.00
11	2539.5	0.0	0.0	315.9	83.7	0.0	0.0	0.00
12	2090.3	0.0	0.0	260.0	68.9	0.0	0.0	0.00
13	245.1	0.0	0.0	0.0	0.0	0.0	0.0	0.00
14	1602.8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
15	315.9	0.0	0.0	0.0	0.0	0.0	0.0	0.00

Table 3A - Center of Pressure of Water Loads On the 15 Slices
Only Applicable Slices Listed

Slice No.	X-Ubeta (ft)	Y-Ubeta (ft)	Ubeta-Moment (ft/lbs)

Table 3B - Center of Pressure of Distributed Loads On the 15 Slices
Only Applicable Slices Listed

Slice No.	X-Dload (ft)	Y-Dload (ft)	Dist-Load (lbs)	Dload-Moment (ft/lbs)
15	123.28	542.40	0.138689E+03	0.000000E+00

TOTAL WEIGHT OF SLIDING MASS = 36386.17(lbs)

EFFECTIVE WEIGHT OF SLIDING MASS = 32963.93(lbs)

TOTAL AREA OF SLIDING MASS = 303.22(ft2)

TABLE 4 - SOIL STRENGTH & SOIL OPTIONS DATA ON THE 15 SLICES

Slice No.	Soil Type	Cohesion (psf)	Phi(Deg)	Options
1	4	150.79	0.00	R
2	4	221.64	0.00	R
3	4	201.14	0.00	R
4	4	208.84	0.00	R
5	4	212.96	0.00	R
6	4	235.44	0.00	R
7	4	280.88	0.00	R
8	4	326.86	0.00	R
9	4	310.52	0.00	R
10	4	289.02	0.00	R
11	4	244.68	0.00	R
12	4	212.45	0.00	R
13	1	40.00	25.00	
14	1	40.00	25.00	
15	1	40.00	25.00	

SOIL OPTIONS: A = ANISOTROPIC, C = CURVED STRENGTH ENVELOPE (TANGENT PHI),
F = FIBER-REINFORCED SOIL (FRS), N = NONLINEAR UNDRAINED SHEAR STRENGTH,
R = RAPID DRAWDOWN SHEAR STRENGTH
NOTE: Phi and C in Table 4 are modified values based on specified
Soil Options (if any). Zero values indicate that the normal stress = 0.0

TABLE 5 - Total Base Stress Data on the 15 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Stress (psf)	Total Vert. Stress (psf)	Total Normal/Vert. Stress Ratio
1	-16.51	75.18	4.54	246.86	164.41	1.502
2	-16.51	79.53	4.54	638.22	493.22	1.294
3	10.25	83.65	3.96	673.95	693.30	0.972
4	10.25	87.55	3.96	742.54	764.66	0.971
5	10.25	89.61	0.23	778.83	802.42	0.971
6	10.25	92.29	5.20	826.91	851.37	0.971
7	10.25	97.41	5.20	919.13	945.10	0.973
8	10.25	102.53	5.20	1011.37	1038.83	0.974
9	29.35	106.81	3.94	842.54	1038.50	0.811
10	29.35	109.99	3.35	770.57	951.21	0.810
11	36.50	112.96	3.77	624.90	837.07	0.747

12	36.50	116.00	3.77	510.75	688.99	0.741
13	36.50	117.72	0.50	432.38	605.06	0.715
14	41.70	119.57	4.43	318.85	484.52	0.658
15	47.43	121.70	1.41	161.82	330.58	0.490

TABLE 5A - Total Base Force Data on the 15 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Force (lbs)	Total Vert. Force (lbs)	Total Normal/Vert. Force Ratio
1	-16.51	75.18	4.54	1120.30	715.33	1.566
2	-16.51	79.53	4.54	2896.33	2145.99	1.350
3	10.25	83.65	3.96	2670.02	2702.85	0.988
4	10.25	87.55	3.96	2941.73	2981.04	0.987
5	10.25	89.61	0.23	180.10	182.59	0.986
6	10.25	92.29	5.20	4302.97	4359.55	0.987
7	10.25	97.41	5.20	4782.82	4839.51	0.988
8	10.25	102.53	5.20	5262.84	5319.46	0.989
9	29.35	106.81	3.94	3321.36	3568.55	0.931
10	29.35	109.99	3.35	2581.46	2777.74	0.929
11	36.50	112.96	3.77	2358.58	2539.54	0.929
12	36.50	116.00	3.77	1927.74	2090.28	0.922
13	36.50	117.72	0.50	217.88	245.07	0.889
14	41.70	119.57	4.43	1412.59	1602.81	0.881
15	47.43	121.70	1.41	228.54	315.86	0.724

TABLE 6 - Effective and Base Shear Stress Data on the 15 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Stress (psf)	Available Shear Strength (psf)	Mobilized Shear Stress (psf)	Rapid Drawdown Strength Type
1	-16.51	75.18	4.54	188.66	171.66	131.79	Undrained
2	-16.51	79.53	4.54	379.75	221.64	170.16	Undrained
3	10.25	83.65	3.96	305.52	201.14	154.42	Undrained
4	10.25	87.55	3.96	333.70	208.84	160.34	Undrained
5	10.25	89.61	0.23	348.59	212.96	163.49	Undrained
6	10.25	92.29	5.20	428.71	235.44	180.75	Undrained
7	10.25	97.41	5.20	587.35	280.88	215.64	Undrained
8	10.25	102.53	5.20	746.00	326.86	250.94	Undrained
9	29.35	106.81	3.94	693.84	311.70	239.30	Undrained
10	29.35	109.99	3.35	686.17	309.48	237.60	Undrained
11	36.50	112.96	3.77	554.21	271.33	208.31	Undrained
12	36.50	116.00	3.77	452.35	242.15	185.91	Undrained
13	36.50	117.72	0.50	440.26	336.46	258.31	Undrained
14	41.70	119.57	4.43	326.43	331.64	254.61	Undrained
15	47.43	121.70	1.41	172.09	328.79	252.42	Undrained

TABLE 6A - Effective and Base Shear Force Data on the 15 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Force (lbs)	Available Shear Force (lbs)	Mobilized Shear Force (lbs)
1	-16.51	75.18	4.54	1045.69	667.62	512.55
2	-16.51	79.53	4.54	2672.51	1005.84	772.21
3	10.25	83.65	3.96	2395.35	796.87	611.78
4	10.25	87.55	3.96	2638.79	827.38	635.21
5	10.25	89.61	0.23	161.54	49.24	37.81
6	10.25	92.29	5.20	3859.95	1225.14	940.58
7	10.25	97.41	5.20	4291.03	1461.61	1122.12
8	10.25	102.53	5.20	4722.27	1700.84	1305.79
9	29.35	106.81	3.94	2911.97	1224.39	940.00
10	29.35	109.99	3.35	2262.80	972.37	746.51
11	36.50	112.96	3.77	2042.64	932.53	715.93
12	36.50	116.00	3.77	1667.69	811.93	623.34
13	36.50	117.72	0.50	217.88	121.75	93.47
14	41.70	119.57	4.43	1412.59	835.91	641.75
15	47.43	121.70	1.41	228.54	163.06	125.19

SUM OF MOMENTS = -0.245183E-04 (ft/lbs);Imbalance (Fraction of Total Weight) = -0.6738365E-09
SUM OF FORCES = 0.260596E-06 (lbs);Imbalance (Fraction of Total Weight) = 0.7161953E-11

Sum of Available Shear Forces = 19467.82(lbs)

Sum of Mobilized Shear Forces = 14946.00(lbs)

FS Balance Check: FS = 1.302544

**** END OF GEOSTASE OUTPUT FOR RAPID DRAWDOWN STAGE 2 ****

Iter. No.	Theta (deg) (fx=1.0)	FS (Moment)	FS (Force)	Lambda	Delta FS
1	10.0000	1.432396	1.241214	0.176	0.1911820E+00
2	13.3000	1.333431	1.256064	0.236	0.7736694E-01
3	15.5410	1.237060	1.266876	0.278	0.2981613E-01
4	14.9182	1.266891	1.263806	0.266	0.3084758E-02
5	14.9772	1.264177	1.264094	0.268	0.8295680E-04
6	14.9788	1.264102	1.264102	0.268	0.2406950E-06

Factor Of Safety For The Preceding Specified Surface = 1.264
Theta (fx = 1.0) = 14.98 Deg Lambda = 0.268

The Spencer Method Has Been Selected For FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR ANALYSIS METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 10.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = -45.00 ; Maximum theta(deg) = 45.00
Theta convergence Step Factor = 1000.00
Maximum number of iterations = 20
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance(if Applicable) = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

Tension Crack Water Force = 178.82(lbs)

Specified Tension Crack Water Depth Factor = 1.000

Depth of Tension Crack (zo) at Side of Last Slice = 2.394(ft)

Depth of Water in Tension Crack = 2.394(ft)

Theoretical Tension Crack Depth = 1.046(ft)

NOTE: In Table 1 following, when a tension crack with water is present on the first slice (right facing slope) or on the last slice (left facing slope), the "side force" in the tension crack is set equal to the water pressure resultant.

*** Table 1 - Line of Thrust(if applicable) and Slice Force Data ***

Slice No.	X Coord.	Y Coord.	h/H	Side Force (lbs)	fx	Force Angle (Deg)	Vert. Shear Force(lbs)
1	77.35	525.94	0.448	862.56	1.000	14.98	222.9
2	81.70	525.49	0.378	2510.91	1.000	14.98	649.0
3	85.60	526.41	0.376	2660.93	1.000	14.98	687.7
4	89.50	527.34	0.376	2785.51	1.000	14.98	719.9
5	89.73	527.40	0.377	2792.00	1.000	14.98	721.6
6	94.85	528.59	0.373	2986.21	1.000	14.98	771.8
7	99.97	529.69	0.358	3282.45	1.000	14.98	848.4
8	105.09	530.71	0.338	3682.90	1.000	14.98	951.9
9	108.53	532.35	0.335	2874.77	1.000	14.98	743.0
10	111.45	533.76	0.334	2261.49	1.000	14.98	584.5

11	114.48	535.64	0.341	1427.43	1.000	14.98	368.9
12	117.51	537.66	0.380	778.58	1.000	14.98	201.2
13	117.92	537.91	0.382	724.92	1.000	14.98	187.4
14	121.23	540.26	0.419	267.46	1.000	14.98	69.1
15	122.18	540.80	0.798	178.82	1.000	14.98	0.0

NOTE: A value of 0.000- for h/H indicates that the line of thrust is at or below the lower boundary of the sliding mass. A value of 1.000+ for h/H indicates that the line of thrust is at or above the upper boundary of the sliding mass.

Table 2 - Geometry Data on the 15 Slices

Slice No.	Width (ft)	Height (ft)	X-Cntr (ft)	Y-Cntr-Base (ft)	Y-Cntr-Top (ft)	Alpha (deg)	Beta (deg)	Base Length (ft)
1	4.35	1.37	75.18	525.36	526.73	-16.51	18.43	4.54
2	4.35	4.11	79.53	524.07	528.18	-16.51	18.43	4.54
3	3.90	5.78	83.65	523.77	529.55	10.25	18.43	3.96
4	3.90	6.37	87.55	524.48	530.85	10.25	18.43	3.96
5	0.23	6.69	89.61	524.85	531.54	10.25	18.43	0.23
6	5.12	7.09	92.29	525.33	532.43	10.25	18.43	5.20
7	5.12	7.88	97.41	526.26	534.14	10.25	18.43	5.20
8	5.12	8.66	102.53	527.19	535.84	10.25	18.43	5.20
9	3.44	8.65	106.81	528.61	537.27	29.35	18.43	3.94
10	2.92	7.93	109.99	530.40	538.33	29.35	18.43	3.35
11	3.03	6.98	112.96	532.35	539.32	36.50	18.43	3.77
12	3.03	5.74	116.00	534.59	540.33	36.50	18.43	3.77
13	0.41	5.04	117.72	535.86	540.91	36.50	18.43	0.50
14	3.31	4.04	119.57	537.49	541.52	41.70	18.43	4.43
15	0.96	2.75	121.70	539.48	542.23	47.43	18.43	1.41

Table 2A - Coordinates of Slice Points Defining the Slip Surface

Point No.	X-Pt (ft)	Y-Pt (ft)
1	73.000960	526.000320
2	77.351963	524.710560
3	81.702965	523.420801
4	85.601483	524.125648
5	89.500000	524.830495
6	89.727554	524.871636
7	94.848187	525.797440
8	99.968820	526.723243
9	105.089453	527.649047
10	108.525694	529.580947

11	111.445903	531.222726
12	114.479746	533.468009
13	117.513590	535.713292
14	117.918626	536.013052
15	121.226644	538.960000
16	122.182136	540.000000

Table 3 - Force and Pore Pressure Data On The 15 Slices (Excluding Reinforcement)

Slice No.	Weight (lbs)	Ubeta Force Top (lbs)	Ubeta Stress Top (psf)	Ualpha Force Bot (lbs)	Pore Pressure (psf)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Distributed Load (lbs)
1	715.3	0.0	0.0	74.6	16.4	0.0	0.0	0.00
2	2146.0	0.0	0.0	223.8	49.3	0.0	0.0	0.00
3	2702.9	0.0	0.0	274.7	69.3	0.0	0.0	0.00
4	2981.0	0.0	0.0	302.9	76.5	0.0	0.0	0.00
5	182.6	0.0	0.0	18.6	80.2	0.0	0.0	0.00
6	4359.6	0.0	0.0	443.0	85.1	0.0	0.0	0.00
7	4839.5	0.0	0.0	491.8	94.5	0.0	0.0	0.00
8	5319.5	0.0	0.0	540.6	103.9	0.0	0.0	0.00
9	3568.5	0.0	0.0	409.4	103.9	0.0	0.0	0.00
10	2777.7	0.0	0.0	318.7	95.1	0.0	0.0	0.00
11	2539.5	0.0	0.0	315.9	83.7	0.0	0.0	0.00
12	2090.3	0.0	0.0	260.0	68.9	0.0	0.0	0.00
13	245.1	0.0	0.0	0.0	0.0	0.0	0.0	0.00
14	1602.8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
15	315.9	0.0	0.0	0.0	0.0	0.0	0.0	0.00

Table 3A - Center of Pressure of Water Loads On the 15 Slices
Only Applicable Slices Listed

Slice No.	X-Ubeta (ft)	Y-Ubeta (ft)	Ubeta-Moment (ft/lbs)

Table 3B - Center of Pressure of Distributed Loads On the 15 Slices
Only Applicable Slices Listed

Slice No.	X-Dload (ft)	Y-Dload (ft)	Dist-Load (lbs)	Dload-Moment (ft/lbs)
15	123.28	542.40	0.138689E+03	0.000000E+00

TOTAL WEIGHT OF SLIDING MASS = 36386.17(lbs)

EFFECTIVE WEIGHT OF SLIDING MASS = 32963.93(lbs)

TOTAL AREA OF SLIDING MASS = 303.22(ft2)

TABLE 4 - SOIL STRENGTH & SOIL OPTIONS DATA ON THE 15 SLICES

Slice No.	Soil Type	Cohesion (psf)	Phi(Deg)	Options
1	4	73.00	17.83	R
2	4	221.64	0.00	R
3	4	201.14	0.00	R
4	4	208.84	0.00	R
5	4	212.96	0.00	R
6	4	235.44	0.00	R
7	4	280.88	0.00	R
8	4	326.86	0.00	R
9	4	73.00	17.83	R
10	4	73.00	17.83	R
11	4	73.00	17.83	R
12	4	73.00	17.83	R
13	1	40.00	25.00	
14	1	40.00	25.00	
15	1	40.00	25.00	

SOIL OPTIONS: A = ANISOTROPIC, C = CURVED STRENGTH ENVELOPE (TANGENT PHI),
F = FIBER-REINFORCED SOIL (FRS), N = NONLINEAR UNDRAINED SHEAR STRENGTH,
R = RAPID DRAWDOWN SHEAR STRENGTH
NOTE: Phi and C in Table 4 are modified values based on specified
Soil Options (if any). Zero values indicate that the normal stress = 0.0

TABLE 5 - Total Base Stress Data on the 15 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Stress (psf)	Total Vert. Stress (psf)	Total Normal/Vert. Stress Ratio
1	-16.51	75.18	4.54	250.41	164.41	1.523
2	-16.51	79.53	4.54	643.11	493.22	1.304
3	10.25	83.65	3.96	674.48	693.30	0.973
4	10.25	87.55	3.96	743.05	764.66	0.972
5	10.25	89.61	0.23	779.34	802.42	0.971
6	10.25	92.29	5.20	827.50	851.37	0.972
7	10.25	97.41	5.20	919.88	945.10	0.973
8	10.25	102.53	5.20	1012.29	1038.83	0.974
9	29.35	106.81	3.94	839.95	1038.50	0.809
10	29.35	109.99	3.35	768.18	951.21	0.808
11	36.50	112.96	3.77	621.92	837.07	0.743
12	36.50	116.00	3.77	508.24	688.99	0.738
13	36.50	117.72	0.50	430.01	605.06	0.711

14	41.70	119.57	4.43	316.56	484.52	0.653
15	47.43	121.70	1.41	159.68	330.58	0.483

TABLE 5A - Total Base Force Data on the 15 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Force (lbs)	Total Vert. Force (lbs)	Total Normal/Vert. Force Ratio
1	-16.51	75.18	4.54	1136.39	715.33	1.589
2	-16.51	79.53	4.54	2918.51	2145.99	1.360
3	10.25	83.65	3.96	2672.10	2702.85	0.989
4	10.25	87.55	3.96	2943.76	2981.04	0.987
5	10.25	89.61	0.23	180.22	182.59	0.987
6	10.25	92.29	5.20	4306.02	4359.55	0.988
7	10.25	97.41	5.20	4786.73	4839.51	0.989
8	10.25	102.53	5.20	5267.62	5319.46	0.990
9	29.35	106.81	3.94	3311.16	3568.55	0.928
10	29.35	109.99	3.35	2573.47	2777.74	0.926
11	36.50	112.96	3.77	2347.34	2539.54	0.924
12	36.50	116.00	3.77	1918.27	2090.28	0.918
13	36.50	117.72	0.50	216.68	245.07	0.884
14	41.70	119.57	4.43	1402.46	1602.81	0.875
15	47.43	121.70	1.41	225.51	315.86	0.714

TABLE 6 - Effective and Base Shear Stress Data on the 15 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Stress (psf)	Available Shear Strength (psf)	Mobilized Shear Stress (psf)	Rapid Drawdown Strength Type
1	-16.51	75.18	4.54	241.86	150.79	119.29	Drained
2	-16.51	79.53	4.54	588.90	221.64	175.33	Undrained
3	10.25	83.65	3.96	604.62	201.14	159.12	Undrained
4	10.25	87.55	3.96	666.07	208.84	165.21	Undrained
5	10.25	89.61	0.23	698.59	212.96	168.47	Undrained
6	10.25	92.29	5.20	741.78	235.44	186.25	Undrained
7	10.25	97.41	5.20	824.62	280.88	222.20	Undrained
8	10.25	102.53	5.20	907.49	326.86	258.57	Undrained
9	29.35	106.81	3.94	738.47	310.52	245.65	Drained
10	29.35	109.99	3.35	671.60	289.02	228.63	Drained
11	36.50	112.96	3.77	533.76	244.68	193.56	Drained
12	36.50	116.00	3.77	433.57	212.45	168.07	Drained
13	36.50	117.72	0.50	432.38	241.62	191.14	Drained
14	41.70	119.57	4.43	318.85	188.68	149.26	Drained
15	47.43	121.70	1.41	161.82	115.46	91.34	Drained

TABLE 6A - Effective and Base Shear Force Data on the 15 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Force (lbs)	Available Shear Force (lbs)	Mobilized Shear Force (lbs)
1	-16.51	75.18	4.54	1061.78	672.80	532.23
2	-16.51	79.53	4.54	2694.68	1005.84	795.69
3	10.25	83.65	3.96	2397.43	796.87	630.39
4	10.25	87.55	3.96	2640.82	827.38	654.52
5	10.25	89.61	0.23	161.66	49.24	38.96
6	10.25	92.29	5.20	3863.00	1225.14	969.18
7	10.25	97.41	5.20	4294.93	1461.61	1156.24
8	10.25	102.53	5.20	4727.05	1700.84	1345.50
9	29.35	106.81	3.94	2901.77	1221.10	965.99
10	29.35	109.99	3.35	2254.81	969.80	767.18
11	36.50	112.96	3.77	2031.40	928.91	734.84
12	36.50	116.00	3.77	1658.22	808.88	639.88
13	36.50	117.72	0.50	216.68	121.20	95.87
14	41.70	119.57	4.43	1402.46	831.19	657.53
15	47.43	121.70	1.41	225.51	161.65	127.88

SUM OF MOMENTS = -0.189944E-03 (ft/lbs);Imbalance (Fraction of Total Weight) = -0.5220228E-08
SUM OF FORCES = 0.191922E-06 (lbs);Imbalance (Fraction of Total Weight) = 0.5274595E-11

Sum of Available Shear Forces = 19466.06(lbs)

Sum of Mobilized Shear Forces = 15399.12(lbs)

FS Balance Check: FS = 1.264102

**** END OF GEOSTASE OUTPUT FOR RAPID DRAWDOWN STAGE 3 ****

CASE STUDY-2
SUMMARY OF SLOPE STABILITY ANALYSES
PGBT – Roadway Embankment
Dallas County, Texas

Analysis Plate Number	Condition Analyzed	Calculated Factor of Safety	Minimum Recommended Factor of Safety
Plate C.11	Non-Reinforced Condition – Heavy Rainfall	1.066 (NG)	1.3
Plate C.12	Reinforced Condition – FRS - Normal Rainfall	1.546 (OK)	1.5
Plate C.13	Reinforced Condition – FRS - Heavy Rainfall	1.313 (OK)	1.3

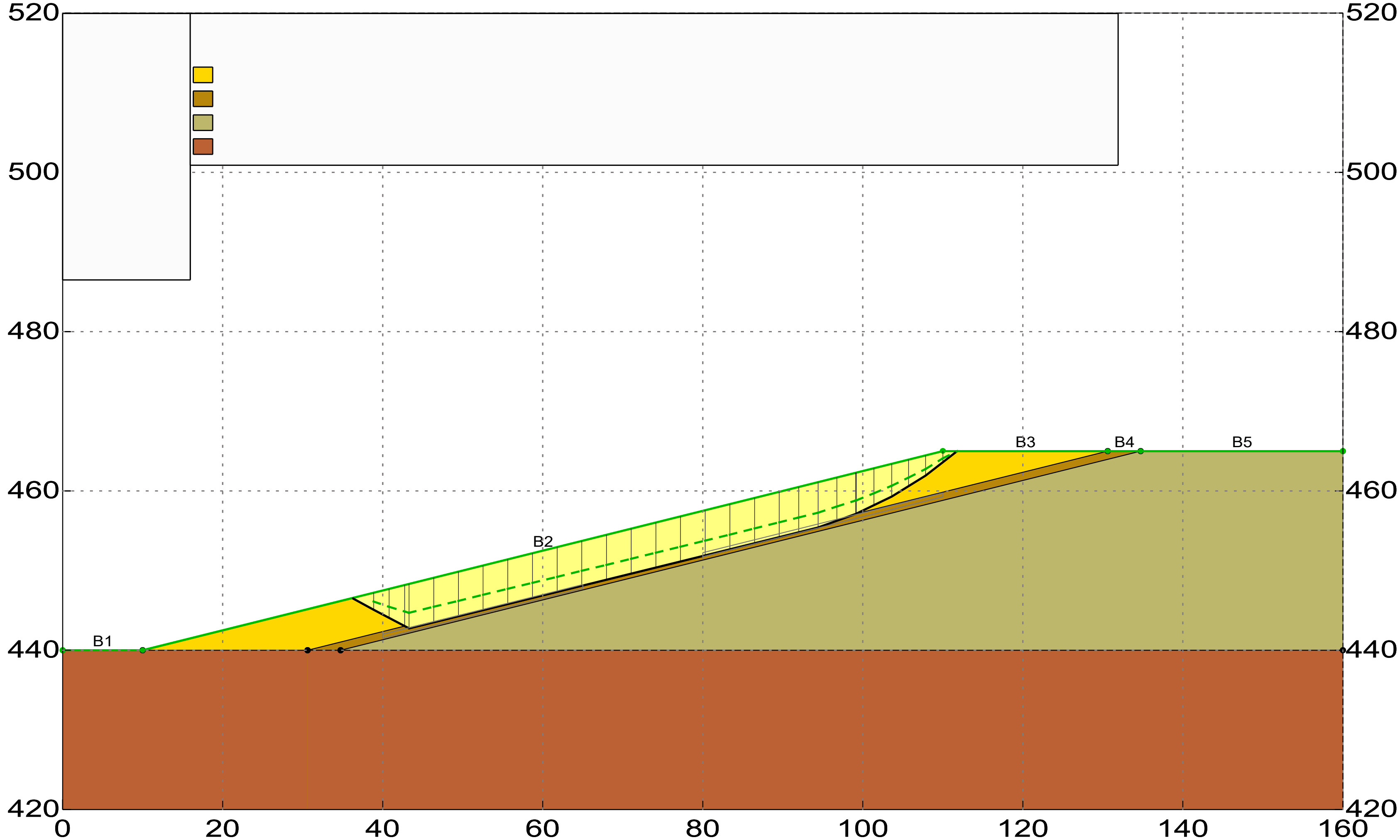
FRS content = 6.0 lb/yd^3

Note: Factor of Safety values are expressed to 3 decimal places to provide relative comparisons among the various analyses. This does not imply actual accuracy to 3 decimal places. Factor of safety values rounded to one decimal place should be considered as the typical actual level of accuracy for the analyses. **FS = Calculated Factor of Safety Value, NG= No Good, OK = Acceptable Value of Calculated FS**

PGBT - ROADWAY EMBANKEMENT
Non-Reinforced Condition - Long-Term - Heavy Rainfall

GREGORY GEOTECHNICAL - GHG

\PGBT-Non-FRS-Heavy Rainfall.gsd



GEOSTASE FS = 1.066

Spencer Method

GEOSTASE Slope Stability Analysis

GREGORY GEOTECHNICAL

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

PLATE C.11

PGBT-Non-FRS-Heavy Rainfall.OUT
*** GEOSTASE ***

****
SLOPE STABILITY ANALYSIS SOFTWARE
Simplified Bishop, Simplified Janbu, or General Equilibrium (GE) Options.
(Spencer, Morgenstern-Price, USACE, and Lowe & Karafiath)
Including Pier/Pile, Planar Reinf, Nail, Tieback, Line Loads
Nonlinear Undrained Shear Strength, Curved Strength Envelope,
Anisotropic , Fiber-Reinforced , Distributed Loads, Water
Surfaces, Pseudo-Static & Newmark Earthquake, and Applied Forces.
****

Analysis Date:
Analysis Time:
Analysis By: GREGORY GEOTECHNICAL - GHG

Input File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Stufy - 2\PGBT-Non-FRS-Heavy Rainfall.gsd

Output File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Stufy - 2\PGBT-Non-FRS-Heavy Rainfall.OUT

Unit System: English

PROJECT: PGBT - ROADWAY EMBANKEMENT

DESCRIPTION: Non-Reinforced Condition - Long-Term - Heavy Rainfall

BOUNDARY DATA

5 Surface Boundaries
10 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	440.000	10.000	440.000	4
2	10.000	440.000	110.000	465.000	1
3	110.000	465.000	130.610	465.000	1
4	130.610	465.000	134.730	465.000	2
5	134.730	465.000	160.000	465.000	3
6	10.000	440.000	30.610	440.000	4
7	30.610	440.000	130.610	465.000	2
8	30.610	440.000	34.730	440.000	4
9	34.730	440.000	134.730	465.000	3
10	34.730	440.000	160.000	440.000	4

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 420.000(ft)

MOHR-COULOMB SOIL PARAMETERS

4 Type(s) of Soil Defined

Soil Number Moist Saturated Cohesion Friction Pore Pressure Water Water

and Description	Unit Wt. (pcf)	Unit Wt. (pcf)	Intercept (psf)	Angle (deg)	Pressure Ratio(ru)	Constant (psf)	Surface No.	Option
1 Weathered Fill	125.0	130.0	100.00	20.00	0.280	0.0	0	0
2 Weak Zone	125.0	130.0	0.00	20.00	0.280	0.0	0	0
3 Fill	125.0	130.0	200.00	20.00	0.000	0.0	0	0
4 In Situ	125.0	130.0	200.00	18.00	0.000	0.0	0	0

CURVED STRENGTH PARAMETERS
2 Soil Type(s) Assigned Curved Strength Envelope Properties

Pa = 2116.800(psf)
A Value of 1.0 indicates Dimensional Coefficients

Soil Type 1:

Curve Coefficients a, b, and T are User Input Values

Coefficient a = 0.2723 Coefficient b = 0.8691
Cohesion(c) = 0.00000(psf) Coefficient T = 0.00000

A Power Curve Function Has Been Selected to Model
Stress-Dependent Shear Strength (C = 0).

Soil Type 2:

Curve Coefficients a, b, and T are User Input Values

Coefficient a = 0.2723 Coefficient b = 0.8691
Cohesion(c) = 0.00000(psf) Coefficient T = 0.00000

A Power Curve Function Has Been Selected to Model
Stress-Dependent Shear Strength (C = 0).

A Non-Circular Zone Search Has Been Selected For Analysis
Using Random Generation Within Specified Zones.

2 Zones Defined For Generation Of Non-Circular Surfaces

1000 Trial Surfaces Have Been Generated.

Length Of Line Segments For Active And Passive Portions Of
Non-Circular Zone Search = 5.00(ft)

Zone No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Height (ft)
1	40.00	441.75	65.00	448.00	0.50
2	80.00	452.00	110.00	459.50	0.50

The Spencer Method Was Selected for FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR SPENCER METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 9.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = 0.00 ; Maximum theta(deg) = 90.00
Theta convergence Step Factor = 500.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)

Maximum moment imbalance = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

Specified Tension Crack Water Depth Factor = 0.000

Total Number of Trial Surfaces Attempted = 1000

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence = 20
Maximum Normal Stress Difference (%) = 0.005000

Warning: Convergence not achieved on 31
surfaces during curved strength envelope calculations.
Maximum Normal Stress Difference (%) = Infinity

WARNING! The Factor of Safety Calculation for one or More Trial Surfaces
Did Not Converge in 50 Iterations.

Number of Trial Surfaces with Non-Converged FS = 35

Number of Trial Surfaces With Valid FS = 965

Percentage of Trial Surfaces With Non-Converged and/or
Non-Valid FS Solutions of the Total Attempted = 3.5 %

Statistical Data On All Valid FS Values:
FS Max = 1.561 FS Min = 1.066 FS Ave = 1.187
Standard Deviation = 0.076 Coefficient of Variation = 6.43 %

Critical Surface is Sequence Number 921 of Those Analyzed.

*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****

Iter. No.	Theta (deg) (fx=1.0)	FS (Moment)	FS (Force)	Lambda	Delta FS
1	9.0000	1.183659	1.041610	0.158	0.1420490E+00
2	11.9700	1.108403	1.059699	0.212	0.4870482E-01
3	13.5166	1.036768	1.070112	0.240	0.3334403E-01
4	12.8893	1.069771	1.065798	0.229	0.3973256E-02
5	12.9572	1.066490	1.066259	0.230	0.2310739E-03
6	12.9614	1.066286	1.066287	0.230	0.1744088E-05
7	12.9614	1.066287	1.066287	0.230	0.3257224E-08

Factor Of Safety For The Preceding Specified Surface = 1.066
Theta (fx = 1.0) = 12.96 Deg Lambda = 0.230

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence = 20
Maximum Normal Stress Difference (%) = 0.005000

The Spencer Method Has Been Selected For FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR ANALYSIS METHOD:
Initial estimate of FS = 1.500

FS tolerance = 0.00000100
Initial estimate of theta(deg) = 9.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) =   0.00 ; Maximum theta(deg) = 90.00
Theta convergence Step Factor = 500.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance(if Applicable) = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

Tension Crack Water Force =   0.00(lbs)

Specified Tension Crack Water Depth Factor = 0.000

Depth of Tension Crack (zo) at Side of Last Slice =   0.000(ft)

Depth of Water in Tension Crack =   0.000(ft)

Theoretical Tension Crack Depth =   3.271(ft)

NOTE: In Table 1 following, when a tension crack with water is present on the first slice (right facing slope) or on the last slice (left facing slope), the "side force" in the tension crack is set equal to the water pressure resultant.

*** Table 1 - Line of Thrust(if applicable) and Slice Force Data ***

Slice No.	X Coord.	Y Coord.	h/H	Side Force (lbs)	fx	Force Angle (Deg)	Vert. Shear Force(lbs)
1	38.87	446.12	0.488	477.94	1.000	12.96	107.2
2	40.80	445.44	0.381	1297.99	1.000	12.96	291.1
3	42.74	444.87	0.356	2504.35	1.000	12.96	561.7
4	43.29	444.70	0.352	2915.36	1.000	12.96	653.9
5	46.37	445.46	0.349	2855.66	1.000	12.96	640.5
6	49.46	446.21	0.346	2795.82	1.000	12.96	627.1
7	52.54	446.96	0.343	2735.83	1.000	12.96	613.6
8	55.63	447.71	0.341	2675.68	1.000	12.96	600.1
9	58.71	448.46	0.339	2615.39	1.000	12.96	586.6
10	61.80	449.22	0.336	2554.95	1.000	12.96	573.1
11	64.88	449.97	0.334	2494.36	1.000	12.96	559.5
12	67.96	450.73	0.332	2433.62	1.000	12.96	545.8
13	71.05	451.49	0.331	2372.73	1.000	12.96	532.2
14	74.13	452.25	0.329	2311.69	1.000	12.96	518.5
15	77.22	453.01	0.328	2250.50	1.000	12.96	504.8
16	80.30	453.77	0.327	2189.15	1.000	12.96	491.0
17	83.39	454.53	0.327	2127.66	1.000	12.96	477.2
18	86.47	455.29	0.326	2066.02	1.000	12.96	463.4
19	89.56	456.06	0.326	2004.23	1.000	12.96	449.5
20	91.98	456.66	0.327	1955.51	1.000	12.96	438.6
21	94.41	457.27	0.327	1906.70	1.000	12.96	427.7
22	96.76	458.03	0.327	1686.99	1.000	12.96	378.4
23	99.11	458.80	0.327	1479.70	1.000	12.96	331.9
24	99.17	458.83	0.327	1469.94	1.000	12.96	329.7
25	101.39	459.73	0.326	1150.06	1.000	12.96	258.0
26	103.61	460.63	0.326	867.97	1.000	12.96	194.7
27	105.73	461.69	0.323	538.70	1.000	12.96	120.8
28	107.85	462.76	0.325	284.63	1.000	12.96	63.8
29	110.00	464.10	0.352	61.03	1.000	12.96	13.7
30	111.78	465.00	0.000	0.00	1.000	12.96	0.0

NOTE: A value of 0.000- for h/H indicates that the line of thrust is at or below the lower boundary of the sliding mass. A value of 1.000+ for h/H indicates that the line of thrust is at or above the upper boundary of the sliding mass.

Table 2 - Geometry Data on the   30 Slices

Slice No.	Width (ft)	Height (ft)	X-Cntr (ft)	Y-Cntr-Base (ft)	Y-Cntr-Top (ft)	Alpha (deg)	Beta (deg)	Base Length (ft)
1	2.67	1.07	37.53	445.81	446.88	-28.83	14.04	3.05
2	1.94	2.89	39.83	444.57	447.46	-27.83	14.04	2.19
3	1.94	4.40	41.77	443.54	447.94	-27.83	14.04	2.19
4	0.55	5.37	43.01	442.89	448.25	-27.83	14.04	0.62
5	3.08	5.58	44.83	443.12	448.71	13.91	14.04	3.18
6	3.08	5.59	47.92	443.89	449.48	13.91	14.04	3.18
7	3.08	5.60	51.00	444.65	450.25	13.91	14.04	3.18
8	3.08	5.60	54.08	445.42	451.02	13.91	14.04	3.18
9	3.08	5.61	57.17	446.18	451.79	13.91	14.04	3.18
10	3.08	5.62	60.25	446.95	452.56	13.91	14.04	3.18
11	3.08	5.63	63.34	447.71	453.33	13.91	14.04	3.18
12	3.08	5.63	66.42	448.47	454.11	13.91	14.04	3.18
13	3.08	5.64	69.51	449.24	454.88	13.91	14.04	3.18
14	3.08	5.65	72.59	450.00	455.65	13.91	14.04	3.18
15	3.08	5.65	75.68	450.77	456.42	13.91	14.04	3.18
16	3.08	5.66	78.76	451.53	457.19	13.91	14.04	3.18
17	3.08	5.67	81.84	452.29	457.96	13.91	14.04	3.18
18	3.08	5.67	84.93	453.06	458.73	13.91	14.04	3.18
19	3.08	5.68	88.01	453.82	459.50	13.91	14.04	3.18
20	2.43	5.69	90.77	454.51	460.19	13.91	14.04	2.50
21	2.43	5.69	93.20	455.11	460.80	13.91	14.04	2.50
22	2.35	5.56	95.58	455.83	461.40	19.91	14.04	2.50
23	2.35	5.30	97.94	456.68	461.98	19.91	14.04	2.50
24	0.06	5.16	99.14	457.13	462.29	25.91	14.04	0.07
25	2.22	4.89	100.28	457.68	462.57	25.91	14.04	2.46
26	2.22	4.37	102.50	458.76	463.12	25.91	14.04	2.46
27	2.12	3.71	104.67	459.96	463.67	31.91	14.04	2.50
28	2.12	2.92	106.79	461.28	464.20	31.91	14.04	2.50
29	2.15	1.96	108.93	462.77	464.73	37.91	14.04	2.72
30	1.78	0.69	110.89	464.31	465.00	37.91	0.00	2.26

Table 2A - Coordinates of Slice Points Defining the Slip Surface

Point No.	X-Pt (ft)	Y-Pt (ft)
1	36.192749	446.548187
2	38.866513	445.076558
3	40.802846	444.054426
4	42.739179	443.032295
5	43.288269	442.742447
6	46.372803	443.506598
7	49.457336	444.270749
8	52.541870	445.034900
9	55.626404	445.799051
10	58.710938	446.563202
11	61.795471	447.327353
12	64.880005	448.091504
13	67.964539	448.855655
14	71.049072	449.619806
15	74.133606	450.383957
16	77.218140	451.148108
17	80.302673	451.912259
18	83.387207	452.676410
19	86.471741	453.440561
20	89.556274	454.204712
21	91.982918	454.805880
22	94.409562	455.407047
23	96.760073	456.258575
24	99.110584	457.110103
25	99.174361	457.141090
26	101.391099	458.218155

27	103.607836	459.295219
28	105.729941	460.616837
29	107.852045	461.938456
30	110.000000	463.611443
31	111.782775	465.000000

Table 3 - Force and Pore Pressure Data On The 30 Slices (Excluding Reinforcement)

Slice No.	Weight (lbs)	Ubeta Force Top (lbs)	Ubeta Stress Top (psf)	Ualpha Force Bot (lbs)	Pore Pressure (psf)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Distributed Load (lbs)
1	357.6	0.0	0.0	114.3	37.5	0.0	0.0	0.00
2	700.3	0.0	0.0	221.7	101.3	0.0	0.0	0.00
3	1064.8	0.0	0.0	337.1	154.0	0.0	0.0	0.00
4	368.3	0.0	0.0	116.6	187.8	0.0	0.0	0.00
5	2152.7	0.0	0.0	621.0	195.4	0.0	0.0	0.00
6	2155.4	0.0	0.0	621.7	195.7	0.0	0.0	0.00
7	2158.0	0.0	0.0	622.5	195.9	0.0	0.0	0.00
8	2160.7	0.0	0.0	623.3	196.1	0.0	0.0	0.00
9	2163.4	0.0	0.0	624.1	196.4	0.0	0.0	0.00
10	2166.1	0.0	0.0	624.8	196.6	0.0	0.0	0.00
11	2168.8	0.0	0.0	625.6	196.9	0.0	0.0	0.00
12	2171.5	0.0	0.0	626.4	197.1	0.0	0.0	0.00
13	2174.2	0.0	0.0	627.2	197.4	0.0	0.0	0.00
14	2176.9	0.0	0.0	628.0	197.6	0.0	0.0	0.00
15	2179.6	0.0	0.0	628.7	197.9	0.0	0.0	0.00
16	2182.3	0.0	0.0	629.5	198.1	0.0	0.0	0.00
17	2185.0	0.0	0.0	630.3	198.3	0.0	0.0	0.00
18	2187.7	0.0	0.0	631.1	198.6	0.0	0.0	0.00
19	2190.4	0.0	0.0	631.8	198.8	0.0	0.0	0.00
20	1725.1	0.0	0.0	497.6	199.0	0.0	0.0	0.00
21	1726.7	0.0	0.0	498.1	199.2	0.0	0.0	0.00
22	1634.6	0.0	0.0	486.8	194.7	0.0	0.0	0.00
23	1557.1	0.0	0.0	463.7	185.5	0.0	0.0	0.00
24	41.1	0.0	0.0	12.8	180.6	0.0	0.0	0.00
25	1355.3	0.0	0.0	421.9	171.2	0.0	0.0	0.00
26	1210.4	0.0	0.0	376.8	152.9	0.0	0.0	0.00
27	984.4	0.0	0.0	324.7	129.9	0.0	0.0	0.00
28	774.6	0.0	0.0	255.5	102.2	0.0	0.0	0.00
29	525.3	0.0	0.0	186.4	68.5	0.0	0.0	0.00
30	154.7	0.0	0.0	54.9	24.3	0.0	0.0	0.00

Table 3A - Center of Pressure of Water Loads On the 30 Slices
Only Applicable Slices Listed

Slice No.	X-Ubeta (ft)	Y-Ubeta (ft)	Ubeta-Moment (ft/lbs)

Table 3B - Center of Pressure of Distributed Loads On the 30 Slices
Only Applicable Slices Listed

Slice No.	X-Dload (ft)	Y-Dload (ft)	Dist-Load (lbs)	Dload-Moment (ft/lbs)

TOTAL WEIGHT OF SLIDING MASS = 46753.00(lbs)

EFFECTIVE WEIGHT OF SLIDING MASS = 33662.16(lbs)

TOTAL AREA OF SLIDING MASS = 374.02(ft2)

TABLE 4 - SOIL STRENGTH & SOIL OPTIONS DATA ON THE 30 SLICES

Slice Soil Cohesion Phi(Deg) Options

No.	Type	(psf)		
1	1	8.41	18.23	C
2	1	18.74	16.27	C
3	1	26.53	15.48	C
4	2	31.30	15.12	C
5	2	20.11	16.11	C
6	2	20.14	16.11	C
7	2	20.16	16.10	C
8	2	20.18	16.10	C
9	2	20.20	16.10	C
10	2	20.22	16.10	C
11	2	20.25	16.09	C
12	2	20.27	16.09	C
13	2	20.29	16.09	C
14	2	20.31	16.09	C
15	2	20.33	16.08	C
16	2	20.35	16.08	C
17	2	20.38	16.08	C
18	2	20.40	16.08	C
19	2	20.42	16.07	C
20	2	20.44	16.07	C
21	2	20.46	16.07	C
22	2	18.91	16.25	C
23	2	18.12	16.35	C
24	2	16.65	16.55	C
25	1	15.89	16.66	C
26	1	14.39	16.90	C
27	1	11.67	17.41	C
28	1	9.45	17.93	C
29	1	6.16	19.04	C
30	1	2.45	21.63	C

SOIL OPTIONS: A = ANISOTROPIC, C = CURVED STRENGTH ENVELOPE (TANGENT PHI & C),
F = FIBER-REINFORCED SOIL (FRS), N = NONLINEAR UNDRAINED SHEAR STRENGTH,
R = RAPID DRAWDOWN OR RAPID LOADING (SEISMIC) SHEAR STRENGTH
NOTE: Phi and C in Table 4 are modified values based on specified
Soil Options (if any). Zero values for both phi & c indicate normal stress = 0.0

Calculated Secant Phi Values

Slice No.	Phi(Deg)
1	20.75
2	18.57
3	17.68
4	17.27
5	18.38
6	18.38
7	18.38
8	18.37
9	18.37
10	18.37
11	18.36
12	18.36
13	18.36
14	18.36
15	18.35
16	18.35
17	18.35
18	18.35
19	18.34
20	18.34
21	18.34
22	18.54
23	18.65
24	18.87
25	19.00
26	19.26
27	19.83

28	20.42
29	21.66
30	24.52

NOTE: The slices in the table above with phi marked with an * are unmodified phi values for soil type(s) not specified to have curved strength envelope (if any).

TABLE 5 - Total Base Stress Data on the 30 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Stress (psf)	Total Vert. Stress (psf)	Total Normal/Vert. Stress Ratio
1	-28.83	37.53	3.05	207.01	133.75	1.548
2	-27.83	39.83	2.19	527.51	361.65	1.459
3	-27.83	41.77	2.19	790.02	549.92	1.437
4	-27.83	43.01	0.62	957.03	670.76	1.427
5	13.91	44.83	3.18	657.85	697.89	0.943
6	13.91	47.92	3.18	658.67	698.76	0.943
7	13.91	51.00	3.18	659.49	699.63	0.943
8	13.91	54.08	3.18	660.32	700.51	0.943
9	13.91	57.17	3.18	661.14	701.38	0.943
10	13.91	60.25	3.18	661.96	702.25	0.943
11	13.91	63.34	3.18	662.78	703.13	0.943
12	13.91	66.42	3.18	663.61	704.00	0.943
13	13.91	69.51	3.18	664.43	704.87	0.943
14	13.91	72.59	3.18	665.25	705.74	0.943
15	13.91	75.68	3.18	666.08	706.62	0.943
16	13.91	78.76	3.18	666.90	707.49	0.943
17	13.91	81.84	3.18	667.72	708.36	0.943
18	13.91	84.93	3.18	668.55	709.24	0.943
19	13.91	88.01	3.18	669.37	710.11	0.943
20	13.91	90.77	2.50	670.11	710.89	0.943
21	13.91	93.20	2.50	670.75	711.57	0.943
22	19.91	95.58	2.50	625.38	695.42	0.899
23	19.91	97.94	2.50	595.62	662.44	0.899
24	25.91	99.14	0.07	552.69	645.00	0.857
25	25.91	100.28	2.46	523.71	611.38	0.857
26	25.91	102.50	2.46	467.39	546.02	0.856
27	31.91	104.67	2.50	377.03	463.90	0.813
28	31.91	106.79	2.50	296.01	365.01	0.811
29	37.91	108.93	2.72	186.87	244.57	0.764
30	37.91	110.89	2.26	65.41	86.78	0.754

TABLE 5A - Total Base Force Data on the 30 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Force (lbs)	Total Vert. Force (lbs)	Total Normal/Vert. Force Ratio
1	-28.83	37.53	3.05	631.80	357.63	1.767
2	-27.83	39.83	2.19	1155.01	700.27	1.649
3	-27.83	41.77	2.19	1729.78	1064.84	1.624
4	-27.83	43.01	0.62	594.22	368.31	1.613
5	13.91	44.83	3.18	2090.49	2152.66	0.971
6	13.91	47.92	3.18	2093.11	2155.35	0.971
7	13.91	51.00	3.18	2095.72	2158.05	0.971
8	13.91	54.08	3.18	2098.34	2160.74	0.971
9	13.91	57.17	3.18	2100.95	2163.43	0.971
10	13.91	60.25	3.18	2103.57	2166.12	0.971
11	13.91	63.34	3.18	2106.18	2168.82	0.971
12	13.91	66.42	3.18	2108.80	2171.51	0.971
13	13.91	69.51	3.18	2111.42	2174.20	0.971
14	13.91	72.59	3.18	2114.03	2176.89	0.971
15	13.91	75.68	3.18	2116.65	2179.58	0.971
16	13.91	78.76	3.18	2119.26	2182.28	0.971

17	13.91	81.84	3.18	2121.88	2184.97	0.971
18	13.91	84.93	3.18	2124.49	2187.66	0.971
19	13.91	88.01	3.18	2127.11	2190.35	0.971
20	13.91	90.77	2.50	1675.26	1725.07	0.971
21	13.91	93.20	2.50	1676.88	1726.74	0.971
22	19.91	95.58	2.50	1563.46	1634.60	0.956
23	19.91	97.94	2.50	1489.05	1557.06	0.956
24	25.91	99.14	0.07	39.19	41.14	0.953
25	25.91	100.28	2.46	1290.70	1355.27	0.952
26	25.91	102.50	2.46	1151.91	1210.39	0.952
27	31.91	104.67	2.50	942.58	984.44	0.957
28	31.91	106.79	2.50	740.02	774.60	0.955
29	37.91	108.93	2.72	508.78	525.32	0.969
30	37.91	110.89	2.26	147.81	154.72	0.955

TABLE 6 - Effective and Base Shear Stress Data on the 30 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Stress (psf)	Available Shear Strength (psf)	Mobilized Shear Stress (psf)
1	-28.83	37.53	3.05	169.56	64.25	60.26
2	-27.83	39.83	2.19	426.25	143.16	134.26
3	-27.83	41.77	2.19	636.04	202.72	190.11
4	-27.83	43.01	0.62	769.22	239.14	224.27
5	13.91	44.83	3.18	462.44	153.67	144.11
6	13.91	47.92	3.18	463.02	153.83	144.27
7	13.91	51.00	3.18	463.59	154.00	144.43
8	13.91	54.08	3.18	464.17	154.17	144.58
9	13.91	57.17	3.18	464.75	154.33	144.74
10	13.91	60.25	3.18	465.33	154.50	144.90
11	13.91	63.34	3.18	465.91	154.67	145.05
12	13.91	66.42	3.18	466.49	154.83	145.21
13	13.91	69.51	3.18	467.07	155.00	145.37
14	13.91	72.59	3.18	467.65	155.17	145.52
15	13.91	75.68	3.18	468.22	155.34	145.68
16	13.91	78.76	3.18	468.80	155.50	145.84
17	13.91	81.84	3.18	469.38	155.67	145.99
18	13.91	84.93	3.18	469.96	155.84	146.15
19	13.91	88.01	3.18	470.54	156.00	146.30
20	13.91	90.77	2.50	471.06	156.15	146.44
21	13.91	93.20	2.50	471.51	156.28	146.57
22	19.91	95.58	2.50	430.66	144.45	135.47
23	19.91	97.94	2.50	410.14	138.44	129.84
24	25.91	99.14	0.07	372.09	127.21	119.30
25	25.91	100.28	2.46	352.52	121.38	113.83
26	25.91	102.50	2.46	314.51	109.92	103.09
27	31.91	104.67	2.50	247.14	89.14	83.60
28	31.91	106.79	2.50	193.81	72.17	67.68
29	37.91	108.93	2.72	118.39	47.02	44.10
30	37.91	110.89	2.26	41.11	18.75	17.59

TABLE 6A - Effective and Base Shear Force Data on the 30 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Force (lbs)	Available Shear Force (lbs)	Mobilized Shear Force (lbs)
1	-28.83	37.53	3.05	517.50	196.10	183.91
2	-27.83	39.83	2.19	933.29	313.45	293.97
3	-27.83	41.77	2.19	1392.64	443.86	416.26
4	-27.83	43.01	0.62	477.61	148.48	139.25
5	13.91	44.83	3.18	1469.52	488.32	457.96
6	13.91	47.92	3.18	1471.36	488.85	458.46
7	13.91	51.00	3.18	1473.20	489.38	458.95
8	13.91	54.08	3.18	1475.04	489.91	459.45
9	13.91	57.17	3.18	1476.88	490.44	459.95

10	13.91	60.25	3.18	1478.72	490.97	460.45
11	13.91	63.34	3.18	1480.56	491.50	460.95
12	13.91	66.42	3.18	1482.40	492.03	461.44
13	13.91	69.51	3.18	1484.24	492.56	461.94
14	13.91	72.59	3.18	1486.08	493.09	462.44
15	13.91	75.68	3.18	1487.91	493.62	462.94
16	13.91	78.76	3.18	1489.75	494.15	463.43
17	13.91	81.84	3.18	1491.59	494.68	463.93
18	13.91	84.93	3.18	1493.43	495.21	464.43
19	13.91	88.01	3.18	1495.27	495.74	464.92
20	13.91	90.77	2.50	1177.64	390.38	366.11
21	13.91	93.20	2.50	1178.78	390.71	366.42
22	19.91	95.58	2.50	1076.66	361.12	338.67
23	19.91	97.94	2.50	1025.34	346.11	324.60
24	25.91	99.14	0.07	26.38	9.02	8.46
25	25.91	100.28	2.46	868.80	299.14	280.54
26	25.91	102.50	2.46	775.12	270.90	254.06
27	31.91	104.67	2.50	617.85	222.86	209.00
28	31.91	106.79	2.50	484.52	180.41	169.20
29	37.91	108.93	2.72	322.34	128.02	120.07
30	37.91	110.89	2.26	92.90	42.38	39.74

Average Effective Normal Stress = 411.4363(psf)
Average Available Shear Strength = 137.8345(psf)
Total Length of Failure Surface = 80.7010(ft)

SUM OF MOMENTS = -0.715367E-05 (ft/lbs);Imbalance (Fraction of Total Weight) = -0.1530099E-09
SUM OF FORCES = -.219460E-06 (lbs);Imbalance (Fraction of Total Weight) = -0.4694039E-11

Sum of Available Shear Forces = 11123.38(lbs)

Sum of Mobilized Shear Forces = 10431.88(lbs)

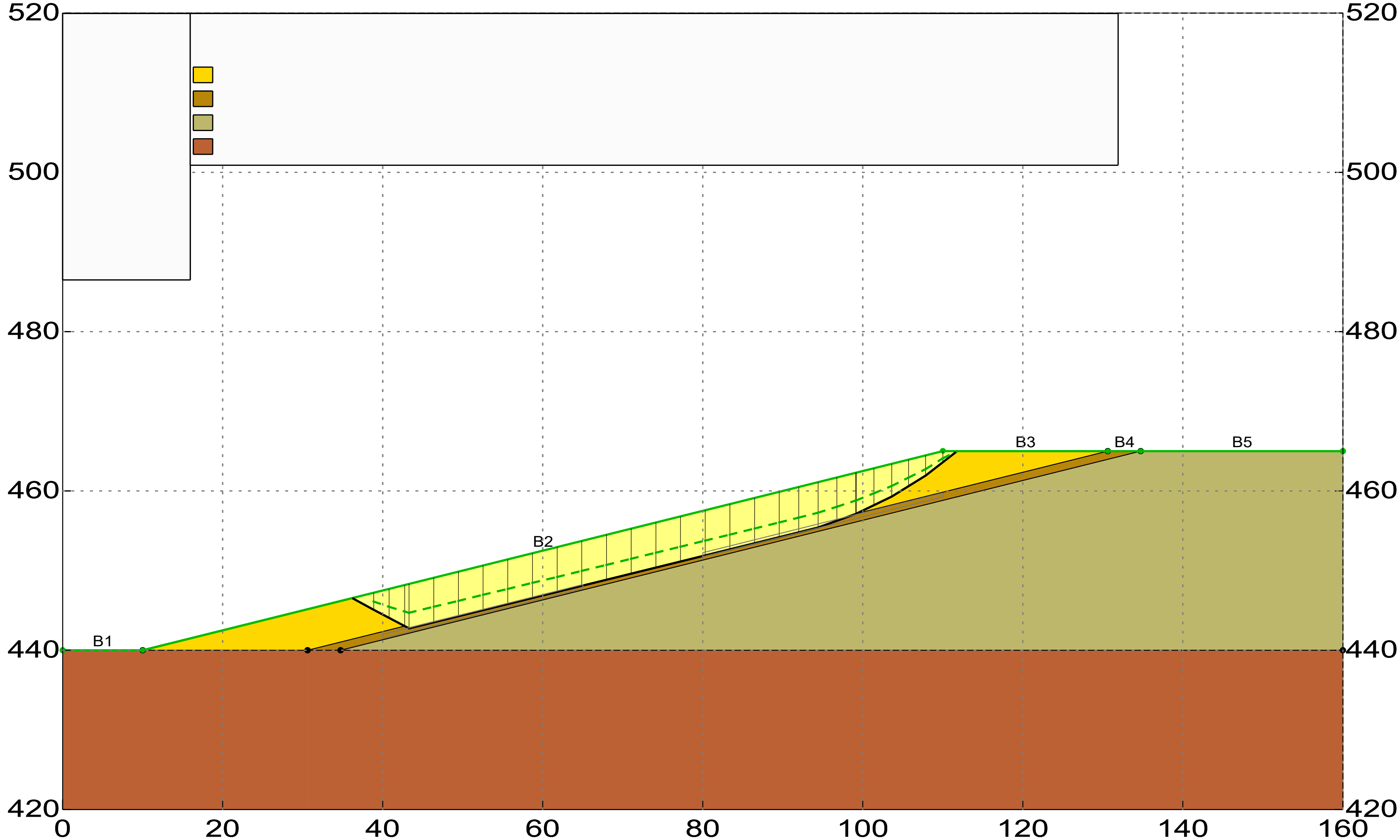
FS Balance Check: FS = 1.066287

**** END OF GEOSTASE OUTPUT ****

PGBT - ROADWAY EMBANKEMENT
Reinforced Condition - Long-Term - FRS - Normal Rainfall

GREGORY GEOTECHNICAL - GHG

\PGBT-FRS-Normal Rainfall.gsd



GEOSTASE FS = 1.546

Spencer Method

GEOSTASE Slope Stability Analysis

GREGORY GEOTECHNICAL

PLATE C.12

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

PGBT-FRS-Normal Rainfall.OUT

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SLOPE STABILITY ANALYSIS SOFTWARE
Simplified Bishop, Simplified Janbu, or General Equilibrium (GE) Options.
(Spencer, Morgenstern-Price, USACE, and Lowe & Karafiath)
Including Pier/Pile, Planar Reinf, Nail, Tieback, Line Loads
Nonlinear Undrained Shear Strength, Curved Strength Envelope,
Anisotropic , Fiber-Reinforced , Distributed Loads, Water
Surfaces, Pseudo-Static & Newmark Earthquake, and Applied Forces.
****

Analysis Date:
Analysis Time:
Analysis By: GREGORY GEOTECHNICAL - GHG

Input File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Stufy - 2\PGBT-FRS-Normal Rainfall.gsd

Output File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Stufy - 2\PGBT-FRS-Normal Rainfall.OUT

Unit System: English

PROJECT: PGBT - ROADWAY EMBANKEMENT

DESCRIPTION: Reinforced Condition - Long-Term - FRS - Normal Rainfall

BOUNDARY DATA

5 Surface Boundaries
10 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	440.000	10.000	440.000	4
2	10.000	440.000	110.000	465.000	1
3	110.000	465.000	130.610	465.000	1
4	130.610	465.000	134.730	465.000	2
5	134.730	465.000	160.000	465.000	3
6	10.000	440.000	30.610	440.000	4
7	30.610	440.000	130.610	465.000	2
8	30.610	440.000	34.730	440.000	4
9	34.730	440.000	134.730	465.000	3
10	34.730	440.000	160.000	440.000	4

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 420.000(ft)

MOHR-COULOMB SOIL PARAMETERS

4 Type(s) of Soil Defined

Soil Number Moist Saturated Cohesion Friction Pore Pressure Water Water

and Description	Unit Wt. (pcf)	Unit Wt. (pcf)	Intercept (psf)	Angle (deg)	Pressure Ratio(ru)	Constant (psf)	Surface No.	Option
1 Weathered Fill	125.0	130.0	100.00	20.00	0.140	0.0	0	0
2 Weak Zone	125.0	130.0	0.00	20.00	0.140	0.0	0	0
3 Fill	125.0	130.0	200.00	20.00	0.000	0.0	0	0
4 In Situ	125.0	130.0	200.00	18.00	0.000	0.0	0	0

FIBER-REINFORCED SOIL PROPERTIES
2 Soil Type(s) With Fiber Reinforcement

Soil Type 1:

Fiber Length = 2.65(in) Fiber Width = 0.04700(in)
Fiber Thickness = 0.00149(in) Fiber Equivalent Dia. = 0.00944(in)
Friction Coefficient = 0.50 Cohesion Coefficient = 0.50
Specific Gravity of Fiber = 0.910 Application Rate = 0.222 (pcf)

Soil Type 2:

Fiber Length = 2.65(in) Fiber Width = 0.04700(in)
Fiber Thickness = 0.00149(in) Fiber Equivalent Dia. = 0.00944(in)
Friction Coefficient = 0.50 Cohesion Coefficient = 0.50
Specific Gravity of Fiber = 0.910 Application Rate = 0.222 (pcf)

Fiber-Reinforced Shear-Strength Properties

Soil Type 1: FRS c = 103.69 (psf) FRS Phi = 24.25 Deg.
Delta(c) = 3.694(psf) Tan(DeltaPhi) = 0.074242
Soil Type 2: FRS c = 0.00 (psf) FRS Phi = 24.25 Deg.
Delta(c) = 0.000(psf) Tan(DeltaPhi) = 0.074242

CURVED STRENGTH PARAMETERS
2 Soil Type(s) Assigned Curved Strength Envelope Properties

Pa = 2116.800(psf)
A Value of 1.0 indicates Dimensional Coefficients

Soil Type 1:

Curve Coefficients a, b, and T are User Input Values

Coefficient a = 0.2723 Coefficient b = 0.8691
Cohesion(c) = 0.00000(psf) Coefficient T = 0.00000

A Power Curve Function Has Been Selected to Model
Stress-Dependent Shear Strength (C = 0).

Soil Type 2:

Curve Coefficients a, b, and T are User Input Values

Coefficient a = 0.2723 Coefficient b = 0.8691
Cohesion(c) = 0.00000(psf) Coefficient T = 0.00000

A Power Curve Function Has Been Selected to Model
Stress-Dependent Shear Strength (C = 0).

A Non-Circular Zone Search Has Been Selected For Analysis
Using Random Generation Within Specified Zones.

2 Zones Defined For Generation Of Non-Circular Surfaces

1000 Trial Surfaces Have Been Generated.

Length Of Line Segments For Active And Passive Portions Of
Non-Circular Zone Search = 5.00(ft)

Zone No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Height (ft)
1	40.00	441.75	65.00	448.00	0.50
2	80.00	452.00	110.00	459.50	0.50

The Spencer Method Was Selected for FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR SPENCER METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 9.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = 0.00 ; Maximum theta(deg) = 90.00
Theta convergence Step Factor = 500.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

Specified Tension Crack Water Depth Factor = 0.000

Total Number of Trial Surfaces Attempted = 1000

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence = 22
Maximum Normal Stress Difference (%) = 0.005000

Warning: Convergence not achieved on 22
surfaces during curved strength envelope calculations.
Maximum Normal Stress Difference (%) = Infinity

WARNING! The Factor of Safety Calculation for one or More Trial Surfaces
Did Not Converge in 50 Iterations.

Number of Trial Surfaces with Non-Converged FS = 25

Number of Trial Surfaces With Valid FS = 975

Percentage of Trial Surfaces With Non-Converged and/or
Non-Valid FS Solutions of the Total Attempted = 2.5 %

Statistical Data On All Valid FS Values:
FS Max = 2.235 FS Min = 1.546 FS Ave = 1.714
Standard Deviation = 0.104 Coefficient of Variation = 6.05 %

Critical Surface is Sequence Number 932 of Those Analyzed.

*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****

Iter. No.	Theta (deg) (fx=1.0)	FS (Moment)	FS (Force)	Lambda	Delta FS

1	9.0000	1.712053	1.512309	0.158	0.1997437E+00
2	11.9700	1.603998	1.536814	0.212	0.6718436E-01
3	13.4723	1.505751	1.550446	0.240	0.4469523E-01
4	12.8733	1.550056	1.544901	0.229	0.5155372E-02
5	12.9363	1.545753	1.545477	0.230	0.2752295E-03
6	12.9399	1.545508	1.545510	0.230	0.1838908E-05
7	12.9399	1.545510	1.545510	0.230	0.3592463E-08

Factor Of Safety For The Preceding Specified Surface = 1.546
Theta (fx = 1.0) = 12.94 Deg   Lambda =   0.230

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence =   22
Maximum Normal Stress Difference (%) =   0.005000

The Spencer Method Has Been Selected For FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR ANALYSIS METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 9.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) =   0.00 ; Maximum theta(deg) = 90.00
Theta convergence Step Factor = 500.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance(if Applicable) = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

Tension Crack Water Force =   0.00(lbs)

Specified Tension Crack Water Depth Factor = 0.000

Depth of Tension Crack (zo) at Side of Last Slice =   0.000(ft)

Depth of Water in Tension Crack =   0.000(ft)

Theoretical Tension Crack Depth =   3.007(ft)

NOTE: In Table 1 following, when a tension crack with water is present on the first slice (right facing slope) or on the last slice (left facing slope), the "side force" in the tension crack is set equal to the water pressure resultant.

*** Table 1 - Line of Thrust(if applicable) and Slice Force Data ***

Slice No.	X Coord.	Y Coord.	h/H	Side Force (lbs)	fx	Force Angle (Deg)	Vert. Shear Force(lbs)
1	38.87	446.12	0.487	462.08	1.000	12.94	103.5
2	40.80	445.44	0.380	1258.21	1.000	12.94	281.7
3	42.74	444.86	0.355	2434.36	1.000	12.94	545.1
4	43.29	444.70	0.351	2833.23	1.000	12.94	634.4
5	46.37	445.45	0.348	2774.32	1.000	12.94	621.2
6	49.46	446.20	0.345	2715.27	1.000	12.94	608.0
7	52.54	446.95	0.342	2656.08	1.000	12.94	594.8
8	55.63	447.70	0.340	2596.77	1.000	12.94	581.5
9	58.71	448.46	0.337	2537.31	1.000	12.94	568.2
10	61.80	449.21	0.335	2477.72	1.000	12.94	554.8
11	64.88	449.96	0.333	2418.00	1.000	12.94	541.5
12	67.96	450.72	0.331	2358.14	1.000	12.94	528.1
13	71.05	451.48	0.329	2298.15	1.000	12.94	514.6

14	74.13	452.23	0.328	2238.02	1.000	12.94	501.2
15	77.22	452.99	0.326	2177.76	1.000	12.94	487.7
16	80.30	453.75	0.325	2117.36	1.000	12.94	474.1
17	83.39	454.52	0.324	2056.83	1.000	12.94	460.6
18	86.47	455.28	0.324	1996.16	1.000	12.94	447.0
19	89.56	456.05	0.324	1935.35	1.000	12.94	433.4
20	91.98	456.65	0.324	1887.42	1.000	12.94	422.6
21	94.41	457.25	0.324	1839.41	1.000	12.94	411.9
22	96.76	458.02	0.324	1623.31	1.000	12.94	363.5
23	99.11	458.79	0.325	1419.12	1.000	12.94	317.8
24	99.17	458.82	0.325	1409.52	1.000	12.94	315.6
25	101.39	459.72	0.324	1101.21	1.000	12.94	246.6
26	103.61	460.62	0.323	829.60	1.000	12.94	185.8
27	105.73	461.68	0.319	511.98	1.000	12.94	114.6
28	107.85	462.75	0.321	267.78	1.000	12.94	60.0
29	110.00	464.10	0.353	54.65	1.000	12.94	12.2
30	111.78	465.00	0.000	0.00	1.000	12.94	0.0

NOTE: A value of 0.000- for h/H indicates that the line of thrust is at or below the lower boundary of the sliding mass. A value of 1.000+ for h/H indicates that the line of thrust is at or above the upper boundary of the sliding mass.

Table 2 - Geometry Data on the 30 Slices

Slice No.	Width (ft)	Height (ft)	X-Cntr (ft)	Y-Cntr-Base (ft)	Y-Cntr-Top (ft)	Alpha (deg)	Beta (deg)	Base Length (ft)
1	2.67	1.07	37.53	445.81	446.88	-28.83	14.04	3.05
2	1.94	2.89	39.83	444.57	447.46	-27.83	14.04	2.19
3	1.94	4.40	41.77	443.54	447.94	-27.83	14.04	2.19
4	0.55	5.37	43.01	442.89	448.25	-27.83	14.04	0.62
5	3.08	5.58	44.83	443.12	448.71	13.91	14.04	3.18
6	3.08	5.59	47.92	443.89	449.48	13.91	14.04	3.18
7	3.08	5.60	51.00	444.65	450.25	13.91	14.04	3.18
8	3.08	5.60	54.08	445.42	451.02	13.91	14.04	3.18
9	3.08	5.61	57.17	446.18	451.79	13.91	14.04	3.18
10	3.08	5.62	60.25	446.95	452.56	13.91	14.04	3.18
11	3.08	5.63	63.34	447.71	453.33	13.91	14.04	3.18
12	3.08	5.63	66.42	448.47	454.11	13.91	14.04	3.18
13	3.08	5.64	69.51	449.24	454.88	13.91	14.04	3.18
14	3.08	5.65	72.59	450.00	455.65	13.91	14.04	3.18
15	3.08	5.65	75.68	450.77	456.42	13.91	14.04	3.18
16	3.08	5.66	78.76	451.53	457.19	13.91	14.04	3.18
17	3.08	5.67	81.84	452.29	457.96	13.91	14.04	3.18
18	3.08	5.67	84.93	453.06	458.73	13.91	14.04	3.18
19	3.08	5.68	88.01	453.82	459.50	13.91	14.04	3.18
20	2.43	5.69	90.77	454.51	460.19	13.91	14.04	2.50
21	2.43	5.69	93.20	455.11	460.80	13.91	14.04	2.50
22	2.35	5.56	95.58	455.83	461.40	19.91	14.04	2.50
23	2.35	5.30	97.94	456.68	461.98	19.91	14.04	2.50
24	0.06	5.16	99.14	457.13	462.29	25.91	14.04	0.07
25	2.22	4.89	100.28	457.68	462.57	25.91	14.04	2.46
26	2.22	4.37	102.50	458.76	463.12	25.91	14.04	2.46
27	2.12	3.71	104.67	459.96	463.67	31.91	14.04	2.50
28	2.12	2.92	106.79	461.28	464.20	31.91	14.04	2.50
29	2.15	1.96	108.93	462.77	464.73	37.91	14.04	2.72
30	1.78	0.69	110.89	464.31	465.00	37.91	0.00	2.26

Table 2A - Coordinates of Slice Points Defining the Slip Surface

Point No.	X-Pt (ft)	Y-Pt (ft)
1	36.192749	446.548187
2	38.866513	445.076558

3	40.802846	444.054426
4	42.739179	443.032295
5	43.288269	442.742447
6	46.372803	443.506598
7	49.457336	444.270749
8	52.541870	445.034900
9	55.626404	445.799051
10	58.710938	446.563202
11	61.795471	447.327353
12	64.880005	448.091504
13	67.964539	448.855655
14	71.049072	449.619806
15	74.133606	450.383957
16	77.218140	451.148108
17	80.302673	451.912259
18	83.387207	452.676410
19	86.471741	453.440561
20	89.556274	454.204712
21	91.982918	454.805880
22	94.409562	455.407047
23	96.760073	456.258575
24	99.110584	457.110103
25	99.174361	457.141090
26	101.391099	458.218155
27	103.607836	459.295219
28	105.729941	460.616837
29	107.852045	461.938456
30	110.000000	463.611443
31	111.782775	465.000000

Table 3 - Force and Pore Pressure Data On The 30 Slices (Excluding Reinforcement)

Slice No.	Weight (lbs)	Ubeta Force Top (lbs)	Ubeta Stress Top (psf)	Ualpha Force Bot (lbs)	Pore Pressure (psf)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Distributed Load (lbs)
1	357.6	0.0	0.0	57.2	18.7	0.0	0.0	0.00
2	700.3	0.0	0.0	110.9	50.6	0.0	0.0	0.00
3	1064.8	0.0	0.0	168.6	77.0	0.0	0.0	0.00
4	368.3	0.0	0.0	58.3	93.9	0.0	0.0	0.00
5	2152.7	0.0	0.0	310.5	97.7	0.0	0.0	0.00
6	2155.4	0.0	0.0	310.9	97.8	0.0	0.0	0.00
7	2158.0	0.0	0.0	311.3	97.9	0.0	0.0	0.00
8	2160.7	0.0	0.0	311.6	98.1	0.0	0.0	0.00
9	2163.4	0.0	0.0	312.0	98.2	0.0	0.0	0.00
10	2166.1	0.0	0.0	312.4	98.3	0.0	0.0	0.00
11	2168.8	0.0	0.0	312.8	98.4	0.0	0.0	0.00
12	2171.5	0.0	0.0	313.2	98.6	0.0	0.0	0.00
13	2174.2	0.0	0.0	313.6	98.7	0.0	0.0	0.00
14	2176.9	0.0	0.0	314.0	98.8	0.0	0.0	0.00
15	2179.6	0.0	0.0	314.4	98.9	0.0	0.0	0.00
16	2182.3	0.0	0.0	314.8	99.0	0.0	0.0	0.00
17	2185.0	0.0	0.0	315.1	99.2	0.0	0.0	0.00
18	2187.7	0.0	0.0	315.5	99.3	0.0	0.0	0.00
19	2190.4	0.0	0.0	315.9	99.4	0.0	0.0	0.00
20	1725.1	0.0	0.0	248.8	99.5	0.0	0.0	0.00
21	1726.7	0.0	0.0	249.1	99.6	0.0	0.0	0.00
22	1634.6	0.0	0.0	243.4	97.4	0.0	0.0	0.00
23	1557.1	0.0	0.0	231.9	92.7	0.0	0.0	0.00
24	41.1	0.0	0.0	6.4	90.3	0.0	0.0	0.00
25	1355.3	0.0	0.0	210.9	85.6	0.0	0.0	0.00
26	1210.4	0.0	0.0	188.4	76.4	0.0	0.0	0.00
27	984.4	0.0	0.0	162.4	64.9	0.0	0.0	0.00
28	774.6	0.0	0.0	127.8	51.1	0.0	0.0	0.00
29	525.3	0.0	0.0	93.2	34.2	0.0	0.0	0.00
30	154.7	0.0	0.0	27.5	12.1	0.0	0.0	0.00

Table 3A - Center of Pressure of Water Loads On the 30 Slices
Only Applicable Slices Listed

Slice No.	X-Ubeta (ft)	Y-Ubeta (ft)	Ubeta-Moment (ft/lbs)

Table 3B - Center of Pressure of Distributed Loads On the 30 Slices
Only Applicable Slices Listed

Slice No.	X-Dload (ft)	Y-Dload (ft)	Dist-Load (lbs)	Dload-Moment (ft/lbs)

TOTAL WEIGHT OF SLIDING MASS = 46753.00(lbs)

EFFECTIVE WEIGHT OF SLIDING MASS = 40207.58(lbs)

TOTAL AREA OF SLIDING MASS = 374.02(ft2)

TABLE 4 - SOIL STRENGTH & SOIL OPTIONS DATA ON THE 30 SLICES

Slice No.	Soil Type	Cohesion (psf)	Phi(Deg)	Options
1	1	13.31	21.80	C F
2	1	24.63	19.92	C F
3	1	33.22	19.17	C F
4	2	34.15	18.82	C F
5	2	23.76	19.59	C F
6	2	23.79	19.59	C F
7	2	23.81	19.59	C F
8	2	23.84	19.58	C F
9	2	23.86	19.58	C F
10	2	23.89	19.58	C F
11	2	23.92	19.58	C F
12	2	23.94	19.57	C F
13	2	23.97	19.57	C F
14	2	23.99	19.57	C F
15	2	24.02	19.57	C F
16	2	24.04	19.56	C F
17	2	24.07	19.56	C F
18	2	24.10	19.56	C F
19	2	24.12	19.56	C F
20	2	24.14	19.56	C F
21	2	24.16	19.55	C F
22	2	22.57	19.70	C F
23	2	21.63	19.79	C F
24	2	20.10	19.96	C F
25	1	23.40	20.06	C F
26	1	21.59	20.28	C F
27	1	18.48	20.73	C F
28	1	15.77	21.22	C F
29	1	11.85	22.22	C F
30	1	7.26	24.64	C F

SOIL OPTIONS: A = ANISOTROPIC, C = CURVED STRENGTH ENVELOPE (TANGENT PHI & C),
F = FIBER-REINFORCED SOIL (FRS), N = NONLINEAR UNDRAINED SHEAR STRENGTH,
R = RAPID DRAWDOWN OR RAPID LOADING (SEISMIC) SHEAR STRENGTH
NOTE: Phi and C in Table 4 are modified values based on specified
Soil Options (if any). Zero values for both phi & c indicate normal stress = 0.0

Calculated Secant Phi Values

Slice No.	Phi(Deg)
1	24.18
2	22.09
3	21.24

4	20.86
5	21.72
6	21.71
7	21.71
8	21.71
9	21.71
10	21.70
11	21.70
12	21.70
13	21.70
14	21.69
15	21.69
16	21.69
17	21.69
18	21.68
19	21.68
20	21.68
21	21.68
22	21.84
23	21.95
24	22.13
25	22.24
26	22.49
27	22.99
28	23.54
29	24.65
30	27.32

NOTE: The slices in the table above with phi marked with an * are unmodified phi values for soil type(s) not specified to have curved strength envelope (if any).

TABLE 5 - Total Base Stress Data on the 30 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Stress (psf)	Total Vert. Stress (psf)	Total Normal/Vert. Stress Ratio
1	-28.83	37.53	3.05	203.51	133.75	1.522
2	-27.83	39.83	2.19	520.27	361.65	1.439
3	-27.83	41.77	2.19	780.85	549.92	1.420
4	-27.83	43.01	0.62	944.08	670.76	1.407
5	13.91	44.83	3.18	657.85	697.89	0.943
6	13.91	47.92	3.18	658.67	698.76	0.943
7	13.91	51.00	3.18	659.50	699.63	0.943
8	13.91	54.08	3.18	660.32	700.51	0.943
9	13.91	57.17	3.18	661.14	701.38	0.943
10	13.91	60.25	3.18	661.96	702.25	0.943
11	13.91	63.34	3.18	662.79	703.13	0.943
12	13.91	66.42	3.18	663.61	704.00	0.943
13	13.91	69.51	3.18	664.43	704.87	0.943
14	13.91	72.59	3.18	665.26	705.74	0.943
15	13.91	75.68	3.18	666.08	706.62	0.943
16	13.91	78.76	3.18	666.90	707.49	0.943
17	13.91	81.84	3.18	667.73	708.36	0.943
18	13.91	84.93	3.18	668.55	709.24	0.943
19	13.91	88.01	3.18	669.37	710.11	0.943
20	13.91	90.77	2.50	670.11	710.89	0.943
21	13.91	93.20	2.50	670.75	711.57	0.943
22	19.91	95.58	2.50	625.24	695.42	0.899
23	19.91	97.94	2.50	595.50	662.44	0.899
24	25.91	99.14	0.07	552.23	645.00	0.856
25	25.91	100.28	2.46	522.70	611.38	0.855
26	25.91	102.50	2.46	466.48	546.02	0.854
27	31.91	104.67	2.50	375.56	463.90	0.810
28	31.91	106.79	2.50	294.76	365.01	0.808
29	37.91	108.93	2.72	185.28	244.57	0.758
30	37.91	110.89	2.26	64.23	86.78	0.740

TABLE 5A - Total Base Force Data on the 30 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Force (lbs)	Total Vert. Force (lbs)	Total Normal/Vert. Force Ratio
1	-28.83	37.53	3.05	621.11	357.63	1.737
2	-27.83	39.83	2.19	1139.16	700.27	1.627
3	-27.83	41.77	2.19	1709.71	1064.84	1.606
4	-27.83	43.01	0.62	586.18	368.31	1.592
5	13.91	44.83	3.18	2090.50	2152.66	0.971
6	13.91	47.92	3.18	2093.11	2155.35	0.971
7	13.91	51.00	3.18	2095.73	2158.05	0.971
8	13.91	54.08	3.18	2098.35	2160.74	0.971
9	13.91	57.17	3.18	2100.96	2163.43	0.971
10	13.91	60.25	3.18	2103.58	2166.12	0.971
11	13.91	63.34	3.18	2106.19	2168.82	0.971
12	13.91	66.42	3.18	2108.81	2171.51	0.971
13	13.91	69.51	3.18	2111.42	2174.20	0.971
14	13.91	72.59	3.18	2114.04	2176.89	0.971
15	13.91	75.68	3.18	2116.65	2179.58	0.971
16	13.91	78.76	3.18	2119.27	2182.28	0.971
17	13.91	81.84	3.18	2121.88	2184.97	0.971
18	13.91	84.93	3.18	2124.50	2187.66	0.971
19	13.91	88.01	3.18	2127.12	2190.35	0.971
20	13.91	90.77	2.50	1675.27	1725.07	0.971
21	13.91	93.20	2.50	1676.89	1726.74	0.971
22	19.91	95.58	2.50	1563.10	1634.60	0.956
23	19.91	97.94	2.50	1488.75	1557.06	0.956
24	25.91	99.14	0.07	39.16	41.14	0.952
25	25.91	100.28	2.46	1288.22	1355.27	0.951
26	25.91	102.50	2.46	1149.67	1210.39	0.950
27	31.91	104.67	2.50	938.91	984.44	0.954
28	31.91	106.79	2.50	736.91	774.60	0.951
29	37.91	108.93	2.72	504.43	525.32	0.960
30	37.91	110.89	2.26	145.13	154.72	0.938

TABLE 6 - Effective and Base Shear Stress Data on the 30 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Stress (psf)	Available Shear Strength (psf)	Mobilized Shear Stress (psf)
1	-28.83	37.53	3.05	184.78	87.20	56.42
2	-27.83	39.83	2.19	469.64	194.86	126.08
3	-27.83	41.77	2.19	703.86	277.88	179.80
4	-27.83	43.01	0.62	850.18	323.98	209.63
5	13.91	44.83	3.18	560.14	223.11	144.36
6	13.91	47.92	3.18	560.85	223.36	144.52
7	13.91	51.00	3.18	561.55	223.61	144.68
8	13.91	54.08	3.18	562.25	223.86	144.84
9	13.91	57.17	3.18	562.95	224.10	145.00
10	13.91	60.25	3.18	563.65	224.35	145.16
11	13.91	63.34	3.18	564.35	224.60	145.33
12	13.91	66.42	3.18	565.05	224.85	145.49
13	13.91	69.51	3.18	565.75	225.10	145.65
14	13.91	72.59	3.18	566.45	225.35	145.81
15	13.91	75.68	3.18	567.15	225.60	145.97
16	13.91	78.76	3.18	567.85	225.85	146.13
17	13.91	81.84	3.18	568.56	226.10	146.29
18	13.91	84.93	3.18	569.26	226.35	146.45
19	13.91	88.01	3.18	569.96	226.60	146.62
20	13.91	90.77	2.50	570.58	226.82	146.76
21	13.91	93.20	2.50	571.13	227.01	146.89
22	19.91	95.58	2.50	527.88	211.59	136.91
23	19.91	97.94	2.50	502.76	202.57	131.07

24	25.91	99.14	0.07	461.93	187.81	121.52
25	25.91	100.28	2.46	437.11	183.02	118.42
26	25.91	102.50	2.46	390.04	165.73	107.23
27	31.91	104.67	2.50	310.62	136.04	88.02
28	31.91	106.79	2.50	243.66	110.39	71.42
29	37.91	108.93	2.72	151.04	73.56	47.60
30	37.91	110.89	2.26	52.08	31.14	20.15

TABLE 6A - Effective and Base Shear Force Data on the 30 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Force (lbs)	Available Shear Force (lbs)	Mobilized Shear Force (lbs)
1	-28.83	37.53	3.05	563.96	266.14	172.20
2	-27.83	39.83	2.19	1028.30	426.65	276.06
3	-27.83	41.77	2.19	1541.14	608.43	393.67
4	-27.83	43.01	0.62	527.87	201.16	130.16
5	13.91	44.83	3.18	1780.02	708.98	458.74
6	13.91	47.92	3.18	1782.24	709.78	459.25
7	13.91	51.00	3.18	1784.47	710.57	459.76
8	13.91	54.08	3.18	1786.70	711.36	460.28
9	13.91	57.17	3.18	1788.92	712.15	460.79
10	13.91	60.25	3.18	1791.15	712.95	461.30
11	13.91	63.34	3.18	1793.38	713.74	461.81
12	13.91	66.42	3.18	1795.61	714.53	462.33
13	13.91	69.51	3.18	1797.83	715.32	462.84
14	13.91	72.59	3.18	1800.06	716.11	463.35
15	13.91	75.68	3.18	1802.29	716.91	463.86
16	13.91	78.76	3.18	1804.51	717.70	464.38
17	13.91	81.84	3.18	1806.74	718.49	464.89
18	13.91	84.93	3.18	1808.97	719.28	465.40
19	13.91	88.01	3.18	1811.20	720.07	465.91
20	13.91	90.77	2.50	1426.46	567.05	366.90
21	13.91	93.20	2.50	1427.84	567.54	367.22
22	19.91	95.58	2.50	1319.70	528.97	342.27
23	19.91	97.94	2.50	1256.90	506.43	327.68
24	25.91	99.14	0.07	32.75	13.32	8.62
25	25.91	100.28	2.46	1077.27	451.06	291.85
26	25.91	102.50	2.46	961.27	408.45	264.28
27	31.91	104.67	2.50	776.54	340.11	220.06
28	31.91	106.79	2.50	609.15	275.97	178.56
29	37.91	108.93	2.72	411.21	200.29	129.59
30	37.91	110.89	2.26	117.68	70.37	45.54

Average Effective Normal Stress = 495.8070(psf)
Average Available Shear Strength = 200.1197(psf)
Total Length of Failure Surface = 80.7010(ft)

SUM OF MOMENTS = -0.544474E-05 (ft/lbs);Imbalance (Fraction of Total Weight) = -0.1164575E-09
SUM OF FORCES = -.151987E-06 (lbs);Imbalance (Fraction of Total Weight) = -0.3250846E-11

Sum of Available Shear Forces = 16149.87(lbs)

Sum of Mobilized Shear Forces = 10449.54(lbs)

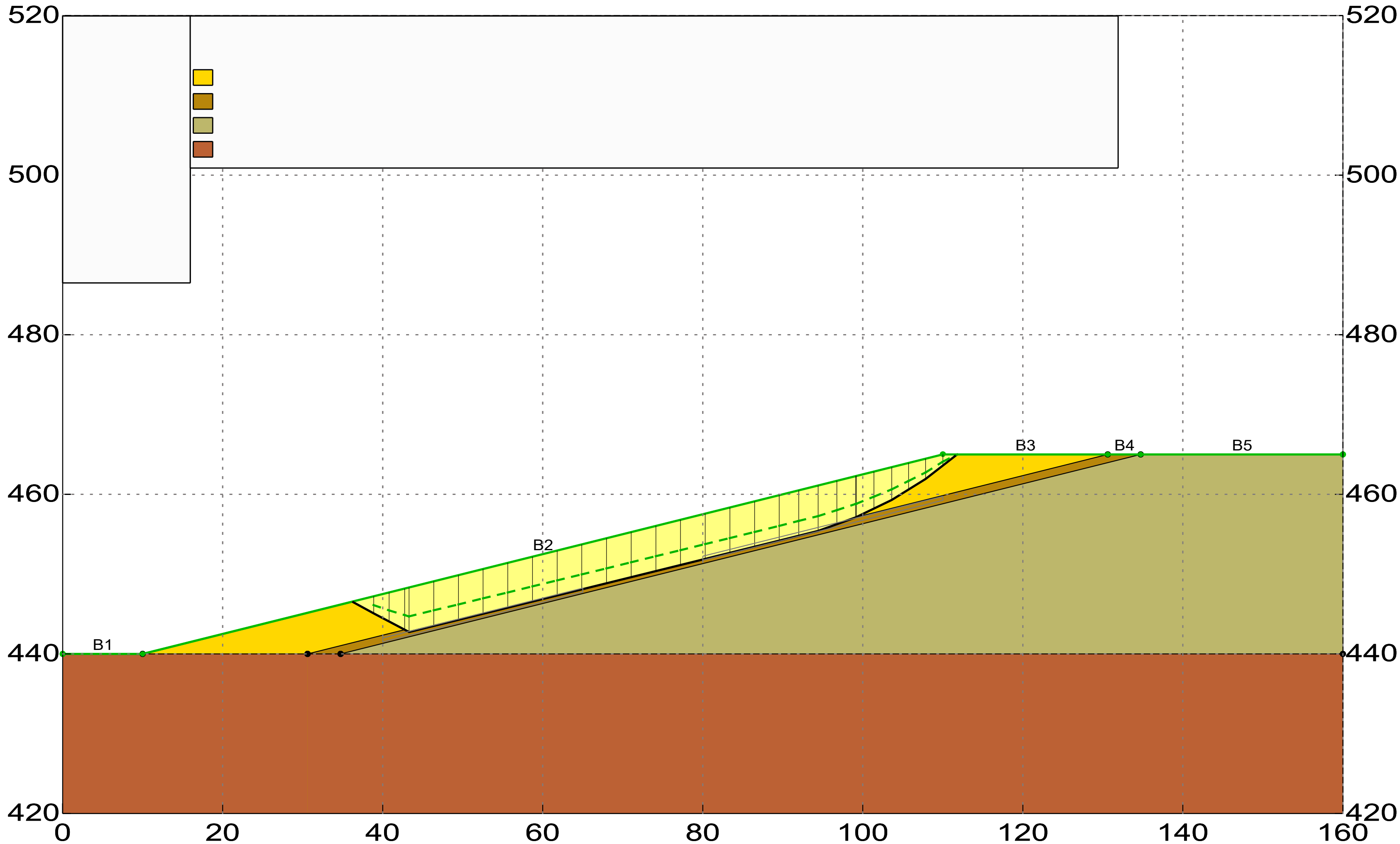
FS Balance Check: FS = 1.545510

**** END OF GEOSTASE OUTPUT ****

PGBT - ROADWAY EMBANKEMENT
Reinforced Condition - Long-Term - FRS - Heavy Rainfall

GREGORY GEOTECHNICAL - GHG

\PGBT-FRS-Heavy Rainfall.gsd



GEOSTASE FS = 1.313

Spencer Method

GEOSTASE Slope Stability Analysis

GREGORY GEOTECHNICAL

GEOSTASE® by GREGORY GEOTECHNICAL SOFTWARE

PLATE C.13

PGBT-FRS-Heavy Rainfall.OUT

*** GEOSTASE ***

****
SLOPE STABILITY ANALYSIS SOFTWARE
Simplified Bishop, Simplified Janbu, or General Equilibrium (GE) Options.
(Spencer, Morgenstern-Price, USACE, and Lowe & Karafiath)
Including Pier/Pile, Planar Reinf, Nail, Tieback, Line Loads
Nonlinear Undrained Shear Strength, Curved Strength Envelope,
Anisotropic , Fiber-Reinforced , Distributed Loads, Water
Surfaces, Pseudo-Static & Newmark Earthquake, and Applied Forces.
****

Analysis Date:
Analysis Time:
Analysis By: GREGORY GEOTECHNICAL - GHG

Input File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Stufy - 2\PGBT-FRS-Heavy Rainfall.gsd

Output File Name: C:\Users\Dr. Garry H. Gregory\Documents\OU-FRS-SLOPE\Case Stufy - 2\PGBT-FRS-Heavy Rainfall.OUT

Unit System: English

PROJECT: PGBT - ROADWAY EMBANKEMENT

DESCRIPTION: Reinforced Condition - Long-Term - FRS - Heavy Rainfall

BOUNDARY DATA

5 Surface Boundaries
10 Total Boundaries

Boundary No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Soil Type Below Bnd
1	0.000	440.000	10.000	440.000	4
2	10.000	440.000	110.000	465.000	1
3	110.000	465.000	130.610	465.000	1
4	130.610	465.000	134.730	465.000	2
5	134.730	465.000	160.000	465.000	3
6	10.000	440.000	30.610	440.000	4
7	30.610	440.000	130.610	465.000	2
8	30.610	440.000	34.730	440.000	4
9	34.730	440.000	134.730	465.000	3
10	34.730	440.000	160.000	440.000	4

User Specified X-Origin = 0.000(ft)

User Specified Y-Origin = 420.000(ft)

MOHR-COULOMB SOIL PARAMETERS

4 Type(s) of Soil Defined

Soil Number Moist Saturated Cohesion Friction Pore Pressure Water Water

and Description	Unit Wt. (pcf)	Unit Wt. (pcf)	Intercept (psf)	Angle (deg)	Pressure Ratio(ru)	Constant (psf)	Surface No.	Option
1 Weathered Fill	125.0	130.0	100.00	20.00	0.280	0.0	0	0
2 Weak Zone	125.0	130.0	0.00	20.00	0.280	0.0	0	0
3 Fill	125.0	130.0	200.00	20.00	0.000	0.0	0	0
4 In Situ	125.0	130.0	200.00	18.00	0.000	0.0	0	0

FIBER-REINFORCED SOIL PROPERTIES
2 Soil Type(s) With Fiber Reinforcement

Soil Type 1:

Fiber Length = 2.65(in) Fiber Width = 0.04700(in)
Fiber Thickness = 0.00149(in) Fiber Equivalent Dia. = 0.00944(in)
Friction Coefficient = 0.50 Cohesion Coefficient = 0.50
Specific Gravity of Fiber = 0.910 Application Rate = 0.222 (pcf)

Soil Type 2:

Fiber Length = 2.65(in) Fiber Width = 0.04700(in)
Fiber Thickness = 0.00149(in) Fiber Equivalent Dia. = 0.00944(in)
Friction Coefficient = 0.50 Cohesion Coefficient = 0.50
Specific Gravity of Fiber = 0.910 Application Rate = 0.222 (pcf)

Fiber-Reinforced Shear-Strength Properties

Soil Type 1: FRS c = 103.69 (psf) FRS Phi = 24.25 Deg.
Delta(c) = 3.694(psf) Tan(DeltaPhi) = 0.074242
Soil Type 2: FRS c = 0.00 (psf) FRS Phi = 24.25 Deg.
Delta(c) = 0.000(psf) Tan(DeltaPhi) = 0.074242

CURVED STRENGTH PARAMETERS
2 Soil Type(s) Assigned Curved Strength Envelope Properties

Pa = 2116.800(psf)
A Value of 1.0 indicates Dimensional Coefficients

Soil Type 1:

Curve Coefficients a, b, and T are User Input Values

Coefficient a = 0.2723 Coefficient b = 0.8691
Cohesion(c) = 0.00000(psf) Coefficient T = 0.00000

A Power Curve Function Has Been Selected to Model
Stress-Dependent Shear Strength (C = 0).

Soil Type 2:

Curve Coefficients a, b, and T are User Input Values

Coefficient a = 0.2723 Coefficient b = 0.8691
Cohesion(c) = 0.00000(psf) Coefficient T = 0.00000

A Power Curve Function Has Been Selected to Model
Stress-Dependent Shear Strength (C = 0).

A Non-Circular Zone Search Has Been Selected For Analysis
Using Random Generation Within Specified Zones.

2 Zones Defined For Generation Of Non-Circular Surfaces

1000 Trial Surfaces Have Been Generated.

Length Of Line Segments For Active And Passive Portions Of
Non-Circular Zone Search = 5.00(ft)

Zone No.	X - 1 (ft)	Y - 1 (ft)	X - 2 (ft)	Y - 2 (ft)	Height (ft)
1	40.00	441.75	65.00	448.00	0.50
2	80.00	452.00	110.00	459.50	0.50

The Spencer Method Was Selected for FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR SPENCER METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 9.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = 0.00 ; Maximum theta(deg) = 90.00
Theta convergence Step Factor = 500.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

Specified Tension Crack Water Depth Factor = 0.000

Total Number of Trial Surfaces Attempted = 1000

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence = 24
Maximum Normal Stress Difference (%) = 0.005000

Warning: Convergence not achieved on 31
surfaces during curved strength envelope calculations.
Maximum Normal Stress Difference (%) = Infinity

WARNING! The Factor of Safety Calculation for one or More Trial Surfaces
Did Not Converge in 50 Iterations.

Number of Trial Surfaces with Non-Converged FS = 34

Number of Trial Surfaces With Valid FS = 966

Percentage of Trial Surfaces With Non-Converged and/or
Non-Valid FS Solutions of the Total Attempted = 3.4 %

Statistical Data On All Valid FS Values:
FS Max = 1.931 FS Min = 1.313 FS Ave = 1.466
Standard Deviation = 0.096 Coefficient of Variation = 6.53 %

Critical Surface is Sequence Number 923 of Those Analyzed.

*****BEGINNING OF DETAILED GEOSTASE OUTPUT FOR CRITICAL SURFACE FROM A SEARCH*****

Iter. No.	Theta (deg) (fx=1.0)	FS (Moment)	FS (Force)	Lambda	Delta FS

1	9.0000	1.454832	1.282423	0.158	0.1724088E+00
2	11.9700	1.361970	1.305016	0.212	0.5695398E-01
3	13.4322	1.279383	1.317305	0.239	0.3792205E-01
4	12.8489	1.316611	1.312301	0.228	0.4310087E-02
5	12.9095	1.313040	1.312814	0.229	0.2256233E-03
6	12.9128	1.312841	1.312842	0.229	0.1454242E-05
7	12.9128	1.312842	1.312842	0.229	0.2883878E-08

Factor Of Safety For The Preceding Specified Surface = 1.313
Theta (fx = 1.0) = 12.91 Deg   Lambda = 0.229

Maximum Number of Iterations Required for Curved
Strength Envelope Convergence = 24
Maximum Normal Stress Difference (%) = 0.005000

The Spencer Method Has Been Selected For FS Analysis.

Selected fx function = Constant (1.0)

SELECTED CONVERGENCE PARAMETERS FOR ANALYSIS METHOD:
Initial estimate of FS = 1.500
FS tolerance = 0.00000100
Initial estimate of theta(deg) = 9.00
Theta tolerance(radians) = 0.0001000
Minimum theta(deg) = 0.00 ; Maximum theta(deg) = 90.00
Theta convergence Step Factor = 500.00
Maximum number of iterations = 50
Maximum force imbalance = 100.000000(lbs)
Maximum moment imbalance(if Applicable) = 100.000000 (ft/lbs)

Selected Lambda Coefficient = 1.00

Tension Crack Water Force = 0.00(lbs)

Specified Tension Crack Water Depth Factor = 0.000

Depth of Tension Crack (zo) at Side of Last Slice = 0.000(ft)

Depth of Water in Tension Crack = 0.000(ft)

Theoretical Tension Crack Depth = 3.635(ft)

NOTE: In Table 1 following, when a tension crack with water is present on the first slice (right facing slope) or on the last slice (left facing slope), the "side force" in the tension crack is set equal to the water pressure resultant.

*** Table 1 - Line of Thrust(if applicable) and Slice Force Data ***

Slice No.	X Coord.	Y Coord.	h/H	Side Force (lbs)	fx	Force Angle (Deg)	Vert. Shear Force(lbs)
1	38.87	446.12	0.487	485.76	1.000	12.91	108.6
2	40.80	445.44	0.381	1312.84	1.000	12.91	293.4
3	42.74	444.87	0.356	2530.84	1.000	12.91	565.6
4	43.29	444.71	0.352	2942.80	1.000	12.91	657.6
5	46.37	445.46	0.349	2880.23	1.000	12.91	643.6
6	49.46	446.21	0.346	2817.52	1.000	12.91	629.6
7	52.54	446.96	0.343	2754.67	1.000	12.91	615.6
8	55.63	447.71	0.340	2691.68	1.000	12.91	601.5
9	58.71	448.46	0.338	2628.56	1.000	12.91	587.4
10	61.80	449.21	0.336	2565.29	1.000	12.91	573.3
11	64.88	449.97	0.333	2501.89	1.000	12.91	559.1
12	67.96	450.72	0.331	2438.34	1.000	12.91	544.9
13	71.05	451.48	0.330	2374.66	1.000	12.91	530.7

14	74.13	452.24	0.328	2310.83	1.000	12.91	516.4
15	77.22	453.00	0.327	2246.87	1.000	12.91	502.1
16	80.30	453.76	0.326	2182.77	1.000	12.91	487.8
17	83.39	454.52	0.325	2118.52	1.000	12.91	473.4
18	86.47	455.28	0.325	2054.14	1.000	12.91	459.0
19	89.56	456.05	0.325	1989.62	1.000	12.91	444.6
20	91.98	456.65	0.325	1938.76	1.000	12.91	433.3
21	94.41	457.26	0.325	1887.82	1.000	12.91	421.9
22	96.76	458.02	0.325	1665.49	1.000	12.91	372.2
23	99.11	458.80	0.326	1455.33	1.000	12.91	325.2
24	99.17	458.82	0.326	1445.47	1.000	12.91	323.0
25	101.39	459.72	0.324	1129.86	1.000	12.91	252.5
26	103.61	460.63	0.324	851.72	1.000	12.91	190.3
27	105.73	461.68	0.320	526.06	1.000	12.91	117.6
28	107.85	462.75	0.321	275.54	1.000	12.91	61.6
29	110.00	464.10	0.353	56.21	1.000	12.91	12.6
30	111.78	465.00	0.000	0.00	1.000	12.91	0.0

NOTE: A value of 0.000- for h/H indicates that the line of thrust is at or below the lower boundary of the sliding mass. A value of 1.000+ for h/H indicates that the line of thrust is at or above the upper boundary of the sliding mass.

Table 2 - Geometry Data on the 30 Slices

Slice No.	Width (ft)	Height (ft)	X-Cntr (ft)	Y-Cntr-Base (ft)	Y-Cntr-Top (ft)	Alpha (deg)	Beta (deg)	Base Length (ft)
1	2.67	1.07	37.53	445.81	446.88	-28.83	14.04	3.05
2	1.94	2.89	39.83	444.57	447.46	-27.83	14.04	2.19
3	1.94	4.40	41.77	443.54	447.94	-27.83	14.04	2.19
4	0.55	5.37	43.01	442.89	448.25	-27.83	14.04	0.62
5	3.08	5.58	44.83	443.12	448.71	13.91	14.04	3.18
6	3.08	5.59	47.92	443.89	449.48	13.91	14.04	3.18
7	3.08	5.60	51.00	444.65	450.25	13.91	14.04	3.18
8	3.08	5.60	54.08	445.42	451.02	13.91	14.04	3.18
9	3.08	5.61	57.17	446.18	451.79	13.91	14.04	3.18
10	3.08	5.62	60.25	446.95	452.56	13.91	14.04	3.18
11	3.08	5.63	63.34	447.71	453.33	13.91	14.04	3.18
12	3.08	5.63	66.42	448.47	454.11	13.91	14.04	3.18
13	3.08	5.64	69.51	449.24	454.88	13.91	14.04	3.18
14	3.08	5.65	72.59	450.00	455.65	13.91	14.04	3.18
15	3.08	5.65	75.68	450.77	456.42	13.91	14.04	3.18
16	3.08	5.66	78.76	451.53	457.19	13.91	14.04	3.18
17	3.08	5.67	81.84	452.29	457.96	13.91	14.04	3.18
18	3.08	5.67	84.93	453.06	458.73	13.91	14.04	3.18
19	3.08	5.68	88.01	453.82	459.50	13.91	14.04	3.18
20	2.43	5.69	90.77	454.51	460.19	13.91	14.04	2.50
21	2.43	5.69	93.20	455.11	460.80	13.91	14.04	2.50
22	2.35	5.56	95.58	455.83	461.40	19.91	14.04	2.50
23	2.35	5.30	97.94	456.68	461.98	19.91	14.04	2.50
24	0.06	5.16	99.14	457.13	462.29	25.91	14.04	0.07
25	2.22	4.89	100.28	457.68	462.57	25.91	14.04	2.46
26	2.22	4.37	102.50	458.76	463.12	25.91	14.04	2.46
27	2.12	3.71	104.67	459.96	463.67	31.91	14.04	2.50
28	2.12	2.92	106.79	461.28	464.20	31.91	14.04	2.50
29	2.15	1.96	108.93	462.77	464.73	37.91	14.04	2.72
30	1.78	0.69	110.89	464.31	465.00	37.91	0.00	2.26

Table 2A - Coordinates of Slice Points Defining the Slip Surface

Point No.	X-Pt (ft)	Y-Pt (ft)
1	36.192749	446.548187
2	38.866513	445.076558

3	40.802846	444.054426
4	42.739179	443.032295
5	43.288269	442.742447
6	46.372803	443.506598
7	49.457336	444.270749
8	52.541870	445.034900
9	55.626404	445.799051
10	58.710938	446.563202
11	61.795471	447.327353
12	64.880005	448.091504
13	67.964539	448.855655
14	71.049072	449.619806
15	74.133606	450.383957
16	77.218140	451.148108
17	80.302673	451.912259
18	83.387207	452.676410
19	86.471741	453.440561
20	89.556274	454.204712
21	91.982918	454.805880
22	94.409562	455.407047
23	96.760073	456.258575
24	99.110584	457.110103
25	99.174361	457.141090
26	101.391099	458.218155
27	103.607836	459.295219
28	105.729941	460.616837
29	107.852045	461.938456
30	110.000000	463.611443
31	111.782775	465.000000

Table 3 - Force and Pore Pressure Data On The 30 Slices (Excluding Reinforcement)

Slice No.	Weight (lbs)	Ubeta Force Top (lbs)	Ubeta Stress Top (psf)	Ualpha Force Bot (lbs)	Pore Pressure (psf)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Distributed Load (lbs)
1	357.6	0.0	0.0	114.3	37.5	0.0	0.0	0.00
2	700.3	0.0	0.0	221.7	101.3	0.0	0.0	0.00
3	1064.8	0.0	0.0	337.1	154.0	0.0	0.0	0.00
4	368.3	0.0	0.0	116.6	187.8	0.0	0.0	0.00
5	2152.7	0.0	0.0	621.0	195.4	0.0	0.0	0.00
6	2155.4	0.0	0.0	621.7	195.7	0.0	0.0	0.00
7	2158.0	0.0	0.0	622.5	195.9	0.0	0.0	0.00
8	2160.7	0.0	0.0	623.3	196.1	0.0	0.0	0.00
9	2163.4	0.0	0.0	624.1	196.4	0.0	0.0	0.00
10	2166.1	0.0	0.0	624.8	196.6	0.0	0.0	0.00
11	2168.8	0.0	0.0	625.6	196.9	0.0	0.0	0.00
12	2171.5	0.0	0.0	626.4	197.1	0.0	0.0	0.00
13	2174.2	0.0	0.0	627.2	197.4	0.0	0.0	0.00
14	2176.9	0.0	0.0	628.0	197.6	0.0	0.0	0.00
15	2179.6	0.0	0.0	628.7	197.9	0.0	0.0	0.00
16	2182.3	0.0	0.0	629.5	198.1	0.0	0.0	0.00
17	2185.0	0.0	0.0	630.3	198.3	0.0	0.0	0.00
18	2187.7	0.0	0.0	631.1	198.6	0.0	0.0	0.00
19	2190.4	0.0	0.0	631.8	198.8	0.0	0.0	0.00
20	1725.1	0.0	0.0	497.6	199.0	0.0	0.0	0.00
21	1726.7	0.0	0.0	498.1	199.2	0.0	0.0	0.00
22	1634.6	0.0	0.0	486.8	194.7	0.0	0.0	0.00
23	1557.1	0.0	0.0	463.7	185.5	0.0	0.0	0.00
24	41.1	0.0	0.0	12.8	180.6	0.0	0.0	0.00
25	1355.3	0.0	0.0	421.9	171.2	0.0	0.0	0.00
26	1210.4	0.0	0.0	376.8	152.9	0.0	0.0	0.00
27	984.4	0.0	0.0	324.7	129.9	0.0	0.0	0.00
28	774.6	0.0	0.0	255.5	102.2	0.0	0.0	0.00
29	525.3	0.0	0.0	186.4	68.5	0.0	0.0	0.00
30	154.7	0.0	0.0	54.9	24.3	0.0	0.0	0.00

Table 3A - Center of Pressure of Water Loads On the 30 Slices
Only Applicable Slices Listed

Slice No.	X-Ubeta (ft)	Y-Ubeta (ft)	Ubeta-Moment (ft/lbs)

Table 3B - Center of Pressure of Distributed Loads On the 30 Slices
Only Applicable Slices Listed

Slice No.	X-Dload (ft)	Y-Dload (ft)	Dist-Load (lbs)	Dload-Moment (ft/lbs)

TOTAL WEIGHT OF SLIDING MASS = 46753.00(lbs)

EFFECTIVE WEIGHT OF SLIDING MASS = 33662.16(lbs)

TOTAL AREA OF SLIDING MASS = 374.02(ft2)

TABLE 4 - SOIL STRENGTH & SOIL OPTIONS DATA ON THE 30 SLICES

Slice No.	Soil Type	Cohesion (psf)	Phi(Deg)	Options
1	1	12.73	21.96	C F
2	1	23.06	20.10	C F
3	1	30.89	19.34	C F
4	2	31.32	19.00	C F
5	2	20.12	19.95	C F
6	2	20.14	19.95	C F
7	2	20.16	19.95	C F
8	2	20.18	19.95	C F
9	2	20.20	19.94	C F
10	2	20.22	19.94	C F
11	2	20.25	19.94	C F
12	2	20.27	19.94	C F
13	2	20.29	19.93	C F
14	2	20.31	19.93	C F
15	2	20.33	19.93	C F
16	2	20.36	19.93	C F
17	2	20.38	19.92	C F
18	2	20.40	19.92	C F
19	2	20.42	19.92	C F
20	2	20.44	19.92	C F
21	2	20.46	19.92	C F
22	2	18.92	20.09	C F
23	2	18.13	20.18	C F
24	2	16.67	20.37	C F
25	1	20.12	20.48	C F
26	1	18.62	20.71	C F
27	1	15.90	21.20	C F
28	1	13.68	21.70	C F
29	1	10.37	22.77	C F
30	1	6.65	25.26	C F

SOIL OPTIONS: A = ANISOTROPIC, C = CURVED STRENGTH ENVELOPE (TANGENT PHI & C),
F = FIBER-REINFORCED SOIL (FRS), N = NONLINEAR UNDRAINED SHEAR STRENGTH,
R = RAPID DRAWDOWN OR RAPID LOADING (SEISMIC) SHEAR STRENGTH
NOTE: Phi and C in Table 4 are modified values based on specified
Soil Options (if any). Zero values for both phi & c indicate normal stress = 0.0

Calculated Secant Phi Values

Slice No.	Phi(Deg)
1	24.36
2	22.29
3	21.44

4	21.06
5	22.12
6	22.12
7	22.12
8	22.12
9	22.11
10	22.11
11	22.11
12	22.10
13	22.10
14	22.10
15	22.10
16	22.09
17	22.09
18	22.09
19	22.09
20	22.08
21	22.08
22	22.28
23	22.38
24	22.59
25	22.71
26	22.97
27	23.51
28	24.07
29	25.25
30	28.00

NOTE: The slices in the table above with phi marked with an * are unmodified phi values for soil type(s) not specified to have curved strength envelope (if any).

TABLE 5 - Total Base Stress Data on the 30 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Stress (psf)	Total Vert. Stress (psf)	Total Normal/Vert. Stress Ratio
1	-28.83	37.53	3.05	208.62	133.75	1.560
2	-27.83	39.83	2.19	529.36	361.65	1.464
3	-27.83	41.77	2.19	793.13	549.92	1.442
4	-27.83	43.01	0.62	957.61	670.76	1.428
5	13.91	44.83	3.18	657.88	697.89	0.943
6	13.91	47.92	3.18	658.70	698.76	0.943
7	13.91	51.00	3.18	659.52	699.63	0.943
8	13.91	54.08	3.18	660.35	700.51	0.943
9	13.91	57.17	3.18	661.17	701.38	0.943
10	13.91	60.25	3.18	661.99	702.25	0.943
11	13.91	63.34	3.18	662.82	703.13	0.943
12	13.91	66.42	3.18	663.64	704.00	0.943
13	13.91	69.51	3.18	664.46	704.87	0.943
14	13.91	72.59	3.18	665.29	705.74	0.943
15	13.91	75.68	3.18	666.11	706.62	0.943
16	13.91	78.76	3.18	666.93	707.49	0.943
17	13.91	81.84	3.18	667.76	708.36	0.943
18	13.91	84.93	3.18	668.58	709.24	0.943
19	13.91	88.01	3.18	669.40	710.11	0.943
20	13.91	90.77	2.50	670.14	710.89	0.943
21	13.91	93.20	2.50	670.78	711.57	0.943
22	19.91	95.58	2.50	625.58	695.42	0.900
23	19.91	97.94	2.50	595.83	662.44	0.899
24	25.91	99.14	0.07	553.10	645.00	0.858
25	25.91	100.28	2.46	523.43	611.38	0.856
26	25.91	102.50	2.46	467.13	546.02	0.856
27	31.91	104.67	2.50	376.67	463.90	0.812
28	31.91	106.79	2.50	295.63	365.01	0.810
29	37.91	108.93	2.72	186.27	244.57	0.762
30	37.91	110.89	2.26	64.53	86.78	0.744

TABLE 5A - Total Base Force Data on the 30 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Total Normal Force (lbs)	Total Vert. Force (lbs)	Total Normal/Vert. Force Ratio
1	-28.83	37.53	3.05	636.71	357.63	1.780
2	-27.83	39.83	2.19	1159.07	700.27	1.655
3	-27.83	41.77	2.19	1736.60	1064.84	1.631
4	-27.83	43.01	0.62	594.58	368.31	1.614
5	13.91	44.83	3.18	2090.59	2152.66	0.971
6	13.91	47.92	3.18	2093.21	2155.35	0.971
7	13.91	51.00	3.18	2095.82	2158.05	0.971
8	13.91	54.08	3.18	2098.44	2160.74	0.971
9	13.91	57.17	3.18	2101.05	2163.43	0.971
10	13.91	60.25	3.18	2103.67	2166.12	0.971
11	13.91	63.34	3.18	2106.28	2168.82	0.971
12	13.91	66.42	3.18	2108.90	2171.51	0.971
13	13.91	69.51	3.18	2111.52	2174.20	0.971
14	13.91	72.59	3.18	2114.13	2176.89	0.971
15	13.91	75.68	3.18	2116.75	2179.58	0.971
16	13.91	78.76	3.18	2119.36	2182.28	0.971
17	13.91	81.84	3.18	2121.98	2184.97	0.971
18	13.91	84.93	3.18	2124.59	2187.66	0.971
19	13.91	88.01	3.18	2127.21	2190.35	0.971
20	13.91	90.77	2.50	1675.34	1725.07	0.971
21	13.91	93.20	2.50	1676.96	1726.74	0.971
22	19.91	95.58	2.50	1563.96	1634.60	0.957
23	19.91	97.94	2.50	1489.58	1557.06	0.957
24	25.91	99.14	0.07	39.22	41.14	0.953
25	25.91	100.28	2.46	1290.01	1355.27	0.952
26	25.91	102.50	2.46	1151.26	1210.39	0.951
27	31.91	104.67	2.50	941.67	984.44	0.957
28	31.91	106.79	2.50	739.07	774.60	0.954
29	37.91	108.93	2.72	507.14	525.32	0.965
30	37.91	110.89	2.26	145.82	154.72	0.942

TABLE 6 - Effective and Base Shear Stress Data on the 30 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Stress (psf)	Available Shear Strength (psf)	Mobilized Shear Stress (psf)
1	-28.83	37.53	3.05	171.17	81.73	62.26
2	-27.83	39.83	2.19	428.10	179.73	136.90
3	-27.83	41.77	2.19	639.15	255.28	194.44
4	-27.83	43.01	0.62	769.80	296.45	225.80
5	13.91	44.83	3.18	462.47	188.01	143.21
6	13.91	47.92	3.18	463.05	188.22	143.37
7	13.91	51.00	3.18	463.63	188.43	143.53
8	13.91	54.08	3.18	464.21	188.64	143.69
9	13.91	57.17	3.18	464.78	188.85	143.85
10	13.91	60.25	3.18	465.36	189.06	144.01
11	13.91	63.34	3.18	465.94	189.27	144.17
12	13.91	66.42	3.18	466.52	189.48	144.33
13	13.91	69.51	3.18	467.10	189.69	144.49
14	13.91	72.59	3.18	467.68	189.90	144.65
15	13.91	75.68	3.18	468.26	190.11	144.81
16	13.91	78.76	3.18	468.83	190.32	144.97
17	13.91	81.84	3.18	469.41	190.53	145.13
18	13.91	84.93	3.18	469.99	190.74	145.29
19	13.91	88.01	3.18	470.57	190.95	145.45
20	13.91	90.77	2.50	471.09	191.14	145.59
21	13.91	93.20	2.50	471.54	191.30	145.71
22	19.91	95.58	2.50	430.87	176.49	134.44
23	19.91	97.94	2.50	410.35	168.97	128.71

24	25.91	99.14	0.07	372.50	154.99	118.05
25	25.91	100.28	2.46	352.24	151.69	115.54
26	25.91	102.50	2.46	314.24	137.41	104.67
27	31.91	104.67	2.50	246.78	111.60	85.00
28	31.91	106.79	2.50	193.43	90.65	69.05
29	37.91	108.93	2.72	117.79	59.81	45.55
30	37.91	110.89	2.26	40.23	25.64	19.53

TABLE 6A - Effective and Base Shear Force Data on the 30 Slices

Slice No. *	Alpha (deg)	X-Coord. Slice Cntr (ft)	Base Leng. (ft)	Effective Normal Force (lbs)	Available Shear Force (lbs)	Mobilized Shear Force (lbs)
1	-28.83	37.53	3.05	522.41	249.45	190.01
2	-27.83	39.83	2.19	937.36	393.53	299.75
3	-27.83	41.77	2.19	1399.46	558.94	425.75
4	-27.83	43.01	0.62	477.97	184.06	140.20
5	13.91	44.83	3.18	1469.62	597.45	455.08
6	13.91	47.92	3.18	1471.46	598.12	455.59
7	13.91	51.00	3.18	1473.30	598.79	456.10
8	13.91	54.08	3.18	1475.14	599.45	456.61
9	13.91	57.17	3.18	1476.98	600.12	457.12
10	13.91	60.25	3.18	1478.82	600.79	457.62
11	13.91	63.34	3.18	1480.66	601.46	458.13
12	13.91	66.42	3.18	1482.50	602.12	458.64
13	13.91	69.51	3.18	1484.34	602.79	459.15
14	13.91	72.59	3.18	1486.18	603.46	459.66
15	13.91	75.68	3.18	1488.01	604.12	460.16
16	13.91	78.76	3.18	1489.85	604.79	460.67
17	13.91	81.84	3.18	1491.69	605.46	461.18
18	13.91	84.93	3.18	1493.53	606.12	461.69
19	13.91	88.01	3.18	1495.37	606.79	462.20
20	13.91	90.77	2.50	1177.72	477.84	363.97
21	13.91	93.20	2.50	1178.86	478.25	364.29
22	19.91	95.58	2.50	1077.16	441.23	336.09
23	19.91	97.94	2.50	1025.87	422.43	321.77
24	25.91	99.14	0.07	26.41	10.99	8.37
25	25.91	100.28	2.46	868.11	373.85	284.76
26	25.91	102.50	2.46	774.46	338.66	257.96
27	31.91	104.67	2.50	616.94	278.99	212.51
28	31.91	106.79	2.50	483.57	226.62	172.62
29	37.91	108.93	2.72	320.70	162.83	124.03
30	37.91	110.89	2.26	90.91	57.93	44.13

Average Effective Normal Stress = 411.5854(psf)
Average Available Shear Strength = 169.6066(psf)
Total Length of Failure Surface = 80.7010(ft)

SUM OF MOMENTS = -0.521263E-05 (ft/lbs);Imbalance (Fraction of Total Weight) = -0.1114929E-09
SUM OF FORCES = -.153867E-06 (lbs);Imbalance (Fraction of Total Weight) = -0.3291062E-11

Sum of Available Shear Forces = 13687.43(lbs)

Sum of Mobilized Shear Forces = 10425.80(lbs)

FS Balance Check: FS = 1.312842

**** END OF GEOSTASE OUTPUT ****

Appendix D – (GSP016) SOIL REINFORCEMENT FIBERS - GUIDE SPECIFICATION

1.00 GENERAL

This guide specification is furnished as a convenience and as a general guide only. This guide specification is not intended and should not be used as a construction specification. The project civil engineer may use this guide specification as a general guideline in developing the appropriate construction specifications. *GREGORY GEOTECHNICAL* (GREGEO) should be retained to review those portions of the project plans and specifications developed using this guide specification, as a means to determine if our recommendations have been interpreted as intended.

1.01 WORK INCLUDED

Furnish labor, materials, equipment and incidentals necessary to install fibers for soil reinforcement. Use the fibers in conjunction with earth fill for stabilization of embankments and slopes or other areas as recommended. The fibers, when mixed with earth fill as recommended, should provide uniformly distributed reinforcement throughout the soil mass.

1.02 QUALITY STANDARDS

A. DESIGN CRITERIA

1. The fiber-reinforced soil should be installed in the recommended areas. The limits of the fiber-reinforced soil should be shown on the construction plans by appropriate cross sections and plan views. **The dosage rate should be clearly designated in the construction documents.**

2. The fibers should be polypropylene fibers and should be inert to commonly encountered chemicals, hydrocarbons, mildew and rot resistant, resistant to ultraviolet light exposure, insect and rodent resistant, and conform to the properties in the following table.

Property	Test Method	Requirements
Polypropylene	ASTM D4101 Group 1/Class 1/Grade 2	99% min.
Moisture Absorption	--	Nil
Fiber Length	Measured	3.5-inch min.
Aspect Ratio	Measured/Calculated	360 min.
Carbon Black Content	ASTM D1603	0.6% min.
Tensile Strength	ASTM D2256	40,000 psi min.
Tensile Elongation	ASTM D2256	15% max.
Young's Modulus	ASTM D2101	600,000 psi min.

B. PACKING, IDENTIFICATION, AND STORAGE REQUIREMENTS

The fibers should be packaged in sealed polyethylene or heavy paper bags placed in cardboard or other suitable cartons. The carton should be properly identified with a clearly readable label. The label should list the following information:

a. A unique carton or package number
b. Name of fiber manufacturer
c. Product brand name and style designation (if applicable)
d. Fiber length
e. Net weight of fiber in each bag

Store the fiber cartons in a manner to protect the fibers from moisture and direct sunlight.

C. SAMPLING AND COMPLIANCE REQUIREMENTS

A competent laboratory should be maintained by the producer of the fibers at the point of manufacture to provide quality control in accordance with ASTM testing procedures. The laboratory should maintain records of its quality control results and provide a manufacturer's certificate to the owner prior to shipment. The certificate should include:

1. Name of manufacturer
2. Chemical composition
3. Product description
4. Statement of compliance to specification requirements
5. Signature of legally authorized official attesting to the information required

2.00 PRODUCTS

2.01 MATERIALS

SOIL – REINFORCEMENT FIBERS – Plain -Tape Polypropylene Fibers
Fibrillated (slit) fibers will not be allowed.

3.00 EXECUTION

3.01 INSTALLATION

A. Earthwork - All earthwork in conjunction with soil - reinforcement fibers for should be performed in accordance with all applicable recommendations contained in the EARTHWORK section of the Geotechnical Engineering Study report provided by GREGEO for this project. This includes, but is not limited to, lift thickness, moisture content, density, and soil processing. A roto-till pulverizer should be used for processing of fiber reinforced earth fill, rather than a disk plow.

B. Fiber Application - Following spreading of each loose lift of earth fill, the fiber bags should be opened and spread on the lift in a specific, regular pattern determined by the fiber dosage rate calculated based upon the dry unit weight of the soil. The fibers should be uniformly spread over the entire surface area of each lift.

C. Processing - Following uniform spreading of the fibers at the prescribed dosage rate, the fibers should be thoroughly blended with the soil by multiple passes of a roto-till pulverizer with fully-penetrating blades (blades long enough to completely penetrate through the full loose lift thickness). A minimum of three passes of the roto-till pulverizer should be achieved. The number of passes should be increased as required to achieve uniform, isotropic dispersion of the fibers without clumping or balling of the fibers. Where space permits, each pass should be at right angles to the previous pass.

D. Compaction - Following processing of each fiber-reinforced earth fill lift, the lift should be compacted as recommended in the EARTHWORK section of this report.

END OF SECTION