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16. Abstract:
A research implementation project was undertaken to demonstrate the use of an innovative technology known as "in-situ soil vitrification" for slope stabilization purposes. The equipment needed to accomplish vitrification in the field, called SOVIT, was developed at Texas Tech University as part of a previous TxDOT sponsored research project. Three sites with a history of frequent slope failure were selected for stabilization. The first of these was on the approach embankment to Motley Drive overpass over I-30 in Dallas District. The most critical failure surface was identified through analysis and a row of eleven vitrified piers, each 3 ft deep was installed at 6-ft spacing to intercept the failure surface. The second slope was a highway cut on the south side SH-36 near Hamilton, Waco District. At this site, slope movement had occurred at the interface between the near-surface weathered material and the unweathered material found at depths below 2 ft . Since the failure area was not accessible from the road level, a temporary access road was cut parallel to the slope. A row of sixteen vitrified piers was installed to a depth of 3-4 ft. The center-to-center spacing between piers was 6 ft. The third site in Tyler had to be abandoned due to unfavorable weather.

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STABILIZATION OF SOIL USING IN-SITU VITRIFICATION

by

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James C. Dickens and Shome S. Dey

Research Report Number 5-1860-01-1

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Project Title: Stabilization of Soils Using In-Situ Vitrification

conducted for

Texas Department of Transportation

by the

CENTER FOR MULTIDISCIPLINARY RESEARCH IN TRANSPORTATION

TEXAS TECH UNIVERSITY

October 2002

IMPLEMENTATION STATEMENT

Implementation of this project was undertaken to demonstrate the use of an innovative technology known as "in-situ vitrification" for slope stabilization. The SOVIT vitrification machine was developed at Texas Tech University for this purpose and used on 2 sites with known slope failure history. The demonstrations were successful. Future implementation should include training TxDOT personnel and utilizing the SOVIT machine at several TxDOT locations. Use of the SOVIT nationally should also be sought by TxDOT engineers.

Prepared in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

AUTHOR'S DISCLAIMER
The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Texas Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

PATENT DISCLAIMER
This phase of the project did not involve the development of any patentable products.

ENGINEERING DISCLAIMER
Not intended for construction, bidding, or permit purposes. The engineer in charge of the research study was P.W. Jayawickrama, Texas Tech University.

TRADE NAMES AND MANUFACTURERS' NAMES
The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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 yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
	VOLUME			
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in 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)			
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°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	35.71	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)			
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°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 inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate

(Revised September 1993)

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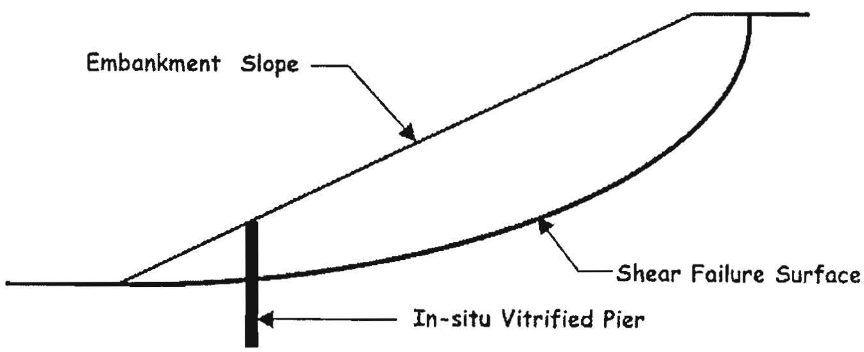
PROJECT 5-1860: STABILIZATION OF SOIL USING IN-SITU VITRIFICATION

1.0 INTRODUCTION

This report documents the work accomplished in the Implementation Project 5-1860-01: Stabilization of Soil Using In-Situ Vitrification. This one-year implementation project started on September 1, 2001 and was completed on August 31, 2002. The primary objectives of this project were to select 2 to 3 candidate sites with a history of frequent slope failure and stabilize them using in-situ vitrification technology.

In-situ vitrification is achieved by heating soil inside pre-drilled holes above its melting temperature and allowing the melt to cool down and solidify. This process results in the formation of monolithic columns of rock-like material that has high strength and stiffness (See Figure 1a below). When in-situ vitrification is used for slope stabilization, vitrification is carried out at selected locations on the slope so that the columns of vitrified soil will intercept potential failure surfaces (See Figure 1b). In this manner, the resistance to shear failure of the slope is greatly increased.

(a)



(b)

Figure 1 – (a) A Column of Vitrified Soil Exhumed from a Field Demonstration Site, (b) Use of In-Situ Vitrification for Slope Stabilization

In this project, vitrification of soil was achieved using an emerging technology known as Concentric Graphic Arc-Melter (CGAM) technology. For application of the CGAM technology in the field, it was necessary to have a mobile soil vitrification system. The necessary field vitrification system, called SOVIT, was developed by the Texas Tech University researchers as a part of a previous TxDOT sponsored research project. In this implementation project, the SOVIT system was utilized in several slope stabilization projects.

2.0 SITE SELECTION

The first task in this research implementation effort involved the selection of suitable candidate sites for stabilization using the new vitrification technology. Site selection was accomplished with the assistance from TxDOT Implementation Director, Mr. Tracy Cumby. The three candidate sites that were identified are: (a) Motley Drive Site (DAL), (b) Hamilton Site (WAC), and (c) Tyler Site (TYL).

2.1 Motley Drive Site, Dallas District

Motley Drive site is located at the Motley Drive overpass over Interstate Highway 30 in Mesquite. The vitrification was done on the northeast side of the approach embankment. Based on the information provided by Benny McCormack, Maintenance Manager, Dallas, this built-up embankment had a history of recurrent failure, especially after heavy rainfall. Lime treatment of embankment soil and geogrid reinforcement had been used in the past to repair the slope after failure. A concrete paved surface drain was found over the entire length of the embankment. The site did not have direct access either from I-30 or Motley Drive. A narrow alleyway from side streets provided access to the site.

2.2 Hamilton Site, Waco District

Hamilton site is located on US Highway 36 in Waco district. The slope that was selected for stabilization is a highway cut in a natural soil deposit. It is located approximately ten miles east of the city of Hamilton. The concerned slope is on the south side of US-36. The actual slope starts about twenty feet from the edge of the road. At the bottom of the slope there was an unlined longitudinal drain. Mr Glenn Christian, Maintenance Supervisor, Hamilton County, explained that the site had a problem of recurrent failure and that TxDOT had to make arrangements to repair the slope every alternate year. The slope had vegetation during the surveying stage but was mowed before the vitrification was done.

2.3 Tyler Site, Tyler District

Tyler site is located on US Highway 69 in Tyler district. The slope under consideration is a natural slope. The embankment slope is located on the east side of US-69. The main slope starts about fifteen feet from the edge of the road. At the bottom of the road there is an unlined longitudinal drain. At the southern end of the slope there is a narrow road going up the slope. This can serve as an approach road for the vitrification equipment. Based on information available from TxDOT personnel, this slope required frequent maintenance due to movement of soil down the slope. The vitrification at this site was scheduled for the fourth week of July. However, due to heavy rain that was received in Tyler area, it was not possible for TxDOT District crew to perform the necessary site preparation work until the third week of August. This time frame did not suit the schedules of remaining project tasks and, as a result this site was abandoned.

3.0 PRE-VITRIFICATION SITE EVALUATION

Evaluation of the site prior to stabilization by vitrification included the following activities: (1) surveying of the site to determine the slope profile, (2) drilling, sampling of the embankment soil and analysis by laboratory testing in the soil laboratory of Civil Engineering department of Texas Tech University. These activities were undertaken for Motley and Hamilton sites, but not for the Tyler site. The results from the pre-vitrification site evaluation are as follows.

3.1 Surveying

The slope profiles established based on surveying conducted at the Motley Drive and Hamilton sites are shown in Figures 2 and 3 respectively. The average slope angle at the Motley Drive site was found to be 17 degrees while the average slope angle at the Hamilton site was 19 degrees.

3.2 Soil Characterization

3.2.1 Motley Drive Site

Soil samples were retrieved from the Motley Drive slope, by drilling and sampling with thin-wall Shelby tubes. The sampling of soil was conducted by the TxDOT Dallas district and the samples were subsequently sent to the Department of Civil Engineering of Texas Tech University for testing. The results from the geotechnical characterization tests conducted at Texas Tech are shown in Table 1.

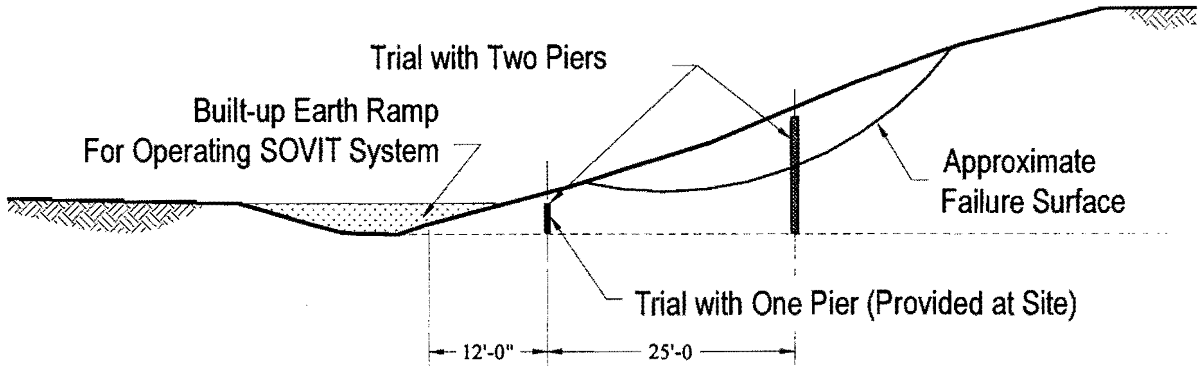


Figure 2 Slope Profile; Motley Drive Site

Table 1 – Results from Soil Characterization; Motley Drive Site

Test Parameter	Test Designation	Sampling Depth	
		6.0 ft	**14.0 ft**
Natural Moisture Content (%)	ASTM D2216	37.1	22.2
Percent Passing No 200	ASTM D1140	94.0	98.7
Liquid Limit	ASTM D4318	66.5	61.5
Plastic Limit	ASTM D4318	23.5	23.4
Plasticity Index	ASTM D4318	43.0	38.1
USCS Classification	ASTM D2487	CH	CH
AASHTO Classification	AASHTO-M145	A-7-6	A-7-6

3.2.2 Hamilton Site

The soil investigation conducted at the Hamilton site included three boreholes. Boreholes No. 1 and 2 were located at horizontal distances of 9.0 ft and 27.0 ft from the toe of the slope. Borehole No.3 was located 5.0 ft from the crest of the slope. Borehole locations are shown in Figure 3. The borehole data revealed that the soil profile consisted of approximately 2.0 ft thick weathered zone. The soil below the 2 ft depth consisted of inter-bedded layers of unweathered limestone and very stiff clay. This was confirmed by direct observation of the exposed soil profile when a road was cut on the slope to provide access to the SOVIT equipment. It was also evident that the failure was confined to shallow depths and most likely occurred at the interface between the weathered and unweathered zones. During soil sampling intact samples could not be retrieved from the top 2.0 ft. Intact samples were retrieved from the unweathered material below 2.0ft depth. However, no laboratory testing was conducted on these samples because their shear strengths would have no relevance to the failure that occurred within the top 2.0ft only.

4.0 SITE PREPARATION

4.1 Motley Drive Site

The site was mowed to clear the vegetation. A horizontal access ramp was built, by TxDOT, over the concrete surface drain at the base of the slope (See Figure 2). The access ramp was necessary so that the trailer mounted CGAM could be stationed on level ground. The ramp allowed the vitrification to be achieved at a distance of 12.0 ft into the slope from its toe.

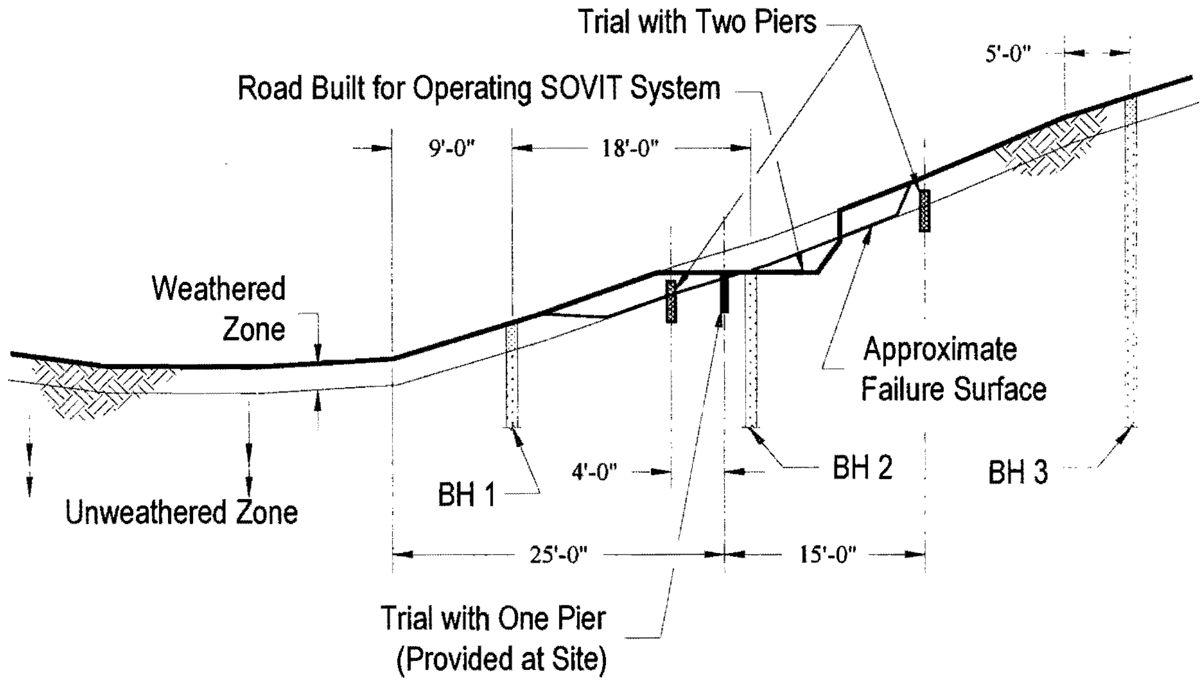


Figure 3 Slope Profile; Hamilton Site

4.2 Hamilton Site

The site was mowed to clear the vegetation. A 12.0 ft wide access road was built on the slope by TxDOT. The centerline of the road was at a distance of 25.0 ft from the toe of the slope, as shown in Figure 3. The access road enabled the trailer mounted CGAM to be stationed on level ground during its operation. Also it allowed the vitrified piers to be placed at a distance of 25.0 ft from the toe of the slope.

5.0 DESIGN OF STABILIZATION SYSTEMS

The next step in the stabilization of the two selected slopes included the design of a suitable configuration of vitrified piers for each site to achieve the desired target factor of safety. In other words, the optimum locations of the piers, spacing between piers and depths must be determined based on the slope profile and soil shear strengths using appropriate slope stability analyses. This was accomplished by using a slope stability software named GSTABL7. GSTABL7 is a two dimensional slope stability program that works in conjunction with a graphical user interface, STEDwin [1].

5.1 Motley Drive Site

The unit weights of soil were determined from laboratory analysis. The average plasticity index (PI) of the soil was also found from laboratory tests. Using this PI value and Plasticity Index-sin ϕ' relationship presented by Mitchell, 1993 [2], the effective friction angle, ϕ' was determined to be 26°. The method of analysis that was used at the Motley Drive site is *Bishop's Modified Method.* In this method, the failure surface is assumed to be a circular arc. Circular arc analysis is considered to be most appropriate for slopes where homogeneous soil conditions exist. Since the Motley Drive site involved a built-up embankment, the assumption of homogeneous soil conditions was deemed to be reasonable. Once the ϕ' angle is known, the effective cohesion c′ for the soil could be determined through back analysis of the unreinforced soil slope. Given that failures have occurred in the past, when the unreinforced embankment slope reached saturation, the value of effective cohesion c′ could be determined by assuming a factor of safety was 1.0 for the slope. The value of c′ that was determined in this manner was 39 psf. These soil parameters were then used in the next stage of the analysis to investigate the stability of the slope after it has been reinforced with vitrified soil piers.

To analyze the slope after it had been stabilized with vitrified piers, one must specify the allowable shear load on a single pier. The allowable shear load depends on the cross-sectional area of the pier and the shear strength of the vitrified material. Previous research conducted at Texas Tech showed that the average compressive strength of vitrified material was about 3000psi [3]. But no tests data was available on the shear strength of this material. Therefore, a conservative estimate for the shear strength of vitrified soil was obtained by reviewing available data on mechanical properties of rocks. Available data indicate that shear strength of weak rocks with a compressive strength of 3000psi is about 400psi [4]. Accordingly, the allowable shear load on a vitrified soil pier of diameter 10.0inches was calculated to be 28,000 lb. A resistance factor of 0.9 was used in this calculation.

Using a shear load of 28.0 kips/pier, slope analysis was performed for different pier configurations. Out of these only two are shown here. The first, called the *design pier configuration*, identifies the optimum locations and depths of vitrified soil piers to achieve a target factor of safety of 1.30. This involved two rows of piers with a spacing of 6.0ft between piers in each row. The first row of piers is placed at a distance of 12.0ft from the toe of the slope, as shown in Figure 2. These piers are 3.0ft deep. The second row of piers is placed at a distance of 37.0ft from the toe of the slope. They are 13.0ft deep.

The second pier configuration represents the actual pier layout used at the Motley Drive site. During implementation it became clear that, with the current limitations of the SOVIT system, it was not practical to place the second row of piers at a distance of 37.0ft from the toe. This would require building an earth ram that is more than 10.0ft in height. Therefore, only the first row of piers was placed. Single row of piers near the toe would prevent the slope from failing in the same manner that it had failed previously. However, the factor of safety calculated for these conditions suggest that a failure could occur further up the slope almost as easily. The results of the factors of safety calculated for these two piers configurations are shown in Table 2.

Table 2 Factors of Safety for Selected Pier Configurations; Motley Drive Site

Pier Configuration	Description of Piers Layout	F.O.S.
No Piers	None	1.00
Design Pier Configuration	– Two rows of piers with 6.0ft spacing between piers – Row No.1: 3.0ft deep piers placed at a distance of 12.0ft from the toe – Row No.2: 13.0ft deep piers placed at a distance of 37.0ft from the toe	1.30
Pier Configuration Used in Implementation	– A single row of piers with 6.0ft spacing between piers – 3.0ft deep piers placed at a distance of 12.0ft from the toe	1.00

5.2 Hamilton Site

At the Hamilton site, the top 2.0 ft of the soil profile consisted of weathered material while competent, unweathered material was found at depths greater than 2.0ft. It was obvious that the failure that had occurred on this slope was confined to the upper soil horizon. Unfortunately, no intact samples of the weathered material found in the upper soil horizon were recovered during soil investigation. Therefore, the shear strength parameters for the soil were determined through inverse analysis. As a first step, the effective friction angle of the soil, ϕ' was determined based on available technical literature on residual soils. Review of data published by Burns (1999) on residual soils of similar origin showed that 15 degrees was a reasonable estimate for the effective friction angle, ϕ' of this soil [5]. Secondly, slope stability analysis of the unstabilized slope was conducted using $\phi' = 15°$ and trial values for effective cohesion, c'. The c' was then adjusted until a factor of safety of 1.0 was obtained. The c' value that was estimated in this manner was 40 psf. The method used in the analysis of Hamilton slope is known as the *Spencer Method.* A non-circular failure surface that closely matched the actual failure surface was used in this analysis. This failure surface is shown in Figure 3.

The next step involved stability analysis of the stabilized slope. Accordingly, analysis was conducted, using GSTABL7, to determine the factors of safety of the slope for various pier configurations. This analysis, once again, was based on non-circular failure surfaces and a c' value of 40 psf and ϕ' of 15°. The allowable shear load on the vitrified soil piers was 28 kips/pier. The factors of safety calculated for two separate pier configurations are shown in Table 3.

The first pier configuration, called the *design pier design*, provides the maximum improvement in factor of safety for a specified length of installed pier. This requires two rows of piers, each 3ft deep running along the length of the slope. The spacing between piers in each row will be 6ft. The first row will be placed at a distance of 21.0ft from the toe of the slope and the second will be placed at a distance of 40.0ft from the toe. Piers that are installed according to this particular configuration will arrest any failure that is similar to the slides that have occurred on this slope previously. They will also prevent any other failure involving the upper or lower reaches of the slope. The factor of safety that is achieved with the above optimum pier configuration is 1.24.

Table 3 Factors of Safety for Selected Pier Configurations; Hamilton Site

Pier Configuration	Description of Piers Layout	F.O.S.
No Piers	None	1.00
Design Pier Configuration	– Two rows of piers with 6.0ft spacing between piers – Row No.1: 3.0ft deep piers placed at a distance of 21.0ft from the toe – Row No.2: 3.0ft deep piers placed at a distance of 40.0ft from the toe	1.24
Pier Configuration Used in Implementation	– A single row of piers with 6.0ft spacing between piers – 3.0ft deep piers placed at a distance of 25.0ft from the toe	1.00

The second pier configuration that is shown in Table 3 is the one that was actually used in this implementation project. Due to the limited mobility of the current SOVIT system, it was not possible to install two separate rows of piers as determined through analysis. Therefore, a single row of vitrified columns was installed at a distance of 25.0 ft from the toe of the slope. The pier depth and the spacing were the same as in the design pier configuration. The pier configuration used in implementation will be effective in preventing the type of failure that had occurred in the past. However, a single row of piers will not be capable of preventing failure within the upper or lower reaches of the slope. For this reason, the overall factor of safety calculated for the slope remains 1.0.

6.0 SOVIT SYSTEM OPERATION

6.1 Equipment

The SOVIT system used in this implementation project consisted of two major trailer mounted subsystems: the Concentric Graphite Arc Melter (CGAM) and the Power Conditioning Unit (PCU). The above equipment was developed during the preceding research phases of this project. A 180 kW, 3 phase, 460 V, diesel generator that was necessary to power the SOVIT system was purchased during this implementation project. The equipment also included two 15 hp gasoline engine driven air compressors. The diesel generator and the compressors are mounted on a second trailer. During operation, the AC output from the generator is connected, through an isolation transformer mounted on the SOVIT trailer, to the PCU; which then supplies current to the CGAM. The compressed air is connected to the CGAM, supplying 5-15 cfm of air to the channel between the concentric solid graphite cylinder cathode and the outer graphite cylinder anode. In addition, air is supplied between the outside surface of the anode and the thin protective steel casing to provide cooling for the anode.

6.2 Basic Operation

There are three identical separate units that make up the PCU. The three units, in parallel, each convert the 3-phase AC input to a regulated DC output current. The three DC currents are combined into a single DC current at the CGAM. It is this current, passing perpendicularly through the downward flowing air between the cathode and anode cylinder surfaces that heat the air, which becomes very high temperature (20,000°F) plasma. This plasma is hot enough to melt soil.

In operation, the CGAM is lowered vertically into a pre-drilled hole such that the bottom of the CGAM, from which plasma exits, is a couple of inches above the surface of the soil in the hole. The hole's diameter is larger than the CGAM's so that additional soil can be added as the soil at the bottom of the hole melts. The CGAM is slowly raised during operation, gradually filling the hole with molten material.

6.3 Operating Parameters

The three major down-hole operating parameters are: the total current, the height of the bottom of the CGAM above the top surface of the melted soil, and the length of time that the CGAM is kept at one position. During the start-up of the melting process, the CGAM remains stationary and the total current is gradually increased from 300 Amps to 1200-1500 Amps. The start-up process takes about 5 minutes. The maximum electric power to the arc is limited by the generator output, which for steady state operations, is kept below about 160 kW. The arc voltage is directly related to the distance between the bottom of the GCAM and the top of the melt. In normal operations, the CGAM is positioned such that the voltage is between 70 and 100 volts. Each PCU is limited a to maximum of 600 Amps output current; to protect the PCU the steady state current from each is limited to 550 Amps. Thus, the operating range is bounded by the total power, total PCU output current and the distance of the CGAM above the melt.

The last parameter, the time that the CGAM is held at one position, influences the porosity of the solidified soil. The plasma is a source of gas in the melt; also, gases are produced during the heating and melting of the soil. If the melt cools too quickly, these gases can be trapped, leaving voids in the solidified soil. These voids decrease the strength of the product. Typically the compressor air (plasma) flow is constant for all soils, so the two variables that affect the porosity of the soil are the original soil composition and length of time that the soil at one location is in the melted state. (Note that the top of the melt bubbles just like heated water in a pot). To produce the maximum strength in the solidified soil, the porosity must be minimized; to do this, the melting process is lengthened by keeping the CGAM longer at each depth in the hole.

6.4 SOVIT Operation at Motley Drive Site

Eleven holes, each 3.0-3.5ft deep and 6.0 center to center spacing, were vitrified at the Motley Drive site. At the Motley Drive site, a current of 1300 Amps was used. Nevertheless, the melt process was very slow due to difficulties in feeding soil into the hole. The soil available at the site had large lumps that did not fit easily within the space between the CGAM and the side of the hole. In addition, the holes at this site had a tendency to cave in more than the holes vitrified at other sites. Because of these problems, only two holes were completed during each of the first two days. The melt process on each hole took two to three hours. A modification of the melt process allowed seven holes to be vitrified on the third day. After each addition of soil, the CGAM was moved up and down for a couple of minutes. This action worked the soil down to the top of the existing melt. This approach reduced the time to complete a hole to less than an hour. Also, the current was increased to 1400 Amps on the third day. Figure 4 below shows the operation of SOVIT system at the Motley Drive site.

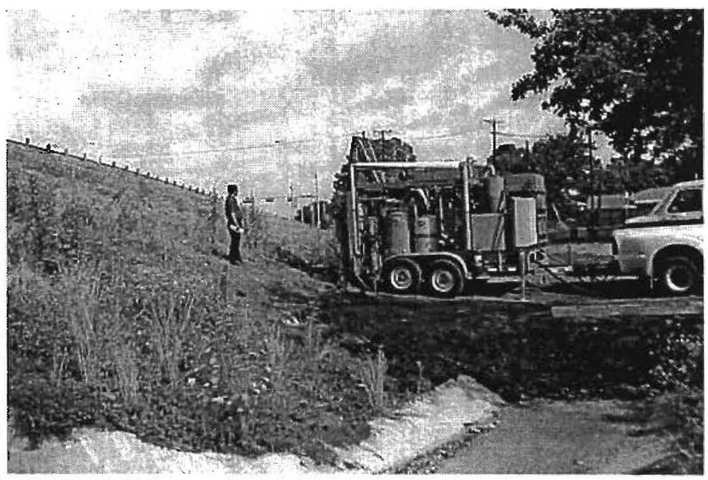


Figure 4 Operation of SOVIT System at the Motley Drive Site

Sixteen holes were vitrified at Hamilton in two days, six the first day and ten the second day. The average time from the start of setting up for a hole, to completion of melt and movement to the next hole was one hour. All holes were 3.0 feet deep and vitrified to within three inches from the surface. By the beginning of the second day, two to three inches of water had seeped into the bottom of a few holes that had been excavated a day earlier. The water in the holes had little impact on the operations. When water was present, the start up took a little longer (approximately 3 additional minutes). Besides that, there was no difference between the SOVIT operation in these holes and in dry holes. On-site soil was used during vitrification. Any clods found in the soil were broken up before the soil was fed into the hole. The average operating current was 1400 Amps at 85V. Figure 5 shows the SOVIT system in operation at the Hamilton site.

7.0 SLOPE PERFORMANCE AFTER STABILIZATION

7.1 Motley Drive Site

Observations made during the limited time period (four months) subsequent to the stabilization of Motley Drive slope show that there has been no further slope movement. Mr. Bennie McCormack, Maintenance Supervisor, Dallas District had made a number of visits to the site to monitor the performance of the slope. His most recent visit had been on October 22, 2002. It should also be noted that the area had received significant rainfall during this period of observation. The data from the weather station located at the First Baptist Academy in Dallas indicates that the area has received 8.90 inches of rain in October 2002, with much of the precipitation occurring between the dates of October 8 through October 24, 2002 (a 16 day span). Also, the area had received 5 inches of rain during the October 19 and 20 weekend.

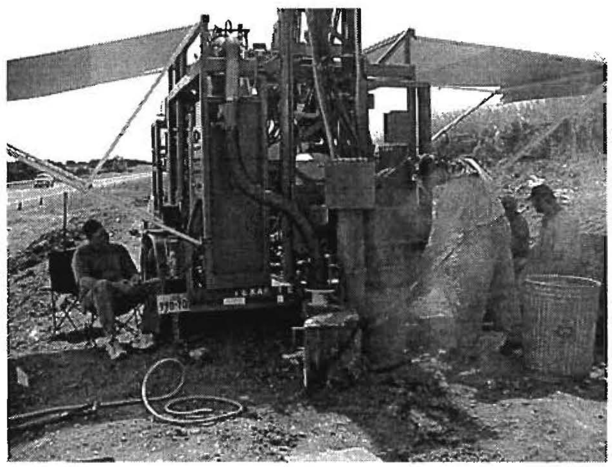


Figure 5 SOVIT System in Operation at the Hamilton Site

7.2 Hamilton Site

About one week after the vitrification was completed, the slope was brought back to its original contour by TxDOT maintenance crew by filling the cut that was made for equipment access. To accomplish this, the soil materials that were removed from the slope were track-walked into place with a bulldozer. Online weather information for one month (September 22-October 22, 2002) in Hamilton, TX indicates that the area has received 4.44 inches of rain to date, and that this rainfall has occurred between the dates of October 6-22, 2002. Mr. Eddy Sleeper, the office manager in the Hamilton maintenance office had made a number of visits to the site and no signs of slope movement had been observed.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The PCU adjustments made just before the beginning of the implementation project and the purchase of a larger generator (180 kW versus 125 kW generator that was rented) have made a significant reduction in the melt time per hole. During the research phase of the project, there were numerous electrical component failures in the PCUs. During the implementation project there were no PCU failures in more than 30 vitrification holes completed. Without the delays due to failures and fixes experienced during prior operations, operator performance and skills have significantly improved. During the two implementation projects, the SOVIT system was run almost continuously throughout the entire day for several days. Also, it was operated under extreme temperatures (over 100°F on some days).

The only equipment problem experienced during the implementation stage was with the generator. The generator's current cut-off switch frequently turned the machine off at a lower current than for which it was set. This problem was overcome by raising the cut-off current settings to levels much higher than the currents being used.

The primary limitation of the SOVIT system in slope stabilization applications is its inability to perform vitrification at various locations on the slope while the main unit remains parked at the base or crest of the slope. In other words, for this equipment to be used as practical tool, the CGAM electrodes must be provided with independent mobility. This can be achieved by mounting the electrodes on an articulated system.

Secondly, it is necessary to have the current cut-off switch repaired in the generator prior to any future field operation. In addition, one of the three PCU units needs to be adjusted. The SOVIT control system allows for setting the total current. At a typical setting of say 1300 Amps, one PCU produces 500 Amps, the second produces 470 but the third only produces 330 Amps. This is due to a slightly different parameter in this PCU's control circuit which was not detected until the Hamilton operations. When corrected the result will be an increase of about 100 Amps total output, without increasing the operating output of the other two PCUs.

9.0 REFERENCES

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