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16. Abstract:
Phase I of this research study demonstrated the feasibility of using Concentric Graphite Arc Melter (CGAM) vitrification technology for stabilizing weak subgrade soils. In Phase I, soil vitrification was achieved in the laboratory environment using the main power supply. The primary goal of the Phase II study, described in the report, was to develop a mobile, trailer mounted soil vitrification (SOVIT) system and its demonstration in the field. There are three major subsystems in mobile SOVIT. The first subsystem, the CGAM, was developed by MONTEC Associates in Butte, Montana. The second, Power Conditioning Unit (PCU) was developed by Texas Tech University. The third part is the 2-axle trailer that was bought locally in Lubbock, Texas. After successful check out of SOVIT system, its' functionality and operation were demonstrated at two selected sites in Lubbock and Dimmitt, TX. In Lubbock, the mobile SOVIT system was able to vitrify soil at 4 feet below the ground. It operated at one third of its intended design power. Next, SOVIT system was used at the TxDOT maintenance facility in Dimmitt to vitrify subgrade/subbase soils. Based on the findings from a pre and post-vitrification evaluation at Dimmitt, it was concluded that SOVIT technology is best suited for soil slope stabilization purposes.

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SUBGRADE REPAIR AND STABILIZATION USING IN-SITU VITRIFICATION – PHASE II: FINAL REPORT

By

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Research Report Number 0-1860

Conducted for
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By the

CENTER FOR MULTIDISCIPLINARY RESEARCH IN TRANSPORTATION
TEXAS TECH UNIVERSITY
and
MONTEC ASSOCIATES

September 2003

IMPLEMENTATION STATEMENT

Phase II of the Project 0-1860 was concerned with the development of a mobile, trailer mounted soil vitrification system (SOVIT) that will allow soil vitrification to be achieved in the field. Field tests conducted during this phase show that the SOVIT system is best suited for slope stabilization purposes. Therefore, it is recommended that, suitability of SOVIT for slope stabilization be fully investigated during Phase III research. It is anticipated that full-scale implementation of the SOVIT technology will be possible at the conclusion of Phase III research.

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

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Engineering Disclaimer

Not intended for construction, bidding, or permit purposes.

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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1. INTRODUCTION

This report documents the work accomplished and the results obtained from the second phase of TxDOT Research Project 0-1860: Subgrade Repair and Stabilization Using In-situ Vitrification. Phase I of this study was completed earlier.

Phase I work involved the demonstration of the potential of using Concentric Graphite Arc Melter (CGAM) vitrification technology for soil stabilization purposes. Accordingly, seven soil types that are representative of subgrade soils commonly found in Texas were selected for the Phase I study. Large samples of each soil type were obtained and placed in 55-gallon drums. In some samples, the initial water content and density were varied so that the influence of these variables on the effectiveness of stabilization could be determined. Using the CGAM equipment available at Montec Associates' research laboratories in Butte, Montana, a total of 10 soil samples were vitrified. Once vitrification of all soil samples was complete, the vitrified products were shipped back to Texas Tech University for further evaluation. Texas Tech University test program included characterization of each vitrification product with respect to strength, stiffness, density, porosity and resistance to moisture attack. The test results showed that vitrification had been successfully achieved in all soils, initial water contents and densities. The results further revealed that the strength, stiffness and other mechanical properties of the vitrified soils varied significantly. On the average the strengths were similar to that of Portland cement concrete while the modulii of elasticity were lower. Both the strength and stiffness showed close correlation with the density and porosity of the vitrified product. In other words, the strength and stiffness increased with increasing density and decreasing porosity. Complete documentation of Phase I research activities and the findings can be found in TxDOT Research Report No. TX/99/1860-1 (*1*).

In the first phase, as mentioned above, several Texas soil samples have successfully been fused and vitrified in the laboratory at Montec. The second phase of this study was intended to develop a mobile unit for the purpose of soil vitrification in the field. Montec developed the vitrification unit and the Electrical Engineering Department of Texas Tech University developed the power supply and conditioning unit. This mobile unit is named SOVIT. There are two objectives in this phase of the research.

The first objective was to design and build the SOVIT and check it out. There are three major subsystems to the SOVIT: the CGAM from Montec, the power conditioning unit (PCU) from Texas Tech University (TTU), and a 2-axle 10,000 pound load trailer from West Texas Lee Co. of Idalou, TX. After completing the checkout of the assembled SOVIT, the next objective was to demonstrate the operation of the SOVIT in Lubbock and Dimmitt.

Functionality and operation of this mobile unit was demonstrated in this report. Two sites were selected to demonstrate the SOVIT system. The initial trial was in Lubbock at Texas Tech University campus. The second demonstration was in Dimmitt at TxDOT maintenance facility yard. A later demonstration was more comprehensive.

The first demonstration was to check whether the mobile unit could actually vitrify soil in the field environment. This was done in a parking area of the TTU research park and successfully vitrified the soil. The second demonstration at Dimmitt was designed to vitrify subgrade soil. In this demonstration five holes were used in which to vitrify the added soil using various electrical outputs (current and voltage) from the SOVIT and various soil mixes and amounts.

Results from these two demonstrations were very useful in identifying appropriate future applications. A third phase of the study was planned to demonstrate the identified application.

2. DEVELOPMENT OF SOVIT SYSTEM AS MOBILE UNIT

2.1 The Manufacturing and Operation of the SOVIT System

The Montec subsystem, CGAM, is actually more than just the graphite cylinder shown at the rear of the trailer (Figure 1). This is the "working" element of the CGAM and is called the torch. The subsystems that support the torch consist of: water cooling, compressed air cooling, off gas, support structure, torch support and the control panel. In Figure 1, the CGAM occupies the rear 70% of the trailer and is enclosed by the rectangular support structure.

During operation, the CGAM compresses airflows down between the solid graphite cylinder (cathode) and the open outer cylinder (anode) of the torch. A second cooling path, with a smaller amount of air between the outside of the anode and a metal cylinder, covers and protects the graphite anode. The air from the cathode-anode path, besides cooling the cathode and anode, passes through the cathode-anode arc and is heated to plasma temperature. The plasma (~ $10{,}000^{+}$ °C) melts the soil.

Both air streams end up in the pre-dug-hole with the liquid soil. There is a significant amount of gas, which depending upon the soil, can contain, toxic and carcinogen vapors. A round shroud with a hole on the top for the torch is placed over the hole to confine the gas. Also attached to the top of the shroud is an exhaust hose which is the first element of the off gas subsystem. The gases from the hole are cooled by air and water in the off gas system and exhausted vertically at a temperature of less the 200 °F. At this temperature the toxic and carcinogen agents have been eliminated.

The second function of the water-cooling subsystem is to cool the head of the torch. This recycling water supply is contained in a 50-gallon tank.

The torch subsystem can be raised and lowered by an electric motor, wench and cable, and can be moved back and forward by hand. The up and down movement of the torch is controlled by the operator with a hand held cable connected switch. Thus the torch can be raised or lowered in the hole and even moved out of the shroud by the operator. The other operation functions are controlled from the operating panel, which also displays the subsystems status during operation.

Montec checked out the CGAM subsystem at Butte using commercial power and their laboratory power-conditioning unit (PCU). This Montec PCU is stationary, uses very robust components, and is large and heavy. The design with commercial power and a stationary directly connected PCU is not suited for field operations as envisioned for the SOVIT. The field CGAM is operated by a trailer mounted electric generator, 160-180kW and 460VAC, as shown in Figure 2.

Figure 1 – Portable, Trailer-Mounted SOVIT System

Figure 2 – Electric Power Generator Used with SOVIT

Once the weight and dimensions of the CGAM and PCU were established, the trailer was designed, manufactured and transported to Montana. The CGAM was installed over night and the trailer with CGAM returned to Lubbock. These two subsystems were at TTU on schedule, however, all of the PCU components did not arrive in Lubbock until weeks later.

The three major components of the PCU are: the 150kW isolation transformer (which electrically separates the generator from the CGAM), the high power electronic AC-DC modules (which converts 480VAC to DC), and output inductors (which reduce the ripple in the DC current which is supplied to the torch).

The isolation transformer was easy to specify and order. The specifications for the output inductors could not be finalized until after the high power electronic module was designed and tested. In our original discussions with the inductor manufacture there was no indication that there would be a long delay between order and delivery. However, when the order was made, we were informed that the inductors would not be shipped for 22 weeks! Incidentally, this is the same shipment delay that is always quoted by the US marketing agent for the IGBT electronic component used in the PCU. The IGBT's, which have been on the market for less than a year, are made in Japan, assembled in Germany and marketed by a US company in New Jersey. The IGBT's are a $2,200 item, and they are, current, power and total energy limited. The published specifications did not include this information.

The PCU design output to the torch was 100kW at 1200A at 80VDC. To accomplish this, three identical modules were made, each with one IGBT and producing 400A, and connected in parallel.

Once the PCU components were delivered, the PCU was made at TTU. The PCU was installed on the trailer and connected to the CGAM, as shown in Figure 3. At this point, a checkout of the SOVIT was initiated. Prior to installation, each PCU module had been individually checked out using utility power and a dummy load. The two words to note in the last sentence are: utility and dummy. A diesel/ generator set does not produce the same steady power that the utility does, and a dummy steady load is different from the variable non-steady load of the arc produced by the torch. The purpose of the PCU is to match the power used with the load demand. The job of doing this with a generator and an arc is much more difficult than that done in the typical commercial application.

During the checkout phase, we burned out one IGBT due to over current. Other failures occurred due to overheating of the IGBT and in "cross talk" between parallel modules. Given the operating range we were running (400A maximum for each module vs. an advertised 600A maximum rating), this should not have happened.

Figure 3 – Power Conditioning Unit (PCU)

All module repairs were usually accompanied by adjustments in the circuit design, sensors, and the automatic control system. Again, contrary to the specifications, we found that it was necessary to very rapidly (> 1/10,000 of a second) sample the DC current in the power transistors (IGBT's) in order to control the over current. The control process and logic had to be modified as we learned more about the operation of the IGBT's.

In addition to the learning delays we experienced with the IGBT's, we also had very long delays (3 to 5 months) before receiving replacement IGBT's. These were the two major causes for not being able to accomplish the Phase II tasks within the scheduled time.

<u>2.2 Initial PCU Design and Short Technical Discussion</u>

The output of the generator is connected to the experimental SOVIT unit via a "00" SOW cable. This cable feeds into a primary fuse box and via a small jumper, into an auxiliary fuse box. The auxiliary fuse panel feeds three 480V-220/110 transformers that in turn supply power required for the blowers, pumps, winches, power processing controller, and monitoring systems. The primary fuse panel feeds into a 440 amp-480V, 150kW isolation transformer that provides the input to the SOVIT trailer. The 480VAC output of the isolation transformer is split into three fuse blocks that feed the power-processing unit.

The power-processing unit was initially designed as a single unit with three stages. After initial construction and testing, the power-processing unit was redesigned using a modular approach. This modular approach gives more flexibility and reliability by using three identical modules with parallel inputs and outputs. Each stage was de-signed to be independent and capable of providing 650A of output at the required 100V.

Each module of the PPU has a three-phase rectifier receiving 480VAC power from the isolation transformer. The output of the three-phase rectifier is fed into the filter capacitor bank, which forms a 630VDC buss. The highly filtered DC buss forms the in-put stage of a buck converter. The buck converter was constructed using highly integrated IGBT modules built by Semikron Corporation. These modules are air-cooled and have integrated gate drivers and sophisticated status monitoring. They also contain a tightly coupled, low inductance buck diode. The DC buss on each module is filtered at the input terminals using high quality, low ESR/ESL film capacitors.

The output of the IGBT buck module is feed into the filter inductor and then into the torch head. The filter inductors are 140uH and are DC rated for 800A. In addition, they are air-cooled and have a 20 percent current ripple rating.

Each IGBT module has an independent PWM controller and feedback circuit. The controller was designed around a commercial PWM buck controller IC. The switching speed of the PWM was designed at 10Khz. The output current of each module is measured using an active Hall current monitor. These monitors have a 100Khz bandwidth and 1000A full-scale reading.

The loop bandwidth was designed around 100Hz. This bandwidth was based upon previous operating data and performance. As testing progressed with an active load, (i.e. in hole torch) it became apparent that the loop bandwidth was too narrow and was extended to 500Hz. Due to the severe instabilities in the melting process, this loop bandwidth is still to narrow, and will be part of the focus in the next design iteration.

3. SITE SELECTION

The second phase of the study was designed to demonstrate the ability of the SOVIT system in a field environment. Two sites, close to Texas Tech University campus, were selected for such trial and demonstration.

3.1 TTU Campus, Lubbock

The first selected site for the initial trial was at Texas Tech University campus parking lot of the Research Foundation located just outside East Loop 289. Since the intended application was to vitrify subgrade soil for roads and highways, the parking area would give the closest resemblance to it. It was tried at a 4 foot depth to make sure the SOVIT worked at that level, since some of the subgrade soil may be at 4 feet or deeper. Since the objective was only to observe whether or not the SOVIT system could actually vitrify soil in the field, there was no pre-vitrification evaluation. Figure 4 shows the site on the Map.

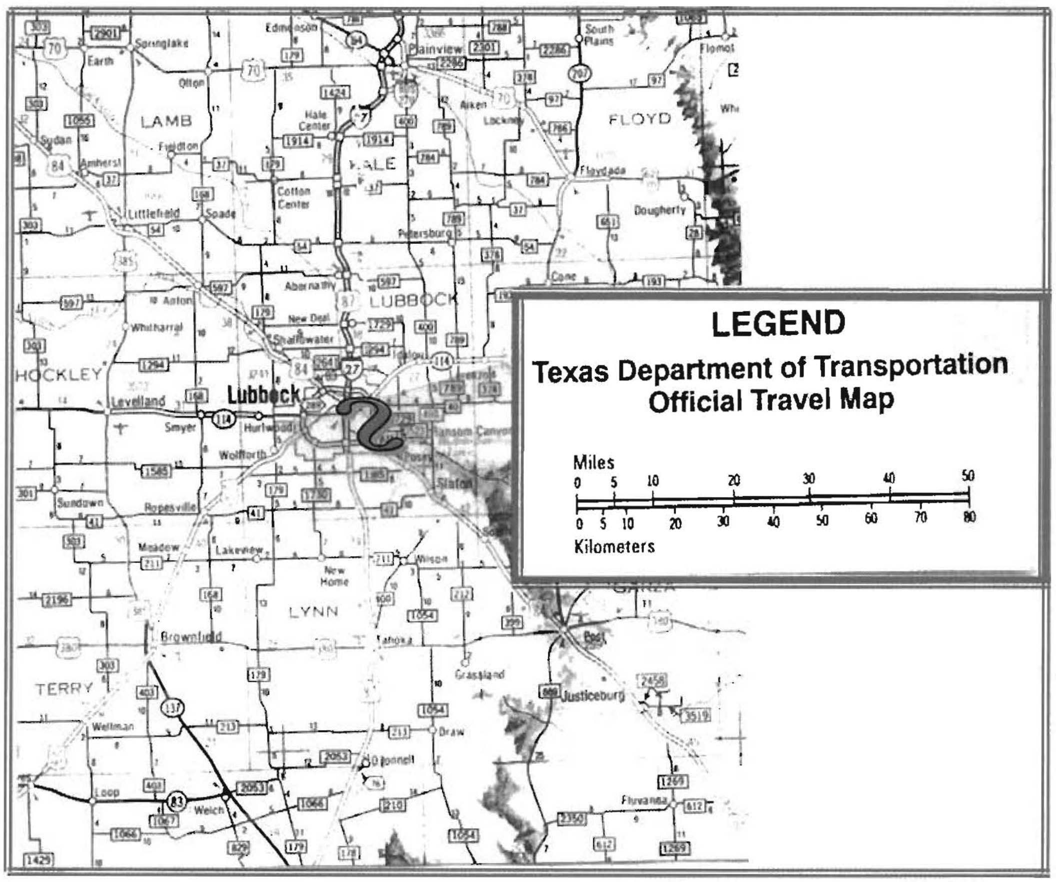


Figure 4 – Selected Site at Texas Tech University Campus in Lubbock

3.2 TxDOT Maintenance Office, Dimmitt

A second trial was designed to demonstrate the SOVIT system to Texas Department of Transportation (TxDOT). The selected location for this demonstration was located at the TxDOT maintenance facility yard at Dimmitt, Texas. Two spots were selected. One was on the access road to the yard and another was in the yard itself. The yard and access road was both flexible pavement. Limited visual and engineering evaluation was performed on these locations. Figure 5 shows the site on the Map.

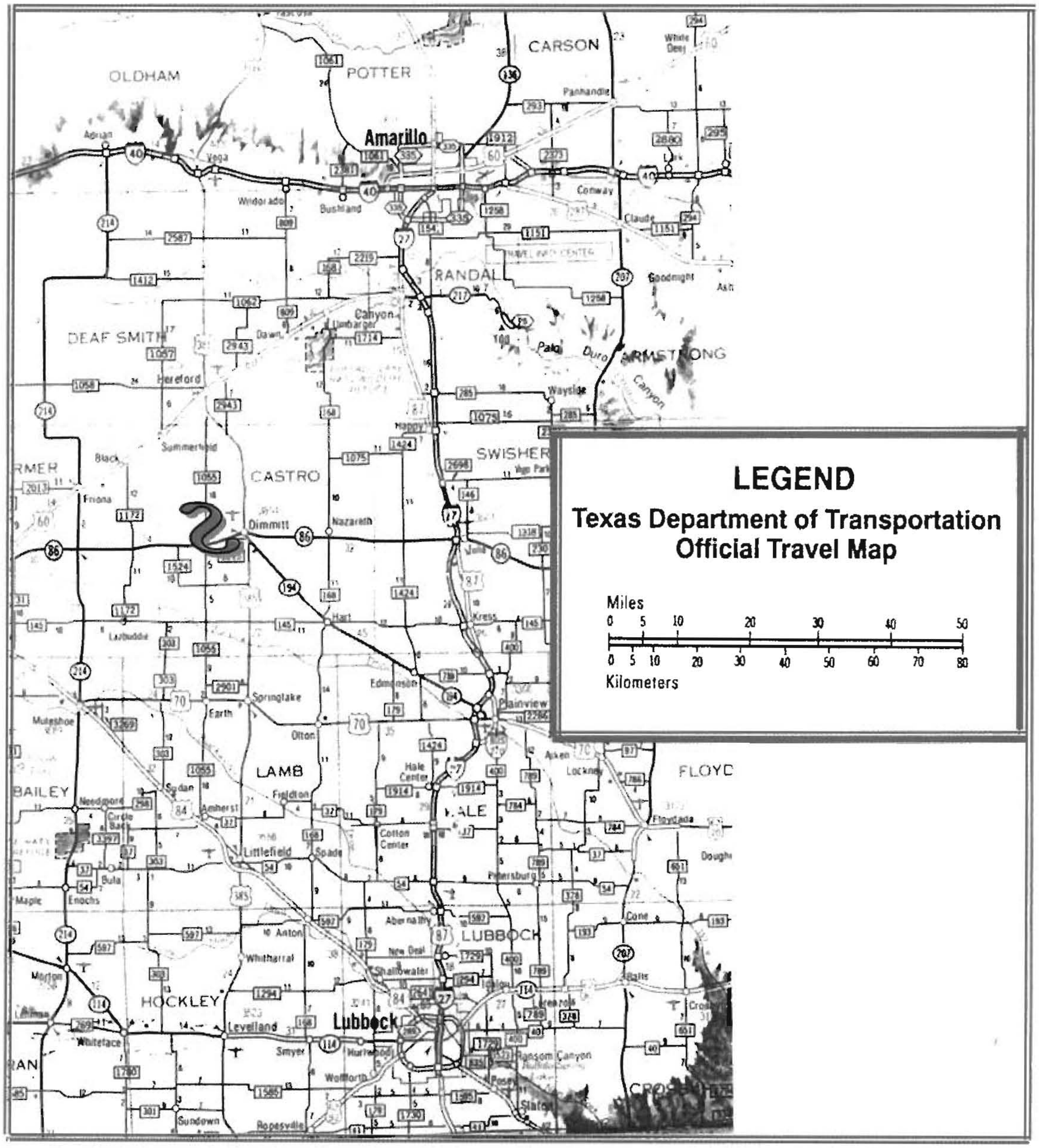


Figure 5 – Selected Site at TxDOT Maintenance Office in Dimmitt.

4. SITE CHARACTERIZATION OF DIMMITT

The characterization of the selected site at TxDOT maintenance office in Dimmitt involved both visual and engineering evaluation. This site was used for the first full demonstration of the SOVIT system. Therefore, the site was selected to represent the best possible condition of intended use. As explained earlier, the basic goal of this demonstration was to show the capabilities of the SOVIT system. Two spots were selected for evaluation: a 20' x 20' area inside the TxDOT maintenance facility yard and a 10' x 60' area of the access road to the yard. Figure 6 shows the schematic diagram of the selected spots. Engineering evaluation was performed using Falling Weight Deflectometer (FWD) and Dynamic Cone Penetrometer (DCP) tests.

The falling weight deflectometer (FWD) is a very effective means of evaluating the structural condition of pavements through non-destructive testing. The system develops forces from the acceleration caused by the arrest of a falling weight and these forces are transmitted onto the surface of a pavement, causing it to deflect as much as it would deflect from the weight of a passing wheel load. The deformation of the pavement is referred to as a "deflection basin". A series of velocity sensors positioned along a line is used to automatically determine the amplitude and shape of this deflection basin. By using the back calculation program "MODULUS 5.0", the strength and condition of the various layers of the pavement could be determined from "deflection basin" and applied load. Figures 7 and 8 show the grid points used to drop the load for FWD testing for the yard and access road sites, respectively. The readings from the sensors are attached in Appendix A. Figures 9 and 10 are the plots of average "deflection basin" for the yard and access road sites, respectively.

Dynamic cone penetrometer (DCP) is a simple in-situ field-testing device that permits testing of soils and paving materials with a full spectrum of strength to depths that are typically considered sufficient. There is a direct correlation between the strength of paving materials (including soil) and resistance to the penetration by cone penetrometer. The DCP consists of steel rod with a cone at one end, which is driven into the pavement structure and subgrade by means of a sliding hammer. Material strength is indicated by the penetration achieved (usually blows are counted per 4 inch penetration) per hammer blow. The cone has an angle of 45 degrees with a diameter of 1.4 inches. The hammer mass is 35 pounds with a drop height of 15 inches. It usually works better with fine-grained soil. DCP was tried at the selected site in Dimmitt, TX. The DCP test was not very successful, since it could not be used after vitrification of soil. The DCP could not penetrate the rock produced. Figure 11 shows a typical result obtained in the yard site.

A seismic pavement analyzer (SPA) was also used with minimum success for the intended use.

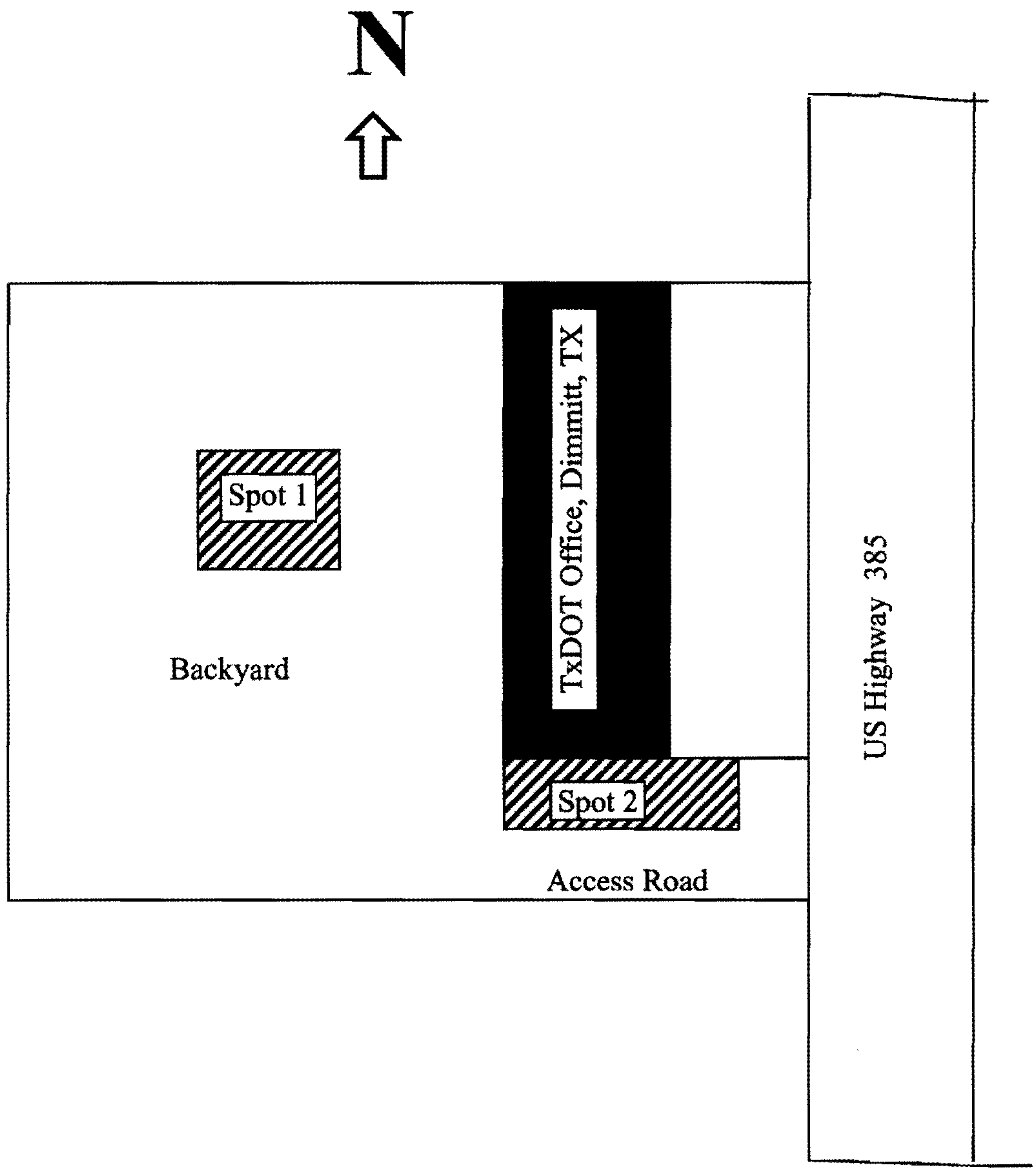
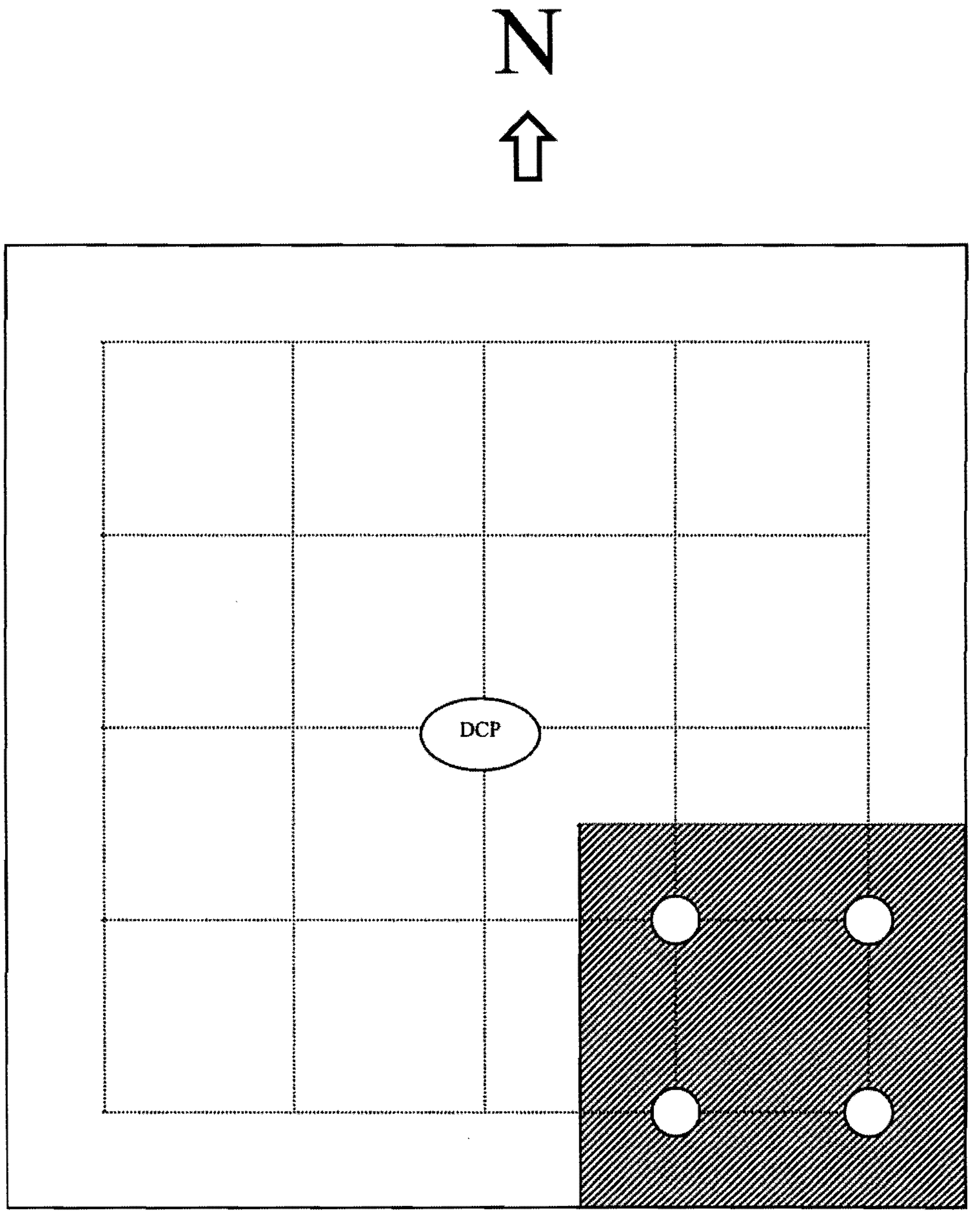
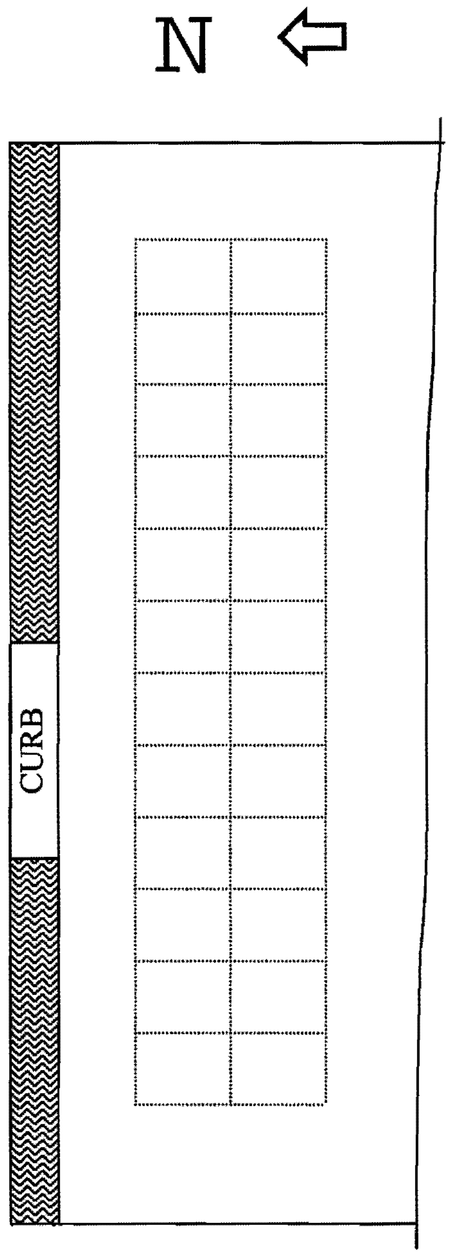


Figure 6 – Selected Sites at Dimmitt, TX.



*Approximate center-to-center spacing is 5 feet for FWD readings.
** Shaded area is vitrified at four locations as indicated by circles.

Figure 7 – Grid Points for FWD Reading at TxDOT Yard Site in Dimmitt.



*Approximate center-to-center spacing is 5 feet for FWD readings.

Figure 8 – Grid Points for FWD Reading at Access Road Site in Dimmitt.

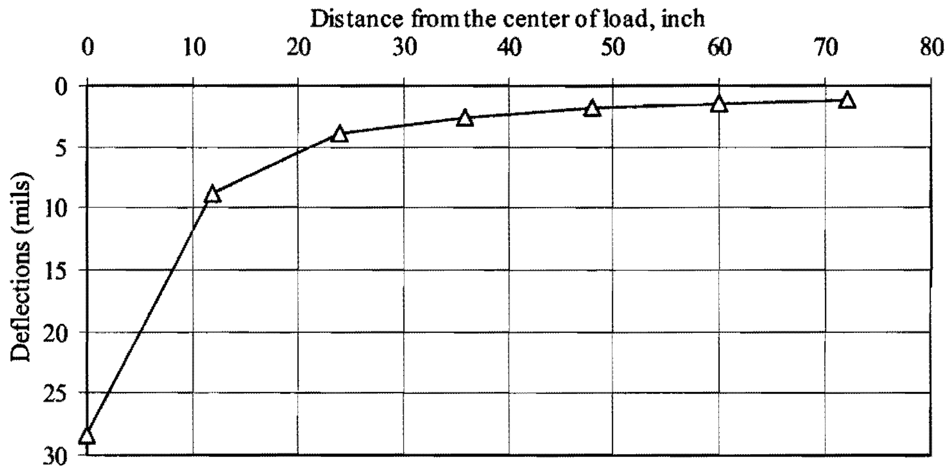


Figure 9 – FWD "Deflection Basin" for TxDOT Yard Site in Dimmitt.

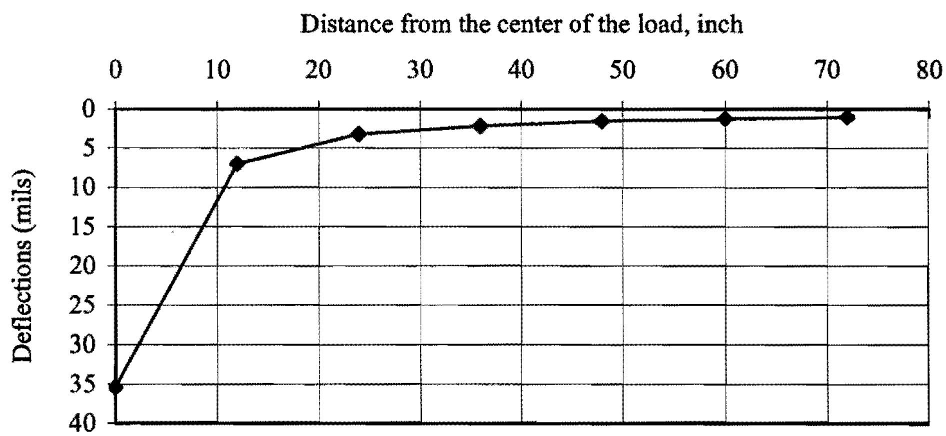


Figure 10 – FWD "Deflection Basin" for Access Road Site in Dimmitt.

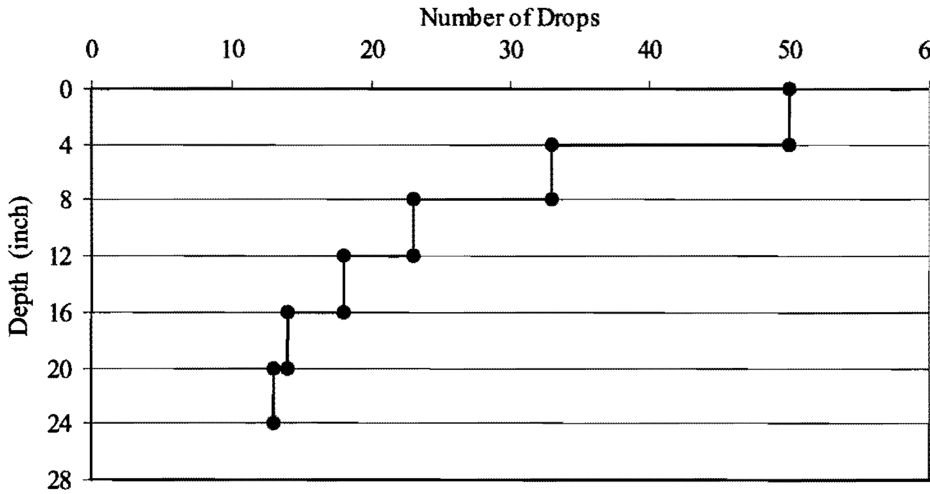


Figure 11 – DCP Reading at the Middle Point of TxDOT Yard Site in Dimmitt.

5. FIELD DEMONSTRATION

The SOVIT performed two field demonstrations: one in Lubbock at TTU's east building facility and the second one in the yard at TxDOT's Dimmitt regional office. Both of these demonstrations addressed road subgrade repair, and only required support to drill holes in the surface. Typically, a 10-inch diameter hole was dug 2 to 3 feet deep.

5.1 Field Demonstration in Lubbock

The Lubbock demonstration was the first long duration (~ 1 hour) operation of the SOVIT with diesel generator power. Due to IGBT failures in the laboratory, we only had two modules in the SOVIT for this demonstration. The current output from each module was kept in the 200-300A range in order to insure no failure of the two remaining IGBT's. This maximum current output of ~ 500A was sufficient to slowly melt the soil, however we did not add enough soil during operation to produce a very large "rock".

The vitrified soil was removed for a visual evaluation. A small portion of soil was vitrified as shown in the Figure 12. The vitrified soil (rock) has a light greenish color and very porous texture. While this demonstration demonstrated that the SOVIT could operate in the field, the product was not spectacular. We did not provide sufficient soil during the melt, and the porosity was a result of the low level current. The rate of soil to be added is directly related to the current. This was our first operation of these two factors at the same time. Obviously, we need to improve over understanding of this relationship.

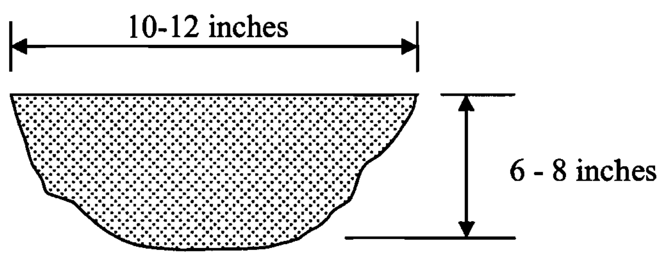


Figure 12 – Schematic Diagram of Vitrified Soil at Lubbock Site.

5.2 Field Demonstration in Dimmitt

The operation at Dimmitt was carried out, again with only two modules in the PCU, over three days with five holes vitrified at various depths. The SOVIT operating time for the holes varied from 60-90 minutes and the total current varied from 500-800A. The last day one hole was vitrified during a rainstorm, which unintentionally demonstrated that the SOVIT operates in the rain. There is potential for an accident during these conditions, with the present design of the SOVIT and the generator combination, this type of operation is not recommended.

As mentioned above, five points at TxDOT maintenance facility yard site in Dimmitt were vitrified. Each one of them was a ten-inch diameter hole, which was filled and compacted after vitrification. It was very difficult to compact them to the pre-vitrification conditions. Also, there was a discontinuity along the horizontal extent between vitrified soil and the surrounding soil. Both of these would affect the FWD results, especially the "deflection basin". After vitrification, FWD data was collected at the middle point in addition to all four points, as shown in the Figure 7. More than one sensor orientation along the diametric axis was used for all five points. Four measurements were taken at the middle point outward along each of the four points. Three measurements on each of the four points were taken. One measurement was along the same direction as before vitrification. The other two measurements were along the middle point. In one case, sensors were placed toward the middle point; in the other case, sensors were placed away form the middle point. There were a total of sixteen (16) measurements taken and summarized in Appendix A. An average profile of deflection basin is drawn in Figure 13 along with the pre-vitrification deflection basin. Due to the limited horizontal extent of vitrified soil and softer fill material on top, such a FWD evaluation did not turn out to be useful for engineering evaluation.

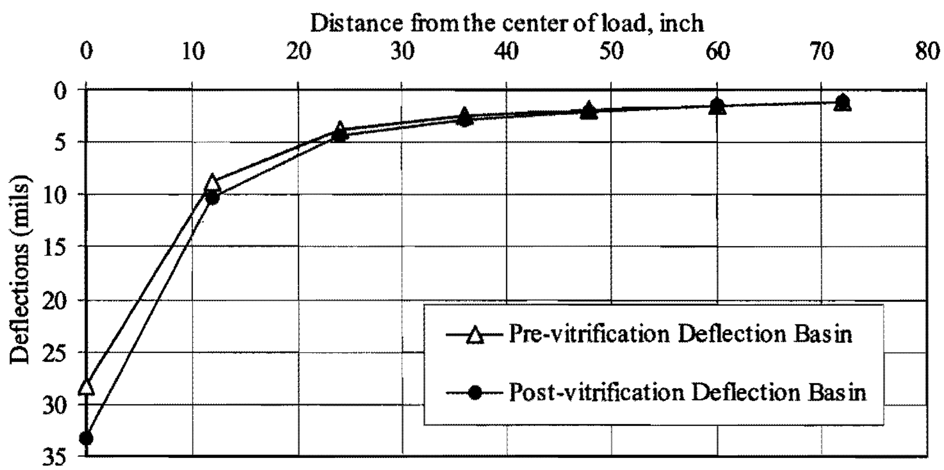


Figure 13 – FWD "Deflection Basin" for the Dimmitt Site (Post-Vitrification).

The limited horizontal extent of the vitrified soil was observed during the Dimmitt operation. In one case, the vitrified soil was pulled out with the graphite rod while it was still hot. It was clearly shown that the horizontal extent was limited to the diameter of the hole. Another, more scientific observation, was performed by measuring the temperature distribution in surrounding soil media. The temperature probe was placed within 1-2 inches of the boundary of the borehole and a temperature drop of 2000° F to 400° F was observed within an inch of horizontal extent into the soil media. Such a temperature drop would definitely confine the melting of soil inside the borehole. One important thing to note here is that the SOVIT system was not operated at its full capacity; rather, it operated at about a 3rd of its optimum power. Also the subgrade soil at Dimmitt was very dry at the time of SOVIT operation.

5.3 Summary and Discussion

The SOVIT system operated successfully in a field environment with required flexibility of depth of vitrification. The operation was safe. There was no apparent fire hazard or health hazard observed during the demonstration. The significant finding is the limited horizontal extent of vitrification with economically viable operation time. This was not evident during the laboratory investigation of the phase I study, because the tests were done at over 1000A. The soil mass used in the laboratory was confined in a 55-gallon drum. On the other hand, the soil media in the field has an infinite horizontal extent, which makes it uncertain as to what the heat conduction will be beyond the borehole. This observation made the SOVIT system questionable for subgrade repair.

During the Dimmitt demonstration there were TxDOT visitors from Austin and the west Texas region. During a post demonstration discussion, Dr. German Claros recommended that the SOVIT be used for slope stabilization rather than roadbed repair. It was pointed out that the present design of the SOVIT would require additional onsite support to perform on sloped surfaces.

Dr. Claros believes, and we concur, that there is a higher cost saving potential to TxDOT in slope stabilization than in roadbed repair. For this reason, it was decided that for the Phase III Dallas area demonstrations, the SOVIT would be used for slope stabilization.

6. CONCLUSIONS AND RECOMMENDATIONS

Phase II of this study was very significant for the future of this research. During this phase it was observed, without any doubt, that vitrification could be performed in a field environment using a mobile unit. The conclusions of this study are as follows:

- A complete soil vitrification system, SOVIT, could be mounted on a trailer and operated as a mobile unit.
- The SOVIT system operated independently in a real field environment.
- The SOVIT system can melt and fuse soil anywhere on a project site.
- The SOVIT has sufficient vertical flexibility to work at enough depth in the borehole.
- The horizontal extent of vitrification in the field has not been established with certainty.

The SOVIT system is recommended for the stabilization of the soil slope. This operation would be similar to producing an in-situ mini-pile for the purpose of slope stabilization. Therefore, a trial demonstration is planned for the third phase of this study.

APPENDIX A

Table A-1: Pre-Vitrification FWD Data for Yard Site at Dimmitt, TX

INPUTFILE: A:\MOD51\DIMMITT\DIMMITT.CMT
DISTRICT: 0 COUNTY: 0 HIGHWAY: PLATE RADIUS: 5.900 NUMBER OF

PMIS '98
*0000 +00.0

SENSOR SPACING:			0.0	12.0	24.0	36.0	48.0	60.0	72.0	AIR	
STATION	LNE	LOAD	W1	W2	W3	W4	W5	W6	W7	TEMP	C
0.000		6622	27.99	8.51	3.72	2.17	1.59	1.35	1.17	71	
5.000		7361	26.51	9.28	3.78	2.53	1.83	1.46	1.22	72	
10.000		7151	34.64	9.60	3.93	2.91	2.04	1.69	1.26	71	
15.000		7115	31.39	10.09	4.45	2.90	2.10	1.82	1.51	72	
20.000		7186	29.73	8.72	3.76	2.55	1.70	1.39	1.07	72	
0.000		7155	33.02	8.96	4.11	2.63	1.87	1.60	1.22	75	f
5.000		7155	28.87	8.59	4.04	2.71	1.95	1.39	1.22	77	
10.000		7572	25.02	7.72	3.94	2.58	1.96	1.48	1.30	76	
15.000		7445	22.76	8.15	4.05	2.81	2.08	1.72	1.44	76	
21.000		7321	24.50	8.79	4.19	2.81	2.00	1.61	1.37	76	
0.000		7135	29.15	9.55	4.43	2.98	1.98	1.60	1.33	76	f
5.000		6880	39.50	11.09	4.12	2.78	1.79	1.47	1.20	77	
10.000		7540	22.54	7.93	3.83	2.67	2.07	1.61	1.17	77	
15.000		7353	19.98	7.80	3.73	2.58	1.84	1.46	1.27	77	
24.000		7433	20.28	7.22	3.53	2.65	1.87	1.49	1.15	77	
0.000		6857	34.10	9.53	3.86	2.58	1.84	1.37	1.09	78	f
5.000		7111	34.84	8.94	3.82	2.59	1.88	1.48	1.19	77	
11.000		7365	32.09	9.75	3.88	2.58	2.01	1.52	1.41	77	
15.000		7417	24.73	8.98	3.87	2.57	1.84	1.49	1.23	77	
21.000		7695	23.02	8.27	3.80	2.74	1.92	1.68	1.18	76	
0.000		6952	26.94	9.15	4.05	2.47	1.54	1.20	1.02	77	f
5.000		7004	35.65	8.73	3.64	2.43	1.66	1.43	1.04	78	
10.000		7309	25.91	8.16	3.32	2.19	1.52	1.29	1.05	78	
15.000		7413	23.13	8.59	3.78	2.33	1.69	1.43	1.13	78	
22.000		7540	24.33	8.90	4.04	2.54	1.85	1.90	1.47	77	
0.000		7123	31.19	9.58	4.07	2.26	1.45	1.28	0.99	77	
5.000		6972	38.07	9.15	3.39	2.29	1.67	1.38	1.08	77	
9.000		7103	28.78	8.24	3.90	2.41	1.78	1.48	1.27	78	
15.000		7274	25.94	9.52	3.69	2.43	1.86	1.48	1.06	76	
21.000		7349	24.31	8.46	3.73	2.42	1.70	1.43	1.12	76	

IN-SITU VITRIFICATION - PHASE II

Table A-2: Pre-Vitrification FWD Data for Access Road at Dimmitt, TX.

```
INPUTFILE: A:\MOD51\DIMMITT\SERVICE.CMT
DISTRICT:  0    COUNTY:   0    HIGHWAY:          PLATE RADIUS:  5.900  NUMBER OF

PMIS '98
*0000 +00.0
```

SENSOR SPACING:			0.0	12.0	24.0	36.0	48.0	60.0	72.0	AIR	
STATION	LNE	LOAD	W1	W2	W3	W4	W5	W6	W7	TEMP	C
0.000		6332	62.06	6.46	2.91	2.11	1.63	1.34	1.17	78	
5.000		6289	58.83	4.30	2.81	2.11	1.49	1.26	1.06	78	
11.000		6316	56.07	3.37	3.15	2.20	1.75	1.32	1.09	79	
15.000		6300	43.66	7.65	3.53	2.15	1.68	1.34	1.15	78	
20.000		6360	43.28	7.56	2.93	2.07	1.50	1.28	1.09	79	
25.000		6340	44.37	6.39	2.91	2.15	1.46	1.25	1.01	80	
31.000		6336	47.59	7.35	3.20	2.34	1.44	1.26	1.08	79	
35.000		6273	39.63	7.17	3.20	2.28	1.66	1.28	0.98	78	
41.000		6281	38.91	8.30	3.36	2.40	1.77	1.41	1.18	78	
45.000		6221	38.86	7.45	3.92	2.79	1.83	1.48	1.26	78	
50.000		6201	47.48	9.55	3.83	2.59	1.94	1.56	1.27	78	
55.000		5911	72.57	9.84	3.73	2.60	1.87	1.67	0.56	79	
60.000		5828	70.58	11.75	3.62	2.57	1.80	1.48	1.34	78	1
2.000		6201	36.24	7.61	3.38	2.26	1.53	1.20	1.04	78	
5.000	e	6285	38.15	7.35	3.06	2.09	1.52	1.20	0.96	79	
11.000	e	6177	39.24	7.41	3.26	2.15	1.52	1.23	0.95	80	0
15.000	e	6543	32.48	7.48	3.26	2.23	1.51	1.26	0.98	80	
20.000	e	6567	34.22	5.87	2.91	2.02	1.44	1.19	0.93	80	
25.000	e	6555	30.02	6.05	2.90	2.05	1.44	1.20	0.98	80	
30.000	e	6579	30.54	6.61	3.07	2.22	1.34	1.18	0.97	80	
35.000	e	6797	34.46	7.21	3.41	2.39	1.75	1.46	1.09	80	
41.000	e	6622	34.04	8.70	3.91	2.56	1.76	1.57	1.11	81	
45.000	e	6475	31.50	8.93	3.99	2.79	1.80	1.45	1.13	81	
50.000	e	6531	32.42	9.24	3.96	2.58	1.83	1.48	1.16	81	
56.000	e	6376	39.20	9.13	4.06	2.62	1.89	1.55	1.38	81	
60.000	e	6026	55.84	8.70	3.57	2.47	1.92	1.55	1.36	82	
0.000	e	5955	23.43	5.81	2.64	1.81	1.26	1.03	0.75	82	
5.000	e	5939	20.80	6.09	2.69	1.78	1.21	0.99	0.76	83	
10.000	e	6344	24.09	5.96	2.89	1.98	1.33	1.06	0.81	81	
15.000	e	6571	20.13	5.81	2.81	1.90	1.56	1.11	0.93	81	
20.000	e	6185	18.85	4.56	2.50	1.74	1.16	1.04	0.74	81	
25.000	e	6328	19.48	5.43	2.65	1.83	1.36	1.00	0.81	80	
30.000	e	6507	17.24	5.08	2.65	1.90	1.31	1.11	0.84	80	
35.000	e	6392	16.06	5.38	2.82	1.93	1.33	1.08	0.87	80	
42.000	e	6138	17.52	6.02	3.06	2.04	1.41	1.11	0.92	81	
45.000	e	6014	22.13	6.06	3.17	2.11	1.44	1.15	0.86	81	
50.000	e	5808	15.31	5.93	3.14	2.16	1.48	1.21	1.00	82	
55.000	e	6134	16.39	6.83	3.21	2.18	1.51	1.17	0.93	83	
60.000	e	5863	19.22	7.55	3.76	2.48	1.54	1.32	1.01	83	

IN-SITU VITRIFICATION - PHASE II

Table A-3: Post-Vitrification FWD Data for Yard Site at Dimmitt, TX

INPUTFILE: A:\MOD51\DIMMITT\DIMMIT01.CMT
DISTRICT: 0 COUNTY: 0 HIGHWAY: PLATE RADIUS: 5.900 NUMBER OF

6000 + -
*0000 +00.0

SENSOR SPACING:			0.0	12.0	24.0	36.0	48.0	60.0	72.0	AIR	
STATION	LNE	LOAD	W1	W2	W3	W4	W5	W6	W7	TEMP	C
0.000		6571	24.06	8.05	3.55	2.33	1.94	1.92	1.22	59	C
0.047		7087	22.49	7.69	3.86	2.93	2.07	1.59	0.96	61	C
0.102		6936	26.07	8.15	4.63	3.07	2.48	0.32	0.31	62	C
0.142		6706	24.72	7.75	4.11	2.81	2.22	1.72	1.26	62	C
0.191		6412	41.07	8.93	4.13	2.48	2.20	2.00	1.36	63	S
0.192		5891	36.39	10.55	2.86	2.99	2.33	1.50	1.30	63	S
0.192		6491	28.83	11.98	5.10	3.04	2.07	1.95	1.10	63	
0.193		6622	38.17	10.29	4.78	2.72	1.97	1.76	1.26	62	N
0.232		6146	36.18	12.51	5.27	3.08	2.23	1.20	1.25	61	S
0.234		6197	36.07	11.71	4.67	2.90	1.96	1.61	1.18	60	N
0.281		6582	35.56	8.45	4.20	2.85	2.13	1.72	1.33	60	S
0.282		6348	36.69	13.12	5.07	2.90	2.15	1.45	1.24	61	N
0.316		6436	33.85	13.26	5.20	3.09	1.76	1.57	1.51	61	N
0.319		6257	32.67	11.15	5.19	3.33	2.19	1.87	1.54	62	S
0.402		6368	39.05	11.59	4.52	2.76	1.93	1.57	1.30	62	N
0.404		6384	39.67	8.55	3.99	2.44	2.18	2.16	0.99	63	

IN-SITU VITRIFICATION-PHASE II