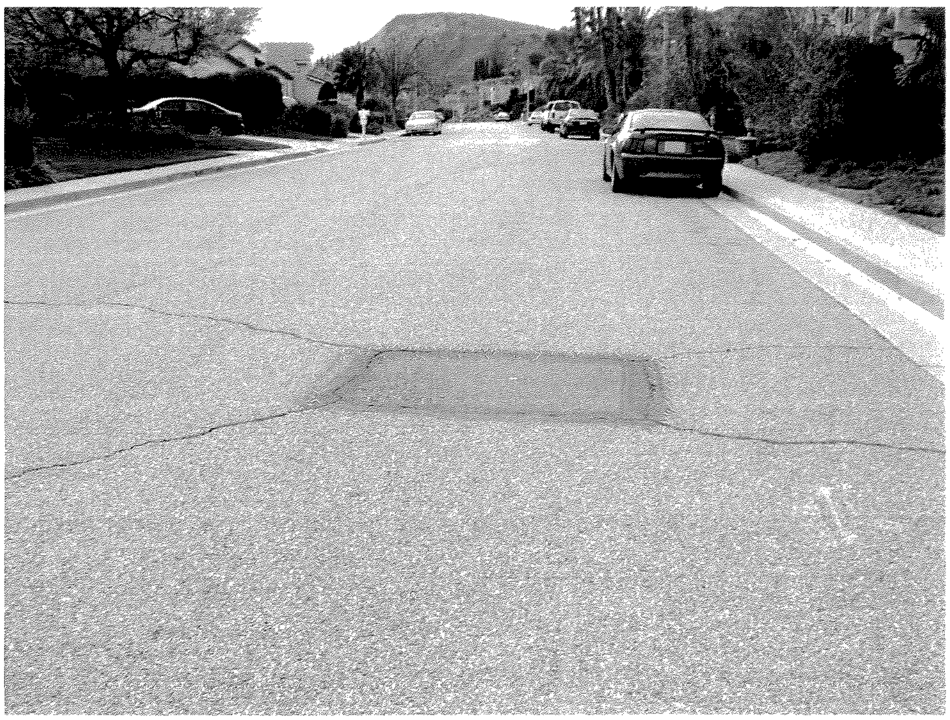
Street Damage Restoration Fee Study

Testing Portion



City of Los Angeles

Department of General Services

Bureau of Street Services

Shahin and Associates

March 2017

Form GS/STD 911

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Test Report of
Los Angeles Street Damage Restoration Fee (SDRF) Update Study

At the request of the Bureau of Street Services, Standards Division of the Department of General Services conducted pavement testing, analysis and overlay designs for the Los Angeles Street Damage Restoration Fee Update Study. The project was developed and conducted under the guidance of Dr. Mo Shahin, an Engineering Consultant retained by the Bureau of Street Services. Testing was performed on trenched street sections as provided by Dr. Shahin. Seventy-eight (78) sections were qualified for the study from a total of one hundred and twenty-two (122) street sections analyzed.

The Falling Weight Deflectometer (FWD), Geoprobe equipment and a core cutter were used to complete the testing portion for this study. The FWD was used to determine both the deflections of the existing asphalt concrete pavement of the street sections tested and the extent of damage caused by the utility trench to the surrounding area. The Geoprobe equipment was used to conduct a soil investigation of the subgrade in order to determine soil type and penetration resistance. A core cutter was used to cut pavement cores to determine asphalt concrete (AC) pavement thickness of the street sections.

The AC overlay thickness designs and the total flexible pavement structures were then calculated for the patched and non-patched areas.

Included in this report are the testing data and related analysis for the study.

If you have any questions, please contact me or Mr. Ricardo Villacorta of my staff at (213) 485-2242.

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Introduction

At the request of the Bureau of Street Services of the Department of Public Works, Standards Division of the Department of General Services has conducted testing research, overlay design, and analysis for the Los Angeles **Street Damage Restoration Fee update study**.

The project was developed and conducted under the guidance of Dr. Mo Shahin, an engineering consultant retained by the Bureau of Street Services. The study was performed on **Select** (high traffic) and **Local** (low traffic) streets. One-hundred and twenty two possible sections (each section includes: utility-trenches & respective control areas) were chosen for testing and from this total, seventy eight sections (thirty local and forty-eight select sections) were qualified for the study.

The conditions of the qualified streets were essentially surveyed through two methods: A) Pavement Condition Index (PCI) & B) Pavement Evaluation Testing. PCI (part A) was carried out by Prof. Shahin's team and Standards Division conducted all the testing required (part B) for the study and determined the overlay designs for all the sections analyzed. In addition, attached are conclusive graphs of the data collected during the update study.

The testing and analysis utilized during the study are as follows:

- The Falling Weight Deflectometer (FWD) was used to determine the deflections of each trench (patched) and control (non-patched) areas. In addition, the FWD also determined the extent of damage caused by the utility trench to the surrounding area.
- Pavement cores were cut to determine the existing pavement structural thickness in both areas.
- Piezocone Penetration Testing (CPTU) was performed to estimate the SPT (N_{60}) values, pore pressure and type of soil underneath of each patched and non-patched area.
- Overlay Thickness designs (DARWin Pavement Design Program) were performed for all sections including the utility trench and control area.

Included also is the approximate location of all the Local and Select SDRF sites in a City of LA map. Please see below the location map (**Figure 1**).

N	Legend ☐ = Local Site ■ = Select Site	SDRF Sites Location Map	City of Los Angeles Department of General Services **Standards Division**	
W.O.# S17A0003	Project Title: STREET DAMAGE RESTORATION FEE			March 2017

Figure 1

Procedure:

Before testing the designated locations, the PCI surveyor determined two areas: A) The control area and B) The trench area that comprised the utility-trench. Each area was no less than 1500 ft^2. The control area did not have any trench inside of the determined area and was at least 10 ft. away from any other trench. The control area also met the following requirements:

a. All selected sections were flexible pavements (PCC pavements are excluded) and both areas (trench & control) consisted of the same pavement structure, same thickness, mix, and age.
b. Trench and control areas had the same traffic flow (same lane).
c. The control area was located as close as possible to the trench area and when it was viable the control area was located immediately adjacent to trench area.

Cores were obtained with the following criteria:

a. Pavement thickness was determined: i) In the trench, ii) Outside the trench, and iii) In the control area.
b. Cores in each site were located at equal distance from the curb face.
c. The difference in total pavement thickness between the control and outside trench cores should be less than 1 in.
d. As many cores as necessary (minimum 2 cores) were cut in the "Control FWD testing area" to verify thickness consistency.
e. The pavement structure was similar in both areas including base.

Falling Weight Deflectometer (FWD) criteria:

a. A minimum of eight deflections were measured on the joint around the trench. The measurements were obtained by positioning the FWD loading plate so that the edge of the plate was no more than 0.5 in. away from the joint of the trench. On 95% of the locations the sensors fell parallel to this joint, on very narrow streets; the sensors fell perpendicular to the joint. It was noted that trench corners usually showed the highest deflection.
b. One additional deflection was measured in the center of the trench for trench repair evaluation purposes.
c. Eight deflections were measured in the control area along the same line as the coring locations. The spacing between deflections depended on the size of the control area.

Deflection readings were taken at equal distance apart on control pavement area that showed consistent pavement thickness with the tested trench area. If no consistency of thickness was established, the tested control area was discarded and relocated.

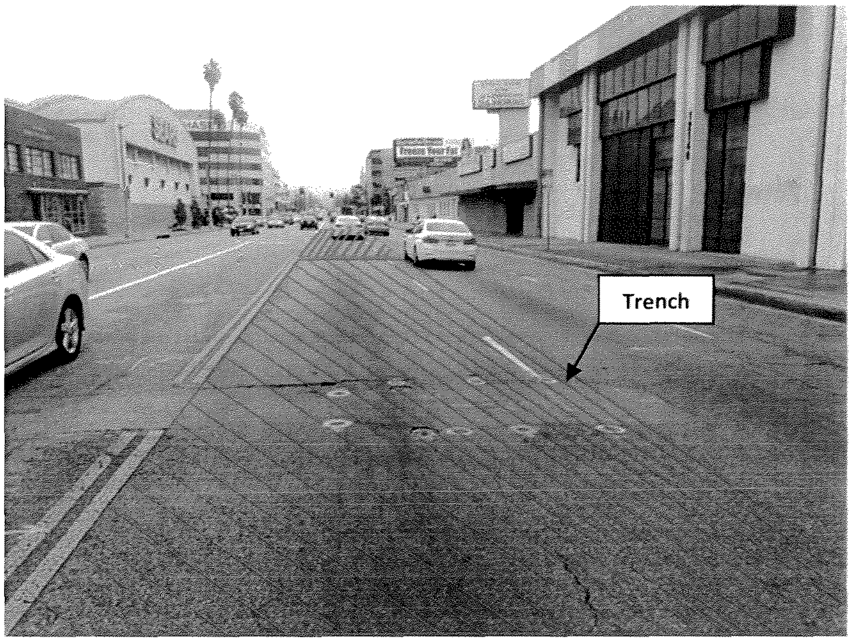

Figure 2: Shows both Trench and Control area (S37)

Figure 3: Shows FWD to be measured in a control area with consistent Asphalt thickness structure.

Pavement Deflections (FWD)

A total of 2323 pavement deflection tests were performed during the project. Pavement deflection is one of the required parameters necessary for pavement evaluation to determine the pavement structural capacity and to calculate the pavement and overlay design. Deflections, measured in thousandths of an inch (mils), were directly measured using a truck mounted Falling Weight Deflectometer.

A truck mounted Foundation Mechanics model Jils 20T Falling Weight Deflectometer (FWD) with an equivalent load of 9,000 pounds was used to measure the pavement surface deflections of the existing asphalt concrete pavements in the trench (patched) and control (non-patched) areas. The FWD is a load-deflection device that applies an impulse load by dropping a mass onto a circular load plate of 6 inches radius placed on the pavement surface to simulate a moving wheel load. This device uses deflection transducers that measure the resulting pavement deflections in the "deflection basin." One transducer is located at the center of the loading plate, with the remaining six transducers spaced at intervals of 8, 12, 18, 24, 36, and 60 inches from the center of the plate.

The FWD survey was performed by measuring nine (9) pavement deflections in each trench area (one inside the trench and eight at the outside edge of the trench) and eight (8) deflections in the corresponding control area. The pavement deflection measurements were determined in accordance with ASTM Designation: D 4695 – 03.

The measurements obtained are presented in **Appendix B**. All deflection measurements were normalized to 9 kips and 68^{o} F using AASHTO Guide for Design of Pavement Structures 1993, AC Temperature Adjustment Factor Table (**Figure 5.6, pg. III-99**).

Accumulated deflection, D_0 (Normalized to 9 Kips and 68^{o} F) of Local Trenches and respective Controls clearly shows higher accumulated deflection on trenches than controls. The values are 560 mils and 398 mils, correspondingly. The same observation is seen in Select Trenches vs. Controls where the values are 504 mils and 334 mils, respectively (**See Figure 4**). The average normalized deflection (D_0) of Local Trenches was 41% higher than their corresponding Control. The average normalized deflection (D_0) of Select Trenches was also 51% higher than their corresponding Control (**See Figure 5**). This shows that the pavement surrounding each trench has been weakened more than the rest of the pavement section, thereby accelerating pavement failure under traffic. It was also observed that the damage was higher among select streets than local streets.

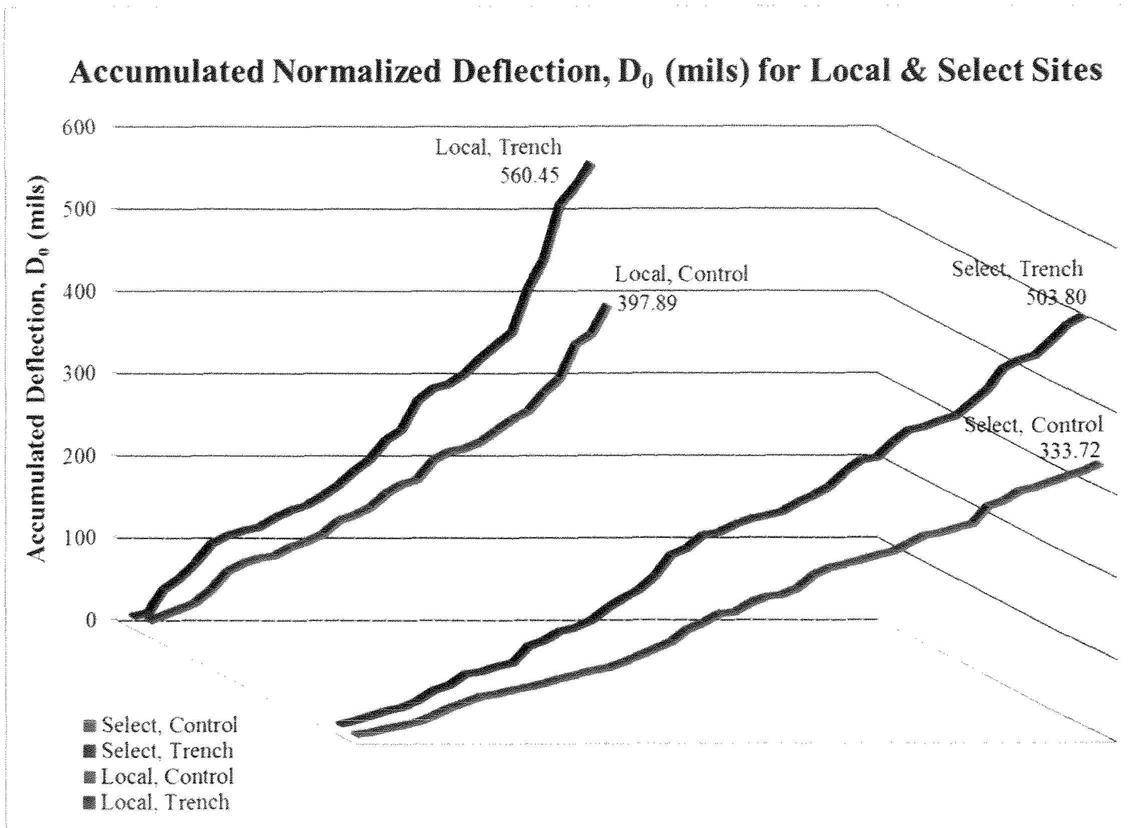

Figure 4

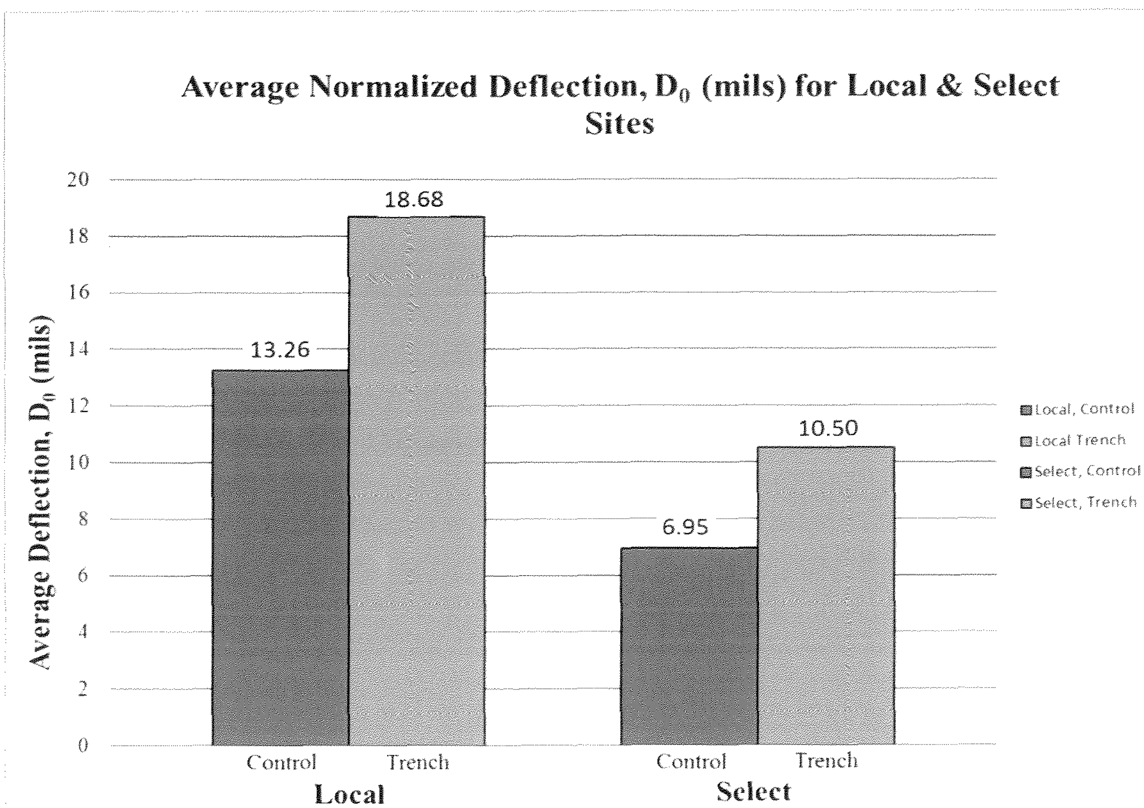

Figure 5

A regression analysis was performed to determine the relationship between the average normalized deflections (D_0) of Local and Select trenches and their respective controls by means of a scatter plot **(See Figure 6)**, then a straight line (the best fit of the regression line) that describes such relationship in the best possible manner was calculated and drawn with the Excel program.

The trend of the regression line clearly shows that the normalized deflections in the trench area are higher than the control area or that the trench area has been debilitated by the utility trench.

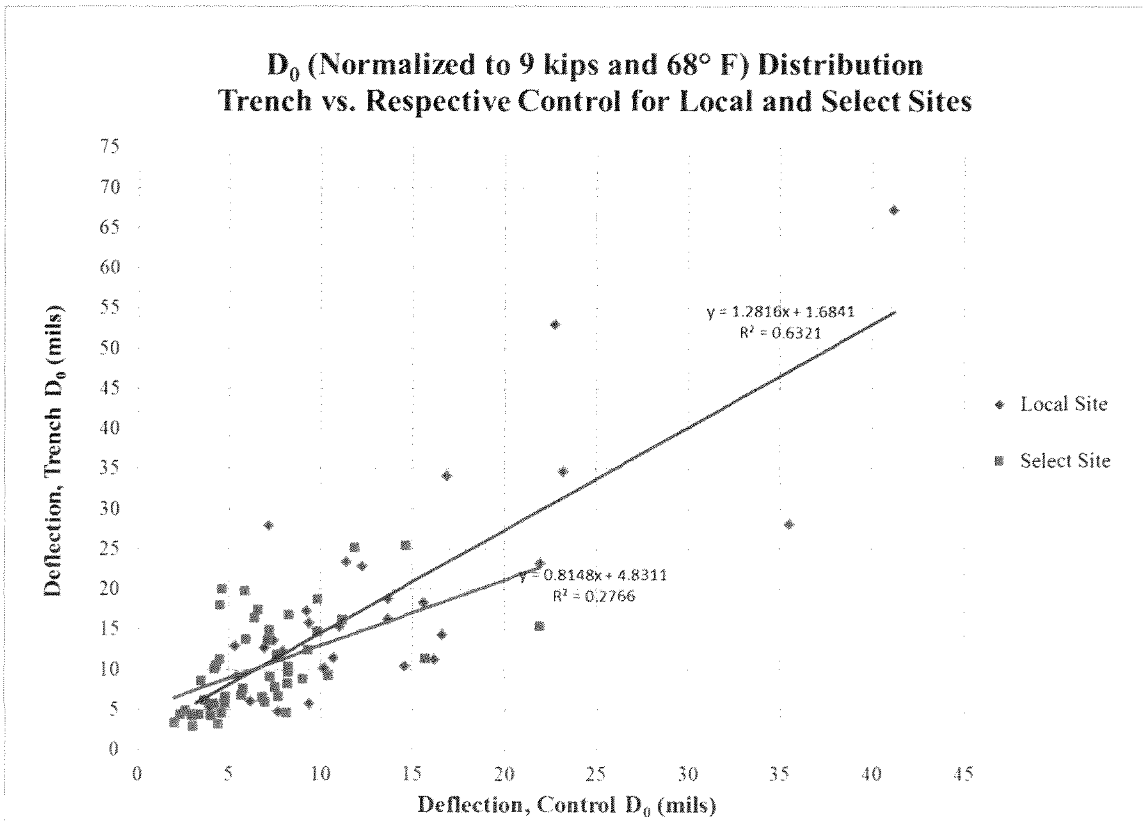

Figure 6

Existing Pavement Thickness (Coring)

Existing structural pavement thickness was also determined in order to find out if utility trenches were properly overlaid to match the original pavement thickness structure and to calculate the overlay thickness design for both areas. The pavement thickness for each trench and respective control was determined by coring and are shown in **Appendices B & C.**
A total of four-hundred-eighteen (418) cores were cut for this entire investigation. Pavement cores were cut using an Acker Model PT-22 truck-mounted core cutter with an eight-inch core bit and Geoprobe Model 6600.

Coring data shows that inside of trench **(Trench-In)** asphalt concrete thickness is much less than outside of the trench (**Trench-Out**) see **Figures 7, 8 and 9**.

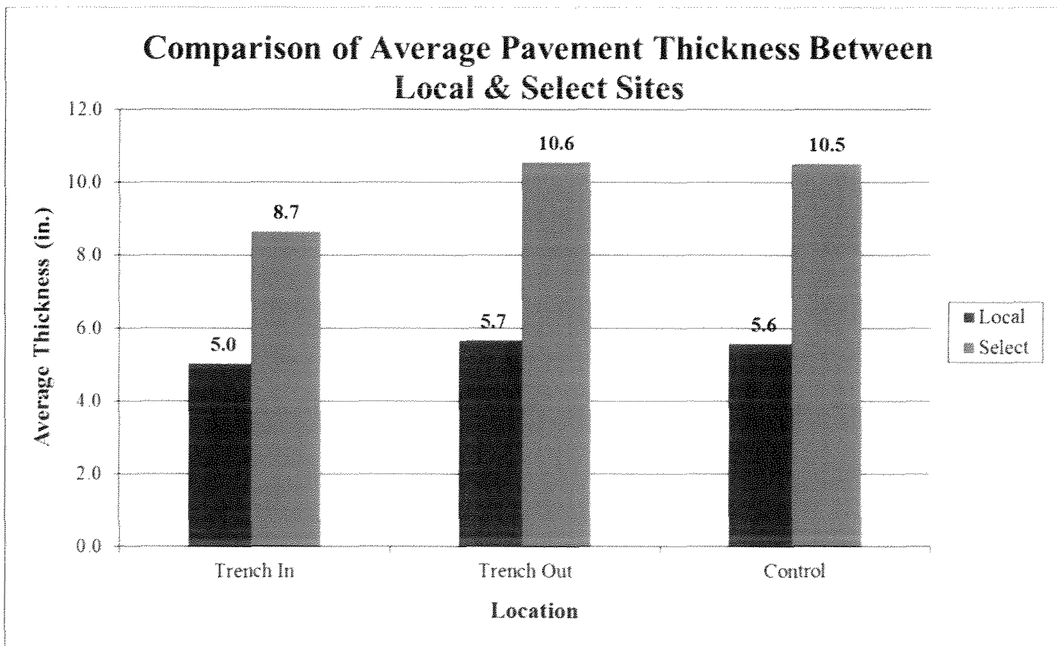

Figure 7

The comparison of the average pavement thickness between Local and Select streets **(Figure 7)** demonstrates that in both classifications **(Local and Select)**, the pavement thickness inside of the trench **(Trench-In)** was less than in the vicinity of the trench **(Trench-Out)** and its respective control. Furthermore, this difference is more significant among Select than Local streets.

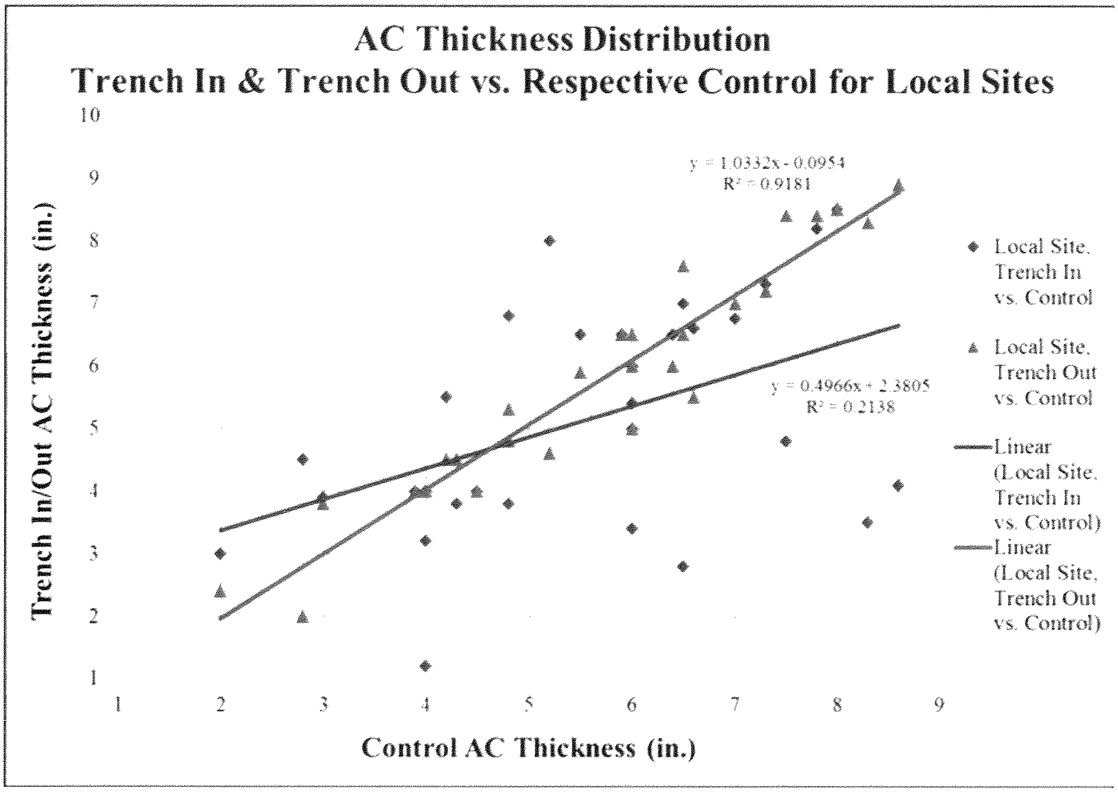

Figure 8

The simple linear regression analysis of pavement thickness distribution among inside of trench **(Trench-In)**, out of the trench **(Trench-Out)** and respective control area **(Figures 8 & 9)**, displays basically a relationship of 1 to 1 thickness between Trench-Out and Control area for both classifications **(Local and Select)**. However the regression analysis between Trench-In and Control in both classifications are not conclusive due to the inconsistency of the trench repair, which indicates that utility trenches were not properly restored to match the original pavement thickness structure.

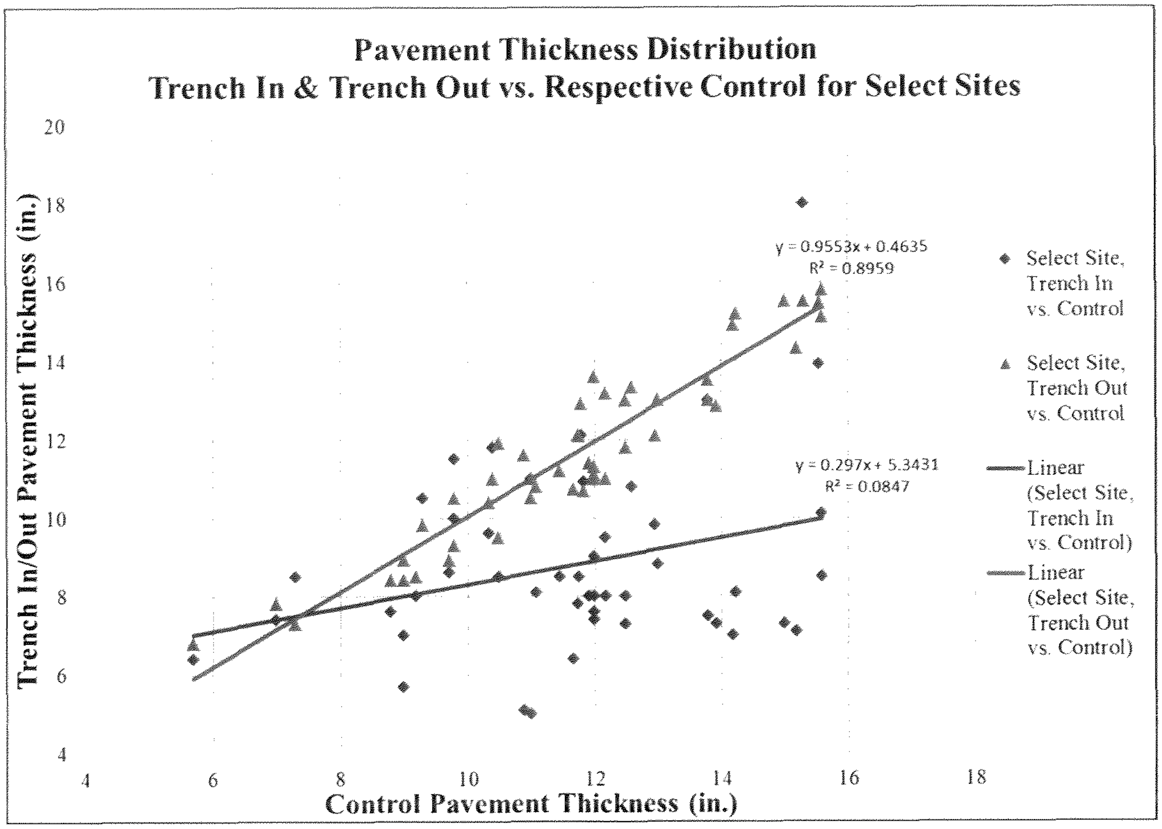

Figure 9

Figure 10: Existing pavement thickness determination Trench-in & Trench-out.

Piezocone Penetration Testing

Two hundred- thirty- four (234) CPTU Piezocone Penetration Test soundings were performed and data was collected to a depth of two (2) feet unless refusal depth was reached **(See Appendix C)**. The CPTU soundings were conducted using a truck-mounted Geoprobe Model 6600 and a 20 ton capacity cone with a base area of 10 cm^2 and a friction sleeve of 150 cm^2 located above the Piezocone.

N_{60} is a parameter classically determined from SPT blow counts and provides an indication of the relative density and strength of the soil. In this study, N_{60} is a calculation resulting from pushing a Piezocone, or cone penetrometer with pore pressure measurement through the undisturbed soil underneath the pavement and recording data with a computer program. A comparison average of N_{60} values for Local and Select trenches and respective controls are presented in **Figure 11.**

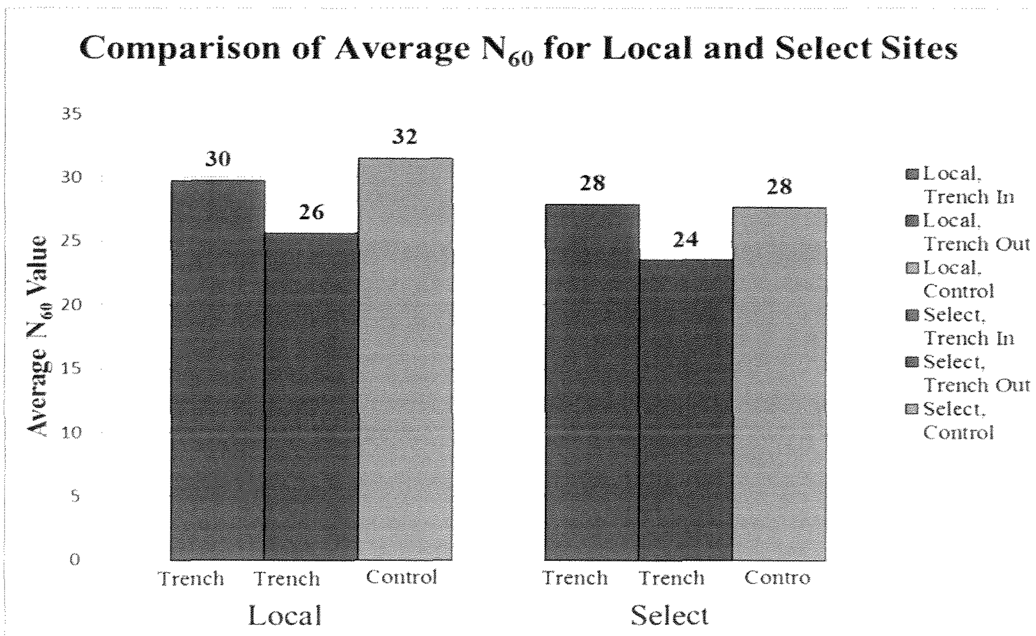

Figure 11

In this comparison, both classifications exhibit the Control N_{60} values higher than the Trench-Out which indicates that the utility trench disturbed and debilitated the strength of the soil under the adjacent pavement. Furthermore, it was determined that 30% of Local and 25% of Select trenches were treated with liquefied soil cement slurry, consequently improving the average of the N_{60} Trench-In values compared with their respective Controls.

Additional parameters in this dynamic procedure includes measurement of tip resistance (**qc**), sleeve friction (**fs**), and pore water pressure (**U_2**), These measurements determine soil stratigraphy and corrected SPT energy ratio N_{60} values. This is all done by operating the computer programs CPT-log and CPT-pro. On a few occasions, the trench is backfilled with cemented sand, which is extremely hard. While we are unable to penetrate this layer with the cone, we were able to penetrate the subgrade below the outside edge of the trench. We found that N_{60} values of the subgrade below the outside edge of the trench are lower than the N_{60} values of the subgrade in the control. This means that the disturbance of the soil caused by the excavation of the trench has weakened the surrounding subgrade, which will cause premature failure of the pavement adjacent the trench.

The Piezocone takes measurements at 2 cm intervals of bearing resistance (**qc**), unit sleeve friction resistance (**fs**), and pore pressure behind cone (**U_2**). All CPTU soundings were performed in accordance to ASTM D-5778 Standard Test Method for Performing Electronic Friction Piezocone Penetration Testing of Soils.

All CPTU data was collected by a wireless CPTU cone (serial No. 4130, calibrated on 07/22/2016, traceable to NIST) manufactured by Geotech AB Company. Soil classification is based on **Rf** (friction ratio) and **qt** (corrected cone resistance), Robertson 1986, using CPT-pro software by Geosoft company.

The measurements that we obtained are presented in **Appendix B**, with their corresponding graphical CPTU test results.

Below is a summarized table with percentages of different classification of soils encountered under pavement structures in both groups.

Table 1

Local Streets						
Classification	**Sand**	**Silty-Sand**	**Sandy-Silt**	**Clayey-Silt**	**Sensitive Fine-Grained**	**Total**
Sites	**8**	**5**	**4**	**2**	**11**	**30**
Percentage	**27**	**17**	**13**	**7**	**37**	**100**
Select Streets						
Classification	**Sand**	**Silty-Sand**	**Sandy-Silt**	**Clayey-Silt**	**Sensitive Fine-Grained**	**Total**
Sites	**15**	**14**	**9**	**0**	**10**	**48**
Percentage	**31**	**29**	**19**	**0**	**21**	**100**

Overlay Thickness Designs Required

A total of one-hundred-fifty-six (156) overlay thickness designs and (156) Flexible Pavement designs were calculated. Overlay thickness design is the required addition of compacted Hot Mix Asphalt (HMA) to an existing pavement in order to sustain predicted repeated structural loading from traffic over the design life of the pavement.

The overlay and pavement designs were determined utilizing the 1993 AASHTO Guide for Design of Pavement Structures, **AASHTOWare DARWin 3.1 Pavement Design**, **Analysis & Rehabilitation for Windows computer software**. The average mid-depth temperature was calculated based on **BELLS3** (Routine testing methods) by using a computer program in which the computer source code is provided by FHWA.

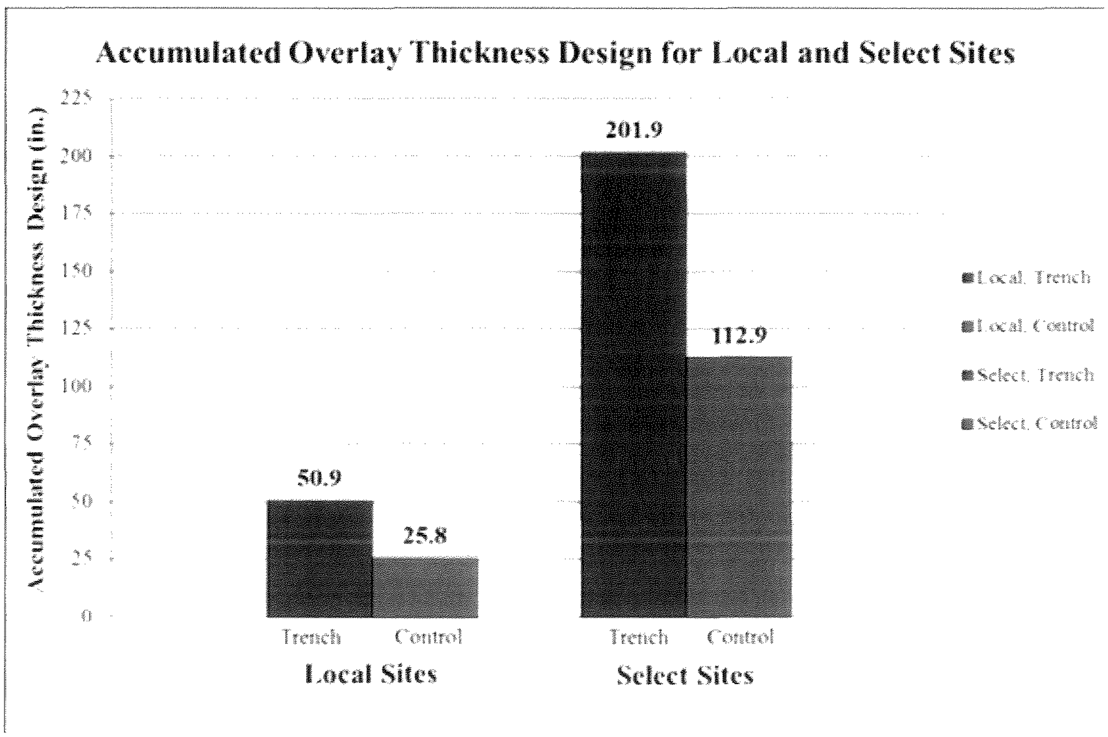

Figure 12

The accumulated overlay thickness design, in inches, for Local and Select trenches and their respective control areas are presented in **Figure 12**. In both street classifications, the accumulated required thickness design is significantly higher in the Trench area than the Control area (98% higher for Local & 79% higher for Select).

In addition, the average overlay thickness design has also been calculated to illustrate how the weakness inflicted in the pavement by the utility trench has to be restored with "additional thickness structure" to meet traffic demands when compared with the control average overlay thickness design required to meet such demands (**see Figure 13**). Using this figure we conclude that the Local trench areas require an average of **0.84** inches more structure than its respective control and an average of **1.86** inches more structure is required for the Select trench area than its respective control. This means that the trench's surrounding pavement has been negatively affected by the excavation of the trench, and the effects are very significant and costly in order to remediate the damage caused by the trench in bringing the structure back to its original capacity.

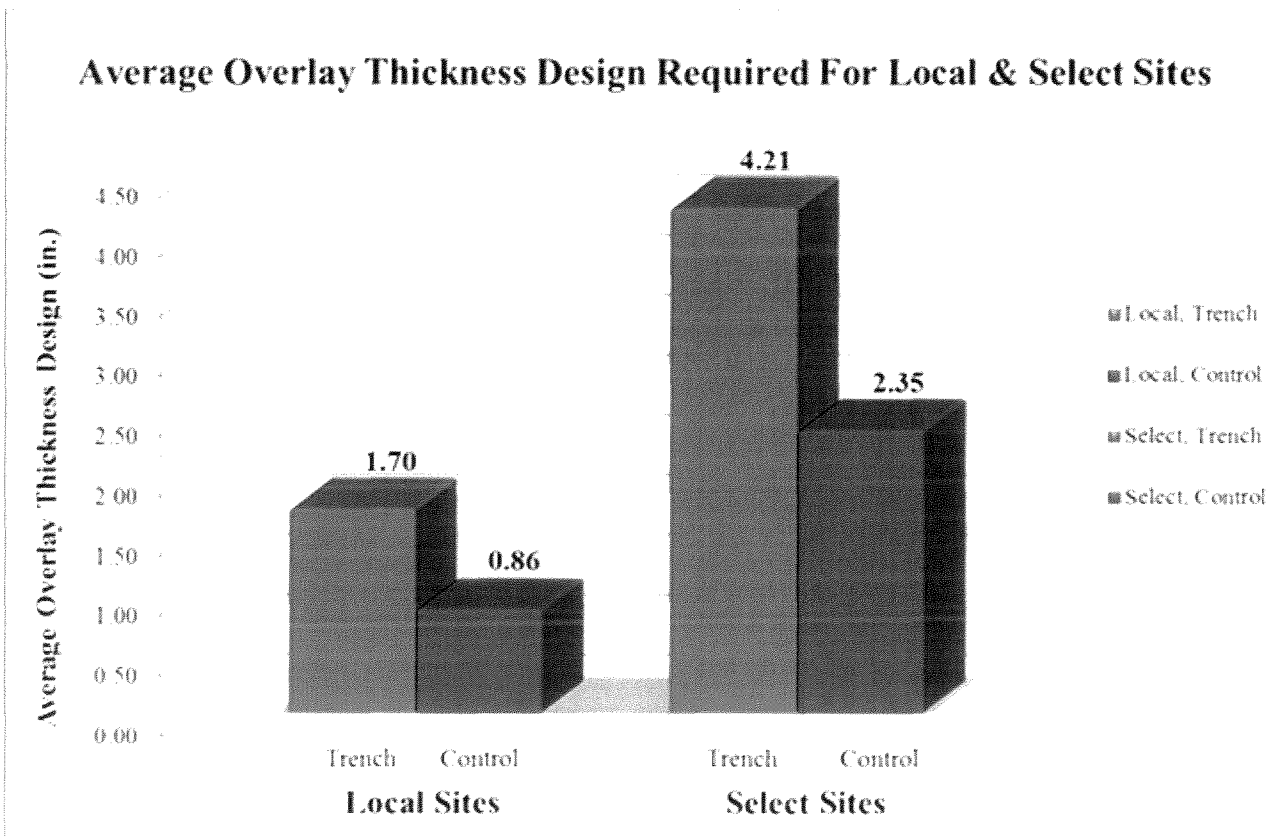

Figure 13

Asphalt Concrete Thickness Designs versus Traffic: Asphalt concrete thickness designs were calculated for all trench and control areas (Local and Select collectively) using the above-mentioned DARWin program and the data acquired in this study were plotted in a graph as AC Thickness in inches (Y) versus Cumulative 18-Kip ESAL Traffic in Millions (X). A power trendline was then calculated and drawn with the Excel program **(see Figure 14)**. The best fit-line in this case is a power trendline that demonstrates that the AC thickness designs are directly related to traffic **(more traffic = more thickness)** notwithstanding the reduction of the positive rate of thickness/traffic at high levels of traffic. Therefore the cost to repair the damage in Select or high traffic pavement is a lot higher than the cost in Local or low traffic pavement.

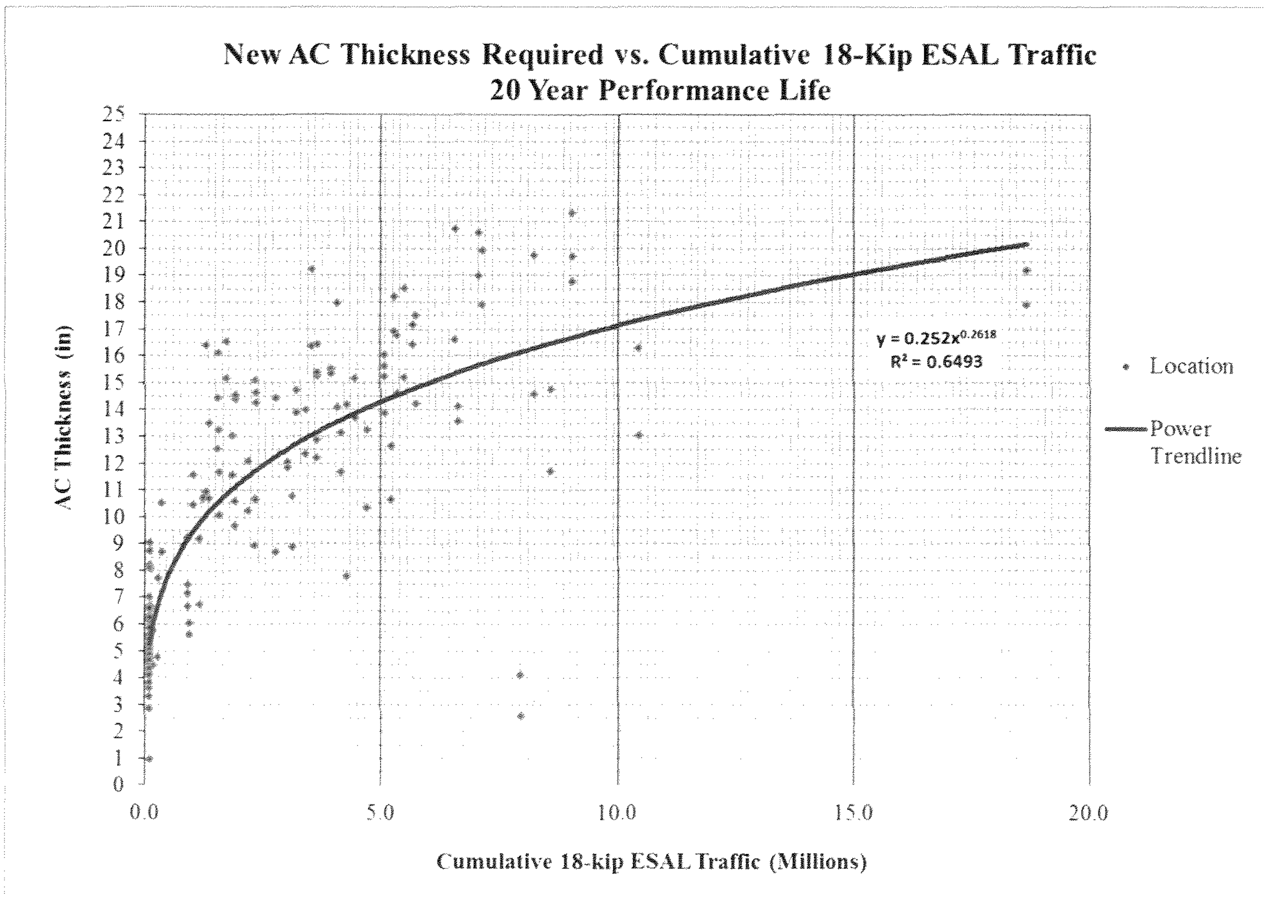

Figure 14

Area of Influence

A few trenches were also selected for Area of Influence determination. Starting at the edge of each trench, deflections were measured one foot apart, moving away from the edge until the change in deflection from the previous deflection reached near-zero. The purpose of this testing was to determine the distance away from each trench where the subgrade was found to be unaffected by the utility cut. The area from the edge of the trench to where change in deflection is near-zero is called the Area of Influence. It was determined that the area of influence fluctuates between 8 to no more than 10 feet. **(See figures 15, 16, 17, and 18)**

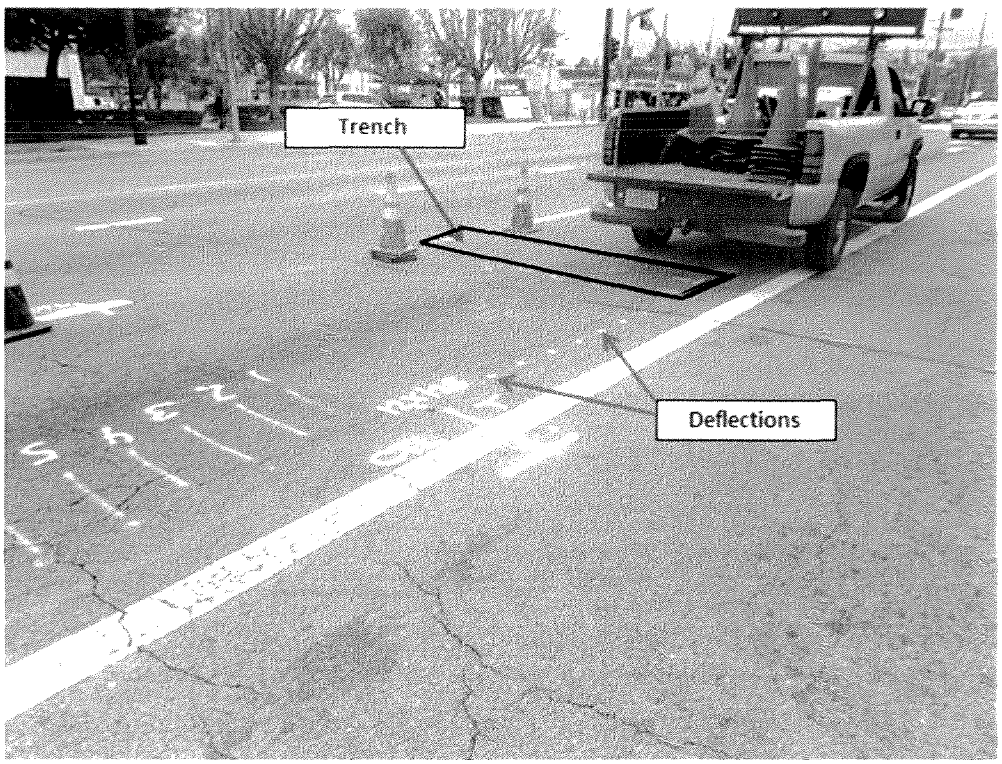

Figure 15: Area of Influence Select Trench No. 74

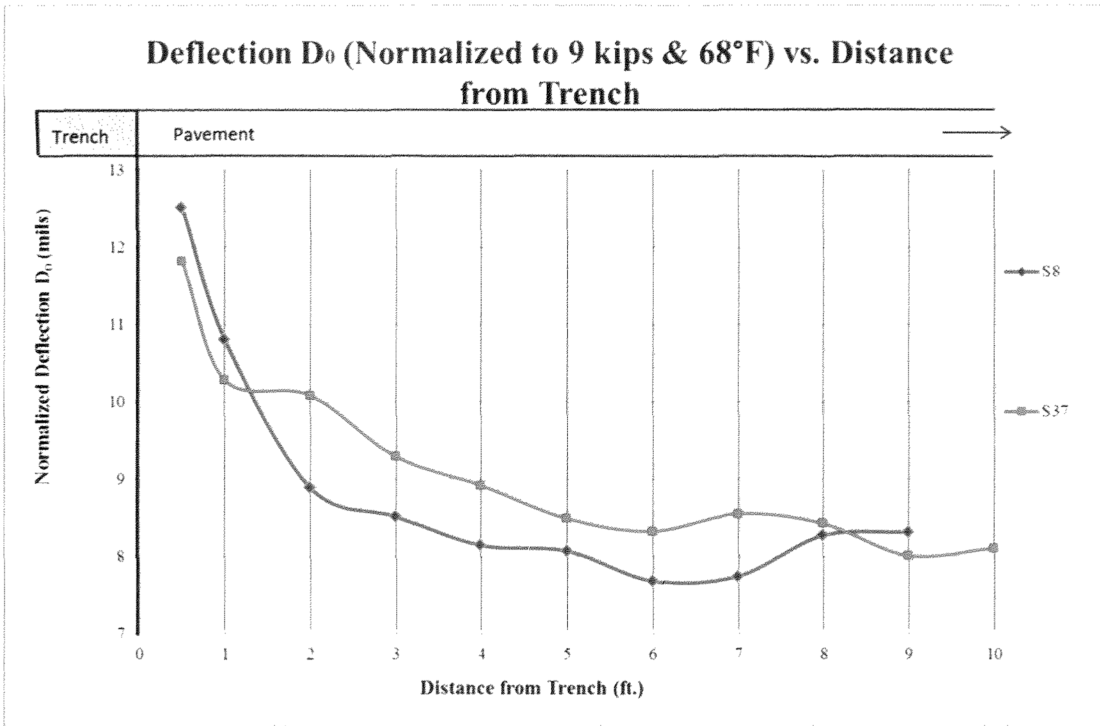

Figure 16 Determinations of "Area of Influence" for Select Trenches No. 8 & 37

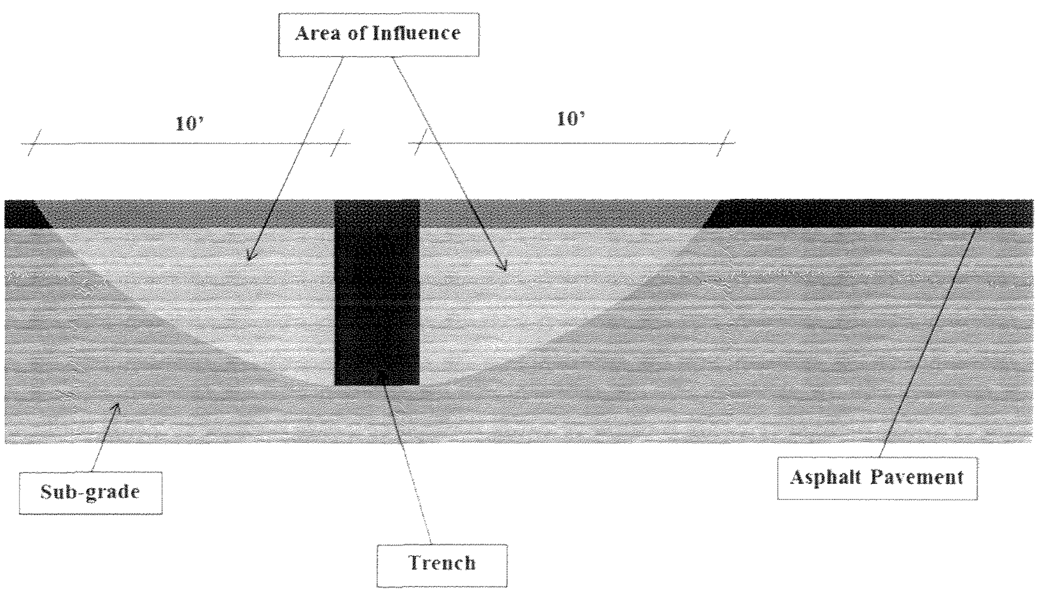

Figure 17: Sketch of Area of Influence under pavement.

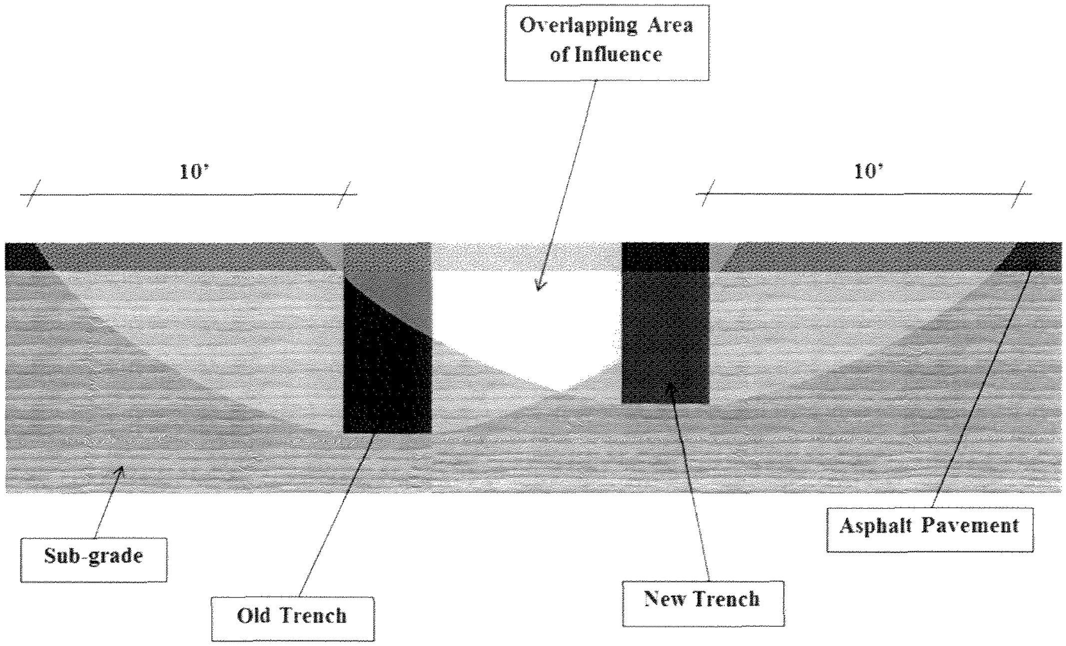

Figure 18: Sketch of Overlapping Area of Influence under pavement.

Figures 17 & 18 show that regardless of the life of asphalt concrete pavement, utility cuts weaken the underlying subgrade of the pavement thus requiring a thicker overlay.

Conclusion

Based on all the tests and analysis performed in this study, it is evident that there is significant damage inflicted by utility trenches to the adjacent pavement structures and underlying subgrade. Regardless of the age of the asphalt concrete pavement, the damage to the underlying subgrade of the pavement adjacent to the utility cuts remains significant; consequently, the overlay thickness design to repair such damage practically doubled the overlay thickness design required on the non-patched area as intended for future traffic in the same section.

Furthermore, the study indicated that utility trenches were not properly restored to match the original pavement condition. It is also evident that the damage and the repairs on higher traffic streets **(Select)** due to utility trenches are higher and therefore, costlier than low traffic streets **(Local)**.

Appendices