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City of Seattle

Impact of Utility Cuts on Performance of Seattle Streets

Final Report

Submitted to:

City of Seattle
Seattle Transportation
810 Third Avenue
Seattle, Washington 98104-1618

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Nichols • Vallerga & Associates
Pavement & Materials Engineers

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1. BACKGROUND

The City of Seattle possesses a transportation system that is vital to the economic health of the City and the enhancement of the City's quality of life. Millions of dollars in public funds have been invested to construct, maintain, and repair streets and the City holds these streets as a valuable public asset for its citizens.

Public rights-of-way are essential to the economical vitality of the city. The City of Seattle grants utility and telecommunication companies reasonable access to the public right-of-way to provide services to the community. However, in order for utility and telecommunications companies to maintain or upgrade their services, they need to access the pavement structure and this, in turn, affects pavement performance. The impact of utility company activity on pavement performance has been a concern of public agencies for many years.

The taxpayers should be entitled to compensation for the use of the valuable transportation assets they have diligently maintained and operated for the function of moving vehicles and pedestrians through, into, and around our communities.

In large cities such as the City of Seattle, thousands of utility cuts are made every year. These cuts are made to install, inspect or repair buried facilities.

Public agencies and the utility companies have each sponsored engineering investigations to determine the impact of utility cuts on pavement performance. Until recently, most studies focused on the effects of backfill type and in-place density on potential surface settlement. Few studies investigated the impacts of utility cuts on the frequency of maintenance and rehabilitation activities and the costs associated with these activities.

Pavement performance trends and trenching practice vary widely from region to region and as a result national studies of the impact of utility cuts have not been undertaken. Recent studies sponsored by public agencies attempt to quantify the financial impact of utility cut patching of roadway performance. Utility companies' research has focused on the need for specific backfill/restoration specifications (i.e., T-sections).

The City of Seattle adopted Resolution 29587 stating the City's intent to review permit fees and rates paid by the public and private utilities and other entities that obtain permits to cut City streets. The review was to determine if such fees and rates cover the full cost of restoring the street to its original condition and to reflect compensation for any loss off, or reduction in, the useful life of the street.

Ordinance 118751, enacted by the City in 1997, seeks to preserve the City's transportation assets and ensure that the street area around utility cuts is restored to its original condition as quickly and efficiently as possible. The Ordinance directs the Director of Transportation to determine a charge from a schedule adopted by Ordinance reflecting the loss in useful life of street, alley, or other public places as a result of utility cuts.

Seattle Transportation initiated this engineering study in 1999 to study the impacts of utility cuts on street pavements. Nichols • Vallerga & Associates (NV&A) was commissioned to perform this study, which was to determine the extent of pavement degradation and costs associated with maintenance repair and rehabilitation due to the presence of utility cuts. This report summarizes the results of the study that was conducted in response. Briefly, it includes the following:

- A summary of recent utility cut studies performed by various cities around the country (Appendix A).
- A description of the engineering approaches that were used to determine the impacts of utility cuts on Seattle's streets.
- The results of the engineering approaches used.
- Development of a fee schedule for utility cuts.
- A guide to the legal aspects of trench cuts (Appendix B).

1.1 Recent Studies

Interest in the impact of utility cuts on roadway performance has increased in the last ten years. This summary is not intended to provide an exhaustive review of the available literature, but rather a review of the relevant studies conducted since 1990 (additional information is contained in Appendix A). Furthermore, the review does not include information on the studies investigating trench repair techniques (i.e., low strength flowable fills, etc). Findings from studies funded by utility companies and public agencies are often contradictory. Whenever possible, follow up information (i.e., ordinance development and implementation) is included.

The results of studies conducted by public agencies show that the presence of utility cuts lower measured pavement condition scores (indexes) compared to pavements of the same age with no utility cuts (i.e., *Impact of Excavation on San Francisco Streets, September 1998*). Also, the link between the presence of utility cuts and accelerated pavement deterioration is accepted by most agencies. The recent San Francisco study concedes that high quality workmanship in the repair of utility trenches may reduce the structural damage to pavements, but contends that lower ride quality, and increased cracking still result and therefore service lives are diminished.

The resulting reduction in pavement life despite high quality workmanship repairing the cut can be explained by considering the trenching operation. Figure 1.1 shows a schematic of a typical trench excavation. The process of opening the trench causes sagging or slumping of the trench sides as the lateral support of the soil is removed. The degree of sagging is determined in part by the soil type, moisture content of the soil, and depth of the trench. Quantifying the extent of sagging is very complex but regardless of the extent, the adjacent pavement is adversely affected.

This "zone" of weakened pavement adjacent to the utility cut can fail more rapidly than other parts of the pavement. This can be observed in the field by the presence of fatigue (alligator) cracking occurring around the edges of the cut, or spalling around the cut edges.

In addition, the introduction of cuts is much like the introduction of cracks on the pavement. If improperly sealed, water intrusion can occur, resulting in loss of fine materials from the underlying base and subgrade and consequently, loss of pavement strength. This can occur even with the best patching or backfill practices if the edges of the cut are not properly sealed. The more cuts on a pavement, the higher the possibility of water intrusion and subsequent loss of strength.

Several studies (i.e., Union City and San Mateo County, CA) have quantified or are in the process of quantifying the extent of damage due to utility cuts through deflection testing. Typically, deflection measurements are taken on the trench, adjacent to the trench and in a control area some distance from the trench. These studies show that trenching operations reduce pavement strength in a zone from 3 to 6 feet either side of the centerline of the trench. By implication, these zones of weaker pavement require more costly rehabilitation and maintenance activity.

The economic impact of utility cuts is often calculated based on the cost of increased overlay thickness required to account for the presence of the utility cut. The increased overlay costs are extrapolated to the entire street section and from the sampled sections to the entire network. Alternatively, the costs associated with shortened cycle times between rehabilitation or maintenance work necessitated by utility cuts are estimated. These costs are then extrapolated to the entire roadway network.

Many agencies have adopted a graduated fee schedule that reduces the utility cut fee based on the pavement age (time since last overlay). The reasoning is that roads older than 20 or 25 years require rehabilitation regardless of the presence of utility cuts and therefore the roadway suffers no additional damage as a result of utility cuts. This approach is frequently used and has intuitive appeal. However if utility cuts weaken the base, subbase, and subgrade layers through slumping of the trench sides, then more costly rehabilitation could be required regardless of the age of the pavement.

Some agencies impose moratoriums on any non-emergency utility cuts for one or more years following street rehabilitation. To ease the impact of the moratorium, one agency (Sacramento, CA) implemented a coordination clause asking the utilities to prepare five-year master repair plans. When utility companies comply by coordinating repair and upgrade activities with the city's master rehabilitation plan, then utility cut fees may be waived. A comparison of Los Angeles and Sacramento programs in shown in Table 1.1.

Although not the direct subject of study, the language of the utility cut fee ordinance and existing franchise agreements are critical to successfully implementing a utility cut fee schedule. The Metropolitan Transportation Commission authorized a study of the legal issues related to the development of utility cut fee schedules for use by San Francisco Bay area agencies (see Appendix B). Some utilities may be exempt based on their franchise agreement with the agency. For example, Southern California Gas Co. was ruled to be exempt from the Los Angeles utility cut fee based on their franchise agreement.

The utility companies have funded and continue to fund studies examining the impact of utility cuts. Case studies have focused on controlled experiments with variables including hot vs. cold patching, standard vs. T-section repairs, and different backfill densities. In part, these studies are reactive to the initiatives of governmental agencies to change trench repair specifications.

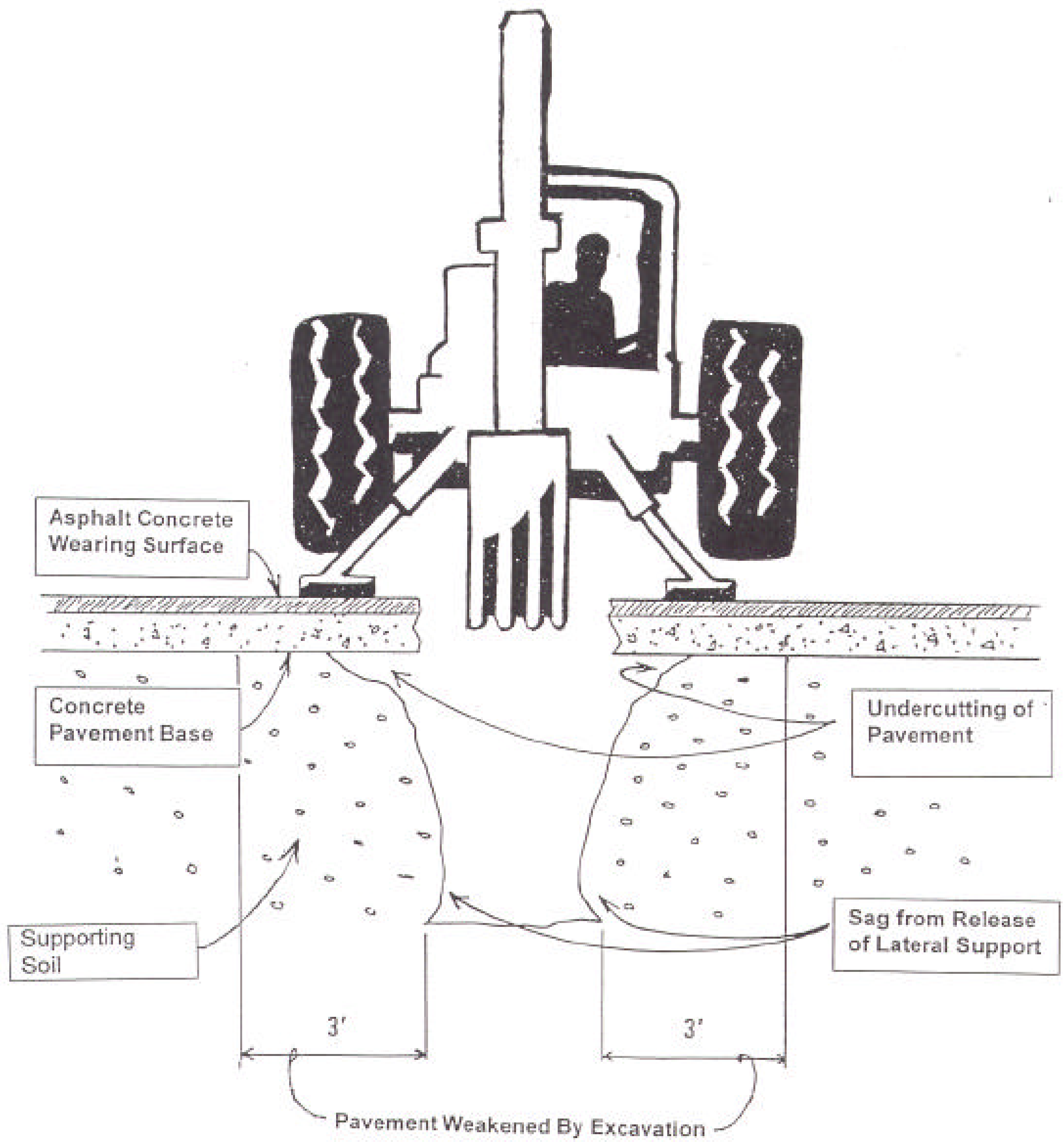


Figure 1.1 Typical Trench Excavation (*Impact of Excavation on San Francisco Streets, September 1998*).

Studies of two cities in California showed that "T-section" repairs did not perform significantly better than standard repairs (see Southern California Gas Co citations in Appendix A). These studies showed that, within limits, density control of the backfill had only limited influence on patch performance. Another study concluded that good compaction was the single most important factor in ensuring successful patch performance.

1.2 Overview of Study Approach

This study for Seattle Transportation relies on two distinct, but related, methodologies to establish the effects of utility trenches and patches on pavement performance and to develop a fee schedule for use by the City. Separately, these two approaches demonstrate the impact of utility trenching on streets in Seattle. When combined, the information allows the development of a utility cut fee schedule that is defensible and specific to the City of Seattle.

The first methodology relies on the City's pavement management system (PMS) to demonstrate differences in pavement performance resulting from the presence of utility cuts. The PMS contains pavement condition indexes for each roadway section as well as inventory information such as pavement age and surface type. Statistical analyses of sections with and without utility cuts should demonstrate that pavement condition scores are lower for pavements of the same type and age with utility cuts. The success of this approach depends on the quality of the PMS database. If the available information on the number of utility cuts is not available in the PMS database, then field surveys will be conducted to determine the number of cuts.

The 1998 San Francisco study used this methodology. The San Francisco PMS included information on the number of utility cuts present on each roadway section. When combined with their pavement condition index scores, the effects of utility cut were determined. Figure 1.2 shows the loss in pavement condition score resulting from utility cuts in San Francisco.

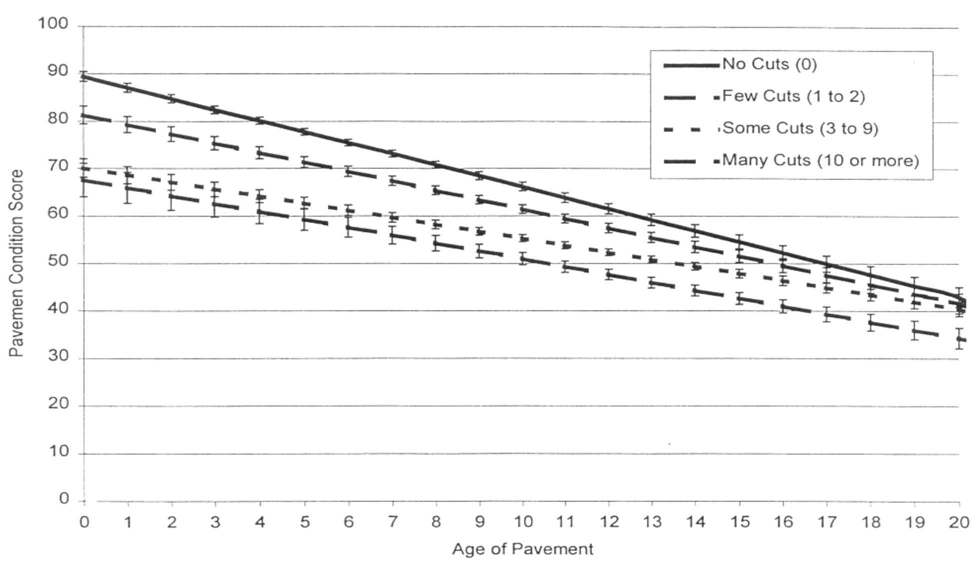


Figure 1.2 Effect of Utility Cuts on Pavement Condition (*1998, San Francisco Study)*

Table 1.1 Comparison of Los Angeles and Sacramento Utility Fee Programs

<table>
<tr><th></th><th colspan="2">Los Angeles</th><th colspan="3">Sacramento</th></tr>
<tr><td>Moratorium</td><td colspan="2">1 year</td><td colspan="3">None</td></tr>
<tr><td>Exemption</td><td colspan="2">Excavations in a street scheduled for repaving within one year of the date of the proposed excavation</td><td colspan="3">a) Demonstrated coordination effort
b) Work on street scheduled for resurfacing during immediate or next fiscal year.
c) Work on street with less than “4” Pavement Quality Index
d) Potholing
e) Willingness to overlay entire lane</td></tr>
<tr><td>Coordination of Excavation</td><td colspan="2">Does not require utility companies to prepare and submit a utility master plan nor is City required to prepare a five year repaving schedule</td><td colspan="3">Utility companies shall prepare and submit a 5-year utility master plan. City shall prepare a five-year repaving schedule.
Refunds a portion of fee paid by utility company during a calendar year if utility demonstrates a specified high level of coordination during that year.</td></tr>
<tr><td>Special Paving Requirement</td><td colspan="2">Streets that have been resurfaced less than one year from the date of the proposed cut shall not be cut unless the whole block within such cut is to be paved by the entity seeking to make the cut. Such repaving of the entire block shall be in lieu of the trench cut fee.</td><td colspan="3">No special paving requirement</td></tr>
<tr><td colspan="6">Fee Schedule</td></tr>
<tr><td>Road Type</td><td>Pvt. Age, yrs</td><td>Sq. ft.</td><td>Cut Direction</td><td>Pvt. Age, yrs</td><td>Linear ft</td></tr>
<tr><td rowspan="3">Major Roads</td><td>1 - 5</td><td>$14.08</td><td rowspan="4">Longitudinal</td><td><5</td><td>$3.50</td></tr>
<tr><td>5 - 10</td><td>11.73</td><td>5 - 10</td><td>$3.00</td></tr>
<tr><td>10 - 15</td><td>9.39</td><td>10-15</td><td>$2.00</td></tr>
<tr><td rowspan="5">Local Roads</td><td>1 - 5</td><td>5.15</td><td>> 15</td><td>$1.00</td></tr>
<tr><td>5 - 10</td><td>4.57</td><td rowspan="4">Transverse</td><td>< 5</td><td>$7.00</td></tr>
<tr><td>10 - 15</td><td>4.29</td><td>5 - 10</td><td>$6.00</td></tr>
<tr><td>15 - 20</td><td>3.88</td><td>10-15</td><td>$4.00</td></tr>
<tr><td>20 - 25</td><td>3.43</td><td>> 15</td><td>$2.00</td></tr>
</table>

The second methodology utilizes deflection testing on selected streets to establish the relative loss of structural capacity resulting from the presence of utility cuts. This loss of structural capacity necessitates thicker overlays, thus increasing the cost of rehabilitation for a street with utility cuts over the costs for a street without cuts. Deflection testing will be conducted on the utility cut, adjacent to but off the utility cut and approximately 10 feet from the cut as shown in Figure 1.3.

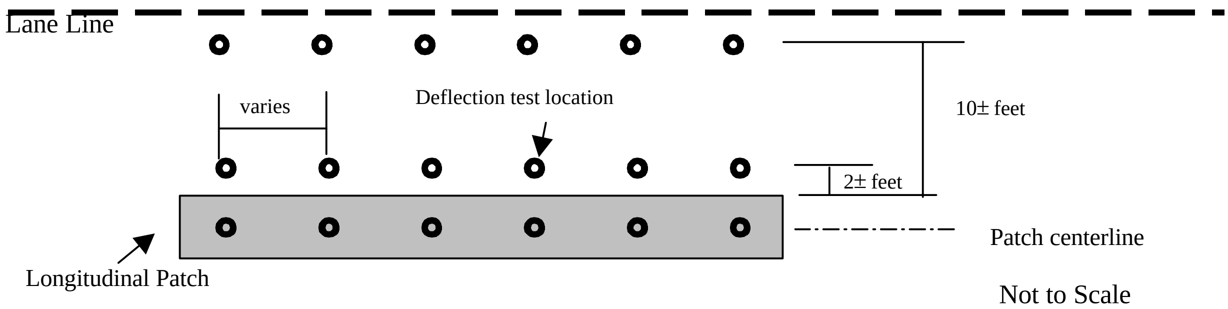


Figure 1.3 Description of deflection testing program

This approach requires substantial field data collection and fewer sections will be included. This smaller data set will be a subset of the pavement condition data set defined above.

The combination of the methodologies will allow a defensible fee schedule to be developed. The first approach demonstrates, in a statistically valid way, that the condition of the entire network is adversely affected by the presence of utility cuts. This provides robustness to the results. The second approach provides specificity by establishing the differences in required overlay thickness attributable solely to the presence of utility cuts.

1.3 Available Data

At the time of this study, the Seattle Pavement Management System database includes approximately 30,000 sections. Of these, approximately 7,200 sections are designated arterials and the remaining sections are described as residential streets. No condition survey or pavement type information is available for the residential sections and therefore these sections are not included in the analysis. The distribution of arterial streets by pavement type is shown in Table 1.1.

The pavement age for arterials is identified in the PMS database as the time since construction or the last rehabilitation activity. The 1998 study by the City and County of San Francisco concluded that only streets with ages less than or equal to twenty years should be included in their utility cut study. In that study older streets were excluded in part because the Department of Public Works was unsure of the completeness of the data on older streets and the older streets reflected “survivors” – old streets with unusually good condition scores for their age. Based on this information, the same approach was followed for this study. After applying this filter, the available data are shown in Table 1.2.

Table 1.1 Arterial Streets in Seattle

Pavement Type	No. of Sections in Arterial Database	Percent of Total	Percent of those with Identified Types
Asphalt – ACP	518	7.2	10.6
Composite – APC	2940	40.9	60.5
Concrete - PCC	1309	18.2	26.9
Surface Treatment – BST	82	1.1	1.7
Asphalt Treated Base – ATB	11	0.1	0.2
Brick – BRK	1	0.0	0.0
No type listed	2332	32.4	--
TOTALS	**7193**	**100**	**100**

Table 1.2 Distribution of Pavement Sections less than or equal to 20 years old

Pavement Type	No. of Sections in Arterial Database with Pavement Age less than or equal to 20 years	Percent of 2016 Sections
Asphalt – ACP	369	18.3
Composite – APC	1561	77.4
Concrete – PCC	1	0.0
Surface Treatment – BST	74	3.7
Asphalt Treated Base – ATB	11	0.5
TOTALS	**2016**	**100**

2. UTILITY CUT SURVEYS

The purpose of this phase of the study is to establish the influence of utility cut patching on the pavement by comparing the pavement condition indices of roads with and without utility cut patches.

2.1 Approach

As noted in the project approach, the City's PMS established the impact of utility cuts on pavement performance. The Flexible Pavement Surface Condition Rating Manual for the Seattle Pavement Management System ("Centerline PMS, Flexible Pavement Surface Condition Rating Manual-Draft," MRC, December 1998) includes a provision for collecting information on patching distress.

Initial analysis comparing the available patching distress measurements to the calculated pavement condition indices showed no readily discernable relationships (see Appendix C). The nine calculated indices included in this analysis are as follows:

- IX_CDI Measured combined distress index
- IX_CNI Measured combined non-structural distress index
- IX_CSI Measured combined structural distress index
- IX_OCI Overall combined/condition index
- IX_RDI Measured ride distress index
- IX_AVG_CDI Straight average of all sample CDI values.
- IX_AVG_CNI Straight average of all sample CNI values.
- IX_AVG_CSI Straight average of all sample CSI values.
- IX_AVG_OCI Straight average of all sample OCI

It was therefore necessary to conduct field surveys to determine the number of utility cuts present in a sample of the arterial system.

A range of pavement ages and spatially distributed samples were selected to reduce bias in the data set. At the request of City staff, only asphalt-surfaced arterials were considered for inclusion in the database. Funds were available to survey approximately 300 sections. To assist in selecting the sections, the range of pavement ages (0 to 20 years) were divided into four categories:

Category 1 - 0 to 5 years

Category 2 - 6 to 10 years

Category 3 - 11 to 15 years

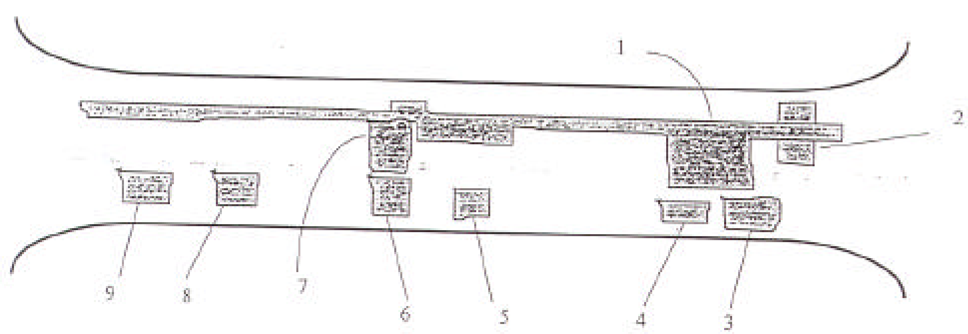
Category 4 - 16 to 20 years

Next, asphalt-surfaced arterials fitting one of the four age categories were located using the Thomas Guide ("King County Street Guide and Directory," Thomas Bros. Maps, 1999). The map page and grid numbers were identified for all asphalt-surfaced arterials. This technique allowed the identified survey sections to be geographically distributed across the City. Finally, sections in each age category, geographic area and pavement type were selected for utility cut survey. The list of the selected survey sections is shown in Appendix C.

Surveys were conducted between April 26th and 30th, 1999. Two one-person crews performed the surveys. During a walking survey of the entire section, the total number of patched utility cuts was recorded using the instructions shown below. The orientation (transverse, longitudinal or other) of the patches was also noted. The weather during the survey days was overcast and warm, with a little rain.

Survey Instructions

Regardless of shape or size, each trench is counted as one trench as shown below. Trench #1 is counted as one utility cut, including the notches. Trench #2 is also counted as one cut although Trench #1 subsequently divided it into two cuts. Trenches #3 through #9 are counted as seven separate cuts. Additionally, trenches oriented longitudinally or transversely were identified as such. Square, nearly square patches or those without a predominant orientation were identified as Other.



2.2 Results

Table 2.1 shows number and type of pavement sections surveyed by Nichols • Vallerga & Associates. Sections were selected to approximately mirror the distribution of pavement types present in the arterial database. The City requested the addition of portland cement concrete sections after the initial surveys were complete.

Table 2.1 Utility Survey Pavement Type Distribution

Pavement Type (based on PMS database)	Number of sections included in survey	Percent of Total Section Surveyed	Percent of Asphalt Arterial Sections less than or equal to 20 years old
Asphalt – ACP	57	18.1	18.3
Composite – APC	233	74.0	77.4
Surface Treatment – BST	15	4.8	3.7
Portland Cement – PCC*	10	3.2	--
TOTALS	**315**	**100**	

*PCC were not included in the April surveys but were surveyed in May during deflection testing.

The age categories of surveyed sections are shown below. For ACP and APC pavement types the distribution of age categories is almost equal. Most of the BST types were drawn from the first two age categories (1 & 2). This is because most BST-surfaced pavement would not be expected to last beyond ten years.

Table 2.2 Utility Survey Age Category Distribution

Pavement Type (based on PMS database)	**Age Category**				**Total**
	1	**2**	**3**	**4**	
Asphalt – ACP	14	19	14	10	57
Composite – APC	52	51	63	66	232
Surface Treatment – BST	7	5	2	1	15
Portland Cement Concrete – PCC*	1	1	3	0	5
TOTALS	**74**	**76**	**82**	**77**	**309**

* PCC sections were not part of the original survey conduct in April 1999.

Note: The Pavement Management System does not include age for six sections; 5 PCC sections and 1 APC section. This accounts for the discrepancy between Tables 2.1 and 2.2.

Initial analyses of the utility cut data included plots of condition indices versus pavement age and the number of utility cuts. Appendix C contains plots of pavement age versus condition indices for each pavement condition index included in the PMS database. In addition, the Appendix contains plots of the various condition indices versus the number of cuts present. A typical relationship is shown in Figure 2.1.

Figure 2.1 shows the relationship between the Overall Condition Index OCI) and pavement age for the surveyed sections when the 1997 condition survey information was used to calculate the OCI. These data describe an unexpected trend. Specifically the recorded OCI values range between 13 and 85 only one year after rehabilitation when one would expect the OCI value to be near 100. In addition, the OCI does not appear to decline with increasing age as would be expected. These trends are counter-intuitive and indicate that the pavement age, the OCI or both are incorrectly recorded in the database.

Figure 2.1 1997 Based Overall Condition Index versus Age

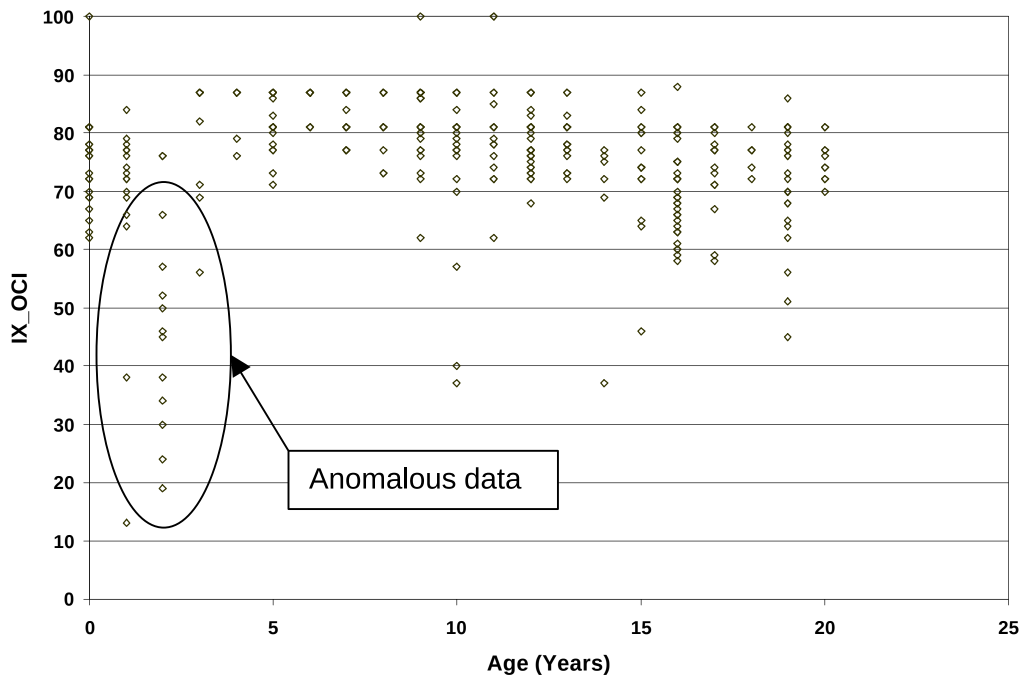


Figure 2.2 shows the average number of utility cuts present versus the age category for all surveyed pavement sections. As expected, the number of cuts increase with age for the first fifteen years (through Category 3). The number of cuts then drops in Category 4. One possible reason for this apparent anomaly is that pavement sections with many utility cuts are being rehabilitated (overlaid) leaving only those streets with fewer cuts in Category 4. Another possible explanation is that the pavement ages contained in the PMS database are in error.

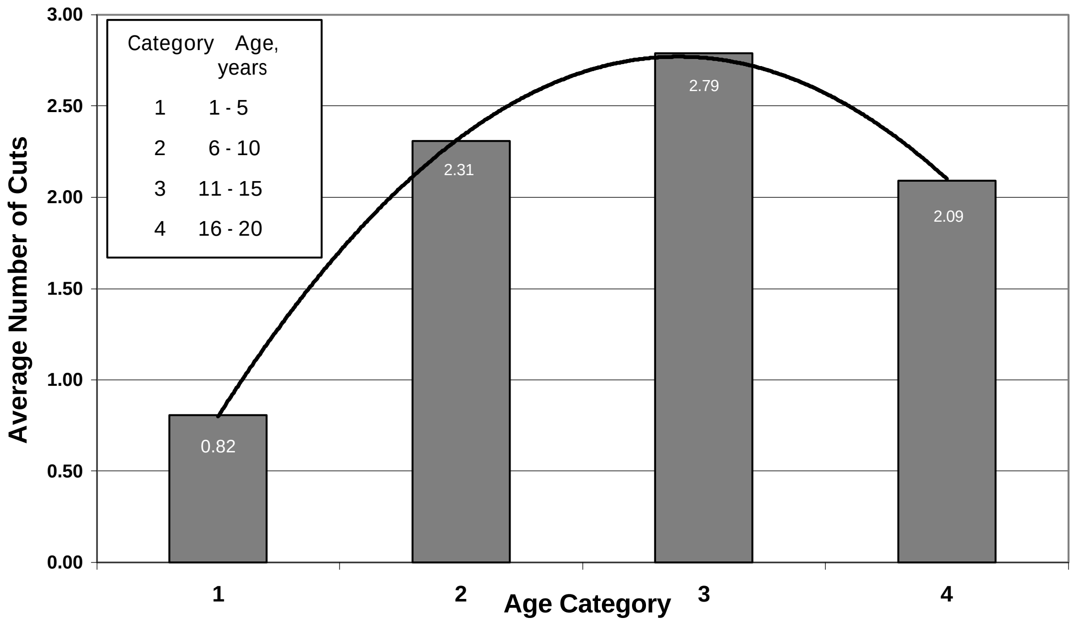


Figure 2.2 Average number of utility patches in each age category

These results prompted the City to review their PMS data. OCI values based on the 1994 rather than the 1997 automated condition survey data were provided for further analysis. Figure 2.3 uses the 1994-based OCI data to compare age and OCI. The revised OCI data (projected from the 1994 survey data) more closely model expected trends, i.e., OCI values for sections less than 5 years old are near 100.

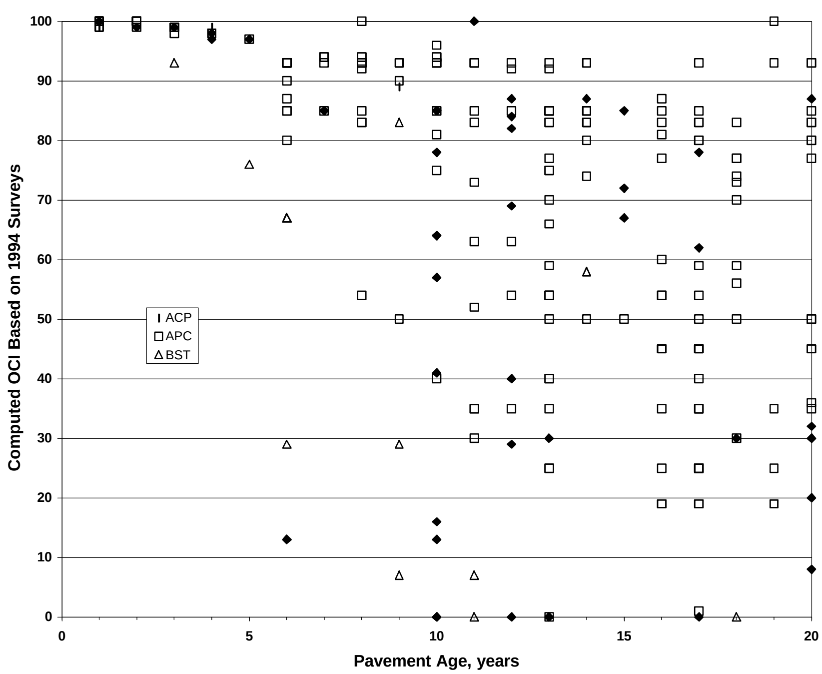


Figure 2.3 Condition Index versus age using 1994 survey data

Although the OCI values changed as a result of using the survey data from 1994 rather than the 1997 data, the pavement ages unchanged. This is because the pavement age is computed by subtracting the current year (1999) from the date of last rehabilitation (or construction) available from the PMS database. Therefore the results shown in Figure 2.2 remain unchanged.

Condition surveys were also conducted on each of the thirty-seven deflection test sites. The surveys were conducted following the MicroPAVER technique and the Pavement Condition Index (PCI) was computed. Figure 2.4 shows each test site and the on-cut and off-cut PCI scores. A PCI of 100 would be a new Pavement, and a PCI of 0 would be completely failed. A PCI was calculated to include the patched area for each section, and another was calculated without the patched areas.

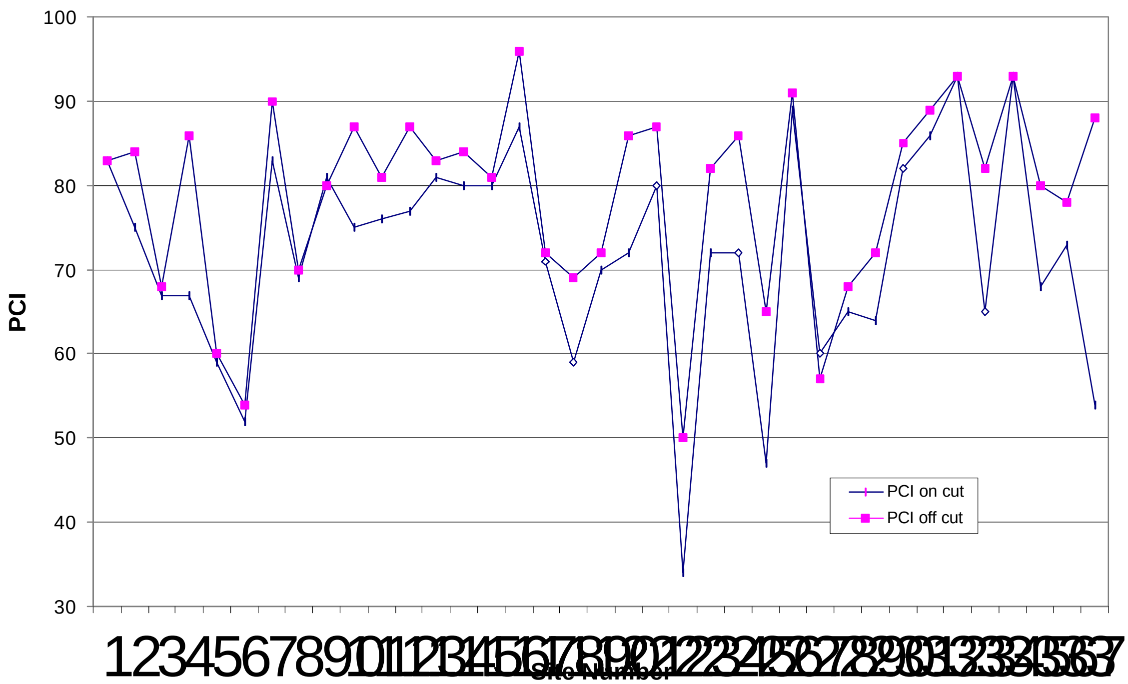


Figure 2.4 MicroPAVER Condition Indices for Deflection Sites

These results are summarized by pavement type in Table 2.3. The results demonstrate a decline in condition index of approximately 14 and 7 points for asphalt and composite streets, respectively. The portland cement concrete sections show little difference, probably because the City requires full slab replacement in areas of utility work.

Statistical analyses by pavement type shows that the MicroPAVER surveys of “on-cut” and “off-cut” sections for both the ACP and APC pavement are statistically different at the ten percent level using the t-test. Similar analysis of the PCC sections showed that the “on-cut” and “off-cut” survey data are statistically the same.

Table 2.3 PCI values for deflection sites

Pavement type	Number of Sections	Pavement Condition Index			T-test Results- Probability that values are equal
		Average of Sections including Utility Cut Area	Average of sections not including Utility Cut area	Difference in PCI	
ACP – Asphalt	9	61.6	75.4	13.8	7.5%
APC – Composite	18	71.9	78.6	6.7	4.2%
PCC – Concrete	10	81.3	82.5	1.2	77.7%
Total/Average	37	71.3	78.9	7.6	

In order to expand the pavement condition database (at the request of the City of Seattle), additional field surveys were conducted on 306 sections (153 patched sections and 153 control, i.e. no-patch sections) during November 1999. Surveys and subsequently computed values of PCI were based on MicroPAVER techniques and the procedures described previously in this report. Statistical analyses of this additional data set were performed in order to compare with the findings from the initial investigation.

Plots of the data are provided to illustrate some general trends and relationships. These visual summaries of the data provide useful information in addition to that provided by formal statistical inference, which is presented later in this report. Variables in this study and statistical analyses include the following:

Patch PCI	= PCI for the patched section of the road
No Patch PCI	= PCI for the matched, control section of the road
Delta PCI	= No Patch PCI - Patch PCI
FC	= functional class (A= arterial, R = residential)
Cuts	= number of cuts in the patched section, including transverse, longitudinal and diagonal

<u>Comparing Patch and No Patch PCI</u>

Figure 2.5 shows a plot of PCI values for patched sections (shown as “Patch PCI”) versus sections without patches (“No Patch PCI”). The diagonal line given for reference is Patch PCI = No Patch PCI. Points above the line indicate that the PCI is higher for the patched section for that roadway, while points below the line indicate the PCI is higher for the section without a patch. The bulk of the points fit the latter category, indicating that for the majority of the sections in this sample the pavement condition was superior for the sections without patches.

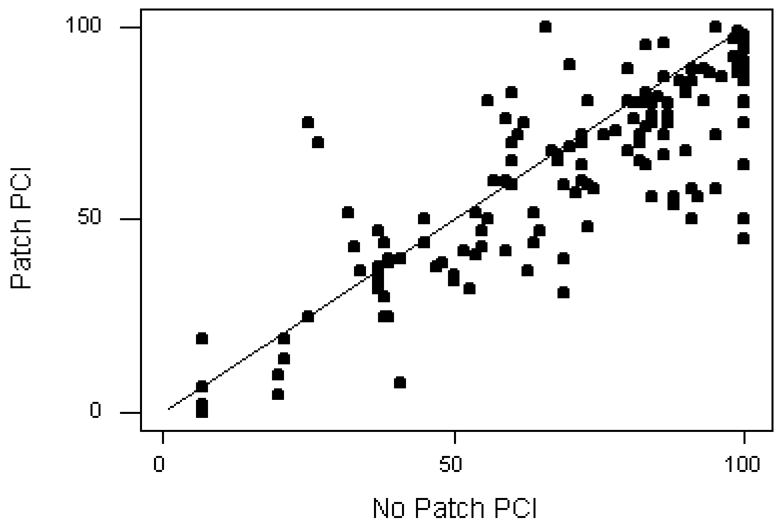


Figure 2.5 Patch vs. No Patch PCI Values

Alternatively, Figure 2.5 above can be illustrated as shown below (see Figure 2.6). Here, the Delta PCI has been plotted for every site. Recall that a positive Delta PCI indicates that the no-patch PCI is *higher* than the patch PCI. Again, from a visual inspection, it is apparent that the sites with no patches have a higher PCI than sites with patches.

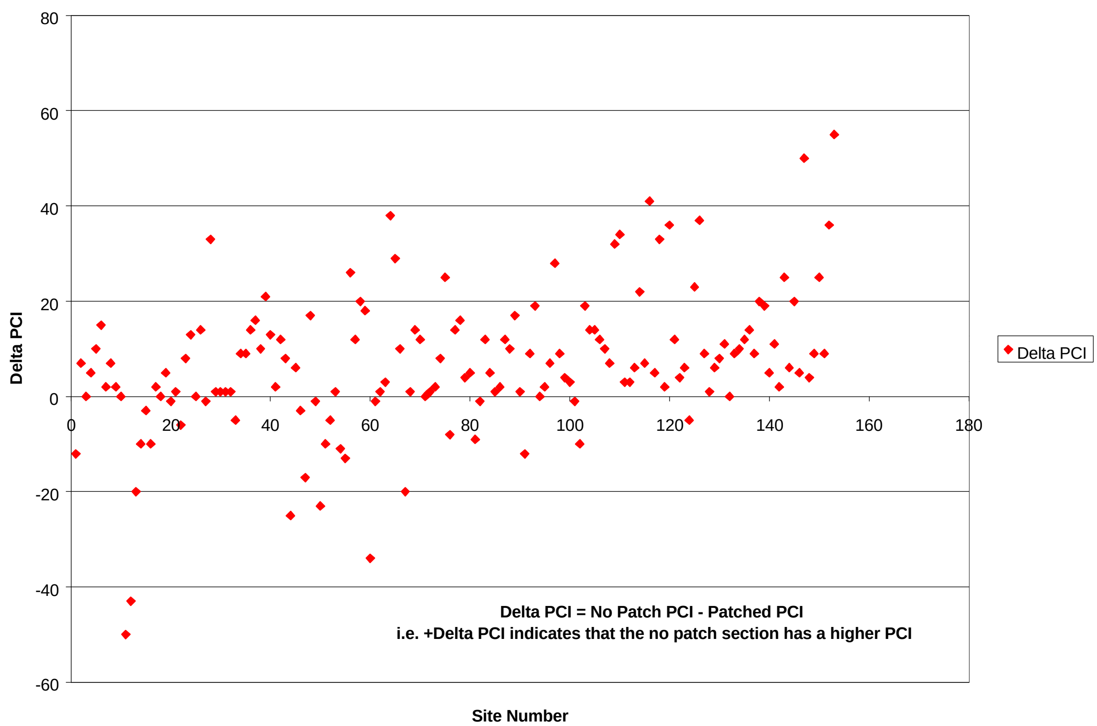


Figure 2.6. Delta PCI for All Sites

Comparing Delta PCI for Arterials and Residential Streets

Figure 2.7 shows boxplots of the Delta PCI values, separately for arterial and residential streets. Boxplots divide the data into fourths, as follows. The lowest quarter extends from the lowest asterisk to the bottom of the box. The next (second) quarter ranges from the bottom of the box to the median (horizontal) line. The third quarter ranges from the median line to the top of the box, and the highest quarter is from the top of the box to the highest asterisk. The vertical lines extend 1.5 times the length of the box, beyond which individual datapoints are represented with asterisks. Figure 2.7 shows that the range of the middle half of the Delta PCI values (depicted by the box) is almost identical for arterial and residential streets. In fact, the only difference in the two sets of values is that the highest and lowest values are slightly more extreme for residential streets than for arterials.

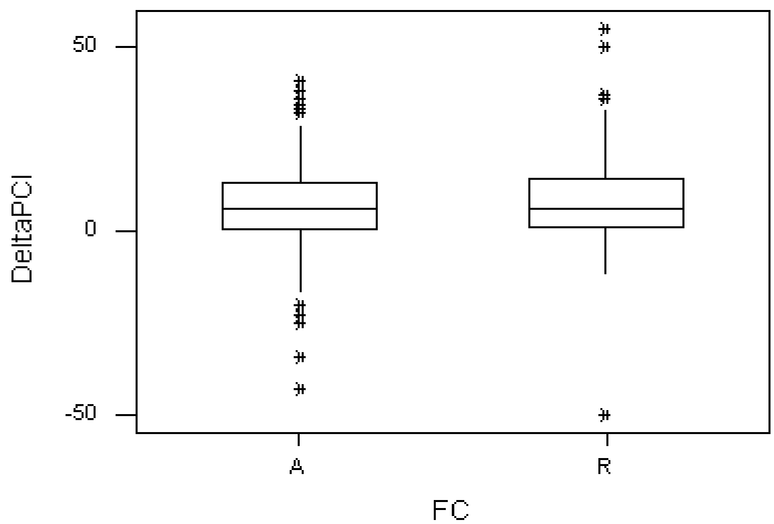


Figure 2.7 Boxplots of Delta PCI for Arterials (A) and Residential Streets (R)

Delta PCI versus Control PCI for Arterials and Residential Streets

Figure 2.8 shows a plot of the Delta PCI versus the PCI of the control section, with separate symbols for arterials and residential streets. The horizontal reference line is Delta PCI = 0, indicating equal PCI for the patched and control sections of the roadway. Figure 2.8 illustrates that the PCI tends to be lower in general for residential streets. Also, the higher the PCI for the control section, the more likely the PCI for the patched section is lower than the control PCI (points above the line), which is logical since the maximum the PCI value can be is 100. Finally, Figure 2.8 shows that the relationship between Delta PCI and control section PCI is similar for arterials and residential streets.

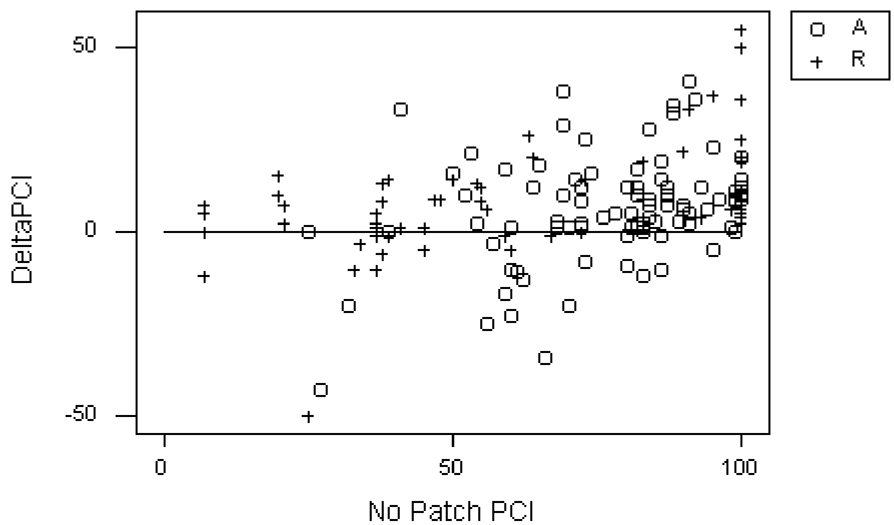


Figure 2.8 Delta PCI vs. Control Section PCI for Arterials (A) and Residential Streets (R)

A Brief Overview of Statistical Hypothesis Testing and Estimation

Before proceeding with the results from statistical analyses, a brief discussion is presented to help clarify terms and procedures and to help interpret findings.

Statistical inference is used when available sample data can be considered to be representative of a larger population. Measurements related to the population cannot be made precisely, but probability assessments can be used to resolve questions of interest. Questions about comparisons of the data shown in Figures 2.5 through 2.8 can be addressed with a statistical hypothesis test and confidence interval. In general, this proceeds as follows:

1. Define a population parameter of interest. Specify a null hypothesis by stating the value the population parameter would equal if nothing has changed or there is no relationship between two variables. Specify an alternative hypothesis giving a range of values for the population parameter that indicates a change or a relationship.
2. Compute a summary of the data, called a "test statistic" that measures how far the data fall from the condition specified by the null hypothesis.
3. Compute a "p-value," which gives the probability of observing data as far from the null hypothesis or more so, by chance, if the null hypothesis is actually true.
4. Make a decision based on the p-value. If it is small (0.05, i.e. 5%, is typically used as a threshold for "small"), reject the null hypothesis and conclude that the alternative hypothesis is true. In other words, conclude that if the null hypothesis were true, data as extreme as that observed would be unlikely, so it is preferable to believe that the alternative hypothesis is true.
5. To assess the magnitude of the difference or relationship, use the sample data to compute a 95% "confidence interval" for the parameter of interest. This is an interval of values that almost certainly (with 95% confidence) covers the true but unknown population parameter.

<u>Results from Statistical Hypothesis Testing and Estimation</u>

Question 1: Is the average difference between PCI for non-patched and patched sections of roadway significantly different from 0?

1. The null hypothesis is that the average Delta PCI for non-patched and patched sections is 0 for the population of roads represented by this sample. The alternative hypothesis is that the average Delta PCI is not 0.
2. The appropriate test in this case is a paired t-test for the difference between No patch PCI and Patch PCI, or equivalently, a one-sample t-test that average Delta PCI is 0. The test statistic is $t = 5.82$, $df=152$ *(df = degrees of freedom =* $n - 1$*).*
3. The *p-value* $= 3.4 \times 10^{-8}$. In other words, if average Delta PCI in the population is 0, then the probability of observing a sample mean Delta PCI as large as or larger than the one observed (6.98) is essentially zero. (Note that this is also the difference between the mean PCI of 69.73 for non-patched sections and mean PCI of 62.75 for patched sections.)
4. Because the *p-value* is so small, reject the null hypothesis and conclude that average Delta PCI for the population is significantly different from 0.
5. A 95% confidence interval for the average Delta PCI for all roadways similar to those in the sample is 4.6 to 9.4. This interval is consistent with the results of the hypothesis test because the entire interval falls well above 0, indicating that an average difference of 0 is not plausible. Even a 99.9% confidence interval for the difference does not cover 0, ranging from 3.0 to 11.0. In other words, with 99.9% confidence, the interval from 3 to 11 covers the actual difference between PCI for no patch control sections and patched sections of roadway for the population.

Question 2: Is there a significant difference in the average change in PCI (Delta PCI) for arterial versus residential streets?

1. The null hypothesis is that the average Delta PCI for arterials in the population is the same as the average Delta PCI for residential streets. In other words, the difference in the average Delta PCI for arterials and residential streets is 0. The alternative hypothesis is that the difference in the two averages is not 0.
2. The appropriate test in this case is a t-test for two independent samples. The test statistic is *t = -0.94, df = 134.*
3. The *p-value = 0.35.* In other words, if there really is no difference between the average Delta PCI for arterial and residential streets in the population, then the probability of observing a difference in the sample means as large as or larger than the one observed (6.0 for arterials, 8.3 for residential streets) is 0.35.
4. Because the *p-value* is not small enough to provide evidence against the null hypothesis, it is not rejected. In other words, there is no convincing evidence from which to conclude that average Delta PCI differs for arterials and residential streets.
5. A 95% confidence interval for the difference in average delta PCI for arterials and residential streets is –7.1 to +2.5. This is consistent with the hypothesis test because a difference of 0 is included in the interval.

Question 3: Is there a significant relationship between number of cuts in the patched section and Delta PCI?

1. Only a linear relationship was examined. The null hypothesis is that the correlation between number of cuts and Delta PCI in the population is 0. The alternative hypothesis is that the correlation is not 0, indicating a linear relationship between the two variables. An equivalent test is based on the slope of the least-squares line between Delta PCI and number of cuts. The null hypothesis is that the slope is 0, the alternative hypothesis is that it is not 0.
2. The appropriate test statistic is a t-test for whether or not the slope is 0. The test statistic is *t = -0.37, df = 150.*
3. The *p-value* is 0.71. In other words, if the correlation between Delta PCI and number of cuts is really 0, and thus the slope for the least squares line relating them is also 0, then the probability of observing a slope as far from 0 as that observed (–0.14) or more so is 0.71.
4. The *p-value* of 0.71 is large enough to indicate that the slope of the line for the sample, and thus the correlation, is not significantly different from 0. There is not a significant linear relationship between total number of cuts and Delta PCI.
5. A 95% confidence interval for the slope of the line is –0.86 to +0.59. This is consistent with the hypothesis test, which did not reject a slope of 0 as a plausible value.

A final effort in the analysis addressed potential differences in the variance for the data sets shown in Figures 2.5 through 2.8 because there may be differences in variance as Delta PCI increases and for arterials versus residential streets. Statistical methods to accommodate differences in variance include transformations and nonparametric procedures. These procedures were applied and compared with the analyses presented, and there were no changes in the conclusions. There were minor differences in numerical values but they did not alter the findings.

For example, a (nonparametric) Mann-Whitney test and confidence interval were done to compare Delta PCI for arterials and residential streets. The null hypothesis for this test is that the difference in medians is 0, while the alternative hypothesis is that the difference in medians is not 0. The resulting *p-value* for the test was 0.70, leading to the same conclusion as in Question 2 above, that there is no significant difference in average delta PCI for arterials and residential streets. (In the original test "average" is defined as arithmetic mean, while in this test it is defined as median.) A 95% confidence interval for the difference in medians is from –5.0 to +3.0, similar to the 95% confidence interval for the difference in means (–7.1 to +2.5).

2.3 Summary

- The number and orientation of utility cut patches were recorded on approximately 300 pavement sections. These pavement sections have various ages, material types, and geographical locations.
- No obvious correlation could be drawn between the pavement condition indices and the age of pavement when the 1997-based OCI data was evaluated.
- Use of the 1994-based OCI data addressed many of the observed anomalies in the 1997 data regarding the relationship between OCI and pavement age.
- The relationship between the number of utility cuts and overall condition index (OCI) were as expected for the first 15 years and the decline apparent in Age Category 4 (16 – 20 years) may be explained by normal rehabilitation activities.
- MicroPAVER condition surveys results showed a difference in condition index values for sections with and without utility cuts for ACP and APC pavements of about 8 points. Differences in portland cement concrete sections were not apparent.
- The expanded database (from November 1999) confirms previous findings:

  - ✓ there is a significant difference between average PCI for non-patched and patched sections
  - ✓ there is no significant difference between the average Delta PCI for arterial and residential streets
  - ✓ there is no significant relationship between number of cuts in a patched section and Delta PCI

3. STRUCTURAL ANALYSIS

The second methodology used in this project was to establish the increased cost of rehabilitation necessitated by the presence of a utility cut patch in a given section of roadway. Asphalt overlays were selected as the appropriate rehabilitation alternative for all roadway types regardless of existing pavement type.

3.1 Approach

This methodology compares the overlay thickness required in areas with and without utility cuts to estimate the increased costs associated with the presence of the cut. Overlay thickness was determined for each site using the widely accepted 1993 AASHTO Pavement Design Guide ("AASHTO Guide for the Design of Pavement Structures 1993," American Association of State Highway and Transportation Officials, 1993). The procedure recommends that the thickness design be based on deflection measurements taken on the existing pavement. This approach was used for each site.

A minimum of five measurements were taken at each of three locations; on the cut, approximately 2 feet off the edge of the cut and 10 to 12 feet from the edge of the cut (see Figure 1.3). Note that the locations 10 feet from the cut represent the control section. The average maximum deflection at each of the three locations was plotted to determine whether the utility cut negatively impacted the roadway. If this comparison showed that the cut did impact the roadway, then an overlay design was completed.

3.2 Results

Thirty-two test sites were identified for deflection testing. A falling weight deflectometer (FWD) was used. The 32 sites were selected from the list of 300 sections previously surveyed. The presence of a longitudinal utility cut and relatively wide lane to accommodate the test equipment were the principal selection criteria. All sections were asphalt concrete (AC) surface pavements. Immediately prior to testing, City personnel requested that the total number of sites be increased to 36 by adding 10 PCC sites and removing 6 ACP sites from the pre-selected list.

Deflection data were collected between May 17 and 21, 1999. Deflection measurements were collected down the centerline of the longitudinal utility cuts, approximately 2 feet from the end of the patch and 10 to 12 feet from the cut in an area unaffected by the cut (see Figure 1.3). As noted in Section 2.0, MicroPAVER condition surveys were conducted at each site.

Of the original 36 sections, approximately one-third could not be tested due to constraints of parked cars, heavy traffic, traffic control problems, and location of cut. Alternate sites were selected and 37 sites were tested including; nine ACP sites, eighteen APC sites, and ten PCC sites. Table 3.1 shows information on each site tested.

Table 3.1 Deflection Test Sites

Site Number	Street Name	From	To	Material Type	Age
1	32ND AV W	W WHEELER ST	W SMITH ST	PCC	2
2	EASTLAKE AV E	E EDGAR ST	E HAMLIN ST	APC	11
3	BELL STREET	7TH AV	8TH AV	PCC	NA
4	DEXTER AV N	HALLADAY ST	4TH AV N	ACP	11
5	FREMONT AV N	N 34TH ST	N 35TH ST	APC	16
6	3RD AV NW	NW 115TH ST	NW 117TH ST	ACP	20
7	N 130TH ST	AURORA AV N	STONE AV N	ACP	10
8	UNIVERSITY WY NE	NE 47TH ST	NE 50TH ST	APC	13
9	24TH AV E	E MILLER ST	E MONTLAKE PL E	APC	11
10	E PIKE ST	HARVARD AV	BROADWAY	APC	6
11	BELLEVUE AV E	E LORETTA PL	E JOHN ST	APC	8
12	WESTLAKE AV	7TH AV	LENORA ST	APC	13
13	6TH AV	BLANCHARD ST	BELL ST	PCC	NA
14	S JACKSON ST	OCCIDENTAL AV S	2ND AV S	APC	13
15	M L KING JR WY S	S NORMAN ST	S ELMWOOD PL	PCC	NA
16	31ST AV S	S ATLANTIC ST	S MASSACHUSETTS ST	APC	7
17	S COLLEGE ST	15TH AV S	16TH AV S	PCC	NA
18	50TH AV S	S ALASKA ST	S ANGELINE ST	APC	NA
19	S ORCAS ST	52ND AV S	WILSON AV S	PCC	13
20	BEACON AV S	S CLOVERDALE ST	S DONOVAN ST	APC	11
21	RAINIER AV S	S NORFOLK ST	S COOPER ST	APC	17
22	S BANGOR ST	53RD AV S	55TH AV S	ACP	23
23	SW 106TH ST	31ST AV SW	32ND AV SW	ACP	20
24	35TH AV SW	SW CAMBRIDGE ST	SW ROXBURY ST	ACP	20
25	SW ORCHARD ST	DUMAR WY SW	DELRIDGE WY SW	ACP	21
26	FAUNTLEROY WY SW	SW EDMUNDS ST	SW HUDSON ST	PCC	14
27	SW MANNING ST	35TH AV SW	36TH AV SW	APC	1
28	SW ADMIRAL WY	CALIFORNIA AV SW	44TH AV SW	APC	17
29	2ND AV	VIRGINIA ST	LENORA ST	APC	18
30	VIRGINIA ST	9TH AV	TERRY AV	APC	13
31	8TH AV	LENORA ST	BLANCHARD ST	PCC	NA
32	15TH AV NE	NE 82ND ST	NE 85TH ST	PCC	11
33	GREENWOOD AV N	N 90TH ST	N 92ND ST	APC	13
34	1ST AV NE	NE 75TH ST	NE 77TH ST	PCC	13
35	N 80TH ST	STROUD AV N	MERIDIAN AV N	APC	16
36	NW 46TH ST	LEARY WY NW	9TH AV NW	ACP	10
37	THORNDYKE AV W	W CROCKETT ST	W BOSTON ST	ACP	12

NA – Not Available

The structural analyses were separated by pavement type and each is discussed below.

ASPHALT CONCRETE PAVEMENT

A review of the maximum deflection plots showed that all nine asphalt sections (ACP) were adversely affected by the presence of the utility cut. A typical plot is shown in Figure 3.1 for Site 6. In this case, both the average deflection measurements on the cut and adjacent to the cut are higher than the average measurement taken in the control area indicating that the control area would require a thinner overlay than either the area on the patch or 2 foot off the patch. This confirms the slumping of the trench sides described in Section 1.0.

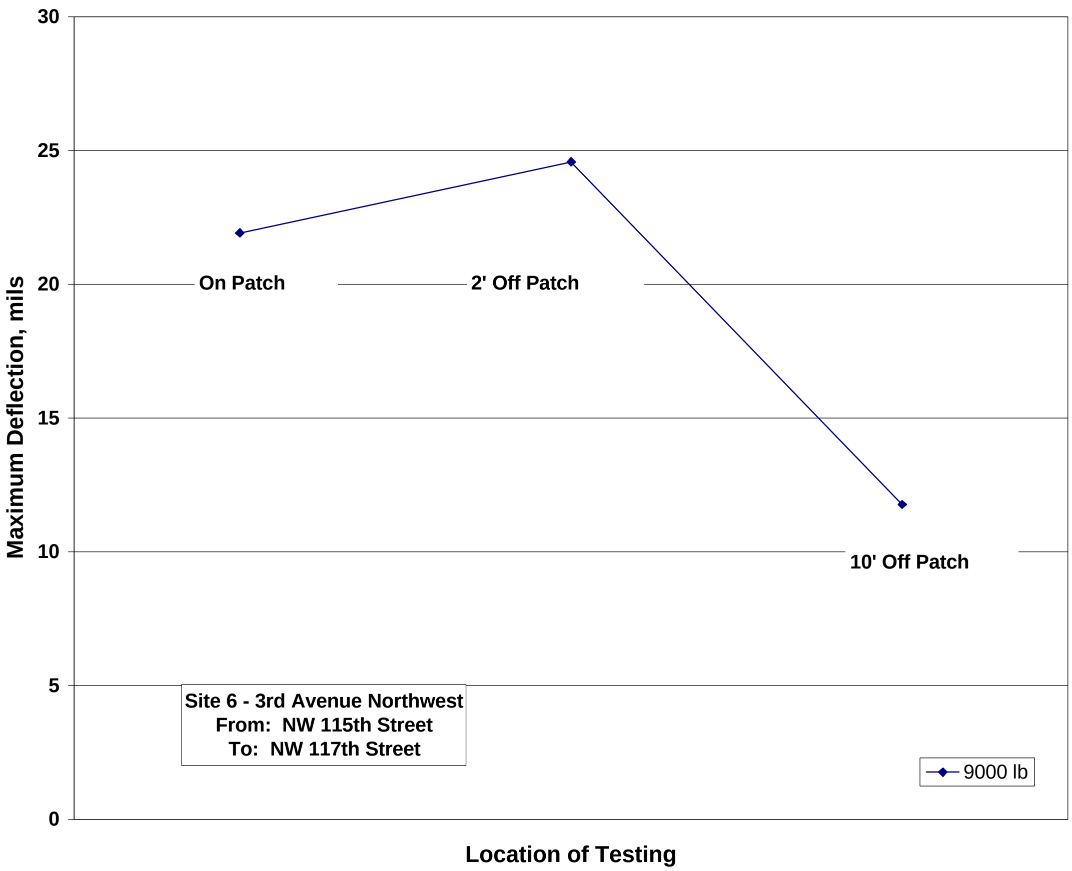


Figure 3.1 Typical ACP maximum deflection test results

Overlay designs were completed for each of the three locations (on-cut, 2' off-cut, and 10' off-cut) for each site. The thickness of the existing pavement layers is not critical to the overlay design provided that within a given site the layers are assumed to be equal. Using this methodology it is the difference in required overlay thickness between the locations is most important. The AASHTO design procedure allows one to complete the design by holding all design inputs constant for a given design.

To account for possible variation in the existing pavement, the thicknesses of layers were varied in two-inch increments. Surface and base thicknesses were varied in two-inch increments from 4 to 8 and 6 to 12 inches, respectively to cover the range of pavement designs present in Seattle. The design results are summarized in Table 3.2

Table 3.2 Additional overlay thickness required in the utility cut area compared to the control area

ACP Site Number	Average additional overlay thickness required as a result of the utility cut, inches
4	2.2
6	2.7
7	1.5
22	0.3
23	0.8
24	0.4
25	1.0
36	3.3
37	2.4
Average (standard deviation)	1.6 (1.1)

PORTLAND CEMENT CONCRETE PAVEMENT

Review of maximum deflection plots showed that only four of the ten tested PCC sections were adversely affected by the presence of the utility cut (i.e., see Figure 3.2). For the remaining six sections, the maximum deflection measurements in the control area were equal to or greater than the maximum measurements taken on or near the cut. This may be due to the relative stiffness of the PCC sections combined with the present City PCC cut policy that requires complete slab replacement. The approach would minimize the effects of the utility cut and mask the presence of the cut.

Designs were completed for the four sites in which the presence of the utility cut was thought to necessitate a thicker overlay. As was the case for the asphalt sections, the thickness of the existing pavement layers do not affect the relative thickness of overlay provided that all design inputs are held constant for given design. Comparative designs were completed for the four sites that were adversely affected by the cut. The PCC thicknesses were assumed to be 8 and 10 inches. There was no consistent pattern in the required overlay thickness for all four sites.

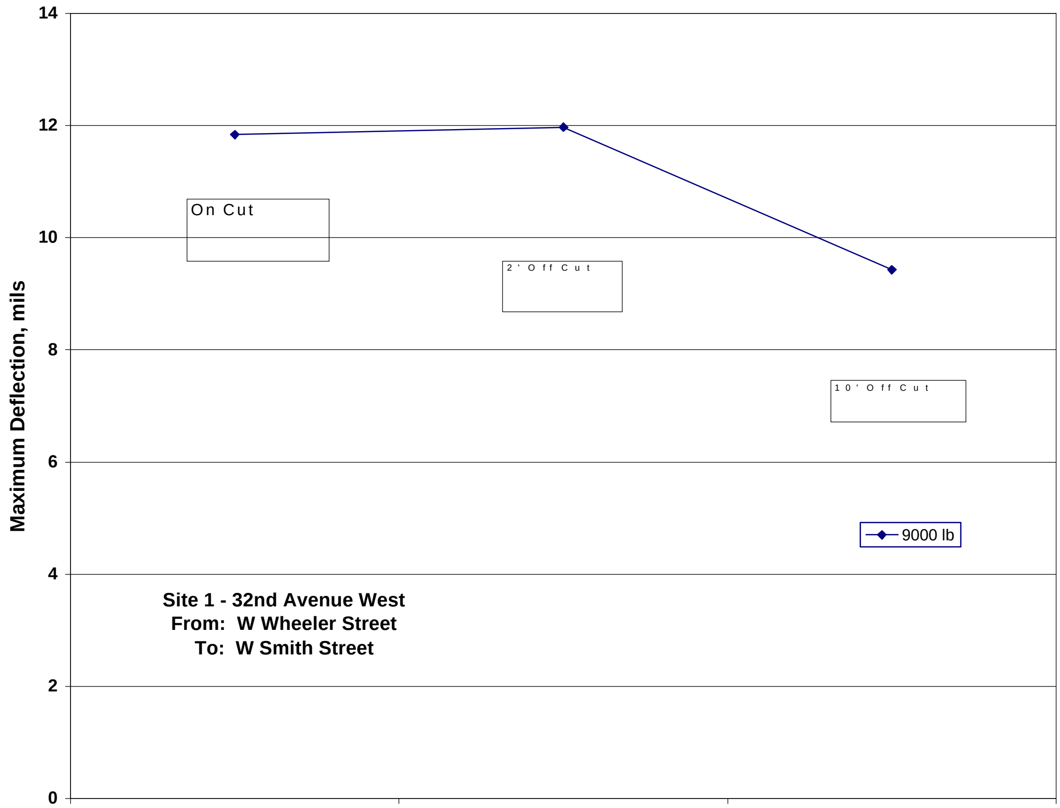


Figure 3.2 Comparison of PCC maximum deflection measurements

COMPOSITE PAVEMENTS (APC)

A review of maximum deflection plots showed that 8 of 18 tested composite sections (APC) were adversely affected by the presence of the utility cut. A typical plot is shown in Figure 3.3 for Site 2. In this case, both the average deflection measurements on the cut and adjacent to the cut are higher than the average measurement taken in the control area indicating that the control area would require a thinner overlay than either the area on the patch or 2 foot off the patch.

Designs were completed for each of the eight sites. The structure of the existing pavement and the condition of the interface between the concrete and asphalt layers affect the relative thickness of overlay required for each location. For this reason, each site was cored to determine pavement layer thicknesses. These thicknesses are shown in Table 3.3. Twelve sites listed in the PMS database as APC were cored, however four of the 12 were found to have only asphalt and were reclassified as ACP.

The results of the designs are summarized in Table 3.4. Designs were completed for both the fully bonded interface and unbonded interface conditions because coring operations often mask the true interface condition. If the existing asphalt is not well bonded to the concrete, then an increase in required overlay thickness of 0.2 inches results.

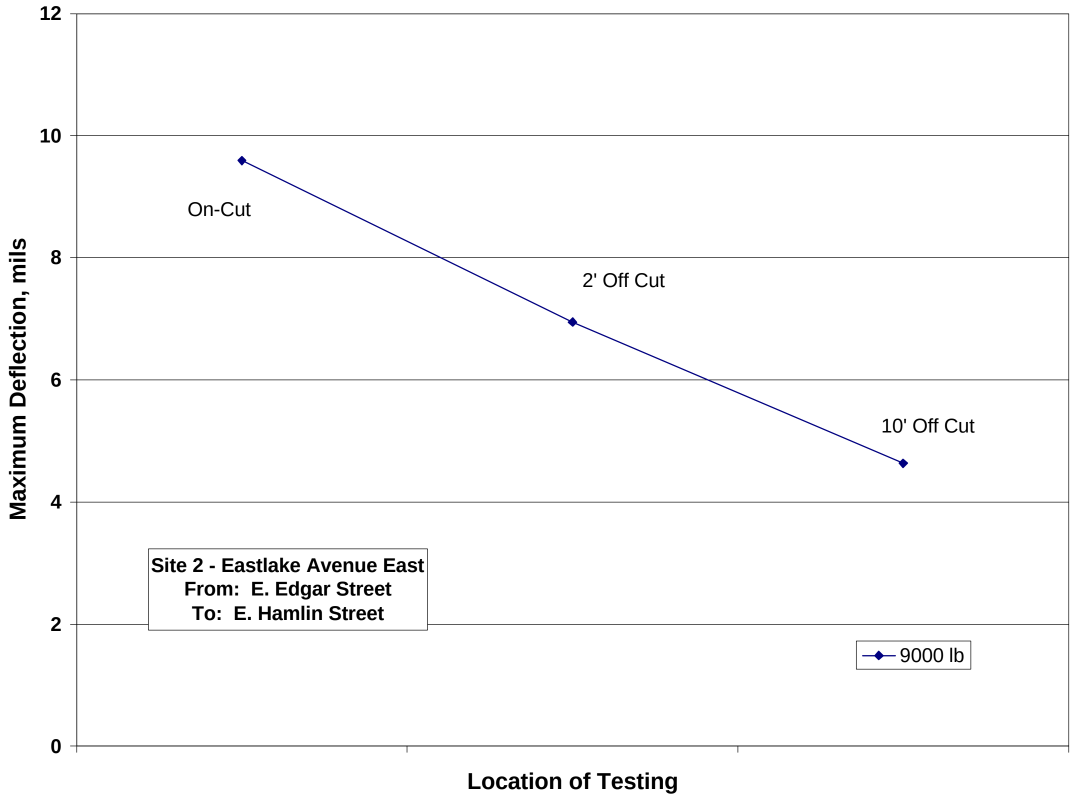


Figure 3.3 Average maximum deflections for Site 2

Table 3.3 Pavement layer thicknesses for APC sites from cores

Site	Asphalt thickness, in.	Concrete thickness, in.
2	6.6	6.2
5	1.8	7.6
9	2.5	6.6
16	7.2	6.6
18	1.9	7.4
21	4.2	8.2
28	3.2	6.0
30	5.6	4.8

Table 3.4 Additional overlay thickness required in utility cut area compared to control section

Site No.	Fully Bonded Interface	Unbonded Interface	Comments
2	2.5	2.4	
5	2.6	3.5	
9	1.8	1.7	
16	0.9	0.9	
18	1.0	0.9	
21	0.0	0.0	
28	2.3	2.7	
30	--	--	Deflections are highest on the cut; however deflections fall outside AASHTO design parameters
Mean	**1.5**	**1.7**	

3.3 Summary

- Deflection testing of 37 arterial sites included nine asphalt, ten concrete and 18 composite (asphalt over concrete) sections.
- Preliminary screening using comparisons of the average maximum deflection showed that in the majority of the cases (21 of 37 or 57%), the presence of the utility cut adversely impacted the roadway.
- Asphalt overlay designs were completed on the 21 sections following the 1993 AASHTO design procedure.

Asphalt Sections

- The design results show all of the asphalt sections require additional overlay thickness in the area of the utility cut compared to the control area.
- The increase in overlay thickness varied from 0.3 to 3.3 inches with a mean of 1.6 inches.

Portland Cement Concrete Sections

- The average maximum deflection was highest in the area of the utility cut in four of the ten sites tested.
- Designs completed on the four sites showed no consistent increase in overlay thickness due to utility cuts.
- The remaining six sites didnot require extra overlay thickness in the vicinity of the utility cut.

- Current City policy requiring full slab replacement when utility cuts are made in PCC streets may mitigate the negative impacts of the utility.

Composite Sections

- Eight of the eighteen composite sections (44%) had higher average maximum deflection measurements in the area of the utility cut.
- These sites require additional overlay thickness as a result of the utility cut. The average thickness increase varies from 1.5 to 1.7 inches depending on assumed interface condition.

4. FEE SCHEDULE DEVELOPMENT

To recapitulate, the previous chapters have described in considerable detail the engineering approach used for this study. Chapter 2 describes the process using the City's PMS data to establish a prediction model. Although no models could be established for the reasons previously described, an obvious drop in the pavement condition index (PCI) was found for sections with and without utility cuts.

In Chapter 3, the structural analysis approach was described and the results showed a clear increase in overlay thickness for all asphalt sections, and for 44% of the composite sections. In summary, the presence of utility cuts resulted in an additional 1.6 inches of asphalt concrete.

The third phase of this project is to develop a methodology to determine utility cut fees based upon damage induced to the pavement from these cuts. Details of the procedure are outlined along with a brief description of pertinent waivers and moratoriums that Seattle may wish to consider.

4.1 Approach

This section describes the approach used to develop unit cost fees for utility cuts. The basis for assessing these fees and the specific components of the fees are discussed. These fees are based upon full recovery of damage caused to pavements from utility cuts.

The results in Chapter 3 indicated that the presence of utility cuts resulted in an additional thickness of 1.6 inches of asphalt concrete. However, Seattle's management practice is to apply a minimum of 2 inches of asphalt concrete overlay as a minimum. In other words, when an overlay is required, a minimum of 2 inches is used. This is a typical policy for most cities, generally for constructability reasons (i.e. uneven existing surface, maximum size of aggregate used in mix, temperature and density requirements etc).

Therefore, for the development of this fee schedule, 2 inches was used instead of 1.6 inches.

In order to develop the fee schedule, it is necessary to ask the question:

- How many or how much area of utility cuts must be present before an overlay will be triggered?

This answer is found in the City's maintenance policies and practices as detailed in the PMS.

In Seattle's pavement management system (PMS), trigger levels based upon the Overall Condition Index (OCI) have been established. The lower a pavement's condition index, the more extensive the repair required. Figure 4.1 shows a typical OCI versus Time curve. This figure illustrates the trigger points built into the pavement management system.

From the figure it is evident that routine maintenance is performed on pavements with an OCI greater than 85. A thin overlay is recommended for pavements with condition indices between 85 and 70. Between 70 and 25, different levels of base repairs and other activities are used as the OCI decreases. Below an OCI of 25, reconstruction is recommended for pavements. Again, it must be emphasized that Figure 4.1 is an illustration of the City's maintenance and rehabilitation policies and which has been documented in the PMS.

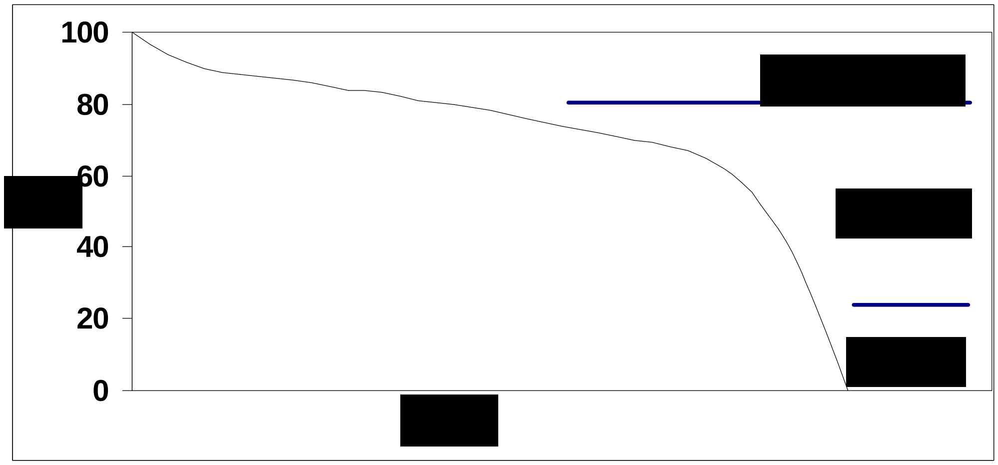


Figure 1: Typical OCI versus Time Curve

A relationship between the degree of utility cut patching and corresponding recommended repair was required to develop the fee schedule. The first step in determining this relationship was to analyze OCI versus patching levels. Seattle's PMS has established deduct values that determine the OCI based on the extent of low severity patching.

The City's maintenance policy indicates that a thin overlay is required when the OCI reaches 85. Further, 10% of the pavement surface area must be covered with low severity utility cuts (and no other distresses) before the OCI reaches 85. Therefore, an OCI of 85 is the first trigger level where a thin overlay is required. Similarly, 38.6% of the pavement area must exhibit low severity patching before the OCI reaches a value of 70. This is the first "zone" (i.e. 70<OCI<85) where a thin overlay is needed.

Since the first trigger level for an overlay is an OCI of 85, this was selected as the basis of the fee schedule. The next step in fee schedule development is to determine the unit costs associated with thin overlays.

Again, the City's maintenance policy when an OCI of 85 is triggered is a 2 in. AC overlay. Recall from the previous paragraph that this is the minimum thickness of an overlay used by Seattle for constructability reasons.

The cost breakdown for a 2 in. AC overlay with milling is shown in Table 4.1 below. These costs are based upon an analysis of maintenance and repair costs from previous project cost records.

Cost Item	Unit Cost $/SY	Comments
2" ACP (asphalt concrete pavement)	5.36	Material Cost.
Digout & New ACP Base	0.00	No digging or base material required for simple overlay.
Surface Prep., Plane Bituminous Pavement	5.00	Old surface must be milled and cleaned prior to overlay.
Mobilization	1.04	Costs of moving and setting up equipment at site. Generally 10% of the contract cost.
Total Contractor Cost	**11.40**	**Sum of above items.**
Contingency	1.71	At 15%
Design/admin. Cost	1.14	At 10%
Construction Mgt.	1.71	At 15%
Total Project Cost (Materials and Labor)	**15.96/SY**	
	$1.77/SF	

Note, however, that the costs above do not include:

- Costs of disruption to businesses i.e. loss of business due to reduced accessibility or traffic congestion during construction.
- Delay costs borne by the public due to traffic congestion during construction.
- Increased wear and tear and fuel usage on vehicles caused by rougher pavements during construction.
- Health impacts e.g. increased exposure to dust and noise during construction
- Safety impacts e.g. if emergency vehicles are negatively affected by construction.

In short, there has been no consideration or inclusion of user costs in the determination of this fee schedule. The resulting unit cost is therefore lower than if user costs were to be included. It was not within the scope of this study to perform an extensive economic analysis of the factors mentioned above.

The final step is to determine the fees required to repair the damage caused by the cuts. This fee calculation is based upon full recovery of costs. The fee equation was developed with the following rationale.

If the utility cut is large enough (or numerous enough) to require an overlay, then the utility company will pay the full amount of the overlay cost. For smaller utility cut areas, the fee is based upon the ratio of the cut size to the cut size that results in an overlay (i.e. 10% of Area of Section).

For example, the fee for a 10% cut would be the total section overlay cost (100%) while the fee for a 2% cut would be 2%/10% or 20% of the total overlay cost. This is explained in detail below.

Total Overlay Cost = Unit Cost * Area of Section to Overlay

If Area of Cut ≥ 10% Area of Section:

Fee = Total Overlay Cost

If Area of Cut < 10% Area of Section:

Fee = (Area of Cut/10% Area of Section) * Total Overlay Cost

Incorporating Unit Costs:

Fee = (Area of Cut/10% Area of Section) * (Unit Cost * Area of Section)

Simplifying, by eliminating Area of Section:

Fee = (Area of Cut/10%) * Unit Cost

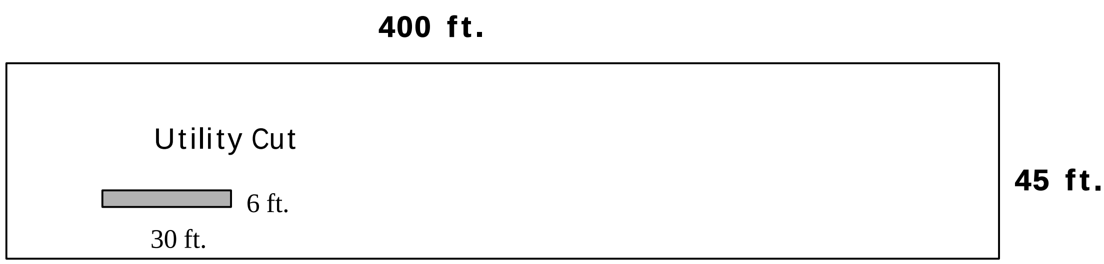


Figure 4a: 1% Utility Cut

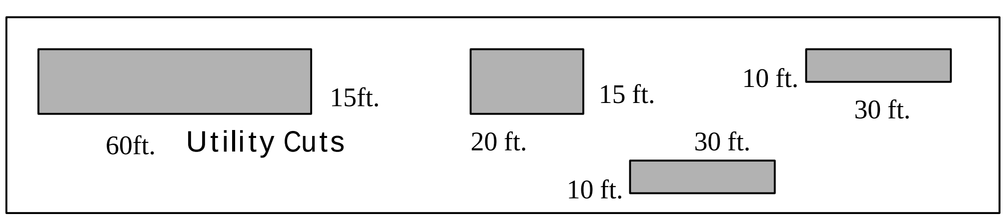


Figure 4b: 10% Utility Cuts

This concept is illustrated by an example. Figures 4.2a and 4.2b show in plan view a typical pavement section, 45 ft. wide by 400 ft. long with utility cuts. This is a typical block size. In Figure 4.2a, the utility cut constitutes 1% of the section area (180SF). Therefore the fee, assuming $1.77/SF unit cost is:

- ✓ Fee = 180SF/(10%*18,000SF) * $1.77/SF * 18,000SF = 1,800SF * $1.77/SF = $3,186.

In Figure 4.2b, the utility cut constitutes 10% of the section area (1800 SF). The fee is then:

- ✓ Fee = 1,800SF/(10%*18,000SF) * $1.77/SF * 18,000SF = 18,000SF * $1.77/SF = $31,860.
- ✓ In this case, $31,860 is the total overlay cost.

Note that in both cases, the fee equation may be simplified to:

Fee = (Area of Cut /10%) * Unit Cost

- ✓ (180SF/0.1) * $1.77/SF = 1800SF * $1.77/SF = $3,186
- ✓ (1800SF/0.1) * $1.77/SF = 18000SF * $1.77/SF = $31,860

Both agree with the previous calculations.

∴ Fee = (Area of Cut / 10%) * Unit Cost of Overlay
= (Area of cut / 10%) * $1.77/SF
= (Area of cut) * $17.70/SF

For comparison purposes, fee schedules from other cities are shown in the table below. The purpose of these fees is to pay for long-term damage. These fees, however, are **not** designed to obtain full recovery of damages.

City	Fee Schedule	Comments
Sacramento, CA	$3.50-7.50 per L.F.	Decreases with age
Los Angeles, CA	$3.43-14.08 per S.F.	Decreases with age. Considering flat fee.
San Francisco, CA	$3.50-1.00 PER S.F.	Decreases with age
Union City, CA	$17.50 per L.F.	Single flat fee
Oxnard, CA	$0.55 per S.F.	
Bakersfield, CA	$4.50-8.50 per S.F.	
Redlands, CA	$0.25 – 2.00 per S.F.	Decreases with age and condition
Seattle, WA	$17.70 per S.F.	Single flat fee

Note, however, that the approach above does not include two very important assumptions:

- From the deflection analysis that was performed in Chapter 3, it is clear that there is a weakened zone of influence at least 2 feet away from the edge of the cut. However, the application of the fee schedule would only apply to the cut area itself, not the weakened zone around the cut.
- The selection of 10% cuts as the basis for determination of the fee schedule may be on the conservative side. The City rarely has more than 10% cuts on any pavement section as a general rule. This is based on observations made by NV&A staff as well as city staff. This study did not conduct an extensive analysis of the percent area of cuts on Seattle's streets due to a lack of resources.

4.2 Moratoriums

Many cities have moratoriums in their ordinances. Typically, moratoriums are established for 5-year periods (or less) after a street has been reconstructed, repaved or resurfaced. The moratorium disallows any excavation or utility cuts within the 5-year period. However, exceptions may be granted in specific cases (usually for "good cause") such as:

- To repair leaks
- To avoid interruptions to essential utility service.
- To respond to emergencies which many endanger life or property
- To provide services to buildings where no other reasonable means of providing service exists
- Work that is mandated by City, state or federal legislation.
- For potholing to verify utility depth or location
- For deployment of new technology (as per any applicable City policies) such as trenchless excavations.
- Other situations deemed by the City to be in the best interests of the general public.

4.3 Waivers and Exemptions

As with all ordinances, situations exist where waivers and exemptions are applicable. Typically, the waivers are dependent on the City's objectives and needs. For instance, the City of Sacramento has waivers for fees where utility companies have shown that they coordinate all utility work with the City's paving program. Other situations where Seattle may wish to consider waivers include:

- Utility cuts in Portland cement concrete pavements
- Utility cuts in pavements that are not maintained by Seattle Transportation e.g. alleys, private streets.

- The utility company repaves or reconstructs the entire block (or a minimum area such as 50 feet across all travel lanes) affected by the excavation.
- Excavations are performed to relocate utility facilities to accommodate the City's use of the pavement or right-of-way.
- Excavation on pavements that are older than a defined age e.g. 20 years or if condition is below a certain OCI (usually where reconstruction is already required).
- Excavation occurring in pavements that are scheduled to be repaved within 2 years.
- Exemption of fee if utility cut activities are coordinated with the City's maintenance/resurfacing programs.

4.4 Summary

- A utility trench cutting fee schedule was developed based on the cost incurred to rehabilitate pavements that are affected.
- The fee schedule is based upon the percentage of damage incurred from cutting. The maintenance policies of the City indicate that an overlay is required when 10% of the pavement has utility cuts.
- A flat fee of $17.70/sf of cut is recommended.
- Specific conditions may exist resulting in elimination of fee assessment.

5. SUMMARY

This report documents the results of applying the two methodologies used to establish the effects of utility cuts on pavement performance in the City of Seattle.

The first methodology used to establish the impact of utility cuts on the performance of streets in the City of Seattle relies on the existing PMS database. The pavement management system uses the Overall Condition Index (OCI) to characterize performance. Despite using OCI values computed from 1994 and 1997 survey data for approximately 300 sections, obvious trends defining the negative impact of utility cuts on performance are not apparent. Therefore, it was decided that further statistical analysis would not be cost-effective.

As part of the deflection testing, MicroPAVER condition surveys were conducted on 37 streets. Statistical analysis of these data showed that for the asphalt and composite pavement types, the presence of utility cut reduced the condition of the street by 14 and 7 points, respectively. These results are significant at the 10 percent level. The Portland cement concrete sections did not show a statistical difference.

The second methodology relies on deflection testing and overlay designs to establish the impact of utility cuts on roadways. All nine asphalt sections require additional overlay thickness as a result of the presence of the utility cut. The average required increase in 1.6 inches. Eight of eighteen composite sections require additional overlay thickness averaging between 1.5 and 1.7 inches depending on the assumed interface condition. Portland cement concrete sections did not require and increase in overlay thickness due to the utility cut.

The development of the fee schedule was based on the deflection testing approach described in Chapter 3. In addition, the City's maintenance policies indicated that 10% of the pavement surface area had to be covered with low severity utility cuts before an overlay was required. For constructability reasons, the minimum overlay applied in the City is 2 inches; therefore, the fee schedule is based on a 2 inch overlay. The fee that is recommended to the City is $17.70/sf – this includes all engineering design, material and contract costs. However, costs incurred by the public and businesses affected by the construction have not been included, not health and safety impacts. Finally, typical situations where the City may want to consider waivers or exemptions are also included.

APPENDIX A
LITERATURE REVIEW

Impact of Utility Cut Repairs on Performance of Street Pavements

City of Seattle - Literature Review

Background

Interest in the impact of utility cuts on roadway performance has increased, particularly in the last ten years. This review is not intended to provide an exhaustive review of the available literature, but rather a summary of the relevant studies conducted since 1990. Furthermore, the review does not include information on the studies investigating trench repair techniques (i.e., low strength, flowable fills, etc).

Studies conducted by both utility companies and governmental agencies were included in this review. Findings from studies funded by these different entities are often contradictory. Whenever possible, follow up information (i.e., ordinance development and implementation) is also included.

Summary

Studies Funded by Governmental Agencies

- Results show that the presence of utility cuts in the roadway results in lower measured pavement condition scores compared to pavements of the same age with no utility cuts.
- Studies have demonstrated the link between the presence of utility cuts and accelerated pavement deterioration. The accelerated pavement deterioration is linked to reduced pavement life.
- The recent San Francisco study concedes that high quality workmanship in the repair of utility trenches may reduce the structural damage to pavements, but contends that lower ride quality, increased cracking still result and therefore service lives are diminished.
- Deflection testing in areas adjacent to the trench show that trenching operations reduce pavement strengths in a zone from 3 to 6 feet either side of the centerline of the trench.
- The economic impact of utility cuts is often calculated based on the increased thickness of overlay required to compensate for the presence of the utility cut. Full recovery of the cost does not appear politically possible in most cases.
- Many agencies have adopted a graduated scale that reduces the utility cut fee based on the age (time since last overlay) of the pavement. Some have imposed moratoriums on any utility cuts for one or more years following street rehabilitation.
- One agency (Sacramento, CA) has imposed a coordination clause asking the utilities to prepare five-year master repair plans. Utility cut fees may be waived for full coordination cooperation. A comparison of Los Angeles and Sacramento programs in shown in the following table.

Although not the direct subject of study, the language of the franchise agreement is critical to successfully imposing a utility cut fee schedule. Some utilities may be exempt based on their agreement with the agency.

Comparison of Los Angeles and Sacramento Utility Fee Programs

	Los Angeles	Sacramento
Moratorium	1 year	None
Exemption	Excavations in a street scheduled for repaving within one year of the date of the proposed excavation	f) Demonstrated coordination effort g) Work on street scheduled for resurfacing during immediate or next fiscal year. h) Work on street with less than "4" Pavement Quality Index i) Potholing j) Willingness to overlay entire lane
Coordination of Excavation	Does not require utility companies to prepare and submit a utility master plan nor is City required to prepare a five year repaving schedule	Utility companies shall prepare and submit a 5-year utility master plan. City shall prepare a five-year repaving schedule. Refunds a portion of fee paid by utility company during a calendar year if utility demonstrates a specified high level of coordination during that year.
Special Paving Requirement	Streets that have been resurfaced less than one year from the date of the proposed cut shall not be cut unless the whole block within such cut is to occur be paved by the entity seeking to make the cut. Such repaving of the entire block shall be in lieu of the trench cut fee.	No special paving requirement

Fee Schedule					
Road Type	Pvt. Age, yrs	Sq. ft.	Cut Direction	Pvt. Age, yrs	Linear ft
Major Roads	1 - 5	$14.08	Longitudinal	<5	$3.50
	5 - 10	11.73		5 - 10	$3.00
	10 - 15	9.39		10-15	$2.00
Local Roads	1 - 5	5.15		> 15	$1.00
	5 - 10	4.57	Transverse	< 5	$7.00
	10 - 15	4.29		5 - 10	$6.00
	15 - 20	3.88		10-15	$4.00
	20 - 25	3.43		> 15	$2.00

Studies Funded by Utility Companies

- Case studies have focused on controlled experiments with variables including hot vs. cold patching, standard vs. T-section repairs, and different backfill densities. In part, these studies are reactive to the initiatives of governmental agencies to change trench repair specifications.
- Case studies of two cities in California showed that "T-section" repairs did not

perform significantly better than standard repairs

- These same studies showed that, within limits, density control of the backfill had only limited influence patch performance.
- Another study concluded that good compaction was the single most important factor in ensuring successful patch performance.

Publications Pertaining to Utility Trench Cuts

Detailed Summaries

Study Title:

The Effect of Utility Cuts on the Service Life of Pavements in San Francisco

Study Completion Date:

May 1995

Funding Source:

Department of Public Works, City of San Francisco

Department of Public Works, County of San Francisco

Study Conducted By:

Tarakji, G., San Francisco State University

Study Objective(s):

The objective was to show that utility cuts shorten the life of any given asphalt pavement.

Study Results/Conclusions:

1. Streets that had some cuts (3-9) had lower condition scores than streets with few cuts (0-2).
2. Streets that had many cuts (more than 9) had lower condition scores than streets with some cuts (3-9).
3. The study concluded that when compared to streets with fewer than 3 cuts, on average, streets with 3 to 9 cuts had a 30% shorter service life.
4. When compared to streets with fewer than 3 cuts, on average, streets with more than 9 cuts had a 50% shorter service life.

Study Title:

The Impact of Excavation on San Francisco Streets

Study Completion Date:

September 1998

Funding Source:

Department of Public Works, City of San Francisco

Department of Public Works, County of San Francisco

Study Conducted By:

Panel of pavement experts, a statistical consultant and DPW staff

Study Objective(s):

The objective was to show that utility cuts shorten the life of any given asphalt pavement and that thicker overlays are required to compensate for the utility cut patches. This study was initiated when the 1995 study by Tarakji (see above) was challenged in a report by the Construction Technology Laboratories, Inc.

Study Results/Conclusions:

1. On average, pavements with utility cuts have lower condition scores than pavements without cuts.
2. On average, increasing the number of cuts reduces condition scores.
3. A large number of cuts early in the life of a pavement will dramatically reduce pavement performance.
4. Above three statements are true whether considering the number of cuts per block, number of cuts in an area, or the percentage of area cut.
5. Above three statements are supported at a 95% confidence level.
6. Street cuts disrupt surface integrity, which creates surface roughness. Surface roughness reduces pavement strength and allows the entry of moisture, which accelerates long term deterioration.
7. Street cuts disrupt pavement layers and supporting soil in the area surrounding the trench. This disruption can be minimized, but cannot be eliminated. As a result, trenching causes unavoidable damage to the pavement layers and soil supporting the pavement around the perimeter of the utility cut.
8. Similar to a protective membrane, pavement layers perform best with no cuts or breaks. Street cuts create joints in the pavement layers that reduce the structural integrity of those pavement layers.
9. Although high quality workmanship may reduce the structural damage caused utility cuts, the street will still incur ride quality and cracking damage and its service life will be diminished

Study Title:

Economic Report: Estimated Costs of Accelerated Repaving Required as a Result of Utility Excavation in San Francisco Streets

Study Completion Date:

Undated, (completed after September 1998)

Funding Source:

Department of Public Works, City of San Francisco

Department of Public Works, County of San Francisco

Study Conducted By:

William B. Marcus, JBS Energy, Inc.

Study Objective(s):

Determine the total annual costs of repaving due to excavation in City streets and devise a method to reasonably allocate the cost among all excavators.

Study Results/Conclusions:

1. Computed costs did not include excavation in concrete streets, costs of routine maintenance or repainting/restriping associated with excavation or litigation costs resulting from excavation. No public user costs (i.e., delay, vehicle maintenance costs) were included.
2. Actual computed repaving costs associated with excavation activities range from $5.25 to $8.38 per square foot.
3. The Department of Public Works proposed the fee schedule shown below:

AGE OF STREET: Years since last repaving	FEE AMOUNT: Per square foot of excavation
0-5	$ 3.50
6-10	$ 3.00
11-15	$ 2.00
16-20	$ 1.00

4. The fee schedule shown above will not fully recover the cost of repaving determined in this study, but is reasonable and defensible.
5. Reviews and updates on three-year cycles were recommended.

Study Title:

The Effects of Utility Cut Patching on Pavement Life Span and Rehabilitation Costs

Study Completion Date:

July 1996, Interim report

Funding Source:

City of Los Angeles, Department of Public Works

Study Conducted By:

Shahin, M.Y., Chan, Steven, Villacorta, Ricardo

Study Objectives:

Assess the effects of utility cut patching on pavement life and rehabilitation costs using a combination of condition surveys and deflection testing.

Study Results/Conclusions:

A total of 100 sections were studied in detail, fifty local and fifty "select" (major) streets representing seven age categories. Visual inspections, deflection testing and penetrometer tests were conducted on each section and an adjacent control. Families of performance (condition) curves were developed for local and major roads with and without patching.

Significant rehabilitation cost analyses were conducted. Average rehabilitation costs were derived for each category of street and summed for the entire road network.

Extra rehabilitation costs for Major roads = $12.9 million/yr

Extra rehabilitation costs for Local roads = $3.5 million/yr

From this a fee recovery schedule was derived as follows:

A Fee Schedule was developed based on this study. City Council adopted ordinances implementing the fee schedule shown below:

Type of street	Age (Years)	Fee ($/SF)
Major	1 to 5	14.08
	5 to 10	11.73
	10 to 15	9.39
Local	1 to 5	5.15
	5 to 10	4.57
	10 to 15	4.29
	15 to 20	3.88
	20 to 25	3.43

One utility company (Southern Gas) successfully challenged the fee based on their existing franchise agreement with the City and are exempt from the fee schedule shown above. To date, no other utilities are exempt.

Study Title:

Utility Cut Damage Assessment for the City of Sacramento

Study Completion Date:

October 1997

Funding Source:

City of Sacramento, Department of Public Works

Study Conducted By:

CHEC Consulting Engineers, Inc.

Study Objectives:

To establish the damage and associated costs resulting from the presence of utility cuts in roadways.

Study Results/Conclusions:

Pavement deflection responses in and adjacent to utility trenches at various locations throughout the city were evaluated. From these data, it was determined that damage from utility cut patching is equivalent to 1.5 inches of additional overlay within the zone of influence. A fee schedule was set up as follows:

Type of Excavation	Age (Years)	Cost ($/LF)
Longitudinal	<5	3.50
	5 to 10	3.00
	10 to 15	2.00
	Over 15	1.00
Transverse	<5	7.00
	5 to 10	6.00
	10 to 15	4.00
	Over 15	2.00

Study Title:

Trench Cut Fee Evaluation Study for the City of Union City

Study Completion Date:

October 1998

Funding Source:

City of Union City, California, Department of Public Works

Study Conducted By:

CHEC Consulting Engineers, Inc.

Study Objectives:

The purpose of this study was to verify that Union City's streets experience damage due to utility cut trenching and to quantify that damage in order to establish a fee to offset the cost of damage.

Study Results/Conclusions:

This report concluded that:

- Of sixteen street segments evaluated, 68% show a significant loss in strength as a result of being in the zone of influence around the trench of utility cut area.
- The increase in deflection values within the zone of influence near a utility cut ranged from 0% to 74%.
- Deflection tests on transverse trenches show a zone of influence of 4 to 7 feet on each side of the trench or repair area.
- The loss in strength defined in terms of additional asphalt thickness at time of rehabilitation, ranged from 0.0 to 0.25 feet in thickness with an average of 0.11 feet (1.3 inches).
- There was no definitive correlation between trenches that have caused damage and the subgrade soil types identified in this study.
- Trench width, and whether the trench was housing either sewer or cable had no influence on the damage magnitude. This coincides with results found in the Sacramento study.
- The cost consequence of a trench at time of rehabilitation of pavement is at least $17.30 per lineal foot without consideration for life cycle costing.

Study Title:

Impact of Utility Cuts on Performance of Street Pavements

Study Completion Date:

1995

Funding Source:

City of Cincinnati, Ohio and American Public Works Association

Study Conducted By:

Bodsci, A., Pant, P.D., Aktan, A.E., Arudi, R.S., University of Cincinnati

Study Objectives:

The goals of this study were to:

- Develop field techniques to evaluate utility cuts based upon visual inspection and deflection testing.
- Develop cost models and procedures to assess the monetary impact of utility cuts.
- To develop a utility cut management system (UCMS) to coordinate between cut evaluation and cost recovery.

Study Results/Conclusions:

The UCMS visual surveys were developed for asphalt concrete with nine pavement distresses that are most common to asphalt concrete utility cut patches. Deflection testing was done inside and around utility cut patches. A statistical analysis of the data was done to establish the extent of area influenced by the cuts. The average utility cut size in Cincinnati is five feet by four feet. The results indicated that the extent of damage extends three feet from the edges of the utility cut, and the average overlay thickness required to restore pavement to its pre-utility cut strength was found to be 1.75 inches.

Study Title:

Comprehensive Study to Evaluate Repair Patches for Asphalt Paved Streets

Study Completion Date:

December 1989

Funding Source:

Southern California Gas Company

Study Conducted By:

ARE, Inc. and Institute of Gas Technology

Study Objectives:

Conduct an engineering investigation to compile information pertaining to current utility cut and pavement repair practices and to carry out a theoretical analysis to evaluate critical elements of pavement repair.

Study Results/Conclusions:

This report concludes that three dominant factors influencing the performance of street repairs are:

- Density of soil used for backfill
- Type of backfill soil
- Water content of backfill material

T-sections were thought to improve performance, but quantifiable information was not available.

Additional study was recommended.

Study Title:

Economic and Environmental Issues in Utility Cuts

Study Completion Date:

December 1995

Funding Source:

Gas Research Institute, Southern California Gas Co., Brooklyn Union Gas, Public Service Electric and Gas of New Jersey, Consolidated Edison Co. of New York, and Pacific Gas and Electric

Study Conducted By:

Todres, H.A., Construction Technology Laboratories, Inc.

Study Objectives:

To update information contained in the Comprehensive Study to Evaluate Repair Patches for Asphalt Paved Streets (December 1989). This study had several findings and reviewed much of the available literature.

Study Results/Conclusions:

Their main points are as follows:

- Many measures currently taken by agencies (i.e., requiring higher backfill densities, thickened pavement sections, T-sections) have not been demonstrated to improve patch performance.
- Good compaction of backfill is the most important factor in ensuring successful pavement restoration for utility cuts.
- T-Section patches alone have a negligible effect on behavior of restored utility cuts

Study Title:

Comparison of Standard versus T-section Repair Performance on Carson Street in Hawaiian Gardens, CA

Study Completion Date:

April 1995

Funding Source:

Southern California Gas Company

Study Conducted By:

Maxim Technologies, Inc.

Study Objectives:

Conduct a controlled experiment to investigate the effects of different backfill densities and repair sections (standard vs. T-sections) on the performance of utility patches. Sections were monitored for two years.

Study Results/Conclusions:

Patches were placed in the wheelpath of an area with heavy traffic (TI=9.5). Cut dimensions were three feet by four feet. All variables were held constant except for:

- Surface type varied between Hot and Cold mix asphalt.
- Backfill density was varied between low, medium, and high.
- Repair configuration varied between a standard patch and a T-Section patch.

For the two-year monitoring period, extensive surface profiles were determined over a two-dimensional grid, and non-destructive testing was performed by means of a falling weight deflectometer. This report concluded that:

- There is no significant difference in the performance of standard versus "T" repairs
- Cold mix asphalt concrete should not be used for permanent repairs of utility cuts. Cold mix could possibly be used in very low traffic volume situations, however, revisions in material makeup and compaction procedures are deemed essential.
- The statistical analysis and regression analysis did not indicate that the backfill density had any significant influence on the performance of a utility cut.

Study Title:

Comparison of Performance of Various Standard and T-Section Utility Cut Repair Alternatives on Florence Avenue in Downey, CA

Study Completion Date:

October 1995

Funding Source:

Southern California Gas Company, Inc.

Study Conducted By:

unknown

Study Objectives:

Conduct a controlled experiment to investigate the effects of different backfill types and densities. Repair sections (standard vs. T-sections) and surface type were also investigated. Sections were monitored for two years.

Study Results/Conclusions:

These patches were placed in the wheelpath of a moderately trafficked lane (ADT=3200 with a fair number of trucks). All variables were held constant except for:

- Backfill type varied between Native, Crushed Aggregate Base (CAB), and Crushed Miscellaneous Base (CMB).
- Backfill density varied between 80 and 90 percent.
- Repair configuration varied between a standard patch and a T-section patch.
- Surface type varied between hot mix asphalt concrete (HMAC), cold mix asphalt concrete (CMAC), hot mix asphalt concrete overlayed on top of cold mix asphalt concrete.

For the two-year monitoring period, extensive surface profiles were determined over a two-dimensional grid, and non-destructive testing was performed by means of a falling weight deflectometer. This report concluded that:

- There is no significant difference in the performance of standard versus "T" repairs
- Backfill, when compacted to 80% or 90% relative density, has no practical significance or influence on performance.
- Cold mix asphalt concrete should not be used for permanent repairs of utility cuts in high volume areas.
- Even with minimum density control the normal repair sections performed as well as the sections with thicker surface layers.

Study Title:

Asphalt Paving Repairs Study-Theoretical Modeling

Study Completion Date:

December 1990

Funding Source:

Southern California Gas Company

Study Conducted By:

Todres, H.A. and Saha, N.C., Institute of Gas Technology

Study Objectives:

To investigate, using theoretical modeling, small-scale excavation repairs and show the effects of variations in compaction and material properties of restored utility excavation in terms of deflections, stresses and strains.

Study Results/Conclusions:

Stresses and strains were calculated for each layer and used in fatigue equations to determine patching performance. All variables were held constant except for:

- Bell hole diameter size equaled 24", 36", and 48".
- Three pavement layers were tested. They were 2" AC/ 4" CSB, 4" AC/ 8" CSB, and 8" full depth AC.
- Subgrade compaction was varied between high and low.

From these tests the following conclusions were drawn:

- The largest factor causing surface deflection of utility cut patches is compaction of the layers under the surface material. The layer having the single highest effect would be the subgrade.
- This above point is especially evident in lighter pavement structures. In heavier sections a well compacted AC and CSB layers appear to mitigate to some extent poor subgrade compaction.
- The size of the cut is important in the structural responses in some cases. Where there is an effect, the smaller the cut the better.

Field verification of these results was recommended.