Analysis of the Impact of Utility Cuts on Rehabilitation Costs in Santa Cruz County, CA

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1. PURPOSE – The purpose of this report is to summarize the results of utility cut patching studies conducted by other agencies. This will include the estimated effect of utility cut patching on pavement life and increase pavement rehabilitation costs.

2. SUMMARY of RELEVANT STUDIES – Dr. Shahin has participated in several efforts to study the effects of utility cuts on pavement degradation. Four of these efforts are similar in nature to the study for Santa Cruz County. To better understand the methods and results of the study, a review of these past efforts is valuable. These studies were conducted for and on the City of Burlington, VT (1986), the City of Los Angeles, CA (1996), the City and County of San Francisco, CA (1998), and the City of Sacramento, CA (1996). Detailed summaries of these studies are attached as Appendices A thru D.

   a. City of Burlington, VT (Appendix A) – A representative sample of streets (50 pavement sections) was randomly chosen from areas throughout the city. A Pavement Condition Index (PCI) (ASTM D-6433) survey was conducted to determine the effect of utility cut patching on the PCI and subsequent pavement life. A nondestructive deflection testing (NDT) program was also conducted at positions in and around patched areas using a falling weight deflectometer (FWD) to measure the effects of patching on the structural performance of the pavement.

      The PCI analysis indicated that the utility patches reduced the pavement life by a factor of at least 1.64. The NDT program data indicated a significant increase in overlay thickness required by the patched areas. This increase ranged from 0.75 in. to 1.5 in. in depth. Based on these results, the extra costs required annually for pavement maintenance and rehabilitation was estimated at $500,000.

   b. City of Los Angeles, CA (Appendix B) – A representative sample of streets (100 pavement sections) was randomly chosen from areas throughout the city. These sections were split evenly between local streets and select streets. A PCI survey was conducted to determine the effect of utility cut patching on the PCI and subsequent pavement life. An NDT program was also conducted at positions in and around patched areas using an FWD to measure the effects of patching on the structural performance of the pavement. In addition, a standard penetration test was conducted to test the relative strength of the soil in the patch versus the original pavement.

      The PCI analysis indicated that the utility patches reduced the pavement life by a factor of 1.21 for local roads and 1.52 for select roads. The NDT program data indicated a significant increase in overlay thickness required by the patched areas. This increase ranged from 0.66 in. for local roads to 2.31 in. for select roads. Based on these results, the extra costs required annually for pavement maintenance and rehabilitation was estimated at $3.5 million for local roads and $12.9 million for local roads.

c. City and County of San Francisco, CA (Appendix C) – The City of San Francisco commissioned a study in 1992 to study the effects of utility cuts on pavement service life. That study concluded that streets with utility cuts experienced decreases as high as 50% in service life and reduced condition scores. Local utility companies commissioned a critical review and expressed concerns over the data and methods used in the analysis. To address the concerns, the City commissioned an expert panel to reevaluate the results of the original study and expand its scope based on new engineering techniques.

   The panel of experts concluded that the results of the 1992 study were legitimate. The expert panel concluded that utility cuts reduce condition scores and pavement service life. In addition, even high quality patching disrupts the surface integrity and supporting soils for the pavement, thereby reducing the service life. Lastly, the panel's findings were consistent with the findings of engineering-based studies which used deflection testing to conclude that utility cuts inevitably and irreparably disrupt the subsurface of a street and that this damage extends beyond the perimeter of the trench.

d. City of Sacramento, CA (Appendix D) – A representative sample of streets was collected and grouped in four zones based on soil and traffic conditions. No distress survey or visual condition rating was performed as part of the study. A nondestructive deflection testing (NDT) program was conducted at positions in and around patched areas using a Dynaflect to measure the loss of strength and area extent of influence of the utility cuts on surround pavement. A coring program was used to determine asphalt concrete (AC) thicknesses.

   Two Separate analyses were performed one for longitudinal cuts and one for transverse cuts. For longitudinal cuts it was determined that an additional 1.5 inch of overlay is required to make up for the pavement structural weakening by the patch. For transverse patching, it was determined that the average extent of damaging influence from patch edge is 3.64 feet.

The prior studies all indicate a strong relationship between utility patches and increased maintenance and rehabilitation costs. These costs are the result of both faster pavement deterioration and increased requirements for overlays. The following conclusions can be drawn based on the results of the previous studies.

- Pavement performance is significantly affected by utility cut patches
- Pavement service life is significantly decreased by utility cut patches
- Overlay thickness requirements are increased by utility cut patches
- Utility cut patches create increased pavement rehabilitation costs for local governments
- Utility cut patches negatively affect pavement outside of the patch area

3. ECONOMIC ANALYSIS – Based on the results presented in the previous sections of this report (Figure 1), it will be assumed that the utility patches decrease the life of the pavement by at least 25%. Also based on the studies presented, an additional asphalt thickness of 1.5 inch is required to bring the deflection to the same level before the utility cut. To maintain roads in good condition, Santa Cruz must therefore perform rehabilitation practices at a greater frequency, thereby increasing their costs over a given time period. To estimate the extra costs incurred, the following assumptions were made:

   - Current overlay practices call for a 2" asphalt overlay
   - The expected life without a utility cut is 20 years
   - The expected life with a utility cut is 15 years (25% life reduction based on PCI analysis)
   - Santa Cruz has a total of 600 miles with an average width of 27 feet
   - Approximately 70% of the miles have patching
   - Percentage of streets with manholes is 45%
   - Manhole realignment cost is $2500/mile
   - Approximately 50% of the roads will require cold planing prior to overlay
   - The cost of cold planing is $1.5/sy/inch
   - The cost per short ton of asphalt is $54.50

Rehabilitation Costs for Areas without Utility Cuts

The first step in the process is to calculate the rehabilitation costs for areas without utility cuts. The basic cost for overlays (OL) on an annual basis is shown by the following equation:

Annual OL Cost = Overlay thickness x Cost of Asphalt x Number of miles / Frequency of Rehab

Annual OL Cost = 2"/12 ft x 5280 ft x 27 ft x .075 tons/ft^3 x $54.5 x 600/20 = $2,913,570/yr

However, the cost for manhole realignments and cold planing associated with the overlay must also be considered.

Annual Manhole Realignment Cost = Cost per mile x Number of miles with manholes / Frequency of Realignment

Annual Manhole Realignment Cost = $2500/mile x (0.45 x 600) x (1/20) = $33,750

Annual Cold Planing Cost = Cost per mile x Number of miles / Frequency of Cold Planing

Cold Planing Cost per Mile = $1.5 x 2 in x (5280 x 27/9) = $47,520 without utility cut patching

Annual Cold Planing Cost = $47,520/mile x (0.5 x 600) x 1/20) = $712,800

Total Annual Cost for unpatched areas is $3,660,120

Rehabilitation Costs for Areas with Utility Cuts

The second step in the process is to calculate the rehabilitation costs given that utility cuts do occur. It is assumed that 70% of the roads have areas of utility cut patching:

Annual OL $Cost_{cut}$ = Overlay thickness x Cost of Asphalt x Number of miles / Frequency of Rehab

Annual OL $Cost_{nocut}$ = Overlay thickness x Cost of Asphalt x Number of miles / Frequency of Rehab

Annual OL $Cost_{cut}$ = 3.5"/12 ft x 5280 ft x 27 ft x .075 tons/ft^3 x \$54.5 x 600 x 0.7 x 1/15 = \$4,758,831/yr

Annual OL $Cost_{nocut}$ = \$2,913,570 x 0.3 = \$874,071/yr

Total Annual Overlay Cost = \$5,632,902

The manhole alignment and cold planing calculations differ slightly in with the utility patches. Based on the greater thickness of overlays on patched areas, the thickness of cold planing will be 3.5 inch for patched areas.

Number of miles with manholes and patches = 70% x (45% x 600) = 189 miles

Number of miles with manholes and no patches = 600 x 45% – 189 = 81 miles

Annual Manhole Cost = Cost per mile x Number of miles with manholes / Frequency of Realignment

Annual Manhole $Cost_{nocut}$ = \$2500/mile x 81 x (1/20) = \$10,125

Annual Manhole $Cost_{cut}$ = \$2500/mile x 189 x (1/15) = \$31,500

Total Annual Manhole Realignment Cost = \$41,625

Annual Cold Planing = Cost per mile x Number of miles / Frequency of Cold Planing

Annual Cold $Planing_{nocut}$ = \$42,520/mile x (600 x 0.5) x 0.3 x 1/20 = \$213,840

Cold Planing Cost per Mile for Areas with Utility Cut Patching = \$1.5 x 3.5 in x (5280 x 27/9) = \$83,160

Annual Cold $Planing_{cut}$ = \$83,160/mile x (600 x 0.5) x 0.7 x 1/15 = \$1,164,240

Total Annual Cold Planing Cost = \$1,378,080

Total Annual Cost for areas including utility cuts is \$7,052,607

Based on the calculations above, the average annual increase in rehabilitation costs is estimated at \$3,392,487, or approximately \$3.4 million. The costs are further illustrated in Figure 2.

Figure 1 – Summary of Results from Relevant Studies

		Life Reduction Factor	Extra Overlay Thick. Required, inch
City of Burlington, VT		1.64	1.50
City of Los Angeles, CA	Local Roads	1.21	0.65
	Select Roads	1.52	2.31
City & County of San Francisco, CA		2.00	NA
City of Sacramento, CA		NA	1.50

$$\text{Life Reduction Factor} = \frac{\text{Pavement Life without Utility Cuts (years)}}{\text{Pavement Life with Utility Cuts (years)}}$$

Figure 2 – Extra Rehabilitation Costs Incurred as a Result of Utility Cuts

	Overlay Cost	Manhole Alignment	Curb Replacement	TOTAL
Areas without Utility Patches	$2,913,570	$33,750	$712,800	$3,660,120
Areas with Utility Patches	$5,632,902	$41,625	$1,378,080	$7,052,607
			Extra Cost	**($3,392,487)**

I. Introduction

The City of Burlington, VT commissioned a study in 1984 to determine the average life of pavements with and without utility cut patches. Visual inspection and nondestructive testing (NDT) methods were employed. The results were analyzed to 1) determine the effect of patching on pavement life, and 2) to determine what level of rehabilitation is necessary to upgrade the patched areas to levels equivalent to non-patched areas.

II. Pavement Testing Program

A representative sample of streets (a total of 50 pavement sections) was randomly chosen from areas throughout the city. A paired experiment was conducted in each section to determine the effect of utility cut patching on the Pavement Condition Index (PCI) for streets of various ages throughout the city. An NDT program was also conducted at positions in and around patched areas using a falling weight deflectometer (FWD) to measure the effects of patching on the structural adequacy of the pavement.

III. PCI Data Analysis and Results

The PCI is a surface distress based index on a scale from 0 to 100, with 100 being a perfect score. Specific types of cracking and other distresses are recorded by quantity and severity level. The PCI survey results were analyzed to determine the effect of utility cut patching on pavement life. Pavement life was defined as the age in years that the street can be economically maintained without the need for major rehabilitation such as an overlay. This was defined as the pavement age at which a PCI value of 70 would be reached. Three methods were used to determine the average pavement life before PCI of 70 would be reached. These methods were the Rate of Deterioration, Best Line fit through PCI vs. Age Data, and Best Curve fit through PCI vs. Age Data. Table 1 presents a summary of the results obtained from the three analysis methods. As can be seen from this table, the life reduction factor varies from 1.64 to 3.71. For the purposes of follow-up analysis, the 1.64 factor was used as the most conservative assessment of the damage caused as a result of utility cut patching.

IV. Structural Data Analysis and Results

The structural strength of pavement sections with and without patching was measured by recording the magnitude (Do) that the surface of the pavement deflected under a load impulse similar in magnitude and duration to a moving truck wheel load. Measured Do data were grouped into four categories based on the test locations illustrated in Figure 1. In sound pavement areas (PVT), the average measured Do was 20.43 mils

(1 mil = .001 inch). Actual values varied from 9.4 to 50.5 mils. In PVT-E areas, an average value of 29.07 mils was calculated with a range from 13 to 73.9 mils. In PAT-E areas, an average value of 27.68 mils was calculated with a range from 13.6 to 54.3 mils. In central patch areas (PAT), the average value was 25.21 mils with a range from 12.6 to 54.8 mils. The results are presented in Figure 2. For comparative purposes, overlay design requirements were calculated for pavements with and without patches. Pavements with patching are those in locations PVT-E, PAT-E, and PAT. Pavements without patches are those in test locations PVT. The overlay thickness requirements were determined using the Asphalt Institute method and the results are shown in Table 2.

V. Calculation of Extra Rehabilitation Costs Due to Utility Cut Patching

To compute the extra rehabilitation costs associated with utility cut patching, the results obtained from both the PCI and deflection analyses were utilized. The life reduction factor of 1.64, as determined from the PCI analysis, and the overlay thickness requirements for 10 ESAL/day, as determined from the overlay requirement analysis, were used to compute the overlay costs in 1984 dollars. Inflation and interest rate adjustments were excluded from the cost figures. The average annual rehabilitation cost was calculated as the sum of the overlay cost, curb replacement cost, and manhole alignment cost. The total network of streets in the city contains 87 miles of pavement with an average width of 30 feet. At the time of the study, 88% of this mileage contained utility cut patching. The annual cost was calculated for the total network assuming no utility cut patching and repeated with 88% of the pavement patched. The annual costs from the calculations were $599,443 and $1,113,655 respectively. Thus, the annual extra rehabilitation cost for the network was calculated as the difference between the two costs or $514,212 per year.

VI. Conclusion

Based on the analysis presented, it was concluded that pavement performance is significantly affected by utility cut patching. The life reduction factor, computed from the PCI survey, and the increased overlay requirements, computed from the FWD analysis, result in significant rehabilitation costs to the city. The increase was calculated at approximately $514,000 annually for the paved street system. These costs were based on a minimum acceptable PCI value of 70 to avoid excessive reconstruction costs at lower PCI values. Furthermore, it was concluded that utility patching operations on streets with PCI values below 40 would produce no consequential damage.

Table 1: Comparison of Average Pavement Lives For Patched and Non-Patched Pavements

Reduction Analysis Method	Average Life of Non-Patched Pavements (yrs)	Average Life of Patched Pavements (yrs)	Life Reduction Factor
Method 1: Rate of Deterioration	20.1	11.6	1.73
Method 2: Best-fit Line through data			
• All data	19.8	12.1	1.64
• PCI>40	30.0+	11.9	2.52
Method 3: Best-fit Curve through data			
• All data	25.9	8.5	3.05
• PCI>40	28.9	7.8	3.72

Table 2: Overlay Requirements

Traffic	Non-Patched Areas	Patched Areas
2 ESAL/day	0.00"	1.50"
10 ESAL/day	2.25"	3.00"
20 ESAL/day	3.00"	3.75"

Figure 1: FWD Test Locations

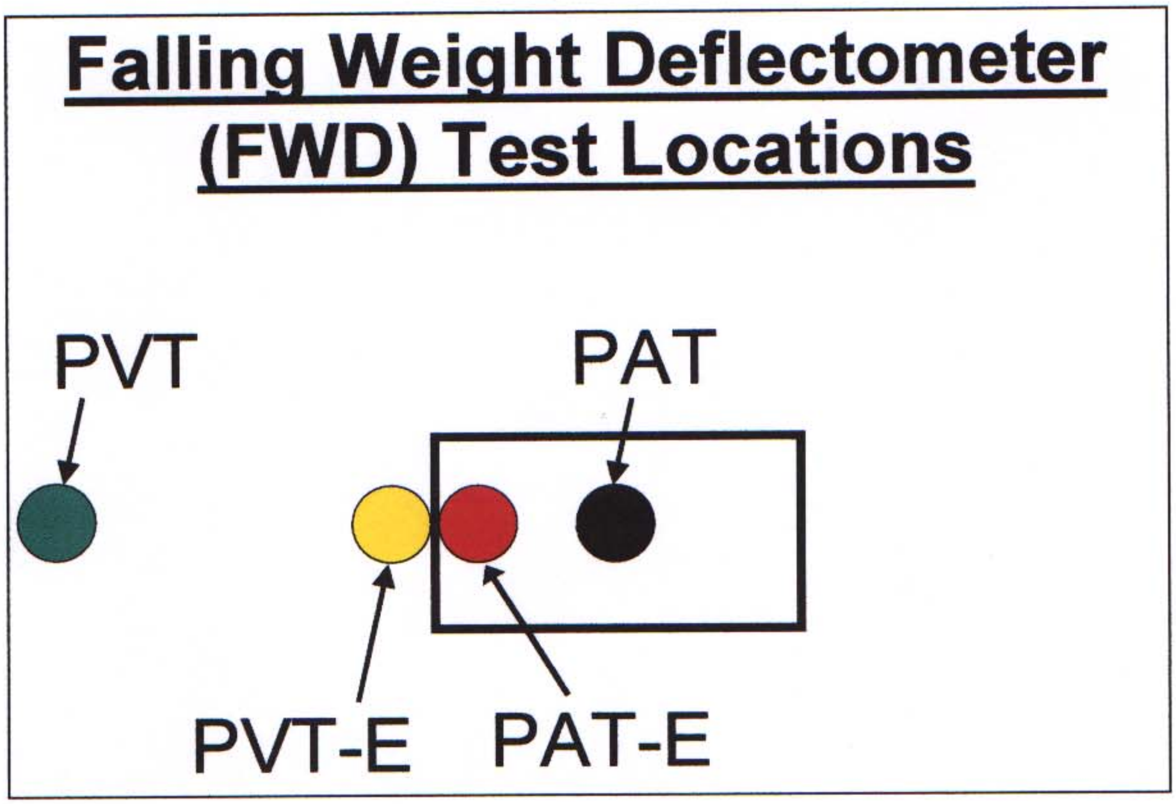
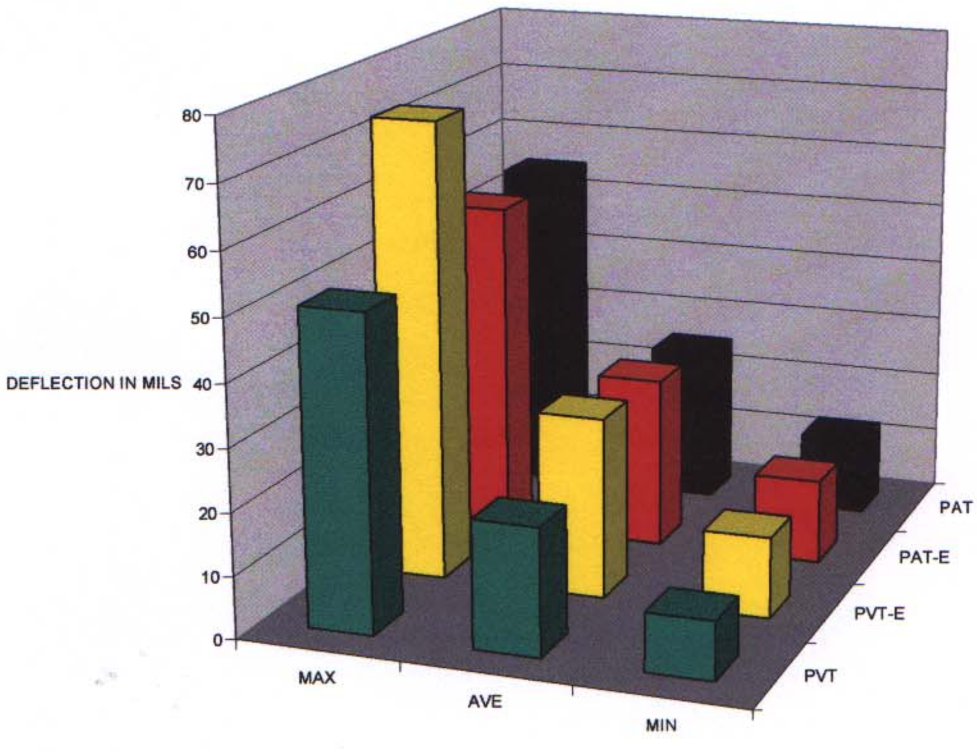


Figure 2: Effect of Patching on Deflection (Do)



APPENDIX B

City of Los Angeles, CA

References:

Shahin, M.Y., Chan, S., and Villacorta, R., 1996, "The Effects of Utility Cut Patching on Pavement Life Span and Rehabilitation Costs", City of Los Angeles, CA.

- I. Introduction
- II. Pavement Testing Program
- III. PCI Data Analysis and Results
- IV. Structural Data Analysis and Results
- V. Calculation of Extra Rehabilitation Costs Due to Utility Cut Patching
- VI. Conclusion

I. Introduction

The City of Los Angeles, CA commissioned a study in 1996 to assess the effects of utility cut patching on the pavements' lifespan and rehabilitation costs. Visual inspection and nondestructive testing (NDT) methods were employed. Based on the available data, a cost analysis was conducted to quantify the extra rehabilitation cost incurred by the city due to utility cut patching.

II. Pavement Testing Program

A total of 100 street sections were randomly selected and surveyed to provide a representative data sample. Fifty of these sections were functionally classified as "Local" and the other fifty as "Select." All selected sections were flexible (asphalt) pavements. Two adjacent inspection units (2500 Sqft ± 40%) were selected from each section where one of the units had utility cut patches while the adjacent unit did not. The surface condition was quantified using the Pavement Condition Index (PCI) method. The structural adequacy of the patched and non-patched pavement was evaluated using a falling weight deflectometer (FWD). Pavement deflections were measured inside and outside the patches. A standard penetration test was also conducted to determine the relative strength of the soil in the patch as compared to the original pavement.

III. PCI Data Analysis and Results

The PCI is a surface distress based index on a scale from 0 to 100, with 100 being a perfect score. Specific types of cracking and other distresses are recorded by quantity and severity level. The PCI results were used to establish four pavement deterioration models (also known as family curves):

1) Select without patching
2) Select with patching
3) Local without patching
4) Local with patching

The family curves were developed using least squared polynomial curve fitting. Each family curve has what is known as the Critical PCI Value. A Critical PCI is the PCI Value beyond which the rate of pavement deterioration increases significantly, and the pavement can no longer be economically maintained without the need for major rehabilitation such as overlay. Therefore, a pavement life span was defined as the pavement age at which the pavement reaches its' Critical PCI. Table 1 shows the Critical PCI and corresponding life span for each family. It should be noted that the Critical PCI was kept the same for within the Select and Local networks to allow for comparison of the effect of utility cut patching on pavement life.

IV. Structural Data Analysis and Results

The Falling Weight Deflectometer (FWD) was used to determine the deflections of the existing asphalt concrete pavements in the patched and non-patched areas (Figure 1). Figures 2 and 3 show a comparison of the center load plate deflections for both Select and Local networks respectively. The figures show deflections for pavement away from utility cut patching (Avg PAT: average of PVT1 and PVT2), pavement edge next to patching (Avg PVTE: average of PVTE1 and PVTE2), patch center (PATC), and patch edge (Avg. PATE: average of PATE1 and PATE2). As can be seen, on the average, there is a considerable increase in deflection in and around the patching areas and adjacent pavement edges as compared to the original pavement. This translates into weaker structural support for traffic and shorter pavement life span.

Pavement cores were cut to determine the thickness of the pavement structure. A soil investigation of the sub-grade was also conducted to determine type of soil (USCS Classification), moisture content, and standard penetration values. The results of pavement coring (Figures 4 and 5) show that, on the average, the patch asphalt (AC) surface thickness is considerably less than the original pavement asphalt surface thickness. This also translates into weaker support and shorter pavement life span. The deflection results were used to determine the overlay requirement for each area utilizing the 1993 AASHTO Darwin Pavement Design program. Figure 6 shows a summary of the average overlay requirements for both Select and Local streets with and without patching.

V. Calculation of Extra Rehabilitation Cost Due to Utility Cut Patching

The PCI and FWD results were used to calculate the extra annual rehabilitation cost for the Select and Local roads. The Select roads network in the City consisted of 1,469.5 centerline miles with an average width of 53.5 feet. The Local roads network consisted of 3,963.28 centerline miles with an average width of 33.86 feet. Approximately 70% of the Select and Local roads had utility cut patching.

The rehabilitation costs included cold planing, profiling, overlay, and manhole alignment. The cost analysis was performed in 1996 dollars. The annual cost was calculated once assuming no utility cut patching and a second time with 70% of the pavement patched. For Select roads, the annual costs were $11,412,427 and $24,349,378 respectively. In Local roads, the annual costs were $4,180,299 and $7,656,672 respectively. Thus, the extra annual rehabilitation cost was calculated as approximately $12.9 million for Select roads and $3.5 million for Local roads.

VI. Conclusion

Based on the analysis presented, it was concluded that pavement performance is significantly affected by utility cut patching. A life reduction factor of 1.21 for local roads and 1.52 for select roads was determined. The life reduction factor, computed from the PCI survey, and the increased overlay requirements, computed from the FWD analysis, result in significant rehabilitation costs to the city. The increase was calculated at approximately $12.9 million for Select roads and $3.5 million for Local roads. These costs were based on Critical PCI values of 55 for Select roads and 65 for Local roads to avoid excessive reconstruction costs at lower PCI values.

Table 1: Critical PCI and Life Span for Each Family

Pavement Family	Critical PCI	Life Span (years)
Select without patch	55	25.0
Select with patch	55	16.5
Local without patch	65	34.5
Local with patch	65	28.5

Figure 1: FWD Test Locations

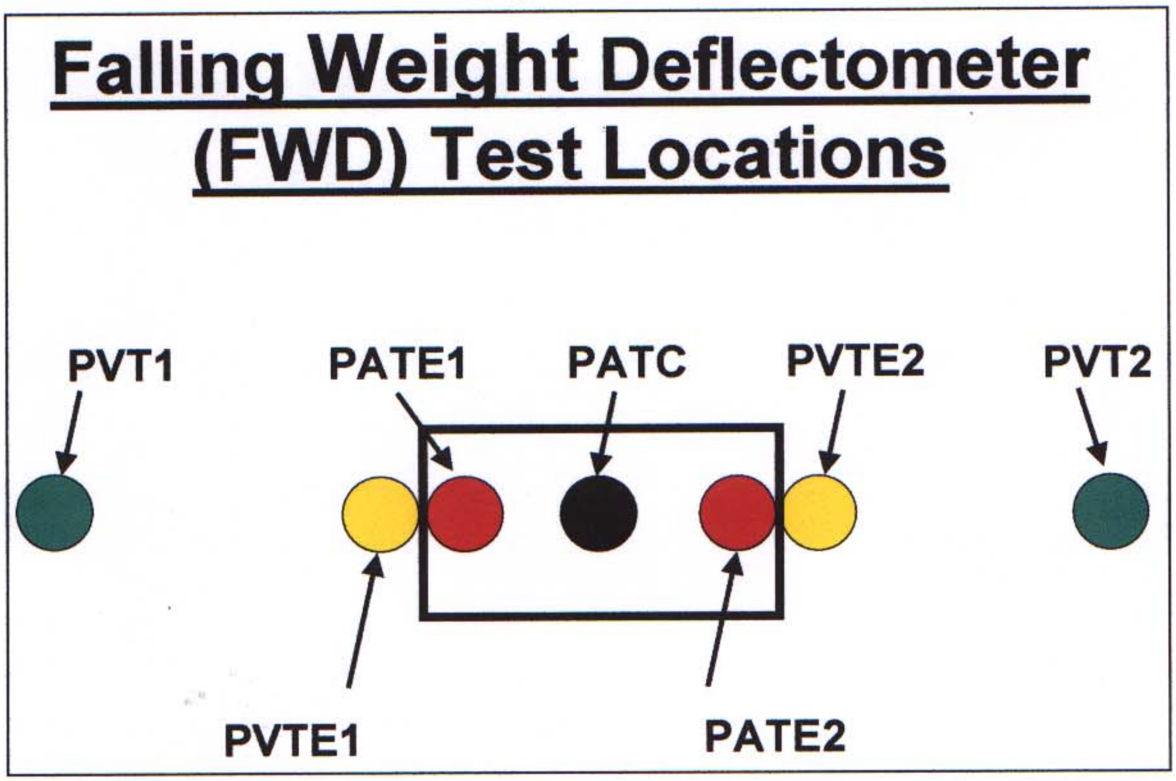


Figure 2: Center load plate deflections for Select roads (1 mil = .001 inch)

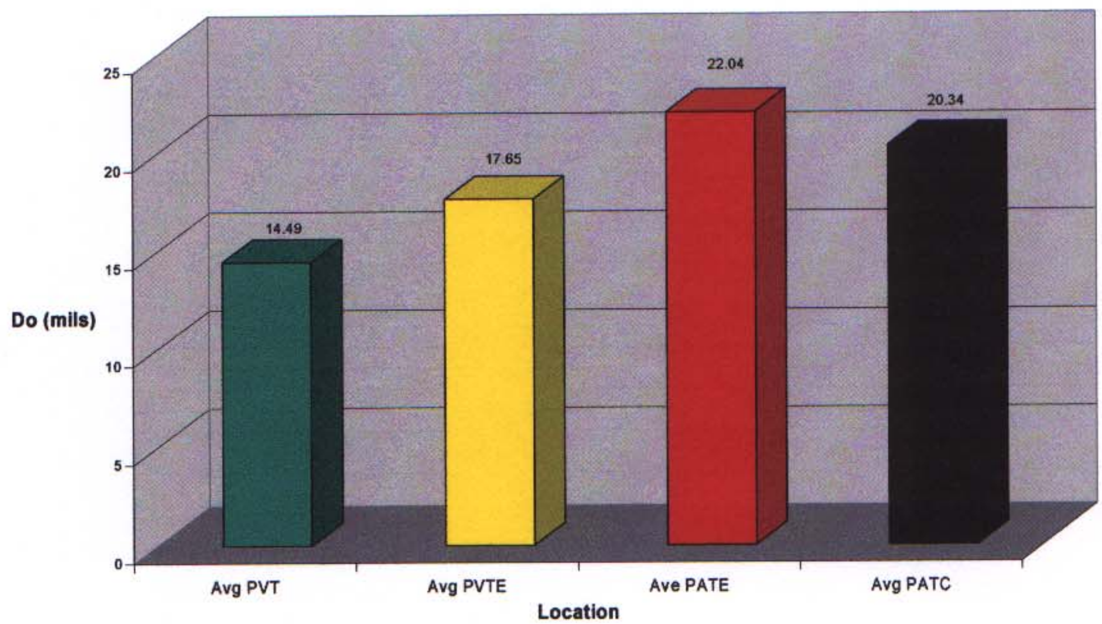


Figure 3: Center load plate deflections for Local roads (1 mil = .001 inch)

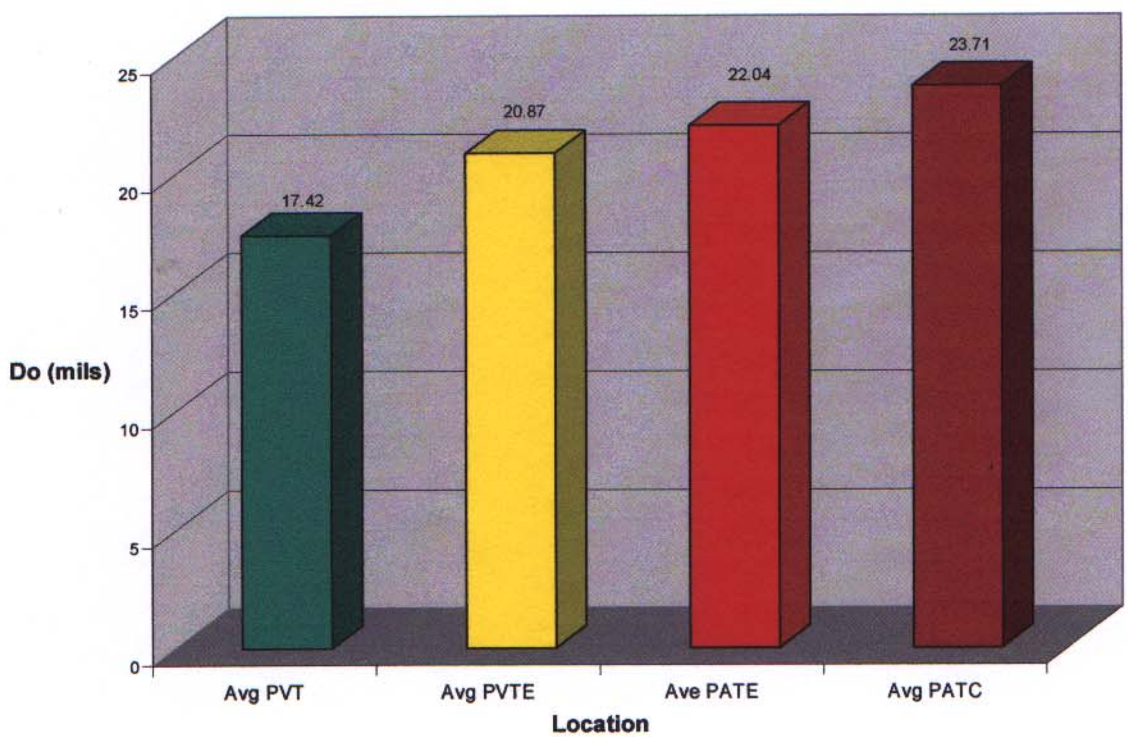


Figure 4: Average Asphalt Thickness for Select roads

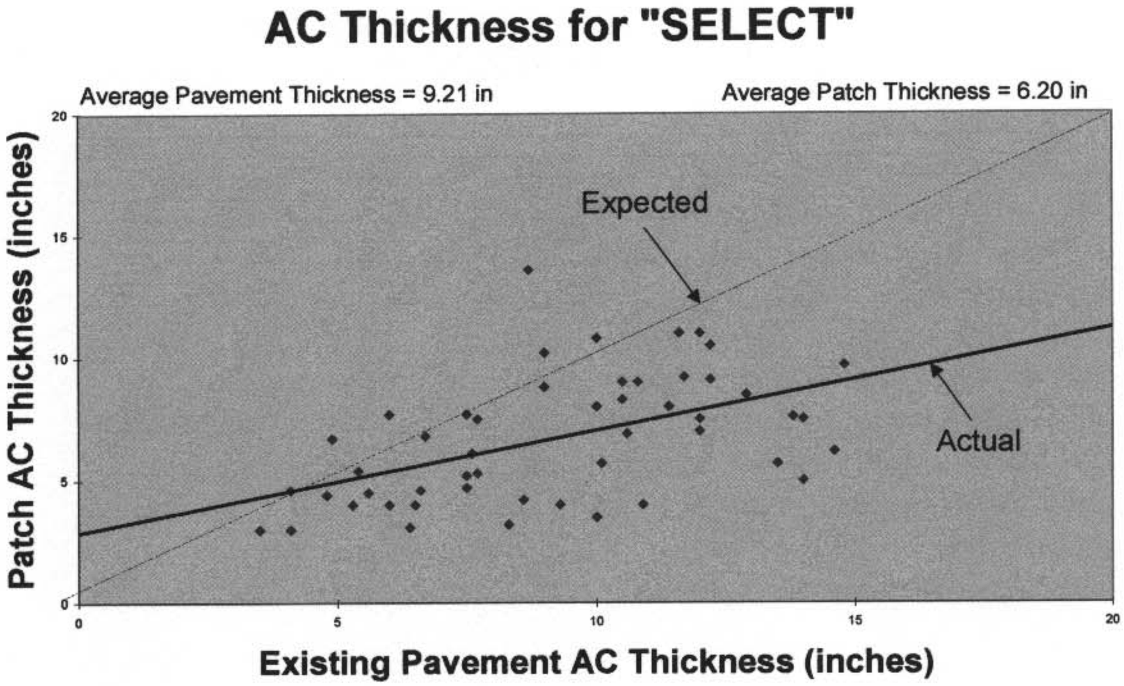


Figure 5: Average Asphalt Thickness for Local roads

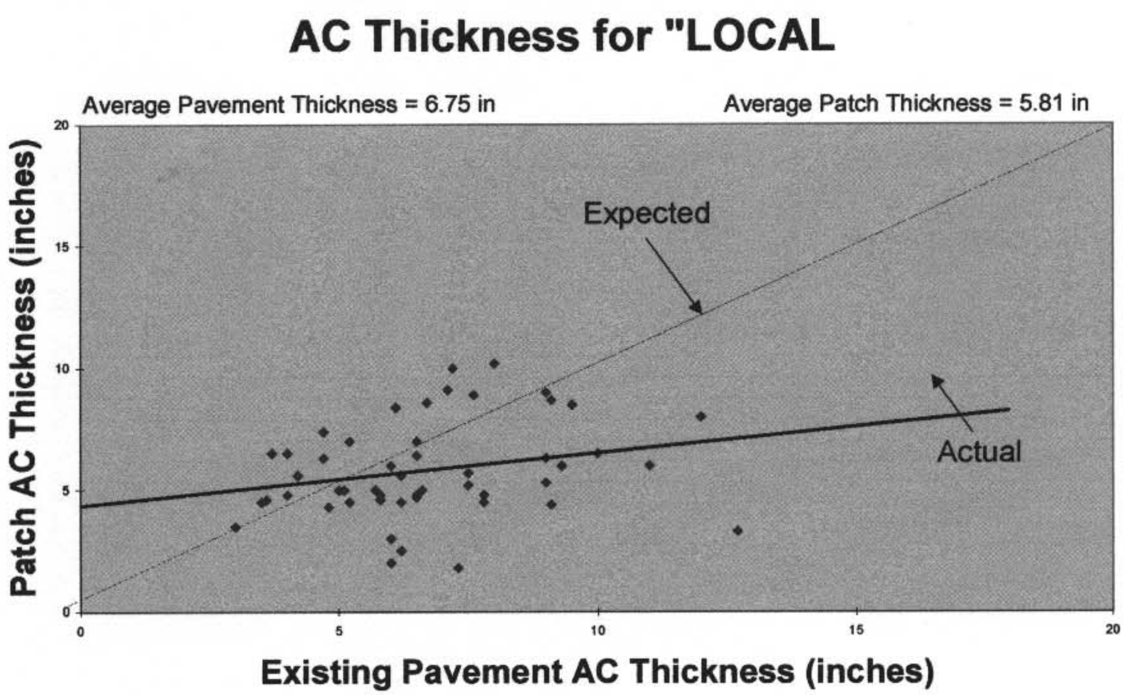
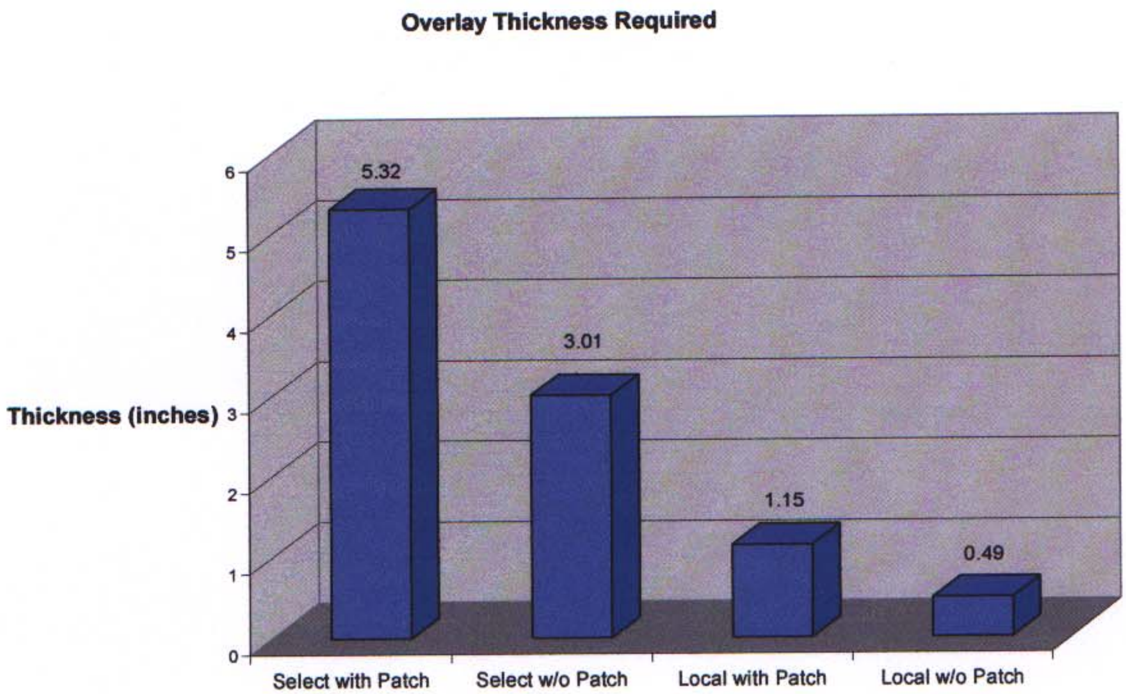


Figure 6: Average Overlay Requirements with and without patching



APPENDIX C

City and County of San Francisco, CA

References:

Department of Public Works for City and County of San Francisco and The Blue Ribbon Panel on Pavement Damage, 1998, "The Impact of Excavation on San Francisco Streets", City and County of San Francisco, CA.

Marcus, William B., 1998, "Economic Report: Estimated Costs of Accelerated Repaving Required as a Result of Utility Excavation in San Francisco Streets", City and County of San Francisco, CA.

I. Introduction

In 1992, the City commissioned a study to determine the effects of utility cuts on the service life of City streets. The City retained Dr. Ghassan Tarakji, Ph.D., P.E., of the Engineering Design Center at San Francisco State University (SFSU), to perform this task. Local utility companies commissioned a critical review and expressed concerns over the data and methods used in the analysis. In response, the city commissioned an expert panel to reevaluate the results of the original study and expand its scope based on new engineering techniques.

II. Initial Study

The SFSU Study took data from the PMMS and compared the Pavement Condition Scores for streets with few (0-2), some (3-9), and many (more than 9) utility cuts. The data used in the City and County of San Francisco study was obtained from their existing Pavement Management and Mapping System (PMMS). The PMMS contained a description of each block in the City, the condition of the pavement, number of utility cuts, and other key information. Pavement Condition is measured by the Pavement Condition Score (PCS). The best score a pavement can get is 100. "Points are deducted based on three factors: RIDE, which represents the smoothness or ride quality of the block; RAVELING, which describes the severity and extent of surface erosion from weathering and traffic; and CRACKING, which considers the amount and severity of cracks in the pavement. Points are not deducted for utility cuts unless cracks form around them."

The SFSU Study concluded that streets with some cuts have lower condition scores than streets with few cuts and that streets with many cuts have lower condition scores than streets with some or few cuts. These conclusions were consistent for every functional class of asphalt street and for concrete streets.

Assuming streets require repaving when they reach a pavement condition score of 65, the SFSU Study concluded that:

Asphalt Streets With:	Have a Service Life of:
Less than 3 cuts	26 years
Between 3 and 9 cuts	18 years
More than 9 cuts	13 years

III. Follow Up Study

In 1997, the City assembled a panel of experts to provide an objective assessment of whether engineering evidence and statistical analyses supported the SFSU conclusion that excavation reduces the condition and service life of City streets. The panel included five Engineers with expertise in pavements and a Statistician with expertise in analyzing pavement data. The panel members were:

Jon Epps, P.E., Ph.D., is Professor of the Civil Engineering Department at the University of Nevada, Reno.

R. G. "Gary" Hicks, P.E., Ph.D., is Professor Emeritus of the Civil Engineering Department at Oregon State University.

Ram Kulkarni, Ph.D., is Vice-President and Senior Principal of Woodward-Clyde Consultants.

Olga J. Pendleton, Ph.D, is Research Statistician and Co-President of
Pen-Hock Statistical Consultants.

M. Y. Shahin, P.E., Ph.D., is a national and international pavement evaluation and management consultant. He is also a Principal Investigator for the U. S. Army Corps of Engineers.

Roger Smith, P.E., Ph.D., is Associate Professor of the Department of Civil Engineering at Texas A & M University and Associate Research
Engineer for the Texas Transportation Institute.

The panel used the data from the PMMS and grouped the pavement blocks based on number of utility cuts: none, few (1-2), some (3-9), and many (10 or more). The 1997 Statistical Study was performed using updated PMMS information and included the variables of functional class, age, number of utility cuts, and area and type of utility cuts. Table 1 shows the sample sizes for the data used in the 1997 Analysis, divided into groups by age and the number of cuts present. The Panel and the Statistician determined that the sample size for the 1997 Analysis was more than sufficient to make statistically significant conclusions regarding the impact of utility cuts on the condition of the City's pavement.

IV. Follow Up Study Results

The Statistician determined that the most significant variables were age and number of utility cuts – the same variables used in the SFSU Study. Figure 1 is a bar chart presentation of the analysis. The chart shows the average of pavement condition scores for streets with zero, few, some, and many cuts in various age groups. As can be seen from Figure 1, the average condition score of streets with trenches is lower than the average condition score of streets with no trenches. Based on the review of the literature, the findings derived from the 1997 Analysis, and their engineering expertise, the Panelists arrived at the following conclusions regarding the impact of utility cuts on the service life of San Francisco's asphalt streets:

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 dramatically reduces pavement performance.
4. Conclusions 1-3 remain the same, whether considering the number of cuts per block, number of cuts in an area, or the percentage of area cut.
5. Conclusions 1-3 are statistically supported by data to at least a 95% confidence level.
6. The findings of the 1997 Analysis and other municipal utility cut studies are consistent with the following universally accepted engineering principles:
   - Street cuts disrupt surface integrity, creating surface roughness, reducing pavement strength, and allowing for entry of moisture, which accelerates long-term deterioration, Figure 2.
   - 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.
   - 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; and
   - Although high quality patching may reduce the structural damage caused by utility cuts, the street will still incur ride quality and cracking damage, and its service life will be diminished.
7. The statistical findings of the 1997 Analysis are consistent with the findings of engineering-based studies which used deflection testing to conclude that utility cuts inevitably and irreparably disrupt the subsurface of a street, and that this damage extends beyond the perimeter of the trench.

V. Economic Analysis

The City retained an economist to estimate the extra cost of pavement rehabilitation as a result of utility excavation. The procedure used to perform the analysis is summarized in the following steps:

1. Identify the total number of blocks that require repaving, "repaving candidates." This was done using two methods:
   a. Using the decision tree built into the City's pavement management system (PMMS). This method does not consider budgetary constraints.

b. Using what the economist termed the Excess Failed Street Method (EFS). The EFS method identifies Repaving Candidates as those blocks with a PCS of less than 53. This generally reflects the reality of the City's current repaving practices.

2. Identify the number of "excess" blocks requiring repaving due to excavation.
   This was determined by comparing the number of repaving candidates with "no cuts" to the number of repaving candidates with "few, some, or many cuts." The analysis presumes that, absent excavation damage, there should be proportionally the same number of repaving candidates in each cut group of the same age. In other words, of streets age 0-5, there should be proportionally the same number of repaving candidates with no cuts, as with few, some, or many cuts.
3. Identify and annualize the total cost to repave excess repaving candidates. The total cost was determined by multiplying the average cost of repaving a block by the total number of excess repaving blocks. The total cost is then annualized over a 26-year paving cycle using a 5.58% discount rate. The 26 years was selected as the City estimated that it repaves the streets at a rate equivalent to 26 years.
4. Convert the annual cost into a square foot cost. This was done by dividing the annual cost by the number of square feet likely to be excavated in a year.

All the above steps were performed twice: once by analyzing only pavement under 20 years, and a second time using all pavements. The 20 years was selected since the City had more confidence in the data for pavement 20 years or less. Table 2 shows a summary of the Analysis findings. The City, however, has proposed a conservative fee shown in Table 3.

VI. Conclusion

Based on the results from the 1997 analysis and the subsequent economic report, it can be concluded that utility cuts lower pavement condition scores, reduce pavement service life, and increase pavement rehabilitation costs due to accelerated repaving requirements.

Table 1. Number of Blocks in 1997 Analysis By Age and Number of Cuts

AGE	No Cuts (0)	Few Cuts (1 to 2)	Some Cuts (3 to 9)	Many Cuts (10 or more)	Total
0-5 Years	1248	399	246	53	1946
6-10 Years	373	271	451	127	1222
11-15 Years	232	331	669	295	1527
16-20 Years	75	97	232	105	509
Total	1928	1098	1598	580	5204

Table 2. Economic Analysis Findings

	EFS Method (Age $\leq$ 20 Sample)	PMMS Method (Age $\leq$ 20 Sample)	EFS Method (Entire Sample)	PMMS Method (Entire Sample)
Number of Repaving Candidates	1546	2653	2756	3992
Number of Excess Repaving Candidates	566	568	1153	1000
Total Repaving Cost	$44.5 million	$45.4 million	$69.3 million	$60.1 million
Annual Repaving Cost	$3.3 million	$3.4 million	$5.1 million	$4.4 million
Square Foot Cost	$5.37	$5.49	$8.38	$7.27

Table 3. Proposed Restoration Fees

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
15 – 20	$1.00

Figure 1. Effect of Utility Cuts on Pavement Condition

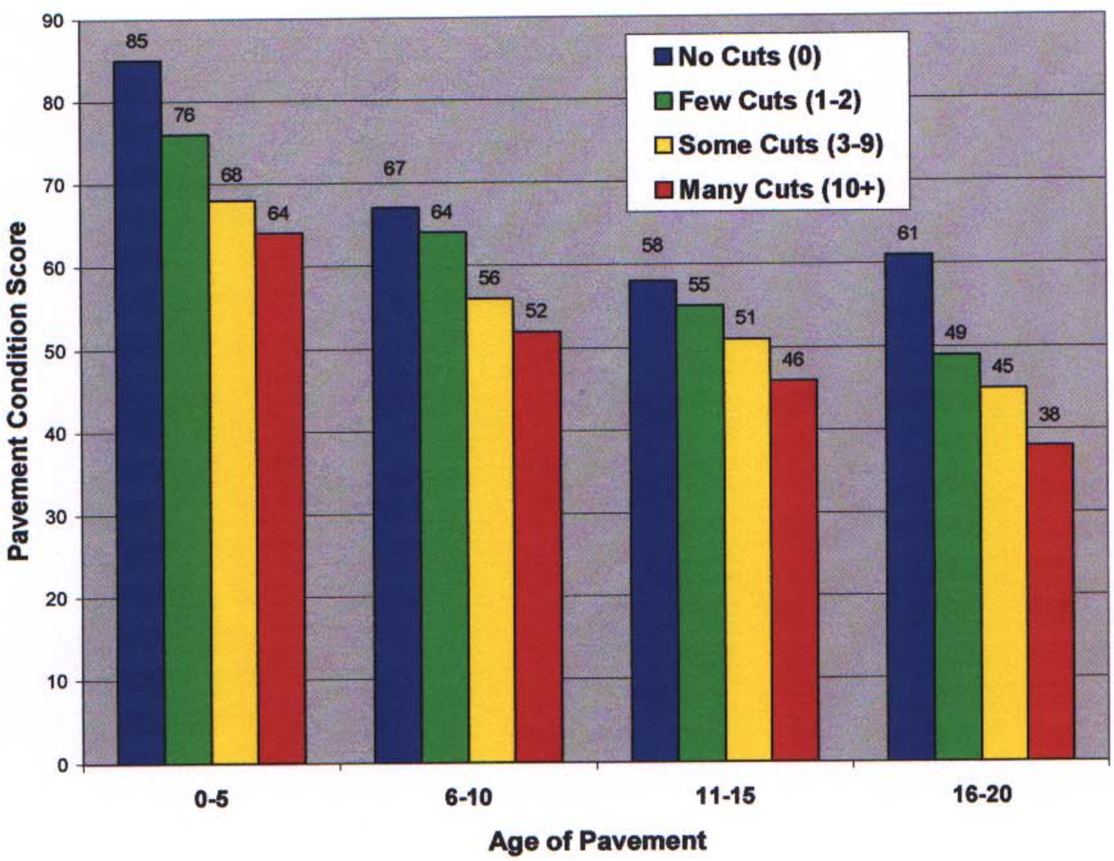
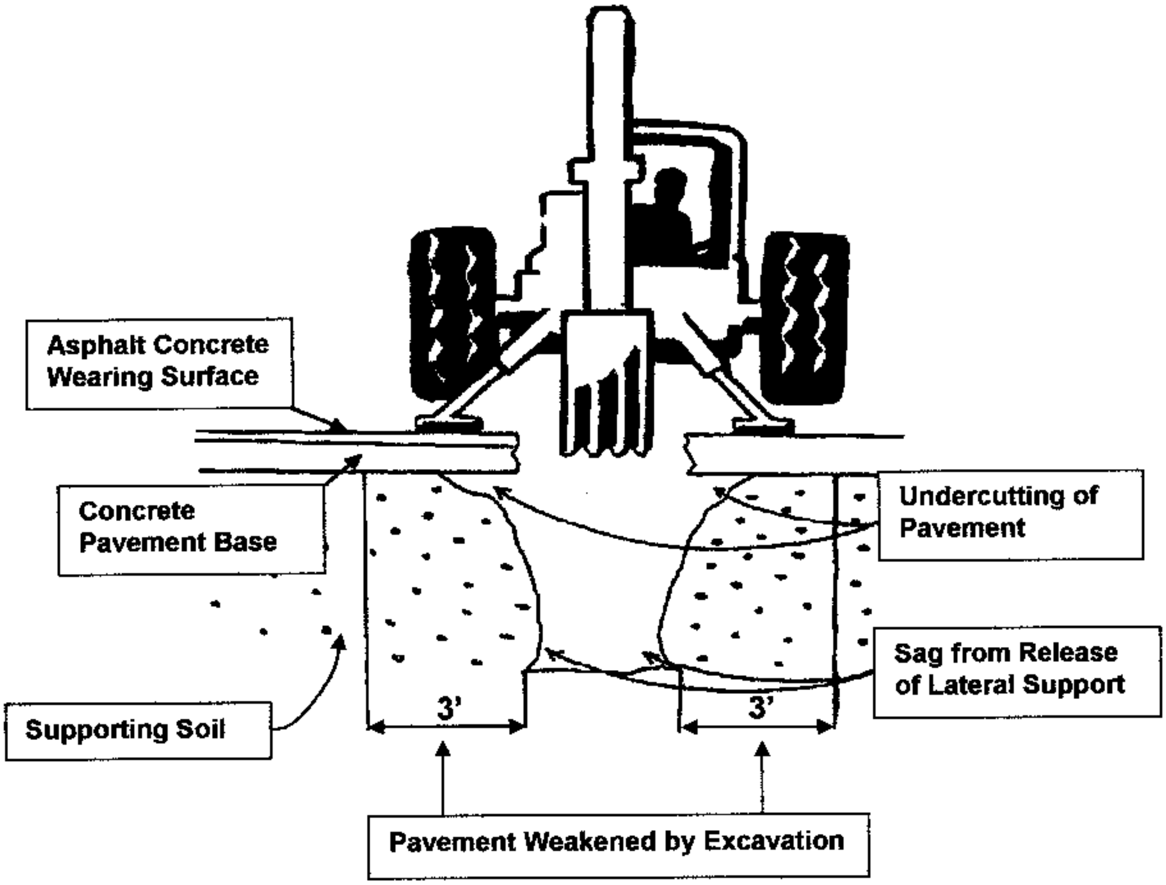


Figure 2. Pavement Surface and Soil Disruption from Excavation



APPENDIX D

City of Sacramento, CA

References:

CHEC Consultants, Inc., 1996, "Impact of Utility Cuts on Street pavements", City of Sacramento, CA.

I. **Introduction**
II. **Pavement Testing Program**
III. **Longitudinal Utility Cuts Data Analysis and Results**
IV. **Transverse Utility Cuts Data Analysis and Results**
V. **Calculation of Extra Rehabilitation Costs Due to Utility Cut Patching**
VI. **Conclusion**

I. Introduction

In 1996, the City of Sacramento, CA contracted with Chec Engineering Consultants to determine the extent and quantify cost associated with utility cuts. Dr. M.Y. Shahin was retained by the City as an independent consultant to review the results of the report prepared by Chec Engineering and to participate in City Council meetings during the discussion of the damage resulting from utility cuts. The following sections present a summary of the study performed by Chec Engineering.

II. Pavement Testing Program

The testing program was limited to deflection testing using the Dynaflect device and a coring program to determine asphalt concrete (AC) surface thicknesses. No distress survey or visual condition rating was performed as part of the study. The test sections were grouped in four zones based on soil and traffic conditions.

Separate data collection and analysis were performed for longitudinal and transverse utility cuts. Longitudinal cuts were tested for loss of strength and associated difference in AC overlay requirements. Dynaflect testing was performed on each cut as well as two feet left and right of the trench, if possible. A base line test was also conducted in the same pavement section for comparison purposes.

Transverse cuts were tested for loss of strength and extent of influence from the cut. Each wheel path was tested five feet on either side of the patch, at one-foot intervals. A baseline test was also conducted in the same section for comparison purposes.

III. Longitudinal Utility Cuts Data Analysis and Results

Each of the pavement sections was analyzed to determine the overlay requirement and the difference between the test area and baseline overlay requirements calculated. The overall average from the four zones (Table 1) showed an extra 1.5 inches of AC overlay is required relative to the baseline.

IV. Transverse Utility Cuts Data Analysis and Results

The purpose of the testing was to determine the distance from the edge of the cut that the pavement is affected. The assumption made is that the only repair needed would be the replacement of the surrounding weak areas prior to overlay. The results of the analysis (Table 2) showed that the average influence from the cut edge is 3.64 feet.

V. Calculation of Extra Rehabilitation Costs Due to Utility Cut Patching

For longitudinal cuts, the extra cost was limited to the cost associated with the additional AC thickness required, which was determined to be 1.5

inches. The costs associated with manhole adjustment or cold milling were not included. Using and AC cost of $26/ton, two separate costs were calculated based on whether the extra overlay thickness will be applied to one or two lanes. If the utility cut is within three feet of a lane line, then two lanes will require the extra overlay thickness. For one lane, the extra cost was calculated as $16,068/mile or approximately $3/linear foot. For two lanes, the extra cost was approximately $6/linear foot.
For transverse cuts, only the cost associated with replacing the weakened area prior to overlay was considered. A full depth AC patch (approximately $3/square foot), was assumed for the calculation. Using the 3.64 feet average influence extent, two costs were calculated: one for cuts that go across the entire street width, and another for cuts that cover less than the entire street width. Cuts that cover less than the entire street width exert influence on four sides rather than two. The first cut was assumed to be 2 ft by 24 ft. Therefore, the area to be replaced prior to the overlay is [(2 + 2 x 3.64) x 24] or 223 square feet. At $3/square foot, the cost is $669 or $13.94 per square foot of actual cut. The second cut size was assumed to be 4 ft by 5 ft. Therefore, the area to be replaced prior to the overlay is [(4 + 2 x 3.64) x (5 + 2 x 3.64)] or 139 square feet. At $3/square foot, the cost is $417 or $20.85 per square foot of actual cut.

VI. Conclusion

The study has proven that utility cuts cause a discontinuity in the pavement structure and cause a loss of strength within the adjacent pavement. The approximate extent of influence was also determined.

Table 1: Average Additional AC Overlay Required for Utility Cuts

ZONE	Average Additional AC Overlay Required (feet)
Zone 1	0.13
Zone 2	0.13
Zone 3	0.11
Zone 4	0.14
OVERALL	**0.13**

Table 2: Influence of Utility Cuts on Surrounding Pavement

ZONE	Influence from Cut Edge (feet)
Zone 1	3.35
Zone 2	3.16
Zone 3	3.81
Zone 4	4.24
OVERALL	**3.64**