TABLE OF CONTENTS

	Page
1. Background	C-4
2. Distress Evaluation Form	C-5
3. Alligator Cracking	C-6
4. Edge Cracking	C-7
5. Transverse Cracking	C-8
6. Potholes	C-9
7. Rutting	C-10
8. Ravelling and Weathering	C-11
9. Cut-to-Adjacent Pavement Drop-Off	C-12
10. Edge Separation	C-13
11. Corner Breaks	C-14

Background

Several manuals have been developed for identification of distresses on pavements. Generally these manuals, for various types of pavements, present distresses commonly observed, their severity, extent and method of measurement. Engineers have the option to adopt one of the existing manuals for the distress survey with modifications, if necessary. A survey thus carried out presents the condition of pavements on an extended section of a highway at a global level. But, when the distresses are localized, a micro level investigation would be imminent. The city engineers are often confronted with this situation because of the utility cuts, the size of which usually range from 15 sq. ft. to 50 sq. ft. Since the influenced area in and around the utility cut is very small in comparison with the extended pavement section, it is obvious that a micro level investigation of the distress mechanism would be in order. Unfortunately, the manuals currently available do not make a clear distinction between the evaluation of extended pavement section and utility cuts. The research team currently involved in the evaluation of distresses in and around utility cuts, after a thorough review of the manuals available, realize the need for specific guidelines for utility cuts. Several new distresses not addressed in those manuals have been noticed by the researchers. Also it is believed that only the severity of distress, and not the extent, is relevant in view of the relatively small area of utility cuts.

This manual is a first attempt to list the predominantly present distresses in utility cuts. In all, nine types of distresses have been listed. Since these are found to be independent of the type of pavement, it is suggested that the same set of distresses be used irrespective of the type of pavement. A revision of this manual is anticipated in the future.

City Cincinnati

Prepared by: _____ Date of Survey: _____

Location: _____ Time of Survey: _____

Surface Profile (enter a number)	very poor	poor	fair	good	excellent
	0 - 20	21 - 40	41 - 60	61 - 80	81 - 100

Distresses (Rate by severity. If different levels exist, rate by highest severity)	Cut			Vicinity			Any additional distress?
	low	moderate	high	low	moderate	high	
Alligator Cracking							
Edge Cracking							
Transverse Cracking							Overall condition
Potholes							
Rutting							
Ravelling & Weathering							
Cut-to-Adjacent Pavement Drop-off							Recommended action
Edge Separation							
Corner Breaks							

Overall condition:
- very poor (0-20)
- poor (21-40)
- fair (41-60)
- good (61-80)
- excellent (81-100)

Recommended action:
- do nothing
- surface treatment
- overlay
- reconstruct

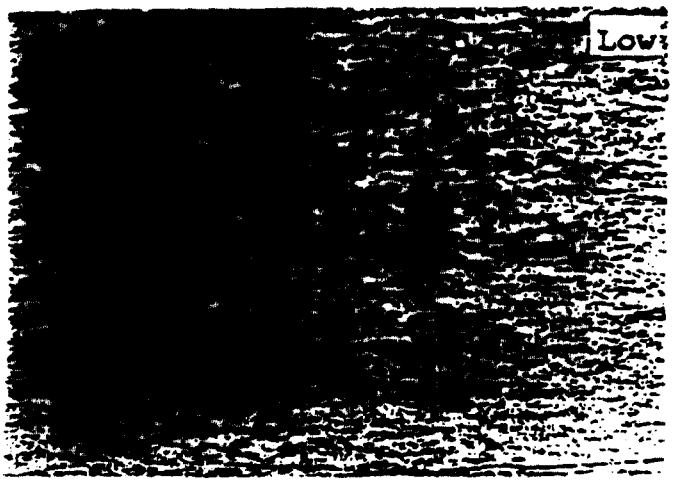
Additional Remarks:

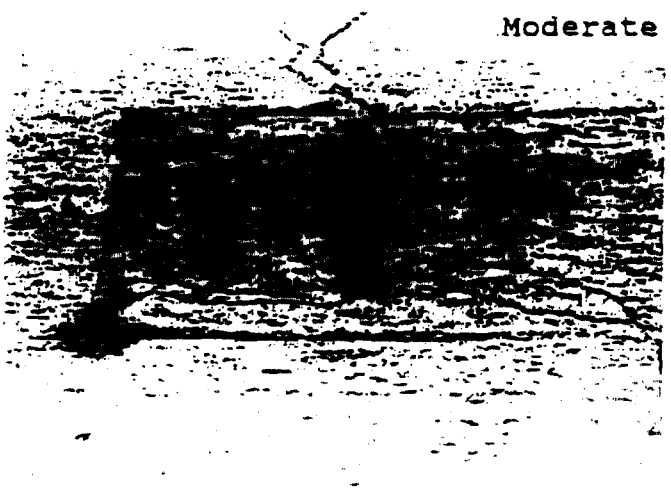
Alligator Cracking: Series of interconnected cracks, chicken wire/alligator pattern

Cause: Repeated traffic loading, base course saturation

Severity Levels

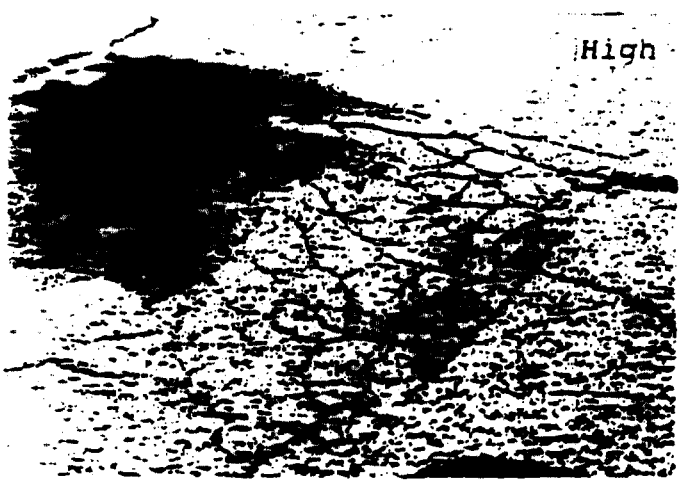
Low: Fine, longitudinal disconnected, unspalled hair line cracks running parallel to each other





Moderate: Development of light alligator cracks into a network of cracks that may be lightly spalled

High: Cracks severely spalled at the edges, loosened pieces rock under traffic

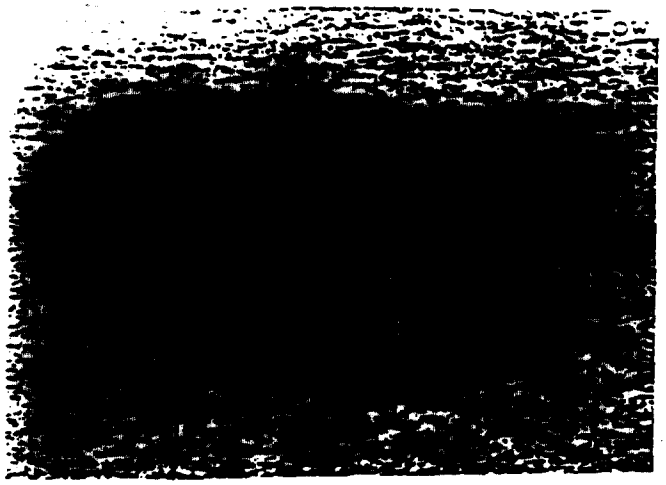


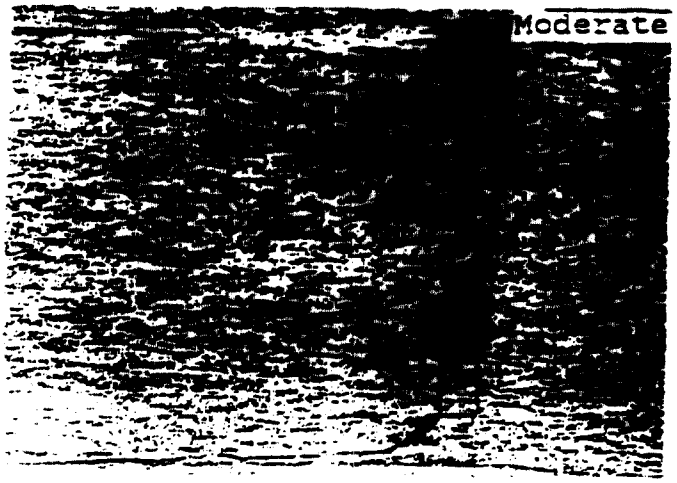
Edge Cracking: Parallel to and within 6 inches of the edge

Cause: Weak base or subgrade

Severity Levels

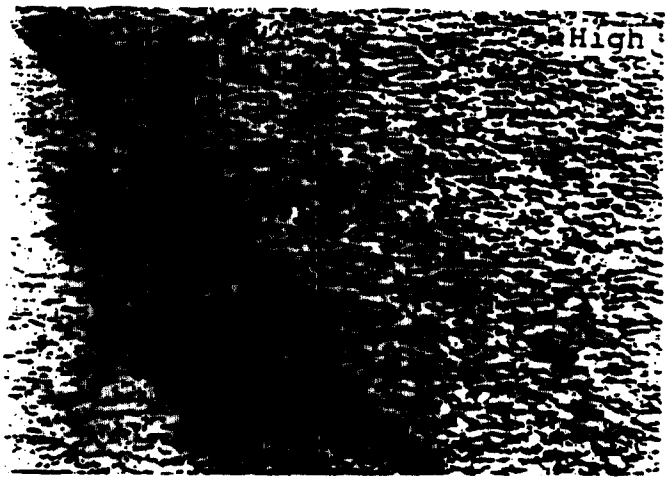
Low: Cracking with no break up or ravelling





Moderate: Cracking with some break up or ravelling

High: Considerable break up or ravelling along the edge

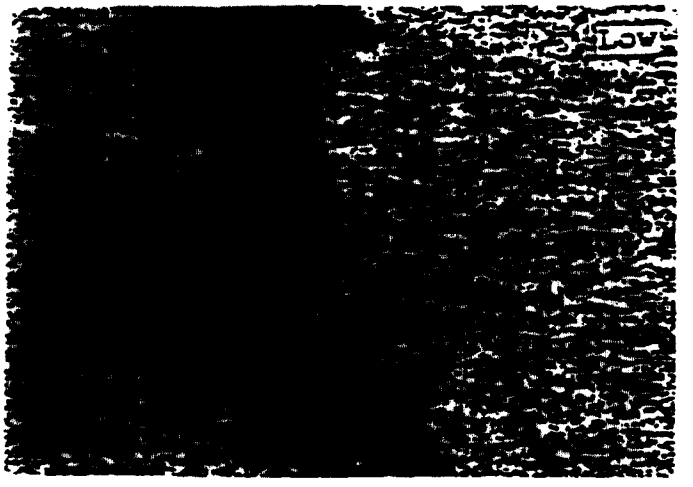


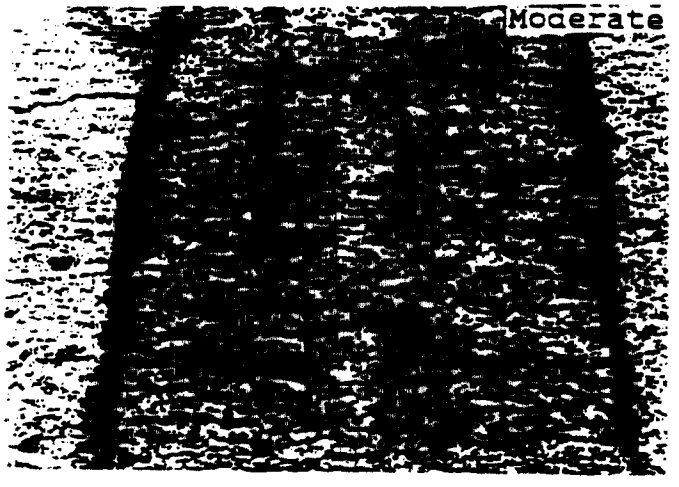
Transverse Cracking: Cracks running across the pavement

Cause: Shrinkage due to low temperature; hardening of asphalt

Severity Levels

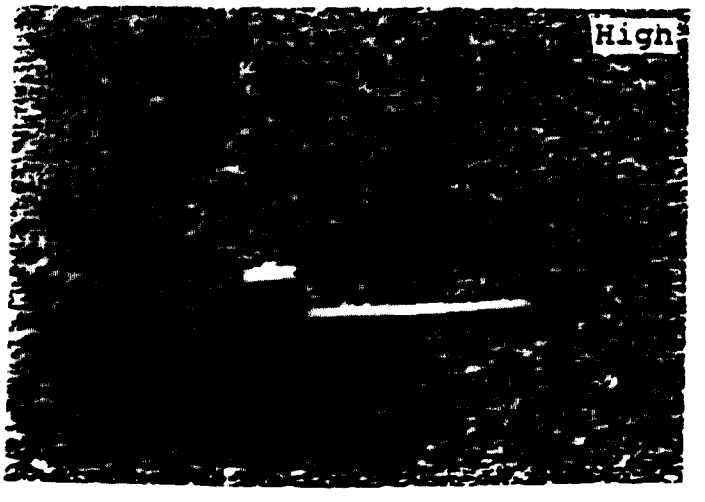
Low: Crack width less than 1/4"; no spalling





Moderate: Crack width 1/4" to 3/4"; moderate spalling

High: Crack width greater than 3/4"; spalled cracks



Potholes: Bowl shaped depressions

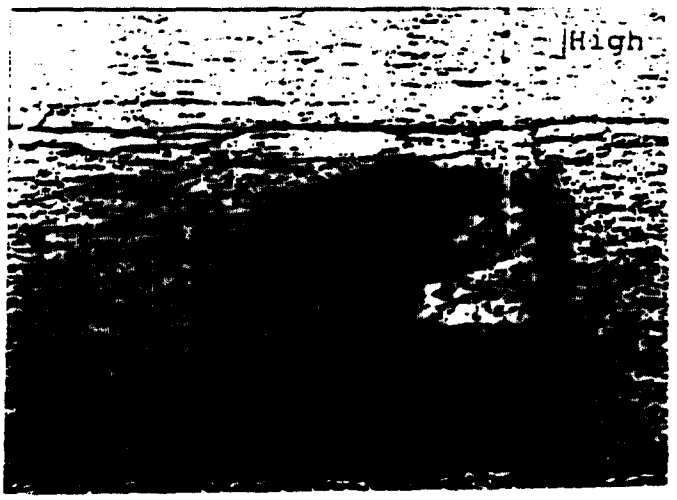
Cause: Loss of material, poor surface mixture, weak spots in the base or subgrade, high severity alligator cracking

Severity Levels

Low: Maximum depth up to 1"

Moderate: Maximum depth 1" to 2"

High: Maximum depth greater than 2"



Rutting: Longitudinal surface depression

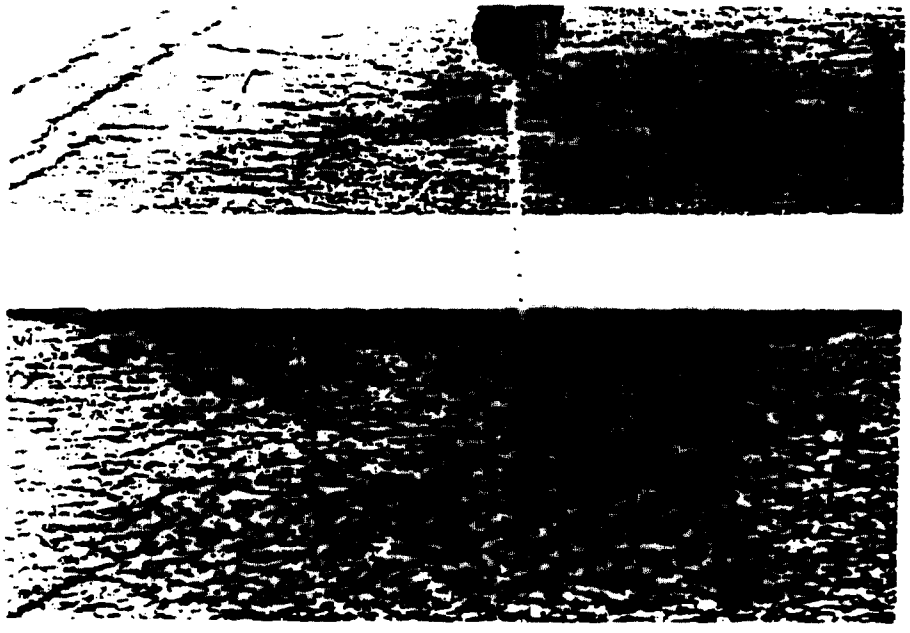
Cause: Permanent deformation of pavement layers or subgrade due to traffic load

Severity Levels

Low: Mean rut depth up to 1/4"

Moderate: Mean rut depth 1/4" to 3/4"

High: Mean rut depth greater than 3/4"

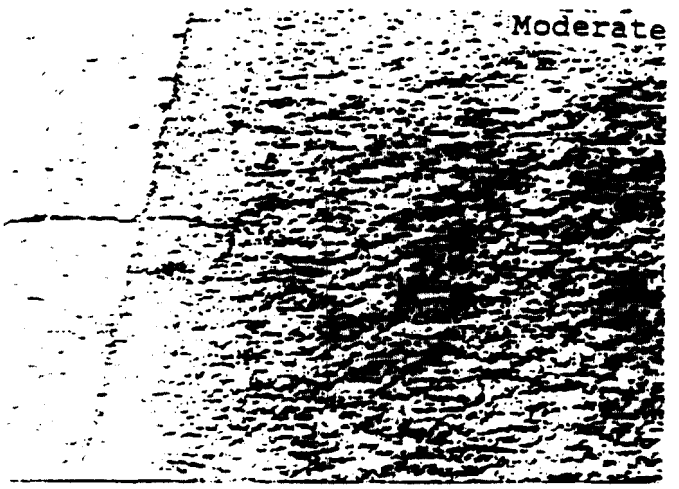


Ravelling and Weathering: Wearing away of the surface due to loss of asphalt and dislodged aggregate particles

Cause: Softening of the surface; oil spillage

Severity Levels

Low: Aggregate or binder started to wear away; surface started to pit



Moderate: Aggregate or binder worn away; surface texture moderately rough and pitted

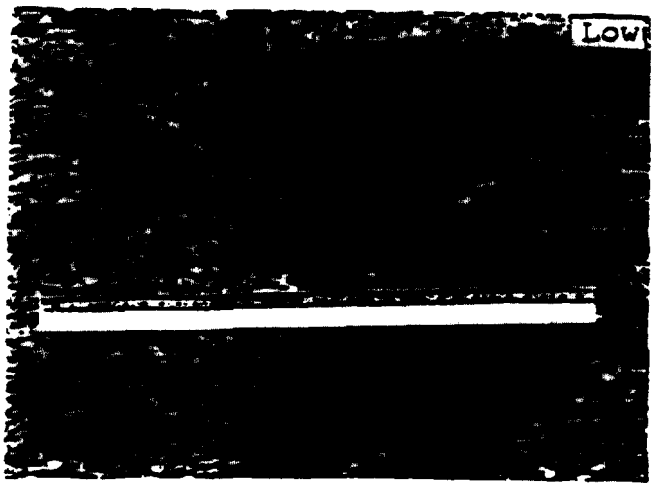
High: Aggregate or binder worn away considerably; surface texture very rough and severely pitted

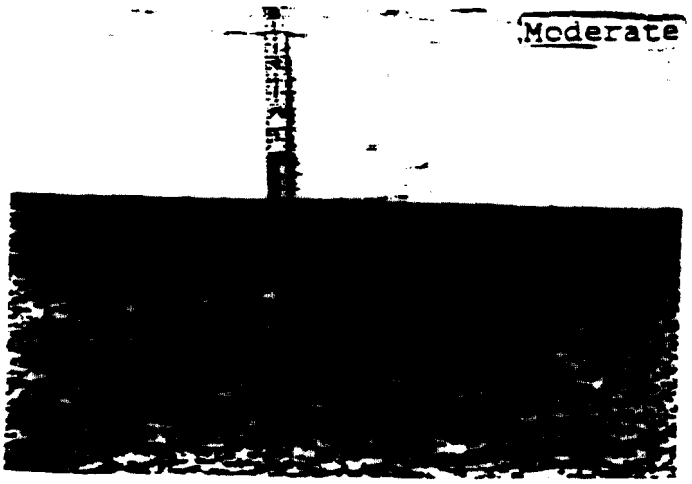
Cut-to-Adjacent Pavement Drop-Off: Difference between the utility cut and the adjacent pavement near the edges

Cause: Settlement of the cut, inadequate compaction, improper construction, inferior material

Severity Level

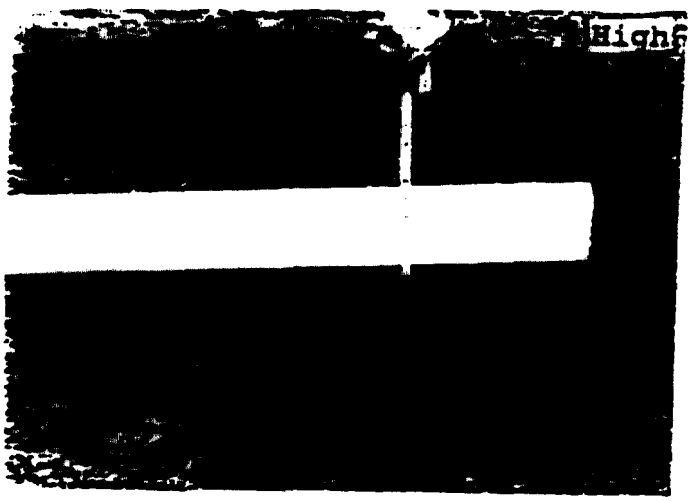
Low: Difference in elevation up to 1/2"





Moderate: Difference in elevation 1/2" to 1"

High: Difference in elevation greater than 1"

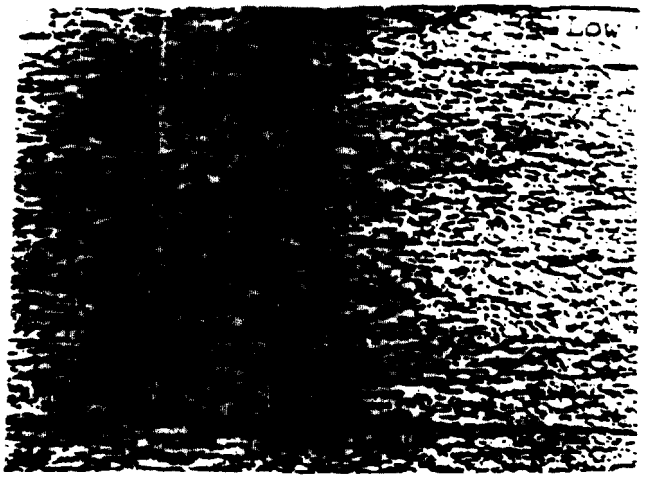


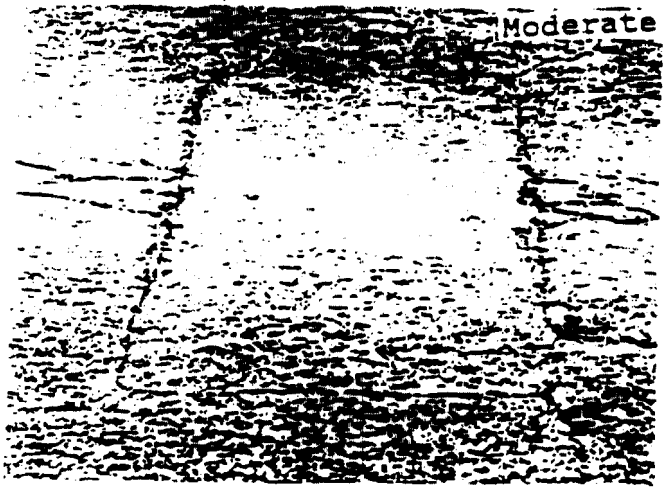
Edge Separation: Utility cut separated from the adjacent pavement section

Cause: Inadequate bond, faulty construction, use of inferior material

Severity Level

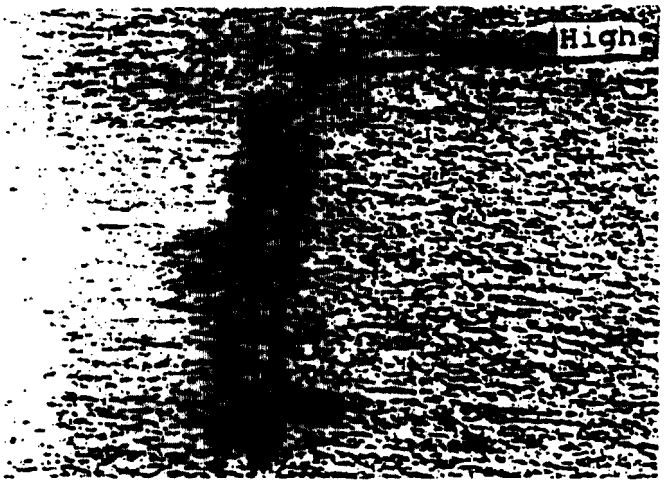
Low: Gap up to 1/4"





Moderate: Gap 1/4" to 1/2"

High: Gap greater than 1/2"

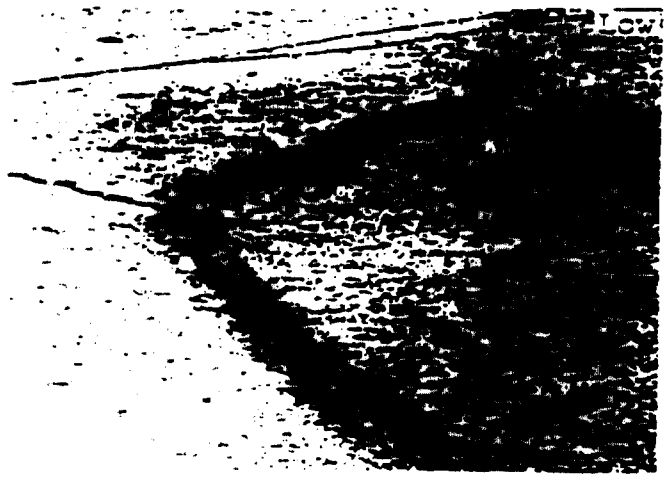


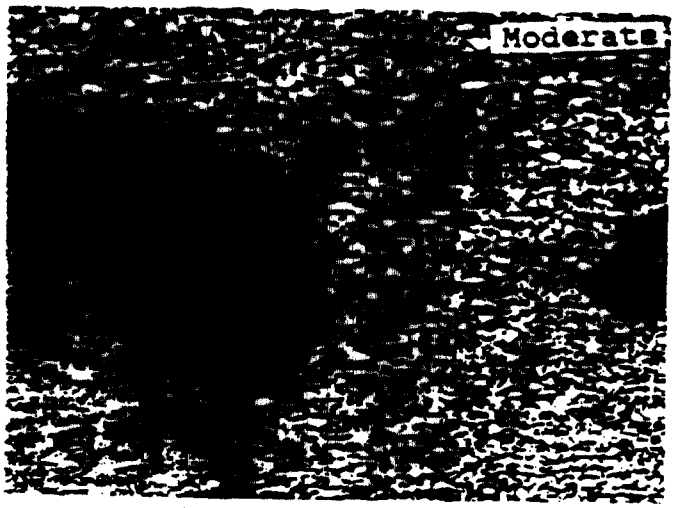
Corner Breaks: Crack at corner of slab that intersects the joints less than 6" from the corner on each side

Cause: Heavy repeated loads combined with poor load transfer and inadequate drainage

Severity Level

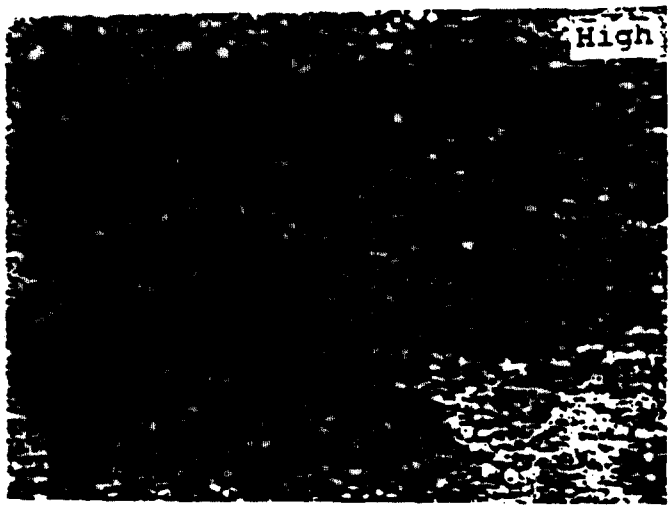
Low: Crack well sealed: no faulting or break-up





Moderate: Slightly broken; faulting of crack or joint less than 1/2"

High: Badly broken at the corner into two or more pieces: Faulting of crack or joint greater than 1/2"



THE EFFECTS OF UTILITY CUT PATCHING ON PAVEMENT PERFORMANCE IN PHOENIX, ARIZONA

Project 499
City of Phoenix, AZ

7/18/90

ERES International

Table of Contents

Introduction 1

Chapter 1: Pavement Condition Survey and Deflection Testing 2
- Pavement Condition Index Rating 2
  - Selecting and Surveying Representative Test Sections 3
  - Analysis of the PCI Survey Results 3
- Deflection Testing and Analysis of Results 3

Chapter 2: Overlay Design Requirements 5

Chapter 3: Cost Analysis 6
- Method 1 - Non-patched Pavements 6
  - Overlay Cost 6
  - Manhole and Sewer Alignment 7
  - Curb Replacement Costs 7
- Method 1 - Patched Pavements 8
  - Overlay Cost 8
  - Manhole and Sewer Alignment 8
  - Curb Replacement Costs 8
- Method 2 9
  - Overlay Cost 9
  - Milling Costs 9
  - Total Cost 9

Chapter 4: Conclusions 11

References 12

Appendix A A1-A100

Appendix B B1-B50

Appendix C C1-C84

Introduction

This report discusses the results of an investigation conducted by ERES International, Inc. (EI), for the City of Phoenix, to assess the effects of utility cut patching on the pavements' life span, and performance. Fifty street sections, each approximately one half mile long, were selected from the City Center. Two adjacent 150 ft pavement units were selected from each sections 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. Based on the available data, a cost analysis was conducted, to quantify the rehabilitation cost incurred by the city, due to utility cut patching.

Chapter 1: Pavement Distress Condition Survey and Deflection Testing

This chapter presents the results of the pavement distress condition survey and deflection testing conducted to determine the effect of utility cut patching on pavement performance and structural adequacy. The pavement distress condition survey was performed using the Pavement Condition Index (PCI) method. The PCI decrease over time was used to measure the difference in performance between utility patched and non-patched pavements. Deflection testing was conducted using the Falling-Weight-Deflectometer (FWD). The maximum deflection under a normalized load of 9000 lbf was used to compare the structural adequacy of the utility patched and non-patched pavements. A pavement is structurally adequate if it is able to carry traffic safely for the design period.

The PCI and FWD testing procedures are briefly described below and the results presented.

Pavement Condition Index Rating Procedure

The Pavement Condition Index (PCI) survey method was developed by the U.S. Army Corps of Engineers to provide a systematic method of measuring pavement distresses and quantifying their effect on pavement performance. The PCI is a numerical indicator of the pavement condition which ranges from 0 to 100 with 100 being excellent. The PCI is computed based on the amount and severity of the pavement's existing distress. For flexible pavements, nineteen (19) distresses have been identified. Curves have been developed, reflecting the relative effects of each distress on the quality and structural integrity of the pavement and the surface operational condition. The number of penalty points associated with the type and severity of each distress, are called deduct values. Figure 1 summarizes the PCI rating procedure, while the detailed procedure and actual charts are available through the U.S. Army Corps of Engineers, CERL Technical Report M-294 (Ref 1).

Selecting and Surveying Representative Test Sections

The PCI survey was designed to provide a paired experiment of PCI values for patched vs. non-patched pavements. Eleven (11) streets were selected at random from the center the city of Phoenix. Each street was divided into one or more 300 ft. sections. Two adjacent 150 ft. pavement units were selected from each section; one of the units has utility curb patching and the other did not.

The detailed results of the PCI survey are presented in Appendix A, and summarized in Table 1. Inherent in the PCI procedure the fact that patches, regardless of their quality, are points of discontinuity in the pavement structure. Planes of weakness, and soil disturbance are created at the patch edges due to the cutting action. Usually, proper compaction to restore the lost density is not obtained for reasons such as: 1) lack of experienced operators, 2) inadequate compaction machines, 3) inadequate soil moisture etc... Consequently, pavements are penalized based on the patch severity level (e.g. a good patch is rated low severity).

Analysis of the PCI Survey Results

A pavement may be considered failed, when it can no longer be economically maintained without the need for major rehabilitation, such as an overlay. Considering that a typical pavement design life is 20 years, the sections were grouped into families, patched and non-patched, having an age of 20 years or less. The analysis revealed that, for the non-patched areas, a terminal PCI of 69 is obtained at the age of 20 years (see Figure 2). However, the patched sections would be expected to attain such a value in about 15.5 years, therefore shortening the expected pavement life by 4.5 years (see Figure 3). Therefore, to maintain the pavement in economic condition, rehabilitative measures must be undertaken when the PCI reaches the value of 69 which is 20 years for non-patched, and 15.5 years for utility patched pavements. Allowing the pavement to deteriorate beyond this PCI value, would result in a rapid increase in restoration costs. This concept is illustrated in Figure 4, adopted from the report published by the American Public Work Association (Ref 2).

Individual sections PCI values are presented in Table 1. It can be seen that, in general, the patched sections had lower PCI values. This difference is more evident when compared to the average PCI

per street for the patched and non-patched sections. In this case, the PCI values for the patched areas were as much as 22 points lower than the non-patched (see Table 2 & Figure 5), thereby indicating a faster deterioration rate.

Deflection Testing and Analysis of Results

The pavement deflections were measured using an Falling-Weight-Deflectometer. The FWD is a non-destructive testing machine, capable of delivering an impulse load, similar in magnitude and duration to a moving truck wheel load. The pavement's deflections are measured using seven velocity transducers, one of which is located in the center of the load plate (See Figure 6). The operation is controlled by an on-board computer, and the data are stored on a magnetic tape.

Three load levels were used at each test location, 6,000, 9,000, and 15,000 lbs. and, the 9,000 lbf. load was selected as the design load. The testing was performed in the wheel path (i.e., 18" to 24" from the edge of the pavement) at approximately 25 ft. intervals except where patches were encountered. In such a case, five locations were tested, two on the outside boundaries of the patch (PVE), two on the inside edges (PAE), and one in the middle of the patch (PA), (see Figure 7). Detailed NDT data are presented in Appendixes B and C.
The measured deflections are indicative of the pavement strength with lower deflections reflecting a stronger structure. Note that, while bearing in mind the variability in materials and construction, a certain degree of uniformity in the measured deflections is desired, indicating a uniform foundation support for any future strengthening by overlays. Generally, patches have a direct effect on this uniformity, since they are considered points of discontinuity, with adverse effects on future pavement performance. It is doubtful that, even with a structural overlay, the discontinuity effects will be corrected. It is impossible in this case to quantify the exact effects of the patches since they are a function of the patchs' type and size, age relative to the pavement, material used, construction procedure, climate, etc...

The structural indicator for the purpose of this analysis, was the maximum deflection under the load plate (Do). This measure is

capable of providing an assessment of the pavement strength and the approximate remaining life. An increase in the magnitude of the deflections is coupled with an increase in the critical strains and stresses in the pavement's layers, resulting in an accelerated fatigue failure. Hence, the use of structurally designed overlays to reduce the deflections, and extend the life of the pavement.

The data analysis of the deflection data indicated that, on the average, the deflections within and around the patched areas were about 25% greater than the non-patched sections (see Table 3 and Figure 8).

Chapter 2: Overlay Design Requirements

The overlay thickness requirements for each section was determined using the Asphalt Institute method (MS-17)(Ref 3). For the sake of comparison, thicknesses were determined for both, patched and non-patched sections. The maximum deflections produced at the 9000 lbs. load level were used as input to the design. Other required input are:

1. The seasonal adjustment factor, which is the ratio of the deflection taken during the most critical time of the year to that measured at the time of testing. Considering the time of the testing (April, 1990), and the minimal variation in seasons in the Phoenix area, a factor of 1.0 was used.

2. The temperature adjustment factor, used to normalize the measured deflections to 70°F. The mean 5-day temperature was obtain from the "Phoenix Water Conservation & Resources Division" which was used to calculate the adjustment factor for each test section.

3. Traffic counts for the tested sections, obtained from the City of Phoenix, along with a rough estimate of the percent trucks using the streets. For design purposes, it was assumed that 10% of the traffic is trucks, and the traffic growth factor is 2%.

4. Pavement layers thicknesses for each section; for the most part were available or reasonably estimated based on information supplied by the City of Phoenix personnel.

The design deflection used in the analysis is computed using the relation:

$$(Do)_{design} = (X + S) \cdot C \cdot F$$

where

X = Mean pavement deflection, mils.,
S = Standard deviation of deflections, mils.,
C = Seasonal adjustment factor,
F = Temperature adjustment factor.

A computerized version of the Asphalt Institute method (MS-17),

CP-4, was utilized to expedite the design process. The results are shown in Table 4, where it can be seen that, on the average, the patched sections required about an extra 1¼ in. of overlay relative to their non-patched counterparts. The reported answers reflect a 20 year design period.

Chapter 3: Cost Analysis

Based on the results obtained in chapter 2, and considering the direct and indirect costs associated with an overlay, a cost analysis was prepared. Such costs will include manhole and sewer alignment and curb replacement. This approach assumes that no reconstruction will be necessary if the PCI is kept above 69 utilizing properly scheduled maintenance.

The curb reveal is assumed to be 6 inches and the curbing will not be replaced unless future overlay thicknesses exceed this value. Manholes and sewers adjustments will be completed prior to each overlay. Prices may vary with local, contractors and construction procedures. For the sake of illustration some realistic figures, based on national averages, were assumed and summarized as follows:

1. Asphalt patch material cost $38/ton, in place.
2. Asphalt patch material weigh 150 lbs/ft^3.
3. Manhole and sewer cost $2,500/mile.
4. Curbing costs are $147,840/mile, in place.

In addition, the street width was assumed to be 33 ft. wide and, based on the results obtained in chapter 2, an overlay of 2 in. is required for the nonpatched areas, while a 3.2 in. overlay is required for the patched.

Accordingly, the cost of each component can be calculated as follows:

Total Cost = Overlay + Manhole & Sewer + Curb

1. Overlay Cost (Non-patched):

Material cost = Quantity * Cost, therefore, for a 2 in. overlay;

Quantity = Overlay Thick x Lane Width x 5,280 ft/mile
= 2/12 ft. x 33 ft. x 5,280 ft / mile
= 29,040 cu.ft./ mile
= 2,178 tons / mile

Material Cost = 2,178 x $38 / ton

	=	$82,764 / mile
Yearly C	=	Overlay Cost / Design Life
	=	82,764 / 20 years
	=	4,138.2 $ / mile/year

2. Manhole and Sewer Alignment (Non-patched):

Cost = Cost per mile / Design life
= $2,500 / mile / 20 yrs
= $125 / mile / year

3. Curb Replacement Costs (Non-patched):

This cost will be accrued when curbing becomes necessary due to the increased pavement thickness. Assuming that the curb height is 6 inches, the replacement of the curbing will be required approximately, every third overlay, giving a service life of 60 years (assuming each overlay will last 20 years). accordingly, the associated costs are computed as follows:

Curb Cost = Cost per mile / Design life
= $147,840 / mile / (20 yrs. x 3)
= $2,464 / mile / yr.

Therefore, the total yearly cost for a road that is one mile long, 33 ft. wide, and requiring a 2 inch overlay will be:

Total Cost = 4,138.2 + 125 + 2,464 (Nonpatched)
= $6,727.2/mile/yr.

However, patched pavements have a life expectancy of 15.5 years compared to 20 years for the nonpatched. In addition, a patched pavement will require a 3.2 in. overlay, thereby reducing the life of the curbes to about 31 years instead of 60 years. Applying these considerations, the yearly cost of a patched pavement can be computed as follows:

1. Overlay Cost (Patched):

Material cost = Quantity x Cost

Therefore, for a 3.2 in. overlay;

Yearly Cost = 3.2/12 x 33 x 5,280 x .075 x 38 / 15.5 yrs
= $8,543.39/mile/yr.

2. Manhole and Sewer Alignment (Patched)

Cost = $2,500/mile / 15.5 yrs
= $161.29/mile/year

3. Curb Replacement Costs (Patched):

Curb Cost = $147,840/mile / (15.5 yrs. x 2)
= $4,769/mile/yr.

Therefore, the total yearly cost for a patched road that is one mile long, 33 ft. wide, and requiring a 3.2 inch overlay will be:

Total Cost = 8,543.39 + 161.29 + 4,769
(Patched) = $13,473.68/mile/yr.

To assess the city's cost, the total number of lane miles was obtained from the City of Phoenix Streets and Traffic Department, with a guesstimate of the percent patching in the streets. The numbers utilized for this analysis are 872 lane miles with 95% patching, and the average yearly cost is computed as follows:

Total Cost = (# of miles).[%Patch. (13473.68) + %Nonpatch. (6727.2)]
= 872 . [0.95(13473.68) + 0.05(6727.2)]
= $11,454,902/year

Cost to the City = $11,454,902 - (872 x 6727.2)
= $5,588,784/year (6,409 $/yr/mile)

Bear in mind that the above number is based on an approximate street width of 33 ft. and the assumed costs per mile. If different numbers are deemed more feasible, simply follow the outlined steps and substitute the new numbers in the formulae. In addition, to calculate the cost per square yard of patching, use the following relation:

Cost per yd^2
of patching = Total Cost per mile x % Patches per mile

It should be emphasized that the reported figures do not include