AN EVALUATION OF DISTRESS IN ASPHALT PAVEMENTS AND SOME PREVENTIVE MEASURES

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I N T R O D U C T I O N

Over the past 100 years, and in an accelerated fashion in the past 25 years, the USA has developed an extensive road system. The main part of this system is a network of about two million miles of paved roads, that have an obvious impact on the economy, education, recreation, life style and national defense of the country. Realizing the vitality of roads to the country and to the individual, it is a matter of concern that there is a gradual decrease in its percentage of good milage, both rural and urban, as also stated by the Secretary of Kansas Dept. of Transportation during the March, 1985 Annual Transportation Conference at Kansas State University.

> " ---29 percent of the state roads are deteriorating rapidly, and 11 percent have already deteriorated; ---- if nothing is done, 90 percent of the state interstate by 1990 would be classified as deficient---"

As a majority of total milage of roads in this country are asphaltic, the topic of this report is, " AN EVALUATION OF DISTRESS IN ASPHALT PAVEMENTS AND SOME PREVENTIVE MEASURES ".

As a natural phenomenon, any type of road starts wearing out once opened to traffic. The badly deteriorated roads not only cost more to maintain and rehabilitate, they drastically and adversely affect vehicle fuel consumption, operating costs, and traffic delays resulting in significant economic loss as shown in Figure 1 and Table 1.

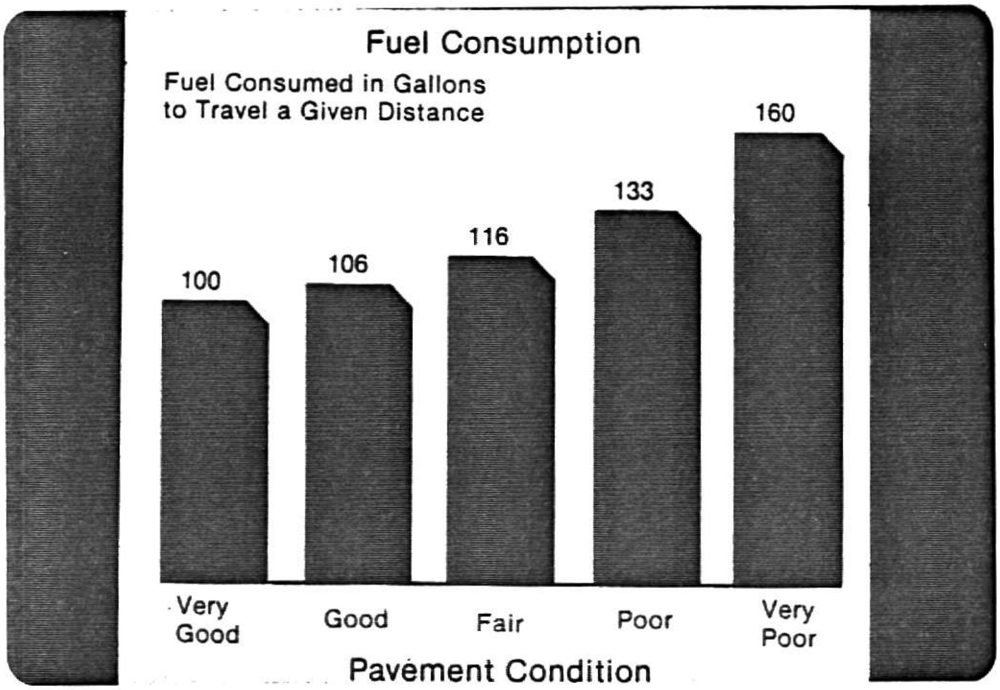
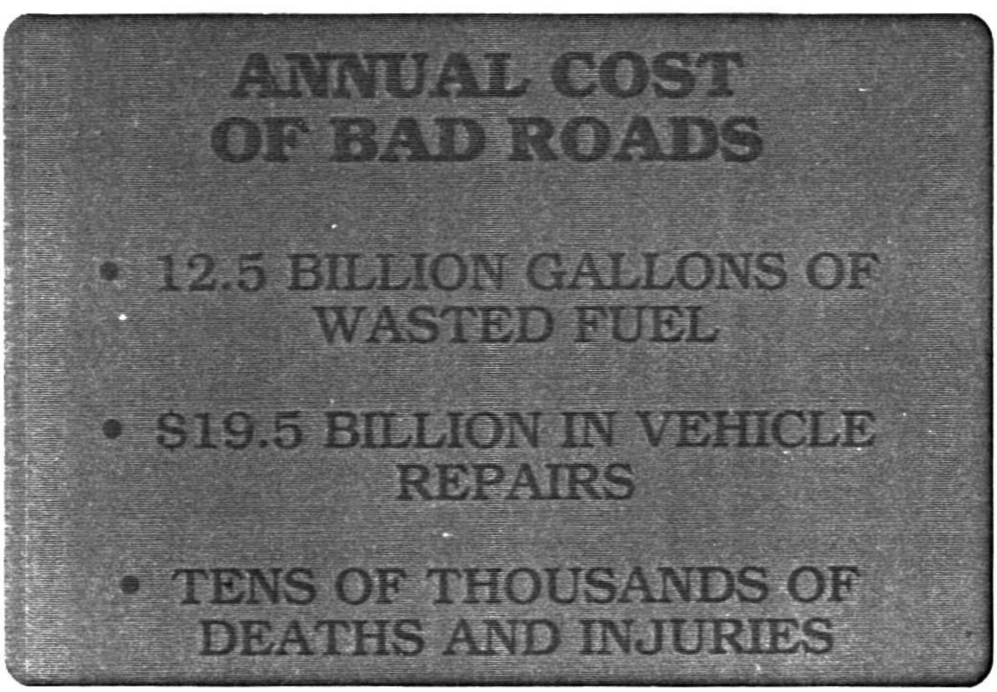


Fig. 1. FUEL CONSUMPTION. (From The Asphalt Institute, 1983.)

Table 1. (from The Asphalt Institute, 1983.)



The key to good roads is timely maintenance, of which the initial step is to identify which pavements need immediate attention for maintenance purposes, and then to arrange a program of preventive measures according to their condition. The condition of the pavement is defined as a function of quality over its design life, which is the number of years a pavement is designed to serve the forecasted traffic identified at the time of design. The life cycle of a typical pavement is shown in Figure 2, where the quality of the pavement shown on the ordinate is defined as its ability to serve high speed, high volume, mixed traffic in its existing condition. It is basically related to the Present Serviceability Index (PSI) that provides an estimate of the subjective rating of the travelling public about its quality.

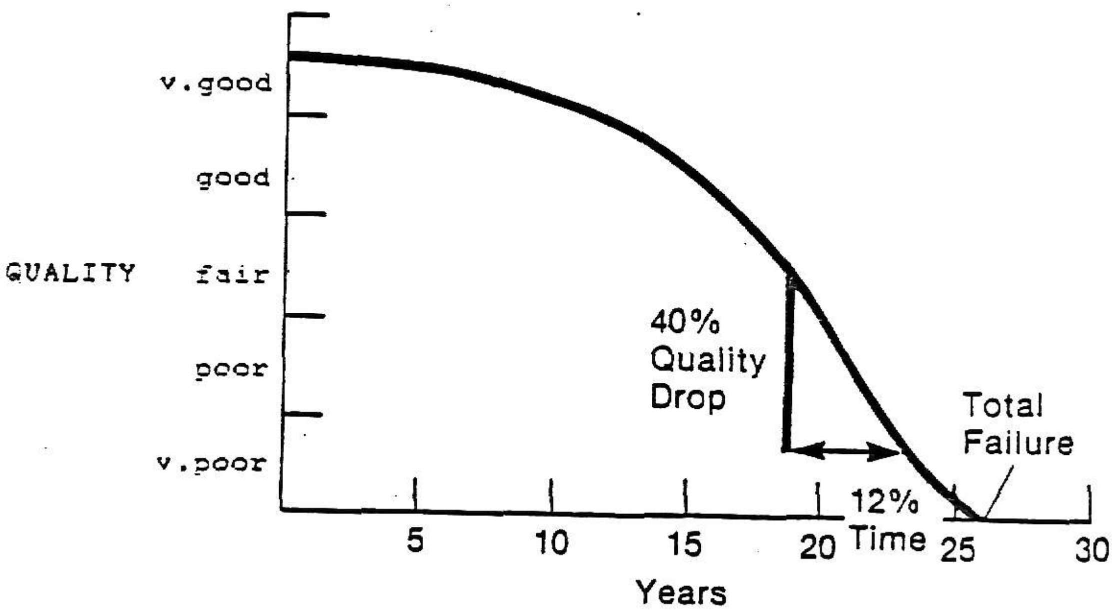


Fig. 2. PAVEMENT LIFE. (From Yoder and Witczak, 1975, and The Asphalt Institute, 1983.)

In a design life of twenty years, change in pavement condition during the first 8 to 10 years is minimal. Only after 15 to 16 years does a typical pavement cross the line from good to fair, having used up 75 percent of its design life. To return the pavement to good or new-like conditions, maintenance is required. However if maintenance is deferred at this stage, deterioration accelerates, the cracks become potholes and surface irregularities degenerate into rough surfaces, and within a short time the pavement condition drops another 40 percent from fair to poor and very poor, and then has to be re-constructed. This means that each dollar saved by deferring rehablitation needed between the 15th. and 17th. year may cost five to six dollars in a short time of one to two years. Thus, timely maintenance not only saves money in the long run, it also extends the design life of the pavement as shown in Figure 3.

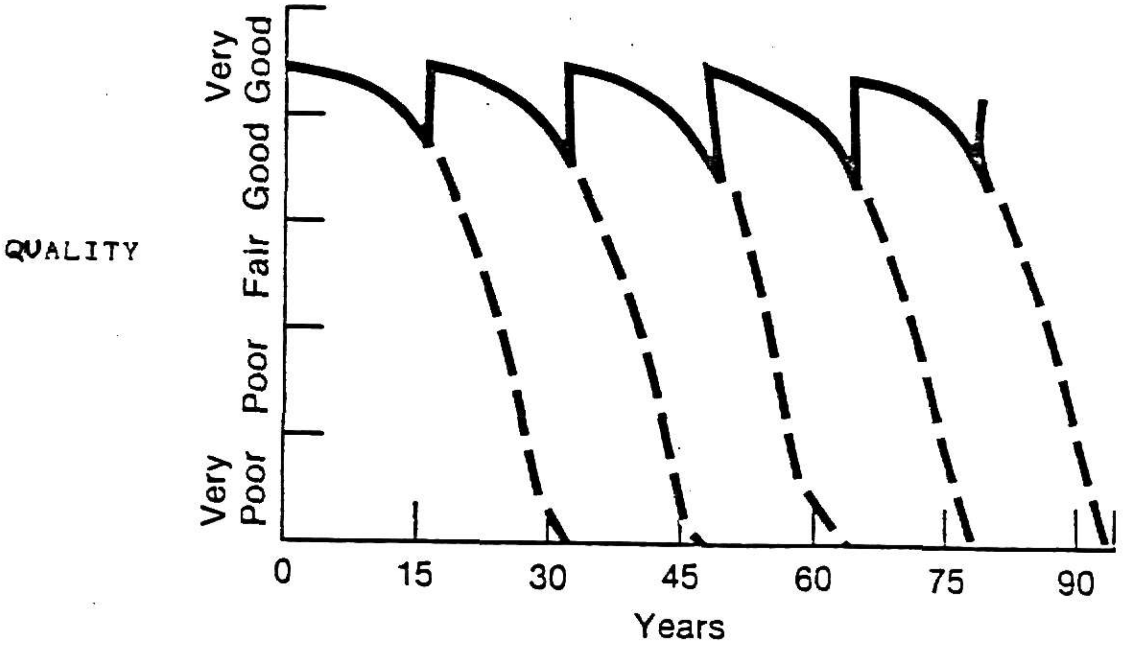


FIG. 3. TIMELY MAINTENANCE. (From Yoder and Witczak, 1975.)

A PAVEMENT MAINTENANCE PROGRAM

There are two types of maintenance activities:

-- preventive maintenance,

-- rehabilitative maintenance.

Preventive maintenance are the frequent measures taken by a road department to keep the pavement system functioning as intended and prevent failures known as " functional failures " of the pavement.

Functional failure is usually defined from the subjective rating of the pavement, and / or by means of deflection measurements, further illustrated in the section, " Roughness or Deflection Survey ", that follows. The replacing of isolated failures, filling of cracks and improving drainage are examples of preventive maintenance operations, which if not carried out in a timely manner, result in structural failures of pavement.

Rehabilitative maintenance activities are those actions that must be taken when the pavement system, or portion of the system, must either be upgraded to accomodate heavier traffic or the condition of the pavement has reached from medium to severe type of "structural failure", and major action must be taken.

Structural failure is defined from identification of distress in the pavement which is the result of a detailed examination of different types of failures as described in the following sections.

D I S T R E S S   I D E N T I F I C A T I O N

One of the basic measures of identifying structurally failed and also funtionally failed pavements is their "existing distress". There are various kinds of defects and different severity levels for each distress type which, when known, provide great insight into pavement deterioration. Based on measurement of distress surveys and other informations such as roughness, and present serviceability index, a maintenance program can be selected. The distress survey is performed first, followed by a roughness survey and evaluation of serviceability.

D I S T R E S S   S U R V E Y

A previous study (1) showed that the distress survey or categorization of distress into distinct types is controversial and variable between agencies and even between individuals within the same agency. The reason for this variability is variable design methods, different climatic conditions, different soil types, and various approaches towards distress diagnosis.

Significant progress has been made in the standardization of distress identification (1) (3) (5) (9). To properly identify distress, three factors must be considered:

1. TYPE: based on similar mechanisms or cause of occurance.
2. SEVERITY: a given distress type can take place on a variety of severity conditions.
3. AMOUNT: the quantity and severity of each type is measured.

The description of each type of distress, its cause and measurements are described in the following pages. Severity of distress has been divided into three levels. These are somewhat arbitrary groupings, but generally provide distinct categories of the level of deterioration within the same distress type. In addition, the photographs of the distress showing various levels of severity are an indispensible part of the identification process. The following are some of the distress descriptions. (2) (3) (5) (9).

T Y P E [1] S U R F A C E C R A C K I N G

This is mostly considered a structural failure.

Name of distress: FATIGUE OR ALLIGATOR CRACKING.

Description and cause: Fatigue cracking, shown in Figure 4, is a series of interconnecting cracks caused by fatigue failure of the asphalt concrete surface or stabilized base under repeated traffic loading. The cracking initiates at the bottom of the asphalt surface layer or the stabilized base where the tensile stress and strain is highest under a wheel load as shown in Figure 5. The cracks propagate to the surface initially as one or more parallel cracks. After repeated traffic loadings, the cracks connect, forming many sided, sharp-angled pieces that develop a pattern resembling the skin of an alligator and hence is called alligator cracking. This type of cracking is considered as a major structrual failure.

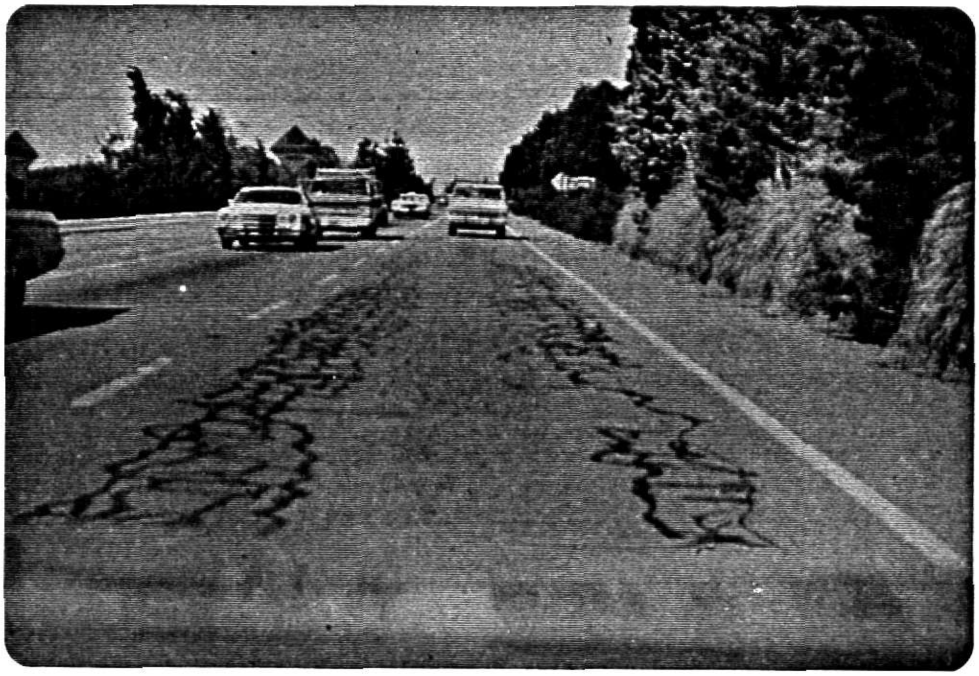


Fig. 4. FATIGUE OR ALLIGATOR CRACKING. (From U S Dept. of Transportation and Federal Highway Administration, 1984.)

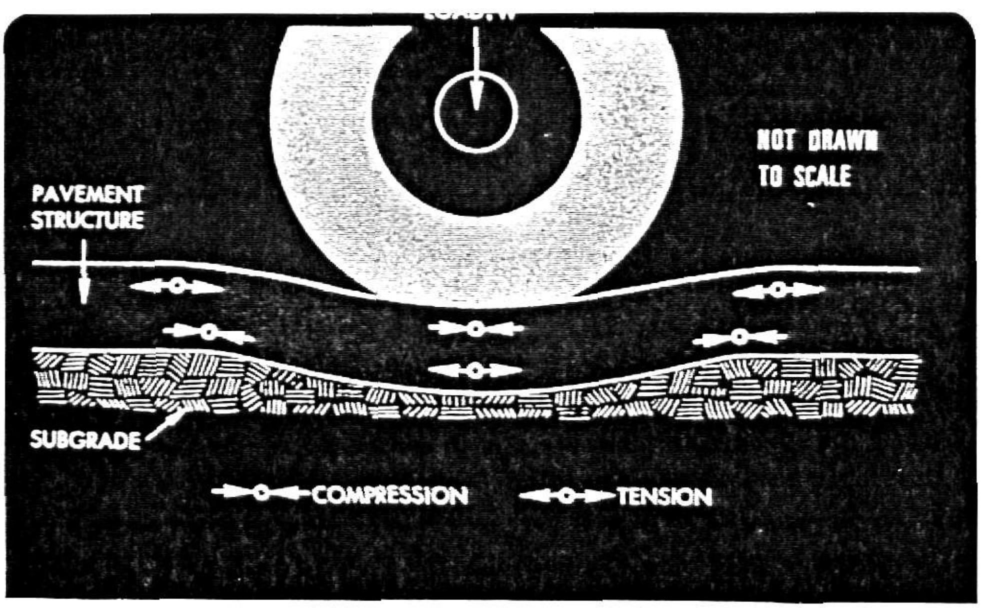


Fig. 5. MAXIMUM TENSION UNDER THE WHEEL LOAD.

(From The Asphalt Institute, 1983.)

Severity Levels:

Low--- Longitudinally, somewhat connected minor cracks run parallel to each other. The cracks are not spalled and initially there may be a single, or just a few, crack(s) in the wheel path.

Medium--- Further development of low severity alligator cracking into a pattern of pieces formed by connected cracks that may be lightly surface spalled. (See Figure 6.)

High--- Medium alligator cracking that has progressed so that pieces are more severely spalled at the edges and loosened to move under the traffic. (See Figure 7.)

Measurement (Amount): Fatigue or Alligator cracking is measured in square feet or square meter of the affected surface area. The major difficulty in measuring this type of distress is that many times two or three levels of severity exist within one distress area. If these portions can be easily distinguished from each other, these are measured and recorded separately. However if the different levels of severity cannot be easily divided, the entire area should be rated at the highest severity level present.

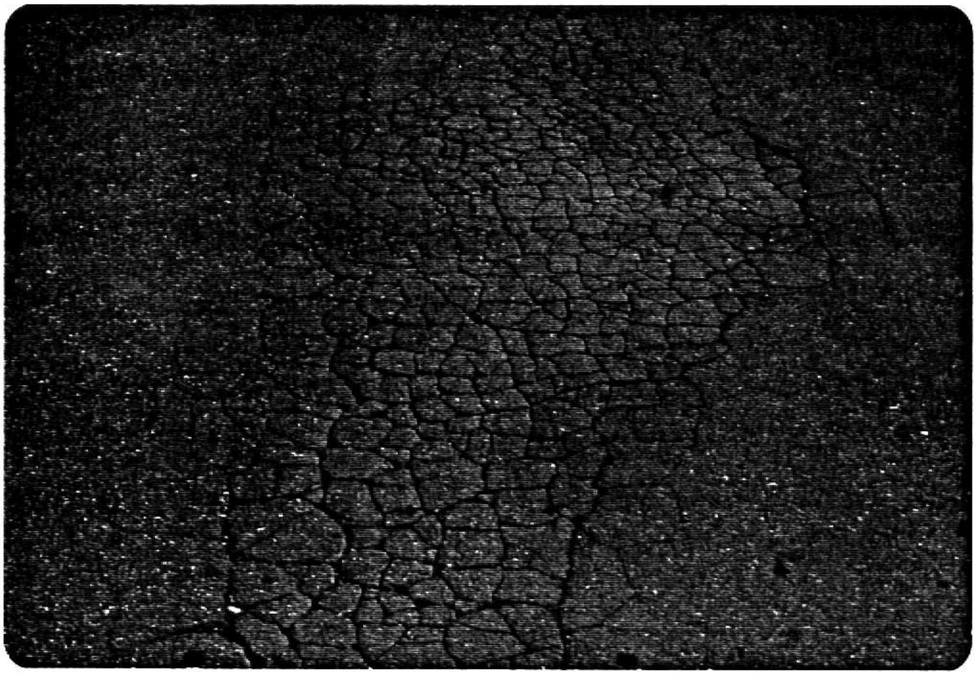


Fig. 6. MEDIUM SEVERITY FATIGUE CRACKING. (From U S Dept. of Transportation and Federal Highway Administration, 1984.)

Fig. 7. HIGH SEVERITY FATIGUE CRACKING. (From U S Dept. of Transportation and Federal Highway Administration, 1984.)

Name of distress: LONGITUDANAL, LANE JOINT, EDGE and TRANSVERSE CRACKING.

Description and cause: Longitudnal cracks are parallel to the pavement centerline or laydown direction, whereas transverse cracks are perpendicular to it, as shown in Figure 8. They may be caused by poorly constructed paving lane joints or a weak seam between the pavement and the shoulder in the case of edge cracking, as shown in Figure 9.

Severity Levels:

Low: ---- Cracks have either minor spalling or no spalling and width of the cracks is not more than 1/4 of an inch as shown in Figure 10. No significant bump occurs when a vehicle crosses the crack.

Medium---- One of the following conditions exists: (i) cracks are moderately spalled; (ii) cracks are not spalled or have minor spalling but the previous sealing is such that water can freely infiltrate; (iii) crack width is greater than 1/4 of an inch;(iv) Low severity random cracking exists near the crack or at corners of cracks; (v) the crack causes a significant bump to a vehicle. (See Figure 11.)

High----- (i) Cracks are severely spalled and/or medium to high random cracking exists near the crack or at corners of intersecting cracks; (ii) crack width is greater than 1/2 inch; (iii) the crack causes a severe bump to a vehicle. (See Figure 12.)

Fig. 8. LONGITUDNAL AND TRANSVERSE CRACK. (From U S Dept. of Transportation and Federal Highway Administration 1984.)

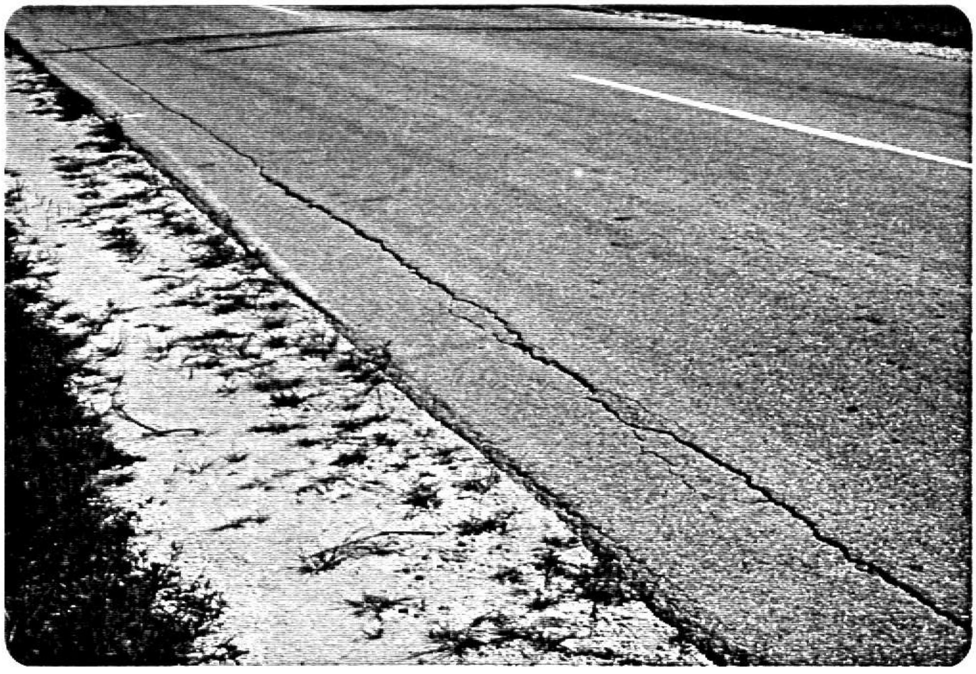


Fig. 9. EDGE CRACKING. (From The Asphalt Institute, 1983.)

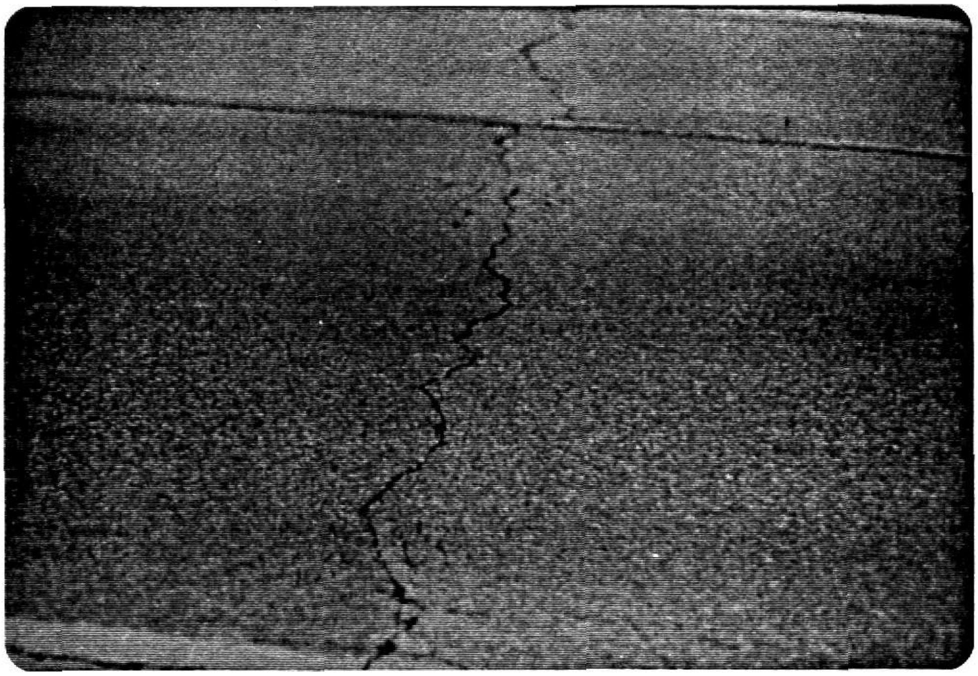


Fig. 10. LOW SEVERITY TRANSVERSE CRACK. (From U S Dept. of Transportation and Federal Highway Administratation. 1984.)

Fig. 11. MEDIUM SEVERITY TRANSVERSE CRACK.

(From The Asphalt Institute. 1983.)

Measurement (Amount): The longitudnal cracks are measured in linear feet or linear meters. The length and severity of each crack is identified and recorded. The vehicle used to determine bump severity is a mid to full sedan weighing 3000 to 3500 lb. moving over the inspection section at the posted speed.

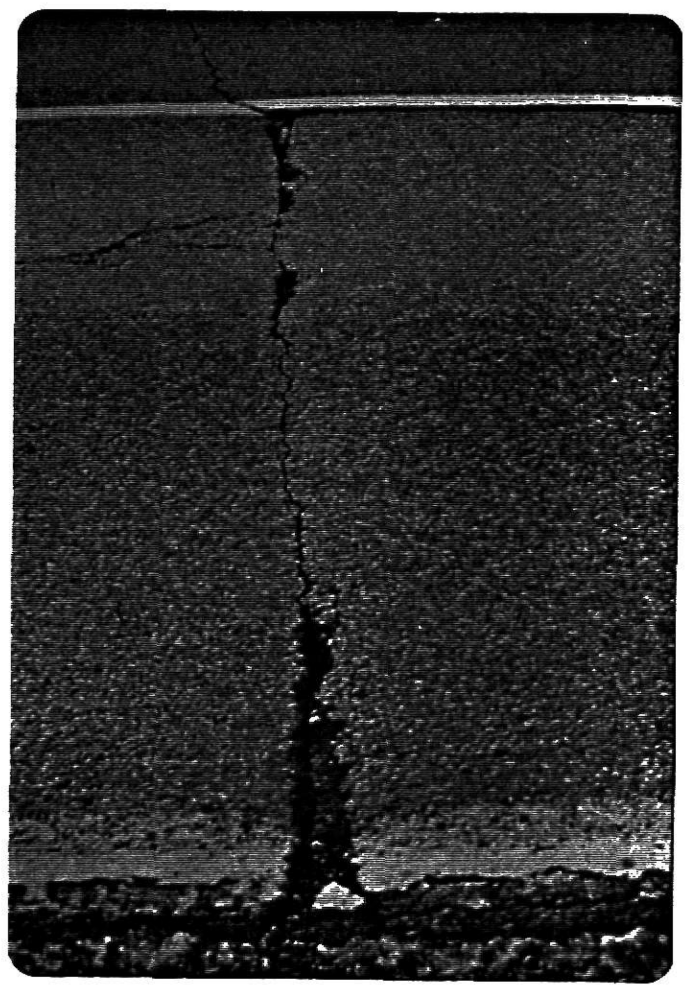


Fig.12. HIGH SEVERITY TRANSVERSE CRACK (From U S Dept. of Transportation and Federal Highway Administration, 1984.)

Name of distress: SLIPPAGE AND REFLECTION CRACKS.

Description and cause: Slippage cracks are crescent shaped cracks that usually point in the direction of the thrust of the wheel on the pavement surface as shown in Figure 13; however, they do not always point in the direction of the traffic. For example if brakes are applied down a hill the thrust of the wheels is reversed. Slippage occuring in this circumstance will result in cracks pointing uphill. The cause of such cracks is lack of good bond between the surface layer and the course beneath it. The lack of bond may be due to dust, oil, water or other non adhesive material between the two courses.

Reflection cracks are in asphalt overlays which reflect the crack pattern in the pavement structure underneath as shown in Figure 14. The pattern may be longitudnal, transverse, diagonal or block in the asphalt overlays on a portland cement layer or on an asphalt layer. They are most severe whenever cracks in the old pavement have not been properly repaired before construction of the overlay. Reflection cracks are caused by a vertical or horizontal movement in the pavement beneath the overlay, brought on by expansion and contraction with temperature or moisture changes. They may be caused by traffic or earth movements and / or by loss of moisture in subgrade with high clay contents.

Measurement (Amount): The level of severity and method of measurement is same as explained for other previously mentioned distress.

Fig. 13. SLIPPAGE CRACK. (From The Asphalt Institute, 1983.)

Fig. 14. REFLECTION CRACK. (From U S Dept. of Transportation and Federal Highway Administration, 1984.)

TYPE [II] SURFACE DISTORTION

This is mostly considered both functional and structural failure.

Name of distress: R U T T I N G.

Description and cause: A rut is a surface depression in the wheel path. Pavement uplift may occur along the sides of the rut, as shown in Figure 15. Rutting stems from a permanent deformation in any of the pavement layers or subgrade, usually caused by consolidation or lateral movement of the materials due to traffic loads. Rutting may also be caused by plastic movement in the mix in hot weather, or inadequate compaction during construction. Significant rutting can lead to major structural failure of the pavement and hydroplaning potential.

Measurement (Amount): Rutting is measured in square feet or square meters of surface area and its severity is determined by mean depth of rut. To determine the mean rut depth, a four feet straight edge is laid across the rut and maximum depth is measured. The mean depth should be computed from measurements taken every 20 feet along the length of the rut as in Table 2.

Table 2. SEVERITY AND RUT DEPTH. (From U S Dept. of Transportation and Federal Highway Administration. 1984.)

Severity Level	Mean Rut Depth Criteria
Low	1/4 ---- 1/2 inch.
Medium	>1/2 --- 1 inch.
High	> 1 inch.

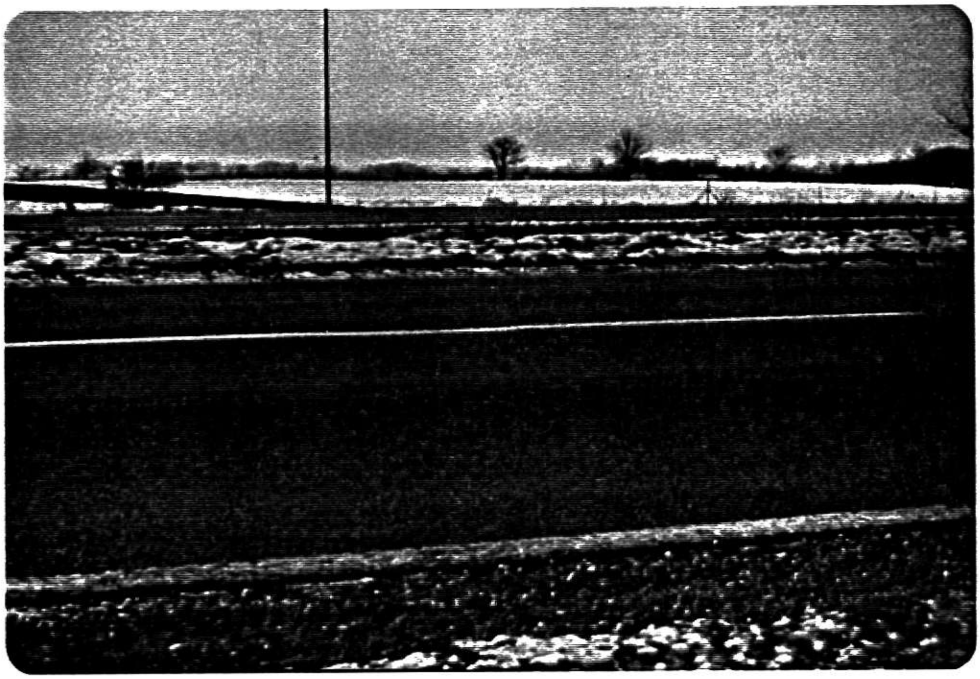


Fig. 15 RUTTING IN THE WHEEL PATH. (From U S Dept. of Transportation and Federal Highway Administration, 1984.)

Name of distress: SHOVING, CORRUGATION, AND DEPRESSION.

Description and cause: Shoving is a condition where localized pavement surface areas have elevations slightly lower than those of the surrounded pavements. In many instances, light shoving is not noticeable until after a rain, when ponding water creates bird bath areas as shown in Figure 16. Shoving is caused by settlement of the foundation soil, which can be a result of inadequate compaction during costruction.

Corrugation is shown in Figure 17. It is sometimes called washboarding and is a form of plastic movement typified by ripples across the asphalt pavement surface. The cause may be lack of stability in the mix which was too rich in asphalt or contains too soft an asphalt cement, or has a high proportion of fine which may be round and smooth in texture. The other type of corrugations or depressions may be due to a utility cut caused by lack of adequate compaction of backfill or upheavals caused by the swelling affect of moisture on expansive soils. Frost heaves are examples of upheavals as shown in Figure 18. The shoving, corrugations and upheavals are a source of roughness. The consequence is a fuctional failure, and when filled with water to a sufficient depth could cause hydroplaning of vehicles.

Severity Levels:

Low: Depressions or upheavals cause some bounce of the vehicle which causes no discomfort.

Medium: Depressions or upheavals cause significant bounce of the vehicle which causes some discomfort.

High: Depressions or upheavals showing excessive bounce of the vehicle which causes substancial discomfort and/or vehicle damage requiring a reduction in speed for safety.

Measurement (Amount): The depressions or upheavals are measured in square feet or square meters in each inspection unit. Each of the distress is rated according to its level of severity. The severity is measured by riding in a mid to full-size sedan weighing 3000 to 3500 lb. over the pavement inspection section at the posted speed limit.

Fig. 16. SHOVING, BIRDBATH. (From The Asphalt Institute, 1983.)

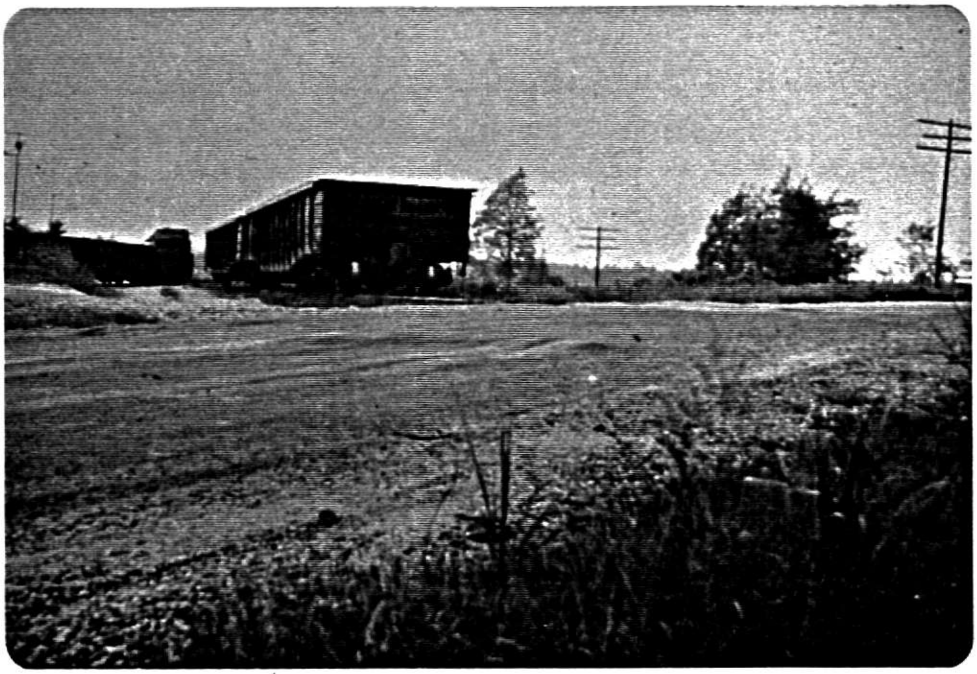


Fig. 17. CORRUGATION. (From U S Dept. of Transportation and Federal Highway Administration, 1984.)

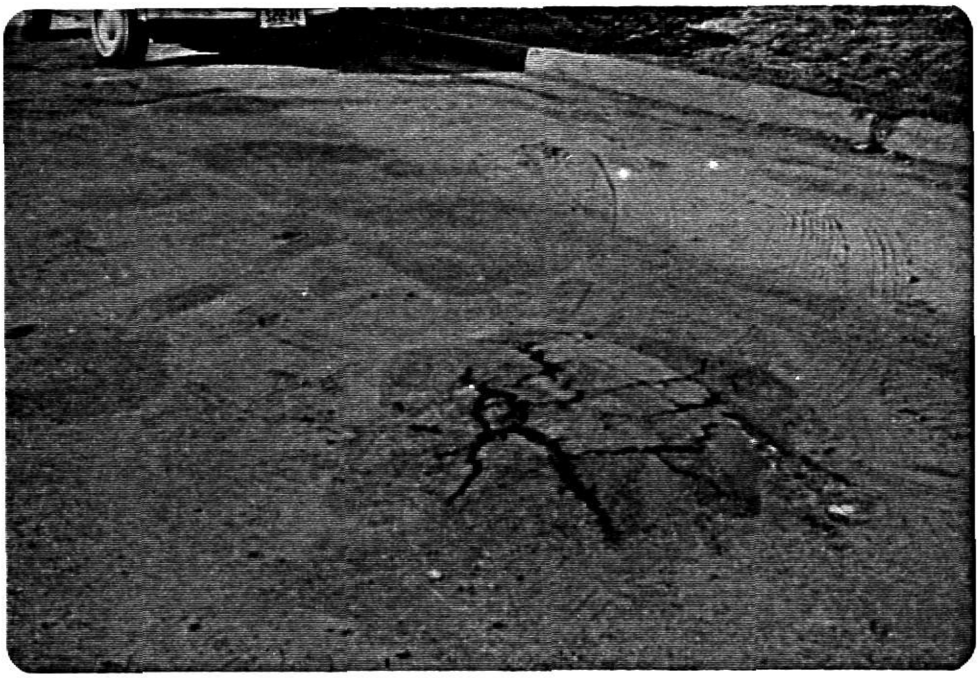


Fig. 18. UPHEAVAL. (From The Asphalt Institute, 1983.)

TYPE [III] SURFACE DISINTEGRATION

This is mostly considered as structural failure.

Name of distress: POTHOLES, RAVELING.

Description and cause: Potholes are various sizes of bowl-shaped holes in pavements resulting from localized disintegration as shown in Figure 19. The cause may be: (i) pavements that have insufficient thickness to support traffic during winter/spring thaw cycles without localized failures; (ii) freezing and thawing of the base or subgrade; (iii) poor drainage which will usually cause failure in combination with thin pavements but can also affect thick pavements and new overlays; (iv) failures at utility trenches; and (v) miscellaneous paving defects and cracks left unmaintained or unsealed from water intrusion.

Raveling is the progressive separation of aggregate particles in a pavement from the surface downward or from the edges inward as shown in Figure 20. Usually the fine aggregate comes out first and leaves little "pock marks" on the pavement surface. As the errosion continues, larger and larger particles are broken free and the pavement soon has a rough and jagged appearance, typical of surface errosion. The cause of raveling is lack of compaction, construction of a thin layer during cold weather, dirty or disintegrated aggregates in the mix, too little asphalt in the mix, or overheating of the asphalt in the mixing plant.
The rate of severity for raveling and potholes is obtained in one of the ways as explained in other above-mentined distress types.

Measurement (Amount): This type of distress is measured in square meter or square feet in each inspection unit.

Fig. 19. A POTHOLE. (From The Asphalt Institute, 1983.)

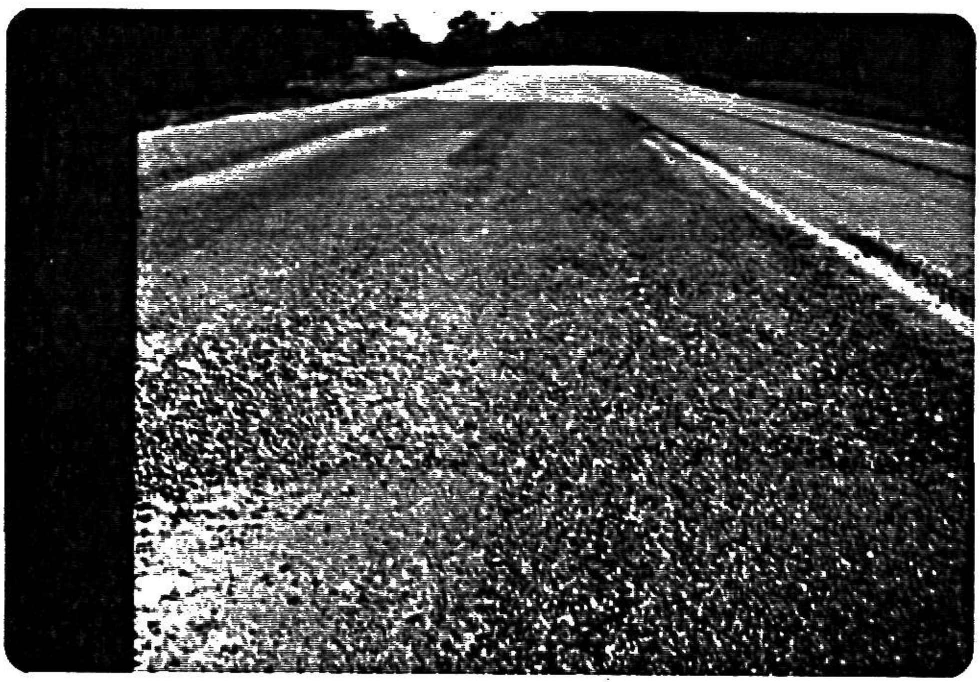


Fig. 20. RAVELING. (From U S Dept. of Transportation and Federal Highway Administration, 1984.)

T Y P E [IV] S K I D H A Z A R A D

This is mostly a functional failure.

Name of distress: ASPHALT BLEEDING AND POLISHED AGGREGATES.

Description and cause: Bleeding or flushing is the upward movement of asphalt in an asphalt pavement resulting in the formation of a film of asphalt on the surface. The cause of bleeding, which usually occurs in hot weather, is too much asphalt in one or more pavement courses. This can result from an improperly constructed seal coat, too rich a mix, and / or too heavy a prime or tack coat. Also, traffic may cause added compression of a pavement containing too much asphalt, forcing it to the surface. (See Figure 21.)

Polished aggregate are aggregate particles in the surface of a pavement that have been polished smooth. This includes both naturally smooth uncrushed gravels and crushed rock that wear down quickly under the action of traffic. These polished aggregates are slippery when wet thus adding to the skid hazard. (See Figure 22.)

Severity level for bleeding.

Low: Asphalt is barely noticeable in its covering of aggregates.

Medium: Asphalt is covering large areas of aggregates.

High: Asphalt is totally covering the aggregate.

Measurement: It is done in square meter or square feet over the inspection area.

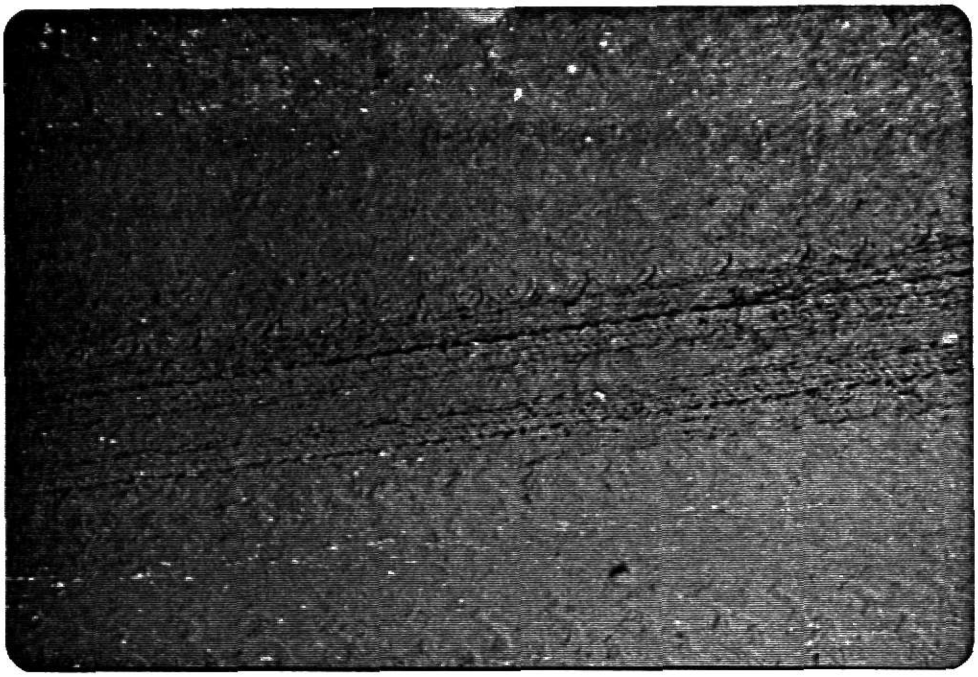


Fig. 21. BLEEDING OF ASPHALT. (From U S Dept. of Transportation and Federal Highway Administration, 1984.)

Fig. 22. POLISHED AGGREGATE. (From U S Dept. of Transportation and Federal Highway Administration, 1984.)

E V A L U A T I O N   O F
T H E   D I S T R E S S   D A T A

The distress information for the entire project is recorded on data sheets after measurements and photographs are taken for development of a maintenance program. The information is used in the following ways:

* Quantity of repair by identification of structural failures and or functional failures is determined and increased by 10 to 20 percent to account for future deterioration before actual maintenance begins on the road.

* An overall examination of the data will indicate if there are significantly different areas of pavement condition along the project. For example a change in subgrade, traffic, or materials may result in a significant change in distress occurance. On multiple lanes the inner lanes show significantly less distress occurance (or at least low severity level). Thus the maintenance design may be varied along the project or across lanes to reduce costs.

* The data provides documentation of the condition of the existing pavement before a maintenance project is undertaken and is useful in evaluation of the performance of the pavement after the maintenance is completed.

* The distress data provides valuable insight into the reasons and mechanisms of pavement deterioration. As a first evaluation the distress can be separated into two general categories:

(i) Primarily load caused, (ii) primarily material and climate caused, or caused by combination of load, material and climate. Table 3 shows an approximate breakdown of these categories.

Table 3. GENERAL CATEGORIZATION OF ASPHALT PAVEMENT DISTRESS. (From US Dept. of Transportation and Federal Highway Administration, 1984.)

DISTRESS TYPE	PRIMARILY TRAFFIC LOAD	PRIMARILY CLIMATE/MATRL.
ALLIGATOR OR FATIGUE CRACKING	*	
LONGITUDANAL & TRANSVERSE CRACKING		*
SLIPPAGE & REFLECTION CRACKING		*
RUTTING	*	*
CORRUGATION, UPHEAVAL & SHOVING		*
POTHOLES	*	
RAVELING	*	*
BLEEDING		*
POLISHED AGGREGATES	*	

* The distress affects roughness and hence provides a basis for functional rating called the Present Serviceability Rating or the users' response. Furthermore the distress data with the roughness information enables the computation of the " distress index " called the PRESENT SERVICEABILITY INDEX (explained in the following sections), which gives an overall assesement of the pavement condition and is used to evaluate the need for maintenance works.

R O U G H N E S S   S U R V E Y

Roughness is defined as irregularities in the pavement surface that adversely affect riding quality, safety and vehicle maintenance cost and cause mostly functional type of failures, which with the passage of time, generate into structural failures as described earlier. Roughness is caused by surface irregularities that are built into a pavement during construction or develop after construction due to traffic, climate and other factors.

The purpose for roughness measurement is to provide an index of the user response to the condition of the pavement that helps to justify the maintenance work. The PRESENT SERVICEABILITY INDEX (P S I) can be computed from the roughness data as described later. The overall benefits of the maintenance work to the user can also be determined by measuring the roughness before and after the work. There are various types of roughness measuring equipment available, like the B P R (Bureau Of Public Roads) Roughometer, or the PCA (Portland Cement Association) Roadmeter. The BPR roughometer as shown in Figure 23, measures the cumulative movements of a wheel mounted on a standardized single wheel trailer (data is recorded in terms of inches per mile), and the roadmeter as the one shown in Figure 24 measures the vertical movements of the instrumented rear axle of an automobile. It is important to use the same type of equipment for the survey of the same project.

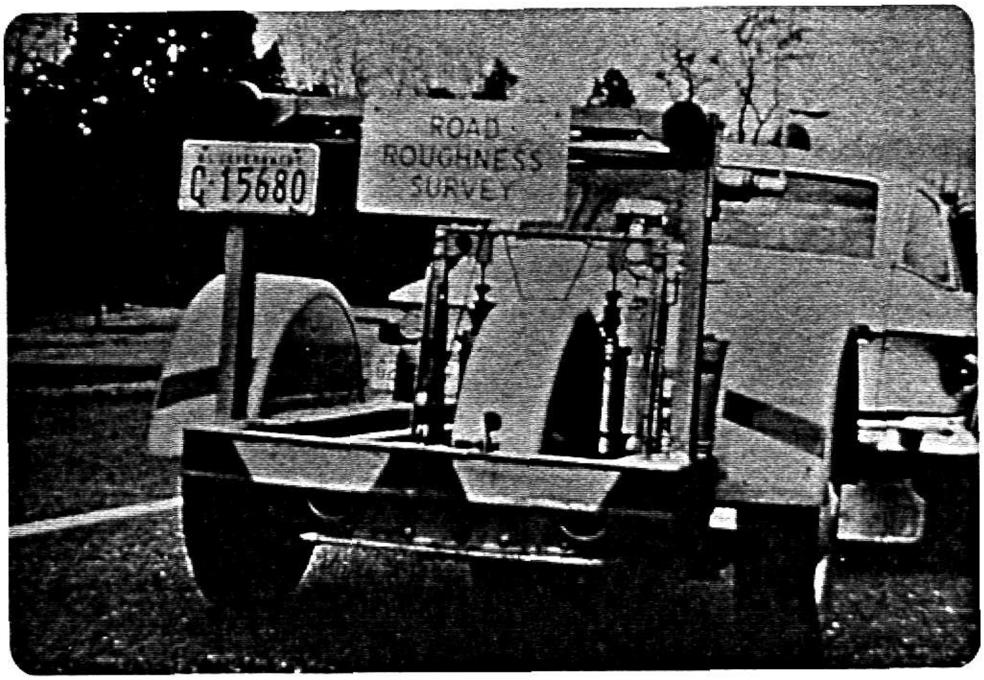


Fig. 23. A ROUGHOMETER. (From U S Dept. of Transportation and Federal Highway Administration, 1984.)

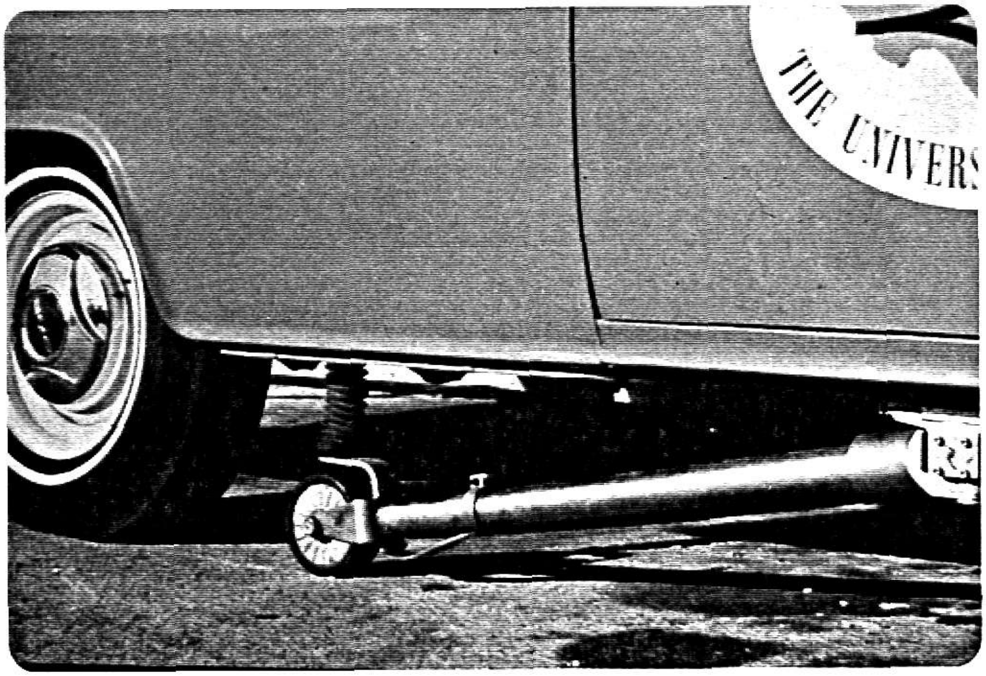


Fig. 24. A ROADMETER. (From U S Dept. of Transportation and Federal Highway Administration, 1984.)

S E R V I C E A B I L I T Y (1) (6) (11)

After the identification and measurement of distress and roughness or slope variance, the Present Serviceability Index is calculated from the following AASHTO Road Test Regression Equation for flexible pavements. It contains both distress and roughness terms.

$$PSI = 5.03 - 1.91 \log (1 + SV) - 1.38 (RD)^{2} - 0.01 (C+P)^{1/2}.$$

where:

SV = Slope Variance (statistics derived from roughness data).

RD = Mean Rut Depth, inches.

C = Alligator Cracking, $Ft.^2 / 1000\ Ft.^2$

P = Potholes or other Patching, $FT.^2 / 1000\ Ft.^2$

The P S I as explained earlier, is basically an index that provides an estimate of the subjective rating of the travelling public, relative to the pavement condition. Thus, it is an estimate of the user as to the ability of the pavement to serve high-speed and high-volume mixed traffic in its existing. Its value and subjective rating zones are in Table 4.

Table 4. SUBJECTIVE RATING ZONE. (From Yoder and Witczak, 1975.)

0----1	Very Poor.
1----2	Poor.
2----3	Fair.
3----4	Good.
4----5	Very Good.

E V A L U A T I O N   O F   S E R V I C E A B I L I T Y

Based on user response, the values of P S I given in Table 5 are generally considered critical and establish needs of maintenance work.

Table 5. CRITICAL VALUES OF PSI.(From U S Dept. of Transportation and Federal Highway Administration, 1984.)

AVERAGE DAILY TRAFFIC	Critical P S I
High Traffic Volume	
ADT ≥ 10000	3.0 -- 3.5
Medium Traffic Volume	
ADT = 3000 to 10000	2.5 -- 3.0
Low Traffic Volume	
ADT < 3000	2.0 -- 2.5

The ready use of information about distress, roughness, and present serviceability index is further enhanced by storing data on a computer software program that has multi selective retrieval capabilities.

DEVELOPMENT OF A PAVEMENT RATING SYSTEM (3) (5) (6) (9)

When basing a maintenance program from the data obtained by distress identification, roughness survey and measurements by the roughometer or roadmeter equipment, it becomes difficult or uneconomical to obtain adequate survery data to make a decision at a city or county level. It is difficult to determine what roads or streets should get what type of maintenance because of low budgets for maintenance projects as well as political reasons. Some factors complicating the decisions are the identification of a variety of pavement distress, some serious and others insignificant, shortage of qualified survey crew and limited time. This is true for the City of Manhattan, where the Director of Public Works is of the opinion that instead of spending money on performing extensive distress surveys and measuring the roughness, the same amount of money could be utilized in maintenance works which come up on routine basis or on users' demands.

Considering the problems faced at the small City level, this study proposes a short and economical method, for pavement rating or condition survey, which may be used by a qualified person to determine the deficiencies in the various portions of the city streets or county roads. The gradation of the street system is done by inspecting the pavement, as any distress will be reflected in the surface in the form of cracking or rutting and so on. The observation of the pavement, under the loads that it carries, will provide data on the type of maintenance required.

The form in Table 6 represents use of this method.

Table 6. PAVEMENT RATING OR CONDITION FORM. (LOW TRAFFIC VOLUME)

LOCATION____DATE___________

TYPE	DISTRESS	PAVEMENT CONDITION RATING		
		0--1.7	1.8--3.5	3.6--5
SURFACE CRACKING	ALLIGATOR			
	LONGITUDANAL			
	TRANSVERSE			
	REFLECTION			
	SLIPPAGE			
SURFACE DISTORTION	RUTTING			
	SHOVING, CORRUGATION			
	FROST HEAVE			
SURFACE DEFECTS	POTHOLES			
	RAVELING			
	BLEEDING			
	POLISHED AGG.			

TOTAL SCORE :-------------------------------------

INTERPRETING THE PAVEMENT RATING

0~~~~~~~~~~~~~~~~~~~~20-------------------30- - - - - - - - - - -

RECONSTRUCTION SURFACE RESTORATION ROUTINE MAINTENANCE

PROCEDURE OF RATING

1. An effective way of inspecting a pavement will be, first, to drive slowly over the inspection area of the road to get an overall impression of its condition.

2. Then make a thorough inspection of the pavement going block-wise as the coverage unit per form, keeping in mind the following terms as refered to in the " distress survey ".

   (i) pavement is rated within good condition when the distress severity level is "low".

   (ii) pavement is rated within fair condition when the distress severity level is "medium".

   (iii) pavement is rated within poor condition when the distress severity level is "high".

3. Since the system is based on judgement, or the subjective feeling of the inspecting person, better results should be obtained when two or more experienced individuals independently rate the pavement and the results are treated statistically.

4. After the inspection is complete, the rating form is filled out for each block. The coverage unit may be increased if pavement condition is found to be *uniform*, i.e. one form for several blocks or decreased for sections of severe distress of less than one block.

5. The interpretation of the overall, averaged sum of the rating is as follows:

Routine Maintenance (Pavement rated above 30) Pavement is in better than average condition with no conspicuous evidence of deformation or incipient failures and few, if any, longitudnal, transverse, slippage, or other types of cracks exist. All existing defects are to be maintained under routine maintenance.

Surface Restoration (Pavement rated 20 to 30) Pavement with higher percentage of longitudnal, or other pattern of medium to high severity cracking, defects such as raveling or a weathered surface, and deformations by rutting and corrugations are observed over a larger part of the inspection area. A surface restoration is recommended.

Reconstruction (Pavement rated below 20) Pavement has severe permanent deformation, such as rutting, shear failure, heave or ravelling, high severity cracking and evidence of intrusion of surface water into the subsurface layer. Reconstruction of such a section is desireable.

6. The information so collected for each street may be recorded on forms, files, maps and video tapes. The rating is updated at a predecided interval of time. A city street map is used for marking the pavement condition using colored pins, which in turn follow the above mentioned interpretations.

7. The Figure 25 illustrates the suggested essential elements of a network management system emphasizing the activities concerned with maintenance, when data is collected and recorded.

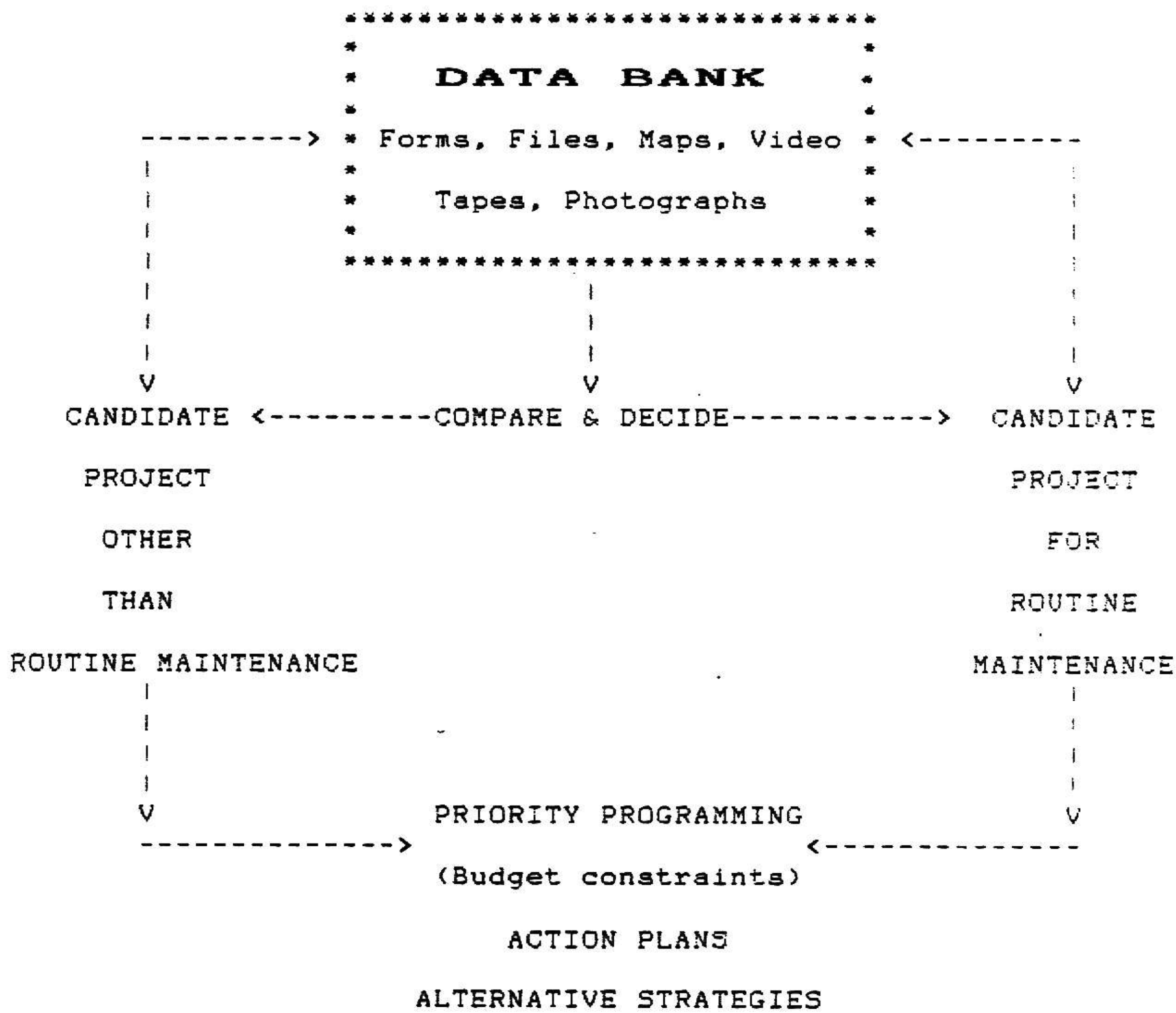


Fig. 25. NETWORK MANAGEMENT SYSTEM.

(From Ralph, Haas and Hudson, 1978.)

E X A M P L E   R A T I N G

Some of the Manhattan streets, as shown in dark in Figure 26, are rated using the form in Table 6 , as an example. A detailed view of each block of 3 rd. Street is shown in Figure 27.

The individual block rating and recommended maintenance is as shown in Tables 7, 8, 9, 10, 11, 12, 13, and 14.

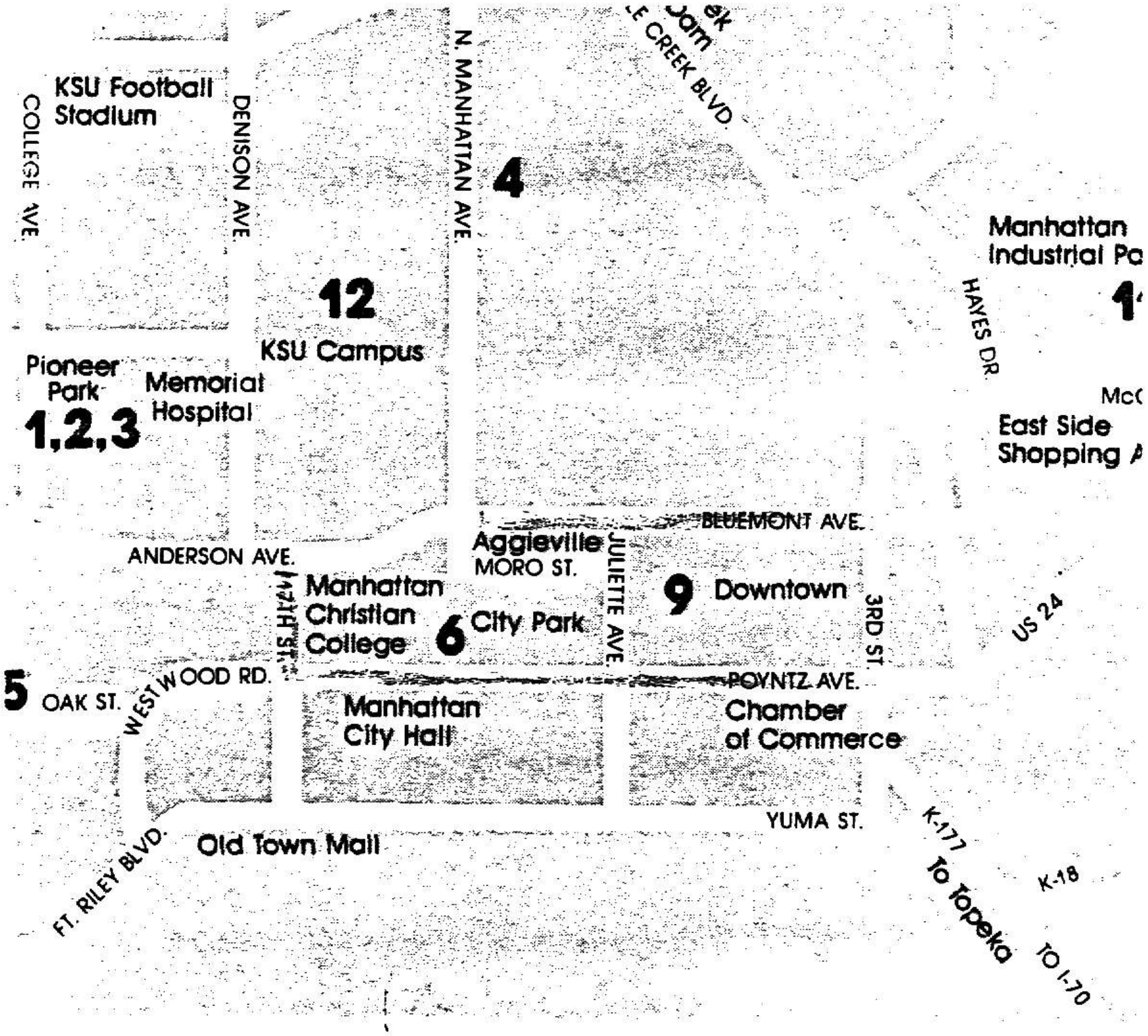
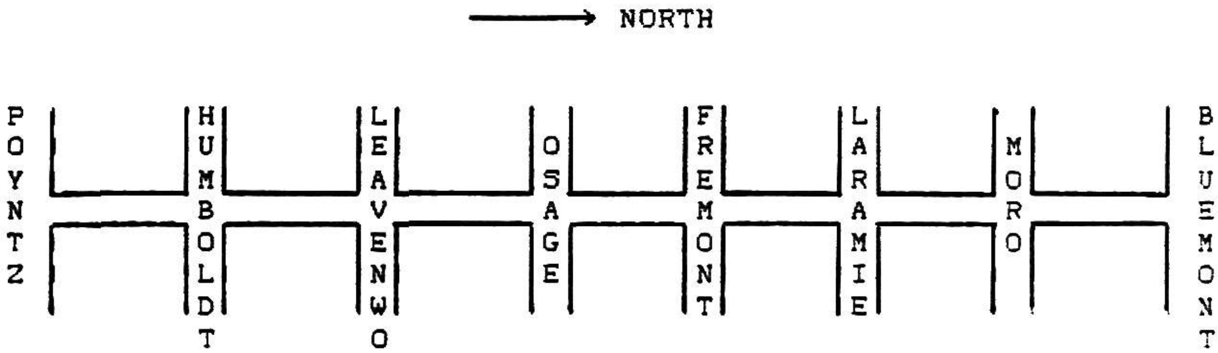


Fig. 26. PLAN OF SOUTH MANHATTAN. (From Kansas State University Library, 1978.)



DATE APRIL 7 1985

(Not to scale)

ROUTINE MAINTENANCE 0

SURFACE RESTORATION 0

RECONSTRUCTION 0

RATED BY ARIF M KAZMI

Fig. 27 BLOCKS OF 3rd STREET, MANHATTAN.

Table 7. Blockwise Pavement Rating.

NAMES OF THE BLOCKS OF 3 rd. STREET MANHATTAN	PAVEMENT RATING (for details see forms)
POYNTZ--HUMBOLDT	32.2
HUMBOLDT--LEAVENWORTH	28.3
LEAVENWO--OSAGE	26.3
OSAGE--FREEMONT	29.4
FREMONT--LARAMIE	32.9
LARAMIE--MORO	34.2
MORO--BLUEMONT	32.6

The form in Table 6 represents use of this method.

Table 8 PAVEMENT RATING OR CONDITION FORM. (LOW TRAFFIC VOLUME)

LOCATION 3rd Street Poyntz--Humboldt DATE 4/8/85

TYPE	DISTRESS	PAVEMENT CONDITION RATING ✓ 0--1.7	1.8--3.5	3.6--5
SURFACE CRACKING	ALLIGATOR	—	—	3.6
	LONGITUDANAL	—	1.8	—
	TRANSVERSE	—	1.8	—
	REFLECTION	—	1.8	—
	SLIPPAGE	—	—	3.6
SURFACE DISTORTION	RUTTING	1.7	—	—
	SHOVING, CORRUGATION	—	1.8	—
	FROST HEAVE	—	—	4.0
SURFACE DEFECTS	POTHOLES	1.5	—	—
	RAVELING	—	3.2	—
	BLEEDING	—	—	4.0
	POLISHED AGG.	—	—	4.0

TOTAL SCORE : 32.2

INTERPRETING THE PAVEMENT RATING

0--------------------20--------------------30- 32.2 - - - - - - - -

RECONSTRUCTION SURFACE RESTORATION ✓ROUTINE MAINTENANCE

The form in Table 6 represents use of this method.

Table 9 PAVEMENT RATING OR CONDITION FORM. (LOW TRAFFIC VOLUME)

LOCATION 3rd Street Humboldt--Leavenworth DATE 4/8/85

TYPE	DISTRESS	PAVEMENT CONDITION RATING 0--1.7	1.8--3.5	✓ 3.6--5
SURFACE CRACKING	ALLIGATOR ✓	1.5	—	—
SURFACE CRACKING	LONGITUDANAL	1.7	—	—
SURFACE CRACKING	TRANSVERSE	1.5	—	—
SURFACE CRACKING	REFLECTION	1.5	—	—
SURFACE CRACKING	SLIPPAGE	—	—	3.6
SURFACE DISTORTION	RUTTING	1.5	—	—
SURFACE DISTORTION	SHOVING, CORRUGATION	1.7	—	—
SURFACE DISTORTION	FROST HEAVE	—	—	4.0
SURFACE DEFECTS	POTHOLES	—	1.8	—
SURFACE DEFECTS	RAVELING	—	2.5	—
SURFACE DEFECTS	BLEEDING	—	—	4.0
SURFACE DEFECTS	POLISHED AGG.	—	3.0	—

TOTAL SCORE : 28.3

INTERPRETING THE PAVEMENT RATING

0 -------------------- 20 -------------- 28.3 -------- 30 - - - - - - - - -

RECONSTRUCTION ✓SURFACE RESTORATION ROUTINE MAINTENANCE

The form in Table 6 represents use of this method.

Table 10 PAVEMENT RATING OR CONDITION FORM. (LOW TRAFFIC VOLUME)

LOCATION 3rd Street Leavenworth--Osage DATE 4/8/85

TYPE	DISTRESS	PAVEMENT CONDITION RATING 0--1.7	1.8--3.5	3.6--5
SURFACE CRACKING	ALLIGATOR	1.5	—	—
	LONGITUDANAL	1.5	—	—
	TRANSVERSE	1.0	—	—
	REFLECTION	1.5	—	—
	SLIPPAGE	—	3.5	—
SURFACE DISTORTION	RUTTING	1.5	—	—
	SHOVING,CORRUGATION	1.7	—	—
	FROST HEAVE	—	—	3.6
SURFACE DEFECTS	POTHOLES	1.5	—	—
	RAVELING	—	2.0	—
	BLEEDING	—	—	4.0
	POLISHED AGG.	—	3.0	—

TOTAL SCORE : 26.3

INTERPRETING THE PAVEMENT RATING

0 ---------- 20 ---------- 26.3 ---------- 30 ----------

RECONSTRUCTION ✓SURFACE RESTORATION ROUTINE MAINTENANCE

The form in Table 6 represents use of this method.

Table 11 PAVEMENT RATING OR CONDITION FORM. (LOW TRAFFIC VOLUME)

LOCATION 3rd Street Osage--Fremont DATE 4/8/85

TYPE		DISTRESS	PAVEMENT CONDITION RATING 0--1.7	1.8--3.5	3.6--5
SURFACE	CRACKING	ALLIGATOR	—	2.5	—
		LONGITUDANAL	1.5	—	—
		TRANSVERSE	1.5	—	—
		REFLECTION ✓	1.5	—	—
		SLIPPAGE	—	—	4.0
SURFACE	DISTORTION	RUTTING	1.7	—	—
		SHOVING, CORRUGATION	1.7	—	—
		FROST HEAVE	—	—	4.0
SURFACE	DEFECTS	POTHOLES	1.5	—	—
		RAVELING	—	2.5	—
		BLEEDING	—	—	4.0
		POLISHED AGG.	—	3.0	—

TOTAL SCORE : 29.4

INTERPRETING THE PAVEMENT RATING

0--------------------20----------29.4----------30- - - - - - - - - - -

RECONSTRUCTION ✓SURFACE RESTORATION ROUTINE MAINTENANCE

The form in Table 6 represents use of this method.

Table 12 PAVEMENT RATING OR CONDITION FORM. (LOW TRAFFIC VOLUME)

LOCATION 3rd Street Fremont--Laramie DATE 4/8/85

TYPE		DISTRESS	PAVEMENT CONDITION RATING 0--1.7	1.8--3.5	3.6--5
SURFACE	CRACKING	ALLIGATOR	—	3.0	—
		LONGITUDANAL	—	2.0	—
		TRANSVERSE	—	1.8	—
		REFLECTION	—	1.8	—
		SLIPPAGE	—	—	4.0
SURFACE	DISTORTION	RUTTING	—	2.0	—
		SHOVING, CORRUGATION	—	1.8	—
		FROST HEAVE	—	—	4.0
SURFACES	DEFECTS	POTHOLES	—	2.0	—
		RAVELING	—	3.0	—
		BLEEDING	—	—	4.0
		POLISHED AGG.	—	3.5	—

TOTAL SCORE : 32.9

INTERPRETING THE PAVEMENT RATING

0 ---------- 20 ---------- 30 - - 32.9 - - - - -

RECONSTRUCTION SURFACE RESTORATION ✓ROUTINE MAINTENANCE

The form in Table 6 represents use of this method.

Table 13 PAVEMENT RATING OR CONDITION FORM. (LOW TRAFFIC VOLUME)

LOCATION 3rd Street Laramie--Moro DATE 4/8/85

TYPE	DISTRESS	PAVEMENT CONDITION RATING 0--1.7	1.8--3.5	3.6--5
SURFACE CRACKING	ALLIGATOR	—	3.5	—
	LONGITUDANAL	—	2.0	—
	TRANSVERSE	—	1.8	—
	REFLECTION	—	1.8	—
	SLIPPAGE	—	—	4.0
SURFACE DISTORTION	RUTTING	—	2.5	—
	SHOVING, CORRUGATION	—	2.0	—
	FROST HEAVE	—	—	4.0
SURFACE DEFECTS	POTHOLES	—	2.0	—
	RAVELING	—	3.0	—
	BLEEDING	—	—	4.0
	POLISHED AGG.	—	—	3.6

TOTAL SCORE : 34.2

INTERPRETING THE PAVEMENT RATING

0 -------------------- 20 -------------------- 30 - - 34.2 - - - - - - -

RECONSTRUCTION SURFACE RESTORATION ✓ROUTINE MAINTENANCE

The form in Table 6 represents use of this method.

Table 14 PAVEMENT RATING OR CONDITION FORM. (LOW TRAFFIC VOLUME)

LOCATION 3rd Street Moro--Bluemont DATE 4/8/85

TYPE	DISTRESS	PAVEMENT CONDITION RATING 0--1.7	1.8--3.5	3.6--5
SURFACE CRACKING	ALLIGATOR	—	3.0	—
	LONGITUDANAL	—	1.8	—
	TRANSVERSE	—	1.8	—
	REFLECTION	1.5	—	—
	SLIPPAGE	—	—	4.0
SURFACE DISTORTION	RUTTING	—	2.0	—
	SHOVING, CORRUGATION	—	2.0	—
	FROST HEAVE	—	—	4.0
SURFACE DEFECTS	POTHOLES	—	2.0	—
	RAVELING	—	3.0	—
	BLEEDING	—	—	4.0
	POLISHED AGG.	—	3.5	—

TOTAL SCORE : = 32.6

INTERPRETING THE PAVEMENT RATING

0--------------------20--------------------30- - 32.6 - - - - - - -

RECONSTRUCTION SURFACE RESTORATION ✓ROUTINE MAINTENANCE

R E P A I R   M E T H O D S (2) (3) (7)

The next step is to identify the maintenance or the repair methods to be undertaken for maintaining the pavement under desired serviceability conditions.

This study of quoted references describes repair methods in a step-by-step procedure. Also included are the recommended crew size, equipment, and material required to accomplish the work and a suggested production rate for performing that type of repair. The crew and equipment requirements, material requirements and performance standards conform to past experiance and observation of maintenance works being done by various agencies.

Each of these repair methods is provided only as a recommendation for correcting a given distress. It is recognized that factors such as availability of manpower, equipment and size of the area to be repaired depends on each individual situation. Furthermore the procedures given represent typical, commonly used methods of accomplishing the repair. If followed, they should produce satisfactory results for the deficiencies indicated.

Variations from the indicated procedures do exist and can be used where previously proven successful. The probable effectiveness of any repair depends on traffic conditions and climatic factors as well as repair methods, so it is not possible to predict the efficiency of any method as to the length of time before further repairs are required.

Preferably, maintenance work should be done during warm (45 degree farenheit or above), and dry weather. A common goal should also be to minimize disruption of traffic flow while providing maximum safety for the public and the mainteance crew. Procedures for controlling traffic are contained in the Manual of Uniform Traffic Control Devices (MUTCD). (4)

Table 15. SUGGESTED REPAIR METHODS (From The Asphalt Institute, 1983, and Russell and Scholer, 1984.)

C R A C K F I L L I N G W I T H A S P H A L T

(For low to medium severity distress in routine maintenance.)

Required for: (i) Longitudnal cracks.

(ii) Reflection cracks.

(iii) Other Surface cracks.

Crew required:

Laborers	2
Flagman	1
Truck Driver	1

Equipment required:

Asphalt Kettle	1
Dump Truck	1
Air Compressor	1

Material required:

Liquid asphalt

Fine sand

Daily production per crew:

About 3000 linear feet of cracks.

Repair procedures:

(i) Place signs and other safety control devices.

(ii) Clean out crack with stiff broom and compressed air.

(iii) Fill crack with liquid asphalt using a pouring pot and a squeege. Do not overfill and cause excess asphalt on surrounding pavement.

(iv) Sprinkle surface with dry sand to prevent pickup by traffic.

(v) Clean up the area and remove signs.

DEEP PATCHING WITH PREMIX

(For medium to high severity distress in routine maintenance).

Required for (i) Alligator Cracks
(ii) Slippage Cracks
(iii) Potholes
(v) Edge failures

Crew Required:

Equipment Operator	1
Truck Driver	1
Laborers	2
Flagman	1

Equipment Required:

Dump Truck	1
Portable Roller	1
Asphalt Kettle	1
Gradall or Front end	
Loader (For larger works)	1
Mechanical Saw	1
Air Compressor	1
Motor Grader (large works)	1

Material Requried:

Hot premix asphalt concrete.

Liquid asphalt tack coat.

Base material and underdrain pipe if required.

Daily production per crew:

About 20 tons of asphalt concrete or more when equipment is used.

Repair Procedure:

(i) Place signs and other safety control devices as per Manual of Uniform Traffic Control Devices.

(ii) Break out and remove old pavement. Cut vertical edges six inches outside the distressed area on all sides. Make cuts square with roadway centerline.

(iii) Install underdrains if required.

(iv) Replace unsuitable base material, if required. grade and recompact new base material.

(v) Apply light and even tackcoat of heated asphalt to the vertical sides of the area.

(vi) Place premix (preferably hot or warm) into the area from sides to center, using a motor grader or by hand in case of small sized area under repair. Spread material in layers not exceeding three inches in thickness. Hand compact or roll each layer before applying another layer.

(vii) During compaction of the final layer check the surface with a straight edge to assure that it is levelled and flush with the adjacent surface.

(viii) Clean up the area and remove all signs.

L E V E L L I N G W I T H P R E M I X

(For medium to high severity distress for an overlay).

Required for :
- (i) Rutting.
- (ii) Corrugations.
- (iii) High cracking and all other failures.
- (iv) Asphalt bleeding and polished aggregates.

Crew required :

Equipment operator	1
Truck drivers	2
Rakemen	2
Laborers	2
Flagman	1

Equipment Required:

Dump Trucks	2
Distributor Truck	1
Roller	1
Power broom	1
Motor Grader and/or	1
Asphalt Spreader	1
(for large works)	

Material required:

Hot premix asphalt concrete

Liquid asphalt tack coat

Daily production per crew:

About 200 tons of asphalt concrete.

Repair procedures:

(i) Place signs and other safety control devices.

(ii) Repair and clean the existing surface according to the procedures defined above.

(iii) Apply light uniform tack coat material covering entire surface to receive levelling course.

(iv) Spot dump premix from trucks along area to be levelled.

(v) Spread premix with motor grader or an asphalt spreader.

(vii) Roll each layer immediately after spreading.

(viii) Clean loose material from roadway with power broom.

(ix) Clean up the area and remove signs.

CONCLUSION AND RECOMMENDATIONS

The study has been focused to identification and evaluation of distress in asphalt pavements and shows some preventive repair methods. It is also directed primarily to repairs for roads or streets within a City or County juridiction. Review of literature and some field inspections under this study indicate that there are no miracle methods, materials, or machines available that by themselves constitute a " breakthrough " in current maintenance practice. The examination however emphasizes that in all cases of pavement distress, it is best to determine first the causes of the distress. Then repairs are made which correct the damage and also prevent or retard its happening again.

Some of the key recommendations are:

* Improved management can produce better and more efficient results. NCHRP Report Number 161 states that non-productive time in maintenance operations averages 58 percent. On the other hand technical gains tend to be relatively perishable since technology is continually changing.

* Expected longevity and quality of the work should be determined before the repair site is occupied. A plan of action reviewed before starting a job, eliminates lost on-site instructional time and helps avoid logistical problems.

* The special traffic safety crew should preplan the traffic safety control effort and arrive on-site before the maintenance forces. Complete sets of signs and equipment for traffic control should be prepackaged on trucks for maintenance projects in a manner that facilitates their rapid removal and correct placement on the highway. Portable crash cushions trailered behind shadow vehicles are an improvement in traffic control at maintenance sites. The cushions provide protection to maintenance crew vehicles that are vulnerable to rear end collisions. Single individual responsibility should be set up for project traffic control.

* Economy of providing whatever material and equipment is necessary to achieve the most rapid repair possible and reduce the time of roadway occupancy, becomes obvious when user delay costs are examined. An unpublished report on, "Improved methods for patching high volume roads" by Byrd, Tallay, MacDonald & Lewis, states that a one lane closure for an eight hour workday on a four lane highway with an ADT of 8000 vehicles will cost the motorists approximately $18500.

* Cutting out is the slowest and most time consuming operation during maintenance jobs. Milling machines cut faster and smoother. The above mentioned unpublished report also states that chemical additives to cold patch material require little preparation of the disintegrated area, and also require little or no compaction.

* Pavement heaters using propane or infrared heating are proving useful for repairing potholes, removing bumps, solving shoving problems, making crack repairs, and for use where additional new patching material may be hard to find. Commercially available fiber glass cloth patching strips, used to prevent reflective cracking from coming through patches, has also proved effective.

In short the agencies obtaining good results are following standard repair methods but are doing the job better through careful distress identification by qualified engineers, and repair by trained and experienced workers. Too often some agencies or departments ignore these methods due to pressure to repair quickly and cheaply. The folly of these exceptions is readily apparent in late winter or early spring when repair work fails in a short time and has to be done over.

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AN EVALUATION OF DISTRESS IN ASPHALT PAVEMENTS AND SOME PREVENTIVE MEASURES

by

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1973

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Civil Engineering

Kansas State University

Manhattan, Kansas

1985

A B S T R A C T

Maintenance is needed on asphalt roads when distressed pavement areas constitute a hazarad to public safety or cause excessive damage to vehicles. Maintenance on roads is defined as preventive measures to keep the road pavement, under normal conditions of traffic and normal forces of nature, as nearly as possible in its as-constructed condition or work performed to restore it to good condition.
Under these circumstances, repair is essential to hold down the substantial increased costs to the public to keep the distressed area from becoming larger and more costly to repair.

In response to the problem of providing maintenance, on a systematic rational basis a study entitled " AN EVALUATION OF DISTRESS IN ASPHALT PAVEMENTS AND SOME PREVENTIVE MEASURES " was initiated.
Under this study, a literature search was conducted of material pertaining to pavement distress, its evaluation and case history reports of pavement maintenance works. The information presented consists of survey of different types of distress and roughness in asphalt pavements, development of a survey to obtain data for computing the Present Serviceability Index (P S I) along the project. The method develops a simple and economical procedure for rating of pavements at a small city or at the county level. It identifies present repair practices and concludes with some suggested improvements in the methods currently used by highway maintenance agencies.