

# Deterioration of Bituminous Roads

## Base, Surface and Material Types

- ▶ Granular Base
- ▶ Asphalt Base
- ▶ Asphalt Pavement Base
- ▶ Stabilized Base

### Asphalt Mix

- ▶ Asphalt Concrete
- ▶ Hot Rolled Modified Asphalt
- ▶ Rubberized Asphalt
- ▶ Polymer Asphalt Concrete
- ▶ Soft Bitumen Mix (Cold Mix)
- ▶ Porous Asphalt
- ▶ Stone Mastic

### Surface Treatment

- ▶ Cape Seal
- ▶ Double Bituminous Surface Dressing
- ▶ Single Bituminous Surface Dressing
- ▶ Slurry Seal
- ▶ Penetration Macadam

# General Distress Modes

- ▶ **Surfacing Distress**
  - ▶ Cracking
  - ▶ Ravelling
  - ▶ Potholing
  - ▶ Edge-Break
- ▶ **Deformation Distress**
  - ▶ Rutting
  - ▶ Roughness
- ▶ **Pavement Surface Texture Distress**
  - ▶ Texture Depth
  - ▶ Skid Resistance
- ▶ **Drainage Distress**
  - ▶ Drainage



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# Distress Modes



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## Distress Modes



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## Surfacing Distress

- **Cracking Area:** Sum of rectangular areas circumscribing manifest distress (line cracks are assigned a width of 0.5 m), expressed as a percentage of carriageway area.
  - Structural Cracking
    - Narrow Cracking (1-3 mm crack width)
    - Wide Cracking (> 3 mm crack width)
    - Thermal Transverse Cracking
  - **Ravelling Area:** Area of loss of material from wearing surface, expressed as a percentage of carriageway area.



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## Surfacing Distress

- ▶ **Number of Potholes:** Number of potholes per kilometer expressed in terms of the number of 'standard' sized potholes of area 0.1 m<sup>2</sup>. A pothole being defined as an open cavity in road surface with at least 150 mm diameter and at least 25 mm depth.
- ▶ **Edge Break Area:** Loss of bituminous surface material (and possibly base materials) from the edge of the pavement, expressed in square meters per km.

HDM-4 assigns a depth of 100 mm to potholes and edge break area



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## Deformation Distress

- ▶ **Rutting:** Permanent traffic-associated deformation within pavement layers which, if channelised into wheelpaths, accumulates over time and becomes manifested as a rut, expressed as the maximum depth under 2 m straightedge placed transversely across a wheelpath.
- ▶ **Roughness:** Deviations of surface from true planar surface with characteristic dimensions that affect vehicle dynamics, ride quality, dynamic loads and drainage, expressed in the International Roughness Index, IRI (m/km).



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## Roughness Scales

	International Roughness Index IRI m/km	Bump Integrator Trailer TRRL BI mm/km	Quarter-car Index Index QI counts/km	Present Serviceability Index PSI
	0	0	0	5.0
	1	700	13	4.2
Good Paved	2	1400	26	3.5
	3	2200	40	3.0
	4	3000	50	2.4
	5	3800	65	2.0
Good Unpaved	6	4700	80	1.7
	8	6500	100	1.2
Poor Paved	10	8300	130	0.6
	12	10000	156	0
	16	14000	210	
Poor Unpaved	20	18000	260	
	24	22000	310	



$$BI = 360 IRI^{1.12}$$

$$QI = 13 IRI$$

$$SI = 5 e^{(-0.18 IRI)}$$

$$IRI = 0.0032 BI^{0.89}$$

$$IRI = QI / 13$$

$$IRI = 5.5 \ln (5.0/SI)$$


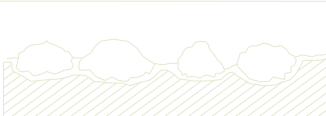


## Pavement Surface Texture Distress

- Texture Depth:** Average depth of the surface of a road expressed as the quotient of a given volume of standardized material (sand) and the area of that material spread in a circular patch on the surface being tested.
- Skid Resistance:** Resistance to skidding expressed by the sideways force coefficient (SDF) at 50 km/h measured using the Sideways Force Coefficient Routine Investigation Machine (SCRIM).



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## Texture Depth and Skid Resistance

SURFACE	SCALE OF TEXTURE	
	MACRO	MICRO
A 	COARSE $T_D \sim 2\text{mm}$	HARSH $SFC_{50} \sim 0.6$
B 	COARSE $T_D \sim 2\text{mm}$	POLISHED $SFC_{50} \sim 0.4$
C 	FINE $T_D \sim 0.35\text{mm}$	HARSH $SFC_{50} \sim 0.6$
D 	FINE $T_D \sim 0.35\text{mm}$	POLISHED $SFC_{50} \sim 0.4$

## Drainage Distress

- **Drainage:** Drainage condition (excellent, good, fair, poor or very poor), which defines the drainage factor.

The drainage factor, DF, is a continuous variable whose value can range between 1 (excellent) and 5 (very poor), depending on the type of drain (Paterson, 1998). The user will be required to input the type of drain (as listed in Table C2.10) and the condition of the drain as **excellent**, **good**, **fair**, **poor** or **very poor**.

Table C2.10 Suggested range of drainage factor values

Drain type	Drain condition	
	Excellent $DF_{min}$	Very poor $DF_{max}$
Fully lined and linked	1	3
Surface lined	1	3
V-shaped - hard	1	4
V-shaped - soft	1.5	3
Shallow - hard	2	5
Shallow - soft	2	5
No drain - but required	3	5
No drain - not required	1	1



## Basic Roadway Evaluation Criteria Pavement Rating System

- The first step in developing the Pavement Management System was to establish a consistent system of pavement evaluation based upon visual observations only.
- Higher numerical values are assigned to severe or frequently occurring defects.
- The numerical values for each defect are added together, multiplied by two, and then subtracted from 100.
- The resulting number, termed a pavement condition rating, defines the overall condition of the pavement for the roadway.
  - For example, a condition rating of 100 would be assigned to a perfect roadway with no cracks, potholes or other defects.
  - Pavement in need of total reconstruction, with numerous defects, may have a condition rating of 64 or less.



## Load Related Distresses

- Fatigue Cracking
- Potholes
- Rutting
- Edge Cracking
- Shoving



## Basic Roadway Evaluation Criteria Types of Defects

- ▶ Alligator Cracks
  - ▶ This condition is characterized by a series of interconnecting cracks that divide the pavement into many-sided, sharp-angled pieces resembling an alligator's hide. The pieces are typically less than one foot in any dimension. Alligator cracking usually occurs in wheel paths or other areas subjected to loading. Alligator cracking can be caused by weakness in the subbase or subgrade, which result in the fatigue failure of the asphalt surface under repeated loading.



## Basic Roadway Evaluation Criteria Types of Defects

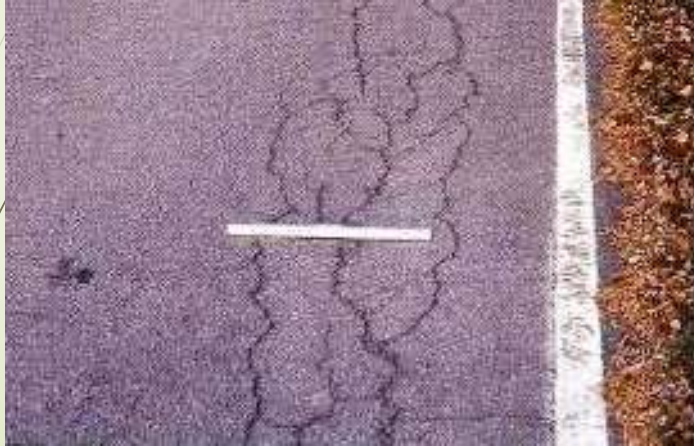
### Low Severity Fatigue Cracking





## Basic Roadway Evaluation Criteria Types of Defects

### Moderate Severity Fatigue Cracking

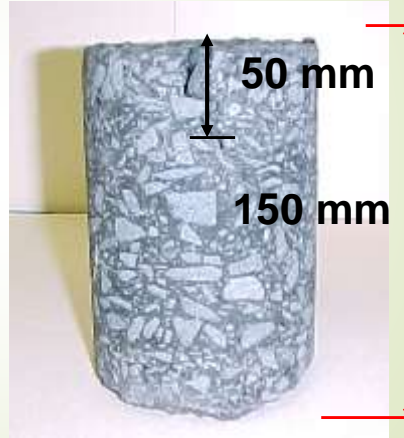


## Basic Roadway Evaluation Criteria Types of Defects

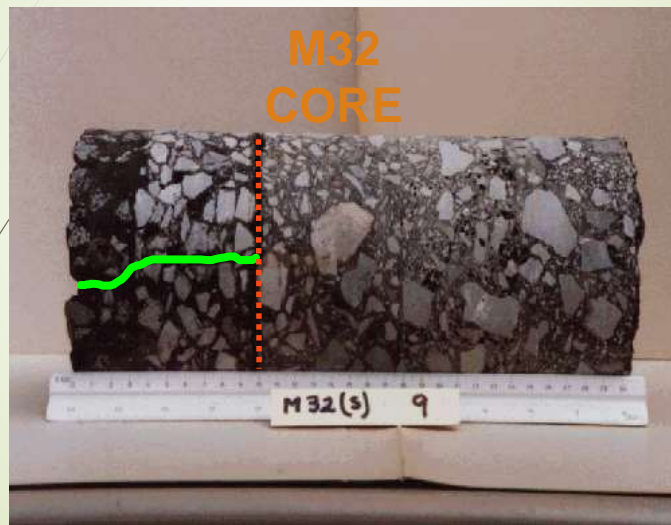
### High Severity Spelled Fatigue Cracking



Washington State - Top-Down in  
Asphalt Pavements > 150 mm



TRL



# Rutting

- In Subgrade/Base
  - Design Problem
- In the AC Layer
  - Plastic Flow--Material/Mix Design
  - Consolidation--Compaction
  - Surface Wear



## Basic Roadway Evaluation Criteria Types of Defects

### Rutting

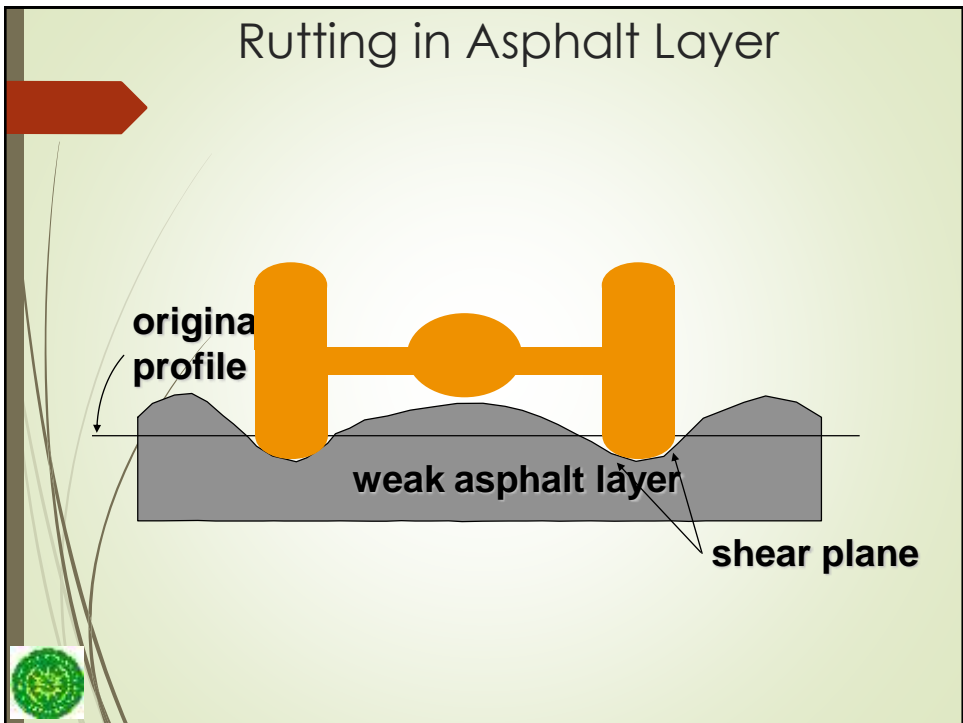
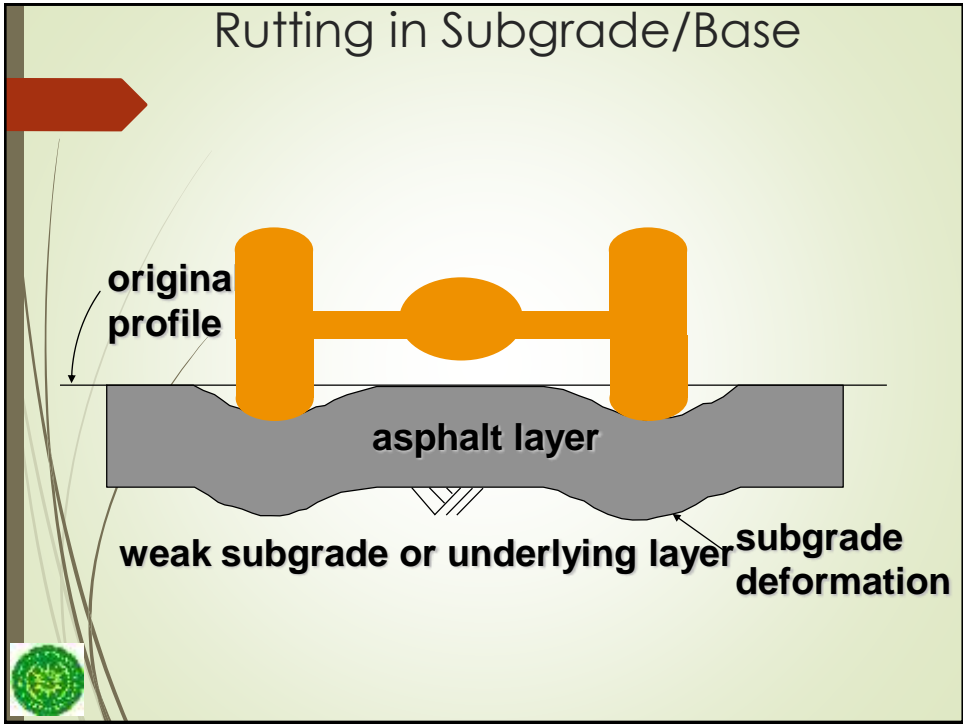


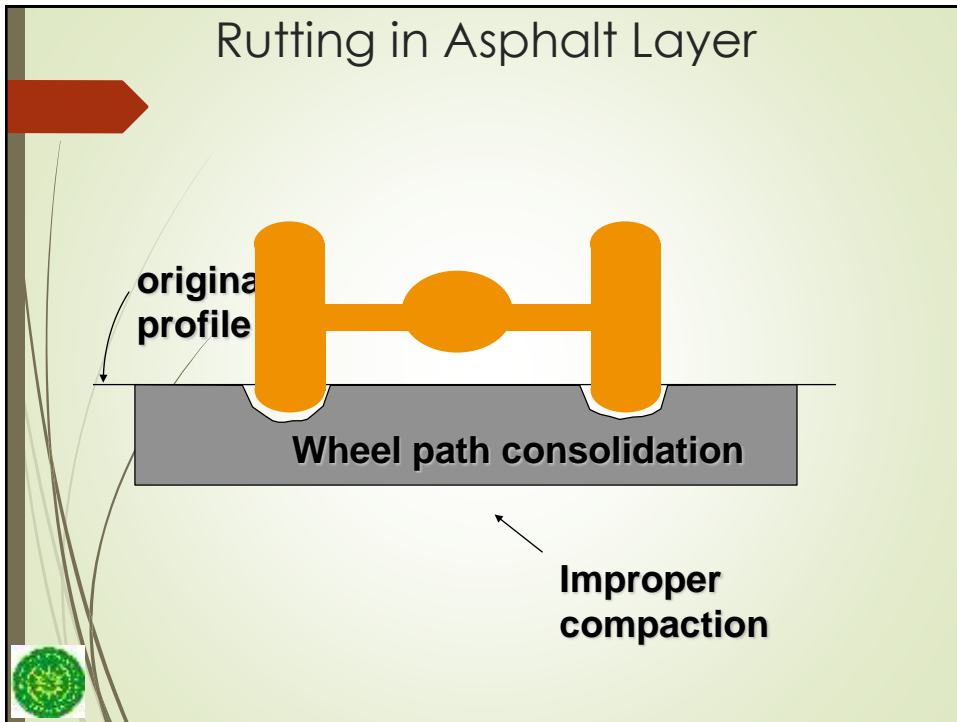
## Rutting



## Rutting







- ## Shoving
- "Washboarding"
  - Occurs at high stress locations
    - Intersections
    - Steep Grades
    - Ramps
  - Weak unstable mix
  - Unstable base



## Basic Roadway Evaluation Criteria

### Types of Defects

#### Shoving (Heavy Weight Impact)



#### Potholes

- Severe, uncorrected result of another distress
  - Alligator Cracking
  - Raveling
  - Failed Patches
- Thin/Weak Pavement





## Basic Roadway Evaluation Criteria Types of Defects

### ► Potholes

- This condition is characterized by holes in the pavement surface at least ½" deep and at least one square foot in surface area. Potholes generally occur when a serious distress, such as alligator cracking, combines with excess water, freeze-thaw cycling, and traffic loads. These results in localized disintegration of the pavement materials and the materials are then dislodged by traffic.



## Potholes



## Potholes



## Climate Related Distresses

- Block Cracking
- Joint Reflective Cracking
- Thermal Cracking
- Weathering/Raveling



## Block Cracking

- ▀ Divides the pavement into rectangular pieces
- ▀ 1ft x 1ft to 10ft x 10ft
- ▀ Oxidation (Aging)
- ▀ Low AC% Mix
- ▀ Absorptive Aggregates



## Block Cracking



## Block Cracking



## Reflective Cracking

- Generally over PCC pavements
- Caused by movement of the underlying layer
  - Vertically (Load)
  - Horizontally (Thermal)



## Reflective Cracking



## Longitudinal/Transverse Cracking

- Transverse cracking is generally thermally induced
- Longitudinal Cracking
  - paving lane joints
  - poor compaction



## Basic Roadway Evaluation Criteria Types of Defects

### ▶ Transverse / Longitudinal Cracks

- ▶ This condition is characterized by visible fractures or separations of the pavement surface occurring transversely (across) or longitudinally (down) the roadway. This cracking may be caused by a poorly constructed paving joint, shrinkage of the surface due to low temperature, asphalt hardening, or a reflection crack from an underlying rigid base.



## Longitudinal/Transverse Cracking



## Longitudinal/Transverse Cracking



## Longitudinal/Transverse Cracking



## Weathering/Raveling



## Basic Roadway Evaluation Criteria Types of Defects

### ► Polishing

- This condition is characterized by the wearing away of the pavement surface caused by the dislodging of aggregate particles and loss of asphalt binder. The pavement surface becomes smooth and rounded (and subsequently slippery) under the action of traffic. Polishing is normally caused by oxidation of the asphalt binder of the mix, resulting in loss of flexibility and ability to hold the aggregate.





## Polished Aggregate



## Other Distresses

- Bleeding
- Bumps/Sags
- Corrugation/  
Shoving
- Depressions
- Lane/Shoulder  
Drop Off
- Patching/Utility  
Cuts
- Polished  
Aggregate
- Railroad  
Crossings
- Slippage Cracks

## Bleeding

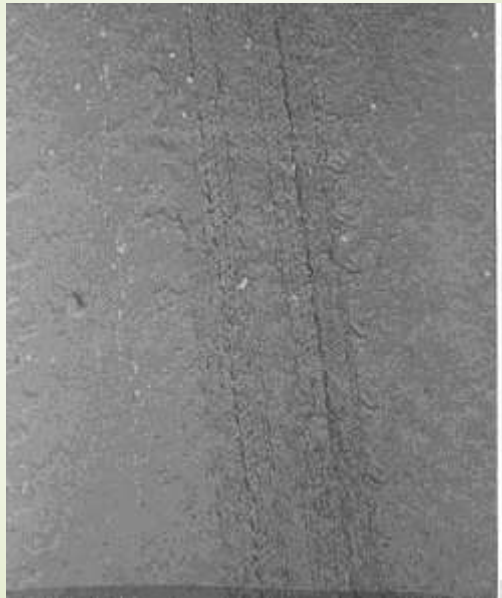
- Excessive Asphalt
  - Too much asphalt in mix
  - Too much crack sealant below overlay
  - Too heavy prime or tack coat?
- Low air voids



## Bleeding



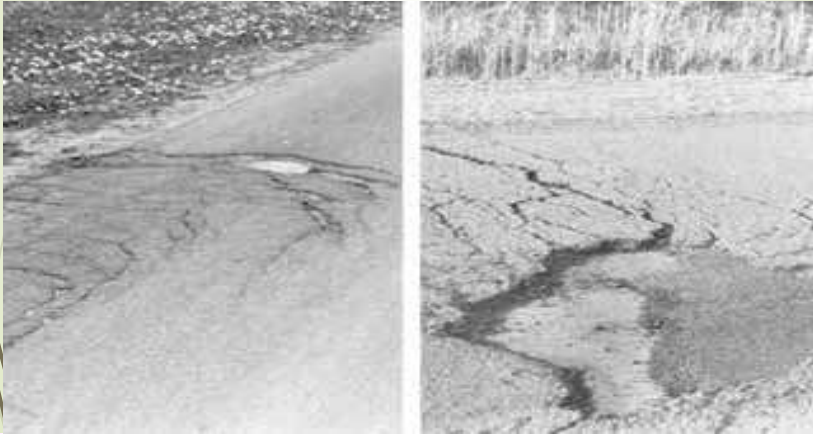
## Bleeding



## Slippage Cracks

- Caused by a shear plane in the pavement structure
  - Too little tack
  - Too much tack

## Slippage Cracks



## Basic Roadway Evaluation Criteria Types of Defects

- ▶ Pavement Distortions
  - ▶ This condition is characterized by the pavement being out of its natural or proper shape. Pavement distortions can be caused by subbase or sub-grade failure, shoving, or rutting.



## Basic Roadway Evaluation Criteria Types of Defects

### ► Drainage/Ponding Problems

- This condition is typically characterized by inadequate roadway cross slopes and gutter slopes holding water on a roadway. This condition can also be attributed to improper shaping of the road, improper spacing and sizing of drainage inlets, and blocked culverts.



## Basic Roadway Evaluation Criteria Types of Defects

### ► Riding Quality (Smoothness)

- This condition is characterized by the feel when driving an automobile through a segment of a roadway at the posted speed limit. If the pavement appeared to be new and there was no discernible roughness felt in the ride of the vehicle, the pavement smoothness was rated excellent. The pavement smoothness was rated good if the ride of the vehicle remained smooth, yet the pavement appeared to show some signs of distress. A rating of fair for pavement smoothness was given if there was notable roughness felt in the ride of the vehicle but little discomfort sensed by the driver. If there was substantial roughness felt in the ride of the vehicle, and it became necessary to lower the speed of the vehicle below the posted limit, the pavement smoothness was rated as poor.



## Basic Roadway Evaluation Criteria Rating of Defects (0 to 5)

- **Excellent (0)**
  - No visible distress observed
- **Very Good to Good (1)**
  - Some alligator cracking (< 10%).
  - Random potholes (< 2 square feet)
  - First signs of minor polishing
  - No pavement distortions
  - No patching or very few patches in excellent condition
  - No longitudinal cracks except reflection of pavement joints
  - Occasional transverse cracks, widely spaced (40' or greater)
  - All cracks sealed or tight (open less than 1/4")
  - Longitudinal cracks (open 1/4") due to reflection or paving joints
  - Transverse cracks (open 1/4") spaced 10' or more apart



## Basic Roadway Evaluation Criteria Rating of Defects (0 to 5)

- **Good to Fair (2)**
  - Some alligator cracking (<15%)
  - Occasional pothole (< 2 square feet)
  - Slight polishing
  - Occasional pavement distortion (less than 1/2" deep)
  - Occasional patching in good condition
  - Longitudinal cracks (open 1/4" to 1/2") with some spaced less than 20'
  - First signs of minor longitudinal cracks near pavement edge
  - Transverse cracks (open 1/4" to 1/2") show first signs of minor secondary cracks
- **Fair (3)**
  - Some alligator cracking (<20%)
  - Potholes (> 2 square feet) in several areas
  - Moderate polishing
  - Moderate distortions (1/2" to 1" deep)
  - Occasional patching in fair condition
  - Longitudinal cracks (open 1/4" to 1/2") with some spaced less than 10'
  - Signs of moderate longitudinal cracks near pavement edge
  - Transverse cracks (open 1/4" to 1/2") show first signs of moderate secondary cracks



## Basic Roadway Evaluation Criteria Rating of Defects (0 to 5)

- **Poor to Very Poor (4)**
  - Alligator cracking (> 25%)
  - Potholes (> 3 square feet) in several areas
  - Severe polishing
  - Severe distortions (over 1-1/2" deep)
  - Patches in poor condition
  - Longitudinal and transverse cracks often showing raveling (loosening of stones from the surface of a pavement) and crack erosion
- **Failed (5)**
  - Severe loss with extensive loss of surface integrity



## Basic Roadway Evaluation Criteria Rating of Defects (0 to 5)

- Excellent condition (0)
  - like new
- Very good condition (1)
  - Older, but no problems noted
- Good condition (2)
  - some minor problems
- Satisfactory to fair condition (3)
  - structural elements are sound but have minor section loss, cracking, spalling, and improper alignment
- Poor Condition (4)
  - advanced section loss, deterioration spalling, improper alignment, and severe cracking
- Failed (5)
  - needs total replacement



## Additional Criteria (Infrastructure Issues)

- Sanitary Sewers
  - Video inspection of the piping and visual observations of the manholes
  - Lateral replacement based upon information provided by the Sewer Department regarding the relative age and type of material of the laterals
- Water Mains
  - Based upon current water usage in the Borough (between 1.0 and 1.3 million gallons per day)
    - Existing 4" diameter water mains need to be replaced
    - Existing 6" diameter water mains are undersized, but can remain in service provided that they are relatively new and in good condition, with no major water pressure issues documented (fire hydrant testing or resident complaints)
    - For water mains that are 8" diameter or greater, proposed replacement/repairs are based upon the following:
      - History of problems (breaks, resident complaints)
      - Age
      - Type of project
      - Priority/cost effectiveness
  - Replacement of individual service connections based upon information provided by the Water Department regarding the relative age and material of the service connection

## Additional Criteria (Infrastructure Issues)

- Stormwater/Drainage
  - Extend or upgrade stormwater piping (where feasible) to correct drainage issues and/or provide a sump pump collector system, where necessary
  - Add new piping and/or outfalls to correct identified drainage/sump pump discharge issues (Sylvan Lake Avenue)
- Road Cores/Soil Borings
  - Obtain samples at specified intervals and document:
    - Pavement thickness and type
    - Subbase thickness and type
    - Subgrade type (good, fair, poor)
  - This information is one factor used to develop the following revised appropriate pavement treatments:
    - Mill and Overlay
    - Full Depth Reconstruction
    - Full Depth Reclamation (Pulverization, Stabilization, Overlay)
    - Cold in Place Recycling (Milling and recycling existing asphalt into new subbase material)
    - Concrete Recycling (pulverization and overlay of existing concrete roadway)



## Additional Criteria (Infrastructure Issue)

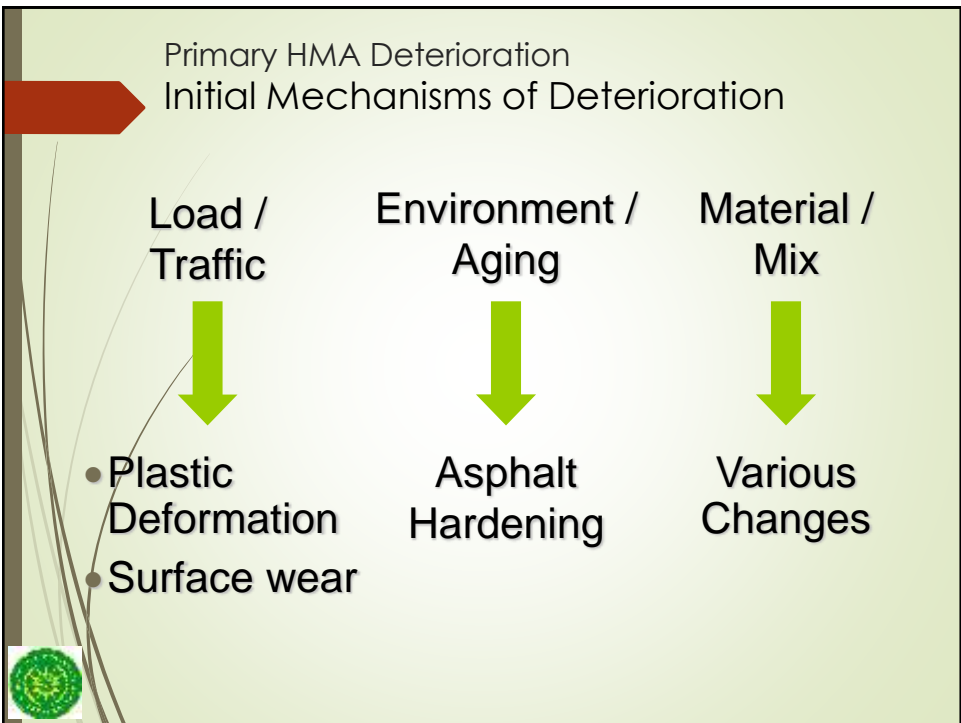
- Traffic Data
  - Traffic data (volume and speed) can be added to the ranking system to prioritize high traffic streets.
- Revised Cost Data
  - Include replacement of all concrete curb and driveway aprons
  - Include replacement of 15% of sidewalks due to grading/drainage issues
  - Include replacement of all sewer laterals and water services
  - Include replacement of all 4" diameter water mains

## New Infrastructure Management Sys

- Analyze the data and relationships between the following factors:
  - Pavement Condition
  - Traffic Data
  - Underground Utility Evaluations
    - Sanitary Sewer
    - Water Main
    - Stormwater/Sump Pump Collector Systems
  - Road Cores/Soil Borings/Treatments
  - Revised Cost Data
- Revised Report that outlines proposed streets in five (5) year increments



# DISTRESS REVIEW



## Primary HMA Deterioration Load-Related Distresses



## Primary HMA Deterioration Traffic-Related Distresses



# Primary HMA Deterioration Environment/Aging-Related Distresses

Environment/  
Aging

↓  
Asphalt  
Hardening



Block Cracking

Raveling/Weathering



# Primary HMA Deterioration Material/Mix-Related Distresses

Material Problems



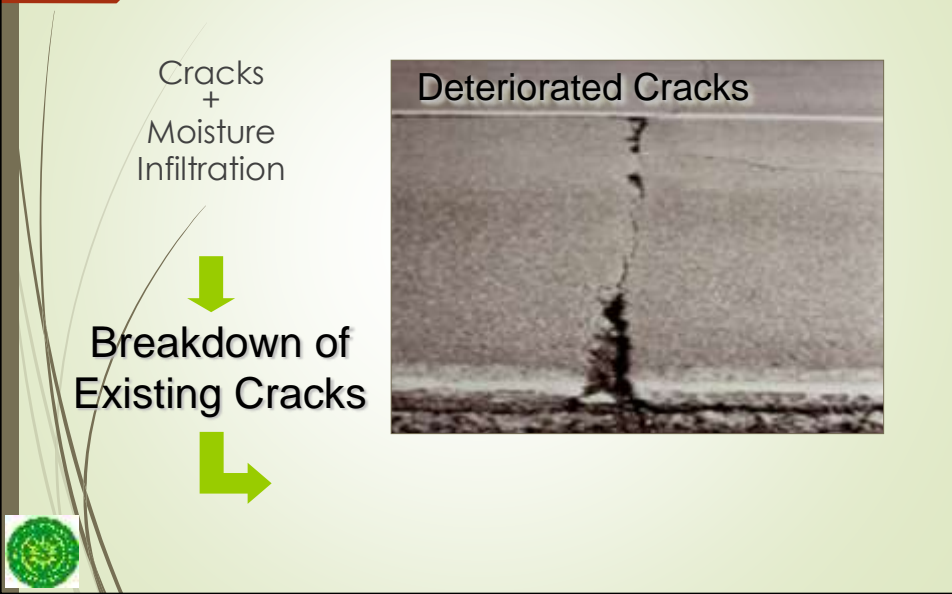
Bleeding/Flushing



Friction Loss



## Secondary HMA Deterioration Influence of Moisture Infiltration



## Secondary HMA Deterioration Influence of Moisture Infiltration

