APPENDIX A

FLEXIBLE PAVEMENT DISTRESS TYPES, SEVERITIES, MEASUREMENT AND REPAIR OPTIONS

ALLIGATOR CRACKING (Distress Type 1)

Alligator or fatigue cracking is a series of interconnecting cracks by fatigue failure of the asphalt concrete surface under repeated traffic loading. Cracking begins at the bottom of the asphalt surface (or stabilized base) where tensile stress and strain are highest under a wheel load. The cracks propagate to the surface initially as a series of parallel longitudinal cracks. After repeated traffic loading, the cracks connect, forming many sided, sharp-angled pieces that develop a pattern resembling chicken wire or the skin of an alligator. The pieces are generally less than 2ft (0.6m) on the longest side.

Alligator cracking occurs only in areas subjected to repeated traffic loading, such as wheel paths. Therefore, it would not occur over an entire area unless the entire area was subjected to traffic loading. (Pattern-type cracking that occurs over an entire are not subjected to loading is called "block cracking," which is not a load-associated distress.)

Alligator cracking is considered a major structural distress and is usually accompanied by rutting.

SEVERITY LEVELS (FIGURE A-1)		OPTIONS FOR REPAIR
LOW	Fine, longitudinal hairline cracks running parallel to each other with no, or only a few interconnecting cracks. The cracks are not 'spalled'	Do nothing; Surface seal; Overlay
MEDIUM	Further development of light alligator cracks into a pattern or network of cracks that may be lightly spalled	Partial or full-depth patch; Overlay: Reconstruct
HIGH	Network or pattern cracking has progressed so that the pieces are well defined and spalled at the edges. Some of the pieces may rock under traffic	Partial or full-depth patch; Overlay; Reconstruct

How to Measure

Alligator cracking is measured in square feet of surface area. The major difficulty in measuring this type of distress is that two or three levels of severity often exist within one distressed area. If these portions can be easily distinguished from each other, they should be measured and recorded separately. However, if the different levels of severity cannot be divided easily, the entire area should be rated at the highest severity present. If alligator cracking and rutting occur in the same area, each is recorded separately as its respective severity level.

LOW

MEDIUM

HIGH

Figure A-1: Alligator Cracking

BLEEDING (Distress Type 2)

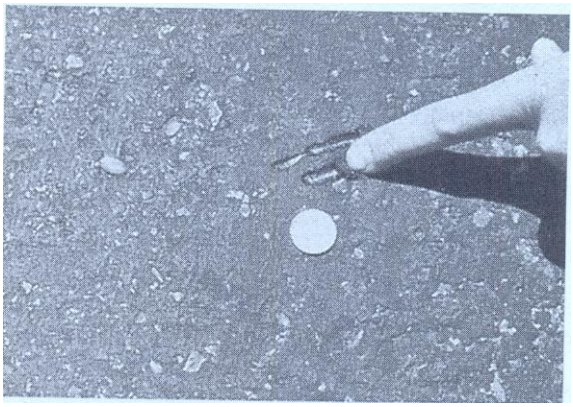
Bleeding is a film of bituminous material on the pavement surface that creates a shiny, glasslike, reflecting surface that usually becomes quite sticky. Bleeding is caused by excessive amounts of asphaltic cement. It occurs when asphalt fills the void of the nous sealant, and/or low air void content. It occurs when asphalt fills the void of the mix during hot weather and then expands onto the pavement surface. Since the bleeding process in not reversible during cold weather, asphalt or tar will accumulate on the surface.

How to Measure

Bleeding is measured in square feet o surface area. If bleeding is counted, polished aggregate should not be counted.

SEVERITY LEVELS (FIGURE A-2)		OPTIONS FOR REPAIR
LOW	Bleeding has only occurred to a very slight degree and is noticeable only during a few days of the year. Asphalt does not stick to shoes or vehicles	Do nothing
MEDIUM	Bleeding has occurred to the extent that asphalt sticks to shoes and vehicles during only a few weeks of the year	Apply sand/aggregate and roll
HIGH	Bleeding has occurred extensively and considerable asphalt sticks to shoes and vehicles during at least several weeks of the year	Apply sand/aggregate and roll

LOW



MEDIUM

HIGH

Figure A-2: Bleeding

BLOCK CRACKING (Distress Type 3)

Block cracks are interconnected cracks that divide the pavement into approximately rectangular pieces. The blocks may range in size from approximately 1 by 1ft (0.3 by 0.3m) to 10 by 10ft (3 by 3m). Block cracking is caused mainly by shrinkage of the asphalt concrete and daily temperature cycling (which results in daily stress/strain cycling). It is not load associated. Block cracking usually indicates that the asphalt has hardened significantly. Block cracking normally occurs over a large portion of the pavement area, but sometimes will occur only in non-traffic areas. This type of distress differs from alligator cracking in that alligator cracks form smaller, many sided pieces with sharp angles. Also, unlike block, alligator cracks are caused by repeated traffic loadings and are therefore found only traffic area (i.e., wheel paths).

How to measure

Block cracking is measured in square feet of surface area. It usually occurs at one severity level in a given pavement section. However, if areas of different severity levels can be easily distinguish from one another, they should be measured and recorded separately.

SEVERITY LEVELS (FIGURE A-3)		OPTIONS FOR REPAIR
LOW	Blocks are defined by low severity cracks	Seal cracks over 1/8 in; Surface seal
MEDIUM	Blocks are defined by medium severity cracks	Seal cracks; Recycle surface; Heater scarify and overlay
HIGH	Blocks are defined by high severity cracks	Seal cracks; Recycle surface; Heater scarify and overlay

CORRUGATION (Distress Type 4)

Corrugation (also known as "washboarding") is a series of closely spaced ridges and valleys (ripples) occurring at fairly regular intervals usually < 10 ft (3m) along the pavement. The ridges are perpendicular to the traffic direction. This type of distress is usually caused by traffic action combined with an unstable pavement surface or base. If bumps occur in a series of < 10ft (3m), due to any cause, the distress is considered corrugation.

How to Measure: Corrugation is measured in square meters (feet) of surface area.

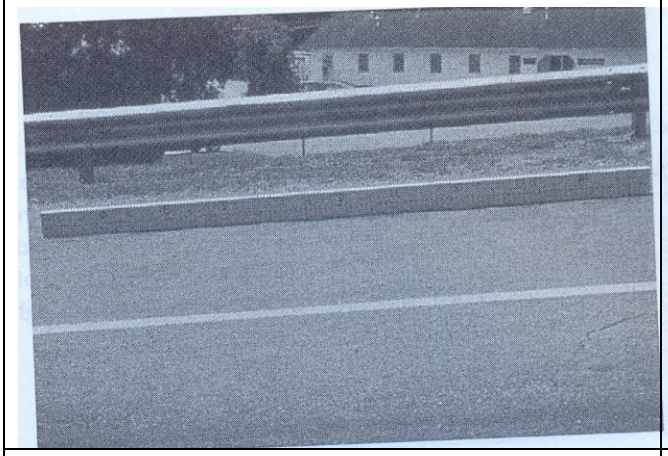
SEVERITY LEVELS (FIGURE A-4)		OPTIONS FOR REPAIR
LOW	Corrugation produces low severity ride quality	Do nothing
MEDIUM	Corrugation produces medium-severity ride quality	Reconstruct
HIGH	Corrugation produces high-severity ride quality	Reconstruct

LOW

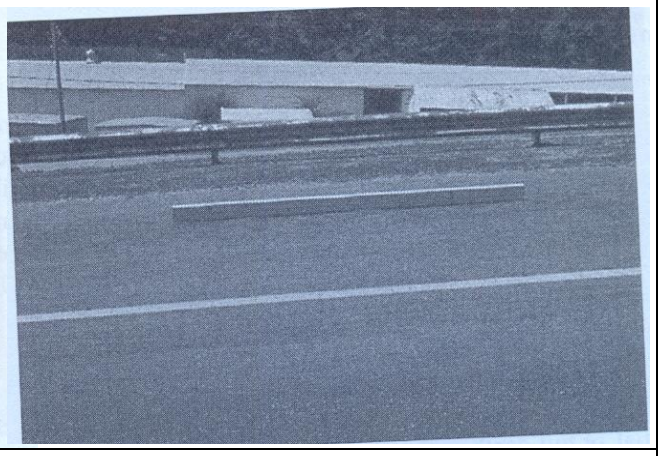
MEDIUM

HIGH

Figure A-3: Block Cracking



LOW



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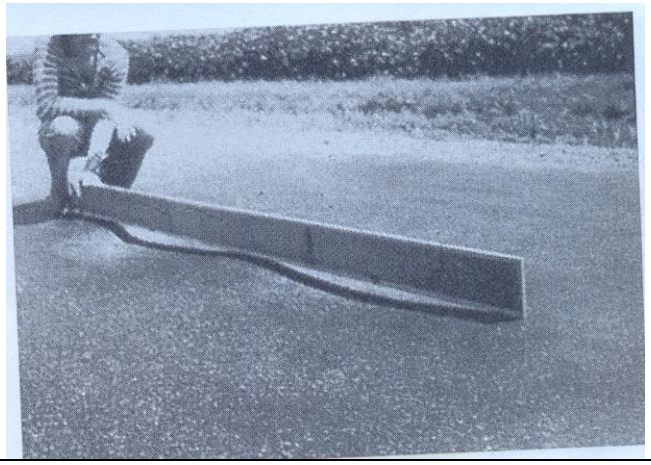

HIGH

Figure A-4: Corrugation

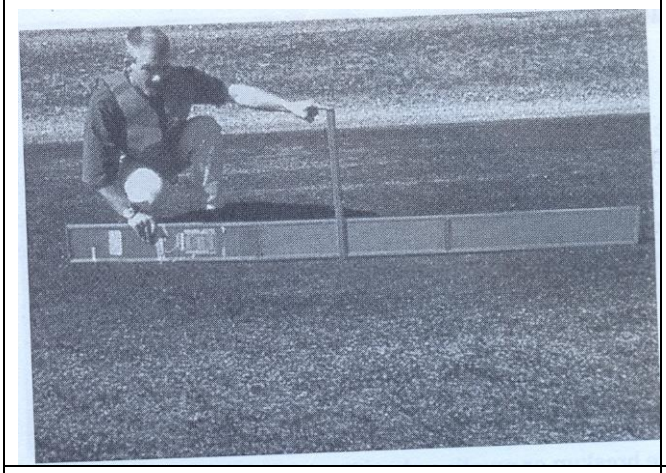
DEPRESSION (Distress Type 5)

Depressions are localized pavement surface areas with elevations slightly lower than those of the surrounding pavement. In many instances, light depressions are not noticeable until after a rain, when ponding water creates a "birdbath" area. On dry pavement, depressions can be spotted by looking for stains caused by ponding water. Depressions are created by settlement of the foundation soil or are a result of improper construction. Depressions cause some roughness, and when deep enough or filled with water, can cause hydroplaning.

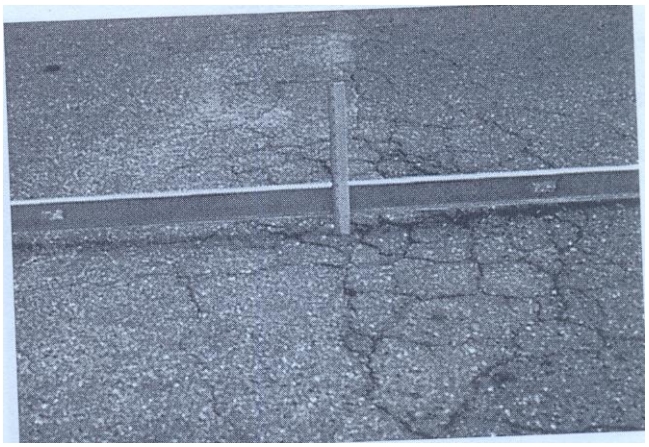
Sags, unlike depressions are abrupt drops in elevation.

How to Measure: Depressions are measured in square meters (feet) of surface area.

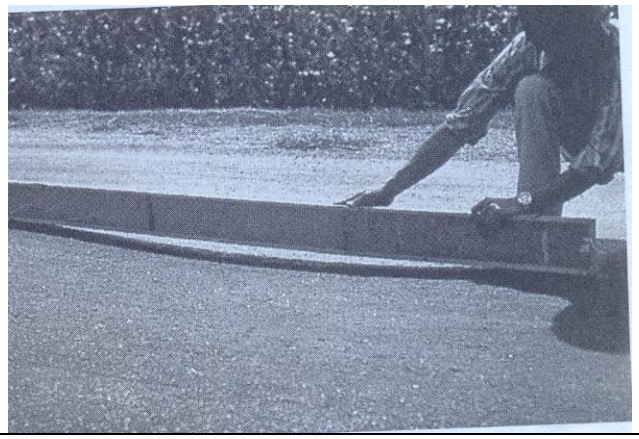
SEVERITY LEVELS Maximum Depth of Depression (FIGURE A-5)		OPTIONS FOR REPAIR
LOW	13 to 25 mm (1/2 to 1 in)	Do nothing
MEDIUM	25 to 50 mm (1 to s2 in)	Shallow, partial, or full-depth patch
HIGH	more than 50 mm (2 in)	Shallow, partial, or full-depth patch



LOW



MEDIUM



HIGH

Figure A-5: Depression

EDGE CRACKING (Distress Type 6)

Edge cracks are parallel to and usually within 1 to 2 ft (0.3 to 0.6m) of the outer edge of the pavement. This distress is accelerated by traffic loading and can be caused by frost-weakened base or sub grade near the edge of the pavement. The area between the crack and pavement edge is classified as raveled if it is broken up (sometimes to the extent that pieces are removed)

How to Measure: Edge cracking is measure in linear feet.

SEVERITY LEVELS (FIGURE A-6)		OPTIONS FOR REPAIR
LOW	Low or medium cracking with no breakup or raveling	Do nothing; Seal cracks over 1/8 in (3 min)
MEDIUM	Medium cracks with some break up and raveling	Seal cracks; Partial-depth patch
HIGH	Considering break up or raveling along edge	Partial-depth patch

LOW

MEDIUM

HIGH

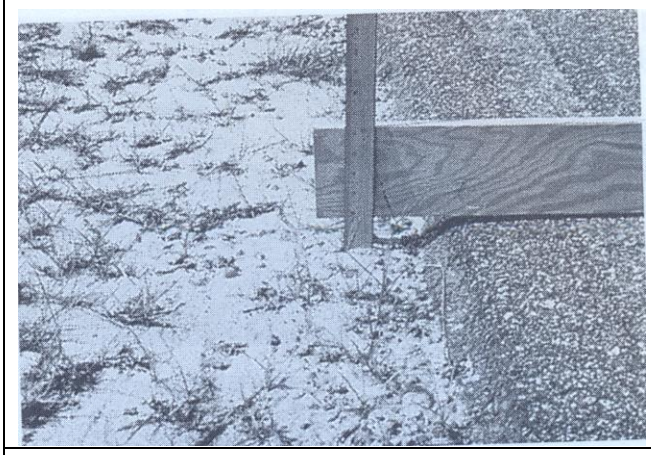
Figure A-6: Edge Cracking

LANE/SHOULDER DROP OFF (Distress Type 7)

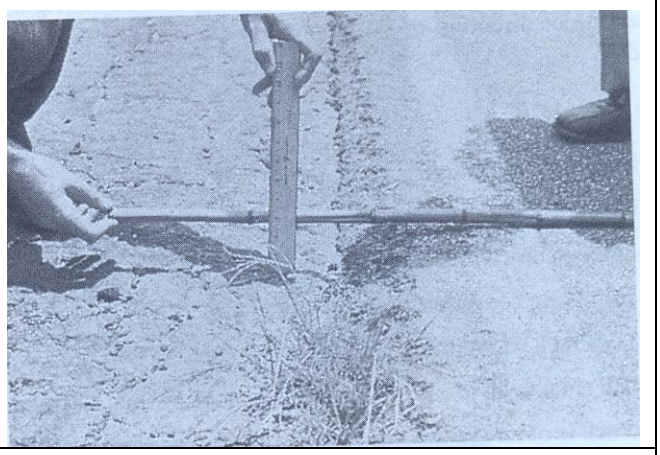
Lane/shoulder drop off is a difference in elevation between the pavement edge and the shoulder. This distress is caused by shoulder erosion, shoulder settlement, or by building up the roadway without adjusting the shoulder level.

How to Measure: Lane/shoulder drop off is measured in linear feet (metres)

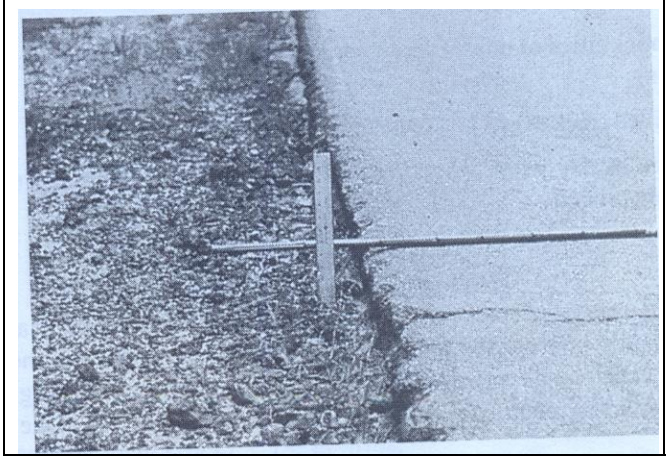
SEVERITY LEVELS (FIGURE A-7)		OPTIONS FOR REPAIR
LOW	The difference in elevation between the pavement edge and shoulder is 1 to 2 in (25 to 51mm)	Regrade and fill shoulders to match lane height
MEDIUM	The difference in elevation is > 2 to 4 in (51 to 102mm)	Ditto
HIGH	The difference in elevation is >4 in (102 mm)	Ditto



LOW



MEDIUM



HIGH

Figure A-7: Lane / Shoulder Drop-Off

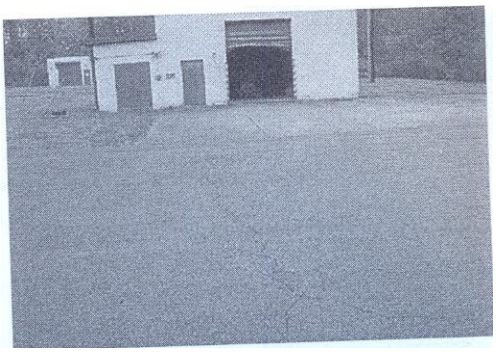
LONGITUDINAL AND TRANSVERSE CRACKING (Distress Type 8)
(NON-PPC SLAB JOINT REFLECTIVE)

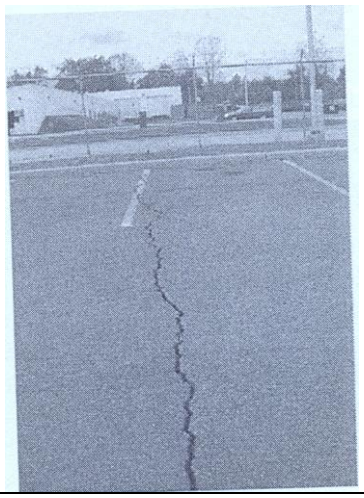
Longitudinal cracks are parallel to the pavement's centerline or lay down direction. They may be caused by:

1. A poorly constructed paving lane joint
2. Shrinkage of the AC surface due to low temperature or hardening of the asphalt and/or daily temperature cycling.
3. A reflective crack caused by cracking beneath the surface course, including cracks in PCC slabs (but not PCC joints)

Transverse cracks extend across the pavement at approximately right angles to the pavement centerline or direction of lay down. These types of cracks are not usually load-associated.

SEVERITY LEVELS (FIGURE A-8)		OPTIONS FOR REPAIR
LOW	One of the following conditions exists: 1. Non-filled crack width is less than 3/8 in. (10mm) 2. Filled crack of any width (filler in satisfactory condition)	Do nothing; Seal cracks >1/8 in. wide
MEDIUM	One of the following conditions exists: 1. Non-filled crack width is 3/8 to 3 in. (10 to 76mm) 2. Non-filled crack is up to 3 in (76mm) surrounded by light and random cracking 3. Filled crack is of any width surrounded by light random cracking	Seal cracks
HIGH	One of the following conditions exists: 1. Any crack filled or non-filled surrounded by medium or high severity random cracking 2. Non-filled crack over 3 in. (76mm) 3. A crack of any width where a few inches of pavement around the crack is severely broken	Seal cracks; Partial-depth patch





LOW

MEDIUM

HIGH

Figure A-8: Longitudinal and Transverse Cracking

How to Measure

Longitudinal and transverse cracks are measured in linear feet. The length and severity of each crack should be recorded after identification. If the crack does not have the same severity level along its entire length, each portion of the crack having a different severity level should be recorded separately. If a bump or sag occurs at the crack, it is also recorded.

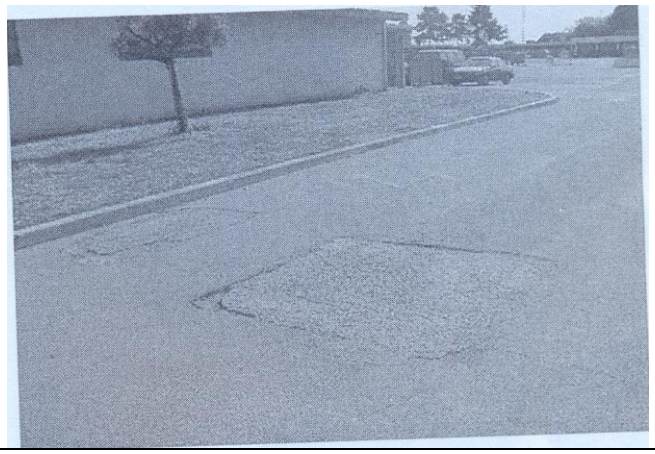
PATCHING AND UTILITY CUT PATCHING (Distress Type 9)

A patch is an area of pavement that has been replaced with new material to repair the existing pavement. A patch is considered a defect no matter how well it is performing (a patched area or adjacent area usually does not perform as well an original pavement section). Generally, some roughness is associated with this distress.

SEVERITY LEVELS (FIGURE A-9)		OPTIONS FOR REPAIR
LOW	Patch is in good condition and satisfactory. Ride quality is rated as low severity or better	Do nothing
MEDIUM	Patch is moderately deteriorated and/or ride quality is rated as medium severity	Do nothing; Replace patch
HIGH	Patch is badly deteriorated and/or ride quality is rated as high severity. Needs replacement soon	Replace patch

LOW

MEDIUM



HIGH

Figure A-9: Patching and Utility Cut Patching

How to Measure

Patching is rated in square feet of surface area. However, if a single patch has areas of differing severity, these areas should be measured and recorded separately. For example, a 25 sq ft (2.32 m^2) patch may have 10 sq ft (0.9m^2) of medium severity and 15 sq ft (1.35 m^2) of low severity. These areas would be recorded separately. No other distresses (e.g., showing or cracking), are recorded within a patch; even if the patch material is shoving or cracking, the area is rated only as a patch. If a large amount of pavement has been replaced, it should not be recorded as a patch, but considered as new pavement (e.g. replacement of a complete intersection).

POLISHED AGGREGATE (Distress Type 10)

This distress is caused by repeated traffic applications. When the aggregate in the surface becomes smooth to the touch, adhesions with vehicle tyres are considerably, reduced. When the portion of aggregate extending above the surface is small, the pavement texture does not significantly contribute to reducing vehicle speed. Polished aggregate should be counted when close examination reveals that the smooth to the touch. This type of distress is indicated when the number on a skid resistance test is low or has dropped significantly from a previous rating.

SEVERITY LEVELS (FIGURE A-10)		OPTIONS FOR REPAIR
LOW	No degrees of severity are defined. However, the degree of polishing should be clearly evident in the sample unit in that the aggregate surface should be smooth to the touch.	Do nothing; Surface treatment; Overlay; Mill and Overly.
MEDIUM		
HIGH		

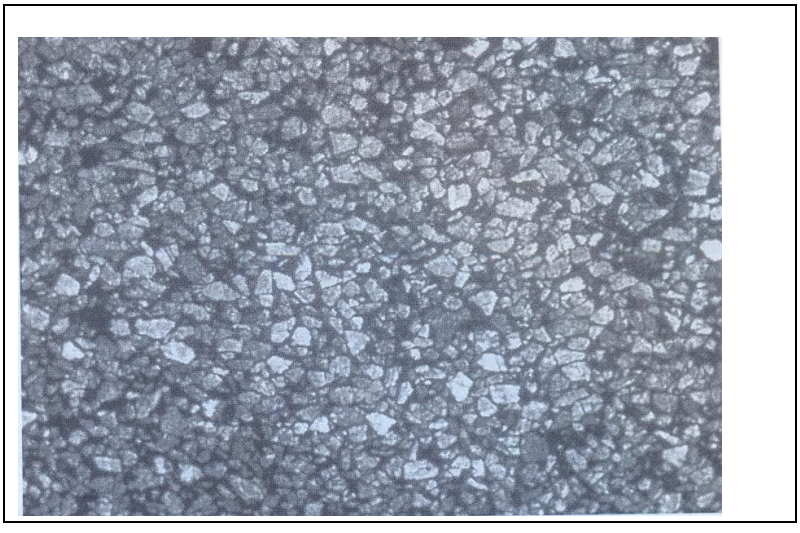


Figure A-10: Polished Aggregate

How to Measure

Polished aggregate is measured in square feet of surface area. If bleeding is counted, polished aggregate should not be counted.

POTHOLES (Distress Type 11)

Potholes are small – usually less than 3 ft (0.9m) in diameter – bowl shaped depressions in the pavement surface. They surface. They generally have sharp edges and vertical sides near the top of the hole. Their growth is accelerated by free moisture collection inside the hole. Potholes are produced when traffic abrades small pieces of the pavement surface. The pavement continues to disintegrate because of poor surface mixtures, weak spots in the base or subgrade, or because it has reached a condition of high severity alligator cracking. Potholes most often are structurally related distresses and should not be confused with raveling and weathering. When holes are created by high severity alligator cracking, they should be identified as potholes, not as weathering.

Severity Levels (Figure A-11)

The levels of severity for potholes less than 30 in (762 mm) in diameter are based on both the diameter and the depth of the pothole, according to Table A-1.

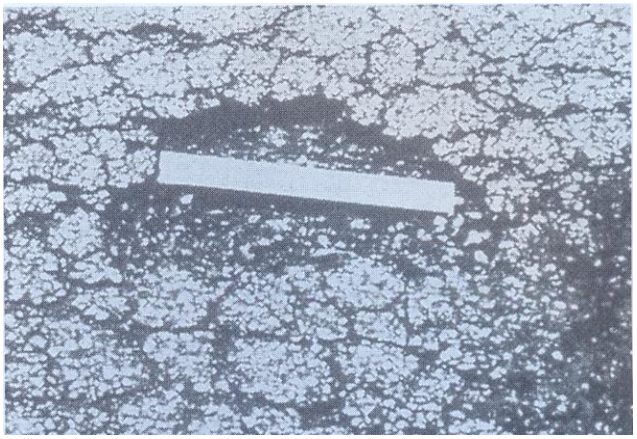
If the pothole is more than 30 in (76mm) in diameter, the area should be determined in square feet and divided by 5 sq ft (0.47 m^2) to find the equivalent number of holes. If the depth is 1 in (25 mm) or less, the holes are considered medium severity. If the depth is more than 1 I n (25 mm), they are considered high severity.

TABLE A-1: LEVELS OF SEVERITY FOR POTHOLES

Average Diameter, in (mm)			
Maximum Depth to Pothole	4 to 8 in, (102 to 203 mm)	8 to 18 in. (203 to 457 mm)	18 to 30 in (457 to 762 mm)
½ to 1 in. (12.7 to 25.4 mm)	L	L	M
>1 to 2 in. (25.4 to 50.8 mm)	L	M	H
>2 in (50.8 mm)	M	M	H

How to Measure

Potholes are measured by counting the number that are low, medium, and high severity and recording them separately.



LOW

MEDIUM

HIGH

Figure A-11: Potholes

Options for Repair

L – Do nothing; Partial or full-depth patch

M – Partial or full-depth patch

H – Full depth patch

RUTTING (Distress Type 12)

A rut is a surface depression in the wheel paths. Pavement uplift may occur along the sides of the rut, but in many instances, ruts are noticeable only after a rainfall when the paths are filled with water. Rutting stems from a permanent deformation in any of the pavement layers or subgrades, usually caused by consolidated or lateral movement of the materials due to traffic load. Significant rutting can lead to major structural failure of the pavement.

SEVERITY LEVELS (FIGURE A-12) (Mean Rut Depth)		OPTIONS FOR REPAIR
LOW	¼ to ½ in.	Do nothing; Mill and overlay
MEDIUM	Greater than ½ in. up to 1 in.	Shallow, partial, or full-depth patch; Mill and overlay
HIGH	Greater than 1 in.	Shallow, partial, or full-depth patch; Mill and overlay

How to Measure

Rutting is measured in square feet of surface area and its severity is determined by the mean depth of the rut (see above). The mean rut depth is calculated by laying a straight edge across the rut, measuring its depth, then using measurements taken along the length of the rut to compute its mean depth in inches.

	
LOW	MEDIUM

HIGH

Figure A-12: Rutting

SHOVING (Distress Type 13)

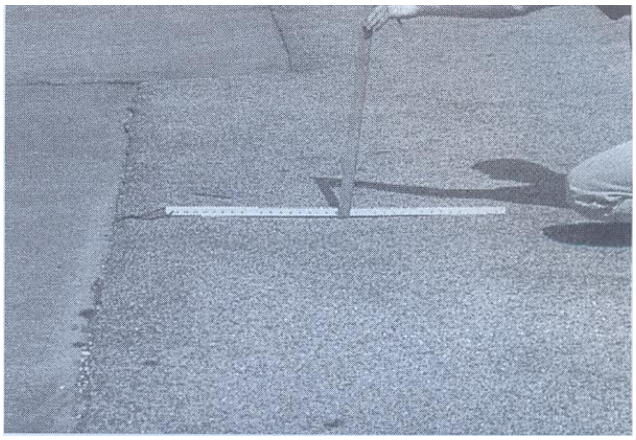
Shoving is a permanent, longitudinal displacement of a localized area of the pavement surface caused by traffic loading. When traffic pushes against the pavement, it produces a short, abrupt wave in the pavement surface. This distress normally occurs only in unstable liquid asphalt mix (cutback or emulsion) pavements.

Shoves also occur where asphalt pavement abuts PCC pavements; the PCC pavements increase in length and push the asphalt pavement, causing the shoving.

SEVERITY LEVELS (FIGURE A-13)		OPTIONS FOR REPAIR
LOW	Shove causes low severity ride quality	Do nothing; Mill
MEDIUM	Shove causes medium severity ride quality	Mill; Partial or full-depth patch
HIGH	Shove causes high severity ride quality	Mill; Partial or full-depth patch

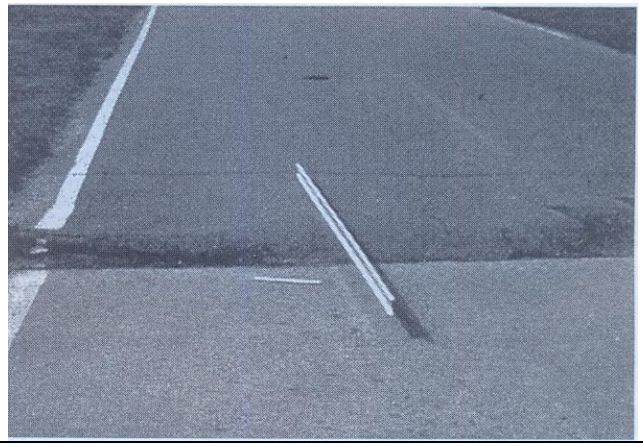
How to Measure

Shoves are measured in square feet of surface area. Shoves occurring in patches are considered in rating the patch, not as a separate distress.



LOW

MEDIUM



HIGH

Figure A-13: Shoving

WEATHERING AND RAVELLING (Distress Type 14)

Weathering and ravelling are the wearing away of the pavement surface due to a loss of asphalt or tar binder and dislodged aggregate particles. These distresses indicate that either the asphalt binder has hardened appreciably or that a poor quality mixture is present. In addition, ravelling may be caused by certain types of traffic, for example, tracked vehicles. Softening of the surface and dislodging of the aggregates due to oil spillage are also included under raveling.

How to Measure

Weathering and raveling are measured in square feet of surface area.

SEVERITY LEVELS (FIGURE A-14)		OPTIONS FOR REPAIR
LOW	Aggregate or binder has started to wear away. In some areas, the surface is starting to pit. In the case of the oil spoilage, the oil stain can be seen, but the surface is hard and cannot be penetrated with a coin.	Do nothing; Surface seal; Surface treatment
MEDIUM	Aggregate or binder has worn away. The surface texture is moderately rough and pitted. In the case of oil spoilage, the surface is soft and can be penetrated with a coin.	Surface seal; Surface treatment; Overlay
HIGH	Aggregate or binder has been worn away considerably. The surface texture is very rough and severely pitted. The pitted areas are less than 4 in (10 mm) in diameter and less than ½ in. (13mm) deep; pitted areas larger than this are counted as potholes. In the case of oil spillage, the asphalt binder has lost its binding effect and the aggregate has become loose.	Surface treatment; Overlay; Recycle; Reconstruct

APPENDIX B

DEDUCT VALUE CURVES FOR FLEXIBLE PAVEMENT

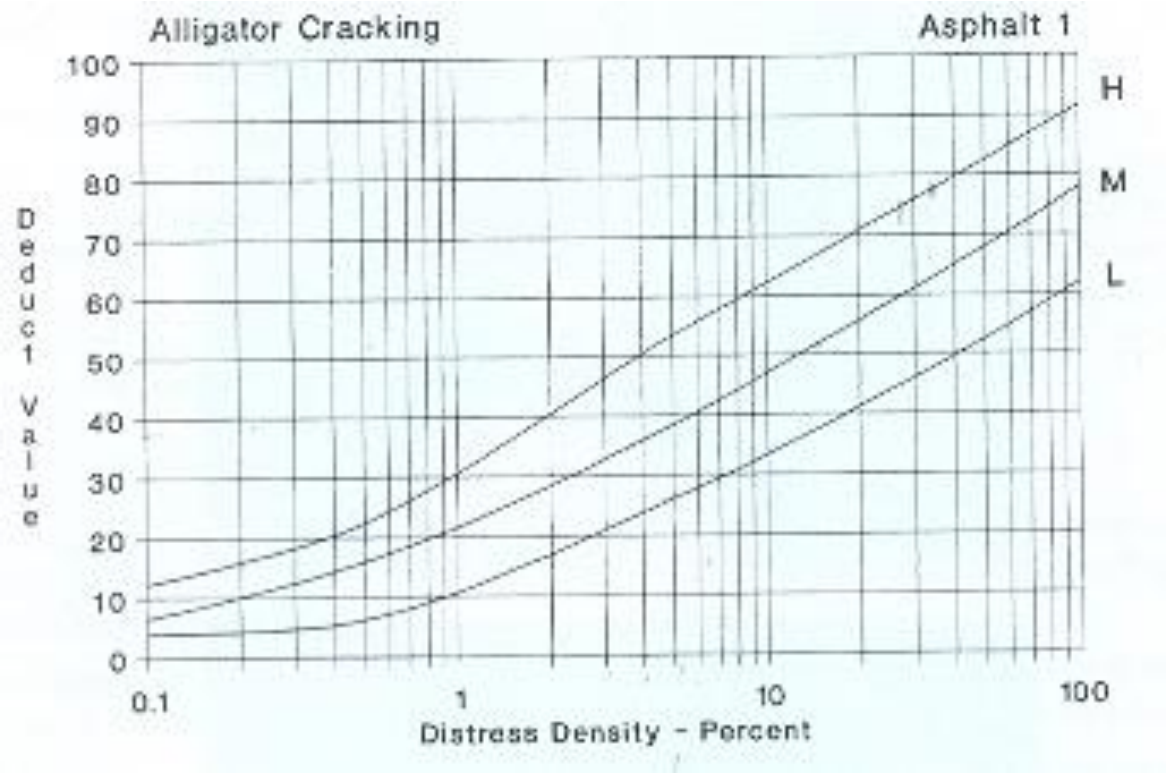


Figure B-1: Distress Deduction Curve for Alligator Cracking

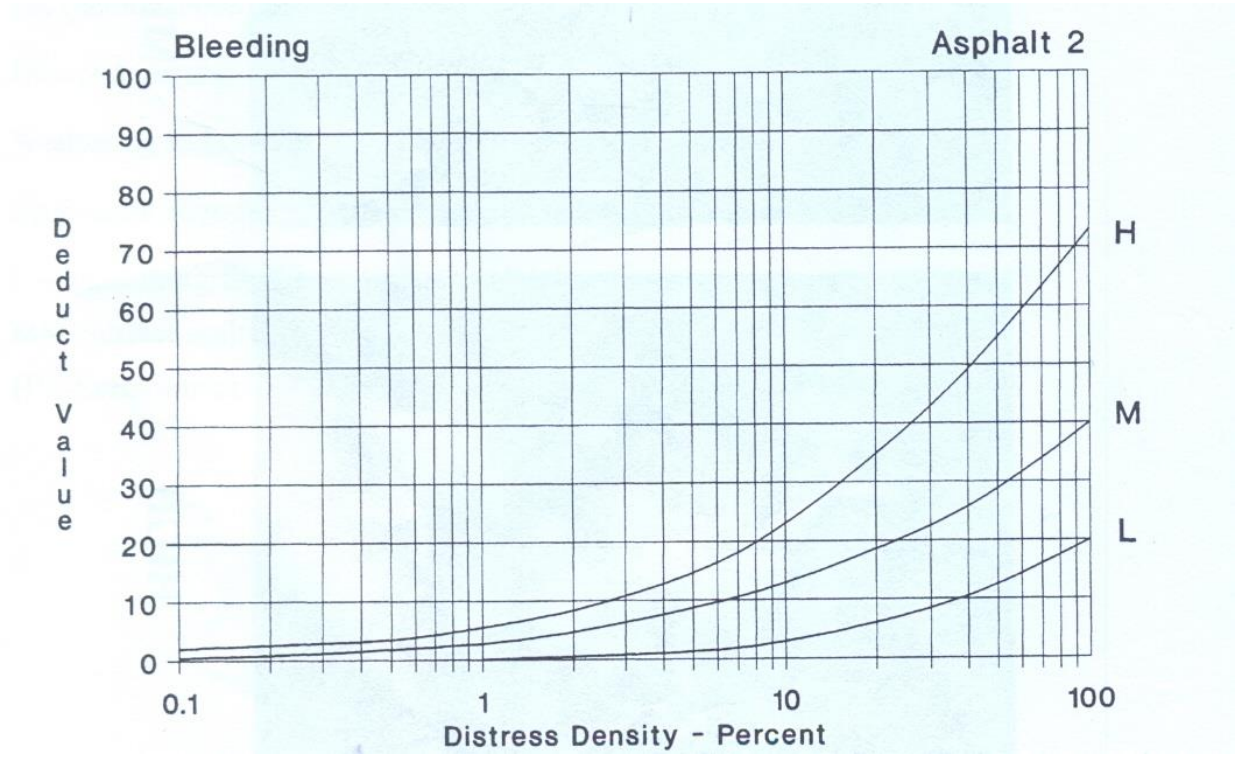


Figure B-2: Distress Deduction Curve for Bleeding

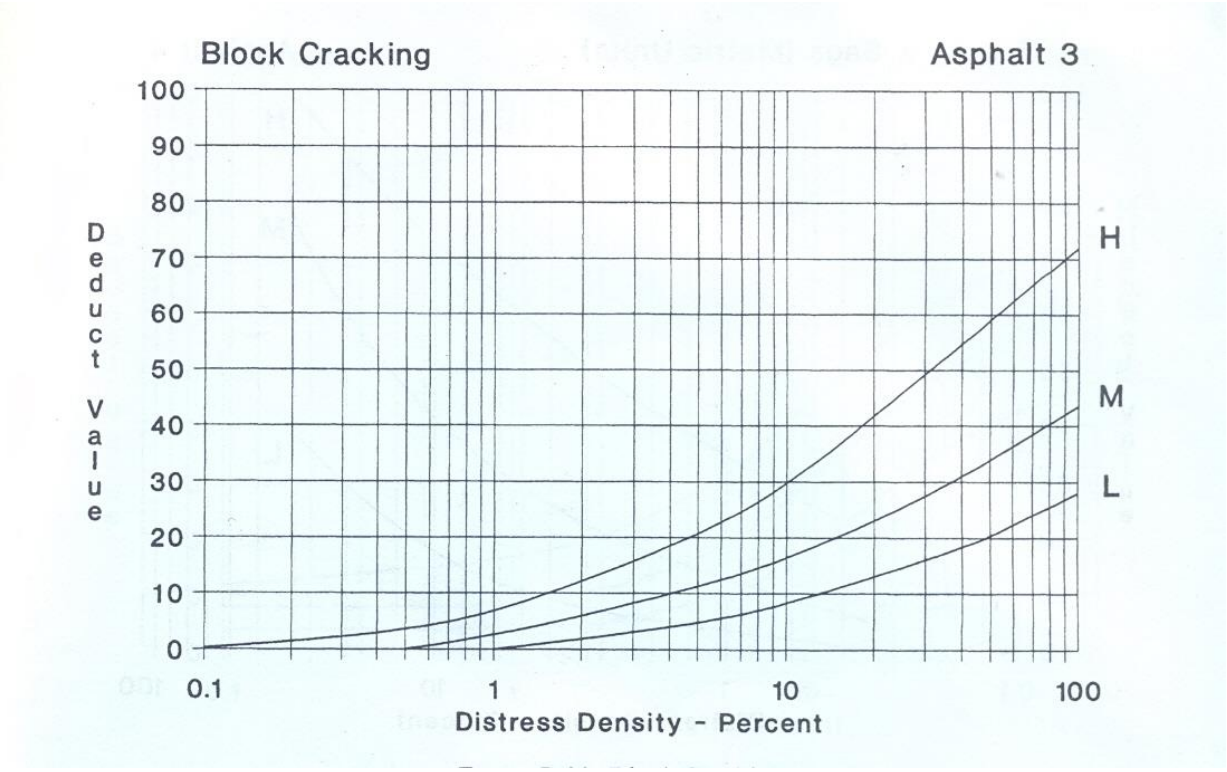


Figure B-3: Distress Deduction Curve for Block Cracking

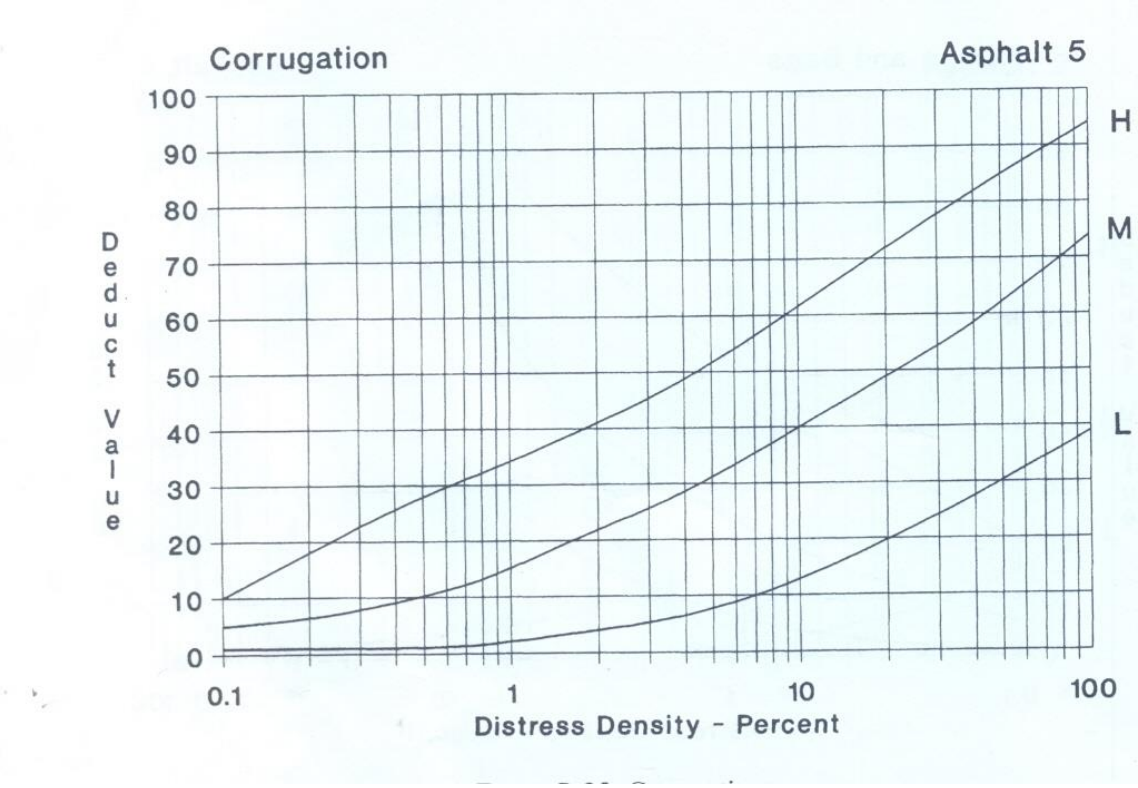


Figure B-4: Distress Deduction Curve for Corrugation

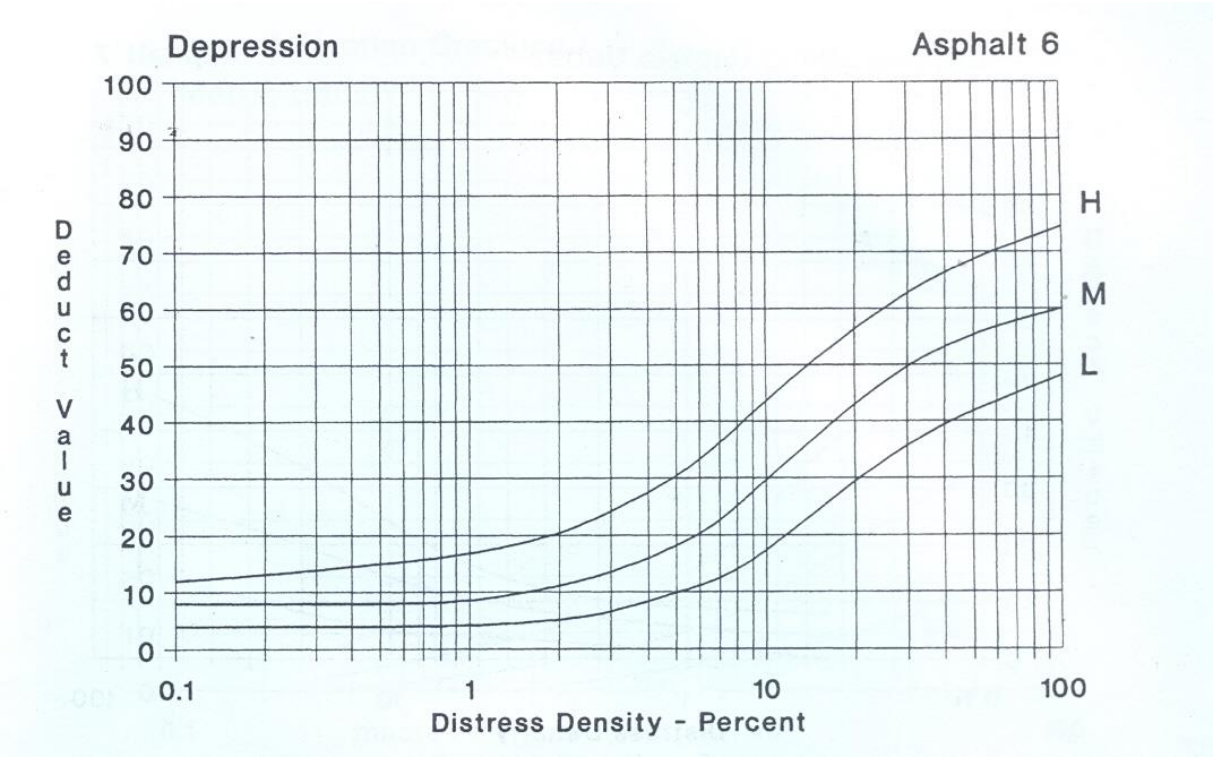


Figure B-5: Distress Deduction Curve for Depression

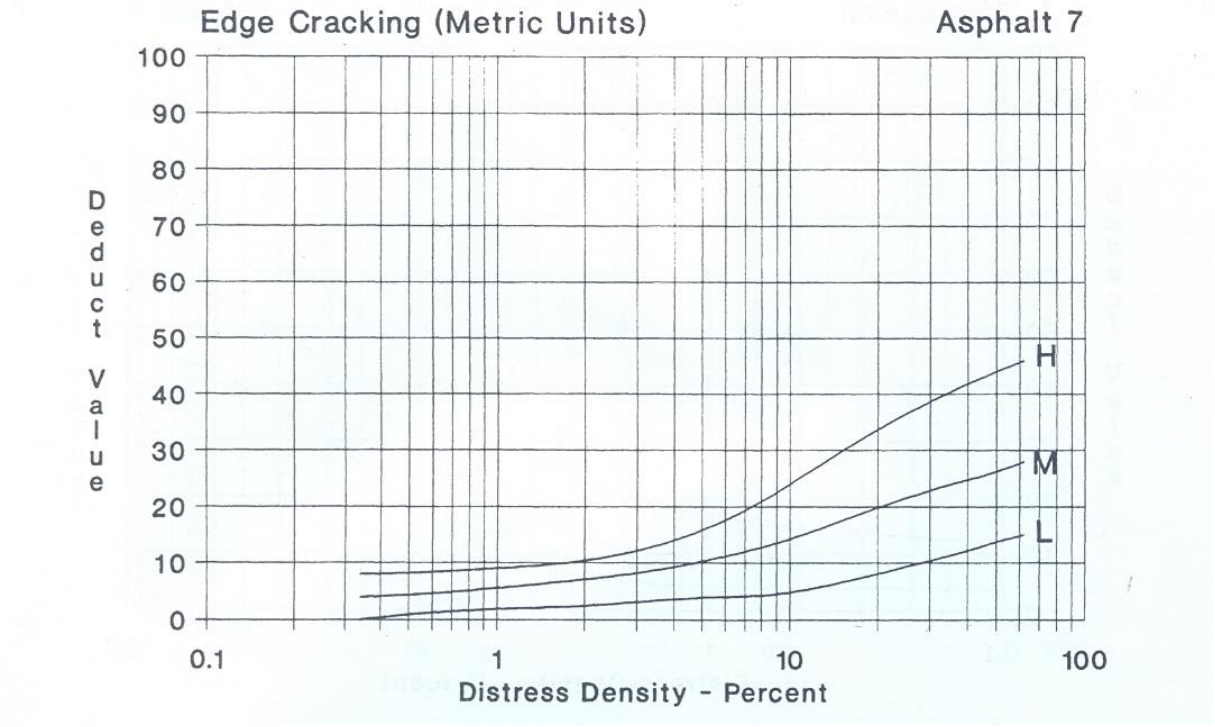


Figure B-6: Distress Deduction Curve for Edge Cracking

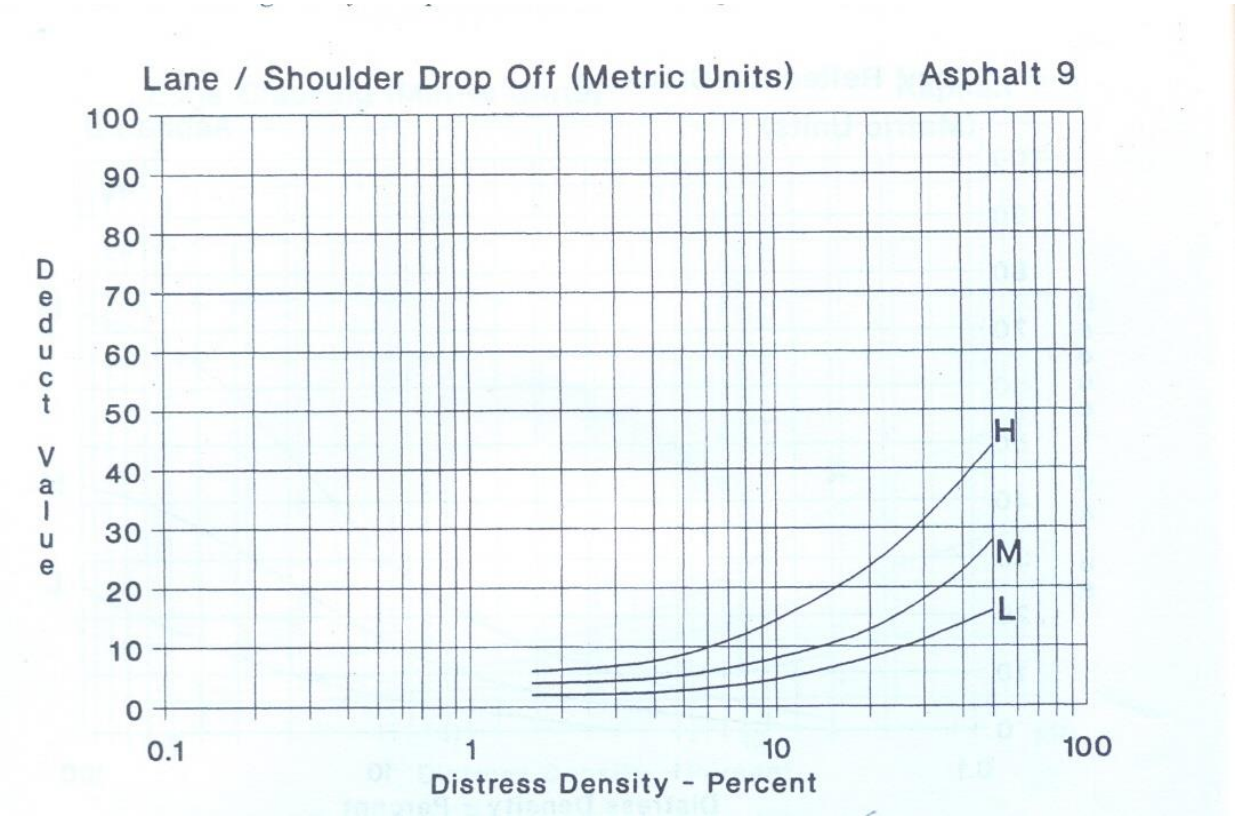


Figure B-7: Distress Deduction Curve for Lane / Shoulder Drop Off

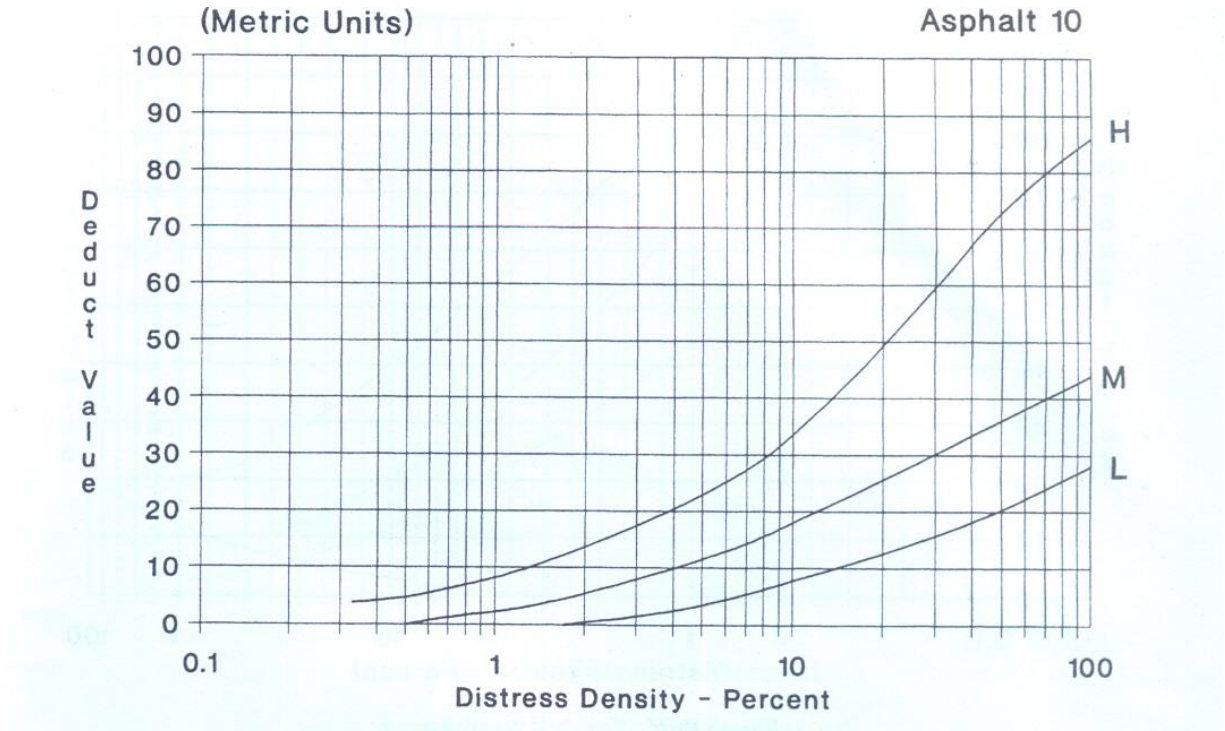


Figure B-8: Distress Deduction Curve for Longitudinal / Transverse Cracking

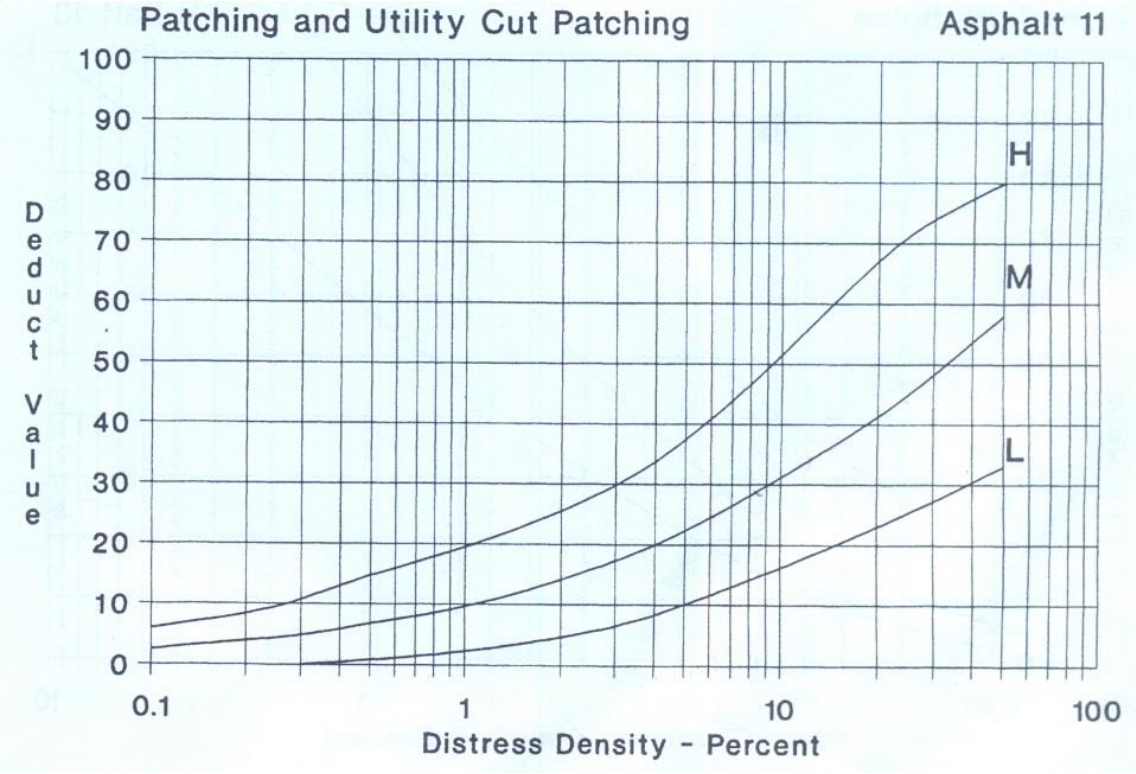


Figure B-9: Distress Deduction Curve for Patching and Utility Cut Patchin

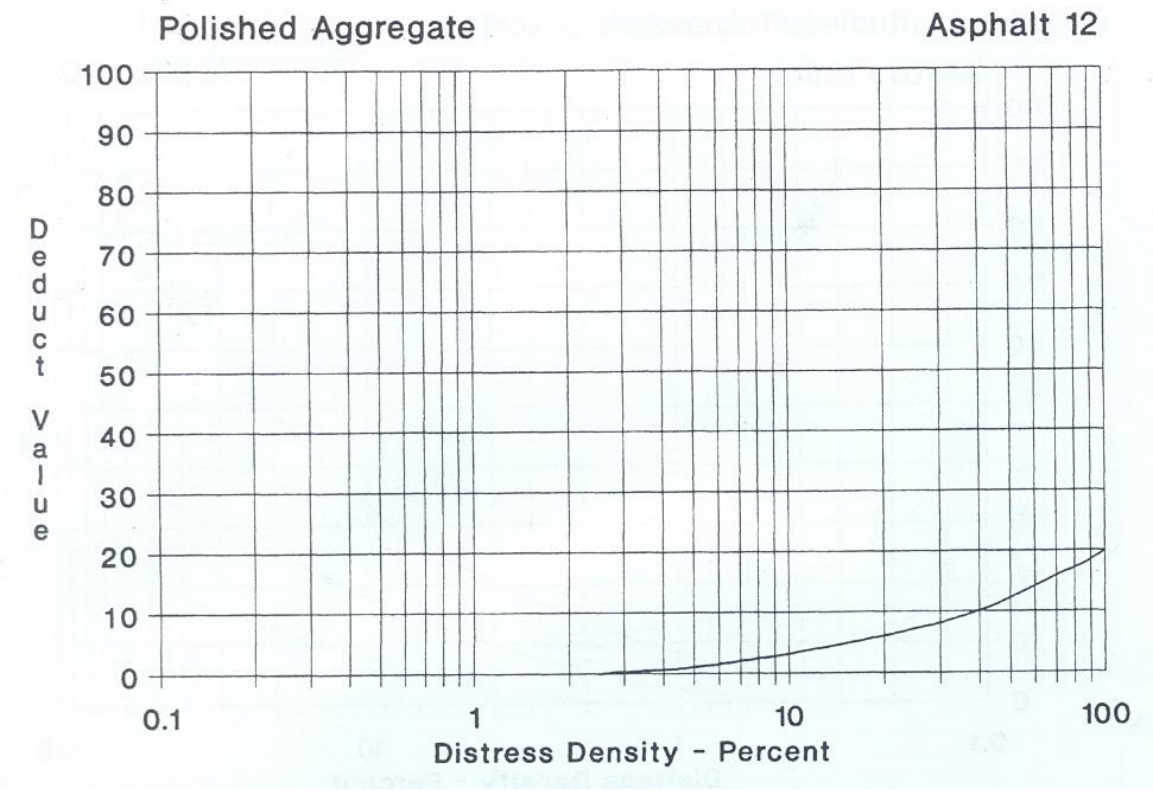


Figure B-10: Distress Deduction Curve for Polished Aggregate

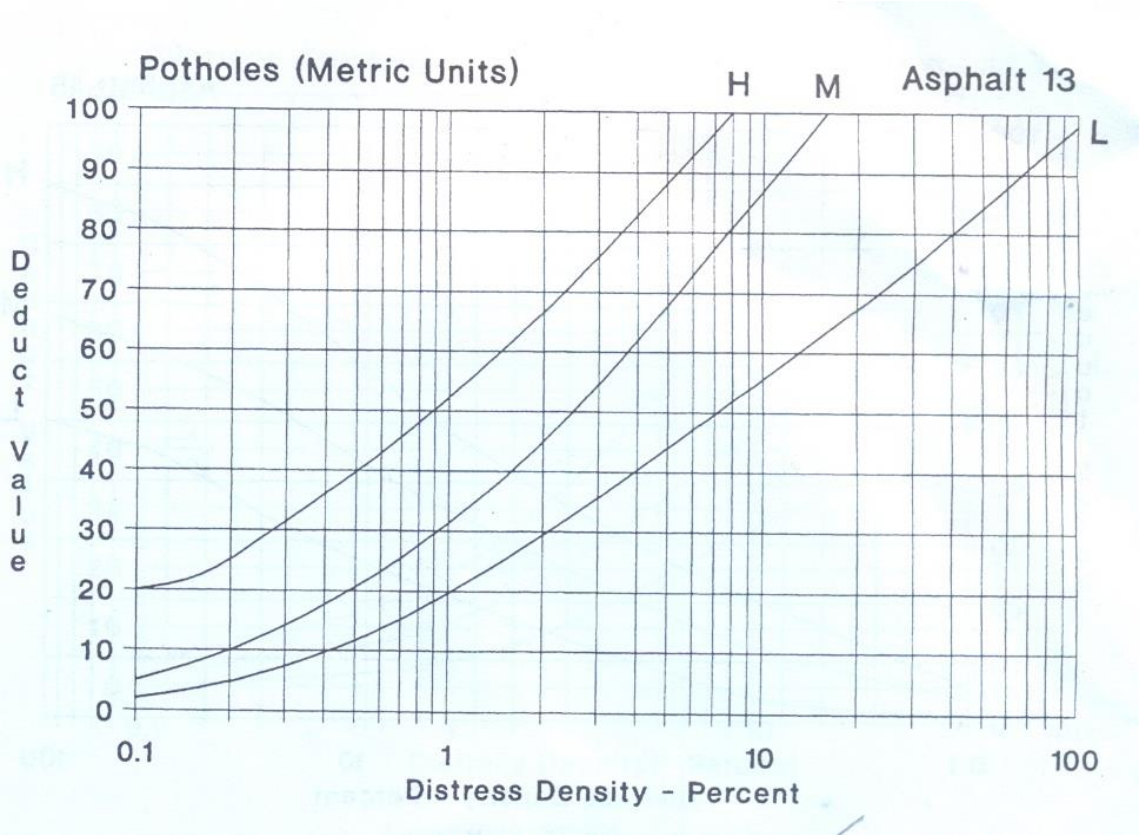


Figure B-11: Distress Deduction Curve for Potholes

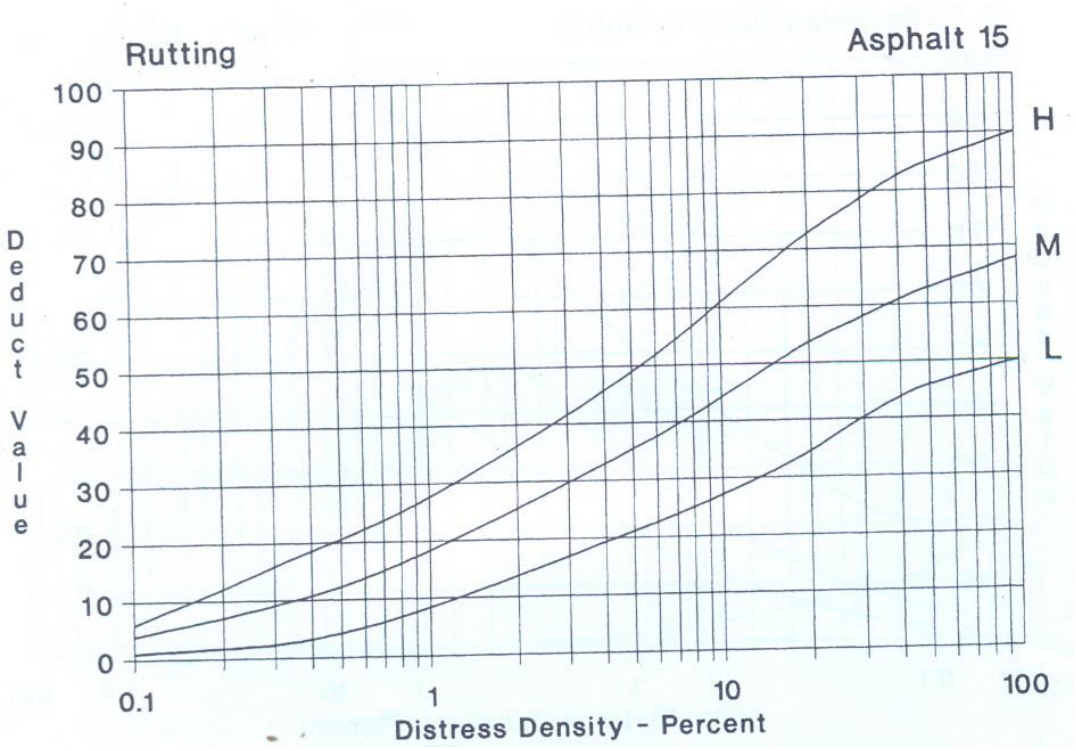


Figure B-12: Distress Deduction Curve for Rutting

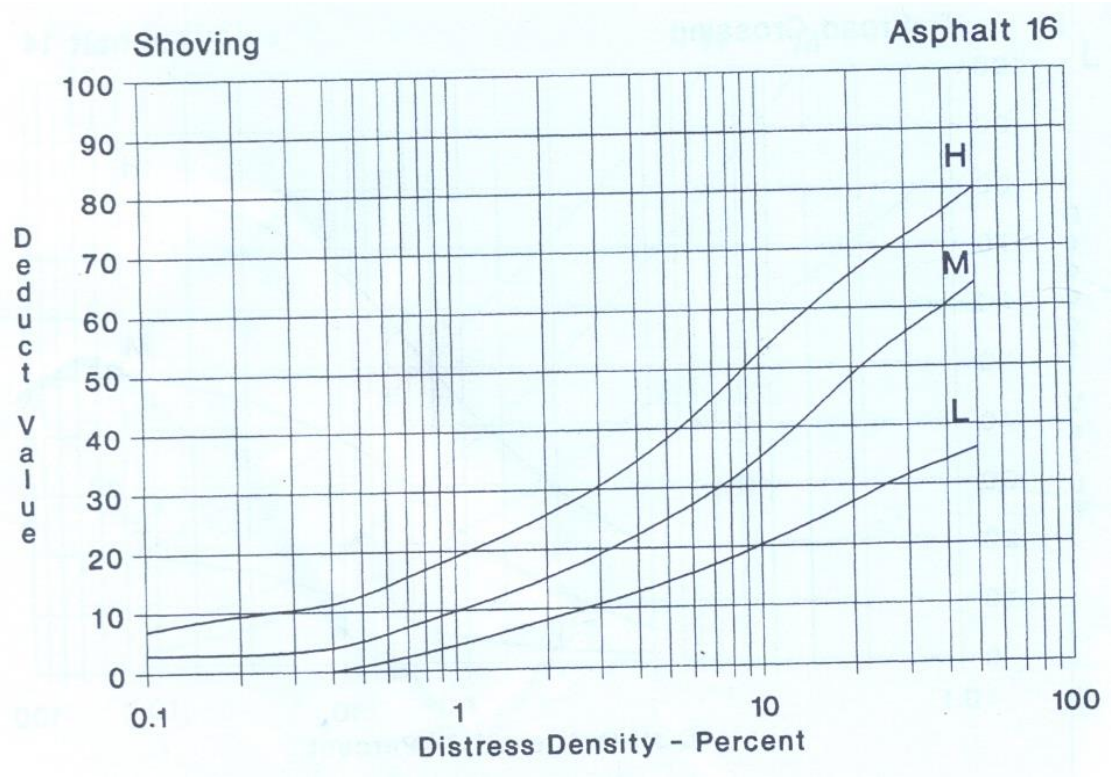


Figure B-13: Distress Deduction Curve for Shoving

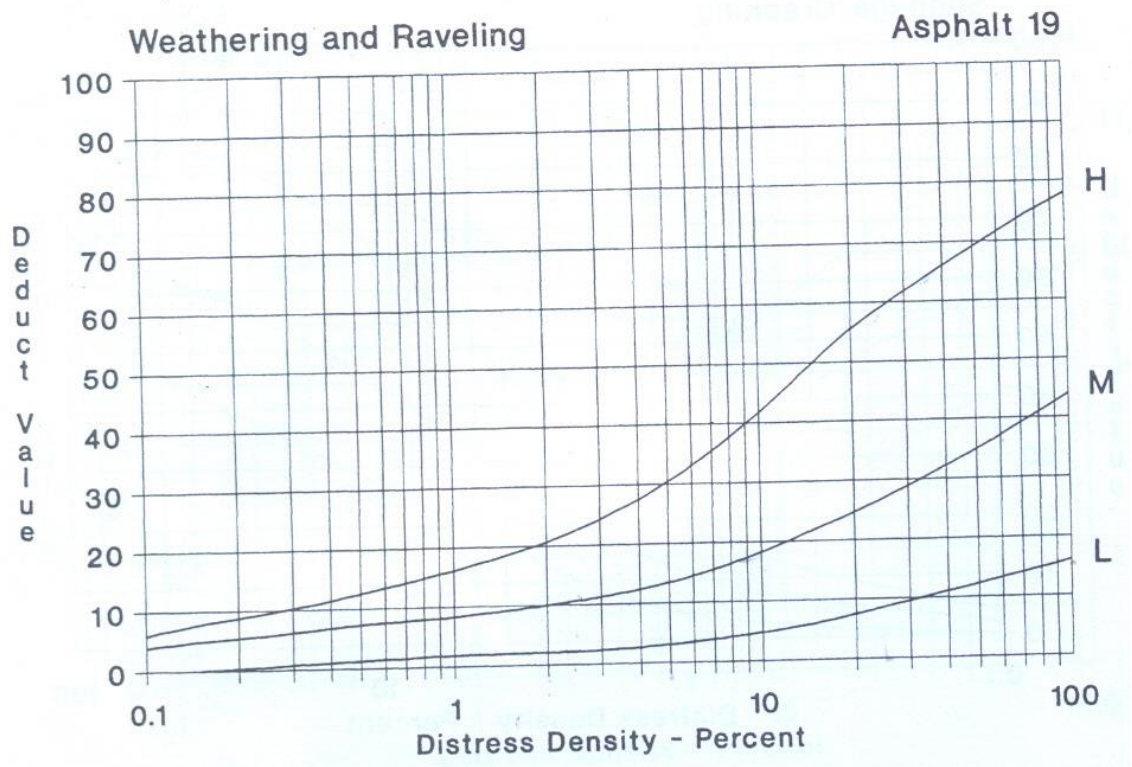
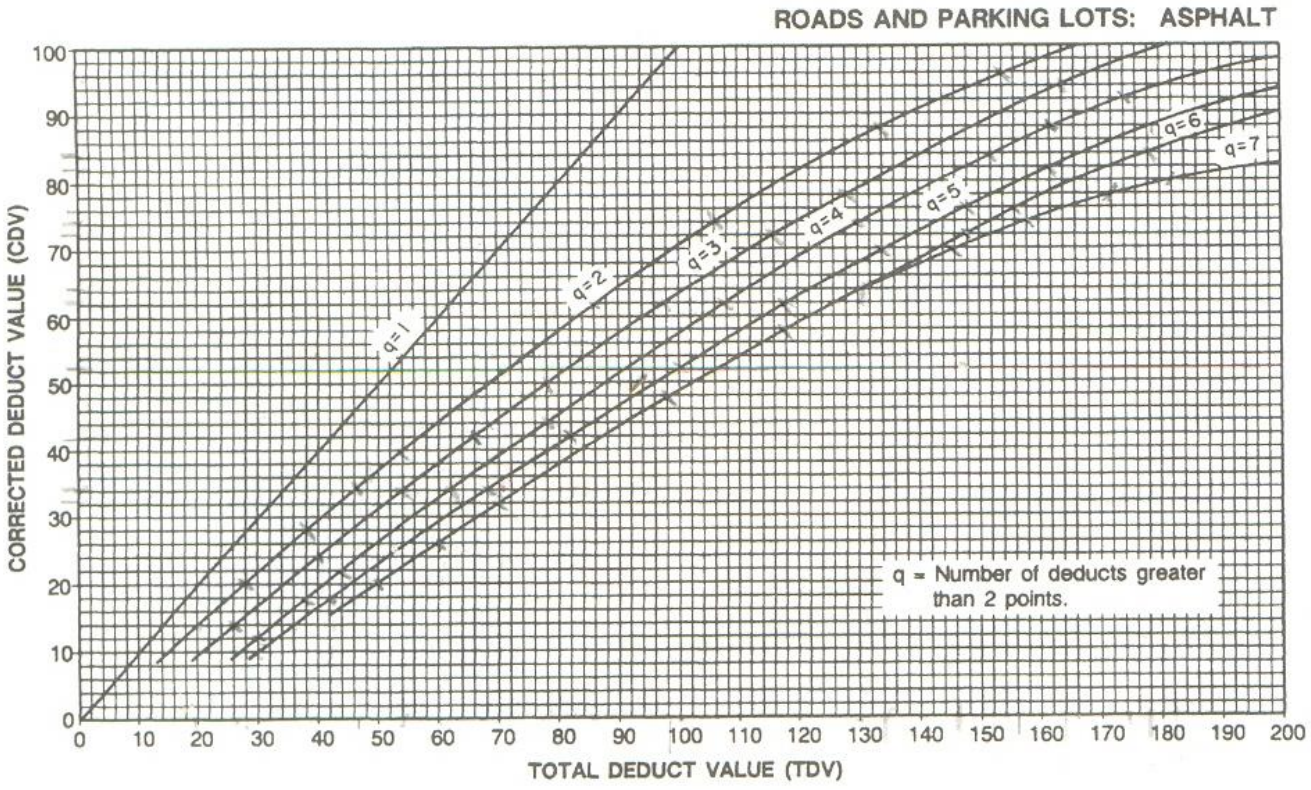


Figure B-14: Distress Deduction Curve for Weathering and Ravelling

APPENDIX C

CORRECTION CURVES FOR ASPHALT SURFACED PAVEMENT



APPENDIX D

QUESTIONNAIRE FOR DEVELOPMENT OF TRANSITION PROBABILITY MATRICES

Name of Rater ……..

Rank (in the Ministry) …….

Age ……..

1. How many years have you been actively involved in road maintenance? ……..
2. How many of those years in (1) were used in the maintenance of flexible pavements (bituminous surface dressed roads and asphaltic concrete pavments)? ……
3. What major maintenance activities have you been executing during these years (a) sealing of potholes and patching (b) resurfacing and overlaying and (c) reconstruction? ……
4. Road deterioration progresses in stages if the road is not maintained over a given period of time. From your experience, is it easy to predict these different stages of deterioration with time? ……..
5. An engineer has classified a road into six different states of disrepair using roughness only as the easiest index of measurement. These states are: 1 (excellent state), 2 (very good state), 3 (good state), 4 (fair state), 5 (poor state) and 6 (failed state). On a chosen scale of measure, there is a score of 1 to 10 to indicate deterioration from one state to another. For example, if the chance that a road in state 1 (excellent state) will remain in the same state after one year if it is left un-maintained is 6, then the probability is 60% (0.6). Based on (5), answer the following questions.

A. (i) What is the chance of the road remaining in state 1 (excellent state) after one year …….

(ii) What is the chance of changing from state 1 to state 2 (excellent to very good)? ……..

(iii) What is the chance of changing from state 1 to state 3 (excellent to good)? ……..

(iv) What is the chance of changing from state 1 to state 4 (excellent to fair)?

……..

(v) What is the chance of changing from state 1 to state 5 (excellent to poor)?

……..

(vi) What is the chance of changing from state 1 to state 6 (excellent to fail)?

……..

B. (i) What is the chance of the road remaining in state 2 (v. good state) after one year?

…….

(ii) What is the chance of changing from state 2 to state 3 (very good to good)?

…….

(iii) What is the chance of changing from state 2 to state 4 (very good to fair)?

…….

(iv) What is the chance of changing from state 2 to state 5 (very good to poor)?

…….

(v) What is the chance of changing from state 2 to state 6 (very good to fail)?

…….

C. (i) What is the chance of the road remaining in state 3 (good state) after one year?

…….

(ii) What is the chance of changing from state 3 to state 4 (good to fair)?

…….

(iii) What is the chance of changing from state 3 to state 5 (good to poor)?

…….

(iv) What is the chance of changing from state 3 to state 6 (good to fail)?

…….

D. (i) What is the chance of the road remaining in state 4 (fair state) after one year?

…….

(ii) What is the chance of changing from state 4 to state 5 (fair to poor)?

…….

(iii) What is the chance of changing from state 4 to state 6 (fair to fail)?

…….

E. (i) What is the chance of the road remaining in state 5 (poor state) after one year?

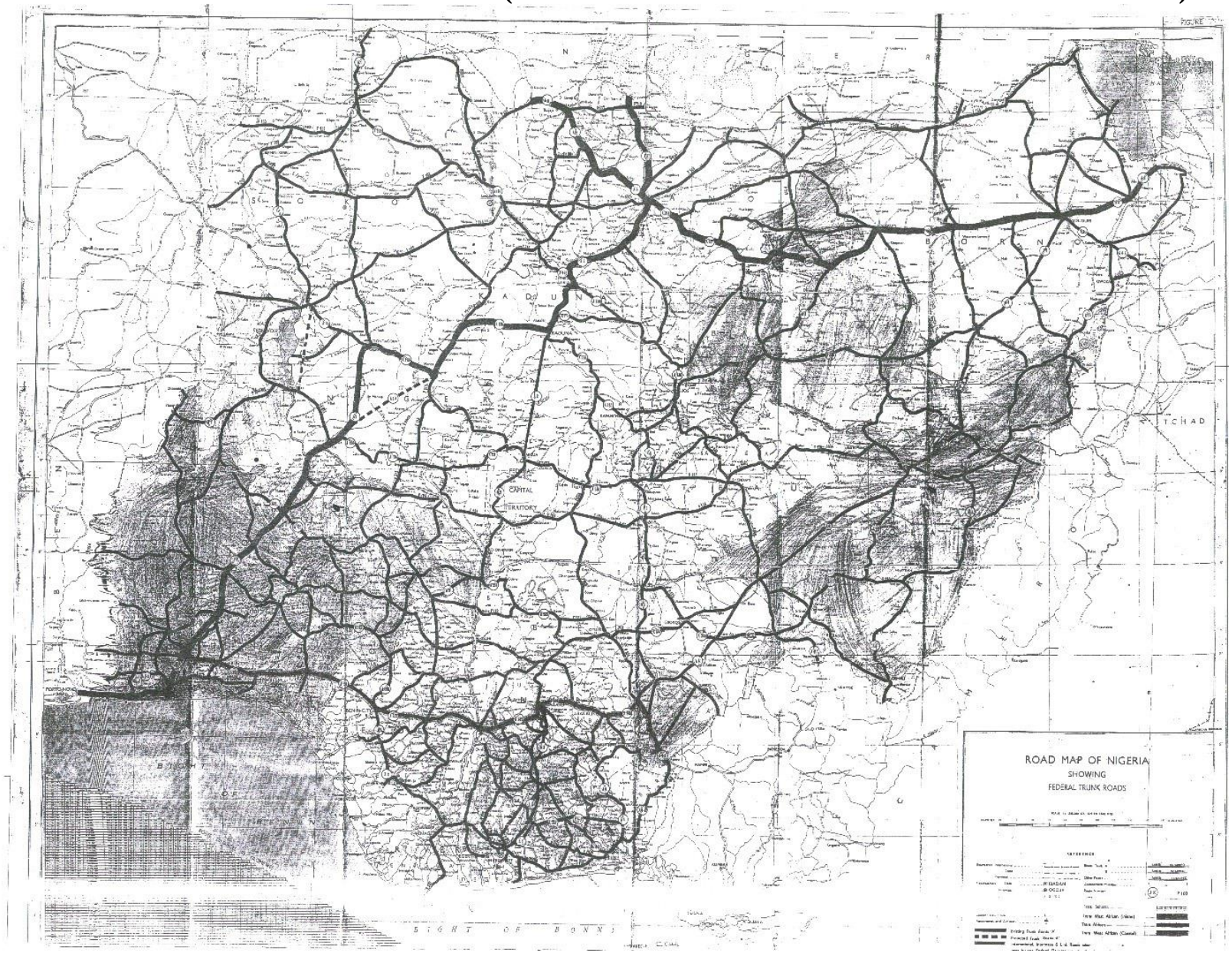
…….

(ii) What is the chance of changing from state 5 to state 6 (poor to fail)?

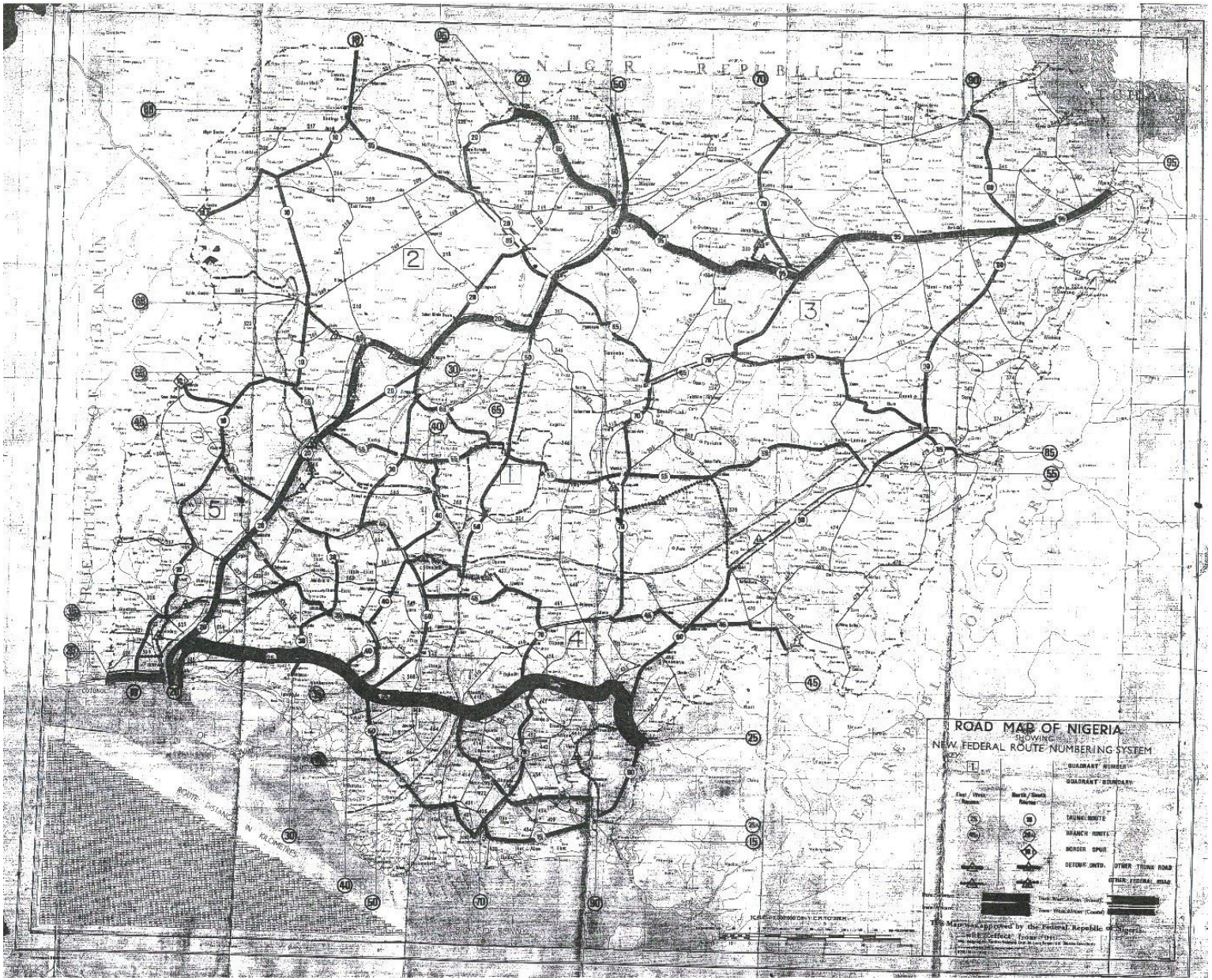
…….

E. What is the chance of the road remaining in state 6 (fail state) is, of course, 1.

APPENDIX E – ROAD MAP OF NIGERIA (SHOWING OLD FEDERAL ROUTE NUMBERING SYSTEM)



APPENDIX F – ROAD MAP OF NIGERIA (SHOWING NEW FEDERAL ROUTE NUMBERING SYSTEM)


NIGER REPUBLIC
2
3
1
5
4
ROAD MAP OF NIGERIA
SHOWING
NEW FEDERAL ROUTE NUMBERING SYSTEM
QUADRANT NUMBER
QUADRANT BOUNDARY
TRUNK ROUTE
BRANCH ROUTE
BORDER SPUR
DETOUR (INTD.
OTHER TRUNK ROAD
OTHER FEDERAL ROAD
ROUTE DISTANCE IN KILOMETERS
This Map was approved by the Federal Republic of Nigeria.

APPENDIX G – MACMILLAN ROAD MAP OF NIGERIA