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STANDARD NOMENCLATURE AND METHODS FOR
DESCRIBING THE CONDITION OF PAVEMENTS

(DRAFT TRH 6)

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PREFACE

The need for describing the condition of pavements occurs frequently in highway engineering. Accurate descriptions are a prerequisite for establishing procedures with which to evaluate the various aspects of the pavement condition. A variety of methods and terms have been used in practice. Consequently descriptions of pavements are apt to be incomplete and ambiguous. This document is a recommendation of a standard usage for South Africa.

It must be emphasised, however, that this document does not give suggestions for the evaluation of the condition of the pavement or recommend those aspects that should be described in given situations. It is for the engineer to decide in which context a pavement is to be evaluated and thus what descriptions are necessary. The necessary inspection schedule can then be set up in accordance with these recommendations. It is also important to note the cost of inspection when setting up a schedule. Detailed descriptions are costly, especially if long stretches of road are involved. Therefore careful attention must be given to how each aspect will be used in the subsequent evaluation and whether the cost is justified, before the schedule is set up.

1. INTRODUCTION

There are two view points from which the condition of a road can be considered. These are the point of view of the road user and that of the road engineer. The road user regards the road as a service provided for transportation and appraises its condition in terms of those characteristics affecting his comfort, safety and convenience. The engineer recognises the functional requirements of a road, but in addition views the road as a structure which must withstand the effects of traffic and other forces. If this is not accomplished the structure will deteriorate and finally be unable to fulfil its functional requirements.

Over past years terms have been brought into use by which the condition of the pavement can be described. It is recognised that clear and unambiguous descriptions are a prerequisite for quantitative assessments of the pavement. However, current terms are not all explicit or used uniformly. Presented herein is a nomenclature for descriptions of pavement condition within the conceptual structure of the evaluation (quantitative assessment) of the condition. Such evaluations are used in the following aspects of road engineering.

(a) The evaluation of the degree of success with which a particular <u>design</u> has met the design criteria and of the cause of failure where the criteria have not been met in order to provide a basis for comparing designs of promoting new designs.

(b) The determination of the type of <u>maintenance</u> required in a specific case and the provision of a basis for establishing maintenance priorities and for comparing maintenance strategies in order to determine the optimum maintenance programme.

(c) The evaluation of the adequacy of the pavement in carrying the required volume and type of <u>traffic</u> in order to provide a basis for sufficiency ratings and needs studies.

(d) <u>Communication</u> between engineers on a technical level, either for transmitting useful observations or for justifying proposed courses of action.

(e) Engineering research, in developing new materials, construction tech-
niques and design methods by means of field trials.

The nature and detail of descriptions of pavement condition will vary
according to the purpose. For example, the description may be a compre-
hensive one over a small area of pavement when describing a particular
problem, whereas it would only be practical to give a less detailed
description of long lengths of road in condition surveys.

The scope of condition evaluation in terms of the points of view given
above is defined more formally in Section 2.

Section 3 discusses in greater detail descriptions of pavement con-
dition from the road user's point of view, whereas Section 4 discusses other
engineering aspects of pavement condition where a description of the pavement
includes details pertaining to the pavement structure. The use of limiting
values of pavement condition is discussed in Section 5. Appendix I gives
methods of describing pavement distress in detail. This is the visible
manifestation of the deterioration of the pavement. Appendix II gives
examples of various schedules for describing pavements with a view to
specific purposes. Finally a glossary is provided giving definitions of
all terms introduced herein.

2. THE SCOPE OF PAVEMENT CONDITION EVALUATION

The pavement is regarded from the outset in the light of its ultimate
function which is to provide a facility for vehicle transportation. This
facility must be maintained at a sufficiently high level of service to
accommodate the requirements of road user's at the lowest possible cost.
Minimum requirements are set according to the funds that can be made
available in competition with those needed for other public requirements.
The assessment of a given pavement in this light will include a consi-
deration of the level of service provided by the facility and an estimation
of any future change in the pavement that will ultimately cause the present
level of service of the pavement to deteriorate. This change is brought
about by the action of traffic and environmental forces on the pavement
structure. If a serious change is foreseen (i.e. one that will prematurely

lead to the pavement not providing the minimum requirements of the road user) then appropriate maintenance measures must be considered which will remedy the deterioration.

The scope of pavement condition evaluation is then:

(a)   The assessment of the level of service provided by the facility in relation to the minimum requirements.   This is the assessment of the degree to which it fulfils its function and is thus the <u>functional evaluation</u> of the pavement;

(b)   The assessment of the capacity of the pavement to withstand the effects of climate and traffic.   This is referred to as the <u>structural</u> capacity of the pavement and the process of assessing this is the <u>mechanistic evaluation</u> of the pavement.   This definition implies that if the future climatic and traffic conditions can be determined, then these can be used together with a knowledge of the structural capacity to predict future changes in the pavement.   Furthermore, if it is known how various maintenance measures will alter the structural capacity of the pavement, appropriate maintenance strategies can be determined which will ensure a given level of service, and the best strategy can then be selected taking economic considerations into account.

The result of a mechanistic and a functional evaluation is to define aspects in which the pavement is deficient and thus to enable appropriate corrective measures to be applied.   These corrective measures are defined as the <u>road's needs</u>.

Ready and uniform methods for doing functional and mechanistic evaluations and for predicting future changes in the pavement are not available.   Various methods are currently used which are a combination of the use of objective, experimental relationships and subjective judgement based on local experience.   The objective of this note is to define various concepts used in such analyses and to enumerate the various factors of pavement condition that may be considered.   A standard nomenclature is necessary for developing uniform recording procedures and evaluation methods.

3.   FUNCTIONAL DESCRIPTION OF PAVEMENT CONDITION

The extent to which a particular road meets its functional requirements which are the speed, safety, comfort and convenience of the road user is defined as the serviceability of the pavement.   The minimum functional requirement specified for a particular road is termed the terminal level of serviceability.   During the life of a road the serviceability will change. The trend of the serviceability with time is defined as the performance of the road.   Figure 1 gives an example of the performance of a hypothetical road in order to illustrate these concepts.

The functional requirements, speed, safety, comfort and convenience are not easily and uniquely measured as such and their respective values would not always be a useful description with respect to serviceability.   For instance, it is not sufficient to know that the safety is inadequate - the reason for this is also required.   Also, these requirements are inter-related (e.g. safety depends on speed) and the relative influence of the interacting parts is not well known.   For these reasons various features of the road have been considered which directly affect the provision of the functional requirements.   For surfaced roads, these are the geometric properties, the skid-resistance, the surface drainage and the riding quality and (to a lesser extent) environmental factors such as noise generation and the aesthetic appearance of the pavement.   The serviceability, terminal value and performance can each be given in terms of one or more features of the road.   These features are listed in Table I together with the factors that contribute to the serviceability and current methods of assessment. These features are discussed in the following:

Riding quality

The riding quality of a road is defined as the general extent to which road users experience, through the medium of their vehicles, a ride that is smooth and comfortable or bumpy (and thus unpleasant and perhaps unsafe). The value of the riding quality can be obtained by obtaining the average rating (on a scale 0 to 5) by a sufficient sample of road users.   A

TABLE I

ASSESSMENT OF PAVEMENT CONDITION TO DETERMINE
THE PRESENT PAVEMENT SERVICEABILITY

FEATURE	FACTORS CONTRIBUTING TO SERVICEABILITY	METHOD OF ASSESSMENT
1. Geometric properties	(a) amount of camber or crossfall (b) road width (c) vertical alignment (d) horizontal alignment	
2. Skid-resistance	(a) surface texture depth (b) harshness of surface (c) water film thickness	SCRIM, NIPR brake-force trailer, pendulum apparatus see (3) below
3. Surface drainage	(a) transverse and longitudinal grades (b) efficiency of drainage system (c) deformation of surface profile, particularly rutting in the wheel paths	levelling, inspection during rain inspection during rain inspection during and after rain, straight-edge measurements
4. Riding quality	(a) longitudinal surface roughness (deformation) (b) rutting in wheel paths (deformation) (c) potholes (d) uneven patching	(i) Subjective rating of PSI in a vehicle (ii) Measurement of PSI using PCA Roadmeter*, BPR Roughometer*, CHLOE Profilometer* straightedge measurements regular inspection inspection (also included in (i) and (ii) above)

*Instruments must be calibrated from present serviceability rating (PSR) results obtained subjectively by a panel of raters.

sufficient sample is considered to be one that is representative of the
road users and large enough to estimate the mean to a desired degree
of accuracy.   The value obtained in this way is termed the PSR (present
serviceability rating) of the road.

The riding quality of a road is determined by the profile of its
surface.   Thus it is reasonable to expect that some form of measurement of
the profile can be used to estimate the riding quality.   The measures that
are commonly used are the longitudinal slope variance of the profile together
with the average transverse rut depth.   The slope variance is defined as
the variance of slope of the road measured longitudinally in the outer wheel
track at intervals of 150 mm, where the slope at a point on the road is
the tangent of the angle the surface of the road makes at that point with a
beam 8 m long supported at each end at equal heights above the road surface,
one end being the point of measurement (see Figure 2).   The slope variance
is commonly measured with the CHLOE profilometer shown in Figure 3.   The
average rut depth is the average maximum deviation measured under a 2 m
straight edge placed transversely, across the outer wheel track at random
points along the road.   A relationship between these parameters and the
riding quality was established during the AASHO Road Test, viz:

$$PSI = 5,03 - 1,91 \log (1 + \overline{SV}) - 1,38 \overline{RD}^2 - 0,01 \sqrt{C + P}$$

where

  PSI = Present serviceability index which is the measure of riding
        quality
  $\overline{SV}$ = slope variance
  $\overline{RD}$ = mean rut depth (in inches)
  C = 10 times the percentage cracking
  P = 10 times the percentage patching

The term C + P was subsequently found not to be significant.   An equivalent
metric equation is then

$$PSI = 5,08 - 2,03 (1 + \overline{SV}) - 0,00212 \overline{RD}^2.$$

where

  $\overline{RD}$ = mean rut depth in mm

As a vehicle moves over a road with poor riding quality the body of the car will oscillate on its suspension relative to the axles. Use of this phenomenon is made in the provision of high speed instruments for estimating riding quality. In these instruments the relative movement between the axle and the body of a vehicle or the frame of a specially made trailor is recorded, weighted according to its amplitude and summed. These values are correlated with values of PSR in order to calibrate the instruments. Subsequent measurements of riding quality with such calibrated instruments are described as values of PSI for a particular instrument under the particular conditions. Examples of such instruments are:

(a) PCA roadmeter (Figure 4). The movement between the rear axle and the body of a sedan car is recorded and each movement is weighted by the square of its amplitude and summed.

(b) The BPR roughometer (Figure 5). The movement between the axle and frame of a specially designed trailer is recorded and each movement is weighted by its amplitude.

The PCA roadmeter operates at 80 km/h or 50 km/h, the BPR roughometer at 40 km/h and the CHLOE Profilometer at 5 km/h. The PCA roadmeter is the least accurate of these instruments but operates at a speed which does not interfere with traffic and is thus suitable for routine measurements by a road authority. The CHLOE profilometer is the most accurate instrument but is unwieldy and slow and requires special traffic control during operation and is thus only used in the calibration of special control road sections that are used in turn to calibrate the other instruments. The BPR roughometer operates at intermediate levels of accuracy and speed and is normally used for research projects.

The performance of a road in terms of riding quality is the most important parameter by which the efficacy of methods of structural design can be evaluated. The reason is that the ultimate effect of any significant structural deterioration of the pavement is the reduction of riding quality.

Riding quality measurement can be carried out at regular intervals by road authorities in order to detect which roads are approaching or are below the terminal level of riding quality set for that class of road, so that effective remedial measures can be programmed.

Skid-resistance

Skid-resistance is a term used to describe the general ability of the road surface to prevent skidding in all or particular manoeuvres generally executed by vehicles. The definition may be narrowed where required to refer to the ability of the road to allow specified manoeuvres under specified conditions. In this case one may talk, for example, of a road having a high skid-resistance for cornering when wet.

The ability of a particular vehicle to execute a particular manoeuvre depends on the coefficient of friction between each of its tyres and the road surface during the manoeuvre. The coefficient of friction is defined as:

$$\mu = F/N$$

where F = the force developed by the friction between the surfaces and is the force by which the manoeuvre is controlled

N = the force normal to the plane of friction due to the weight of the vehicle.

The value μ is however not a constant for a particular section of road but depends on several other factors such as the type of tyre, the type of manoeuvre (mainly the speed and acceleration of the wheel) and on whether the surface has been lubricated (with water or oil). Since this coefficient is not unique, the approach has been to develop instruments that can be used to estimate the average coefficient of friction that would apply to vehicles executing certain manoeuvres under wet conditions. These instruments are operated under specified and carefully controlled conditions (these are generally constant speeds and constant rates of wetting the surface of the road with water). The measurements obtained from these instruments are referred to as coefficients of skid-resistance for the stated instrument and test conditions.

Three types of instruments have been used by the NIRR for measuring skid-resistance. They are the brake-force trailer, SCRIM and the pendulum tester. These are described in the following:

(a) Brake-force trailer. This is a single-wheel brake-force trailer device, which is shown in Figure 6. It is towed by a light-delivery

vehicle which carries a sufficient supply of water for about 25 tests.   At the test speed the smooth-tyred wheel is locked for about 2 seconds over the wetted surface.   This short test period is to limit wear on the tyre.   The braking force is measured by strain gauges and the relation between the braking force and the normal load on the wheel is called the brake-force coefficient (bfc) and is related to the decelerating performance of a vehicle when its wheels are fully locked.

(b)   SCRIM.   SCRIM is an abbreviation for Sideway-force Coefficient Routine Investigation Machine and was developed at the Transport and Road Research Laboratory (TRRL) in Britain (see Figure 7).   The smooth test wheel is inclined at 20° to the direction of travel.   The road is wetted from the water tank on the truck and the test wheel moves continuously over this wetted surface, recording the sideways thrust exerted on the tyre by the road.   The relation between the sideway-force and the normal load on the wheel is termed the sideway-force coefficient of friction (sfc).   The test wheel rotates at one-third of the angular velocity of a wheel that runs straight and the friction developed may be measured continuously.   The side-way force type of measurement determined the lateral friction which is available to a vehicle when it moves in a circular path such as traversing a curve or when it executes a passing manoeuvre.   A rough correlation exists between the bfc and sfc results obtained on the same surface.

(c)   Pendulum tester.   The portable pendulum tester, also developed by the TRRL, is shown in Figure 8.   The instrument is set up so that the pendulum, which has a rubber slider, moves over the surface for a specified length.   The pendulum swings from rest in a horizontal position and the energy loss which occurs as it moves over the surface is a measure of the friction.   This is read off directly from a calibrated scale.   This instrument can be used to obtain an indication of the skid-resistance for stopping from low (= 50 km/h) speeds.

The property of the road surface that contributes directly to its skid-resistance is the component of the shape of its profile which has a wave-length less than the length of the area in contact with the vehicle tyre.

This depends chiefly on the texture of the stone and bitumen mixture comprising the surface. Two important parameters of the profile shape have been defined as the macrotexture and the microtexture.

The macrotexture refers to the separation between the stones protruding from the surface. This allows water to escape from between the tyre and the road surface. This property is measured in terms of the surface texture depth by spreading a known volume of sand over the surface, measuring its area and calculating the average depth.

The microtexture refers to the harshness or roughness of the stones themselves. There is currently no quantitative measure of the microtexture, but this can be qualitatively assessed by examining the stones and determining if they are harsh and angular or smooth and rounded (stones which are smooth have generally become so through the polishing action of traffic and are thus said to be polished). Stones that are resistant to polish have a high polished stone value (PSV).

The macrotexture is of overrriding importance at high speeds (> 100 km/h) whereas the microtexture is of overriding importance at low speeds (< 50 km/h). Since the pendulum tester is an appropriate instrument for measuring skid-resistance for low speeds, it follows that it also provides a measure for the microtexture. In the absence of the facilities of the brake-force trailer or SCRIM, the pendulum value together with the surface texture depth constitute an alternative description of the skid-resistance.

Similar to the procedure used with riding quality, coefficients of skid-resistance can be monitored at regular intervals in order either to evaluate the performance of various surfacings in terms of their skid-resistance, or to identify roads which needs to be considered for an improvement of skid-resistance.

Surface drainage

The surface drainage of a road is the general ability of the road to keep its surface clear of water. This refers to the speed of the run-off of water

during rain and to the extent of ponding of water during and after rain. The former determines the film thickness of the water in the road which is an important factor affecting the skid-resistance whereas the latter is a hazard in the form of water thrown up, especially by fast moving traffic. The function of good surface drainage is also to keep the road surface clear of grit wasted on to the road from the verges. Figure 9 gives an example of section of road covered with grit and with ponding of water.

The surface drainage is determined by the crossfall of the surface, the presence of any deformation of the surface, the capacity of the drainage system and the adjacent land drainage characteristics. The effectiveness of these factors in facilitating surface drainage is the measure of the serviceability of the road in terms of surface drainage. No means have yet been determined for quantifying this effectiveness, although design requirements are given by several authorities. Furthermore, the only factor to change during the life of a road is the deformation of the surface and thus it is only by this that the performance of the road in terms of surface drainage is meaningful. Terminal levels of surface drainage are usually determined subjectively by inspection during rain taking into account the rainfall characteristics of the area.

Note that ponding of water on the surface is undesirable also in that it allows time for water to penetrate through the surface into the pavement structure. However, this consideration is not important in a functional evaluation.

Geometric properties

The geometric properties refer to are those aspects of the geometric design of the road that affect the average safe speed of vehicles travelling on it and to the geometry of specific features that constitute a traffic hazard. The average speed of vehicles will vary during the day according to the traffic volume. Three or more speeds may be defined to describe the situation, these are the free speed, the peak traffic speed and the mean off-peak, day-time speed. The free speed of a road refers to the average speed that various vehicles can attain over the length of the road provided they have unrestricted use of the lane in which they are travelling. Though

the use of the lane is defined to be unrestricted, the driver of the vehicle is still regarded to be travelling in such a way that he is prepared to make an emergency stop should some obstacle be blocking the lane. The peak traffic speed is defined as the average actual speed vehicles can attain during periods of peak traffic density. The mean off-peak, day-time speed is the average actual speed attained by traffic during the day under "normal" (not peak) traffic densities.

The free speed of a road is determined by the lane width, by the horizontal curvature and super elevation of the road, by the gradient and by the sight distance. The sight distance is affected by the alignment of the road and by any road side furniture or natural object such as a tree that may obscure the view around curves.

The actual speed during real traffic conditions is determined by the traffic density, by the number of lanes (this includes passing lanes on upgrades), by the free speed per lane and by the capacity of road junctions.

In general it is true that drivers tend to drive at speeds which are in balance with the risk they are willing to accept of having an accident. Thus the general safety of a road cannot be determined independently of the determination of the free speed. There are, however, certain geometric properties of a road which may add to or detract from its safety when the general alignment of the road is designed for a particular free speed. These are, inter alia, the number and geometry of the merging, diverging and cutting junctions, the shoulder widths, the geometry of railway crossings and the widths of structures and the provision of safety devices such as crash barriers and collapsing road furniture.

The geometric properties of a road is the most important feature of the serviceability of a road, but is particularly difficult to quantify entirely. Values which are of particular interest to the traffic engineer are the free speed (for comparison with the accepted legal speed limits) and the peak traffic speed (for comparison with the lowest desirable speeds for those conditions). On the other hand he may be interested in the traffic

capacity of the road which is the maximum traffic density of the road at the minimum desirable speed for peak hour traffic. The traffic capacity may then be compared with the existing traffic density.

Additional values for describing the serviceability in terms of the geometric properties are by specifying minimum tolerable standards of road junctions, railway crossings, shoulder widths etc. and then to determine the degree to which a given road does not comply with these and thus determine additional roads needs. Alternatively the number of accidents attributable to the geometric properties may be recorded.

The geometric properties are permanent 'built-in' characteristics of the road and as such are not normally connected with the problem of main-tenance in the sense of deterioration of the pavement. The performance of a road in terms of the geometric properties could however be expressed by the trend of the peak traffic speeds (for example) with time, or by the number of accidents attributable to the geometric properties with time.

4. MECHANISTIC EVALUATION

The estimation of the future performance of a pavement can be considered to result from the following process. First a mechanistic evaluation is made of the pavement condition based on various relevant measurements or observations of the pavement condition. A list of such measurements con-stitutes a mechanistic description of the pavement condition whereas the result of the mechanistic evaluation is a measure of the structural capacity of the pavement. Second, evaluations are made of the climatic and traffic conditions and factors are given representing these conditions. Third, the present serviceability is measured. A functional relationship is then as-sumed which can be given conceptually as

$$P_t = f(t; S, C, T, P_O) \quad\text{------------------------------ (1)}$$

where
P_t = serviceability at time t
S = structural capacity
C = climatic factors
T = traffic factors
P_O = present serviceability

A well known example of equation (1) is that used in the estimation of the life of a road using the AASHO Road Test definition of structural number. Here S is given in terms of the structural number of the pavement, C is the regional factor, T is the present traffic volume (in number of equivalent 80 kN axle loads) together with a growth factor and P is the riding quality. It is usual in this application to set P_t as the terminal level of riding quality and to calculate t which then represents the design life of the pavement.

In general it will not always be possible to obtain a value for S objectively from established relationships such as that for the structural number. This is especially true if the evaluation is done at a time when the pavement has deteriorated considerably when many extra factors should be considered and weighed up subjectively (for example the extent of cracking). Similarily the function f may also refer to a subjective assessment of P_t by considering the effects of S, C, T from local experience. However, formally or informally the structure of equation (1) is always implicit in engineering decisions regarding maintenance, road needs or the design life of a pavement.

A comprehensive mechanistic description of the pavement is the set of measured values of the pavement condition which are relevant to the determination of its structural capacity. These values can be grouped under five categories which are measurements of structural response, material properties, surface integrity, drainage and distress. These are discussed in the following and summarised in Table II.

(a) Structural response. By this is meant the stresses and strains that are induced in the pavement by loading on the surface. Measurements relating to the structural response are those of deflection, radius of curvature, elastic moduli and layer thicknesses.

(b). Material properties. Material properties are used here in the sense of the reaction of various pavement materials to stresses, strains and the presence of water. These properties include measurements of stability, fatigue life, plasticity index, CBR, crushed stone value and polished stone value.

TABLE II

FACTORS CONTRIBUTING TO THE MECHANISTIC
DESCRIPTION OF THE PAVEMENT

CATEGORY	EXAMPLES
1. Structural response	Deflection Radius of curvature Elastic moduli Layer thicknesses
2. Material properties	Stability Fatigue Plasticity index CBR
3. Surface integrity	Porosity Texture
4. Drainage	Crossfall Culvert capacity Efficiency of subsurface drainage
5. Distress	Deformation Fracture Loss of stone Potholing Loss of surface texture depth Polishing of stone

(c) Surfacing integrity. This is a measure of the condition of the surfa-
     cing as an intact and durable matrix. It includes values of porosity
     and texture.

(d) Drainage. This is a measure of the ability of the pavement to drain
     free water from the pavement. It includes measurements of the cross-
     fall of the surface and culvert capacities, and estimations of the
     efficiency of subsurface drainage.

(e) Distress. Distress is the visible manifestation of the deterioration
     of the condition of the pavement with respect to either the service-
     ability or the structural capacity. Distress measurements are
     usually convenient since they do not require instruments. They are
     also particularly important in a mechanistic evaluation because, first,
     the development of distress introduces a reduction in the structural
     capacity of the pavement and second, the presence of distress is a
     clear indication of weaknesses in the pavement. For these reasons
     detailed attention is given to concepts used in the classification and
     description of distress in Appendix I.

Note that although a mechanistic evaluation is always based on a mecha-
nistic description of the pavement condition, it is not always possible or
economical (or even necessary) to obtain a comprehensive description.
Usually decisions as to the extent of the data necessary for a particular
evaluation are made sequentially. By observing the distress on the
pavement and judging its mechanism and cause, further measurements are made
of other factors. Based on these measurements others may be prescribed
until further measurements are considered unnecessary or uneconomical.

Note also that some factors are given in both Table I and in Table II.
Even though these factors may be recorded identically they are used for
different purposes. For example, rut depth is used in the evaluation of
riding quality in so far as it is a measure of the unevenness of the road
surface and as such affects vehicle behaviour. On the other hand, when
predicting the future performance of the pavement, the rut depth is a
measure of the stability of the pavement in terms of its traffic history.
Furthermore, under certain conditions, a rut depth of 20 mm is an indication

that the pavement will deteriorate rapidly because cracking usually develops at this level of deformation.

Although the estimation of future performance is always implicit in evaluating the maintenance needs of a road, it is not always followed through explicitly in determining maintenance strategies. Of greater significance may be the estimation of the development of distress itself under the given conditions. This is because

(a) different forms of maintenance are required for different types of distress;

(b) the serviceability generally decreases rapidly with the deterioration of the condition of the pavement; and

(c) as a rule-of-thumb the cost of maintenance increases rapidly with the development of primary and secondary distress.

Note that these are very generalised remarks. The significance of cracking, for example, with respect to future performance and thus to maintenance requirements depends very much on many other factors (such as climate, traffic, etc.). Considerable research is needed to determine optimum maintenance strategies under various circumstances.

It is thus clear that the interpretation of descriptions of pavement condition depends on the purpose for which the information will be used. This is especially true when defining a failure condition, as will be discussed in the following section.

5. LIMITING VALUES OF PAVEMENT CONDITION

Terms such as "failure criteria", "failure condition", "the road has failed" are commonly used in practice and in the literature without clear definitions always having been given to their meanings. To say the road has failed generally suggests that some distress is evident on the road but does not usually indicate the seriousness of the distress. In some cases it does imply that maintenance measures are immanently required for the road. Failure criteria or failure conditions usually refer to some limiting level of distress which is needed for some particular purpose. These purposes

may be the study of a road from a functional mechanistic, maintenance or research point of view. The use of the phrase "failure of a pavement" can thus be vague, ambiguous and confusing and should thus be avoided. The following defines various uses and terms of limiting values of pavement condition.

Terminal values of serviceability relate to limiting values with respect to safety, speed or comfort. If the serviceability of a road is below the accepted terminal level for the particular class of road, this defines a need for that road with respect to user requirements. Specifically one may refer to terminal values of riding quality, skid-resistance or geometric requirements.

On the other hand, a road may receive certain maintenance measures long before it has reached the terminal level of serviceability. This would be because the state of distress and the particular traffic and environmental conditions are such that it would be more costly to implement some major maintenance measure in the future than the relatively minor maintenance needed earlier to arrest the development of distress*. If a road has reached a limiting level of distress which is defined as that level at which it is most profitable to implement some maintenance measure, it is said to be in a critical state of distress with respect to maintenance. If the road is left until the distress increases beyond the critical state, the road can be said to be in a severe state of distress.

A further use of limiting values of pavement condition is that extensively used in research work into the design of new pavements or maintenance measures. Here a pavement (or some component of the pavement) is designed in order to meet a minimum standard over a given period of time. This standard may be a functional requirement or a given trend of distress. If the period of time to reach this level is less than the time prescribed by the design, this can be referred to as a design failure. The minimum

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*This applies in the case of riding quality where distress such as cracking can cause a deterioration in serviceability, even though the state of cracking remains unchanged. In the case of skid-resistance, however, only a deterioration of the distress itself, e.g. fatting, can bring about a change in serviceability: there is therefore no need to carry out maintenance much before the terminal level of serviceability is reached.

standard may be referred to as the <u>limiting criterion</u> of the design.
Examples of such limiting criteria are:

(a)   The use of a terminal level of riding quality in the AASHO road test.
       Here the objective of the design was the preservation of an acceptable
       level of riding quality under conditions of minimal maintenance.

(b)   The use of a limiting value of rut depth by the TRRL to compare the
       resistance of various pavement structural designs to deformation.
       This value is related to their definition of a critical state of
       distress with respect to overlay requirements for roads.

APPENDIX 1

ATTRIBUTES OF DISTRESS

Modes and types of distress

Distress is manifested in one of six modes:

(a) Deformation: the development of a change (unevenness) in the road
     surface profile.

(b) Fracture (cracking).

(c) Loss of stone: this is defined as the loss of stone from a surfacing.

(d) Potholing: this is regarded as a distinct and separate mode of dis-
     tress rather than as an advanced state of fracture or loss of stone.
     It includes breaking of the road edges.

(e) Loss of surface texture depth.

(f) Polishing of stone.

     Some of these modes can be sub-classified into various types of distress.
Fracture can be classified as crocodile cracking, transverse cracking,
longitudinal cracking, etc.; deformation as ruts, depressions, corrugations
etc.; and loss of surface texture depth as wearing of stone, fatting or
embedment of stone.   Examples of types of distress with respect to each mode
are listed in Table III and are discussed further below.

Degree and extent of distress

Important measures of distress are its degree and extent.   The degree of
distress is a measure of its severity.   For example in the case of
cracking the severity is determined by the crack width.   The severity can
be indicated by a class number 1 to 5 where Degree 1 would indicate the
first evidence of a particular mode (or type) of distress and Degree 5 would
indicate the severest degree of distress, or by specifying the degree
directly, for example, in the case of cracking, a crack width of 3mm.

     The extent of distress is given by the proportionate length or area
of road affected.   This can be given directly by stating for example

TABLE III

VARIOUS TYPES OF DISTRESS ASSOCIATED WITH
EACH MODE OF DISTRESS

MODE OF DISTRESS	TYPE OF DISTRESS
Deformation	Depressions Mounds Ruts Ridges Corrugations Distortion
Fracture	Transverse cracks Longitudinal cracks Block cracks Ladder cracks Crocodile cracks Parabolic cracks Star cracks
Loss of stone	
Potholing	Potholes Edge breaks
Loss of surface texture depth	Fatting Embedment Wearing
Polishing	

that 40 per cent of the road (under review) is cracked.   Alternatively the extent of distress can be expressed as a number where

Area (or Length) 1 indicates that less than 10 per cent of the area
                      (linear length) is affected

Area (or Length) 3 indicates that between 10 per cent and 80 per cent of
                      the area (linear length) is affected.

Area (or Length) 5 indicates that more than 80 per cent of the area (linear
                      length) is affected.

A further useful measure of extent especially for rapid inspection surveys is the number of small affected areas and the number of large affected areas in the section of road under review.   A small area is defined as less than 10 m^2 and a large area as greater than 10 m^2.

Stipulating the number of potholes in a given section is a useful way of indicating the extent of this form of distress (see below).

It often happens that a particular type of distress may be evident on a section of road in varying degrees of severity.   In such cases the extent of all the distress of that type from the lowest to the highest degree should be recorded.   For example, cracking of a certain section may be described as Degree 4 Area 1 and Degree 2 Area 5.   The notation Degree 2 Area 5 thus indicates that more than eighty per cent of the road was in a state of distress of at least Degree 2 (i.e. Degree 2 and greater). Where a linear length specification is a more suitable measure of extent (such as in the case of longitudinal cracking) the distress would be described for example as Degree 4 Length 1 and Degree 2 Length 5. Finally for potholes one might have the description: Degree 5 Number 6 and Degree 3 Number 11.

Position and spacing of distress

The position and spacing are further descriptive attributes of distress. The position is usually expressed as the edge (e.g. edge cracking), the wheel path (e.g. rutting in the wheel path), centre line or the lane centre. The spacing is usually (but not exclusively) used in connection with fracture.   It refers in general to the distance between cracks in the

cracked area. The spacing is indicated by, for example, Spa. 1 m where cracks are spaced 1 m apart. This will be discussed in greater detail below for each type of fracture.

Cause and mechanism of distress

The cause of distress refers to an extraordinary circumstance or condition which was necessary for the distress to occur. Examples of causes of distress are the intrusion of water (through, for example, inadequate drainage), unstable materials, excessive loading, underdesign and hardening of the binder. The mechanism of distress is the physical process by which the cause of distress results in the distress. Examples of mechanisms of distress include shear, heave, consolidation, fatigue, shrinkage, plastic flow and pumping.

To a large extent the identification of the cause and mechanism of distress is an alternative to or an aid in the determination of the structural capacity and in this respect is to some extent a mechanistic evaluation of the pavement.

Pavement components

In explaining the cause and mechanism of distress it is usually necessary to refer to one or more of the components of the pavement. These are the shoulder treatment, surface treatment (or surfacing), base, subbase subgrade and fill. These are illustrated in Figure 10.

TYPES OF DISTRESS

1. Deformation

Degree

Deformation is a change in the road surface profile. This can be manifested as an area of road having its surface either below or above that of the original pavement. The degree of distress is determined by measuring the maximum deviation under a 2 m straightedge as illustrated in Figure 11. The classes of degree are:

Degree 1 - less than 10 mm

Degree 2 - 10 to 20 mm

Degree 3 - 20 to 30 mm

Degree 4 - 30 to 40 mm

Degree 5 - greater than 40 mm

The types of deformation are defined in the following:

Types

(a)   Depressions.   Depressions are localised areas of pavement with elevation lower than the surrounding area.

(b)   Mounds.   Mounds are localised areas of pavement with elevation higher than the surrounding area.

(c)   Ruts.   Ruts are depressions extended in length and confined in width.   These usually occur in a longitudinal direction and in the wheel path.

(d)   Ridges.   Ridges are mounds extended in length and confined in width.

(e)   Corrugations.   Corrugations are regularily spaced transverse undulations of the pavement consisting of valleys and crests less than 1 m apart.

(f)   Distortion.   Non-localised, undulating form of deformation - of the type usually associated with active subgrades or the settlement of a fill.

Examples

Figures 12 to 17 illustrate various examples of deformation.   Indications are given of various attributes of the distress where possible and applicable.

(c) <u>Block cracks</u>. Cracks in a block or rectangular pattern. The spacing is given as the average of the shorter distance between the sides of the blocks. (Where the spacing is relatively large i.e. in the order of 4 or 5 metres the block cracking usually occurs through a combination of transverse and longitudinal cracking (often by the shrinking of a stabilised base or subbase). Where the spacing is relatively small i.e. less than 1 m the cracking usually occurs through the hardening of the binder in the surfacing and subsequent thermal shrinkage).

(d) <u>Ladder cracks</u>. A particular type of block cracking formed by two initial longitudinal cracks (about 2 m apart) with subsequent transverse cracks forming between them giving the appearance of a ladder.

(e) <u>Crocodile cracks</u>. Cracking in a polygon pattern resembling that of the hide of a crocodile. (It may occur directly through the fatigue of the surfacing by the action of traffic or as secondary cracking around primary line cracks). The spacing is the average least diameter of the polygons.

(f) <u>Parabolic cracks</u>. Cracks of a parabolic shape. (Usually caused through the slippage of the bituminous surfacing due to the horizontal forces of traffic and therefore more common on sections where rapid acceleration takes place or on steep up-grades).

(g) <u>Star cracks</u>. Cracks radiating from a point. (Occurs through blistering by the accummulation of material beneath the surfacing or as a first stage of crocodile cracking.

<u>Examples</u>

Figures 18 to 31 illustrate various examples of fracture. Indications are given of various attributes of the distress where applicable.

3. <u>Loss of stone</u>

<u>Degree</u>

Loss of stone occurs where individual stones are lost from the surfacing. In the case of thin surface treatments this results in exposure

of the underlying layer and if this is an unbound layer potholing follows.
In the case of a premix surfacing, the surfacing gradually disintegrates
after which it eventually cracks, spalls and develops potholes.   A single
surface treatment consists of one layer of single size stones and conse-
quently any loss of stone exposes the underlying layer directly.   A
multiple surface treatment consists of several layers of stone of
successively smaller size and loss of stone is characterised by the loss
of the fine stones on the surface followed by the loss of the larger stones
in successively exposed layers.   A premix surfacing consists of a mixture
of stones of various sizes.   The fine stones on the surface are lost first
followed by the loosening and loss of the larger stones.   This is repeated
as the premix layer disintegrates.   Because of the different manifes-
tations of the distress in different surfacings, care must be taken when
recording loss of stone to identify and record the type of surfacing
inspected.   Furthermore, the degree of distress is defined in terms of
the type of surfacing as given in the following:

	SINGLE SEALS	MULTIPLE SEALS	PREMIX
Degree 1	No discernable loss of stone	No discernable loss of stone	No discernable loss of stone
Degree 2	*	*	First sign of fine stones lost, sur-face has pitted appearance, (up to 2 mm disintegration)
Degree 3	*	Loss of the stones on the third layer of a triple seal	2-7 mm disintegration of premix
Degree 4	*	Loss of second layer of triple seal or first layer of double seal	7-12 mm disintegra-tion of premix
Degree 5	Loss of stones	Loss of stone from all layers	Disintegration > 12 mm

*This degree is not defined for this type of surfacing.

Note that the seriousness of the mode of distress is the loss of the integrity of the road surface resulting in a loss of imperviousness and in potholing. In many cases however loss of stone may occur without any serious consequences. Examples are:

(a) The loss of the top layer of a triple seal leaving behind an impervious and durable double seal because of a fault in the application of the top layer alone;

(b) the loss of some stone from a single surface treatment over a premix surfacing (because, for example, of insufficient precoating) retaining an impervious surface with adequate skid-resistance. In such cases it is important to record the good state of the surface along with the degree of loss of stone.

Mechanism

Loss of stone occurs through the fracture of the binder (ravelling) or loss of adhesion between the stone and the binder or the fracture of the stone. Where the stone has been separated from the binder by the action of water, the mechanism is said to be stripping.

Extent and spacing

The extent of loss of stone is given as usual by the total proportion of area affected. In some cases, particularly in the case of single seals it is important to give the geometry in terms of the spacing. The spacing is defined for this mode of distress as the average diameter of the patches in which stone has been lost. For example loss of stone from a single seal, Degree 5 Area 1 Spa. 10 mm indicates that less than 10% of the stone has been lost in the form of isolated single stones (see Figure 34). Other examples of the loss of stone from a single seal are given in Figure 35, Figure 36 and Figure 37.

4. Potholing

Potholing is the loss of pavement material (other than the stones from the surfacing) through the crumbling (spalling) of the surfacing and sub-

sequent layers. The two types of this mode of distress are potholes – the cylindrical holes found in pavements, and edge breaks – the breaking away and loss of premix surfacings at the edge of the road. Note that it is not usual to refer to the loss of a surface seal in a circular patch as a pothole if the underlying layer has not been affected.

If necessary the degree of potholing can be expressed by a combination of the diameter of the potholes (or the distance breaking has occurred from the edge of the pavement) and the depth. The various classes of the degree of potholing are:

Degree 1 – no sign of spalling

Degree 2 – spalling of surfacing, small potholes < 50 mm

Degree 3 – potholes between 50 and 150 mm

Degree 4 – large potholes (> 150 mm) up to 50 mm deep

Degree 5 – large potholes deeper than 50 mm

The extent of potholing would normally be given by the "number" attribute in the case of potholes and the "length" attribute in the case of edge breaks.

5.   Loss of surface texture depth

Degree and extent

Loss of surface texture depth occurs when the size of the asperities between the stones in the surfacing (i.e. the macrotexture) is reduced. This also results in a reduction in skid-resistance. Texture depth is measured by the sand patch test (see page 9). The measurement of this form is distress is complicated by the very different textures obtained in the different forms of newly laid surfacings (e.g. single surface treatments, multiple surface treatments, dense graded asphalt, gap-graded asphalt with precoated chippings etc.). A common scale for the degree of loss of surface texture for all types is however desirable, and the following scale is defined with a view to the distress as it affects skid-resistance.

	TEXTURE DEPTH	VISUAL APPEARANCE
Degree 1	above 1,0 mm	stones well proud of binder, > 4 mm depth between stones
Degree 2	0,6 – 1,0 mm	rough texture but with shallow depths (2 – 4 mm) between stones
Degree 3	0,3 to 0,6 mm	smooth appearance with asperities > 2 mm
Degree 4	0,0 to 0,3 mm	smooth appearance to the edge but stones visible in the binder
Degree 5	0,0	film of binder covering all stones

Degree 1 represents a texture depth that would be considered adequate for skid-resistance of roads carrying high speed traffic whereas Degree 5 indicates the worst possible condition for skid-resistance for all roads. This degree denotes a fat surface (fatting is defined as a type of this mode of distress and is duscussed below) and thus is not the most severe form of all types of this distress. Furthermore, in, for example, a dense-graded asphalt a surface-texture denoted by Degree 1 (and possibly Degree 2) cannot be attained even if there is no sign of distress. In such cases – in the event of having no fatting (for example) and no onset of fatting is visible – it is recommended that instead of recording "Fatting, Degree 2", either "no fatting" or "Fatting, Degree 0" should be recorded.

The extent of loss of stone can be given either in the "Area" attribute where it indicates the proportion of the area affected or where the distress is confined to the wheel tracks, by the "Length" attribute.

Types

(a) Fatting. Fatting is evident when the binder rises to the surface thus reducing the surface texture depth. It is characterised by a rich, black (and slick in the cases of Degree 4 and Degree 5) appearance. It can occur in a premix surfacing through compaction of the layer by traffic or in a surface treatment when too much binder has been sprayed or when the stones are pressed into the underlying layer. Apart from the extent of fatting the geometry of the fatted patches is also of interest since whether it is made

up of small or large patches is of importance to the general skid-resistance of the road. The geometry is indicated by the spacing which refers to the average smallest diameter of the fatted patches. When designing remedial treatments for fatted surfaced of Degree 5, the thickness of the film of bitumen is an important consideration. In such cases the thickness of this film should be measured with the aid of a sharp instrument. In premix surfacings the spacing of the fatted patches may provide an indication of the thickness of bitumen film since for such surfacings a rough correlation between thickness of film and size of fatted patch has been noted.

(b) Embedment. Embedment occurs when the stones on the surface get pressed into the surfacing* by the action of traffic without the bitumen flowing to the surface. It is characterised by a low texture depth without the stones being worn and with a dry appearance of the surfacing. This type of distress can occur with gap-graded asphalt with precoated chippings.

(c) Wearing. The breaking off or wearing down of the stone asperities. This may occur through the action of wheels with studded tyres (a situation which is not a problem in South Africa) or the wearing down of the stone by the abrasive action of traffic. After the surfacing has worn completely smooth (Degree 4) the surfacing itself begins to wear away and become thinner, but this has little added significance to skid-resistance or to maintenance. Thus the highest degree of wearing would be Degree 4.

Examples

Examples of a fatty surface are given in Figure 40 and 41.

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*Stones pressed into an underlying layer is a mechanism of fatting and is also commonly referred to as embedment. However, so as not to cause confusion the work embedment is reserved in this text for the type of distress defined above.

6.   Polishing

Polishing is the wearing smooth of the stones on the surface of the road (i.e. the reduction of microtexture) with a concommitant reduction in skid-resistance.   The degree of polish can be estimated by the pendulum tester (see page 8).   The classes of the degree of polish are defined as:

Degree 1 - greater than 75* (stones very harsh; sharp to the touch)

Degree 2 - 75 to 55

Degree 3 - 55 to 45 (stones sharp and angular but not harsh to the touch)

Degree 4 - 45 to 35

Degree 5 -. below 35 (stones rounded and smooth to the touch)

Figure 42 gives an example of a surfacing with no polishing whereas Figure 43 gives an example of a high degree of polish.

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*These figures are expressed in units of the pendulum tester.

APPENDIX II

AD HOC PAVEMENT DESCRIPTIONS

It is generally impossible to give a detailed description of the pavement condition for all sections of road since this would be exorbitantly costly and time-consuming.   Careful thought must therefore be given to those details that are necessary and economically justifiable for a particular study. The following gives three examples of approaches that may be adopted when more than one factor of the pavement condition may be of interest.

(a) Example of a detailed description of distress.   In some cases it may be necessary for an engineer to have a detailed description of the distress of a small section of pavement.   Such a case may arise when he has to make a recommendation as to some corrective measure without being able to visit the site. . An example of such a description* is:

"Cracking*[1] of the premix surfacing*[2] and pumping*[3] of fines from the subbase*[2].   Longitudinal*[4] and transverse*[4] cracking of degree 4 at 3 m spacing over 40% of the area*[5];   crocodile*[4] cracking of degree 3 at 100 to 300 mm spacing over 40 per cent of the area*[5].   The longitudinal and transverse cracking probably originated from shrinkage*[3] due to cement stabilisation*[6] of the base*[2], aggrevated by the settlement of a high fill*[6], and the subsequent crocodile cracking to fatigue*[3] under traffic, worsened by the presence of the shrinkage cracks and ingress of rainwater*[6].

(b) Example of inspection sheet for condition surveys of a road network. In this example a particular road authority has decided to undertake regular condition surveys in order to assess the roads needs of its network.   It is considered impractical to execute a detailed pavement evaluation of the whole network and the following factors were chosen as being justified for the purpose of a road needs evaluation.

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*Such a description will include those attributes of the distress that are relevant and are possible to obtain from a visual inspection.   These are given in the example and are indicated in the following:
*1 - mode of distress
*2 - pavement component
*3 - mechanism
*4 - type of distress
*5 - degree, spacing, extent
*6 - cause

(i) Functional aspects: riding quality, skid-resistance.

(ii) Mechanistic aspects : deflection (structural response), cracking (distress), patching (distress).

Since one of the requirements here is a high speed of recording, only cracking of Degree 3 or higher is considered, as Degree 3 is the lowest degree that is visible in a vehicle travelling at normal traffic speeds. Patching is regarded for this purpose as an indication of a pavement weakness. It is assumed the patching was done to repair sections of road damaged by fracture. After patching, the road still maintains its previous structural weakness which lead to cracking, but the impermeability of the road is restored. Table IV gives an example of the type of inspection sheet used in such a survey.

Examples of such inspection sheets abound in the literature. Each road authority must decide for itself the details which will suit its purpose best. What, however, must always accompany such a scheme is a clear stipulation of how the information is to be used.

(c) Example of a rating scale of the pavement condition confined to the requirements of a specific experiment. Two types of distress are of importance in the evaluation of an experiment to assess the correct amount of bitumen to be used in a single surface seal. These are:

(i) loss of stone;

(ii) fatting.

If the mix is too rich in bitumen fatting will occur and if too lean loss of stone will occur. In order to rate the degree of success of the various bitumen contents after a given period of time, each condition of loss of stone or fatting is ranked according to its need for maintenance by the symbols:

   VG - very good (no need of maintenance)

    G - good

   FG - fairly good

    F - fair (road unsatisfactory, requires immediate maintenance)

    P - poor

    B - bad (road in a state of severe neglect)

TABLE IV

EXAMPLE OF AN INSPECTION SHEET FOR A RAPID ROAD NEEDS SURVEY

LOCATION _____

DISTANCE*	FUNCTIONAL ASPECTS		MECHANISTIC ASPECTS		
	SKID-RESISTANCE	RIDING QUALITY	DEFLECTION+	CRACKING**	PATCHING++

*In increments of 0,1 km

+95 percentile of deflections measured in 0,1 km

**"Area" attribute of cracking of Degree 3 and above

++Area attribute of patching

The further symbol + indicates that the distress is fatting whereas the symbol _ indicates loss of stone. Since fatting and loss of stone are generally mutually exclusive (indicating opposite poles in the bitumen content) only one of the symbols + or _ will be used for a given pavement. An example of how these symbols may be assigned to pavements in the case of fatting according to the experience of the engineer concerned is given in Table V. The case for loss of stone (for a single seal) is given in Table VI. For a given size of stone laid under similar conditions, the symbols are expected to correlate with the bitumen content in the following way:

$$\text{B}_- \quad \text{P}_- \quad \text{F}_- \quad \text{FG}_- \quad \text{G}_- \quad \text{VG} \quad \text{G}_+ \quad \text{FG}_+ \quad \text{F}_+ \quad \text{P}_+ \quad \text{B}_+$$

$$\xrightarrow{\text{Increasing bitumen content}}$$

TABLE V

EVALUATION OF THE FATTING ACCORDING TO ITS DESCRIPTION

	AREA 1	AREA 3	AREA 5
Degree 1	VG	VG	VG
Degree 2	VG	VG	VG
Degree 3	VG	G	FG
Degree 4	G	F	P
Degree 5	G	FG → P	B

TABLE VI

EVALUATION OF THE LOSS OF STONE ACCORDING TO ITS DESCRIPTION

SPACING	AREA 1	AREA 3	AREA 5
0	VG	VG	VG
0 → 20 mm	G	FG → F	P
20 → 100 mm	FG	F → P	B
100 → 500 mm	FG	P → B	B
> 500 mm	FG	P → B	B

GLOSSARY

AASHO PSI	The PSI obtained by the equation established during the AASHO experiment
Area of distress	A measure of the extent of distress
Attributes of distress	The various aspects taken into account when describing distress
Block cracks	A type of distress* of the mode "fracture"
BPR roughometer	An instrument for assessing riding quality developed by the Bureau of Public Roads of the USA
Brake-force trailer	An instrument for assessing skid-resistance
Cause of distress	An extraordinary condition or set of circumstances necessary for the occurrence of the distress
CHLOE profilometer	An instrument for assessing riding quality
Coefficient of friction	The ratio of the force of frictional resistance and the force normal to the contact plane at which the friction occurs
Coefficient of skid-resistance	Coefficients of friction obtained by instruments used to assess skid-resistance under conditions similar to those experienced by skidding vehicles
Component, pavement	One of the various layers comprising the pavement structure
Corrugations	Type of distress* of the mode "deformation"
Crocodile cracks	Type of distress* of the mode "fracture"
Deformation	A mode of distress, the manifestation of unevenness of the surface profile
Degree of distress	A measure of the severity of the distress
Depressions	Type of distress* of the mode "deformation"
Distortions	Type of distress* of the mode "deformation"
Distress	The manifestation of the deterioration of the pavement with respect to either the serviceability or the structural capacity

*The types of distress are defined further, with the aid of photographs, in Appendix I.

Edge breaks	Type of distress* of the mode "potholing"
Embedment	Type of distress* of the mode "loss of surface texture depth"
Extent of distress	Proportion of the pavement exhibiting this distress or the frequency of occurrence of the distress
Fatting	Type of distress* of the mode "loss of surface texture depth"
Fracture	A mode of distress, the manifestation of cracking of the asphalt surfacing
Free speed	The average speed that the various vehicles travelling over the given section of road could attain with unrestricted use of their lane
Functional description	Description of the condition of a road in terms of its ability to fulfil its functional requirements
Functional evaluation	The assessment of the degree to which the road fulfils its functionsl requirements
Functional requirements	The requirements of a road from the point of view of the road user. These requirements are the comfort, safety and convenience that the road should provide in the transportation of vehicles
Geometric properties	Those aspects of the geometric design of a road that affect the average safe speed of vehicles travelling on it and to the geometry of specific features that constitute a traffic hazard
Ladder cracks	Type of distress* of the mode "fracture"
Large areas of distress	Areas greater than 10 m^2 showing a given type (usually crocodile cracks or loss of stone) of distress
Length of distress	A measure of the extent of distress
Longitudinal cracks	Type of distress* of the mode "fracture"
Loss of stone	A mode of distress, the occurrence of individual stones being lost from the surfacing of a road

Loss of surface texture depth	A mode of distress; the occurrence of a reduction in the size of the asperities normally caused by the size and separation of the stones on the road surface
Macrotexture	The height and separation of stones projecting from the surface of the road
Maintenance	A remedial measure to improve the serviceability (not usually the geometric properties) or the structural capacity of the road
Maintenance priorities	A selection of certain maintenance tasks deemed of greater economic value than others
Material properties	The reaction of various road building materials to changes in stress under varying conditions of moisture and density
Mechanism of distress	The physical process by which the cause of the distress results in the distress
Mechanistic description	A list of values of properties of the pavement relevant to a mechanistic evaluation
Mechanistic evaluation	The assessment of the structural capacity of a pavement
Microtexture	The degree to which the stones on the surface of a pavement are harsh and angular or smooth and rounded
Modes of distress	The six major classes of distress
Mounds	Type of distress* of the mode "deformation"
Number of distress	A measure of the extent of distress
Parabolic cracks	Type of distress* of the mode "fracture"
PCA roadmeter	Instrument for assessing riding quality, developed by the Portland Cement Association
Peak traffic speed	Average speed attained by vehicles during conditions of peak hour traffic densities
Pendulum tester	Instrument for assessing skid-resistance

Performance	The trend of serviceability with time
Polishing	A mode of distress, the wearing smooth and round of stones on the surface of the pavement
Position of distress	The situation of distress with respect to the surface of the road
Potholes	Type of distress* of the mode "potholing"
Potholing	A mode of distress, the loss of pavement material through the crumbling of exposed layers
PSI	Present serviceability index, a measure of riding quality obtained by the use of instruments
PSR	Present serviceability rating, an assessment of riding quality obtained by the use of a panel of raters
Ridge	Type of distress* of the mode "deformation"
Riding quality	The general extent to which road users experience, through the medium of their vehicles, a ride that is smooth and comfortable or bumpy and thus unpleasant and perhaps dangerous
Road needs	Deficiencies in the structural capacity or serviceability of the road
Rut	Type of distress* of the mode "deformation"
SCRIM	Instrument for the assessment of skid-resistance
Serviceability	A measure of the extent to which a particular road meets the requirements of the road user
Skid-resistance	The general ability of a particular road surface to prevent skidding of vehicles
Slope variance	A measure of the road surface profile; used in particular to obtain the AASHO PSI
Small areas of distress	Areas less than 10 m^2 showing a given type (usually crocodile cracks or loss of stone) of distress
Spacing	An attribute of distress pertaining to its geometry

Star cracks	Type of distress* of the mode "fracture"
Structural capacity	The ability of the pavement to withstand the effects of climate and traffic
Structural response	The stresses and strains introduced in the pavement by loading on the surface
Surface drainage	The general ability of the road to keep its surface clear of water
Surface texture depth	A measure of the macrotexture established by the sand patch test
Surfacing integrity	A measure of the condition of the surfacing as an intact and durable matrix. (It includes values of porosity and texture)
Terminal level	A minimum acceptable level of some feature of the road in terms of its serviceability
Traffic capacity	The maximum traffic density of the road at the minimum desirable speed for peak hour traffic
Transverse cracks	Type of distress* of the mode "fracture"
Types of distress	The subclassification of the various manifestations of a particular mode of distress
Wearing	Type of distress* of the mode "loss of surface texture depth"

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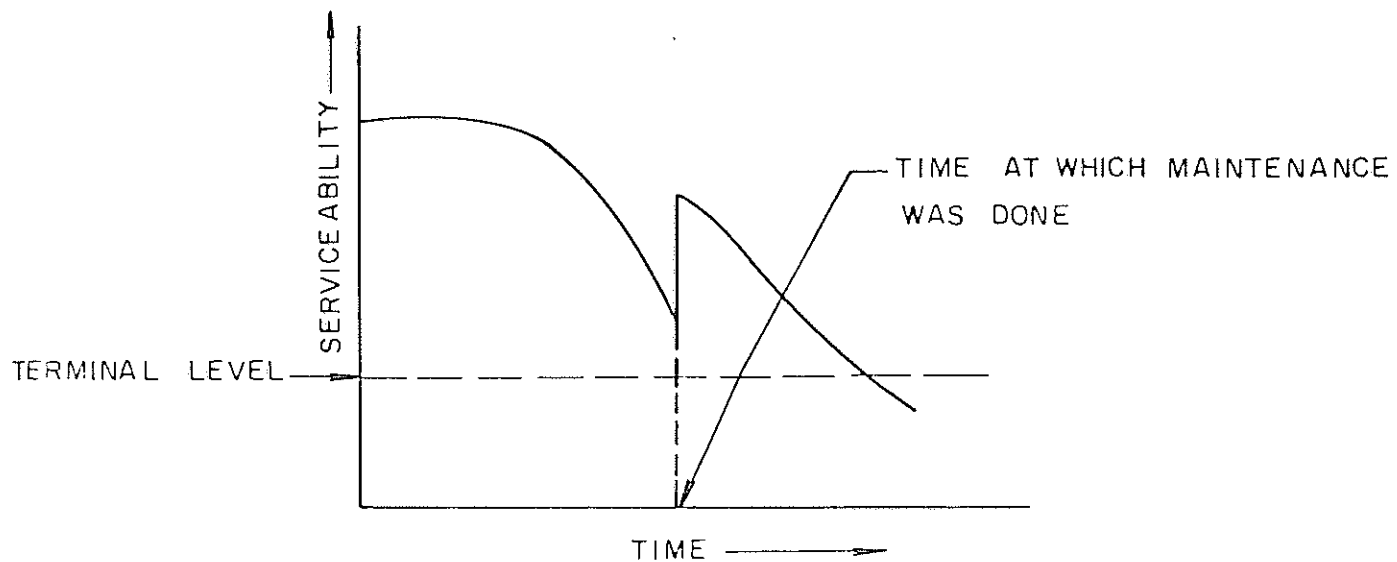
FIGURE 1

THE PERFORMANCE OF A HYPOTHETICAL ROAD

SLOPE = TAN Θ
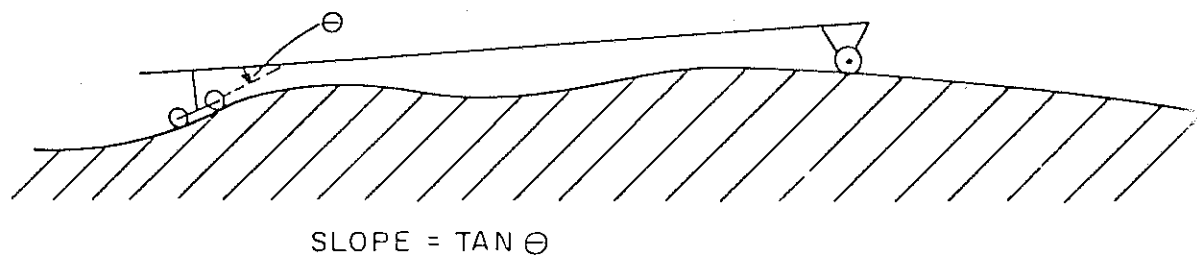
FIGURE 2

ILLUSTRATION OF THE SLOPE OF THE ROAD AT A POINT, DEFINED FOR THE PURPOSE OF CALCULATING THE SLOPE VARIANCE
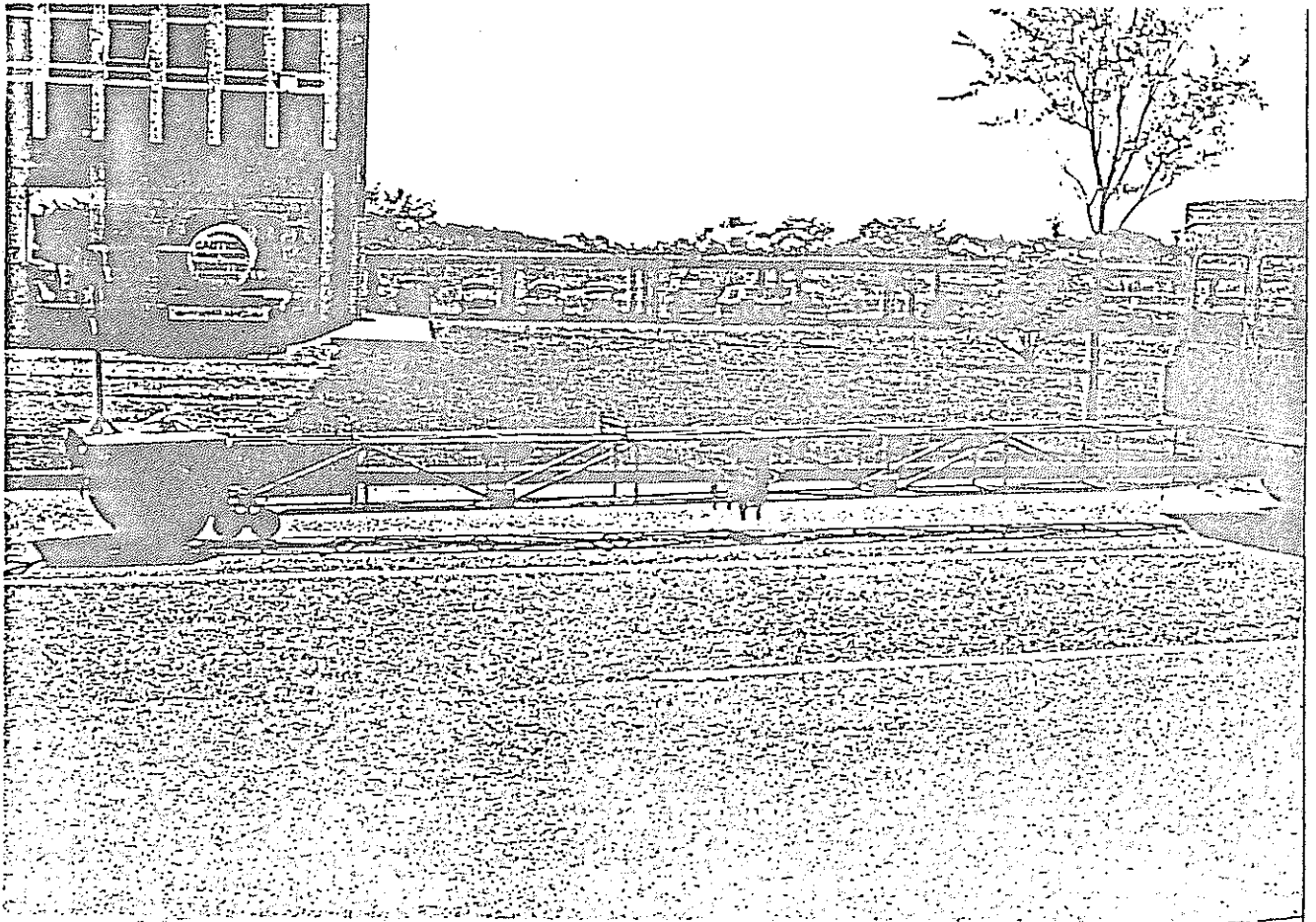
FIGURE 3. The CHLOE profilometer.
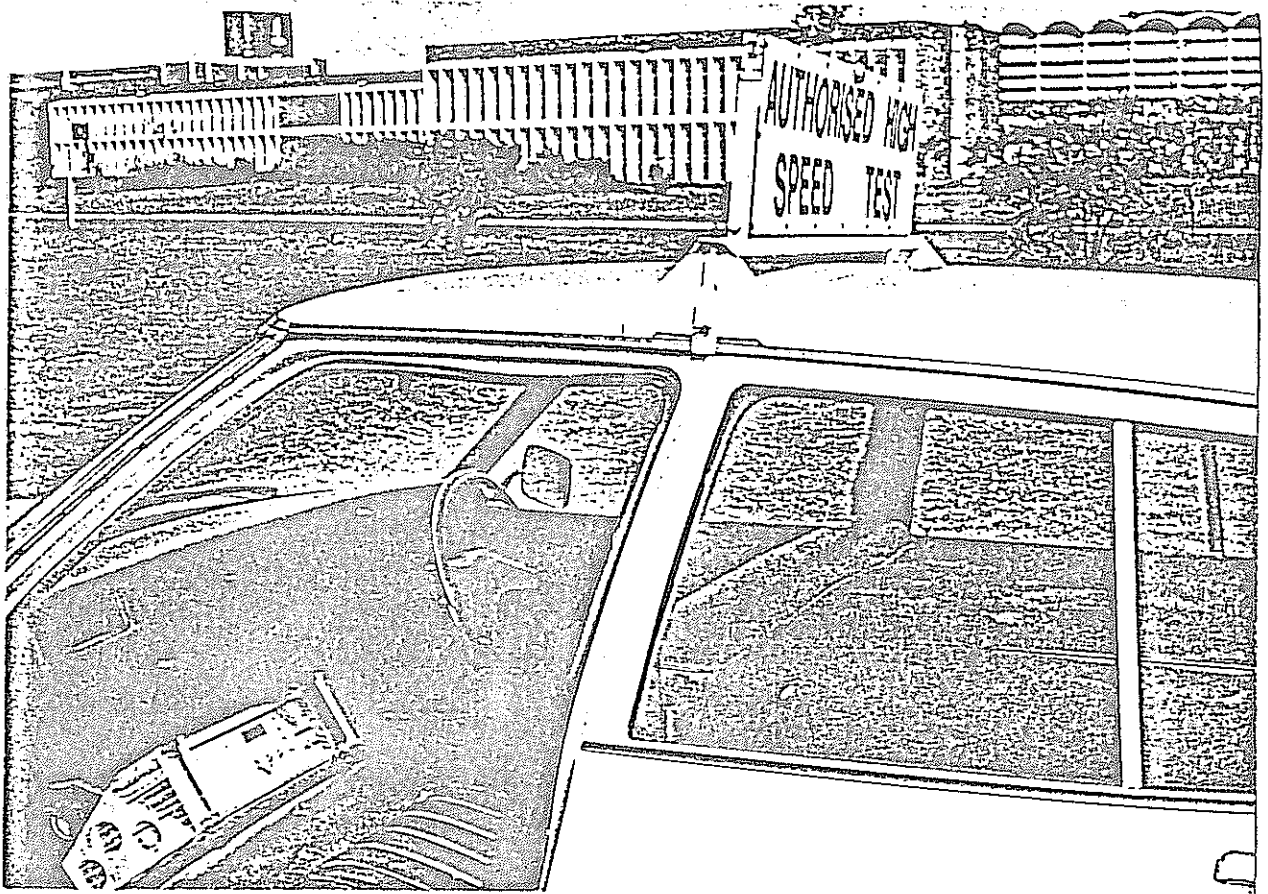
FIGURE 4.   The PCA roadmeter
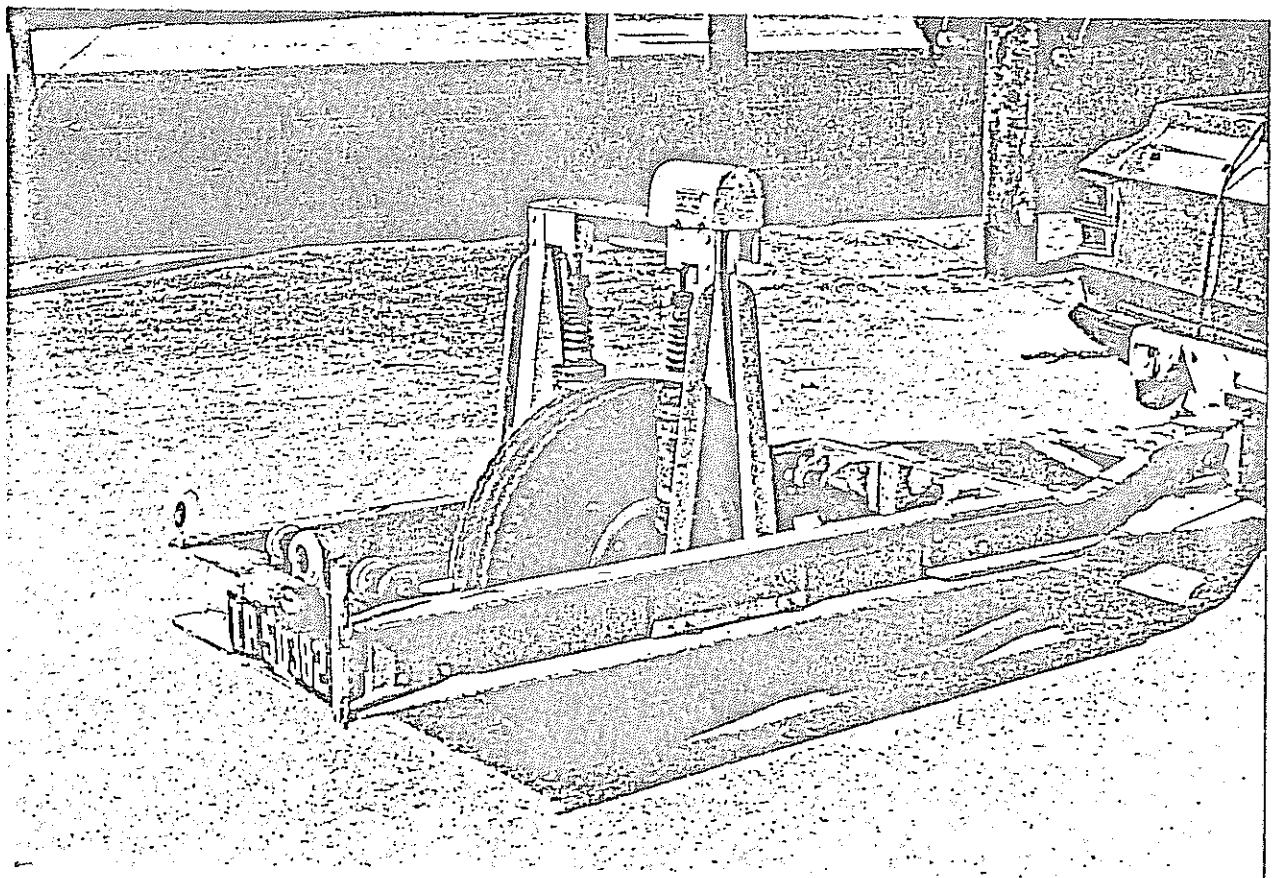
FIGURE 5.   The BPR roughometer
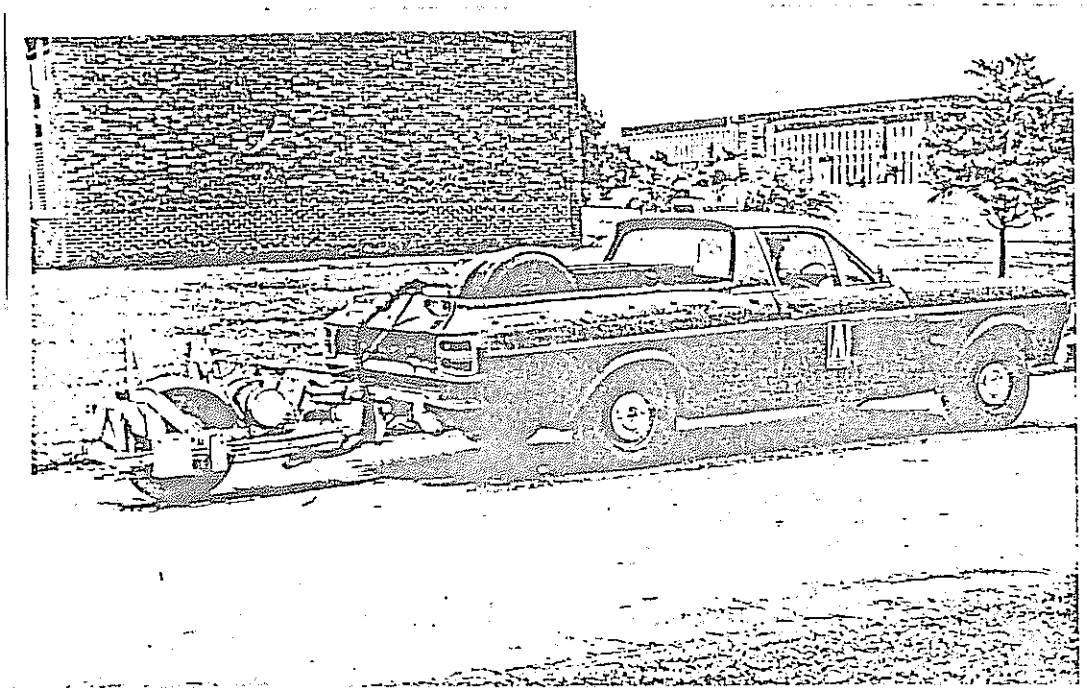
FIGURE 6.   BRAKE-FORCE TRAILER
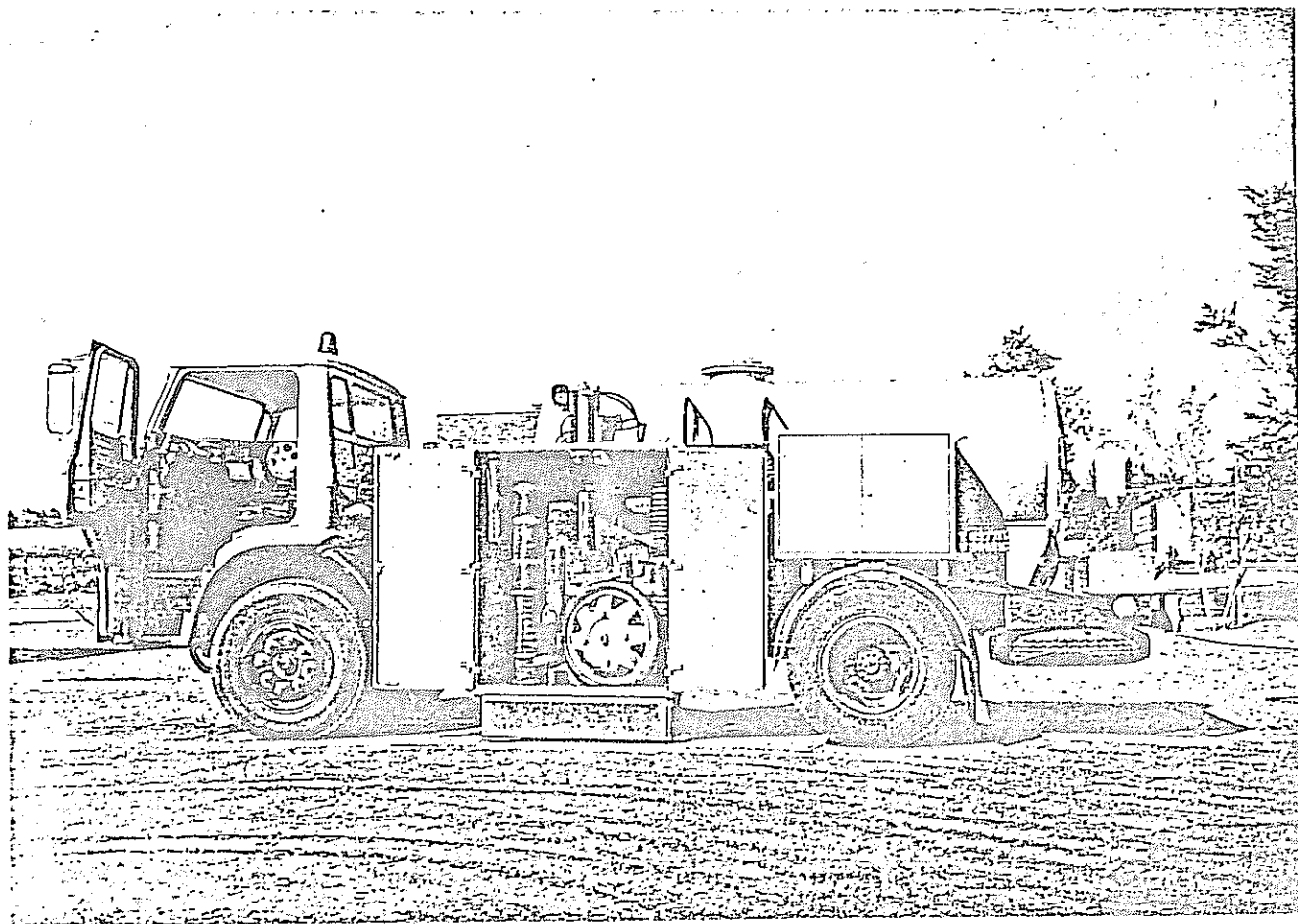
FIGURE 7.   SCRIM
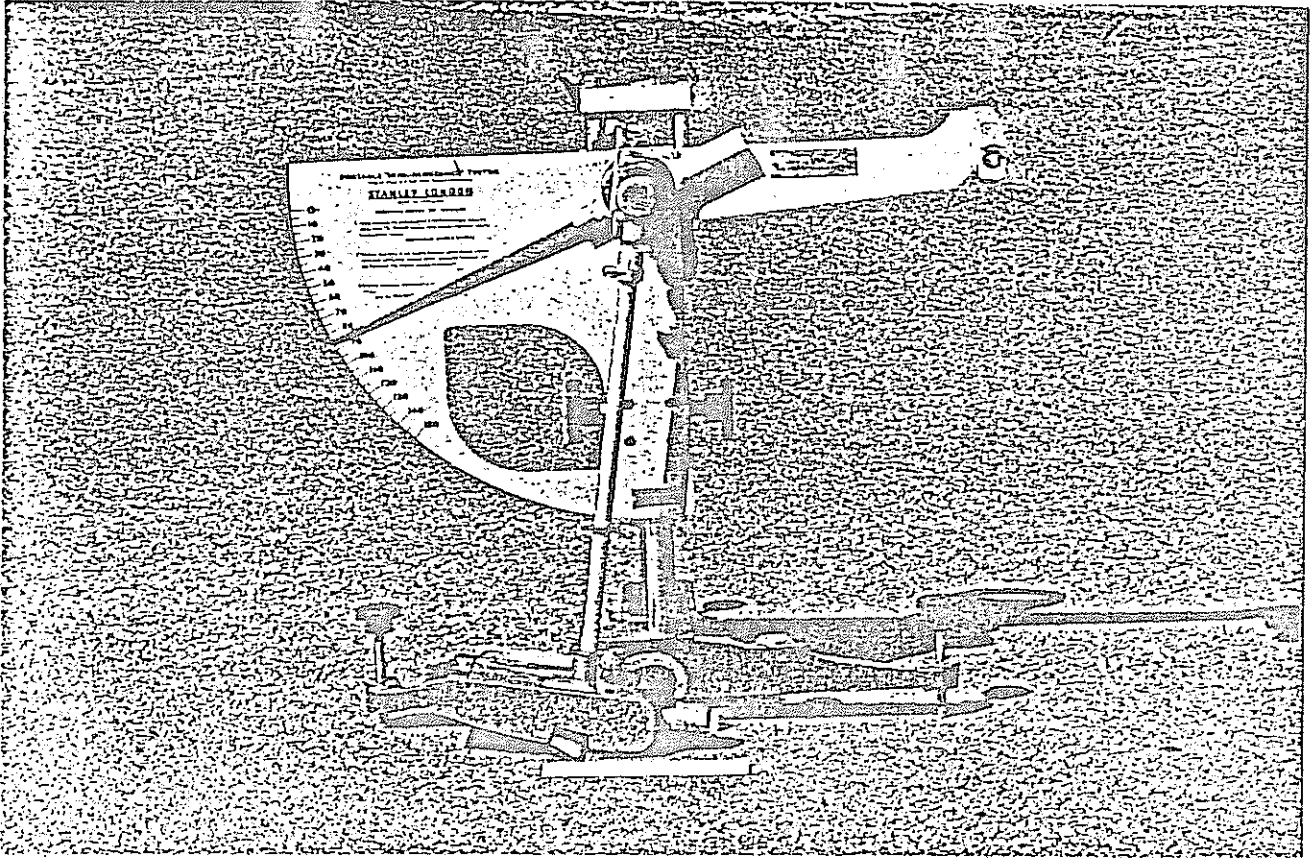
FIGURE 8.   The pendulum tester.

FIGURE 9

A section of road with poor surface drainage
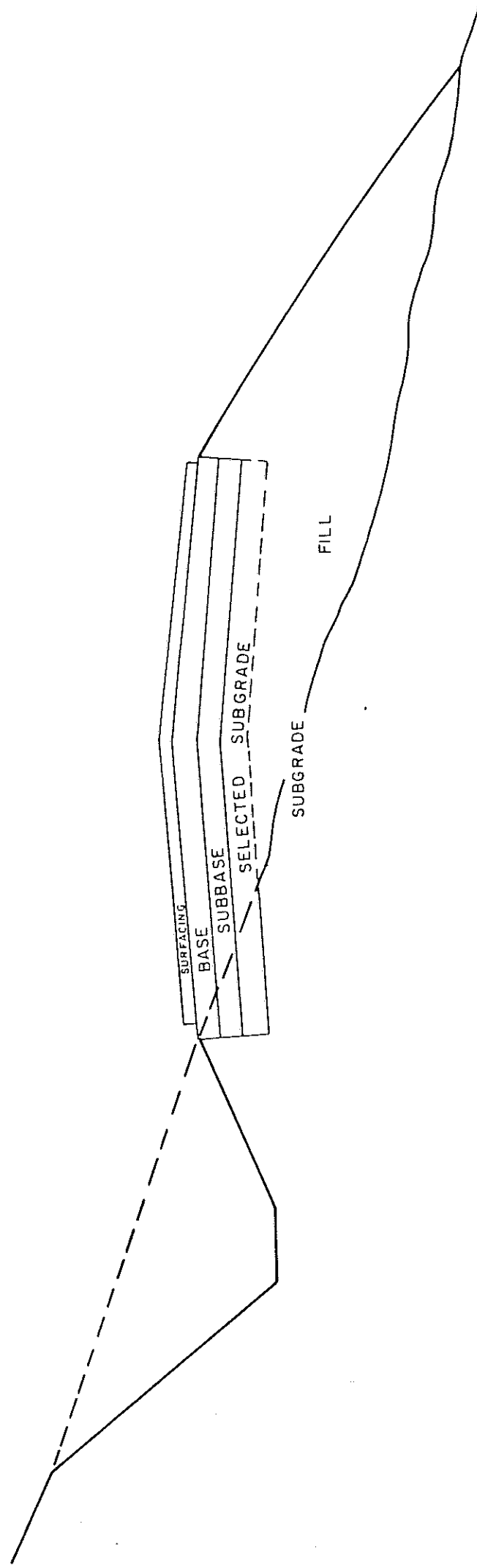
FIGURE 10

COMPONENTS OF THE PAVEMENT STRUCTURE

—2 m STRAIGHT EDGE

—MAXIMUM DEVIATION
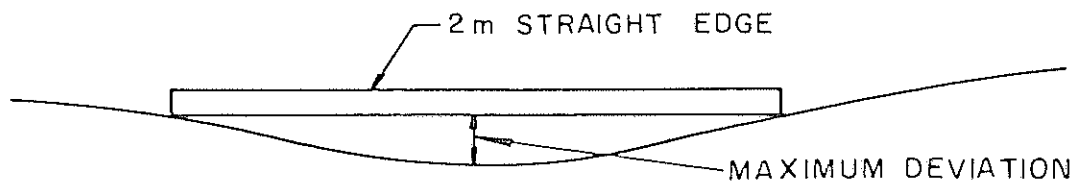
(a) THE MEASUREMENT OF A DEPRESSION

—2 m STRAIGHT EDGE

—MAXIMUM DEVIATION
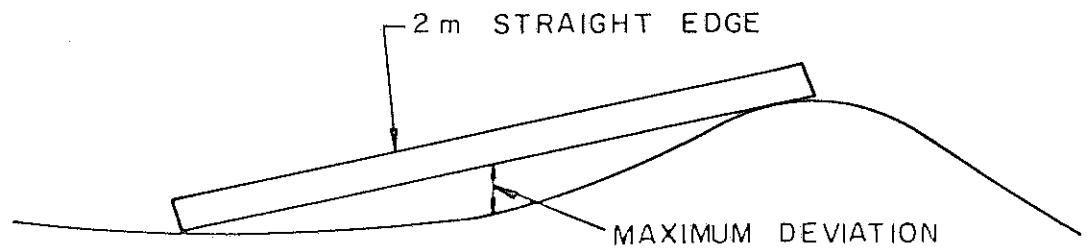
(b) THE MEASUREMENT OF A MOUND

FIGURE II

THE METHOD OF MEASURING THE DEGREE OF DEFORMATION
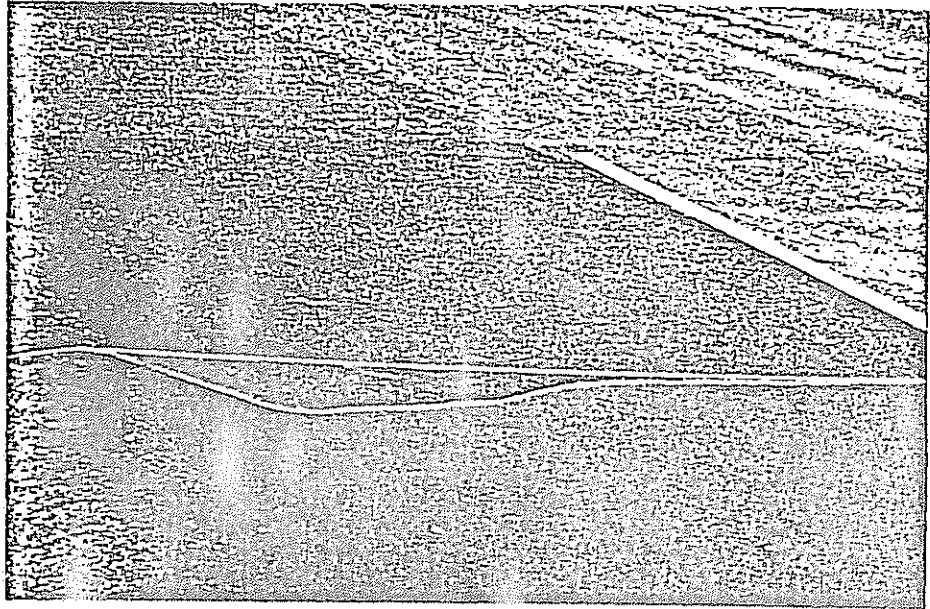
FIGURE 12

Distress   : Depression, Degree 5 in outer wheel path
Cause   : Low grade base material and poor subsurface
             drainage
Mechanism : Plastic flow (shear) of base material.
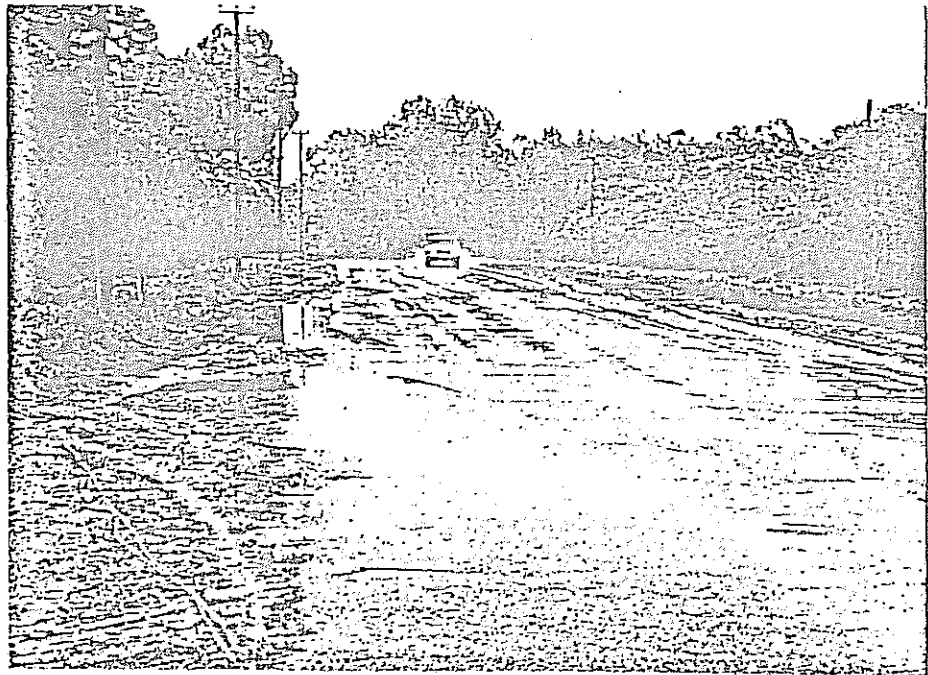
FIGURE 13

Distress   : Depression on edge of pavement
             (causing ponding of water)
Cause   : Poor surface drainage
Mechanism : Compaction of subgrade
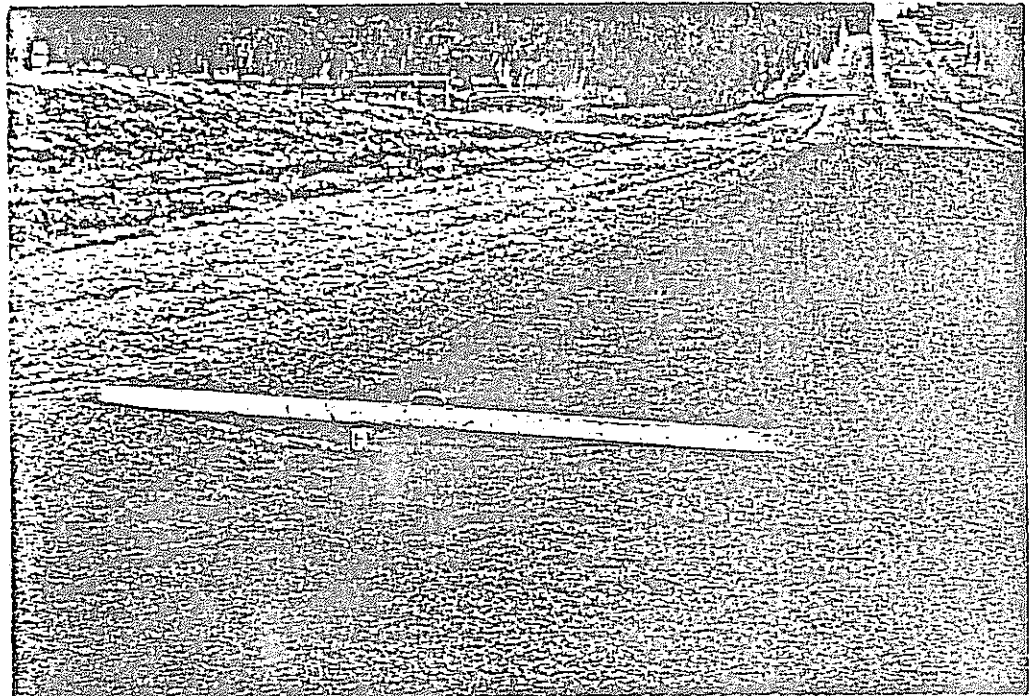
FIGURE 14

Distress	:	Rut in outer wheel path, Degree 5
Cause	:	Poor subsurface drainage
Mechanism	:	Compaction of pavement

FIGURE 15

Distress	:	Transverse ridge
Cause	:	Active clay subgrade
Mechanism	:	Differential heaving of subgrade under culvert because of lesser weight of culvert
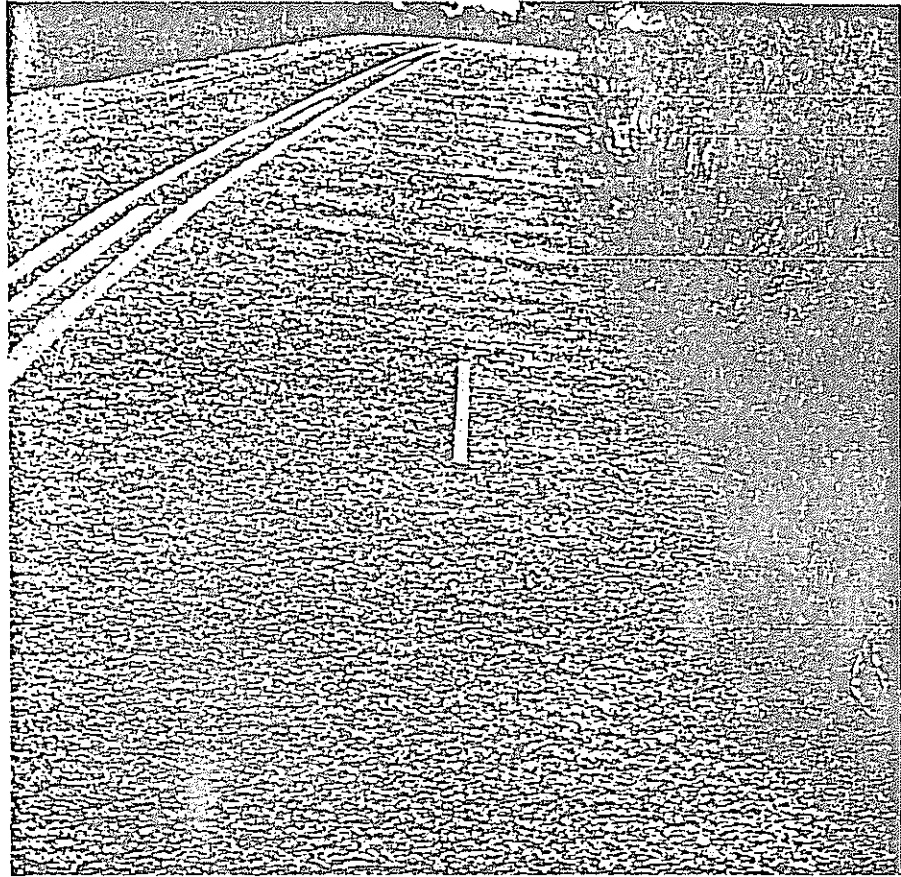
FIGURE 16.

Distress   : Corrugations, Degree 3 Length 5 Spa. 1 m.
Cause   : Unstable base material and tangential forces
              of traffic due to down grade of road.
Mechanism : Shoving
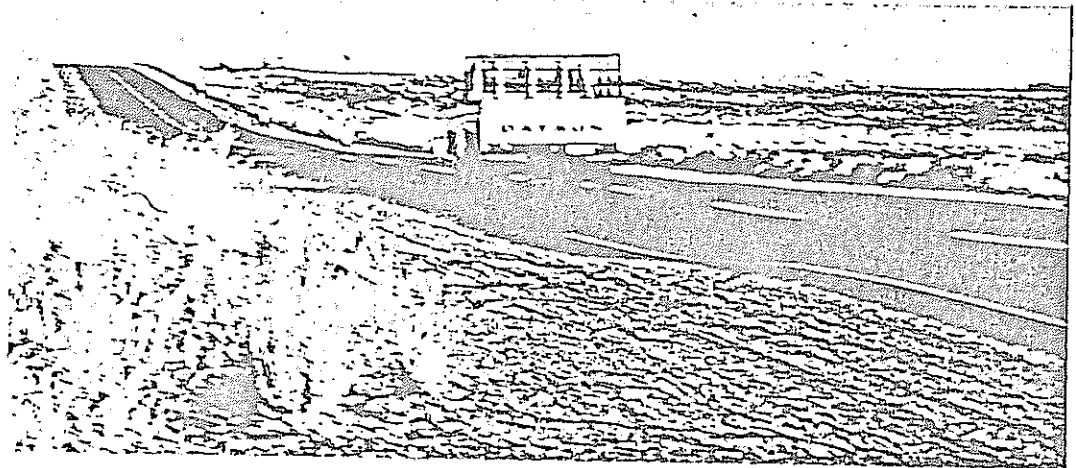
FIGURE 17

Distress   : Distortion
Cause   : Active subgrade
Mechanism : Heave
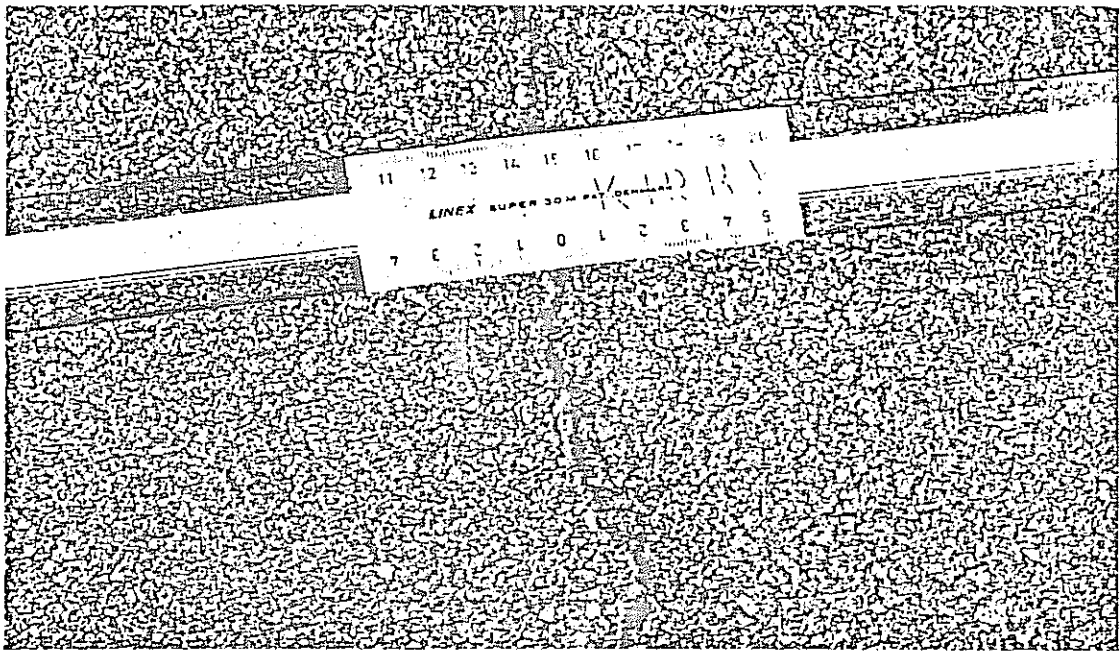
FIGURE 18

Distress   :   Transverse crack, Degree 4
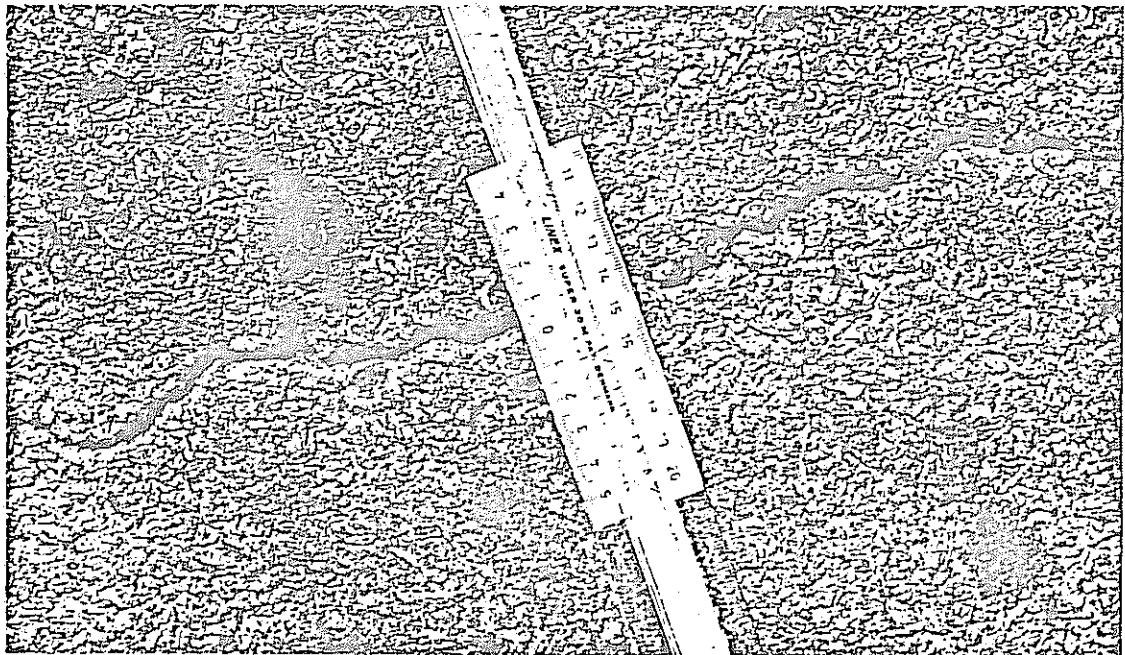
FIGURE 19.

Distress: Transverse crack, Degree 5.
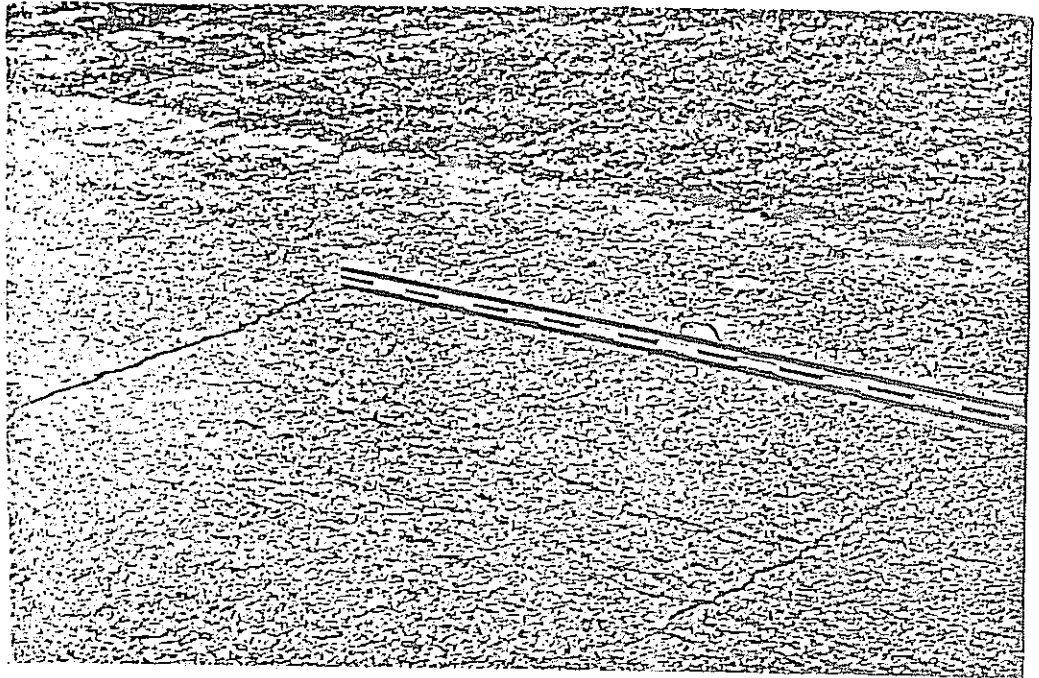
FIGURE 20

Distress	:	Transverse cracks, Degree 5 Spa. 1,8 m.
Cause	:	Shrinkage of natural gravel base.
Mechanism	:	Reflection of cracks through surfacing.
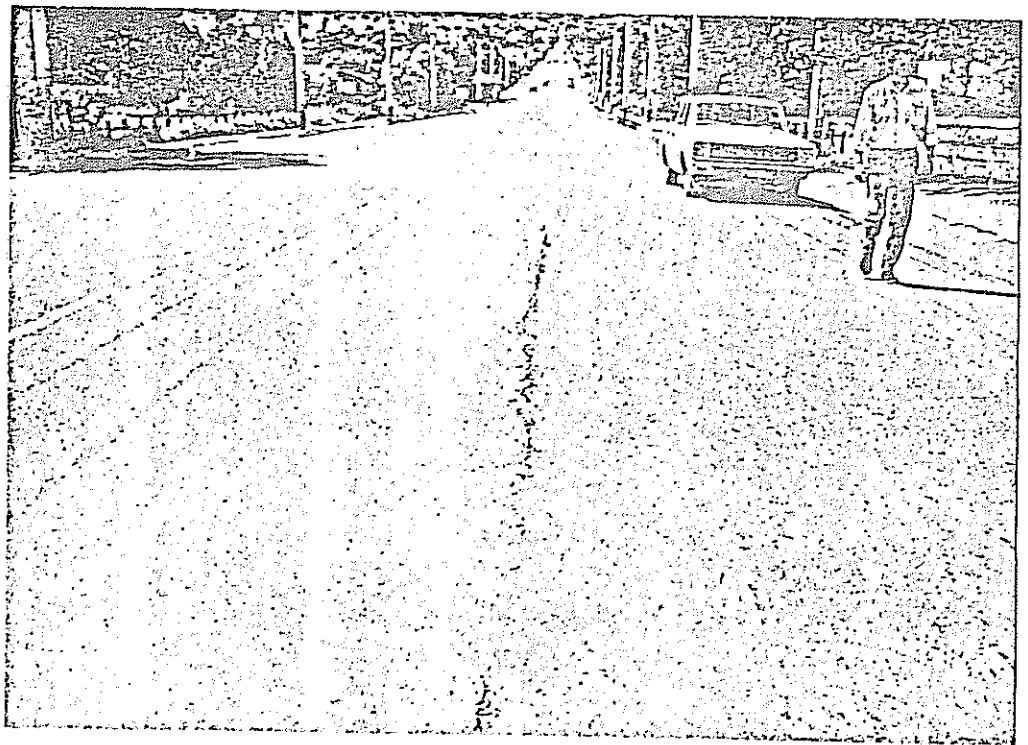
FIGURE 21

Distress	:	Longitudinal crack, Degree 5.
Cause	:	Poor construction joint in premix surfacing.
Mechanism	:	Fatigue.
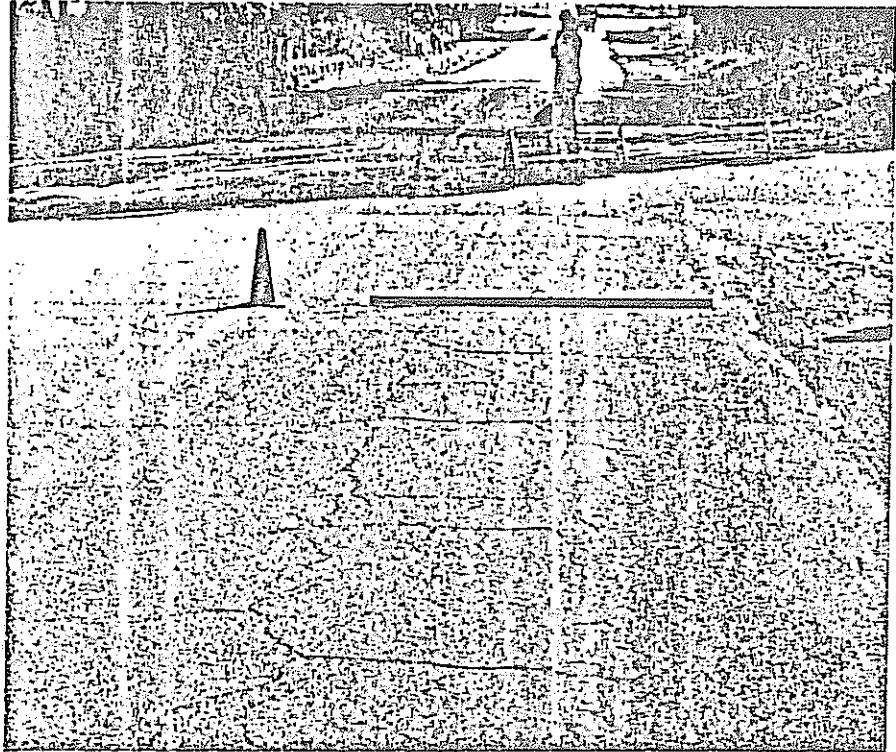
FIGURE 22

Distress   : Block cracks, Degree Spa. 1 m
Cause   : Ageing of binder
Mechanism   : Shrinkage of binder
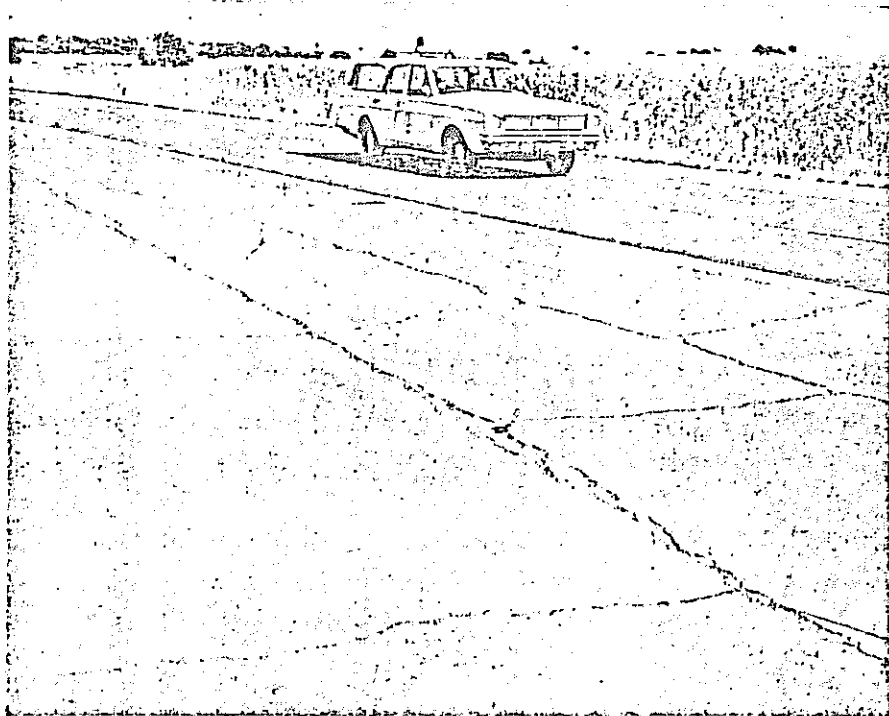
FIGURE 23

Distress   : Block cracks, Degree 5 Spa. 3 m
Cause   : Shrinkage and cracking of stabilised base
Mechanism   : Reflection of cracks through surface
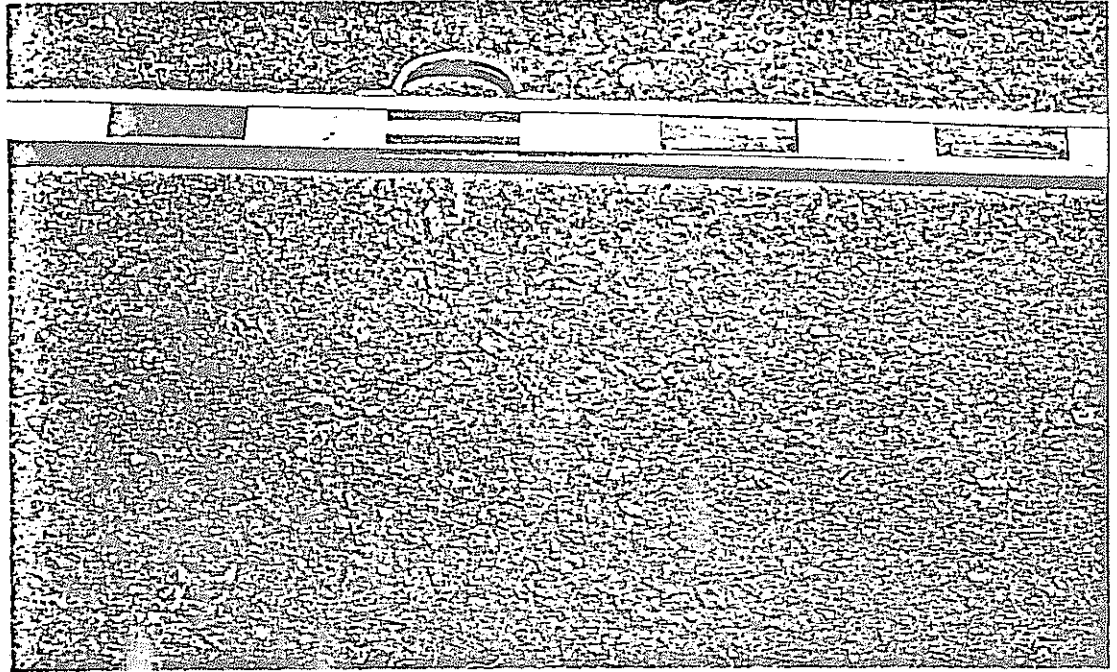
FIGURE 24

Distress : Crocodile cracks, Degree 2
(Straight edge marked horizontally in
decimeters)
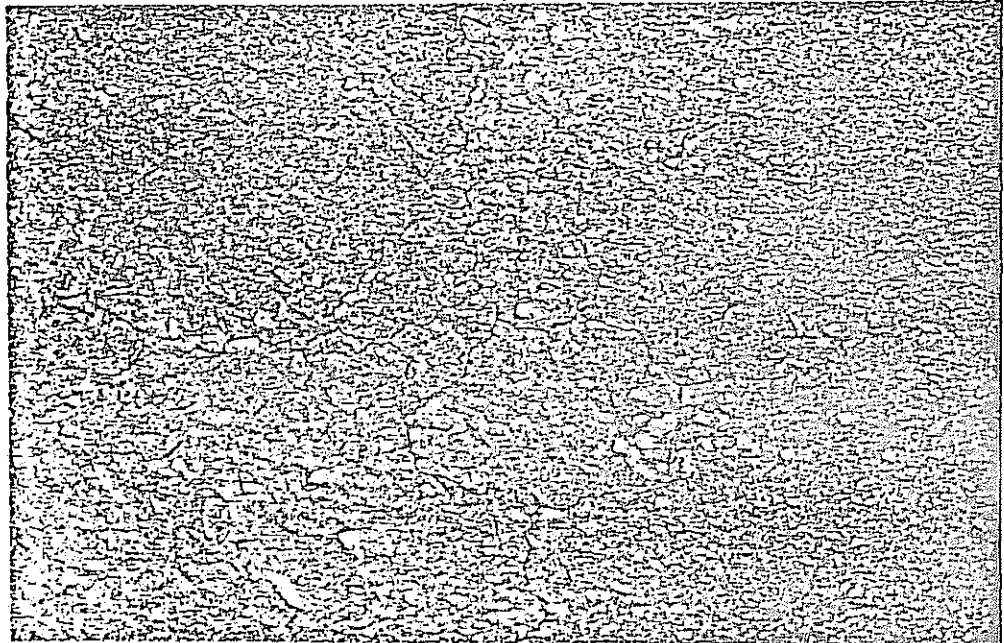
FIGURE 25.

Distress : Crocodile cracks, Degree 3.
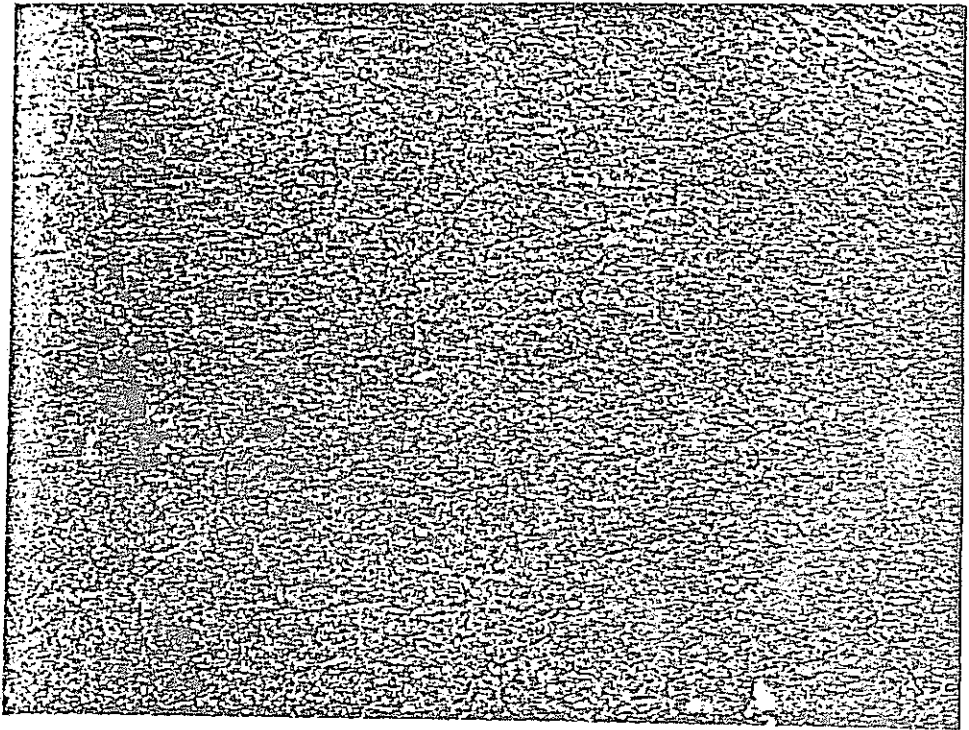
FIGURE 26

Distress : Crocodile cracks, Degree 4.
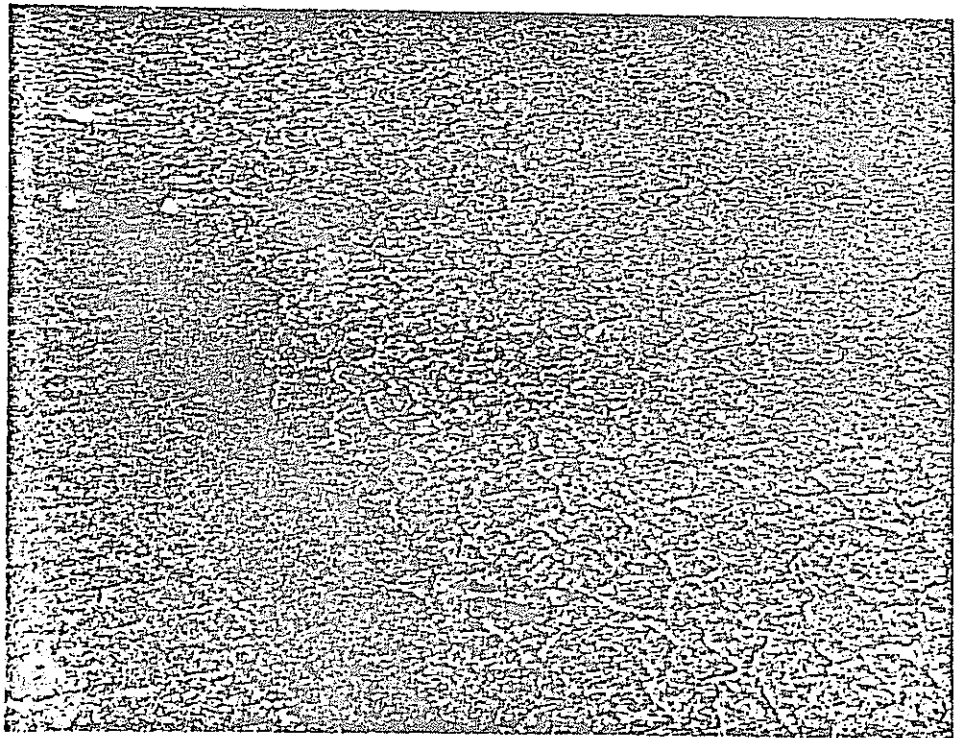
FIGURE 27

Distress : Crocodile cracks, Degree 5.

FIGURE 28

Distress   : Parabolic cracks, Degree 5
Cause   : Poor bond between surfacing and base on steep upgrade
Mechanism   : Shear at the interface of the base and surfacing
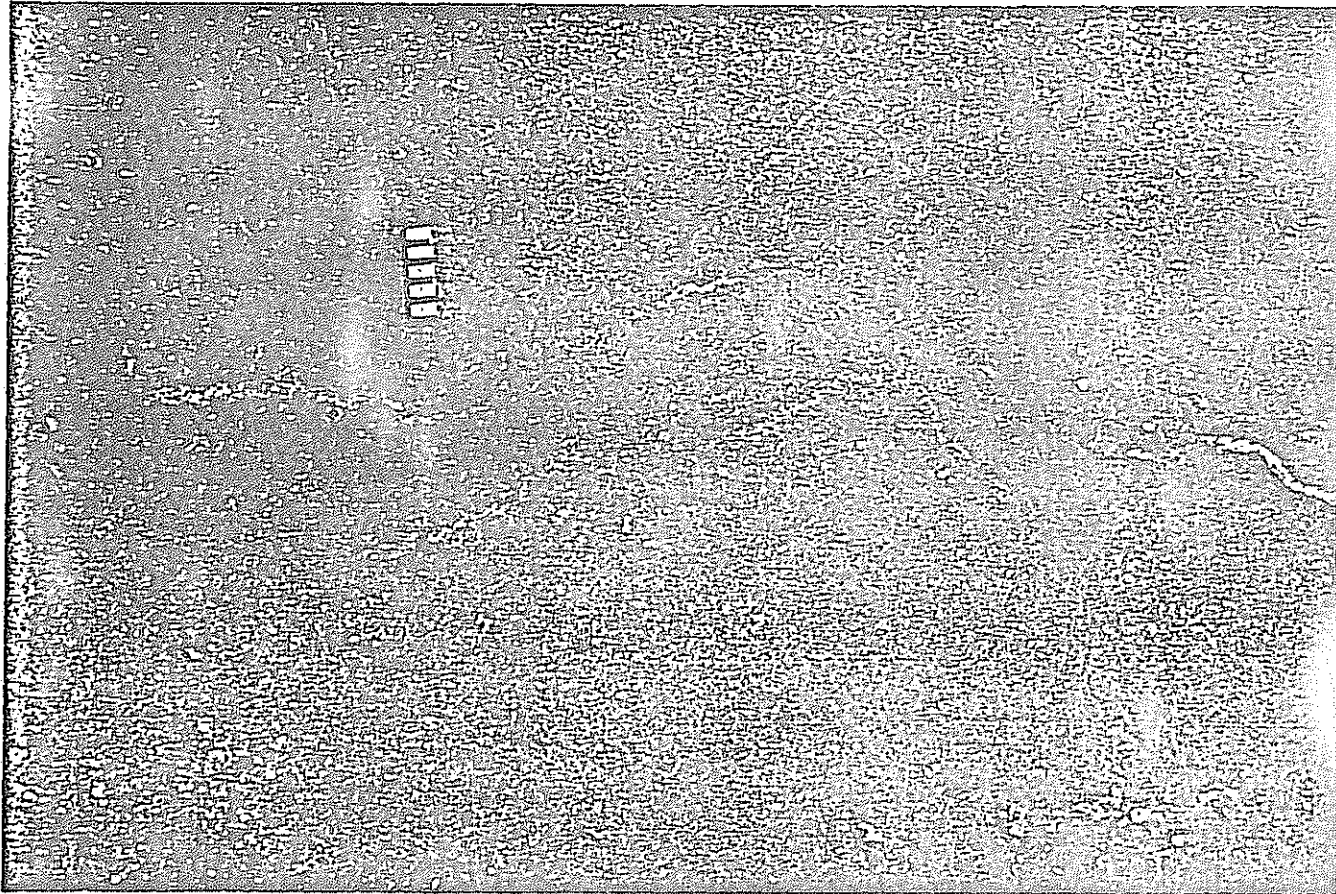
FIGURE 29. The result of pumping through crocodile cracks (degree 2)
(The rule in the figure is calibrated in centimetres)
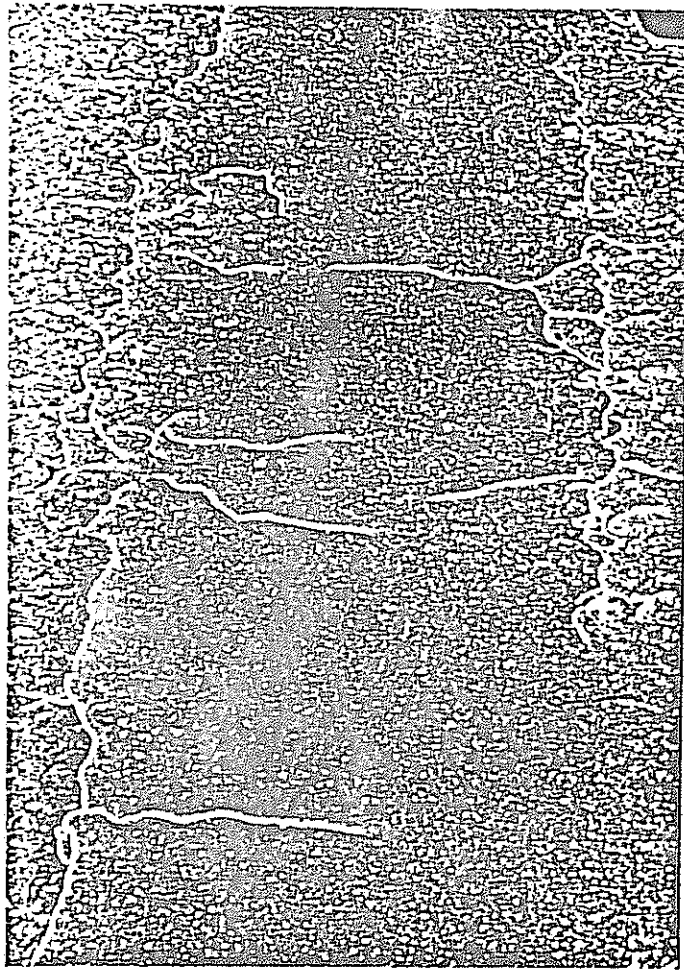
FIGURE 30

Distress	:	Longitudinal cracks with secondary development of ladder cracks
Cause	:	Binder hardening and low structural support
Mechanism	:	Fatigue of surfacing
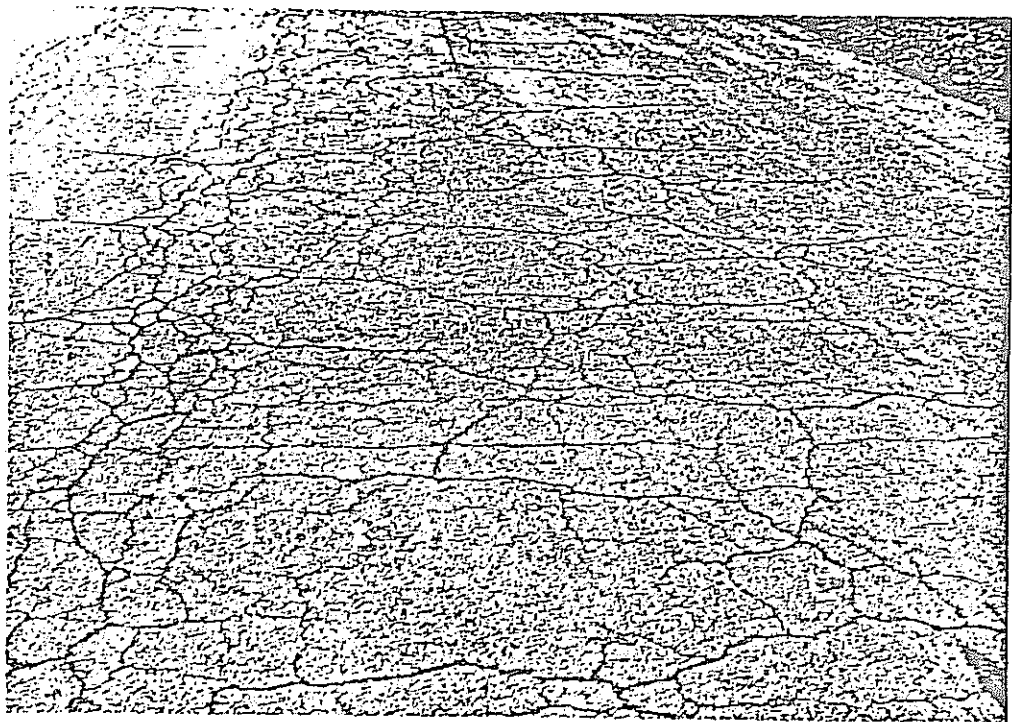
FIGURE 31

Distress	:	Multiple cracks, Degree 5 Primary transverse cracking. Secondary block cracking followed by crocodile cracking
Cause	:	Hard (brittle) binder in surfacing
Mechanism	:	Shrinkage of surfacing
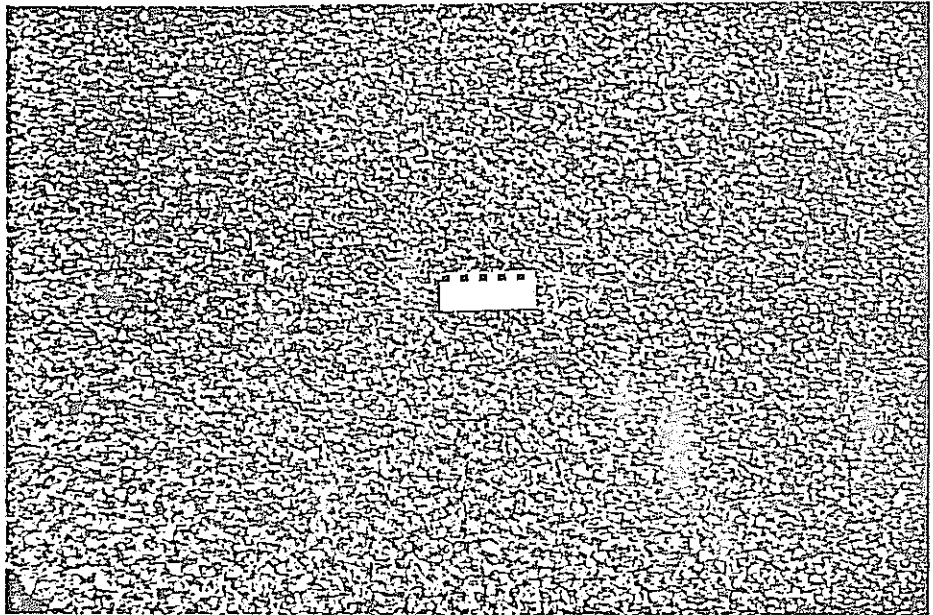
FIGURE 32

Distress : Loss of stone, Degree 1
(good surfacing with intact matrix)
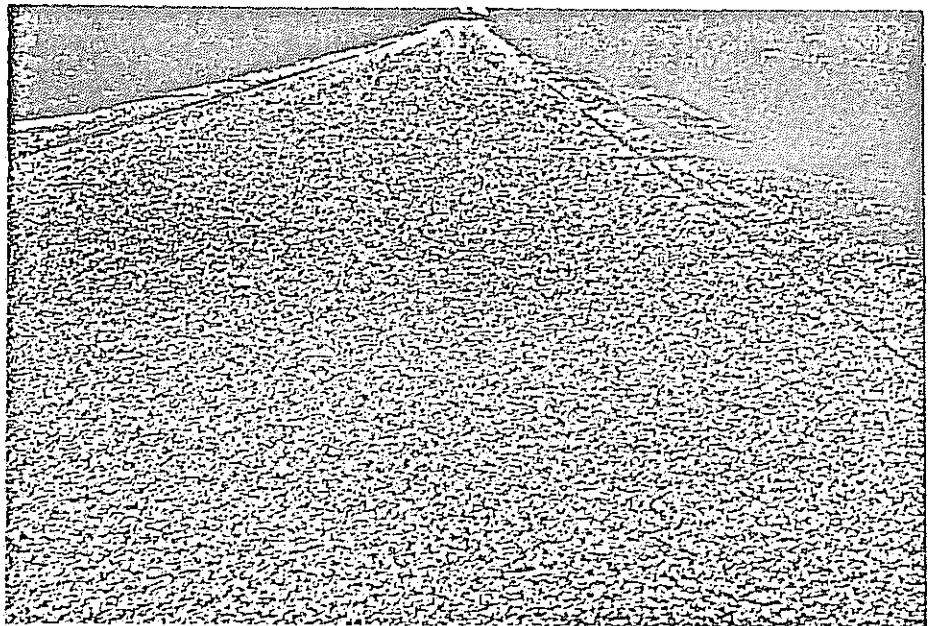
FIGURE 33.

General view of the surfacing in Figure 32.
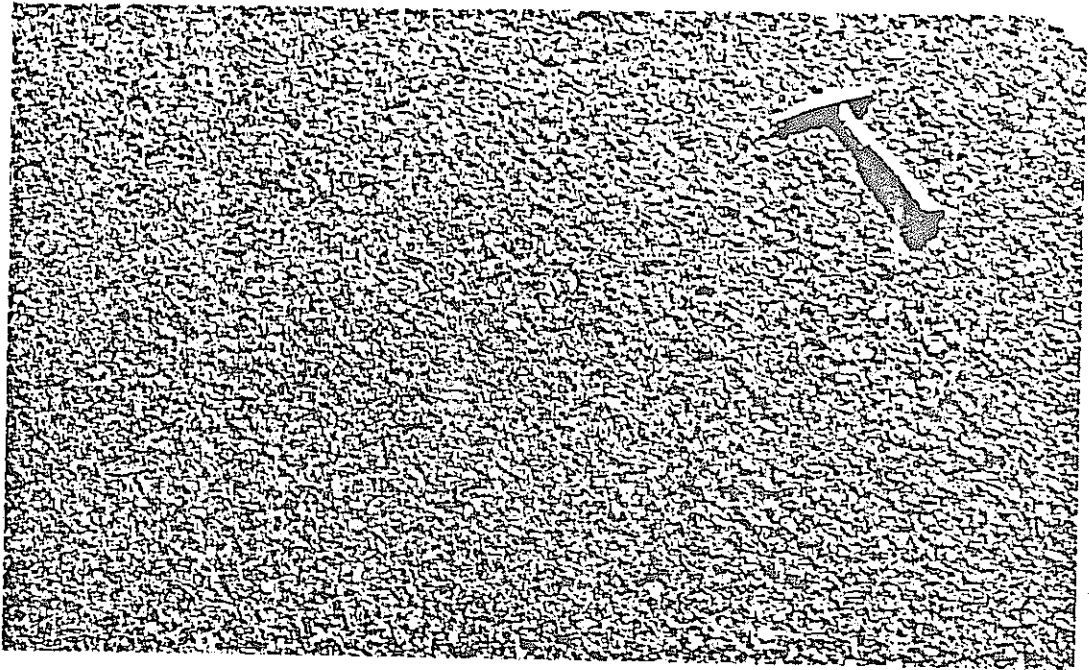
FIGURE 34

Distress   : Loss of stone, Degree 5 Spa. 10 mm
Cause   : Quartzite aggregate contaminated by shale
Mechanism   : Fracture
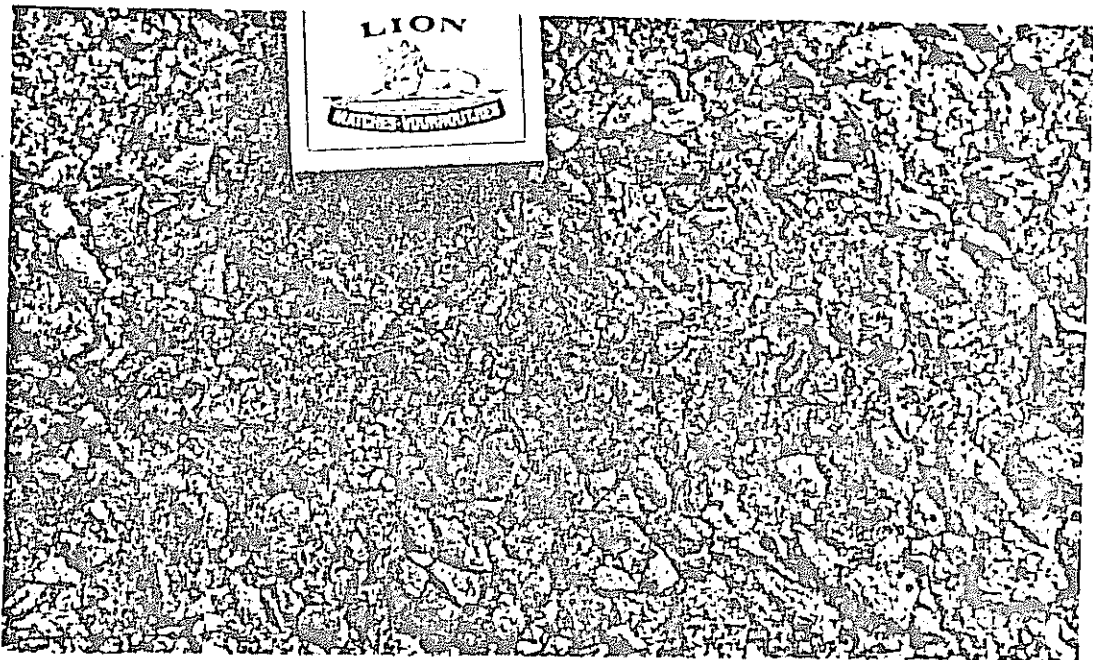
FIGURE 35

Distress   : Loss of stone, Degree 5 Spa. 50 mm
Cause   : Ageing of the binder
Mechanism   : Ravelling

FIGURE 36

Distress   : Loss of stone, Degree 5 Spa. 100 mm
Cause   : Ageing of binder
Mechanism : Ravelling
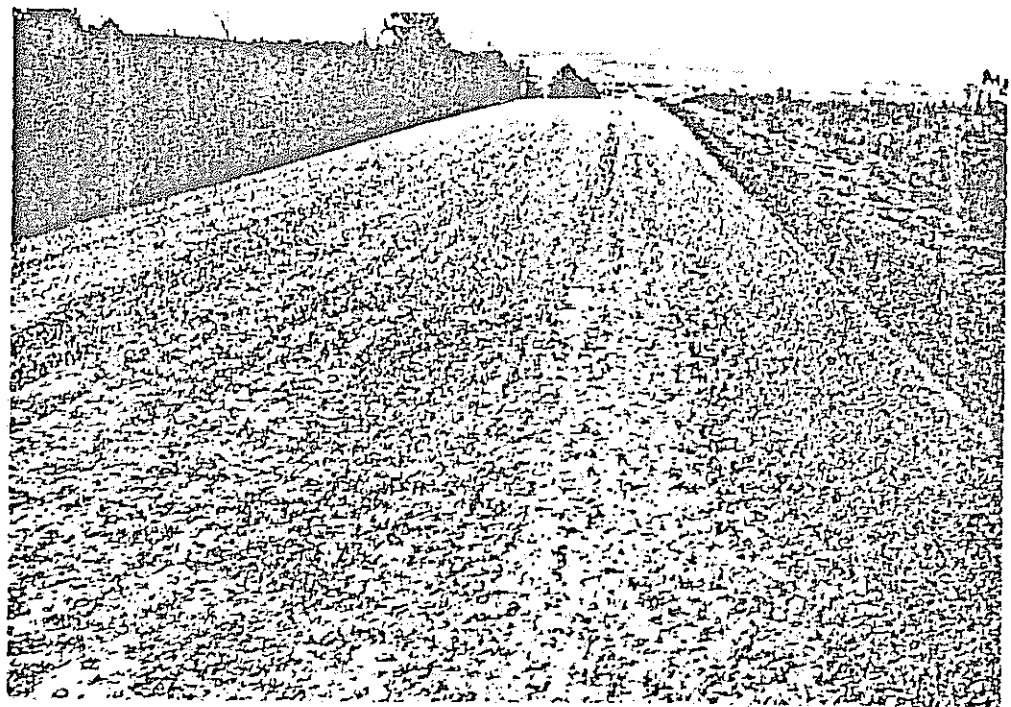
FIGURE 37

Distress   : Loss of stone, Degree 5 Area 5 Spa. > 100 mm
Cause   : Too hard a grade of binder used
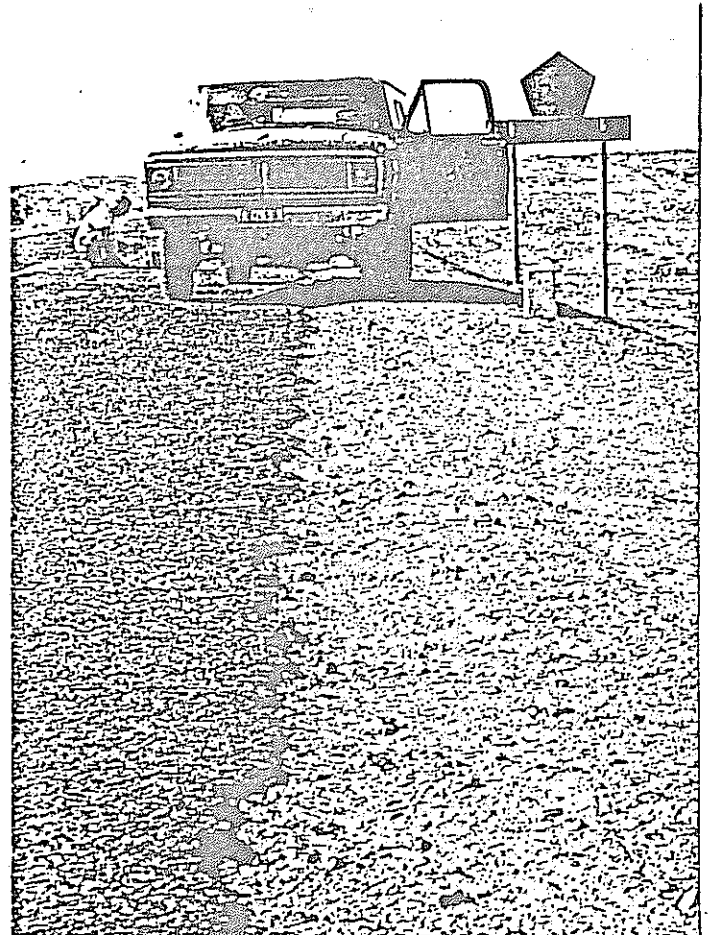Mechanism : Loss of adhesion

FIGURE 38

Distress	:	Pothole, Degree 5
Cause	:	Crocodile cracking of surfacing
Mechanism	:	Spalling

FIGURE 39

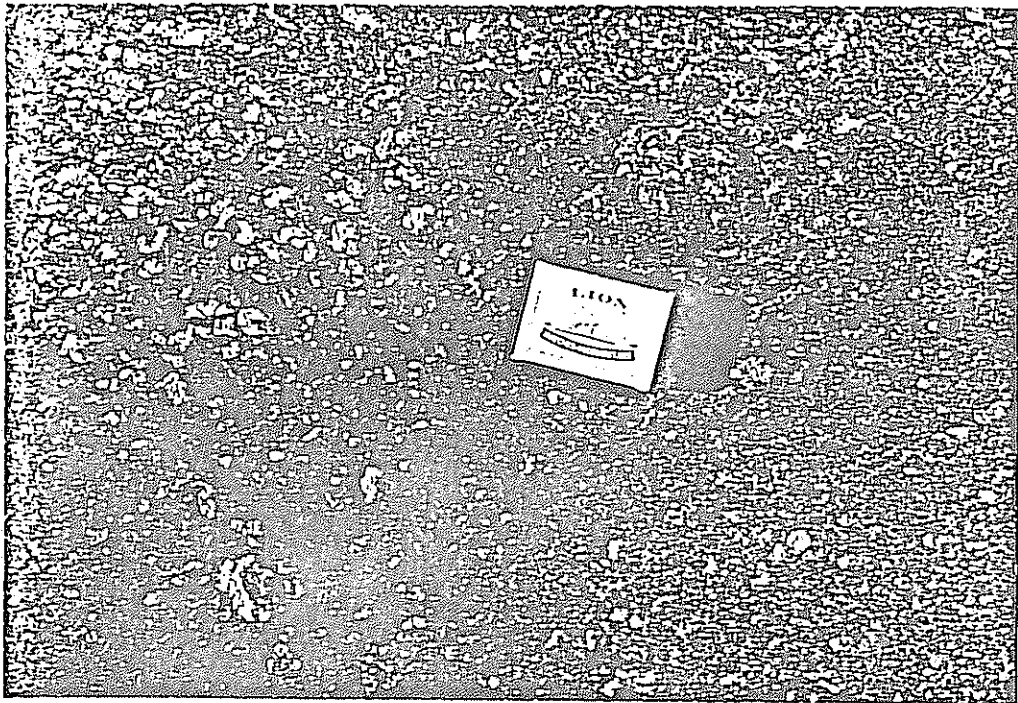|		
Distress	:	Edge break, Degree 4.
Cause	:	Salt action caused loss of aggregate on shoulder and thus weak support for premix
Mechanism	:	Shearing off of premix at edge of pavement

FIGURE 40

Distress   :   Fatting, Degree 4
Cause   :   Surfacing mix too rich
Mechanism   :   Reorientation of stones under traffic

FIGURE 41

General view of the road in Figure 40.
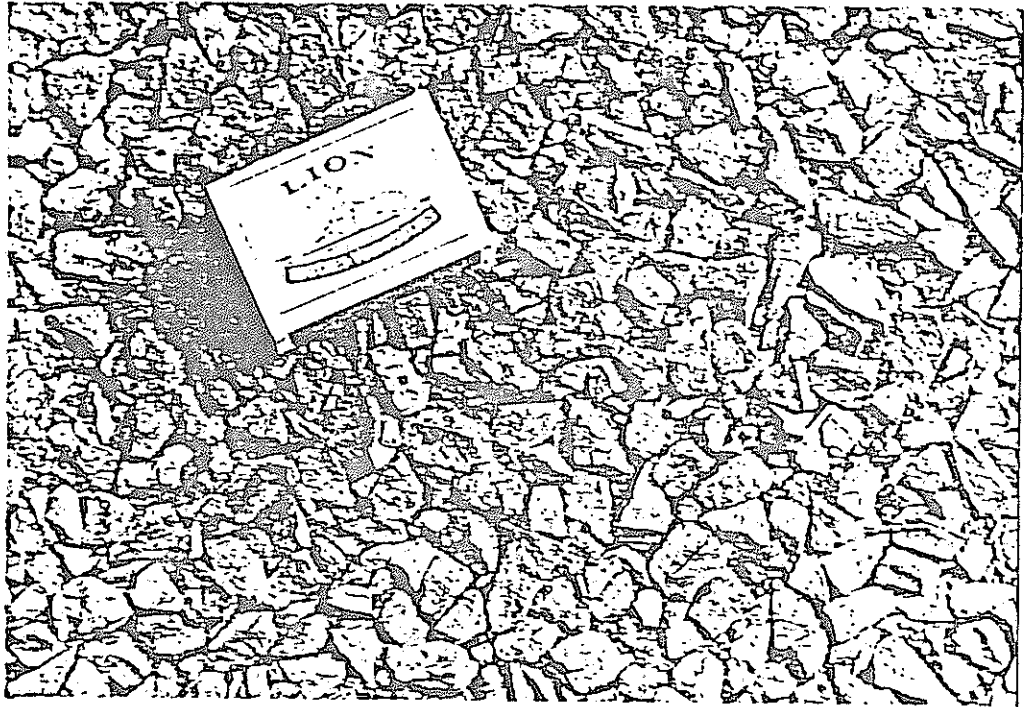
FIGURE 42

Distress : Polishing, Degree 1
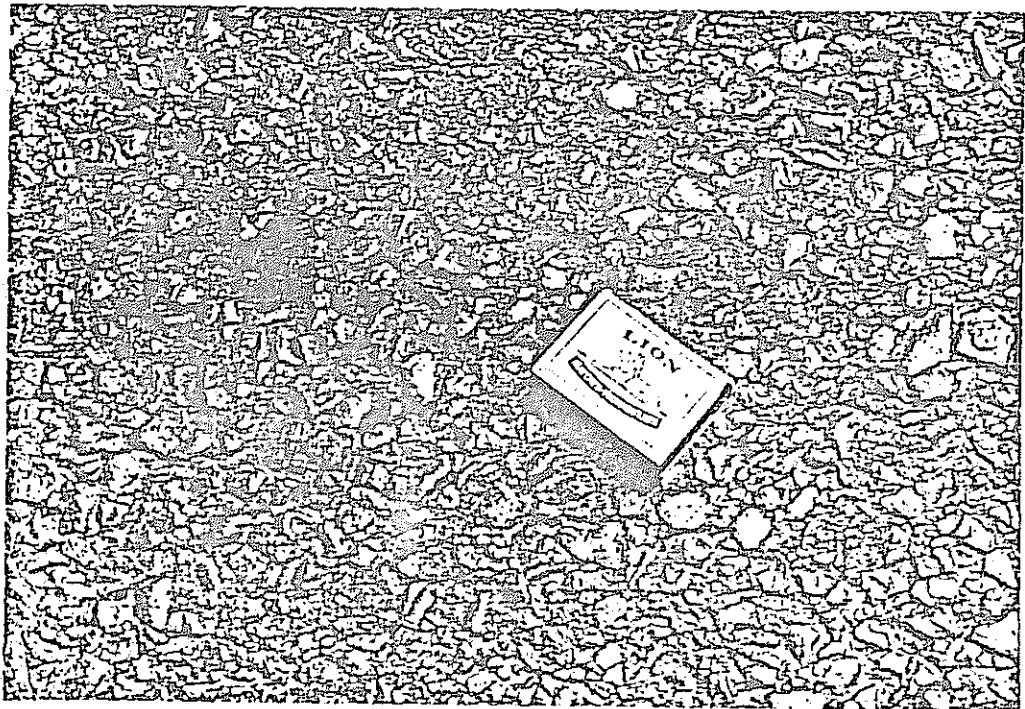   (stones are harsh, sharp and angular)

FIGURE 43

Distress : Polishing, Degree 5
Cause   : Stone has low polish stone value (PSV)