

TECHNICAL RECOMMENDATIONS FOR HIGHWAYS

Draft TRH 19

**STANDARD NOMENCLATURE AND METHODS FOR DESCRIBING THE
CONDITION OF JOINTED CONCRETE PAVEMENTS**

1989

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PREFACE

It is frequently necessary to describe the condition of pavements in highway engineering. A variety of engineering methods and terms has been used and this has tended to make communication difficult. This document promotes the standardisation of terminology for the South African road-building industry. The set of terms presented has been developed along the lines adopted in TRH6: *Nomenclature and methods for describing the condition of asphaltic pavements*.

It must be emphasised, however, that this document does not suggest **evaluations** of the pavement condition or prescribe aspects that should be described in given situations. The engineer must decide the context in which the pavement is to be evaluated and what descriptions are appropriate. The correct inspection schedule can then be set up using the recommended terminology.

SYNOPSIS

A set of standard terms for describing the condition of jointed concrete pavements is proposed. These are divided into two classes: the first covers functional aspects, i.e. those that affect the comfort, safety and convenience of the road user; the second covers structural aspects, i.e. those that determine the resistance of the pavement to the effects of traffic and the environment. Because surface distress plays a major role in assessing pavement conditions, methods for describing it are presented in considerable detail. Examples of the practical application of these terms are given.

SINOPSIS

'n Stel standaard terme vir die beskrywing van die toestand van gevoegde beton plaveisels word voorgestel. Dit word in twee klasse ingedeel. Die eerste dek die funksionele aspekte; dit wil sê, dié wat gemak, veiligheid en gerief van die padgebruiker beïnvloed. Die tweede dek strukturele aspekte, dit wil sê, dié wat die bestandheid van die plaveisel teen die effekte van verkeer en die omgewing bepaal. Omdat verswakking 'n hoofrol speel in die beoordeling van plaveisels, word die metodes vir die beskrywing daarvan in taamlke besonderhede aangebied. 'n Paar voorbeelde van hoe hierdie terme in die praktyk toegepas word, word ingesluit.

KEYWORDS : Nomenclature, distress attributes, concrete pavements, distress mechanism, functional condition, structural condition.

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1 INTRODUCTION

It is frequently necessary to describe the condition of pavements in road engineering, hence the development of a standard set of terms for describing the condition of asphaltic pavements. A similar set of terms is presented in this document for concrete pavements, and these have been developed along the lines adopted in TRH6: *Nomenclature and methods for describing the condition of asphaltic pavements*.

These concepts are divided into two categories: the one deals with the functional description of pavement condition, and the other with the structural description of condition. Section 2 summarises these concepts and methods. The description of surface distress is dealt with in detail in section 3, firstly, because of its importance in the assessment of pavement condition and, secondly, because surface distress on concrete pavements differs substantially from that on asphaltic pavements. Although it is not within the scope of the document to provide recommendations for the evaluation of pavement condition and hence the structuring of individual condition assessment procedures, some examples of practical applications are given in section 4 to illustrate how the document may be used for different circumstances.

This document is aimed specifically at jointed concrete pavements, and includes pavements with dowels and tie-bars. It is also applicable to 'non-road' pavements such as those found at airport aprons, parking areas and terminals. It does, however, exclude continuously-reinforced, jointed reinforced and prestressed pavements as there are relatively few of these pavements in South Africa.

2 CONCEPTS FOR THE DESCRIPTION OF PAVEMENT CONDITIONS

2.1 Functional description of pavement condition

There are properties of the pavement that affect the service it provides to the road user. The functional requirements of a pavement are to meet the standards of these properties.

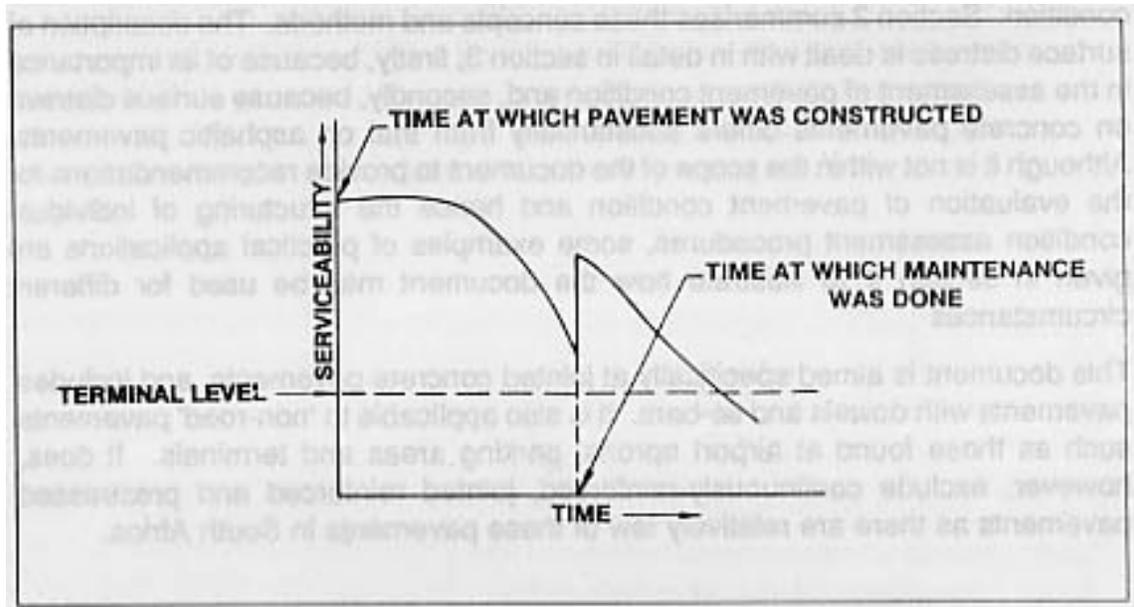


FIGURE 1 The performance of a hypothetical road

They are predominantly those that govern his comfort, safety and speed of travel^{*}. The extent to which a pavement meets the requirements of the user is defined as the serviceability of the pavement. The minimum level of serviceability that may be allowed for a particular pavement (or class of pavement) is called its terminal level of serviceability. The variation of serviceability over a period of time is called the performance of the pavement. i.e. performance is the serviceability as a function of time. Figure 1 gives an example of the performance of a hypothetical pavement in order to illustrate these concepts.

The functional requirements, comfort, safety and speed, are not easy to assess directly. Therefore, various functional features of the pavement which can be measured are defined.

For surfaced roads these are the riding quality, skid resistance and surface drainage of the pavements and, to a lesser extent, environmental factors such as noise generation and the aesthetic appearance of the pavement. The serviceability, terminal values and performance are expressed in terms of one or more of the features (e.g. serviceability in terms of riding quality, etc.) The three most important features are listed in Table I together with the factors that determine their values and the current methods of assessment.

^{*} * Note that the pavement is only one part of the road. The functional requirements of the road as a whole consequently incorporate those of the pavement.

TABLE I Assessment of pavement serviceability

FEATURES	FACTORS CONTRIBUTING TO SERVICEABILITY	METHODS OF ASSESSMENT	OF
1 Riding quality	(a) Longitudinal surface roughness (deformation)	(i) Subjective assessment in a vehicle	
	(b) Faulting	(ii) Measurement of riding quality using PCA roadmeter, LDI,	
	(c) Spalling and scaling		
	(d) Uneven patching	(iii) Visual assessments	
2 Skid resistance	(a) Surface texture depth	SCRIM, DRTT brake-force trailer, pendulum apparatus*, sand patch test	
	(b) Harshness of surface	See (3) below	
	(c) Water film thickness		
3 Surface drainage	(a) Transverse and longitudinal grades	Levelling, inspection during rain	
	(b) Efficiency of drainage system	Assessment of condition of shoulders and drainage paths, inspection during rain	
	(c) Deformation of surface profile, particularly depressions	Inspection during and after rain, straight-edge measurements.	

2.1.1 Riding quality

The riding quality of a pavement 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 or perhaps unsafe). This is determined by the unevenness of the road profile (longitudinal deformation, and the loss of surface material (spalling, scaling etc.). The value of riding quality is determined by having a panel of road users judge a pavement subjectively on a scale of 0 to 5 (where 5 indicates a perfectly smooth pavement) and taking the average rating. The sample of road users must be large enough to be representative of all road users to a desired degree of accuracy.

It is impractical to use large panels for routine assessments of riding quality. Therefore some mechanical method of measuring the characteristics of the pavement surface is required that correlates sufficiently well with panel ratings for use in practice. A number of such instruments has been developed. They are generally calibrated to agree with the panel ratings^{***}. Two such instruments are the PCA roadmeter and the linear displacement integrator (LDI).

2.1.2 Skid resistance

Skid resistance is a term used to describe the general ability of the road surface to prevent skidding in all or particular movements generally executed by vehicles. The definition may be narrowed where required to refer to the ability of the road to allow specified movements under specified conditions. In this case one may talk, for example, of a road having a high skid resistance for vehicles taking a corner in wet conditions. The ability of a particular vehicle to execute a particular movement depends on the coefficient of friction between each of its tyres and the road surface during the movement.

* Instruments must be calibrated from present results obtained subjectively by a panel of raters (see Section 2.1.1)

*** See Section 2.1.2

***The term 'present serviceability index' is widely used overseas to refer to a value of riding quality obtained from instruments. This term causes confusion with the wider concept of serviceability and has therefore not been included in this text. It does, however, remain a very important term when reading the literature.

The coefficient of friction is, however, not a constant for a particular section of road but depends on several other factors: type and pressure of tyre, the type of movement (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, instruments have been developed that can be used to estimate the average coefficient of friction that would apply to vehicles executing similar movements under wet conditions. 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 are currently used in South Africa. These are SCRIM*, the brake-force trailer and the pendulum tester.

The most important property of the pavement to effect its skid resistance is the roughness of the surface on a scale commensurate with the dimensions of the contact area between the pavement and the vehicle tyre, i.e. the surface texture. The two important characteristics of the surface texture that contribute to the skid resistance are the macrotexture and the microtexture.

The macrotexture relates to the gaps between the large protrusions of the surface (e.g. grooves). These allow 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 its average depth. This test is known as the sand patch test.**

The microtexture relates to the harshness or roughness of the concrete itself. There is currently no direct quantitative measure of the microtexture, but this can be qualitatively assessed by examining the surface and determining if it is harsh or smooth.

The macrotexture is of overriding 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 an indirect measure for the microtexture.

2.1.3 Surface drainage

The surface drainage of a road is a measure of the general ability of the road to keep its surface clear of water. This depends on the speed at which water runs off during rain and the extent of ponds of water forming during and after rain. Run-off speed determines the film thickness of the water on the road which is an important factor affecting the skid resistance, whereas ponding creates the hazard of water splashing up, especially by fast moving traffic. 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 drainage characteristics of the adjacent land. The effectiveness of these factors in facilitating surface drainage is a measure of the serviceability of the road in terms of surface drainage. No means have yet been determined for quantifying the effectiveness of drainage and terminal levels of surface drainage are usually determined subjectively by inspection during rain, taking into account the rainfall characteristics of the area.

2.2 Structural evaluation

The object of assessing the condition of existing pavements is usually to determine what action is required to keep them serviceable as economically as possible. Even if the serviceability is satisfactory at the time of the assessment, the pavement may still require maintenance to ensure that it does not become damaged and need costly maintenance in the future. This means that it is necessary to predict the future condition of the pavement from current assessments, taking into account both the functional and structural properties.

The trend of the condition over a period of time is called the behaviour*** of the pavement (i.e. behaviour is the function of condition with time). The factors that determine the behaviour of a particular pavement are the traffic forces and environmental factors acting on it. The pavement is, therefore, evaluated with a view to determining its resistance to traffic and the environment. Accordingly, the structural capacity of the pavement is defined as the ability of the pavement to withstand the effects of traffic and environmental forces.

In principle, a knowledge of the structural capacity and the serviceability, the environment and the expected traffic flow are used to predict the future behaviour of the pavement under alternative maintenance strategies. The most suitable strategy according to functional and economic criteria is usually selected.

In practice, however, the structural condition usually cannot be expressed directly in terms of the structural capacity, but is described in terms of related properties of the pavement. These are the structural indicators of which there is a large variety and often several ways of expressing each of them. The use of such

* The RTT undertakes the measurement of skid resistance with SCRIM as a service to the road authorities.

** This test is described in TMH6: Special methods for testing roads.

*** Note that Just as the serviceability is a special feature of the overall condition of the pavement, so the performance is a special feature of the overall behaviour. One can also refer to the behaviour in terms of one or more aspects of the condition, such as deflection, cracking, etc.

indicators depends on which of the various possible approaches and models is chosen for predicting the behaviour of the pavement. Several classes of these indicators are listed in Table II.

Distress is the visible manifestation of the deteriorating condition of the pavement at the surface affecting either the serviceability or the structural capacity. The measurement of distress is usually convenient since it does not require instruments. Distress is also particularly important as a structural indicator because it clearly identifies weaknesses in the pavement. For these reasons detailed attention is given to concepts used in the classification of the appearance and distribution of distress in section 3.

An expression of the structural indicators alone simply constitutes a description of the condition. An evaluation of the structural condition requires some model which relates the separate factors. Such an evaluation may be an assessment of the structural capacity, the structural strength or the structural adequacy of the pavement or its maintenance requirements. Here the structural strength of the pavement is related to the difference between strains that can be tolerated by the materials in the pavement and the strains placed upon them by a standard axle load under existing environmental conditions. The structural adequacy is an assessment of whether the pavement requires strengthening or maintenance or whether it is adequate to meet the predicted traffic and environmental demands during the period preceding the next assessment. Often the structural adequacy is determined by comparing various structural properties against specified critical values or standards which are set according to traffic, policy, etc. The use of critical values of condition of a pavement is discussed in the following section.

TABLE II Indicators of structural condition

TYPE	MEASURED/JUDGED BY
1. Structural reaction	Differential deflection at joints
	Elastic moduli
	Slab thicknesses
2. Material properties	Strength
	Fatigue resistance
	Durability
3. Structural integrity	Erodibility
	Condition of joints
	Cracking
4. Drainage	Voids (resulting from pumping)
	Crossfall
	Efficiency of surface drainage
5. Distress	Efficiency of subsurface drainage
	Deformation (e.g. faulting)
	Cracking
6. Structural response	Disintegration of surfacing
	Joint distress
	Accelerated behaviour
	(Heavy Vehicle Simulator)
	Past behaviour
	(Normal traffic and environment)

2.3 Critical values of pavement condition

Terms such as "failure criteria", "failed condition", the road has "failed" are commonly used without clear definition. To say a road has "failed" generally suggests that some distress is evident from the condition of the road, but does not indicate the seriousness of the distress. It does not always imply that maintenance measures are immediately required for the road. "Failure criteria" or "failure conditions" usually refer to some critical level of distress related to the condition which is being evaluated. A pavement may be studied from a functional, structural or research point of view. Strictly, a pavement fails (to meet acceptable standards) if it deteriorates beyond some critical level which must be specified (or at least implied) in the context of the assessment. Various types of critical values are used, viz.:

Terminal levels of serviceability are critical values of the pavement condition that provide minimum tolerable levels of comfort, safety or speed for the road user. If the serviceability of a pavement is below the acceptable level for the particular class of road, it defines a maintenance need for that pavement with respect to user requirements. For example, one may refer to terminal levels of riding quality, skid resistance or surface drainage.

On the other hand a pavement may receive maintenance long before it has reached the terminal level of serviceability. That level of distress at which it is the most economical to maintain the pavement is defined as the **critical state of distress** as regards maintenance. If the pavement is left until the distress increases beyond the critical state, the pavement can be said to be in a severe state of distress.

3 SURFACE DISTRESS

3.1 Attributes

A description of distress involves the recording of its main characteristics, the attributes of distress. These are the location, mode, type, degree, extent, spacing and position. These attributes are defined below where methods are given for expressing the values of each of the attributes. Alternative methods exist for expressing the value of some attributes. In certain cases it may be necessary only to consider some of the attributes, or alternatively, logistical constraints may dictate that only a few attributes be recorded. The engineer must decide which method is most suited to his specific requirements and set of circumstances. In addition to describing the appearance of the distress, it is often important also to indicate how the distress came about. This is expressed in terms of the mechanism and cause of distress. These expressions are also defined below.

(a) **Location.** The location of distress is given in terms of two points along the length of the pavement. These points delineate a pavement section to which the subsequent description of distress pertains. These points are chosen on practical grounds. They may demarcate an experimental pavement section, a length of road to be overlaid, or a unit length of pavement for monitoring purposes in a pavement management system.

Generally, if the sections are too long, the description of distress becomes imprecise, whereas the division of the pavement into very short sections makes the task of recording distress tedious and expensive.

(b) **Modes and types.** There are five major ways in which distress occurs. These are called the modes of distress. They are :

- Deformation. This is the development of a change in the profile of the surface of the pavement (unevenness).
- Cracking.
- Disintegration of the surfacing. This is the break-up and loss of the surface. It can, for example, occur through spalling of the material at cracks or joints in the pavement.
- Smoothing of the surface texture. This is the loss of surface texture which leads to a loss of skid resistance.
- Joint seal defects

Each of these modes of distress can occur in one of several different typical manifestations, called the various types of distress. For example, cracking can be classified as transverse cracks or corner breaks, etc. and deformation as faulting or blow ups etc. In the following section the various types of distress are defined and the methods for rating their attributes are given. The modes and types of distress are given in Table III.

(c) **Degree and extent.** The degree of a particular type of distress is a measure of how bad it is at a particular point on the road (which means that the degree of distress can vary over the pavement section). For example, the degree of faulting is a function of the difference in height at the joint between two abutting panels. The degree is indicated by a class number where degree 1 indicates the first evidence of a particular mode (and type) of distress and degree 5 indicates the condition at its worst.

The standard way in which the degree of each type of distress is classified is given below. This can be quite complex. However, Table IV indicates roughly what each class would signify for "typical" pavements in "average" environment and traffic conditions. This table is meant only as a guide to the "frame of reference" against which the classes were defined. Note that in line with this definition a condition "Degree 1" will, in practice, be coded as "no distress". This classification provides a useful standard for coding distress. However, the option is also open to express the degree in terms of direct measurements (e.g. a fault of 3 mm).

The extent of distress is a measure of how widespread the distress is over the pavement section. Usually it is expressed in terms of what proportion of the pavement has a particular type of distress in excess of a given degree. This can be given by expressing either the proportionate length or area of the pavement affected. This procedure is useful when dealing with situations where the distress is of a uniform nature or is prevalent

within fairly well-defined areas. An alternative measure of extent is the number of distress manifestations within a section of pavement. This method is particularly useful in the case of jointed concrete pavements where the number of panels or joints exhibiting specific types of distress may be counted. It is often of interest to describe cases where the degree of a certain type of distress varies considerably over the pavement section. This is expressed by stating the extent for increasing degrees of distress. For example, Degree 2 Area 80 per cent and Degree 4 Area 10 per cent indicates that approximately 80 percent of the road was in a state of distress of at least Degree 2 (i.e. Degree 2 and greater) and that within this 80 per cent, 10 per cent of the road was of Degree 4 and greater.

TABLE III : Various types of distress associated with each mode of distress

Mode of distress	Type of distress
Deformation	faulting (of cracks or joints) shoulder drop off blow up depression heave
Cracking	transverse cracks longitudinal cracks corner breaks or diagonal cracks map cracking parallel cracks joint and crack separation multiple cracks
Disintegration of surface	spalling popouts patches scaling
Smoothing of surface texture	loss of macro texture
Joint seal defects	loss hardening loss of adhesion/cohesion installation

TABLE IV Classification of the degree of distress

Class	Description
Degree 1	Distress difficult to discern visually
Degree 2	Easily discernible distress but of little immediate consequence
Degree 3	Notable with respect to possible consequences
Degree 4	Rouses concern with respect to possible consequences
Degree 5	Extreme with respect to possible consequences

(d) **Position and spacing of distress.** The position of distress refers to where the distress is situated transversely across the pavement. The various options include: the wheelpaths, the shoulder, fast lane, etc. The spacing of distress is an additional dimension of pavement assessment indicating the geometry of the distress. Its definition varies for the different types of distress, but it always represents a linear measurement. For example, for transverse cracks the spacing indicates the average distance between the cracks. In certain cases the spacing dimension may vary considerably within a pavement section, making it difficult to describe the distress in terms of this value. Circumstances will therefore dictate whether this is an appropriate attribute to use.

3.2 AUXILIARY CONCEPTS

3.2.1 Cause and mechanism of distress

The cause of distress refers to an extraordinary circumstance or condition which is necessary for the distress to occur. Examples of causes are intrusion of water (through, for example, inadequate drainage), unstable materials, inadequate design, construction defects, and chemical reaction (for example, alkali aggregate reaction).

The mechanism of distress is the physical process by which the cause manifests the distress. Examples of mechanisms of distress include shear, heave, consolidation, fatigue, shrinkage, pumping and failure of load transfer.

The identification of the cause and mechanism of distress often plays an important part in the structural evaluation of the pavement, i.e. in assessing its structural capacity and determining its maintenance requirements, but it is important not to confuse a mechanism of distress with the distress manifestation itself. For instance, when pumping takes place and there is physical evidence thereof, it is usually noted whilst assessing distress.

3.2.2 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 shoulders, surfacing (or slab), subbase, subgrade and fill.

3.2.3 Primary and secondary distress

Often one type of distress is a result of some other initial distress. In such cases the initial distress is defined as primary distress and all consequent distress as secondary distress.

3.2.4 Structural and functional distress

When evaluating a pavement design, it is often convenient to differentiate between the structural distress and functional distress of the pavement. Structural distress is the type of distress that pertains to the load-bearing capacity of the pavement in either origin or consequence. Functional distress is that distress that pertains only to the serviceability of the pavement. The various types of distress are not uniquely classified in this way and the choice should be made within the context of the particular circumstances.

3.2.5 Severity of distress

The severity of distress is a measure of how serious the distress is, especially in terms of maintenance. In general, it has to take into account all the properties defined above. A scale cannot be defined for severity, firstly, because there is incomplete knowledge of the relative importance of the various properties and secondly, the relative importance depends on external factors such as traffic flow and climate. The term is therefore generally used in a qualitative or relative sense.

3.3 Classification rules for each distress type

3.3.1 Deformation

3.3.1.1 Types

Deformation is a change in the road surface profile. This is manifested as an area of the pavement having its surface either above or below that of the original level. The various types of deformation are defined as follows.

(a) Faults

Faulting is a difference in elevation across joints or cracks, creating a step in the pavement profile. Faulting across transverse joints or cracks is often caused by a build up of material under the approach slab near the joint or crack. This can be caused by ingress of water and subsequent pumping of erodible subbase material under heavy loading. Other contributory factors could be lack of load transfer, and warping or curling of the slab near the joint because of either moisture or temperature gradients. Longitudinal joint faulting may be caused by heavy traffic with subsequent settlement or swelling of the foundation, or shoulder drop off.

The **degree** of faulting can be expressed in millimetres or in terms of one of the following classes :

Degree 1 : less than 1 mm

Degree 2 : 1 to 3 mm

Degree 3 : 3 to 5 mm

Degree 4 : 5 to 7 mm

Degree 5 : greater than 7 mm

The **extent** of faulting can be assessed in a number of ways. The total length of joint or crack exhibiting faulting of a specific degree can be recorded or the number of faulted joints or cracks can be counted. In the case of longitudinal joint or crack faulting the percentage length of a section of pavement exhibiting faulting may be recorded.

(b) Blow ups

This is an upward buckling or shattering of the slabs at a joint or crack and is caused by expansive forces which exceed the pavement's ability to absorb them. This may result from the accumulation of

incompressible material in the joints or a combination of adverse thermal and moisture conditions. In some cases no deformation of the surface profile takes place and only shattering or crushing of the concrete occurs. Here it may be more appropriate to record it as joint spalling.

The **degree** of a blow up is expressed as the measure in millimetres of the vertical displacement from the normal profile, or in terms of one of the following classes :

Degree 1 : less than 5 mm displacement

Degree 2 : 5 to 10 mm

Degree 3 : 10 to 20 mm

Degree 4 : 20 to 50 mm

Degree 5 : greater than 50 mm

The **extent** of blow ups can be expressed as the number of blow ups, within a specific class of degree, over a section of pavement.

(c) Depressions

Depressions are localised areas at a lower level than the pavement surface and may be caused by settlement or consolidation of the supporting structure. They may also have been "built in" during construction. Usually depressions lead to secondary distress in the form of cracking and faulting and may also cause a safety hazard when filled with water.

The **degree** of a depression is expressed as the measurement in millimetres of the vertical displacement from the normal pavement profile, or in terms of one of the classes listed for blow ups. Note that secondary distress such as cracking or faulting are assessed separately.

The **extent** of depressions can be expressed as the number of occurrences within a specific class (degree) over a section of pavement.

(d) Heave

This is the result of an upward movement of the slab and occurs mainly at a joint. Heave is usually accompanied by secondary distress in the form of cracking or faulting. Heave is usually caused by expansive subgrades.

The **degree** of a heave is expressed in the same way as that of a blow up, and secondary distress is assessed completely separately.

The **extent** of heave is also expressed in terms of the total number of occurrences within a specific class (degree) over a section of pavement.

Note : It is often not necessary or even pertinent to describe the deformation in terms of depressions, blow ups, etc. It may be sufficient to express it simply in terms of the riding quality of that section of pavement. Care must therefore be taken in determining which type of description best suits the purpose of the inspection.

3.3.2 Cracking

3.3.2.1 Types

(a) Transverse cracks

These cracks run approximately at right angles to the pavement centre line. They usually occur as a result of one or more of the following: excessive overloading, thermal and moisture gradient stresses, drying shrinkage stresses and construction and design defects such as large joint spacings, late sawing, inadequate joint depth, and excessive subbase restraint resulting from poorly backfilled trenches.

(b) Diagonal cracks

A diagonal crack is a linear crack that extends diagonally across a slab. This type of crack may be caused by: heavy repeated loads, thermal curling and moisture warping stresses, unstable foundation conditions, drying shrinkage stresses and overlong joint spacings.

(c) Corner breaks

A corner break is a diagonal crack that intersects the joints less than half a panel width from the corner. As opposed to a corner spall, a corner break extends vertically through the entire slab thickness. The causes of corner breaks are similar to those of diagonal cracks, but can also include poor load transfer across joints.

(d) Longitudinal cracks

These are cracks that run approximately parallel to the pavement centre line. Possible causes of these type of cracks include: improper construction of longitudinal joints (e.g. inadequate or late joint sawing), heavy load repetitions, loss of foundation support, thermal and moisture gradient stresses, drying shrinkage stresses and expansive soils.

(e) Crazeing

Crazeing is a phenomenon caused by over finishing of the surface. A series of fine cracks appear that extend only into the upper surface of the slab. It may eventually lead to disintegration of the surface as a secondary distress.

(f) Map cracking

Map cracking is usually caused by reactive aggregates which expand, thus disrupting the concrete matrix. It manifests itself as map cracks forming an irregular polygonal pattern. The cracks usually extend deep into the concrete, and may be accompanied by staining of the surface because of the presence of chemical reaction products.

(g) Parallel cracks

These are cracks that run more or less parallel to one another (usually with a close spacing), but may be orientated in various ways in relation to the pavement. They are usually fine cracks. Usually parallel cracks occur through plastic shrinkage, resulting from inadequate curing mainly during hot weather. Sometimes parallel cracks occur as a result of downhill paving. These cracks usually run in a direction normal to the direction of the maximum slope of the pavement.

(h) Joint separation

This occurs when an existing joint widens. Usually it occurs between the traffic lanes and the shoulder, because of movement in the shoulder. Failure to provide tie-bars across longitudinal joints, sufficient tie-bars or incorrect tie-bar installation may contribute toward joint separation.

(i) Multiple cracks

Multiple cracks refer to any combination of cracks where it is difficult or unnecessary to differentiate between the various types.

3.3.2.2 *Degree of cracking.*

The degree of a crack is a function of its width and may conveniently be classified as follows :

- Degree 1: not readily discernible
- Degree 2 : faint cracks (discernible when walking at a reasonable pace)
- Degree 3 : distinct cracks up to 0,5 mm in width (discernible from a slow-moving vehicle)
- Degree 4 : open cracks 0,5-3,0 mm in width (discernible from a fast-moving vehicle)
- Degree 5 : greater than 3 mm (it is usually accompanied by other forms of secondary distress, e.g. spalling)

The above classification is based solely on the width of the crack, and secondary distress such as spalling would be assessed separately.

3.3.2.3 *Extent and spacing of cracking.*

The spacing dimension is more applicable where well-defined crack patterns are evident and refers to the average linear distance between cracks, e.g. with map cracking, the spacing refers to the diameter of the polygons constituting the pattern, or with transverse cracks, it refers to the average distance between successive cracks or between cracks and joints.

The extent of cracks is used to describe how widespread the cracks are and various approaches may be used. Where cracks fall within well-defined areas, the area affected may be assessed, e.g. in the case of map cracks, or the proportionate length of the section in question exhibiting the cracks may be assessed. A useful method, especially with jointed concrete pavements, is merely to count the number of slabs exhibiting certain classes of cracking or even to count the number of distress manifestations themselves.

Because cracking on concrete pavements can be a complex manifestation, a great deal of attention is warranted when compiling a classification system for recording in the field. A classification system could use any combination of the attributes discussed here. A suggested classification system is given in the following section.

3.3.2.4 *Classes of cracking*

In this system panels are assessed by the type of crack and according to the following classes:

(a) Transverse cracks, longitudinal cracks and diagonal cracks.

In this system panels are assessed by the type of crack and according to the following classes.

(a) Transverse cracks, longitudinal cracks and diagonal cracks.

Class 1 : Cracks are barely noticeable (< 1 mm). Maximum of 2 cracks per panel.

Class 2 : Same as Class 1 except that the spacing between cracks or between a crack and joint is less than 600 mm.

Class 3 : Cracks are noticeable (> 1 mm). Maximum of 2 cracks per panel.

Class 4 : Same as Class 3 except that the spacing between cracks or between a crack and joint is less than 600 mm.

Class 5 : There are 3 or more cracks in a panel.

(b) Corner breaks

Class 1 : Crack is barely noticeable (< 1 mm) and one corner is cracked.

Class 2 : Cracks are barely noticeable (< 1 mm) and two corners are cracked.

Class 3 : Crack is noticeable (> 1 mm) and one corner is cracked.

Class 4 : Cracks are noticeable (> 1 mm) and two corners are cracked.

Class 5 : Three or four corners are cracked.

(c) Multiple cracks

Class 1 : Not defined

Class 2 : Not defined

Class 3 : Panel is broken into 3 or 4 pieces and cracks are barely noticeable (< 1 mm)

Class 4 : Panel is broken into 3 or 4 pieces and cracks are noticeable (> 1 mm)

Class 5 : Panel is broken into more than 4 pieces

3.3.3 **Disintegration of surface**

3.3.3.1 *Spalling*

Spalling of joints and cracks is the cracking, breaking or chipping (fraying) in the immediate vicinity of the crack or joint (usually within 100 mm of the crack or joint).

Spalling can also take place at the corner of a slab and this is referred to as a corner spall. A spall usually does not extend vertically through a slab but extends to intersect the joint (or crack) at an angle. Spalling usually results from :

- excessive stress at the joint or crack, caused by infiltration of incompressible material and subsequent expansion of the adjoining slabs;
- Weak concrete at the joint;
- poorly designed or constructed load transfer devices or failure of such devices;
- overstressing of the slab; and
- intersection of grooving and joints

(a) Degree of spalling

The degree of spalling is usually measured according to the width of the spall. Alternatively the degree may be assessed according to one of the following classes :

Degree 1 : spalling less than 10 mm on either side of the joint

Degree 2 : spalling between 10 and 20 mm on either side of the joint

Degree 3 : spalling between 20 and 40 mm on either side of the joint

Degree 4 : spalling between 40 and 80 mm on either side of the joint

Degree 5 : spalling greater than 80 mm on either side of the joint

(b) Extent

The extent of spalling can be expressed as the total length of joint (or crack) exhibiting spalling and may be assessed for each class of spalling. This method may be useful when considering longitudinal joints.

Another method is to count the number of occurrences also within the various classifications according to degree.

3.3.3.2 *Scaling.*

Scaling is the deterioration and loss of the upper part of a concrete slab (5-15 mm). It is usually preceded by map cracks which, combined with other forces such as traffic loads, eventually cause the concrete to deteriorate sufficiently for material to be lost.

(a) Degree of scaling

The degree of scaling refers to the area of a panel exhibiting this type of distress, and can be assessed according to one of the following classes:

Degree 1: Less than 1 % of the panel area exhibiting scaling

Degree 2: Between 1 and 2 % of the panel area exhibiting scaling

Degree 3: Between 3 and 5 % of the panel area exhibiting scaling

Degree 4: Between 5 and 10 % of the panel area exhibiting scaling

Degree 5: More than 10 %

The extent of scaling is best described by counting the number of slabs exhibiting scaling, possibly within certain classes, defined according to degree.

3.3.3.3 *Popouts.*

A popout is similar to scaling except that it occurs in very much smaller areas (25-100 mm in diameter). A popout occurs when a small piece of concrete breaks loose from the surface because of the presence of expansive contaminants or loss of non-durable materials in the surface of the concrete.

(a) Degree of popout

The degree refers to the density of popouts occurring and can be assessed by estimating the number per square meter. Popouts are usually ignored unless they occur more than once per square meter.

(b) Extent and spacing

The extent is usually assessed according to the number of slabs exhibiting popouts within certain classes defined according to degree.

3.3.3.4 *Patching*

Although patching in itself is not a form of distress, it is often important to assess it, insofar as it indicates where other forms of distress have previously occurred. Accordingly the spacing of patches is their average length. The extent of patching can be assessed according to the proportionate length or area within a pavement section which is patched, or by counting the number of patches.

3.3.4 **Joint seal defects**

3.3.4.1 *Types of seal defects*

Joint seals are placed to prevent water entering the pavement and to prevent incompressible material entering the joint which may lead to other forms of distress such as spalling or blow ups. The seal may become damaged or lost in a number of ways, namely : the sealant can become extracted, it may harden because of ageing, or it may loose its bond with the slab edges. Weed growth and incorrect joint dimensions can also cause damage to the seal.

(a) Degree of seal defect

Because seal damage (or loss) can manifest itself in a number of ways, it is appropriate to define the degree descriptively rather than by a physical measurement. The following classification is an example of how this can be done :

Degree 1 : damage or loss is difficult to discern

Degree 2 : damage or loss is discernable but of little immediate consequence with regard to ingress of water or incompressible material

Degree 3 : damage or loss is notable and offers moderate protection against ingress of water or incompressible material

Degree 4 : damage or loss is severe and offers slight protection against ingress of water or incompressible material

Degree 5 : damage or loss is extreme and offers negligible protection against ingress of water or incompressible material.

(b) Extent

The extent of joint seal damage over a section of pavement can be assessed by counting the number of joints exhibiting seal damage, within the categories listed above.

3.3.5 Loss of surface texture

Smoothing of the surface texture mainly involves the loss of macrotexture. Because of the nature of concrete, loss of microtexture is not relevant. The largest proportion of the exposed concrete surface consists of the finer portion of the concrete matrix, where the sand particles usually provide a permanent harsh texture. So, although exposed large aggregates may become polished, the net area of harsh texture still remains high, providing an adequate measure of skid resistance at low speeds.

When macrotexture is lost, high speed skid resistance may be decreased. Loss of macrotexture is seldom brought about by the abrasive action of traffic and more usually results from inadequate texturing during construction.

3.3.5.1 Degree of texture loss

The degree of smoothing is assessed according to the average texture depth as measured by the sand patch test. The following classification may be used.

Texture depth

Degree 1 :	above 1 mm
Degree 2 :	0,6 to 1 mm
Degree 3 :	0,3 to 0,6 mm
Degree 4 :	0,0 to 0,3 mm
Degree 5 :	0,0.

3.3.5.2 Extent of texture loss

The extent of texture loss is described according to the area of surface falling within the categories listed above. However, it is very difficult to assess both the degree and extent of smoothing visually and it is usually far more efficient to assess the skid resistance of the surfacing by means of an instrument such as SCRIM (see section 2.2).

4 PRACTICAL PAVEMENT DESCRIPTIONS

4.1 Introduction

Pavement descriptions are generally required at two levels of detail: the project and the network level.

Project level investigations usually take place with the eventual design of some specific maintenance action in mind. To do this relatively accurate assessments and predictions need to be made of structural capacity, behaviour and performance, and a comprehensive description of the pavement condition is therefore required. However, it is impossible to consider all the detail described in this document and it must be decided exactly what details are necessary for a particular project.

Network level investigation (usually through a network pavement management system) is undertaken in order to plan maintenance over the full network. Predictions of behaviour and performance are also required, but for many more pavement sections. The method of data collection must be carefully planned for this type of assessment because of logistical considerations. Simpler and less comprehensive approaches are usually used. In this section some examples of reporting pavement condition are given to illustrate

- (a) how the terms and units defined in this document are applied in practice: and
- (b) how the purpose and scope of a survey may vary.

4.2 Project level description

Assessments of pavements at this level usually require the condition to be described in some detail, and the method to follow is usually specified in accordance with the requirements for a particular project. Hence the methods used may vary from one project to another. Nevertheless, consistency in the use of nomenclature should still apply.

Although methods of assessment may differ, certain aspects of project investigation procedures have been formalised and standardised. For instance, an initial assessment of the maintenance requirements of a pavement usually includes a detailed description of distress. Figures 2 and 3 are an example of the results of such a proposed method. In this system the degree of distress is indicated on the field recording-form which

is a plan of the pavements. Note that classes of distress, including other attributes, could also have been used in an assessment. For instance, the suggested classes of cracking (given in section 3.3.2.4) could have been noted, thereby recording more than one attribute for a given pavement panel. Other aspects of the pavement condition are usually considered once the investigation progresses towards more detailed assessment and actual design. It is here typically where other structural indicators like material properties, structural response, etc. are usually considered. Even at this detailed level of assessment, the full spectrum of possible indicators is seldom selected.

Note that in Figure 3 the information is presented in the form of severity levels of certain types of distress. This is an interpretation of the descriptive information contained in Figure 2. It is not the purpose of this document to describe nor propose techniques for this sort of interpretation.

CONDITION RATING		CONDITION RATING	
1 SOUND	2 WARNING	3 SEVERE	
PANEL ASSOCIATED DISTRESS CRACKING SPALLING PUMPING PATCHING POP OUTS LOSS OF TEXTURE		JOINT ASSOCIATED DISTRESS CRACKING SPALLING PUMPING PATCHING POP OUTS LOSS OF TEXTURE	
LEGEND <input type="checkbox"/> SOUND <input type="checkbox"/> WARNING <input type="checkbox"/> SEVERE <input type="checkbox"/> MISSING <input type="checkbox"/> REPAIRS <input type="checkbox"/> RECONSTRUCTION		COMMENTS <p style="text-align: center;">EXAMPLE OF THE USE OF THE CONDITION ASSESSMENT FORM FOR JOINTED CONCRETE PAVEMENTS</p>	
ROAD NO. _____ ROAD NAME _____ ROAD TYPE _____		ROAD NO. _____ ROAD NAME _____ ROAD TYPE _____	
DISTANCE FROM START OF ROAD (km) _____		DISTANCE FROM START OF ROAD (km) _____	
DATE OF SURVEY _____		DATE OF SURVEY _____	
SURVEYOR'S NAME _____		SURVEYOR'S NAME _____	
ROAD NO. _____ ROAD NAME _____ ROAD TYPE _____		ROAD NO. _____ ROAD NAME _____ ROAD TYPE _____	
DISTANCE FROM START OF ROAD (km) _____		DISTANCE FROM START OF ROAD (km) _____	
DATE OF SURVEY _____		DATE OF SURVEY _____	
SURVEYOR'S NAME _____		SURVEYOR'S NAME _____	

FIGURE 3 Example of the use of the condition assessment form for jointed concrete pavements

4.3 Network level descriptions

Various pavement management systems are being developed in South Africa in which details of the conditions of the pavement are computerized for storage and analyses. These data are primarily used for assessing maintenance requirements to facilitate planning future expenditure and to guide the policy of the authorities regarding pavement design and maintenance.

The data for such systems usually comes from several sources, for example :

- Mechanical surveillance instruments such as the PCA roadmeter, SCRIM, etc.
- Visual assessments from district staff.
- Traffic counts.
- Records of the pavement structure and past maintenance.

Records of the condition of the pavements in the road network are updated regularly. This involves a great deal of data and requires a rapid means of data collection to be practicable. For visual assessments this means that the amount of detail to be recorded should be kept to a minimum. Also, because much of the

data collection is decentralized and, to a large extent, depersonalized and because much of the processing is automated, the accuracy and standardization of reporting is of crucial importance.

A typical example of a visual assessment form for a pavement management system is given in Figure 4. Such forms would generally be accompanied by a detailed explanatory guide. Although the exact nature of these forms will depend on the pavement management system developed for the particular road authority, this form demonstrates the general principle that only the essential aspects of the condition are recorded, in this type of survey.

Road No.		DATE :			yy:	mm:		DD:		
RANGE		No. OF SLABS WITH CRACKING \geq			No OF FAULTS AT JOINTS \geq	No. OF SPALLED JOINTS \geq		No. OF BLOW ups \geq	No. OF PATCHES	
START km	END km	DEGREE 3	DEGREE 4	DEGREE 5	DEGREE 3	DEGREE 3	DEGREE 5	DEGREE 2	LARGE	SMALL

FIGURE 4 Example of a recording form for a pavement management system

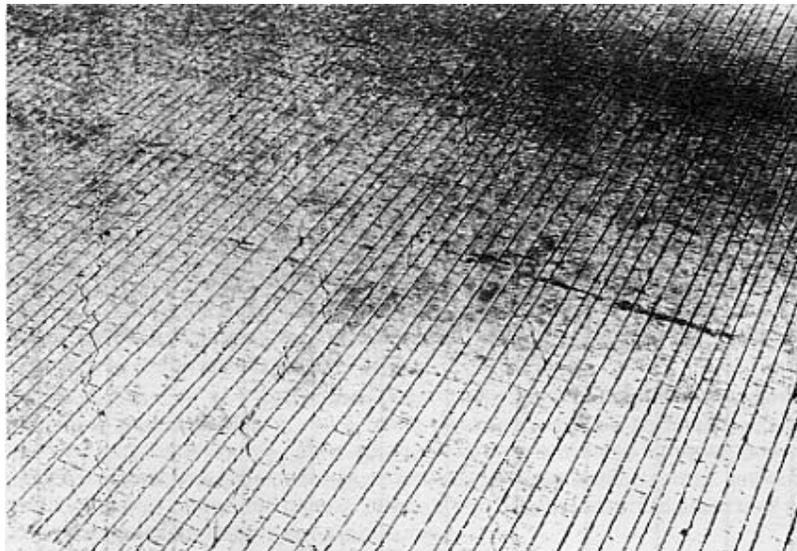


FIGURE 5 Plastic shrinkage cracks, degree 2, spacing 400 mm



**FIGURE 6 Distress: Map cracks, degree 3, spacing 200 mm Cause: Alkali aggregate reaction
Mechanism: Expansion**

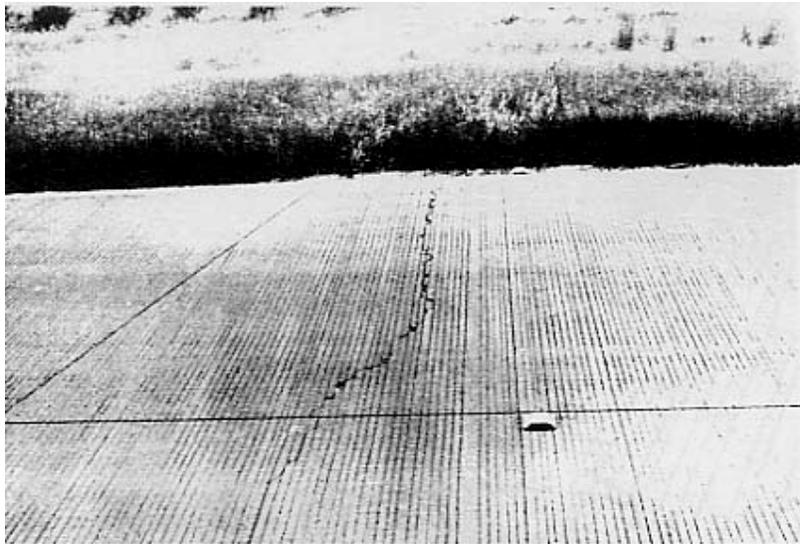


FIGURE 7 Transverse crack, degree 3



FIGURE 8 Transverse crack (primary distress) with spalling, degree 4 (secondary distress)



FIGURE 9 Transverse crack, degree 4 (primary distress) with spalling, degree 3 (secondary distress)



FIGURE 10 Longitudinal crack, degree 5



FIGURE 11 Close-up of longitudinal crack in figure 10



FIGURE 12 Joint separation



FIGURE 13 Diagonal crack, degree 4 (primary distress) with faulting degree 5 (secondary distress)



FIGURE 14 Close-up of crack and fault in figure 13



FIGURE 15 Faulting of transverse joints (degree 2)



FIGURE 16 View of pavement in figure 15 from the opposite direction (joints not visible)

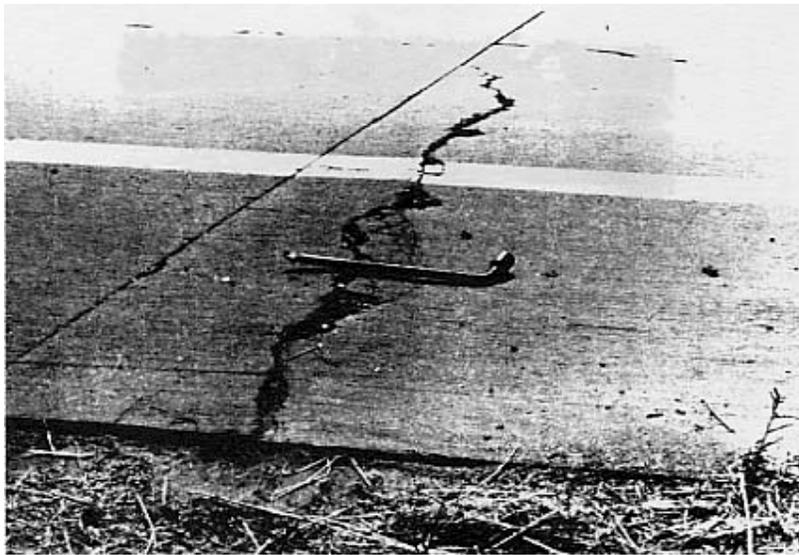


FIGURE 17 Corner break with blow-up (degree 2)

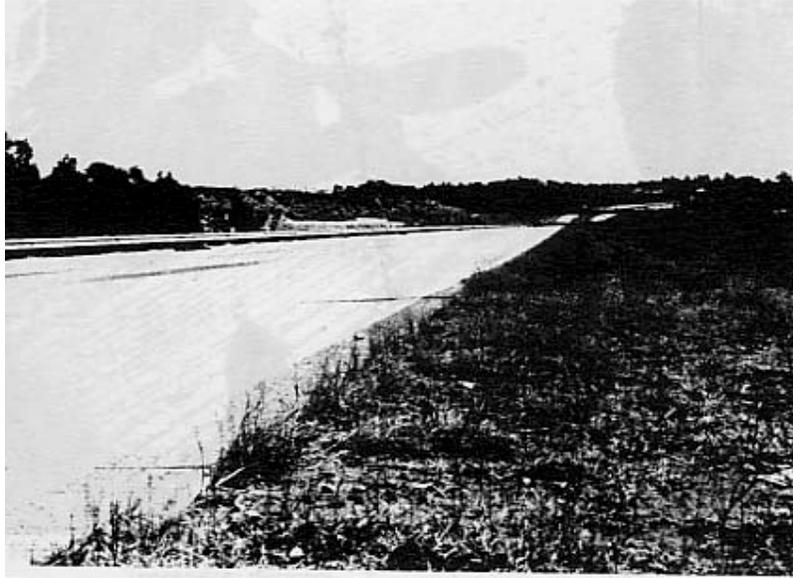


FIGURE 18 Depression



FIGURE 19 Spalling of transverse joint, degree 2



FIGURE 20 Corner break (primary distress) with spalling, degree 3 (secondary distress)



FIGURE 21 Spalling of transverse joint, degree 5



FIGURE 22 Corner spall, degree 5



FIGURE 23 Map cracking (primary distress) Spalling degree 4 (secondary distress)

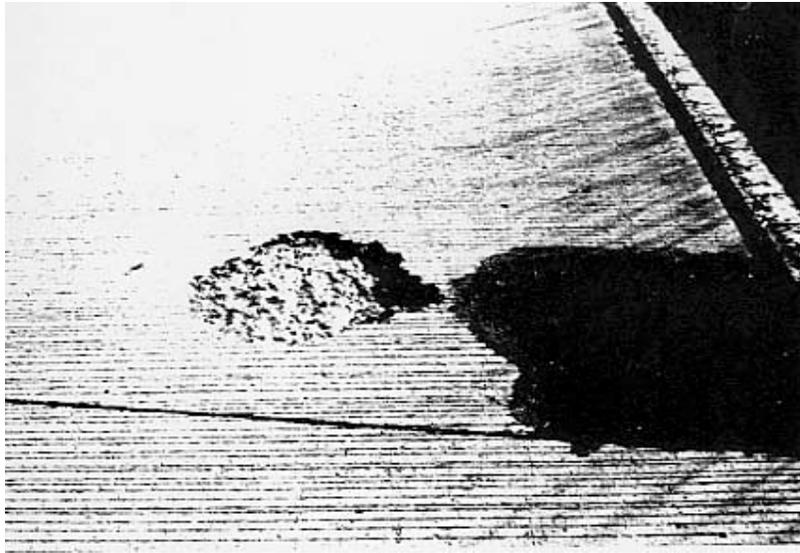


FIGURE 24 Scaling, degree 3