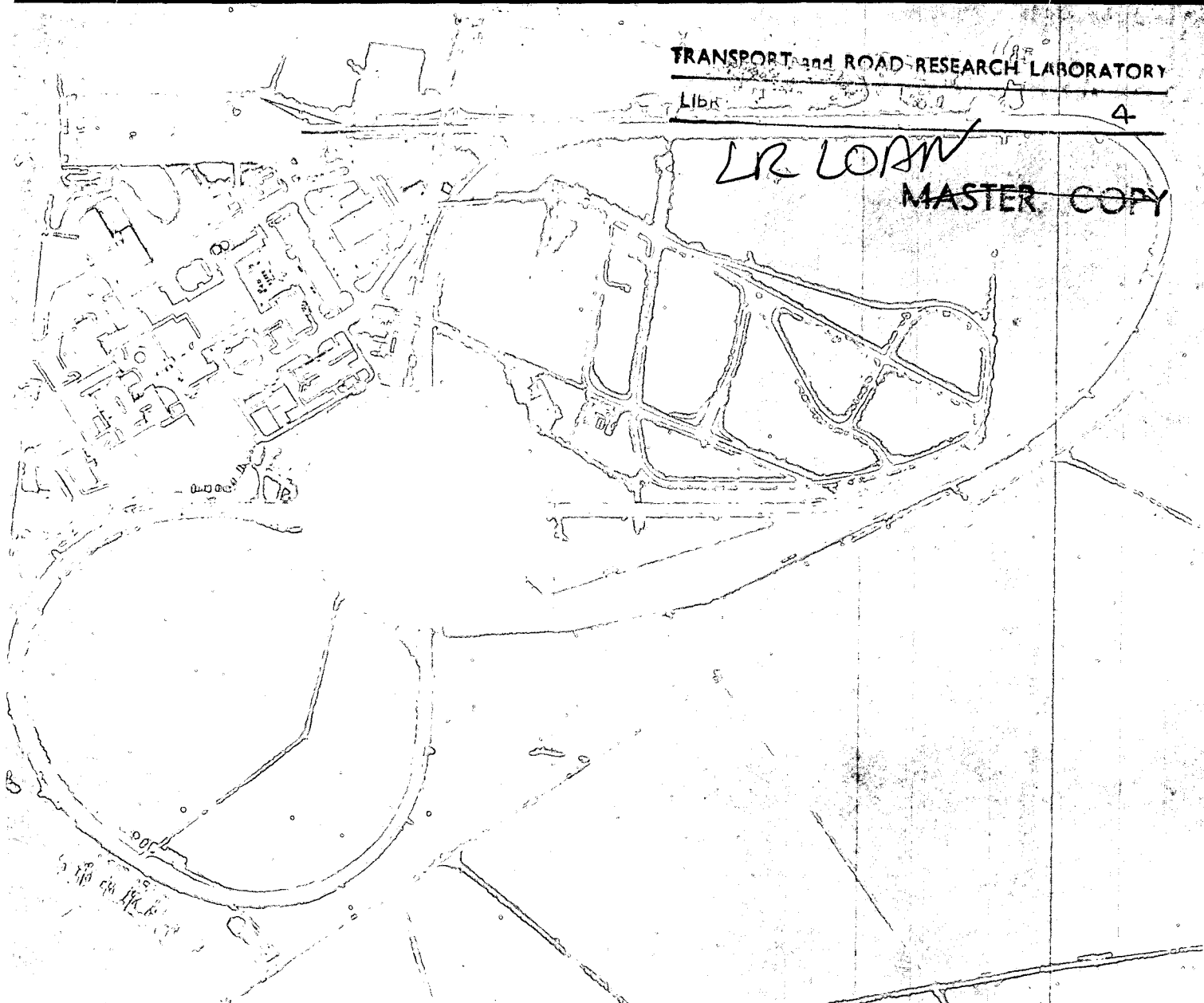


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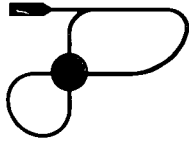
DEPARTMENT of the ENVIRONMENT DEPARTMENT of TRANSPORT



Measurement of pavement deflections in tropical and sub-tropical climates

by

H. R. Smith and C. R. Jones



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TRRL LABORATORY REPORT 935

**MEASUREMENT OF PAVEMENT DEFLECTIONS
IN TROPICAL AND SUB-TROPICAL CLIMATES**

by

H R Smith and C R Jones

**The work described in this Report forms part of the programme
carried out for the Overseas Development Administration, but
any views expressed are not necessarily those of the Administration**

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MEASUREMENT OF PAVEMENT DEFLECTIONS IN TROPICAL AND SUB-TROPICAL CLIMATES

ABSTRACT

The measurement of the deflection of the surface of road pavements under a standard wheel load is common practice in many countries. The main purposes of making deflection measurements are to assist in the evaluation of the structural condition of roads, and to help in the design of road strengthening measures. In developing countries in the tropics the high road temperatures and other climatic effects necessitate the use of a special technique in making deflection tests. This report describes the techniques adopted by the Overseas Unit of the Transport and Road Research Laboratory for the measurement of pavement deflection in tropical developing countries, and discusses factors relevant to the deflection of road pavements in such conditions.

1. INTRODUCTION

In many countries systematic measurements are made of the deflection of road surfaces under a standard wheel load^{1,2,3}. These deflection surveys are made for two main reasons:—

- i) to help in estimating the ability of existing roads to carry future traffic loads and to predict the optimum time for strengthening them,
- ii) to assist with the design of the thickness of strengthening overlays for road pavements.

In developing countries these uses of deflection surveys are particularly relevant because many of the main roads were originally built to carry relatively light traffic, and now they urgently require strengthening to carry the much heavier traffic of the present day.

It is usually more cost-effective to strengthen a road than to reconstruct it, particularly if the thickness of the overlay is varied to match variations in the strength of the existing pavement. Deflection surveys enable strengthening overlays to be designed to match the existing pavement, or indicate whether reconstruction is required^{4,5}.

Details of the standard method adopted for measuring pavement deflections in the United Kingdom have been published^{6,7}. In the tropics, high road temperatures and other climatic effects necessitate the use of somewhat different deflection test procedures. This report describes the deflection technique used in tropical and sub-tropical developing countries by the Overseas Unit of the Transport and Road Research Laboratory, and discusses factors relevant to the deflection of road pavements in such conditions. A method of making deflection surveys for assessing overlay thickness requirements in developing countries has been recommended earlier⁸, a revision of this method is included in the Appendix of this report.

2. THE DEFLECTION BEAM

2.1 Details of the deflection beam

Deflection measurements are normally made with a beam of the type designed by A C Benkelman⁹, used in conjunction with a loaded lorry. The beam has a long slender pivoted arm which can be placed between the dual rear wheels of a lorry.

The pivot is one-third of the way along the beam and is carried by a frame which is supported on three adjustable legs. A dial gauge is mounted on the frame in such a way that it measures movement of the toe of the beam resting on the road surface.

The design of the beam used by the Transport and Road Research Laboratory is illustrated in Plate 1 and the principle dimensions of the beam are given in Figure 1. A narrow sunshade is fitted as standard to the beam to reduce distortion induced by changes in radiation falling on it. For research purposes in the tropics a special sunshade which covers the frame and that part of the beam which is not placed between the lorry wheels is used. This practically eliminates distortion of the instrument due to changes in radiation falling on it.

The dial gauge has a 75 mm diameter face, a travel of 25 mm and 0.01 mm graduations with numbers printed in reverse to enable them to read from above using a mirror mounted at 45° to the gauge.

A locking device protects the dial gauge whilst the beam is being moved and is also used to lock the beam to its frame for transportation. An electric 'buzzer' with a battery and hand switch are mounted on the frame to vibrate the beam pivot and dial gauge to ensure free movement during testing.

The beam can be split into two parts for ease of transportation and it is therefore essential that the connecting plates are tightly secured before use.

It is necessary to treat the dial gauge with care; the stem of the gauge should be polished with a dry, soft cloth and checked for free movement before testing is started. The stem should also be polished periodically during each day of testing to remove any deposits.

2.2 Calibration of the deflection beam

The dial gauge and beam should be calibrated before use to ensure that they are working correctly. A calibration rig, which can be supplied by the beam manufacturer, is shown in Plate 2. The rig is fitted with a variable cam which can impart vertical movements of different magnitudes to the toe of the beam, simulating deflections. With the vibrator working several readings on the dial gauge on both the beam and calibration rig are recorded for each cam setting. If the dial gauge on the beam does not read one half of the dial gauge reading on the calibration rig, the tightness of securing bolts should be examined and the dial gauges should be checked and replaced if necessary. If the gauges are functioning correctly, the beam pivot should be examined and checked for free and smooth operation and the striking plate beneath the dial gauge spindle should be checked to ensure that it is tightly secured and has not become grooved by the dial gauge stylus. The amount of vibration produced by the buzzer must be such that only slight movement of the dial gauge needle can be detected when the buzzer is actuated.

2.3 The loaded lorry

2.3.1 The specification adopted by the Overseas Unit. For the deflection method used by the Overseas Unit of the Transport and Road Research Laboratory a two axle lorry, with twin wheel sets on each end of the rear axle, is loaded so that the load on the rear axle is 62.3 kN (6350 kgf), equally divided between the twin wheel assemblies.

Blocks of dense concrete or boxed scrap metal are ideal materials for loading the lorry. It is important that the load should not be able to move, nor should it be capable of absorbing or trapping water which would cause the magnitude of the axle load to change.

The general dimensions and weights of the vehicle given in Table 1 are recommended. The use of cross-ply tyres rather than radial tyres is recommended because it is normally easier to obtain the correct gap between the walls of the tyres on the dual wheels with cross-ply tyres. If tyres other than those recommended are used then the tyre pressures may have to be adjusted to achieve contact areas as indicated in Table 1 and Figure 2.

TABLE 1
Details of vehicles suitable for deflection testing

Characteristic	Specification
Rear axle load	62.3 kN (6350 kgf) \pm 5%
Dual wheel load	31.1 kN (3175 kgf) \pm 5%
Front axle load	22.6–32.4 kN (2300–3300 kgf)
Wheel base	3.85m (approx)
Tyre size	7.50 x 20) 8.25 x 20) preferred 9.00 x 20 acceptable
Tyre pressure	590 kN/m ² (85 psi)
Gap between walls of dual rear tyres	25–40 mm ($>$ 30 mm is recommended)
Gap between contact area of dual rear wheels	100–150 mm
Contact area of twin rear wheels	Similar to that shown in Figure 2

2.3.2 Other specifications. A common alternative to the specifications given in Table 1 involves the use of a vehicle with an 80 kN (8165 kgf) rear axle load, with consequently larger tyres. Overlay design methods developed on the basis of the heavier axle load are equally as valid as those developed on the basis of a 62.3 kN axle load. Care must be taken however not to confuse the deflection criteria applicable to one axle load with those applicable to the other. The advantages of using a 62.3 kN rear axle load are that a smaller lorry can be used and running costs will be generally lower. With few exceptions, the magnitudes of the deflections measured in the two cases are directly proportional to the wheel loads used.

2.4 Methods of using the deflection beam

There are two basic methods which are commonly used for operating the deflection beam.

2.4.1 The transient deflection test. This type of test has been adopted for measuring deflections in the United Kingdom and is the method used by the Overseas Unit of the Transport and Road Research Laboratory in developing countries.

The procedure is to mark the test point in the verge side wheelpath and to position the lorry parallel to the road edge with its rear axle 1.3m behind the test point. The lorry is aligned such that when it moves forward the test point bisects the distance between the tyres of the verge side dual wheels. With the lorry in the initial stationary position a deflection beam is positioned centrally between the dual rear wheels with its measuring toe resting on the test point, 1.3m in front of the rear axle. By using the adjustable legs and the 'built-in' spirit level the frame of the beam is levelled transversely and having checked the alignment of the beam and adjusted it if necessary, the locking device on the beam is released. Adjustment of the rear foot will ensure that the free end of the sun-shade is clear of the beam and that there is adequate travel of the dial gauge spindle to record the deflection. A suitable method of judging this is to adjust the rear foot so that when the end of the beam under the dial gauge is pushed upwards manually (flexing the beam in the process), 4 to 6 revolutions on the dial gauge are registered before travel ceases.

The vibrator is switched on and the dial gauge scale is rotated until a reading of zero is indicated. When the beam operator has completed his preparations the lorry can be driven forward at creep speed to a point such that the rear axle is not less than 5m beyond the test point. The time taken for the lorry to move a distance of 5m from the starting position should be between 9 and 11 seconds, this time should be checked at regular intervals during each day.

Sometimes during the period between setting the dial gauge to zero and the lorry actually starting to move, the dial gauge reading may change slightly. It is recommended that this new reading is recorded as the initial reading rather than resetting the dial gauge to zero.

Records are kept of the initial, maximum and final dial gauge readings. The difference between the initial and maximum readings is proportional to the transient loading deflection and the difference between the maximum and final readings is proportional to the transient recovery deflection. Because the lengths of the arms of the pivoted beam are in the ratio of 2:1 the differences between the dial gauge readings must be doubled to obtain the actual deflection and recovery of the road surface. The transient deflection is the mean of the loading and recovery deflections in the transient test.

The principal positions of the lorry during the test are shown in Plate 3. In order to measure transient deflections quickly with negligible risk of contact between the tyres and the deflection beam, adjustable pointers should be fitted to the lorry chassis in front of both dual wheel sets as shown in Plate 4. They must be adjustable so that they can be aligned to point to the road surface approximately 1.3m in front of the rear axle and directly in line with the path taken by the centreline of the dual wheel set. Correct alignment of the pointer can be obtained in the following way. Position the lorry as for a deflection test, align a suitable straightedge (not the deflection beam) so that it lies centrally between the dual wheels with one end 1.3m in front of the rear axle and adjust the pointer so that it points to the end of the straight edge. By moving the lorry forward in one metre increments the pointer alignment can be adjusted until it is correct.

Two tests are normally carried out on each test point and the difference between the tests should be within the limits recommended in Table 2.

If the readings differ by more than the limits given then additional tests should be carried out until acceptable repeatability is obtained. If a characteristic deflection for the test point is not obtained after 5 tests have been carried out, then the best estimate from these readings should be taken.

TABLE 2
Repeatability of duplicate deflection tests

Mean deflection ($\times 10^{-2}$ mm)	Maximum permissible difference between the two tests ($\times 10^{-2}$ mm)
< 10	2
10– 30	3
31– 50	4
51–100	5
> 100	6

It should be remembered that due to friction the beam tends to register values which are lower than the true deflections, and adequate vibration and correct operation of the beam pivot and dial gauge are essential.

It is common practice to measure deflections simultaneously in both wheelpaths, but when the lorry is positioned to measure the deflection on the centreline of the verge side wheelpath it may be found that the offside wheels are not in the centre of the offside wheelpath. Additional tests will indicate if the error resulting from measuring the deflection to one side of the centreline of the wheelpath is large enough to warrant the repositioning of the lorry before testing in the offside wheelpath.

2.4.2 The rebound deflection test. The rebound deflection test differs from the previous test in that the dual wheels are positioned immediately above the test point and the toe of the beam is placed on the test point between the dual wheels. The beam is adjusted in the same way as for the transient test and when the initial reading has been noted, the lorry is driven forward at creep speed until the wheels are far enough away to have no influence upon the deflection beam. The final dial gauge reading is recorded and the 'rebound deflection' is twice the difference between the initial and final dial gauge readings. Because the rebound deflection can be influenced by the length of time during which the loading wheels are stationary over the test point care must be taken over the exact procedure used³. The rebound test is not recommended by the Overseas Unit of the Transport and Road Research Laboratory, for reasons which are discussed in detail in Section 3.4.1 of this report.

3. FACTORS AFFECTING DEFLECTION MEASUREMENTS

3.1 Influence of loading wheels upon the deflection beam

At the beginning of the transient deflection test the loading wheels are 1.3m from the toe of the beam and 1.44m from the twin feet of the beam. Occasionally when the lorry is in this position the toe and the

front feet of the beam are within the deflected bowl of the road surface under the loaded wheels. In rare instances small displacements of the rear foot of the deflection beam have also been detected. On roads with crushed stone or weak soil-cement road bases overlying subgrades with CBR values in excess of 8 per cent, the error in the dial gauge reading caused by the influence of the loading wheels, when the lorry is in the initial position can be calculated from the following equation¹⁰:

$$d = \frac{1}{2}D - \frac{7}{5}S + \frac{9}{10}K \quad \text{where,}$$

- d = error in dial gauge reading
- D = depression of the toe of the beam
- S = depression of the front feet of the beam
- K = depression of the back foot of the beam.

The error in the measured transient deflection will be of the order of 0.9 x (the movement of the front feet during the test) or less depending upon the exact shape of the deflected bowl and the measured deflection will, on the roads described above, be larger than the actual deflection.

This solution will not necessarily apply where a stiff pavement has been constructed on a weak subgrade or on roads with very stiff soil-cement road bases.

An example of how a second deflection beam can be used to measure the movement of the beam feet during a deflection test is illustrated in Plate 5. The influence of the front and rear wheels of the lorry on the toe of the beam can be investigated by varying the position of the lorry and beam.

Movements of the feet of deflection beams recorded during extensive deflection surveys in Kenya were only occasionally greater than 6×10^{-2} mm. It is recommended that corrections for movements of this magnitude are not made, and that the use of non-absolute deflections is accepted. If the residual reading on the dial gauge indicates that the magnitude of the movement of the feet of the beam is larger than this, a correction can be made using a second deflection beam as shown in Plate 5.

3.2 Effect of changes in solar radiation on the deflection beam

The deflection beam is sensitive to changes in radiation which can occur in tropical environments when cloud shadow moves onto or away from the beam. A change in dial gauge reading of $\pm 4 \times 10^{-2}$ mm, depending upon whether the shadow moves onto or away from the beam, can occur within ten seconds. The tip of the beam, which is shaded by the lorry at the start of a transient deflection test, is less sensitive to changes in radiation than the reference frame and the rear end of the beam. For research purposes the Overseas Unit has fitted alloy 'sunshades' to its deflection beams (see Plate 1). Each section of the sunshade is free to move at one end. The beams are then virtually insensitive to changes in radiation.

If deflection tests are carried out during continuously cloudy or sunny conditions, errors due to changes in radiation will not occur.

3.3 The condition of the road surface

Consideration must be given to the condition of the road surface, particularly on older road pavements. Badly crazed surfacings may be loose and can cause considerable errors in deflection measurements. It is

often possible to remove loose material and measure the deflection on a firmer lower layer. In this case it may be necessary to have available a beam with an adjustable toe which can reach down to the firmer surface. Errors can also be caused if the surfacing layer is not bonded to the underlying structure.

During hot weather the feet of the beam may sink into the soft bitumen on roads with rich surface dressings. On coarse textured surfaces the positions of the toe and feet of the beam must be selected so that they remain stable during the test.

3.4 The effect of temperature

The stiffness of bituminous materials is susceptible to changes in temperature^{7,11} and therefore the pavement deflection can also be affected by temperature changes. The magnitude of this effect is dependent upon the proportion of the overall pavement stiffness provided by the bituminous material. In certain cases the temperature effect can be such that measured deflections are meaningless, particularly on new or bitumen-rich surfacing layers.

In undertaking deflection surveys it is practical to measure the pavement temperature only on the surface or near the surface and it is recommended that temperature measurement at a standard depth of 40 mm is adopted.

In tropical environments there are normally many days during the year when road temperatures increase continuously during the morning and early afternoon followed by a period when the surface temperature may remain constant or begin to decrease; at this stage the temperature gradient in the pavement is significantly different from when the temperature of the whole pavement is rising. Where the surfacing material is sensitive to changes in temperature there are four main phases in the deflection-temperature relationship. The first phase occurs early in the morning before the road temperature begins to increase. At these lower temperatures some surfacings are considerably stiffer than at higher temperatures, resulting in much smaller deflections being measured. It is sometimes very difficult to obtain reliable relationships between temperature and deflection for these conditions. During the second phase as the road temperature rises a clear relationship may be obtained between increasing temperature and deflection.

Depending upon the nature of the surfacing material a third phase can occur as the temperature rises further in which there is an increasing tendency for the surfacing material to flow plastically upwards between the dual load wheels of the deflection lorry as the temperature of the surfacing increases. The plastic flow can be so large that the measured deflections are meaningless.

Finally the pavement deflection may continue to increase without an increase in surface temperature, because the temperature gradient in the pavement continues to change as lower layers warm up.

It is not possible to give general guidance on the magnitude of temperature-deflection corrections for roads in tropical and sub-tropical environments¹² since such corrections are very much dependent on the type of road pavement. Roads with thin seals such as surface dressings are usually unaffected by changes in temperature, but other roads with substantial layers of bituminous material incorporated in their construction must be tested to determine their temperature-deflection characteristics.

For tropical and sub-tropical conditions the Overseas Unit of the Transport and Road Research Laboratory has adopted a standard reference temperature of 35°C measured at a depth of 40 mm, to which deflections measured on temperature-susceptible materials are corrected.

3.4.1 The effect of plastic flow upon the deflection test method. When the surfacing material flows plastically it squeezes upwards between the dual loading wheels of the deflection lorry¹² which, in the transient deflection test, reduces the transient loading deflection because the upward movement of the material counteracts the downward movement of the pavement. The transient recovery deflection that is measured may be correct but further plastic movement of the raised surfacing material can occur during the time taken for the wheels to move from the test point to the final position, thereby causing an error in the recovery deflection reading.

One of the reasons why the transient deflection test is preferred for use in the tropics is that it is very clear from the test results when plastic flow occurs. Provided that a deflection survey team adopts a standard procedure, an engineer who may not be on site can tell from the field record sheets when plastic flow has occurred by comparing the loading and recovery deflections from the transient test. An example of plastic flow occurring during temperature-deflection tests is shown in Figure 3.

In the rebound test with the wheels located directly over the test point at the start of the deflection test, greater plastic flow will be induced in susceptible materials because of the time during which the wheels remain stationary in this position. When the lorry is driven forward the road surface 'rebounds' but an indeterminate amount of recovery of the displaced surfacing material can occur. There is thus no clear indication from the simple rebound test when plastic flow occurs.

3.5 Effect of hardening of the bitumen in a road pavement

It has been found that the bitumen in surfacing materials can harden very rapidly in tropical environments^{12,13}. A nominal 80/100 penetration grade bitumen recovered from dense mixes can have a penetration value¹⁴ of 20 after four years in the road surface. The effect of this hardening is to stiffen the bituminous layer. An example is shown in Figure 3 where the plastic flow of a bituminous surfacing material at a given temperature decreases with the ageing, or hardening, of the bitumen.

3.6 Effect of seasonal rainfall

Periods of rain or dry weather can cause changes in moisture conditions under pavements, thereby affecting the overall stiffness of the structure and the deflection measured on it. An example of the effect of seasonal rainfall upon deflections is given in Figure 4. It is important to measure pavement deflections at the end of the wettest period of the year, since this is when the pavement is weakest. In many regions annual rainfall patterns vary considerably from year to year, in which case it is desirable to study the longer term variations in rainfall and deflection that occur in a region to assist in interpreting deflection survey results obtained in the region.

Where long periods of drought occur it is important that allowance is made for the increase in pavement deflection which can occur during wet periods, a factor that is particularly important when the thickness of bituminous overlays is being decided upon.

4. ANCILLARY EQUIPMENT

4.1 Temperature measurement

The temperature within bituminous layers can have a significant effect upon deflections, therefore frequent measurements of temperature must be made during surveys on pavements which contain bituminous materials. The exact procedure adopted will depend upon the results of temperature-deflection relationships determined for the particular road.

The method of determining temperature-deflection relationships used by the Overseas Unit is to measure repeatedly the deflection of one point on the road as the temperature increases during a day. Temperatures are measured at depths of 40 mm and at 75 mm and 110 mm if bituminous layers of more than 75 mm and 100 mm in thickness have been used. A number of adjacent points can be tested during the same day, the number being such that approximately ten tests can be completed on each test point during the day. A limited number of tests are carried out as the surfacing temperature decreases.

It has been found that for deflection surveys adequate corrections for temperature effects can be based upon the measurement of temperature at a depth of 40 mm, but it is advisable to check this on pavements which have thick bituminous layers.

During deflection surveys carried out on temperature-sensitive materials, the temperature at a depth of 40 mm should be measured adjacent to each test point.

A simple method of measuring the temperature is to make a hole with a 7 mm diameter percussion drill to such a depth that the centre of the bulb of a mercury in glass thermometer is at a depth of 40 mm. Enough glycerol or oil is placed in the hole so that the thermometer bulb is covered. The thermometer should preferably be one with a short bulb and which requires a small depth of immersion.

4.2 Pavement condition

Deflection values are most useful when they are accompanied by other indicators of pavement performance. Measurements of rut depth, cracking in the wheelpaths, and crack depth, are simple measures of pavement condition that can easily be made at the same time that deflection surveys are being carried out.

4.2.1 Deformation. Deformation or rut depth in the wheelpaths can be measured by placing a 2m straight edge transversely to the road over the test point, any deformation below the straight edge being measured with a calibrated wedge.

4.2.2 Cracking. An assessment of the amount of cracking at a deflection test point can be made by measuring the linear cracking within a one metre square frame. The method developed by the Overseas Unit is to place a one metre square frame over the deflection test point with one side parallel to the edge of the road such that it encloses the maximum length of cracking present, provided that the test point is within the frame. The frame is not placed across the centre line of the road, but centre line cracks are recorded separately since these may be a result of construction faults rather than the effects of traffic. The cracks can be 'chalked in' and measured with a flexible tape.

It has been found that cracking in overlay trials constructed in Kenya invariably starts at the surface. The development of these cracks and the seriousness of them can be assessed from cores cut down through the cracks.

A convenient means of classifying the surface condition at a test point is shown in Table 3.

TABLE 3
Classification of road surface condition

Transverse deformation under a 2m long straight edge		Degree of cracking (visible cracks)	
Classification Index	Deformation	Classification Index	Crack length/unit area
D ₁	Less than 10 mm	C ₁	NIL
D ₂	10 mm to 14 mm	C ₂	Not greater than 1 m/m ²
D ₃	15 mm to 19 mm	C ₃	Greater than 1 m/m ² but not greater than 2 m/m ²
D ₄	20 mm to 25 mm	C ₄	Greater than 2 m/m ² but not greater than 5 m/m ²
D ₅	Greater than 25 mm	C ₅	Greater than 5 m/m ² (ravelling & potholing imminent, immediate maintenance required)

5. MEASUREMENT OF RADIUS OF CURVATURE

It is generally accepted that the measurement of deflection together with the longitudinal radius of curvature of the road surface enables a better estimate to be made of the structural condition of an existing pavement than the measurement of deflection alone. The combined measurements should thus provide a better correlation with overlay performance, particularly where pavements of different or widely variable construction are overlaid^{15,16}.

There are a number of ways of measuring the radius of curvature of the surface of a deflected pavement^{16,17}. The method adopted by the Overseas Unit of TRRL is to use a deflection beam fitted with an LVDT in place of the dial gauge. The LVDT is connected to a chart recorder, the paper of which is driven by a pulse generator actuated by the forward movement of the deflection test lorry. The power source is a pair of 12 volt lead acid batteries. This system provides an influence line obtained during the transient deflection test which represents the shape of the deflected road surface under the loaded dual wheels of the lorry. The magnitude of the transient deflection and an estimate of the radius of curvature can be read from the chart.

The radius of curvature is estimated from the difference between the maximum deflection and the deflection measured when the loading wheels are at a point 125 mm from the point of maximum deflection. This is similar to the method proposed by Dehlen¹⁸.

$$\text{Radius of curvature} = \frac{L^2}{2d}$$

where

L = 125 mm

d = differential deflection

A simpler way of measuring the deflected shape of the road surface is to carry out a normal deflection test, except that the test lorry is moved forward in a series of increments, the dial gauge being read at each increment. An influence line can then be plotted. The disadvantages of this method are that it is very slow and that creep may occur within the pavement layers under the stationary loaded wheels which may significantly affect the magnitudes of the deflection readings. Important advantages are that the test is simple and can be performed with the standard deflection beam.

6. CONCLUSIONS

When measuring pavement deflections in tropical climates using deflection beams and a standard procedure, it is necessary to take account of a number of factors which can influence the magnitude of the recorded deflection. These are:—

- i) the influence of the loaded wheels on the support frame of the deflection beam,
- ii) the effect of solar radiation on the beam,
- iii) the condition of the road surface,
- iv) the effect of temperature on bituminous materials,
- v) the effect of the hardening of bitumen in the bituminous layers of a pavement,
- vi) the effect of seasonal rainfall on pavement strength.

7. ACKNOWLEDGEMENTS

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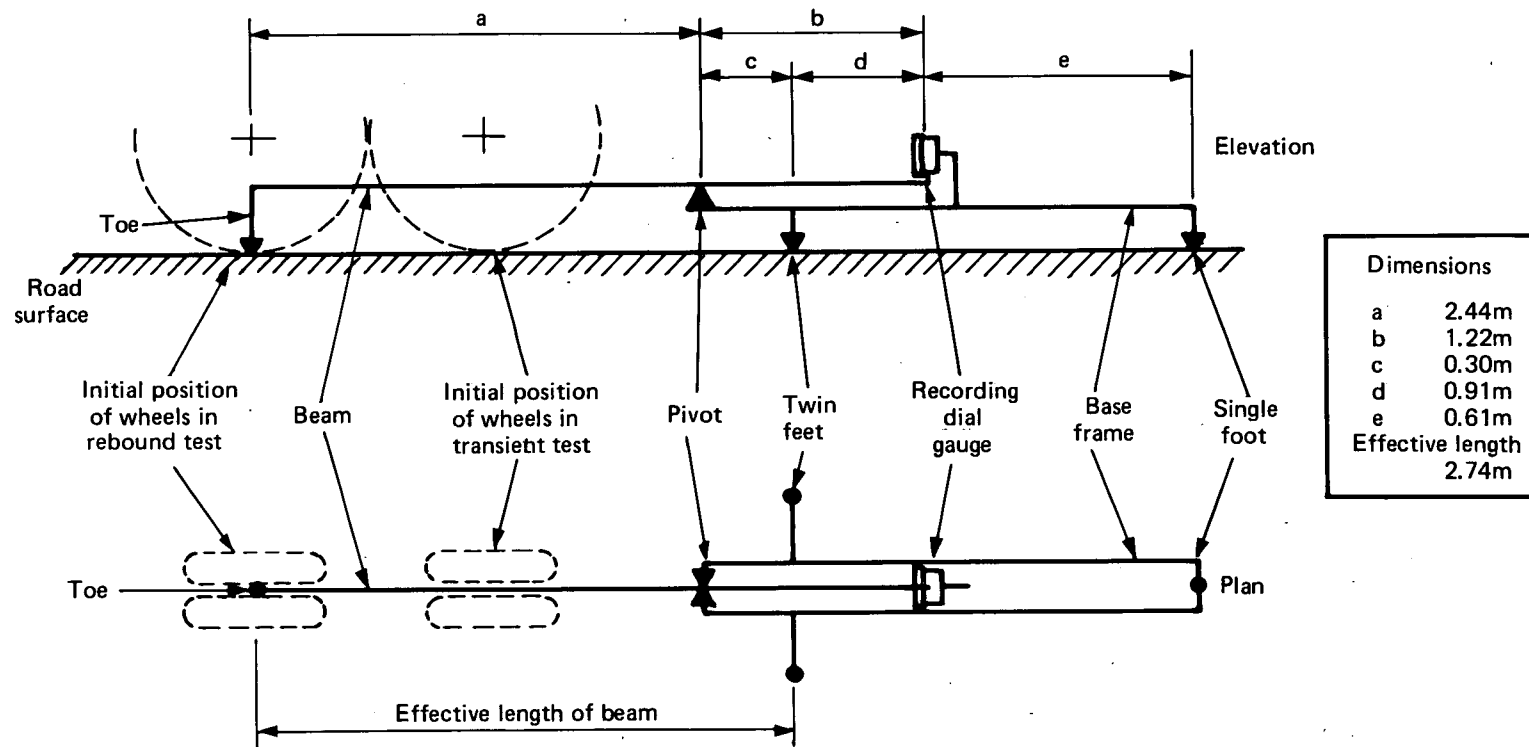
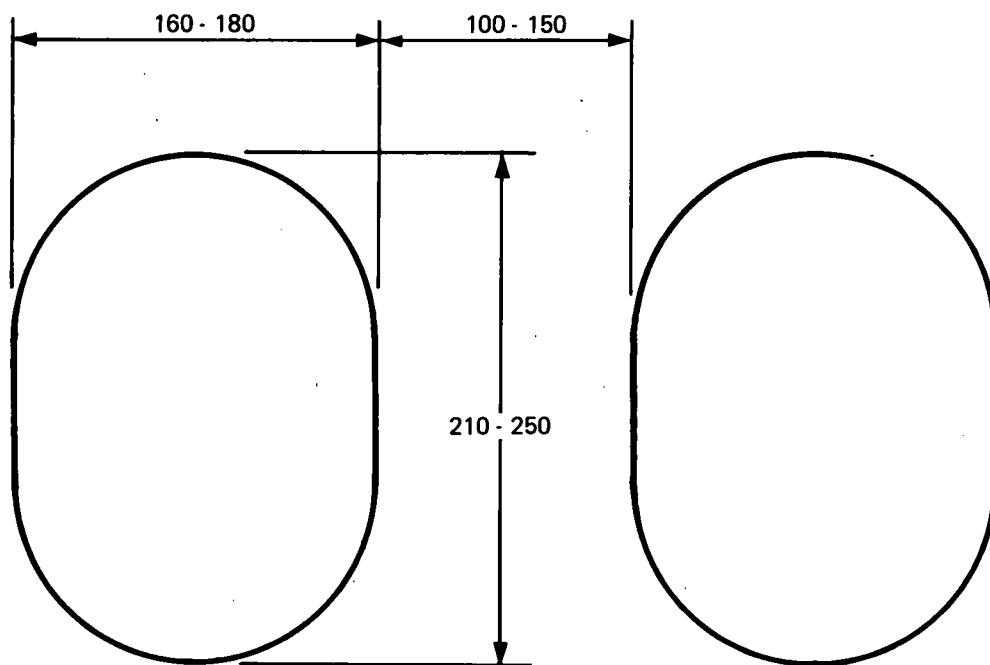


Fig.1 DIAGRAMMATIC REPRESENTATION OF THE DEFLECTION BEAM



(Dimensions in millimetres)

Fig. 2 RANGE OF DIMENSIONS FOR THE CONTACT AREAS OF THE DEFLECTION LORRY TYRES

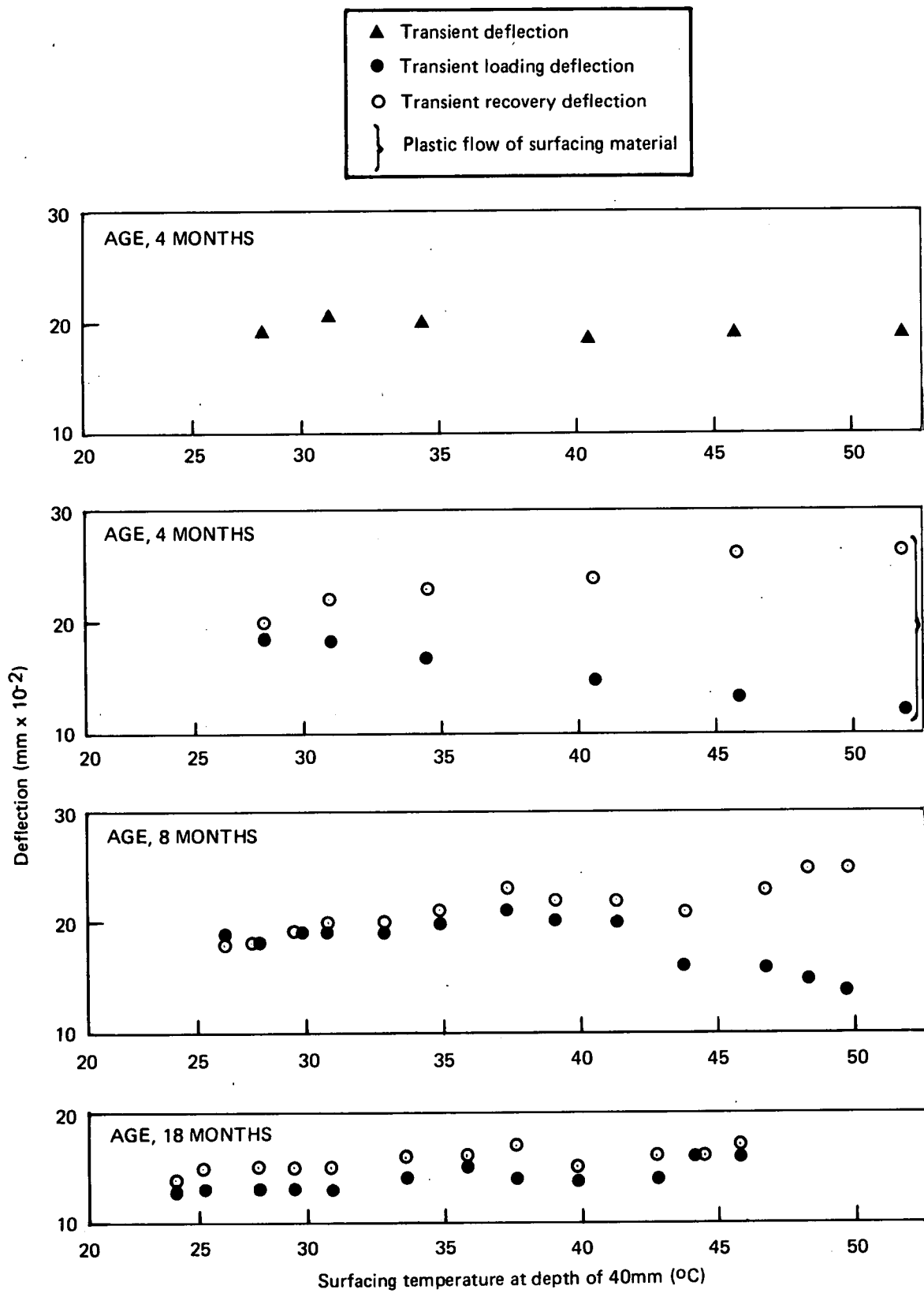


Fig. 3 CHANGE IN TEMPERATURE – DEFLECTION RELATIONSHIP WITH TIME
 (Overlay 100mm Marshall Asphalt)

Wheelpath	Direction
—●—	Towards Mombasa
—○—	Off side
—△—	Off side
---▲---	Verge side

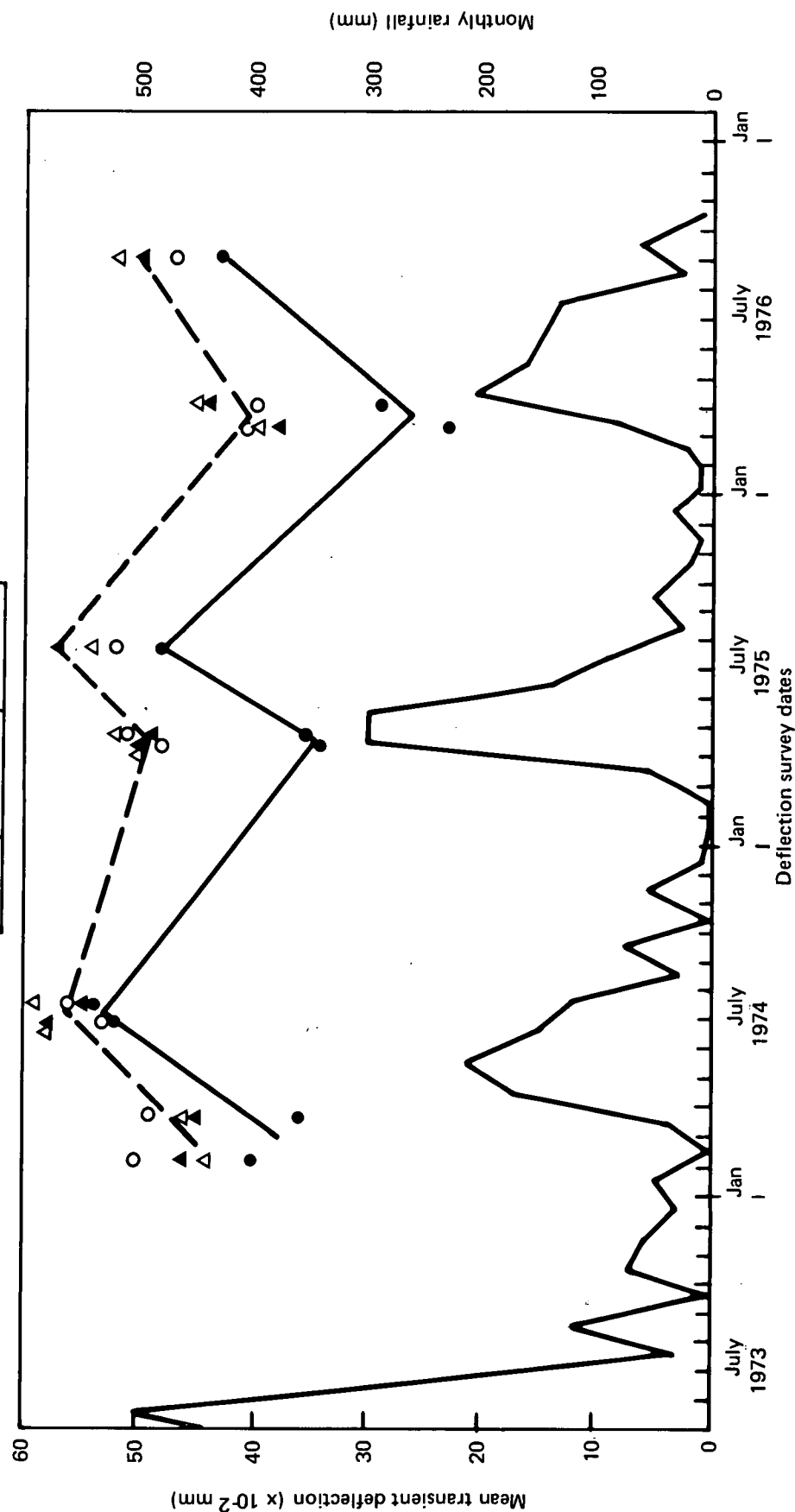
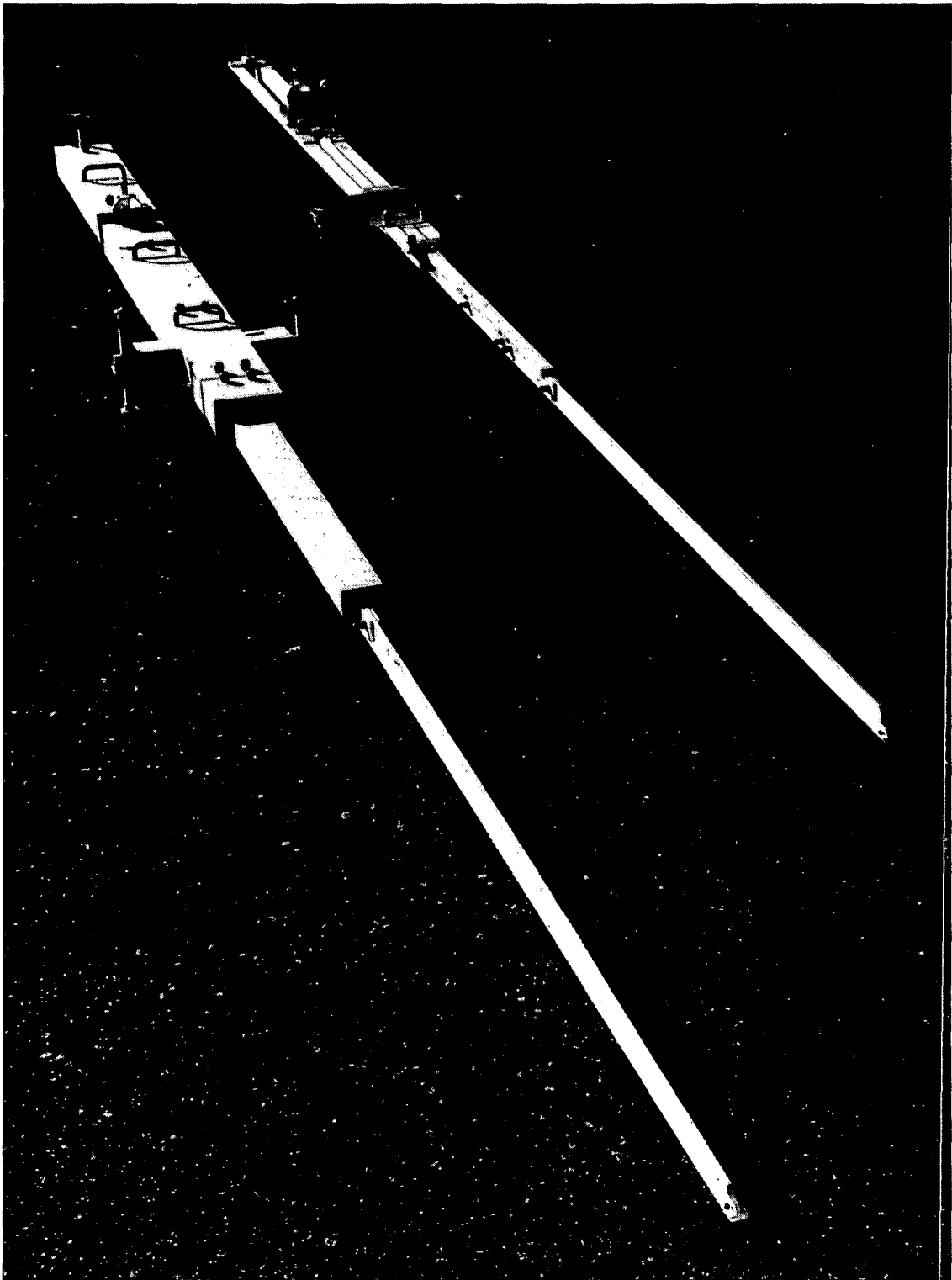
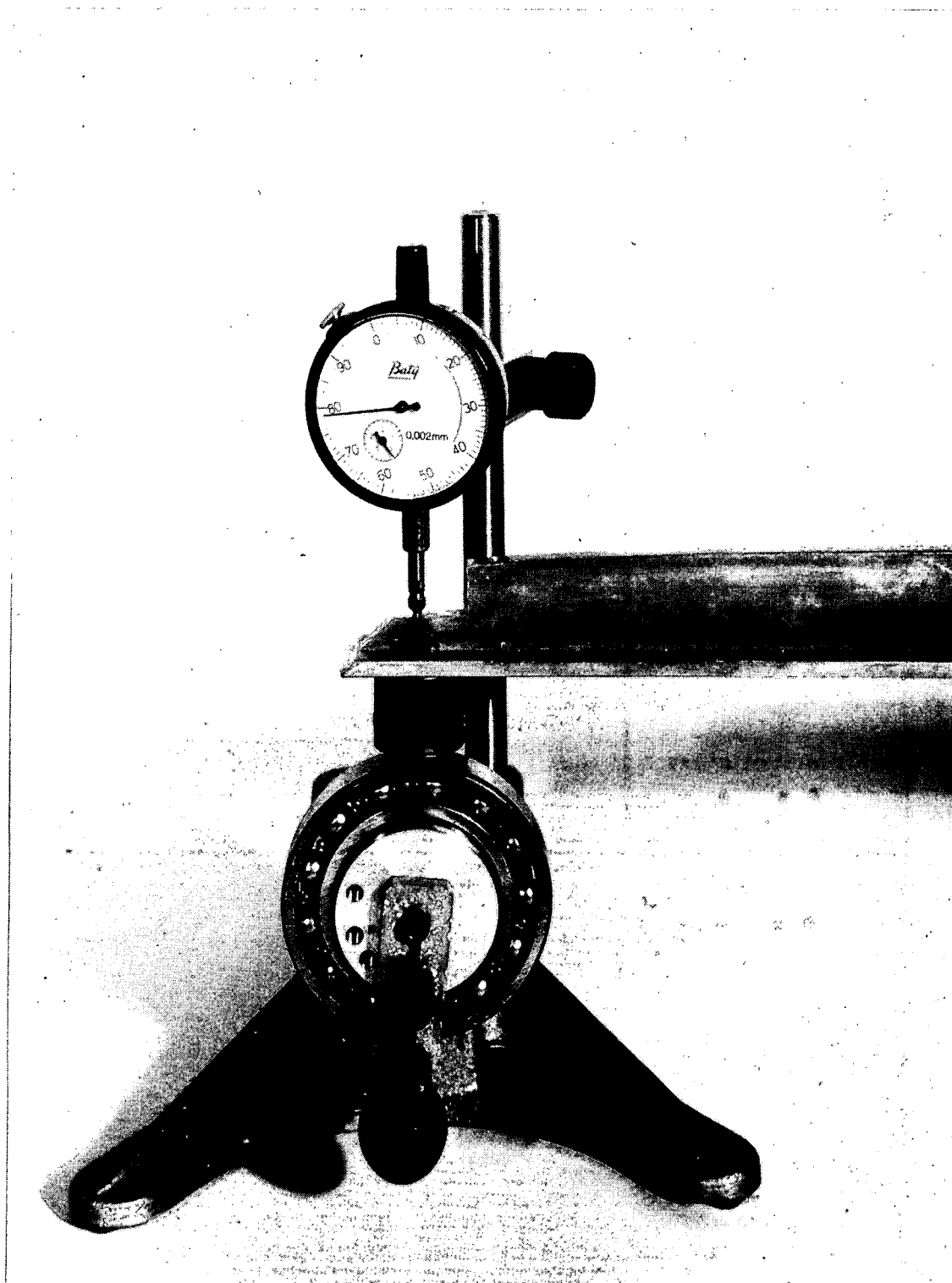


Fig. 4 DEFLECTION HISTORY AT RAMISI (KENYA)



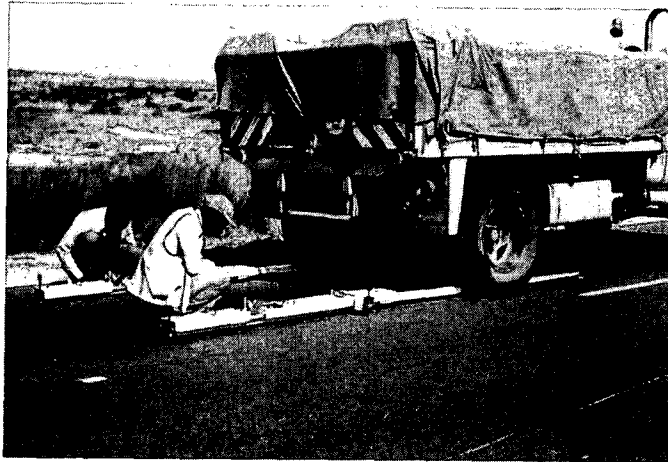
Neg. no. B946/79

Plate 1 THE DEFLECTION BEAM AND BEAM FITTED WITH THE SPECIAL SUNSHADES

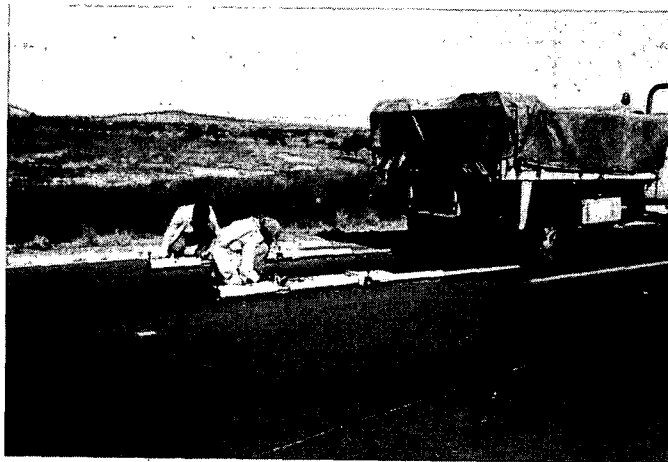


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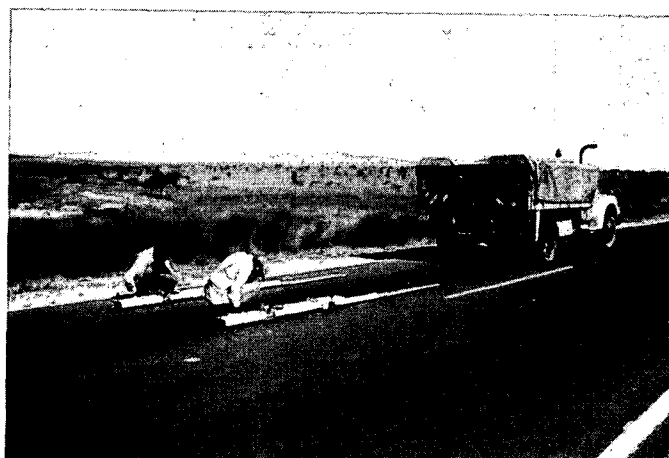
Plate 2 TOE OF DEFLECTION BEAM IN POSITION ON CALIBRATOR



Neg. no. R82/80/14

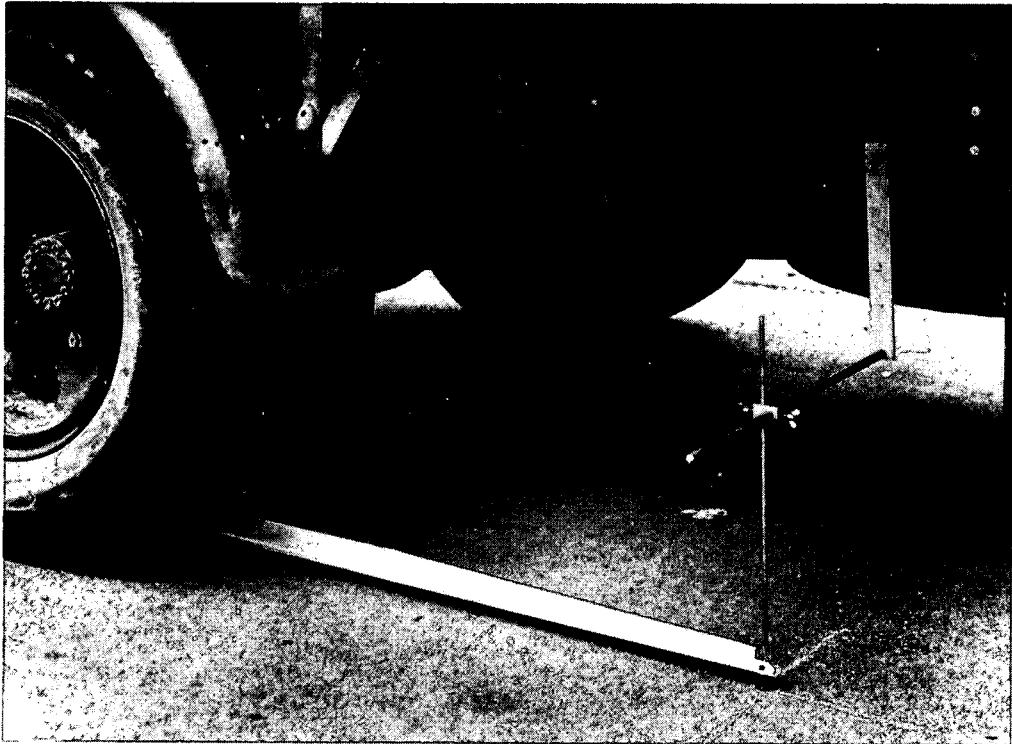


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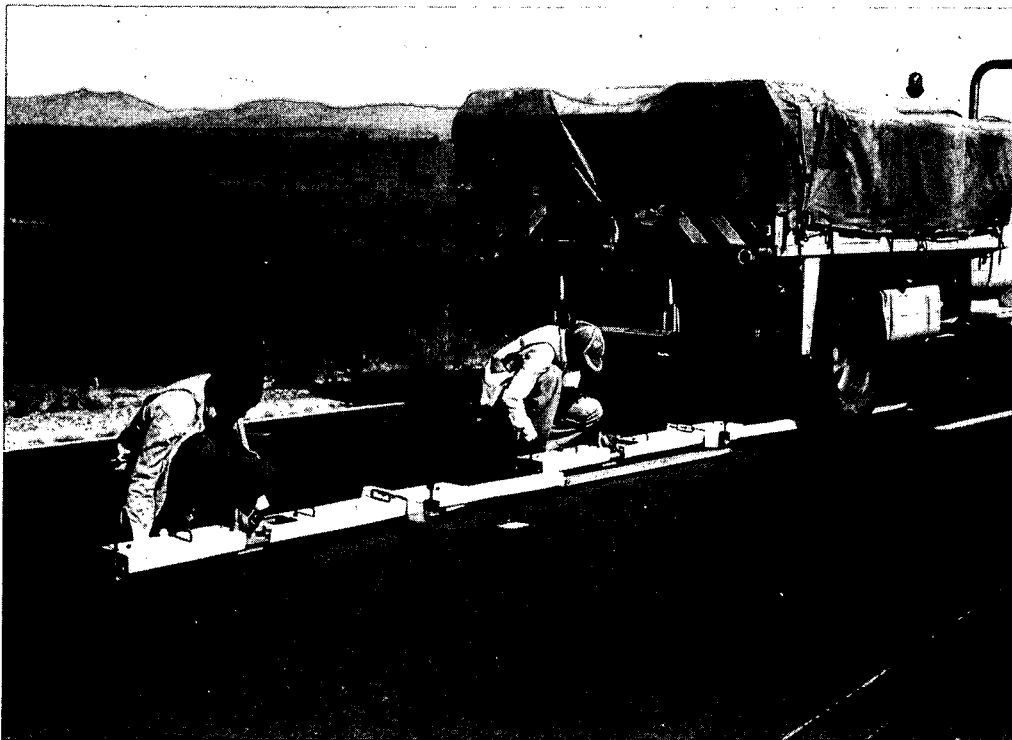
Neg. no. R82/80/2

Plate 3 DEFLECTION BEAM — TEST SEQUENCE



Neg. no. R1340/77/8

Plate 4 DEFLECTION BEAM TRUCK FITTED WITH ADJUSTABLE POINTER



Neg. no. R82/80/18

Plate 5 SHOWING USE OF 2ND BEAM FOR MEASURING FEET MOVEMENT

9. APPENDIX

A DEFLECTION SURVEY METHOD FOR EVALUATING ROADS IN DEVELOPING COUNTRIES

9.1 Introduction

Deflection surveys are being used increasingly in developing countries to provide a basis for overlay thickness design.

Ideally a deflection criterion curve will be available for the type of road structure under investigation. From a knowledge of the traffic loadings carried by the pavement in the past and of the deflection and surface condition histories, the remaining 'life' of the pavement can then be estimated and the most appropriate time for the application of an overlay determined.

At the present time it is unlikely that suitable criterion curves exist for most pavements in developing countries. It is also frequently the case that accurate traffic loading histories are unavailable. The use of deflection surveys in developing countries for overlay thickness design almost invariably implies that the pavement has already suffered some distress. In these circumstances, without historical data or a criterion curve, the overlay design is based largely upon an assessment of pavement condition, the prediction of the deflection after overlaying, and the 'life' of the overlay associated with this level of deflection.

Pavement condition assessments can be of great value for overlay design purposes, in particular the rate of change of pavement condition is most important. In general a pavement which has a cracked but undeformed surface is basically structurally sound and only the surfacing has 'failed'. An uncracked but deformed surface indicates that one or more of the lower layers of the pavement has been unable to withstand adequately the applied traffic stresses, however the rate at which this deformation has developed is important, if it has developed slowly over a number of years it is less serious than deformation which has occurred rapidly perhaps due to a change in traffic loadings.

Analysing the cause of combined deformation and cracking can be difficult. Deformation of the surfacing may have caused it to crack, or cracking of the surfacing, particularly when overlying granular road bases may have allowed water to enter and weaken the structure causing deformation to occur.

If a road is identified as being likely to require overlaying in the near future and measurements of deflection and surface condition have not been made previously, then as a minimum requirement, deflection measurements and surface condition assessments should be made well in advance of applying an overlay. Drainage deficiencies should be rectified and badly damaged areas should be patched and made waterproof. Better estimates of reconstruction and overlay thickness requirements can then be made from the results of a second similar survey carried out after an interval of say one year. During this period axle load surveys should be undertaken.

One of the most difficult tasks in planning an overlay programme is the provision of finance. It is frequently the case that overlays are applied later than the optimal timing because funds are not available at the right time. In addition a length of road which has been included in an overlay programme which is planned to be implemented over a period of two or three years may consequently be excluded from maintenance resealing programmes. Consideration should be given to resealing pavements even if they are included in an overlay programme; seals applied 1 to 2 years before overlaying could well produce net savings in overlay costs or in increased overlay life.

9.2 Deflection survey methods

A survey method which has been found suitable for roads showing variable surface conditions has been suggested⁸. The method which is reproduced below in a revised form indicates the minimum amount of testing which is required.

Deflection measurements should be made in both wheelpaths of the slow lane on dual carriageways and in both lanes of two lane carriageways:

1. Tests on a basic pattern of ten equally spaced tests per kilometre.
2. Additional tests on any area showing surface distress.
3. If any measurement exceeds a predetermined value, which is related to established deflection criteria for the type of pavement concerned, or indicates the need for a much thicker overlay than is required for the adjacent pavement, the extent of the area involved should be determined by additional tests.
4. Additional tests should be made when the variability of the above measurements exceed a certain value.

The deflections used both to check variability and to design the overlay should be the largest reading from either wheelpath at each chainage.

A simple and adequate check on variability can be made in the following way. Ten consecutive measured deflection values are considered as a group and their mean value is calculated (for this purpose all the deflection values at the regular 100m spacings are used but only the maximum reading is taken from any one area tested on account of its surface distress or large deflection). If the largest and smallest values of the group differ from the mean by more than one-third of the mean then four additional tests should be made, each test being made midway between the test points which registered the largest and smallest deflections and their immediate adjacent test points. If any of these four measurements would reduce the distance between test points to less than 5m then the extra measurement may be omitted.

The process is then repeated on another group of ten consecutive deflection values which is formed by taking into the previous group the next deflection value along the road, whilst omitting the first deflection value from the previous group. The process is repeated as each new deflection measurement is made so that a running check on variability is maintained.

The aim should be to have at least 20 measurements per kilometre spaced in such a way that they reflect the variation in pavement conditions. At least 20 measurements per kilometre should be made on pavements which do not show any surface distress.

If time is available measurements should be taken at closer intervals which may increase the accuracy of the method. Testing at 12m intervals is recommended for surveys in the United Kingdom⁷.

After all measurements have been made it is convenient to plot for each lane the maximum deflection (corrected for temperature effect) and the worst pavement surface condition ratings for each cross-section against chainage along the road site. Any area showing exceptional weakness which may require reconstruction or special treatment is delineated. The remainder of the road is then divided into sections by inspection of

the plot in such a way as to minimise variation in deflections within each section. The minimum length of a section should be compatible with the method of resurfacing that it is intended to employ, bearing in mind the frequency of thickness adjustments which can sensibly be made to the paving machine. If deflection values are very high, implying that pavement reconstruction is required, then short lengths of pavement can be considered separately since normally hand labour (assisted by machine) would be used for such an operation.

The final stage is to design the overlay for each section of the road and to determine those areas which merit further investigation. On those areas of pavement where deflections are very high or failure has occurred inspection holes should be dug and a careful note of drainage conditions made.

If it is assumed that the distribution of deflections is normal then only 2.5 per cent of the pavement would be expected to have a deflection in excess of the sample mean plus twice the standard deviation of the sample. The survey method proposed will tend to separate out the very high deflections on areas warranting special treatment or reconstruction and so reduce the effect of skewness, thus the distribution of deflections in each selected section should not be far removed from a normal distribution.

Some authorities recommend an overlay design deflection of the mean plus twice the standard deviation of a sample of readings. It is felt that in developing countries it is not appropriate to go to the expense of such a high degree of certainty which might lead to the expensive over-design of large areas of pavement. Use of the proposed survey method in conjunction with a design deflection of the mean plus 1.0 to 1.5 standard deviations for the section is recommended.

ABSTRACT

Measurement of pavement deflections in tropical and sub-tropical climates: H R SMITH and C R JONES: Department of the Environment Department of Transport, TRRL Laboratory Report 935: Crowthorne, 1980 (Transport and Road Research Laboratory). The measurement of the deflection of the surface of road pavements under a standard wheel load is common practice in many countries. The main purposes of making deflection measurements are to assist in the evaluation of the structural condition of roads, and to help in the design of road strengthening measures. In developing countries in the tropics the high road temperatures and other climatic effects necessitate the use of a special technique in making deflection tests. This report describes the technique adopted by the Overseas Unit of the Transport and Road Research Laboratory for the measurement of pavement deflection in tropical developing countries, and discusses factors relevant to the deflection of road pavements in such conditions.

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