SURFACE DRESSING: ASSESSMENT OF ROAD SURFACE HARDNESS

by

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ABSTRACT

Determination of road surface hardness prior to surface dressing is an important step in arriving at the correct chipping size to use with any particular traffic intensity, an essential prerequisite if adequate surface texture is to be maintained. This Report describes the development of a simple probe test for this purpose and puts forward a graphical method for temperature correction to a standard test temperature of 30°C. Proposed values of penetration corresponding to the five hardness categories defined in Road Note No 39 are:—

- Very hard: 0-2 mm penetration at 30°C
- Hard: 2-5 mm penetration at 30°C
- Normal: 5-8 mm penetration at 30°C
- Soft: 8-12 mm penetration at 30°C
- Very soft: more than 12 mm penetration at 30°C

Measurements of road surface hardness are made in the left-hand wheel track where embedment of chippings under traffic is likely to be at a maximum.

Good correlation between probe test results and rate of embedment of surface dressing chippings into a range of different bituminous surfacings was found using a multi-wheel-tracking test technique.

1. INTRODUCTION

The maintenance of surface texture depth in surface dressing work depends upon the volume of traffic carried and the relative hardness of the old road surface. This is clearly recognised in Road Note No 39 'Recommendations for Road Surface Dressing' where recommendations are made for variations in chipping size and in rates of spread of binder according to these factors. In practice, the Road Note defines five main categories of road surface:—

- Very hard — surfaces such as concrete or exceptionally lean bituminous mixtures. Negligible penetration of chippings will occur even under the heaviest traffic.
- Hard — surfaces containing some hard bituminous mortar into which chippings will penetrate only slightly under heavy traffic.
- Normal — surfaces into which chippings will penetrate moderately under medium and heavy traffic.
- Soft — surfaces into which chippings will penetrate considerably under medium and heavy traffic.
- Very soft — surfaces into which even the largest chippings will be submerged under heavy traffic. Usually rich in binder.
Assessment of the relative hardness or softness of existing road surfaces is still a matter for subjective judgement but incorrect assessment can lead to rapid loss of surface texture where too small a chipping size is specified, or to loss of chippings where an oversized chipping is used. Both conditions are liable to involve extra expenditure to remedy the fault, and so a quantitative method of measuring road surface hardness has been sought to assist engineers in arriving at satisfactory specifications. This is particularly important for roads in the three middle categories of hardness as they constitute the majority of surfaces in the United Kingdom.

This report describes work that has been carried out with that objective.

2. PREVIOUS WORK

Attempts to quantify the complex inter-relationship between road surface hardness and road temperature have been made by workers in South Africa, America, Canada and the United Kingdom. A system favoured by several researchers is based on the depth of penetration of steel balls of varying diameters subjected to various loadings. In the case of the test suggested by Marais\(^2\), a 19 mm (¾ in) diameter ball is given a single blow with a standard Marshall test compaction hammer and the penetration is measured with a depth gauge. Marek and Herrin\(^3\) in America suggest five blows from a 4.5 kg (10 lb) weight falling through a distance of 450 mm (18 in) acting on a 25 mm (1 in) ball. The parameter proposed by Vaughan\(^4\) in laboratory tests is the load causing 7.6 mm (0.3 in) penetration by a 12.7 mm (½ in) ball at a rate of loading of 2.4 mm (0.096 in) per minute. All agree that the mean of a number of determinations be recorded.

United Kingdom workers have shown preference for test procedures based on the penetration of a steel rod into the pavement. Concurrent with TRRL work, methods have been proposed (Watson 1970, Chivers 1972, CTRA 1974) in which static loads are applied to steel rods with a range of tip patterns. Some include arrangements for the probe to be moved laterally and longitudinally along steel bars to bear on any position within the area enclosed by the apparatus. It is generally agreed that accurate measurement of road surface temperature is vital.

A disadvantage in ball-test methods is the considerable difficulty in measuring very small indentations in stony road surfaces. This is less apparent with simple probes and their additional advantage of ready portability led to the selection of this type of instrument for development in Britain.

3. THE HARDNESS PROBE

The instrument in use at TRRL is a modification of a soil assessment cone penetrometer originally designed by the Military Engineering Experimental Establishment (now the Military Vehicle Experimental Establishment) for the rapid determination of \textit{in-situ} soil strengths. The standard cone normally used with the device is replaced by a probe of hardened steel 40 mm long and 4 mm in diameter. Depth of penetration of the probe into the road surface under a load of 35 kgf (343N) applied for 10 seconds is indicated by means of a spring-loaded sliding collar and is measured using a modified dial gauge. The apparatus is illustrated in Plate 1 and its method of operation is described in Appendix 1.
3.1 *Comparison of probe tip shapes*

Three patterns of probe tip shape, flat, hemispherical and $60^\circ$ cone, were compared in a series of tests. The results showed that the flat-ended probe did not achieve sufficient penetration and that the conical shape tended to seek out crevices between stones giving irregular readings. Calculation of the coefficient of variation of a very large number of results obtained by the three probe shapes showed least variation with the hemispherical tip.

During the investigation considerable change in shape occurred with the flat probe which suffered visible rounding of its circular edge; similarly the conical tip had its point severely worn and blunted. The hemispherical tip, although worn, retained its original shape and this probe shape was, therefore, selected for all subsequent work.

3.2 *Calibration of apparatus*

The instrument is designed to apply variable loads, the levels being controlled by a spring and registered on a scale in the head of the apparatus. As the spring strength may vary with time and use it is necessary to standardise a calibration procedure. The simplest method found was to operate the probe on the platform of a suitable balance. The force registered as working load should be $35 \pm 1$ kgf.

3.3 *Measurement of road surface temperature*

Rapid and accurate measurement of the temperature of the road surface at the time of testing is necessary. Early tests showed that disc-type thermometers using bi-metallic elements were ineffective as the area of contact between the disc and the road surface was so small as to make accurate measurement impossible. The need for instruments with a low heat capacity at the tip precluded the use of mercury-in-glass thermometers. Accordingly all temperature measurements were made using electronic-type thermometers where the measuring element is an unsheathed thermocouple. Good contact with the road surface was ensured by light hand pressure of a cube of expanded polystyrene over the thermocouple tip.

### 4. LABORATORY AND ROAD TRIALS

4.1 *Initial laboratory trials*

There are a large number of different types of road surface to which surface dressings are applied; not in all cases will the exact nature of the old road surface be known. In an early series of laboratory trials, three types of surfacing were tested:—

i) Rolled asphalts
ii) Coated macadams
iii) Previously surface-dressed surfacings

Cores were cut from each of these types of road surfacing and subjected to penetration tests in the laboratory at controlled temperatures. The relationships found are shown in Figure 1 and although only a small degree of differentiation between the three types of surfacing was found, the results proved sufficiently encouraging for the method to be translated to direct measurement on the road.
4.2 Road trials

Rolled asphalt surfacings only were considered at this stage as these were thought to be more uniform in composition than other materials and surface dressings are frequently used to renew their surface textures.

Six road sites in the South of England having rolled asphalt surfacings and which were due for surface dressing later in the season were selected for testing. This presented an opportunity to determine also whether a relationship could be established between predictions of substrate hardness obtained by probe measurements and the actual rate of embedment of surface dressing chippings under road conditions by observing changes in texture depth of the applied surface dressings. This work is described in Section 5.

Probe tests were carried out over a temperature range of 10–40°C; the results are given in Figure 2. An exponential curve (of the form $y = 0.78 \times 10^{0.032x}$) was found best to fit the results but from the degree of scatter it became clear that in order to obtain definitive standards of penetration many more results would need to be obtained and examined statistically.

The assistance of County Authorities was sought for obtaining such additional data.

4.2.1 Co-operative work with the County Surveyors’ Society: With the co-operation of Committee No 2 of the County Surveyors’ Society six County Authorities were invited to obtain data on road surface hardness in the course of preparation for their normal surface dressing programmes. Two types of probe were used in the investigations, the hemispherically-ended probe developed at TRRL and a conically-ended instrument developed by the Coal Tar Research Association (now the British Carbonisation Research Association). This instrument is illustrated in Plate 3. The Counties involved were Dorset, Wiltshire, Worcestershire, Durham, Lincolnshire and West Yorkshire. The last three named counties have reported their findings separately to the County Surveyors’ Society through the Northern Counties Soils and Materials Engineers’ Group.

Very extensive data came from this exercise which covered measurements made on a wide range of surfacing materials. The data has been treated in the same three groups as previously, namely, rolled asphalts, coated macadams and surface dressings. Results from the TRRL probe are shown in Figure 3. The outer dotted lines indicate the maximum and minimum values of penetration recorded for any particular road temperature.

Examination of the curves derived showed best fit to be obtained with exponential curves and correlation coefficients of 0.88, 0.59 and 0.83 respectively were found for the rolled asphalt, macadam and surface dressed surfacings. A considerable similarity was noted between the rolled asphalt and the surface dressed surfacings; this is considered to be due to the fact that the majority of the substrates to which the dressings had been applied were rolled asphalts. Additionally, the curve for rolled asphalt surfacings closely resembles that obtained by TRRL during measurements on the road. The most erratic results were found with the coated macadam surfacings.

Results from the conically ended BCRA probe gave a very similar pattern of results, the general level of penetration being some 4-6 mm greater at normal road temperatures of between 20 and 30°C. This is considered to be due to the tendency for the sharply pointed probe to wander in between adjacent aggregate particles. The relationship between TRRL and BCRA probes is discussed in Appendix 2.
4.2.2 Determination of temperature correction factors: When defining road surface hardness on a numerical scale it is necessary to select a standard temperature of test. The temperature selected should be that at which penetration of surface dressing chippings into the existing road under traffic is likely to begin and a temperature of 30°C is suggested. Examination of the curves in Figure 3 indicated that below 20°C gradients are virtually identical for all types of material, but that above that temperature differences between coated macadam surfacings and asphalt or surface dressed areas become apparent.

Over the temperature range 25–35°C mean temperature coefficient factors of 0.4 mm/°C were calculated for both the rolled asphalt and surface dressed materials; the equivalent value for coated macadams was 0.2 mm/°C. However, when the range of results was considered for the various materials (the outer dotted lines in Figure 3) it became apparent that a high degree of variability existed. Under these circumstances, temperature coefficient factors ranged from 0.2 to 0.8 mm/°C for asphalts; from 0.1 to 1.0 mm/°C for coated macadams and from 0.2 to 0.7 mm/°C for surface dressings. In view of this finding it was concluded that a graphical method of determining appropriate temperature corrections would be of greatest value to engineers.

Figure 4 shows the probe depth/temperature relationship plotted for the range of materials investigated and divided into essentially gap-graded materials such as rolled asphalts and continuously-graded materials of the macadam type. In each case the upper portion of the band corresponds to the softer type of material in that category, for instance the coated macadam band covers a range of materials from relatively soft fine cold asphalts to hard asphaltic concretes. Selection of the appropriate curve for surface dressed materials is considered to depend upon the type of material on which it has been laid.

Suggested limits of penetration at the proposed test temperature of 30°C for the five categories of road hardness defined in Road Note No 39 have been superimposed upon these curves. Measurements of probe penetration taken at other temperatures may be corrected to 30°C by reference to the curves given in Figure 4. The upper part of the curves should be used for rich, less stony mixtures whilst the lower part is applicable to higher stone content mixtures.

4.2.3 Proposed hardness scale: Values of penetration using the TRRL probe have been deduced corresponding to the hardness categories defined in Road Note No 39. Suggested figures are:—

| Very hard:   | 0-2 mm penetration at 30°C |
| Hard:        | 2-5 mm penetration at 30°C |
| Normal:      | 5-8 mm penetration at 30°C |
| Soft:        | 8-12 mm penetration at 30°C |
| Very soft:   | more than 12 mm penetration at 30°C |

At temperatures below 10°C all road surfacings appear hard and resistant to the embedment of chippings and probe testing should not be carried out below that temperature. Above 40°C all road surfacings tend to appear soft and penetration measurements may prove unreliable. It is, therefore, recommended that testing should take place at temperatures between 15 and 35°C.
5. CORRELATION OF PROBE TEST RESULTS WITH RATE OF EMBEDMENT OF CHIPPINGS

Concurrent with the development of a numerical system for classifying road surface hardness a further investigation was in train to determine whether a relationship existed between predictions of substrate hardness obtained by probe measurements and the actual rate of embedment of surface dressing chippings under road conditions (see Section 4.2). Accordingly, measurements of surface texture depth were made at six sites which had been surface dressed in the spring (May) as part of a local authority's normal programme. The substrates were in all cases rolled asphalts. When newly applied, surface dressings have very good surface texture, but much of this is lost in the first few weeks of trafficking. This is due more to re-orientation of the applied chippings than to embedment. Surface texture depth was, therefore, measured in the left-hand wheel-track four weeks after laying when the dressings had become stabilised and again after 26 weeks under traffic. On all sites the nominal size of the aggregate used was 10 mm and the traffic corresponded to Category 4 of Road Note No 39 (20–200 commercial vehicles per day per lane in one direction).

The relationship obtained is shown in Figure 5; in spite of the lack of temperature control a reasonable degree of correlation was found.

5.1 The multi-wheel tracking machine

It is well established that the majority of embedment of surface dressing chippings with consequent loss of surface texture depth occurs during relatively short periods when road temperatures approach 45°C. At more normal temperatures the rates of embedment are correspondingly slower. In order to obtain results in a reasonable period of time, a series of laboratory trials was begun which were designed to study the rate of embedment of surface dressing chippings into a variety of substrate materials under simulated heavy traffic. The object of the experiments was to confirm the findings from the road trials mentioned above when tested under more closely controlled conditions.

Laboratory-made samples of road wearing-courses of different degrees of hardness were surface dressed using the paper-strip technique first suggested by Deadman, the chipping size being selected according to the degree of hardness of the substrate determined by penetrometer tests. The samples were then subjected to artificial traffic at a controlled temperature of 45°C in a multi-wheel tracking machine loaded to exert a pressure of 68 lbf/in² (4.78 kgf/cm²) on the specimen. The machine is illustrated in Plate 2. Embedment was assessed by direct measurement of the distance moved downward by the wheels and by determining the loss of surface texture using a sand patch method. In the early stages of the work embedment was further checked by measuring the surface texture depth of the substrate prior to surface dressing and again after removal of the dressing following the tracking period. Similar tests were carried out on 200 mm diameter cores taken from the surface of existing roads known to be due for surface dressing.

Results from this work are shown in Figure 6 and indicate a good relationship between probe penetration values and the rate of embedment of surface dressing chippings at 45°C for a wide range of asphalt and coated macadam substrates. It is, therefore, concluded that the use of the proposed hardness probe will aid engineers in the better assessment of road surface hardness and consequently in the specification of the correct chipping size for a particular site and traffic intensity.
6. CONCLUSIONS

The following conclusions have been drawn from the programme of experimental and field work described in this Report:—

1. Road surface hardness in rolled asphalts and coated macadams can be quantitatively assessed using a simple probe technique. The hardness of previously surface-dressed surfacing was found to be dependent upon the type of substrate to which the dressing was applied.

2. The preferred shape of probe tip proved to be hemispherical; this gave minimum wear in use and the best repeatability of measurement.

3. The following values of penetration are proposed, corresponding to the five hardness categories defined in Road Note No 39:—

<table>
<thead>
<tr>
<th>Category</th>
<th>Penetration at 30°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very hard</td>
<td>0.2 mm</td>
</tr>
<tr>
<td>Hard</td>
<td>2.5 mm</td>
</tr>
<tr>
<td>Normal</td>
<td>5.8 mm</td>
</tr>
<tr>
<td>Soft</td>
<td>8.12 mm</td>
</tr>
<tr>
<td>Very soft</td>
<td>more than 12 mm</td>
</tr>
</tbody>
</table>

Measurements of road surface hardness should be taken in the left-hand wheel-track where maximum embedment of surface dressing chippings is likely to occur.

4. A graphical method for temperature correction of probe measurements to a standard test temperature of 30°C is proposed.

5. Good correlation between probe test results and the rate of embedment of chippings under traffic was found. A multi-wheel tracking test has been developed for this purpose.

7. ACKNOWLEDGEMENTS

The work described in this Report was carried out in the Materials Division (Division Head: Mr G F Salt) of the Highways Department of TRRL.

The Laboratory wishes to acknowledge the valuable help given by the County Surveyors of Dorset, Durham, Lincolnshire, Wiltshire, Worcestershire and West Yorkshire in this investigation and is grateful to all of their staff who carried out the detailed probe measurements.
8. REFERENCES


3. MAREK, C R and M HERREN. Voids concept of design of seal coats and surface treatments. Annual meeting of Highway Research Board, Jan 1971 (University of Illinois).


Fig. 1 RELATIONSHIP BETWEEN PROBE PENETRATION AND TEMPERATURE FOR A RANGE OF SURFACING MATERIALS (LABORATORY TESTS ON CORES CUT FROM ROAD SURFACES)
Fig. 2 RELATIONSHIP BETWEEN PROBE PENETRATION AND TEMPERATURE FOR ROLLED ASPHALT SURFACINGS
RESULTS FROM 6 ROAD SITES

$y = 0.78 (10)^{0.032x}$
Correlation coefficient 0.86
Fig. 3 RELATIONSHIP BETWEEN PROBE PENETRATION AND TEMPERATURE
(TRRL/COUNTIES JOINT INVESTIGATION)
Fig. 4 ROAD SURFACE HARDNESS: RELATIONSHIP BETWEEN DEPTH OF PROBE PENETRATION AND ROAD TEMPERATURE WITH PROPOSED STANDARDS OF HARDNESS AT 30°C SUPERIMPOSED
Fig. 5 RELATIONSHIP BETWEEN PENETRATION VALUES AND LOSS OF SURFACE TEXTURE DEPTH ON THE ROAD
Fig. 6 RELATIONSHIP BETWEEN PENETRATION VALUES AND RATE OF EMBEDMENT OF SURFACE DRESSING CHIPPINGS INTO VARIOUS SUBSTRATES AT 45°C

\[ y = 0.013x + 0.23 \]

Correlation coefficient 0.85
Fig. 7 RELATIONSHIP BETWEEN STANDARD TRRL PROBE AND BCRA PROBE WITH CONICAL AND MODIFIED PROBE TIP

Standard BCRA probe (conical tip)
\[ y = 1.51x + 1.7 \]
Correlation coefficient 0.84

BCRA probe with modified tip
\[ y = 0.96x + 1.6 \]
Correlation coefficient 0.93
Plate 1 TRRL Probe in operation—Detail of probe tip and modified dial gauge used to measure depth of probe.
Plate 2 GENERAL VIEW OF THE MULTI-WHEEL TRACKING MACHINE WITH SURFACE DRESSING IN POSITION
Plate 3 THE BCRA PROBE
(Photograph by courtesy of British Carbonisation Research Association)
(Reproduced with the permission of the Director, BCRA)
All measurements are made in the nearside wheel-track of each traffic lane where maximum embedment of chippings can be expected. At least 10 measurements are required at each location; these should be spaced evenly along the road at intervals of 0.5m, any recently repaired or patched areas being ignored. It has been found useful to mark the 0.5m intervals with a chalk cross and to test at the intersection of the cross. The probe tip should not be centred on large existing stones present in the road.

The penetrometer is assembled using up to four extension rods as convenient and the collar of the probe is slid down the shank until flush with the end of the probe. The friction in the collar device should be checked at intervals. The probe is then centred on the first marked point and pressure applied to give a constant reading of 150 on the right-hand dial on the instrument head. The applied force, equivalent to 35 kgf (343N), is maintained for a period of 10 seconds during which time the probe is maintained in a vertical position. At the end of this time the penetration of the probe is measured directly by means of a modified dial gauge. The dial gauge has a sleeve fitted around the plunger and the protruding probe tip is slipped into this sleeve until the collar butts up against the sleeve. This arrangement is shown in Plate 1.

It sometimes occurs that the point selected for test is below the surface of the remainder of the road. It is then necessary to deduct the measurement of initial projection of the probe from the final figure. On the worn surfaces normally under consideration for surface dressing this step is not often required.

The mean of 10 probe measurements is calculated and reported as the mean penetration at the temperature of test.
10. APPENDIX 2

Relationship between TRRL and BCRA probes

The BCRA road surface hardness probe has been used by certain County Authorities for some time and comparison of results obtained with both instruments show the TRRL results always to be numerically less. This is to be expected considering the blunter pattern of the TRRL probe tip. As the two instruments apply virtually identical loads it was suggested that standardisation of the diameter and shape of the probes would result in unification of results. Research has shown (Section 3.1) that the most repeatable results were obtained when using a hemispherically-ended probe and accordingly the BCRA instrument was modified to this shape. The diameter of the BCRA probe was reduced from 4.76 mm (3/16 in) to 4 mm to correspond to the TRRL pattern.

The results of a series of tests with the two instruments, both on laboratory-prepared and road samples, are given in Figure 7 and include a comparison of the two instruments prior to modification. Best correlation between results obtained with the TRRL probe and the unmodified BCRA probe is given by:

\[ \text{Penetration (mm) BCRA} = 1.5 \times \text{penetration (mm) TRRL} + 1.7. \]

Modification of the BCRA instrument to hemispherically-ended probe tip gave the following correlation:

\[ \text{Penetration (mm) BCRA} = \text{penetration (mm) TRRL} + 1.6. \]

As it is intended to include a range of numerical values for road surface hardness in a future revision of Road Note No 39, this finding is of some commercial importance as it enables engineers to select an instrument in the knowledge that similar results would be achieved with either. Choice of instrument would depend on personal preference, on ease of use and on relative prices.
ABSTRACT

SURFACE DRESSING: ASSESSMENT OF ROAD SURFACE HARDNESS: N Wright: Department of the Environment Department of Transport, TRRL Supplementary Report 573: Crowthorne, 1980 (Transport and Road Research Laboratory). Determination of road surface hardness prior to surface dressing is an important step in arriving at the correct chipping size to use with any particular traffic intensity, an essential prerequisite if adequate surface texture is to be maintained. This Report describes the development of a simple probe test for this purpose and puts forward a graphical method for temperature correction to a standard test temperature of 30°C. Proposed values of penetration corresponding to the five hardness categories defined in Road Note No 39 are:

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