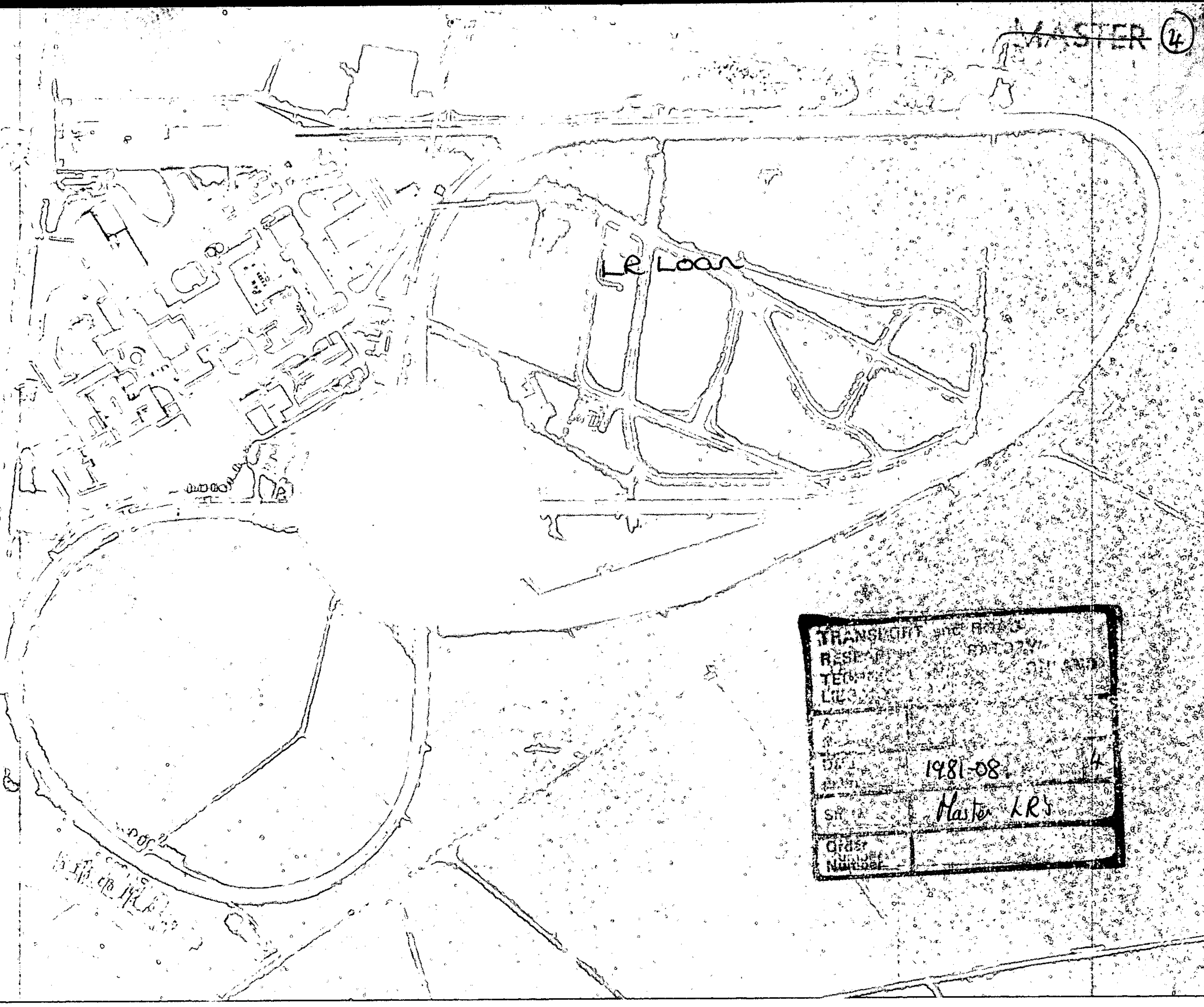
TRRL Laboratory Report 1019

TRANSPORT and ROAD RESEARCH LABORATORY

DEPARTMENT of the ENVIRONMENT DEPARTMENT of TRANSPORT



Surface dressing in developing countries: research in Kenya

by

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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

Overseas Unit
Transport and Road Research Laboratory
Crowthorne, Berkshire
1981
ISSN 0305–1293

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SURFACE DRESSING IN DEVELOPING COUNTRIES: RESEARCH IN KENYA

ABSTRACT

In many developing countries surface dressing is used as a running surface on new low-cost roads as well as a maintenance treatment for existing roads. These countries are usually characterised by combinations of road surface condition, traffic, climate, and materials, that are not found in Britain and that are not favourable for good surface dressing. In such cases the recommendations for road surface dressing given in Road Note 39 which is intended for use in Britain, are not applicable.

Jackson (1963) has proposed a method of surface dressing design based partly upon ideas put forward by Hanson (1935). This method was used to design a total length of 27 km of experimental sections of surface dressing in Kenya during 1975–77.

This report describes the construction, monitoring and performance of the sections during the first 3–4 years trafficking. It is concluded that Jackson's design method works satisfactorily in Kenya conditions over the range of chipping size used in these trials, namely 5 mm to 13 mm average least dimension.

1. INTRODUCTION

Surface dressing seals the surface of a road pavement with a film of binder thus preventing the ingress of water and air. The binder film is covered by a layer of stone chippings which provides a non-skid surface and replaces to some extent stone that may have been lost by attrition from, or embedment into, the existing surface. The surface dressing process is relatively simple and cheap in comparison with other resurfacing treatments, but nonetheless requires close attention to design and control.

Whilst surface dressing is an effective and appropriate surfacing for many new paved roads in developing countries, its most important application is for the maintenance of existing bituminous surfaced roads. Road maintenance presents a growing problem in many developing countries notably because of the ever-increasing demands being made on the material and equipment resources available. Efficient use of the surface dressing process is therefore vital; the designs, materials and plant used must be such that dressings with optimum life and performance are obtained.

Whilst many of the problems encountered with surface dressing in developing countries can be resolved by effective training, there are often problems that are due to the use of inappropriate designs or materials. The design process, particularly, needs to be applied with special care, since there is often a greater possibility of unfavourable combinations of surface conditions, traffic, and climate than usually occur, for example, in Britain.

To study the effect of these factors on the surface dressing process, full-scale road trials have been undertaken in Kenya under a cooperative research programme between the Overseas Unit of the Transport and Road Research Laboratory and the Kenyan Ministry of Transport and Communications (MoTC). The prime objectives of this research programme were:

(i) to examine the validity of a selected surface dressing design method
(ii) to examine the performance of binders of different viscosities
(iii) to examine the lives of surface dressings constructed using chippings of different sizes.

This report describes the construction of the trial sections and gives the results of their performance over 3 years of trafficking.

2. SURFACE DRESSING DESIGN

In 1972 the Transport and Road Research Laboratory issued Road Note 39 'Recommendations for road surface dressing'[1]. The content of this Note can be related directly to UK practice; the materials and conditions of developing countries and the tropics in particular are, however, not considered separately. Road surface temperatures in the tropics are generally higher than in the UK and will influence the embedment of chippings. Wilson[2] has reported temperature measurements made on 4 small experimental pavements laid adjacent to the full-scale experiment at Alconbury by-pass; the area is climatically typical of most of southern England. During a 12 month period June 1967 to May 1968, an 'average' year, thermocouples at a depth of 20 mm recorded the following for the 3 hottest months in 1967.

Temperature range (^{o}C)	Duration of temperature range (hr) (average per day in brackets)		
	June	July	August
25–30	109 (3.6)	126 (4.1)	99 (3.2)
40–45	18 (0.6)	59 (1.9)	8 (0.3)

In contrast, road surface temperatures in Kenya recorded during 1976–77 were invariably higher than 30^{o}C by 1000 hrs, and were usually at 40–45^{o}C by 1200 hrs. A maximum of 52^{o}C was recorded in the early afternoon at two sites which were approximately 500 km apart and which differed in altitude by some 1500m.

It is thus clear that on temperature grounds alone Road Note 39 is not directly applicable to the tropical conditions found in many developing countries where, moreover, chippings are often of poor quality and choice of binder is severely limited.

Several tropical countries have developed national specifications for surface dressing that suit local conditions but there remains a need for a surface dressing design guide that is suitable for tropical developing countries in general.

In 1935 F M Hanson[3] propounded a general approach to the problem of the selection of optimum rates of spread for binder and chippings in surface dressing. This approach takes account of the volume of the voids that exist between the chippings when they are spread, when they are rolled and when they are trafficked, (typically 50, 30 and 20 per cent respectively). Hanson considered the orientation of chippings that occurs due to the effect of traffic and observed that chippings tend to settle in a position in which their least dimension is vertical, thus giving rise to the concept of the 'average least dimension' (ALD) of the chippings.

Hanson's method of design for surface dressing has been adapted by others working in this field[4] and in 1963 Jackson[5] put forward a design method that incorporates the concept of average least dimension and which includes 4 factors representing:

(i) the level of traffic,
(ii) the state of the existing road surface,
(iii) the climate, and
(iv) the nature of the chippings.

Jackson's method of design is summarised in Appendix 1. The method is applicable to conditions that exist in both tropical and temperate climates. In the cooperative research programme between the Overseas Unit, TRRL and the Kenyan MoTC Jackson's method was applied and evaluated in Kenyan conditions.

3. THE RESEARCH PROGRAMME

Full-scale surface dressing trials were constructed at 14 sites in which the following factors were examined:

(i)	Binder viscosity:	The effect of binders of different viscosities on the performance of surface dressings.
(ii)	Chipping size:	The effect of different chipping sizes on the performance of surface dressings.
(iii)	Double surface dressings:	The effect of different combinations of chipping size and the 'split' application of binder.

4. MATERIALS USED IN THE TRIALS

4.1 Chippings

In Kenya it was found that nominal ¾ in (20 mm) tended to contain a substantial proportion of over-size material, whilst the nominal ½ in (14 mm) chippings tended to be undersize, often severely so. Whilst the Kenyan MoTC specifications for chipping sizes are expressed in Metric units[6], in practice during the trials quarries tended to supply nominal Imperial sizes[7].

Tables 1 and 2 give results of grading and other tests[8] performed on samples of the chippings used in the trials. The average least dimensions of the chippings were obtained by the use of a nomograph method[5]. It will be seen from Tables 1 and 2 that many of the samples failed the BS 63[6] grading specification, the failure rate being as follows:

Nominal chipping size	No. of samples that failed
¾ in (20 mm)	5 (45%)
½ in (14 mm)	11 (92%)

TABLE 1

¾ inch (20 mm) chippings supplied for surface dressing, Kenya 1976/77

Province	Eastern						Rift Valley		Western		Coast
Expt/Project	KSD 1	KSD 2	KSD 3	KSD 7	KSD 9	Re-sealing (Kibwezi)	KSD 4/5	KSD 4/5	B.I. Ahero	KSD 12	KSD 15
Sieve (mm) (% pass cum) 28	100	100	99	100	100	100	100	100	99	100	100
20	44	75	94	97	96	90	90	99	56	82	86
14	15	14	24	33	31	7	7	27	9	13	12
10	–	–	1	1	1	2	3	3	1	2	3
6.3	–	–	–	–	–	–	–	–	–	1	2
5	–	–	–	–	–	–	–	–	–	–	2
Per cent nominal size Spec: 60 (min)(1)	29	61	70	64	65	83	83	72	47	69	74
Per cent oversize Spec: 15 (max)(1)	56	25	5	3	4	10	10	1	43	18	14
Per cent undersize Spec: 7 (max)(1)	nil	nil	1	1	1	2	3	3	nil	2	3
Flakiness index Spec: 35 (max)(1)	20	18	30	11	16	13	36	30	20	19	22
Pass/Fail	F	F	P	P	P	P	F	P	F	F	P
Average least dimension (ALD) (mm)	13	11	10	12	12	14	11	11	14	12	13
Aggregate crushing value(2)	19	–	20	–	–	19	–	–	–	–	26
Polished stone value(2)	–	–	–	–	–	–	–	–	–	–	68

Notes: (1) BS 63: (Part 2): 1971
(2) BS 812: 1975

TABLE 2

½ inch (14 mm) chippings supplied for surface dressing, Kenya 1976/77

Province	Eastern							Central	Rift	Western		Coast
Expt/Project	KSD 1	KSD 2	KSD 3	KSD 3	KSD 7	KSD 9	Re-sealing (Kibwezi)	KSD 8	KSD 4/5	B.I. Ahero	KSD 12	KSD 14/15
Sieve (mm) (% pass cum) 28	–	–	–	–	–	–	–	–	–	–	–	–
20	–	–	–	–	–	–	100	100	100	100	100	100
14	100	100	100	100	100	100	97	98	79	83	89	95
10	54	77	88	73	60	67	45	58	23	21	31	47
6.3	14	25	41	14	12	10	3	3	4	1	–	20
5	–	8	20	4	10	2	1	2	2	–	–	–
Per cent nominal size Spec: 60 min(1)	46	23	12	27	40	33	55	40	56	62	68	48
Per cent oversize Spec: 15 (max)(1)	nil	nil	nil	nil	nil	nil	3	2	21	17	11	5
Per cent undersize Spec: 7 (max)(1)	14	25	41	14	12	10	3	3	4	1	nil	20
Flakiness index Spec: 35 (max)(1)	23	18	30	27	23	26	25	26	42	30	25	28
Pass/Fail	F	F	F	F	F	F	F	F	F	F	P	F
Average least dimension (ALD) (mm)	6	6	5	6	6	6	8	7	7	8	8	7
Aggregate crushing value(2)	–	–	21	21	20	–	–	–	19	–	–	–
Polished stone value(2)	–	52	–	–	54	52	54	53	46	47	43	63

Notes: (1) BS 63: (Part 2): 1971
(2) BS 812: 1975

4.2 Binders

Penetration grade bitumen, 80/100 pen, was normally used for maintenance resealing throughout Kenya in 1975–77, the period during which trials were commenced. Since other grades were not obtainable this bitumen was used in all the trials, binders of lower viscosity being made from it by blending 80/100 pen bitumen with diesel fuel shortly before spraying (Plate 1) (kerosene was not available for this purpose). The resultant binders were all in the penetration grade range except for the trial at one site (KSD 8) where the binder viscosity was reduced to 225 sec STV at 40°C (see Table 4). Figure 1 shows the viscosity/temperature relationships determined in the laboratory for 5 of the blends used. The viscosities were measured in centipoises (cp): however, within the relatively small temperature range shown in Figure 1 these viscosities may be equated without significant error to centistokes (dynamic viscosity (cp) = kinematic viscosity (cs) x density at temperature of measurement).

It should be noted that although the blends used in the trials have been classified on the basis of penetration value they would not necessarily have the same curing properties in service as refinery-prepared bitumens of the same penetration which normally contain fluxing oils less volatile than diesel oil.

Figure 2 which includes the results of tests done on blends made in the laboratory and in the field during the trials shows the relationship between the penetration and the dilution with diesel oil of the 80/100 pen bitumen used in the trials. The scatter of the points can be attributed to:

(i) inaccuracy of the contents gauges on the distributors

(ii) the absence, in some cases, of accurate diesel dispensing equipment

(iii) differences in the initial penetration value of the bitumen drawn from stocks at different depots.

In order to investigate the relative rates of curing of the blended binders in Kenyan climatic conditions a series of curing trials was undertaken. Resources available did not permit the removal of specimens of surface dressings from the roads at the required intervals, and thus a set of trays containing simulated surface dressings was exposed on a roof site in Nairobi over a period of 3 years. Whilst these simulated surface dressings would not reflect the effects of tyre rubber and other depositions on the road surface, neither would they be subject to the softening of binder caused by fuel and lubricating oil spillage on vehicles.

Blends, approximately 3 litres each were prepared in the laboratory as shown in Table 3, using either diesel or kerosene (domestic 'paraffin').

TABLE 3

Blends of 80/100 pen bitumen containing diesel or kerosene

Per cent (by volume)	Diesel	Kerosene	Pouring Temp. (°C)
	Penetration at 25°C		
4	248	285	155–165
8	370	648	140–150
	Viscosity (STV) at 40°C		
12	268 sec.	108 sec.	130–140

Galvanised steel trays, area 0.76m^2, were used for the exposure tests. Binder was heated to pouring temperature and spread by scraper to an even film; the weight of binder applied in each case was such as to provide a coverage of approximately 1.6 kg/m^2 (normal resealing range = 0.8 – 1.3 kg/m^2).

The thick film applied was necessary in order to provide adequate sized samples for the subsequent tests. Granite chippings (10 mm to 14 mm) were spread on the hot binder to provide full coverage and were rolled with a 2.5 kg steel cylinder. A small hole was drilled at one corner of each tray above binder level to allow rain water to escape. One-quarter of each tray's contents was removed after 7, 14, 24 and 36 months and the soluble binder recovered using Method IP.105[9] but with the omission of a fractionating column. (This item was not available but it is considered unlikely that significant amounts of cutter oils would have been lost.)

Penetration tests were made on the recovered binders; the results are shown in Figures 3 and 4. The faster rate of curing of the kerosene blends is well demonstrated by the results, which can be summarised as follows:–

	Kerosene	Diesel
Penetration range of 3 blends after 6 months	60/90	80/140
Penetration range of 3 blends after 12 months	40/60	50/80
Penetration range of 3 blends after 24 months	20/30	20/40

5. EQUIPMENT AND WORKFORCE

5.1 Bitumen distributors

The following types of machine were used in the trials:

Type	Manufacturer	Country of manufacture
Constant volume	Etnyre	USA
Constant pressure	Phoenix	UK
Constant pressure	Ashurst	UK

These machines all had a maximum capacity of approximately 5200 litres (1100 Imp. gal.) and were, with one exception, uncalibrated. The Etnyre machine is more complex than the constant pressure machines and as a result the inter-relationship of certain of the binder system controls was not fully understood by most operators.

5.2 Chipping spreaders (or gritters)

Either Hornsey tailboard gritters or pushed metering spreaders were used for the trials, except for one site where a modern self-propelled chipping spreader was employed.

The simple and basically effective tailboard gritters had, in most cases, suffered distortion of the steel floor below the rotary gate. The resulting irregular gap produced uneven distribution of chippings; in severe cases, streaks of bitumen remained unchipped. Much rake and brush work was required to redistribute stone. These devices, moreover, whilst being well suited to the standard 2.25m (7.5 ft) spraybar as normally used in Great Britain, were not ideal for the 3.3m (10 ft) spraybar of the Etnyre machines, and echelon-gritting was necessary. (To have reduced the spraybar width to match the Hornsey gritter would have produced unacceptable complications in calibration and subsequent routine use of the distributor.)

The USA-made pushed gritters generally worked well, although crews tended to operate them at too fast a speed and the significance of the metering system was not fully understood.

5.3 Rollers

Normally Hyster pneumatic tyred rollers were used. At most sites an 8–10 Mg steel-wheeled roller was also available, but this was not used on the trial sections because it invariably cracked or crushed the chippings.

5.4 Workforce

A typical resealing operation required some 25–30 men including supervisory staff and drivers. Approximately 10 general labourers were needed at each resealing site for general duties such as road sweeping which was undertaken by hand.

6. THE TRIAL SECTIONS

6.1 Selection of the sites

The trials were necessarily confined to sites and materials for which maintenance funds had already been allocated. Since resealing units often commenced work at very short notice no detailed preparatory work was possible at a given site, such as a detailed texture survey. Nonetheless it was usually possible to select a length of road for the trial that was reasonably straight and without serious surface defect; gradients however were unavoidable. Table 4 gives details of the 14 trials.

6.2 Design of experiments

6.2.1 Average least dimension and shape of chippings. ALD was determined by a nomograph method[5] (see Figure 5). Occasionally when work commenced at short notice aggregate properties could not be determined in advance; in such cases the design of the surface dressing was done on site, ALD being assessed visually. Subsequent laboratory checks enabled the design to be corrected if necessary but no large discrepancies occurred. The visual classification of flakiness was more difficult. Flaky aggregate is defined[8] as having a least dimension which is less than 0.6 of its nominal size, this size being taken as the mean of the limiting sieve sizes determining the size fraction.

The current British Standard specification for single sized chippings[6] allows a maximum flakiness index of 35; only 2 of the 23 samples examined failed in this respect. However ¾ in (20 mm) nominal sized chippings tended to contain unacceptable quantities of oversized material, whilst ½ in (14 mm) stone was usually undersized. Visual assessment was probably influenced to a large extent by the shape of the undersized material. Six out of 12 samples of ½ in (14 mm) nominal size stone contained unacceptable quantities of material passing ¼ in (6 mm) which is inadmissable for flakiness index determination.

TABLE 4

Surface dressing research, Kenya (1976–1977)
Summary of trial sections constructed to July 1977

Experimental numbers	Location	Trial type	Stone properties: Nominal size In.	Nominal size mm.	ALD mm	Rates of spread (binder) (kg/m^2): Design (original)	Min	Max	Binders used Pen at 25°C	Road Temp. °C (20 mm depth) Min	Max
KSD 1	A 104 Namanga Road 11.4 km from the Mombasa Road	Chipping size	¾	20	13	1.1	0.8	1.4			
			½	14	6	0.8	0.9	1.0	80/100	28	50
			¼	6	3	0.7	0.7	1.0			
KSD 2	A 104 Namanga Road 24 km from the Mombasa Road	Binder viscosity	¾	20	11	1.0	0.9	1.1	200/300	27	43
			½	14	6	0.8	0.6	0.8	300/400		
KSD 3	A 104 Namanga Road 27.2 km from the Mombasa Road	Double seal	¾	20	10	1.1 1st	0.7SA	1.3SA	180/200	24	35
			½	14	5	0.8 1st	0.7SA	1.4SA	200/300		
					6	1.0 2nd	0.7SA	1.2SA			
KSD 4	A 104 Makatano 18.2 km from Molo North Camp	Binder viscosity	¾	20	11	1.1	0.9	1.4	100/150	31	43
			½	14	7	1.0	0.9	1.0	200/300		
KSD 5	A 104 Makatano 19.4 km from Molo North Camp	Chipping size	¾	20	11	1.0	0.9	1.2	100/150		
			½	14	7	0.9	0.7	1.0	180/200	28	45
			⅜	10	5	0.8	0.7	0.8			
KSD 6	A 104 Kipkaren 11.8 km from Turbo Post Office	Triple seal	⅝	16	9	1.0 2nd	0.6S	0.9N	80/100	–	–
			⅜	10	5	0.9 1st	0.9S	0.9N			
			⅜	10	5	0.9 3rd	1.0S	1.0N			
KSD 7	Machakos-Wamunyu (at Makutano)	Double seal	¾	20	12	1.3C	1.0	1.3	80/100	26	31
						1.4UC	1.0	1.3			
			½	14	6	0.9C	0.7	1.1			
						1.0UC	0.8	1.2			
KSD 8	D 407 Limuru–Nairobi (Tigoni) 3.3 km from Bata Co, Limuru	Binder viscosity	½	14	7	0.9	0.7	1.1	180/200 300/400 225 sec (STV) at 40°C	25	44
KSD 9	A 109 (Athi River) Nairobi–Mombasa Road 4.6 km after E 434 turn-off	Binder viscosity	¾	20	12	0.9	0.7	1.0	200/300	33	52
			½	14	6	0.6	0.6	0.9	300/400 600		
KSD 10	A 109 (Athi River) Nairobi–Mombasa Road 14.4 km after E 434 turn-off	Emulsion trial	¾	20	12	1.8	1.5	1.8			
						1.3	1.3	1.3		29	46
			½	14	6	1.2 1st	1.1	1.3	60% emulsion (Cationic)		
						1.5 2nd	1.4	1.4			
KSD 11	ABANDONED										
KSD 12	C 29 (Luanda–Siaya) 13.7 km from B1 turn-off Luanda Village	Double seal	¾	20	12	1.5	0.7SA	1.8SA	200/300	28	50
			½	14	8	1.3 1st	1.0	1.2			
						1.2 2nd	1.2SA	1.8SA			
			Sand	–	–	0.8 2nd	0.8	1.0			
KSD 13	Kamwange–Mugumo Sect. 1 begins approx 4 km East of Thunguri MOW depot	Double seal	¾	20	11	1.3C	1.0	1.5			
			½	14	8	1.2 1st UC	1.1	1.4	200/300	26	50
						1.2 2nd UC	0.8	1.3			
KSD 14	A 14 (TIWI). Section 1 begins 11.2 km from top of Likoni Ferry Ramp (South)	Binder viscosity	½	14	7	0.9	0.7	1.2	200/300 300/400 400/500	30	52
KSD 15	A 109 Mariakani. Section 1 begins approx 5 km Mombasa side of Mariakani	Binder viscosity + chipping size	¾	20	13	1.1	0.9	1.5	180/200		
			½	14	7	0.9 1st	0.7	1.2	200/300	30	45
						1.0 2nd	0.7	1.0	400/500		
			Sand	–	–	0.7 2nd	0.9	0.9			

Abbreviations:
- ALD = Average least dimension
- SA = 'Split Application'; (rates applied as a percentage of total binder both layers)
- C = Coated chippings
- UC = Uncoated chippings
- STV = Standard tar viscometer
- Pen. = Penetration of bitumen at 25°C
- S,N = South, North

Notes

1. Binders used: Binders other than 80/100 or emulsion are blends of 80/100 and diesel fuel. The penetration values obtained on these blends have been considered as falling within the ranges shown, which are either arbitrary (eg 300/400) or represent a penetration range likely to be found in binder specifications in Europe or USA.

2. Stone properties: The metric sizes quoted are the nearest equivalents; exact equivalents are as follows:– ¾ in – 19 mm, ½ in – 12.7 mm, ⅜ in – 9.5 mm

6.2.2 Existing surface condition, traffic and climate. The condition of the existing surface and the traffic was assessed as required in the Jackson design method[5]. The climatic condition of most of the 14 experimental sites was assessed as semi arid (hot/dry) although two sites at approximately 2100m (7,000 ft) altitude were classified as 'temperate' and one other site (at sea level) as 'tropical' (hot/wet).

6.2.3 Design. The design rate of spread for the binder, D, was obtained from the design chart (Figure 6) using the overall factor for the site (see Appendix) in conjunction with the ALD of the stone. It should be recorded however that Jackson's recommendation that rate of spread of binder be reduced by 0.1 kg/m^2 when using penetration grades was not implemented, because of the presence of volatile oils in the blend. Measured rates of spread are reported as D ± x per cent. (For double seals D represents the total design quantity for the 2 layers.)

6.3 Construction

In order to simplify the monitoring of performance, a standard section length of 200m was adopted. Since in a typical experiment binder was applied at the design rate D and D ± 10 per cent a group of three such sections, ie 600 linear metres (average width 7m) could conveniently be constructed from one distributor-load of binder. In practice this represented one batch of blended binder. It was found to be most convenient to spray one half-width of road for three sections, then returning to the start point for the second half-width.

It was normal practice in Kenya for resealing units to spray half the width of road for some distance, the completed work then being kept closed to traffic for several hours whilst rolling continued. It was considered however that experimental work should, as for example in Europe, be exposed to the early-life hazards which affect routine resealing; thus when work moved on or ceased for the day, barriers were removed and all completed work was opened to traffic.

At some sites vehicles entered the road from unsurfaced minor roads; the transported dust or mud adhering to the road could not be entirely removed by the manual means available and the uniformity of the finished work suffered as a consequence in these areas. Distributor drivers sometimes failed to overlap the first spray adequately; also, because of the gritting equipment available, it was not practicable to leave 150 mm of binder unchipped at the centre line during the first pass, to be overlapped on the second application. These two factors produced unsprayed strips at the centre line or double-sprayed and chipped centre line joints which usually developed a ragged appearance under traffic.

6.3.1 Binder and road temperatures. The temperature of binder in distributors was checked regularly by Rotatherm thermometer at the loading hatch; appropriate spraying temperatures were selected for the nominal penetration ranges to which 80/100 pen had been blended.

Air and road temperatures were recorded at hourly intervals as far as possible during experimental surface dressing work. Road temperatures were recorded using a small mercury-in-glass thermometer (0–50°C) with its bulb immersed in an oil-filled hole 15–20 mm deep (see Figure 7).

6.3.2 Rate of spread measurements. Light metal trays approximately 10 mm deep and 0.1m^2 in area were used to check rates of spread. Three trays were placed for each 200m run of the distributor and the weight of binder deposited on each was recorded. The rate of spread, taken as the mean of three trays, assisted in the calibration of the machine and verified the rate of binder actually sprayed. The unsealed squares beneath the trays were repaired by hand in the earlier trials but subsequently they were allowed to remain thus providing a comparison between the original and the resealed surface. Unsealed squares were always repaired during work on new bases. The poor condition of some of the distributors sometimes prevented the required rates of spread from being obtained consistently.

6.3.3 Sampling and testing. Samples of chippings taken during construction, usually from the gritting vehicles, were checked for ALD and other properties. A 5 litre sample of binder was taken from the spray bar after spraying the first 200m pass and this was subsequently tested for penetration or viscosity.

7. POST CONSTRUCTION MEASUREMENTS

The trials were allowed to settle down under traffic before commencing post-construction measurements; the period varied considerably. Most sites were revisited within 2–3 months of construction, but two remote sites which carried very light traffic were not visited for 7 months. Two methods of measurement were used to assess the performance of the surface dressings:–

(i) The sand patch test. The test is described in TRRL Road Note No 27[10] and involves careful formation of a known volume of sand into a circular patch on the road surface (Plate 2). The diameter of the circle is recorded when the sand has been fully accommodated by the road texture, the depth of which is then calculated. Four tests were performed at each of 3 chainages in the wheel tracks and 2 tests out of the wheel tracks at one chainage in each 200m long trial section. The texture depth of a surface dressing tends to decrease under the action of traffic, until an unacceptable level of smoothness is reached; it then becomes necessary to restore texture depth (and hence skid resistance) by resealing.

(ii) The probe depth test. This test measures the hardness of the road surface so that chippings of suitable size can be selected for surface dressing. A Soil Assessment Cone Penetrometer[11], originally evolved for the rapid determination of soil strength in situ, is fitted with a 4 mm diameter hardened steel probe in place of the original cone. A pressure of 278 kg/cm^2 is maintained for 10 seconds and the penetration of the tip into the road surface is recorded (Plate 3). The test is normally performed before the surface dressing is designed but in this case the probe tests were done later, usually in the unsealed squares left by rate-of-spread trays. The test was not used at 3 sites where surface dressings were applied over new crushed-stone bases.

In addition the surface appearance of the surface dressings has been photographed at yearly intervals; a tripod-mounted camera is focussed on a 1m^2 frame alongside each sand patch test point. Contiguous pairs of photographs are taken so that each photo records one wheel track and part of the oil lane. Subjective assessments of each section have also been made annually and traffic counts taken.

8. DISCUSSION AND RESULTS

8.1 Condition of chippings

Chippings stock piles often contained undesirable amounts of dust; at two sites near Nairobi, where rain fell a few hours before the surface dressing was due to start, the dust was found to have formed a thin 'slurry' coating on the chippings. The condition was evidently recognised by local operators as a potential source of failure resulting from non-adhesion of the chippings. However whilst undesirable, this did not prevent the construction of a good surface dressing, provided that binder viscosity was appropriate to road temperature. 'Slurried' stone taken from the stock pile only two hours after heavy rain had fallen dried out rapidly on the road and was wetted readily by 200/300 and 300/400 pen blended binders.

At a subsequent trial near Mombasa, very dusty ½ in (14 mm) limestone chippings were supplied; the stock pile was hosed down immediately before use and, again, good adhesion was obtained.

8.2 Effect of road temperature on binder selection

One of the primary objectives of the trials was to examine the performance of binders of different viscosities in resealing. In effect this implies validation of the chart shown in Figure 8 which was prepared by Shell International Petroleum Company and which shows that, when surface dressing, the binder in use should have a viscosity at road temperature within the range 10^4 to 6 x 10^5 centistokes (for 'heavy' traffic conditions this range is somewhat smaller).

The significance of Figure 8 is that two conditions need to be satisfied simultaneously:

(a) chippings must be wetted by the binder,
(b) chippings once wetted must be retained.

This chart is a guide to the use of hot petroleum bitumens only: coal tars occur very infrequently in developing countries and are not therefore included. Bitumen emulsions on the other hand have a low viscosity; thus spraying and wetting occur readily. Upon 'breaking' the emulsion yields a relatively high viscosity penetration grade bitumen which retains the chipping. The chart in Figure 8 therefore has little relevance to the use of emulsions. Only four sections were constructed with an emulsion binder, which was a cationic (60 per cent) emulsion (site KSD 10). Their usefulness was largely lost because of faulty spraying equipment and no useful conclusions can therefore be drawn from these four sections.

The maximum and minimum temperatures of roads on which different blends were sprayed in the Kenyan trials have been plotted on Figure 8. Since the actual penetration values obtained on certain blends did not fall within the close ranges maintained by commercial producers, the temperature data for these has been plotted on the nearest appropriate grade line. Of the four points which appear below the 400/500 pen-line, two correspond to a 600 pen blend and two represent a blend having a viscosity of 225 sec STV at 40°C (equivalent to 9 x 10^4 centistokes at 40°C).

Of the 46 points plotted, 20 (43 per cent) fall within the permissible range. The remainder would be classified as 'poor wetting' risks according to the chart. However these include binders used at 3 new construction sites and at 3 very lightly trafficked sites where prolonged rolling could proceed unhindered and traffic whip-off risk was virtually non-existent. The softest binders worked excellently; a 600 pen blend held ¾ in (20 mm) stone well under medium-heavy traffic on the Nairobi–Mombasa Road near Nairobi, whilst a 400/500 pen was very effective with a ¾ in (20 mm) dusty stone on the same road near Mombasa. The 225 sec STV at 40°C blend was used successfully with ½ in (14 mm) chippings under medium/heavy traffic near Nairobi.

At the one main site where 80/100 pen binder was used surface temperatures were between 33–50°C, traffic was light and chipping lorries were made to follow close to the distributor. These conditions are much more favourable than those normally experienced in some developing countries and the resultant success using 80/100 pen at this site is not therefore remarkable. Figure 7 shows the relationships between air and road temperatures recorded at surface dressing sites during 1976/77. The scatter of points is due to various causes, eg heating/cooling cycles, changes of wind direction, etc. The chart should, however, assist in predicting road surface temperature from air temperature readings; prediction is likely to be reliable to within plus or minus 5°C of the true value in the road temperature range 25/45°C. This range represents virtually all the sites which were surface dressed in the research programme and should therefore be applicable for routine resealing work in Kenyan conditions. The significance of the predictable accuracy is that, if the binder to be used for resealing is selected such that the predicted road temperature (Figure 7) intersects the binder grade line at 10^5 centistokes (Figure 8), then an error of ± 5°C in prediction will be tolerated by the permissible range of working viscosities. Figure 7 also shows the temperatures at which 4 selected binders have a viscosity of 10^5 centistokes.

8.3 Double surface dressing

Double surface dressings were constructed at four sites, the main features of which can be summarised as follows:–

Site No.	Features
KSD 3	Light traffic; 'split' binder application, delayed and undelayed second seals; 2 stone size combinations.
KSD 7	Very light traffic; standard binder application; delayed and undelayed second seals; coated and uncoated chippings.
KSD 12	Light traffic; split and standard binder application; undelayed second seals; chippings or sand for second seals.
KSD 13	Light traffic, standard binder application; undelayed second dressings; coated and uncoated chippings, 2 stone size combinations.

The standard specification in Kenya for double surface dressing calls for ¾ in (20 mm) chippings to be followed by ½ in (14 mm). Table 2 shows the extent to which nominal ½ in (14 mm) chippings supplied failed to meet British Standard 63[6]. It could be argued that some samples of the ½ in (14 mm) material more nearly represented ⅜ in (10 mm) chippings containing oversize material. Their performance when used as second seal cover aggregate however lends support to the proposition that the aggregate of the second seal should differ in size by at least 50 per cent from that of the first seal. It is suggested, therefore, that for double seals, ¾ in (20 mm) chippings should be followed by ⅜ in (10 mm) material. For example this would be suitable over a rich bituminous surfacing which would permit the larger chipping a degree of embedment. This is illustrated by the experimental site KSD 15 where the old bituminous surfacing was extensively cracked; here the trial sections constructed showed that:

(i) A single seal (nominal ½ in (14 mm) chippings) was not sufficient to seal the badly cracked surface. A double seal ¾ in (20 mm) plus a ½ in (14 mm) was in good condition after 2½ years trafficking.

(ii) A double seal, ¾ in (20 mm) chipping plus sand as second seal cover material, was also in good condition after 2½ years and is potentially an effective treatment. This combination was also tried successfully at a new road site with a crushed rock base (KSD 12).

Some engineers favour the use of double seals for all routine maintenance, irrespective of pavement condition or traffic. Assuming the existence of a sound pavement structure, the main parameter determining the life of a surface dressing is likely to be rate of loss of surface texture, and it is questionable whether or not this is likely to be enhanced by the use of a double rather than single seal. Observation of some completed double seals suggests that, in the absence of good control, the chances of fatting-up are greater than with single seals. Double seals are useful however for the maintenance of roads which are badly cracked or which have a ravelled surface. In all cases experience indicates that the performance of a double seal is improved by delaying the application of the second seal by at least 14 days, as opposed to applying immediately the first seal has been laid.

The double surface dressing trials showed clearly the advantage of allowing the first seal to be trafficked before placing the second. The Jackson design method, applied individually to each layer appeared to produce a correct rate of spread of binder. (Note: the existing surface condition for the second layer was rated as 'very lean bituminous', because of the asperity of the first layer.) In view of the success of this approach it is difficult to justify an arbitrary 'split' of binder between the two layers. However; one authority[12] suggests that the total application of residual binder be split:

First layer	40 per cent
Second layer	60 per cent

This is likely to be safely achieved only on new construction or on a very lightly trafficked road. In other situations the first dressing which is likely to be a ¾ in (20 mm) material may be whipped-off by fast vehicles. This occurred at experiment KSD 11 which was to have been a split-application trial on the Nairobi–Mombasa road (approximately 2500 vpd): sections chipped with a nominal ¾ in (20 mm) material suffered severe whip-off and because of an unavoidable delay the second seal could not be placed before much damage had occurred.

Cost estimates for 6 resealing projects in one province of Kenya show that 45 per cent of the total cost was attributable to the second seal; the potential saving of using single seals only is therefore significant.

8.4 Traffic

For the purpose of designing the trial surface dressings traffic levels were estimated. The results of traffic counts made subsequently are shown in Table 5. Table 6 shows the effect of differences between the estimated and actual traffic classifications on the rate of spread of binder. It will be seen that if traffic is wrongly classified by one traffic category then the design ROS (binder) will be affected approximately as follows:

Stone size (nominal)	Effect of difference of one traffic category
¾ in (20 mm)	D ± 10 per cent
½ in (14 mm)	Negligible

TABLE 5

Experimental surface dressing, Kenya; traffic data (source: Kenya Ministry of Transport and Communications)

Experiment	Survey site	Years	Cars	Light goods	Medium goods	Heavy goods	Buses	Total	Mean total	Traffic class: Actual	Traffic class: As estimated for design
KSD 1/3	a	1976 and 78	187	140	139	10	8	484	473	Light	Very light
KSD 1/3	b	1976 and 78	189	132	126	6	9	462			
KSD 4/5	c	1976/77	219	126	97	32	35	509	509	Medium	Medium
KSD 8	d	1977/78	579	366	106	3	28	1082	1098	Medium/Heavy	Light
KSD 8	e	1977	776	224	68	2	44	1114			
KSD 9/10	f	1976/78	913	450	523	333	119	2338	2376	Medium/Heavy	Heavy
KSD 9/10	g	1976 and 78	976	458	550	291	138	2413			
KSD 12	h	1976	61	91	62	1	17	232	232	Light	Very light
KSD 13	No data: 100 < Estimate < 300									Light	Very light
KSD 14	j	1976 and 78	552	457	225	17	111	1362	1192	Medium/Heavy	Medium
KSD 14	k	1976 and 78	493	439	144	15	86	1177			
KSD 14	l	1976 and 78	451	352	128	19	88	1038			
KSD 15	m	1976 and 78	421	250	180	252	138	1241	1369	Medium/Heavy	Medium/Heavy
KSD 15	n	1977	419	285	301	340	152	1497			

TABLE 6

Effect of incorrect traffic classification on Design ROS (Binder)
(Note: '¾' and '½' are nominal stone size, inches)

Experiment	Overall design factor		Rate of spread (Binder) (D) (kg/m²)		Change in ROS (% of D)	
	Original	Revised	Original	Revised		
KSD 1	–1	–3	¾–1.1 ½–0.8	1.0 0.8	D–10 –	
KSD 2	–1	–3	¾–1.0 ½–0.8	1.0 0.8	– –	
KSD 3	(Lower) –1	–3	¾–1.0 ½–0.8	0.9 0.8	D–10 –	
KSD 3	(Upper) +4	+2	½–1.0	0.9	D–10	
KSD 4/5	+2	+2	No change due to traffic classification (Revised during construction due to old surface)			
KSD 8	–2	–4	½–0.9	0.8	D–11	
KSD 9/10	Single seals only – ¾–5 ½–9†	–3 –7†	0.9 0.6	1.0 0.7	D+11 D+17	Original road surface different Sections 1-9 and Sections 10-19
KSD 12	(Lower) ¾+10	+8	1.5	1.4	D–7	
KSD 12	(Upper) ½+8	+6	1.2	1.1	D–8	
KSD 13	No survey					
KSD 14	½ 0	–1	0.9	0.9	–	
KSD 15	No change required					

† Note: the Jackson design method[5] does not actually include factors for these combinations of traffic/surface/climate/chipping.

Normally a quite rudimentary traffic count should be sufficient to avoid such errors in calculating ROS, which are less than those likely to arise from such causes as bad distributor operation, poor mechanical condition, etc.

8.5 Surface texture measurements

Loss of texture can be caused by:

(i) embedment of chippings
(ii) abrasion of chippings
(iii) excess of binder
(iv) deposition of foreign material.

Embedment could be expected to occur on all but 3 sites, ie KSD 7/12/13, which had new crushed rock bases. The existing surfaces at the remainder of the sites were either premix or old surface dressings. Abrasion of chippings was most likely to occur at only 2 sites, ie KSD 14 and 15, where soft local limestone chippings were used. Deposition of foreign material can take a number of forms, the governing feature being (as far as it affects the sand patch test) whether the deposit consists of bound material (ie clayey or resinous materials) or sand and grit which have no permanent effect on surface texture unless they are retained by excess bitumen in the surfacing.

Loss of surface texture of the trial sections has been calculated as follows:

(i) From tests at 3 chainages in each section the average texture depth for a given wheel track has been calculated for each time the measurements were made.

(ii) The loss of texture depth for a given lane has been taken as the mean of the two wheel tracks in the lane.

The percentage losses in texture depth thus obtained have been plotted against age (months): Figure 9 shows a typical example.

Table 7 shows the average texture depth recorded in a single nearside wheel track for different dressing types in each experiment; this Table is presented in order to record relative magnitudes of texture depth for these dressing types. Table 8 shows the minimum/maximum percentages of texture depth lost under traffic; all experimental variations, ie stone size, binder ROS, wheel track and direction, are combined.

In general terms, texture loss during the first 2 years appears to be:

for light traffic	5–55 per cent
for medium/heavy traffic	35–85 per cent

Table 8 shows clearly that texture loss is rapid during the initial 12–18 months whilst chippings become embedded and interlocked. Subsequent loss appears to be slow unless, as in KSD 15, an abradable stone has been used and/or the surface is relatively soft.

TABLE 7

Texture depths (mm). (Single nearside wheel track only)

Expt. KSD	Stone size (in)	Stone size (mm)	Period under traffic (months) Initial	11–16	22–28	31–36	42–44	54	Vehicles per day	Traffic classification	Dressing type
1	¾	20	5.17	4.74	–	3.51	–	3.66	473	Light	Single
	½	14	2.83	2.61	–	1.88	–	1.99			
	¼	6	0.95	–	–	0.70	–	0.71			
2	¾	20	6.28	–	4.18	3.76	–	3.82	473	Light	Single
	½	14	2.73	–	1.96	1.81	–	1.82			
3	¾ + ½	20 + 14	4.36	–	3.40	3.45	–	–	473	Light	Double 1 day delay
	¾ + ½	20 + 14	4.11	–	2.48	2.24	–	–			Double 14 day delay
	½ + ½	14 + 14	2.73	–	1.54	1.34	–	–			Double 1 day delay
	½ + ½	14 + 14	2.37	–	1.25	1.02	–	–			Double 14 day delay
5	¾	20	5.68	3.01	2.28	–	–	–	509	Medium	Single
	½	14	3.50	1.78	1.10	–	–	–			
	⅜	10	1.86	0.77	0.45	–	–	–			
8	½	14	3.27	1.90	1.57	–	–	–	1098	Medium/heavy	Single
9	¾	20	4.68	2.36	1.96	–	1.75	–	2376	Medium/Heavy	Single
	½	14	2.65	1.35	1.11	–	1.25	–			
12	¾ + sand	20	2.66	1.59	1.80	–	–	–	232	Light	Double
	¾ + ½	20 + 14	2.69	2.04	1.80	–	–	–			
	½ + sand	14	1.81	1.52	1.49	–	–	–			
	½	14	2.71	2.04	1.98	–	–	–			Single
13	¾ + ½	20 + 14	3.03	2.41	–	–	–	–	est. 100-300	Light	Double
	½ + ½	14 + 14	2.51	1.67	–	–	–	–			
14	½	14	3.34	1.65	1.65	–	1.72	–	1192	Medium/Heavy	Single
15	¾ + sand	20	3.62	0.70	0.65	–	–	–	1369	Medium/Heavy	Double
	¾ + ½	20 + 14	3.28	1.08	0.94	–	–	–			
	¾	20	4.48	1.85	1.55	–	–	–			Single
	½	14	2.90	1.18	0.91	–	–	–			

TABLE 8

Texture loss under traffic (to nearest 5 per cent of original texture depth)

Experiment (KSD)	Period under traffic (months)					Vehicles per day	Traffic classification	Dressing type
	11–16	22–28	31–36	42–44	54			
1	5–35		20–50		15–50	473	Light	Single
2		5–45	20–60		25–60	473	Light	Single
3		15–55	10–60			473	Light	Double
5*	25–75	50–85				509	Medium	Single
8	20–55	35–60				1089	Medium/Heavy	Single
9	25–70	40–80		25–70		2376	Medium/Heavy	Single
12†	0–40	5–50				232	Light	Double
13†	0–50					estimated 100–300	Light	Double
14	35–65	35–65		35–70		1192	Medium/Heavy	Single
15	25–80	50–85				1369	Medium/Heavy	Single + 3 double

* Although traffic volumes were moderate, KSD 5 was subjected to some heavy Uganda-bound vehicles

† KSD 12 and 13 were the only sites at which surface dressings were applied directly over a new crushed stone base

8.6 Road hardness (probe depth test)

Figure 10 shows the probe penetration/road temperature relationships obtained; results for only one lane of the road are reported. Four characteristic curves are also shown in Figure 10; these are based on research[11] by the Materials Division, TRRL which has produced the following penetration values corresponding to the hardness categories given in Road Note 39[2]:

Category	Penetration at 30°C (mm)
Very hard	0–2
Hard	2–5
Normal	5–8
Soft	8–12
Very soft	More than 12

(Testing at 20–35°C is recommended, followed by correction to 30°C using the curves shown.)

Assuming that probe penetrations can be validly corrected from temperatures higher than 35°C the penetration values shown in Figure 10 indicate that almost all of the existing surfacings used for the trials would be classified as 'normal' or 'hard'.

8.7 Subjective assessments

The observations made during an inspection in 1979 are summarised for each experimental site in Table 9. In particular the apparent tolerance to under- or over-spray was noted. In assessing the validity of the Jackson design method[5] it is important to note than in the Kenyan trials it was possible to use chippings only in the ALD range 5 to 13 mm. Whilst this might well represent the practical range of ALDs to be expected in most developing countries it should be noted that the design chart (Figure 6) was not tested for chippings with ALDs falling in the upper half of the chart.

Table 9 shows that sections containing ½ in (14 mm) nominal size chippings appear to have an ROS (binder) tolerance of D ± 10 per cent for most traffic situations. For climbing traffic a reduction of 10 per cent is beneficial whilst for fast or downhill traffic an increase of 10 or even 20 per cent would seem desirable. The Jackson design method makes no provision for such adjustments.

It is important that the needs of the whole pavement width be considered when, for example, assessing the performance of a given surface dressing; it would be misleading to relate the surface texture in wheel tracks only to rate of spread of binder. The oil lane, centre line and edges are elements of the surface dressing which are as much at risk as are the more frequently tracked bands of the dressing. It follows that some enrichment, but not fatting up, may have to be accepted in the wheel tracks of channelised traffic if sufficient binder is to be provided for the dressing as a whole.

Blended binders wetted and retained chippings very effectively: possible exceptions were those used at KSD 4/5, which were the first blends attempted in the programme and the required viscosities were not attained. Differences in binder viscosity do not appear to have affected significantly the performances of comparable sections of surface dressing; however two blends which had viscosities at road temperature in the lower half of the permissible range (Figure 8) were very effective in wetting and retaining chippings. On no occasion were chippings lost due to low binder viscosity, although for safety reasons it was considered inadvisable to risk such a situation.

9. CONCLUSIONS

The trial sections of surface dressing constructed in Kenya in 1976–77 have now been trafficked for some 3 years. The following main conclusions can be drawn from their performance up to October 1979:

1. The Jackson design procedure[5] appears to provide a correct rate of spread of binder for Kenyan conditions for chippings which have an ALD in the range 5 to 13 mm. (This is the ALD range of the chippings used in the trials and it is adequate for most resealing operations in Kenya.)

2. Although not prescribed in the Jackson design method it is considered that, in general, the design ROS for binder should be increased by 10–15 per cent for fast or downhill traffic conditions and decreased by 10 per cent for slow or uphill conditions.

3. When applying the Jackson design method it is imperative that all other conditions necessary for good surface dressing are also met, including the selection of correct binder viscosity, rapid and complete application of chippings, good plant operation and job control. *Without these provisions the use of any design method is of little relevance.*

TABLE 9

Experimental surface dressings, Kenya; summarised observations October 1979

Site	Trial type	Traffic category	Site characteristics	Summarised observations
KSD 1	Chipping size	Light	Laden lorries on Nairobi bound lane, partly uphill.	80/100 pen, only, used: for ¾ in (20 mm) chipping D to D+15 acceptable; D–10 is critical downhill but acceptable uphill. For ½ in (14 mm) chipping, D to D+10 acceptable: D+20 excessive but tolerated. ¼ in (6 mm) chipping, D+20 acceptable or slightly excessive.
KSD 2	Binder viscosity	Light	As KSD 1	For ¾ in (20 mm) chippings D–10 probably critical, but rates up to D+15 tolerated. For ½ in (14 mm) chippings D is correct or even slightly excessive; D–20 not tolerated. Blended binders, range 300–400 pen, gave good wetting and retention.
KSD 3	Double seal; 'split' binder application	Light	As KSD 1	Improved appearance without loss of texture when 1st seal is trafficked for 14 days before applying 2nd seal. No advantage apparent in disproportionate splitting of total binder quantity; (inadvisable when road already in use vis a vis new construction). Design ROS appears correct.
KSD 4/5	Binder viscosity and chipping size	Medium	Vehicle count not high but site carries very heavy axles, including lorry/trailer units, en route to Uganda.	Pavement failure developed in 16 months after laying trials. Concluded that binder viscosity could be critical at this site (required viscosity not attained). (Essentially only in 150–200 pen range.) Concluded that: (i) for ¾ in (20 mm) chippings, ROS below 'D' would not be tolerated, in existing poor adhesion conditions. D+10 would have been beneficial but rates greater than this would lead to excessive texture loss. (ii) D–20 tolerated for ½ in (14 mm) chippings and would have been correct for uphill, slow lorry conditions. Overall D to D–10 acceptable. (iii) ⅜ in (10 mm) chippings unsuitable for site conditions but D–20 would have been adequate (Site abandoned 1978 due to extensive damage and repairs).
KSD 8	Binder viscosity	Medium/Heavy	Gradient over most of site. Mainly cars and light/med goods vehicles.	Binders 178 and 317 pen, and 225 sec at 40°C (STV); all wetted and held chippings well. D+20 appears to be tolerated by downhill traffic and D–20 by uphill traffic (only ½ in (14 mm) chippings used). Concluded that D–10 would be correct for uphill and D for level traffic.
KSD 9	Binder viscosity	Medium/Heavy	Undulating main road (Nairobi–Mombasa). Heavy vehicle (+ trailer) combinations.	Blended binders in range 200–400 pen, plus one 600 pen. All wetted and retained chippings well. Concluded that: for ¾ in (20 mm) chippings; D–20 probably tolerated in heavy traffic environment, given good wetting and traffic control. Good performance with 'D' over 3 years. D+10 beneficial for downhill, or D–10 for uphill traffic. For ½ in (14 mm) chippings; over-sprays up to 30 per cent apparently tolerated. Considered to be due possibly to accommodation of undersized material, in binder film with larger stone also held above it.
KSD 10	Emulsion trial	Medium/Heavy	Short trial length (800m) fairly level.	No firm conclusions; problem of 'drainage' prior to break during construction very apparent.
KSD 12	Double seal (new construction)	Light	Steep escarpment for most of length.	Design rate, D, substantiated; 10 per cent reduction for climbing traffic appears correct. Enrichment in wheel tracks not taken to represent binder excess in rest of lane.
KSD 13	Double seal (new construction)	Light (or very light)	Hilly region; road with continuous changes in vertical and horizontal geometry.	The effect of construction traffic may interfere with interpretation of results; also design based on unrepresentative samples of chippings. Result of above is probable cause of apparent over-design of 10 per cent. Moreover, at one section, scuffing was occurring in untrafficked portions on bend; illustrates need to consider whole width, not merely wheel tracks. In general, experiment shows a tolerance of D ± 10 per cent.
KSD 14	Binder viscosity	Medium/Heavy	Level, straight road in coastal belt.	D ± 10 per cent appears to be satisfactory. Possibility of multiple layer of aggregate formed due to large amount of undersize material and dust. Blended binders (218, 373 and 506 pen) wetted aggregate effectively. (Note: aggregate hosed-down and applied still wet.)
KSD 15	Chipping size + double seal	Medium/Heavy	Mainly straight main road with sag curve.	Double seal clearly necessary to seal badly crazed surface. Calculated ROS for double seals correct if uphill/downhill traffic allowed for. For ½ in (14 mm) chippings, a tolerance of D ± 20 (cf KSD 14) appears to operate. For ¾ in (20 mm) chippings, tolerance appears to be D+10 to D–20. (Note: chippings from same source as for KSD 14.)

4. Binders with a viscosity at road temperature in the range 50,000–500,000 centistokes wetted chippings effectively; where excessively dusty chippings occurred it proved to be beneficial to wet stock piles thoroughly with water, provided that good drying conditions prevailed during the spraying and chipping operations.

5. The Jackson design method appears to apply equally well to double seals as to single seals. In spite of poor quality ½ in (14 mm) chippings, double seals employing ½ in plus ½ in chippings are performing very well: similarly ¾ in (20 mm) chippings followed by sand as second cover material have produced well-grouted stable seals. Experience indicates that the performance of a double seal is improved by delaying the application of the second seal by at least 14 days after the first seal, and allowing traffic to use the first during this period.

6. It is recommended that each layer of a double seal is sprayed at its design ROS, rather than adopting an arbitrary 'split' of the total binder required.

7. When any existing surface with a significant degree of surface texture is being resealed, use of the Jackson design method will require it to be rated as 'very lean bituminous'.

10. ACKNOWLEDGEMENTS

The work described in this report forms part of the research programme of the Overseas Unit (Unit Head: Mr J N Bulman) of the Transport and Road Research Laboratory. The research was undertaken with the support and cooperation of the Ministry of Transport and Communications, Republic of Kenya. The cooperation and encouragement shown at all levels in the Roads Branch, is gratefully acknowledged and the assistance of the Maintenance Branch, the Materials Branch, and the Staff Training Department is much appreciated.

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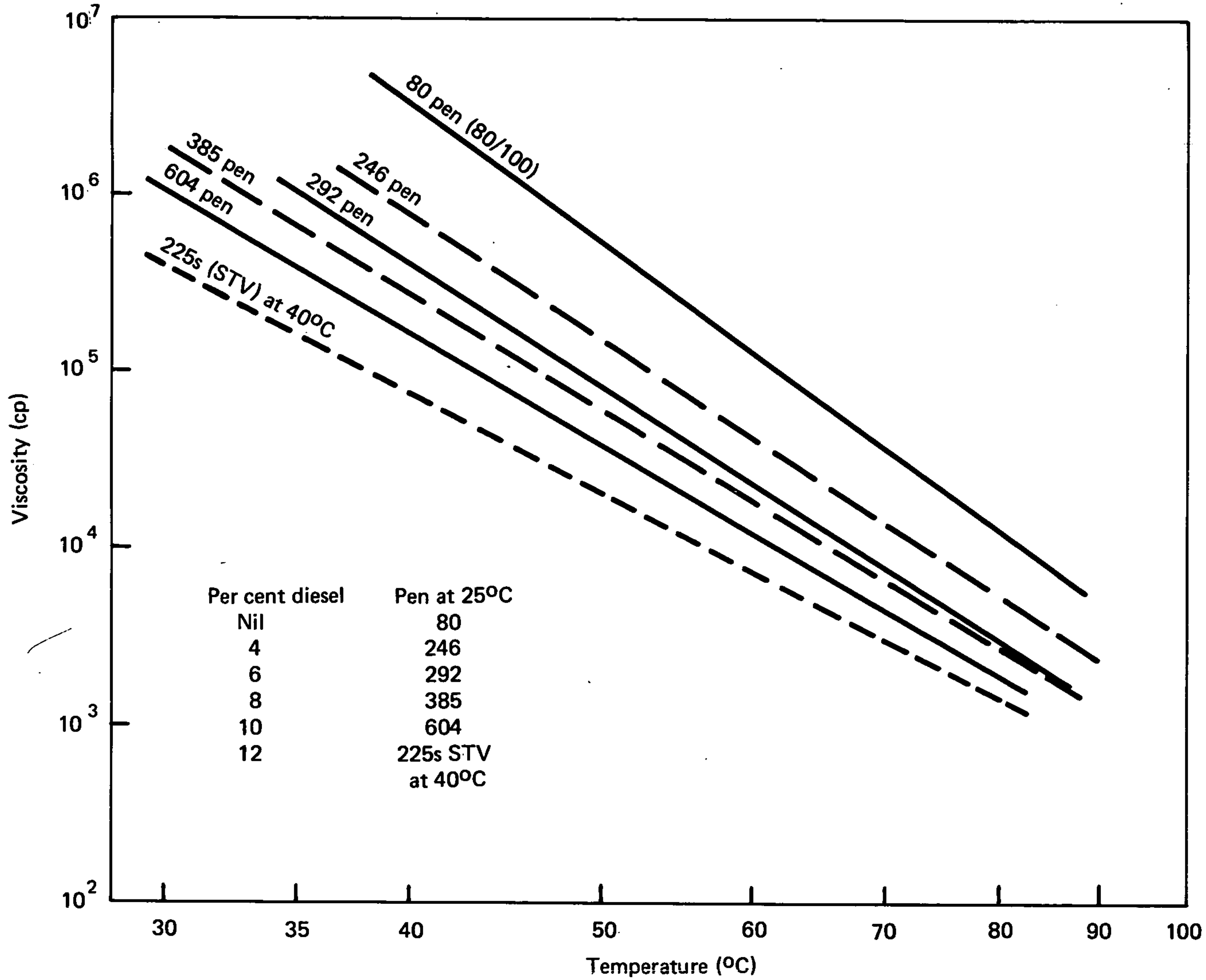

Fig. 1 Blends of 80/100 pen + diesel fuel used for surface dressing : viscosity/temperature relationships

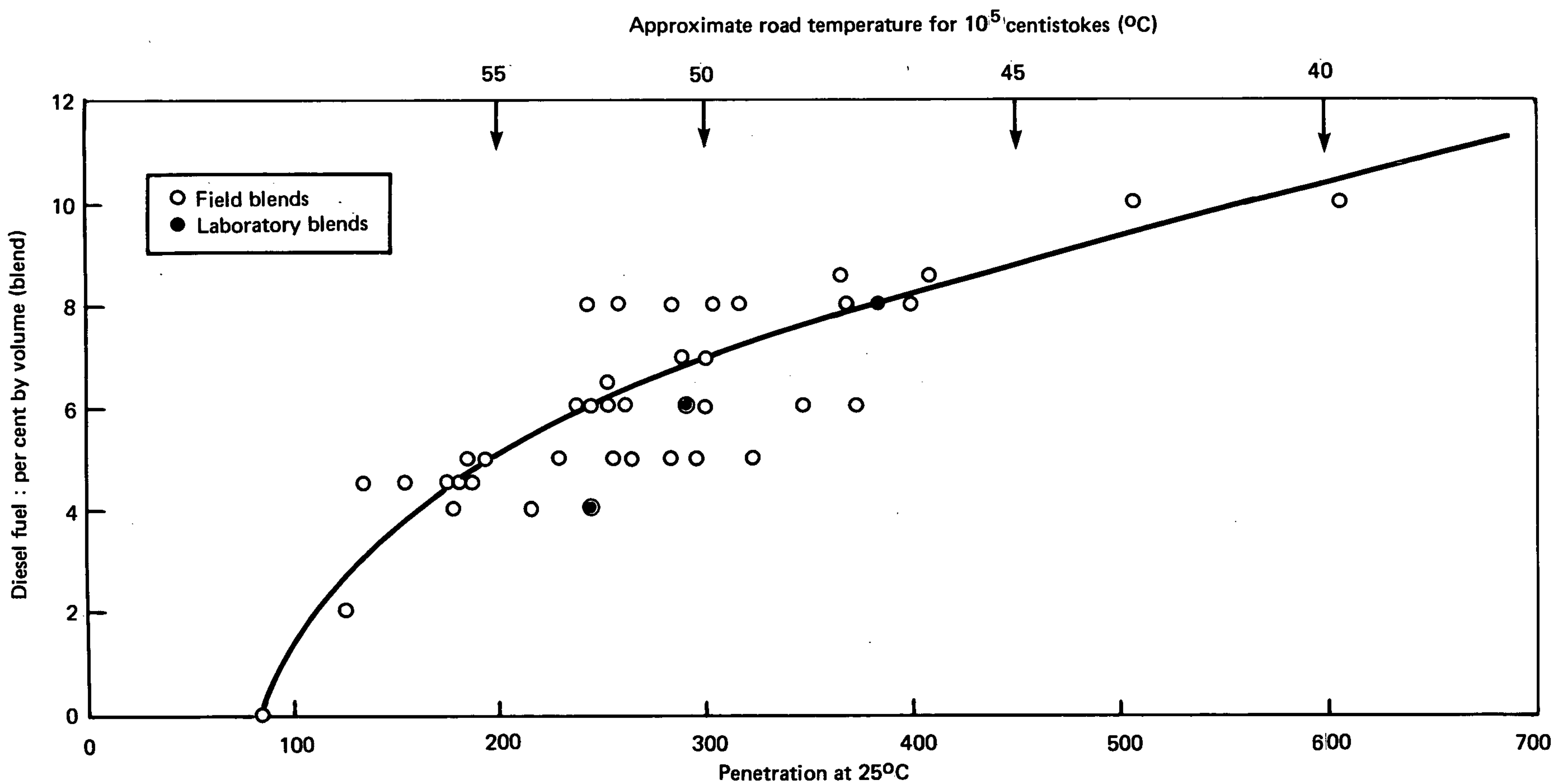

Fig. 2 Blending characteristics of 80/100 pen + diesel fuel

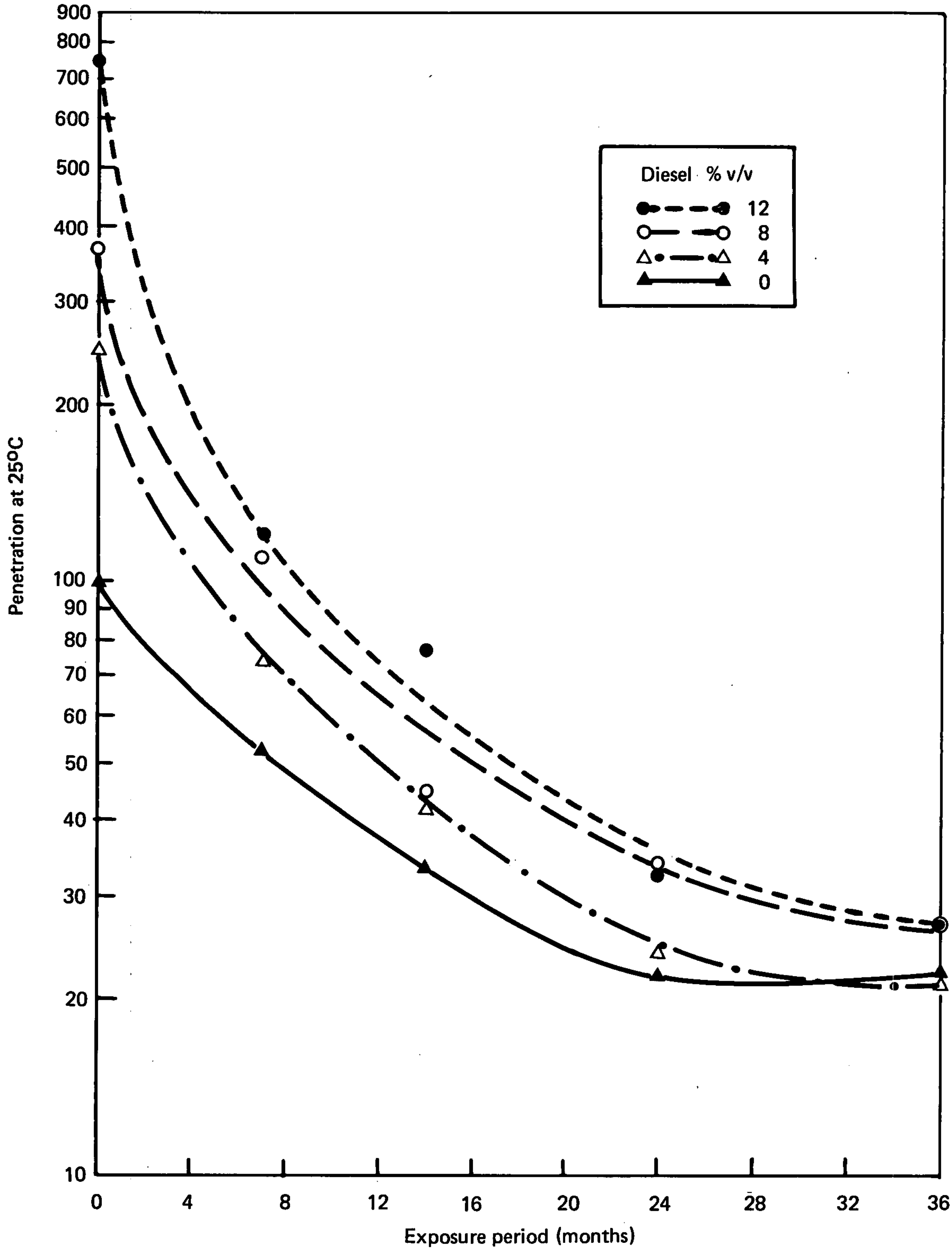

Fig. 3 **Rate of curing trials : blends of 80/100 pen + diesel fuel. Penetration tests on recovered binder**

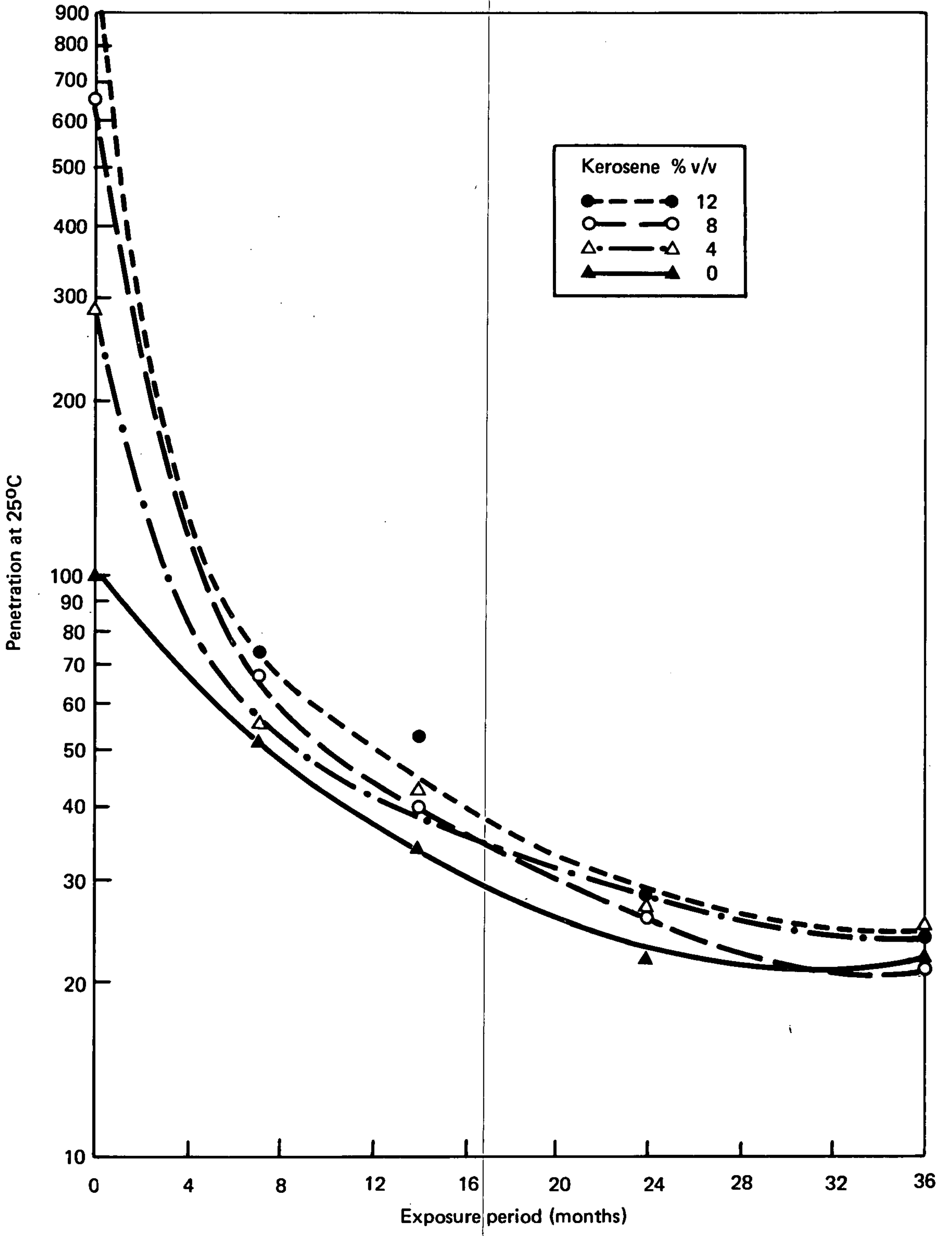

Fig. 4 Rate of curing trials : blends of 80/100 pen + kerosene. Penetration tests on recovered binder

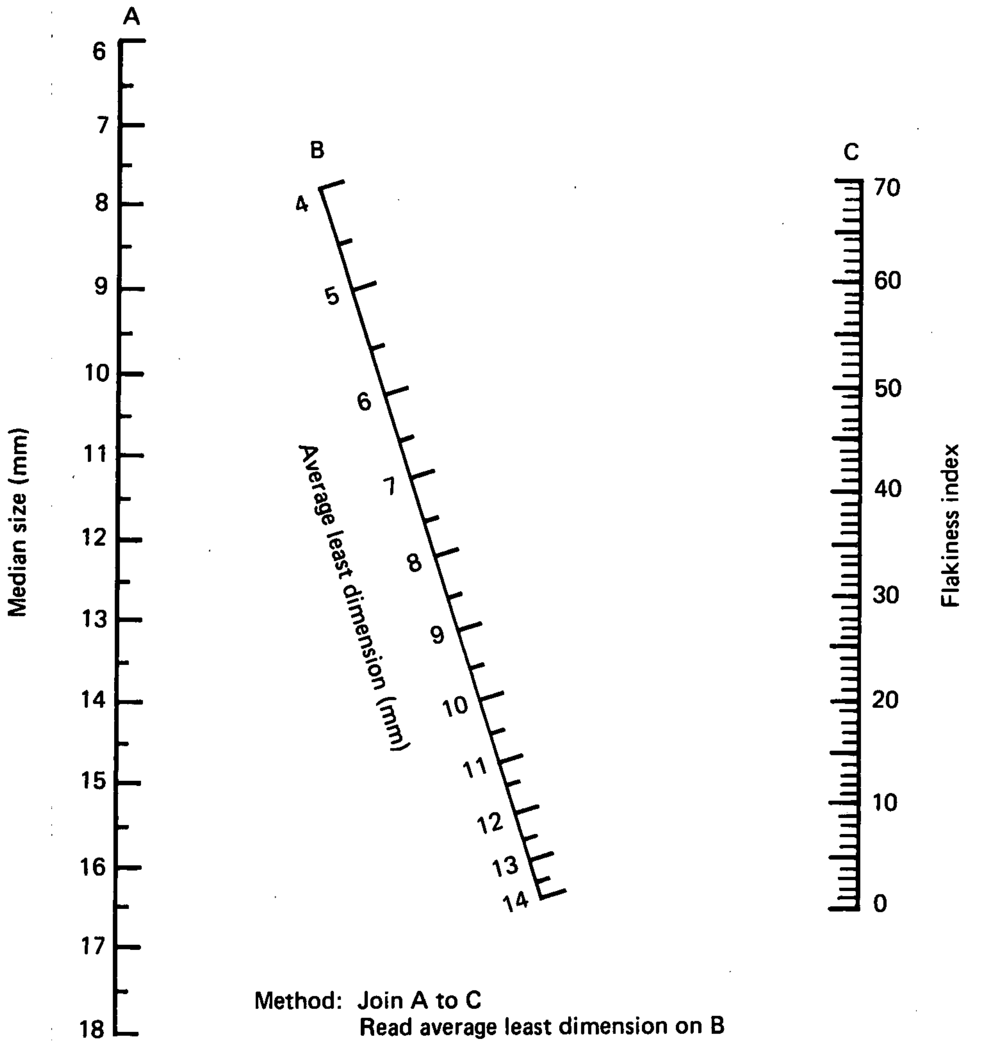

Fig. 5 Determination of average least dimension

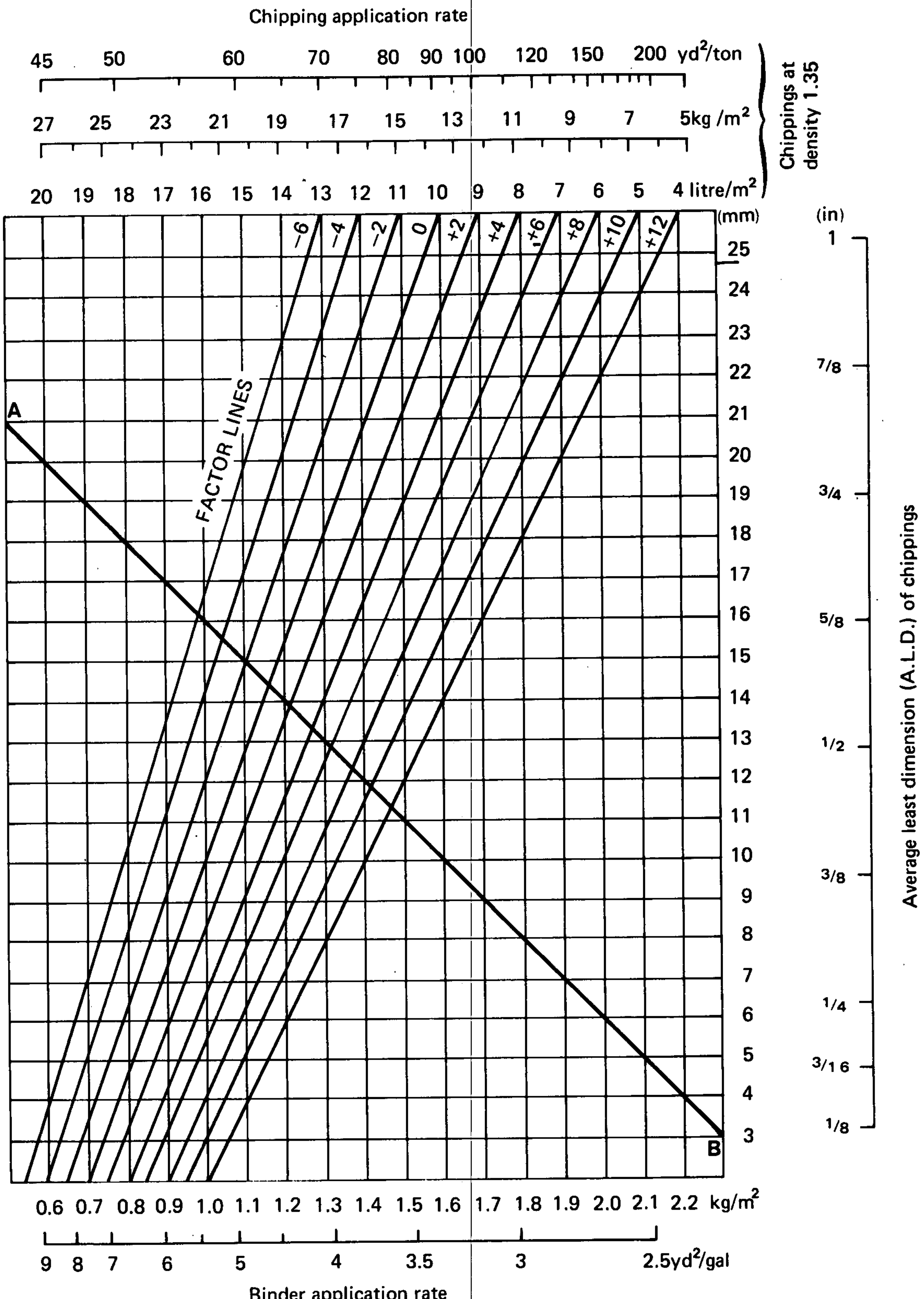

Fig. 6 Surface dressing design chart

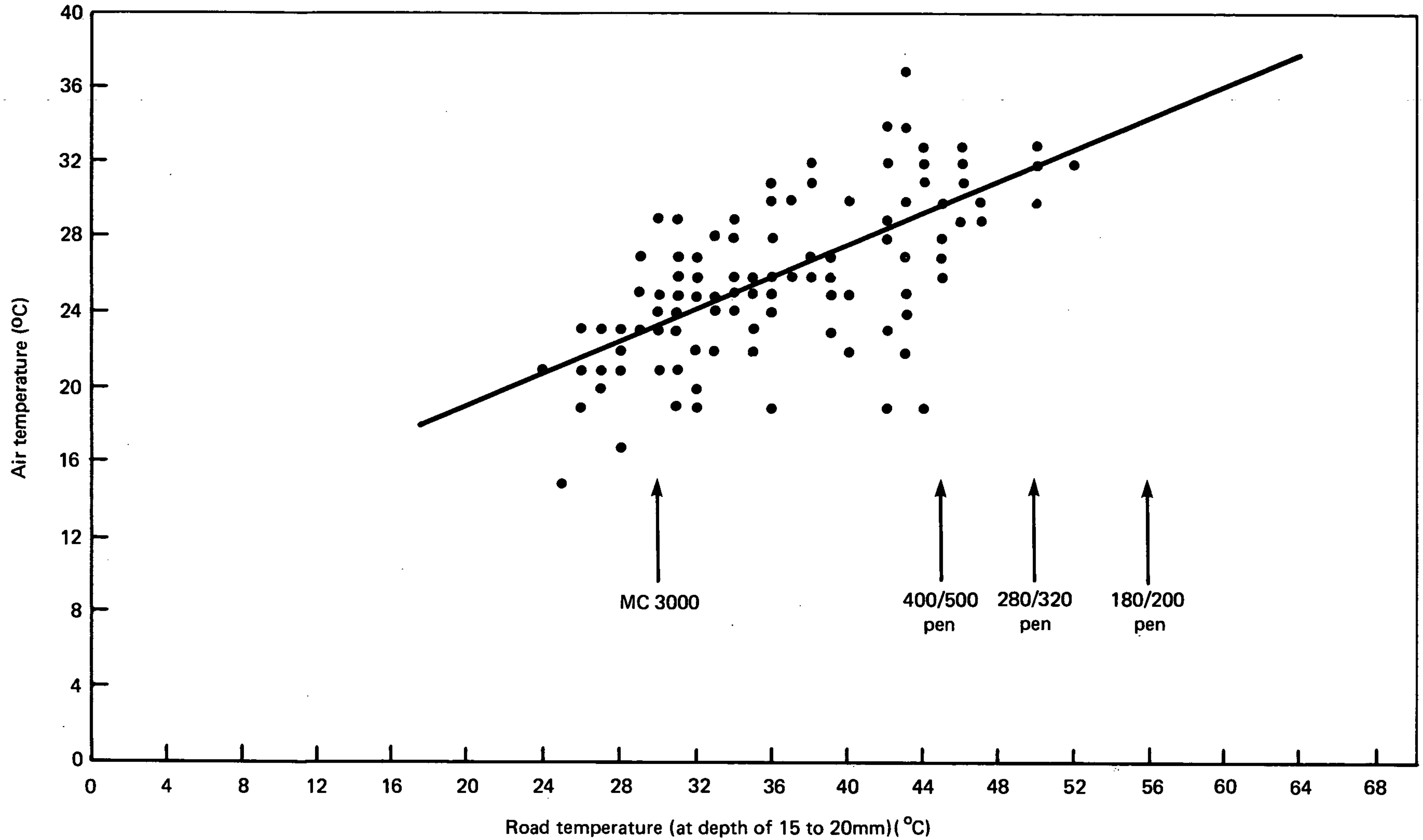

Fig. 7 Air/road temperature relationships, East Africa

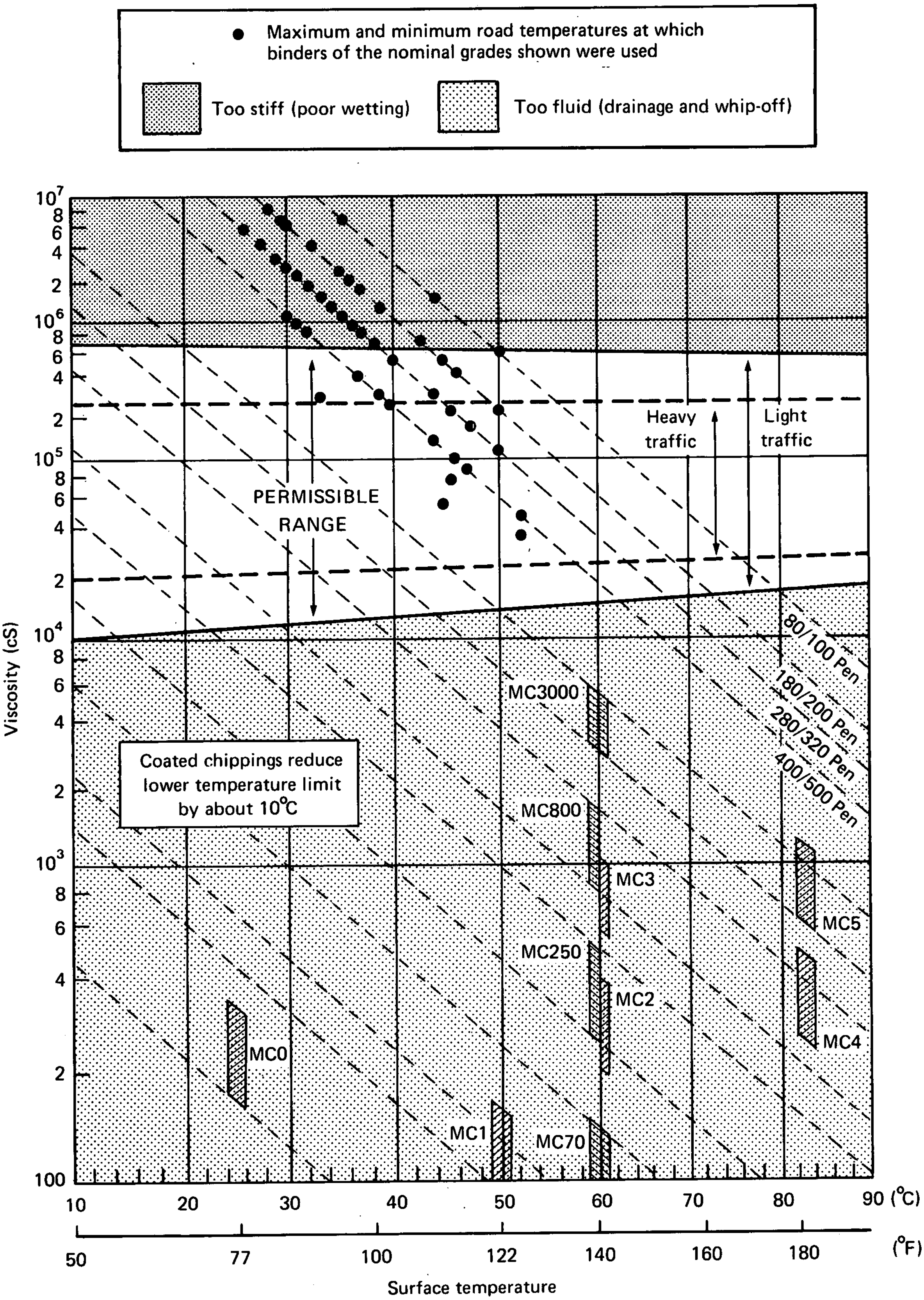

Fig. 8 Surface temperature/choice of binder for surface dressing

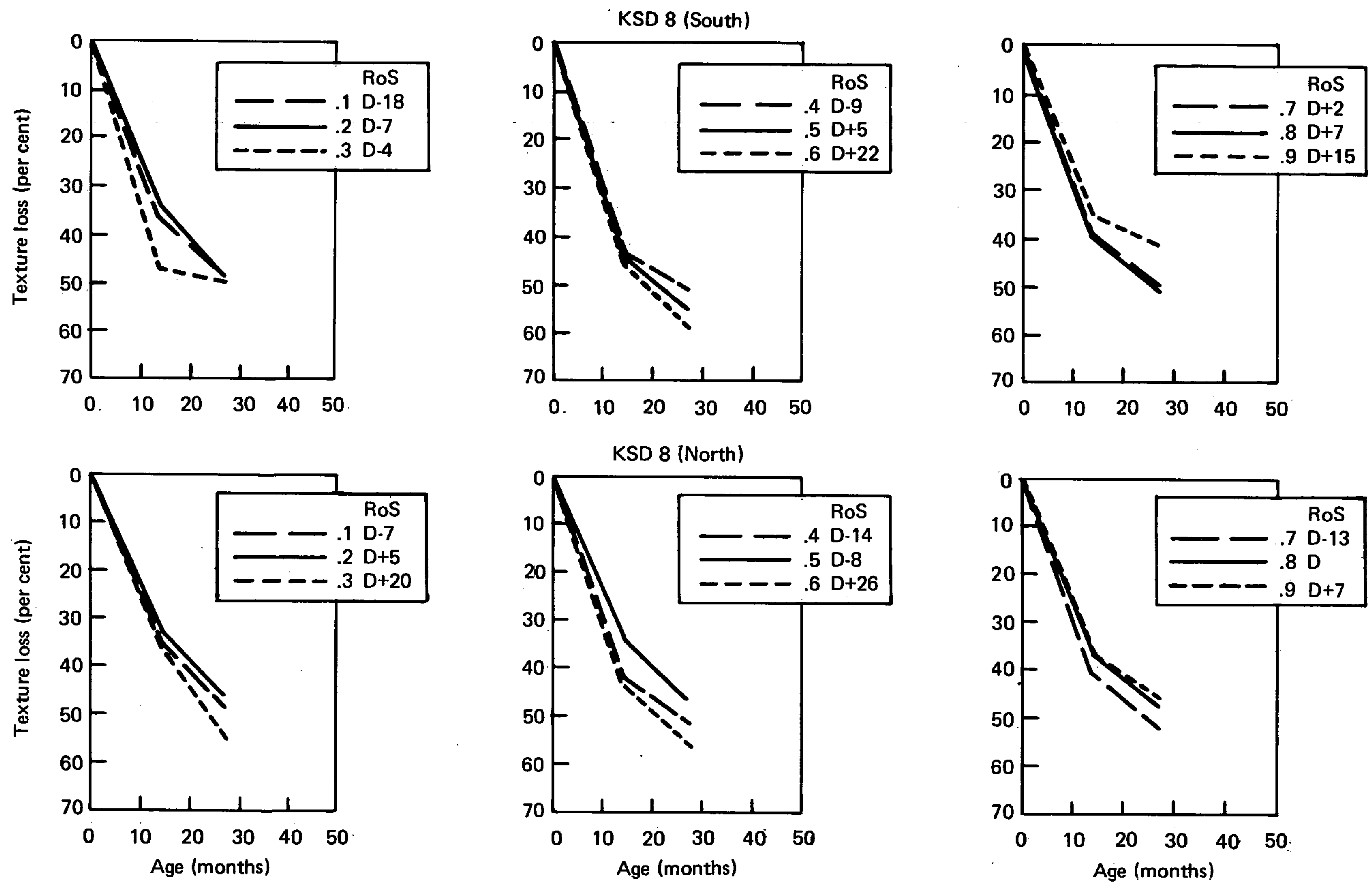

Fig. 9 Texture depth loss/age relationship

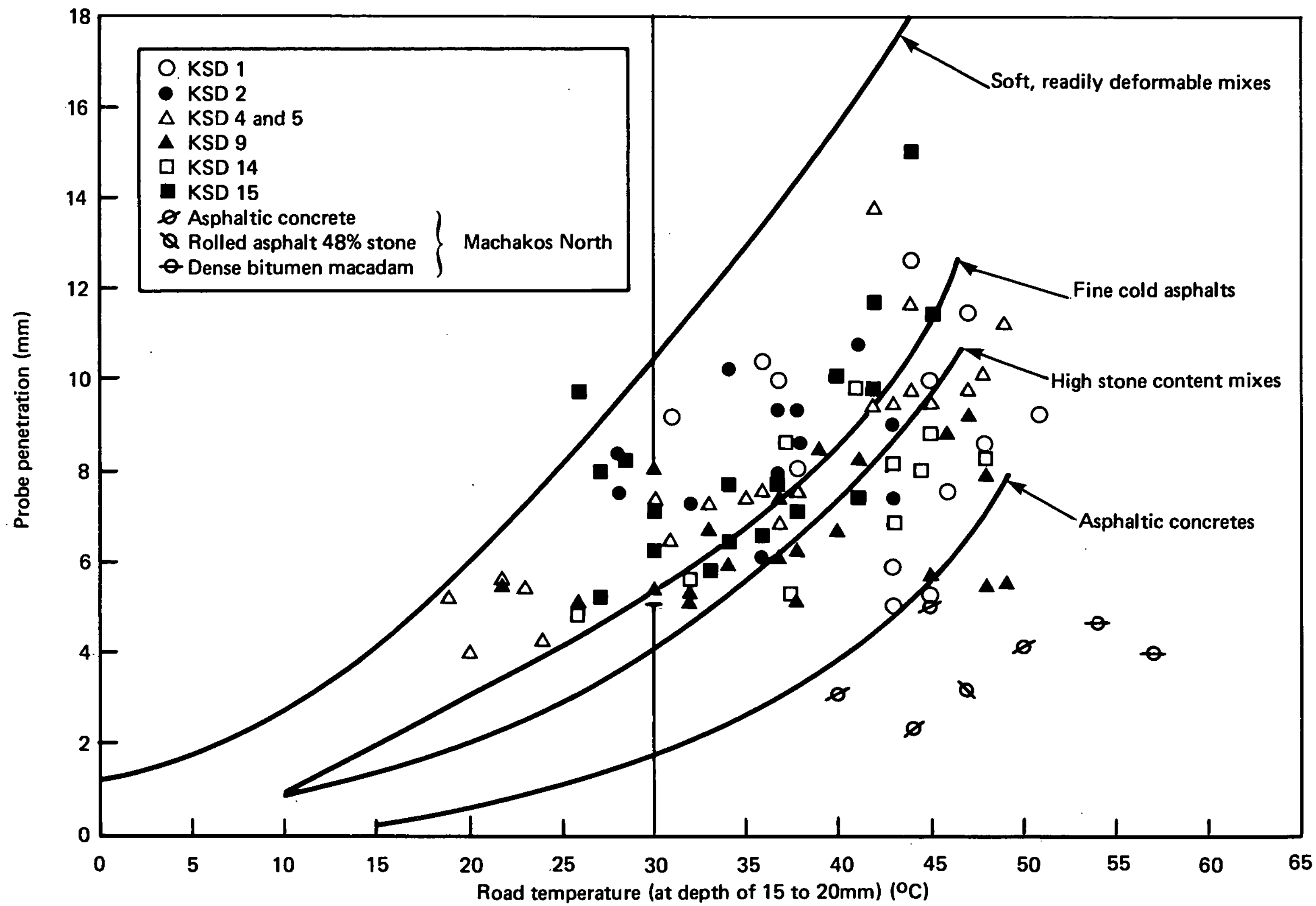

Fig. 10 Probe penetration/road temperature relationship

Plate 1 Preparing blended binder (80/100pen and diesel fuel loaded simultaneously)

Plate 2 Sand patch test

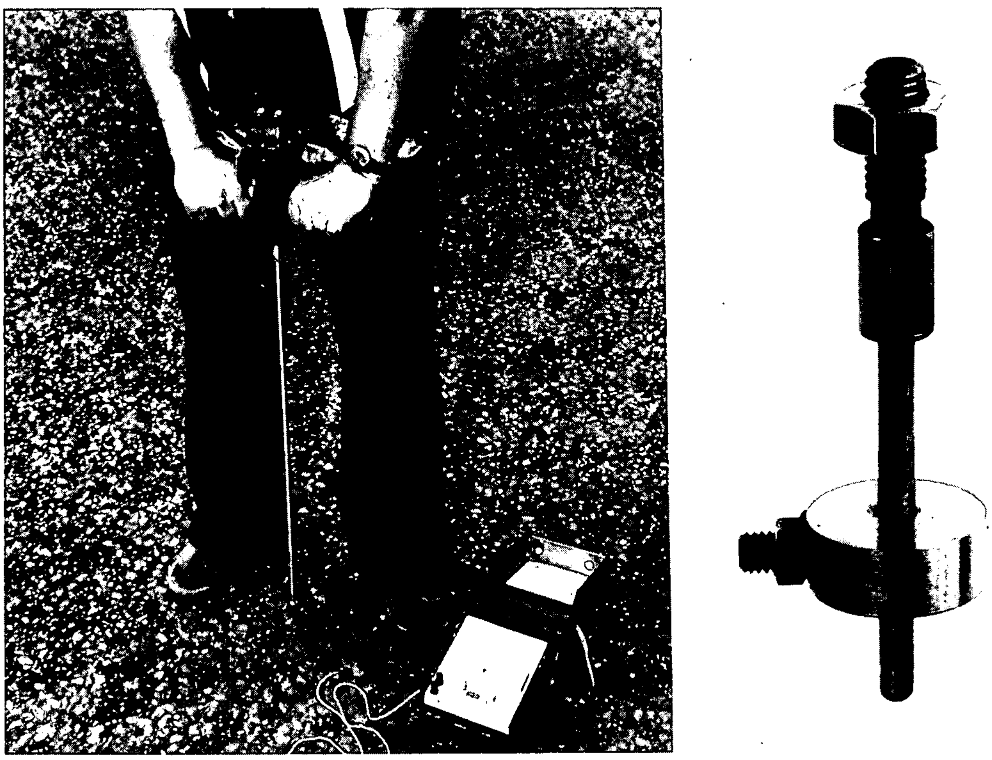

Plate 3 TRRL Probe Test for assessing road hardness (Inset: probe tip)

12. APPENDIX

SURFACE DRESSING DESIGN, JACKSON METHOD: A SUMMARY

This Summary is based on the booklet[5] 'Surface Dressing' by G P Jackson (Shell International Petroleum Co Ltd). 1963.

1. Determination of average least dimension (ALD).

   Method A: Measure the least dimension of approximately 200 representative chippings.

   Method B:
   i) Plot the sieve analysis for chipping sample on a grading chart. Read off theoretical sieve size through which 50 per cent will pass; this is the median size.

   ii) Determine the Flakiness Index (BS 812: 1975[8]).

   iii) Apply (i) and (ii) to Figure 5.

2. Overall design factor to determine rate of spread for bitumen.

   i) Select from the following four tables a factor which, in each case characterises the site to be treated.
   (TRRL note: Until there is evidence of the effect of different axle loadings on surface dressings, the parameter 'vehicles per day' should be interpreted literally without regard to commercial vehicles necessarily, since these will constitute a proportion of traffic on almost all roads. The presence of abnormal proportions of heavy vehicles, however, would clearly indicate a bias towards a heavier traffic category than that indicated by the gross vehicle count.)

Traffic	Veh/day	Constant
Very light	0– 100	+3
Light	100– 500	+1
Medium	500–1000	0
Medium heavy	1000–3000	–1
Heavy	3000–6000	–3
Very heavy	6000+	–5

Type of chippings	
Round/dusty	+2
Cubical	0
Flaky	–2
Pre-coated	–2

Existing surface	
Untreated/primed base	+6
Very lean bituminous	+4
Lean bituminous	0
Average bituminous	–1
Very rich bituminous	–3

Climatic conditions	
North European (wet and cold)	+2
Tropical (wet and hot)	+1
Temperate	0
Semi-arid (dry and hot)	–1
Arid (very dry and very hot)	–2

ii) Sum the four factors to obtain an overall factor.

iii) Entering Figure 6 determine the intercept of ALD and factor line corresponding to (ii) above. A vertical dropped to the baseline will give the design rate of spread for binder. (TRRL note: Jackson recommends that, since the rates obtained from Figure 6 relate to the use of cut-back bitumens of the MC/RC800 or 3000 type or equivalent, when penetration grade bitumen is used rates should be reduced by approximately 0.1 kg/m^2. It should be noted that this reduction was not made during the experimental work in Kenya.)

iv) Determine the intercept of ALD and the line AB; a vertical line drawn from this point to the 3 scales at the top of the chart will indicate the rate of application for chippings, based on a loose density of 1.35. An allowance of 10 per cent has been incorporated to allow for whip-off. (TRRL note: Since, with present day equipment the rate of spread for chippings cannot be pre-set quantitatively, these scales should be regarded as a guide when calculating quantities of stone required. The correct rate of spread will invariably be a matter of adjustment on site. Equally, it is stressed that attempts to spread chippings at pre-calculated excessive rates is pointless and constitutes a wasteful and dangerous practice.)

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Jackson (1963) has proposed a method of surface dressing design based partly upon ideas put forward by Hanson (1935). This method was used to design a total length of 27 km of experimental sections of surface dressing in Kenya during 1975–77.

This report describes the construction, monitoring and performance of the sections during the first 3–4 years trafficking. It is concluded that Jackson's design method works satisfactorily in Kenya conditions over the range of chipping size used in these trials, namely 5 mm to 13 mm average least dimension.

ISSN 0305–1293

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