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OVERSEAS ROAD NOTE 3

A guide to surface dressing in tropical and sub-tropical countries

TRL Limited, Crowthorne, Berkshire, United Kingdom

TRL Limited
Old Wokingham Road
Crowthorne, Berkshire, RG45 6AU

Department for International Development
94 Victoria Street
London, SW1E 5JL

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OVERSEAS ROAD NOTES

Overseas Road Notes are prepared principally for road and transport authorities in countries receiving technical assistance from the British Government. A limited number of copies is available to other organisations and to individuals with an interest in roads overseas, and may be obtained from:

International Development Advisory and Information Unit
TRL Limited
Crowthome, Berkshire, RG45 6AU
United Kingdom

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Preface

This Road Note is the 2nd edition of Overseas Road Note 3 'A guide to surface dressing in tropical and sub-tropical countries'

The revisions include descriptions of a wider range of types of surface dressing, current materials specifications and more detail on the use of bitumen emulsions. An equation has been introduced to allow the design spray rate to be calculated as an alternative to reading from a nomograph. A simplified presentation of spray rate adjustment factors, related to different site conditions, has also been provided.

The durability of surface dressings, particularly for low volume roads, is discussed and additional spray rate adjustment factors have been suggested for these roads. The use of Otta seals has also been suggested for low volume roads.

It is important that this Road Note, is not regarded as a specification. However, the advice contained in this Road Note together with local experience of relevant materials and surface dressing performance should be of value to those drawing up specifications.

1 Introduction

1.1 Surface dressing is a simple, highly effective and inexpensive road surface treatment if adequate care is taken in the planning and execution of the work. The process is used throughout the world for surfacing both medium and lightly-trafficked roads, and also as a maintenance treatment for roads of all kinds.

1.2 Surface dressing comprises a thin film of binder, generally bitumen or tar, which is sprayed onto the road surface and then covered with a layer of stone chippings. The thin film of binder acts as a waterproofing seal preventing the entry of surface water into the road structure. The stone chippings protect this film of binder from damage by vehicle tyres, and form a durable, skid-resistant and dust-free wearing surface. In some circumstances the process may be repeated to provide double or triple layers of chippings.

1.3 Surface dressing is a very effective maintenance technique which is capable of greatly extending the life of a structurally sound road pavement if the process is undertaken at the optimum time. Under certain circumstances surface dressing may also retard the rate of failure of a structurally inadequate road pavement by preventing the ingress of water and thus preserving the inherent strength of the pavement layers and the subgrade.

1.4 In addition to its maintenance role. surface dressing can provide an effective and economical running surface for newly constructed road pavements. Existing roads with bituminous surfacings, carrying in excess of 1000 vehicles/lane/day, have been successfully surfaced with multiple surface dressings. For sealing new roadbases traffic flows of up to 500 vehicles/lane/day are more appropriate, although this can be higher if the roadbase is very stable or if a triple seal is used. A correctly designed and constructed surface dressing should last at least 5 years before resealing with another surface dressing becomes necessary. If traffic growth over a period of several years necessitates a more substantial surfacing or increased pavement thickness, a bituminous overlay can be laid over the original surface dressing when the need arises.

1.5 The success of a surface dressing depends primarily on the adhesion of the chippings to the road surface, hence both the chippings and the road surface must be clean and free from dust during the surface dressing process. Inappropriate specifications, poor materials, and bad workmanship, can also drastically reduce the service life of a surface dressing.

1.6 This Road Note is a general guide to the design and construction of surface dressings in tropical and sub-tropical environments and draws attention to some of the more common mistakes that are made. It provides a framework on which the engineer can base more specific decisions made to suit particular local conditions thereby producing cost effective results. It also contains brief descriptions of certain other types of surface treatment.

2 Types of surface dressing

2.1 Surface dressings can be constructed in a number of ways to suit site conditions. The common types of dressing are illustrated in Figure 1.

Single surface dressing

2.2 When applied as a maintenance operation to an existing bituminous road surface a single surface dressing can fulfil the functions required of a maintenance re-seal, namely waterproofing the road surface, arresting deterioration, and restoring skid resistance. A single surface dressing would not normally be used on a new roadbase because of the risk that the film of bitumen will not give complete coverage. It is also particularly important to minimise the need for future maintenance and a double dressing should be considerably more durable than a single dressing. However, a 'racked-in' dressing (see paragraph 2.7) may be suitable for use on a new roadbase which has a tightly knit surface because of the heavier applications of binder which is used with this type of single dressing.

Double surface dressing

2.3 Double surface dressings are robust and should be used when:

- A new roadbase is surface dressed.
- Extra 'cover' is required on an existing bituminous road surface because of its condition (e.g. when the surface is slightly cracked or patched).
- There is a requirement to maximise durability and minimise the frequency of maintenance and resealing operations.

2.4 The quality of a double surface dressing will be greatly enhanced if traffic is allowed to run on the first dressing for a minimum period of 2-3 weeks (and preferably longer) before the second dressing is applied. This allows the chippings of the first dressing to adopt a stable interlocking mosaic which provides a firm foundation for the second dressing. However, traffic and animals may cause contamination of the surface with mud or soil during this period and this must be thoroughly swept off before the second dressing is applied. Such cleaning is sometimes difficult to achieve and the early application of the second seal to prevent such contamination may give a better result.

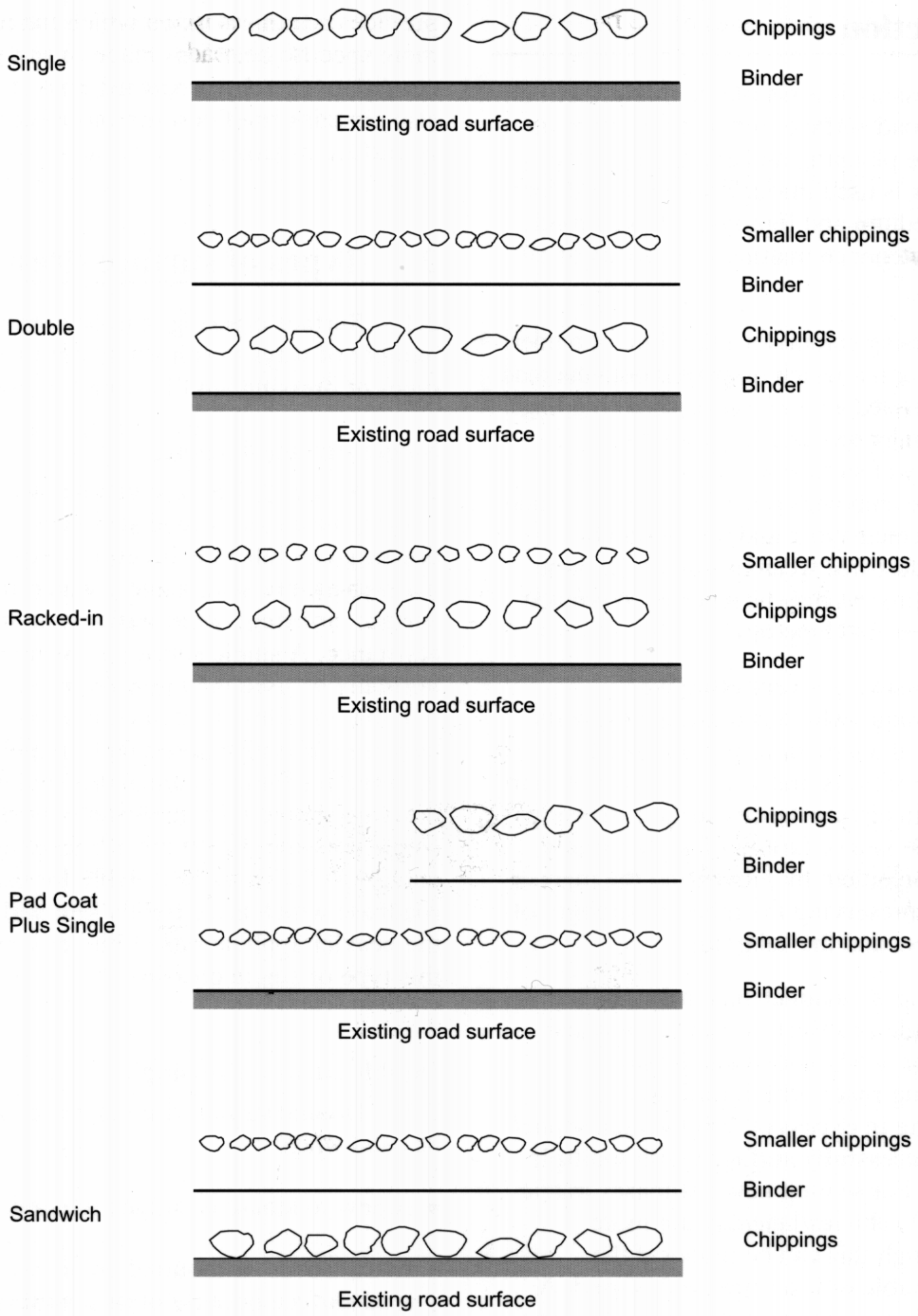

Figure 1 Type of surface dressings

2.5 Sand may sometimes be used as an alternative to chippings for the second dressing. Although it cannot contribute to the overall thickness of the surfacing, the combination of binder and sand provides a useful grouting medium for the chippings of the first seal and helps to hold them in place more firmly when they are poorly shaped. A slurry seal may also be used for the same purpose (see paragraph 8.2).

Triple surface dressings

2.6 A triple surface dressing (not illustrated in Figure 1) may be used to advantage where a new road is expected to carry high traffic volumes from the outset. The application of a small chipping in the third seal will reduce noise generated by traffic and the additional binder will ensure a longer maintenance-free service life.

Racked-in surface dressing

2.7 This system is recommended for use where traffic is particularly heavy or fast (TRL, 1996). A heavy single application of binder is made and a layer of large chippings is spread to give approximately 90 per cent coverage. This is followed immediately by the application of smaller chippings which should 'lock-in' the larger aggregate and form a stable mosaic. The amount of bitumen used is more than would be used with a single seal but less than for a double seal. The main advantages of the racked-in surface dressing are:

- Less risk of dislodged large chippings.
- Early stability through good mechanical interlock.
- Good surface texture.

Other types of surface dressing

2.8 'Sandwich' surface dressings are principally used on existing binder rich surfaces and sometimes on gradients to reduce the tendency for the binder to flow down the slope.

2.9 'Pad coats' are used where the hardness of the existing road surface allows very little embedment of the first layer of chippings, such as on a newly constructed cement stabilised roadbase or a dense crushed rock base. A first layer of nominal 6mm chippings will adhere well to the hard surface and will provide a 'key' for larger l0mm or l4mm chippings in the second layer of the dressing.

3 Chippings for surface dressings

3.1 The selection of chipping sizes is based on the volume of commercial vehicles having unladen weights of more than 1.5 tonnes and the hardness of the existing pavement. Ideally, chippings used for surface dressing should be single sized, cubical in shape, clean and free from dust, strong, durable, and not susceptible to polishing under the action of traffic. In practice the chippings available usually fall short of this ideal but it is recommended that chippings used for surface dressing should comply with the requirements of BS 63: Part 2 (1987) for the nominal size of chipping selected by the engineer. In this standard, some control of shape is ensured by the limits set for the flakiness index for each nominal size (except 6mm). Part of BS 63 is reproduced in Appendix A.

3.2 Samples of the chippings should be tested for grading, flakiness index, aggregate crushing value and, when appropriate, the polished stone value and aggregate abrasion value. Sampling and testing should be in accordance with the methods described in British Standard BS 812 (1985,1989a, 1989b 1990a, 1990b).

3.3 Specifications for maximum aggregate crushing value (ACV) for surface dressing chippings typically lie in the range 20 to 35. For lightly trafficked roads the higher value is likely to be adequate but on more heavily trafficked roads a maximum ACV of 20 is recommended.

3.4 The polished stone value (PSV) of the chippings is important if the primary purpose of the surface dressing is to restore or enhance the skid resistance of the road surface. The PSV required in a particular situation is related to the nature of the road site and the speed and intensity of the traffic (Salt and Szatkowski, 1973). The resistance to skidding is also dependent upon the macro texture of the surface which, in turn, is affected by the durability of the exposed aggregate. This property is measured by the aggregate abrasion value (AAV). Appendix B gives recommended values of PSV and AAV for various road and traffic conditions in Britain and provides an indication of the required aggregate properties.

3.5 The nominal sizes of chippings normally used for surface dressing are 6, 10, 14 and 20 mm. Flaky chippings are those with a thickness (smallest dimension) less than 0.6 of their nominal size. The proportion of flaky chippings clearly affects the average thickness of a single layer of the chippings, and it is for this reason that Jackson (1963) introduced the concept of the 'average least dimension' (ALD) of chippings.

3.6 In effect, the ALD is the average thickness of a single layer of chippings when they have bedded down into their final interlocked positions. The amount of binder required to retain a layer of chippings is thus related to the ALD of the chippings rather than to their nominal size. This is discussed further in Section 5 where guidance is given on the selection of the appropriate nominal size of chipping and the effect of flakiness on surface dressing design.

3.7 The most critical period for a surface dressing occurs immediately after the chippings have been spread on the binder film. At this stage the chippings have yet to become an interlocking mosaic and are held in place solely by the adhesion of the binder film. Dusty chippings can seriously impede adhesion and can cause immediate failure of the dressing.

3.8 The effect of dust can sometimes be mitigated by dampening them prior to spreading them on the road. The chippings dry out quickly in contact with the binder and, when a cutback bitumen or emulsion is used, good adhesion develops more rapidly than when the coating of dust is dry.

3.9 Most aggregates have a preferential attraction for water rather than for bitumen. Hence if heavy rain occurs within the first few hours when adhesion has not fully developed, loss of chippings under the action of traffic is possible. where wet weather damage is considered to be a severe risk, or the immersion tray test, described in Appendix C, shows that the chippings have poor affinity with bitumen, an adhesion agent should be used. An adhesion agent can be added to the binder or, used in a dilute solution to pre-coat the chippings. However, the additional cost of the adhesion agent will be wasted if proper care and attention is not given to all other aspects of the surface dressing process.

3.10 Improved adhesion of chippings to the binder film can also be obtained by pre-treating the chippings before spreading. This is likely to be most beneficial if the available chippings are very dusty or poorly shaped, or if traffic conditions are severe. There are basically two ways of pre-treating chippings:

- Spraying the chippings with a light application of creosote, diesel oil, or kerosene at ambient temperature (NAASRA, 1986). This can be conveniently done as the chippings are transferred from stockpile to gritting lorries by a belt conveyor or. alternatively, they can be mixed in a simple concrete mixer.

- Pre-coating the chippings with a thin coating of hard bitumen such that the chippings do not stick together and can flow freely.

3.11 Chippings which are pre-coated with bitumen enable the use of a harder grade of binder for construction which can provide early strong adhesion and thus help to obtain high quality dressings. The binder used for pre-coating need not necessarily be the same kind as that used for the surface dressing; for example, tar-coated chippings adhere well to a sprayed bitumen film. Pre-coating is usually undertaken in a hot-mix plant and the hardness of the coating, and thus the tendency for the chippings to adhere to each other, can be controlled by the mixing temperature and/or the duration of mixing; typical coating temperature are about 140^{0}C for bitumen binders and 120^{0}C for tar binders. Table 1 indicates the amount of binder recommended for lightly coating chippings.

Table 1 Binder contents for lightly-coated chippings

	Target binder content (per cent by mass)	
Nominal size of chippings (mm)	*Bitumen (TRL, 1996)*	*Tar (TRL, 1992)*
6	1.0	1.2
10	0.8	1.0
14	0.6	0.8
20	0.5	0.7

Reproduced from Road Note 39

3.12 Pre-coated chippings should not be used with emulsions because the breaking of the emulsion will be adversely affected.

3.13 In some countries adhesion agents or pre-treated chippings are often used in an attempt to counteract the adverse effect of some fundamental fault in the surface dressing operation. If loss of chippings has occurred, it is advisable to check whether the viscosity of the binder was appropriate for the ambient road temperature at the time of spraying. The effectiveness of the chipping and traffic control operations should also be reviewed before the use of an adhesion agent or pre-treated chippings is considered.

4 Bitumens

4.1 It is essential that good bonding is achieved between the surface dressing and the existing road surface. This means that non-bituminous materials must be primed before surface dressing is carried out.

Prime coats

4.2 Where a surface dressing is to be applied to a previously untreated road surface it is essential that the surface should be dry, clean and as dust-free as possible. On granular, cement or lime-stabilised surfaces a prime coat of bitumen ensures that these conditions are met. The functions of a prime coat can be summarised as follows.

- It assists in promoting and maintaining adhesion between the roadbase and a surface dressing by pre-coating the roadbase and penetrating surface voids.

- It helps to seal the surface pores in the roadbase thus reducing the absorption of the first spray of binder of the surface dressing.

- It helps to strengthen the roadbase near its surface by binding the finer particles of aggregate together.

- If the application of the surface dressing is delayed for some reason it provides the roadbase with a temporary protection against rainfall and light traffic until the surfacing can be laid.

4.3 The depth of penetration of the prime should be between 3-l0mm and the quantity sprayed should be such that the surface is dry within a few hours. The correct viscosity and application rate are dependent primarily on the texture and density of the surface being primed. The application rate is. however, likely to lie within the range 0.3-1.1 kg/m^2 . Low viscosity cutbacks are necessary for dense cement or lime-stabilised surfaces, and higher viscosity cutbacks for untreated coarse-textured surfaces. It is usually beneficial to spray the surface lightly with water before applying the prime coat as this helps to suppress dust and allows the primer to spread more easily over the surface and to penetrate. Bitumen emulsions are not suitable for priming as they tend to form a skin on the surface.

4.4 Low viscosity, medium curing cutback bitumens such as MC-30, MC-70, or in rare circumstances MC-250, can be used for prime coats (Asphalt Institute, 1983). The relationship between grade and viscosity for cutback primes is shown in Table 2.

Table 2 Kinematic viscosities of current cutback binders

Grade of cutback binder	*Permitted viscosity range (centistokes at 60°C)*
MC 250	250-500
MC 70	70-140
MC 30	30-60
ASTM D2027, 1998	

Bitumens for surface dressings

4.5 The correct choice of bitumen for surface dressing work is critical. The bitumen must fulfil a number of important requirements. They must:

- be capable of being sprayed;
- 'wet' the surface of the road in a continuous film;
- not run off a cambered road or form pools of binder in local depressions;
- 'wet' and adhere to the chippings at road temperature;
- be strong enough to resist traffic forces and hold the chippings at the highest prevailing ambient temperatures;
- remain flexible at the lowest ambient temperature, neither cracking nor becoming brittle enough to allow traffic to 'pick-off' the chippings; and
- resist premature weathering and hardening.

4.6 Some of these requirements conflict. hence the optimum choice of binder involves a careful compromise. For example, the binder must be sufficiently fluid at road temperature to 'wet' the chippings whilst being sufficiently viscous to retain the chippings against the dislodging effect of vehicle tyres when traffic is first allowed to run on the new dressing.

4.7 Figure 2 shows the permissible range of binder viscosity for successful surface dressing at various road surface temperatures. In the tropics, daytime road temperatures typically lie between about 25^0C and 50^0C, normally being in the upper half of this range unless heavy rain is falling. For these temperatures the viscosity of the binder should lie between approximately $l0^4$ and 7 x $l0^5$ centistokes. At the lower road temperatures cutback grades of bitumen are most appropriate. whilst at higher road temperatures penetration grade bitumens can be used.

4.8 The temperature/viscosity relationships shown in Figure 2 do not apply to bitumen emulsions. These have a relatively low viscosity and 'wet' the chippings readily, after which the emulsion 'breaks', the water evaporates. and particles of high viscosity bitumen adhere to the chippings and the road surface.

4.9 Depending upon availability and local conditions at the time of construction, the following types of bitumen are either commonly used in the tropics or are becoming so:

- Penetration grade.
- Cutback**.**
- Emulsion.
- Modified bitumens.

Penetration grade bitumens

4.10 Penetration grade bitumens vary between 80/100 to approximately 700 penetration. The softer penetration grade binders are usually produced at the refinery but can be made in the field by blending appropriate amounts of kerosene, diesel, or a blend of kerosene and diesel. With higher solvent contents the binder has too low a viscosity to be classed as being of penetration grade and is then referred to as a cutback bitumen which, for surface dressing work, is usually an MC or RC 3000 grade. In very rare circumstances a less viscous grade such as MC or RC 800 may be used if the pavement temperature is below 15^0C for long periods of the year.

Bitumen emulsion

4.11 Cationic bitumen emulsion with a bitumen content of 70 to 75 per cent is recommended for most surface dressing work. This type of binder can be applied through whirling spray jets at a temperature between 70 and 85^0C and, once applied, it will break rapidly on contact with chippings of most mineral types. The cationic emulsifier is normally an antistripping agent and this ensures good initial bonding between chippings and the bitumen.

4.12 When high rates of spray are required, the road is on a gradient, or has considerable camber, the emulsion is likely to drain from the road or from high parts of the road surface before 'break' occurs. In these cases it may be possible to obtain a satisfactory result if the bitumen application is 'split', with a reduced initial rate of spray and a heavier application after the chippings have been applied. If the intention was to construct a single seal then the second application of binder will have to be covered with sand or quarry fines to prevent the binder adhering to roller and vehicle wheels. If a double dressing is being constructed then it should be possible to apply sufficient binder in the second spray to give the required total rate of spray for the finished dressing.

4.13 If split application of the binder is used care

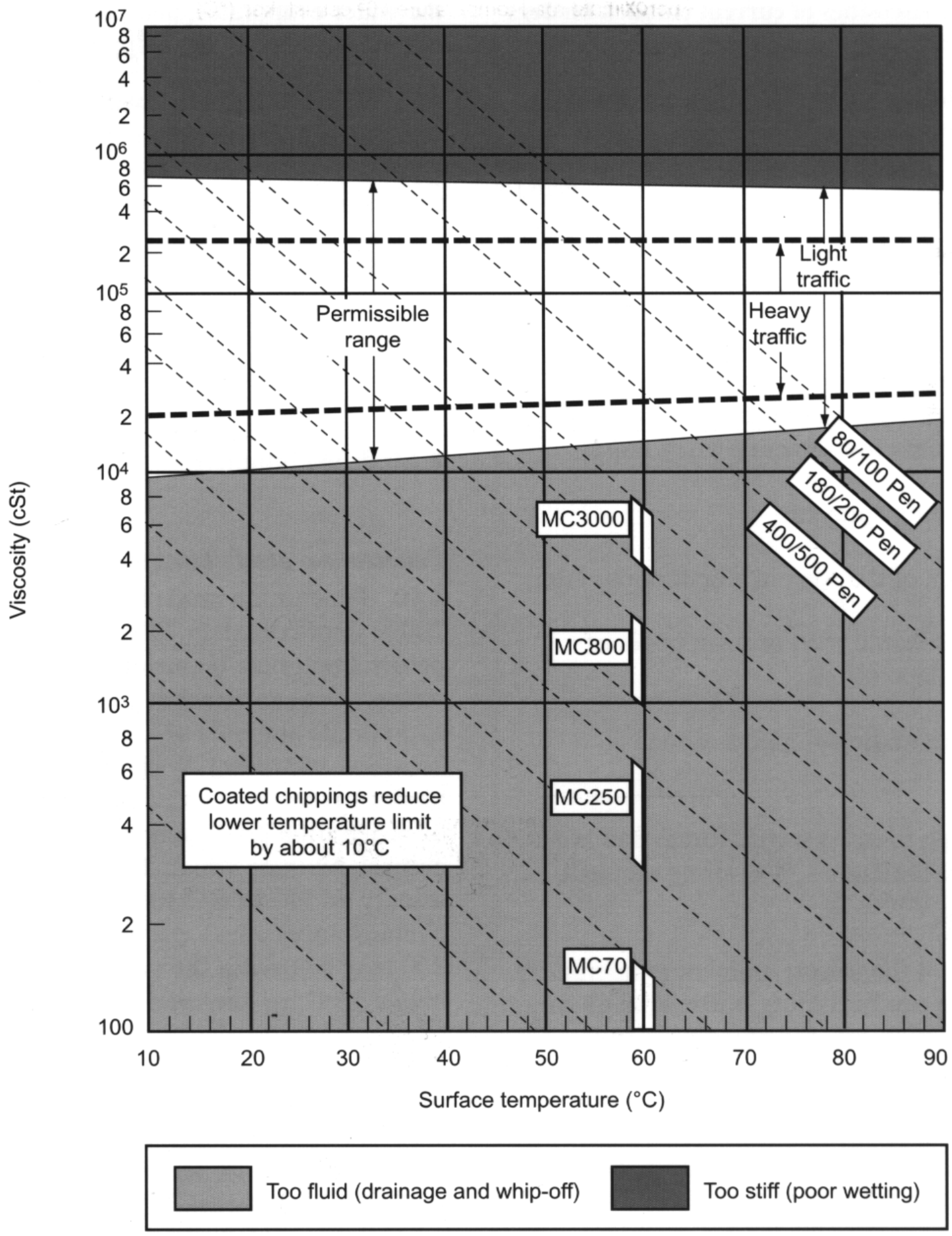

Figure 2 Surface temperature/choice of binder for surface dressings

must be taken with the following:

- The rate of application of chippings must be correct so that there is a minimum of excess chippings.
- The second application of binder must be applied before traffic is allowed onto the dressing.
- For a single seal it will be necessary to apply grit or sand after the second application of binder.

Cutback bitumens

4.14 Except for very cold conditions, MC or RC 3000 grade cutback is normally the most fluid binder used for surface dressings. This grade of cutback is basically an 80/100 penetration grade bitumen blended with approximately 12 to 17 per cent of cutter.

4.15 In some areas of the world the range of binders available to the engineer is restricted. In this situation it may then be necessary to blend two grades together or to 'cut-back' a supplied grade with diesel oil or kerosene in order to obtain a binder with the required viscosity characteristics. Diesel oil, which is less volatile than kerosene and is generally more easily available, is preferable to kerosene for blending purposes. Only relatively small amounts of diesel oil or kerosene are required to modify a penetration grade bitumen such that its viscosity is suitable for surface dressing at road temperatures in the tropics. For example Figure 3 shows that, for the road temperatures prevailing during trials in Kenya, between 2 and 10 per cent of diesel oil was required to modify 80/100 pen bitumen to produce binders with viscosities within the recommended range for use (Figure 2). Figure 4 shows the temperature/viscosity relationships for five of the blends made for these trials.

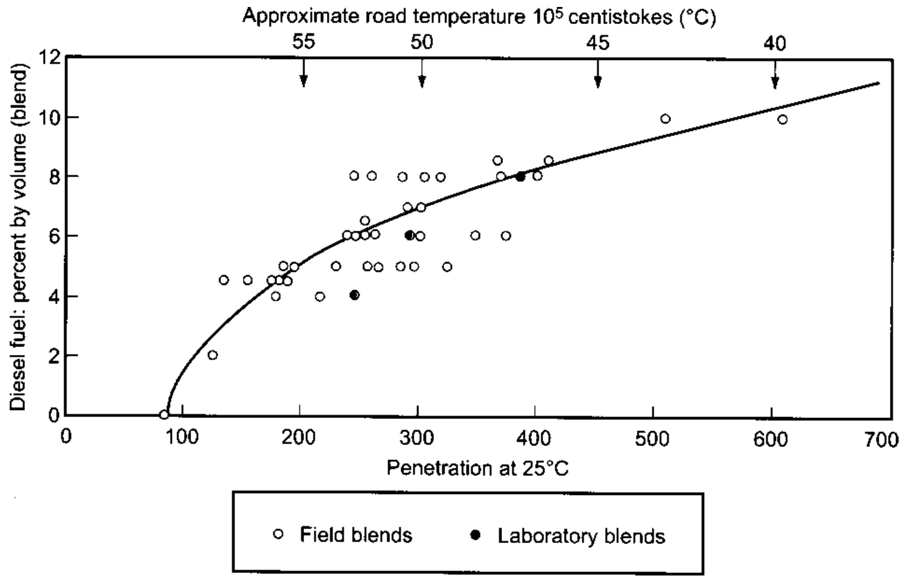

Figure 3 Blending characteristics of 80/100 pen bitumen with diesel fuel

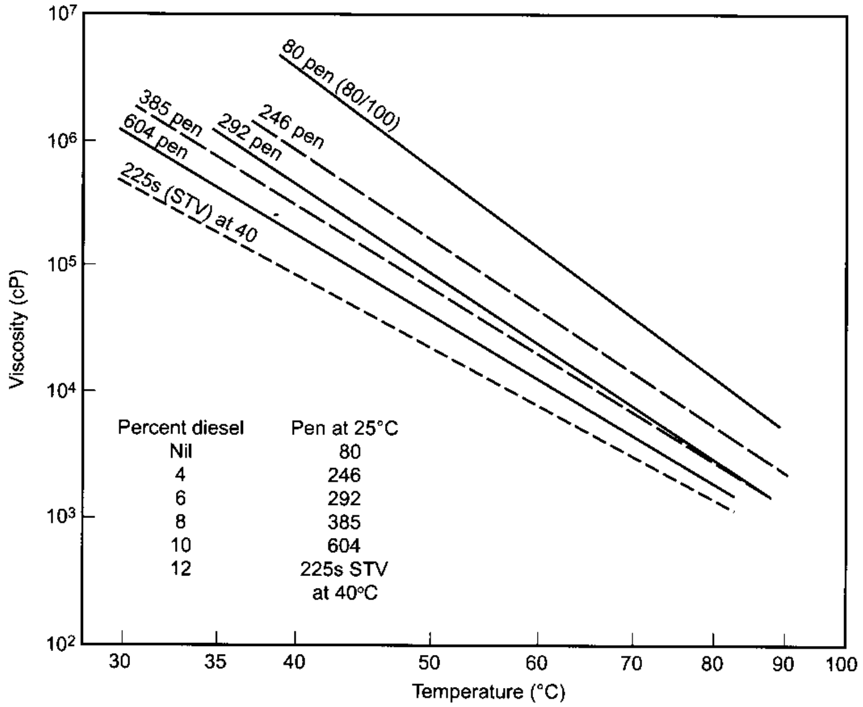

Figure 4 Viscosity/temperature relationships for blends of 80/100 pen bitumen with diesel fuel

4.16 The blending process is not difficult but it must be undertaken with great care by staff who are properly trained. A convenient method is to pump the required amount of cutter (e.g. diesel oil) into the distributor whilst simultaneously pumping in hot bitumen. Before pumping in the cutter, sufficient bitumen should be pumped into the distributor to enable the cutter to discharge below the surface of the bitumen. Because of the fire risk, all the burners must be extinguished and naked lights and smoking prohibited during this operation.

Polymer modified bitumens

4.17 Polymers can be used in surface dressing to modify penetration grade, cutback bitumens and emulsions. Usually these modified binders are used at locations where the road geometry, traffic characteristics or the environment, dictate that the road surface experiences high stresses. Generally the purpose of the polymers is to reduce binder temperature susceptibility so that variation in viscosity over the ambient temperature range is as small as possible. Polymers can also improve the cohesive strength of the binder so that it is more able to retain chippings when under stress from the action of traffic. They also improve the early adhesive qualities of the binder allowing the road to be reopened to traffic earlier than may be the case with conventional unmodified binders. Other advantages claimed for modified binders are improved elasticity in bridging hairline cracks and overall improved durability.

4.18 Examples of polymers that may be used to modify bitumens are proprietary thermoplastic rubbers such as Styrene-Butadiene-Styrene (SBS), crumb rubber derived from waste car tyres and also glove rubber from domestic gloves. Latex rubber may also be used to modify emulsions. Binders of this type are best applied by distributors fitted with slotted jets of a suitable size.

4.19 Rubber modified bitumen may consist, typically, of a blend of 80/100 penetration grade bitumen and three per cent powdered rubber. Blending and digestion of the rubber with the penetration grade bitumen should be carried out by experienced personnel prior to loading into a distributor. This must be done in static tanks which incorporate integral motor driven paddles. The blending temperature is approximately 200^0C.

4.20 Cationic emulsion can be modified in purpose made plant by the addition of three per cent latex rubber. One of the advantages of using emulsions is that they can be sprayed at much lower temperatures than penetration grade bitumens, which reduces the risk of partial degradation of the rubber which can occur at high spraying temperatures.

4.21 Bitumen modified with SBS exhibits thermoplastic qualities at high temperatures while having a rubbery nature at lower ambient temperatures. With three per cent of SBS, noticeable changes in binder viscosity and temperature susceptibility occur and good early adhesion of the chippings is achieved. SBS can be obtained in a carrier bitumen in blocks of approximately 20kg mass. The blocks can be blended, at a concentration recommended by the manufacturer, with 80/100 penetration binder in a distributor. In this procedure it is best to place half of the required polymer into the empty distributor, add hot bitumen from a main storage tank and then circulate the binder in the distributor tank. The remaining blocks are added after about 30 minutes and then about 2 hours is likely to be required to complete blending and heating of the modified binder. Every effort should be made to use the modified bitumen on the day it is blended.

Adhesion agents

4.22 Proprietary additives, known as adhesion agents. are available for adding to binders to help to minimise the damage to surface dressings that may occur in wet weather with some types of stone. When correctly used in the right proportions. these agents can enhance adhesion between the binder film and the chippings even though they may be wet. The effectiveness and the amount of an additive needed to provide satisfactory adhesion of the binder to the chippings in the presence of free water must be determined by tests such as the Immersion Tray Test which is described in Appendix C.

4.23 Fresh hydrated lime can also be used to enhance adhesion. It can be mixed with the binder in the distributor before spraying (slotted jets are probably best suited for this) or the chippings can be pre-coated with the lime just before use. by spraying with a lime slurry. The amount of lime to be blended with the bitumen should be determined in laboratory trials bitt approximately 12 per cent by mass of the bitumen will improve bitumen-aggregate adhesion and it should also improve the resistance of the bitumen to oxidative hardening (Dickinson,1984).

4.24 Cationic emulsions inherently contain an adhesion agent and lime should not be used with this type of binder.

5 Design

5.1 The key stages in the surface dressing design procedure are illustrated in Figure 5.

Existing site conditions

5.2 Selection of a suitable surface dressing system for a road and the *nominal* size of chippings to be used is based on the daily volume of commercial vehicles using each lane of the road and the hardness of the existing pavement surface.

5.3 With time, the action of traffic on a surface dressing gradually forces the chippings into the underlying surface, thus diminishing the surface texture. When the loss of surface texture reaches an unacceptable level a reseal will be required to restore skid resistance. The embedment process occurs more rapidly when the underlying road surface is softer, or when the volume of traffic, particularly of commercial vehicles, is high. Accordingly, larger chippings are required on soft surfaces or where traffic is heavy whilst small chippings are best for hard surfaces. For example, on a very soft surface carrying 1000 commercial vehicles per lane per day, 20mm chippings are appropriate, whilst on a very hard surface such as concrete, 6mm chippings would be the best choice.

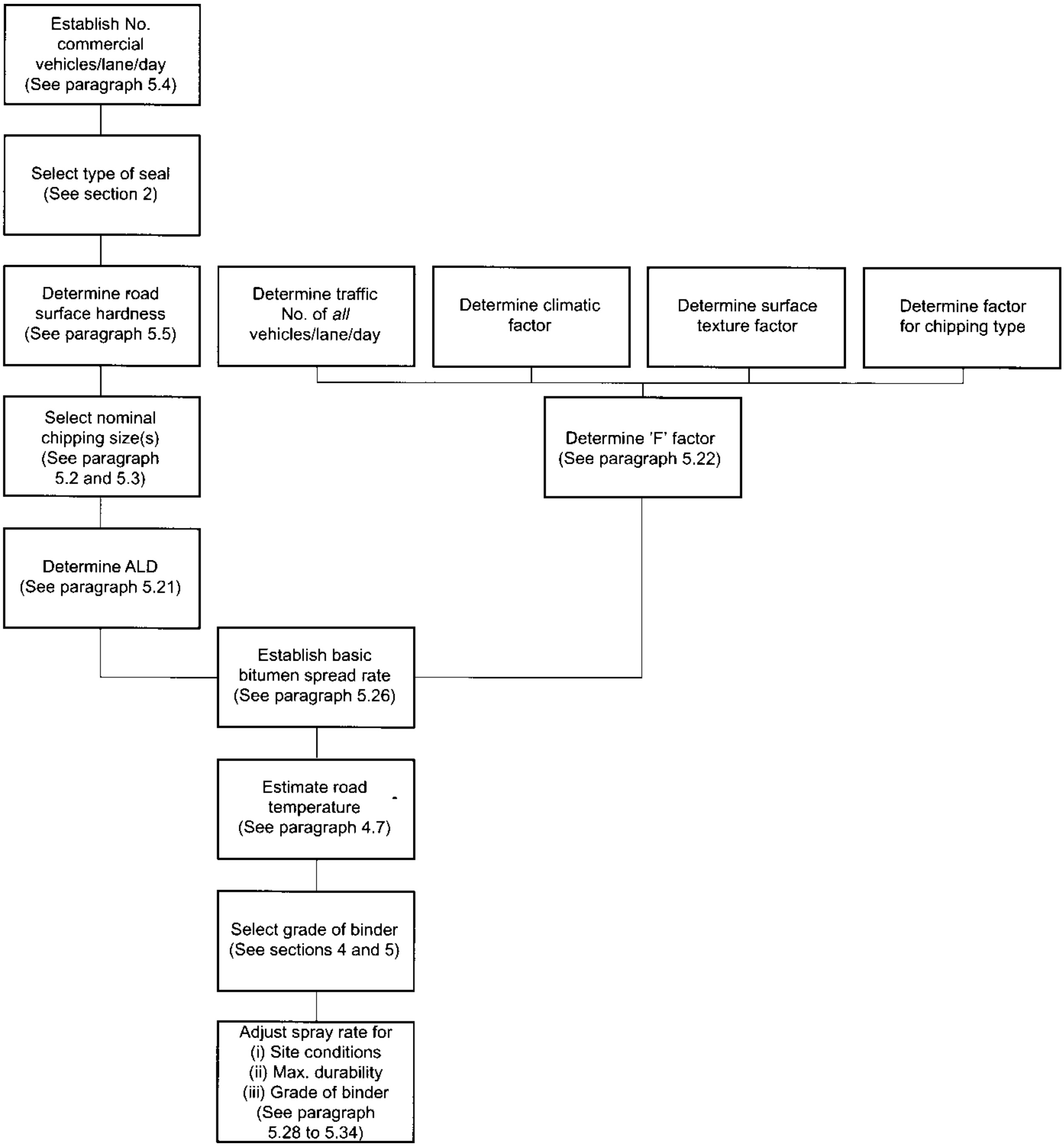

Figure 5 Outline procedure for design of surface dressings

5.4 Guidance on the selection of chipping size for single surface dressings, relating the nominal size of chipping to the hardness of the underlying road surface and the weight of traffic expressed in terms of the number of commercial vehicles carried per lane per day. These recommendations are shown in Table 3.

5.5 Road surface hardness may be assessed by a simple penetration probe test (TRL. 1996). This test utilises a modified soil assessment cone penetrometer and is described briefly in Appendix D. Alternatively the hardness of the existing road surface may be made on the basis of judgement with the help of the definitions given in Table 4.

5.6 Although the recommendations for the selection of chipping size were developed for conditions in the United Kingdom they have been found to be applicable to roads in tropical and sub-tropical countries.

5.7 If larger sized chippings are used than is recommended in Table 3 then the necessary bitumen spray rate, required to hold the chippings in place, is likely to be underestimated by the design procedure

Table 3 Recommended nominal size of chippings (mm)

	Approximate number of commercial vehicles with an unladen weight greater than 1.5 tonnes currently carried per day in the design lane				
Type of surface	*2000-4000*	*1000-2000*	*200-1000*	*20-200*	*Less than 20*
Veryhard	10	10	6	6	6
Hard	14	14	10	6	6
Normal	20$^{\Psi}$	14	10	10	6
Soft	*	20$^{\Psi}$	14	14	10
Very soft	*	*	20$^{\Psi}$	14	10

The size of chipping specified is related to the mid – point of each lane traffic category. Lighter traffic conditions may, make the next smaller size of stone more appropriate.

$^{\Psi}$ *Very particular care should be taken when using 20mm chippings to ensure that no loose chippings remain on the surface when the road is opened to unrestricted traffic as there is a high risk of windscreen breakage.*

* *Unsuitable for surface dressing.*

Table 4 Categories of road surface hardness

Category of surface	*Penetration[1] at 30^{0}C (mm)*	*Definition*
Very hard	0-2	Concrete or very lean bituminous structures with dry stony surfaces. There would be negligible penetration of chippings under the heaviest traffic.
Hard	2-5	Likely to be an asphalt surfacing which has aged for several years and is showing some cracking. Chippings will penetrate only slightly under heavy traffic.
Normal	5-8	Typically, an existing surface dressing which has aged but retains a dark and slightly bitumen-rich appearance. Chippings will penetrate moderately under medium and heavy traffic.
Soft	8-12	New asphalt surfacings or surface dressings which look bitumen-rich and have only slight surface texture. Surfaces into which chippings will penetrate considerably under medium and heavy traffic.
Very soft	>12	Surfaces, usually a surface dressing which is very rich in binder and has virtually no surface texture. Even large chippings will be submerged under heavy traffic.

[1]See Appendix D

described in Section 5. This is likely to result in the 'whip-off' of chippings by traffic early in the life of the dressing and also to have a significant effect on the long term durability of low volume roads.

5.8 In selecting the nominal size of chippings for double surface dressings, the size of chipping for the first layer should be selected on the basis of the hardness of the existing surface and the traffic category as indicated in Table 3. The nominal size of chipping selected for the second layer should preferably have an ALD of not more than half that of the chippings used in the first layer. This will promote good interlock between the layers.

5.9 In the case of a hard existing surface, where very little embedment of the first layer of chippings is possible, such as a newly constructed cement stabilised road base or a dense crushed rock base, a 'pad coat' of 6mm chippings should be applied first followed by l0mm or 14 mm chippings in the second layer. The first layer of small chippings will adhere well to the hard surface and will provide a 'key' for the larger stone of the second dressing.

Selecting the binder

5.10 The selection of the appropriate binder for a surface dressing is usually constrained by the range of binders available from suppliers, although it is possible for the user to modify the viscosity of penetration grade and cutback binders to suit local conditions as described in paragraphs 4.14 to 4.16.

5.11 The factors to be taken into account in selecting an appropriate binder are:

- *The road surface temperature at the time the surface dressing is undertaken.* For penetration grade and cutback binders the viscosity of the binder should be between 1 0^4 and 7x 10^5 centistokes at the road surface temperature (see paragraphs 4.5 to 4.9).

- *The nature of the chippings.* If dusty chippings are anticipated and no pre-treatment is planned, the viscosity of the binder used should be towards the lower end of the permissible range. if the binder selected is an emulsion it should be borne in mind that anionic emulsions may not adhere well to certain acidic aggregates such as granite and quartzite.

- *The characteristics of the road site.* Fluid binders such as emulsions are not suited to steep cross falls or gradients since they may drain off the road before 'breaking'. However, it may be possible to use a 'split application' of binder.

- *The type of binder handling and spraying equipment available.* The equipment must be capable of maintaining an adequate quantity of the selected binder at its appropriate spraying temperature and spraying it evenly at the required rate of spread.

- *The available binders.* There may be limited choice of binders but a balanced choice should be made where possible. Factors which may influence the final selection of a binder include cost, ease of use, flexibility with regard to adjusting binder viscosity on site and any influence on the quality of the finished dressing.

5.12 Consideration of these factors will usually narrow the choice of binder to one or two options. The final selection will be determined by other factors such as the past experience of the surface dressing team.

Choice of binder and timing of construction work

5.13 The choice of cutback grade or penetration grade bitumen for surface dressing work is largely controlled by road temperatures at and shortly after the time of construction. However, there are relative advantages and disadvantages associated with the use of penetration grade binders or cutback bitumen.

5.14 MC 3000 cutback binder typically contains 12 to 17 per cent of cutter. Under warm road conditions this makes the binder very tolerant of short delays in the application of chippings and of the use of moderately dusty chippings. It is therefore a good material to use for training new surface dressing teams and for use in areas where water for cleaning chippings is scarce. However, a substantial percentage of the cutter, especially if it is diesel, can remain in the seal for many months. If road temperatures increase soon after construction, it is likely that MC3000 will be found to be 'tender' and that the seal can be easily damaged. This should not be a problem for lightly trafficked roads and for new roads that are not opened to general traffic for several days after the surface dressing is constructed. If a road must be opened to fast high volume traffic within a few hours of construction then there will be considerable advantage in using as high a viscosity binder as conditions will permit. For instance, if the road temperature is 40^0C then for heavy traffic the chart in Figure 2 would suggest that MC 3000 would be only just viscous enough. 400/500 penetration grade bitumen would be on the limit of being too viscous, however, it would be preferable to cut-back the bitumen to a 500/600 penetration grade rather than use a MC3000 grade. If pre-coated chippings could be used then the use of a 400 penetration grade bitumen would be acceptable.

5.15 Penetration grade bitumens as hard as 80/100 are often used for surface dressing work when road temperatures are high. With such a high viscosity bitumen it is very important that the chippings are applied immediately after spraying and, to achieve this, the chipping spreader must follow closely behind the distributor. The construction team must be well organised and skilful. This type of binder will not be tolerant of delays in the application of the chippings nor of the use of dusty chippings. In either situation, early trafficking is very likely to dislodge chippings and seriously damage the seal.

5.16 The use of penetration grade binders in the range 80/100 to 400 is preferred to MC3000 wherever circumstances allow this. For high volume fast traffic, where very early adhesion of the chippings is essential, consideration should be given to the use of pre-coated chippings. This will allow the use of a more viscous binder for a given road temperature and will ensure that a strong early bonding of the chippings is obtained. A polymer modified or rubberised binder can also provide immediate strong adhesion. Alternatively, emulsions will provide good 'wetting' and early adhesion provided rainfall does not interfere with curing.

5.17 The most difficult situations occur when it is required to start work early in the day and temperatures are considerably lower than they will be in the afternoon. It may appear to be appropriate to use a cutback binder, such as MC3000, for the low road temperature but, by the afternoon, the seal is likely to be too 'soft'. In these situations it better to use a more viscous binder and keep the traffic off of the new seal until it has been rolled in the afternoon.

Designing the surface dressing

Basis for the design method

5.18 Having selected the nominal size of chipping and the type of binder to be used, the next step in the design of a surface dressing is to determine the rate of spread of the binder. In this respect the recommendations given in Road Note 39 (TRL, 1996) for conditions in the United Kingdom are not appropriate for most tropical or sub-tropical countries. Differences in climate, uniformity of road surfaces, the quality of aggregates, traffic characteristics and construction practice, necessitate a more general approach to the determination of the rate of spread of the binder for application in tropical countries.

5.19 The method of surface dressing design put forward by Jackson (1963) is suitable for general application and trials undertaken by the TRL in Kenya (Hitch, 1981) indicate that with some minor modifications, it works well under a range of tropical and sub-tropical conditions. Accordingly this method is recommended as a good basis on which to develop national or regional standards for surface dressing design in tropical countries.

5.20 The Jackson method of design incorporates concepts first put forward by Hanson (1934) which relate the voids in a layer of chippings to the amount of binder necessary to hold the chippings in place. Hanson calculated that in a loose single layer of chippings, such as is spread for a surface dressing, the voids are initially about 50 per cent decreasing to about 30 per cent after rolling and subsequently to 20 per cent by the action of traffic. For best results, between 50 and 70 per cent of the voids in the compacted aggregate should be filled with binder.

Hence it is possible to calculate the amount of binder required to retain a layer of regular, cubical chippings of any size. However, in practice chippings are rarely the ideal cubical shape (especially when unsuitable crushing plant has been used) and this is why the ALD concept was originally introduced.

Determining the average least dimension of chippings

5.21 The ALD of chippings is a function of both the average size of the chippings, as determined by normal square mesh sieves, and the degree of flakiness. The ALD may be determined in two ways.

Method A. A grading analysis is performed on a representative sample of the chippings in accordance with British Standard 812:1985. The sieve size through which 50 per cent of the chippings pass is determined (i.e. the 'median size'). The flakiness index is then also determined in accordance with British Standard 812:1985. The ALD of the chippings is then derived from the nomograph shown in Figure 6.

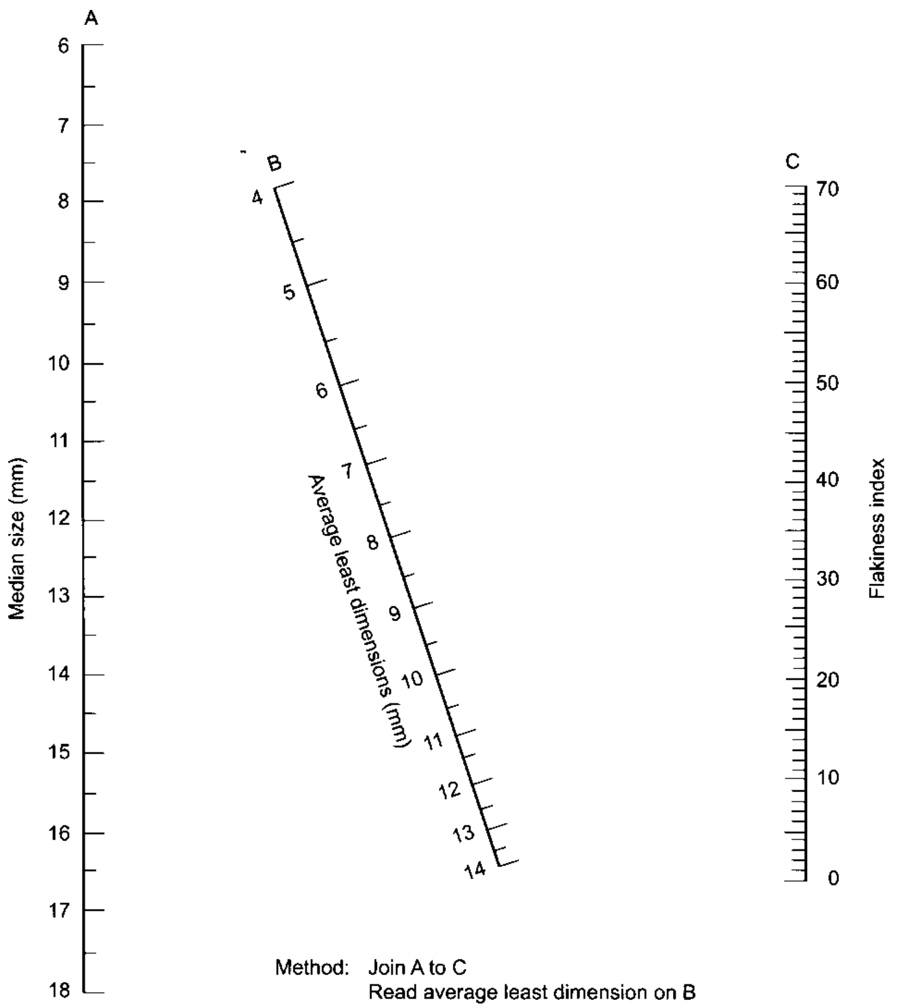

Figure 6 Determination of average least dimension

Method B. A representative sample of the chippings is carefully subdivided (in accordance with British Standard 812:1985) to give approximately 200 chippings. The least dimension of each chipping is measured manually and the mean value, or ALD, is calculated.

Determining the overall weighting factor

5.22 The ALD of the chippings is used with an overall weighting factor to determine the basic rate of spray of bitumen. The overall weighting factor F' is determined by adding together four factors that represent: the level of traffic, the condition of the existing road surface, the climate and the type of chippings that will be used. Factors appropriate to the site to be surface dressed are selected from Table 5.

Table 5 Weighting factors for surface dressing design

Description		*Factor*
Total traffic (all classes)		
	Vehicles/lane/day	
Very light	0 - 50	+3
Light	50 - 250	+1
Medium	250 - 500	0
Medium-heavy	500 - 1500	-1
Heavy	1500 - 3000	-3
Very heavy	3000+	-5
Existing surface		
Untreated or primed base		+6
Very lean bituminous		+4
Lean bituminous		0
Average bituminous		-1
Very rich bituminous		-3
Climatic conditions		
Wet and cold		+2
Tropical (wet and hot)		+1
Temperate		0
Semi-arid (hot and dry)		-1
Arid (very dry and very hot)		-2
Type of chippings		
Round/dusty		+2
Cubical		0
Flaky (see Appendix A)		-2
Pre-coated		-2

5.23 For example, if flaky chippings (factor -2) are to be used at a road site carrying medium to heavy traffic (factor - 1) and which has a very rich bituminous surface (factor -3) in a wet tropical climate (factor +1) the overall weighting factor 'F' is:

$$-2-1-3+1=-5$$

5.24 The rating for the existing surface allows for the amount of binder which is required to fill the surface voids and which is therefore not available to contribute to the binder film that retains the chippings. If the existing surface of the road is rough, it should be rated as 'very lean bituminous' even if its overall colour is dark with bitumen. Similarly, when determining the rate of spread of binder for the second layer of a double surface dressing, the first layer should also be rated 'very lean bituminous'.

5.25 The Jackson method of determining the rate of spread of binder requires the estimation of traffic in terms of numbers of vehicles only. However, if the proportion of commercial vehicles in the traffic stream is high (say more than 20 per cent) the traffic factor selected should be for the next higher category of traffic than is indicated by the simple volume count.

Determining the basic bitumen spray rate

5.26 Using the ALD and 'F' values in equation 1 will give the required basic rate of spread of binder.

$$R = 0.625+(F*0.023)+[0.0375+(F*0.0011)]ALD \quad (1)$$

Where F = Overall weighting factor

ALD = the average least dimension of the chippings (mm)

R = Basic rate of spread of bitumen (kg/m^2)

5.27 Alternatively, the two values can be used in the design chart given in Figure 7. The intercept between the appropriate factor line and the ALD line is located and the rate of spread of the binder is then read off directly at the bottom of the chart. The basic rate of spread of bitumen (R) is the mass of MC3000 binder per unit area on the road surface immediately after spraying. The relative density of MC3000 can be assumed to be 1.0 and the spread rate can therefore also be expressed in 1/m^2, however, calibration of a distributor is easier to do by measuring spray rates in terms of mass.

Spray rate adjustment factors

5.28 Research in Kenya (Hitch, 1981) and elsewhere, has indicated that best results will be obtained if the basic rate of spread of binder is adjusted to take account of traffic speed and road gradient as follows.

- For slow traffic or climbing grades with gradients steeper than 3 per cent, the basic rate of spread of binder should be reduced by approximately 10 per cent.

- For fast traffic or downgrades steeper than 3 per cent the basic rate of spread of binder should be increased by approximately 10 per cent.

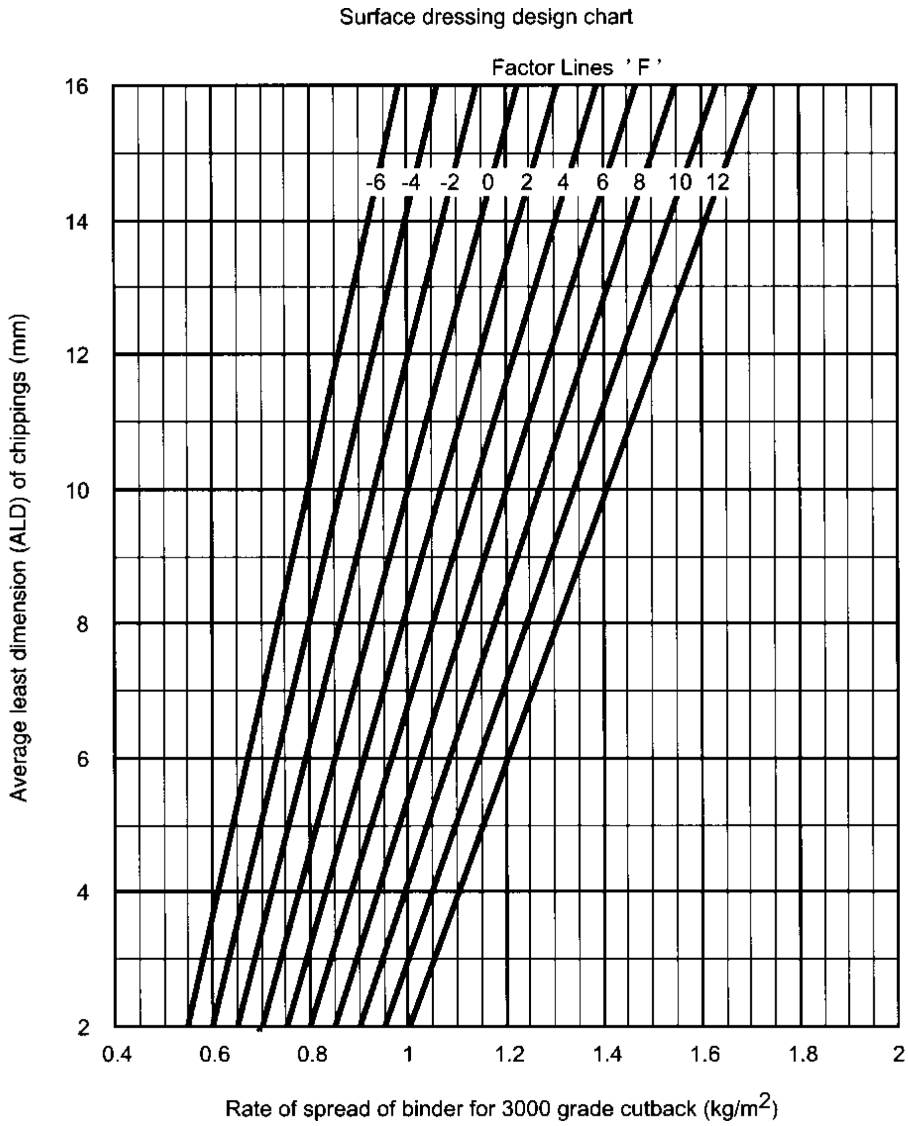

Figure 7 Surface dressing design chart

5.29 The definition of traffic speed is not precise but is meant to differentiate between roads with a high proportion of heavy vehicles and those carrying mainly cars travelling at 80km/h or more.

5.30 The basic rate of spread of binder must also be modified to allow for the type of binder used. The following modifications are appropriate:

- *Penetration grade binders:* decrease the rate of spread by 10 per cent.
- *Cutback binders:* for MC/RC 3000 no modification is required. (In the rare cases when cutbacks with lower viscosity are used the rate of spread should be increased to allow for the additional percentage of cutter used).
- *Emulsion binders:* multiply the rate of spread given in the chart by 90/bitumen content of the emulsion (per cent). This calculation includes a reduction of ten per cent for the residual penetration grade binder.

5.31 Suggested adjustment factors for different binders and different site conditions are given in Table 6. The adjustment factors reflect the amount of cutter used in the base 80/100 penetration grade bitumen but must be regarded as approximate values.

5.32 The amount of cutter required for 'on-site' blending should be determined in the laboratory by making viscosity tests on a range of blends of bitumen and cutter. Work at TRL (Hitch and Stewart, 1987) has shown that MC3000 can be made in the field by blending 90 penetration bitumen with 12 to 14 per cent by volume of a 3:1 mixture of kerosene and diesel. It is suggested that if there is significantly more than 14 per cent of cutter by volume then the spray rate should be adjusted to compensate for this. For binders which have been cutback at the refinery, the cutter content should be obtained from the manufacturer.

5.33 If a different grade of binder is required then the adjustment factor should reflect the different amount of cutter used. For instance, a 200 penetration

Table 6 Typical bitumen spray rate adjustment factors

Binder grade	*Basic spray rate from Figure 7 or equation 1*	*Flat terrain, moderate traffic speeds*	*High speed traffic, down-hill grades >3%*	*Low speed traffic, up-hill grades >3%*
MC3000	R	R	R*l.1	R*0.9
300 pen	R	R*0.95	R*1.05	R*0.86
80/100 pen	R	R*0.9	R*0.99	R*0.81
Emulsion[1]	R	R*(90/%binder)	R*(99/%binder)	R*(8l/%binder)

[1] *'% binder' is the percentage of bitumen in the emulsion.*

binder may have 3 per cent cutter in it and therefore the spray rate is 103 per cent of the rate for a 80/100 penetration bitumen. Appendix E gives an example of the use of the design chart and adjustment factors.

Adjusting rates of spray for maximum durability

5.34 The spray rate which will be arrived at after applying the adjustment factors in Table 6 will provide very good surface texture and use an 'economic' quantity of binder. However, because of the difficulties experienced in many countries in carrying out effective maintenance, there is considerable merit in sacrificing some surface texture for increased durability of the seal. For roads on flat terrain and carrying moderate to high speed traffic it is possible to increase the spray rates obtained by applying the factors given in Table 6 by approximately 8 per cent. The heavier spray rate may result in the surface having a 'bitumen-rich' appearance in the wheel paths of roads carrying appreciable volumes of traffic. However, the additional binder should not result in bleeding and it can still be expected that more surface texture will be retained than is usual in an asphalt concrete wearing course.

Surface dressing design for low volume roads

5.35 If a low volume road, carrying less than about 100 vehicles per day, is surface dressed it is very important that the seal is designed to be as durable as possible to minimise the need for subsequent maintenance.

5.36 A double surface dressing should be used on new roadbases and the maximum durability of the seal can be obtained by using the heaviest application of bitumen which does not result in bleeding.

5.37 Where crushing facilities are put in place solely to produce chippings for a project, it will be important to maximise use of the crusher output. This will require the use of different combinations of chipping sizes and correspondingly different bitumen spray rates. The normally recommended sizes of chippings for different road hardness and low commercial traffic volumes are reproduced in Table 7.

5.38 It may be desirable to use chippings of a larger size than those recommended in Table 7 for reasons of economy. It is likely that the rate of application of

Table 7 Nominal size of chippings for different hardness of road surface

No. of commercial Vehicles/lane/day[1]	*20-100*	*<20*
Category of road surface hardness	*Nominal chipping size (mm)*	
Very hard	6	6
Hard	6	6
Normal	10	6
Soft	14	10

[1] *Vehicles with an unladen weight greater than 1.5 tonnes*

bitumen determined in the normal way will be too low to obtain good durability. Low volumes of traffic are also unlikely to cause the chippings to be 'rotated' into a tight matrix and this will result in the layer being of greater depth than the ALD of the chippings, which is assumed in the design process. It should therefore be safe to increase bitumen spray rates on low volume roads to compensate for the reduced embedment of 'oversize' chippings and the increased texture depth that results from less reorientation of the chippings under light traffic.

5.39 Ideally the ALD of the two aggregate sizes used in a double surface dressing should differ by at least a factor of two. If the ALD of the chippings in the second seal is more than half the ALD of the chippings in the first seal then the texture depth will be further increased and the capacity of the aggregate structure for bitumen will be increased.

5.40 It is suggested that on low volume roads the bitumen spray rates should be increased above the basic rate of spread of bitumen (see paragraphs 5.26 to 5.27*)* by up to the percentages given in Table 8. It is important that these increased spray rates are adjusted on the basis of trial sections and local experience.

Spread rate of chippings

5.41 An estimate of the rate of application of the chippings assuming that the chippings have a loose density of 1.35Mg/m^3, can be obtained from the following equation:

$$\text{Chipping application rate (kg/m}^2\text{)} = 1.364 * \text{ALD}$$

Table 8 Suggested maximum increases in bitumen spray rate for low volume roads

ALD of chippings (mm)	3		6		>6	
All traffic (vehicles/lane/day)	<20	20-100	<20	20-100	<20	20-100
Increase in bitumen spray rate (per cent)	15	10	20	15	30	20

5.42 The chipping application rate should be regarded as a rough guide only. It is useful in estimating the quantity of chippings that is required for a surface dressing project before crushing and stockpiling of the chippings is carried out. A better method of estimating the approximate application rate of the chippings is to spread a single layer of chippings taken from the stockpile on a tray of known area. The chippings are then weighed, the process repeated ten times with fresh chippings, and the mean value calculated. An additional ten per cent is allowed for whip off. Storage and handling losses must also be allowed for when stockpiling chippings.

5.43 The precise chipping application rate must be determined by observing on site whether any exposed binder remains after spreading the chippings, indicating too low a rate of application of chippings, or whether chippings are resting on top of each other, indicating too high an application rate. Best results are obtained when the chippings are tightly packed together, one layer thick. To achieve this. a slight excess of chippings must be applied. Some will be moved by the traffic and will tend to fill small areas where there are insufficient chippings. Too great an excess of chippings will increase the risk of whip-off and windscreen damage.

6 Plant and equipment

Methods of distributing binder

6.1 The success of a surface dressing is very dependent on the binder being applied uniformly at the correct rate of spread. The method adopted for distributing binder must therefore;

- be capable of spreading the binder uniformly and at the predetermined rate of spread; and
- be able to spray a large enough area in a working day to match the required surface dressing programme.

6.2 The use of hand-held containers such as watering cans, perforated buckets etc, has a place for minor works. Any type of binder from penetration grades to emulsion can be applied in this way but uniform spreading of predetermined amounts cannot be achieved by this method and hence it is not recommended for anything other than small-scale work. A rather more controllable method of hand application is to use hand lances. if skilfully used, they can produce an acceptably uniform rate of spread but it is very difficult to achieve a specified rate of spread with them. They cannot therefore be recommended for other than small-scale work and limited maintenance operations. The use of either of these hand methods of binder application for larger scale work invariably results in waste of valuable binder and a poor quality surface dressing which will have a short 'life'.

6.3 The spreading of binder on a larger scale requires the use of a bulk binder distributor, which may be either a self propelled or a towed unit (British Standards BS 1707:1989, and BS 3136:Part 2:1972)

6.4 There are two basic types of bulk binder distributors, the pressurised tank, constant rate of spread, constant volume, and constant pressure machines.

Constant volume distributors

6.5 These distributors are fitted with positive displacement pumps, the output of which can be pre-set. All the binder delivered by the pump is fed to the spray-bar when spraying is in progress and there is no by-pass arrangement for re-circulating binder to the tank. For a spray bar of given length and output, the rate of spread of binder on the road is inversely proportional to the forward road speed of the distributor. On most constant volume machines it is possible to preheat the spray bar by circulating hot binder to it before spraying commences but this facility is not available on all machines.

6.6 Constant volume distributors can spray a wide range of types of binder and they are quite common in tropical developing countries. Disadvantages of constant volume distributors are;

- Calibration involves three inter-related variables, i.e. the pump output, the road speed and the spray bar width; hence the calibration procedures need to be extensive if, for example, it is required to vary spray bar width to allow for different lane widths. However, some constant volume machines have a limited but useful degree of automatic control of bitumen pump speed to compensate for variation in road speed.
- The relative mechanical complexity of the machines means that they are not suitable for operation by partly skilled operators.

6.7 Most distributors manufactured in the USA are constant volume machines.

Constant pressure distributors

6.8 In these machines a pump of adequate capacity delivers binder to the spray bar at a pre-set pressure. A relief valve regulates the pressure and permits binder to bypass the spray bar and return to the tank. The pressure in the spray bar is not affected by the number of jets in use, and hence re-calibration is not required when spray bar extensions are fitted or the number of jets are reduced. As with constant volume machines, the rate of spread of binder varies inversely with the road speed of the distributor.

6.9 Most distributors made in the UK are of the constant pressure type.

Principal components of binder distributors

6.10 Distributors spray the bitumen through a spray bar to which the binder is delivered by a pump. or under pressure, from a heated insulated storage tank. Brief descriptions of these principal components and general guidelines on their operation are given below. Manufacturers' instruction manuals give detailed operating instructions for each model of distributor. These should be carefully followed and used to train operators so that they fully understand the principles and the correct method of operation of their distributor.

Spray bars and spray jets

6.11 There are basically two types of spray jets, slotted jets and whirling spray jets. Slotted jets are usually high output jets and are particularly suitable for spraying polymer modified binders or for grouting. However, some manufacturers can supply jets with a range of different slot widths or whirling spray jets for the same spray bar. Whirling spray jets are of lower output and have the advantage for normal surface dressing in that the forward speed of the distributor can be slower than when slotted jets are used. This can enable the speed to be controlled more easily and for the chipping operation to keep pace with the spraying. Higher bitumen temperatures are necessary when spraying with whirling jets and suitable spraying temperatures for both types of jets are given in Table 9.

6.12 The swirl chamber of whirling spray jets is enclosed in the spray bar so that the jets can be pre-heated effectively by circulating hot binder through the spray bar prior to spraying. The fine spray produced by whirling spray jets necessitates protecting the spray bar with a hood and canvas curtains to prevent wind from deflecting the spray. This is not required with slotted jets.

Table 9 Spraying temperatures for binders

	Whirling spray jets		*Slotted jets*	
Cutback grades	*Min °C*	*Max °C*	*Min °C*	*Max °C*
MC30	50	60	40	50
RC/MC70	65	80	55	70
RC/MC250	95	115	80	90
RC/MC800	115	135	105	115
RC/MC3000	135	150	120	130
Penetration grades				
400/500	160	170	140	150
280/320	165	175	150	160
180/200	170	190	155	165
80/100	180	200	165	175

1 Because of the flammable nature of the solvent used in RC-type cutbacks, application temperatures should be restricted to the lower parts of the ranges given above.

2 It is ***essential*** *to extinguish flames and prohibit smoking when heating, pumping or spraying all cutbacks. Fire extinguishers should always be readily at hand.*

6.13 On constant pressure distributors a pressure gauge fitted to the spray bar registers the spraying pressure during spraying (though not when re-circulating only), and on some machines a temperature gauge is also fitted to the spray bar.

6.14 The uniformity of transverse distribution of a spray bar should be checked by the 'Depot tray test' at least once a year. This test is specified fully in BS 1707:1989 (1989) and is described in Appendix F.

6.15 Attention should also be paid to maintaining the correct height of the spray bar above the road. Whilst jets are positioned on the spray bar so that their sprays overlap to minimise the effect of variations in spray bar height on the uniformity of transverse distribution of binder. some adverse effects are likely if the spray bar is operated at an incorrect height. Slotted jets are more critical than whirling spray jets in this respect.

6.16 Since the spray of the last jet at each end of a spray bar is not overlapped by an adjacent spray the rate of spread of binder is less at the ends of a spray bar than along its length. For this reason, adjacent spraying runs of a distributor are normally overlapped. Some distributors are fitted with a larger jet at the end of the spray bar to compensate for this effect. The alternative practice of turning the last jet of a slotted jet spray bar at right angles is not recommended, nor is the practice of attempting to spray butt joints. This invariably results in narrow unsprayed strips between adjacent paths of the distributor.

6.17 To ensure satisfactory performance of the spray bar, strainers and in-line filters in the binder feed system must be cleaned regularly otherwise blocked jets will result. Before commencing spraying, the spray bar and jets should be preheated by circulating hot binder and then the jets should be operated for a few seconds, discharging on to waste ground, to ensure they are operating freely.

6.18 If spraying is interrupted briefly. for example, to allow the chipping operation to catch up, the spray bar should be kept hot by circulating binder, preferably with the distributor standing off the road. When spraying is stopped for a longer period, such as at the end of the day or when the tank is being re-filled, the binder pump should be opened to air and the feed line to the spray bar, the spray bar itself, and the return line back to the tank emptied. The return valve should then be closed and the jets blown out with air. If the machine is being allowed to cool completely the binder pump should be flushed out with diesel fuel. Most spray bars are fitted with a drain cock so that binder or flushing oil can be drained off when required.

Binder pumps and air pumps

6.19 On most distributors the binder pump is driven by a separate engine, usually mounted either at the rear of the tank or between the tank and the driving cab. The pump itself is normally located inside the binder tank so that it is kept hot by the surrounding binder. The engine drive to the pump is usually through a clutch and the same engine usually drives a small air compressor which supplies air and fuel under pressure to the burners.

6.20 The binder tank should be emptied at the end of a day's work so that when the tank is next filled with hot binder there is no cold binder around the pump to prevent it from warming up quickly. If the binder system is not cleaned out as described above the pump will not work until it has been cleared of cold bitumen. This should be done by turning the engine crank manually as the bitumen in the distributor is heated and not by using the engine.

6.21 On some distributors the pump drives are taken either from the main power transmission of the vehicle or are driven by the main engine through a hydraulic system.

Tanks and burners

6.22 Most binder distributors have tanks with a capacity of between 500 and 16000 litres. The tanks are invariably made of steel and are lagged to reduce heat loss. Baffles are fitted internally to minimise surge. An inspection hatch fitted with a strainer basket provides access at the top of the tank, and a dipstick or contents gauge indicates the level of the binder.

6.23 Flues fitted with burners run through the tank to heat the binder and a thermometer is fitted to indicate the temperature. The burners use either kerosene or diesel fuel which is usually drawn from the main fuel tank of the vehicle. Vaporising burners require the vaporising coil to be heated before they can operate, whilst atomising burners, which are preferable. can start up from cold. Fire extinguishers, suitable for fighting fires fuelled by bitumen or solvents, should be located in convenient positions. It is important that professional advice is obtained on fire-fighting matters well before work commences.

6.24 The burners in a distributor should be used to make only relatively small adjustments to the binder temperature. Wherever possible the main operation of heating the binder should be done in pre-heaters and the binder transferred to the distributor at or above the spraying temperature.

6.25 When heating binder in the tank it is necessary to ensure that the burner flues are fully covered by the binder, preferably with a depth of at least 150mm of binder over the top of the flues. On some distributors a danger level is indicated on the contents gauge. If this precaution is not observed the burner flues may burn out, causing a fire or explosion.

6.26 Burners must not be operated when the distributor is spraying or moving or if any blending is in progress. To prevent 'coking' of binder in the vicinity of the flues it is recommended that the binder is circulated when the burners are lit. This will also speed up the transfer of heat throughout the binder.

Distributor speed control and calibration

6.27 Most binder distributors are equipped with a 'fifth wheel' which operates a low range speedometer. The speedometer is located in the driver's cab in a prominent position so that a steady forward speed can be maintained relatively easily.

6.28 To spray binder at a specified rate of spread all that is necessary with constant pressure machines is to read off the corresponding road speed from the 'Driver's chart' or calibration chart which should be carried by every distributor. With constant volume machines it is necessary to select from the chart both the pump output and the road speed necessary to give the required rate of spread for the width of spray bar being used.

6.29 If the distributor has not previously been calibrated or if the calibration chart has been lost either of the following two methods can be used to calibrate the machine.

> **Method A.** This method is preferred for initial calibration. The distributor is loaded with binder which is raised to the correct spraying temperature and circulated around the spray bar to heat it. Static spraying is done into suitable containers to check the evenness of the appearance of the binder spray.

Binder is then sprayed into weighed containers of suitable dimensions for an accurately measured period of time and the mass of sprayed binder determined by weighing. The mass of binder delivered per unit time is calculated and the rate of spread/speed of distributor relationship is determined as described in Appendix G.

Method B. Four or five weighed metal trays of known area (0.lm square is a suitable size) are placed in the path of the distributor as it makes a spraying run at a constant speed. The trays are then picked up and weighed and the rate of spread of binder is calculated. The process is repeated with different distributor speeds until the required rate of spread/speed chart can be drawn up. This tray test should be repeated periodically during surface dressing operations to check the consistency of the rate of spread of bitumen. It will, of course, be necessary to complete the dressing by hand on the areas where the trays were located.

6.30 Tar and bitumen binders have been found to have different outflow characteristics when sprayed from whirling spray jets; hence, if both kinds of binder are likely to be used, it is advisable to draw up a calibration chart for both binders for machines fitted with this type of jet.

Chip spreaders

6.31 Chippings can be spread on the sprayed binder by hand and good results can be obtained by this method with a well-trained and plentiful labour force. In general, however, better results will be obtained when chippings are spread mechanically since this facilitates a more even distribution and rapid application of the chippings after the binder has been sprayed.

6.32 There are three main types of chip spreader;

- Metering or non-metering 'tail-board' types.
- Pushed metering chip spreaders.
- Self-propelled metering or non metering chip spreaders.

6.33 Non-metering tail board chip spreaders are bolted in place of the tailgate of a normal tipping lorry. They are the cheapest and simplest kind of mechanical chip spreader, having very few moving parts. A serrated steel comb controls the flow of chippings and a rotary gate with a helical edge controls the width of spread and the starting and stopping of the flow. The 'Hornsey gritter' is a popular example of this type. The flow of chippings is controlled by an operator who walks beside the tipper lorry, whilst it is driven in reverse at walking speed with the tipper body partly raised. Since the rate of spread of the chippings is dependent on gravity and the speed of the tipper lorry acting independently, the skill of the lorry driver is crucial in ensuring an even distribution of the chippings. Nevertheless good results can be obtained with these simple machines.

6.34 However, to reduce dependence on the skill of the tipper driver, metering devices are available for tailboard chip spreaders that control the rate of discharge of the chippings by delivering them over a roller which is driven from the road wheels of the lorry or from a fifth wheel attached to the chip spreader. In this way variations in road speed of the tipper produce corresponding variations in the rate of discharge of the chippings.

6.35 Pushed metering chip spreaders operate on a similar principle but the metering roll is located at the base of a wheeled hopper which is pushed along the road by a reversing tipper lorry. The roll is driven by the road wheels of the hopper and the chippings in the hopper are replenished from the raised body of the tipper.

6.36 Self-propelled metering chip spreaders are the most effective machines available for applying chippings. They have a hopper at the rear into which chippings are discharged from the delivering tipper lorry which, during the transfer of the chippings, is towed along in reverse by the chip spreader through a quick release mechanism. Conveyor belts transfer the chippings to a transverse hopper at the front of the machine at the bottom of which is the metering roll that delivers the chippings to the road. However, there are self-propelled models which do not meter the chippings but rely on gravity feed and these machines require careful operation to ensure that a constant road speed is maintained.

6.37 It should be noted that none of these chip spreaders can deliver chippings at a pre-determined rate of spread; they simply facilitate an even distribution of the chippings and the operator must ensure that an adequate, but not excessive, rate of application is maintained.

6.38 The number of tipper lorries must be sufficient to provide a steady supply of chippings at a rate that allows the planned daily output of the surface dressing unit to be achieved. Depending on the distance of the stockpile of chippings from the surface dressing site, a minimum of four or five tippers is usually required plus one spare tipper for applying chippings by hand to awkward shaped corners and other areas that may not have been covered by the chip spreader.

Rollers and other equipment

6.39 The rolling of a surface dressing plays an important part in ensuring the retention of the chippings by assisting in the initial orientation and bedding down of the chippings in the binder. Traditionally, steel-wheeled rollers have been used but these tend to crush weaker aggregates and to crack poorly shaped chippings. Accordingly, if steel-wheeled rollers are used they should not exceed 8 tonnes in weight and should only be used on chippings which are strong enough. Some steel-wheeled rollers are fitted with rubber sleeves which makes them more suitable for surface dressing work but, as for any roller of this type. they will bridge' depressions in the existing road surface. In general. pneumatic tyred rollers are preferred because the tyres have a kneading action which tends to manoeuvre the chippings into a tight mosaic without splitting them and they do not 'bridge' depressions.

6.40 In favourable conditions, adhesion should be well established within 30 minutes of rolling after which considerable benefit can be obtained by allowing slow-moving traffic, particularly heavy lorries, to traverse the dressing *provided that* traffic speed is kept below 20 to 30 km/hr. This is very important and the use of a lead vehicle to 'convoy' traffic at slow speed is recommended.

6.41 Other important items of equipment required for surface dressing are mechanical brooms, binder heaters, decanters and transporters, and front-end loaders. Mechanical brooms, either towed or powered, are invaluable for obtaining a clean road surface prior to spraying the binder. Whilst hand brooming is an alternative, it is difficult to obtain as good results by this method, particularly when sweeping the surface of a newly constructed roadbase from which all loose particles should be removed.

6.42 Binder heaters are required to raise bulk stocks of binder to the spraying temperature. They should have sufficient capacity to supply. at the correct temperature, all the binder required for the planned output of the surface dressing unit. Binder decanters fulfil the same function when the binder is supplied in drums. Their capacity tends to be small hence it is usually necessary to provide several decanters to supply the required quantity of hot binder. When binder is supplied in bulk it is desirable to transport it from the bulk supply point in binder transporters. It is not desirable to use distributors for this, nor should the burners in a distributor be used for raising the binder from pumping temperature, at which it is usually discharged at the supply point, to the spraying temperature.

6.43 Front-end loaders are required primarily for handling chippings. They are essential for loading tipping lorries quickly with chippings at the stockpile to ensure that a continuous supply of chippings is delivered to the surface dressing site. Front-end loaders are, of course, also useful for many general lifting duties such as lifting drums of binder onto decanters. In addition to these major items of equipment a surface dressing unit requires a variety of small equipment such as road signs, hand tools etc. These are listed in Appendix H.

6.44 The routine maintenance and servicing of the mechanical equipment of a surface dressing unit usually has to be undertaken in the field, often remote from a base maintenance workshop. Machine operators do not normally have the skills to undertake running repairs or adjustments to their machines, nor are they usually authorised to do such work. There is thus a need to provide for a certain level of running repairs on site if long delays are to be avoided whilst plant fitters and spares are supplied from a distant maintenance workshop. The employment in the unit of a plant operator who is also a trained filler is therefore an advantage. together with the provision on site of a basic set of spares and the necessary tools.

7 The surface dressing process

Planning

7.1 A typical sequence of events in the planning of a surface dressing operation is as follows:

1 Select lengths of road requiring surface dressing and detail the preliminary work required on each road before the surface dressing can be carried out.

2 Implement the necessary preliminary work such as patching. heating and planing, shoulder and edge repairs, drainage works. reinstatement of service trenches etc. Allow as much time as possible for trafficking before commencement of surface dressing operations.

3 Decide on the type of surface dressing, the binder to be used and nominal chipping sizes, i.e. use the road surface hardness probe and make a preliminary design, taking into account constraints on the supplies of binder and chippings and limitations of plant and labour.

4 Ensure that the chippings will be of adequate quality with suitable ALD value(s). Stockpile chippings at convenient points along the road to be surface dressed so as to minimise haul distances during construction. Sample the chippings and confirm their suitability, modify the surface dressing design if necessary.

5 Order the appropriate binder for the anticipated weather conditions, or make provision for blending and adding adhesion agents as required.

6 Ensure that all the plant and equipment of the unit is in good working order.

7 Instruct the construction team of the details of the work programme.

8 Inform the police and other organisations likely to be affected by the surface dressing operation.

9 Inform the Materials Laboratory and arrange for the testing of aggregates and binder and rate of spread checks during spraying.

The surface dressing operation

7.2 The following sequence of events normally comprises the complete surface dressing operation:

1 Raising the temperature of the binder in the depot tanks is started early in the morning so that the distributor can be loaded with bitumen. The temperature should, preferably, be just above the ideal spraying temperature.

2 The supervisor arrives on site with traffic control equipment and supervises the placing of warning signs, control barriers, traffic cones, etc.

3 The surface dressing unit arrives on site and the distributor is parked off the road, preferably on a level site where the tank can be 'dipped' before and after spraying. If the parking area is not level and alternative site must be located.

4 Whilst the binder temperature is adjusted using the burners; binder is circulated through the spray bar, and the jets are checked for correct operation.

5 The calibrated 'dip-stick' supplied with the distributor is used to measure the volume of binder in the tank at the start of the day's work.

6 The supervisor instructs the distributor crew on the spray rate required, the corresponding road speed and the pump output, where this is necessary.

7 The chipping crew load the tipper lorries with chippings and the lorries line up ready to follow the distributor at the location specified by the supervisor. The rollers also prepare to follow the distributor after the chipping lorries.

8 The road is thoroughly swept and road furniture such as manhole covers, reflective studs etc, is masked so as to prevent contamination with binder.

9 Cut-off sheets of paper or other material are placed at the beginning and end of the spray run. The supervisor checks that the road is in fit condition for spraying and that laboratory staff, if present, are ready to do tray tests.

10 The burners on the distributor are extinguished and the distributor is positioned at the beginning of the spray run.

11 The driver adjusts the guide chain, the fifth wheel is lowered to the ground, and the height of the spray bar is adjusted.

12 The distributor then commences the spraying run, the cut-off sheets being removed immediately the distributor passes to avoid contamination of the wheels of the chip spreader or tipper lorries.

13 The chip spreader, tippers and the rollers should follow closely behind the distributor. Spraying should he stopped if the chipping operation is delayed for any reason. A strip of binder 150mm wide is left un-chipped at the edge of the lane to allow for the overlap of the adjacent run of the distributor.

14 A tipper and crew should move slowly over the new dressing, spreading chippings by hand shovels on areas where there is a deficiency of chippings.

15 The operation is then repeated on the adjacent pass (if any) and traffic is allowed to move slowly over the new dressing.

16 The distributor then returns to the original level parking site and the volume of binder remaining in the tank is checked with the 'dip-stick'. The supervisor records the amount of binder used and, knowing the total area sprayed, calculates the average rate-of-spread.

17 Speed control and other traffic warning signs are left in position along the length of the new surface dressing.

18 At the completion of the day's work the distributor spray bar is cleaned, all vehicles and plant refuelled and lubricated and the supervisor checks that the bitumen heaters are loaded ready to supply the binder required for the next day.

After-care

7.3 After-care is an essential part of the surfacing process and consists of removing excess chippings within 24 to 48 hours of the construction of a dressing. Some of the excess chippings will have been thrown clear by passing vehicles but some loose chippings will remain on the surface and these are a hazard to windscreens and, hence, a source of public complaint. They can be removed by brooming or by purposed-made suction cleaners. Care must be taken with brooming to avoid damage to the new dressing and it is usually best to do this work in the early morning when the surface dressing binder is still relatively stiff. It is Important to stress that over-chipping can reduce the quality of a dressing, make after-care a more time consuming process and also unnecessarily increase costs.

8 Other surface treatments

8.1 Apart from surface dressing there are several other kinds of surface treatment that complement surface dressings, five of which are described briefly below.

Slurry seals

8.2 A slurry seal is a mixture of fine aggregates, Portland cement filler, bitumen emulsion and additional water (ASTM, D 3910, 1996; BS 434, Parts 1 and 2, 1984). When freshly mixed they have a thick creamy consistency and can be spread to a thickness of 5 to 10 mm. This method of surfacing is not normally used for new construction because it is more expensive than surface dressing, does not provide as good a surface texture, and is not as durable as a properly designed and constructed surface dressing. Slurry mixes are best made and spread by purpose made machines as shown in Figure 8.

8.3 Slurry seals are often used in combination with a surface dressing to make a 'Cape-seal'. In this technique the slurry seal is applied on top of a single surface dressing to produce a surface texture which is less harsh than a surface dressing alone and a surface which is flexible and durable. However, the combination is more expensive than a double surface dressing and requires careful control during construction.

8.4 Both anionic and cationic emulsions may be used in slurry seals but cationic emulsion is normally used in slurries containing acidic aggregates, and its early breaking characteristics are also advantageous when rainfall is likely to occur. Suitable specifications for slurry seals and for a Cape-seal are given in Tables 10 and 11.

Table 10 Aggregate particle size distribution for slurry seals

	Percentage by mass of total aggregate passing test sieve		
BS test sieve (mm)	*Fine*	*General*	*Coarse*
10	-	100	100
5.0	100	90-100	70-90
2.36	90-100	65-90	45-70
1.18	65-90	45-70	28-50
0.6	40-60	30-50	19-34
0.3	25-42	18-30	12-25
0.15	15-30	10-21	7-18
0.075	10-20	5-15	5-15
Bitumen content (per cent by mass of dry aggregate)	10-16	7.5-13.5	6.5-12.0

The optimum mix design for the aggregate, filler, water and emulsion mixture should be determined using ASTM D 3910-84 (1996).

Table 11 Typical coverage for a new 'Cape seal'

Size of chipping in surface dressing (mm)	*Coverage (m^2/m^3)*
20	130-170
14	170-240
10	180-250

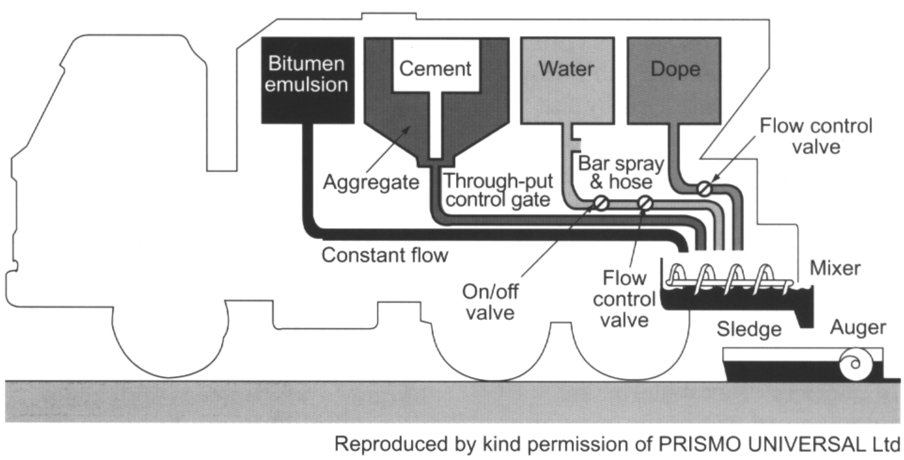

Figure 8 Slurry seal machine (diagrammatic)

Otta seal

8.5 An Otta seal is different to surface dressing in that a graded gravel or crushed aggregate containing all sizes, including filler, is used instead of single sized-chippings. There is no formal design procedure but recommendations based on case studies have been published (Norwegian Public Roads Administration, 1999). An Otta seal may be applied in a single or double layer. Evidence on the performance of these types of seal has shown them to have been satisfactory for over 12 years on roads carrying up to 300 vehicles per day (Overby, 1998).

8.6 The grading of the material is based on the level of traffic expected. Recommended grading envelopes are given in Table 12. Generally for roads carrying light traffic (<100 vehicles per day), a 'coarse' grading should be chosen while a 'dense' grading should be applied to one carrying greater than 100 vehicles per day.

Table 12 Otta seal aggregate grading requirements

	Percentage passing[1]	
Sieve (mm)	*Dense*	*Coarse*
19.0	100	100
16.0	79-100	77-100
12.0	61-100	59-100
9.5	42-100	40-85
4.750	19-68	17-46
2.360	8-51	1-20
1.180	6-40	0-10
0.600	3-30	0-3
0.300	2-21	0-2
0.150	1-16	0-1
0.075	0-10	0-1

[1] Aggregate should be screened to remove stone greater than 19mm

8.7 The viscosities of binders used in construction should reflect the quality of aggregate employed but normally cut back bitumen MC 800, MC 3000 or 150/200 penetration grade bitumen is used depending upon the traffic volumes and type of aggregate cover. Spray rates can not be calculated by design and must be chosen empirically. Typically, spray rates (hot) for single seals are between 1.6 and 2 $1/m^2$ but reference must be made to the Design Guide (NPRA, 1999) so that necessary detailed adjustments can be made.

8.8 It is because of the broad range of materials that may be used and the empirical nature of the design of this type of seal that it is imperative that pre-construction trials be carried out. This strategy will identify any special local conditions concerning the available aggregates and binders to become apparent to enable the engineer to adjust the nominal design.

8.9 An important aspect of Otta seal construction is the need for extensive rolling by pneumatic rollers for two or three days after construction. The action of rolling ensures the binder is forced upwards, coating the aggregate, and thereby initiating the process, continued by subsequent trafficking, of forming a premix like appearance to the surface.

8.10 After care can take as long as twelve days and involves sweeping dislodged aggregate back into the wheelpaths for further compaction by traffic.

Sand seals

8.11 Where chippings for a surface dressing are unobtainable or are very costly to provide, sand can be used as 'cover material' for a seal. Sand seals are less durable than surface dressings; the surface tends to abrade away under traffic. Nevertheless a sand seal can provide a satisfactory surfacing for lightly trafficked roads carrying less than 100 vehicles per lane per day.

8.12 It is not possible to design a sand seal in the same sense that a surface dressing can be designed. The particles of sand become submerged in the binder film, and the net result is a thin layer of sand-binder mixture adhering to the road surface.

8.13 The sand should be a clean coarse sand, with a maximum size of 6mm, containing no more than 15 per cent of material finer than 0.3 mm and a maximum of 2 per cent of material finer than 0.1 5mm. The sand should be applied at a rate of 6 to 7 x 10^{-3} m^3/m^2 (CSRA, 1986). The binder, which may be a cutback or an emulsion, should be spread at a rate of approximately 1.0 to 1.2 kg/m^2 depending on the type of surface being sealed.

Synthetic aggregate and resin treatments

8.14 These treatments are costly and are used only on relatively small areas, usually in urban situations. where high skidding resistance is required. The aggregate is normally a small. single-sized, calcined bauxite which has a high resistance to polishing under traffic. The aggregate is held by a film of epoxy-resin binder (Denning, 1978). The process requires special mixing and laying equipment and is normally undertaken by specialist contractors.

Applications of light bitumen sprays

8.15 There are two main uses for light sprays of bitumen:

- A light film of binder which can be applied as the final spray on a new surface dressing. The advantage of this procedure is that the risk of whip-off of chippings under fast traffic is reduced. This is particularly useful where management of traffic speed is difficult.

- A light spray of binder can be used to extend the life of a bituminous surfacing. This is particularly useful where a surfacing is showing signs of bitumen ageing by fretting or cracking.

8.16 These applications may be referred to by different authorities as Fog Sprays or Enrichment sprays.

Fog sprays

8.17 A light spray of bitumen emulsion is ideal for improving early retention of chippings in a new dressing (CSRA, 1972). The road surface is usually dampened before spraying or, if a low bitumen content emulsion (45 per cent) is available, this dampening can be omitted. Complete breaking of the emulsion must occur before traffic is allowed onto the dressing and it may be necessary to dust the surface with sand or crusher fines to prevent pick-up by traffic. If emulsion is diluted with water, to obtain a 45 per cent bitumen content to ensure the bitumen will flow around the chippings, then the suitability of the water must be established by mixing small trial batches.

8.18 The spray rate for the diluted emulsion will depend upon the surface texture of the new dressing but the best results will be achieved if the residual bitumen in the fog spray is treated as part of the design spray rate for the surface dressing. The spray rate is likely to be between 0.4 and 0.8 litre/m^2. It is important to avoid over application of bitumen which could result in poor skid resistance.

Enrichment sprays

8.19 Surfaces which are showing obvious signs of disintegration through bitumen ageing can be enriched by applying stable grade anionic bitumen emulsion which has been diluted at a rate of 1: 1 with water (CSRA, 1972). The rate of application will depend upon the texture of the surfacing and this must be determined by trial sprays, however, it is likely to be between 0.2 and 0.5 litres/m^2 of residual bitumen. Great care must be taken to avoid leaving a slippery surface and a light application of sand sized fines may be require in some cases.

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Appendix A: Requirements for grading and particle shape (Reproduced from BS 63: Part 2: 1987)

Specified sizes for given nominal sizes are given in Table Al and the grading limits for each nominal size of aggregate are given in Table A2. Specified values which can be applied to roads carrying up to 250 vehicles per day are given in Table A3.

Table Al Specified sizes for given nominal sizes (mm)

	Specified size	
Nominal size	*Passing BS test sieve* [1]	*Retained on BS test sieve*
20	20	14
14	14	10
10	10	6.3
6	6.3	3.35

[1] *In accordance with BS410 (1986), specification for test sieves*

Table A2 Grading limits, specified size and maximum flakiness index for surface dressing aggregates

Grading limits	*Nominal size of aggregates (mm)*			
BS test sieve[1]	*20*	*14*	*10*	*6.3*
28	100	-	-	-
20	85-100	100	-	-
14	0-35	85-100	100	-
10	0-7	0-35	85-100	100
6.3	-	0-7	0-35	85-100
5.0	-	-	0-10	-
3.35	-	-	-	0-35
2.36	0-2	0-2	0-2	0-10
0.600	-	-	-	0-2
0.075	0-1	0-1	0-1	0-1
Specified size	Minimum percentage by mass retained on BS test sieve			
Specified size	65	65	65	65
Maximum flakiness index				
Maximum flakiness index	25	25	25	-

[1] *In accordance with BS 410 (1986), Specification for test sieves*

Table A3 Grading limits, specified size and maximum flakiness index for surface dressing aggregates for lightly trafficked roads

Grading limits	*Nominal size of aggregates (mm)*			
BS test sieve'	*20*	*14*	*10*	*6.3*
28	100	-	-	-
20	85-100	100	-	-
14	0-40	85-100	100	-
10	0-7	0-40	85-100	100
6.3	-	0-7	0-35	85-100
5.0	-	-	0-10	-
3.35	-	-	-	0-35
2.36	0-3	0-3	0-3	0-10
0.600	0-2	0-2	0-2	0-2
0.075	-	-	-	-
Specified size	Minimum percentage by mass retained on BS test sieve			
Specified size	60	60	65	65
Maximum flakiness index				
Maximum flakiness index	35	35	35	-

[1] *In accordance with BS 410 (1986), specification for test sieves*

Appendix B: Recommended polished stone values of chippings for roads in Britain

Table B1 Minimum PSV of chippings for roads in Britain

<table>
<tr><th rowspan="2">Site definition</th><th colspan="14">Traffic (cv/l/d) at design life</th></tr>
<tr><th>0 to 100</th><th>101 to 250</th><th>251 to 500</th><th>501 to 750</th><th>751 to 1000</th><th>1001 to 1250</th><th>1251 to 1500</th><th>1501 to 1750</th><th>1751 to 2000</th><th>2001 to 2250</th><th>2251 to 2500</th><th>2501 to 2750</th><th>2751 to 3250</th><th>Over 3250</th></tr>
<tr><td>1 Motorway (main line).
Dual carriageway (all purpose) non-event sections.
Dual carriageway (all purpose) minor junctions.</td><td colspan="8">55</td><td colspan="2">57</td><td colspan="2">60</td><td>65</td><td>68</td></tr>
<tr><td>2 Single carriageway non-event sections.
Single carriageway minor junctions .</td><td>45</td><td>50</td><td colspan="2">53</td><td>55</td><td colspan="2">57</td><td>60</td><td colspan="2">63</td><td colspan="2">65</td><td colspan="2">68</td></tr>
<tr><td>3 Approaches to and across major junctions (all limbs).
Gradient 5%-10%, longer than 50m (Dual downhill; single uphill and downhill).
Bend (not subject to 64 kph or lower speed limit) radius 100-250m.
Roundabout</td><td>50</td><td>55</td><td>57</td><td colspan="2">60</td><td colspan="2">63</td><td colspan="2">65</td><td colspan="2">68</td><td colspan="3">over 70</td></tr>
<tr><td>4 Gradient >10%, longer than 50m (Dual downhill; single uphill and downhill).
Bend (not subject to 64 kph or lower speed limit) radius <100m.</td><td>55</td><td>60</td><td colspan="2">63</td><td colspan="2">65</td><td colspan="2">68</td><td colspan="3">over 70</td><td colspan="3" rowspan="2"></td></tr>
<tr><td>5 Approach to roundabout, traffic signals, pedestrian crossing, railway level crossing, etc.</td><td>63</td><td>65</td><td colspan="2">68</td><td colspan="7">over 70</td></tr>
</table>

Reference: Design Manual for Roads and Bridges. HD 28/94 (DMRB 7.3.1) Stationery Office, London.

Appendix C: The immersion tray test for determining the concentration of adhesion agent required

The following test procedure has been has been included in Road Note 14 (1964) and editions of Road Note 39, Design Guide for Road Surface Dressing (in the UK) since at least 1964 and it has in the past been published unchanged in ORN3. The method is reproduced below and then suggestions are made which may help to make it more appropriate for tropical conditions.

In this test a tin lid approximately 135mm diameter is covered with 15 to 20g of binder giving a film some l.5mm thick. When this has cooled to the test temperature* it is immersed in water also at test temperature to a depth of about 25mm. Nominal l4mm chippings are then applied by hand and lightly pressed in. At least six pieces of the aggregate are used. The chippings are left for 10 minutes and are then carefully removed from the binder film: the percentage of binder retained on the chippings is assessed visually.

When testing an adhesion agent, a known quantity of agent is added to the binder and thoroughly stirred to ensure good dispersion. The procedure is then as outlined above. The test is repeated with varying concentrations of agent in the binder until the minimum concentration required to give satisfactory results has been found. The concentration normally falls in the range 0.5 to 2.5 per cent by mass of agent.

The agent may be considered satisfactory for use on the road if, in the test, when the chippings are lifted from the binder film the faces which have been in contact with the film are all 90-100 per cent coated with binder.

*** The temperature of water and tray of binder in the above test should be the expected temperature of the road surface during the treatment. Where it is desired to compare the behaviour of different agents with a given stone and binder it is suggested that 20^{0}C should be used as the test temperature.**

Suggested new procedure

For tropical conditions the test bitumen should be of the grade to be used on site and it should be tested at appropriate site temperatures. Testing different adhesion agents at 20^{0}C is not practical if, for instance, hot conditions warrant the use of an 80/100 penetration grade bitumen. It is considered appropriate to test the adhesion agents at a temperature which relates to the design road temperature on which binder selection was based.

A tin lid approximately 135mm diameter, or other suitable tray, is covered with binder to give a film some l.5mm thick. Place at least 10 chippings which are damp, but not with shiny wet surfaces, in the film of binder at the 'design road temperature' and leave for 10 minutes. Then withdraw some of the chips to confirm coating. Add water to about half the depth of the remaining chippings at the chosen test temperature and leave for 10 minutes before withdrawing them and noting the degree of coating. If the coating is less than 90 per cent on any chipping then an adhesion agents should be tried. In this case different percentages of the adhesion agent are added to samples of the binder until 90-100 per cent coverage is obtained, after soaking, on all chippings.

If limestone chippings are available they will provide a good comparison of adhesion properties with the chippings to be used on site because limestone has good affinity with bitumen

Appendix D: The probe penetration for test for measuring road surface hardness

General description

This test utilises a modified soil assessment cone penetrometer, originally designed by the UK Military Engineering Experimental Establishment for the assessment of in-situ soil strength. The standard cone normally used with this penetrometer is replaced by a 4mm diameter probe rod with a hemispherical tip made of hardened steel. The probe is forced into the road surface under a load of 35 kgf (343N) applied for 10 seconds and the depth of penetration is measured by a spring loaded collar that slides up the probe rod. The distance the collar has moved is measured with a modified dial gauge. The temperature of the road surface is recorded and a graphical method is used to correct the probe measurements to an equivalent value at a standard temperature of 30^{0}C.

Method of operation

All measurements are made in the nearside wheel track of each traffic lane where maximum embedment of chippings can be expected. A minimum of ten measurements are required at each location. These should be evenly spaced along the road at intervals of 0.5m. any recently repaired or patched areas being ignored. For convenience the measurement points can be marked with a chalk cross. The probe tip should not be centred on any large stones present in the road surface.

Before each measurement the collar is slid down the probe rod until it is flush with the end of the probe. The probe is then centred on the measurement mark and a pressure of 35 kgf is applied for 10 seconds care being taken to keep the probe vertical. The probe is then lifted clear and the distance the collar has slid up the probe is recorded in millimetres.

It sometimes occurs that the point selected for test is below the general level of the surrounding road surface. It is then necessary to deduct the measurement of the initial projection of the probe tip from the final figure.

The road surface temperature should be measured at the same time that the probe is used and the tests should not be made when the surface temperature exceeds 35^{0}C. This will limit probe testing to the early morning in many tropical countries. The probe readings are corrected to a standard temperature of 30^{0}C using Figure D 1, and the mean of ten probe measurements is calculated and reported as the mean penetration at 30^{0}C. Categories of road surface hardness and the corresponding ranges of surface penetration values are shown in Table 4 (paragraph 5.5).

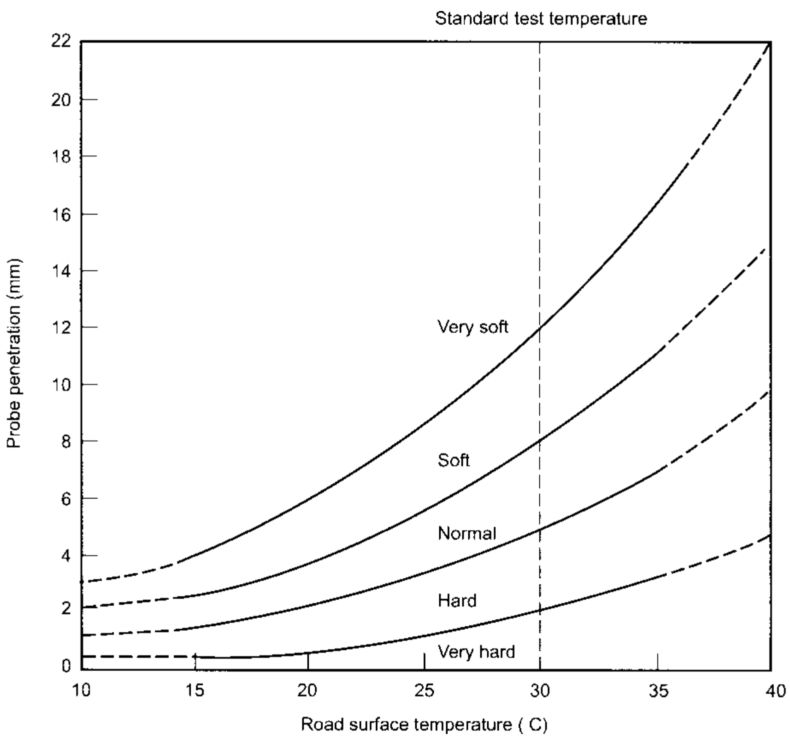

Figure D1 Graphical method for correcting measurements of road surface hardness to the standard test temperature of 30^{o}C

Appendix E: Example of a surface dressing design

Site description

A two-lane trunk road at an altitude of approximately 1500m.

Vehicle count averaged 3370 per day/lane (i.e. 'Heavy' rating).

Bitumen to be used is 400 penetration grade (made by cutting back 80/100 pen bitumen with 6.7 per cent by mass (or approximately 7.5 per cent by volume) of a 3:1 mixture of kerosene and diesel.

Design	**Factor**
Traffic (Heavy)	-3
Existing surface (average bituminous)	-1
Chippings (cubical)	0
Climate (hot/dry)	-1
Overall weighing factor (F)	-5

Aggregate (nominal 19 mm)

Median size (ie 50 per cent passing)	l6mm
Flakiness Index	16
Average Least Dimension (from nomograph, Figure 6)	12

The determination of spread rates of 80/100 and 400 pen bitumen for an F factor of -5 and an ALD of 12 on a site where maximum durability is required are summarised in Table El.

Table El Determination of spread rates for 400 penetration grade bitumen

Type Terrain	*Basic spread rate R for MC3000 (from Fig. 7 or equation 1) (kg/m²)*	*For increased durability R_D = (R*1.08) (kg/m²)*	*Spread rates for penetration grade binders (kg/m2)*	
			*80/100 pen (R_D *0.9)*	*400 pen (R_D *0.9*1.067)*
Flat	0.89	0.96	0.87	0.92
Uphill grade>3%	0.89*0.9=0.80	0.87	0.78	0.84
Downhill grade>3%	0.89*1.1=0.98	1.06	0.95	1.02

Appendix F: Tests for uniformity of transverse distribution of binder (depot tray tests) (reproduced from British Standard 1707:1989)

General

This standard includes requirements and tolerances for uniformity of distribution of binder across the surface being sprayed. A standard method for determining the transverse uniformity of distribution has been developed, the requirements of which are:

- The conditions prevailing during the test are comparable with those occurring during normal operations as regards:

  a Temperature of binder.

  b Viscosity of binder.

  c Height of distributor gear above the test surface.

  d Pressure in the distribution system.

  e Speed of operation of mechanical distributing gear, when applicable.

- The test surface is divided into strips of equal width, usually 50 mm, the length of the strips being parallel to the direction of travel of the distributor.

- The test is so arranged that the distributor can operate for a sufficient period to obtain the normal working conditions, and when this has been achieved the test surface is exposed to the discharge for a suitable period.

- The amount of binder delivered on each 50 mm strip is then measured and the results expressed as a percentage deviation from the mean for all the 50mm units over the effective width. (The effective width is defined as the sprayed width less the 150 mm margin at each side.)

- The rests of the test are recorded in the form indicated in Figure Fl.

Depot tray test apparatus and procedure

The apparatus consists of a wheeled trolley carrying a set of removable containers. Each container is 50 mm wide x 1000 mm long x 150 mm deep, made of 0.9 mm mild steel sheet, and of approximately 7 litres capacity. The containers extend to a width of 150mm greater than the full spray width of the distributor there being six containers per 300 mm of spray width. The rim of each container is lipped on one side in order that the containers will overlap and prevent binder escaping.

Before each test the containers are examined for damage and replacements made if such damage is likely to affect the test. The trolley runs on steel rails fastened to the top of a 1500 litres catch tank, the rails being horizontal and parallel to the sides of the tank and sufficiently long to allow the trolley to lie clear of the spray before the test. The top rim of each container, when fitted on the trolley is parallel to the rails and the same distance below the nozzles or distributing gear as the road surface under normal working conditions.

The distributor is backed into position with the spray bar over the catch tank, precautions being taken to see that the spray-bar is horizontal and at right angles to the rails. The trolley and containers rest on the rails clear of the spray hood. A short preliminary spray is made to ensure that all nozzles are functioning and that the machine is otherwise in normal working condition.

The trolley and containers are then pushed underneath the spray hood; spraying is commenced, and maintained for a period of time sufficient almost to fill the containers. The trolley is then withdrawn to the previous position.

The depth of binder in each container is measured by dipping with a steel rule graduated in millimetres. Each container is dipped in the same position, a convenient place being some 300 mm from one end. Dipping takes place when the froth has settled.

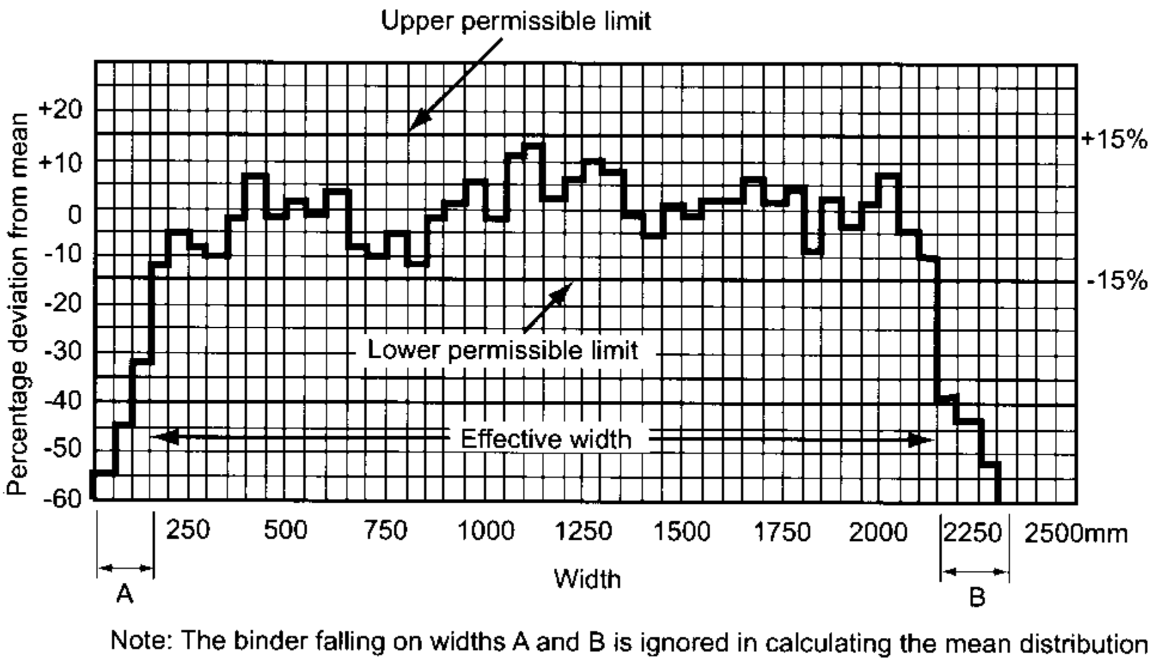

Figure F1 Typical results for uniformity of transverse distribution of binder. Reproduced from British Standard 1707:1970

Appendix G: Bitumen distributor: rate of spread/speed calibration

The output of the spray bar will have been determined for the given bitumen, operating temperature and distributor settings. In the case of constant pressure distributors, the operating pressure must be fixed. Constant volume distributors require separate calibrations for different combinations of bitumen delivery pump speed and number of jets in operation. By varying one of these variable at a time calibration charts can be developed.

Having completed the static calibration tests, so that the rate of delivery of bitumen is known, and determined the design spray rate the required road speed of the distributor can be calculated from equation G1.

$$\text{Speed of distributor} = S/(R*W) \qquad \text{(G1)}$$

Where S is the rate of delivery (mass) from the spray bar in kg/s
R is the design spray rate (mass) in kg/m^2
W is the sprayed width in metres

The required speed will then be in m/s. The calibration should then be checked dynamically as construction work progresses as described in 'Method B' in paragraph 6.29.

Appendix H: Miscellaneous equipment required for a surface dressing unit

1 Fuel and lubricant for servicing plant. (A purpose-built vehicle is often used and this is very effective).

2 Temporary traffic warning signs.

3 Stop/go signs and warning flags.

4 Hand brooms, shovels, wheelbarrows (for chipping small areas) watering cans, hammers and chisels (for opening drums etc.).

5 Masking tape for protecting road furniture and covering road markings.

6 Sample cans and bags.

7 Cut-off sheets of building paper or flattened drums for clean starting and finishing of spraying.

8 'Rotatherm' type thermometers.

9 Cleaning materials for plant and personnel.

10 A walking type distance measuring device.

11 First aid kit, including burn treatment supplies and supply of water

12 Fire extinguishers.

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