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MODERN PRACTICE IN SURFACE DRESSING

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INTRODUCTION

Many thousand miles of roads in various countries of the world (particularly in developing countries) have a surface dressing as their wearing surface only. This type of surfacing will remain popular for many years to come, as the traffic volumes even on the primary highways of such countries are so small that surface dressing is the only type of surfacing which can be justified on economic grounds.

Surface dressing is a multipurpose treatment for bituminous roads. It may be used as a routine treatment to improve and seal the existing road surface, or it may be utilized to improve the non-skidding properties of the road surface which has become slippery by the polishing of aggregates or flushing of excessive bitumen. It could also be employed to arrest the formation of pot holes or ravelling in case of excessively dry and hungry surface. Whatever may be the reason for surface dressing, it is a relatively inexpensive and efficient treatment for the wearing surface of highways.

There have been recent advancements in surface dressing techniques which have greatly improved the performance and life of surface dressing. Australia is a pioneer in this field and some of the surface dressed 4 lanes divided highways near Melbourne are reported to be carrying 20,000 vehicles per day and the average service life of surface dressing in Victoria is indicated as 10 years (1).

In West Pakistan, there are about 14,000 miles of bituminous roads. The cost of surface dressing this length at an average of Rs. 7,000 per mile (considering 10 wide roads) is Rs. 98.0 lakhs. If the life of the surfacing is improved to 8 years compared with existing 5 years, the annual saving would be $\left(\frac{98}{5}-\frac{98}{8}\right)$ = Rs. 7.35 lakhs. The net saving would be sizeable, even after allowing some expenses on field laboratories for quality control. This annual saving (which includes appreciable foreign exchange component) would increase as our roads are widened to 2 lanes and more new roads are constructed.

It is thus imperative that modern advancements in the field of surface dressing are employed to cut down costs and improve performance. This paper

is intended to introduce modern concept in the field of surface dressing. In this context, the design of surface dressing would be dealt with first, followed by a discussion of the engineering properties of surfacing materials relevant to their correct selection to suit surfacing projects.

Design of Surface Dressing

The modern practice is to design a surface dressing project taking cognizance of various local factors such as road surface texture, temperature and traffic volumes etc., rather than to follow the old practice based on "Standard Specifications".

A "Practical Engineer" might look askance at the mention of "design of surface dressing" as the usual practice in this field is so common that hardly any design procedure is expected. But considering the outstanding success achieved in this field and the longevity in life imparted to surface dressing using a rational design approach involving correct quantity of aggregates and binder, such principles of design need to be understood, so that these can be followed extensively for surface dressing.

A rational design procedure was published by Hanson, a New Zealand engineer in 1934. This has been refined and updated by the Country Roads Board, Victoria, Australia, who have used this approach for very many years and obtained consistently good results. Mcleod (1) has this practice in Victoria as giving :—

"The best surface treatment and seal coats in the world"

This approach is also gaining wide acceptance in Canada and U.S.A. The Asphalt Institute of America recommends this procedure with certain modifications to suit American conditions.

The design procedure is based on the use of a single size cover stone whose gradation is based on the general requirement that two thirds (2/3) by weight of the material passes a sieve of a specified size and is retained on a sieve having an opening that is 0.7 of the specified size. For example, if the specified size is 3/4 inch, then 2/3 of the aggregate must pass through a 3/4 in square opening and be retained on an opening which is (0.7) × (0.74) = $\frac{1}{2}$ in square.

The single size cover stone has great many advantages over the graded aggregates in the context of surface dressing. It is relevant to briefly discuss this before the design procedure is explained, because of its reliance on this type of aggregates. The relevant considerations are as follows :—

(1) When single sized aggregates are used with the correct amount of bitumen, there is maximum contact and friction between tyres and surface dressing. This minimizes skidding.

(2) With good design, bitumen rises to a height of about 0.75 thickness of the single size aggregate. The tyres, thus, do not have direct contact with the bitumen and as a result, blackening or flushing of the surface is avoided.

(3) The right quantity of aggregate and binder can be determined quickly from the "Average least dimension" of one size aggregates. (The average least dimension is defined later).

Figure 1 summarises these and other advantages of using one size aggregates for surface dressing.

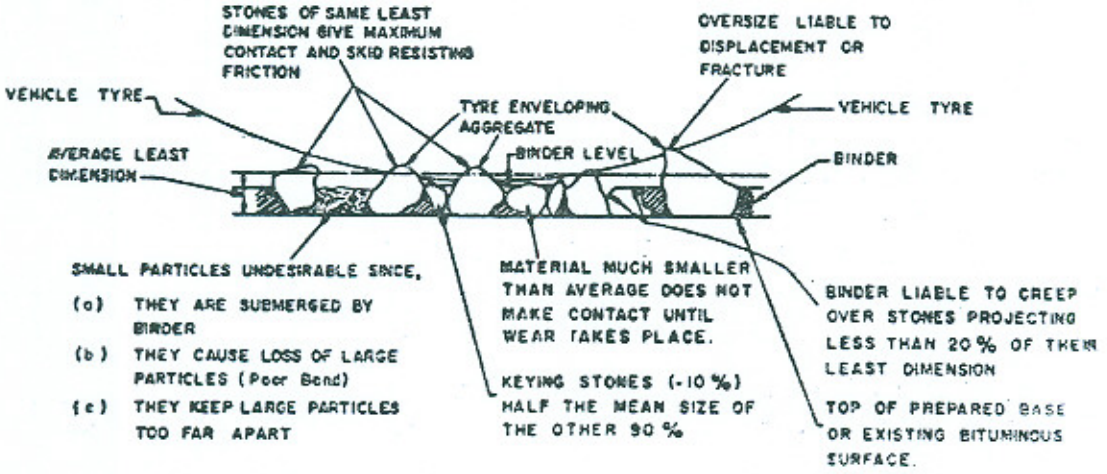


Fig. 1. Advantage of using one size aggregates for surface dressing

The ideal grading is one in which all the particles of stone are very close to the one size. However, for reasons of economy and practicability some departure from the ideal is accepted, but the range of grading of any nominal size of aggregate is limited as far as reasonably practicable.

Tables 1 and 2 indicate satisfactory grading specifications for one size cover stone.

As indicated above, the best aggregate for surface dressing is one in which the cover stones approach the cubical shape. In this context, flakiness index of the material is a relative measure. This is a number which represents the percentage by weight of flat stones having a least dimension less than three fifths of the mean size of the sample of aggregate. As an example, for material passing a 3/4 in square sieve and retained on a $\frac{1}{2}$ in square sieve, the mean size is 5/8 in. The flakiness index of this particular sample would be percentage by weight of stones having a least dimension less than $0.6 \times 5/8 = 3/8$ in. The lower the flakiness index for any particular cover stone sample, the better is its general shape, that is, the closer are all its particles to cubical in shape. The maximum allowable flakiness index for the various size of cover stones used should not exceed 35.

Figure 2 shows the A.L.D's of bad and good samples of aggregates together with an ideal layer of surface dressing. If the difference in size between the largest and smallest size particles is big, then smaller size would be completely covered by bitumen and prevent proper embedding of large particles which may be whipped off by traffic.



A.L.D. OF A BAD SAMPLE OF AGGREGATE



A.L.D. OF A GOOD SAMPLE OF AGGREGATE



AN IDEAL LAYER OF SURFACE DRESSING

Fig. 2 Indicating examples of aggregates and surface dressing. Note that non-Flaky aggregate approaching cubical in shape and single size make good surface dressing

Hanson's Principles of Design

The principles originally published by Hanson are briefly recapitulated below, as they essentially form the basis for the present design approach for surface dressing.

1. When the cover stones are dropped by the spreader over the bituminous film, they lie in a haphazard position and the void space in them is approximately 50 per cent (*see* Figure 3).

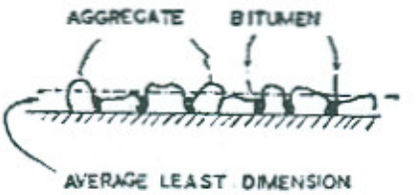


Fig. 3. Indicating the "Helter-skelter" position of stone aggregates after being dropped by the spreader (1)

2. Rolling shifts the cover aggregates and the void space is then reduced to about 30 per cent.

Nominal Size	Tolerance on Oversize				Required Size			Tolerance on Undersize			
	Passing	Per cent by weight	Retained	Per cent by weight maximum	Passing	Retained	Per cent by weight maximum	Passing	Per cent by weight maximum	Passing	Per cent by weight maximum
3/4''	1''	100	3/4''	15	3/4''	1/2''	65	3/8''	7	No. 7;	0.5
1/2''	3/4''	100	1/2''	15	1/2''	3/8''	55	1/4''	7	No. 7	0.5
3/8''	1/2''	100	3/8''	15	3/8''	1/4''	60	3/16''	10	No. 7	1.0
1/4''	3/8''	100	1/4''	15	1/4''	1/8''	70	No. 7	10	No. 25	2.0

TABLE 1.—*Typical one size aggregate grading specification for surface dressing indicating tolerances* (2)

Nominal Size	Percentage passing British Standard Sieves								
	1''	3/4''	5/8''	1/2	3/8''	1/4''	3/16''	No. 7	No. 14
3/4''	100	95-100		0-20	0-5				
5/8''		100	95-100		0-15	0-5			0-0.5
1/2''		100		95-100	0-30	0-5			0-0.5
3/8''				100	95-100	0-40	0-5		0-0.5
3/16''						100	95-100	0-40	0.05

TABLE 2—*Typical aggregate grading specification* (2).

3. Finally, after the surface remains under traffic for quite some time, the cover stones get oriented into their densest position, lying on their flattest sides. The voids at this stage get reduced to about 20 per cent (*see* Figure 4).

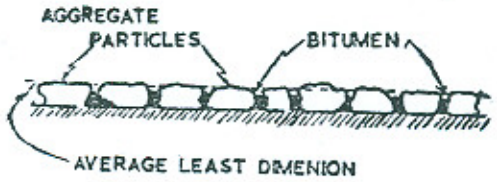


Fig. 4. Indicating the final positioning of the aggregate particles on their flattest sides after considerable traffic (1) Note the average least dimension of the aggregate shown in the Figure.

4. As the aggregate particles finally lie on their flattest sides (which is their stablest position), the average thickness of surface dressing is given by the overall average smallest dimension of the aggregate particles. Hanson called this the "average least dimension" or A.L.D. of the cover aggregates.

Sample	Where expected traffic is		
	Over 1500 V.P.D.	300—1500 V.P.D.	Under 300 V.P.D.
All aggregates	18	27	30 35*

Note.—Materials with higher Los Angeles value may be used where low traffic counts are expected.

TABLE 3.—*Desirable maximum percentage of wear for surface dressing aggregates—Los Angeles Abrasion Test* (2)

Nominal Size	Average least dimension Range		Application Sq. Yds. covered by 1 Cu. Yd. Range	
inch	From	To	From	To
3/4" ..	0.34	0.54	65	40
1/2" ..	0.22	0.34	95	65
3/8" ..	0.15	0.24	140	90
1/4" ..	0.15	0.18	140	115

TABLE 4.—*Normal range of average least dimension and rate of spread per sq. yd. of one size cover stone* (2)

5. The least dimension of an aggregate particle is defined as the smallest perpendicular distance between two parallel plates through which the particle will just pass. Hanson determined this by calipering each particle of a representative sample (consisting of 200 to 300 individual cover stones) for its smallest dimension. He averaged all the measured smallest dimension values to obtain the A.L.D. of the sample.

6. The A.L.D. having been known, the number of square yards covered by each cubic yard of loose stone can be worked out and the quantity of cover stones ordered for the job.

7. The A.L.D. is also the basis for bitumen quantity. Hanson indicated this as 67 per cent of the 20 per cent void space (in the compacted surface dressing).

Present-day Design Procedure

Modifications inevitably have been made to Hanson's method by engineers in U.S.A., Canada and Australia on the basis of their experience. The design procedure described here is after the Australian practice (1) which is based on the aggregate materials being of good quality complying with the specifications for Los Angeles Abrasion test value as given in Table 3.

Determination of Average Least Dimension.—The Country Road Board of Australia have developed a rapid method of determining the average least dimension of one size cover aggregates. First, grading analysis of a representative sample of aggregates is carried out using a sieve with square holes, and the results are plotted on a grading chart. The 50 per cent passing size in inches which is determined from the grading curve is the median size of the aggregate. The median size is that theoretical sieve size in inches through which 50 per cent of the material shall pass.

The flakiness index corresponding to the categories of each size passing one sieve and retained on the next, down to the minimum size (in the sieve analysis above) as indicated in table below is found (by the method given in British Standards 812) by testing particles by particle on appropriate slotted sieves.

Aggregate size designation.	Nominal range of sizes (U.S. Standard sieves, square opening)—Inches		All materials larger than
	Passing	retained	
A ..	3/4	1/2	1/2 in.
B ..	1/2	3/8	3/8 in.
C ..	3/8	No. 3	No. 3 sieve

of aggregate where g is the specific gravity of aggregates and 50 per cent voids are taken.

But 1 yd^3 of loose aggregate cover $\frac{36}{(1.84)\ (A.L.D.)}$ yd^2, so 1 ton of aggregate will cover $\frac{2240}{(62.4g)(27)\times 0.5} \times \frac{36}{(1.84)(A.L.D.)}$

$$= \frac{52}{(g)(A.L.D.)}\ yd^2$$

or $\frac{2240 \times g \times A.L.D.}{52}$ lbs. per sq. yd. including losses

or 42.8 g A.L.D. Without losses, the figure shall be 37.5 g A.L.D. Graphs relating the A.L.D. to the number of square yards covered by 1 yd^3 of surface, or between A.L.D. and the number of square yards covered by 1 ton of aggregates can be prepared. They are handy for day to day use.

Table 4 is reproduced here to indicate two points. First, it shows the normal range of average least dimension of each of the specified one size cover aggregates as experienced by the Country Roads Board of Victoria. This variation in A.L.D. is partly due to particle shape and partly due to gradation tolerance or width of the grading band for each of these aggregates permitted by its specifications.

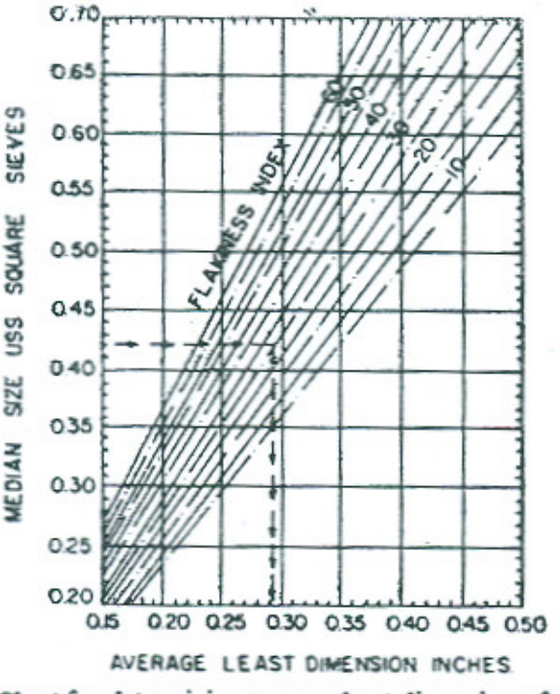


Fig. 5 Chart for determining average least dimension of aggregate

Second, this table shows the wide range of variation in the rates of spread with the variation in A.L.D. of cover stone. It would be seen that two aggregates from two different sources although having the same nominal size, can have different A.L.D. and correspondingly different rates of spread.

Example of Aggregate Rate of Spread.—Consider a road which is carrying 1,500 vehicles/day. It is intended to surface dress the road with $\frac{1}{2}$ in. nominal one size aggregate of the gradation chart as shown in Figure 6. The flakiness index test shows a value of 25.0 per cent. The bulk sp. gravity, g=2.70. Wastage factor due to whip off and handling losses is 7 per cent.

From grading chart figure, median size of aggregate=0.42 in. From figure 5 Average least dimension = 0.29 in, so 1 cubic yd will cover an area

$$\text{(excluding losses)} = \frac{36}{1.6 \times \text{A.L.D.}} = \frac{22.5}{\text{A.L.D.}}$$

1 cubic yd of loose aggregates will cover an area (including losses)

$$= \frac{36}{1.07 \times 1.6 \times \text{A.L.D.}} = \frac{21}{0.29} = 72.41 \text{ sq. yd.}$$

Alternately aggregate to be ordered for the job shall be $37.5 \times 2.7 \times 0.29 \times 1.07$ = 31.5 lbs./sq. yd.

Determination of quantity of Bitumen.—While Hanson suggested that 67 per cent of the 20 per cent void space in the aggregate (compacted under traffic) should be filled with bitumen, it was found on the basis of Australian experience for a number of years, that the percentage (of the 20 per cent voids) to be filled should be related to the volume of traffic, the nature of stone aggregates and the particle shape. Table 5 indicates the Australian binder requirements for the various types of aggregates and traffic volumes. The absorption of binder by the aggregate or road surface has not been accounted for in this table and should be assessed separately and added to the figure for bitumen obtained from this table to arrive at the final figure for bitumen application.

According to the Australian practice, the road surface is designated as "smooth", 1H, 2H, or 'black'. This classification expresses the degree of 'hunger' of the road surface based on the visual appearance of the road surface from the wheel paths. For a road surface classified as smooth, no additional binder is required. For ratings of 1H, 2H, 3H, binder requirements (over the values given in Table 5) are increased by 0.025, 0.05 and 0.075 gal/yd^2, respectively. The rating is indicated as 'black,' when some excesss binder is apparent due to flushing. For black surface, some reduction in the binder requirements is

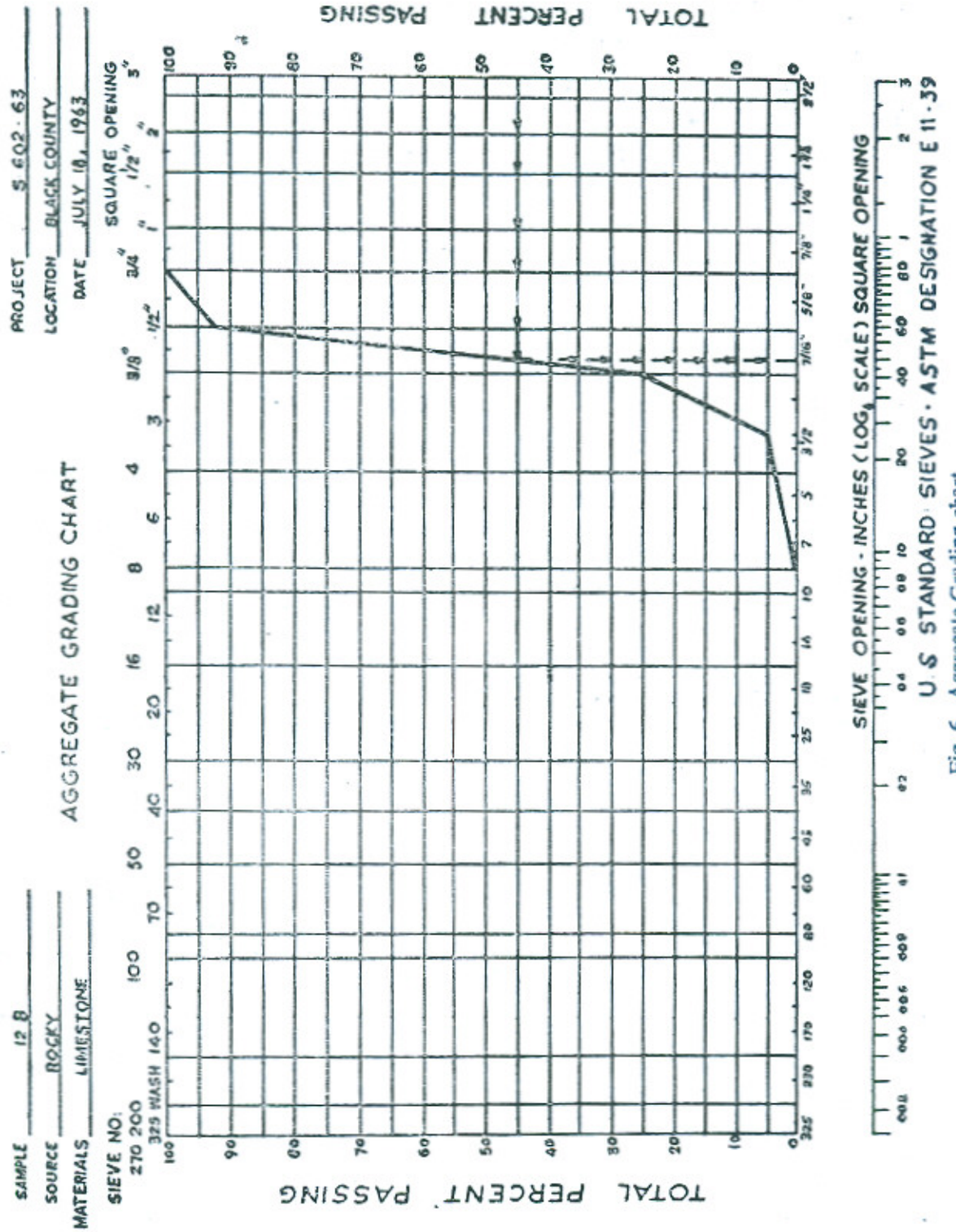


Fig. 6 Aggregate Grading chart

made depending on the degree of flushing. The Australian practice is to give a maximum reduction of 0.025 imp. gal/yd².

Allowances are not generally made by the Country Roads Board, Victoria for absorption of bitumen by aggregates, but when, as happens occasionally, absorptive limestone is used, the quantity of bitumen is increased by 0.025 imp. gal/yd.²

Type of aggregate	Surface condition, primed, smooth, or black Vehicle per day				
	Under 100	100-500	500-1000	1000-2000	Over 2000
Good quality crushed aggregate.	85	75	70	65	60
Quartz gravel & similar	90	80	80	75	75

Note.—The quantities for residual binder specified above do not make allowance for absorption by the road surface or by an absorptive cover aggregate.

TABLE 5.—*Percentage of 20 per cent voids in one size cover aggregate to be filled with residual binder* (2)

Percentage of 20 per cent voids in cover aggregate to be filled by bitumen.	Factor
60	0.56
65	0.61
70	0.66
75	0.70
80	0.75
85	0.80
90	0.84

TABLE 6.—*Rate of spread of bitumen=factor × A.L.D.*

Aggregates	Traffic factor = percentage (expressed as a decimal) of 20 per cent void space in cover aggregates to be filled with bitumen				
	Traffic Vehicle Per Day				
	Under 100	100-500	500-1000	1000-2000	Over 2000
Recognized good type of aggregate.	0.85	0.75	0.70	0.65	0.60

TABLE 7.—*Traffic factor for surface dressing* (3)

Example of Rate of Binder Application.—To illustrate the procedure for working out the rate of bitumen application, consider a road which is carrying 1500 veh./day. It is intended to surface dress the road with $\frac{1}{2}$ in nominal one size good quality crushed aggregates of non-absorptive quality. The degree of hunger estimated for this road is 3H.

Then from Table 5, the percentage of 20 per cent voids in the aggregates to be filled is read to be 65. The thickness of bitumen film is $65/100 \times 20/100 \times 0.29 = 0.0376$ in. As an Imp. gal/yd^2 = 0.214 in thick film of bitumen, the quantity of bitumen per square yard in this case is $\frac{0.0376}{0.214} = 0.177$ gal/yd^2. Since the degree of hunger is 3H, adding on additional 0.075 gal/yd^2 gives a total required quantity of 0.52 gal/yd of residual bitumen for the purpose of surface dressing.

In order to cut down calculations, factors can be calculated with which A.L.D. is multiplied to give directly the rate of application of binder in gallons per yd^2. In the above case, it is $65/100 \times 20/100 \times 1/0.214 = 0.61$. Thus in case of $\frac{1}{2}$'' nominal size, 0.61 multiplied by A.L.D. value of 0.29 would directly give the answer of 0.177 gallon/yd . Table 6 gives such factors for ready use.

In Australia, where road sid e blending for cutbacks is often done, 80 to 100 penetration bitumen is first fluxed with up to 10 parts by volume of heavy diesel fuel oil distillate depending on the traffic volume and the nature of aggregates. Sufficient kerosene oil is then added to this to bring the mixture to the desired viscosity. So, in Australia, the term "residual bitumen" means 80/100 penetration bitumen plus heavy diesel oil, but not the kerosene oil, which is rapidly lost by evaporation.

In other countries where refinery manufactured cutbacks are marketed, the residual bitumen can be taken as the residue after distillation to 680°F.

Before concluding this section, it needs to be mentioned that the binder requirements specified about are given by volume at 60°F, so this figure must be corrected for the corresponding expansion in volume at the application temperature. A graph in Figure 7 shows the relation between volume of 1 gallon of bitumen at 60°F and volume at other temperatures for a wide range of coefficients of linear expansion. It will be seen that if the application temperature is 250°F, it will be necessary to spray 1.075 gallons against a specified quantity of 1 gallon at 60°F, when the coefficient of expansion is 0.0004 per 1°F.

Some General Comments.—The above method is based on Australian practice. The Asphalt Institute of America has modified it slightly (3). To work out the quantity of bitumen, the effect of traffic has been accounted for by a traffic factor, which is used to indicate the percentage of 20 per cent

void space to be filled with binder (*See* Table 7). Only one category of aggregate is acceptable to the Asphalt Institute and traffic factors against traffic volumes of 100, 100 to 500, 500 to 1,000, 1,000 to 2,000 and over 2,000 of vehicles per day are given. A comparison of the values recommended in Table 7 with Australian practice (See Table 5) would suggest that less bitumen is required in the United State for gravel aggregates.

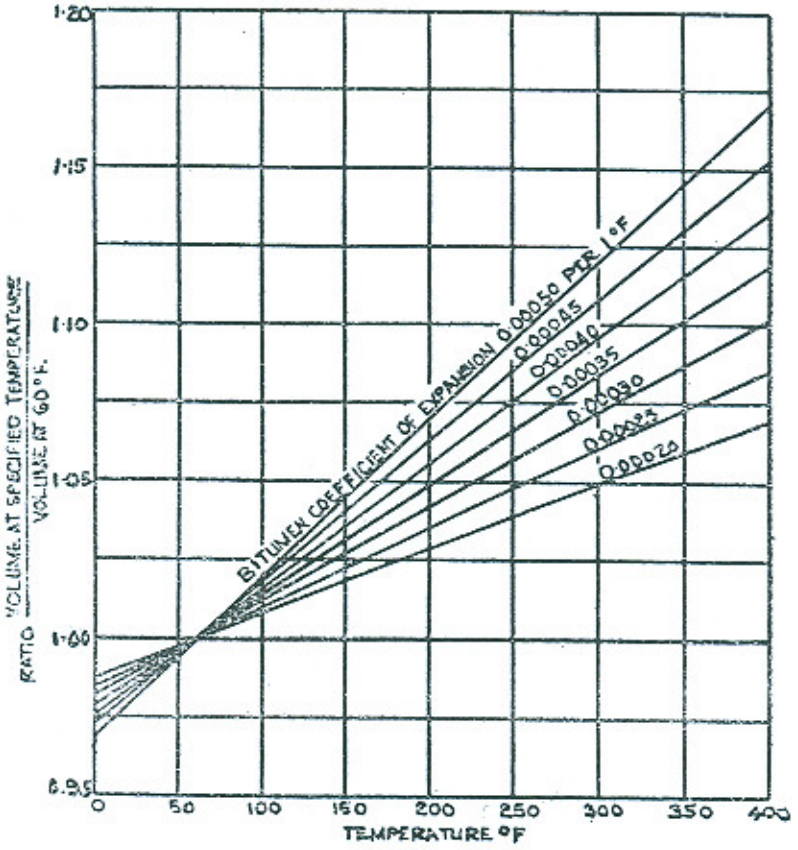


Fig. 7

To take into account the condition of the old road surface, a variable 'V' has been also introduced by the Asphalt Institute. This indicates the number of gallons per square yard to be increased or decreased from the recommended binder quantity (based on a normal road surface). This values of 'V' corresponding to various surface conditions are as below :—

Smooth, non-porous surface	V=0.00
Slightly porous slightly oxidized surface	V=0.03
Slightly poched, porous, oxidized surface	V=0.06
Flushed bituminous surface	V=—0.03

The writer feels that in view of the extensive use of surface dressing in many countries, particularly in the developing countries, the adoption of this design approach with suitable modifications to suit the local conditions is most desirable in the interest of economy.

Thus, for example, it would be necessary to assess the loss due to wastage and whip off under local conditions and allow for it accordingly. This is not being allowed in Pakistan at present and the final quantity being used in surfacing is generally less than the desired quantity.

The quantity of bitumen is important and is most likely to be affected by the climatic conditions, composition of traffic and the grade of bitumen used locally. A typical traffic count on roads in rural areas in West Pakistan would indicate trucks and buses being about 80 per cent of the total traffic. This predominance of heavy vehicles would have a marked effect on the grade of stone and quantity of bitumen. Furthermore, it need to be mentioned that majority of roads in West Pakistan are 10′ wide single lane roads and the wheels of the vehicles (unlike in case of multi-lane roads) have little room to play transversely. This factor, too, would have effect on the quantity of bitumen.

It is felt that the field experiments on different roads (with different volumes of traffic) would need to be done by surface dressing a number of road sections each say 330 ft. long with varying amount of binder both above and below the corrsponding Australian figures and then watching the performance of these road sections before finally recommending the appropriate traffic factors (suitable for local use) for the purpose of extensive use. Alternately, record should be maintained for each mile surface dressed and following information kept for profitably utilizing it subsequently :—

(*a*) Date of surface dressing.
(*b*) Condition of road surface.
(*c*) Specified rate of spread of binder and aggregate and the actual rate of spread. Size and source of cover stones.
(*d*) Weather conditions at the time of application.

The writer favours the Australian categorization of various traffic volumes and two principal categories of aggregates as in Table 5. This is simpler to follow and is more practical in approach.

The present practice in hot countries like Pakistan of distributing bitumen in 45 gallons metallic drums involves wastage in the sense that even with reasonable precautions, leakage does occur during transportation from the refinery to the site of work (sometimes a distance of 350 miles and requiring double or triple handling). Unless the system is radically changed and the chances of bitumen leaking out in hot weather eliminated, it is necessary to allow—while

placing the order—a realistic percentage for bitumen wastage on the same lines as the Australian and American practices allow for aggregate loss during transportation.

The difficulty of completely emptying the drums from a 9 in. dia. hole in relatively cold weather, is another point which lends weight to the consideration of allowing for this unintentional loss of bitumen while working out the quantity of bitumen required for the job. Unless this allowance is introduced, the net quantity actually used in surface dressing would be less than the specified quantity under all normal cases.

The following procedure is suggested to be adopted in Pakistan for the design of surface dressing work :—

(1) The Executive Engineer would decide the miles to be surface dressed. He would collect latest traffic count for the roads. In many cases traffic count would be readily available.

He would decide in favour of particular aggregate and choose the size considering the intensity of traffic and road texture etc. Representative samples would be sent to the Superintending Engineer with relevant particulars.

(2) The Superintending Engineer would send the aggregates to the Road Research and Material Testing Institute for the determination of the A.L.D. of the aggregates.

(3) Based on A.L.D. the texture of surface and traffic the Superintending Engineer would draw out specifications for the rate of spread of aggregate and bitumen per sq. yd.

(4) The Executive Engineer would carry out the work either departmentally or through a contractor. He would give instructions regarding the fluxing and cutting the binder to suit particular field conditions. Experience and judgement of Executive Engineer would play a vital part in determining the flux oil.

(5) The work would be executed under the personal supervision of a qualified engineer and for every piece of separate work in surface dressing, specification shall be drawn out.

Before concluding, it needs to be mentioned that proper execution of surface dressing is as important as following the design procedure to arrive at the correct quantities of bitumen and aggregates, it would be thus necessary to exercise proper quality control, during the laying of the surface dressing.

The importance of proper equipment for surface dressing work cannot be exaggerated, while introducing such new techniques in the developing coun-

tries. By and large a great deal of work is done manually in the Pakistan *e.g.* hand-pumping and hand-spraying bitumen from a 250 gal. boiler, spreading grit manually by baskets, and cleaning the road surface with hand brushes. The cost of modern equipment is not always the stumbling block and what really required is to present the idea to the authorities that mechanically worked bitumen pressure sprayers and grit spreaders give a far more even spread and are a great deal more amenable to site checks in matter of correct application of bitumen and aggregate. With reasonable care, bitumen and chippings can be spread within 5 per cent of the specified rate of application. It also needs to be brought home that this equipment gives a lot more progress in terms of road length surface dressed per day than the manually operated conventional operation. Depending on the lead of materials, an average progress of 1,25,000 sq. ft. *i.e.* about 2.3 miles of 10′ wide road can be achieved with about 15 men. This can relieve the relatively few trained personnel to deal with other maintenance problems more effectively. It is relevant to mention that about 3 months out of the warm period for surface dressing are lost because of the monsoons in Pakistan and thus the need for accelerating the present pace of work cannot be too strongly emphasized.

It may be relevant to mention that the present equipment for surface dressing dates back to the era of 10′ wide roads with low road mileage and cheap labour. With present-day high cost of labour, increased road mileage and rapid change-over to 2 lane roads, it would be necessary to go in for mechanical bitumen sprayers and grit spreaders. It is time that a beginning was made in this direction. These pieces of equipment can be improvised or manufactured locally after some initial purchases, as is being done successfully in Turkey.

Lastly, there is need to introduce rubber tyred rollers for surface dressing work due to their inherent advantage over the steel road rollers which are almost invariably used in countries like India and Pakistan. The rubber tyred rollers which do not crush the cover stones as much as the steel wheeled tyres, are able to kneed the cover stones into the binder. Furthermore, they press maximum number of stone aggregates by not bridging over some of them, as a steel road roller is inclined to do. Slow-moving pneumatic tyres do not have the tendency to dislodge the aggregates. On steep grades or short radius curves they have been found particularly useful. It needs to be mentioned that the function of a roller in surface dressing is only to press the aggregate into position in the binder film and not to cause mechanical interlock.

Engineering Properties of Surface Dressing Materials

The importance of selecting the right grade of aggregates and binder cannot be over-emphasized for success in surface dressing work. The discussion

which follows bears relevance to the design concept of surface dressing already explained.

Engineering Properties of Stone Aggregates

The important engineering properties of cover stones are the following :—

1. Size of the aggregate stone.
2. Grading.
3. Particle shape.
4. Uniformity.
5. Adhesion to binder.
6. Resistance to crushing.
7. Resistance to polishing.
8. Resistance to abrasion.

Size of Aggretage Stone.—The factors which govern the selection of the size of stone are the following :

(*a*) Nature of the traffic and condition of road surface.

If the surface of the road is soft, it is obvious that under traffic, the cover stones will get pressed into the surface and only a part of each will remain projecting. A larger size is thus indicated at such location when the volume of traffic is high. On the other end of spectrum, if the surface is hard and traffic is light, a smaller size stone suggests itself. Recommended size of chippings are tabulated below (5).

Road Surface	Light less than 70 Comm veh/day	Medium, 70-700 Comm veh/day	Heavy, over 700 Comm veh/day
Hard	1/4 in,	1/4 or 3/8 in.	3/8 or 1/2 in
Normal	1/4 or 3/8 in.	3/8 or 1/2 in.	1/2 or 3/4 in
Soft	3/8 or 1/2 in,	1/2 or 3/4 in.	—

If the surface is porous and hard, *e.g.* a coarsely graded coated macadam, or if it is porous and soft, *e.g.* newly laid cold asphalt, then a smaller grade of stone should be used and in this context, the next smaller size is chosen from the table above.

(*b*) The existence or absence of a large number of horizontal curves having radii less than 150 ft.

When the number of sharp curves is large, a smaller size of stone aggregates is indicated, so that dislodging action of traffic on curvature is less serious. Larger stones can be used, if sharp curves are few or do not exist. In case of a few sharp curves, the road at the curves can be individually treated with smaller aggregates, whereas for the rest of the length, larger stone aggregates can be employed.

Dr. McLeod, on the basis of his personal observations is of the view that the size of the aggregate used for surface dressing may have a marked effect on the performance of surface dressing(1). His reason for believing this is that less likelihood of serious bleeding or flushing of the binder occurring when larger stones are used than when smaller sizes are employed. Furthermore, with larger stones, there is a greater factor of safety against loss of cover stones, if inadvertently a lesser quantity of bitumen than the design quantity is applied. In this respect, it may be noted that Australian practice is such that 73 per cent of surface dressing is done using one size stone of $\frac{1}{2}$ in or greater.

The above advantage available with the use of larger size of cover stones can be explained by considering a specific example of the use of $\frac{1}{2}$ in. A.L.D. stone as against $\frac{1}{4}$ in. A.L.D. aggregates in a surface dressing, where traffic volume and aggregate type call for 70 per cent of the 20 per cent void space in the compacted position of the aggregates to be filled. In the case of the $\frac{1}{2}$ in. size, the binder required should be 0.328 Imp gal/yd^2, while in the case of $\frac{1}{4}$ in. stone, this quantity should be 0.164 Imp. gal/yd^2.

Flushing of the binder will generally occur, if due to faulty operation of bitumen sprayer, an excess is applied *e.g.* if the binder fills 100 per cent of the 20 per cent void space. To fill this 100 per cent void space, the quantity of bitumen for $\frac{1}{2}$ in size aggregate need to be 0.469 Imp. gal/yd^2 and for $\frac{1}{4}$ in. size, this should be 0.234 Imp. gal/yd^2. This variation from the design quantity (which corresponds to 70 per cent of the void space filled) is 0.141 Imp. gal/yd^2 for $\frac{1}{2}$ in. size and 0.07 Imp. gal/yd^2 for $\frac{1}{4}$ in. size. A comparison would suggest that while using $\frac{1}{4}$ in. size, the possibility of exceeding the design quantity of bitumen to the extent of filling 100 per cent of the void space is twice as great, as it is in the case of larger size (*i.e.* 0.07 Imp. gal versus 0.141 Imp. gal). In other words, the factor of safety against flushing due to the inadvertent application of excess bitumen is greater while using larger stones.

Continuing the comparison, it is generally believed that to provide adhesion, a minimum of 50 per cent of 20 per cent voids (in the aggregate in their final compacted position) need to be filled with binder. If in the case under question an optimum binder quantity is needed to fill 70 per cent of this void space, then while using 0.6 in A.L.D. aggregates, the quantity of bitumen

required is 0.393 Imp. gal/yd² and 0.281 Imp. gal/yd², corresponding to 70 per cent and 50 per cent void space filled, respectively. There is thus a difference of 0.112 Imp. gal/yd² from the design quantity. As against this, if 0.2 in A.L.D. aggregate is used, the quantity of bitumen is 0.131 Imp. gal/yd² and 0.094 Imp. gal/yd² corresponding to 70 per cent and 50 per cent of the void space filled, respectively. In this case, the variation from the design quantity of bitumen is 0.037 gal/yd². Since very few bitumen sprayers in actual operations can possibly control the uniformity of application within such fine limits, it is obvious that it would be playing safe to use larger size aggregates, as they are relatively less sensitive to variations in bitumen application.

While the two specific cases explained above strikingly illustrate that the factor of safety against bleeding (due to excessive bitumen sprayed) and loss of cover stones (due to inadequate application of bitumen) is greater in the case of a larger stone size than when a smaller stone is used, the writer feels that there is no case for using unduly larger stone size when a smaller size is indicated. It needs to be appreciated that whether the stone is purchased on either a tonnage or cubic yard basis, then quantity for quantity, a larger stone will cover less area and also need more binder. The use of larger size stone is thus uneconomical. Moreover, use of larger size stone such as 3/4 in nominal size is undesirable in cases where traffic is light or road has sharp curves or the stone has high Los Angelese percentage of wear *i.e.*, greater than 40 or where the pavement life is expected to be short. Large size aggregates also cause more tyre noise. It is, however, good to understand the basic principles, so as to be able to strike a compromise between the performance of surface dressing and its cost.

Grading of Aggregate Stone.—The advantages of using single size chippings for surface dressing have already been explained. The Australian specifications for one-size cover stones are shown in Table 1. There is a corresponding British standard for one size stone (6), both for gravel and crushed aggregates. The Punjab Highways Department has adopted the British specifications for one size crushed aggregates for use in the department. The British and Australian specifications are, however, practically the same.

The important point to be watched for when accepting a supply of one size stones is the presence of excessive under-size material, as this is the most common grading fault. For this purpose, it is necessary to take samples and test them by sieve analysis as and when considered necessary.

Particle Shape.—The average least dimension (A.L.D) is the most important single engineering property of the aggregates, as this forms the basis for the quantity of aggregates and binder per unit area of road. For the same

When the number of sharp curves is large, a smaller size of stone aggregates is indicated, so that dislodging action of traffic on curvature is less serious. Larger stones can be used, if sharp curves are few or do not exist. In case of a few sharp curves, the road at the curves can be individually treated with smaller aggregates, whereas for the rest of the length, larger stone aggregates can be employed.

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Particle Shape.—The average least dimension (A.L.D) is the most important single engineering property of the aggregates, as this forms the basis for the quantity of aggregates and binder per unit area of road. For the same

one-size stone, there can be variations in the A.L.D. of the aggregates and it is thus necessary that watch is kept on the aggregate supplies.

To illustrate how much this engineering property matters, an extreme case of two samples of ½ in. stone, one cubical and other flat and elongated, is considered. Let it be assumed that one sample would have an A.L.D. of ½ in. while the other has an A.L.D. of 1/5 in. To cover 1 yd² of road surface while filling 70 per cent of the 20 per cent void space the former would need 0.328 imp. gal. while the latter would need 0.131 imp. gal. of binder. Thus whereas both aggregates might be purchased as ½ in. cover stones and both might just pass a ½ in. square opening, the quantity of binder required in one case will be more than twice that in the other case, due entirely to the different particle shapes, as reflected by the different A.L.D. values. (*See* Figure 8 which diagrammatically illustrates this point.

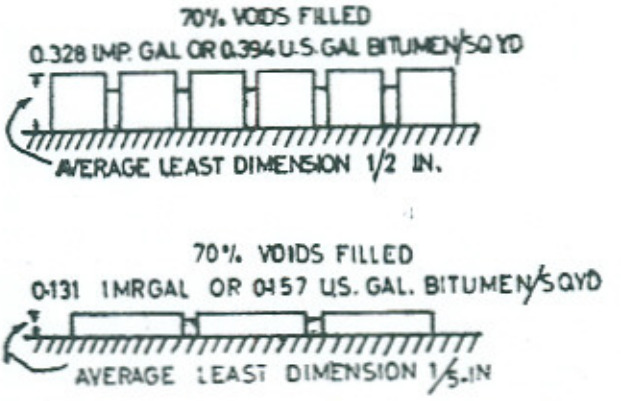


Fig. 8. Illustrating different bitumen requirements for surface dressing with 1/2 in cover stones of different particle shapes (1) one is cubical and the other is flat and elongated.

The A.L.D. of an aggregate supplied to a site from a single source may not necessarily be the same month after month. Variation can occur due to wear of the crusher's jaw or rolls, or to the wear of screens or change in the structure of the aggregates material being crushed. It is, therefore, necessary that the A.L.D. of the supplies received should be checked periodically. Fortunately the equipment required for this purpose is simple and inexpensive. Any measurable change in A.L.D. found as a result of such tests should be accounted for by varying the amount of binder and aggregates per unit area.

The preferable particle shape is cubical or tetrahedral, and the least acceptable is flat and elongated. Flaky chippings do not interlock and form as closely knit mosaic under roller and traffic as do angular chippings. It is for this reason that specifications limit their inclusion.

Both crushed and rounded aggregates are generally acceptable as surface dressing materials. The latter, however, do not interlock, and because of more

void space in the compacted form (*i.e.* more than the normal 20 per cent), they need more bitumen. Rounded gravel, however, is unstable in the early life of surfacing and should not be used for heavily trafficked roads.

Uniformity in Aggregates.—It is essential that aggregates being supplied on a project are as uniform as possible, both in shape and size. It is easy to visualize that day-to-day non-uniformity in the aggregates supply on one job or a stretch of road will reflect in variation in the A.L.D. value from the corresponding design A.L.D. value, leading to incorrect application of binder and cover stones. For instance, if the surface dressing is designed on the basis of the quantity of bitumen and aggregate determined on the basis of the (design) A.L.D. of a representative sample of the stone intended to be used, then one may find patches of inadequate bitumen application (manifested in flushed surface in another extreme case). These defects in the finished job could thus entirely be due to lack of uniformity in the day-to-day supply of cover stones.

Adhesion to Binder.—Satisfactory adhesion between the stone and the binder is important for the satisfactory performance of a surface dressing. Aggregates having surfaces which are smooth, glassy or coarsely crystalline *e.g.* certain types of quartz, flint and coarse grained granites, have lower affinity for bituminous binders. Extra care therefore need to be taken when these materials have to be used; this care is generally reflected in the form of cleaner and drier road surfaces, dry weather, and controlled binder application (1).

It needs to be stressed here that chippings have greater affinity for water than for bitumen, and during the early life of surface dressing, a spell of cold wet weather following soon after the application of the binder can dislodge the cover stones displacing binder. This displacement of binder is more likely with the type of stones indicated above, and as such the endeavour should be to select stones which have micro-crystalline structure, *e.g.* many limestones, basalts and dolerites; these have good affinity for binder and show improved adhesion (1).

Cleanliness of aggregates is an important factor for satisfactory adhesion. If stone particles are dusty, then while they are spread over the bituminous film on the road, the dust is transferred on to this film, thus preventing the wetting of stones with binder. As a result good adhesion does not follow. If the stones are coated with silt or clay, the results are similar. Due to poor adhesion, whip off loss is greater under traffic. If rain falls soon after the completion of surface dressing, it wets the coating of dust and adhesion may be reduced so much that all the cover aggregates may be lost from the surface dressing within

a short time. If an unusually viscous binder is used, its adhesion to dust-coated particles is particularly poor.

Moisture on cover aggregates has a similar effect to that of dust *i.e.* it prevents or delays the development of good adhesion between the stone and the binder. When damp aggregates are used in a surface dressing, they dry out quickly on warm days—but during this drying out phase, uncontrolled high speed traffic may displace the cover stones. If, however, rain falls while adhesion is still poor, traffic may also cause serious damage. A combination of dust and dampness on aggregates is the worst enemy of good work and multiplies the likelihood of poor adhesion and consequent loss of cover aggregates, particularly if cool wet weather follows soon after construction. It is for this reason that the importance of clean and dry aggregates cannot be over-emphasized for a good job in surface dressing.

Resistance to Crushing.—Because chippings are practically exposed on surface dressed roads; their behaviour under traffic is important and demands careful attention. One relevant characteristic is resistance to crushing; the quantitative value of this property can be got from the relevant test described in the British standard for testing mineral aggregates (2). The requirement for resistance to crushing depends on traffic intensity *e.g.* for heavily trafficked roads (*i.e.* over 700 commercial veh/day) the aggregate crushing value should not exceed 20.

Resistance to Polishing.—Aggregates that tend to get polished under traffic should be avoided, as their skid resistance is lowered in the course of time and driving will become hazardous. Only aggregates with polished stone value of not less than 60 should be used in a surface dressing.

Resistance to Abrasion.—A hard tough stone will have a longer life through being more resistant to wear under traffic than a weak material. Resistance to abrasion requirements in terms of Los Angeles Abrasion values are given in Table 3.

Engineering Properties of Bitumen

For the success of a surface dressing, it is important that the proper grade of bituminous binder selected for the job be sprayed at the correct spraying temperature. Bitumen is a thermoplastic material, which becomes fluid through a decrease in viscosity with increasing temperatures. The spraying temperature thus needs to be selected carefully, because the ability to spray satisfactorily at a certain temperature is not the same for different grades and types of

bituminous binders. In other words, temperature/viscosity curves are different for different types of binders.

The importance of the proper selection of the bitumen grade to suit a particular surface dressing job under prevailing conditions cannot be over-emphasized. In this context, various factors need to be taken into account like air temperatures, humidity and wind, condition of road surface, etc., and this aspect needs particular attention, if success in surface dressing is to be ensured.

The paragraphs which now follow deal with the selection of correct spraying temperature for a particular grade of bitumen. Subsequent to this, factors which govern the selection of a proper grade of bitumen shall be discussed.

Bitumen Spraying Temperature

The thermoplastic property of bituminous material is utilized to great advantage in road work. As a result, a most important property of cut back or straight run bitumen is its vitcosity/temperature curve. (Note that when the kinematic viscosity of bitumen is measured at different temperatures and plotted on Cartesian coordiantes, a straight line relation is obtained and this is the viscosity temperature curve of the bitumen).

In American practice, a Saybolt Furol viscometer is used to measure viscosity for cut back bitumen grades. It does so by measuring the time which a sample of bitumen, at a certain temperature, takes to pass through standard sized orifice. In British practice, a standard tar viscometer is used to measure the time again in seconds. The principle underlying the use of both the British and American viscometers is the same. In the discussion which follows, the Saybolt Furol (S.F) approach will be used to express viscosity.

The Saybolt Furol viscosity-temperature relationship is not that of a straight line, as may perhaps be suggested by Figure 9. Figure 9 is, in fact, a

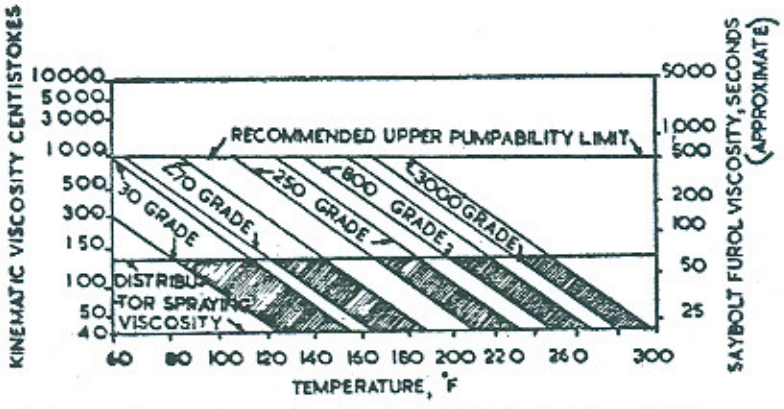


Fig. 9. Temperature viscosity for handling liquid asphalts.

plot of kinematic viscosity versus temperature; however, and without much loss of accuracy, it can be assumed that Saybolt Furol viscosity in seconds at any temperature is approximately one half of the kinematic viscosity at the same temperature (1).

Figure 9 also illustrates the viscosity temperature curves for five American grades of cut back bitumen. Note that instead of a single line curve, bands are shown for various grades; these indicate the range of viscosity for each grade of cut back permitted by specifications. The viscosity temperature band for any single grade of cut back bitumen is the same regardless of its source and method of manufacture. It is because of this that the relationship shown in Figure 9 can be used on a world-wide basis for all cut backs satisfying A.S.T.M. specifications for SC, MC and RC—grades (1).

With respect to straight-run bitumens, it needs to be mentioned also that viscosity/temperature curves are very much dependent on the source of supply of crude oil. For instance, different bitumens which may have exactly the same penetration are most likely to give different viscosity/temperature curves, if the crude oil is obtained from different sources, Figure 10 shows temperature viscosity curves derived for 3 samples of 150/200 penetration bitumen, each from a different source. It is for this reason that it is preferable to specify the viscosity/temperature curves of a binder rather than its penetration value at 77°F, when selecting a straight-run bitumen for surface dressing.

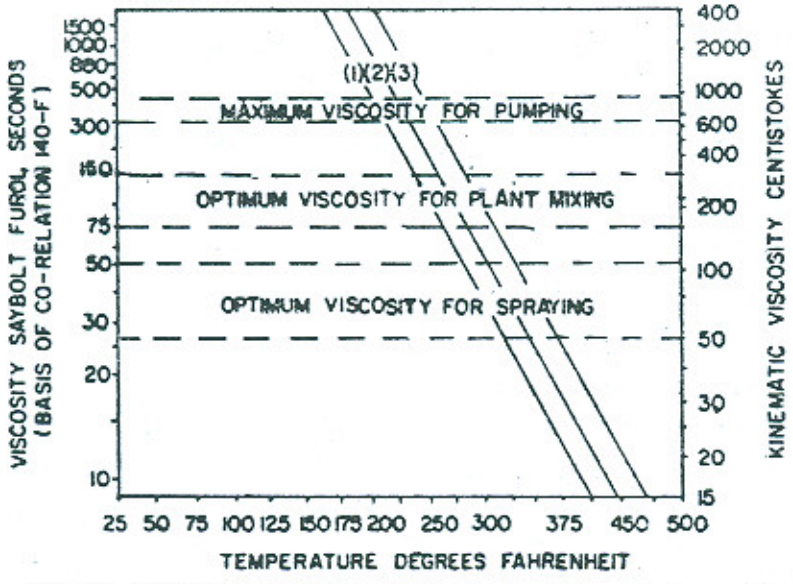


Fig. 10. Illustrating representative temperature/viscosity curves for 150/200 penetration grade bitumen (1).

For most bitumen sprayers, the suitable fluidity for proper spray through the nozzles (to give uniform spray and proper fanning out) corresponds to a

range of about 25-50 sec. Saybolt Furol or about 50-100 Centi-stokes. Note that in the Figures 9 and 10, a horizontal band is marked "distributor spraying viscosity" which corresponds to about 25-50 sec. S.F.

In order to select the correct spraying temperature for a bitumen, the viscosity/temperature curve for the grade of cut back or straight-run bitumen available for surface dressing should be plotted, along with the band corresponding to about 25-50 sec. S.F. The spraying temperature i.e. the temperature to which binder should be heated to attain a viscosity of 25-50 sec. S.F., is then read off from the graph.

Selecting the Correct Grade of Bitumen.—In order to select a proper grade of bituminous binder for surface dressing, the following relevant factors need attention :—

1. Temperature of the road surface.
2. Ambient air temperature.
3. Humidity and wind.
4. Condition of the road surface.
5. Equipment to be used.

A correct grade of bitumen should exhibit the following properties :—

1. At the time of application, it should be sufficiently fluid to be able to spray evenly and uniformly, inch by inch across and along the surface.

2. After application, it should be sufficiently fluid to wet the cover stones and develop fast initial adhesion.

3. After rolling, it should be viscous enough to hold the aggregates tightly to the road surface, so as to prevent it from being dislodged.

4. When applied at the correct rate, it should not bleed nor strip with changing temperature conditions.

Examination of requirements 2 and 3 above would suggest that they are conflicting, *i.e.* the former needs a low viscosity so that wetting is affected easily, while the later requires a relatively high viscosity so that the stones can be held firmly against traffic. A compromise has therefore to be struck between the two in practice.

The paragraphs which follow discuss the selection of proper grade of bitumen for Canadian and Australian conditions. The former refers to cold climate while the latter relates to relatively warm and sunny climate. The two cases fall at the two ends of the scale and their discussion should prove useful, as in any sizable country, the climate can vary between regions from cold to hot, as

in Pakistan. This section shall be concluded with a discussion on relevant factors for Pakistani conditions.

For Canadian Conditions.—The basic approach is provided by the temperature viscosity curves for the various grades of bitumen available in the market. Thus Figure 11 shows a chart which can be used to help select a (proper) grade of bitumen which corresponds to different road surfaces or ambient air temperatures for Canadian conditions. The solid lines crossing from the upper left to the lower right of this figure are viscosity/temperature curves for various grades of bituminous binders. The temperature scale shows the road surface temperatures along with corresponding ambient air temperatures in the shade. Thus it can be seen that it is possible to read off the binder viscosity to be used at each road surface temperature.

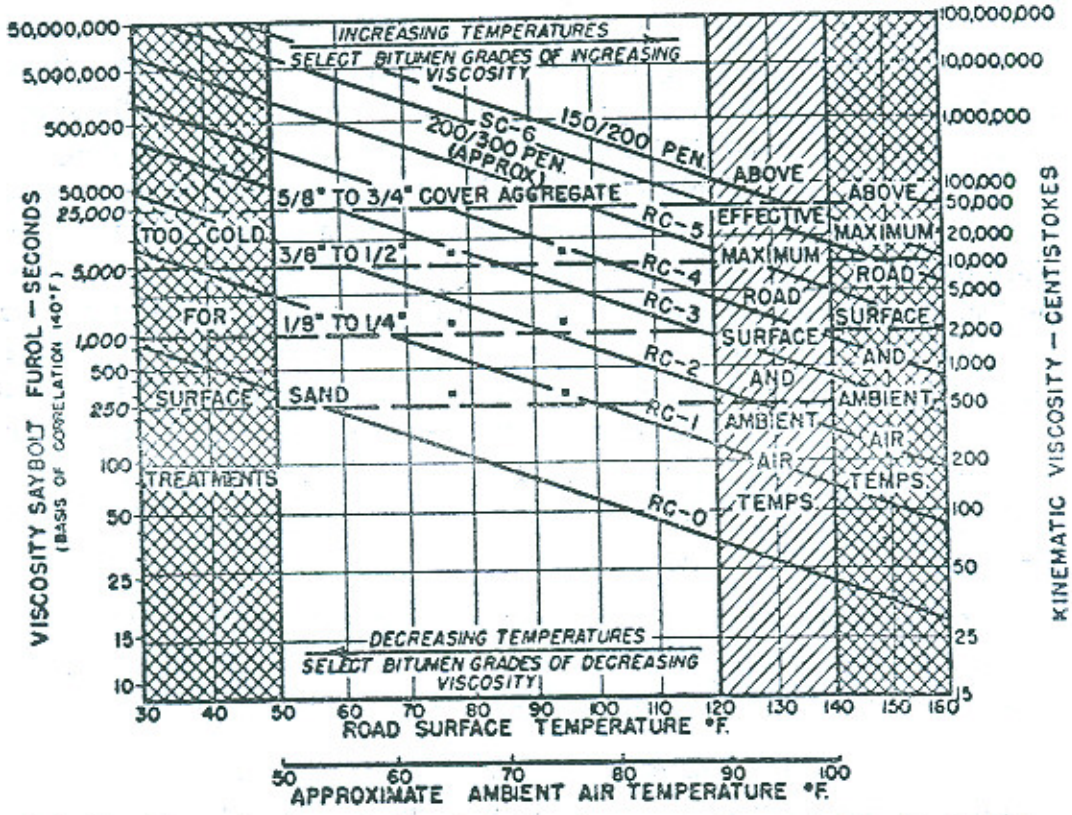


Fig 11. Illustrating interrelation of road surface temperature and viscosity of binder in respect of various size of cover stones for surface dressing under Canadian conditions (1).

The cross-hatched area on the left side of Figure 11 represents the temperature which is too cold for surface dressing. The double cross-hatched areas on the right shows the range of road temperature above the maximum attained in Canada (which is about 140°F). For practical purposes, however, maximum road surface temperature in Canada has been taken as 120°F.

The two conflicting requirements for a proper bitumen grade (as mentioned above) are met with in respect of various sizes of cover stones corresponding to particular viscosity of binder. The Figure 11 illustrates this. In this figure, the various usual sizes of stones are indicated by horizontal lines along with the temperature viscosity curves of various grade of cut backs. For 3/8 in.—½ in. size, the relevant viscosity which strikes compromise is 5,000 sec. S.F. (or about 10,000 centistokes) for Canadian conditions. Thus for a road temperature of 85°F, this figure would show that RC3 is the correct grade of cut back to be used, as this attains a viscosity of 5,000 sec. S.F. at this temperature.

The graph in Figure 11 emphasizes two main points. First, binders of high viscosity need to be chosen for warm periods, whereas those of low viscosity should be selected for use in cold periods for the same size of stones. Second, it would be wrong to use the same grade of bitumen regardless of the road surface temperature conditions. For instance, referring to the Figure 11, it will be seen that for 3/8 to ½ in. cover aggregates, an RC2 would be suitable for a road surface temperature of 60°F, whereas the same grade would be far too fluid and thus unable to hold chippings under traffic, if used at 100°F road temperature. This illustrates the serious error which can be made by an organization which orders only one grade of bitumen for surface dressing work throughout the year. This practice is not uncommon in Pakistan. In passing, it may be mentioned that the relationship in Figure 11 between road surface temperature and ambient air temperature in the shade is an approximate one, as for any ambient air temperature, the road surface temperature on the road will be lower on a cloudy day than on a sunny day. But, nevertheless, since the road surface temperatures control the bitumen performance, it is this temperature which needs to be measured.

It should also be noted that the graph in Figure 11 needs to be updated, as new American grades have since replaced the grades shown in this figure. This, however, does not interfere with the conclusions.

For Australian Conditions.—For many years Country Roads Board, Victoria has been preparing its own cut back bitumen in roadside blending units. These cut backs are carefully proportioned taking cognizance of the air temperatures in the shade, the size of aggregates and the traffic volumes on the road. Instruction for proportioning the cut backs are issued to the road maintenance engineers in a tabular form. Table No. 8 is one example of these tables, this relates to 5/8 or 3/4 in sized aggregate. Similar tables are available from the Country Roads Board, Victoria for other sizes of cover stones.

Working Conditions			BINDER AND AGGREGATE											
			Aggregate Wholly Crushed											
			Nominal sizes 5/8" or 3/4". F. E or No. 6											
Range of air temp. of.		Viscosity Stks. @ 122°F	Traffic—Vehicles per day.											
			Under 100			100—500			500 to 1500			Over 1500		
			Binder by vol.		Parts 60°F	Binder by vol.		Parts 60°F	Binder by vol.		Parts 60°F	Binder by vol.		Parts 60°F.
			Bit.	A. O.	P. K.	Bit.	A. O.	P. K.	Bit.	A. O.	P. K.	Bit.	A. O.	P. K.
40—50	...	22.5	100	7½	17½	100	5	20	100	2½	22½	100	0	25
50—60	...	50	100	7½	12½	100	5	15	100	2½	17½	100	0	20
60*—70	...	150	100	7½	7½	100	5	10	100	2½	12½	100	0	15
70—80	...	350	100	7½	2½	100	5	5	100	2½	7½	100	0	10
80—90	...	750	100	7½	...	100	5	2½	100	2½	5	100	0	7½
Over 90	...	1250	100	7½	...	100	5	...	100	2½	2½	100	0	5

*Minimum working temperature without approval.
Bit.=bitumen (80/100 penetration asphalt).
A.O.=asphaltic oil (heavy diesel fuel distillate).
P.K=power kerosene.

TABLE 8—*Recommended practice by the Country Roads Board Victoria for 5/8 or 3/4 in. size stone for blending 80/100 penetration bitumen with asphaltic oil and kerosene corresponding to different temperature and traffic conditions* (1).

In Australia, the 80/100 straight run bitumen referred to in Table 8 is first fluxed with heavy diesel fuel distillate called "asphaltic oil", and this blend is then further fluxed with kerosene, until the viscosity recommended in the table is attained. Because blending units operate at the roadside, care can be taken "on the spot" of varying temperatures during the day, thus the blend in the trucks sent to the site in the morning can be different from the one sent in the afternoon when the temperature is higher.

Table 8 which was derived on the basis of many years of experience shows that with an increase in traffic, the percentage of asphaltic oil must be reduced and the percentage of kerosene oil is increased. The increase in the percentage of kerosene oil means that the gain in viscosity following the rolling of aggregates takes place at a faster rate and this helps the cover stones to be retained firmly in position against heavy traffic.

For the purpose of illustration, it can be seen from this table that for the size of cover stone (for which this table is meant), corresponding to an air temperature range of 40-50°F, the recommended proportions of asphaltic oil and kerosene is $7\frac{1}{2}$ and $17\frac{1}{2}$ parts respectively for 100 parts of bitumen by volume with a daily traffic of less than 100 vehicles/day. The corresponding figures are 0.0 and 25 parts of asphaltic oil and kerosene when the traffic volume exceeds 1,500 vehicles/day.

Data obtained from Table 8 and similar tables available for other sizes of cover stones has been plotted in the form of a graph as shown in Figure 12. Each point plotted on the graph relates to the specified viscosity or "compromise viscosity" requirement for the binder for the road surface temperature and for the cover stone size. The best fit horizontal straight line has been drawn through such points for each size of the cover stones. The Table 8 and other similar tables refer to air temperatures, whereas really the road surface temperatures are relevant. So in the graph the air temperatures from the tables have been suitably converted into road temperatures, so as to get a working graph under Australian conditions on the same lines as the graph in Figure 11 which refers to Canadian conditions.

Referring to graph in Figure 12, it would be seen that corresponding to road temperatures of 95 deg. F, MC. 5 is the correct grade of cut back for use with 3/8-1/2 in aggregate stones.

Some General Comments :

Figures 11 and 12 indicate how the relevant graphs prepared to suit local conditions can help to select the proper grade of bituminous binder. It is important to appreciate, however, that a comparison of the two figures would reveal different results—thereby indicating in a striking manner that the proper

binder grade is different for different climatic conditions and that either of the two diagrams cannot be applied universally to all the countries of the world. Each country will need to prepare its own graphs following the general principles described above. In fact, different graphs may have to be prepared corresponding to different regions of the country, if the climatic conditions vary greatly.

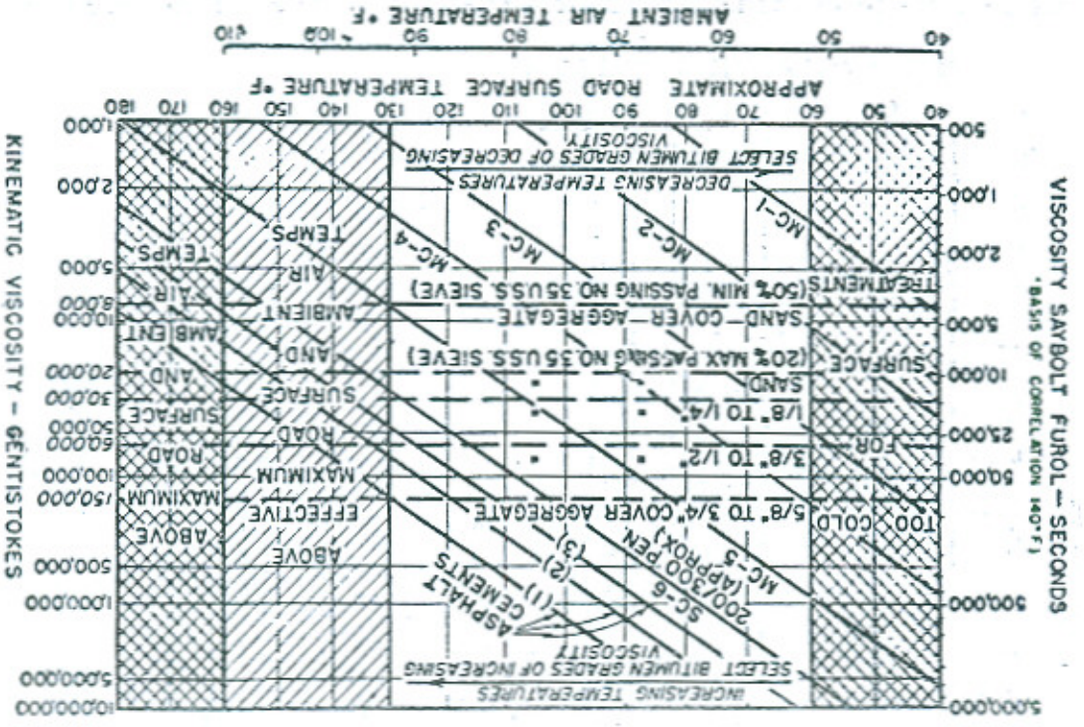


Fig. 12 Illustrating interrelation of road surface temperature and viscosity of binder in respect of various size of cover stones for surface dressing under Australians conditions (1).

Considering surface dressing work in Pakistan, it needs to be mentioned that the relation between ambient temperature and road surface temperature is likely to be different in Pakistan, where sustained periods of high temperatures are likely. The sources of crude for straight run-bitumen are also different from the American and Canadian sources. It is thus necessary that relations are worked out in Pakistan on the basis of research work done both in the laboratory and field and a table like the Table 8 prepared. The Road Research Laboratory (4) has suggested a relation shown in the graph in Figure 13 based on Attock Source. This graph would indicate that for 3/8 in cover stone and ambient temperature of 100°F, a cut back is indicated and not 80/100 straight run bitumen as is generally used. But it must be said that this graph needs to be further updated and refined through extensive use in the field, and ambient temperatures related with road surface temperatures (which really matter). Also in the context of straight run-bitumen, the product from Karachi refinery

needs to be studied, as the source of crude in this case is different from Attock (for which the graph has been prepared in the Road Research Laboratory).

It may be quite some time, before field blending units can be introduced in Pakistan. Till then, it may be useful to obtain refinery prepared cut backs which can be suitable for the most common range of roads surface temperatures on our roads during surface dressing season. The grade obtained from

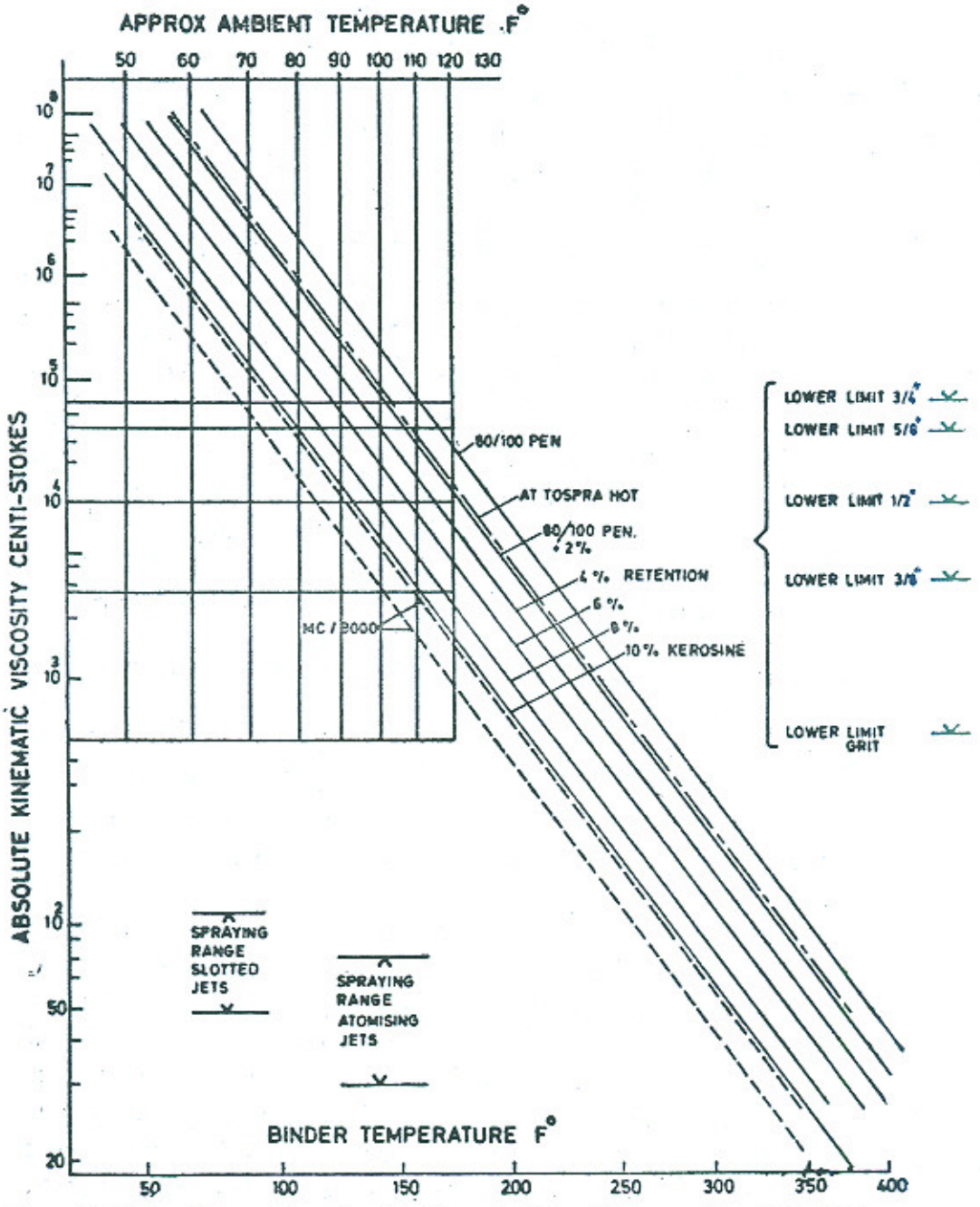


Fig. 13. Temperature viscosity characteristics of Bitumen (Attock 80/100 pen. West Pakistan)

Attock may be soft (suitable for northern areas of Punjab being little cooler), while grade from Karachi may be relatively hard to be utilized for central and southern areas which are hotter.

Finally, it may be noted that in order to determine the proper viscosity for a surface dressing which correspond to a certain size of stone and temperature, the following simple test has been described by the Country Road Board of Victoria :

> "Drop several representative piece of aggregate into the binder from a height of one inch, and allo w them to remain for 1 minute. Carefully remove each piece and examine it for adhesion. Do not throw, press, or push the aggregate to improve its adhesion. Drop it freely and pick it off cleanly. When the binder has the proper viscosity for good adhesion, the binder will be found to have adhered to the pieces of aggregates and coated one face with a thick black film. If there is no adhesion, the binder is much too viscous. When there is adhesion, but the film is very thin and exhibits a brown colour, the binder is too fluid".

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