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UNITED STATES ARMY
CORPS OF ENGINEERS
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
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There are many conditions contributing to the success of a surface treatment. During the actual laying phase, three factors are important, namely the equipment, the quality of work, and the climate (weather conditions). Later damages may be due to erroneous dosage of quantities of binder and aggregate, too heavy traffic load and the geometric and physical surface of the roadbed. This paper deals with the various dressings and application methods and resulting successes and failures.

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EXPERIENCES WITH SURFACE DRESSINGS IN NORWAY

by

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SUMMARY

Surface dressing of roads has been practiced in Norway since the early 1930's, but due to varying results, the method was infrequently used in the early years. From the late 1960's, however, there has been a certain renaissance for the method as being an inexpensive and simple surfacing type. This is partially due to a series of experiments performed around 1970. In conjunction with these tests, an investigation was also performed concerning the surface treatments made by the National Public Roads Administration during the years 1971-75. Some of the increasing interest in surface treatments is probably also due to the positive experiences of surface treatments with gravel (the so-called Otta-covering).

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- erroneous dosage of quantities of binder and aggregate
- too heavy traffic load
- the geometric and physical surface of the roadbed.

An investigation has shown that the four most commonly occurring faults in a surface treatment are:

- Bleeding, 20%
- Stripping, 34%
- Streaking, 27%
- Center joint, 17%.

WHAT IS A SURFACE TREATMENT?

Surface treatment is a concept that can include all operations performed on the surface of a road with the purpose of improving the surface characteristics. In normal terminology, however, surface treatment means a work procedure in which a liquid binder is first sprayed over the road, whereafter a layer of rock material is spread over the binder layer. This operation may be repeated once or several times.

Single surface dressing consists of one layer of binder and one binder of aggregate. Single surface treatments are usually performed on top of existing bituminous road coverings. Figures 1 and 2 show a single layer surface dressing.

FIGURE 1:

A successful single surface dressing

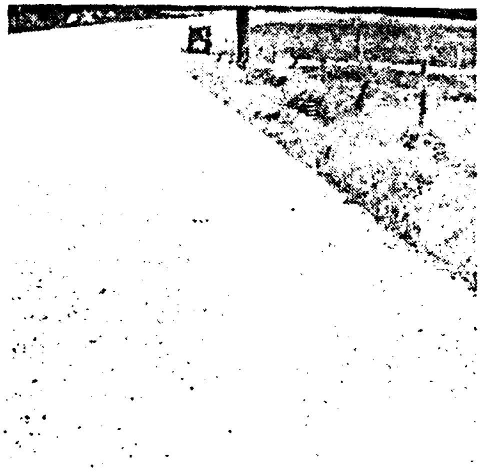
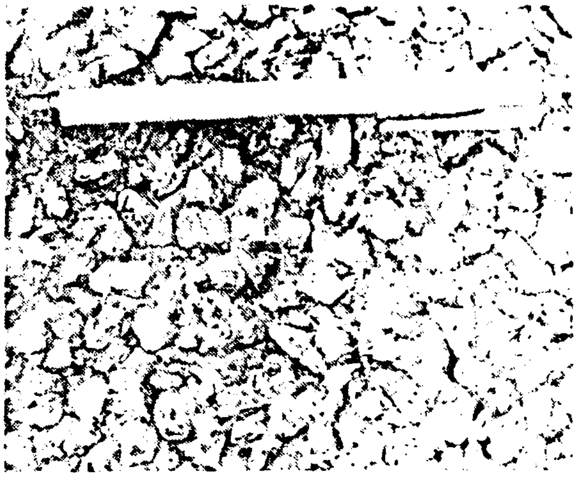


FIGURE 2:

Details of the surface dressing shown in Figure 1.



Double surface dressing is, in principle, a single surface treatment repeated twice and thus consisting of two layers of binder and two layers of aggregate.

In the second layer, an aggregate fraction should be used which is one or two steps smaller than that of the first layer, e.g. 12-16 mm in the first layer and 8-12 mm or 4-8 mm in the second layer. Double surface dressing is a considerably more durable treatment than single surface dressing, and on roads with little traffic it may also be used as the only road surfacing.

Reinforcement of the surface dressing means adding an extra layer of aggregate without previous spraying of binder. The reinforcement material should be at least two fractions smaller than the top layer of the surface dressing.

Surface dressing with gravel (Otta-covering) is a surface treatment where the aggregate material consists of graded gravel. This type of surface treatment can be performed both singly and doubly, but usually, it is applied to a gravel base, as a double dressing.

DEVELOPMENT OF SURFACE DRESSING TO DATE

Surface dressing of the road surface is a road-covering type that was already being used before the turn of the century in other parts of Europe, particularly in Great Britain. The method was introduced in Norway in the early 1930's as a way of reinforcing penetration coverings, a surface type which was widely used since about 1920.

The earliest surface dressings were performed as double surface treatments, with tar being used as a binder. Some bitumen was frequently added to the uppermost layer, and eventually, it became common practice that the top layer consisted of bitumen only. Anionic emulsion was also a common type of binder for this type of surfacing during the late 1930's.

At this time, single surface treatment was relatively infrequent, but on occasion, the method was used as a reinforcement skin (wear layer) on existing bituminous road coverings.

In the years following 1945, the most common binder type was a bitumen solution, without addition of substances to improve the adhesiveness. In combination with increasing traffic, the result was that the quality of applied surface dressings deteriorated continuously; in the years following 1950, this type of road covering disappeared successively, both as wear layer on penetrated filler material, and for maintenance of older, bituminous road coverings.

In the middle of the 1960's, the interest in surface dressings started to increase again, and in the last couple of years before 1970, some experimental dressings were applied under the auspices of the National Public Roads Administration, mainly with a bitumen solution as a binder (1, 2). These experiments were relatively successful, and a renaissance was expected for this simple and inexpensive road surfacing type. The main application was as wear reinforcement on existing bituminous road surfaces, and mostly, single surface treatment was applied. Some of the increasing interest for surface treatments at this time was that positive experiences had been made with surface dressings of gravel, so-called Otta-covers, applied on dirt road or mechanically stabilized carrying layers. This type of road surfacing was developed in the mid-1960's by the Road Laboratory [Veglaboratoriet] in cooperation with some road service offices.

The continued work to develop single surface dressings was performed under the coordination and management by a committee including representatives for the National Public Roads Administration [Statens Vegvesen], the Street Department of Oslo [Oslo Veivesen], and the Association of Asphalt Layers [Asfaltentrepenørernes Forening]. In the years 1972-1976, a number of test dressings were applied on the national roads E 18, Rv 157, Rv 153, Rv 160, Rv 155, Rv 120, and Rv 167 in Akershus, and on a feeder road in Oslo. In these experiments, quantity and type of aggregates and binders were tested, at the same time as one attempted to gain practical experience of performance, control, and follow-up of surface treatments (3, 4, 5, 6).

In conjunction with these activities, a study was also undertaken of surface treatment performed under general contracts for the National Public Roads Administration in the period from 1971 to 1975, in which the importance of climate, application time, and control activities during the laying was investigated. At the same time, the causes of damages and damage mechanisms were studied for clarification (7).

PROCEDURE FOR SURFACE TREATMENTS

In the actual laying phase, three factors have specifically great influence on the quality of the surface dressing, namely the quality and condition of the equipment, the wrokmanship, and the climate. The spraying of the binder is particularly critical, since the quantitative tolerances are small, if one wishes to avoid bleeding or stripping.

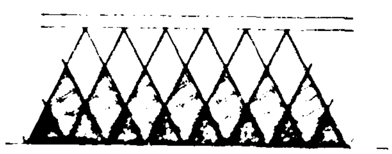
In recent years, there has been a relatively rapid development of spraying ramps for bituminous binders, so that the currently available equipment is fully satisfactory for obtaining the precision necessary for good results. The most modern equipment allows the binder pump to be coupled to the engine of the truck in hydrostatic drive, so that the rpm of the pump, and, consequently, the quantity of binder forwarded to the ramp, will vary with the rpm of the engine.

However, there are still a number of old spray ramps being used, where the pump operates at a constant speed and the quantity of binder applied is thus constant per unit of time. When such equipment is used, the quantity sprayed out will depend on the speed of the sprayer truck, and the skill of the driver will largely determine whether or not the correct quantity is applied.

The cross-wise distribution of binder must also be as even as possible, and in order to achieve this, the spray ramp is constructed so that the jets from several nozzles will overlap, as shown in Figure 3. Where one or more nozzles are plugged up or have the wrong angle to the ramp, this overlapping will not be satisfactory, insofar that the desired even distribution is not achieved. In the calibration of ramps during the treatment of the test fields, variations corresponding to $\pm$ 0.6 kg/m^2 were found between nozzles in one and the same ramp. According to experience, this is not unique, and it is thus recommended that the sprayer ramps be calibrated at least once every season. Furthermore, the ramps should be regularly inspected and cleaned to maintain its precision. Written documentation that the sprayer equipment has been inspected and calibrated during the year of work performance is now required for all works to be performed for the National Public Roads Administration (12).

In order for the aggregate to adhere to the binder, the spreading of the rock material should take place before the viscosity of the binder has increased so much that it is difficult to moisten the aggregate surface. This requires that the aggregate spreader follows as close to the sprayer vehicle as possible. Due to the differences in speed between the aggregate spreader and the binder sprayer, the length of each sprayer section must therefore be limited to approx. 100-150 m.

FIGURE 3: The principle of overlapping spray fans.



It is recommended that self-propelled aggregate spreaders be used for surface treatments, since these produce the most even and satisfactory distribution of the material. Although good results have also been obtained with towed spreaders, these results depend more on the skill of the truck driver.

The execution of joints is important in the application of surface dressing. A badly made joint will not destroy the dressing but it will weaken its function, and the visual impression is bad. Cross-joints should preferably be so executed that bulky or open portions of the joint are avoided. This can be achieved by placing a cardboard strip over the finished piece next to the joint. Thus, the sprayer truck will have reached correct speed and thus distribute the correct quantity from the moment the spray is applied to a new section.

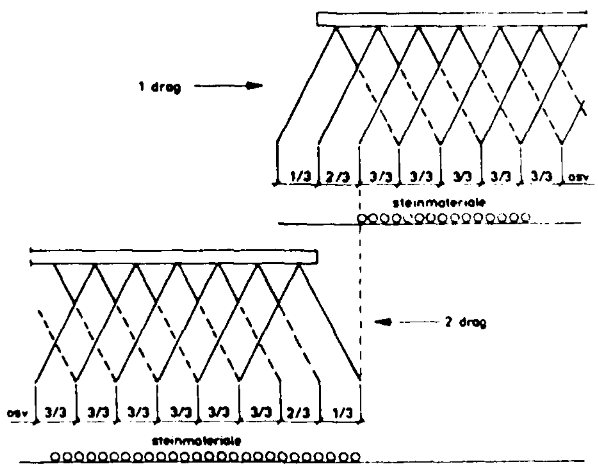
Longitudinal joints are more difficult to execute, and they are often bulky or open. The center joint can be executed in several ways, but only three methods can be said to give satisfactory results for surface dressings with uniformly graded materials.

Method 1

The binder is sprayed as usual, but the aggregate spreader is blocked over the innermost 2 or 3 nozzles, so that after the first pass, the binder remains uncovered. On the parallel pass, binder is sprayed over this field and next to the aggregate material of the first pass, whereafter the aggregate is spread. Theoretically, all parts of the road have then been covered with the appropriate quantity of aggregate and binder - See Figure 4.

FIGURE 4: The principle of overlapping with binder in the center joint.

[At arrows: top - First pass; bottom - Second pass. Under the figure of sprayer nozzles: Aggregate material.]



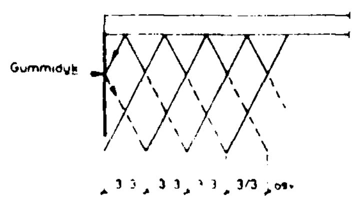
However, it would seem that this method is difficult to apply successfully in the practice. It requires skillful handling of the aggregate spreader and the demands on the operator are great. It is also difficult to avoid truck traffic on the area where the binder is uncovered and thus transferring binder on to the completed surface dressing. This leads to tearing up of the aggregate, and the homogeneous surface is weakened. In the actual center joint, there may be an insufficient quantity of binder if the two passes are not overlapping completely according to the instructions. This will be visible later, in the form of open spots in the center joint; this is not uncommon when this method is used, since the operator of the aggregate spreader must estimate the correct overlapping visually in the first pass. After the second pass, the portions of the center joint that are lacking in binder will not stand out, and potential weaknesses will not become apparent for some time to come.

Method 2

According to the second method, the ends of the sprayer ramp are covered by means of a rubber sheet so that the two outermost nozzles, which are not overlapping, will be blocked. The jets from the outermost nozzle will be deflected by the rubber sheet and spread the full quantity of the binder all the way to the edge, as shown in Figure 5. The two parallel passes are run right next to each other, and spreading of aggregate is performed to the edge of the binder for each pass. That portion of the aggregate which falls outside of the sprayed field must be swept up before the next pass is made. In this case as well, it is necessary to have a skilled operator on the aggregate spreader, but according to this method, he can follow a more defined edge. When the second pass is made with the binder, those locations where the binder does not touch the e _ of the first pass will appear as open spots which must be filled before the aggregate is spread. Thus, this method offers a slightly better chance of correcting the errors committed during the course of the work than does the first method.

FIGURE 5: Closing of the binder distributor at the center joint without overlapping.

[At left in figure: Rubber sheet]



Method 3

In (12), it is assumed that the joint is executed by spreading the first binder width completely with aggregate. The second binder pass is applied with an overlap of 10-15 cm at the center joint, and this pass as well is completely covered with aggregate. In this case as well, it is necessary that the ends of the sprayer ramp is closed off so that the full quantity of binder is distributed to the very edge. This method means that, for example, in case of a single surface treatment, there will be a double layer of surface dressing over the center joint. This will result in a slight bulge over the center joint. This will be of no practical importance if the granular size is small.

If the material is coarser (11-16 mm and larger), there may be a risk of stripping from the top layer of the joint. If this is a disadvantage, the width of the overlap can be reduced to approx. 5 cm.

For surface dressing with gravel, (12) assumes that the gravel spread on the first half of the road is slightly narrower than the binder spread, so that there will always remain an uncovered binder strip of 5-10 cm at the middle of the road. Otherwise, see Method 1. In order to prevent the uncovered strip of the first half of the road from being damaged by traffic, some of the coarser gravel from the gravel-covered road half can be raked over.

The surface dressing should be well compressed so that the rock material adheres well to the surface. It has been found that good compression significantly reduces the possibility of the surface covering being destroyed by the traffic, and the importance of good compression can thus hardly be exaggerated.

THE BINDER HAS GREAT INFLUENCE ON THE QUALITY OF THE SURFACE COVERING

Type of Binder

Bitumen solution, bitumen, cationic emulsions, and "road oil" have all been used as binders. For the time being, the first two mentioned seem to be most suitable.

However, extensive experiments are under way with emulsions, and it is to be expected that this type of binder will be more frequently used in the future.

In each case, the selection of binder must be made with consideration of the weather conditions at the time of application, the climate in general, and the traffic conditions (5, 12).

Quantity of Binder

Correct quantities of binder constitute one of the most important factors for a successful surface treatment. Not enough binder means that the aggregate does not adhere, while an excess will lead to the binder's being drawn up to the surface, so-called bleeding. The studies that have been made show that the margins are very small. Figures 6 and 7 show the results from studies of surface dressings applied under the auspices of the National Public Roads Administration in the years 1971-1975 (7). The figures are based on observations of 57 test areas.

In Figure 6, the quantity of binder is plotted against the quality, expressed as bleeding, and in Figure 7, it has been plotted against the quality expressed as stripping. In both cases, the value of 0 indicates low quality, and 4 stands for the highest quality. A quality index of 2 is regarded as satisfactory. Figure 6 indicates that the chance of bleeding increases for binder quantities exceeding 2.0 kg/m^2 if 12-16 mm aggregate is used, and when 8-12 mm aggregate is used, the tendency increases at a dosage exceeding 1.8 kg/m^2.

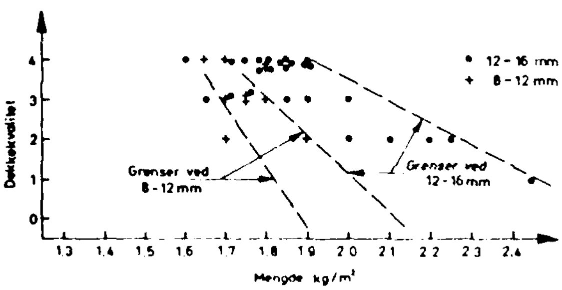
Figure 7 shows that the quantity limit for binder seems to be approx. 1.6 kg/m^2 for 12-16 mm aggregate, this with reference to stripping. On this basis, the quantity of binder should be between 1.7 and 1.9 kg/m^2 when this aggregate fraction is used on normal substratum, if one wishes to have a certain guarantee against stripping and bleeding. However, the results from t test fields show that under favorable application conditions, the limits may be somewhat wider, but the optimal quantity of binders will remain within the same range (6).

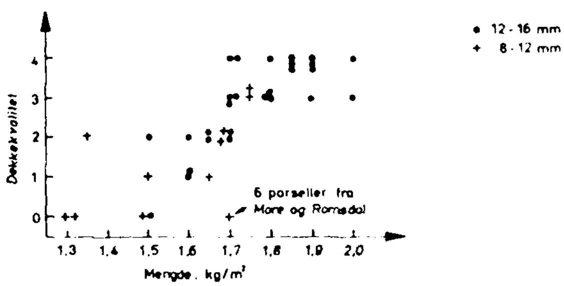
FIGURE 6:

The quality of a finished surface dressing as a function of the binder content, expressed in bleeding.
[Vertically at left: Surface quality]
[Below figure: Quantity, kg/m^2]
[At arrows in figure: Limits when using 8-12 mm / Limits when using 12-16 mm]

FIGURE 7:

The quality of a finished surface dressing as a function of the binder content, expressed in stripping.
[Vertically at left: Surface quality]
[Below figure: Quantity, kg/m^2]
[At arrow in figure, above horizontal axis: 6 test parcels from the Møre and Romsdal regions.]





For surface dressings with gravel, the best results have been obtained with binder quantities as shown in Figure 8.

FIGURE 8: Rates of spread of binder and chipping for surface dressing with gravel.

Aggregate		Binder, kg/m^2
Fraction, mm	Quantity, kg/m^2	
0 - 12	12 - 15	1.7
0 - 20	20 - 25	2.0

Usually, it will be appropriate to use a BL 1500 M (MC 4), but binders that harden more rapidly have also been used.

Experiments have been made using road oil as a binder. The experiences with road oil are somewhat mixed, since the degree of bleeding has varied.

In surface treatments with gravel, one operates with a slightly higher binder content than is the case with uniformly graded aggregate treatments. The reason for this is that the gravel has a slightly higher specific surface area than the uniformly graded materials and thus can absorb more binder.

The Viscosity and Temperature of the Binder

In order to apply the binder in correct quantity and distribute it evenly over the road surface, the viscosity must be held within defined limits. Optimum viscosity for spraying is usually identified as between 50 and 100 mm^2/s (cST) in foreign directives. The Norwegian specifications are based on a somewhat higher viscosity at the time of spraying, i.e. lower temperature. Nine of the parcels in the study (7) have been sprayed at a temperature close to the lower limit in the Asphalt Guidelines (12). Out of these 9, 8 are in very bad condition, while the last one shows marked signs of streak formation which indicates that the viscosity has been too high in this case as well.

Thus, it can be argued that the spray temperature should be somewhat higher than permitted in our Asphalt Guidelines. However, it should be pointed out that too high spray temperature can also be unfavorable. This may lower the quality of the binder and lead to a tendency of its running into wheel tracks and indentations in the road surface.

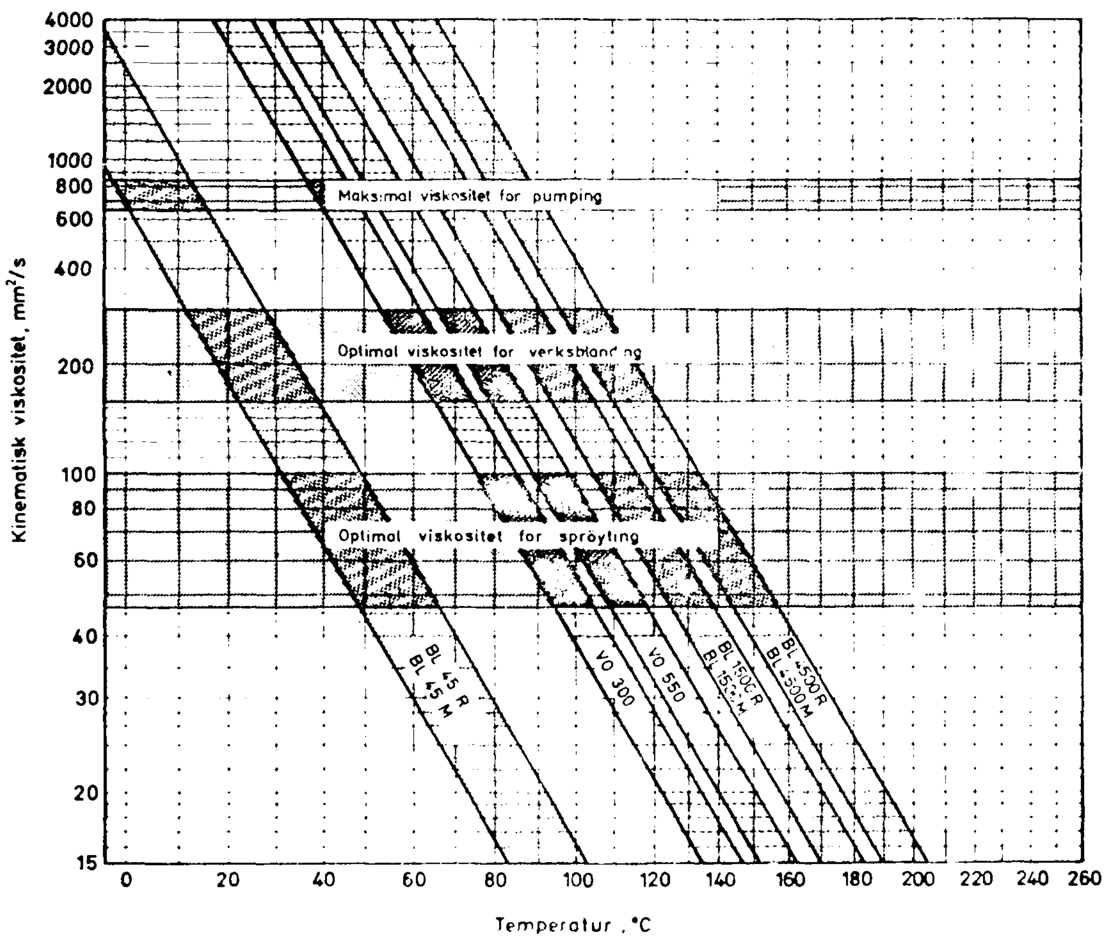
Some attempts have been made to modify the binder for more rapid increase of the viscosity under cooling, but the results of such experiments (3) are uncertain, and hitherto, no quality improvements have been demonstrated which would justify the cost increase which would be caused by additive substances.

Addition of amines to improve the adhesiveness between the aggregates and the binder is absolutely necessary in surface treatments, also when pure bitumen is used as a binder. To a certain extent, the binder will be fluidized by the amine, but normally, this is not harmful to the dressing. Generally, the fluidization is not so marked that it has been necessary to correct the spraying temperature.

Figure 9 shows the correlations between temperature and viscosity for asphalt solutions. Recommended viscosity for spraying is between 45 and 100 mm^2/s according to the investigations by the Asphalt Institute (13). This is illustrated in the bottom shaded area of the figure. The temperatures allowed in the Asphalt Guidelines (12) are generally 120°C for BL 1500 and BL 4500, but they vary slightly for use in surface dressings with gravel (See Figure 9). By comparison, the highest permissible temperature with respect to optimum viscosity will be approx. 140°C for spraying of BL 1500. When weighing these two temperature limits against each other, consideration must be given to the composition and to changes in the chemical structure of the binder as a result of high temperature.

At higher temperatures, there will be a hardening of the binder as a consequence of light components disappearing or forming heavier molecules. In some cases, this may result in reduced resistance to climate and traffic effects, somewhat that must be regarded as undesirable. When the temperature limits were established in the Asphait Guidelines, it was decided to emphasize this effect as well as the fact that the risk for explosion and ignition increases at higher temperatures. According to Figure 9, the lowest spraying temperature is relatively far above that stated in the Asphalt Guidelines, which allow temperatures down to below 100°C. In this context, it should be understood that in many cases, spraying schedules for spray tanks are based on certain viscosities in the optimum range, and when there are major deviations from the assumed viscosity, this will have an effect on the quantity of binder.

FIGURE 9: Temperature/viscosity diagram for cutback asphalt. [At left, vertically: Kinematic viscosity, mm^2/s; below figure: Temperature, °C. Shaded fields, top to bottom: Maximum viscosity for pumping / Optimum viscosity for standard mixing / Optimum viscosity for spraying.]



Another disadvantage of spray temperatures below 100°C is that there may be water or water vapor in the system which cannot be removed, and this will have the effect of reducing the quality of the binder. If hotter binder is added later, there may also be steam explosions of locked-in water. Thus, it is to be recommended that as far as possible, the spray temperature be held above 100°C.

REQUIREMENTS ON THE AGGREGATE

When the surface treatment is correctly executed with a uniformly graded material, the aggregate is to form a wear layer where the individual grains lie embedded as in a mosaic. Thus, the aggregate must have good durability and good mechanical properties, and it must be applied to the road surface in the proper quantities.

The quantity of rock material that remains on the road seems to depend closely upon the applied quantity, as long as there is an excess. For 12-16 mm material, the optimum quantity is approx. 19 - 20 kg/m^2, for 8-12 mm material approx. 13 - 14 kg/m^2 (6). Greater quantities will be worn off during the first period after the application, and in addition to increasing the costs, this also creates the risk of flying rocks and damages.

Quantities below the optimum seem to considerably reduce the useful life of the surface dressing, insofar that the wear increases very rapidly as the quantity of aggregate decreases. It should therefore be carefully checked that the quantity of aggregate is close to the correct one. The available statistics concerning completed works show that there is a tendency to spread too much aggregate.

Aggregates for use in surface dressings should be crushed materials without too high a content of fine particles. For materials of particularly low quality grade, pre-treatment such as washing or pre-bituminizing might be necessary. Very good results have also been obtained by sifting the material through a sieve (thread sieve) with a mesh smaller than the minimum nominal granular size. This removes the flakiest material as well as loose fine particles, at the same time the extra sifting process considerably decreases the fine particle deposits on the aggregate surface. The method is inexpensive and has given results as good as or better than washing. One condition seems to be that the material be relatively dry, but some moisture can be tolerated.

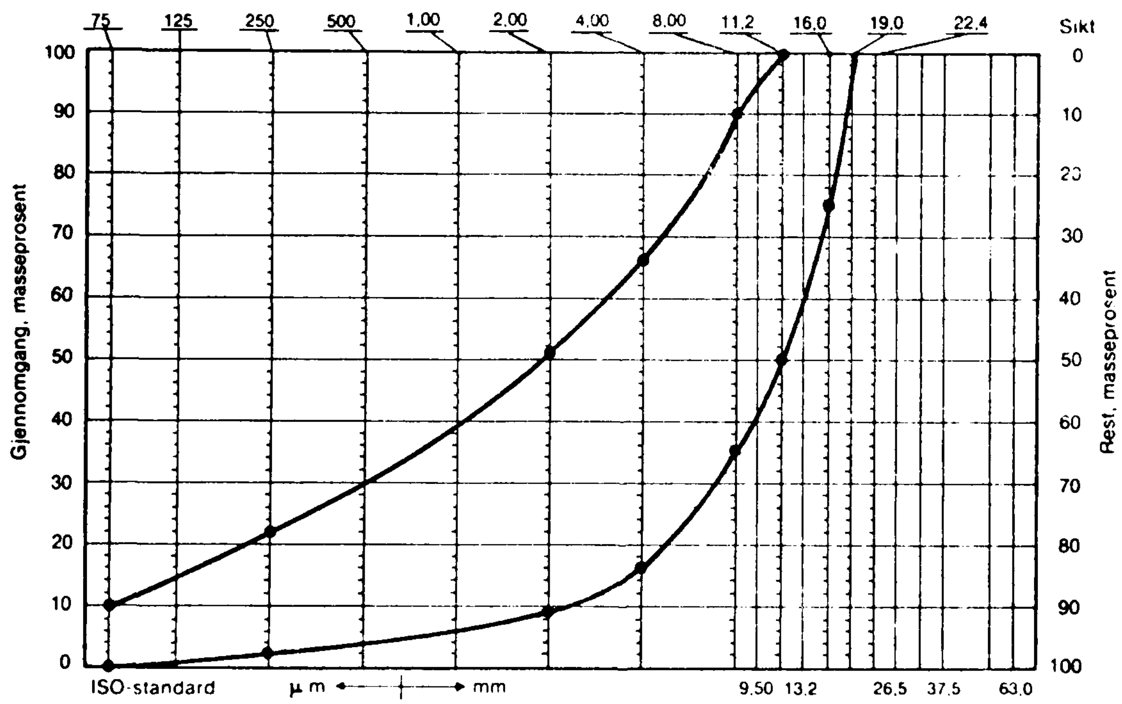
Impure aggregates with a high content of fine particles and too small grains can be destructive to the surface dressing in several ways. Undersized granules fill the spaces in the rock skeleton so that the binder level becomes higher than desirable, and the bleeding risk will increase. Fine particle content has the same effect in addition to preventing the adhesion of the binder to the aggregate surface.

The requirements on the rock material for use in surface dressings with gravel are relatively modest, and this is of economic importance for this type of road covering. Normally, natural deposits of gravel material are used, including its filler and water contents. Figure 10 shows the quantity of gravel materials and granular size. Gravel with a granular grading within the limits shown in Figure 10 has been found suitable for surface dressings with graded gravel.

THE IMPORTANCE OF THE TRAFFIC LOAD AND THE SUBSTRATUM

Depending on the traffic load and the characteristics of the substratum, the aggregate will be pressed down into the substratum after some time. This movement of the aggregate affects the quality of the surface dressing in two ways. It contributes significantly to the adhesion between the covering and the rock material, and not until the rock material has been pressed down to a certain depth will it adhere so well that traffic with studded tires and snow chains can be tolerated without stripping of rock. This depth limit seems to be approx. 1.5 mm, but the normal press-down depth in a successful road dressing is 2-3 mm (7). If the compression is considerably greater, it will cause too great a reduction of the spacing in the aggregate, so that bleeding will occur (6).

FIGURE 10: Grading limits for surface dressing with gravel, so-called "Ottadekke" [Otta-cover]. [Top right of figure: Sieve. Vertically at left: Passing through, percentage of mass. Vertically at right: Remaining, percentage of mass.



The compression of the aggregate will increase with increasing traffic load. This means that optimum binder is reduced in order to avoid bleeding. At the same time, heavy traffic will cause relatively greater stresses during the application period. With small quantities of binder, these stresses may be critical and lead to the tearing up of the surface. Experiences from field tests indicate that the limit for traffic load is somewhat higher than established in (12), namely at an average of 3,000 vehicles per day. In the field tests, good results have been reached even with traffic loads of up to 5,000 - 6,000 vehicles per day, provided the application conditions and the execution were satisfactory (6).

The compression depth will also depend on such factors as the hardness of the binder and the rock contents of the asphalt below, but there are as yet no data to identify these factors.

The geometrical and physical surface seems to be of great importance for the quality and durability of surface dressings. A porous surface will absorb more binder than a dense one, a low-fat surface more than a fatty one, etc. This was investigated in a number of samples taken from surface dressings (7), and the results of these investigations show that the variations in need of binder between different surfaces are greater than had previously been assumed. See Figure 11.

FIGURE 11: The necessary amount of binder on different types of surfaces.

Characteristics of road surface	Need of binder, including solvents if necessary, kg/m^2
Freshly applied, fine grain Ab or Agb	0.10
Somewhat worn Ab or Agb, dense surface	0.15-0.20
Non-fatty covering, dense surface	0.20-0.35
Non-fatty covering, open surface	0.35-0.50
Very open covering (spacing > 10%)	0.50-0.70

The effect of wheel tracks on the bleeding tendency has not been investigated in detail, but experience indicates that more stringent requirements should be identified concerning the depth of wheel tracks on an old road to be surface treated than if it would be be the object of a normal new asphalt application. If the wheel tracks are of some depth, the binder will run towards the middle of the track and cause a localized excess of binder. Combined with the heavier traffic load on the center of the wheel track, this may cause bleeding. Simultaneously, the traffic will cause greater compression in the wheel tracks than outside of them, so that the actual depth of the wheel tracks will increase after the surface treatment of the road.

The geometrical characteristics of the road are also of great importance for the success of a surface treatment, namely in respect to design lines, width, etc. This has not been specifically investigated, but experience would indicate that the surface dressing is subjected to considerably more heavy stress effects if the geometrical standards of the road are not satisfactory (7, 10). For this reason, it is important to tailor the surface treatment to the specific varying conditions along a road section so that, if necessary, the work methods may vary several times along the way.

CLIMATE - GOOD WEATHER CONDITIONS DURING APPLICATION ARE IMPORTANT

In general, surface dressings are sensitive to water. This is not only the case during the application but later as well, even though this sensi-tivity decreases with age.

The border surface between aggregate and binder is exposed to attacks of moisture to a much higher degree than is the case with other bituminous sur-face coverings, and good, active adhesiveness is necessary so that the binder will not peel off. Normally, one attempts to achieve this by adding amines to the binders.

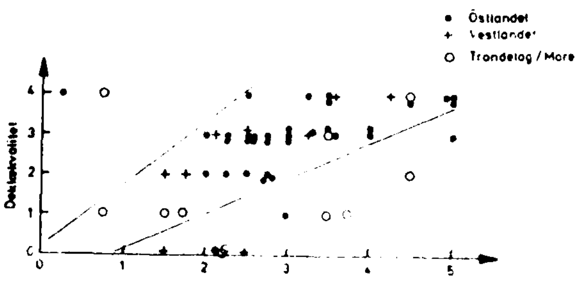
Emulsions frequently contain amines as emulsifiers, and when emulsions are used as binders, the addition of substances to improve the adhesiveness will become superfluous.

The effects of climate and application conditions were investigated on a total of 57 test surfaces laid during the years from 1971 to 1975 (7). The quality of the center joint and the amount of stripping were clearly superior for work performed prior to August 1. This held true for all four regions included in the study: Østlandet, Vestlandet, Trøndelag, and Møre.

Favorable weather conditions for application of surface dressing are warm and calm, with an air temperature of about 20°C. Precipitation or wet weather combined with wind are particularly unfavorable.

Figure 12 shows the correlation between application conditions and quality. The data represented in the figure are taken from the study of work performed under normal contracts in the period 1971-1975 (7). The application indexes express conditions at the time of the application, e.g. an index of 2 means an air temperature of 10°C and some sun but no precipitation or wind, or, 15°C with some precipitation.

<u>FIGURE 12</u>: Correlation between laying conditions and surface quality. [Top right, geographical regions. Vertically at left: Surface quality. Below figure: Application index.]



0 is the lowest value for quality, and 4 is the highest. The value of 2 indicates the lowest tolerable quality, while qualities corresponding to the values of 3 and 4 are regarded as desirable. Figure 12 shows that applica-tion index lower than 2 should not be allowed, i.e., the air temperature should not be below about 10°C during the laying if satisfactory quality is to be ob-tained. The same figure also shows, however, that one will not automatically

achieve a good result if the application conditions are favorable. This means that other factors than climate have influenced the quality, such as traffic, use of material, quantities, etc.

MECHANISMS AND CAUSES OF DAMAGES

The four most common damages to surface dressings are bleeding, stripping, streaking, and open center joint. Figure 13 shows the frequency of these damages.

FIGURE 13: Frequency of different types of damage to surface dressings laid in Norway 1971 - 1975.

Damage	Frequency
Bleeding	20%
Stripping	34%
Streaking	27%
Quality of center joint	17%

The most frequent type of damage is stripping. The cause of this is mainly too late application, but partially also insufficient binder quantities.

The second most frequent type of damage is streaking. Here, one can differentiate between several types, each with specific causes. The most important ones are:

- Streaks due to defective nozzles. These are usually of a constant width and can be found at a constant distance from the edge of the road. They are characterized as being a zone without aggregate, and their limits are frequently sharp. Such streaks are frequently marked by stripped rock material.
- Streaks due to too low temperature during application of binder. These are characterized by alternating portions of excess binder and aggregate slides across the road bed. The distance between these streaks roughly corresponds to the distance between the nozzles of the sprayer ramp.
- Streaks due to rocks stuck in the aggregate spreader. These are narrow streaks about 5 cm wide at the top and occurring for a certain distance only before disappearing again. The cause of them is that rock material gets stuck in the feeder roll of the aggreagate spreader so that the aggregate is not properly distributed. Such streaks differ from those caused by defective nozzles insofar that there is a normal quantity of binder and that there are no marks of thrown rocks.

The investigation does not differentiate between these types. The impression from previous experience is that the first type is more frequent the data in Figure 13 would intimate.

Streaks of this type can be eliminated by good equipment maintenance, which is currently not as common as would be desirable.

The frequency of bleeding is relatively low. On most surface dressings, there will be some blackening in the wheel tracks which is of no significance for the function of the surface dressing. However, such blackening may soon have a negative visual effect, particularly if light-colored aggregates are used, but it is greatly preferred over a binder deficiency, which may cause irreparable damage.

During the application period, the quality control effort has varied. The available data material from applications during the layings in 1971-1975 indicates that the quality control efforts have major importance on the final quality. The average quality of operations where a full time inspector has been at the site is 2.8 (good), while the figure is only 1.9 (tolerable) when the inspector has visited the site only occasionally. As far as it is possible to identify the causes of this difference in quality, they would be that

- the application has been made with incorrect quantities
- the application has been made under unfavorable weather conditions.

Both of these conditions can be prevented if a qualified inspector is present at the site.

FOLLOW UP OF OPERATIONS IN 1977

In order to be able to improve the evaluation of control and follow-up methodology, a major follow-up project of contracted operations in the summer of 1977 was initiated under the auspices of the National Public Roads Administration (9, 10). The work was to be performed on Rv 7 in Buskerud and on Rv 455 in Vest-Agder, and the purpose was to follow up continuously.

The critical situations in application of surface dressing seem to occur in the start-up or finishing of work, changes in climate conditions due to rain or heat, equipment deficiencies, breakdown of machinery, or faulty materials (9). This gives a good indication of where the efforts are to be concentrated.

The follow-up efforts on Rv 7 and Rv 455 have emphasized the necessity of having trained personnel for performing the surface treatments. The minimum requirement is that the team leader and the machine operators are experienced and qualified. The work in Vest Agder was performed by an untrained team, where only the team leader had previous experience of this type of work. The execution proved this in an obvious manner, but it improved considerably as the team had more practice and experience.

Traffic conditions will rapidly create difficulties in surface treatment work. A new surface dressing is very vulnerable to traffic, therefore, speed and driving patterns should be regulated as much as possible. During the application on Rv 7, this was achieved by controlling traffic at the application site. Well ahead of this site, travellers were warned, by means of signs, that they were approaching a work area. Road Under Construction, Reduce Speed, Danger - Flying Rocks and No Passing signs were posted in this order. Restrictions were imposed on traffic speed over the newly applied dressing for some time in order to avoid rock stripping and damages to the surface. Traffic control must be regarded as necessary if the traffic volume exceeds 800 - 1,000 vehicles per day.

The speed must be reduced over freshly applied surface dressing; 40 km/h for two days after the application and 50-60 km/h for about a week after that. This may be difficult to achieve if the flow is heavy but it should be attempted as much as possible, for the risk of damage is considerably reduced if the traffic stress is decreased in the first period after the work.

The follow-up of these operations was performed by two men. Systematically, several types of forms were used to record quantities, execution, weather, etc.

The use of such systematized forms will greatly facilitate later follow-up of such operations, at the same time as it allows recording of all relevant data in a manner that is easy to survey.

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