Dust-Abatement Materials: Evaluation and Selection

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The purpose of this paper is to provide (a) a guide for selecting the correct type of dust palliative and application rate for a given situation, (b) information to evaluate alternatives in terms of cost and energy, and (c) application guidelines to ensure the best job for a given situation. Descriptions of current costs and dust palliatives used in the Pacific Northwest Region, Forest Service, U.S. Department of Agriculture, are given. The type and quantity of dust palliative may be selected by first obtaining the residue content of the dust palliatives considered and then determining the required residue content necessary to give the soil a certain level of cohesion as determined by the modified-pellet-abrasion test. This required residue content can then be converted to the proper product application rate. Determining the energy content of each product and the total energy used in controlling dust by different methods is a major consideration in the selection of the proper dust-abatement strategy. Construction guidelines are presented for penetration and mix-in-place-type applications.

Currently, millions of dollars are being spent each year on dust abatement in the United States. The products being used fall into two categories: petroleum and nonpetroleum based. Typically, specifications currently used for dust-abatement products are identification rather than performance oriented. These specifications were developed by using, more or less, a trial-and-error approach. That is, when a new product was introduced and proved satisfactory, properties that chemically and physically identified that product were adopted and included in a specification. Recent work reported by Langdon (1) was concerned with the development of performance-oriented specifications.

Although improved specifications are available, there still is not a great deal of information available concerning the evaluation, selection, and application of dust palliatives. The purpose of this paper is to summarize the available information to provide dust-palliative users with the following data:

1. A guide to select the type of palliative and its application rate for a given situation,
2. Information to evaluate alternatives in terms of cost and energy, and
3. Application guidelines to ensure the best job for a given situation.

TYPES OF PRODUCTS

This section presents a description of the most commonly used dust-abatement products used in the Pacific Northwest Region, Forest Service, U.S. Department of Agriculture (Figure 1). The region includes the national forests located in the states of Oregon and Washington. This section also includes a record of past and current costs and an energy assessment of each product.

Product Descriptions

DO-1 (Light Arcadia)

DO-1 is a cutback-type dust palliative. The cutter stock or solvent is in the boiling range of kerosene (350°-550°F). The residual material is generally asphalt that has been buffered or softened with a heavy-type solvent such as crankcase oil [U.S. Environmental Protection Agency (EPA) guidelines prohibit crankcase drainings]. The resultant residual is a soft asphalt that would not be solid at normal summer air temperatures. It can be made in a number of ways and quite often uses waste materials, including used crankcase oil. It could be made by blending asphalt, crankcase oil, and kerosene. It could also be made by blending a medium-curing (MC) cutback with crankcase oil or numerous other ways. DO-1 is normally used on dense surfaces.

DO-2 (Medium Arcadia)

DO-2 is very similar to DO-1 with the exception that the cutter stock is more in the diesel boiling range (375°-630°F). It is intended for use with less-dense aggregate than DO-1. It can be made of the same ingredients as DO-1 but with differing percentages of each component.

DO-3 (Heavy Arcadia)

DO-3 is in the same family as DO-1 and DO-2, but it is intended for more open aggregate than DO-2.

DO-4 (Clarified Dust Oil)

DO-4 was originally a waste product of Montana refineries that used Canadian crudes. It is a high-boiling-point oil with a high sulfur content. It was used as fuel oil in the past, but environmental restrictions on burning reduced its use. Its general characteristics would be similar to DO-1. It has little or no asphalt fraction; hence, the residual is softer (lower viscosity). It works best with dense, low-permeability surfaces.

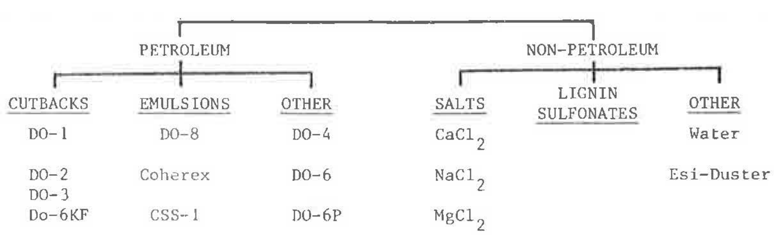
DO-6

DO-6 is a waste petroleum product designed to use reclaimed oil and water. It does not penetrate as well as the Arcadia dust oils (DO-1, 2, and 3). The surface must usually be scarified to allow penetration, and often road mixing is required.

DO-6P

DO-6P has the same characteristics as DO-6 with the exception that some of the water and residual (heavy oil) has been replaced with cutter stock. The handling and residual viscosities are both reduced. The penetration characteristic is improved. It will generally penetrate a compacted surface, but it may be necessary to scarify in cases of quite dense surfaces.

Figure 1. General categories of dust-abatement materials used in the Pacific Northwest Region.



DO-6KF

DO-6KF is an SC-70 cut again with a slow-curing (SC) cutter stock (diesel boiling range). Five percent by weight of product CSS-1 is then added. This product is not an emulsion. It falls between a DO-1 and a DO-2 in residue viscosity.

DO-8

DO-8 is an emulsified product. It is made just like CSS-1 except with a soft base (residual) asphalt. The penetration grade of the base asphalt is 200 plus. Its performance characteristics are somewhat similar to DO-6.

CSS-1

CSS-1 is a standard grade emulsion used for paving. It is also used as a dust palliative. Its handling viscosity is satisfactory, but the viscosity of the base (residual) asphalt is too high to allow penetration and also to allow the treated surface to be rebladable (see discussion on DO-6 and DO-8). It must be road mixed, and this does allow a means of keeping it bladable. If the residual asphalt is kept to a low level, say less than 1 percent, then only the fines are cemented together. This allows dust to be controlled to an acceptable level and still be bladable.

Coherex

Coherex is an emulsified proprietary product produced by Witco Chemical. The residual is a petroleum resin. Its handling and residual viscosity is in an acceptable range. It also has good penetration characteristics that are similar to DO-6PA.

Lignin Sulfonate

Lignin sulfonate is a waste product of the sulfite pulping process in the paper industry. Wood is processed by treatment with sulfuric acid to break it down into wood fiber. The waste consists of spent sulfuric acid, wood sugars, etc. Everything but the fiber is included in the waste. At this point, the waste is called pulp liquor. It is sometimes used in this form as a dust palliative. The waste is normally processed further to form lignin sulfonate.

Basically, the processing consists of neutralizing the acid and reducing the water content. The concentrate is normally available in a 50 percent solid to 50 percent water mixture.

As a dust palliative, it provides a weak cement for stabilizing. It penetrates well and is rebladable when wet. Its big drawback is that it is water soluble and therefore may leach away with rainfall. There may be some residual carryover from year to year. When the pulp liquor is processed for alcohol, reports indicate this material is not as effective as a dust palliative.

ESI-Duster

The ESI-Duster is a guar-gum base powder that mixes with water to form a viscous fluid. It is intended to glue the fines together.

Salts (Calcium, Sodium, and Magnesium Chlorides)

Several salts can be used for dust abatement. The main ones are calcium chloride and magnesium chloride, which are deliquescent, and sodium chloride (common table salt), which is hygroscopic. Deliquescent substances absorb moisture from the atmosphere and liquify. With hygroscopic chemicals, the quantity of water absorbed depends on the exposed surface area; more is absorbed when the substance is finely divided. They all perform by keeping the road surface damp, thus controlling dust. They have little or no cementing action.

Sodium chloride absorbs water when the humidity exceeds 75 percent; consequently, it is of little value in arid regions. Calcium and magnesium chloride cease to absorb moisture when the humidity falls below 30-40 percent.

Salts can be applied either in a water solution or in solid form. The solid form is generally favored, especially when heavy applications are to be made. If dust-free conditions are to be maintained, more than one treatment a year is necessary because these chemicals tend to migrate downwards through the roads. Other disadvantages are that salts are corrosive and may cause vehicles that use the road to rust rapidly and, because of their water-retention property, they also may cause the road surface to be excessively wet when it rains or until some of the salt penetrates below the surface.

Water

Water provides only temporary relief, and the required frequency of application depends on the climate and weather. Experience has shown that several light applications are better than one heavy one. A very heavy application may turn the dust to soft mud, wash away essential fines, and even penetrate to the subgrade, possibly resulting in a road failure.

Seawater is generally more effective than fresh water owing to the presence of small amounts of salt.

Products Cost

Table 1 summarizes the cost trends for each of the above-mentioned products. All products are available on a cost per ton basis. Some of the products may be purchased in a diluted form. The user must always convert the diluted product back to an undiluted state for cost comparisons.

Energy Assessment

Energy considerations are important when selecting a dust palliative. Fuel-eligible materials are herein defined as petroleum products that have a boiling level less than 680°F. The energy contained in petroleum products used in dust abatement are summarized in the table below (2) (note, Btu = British thermal unit):

Product	Btu per Gallon (000s)	Boiling Range (°F)
Gasoline	125	30-440
Kerosene	135	350-550
Fuel Oil		
No. 1	135	350-550
No. 2 (diesel)	139	375-630
No. 3	143	375-630
No. 4	148	400-650
No. 5	152	450-650
No. 6 (Bunker C)	154	≥630
Asphalt cement	158	≥680

Table 2 lists the energy available in dust-abatement products.

Environmental Assessment

Several potential environmental problems exist with

Table 1. Cost of dust-palliative products.

Product	Cost ($/ton) 11/78	11/79	3/80	11/80	7/82
DO-1	76.00	110.00	180.00	180.00	210.00
DO-2	83.76	152.00	188.00	188.00	210.00
DO-4	99.00	160.00	180.00	180.00	175.00
DO-6KF	96.00	145.00	194.00	204.00	215.00
DO-6PA	74.00	87.00	132.75	132.75	152.75
DO-8	74.00	95.00	130.75	130.75	150.00
Coherex (concentrate)	133.00	180.00	245.00	271.08	285.60
CSS-1	74.00	95.00	135.00	136.00	150.00
Lignin sulfonate	55.00	–	–	38.00	40.00
Calcium chloride	–	85.00	–	103.00	114.00
	–	–	–	220.00	230.00
	–	–	–	260.00	273.00
Magnesium chloride	–	–	65.00[a]		67.00
ESI-Duster[b]	8260.00	10 000.00	12 220.00	9800.00	–

Note: All costs are free-on-board (FOB) from the supplier, except for magnesium chloride, which is FOB Portland.
[a]Price for 182 gal/ton.
[b]This product comes in 50-lb bags.

Table 2. Energy contained in dust-abatement materials.

Product	Average Fuel[a] (%)	Average Residue (%)	Energy Below 680°F[b] (Btu/gal)	Total Energy[c] (Btu/gal)
DO-1	22	78	30 580	153 820
DO-2	26	74	36 140	153 060
DO-3	26	74	36 140	153 060
DO-4	10	90	13 900	156 100
DO-6	15	63	20 850	118 500
DO-6PA	20	58	27 800	119 440
DO-6KF	24	63	33 360	127 340
DO-8	10	47	13 900	88 160
CSS-1	2	62	2 780	100 740
Cutbacks (SC)	20	80		
Coherex[d]	1	11	1 390	18 770
Lignin sulfonate 50[e]		50		3 230

[a]Based on distillation tests to 680°F.
[b]Percentage fuel times 139 000 Btu/gal (assumes No. 2 diesel).
[c]Energy below 680°F plus (percentage residue times Btu/gal for asphalt). Use 158 000 Btu/gal for asphalt.
[d]After 4:1 dilution.
[e]Concentrate; 50 percent solid.

the various dust palliatives. Most of what is reported here is based on the work by Gregory at Oregon State University and the California Department of Health Services (3).

Many of the petroleum products listed contain heavy metals such as zinc (Zn), lead (Pb), etc. (3, and work by Gregory). The amount appears to depend on what company makes the product and the formulation used. Work performed by the California Department of Health Services also indicates the presence of polynuclear aromatic hydrocarbons (PAHs). They suggest maximum concentrations of 50 parts per million (ppm) Pb and 200 ppm Zn be used to limit environmental problems. No similar limits for PAHs were recommended.

The potential for environmental problems is increased when dust palliatives are used in watershed areas. It is recommended that the guidelines mentioned above be adopted. For nonwatershed areas, the values could probably be greater.

IMPORTANT PROPERTIES

This section briefly describes the mechanism of dust palliation, the types of dust-abatement systems used, important properties, and tests to evaluate these properties. (Complete test procedures are available from the Forest Service, Pacific Northwest Region, Portland, Oregon.)

Mechanism of Dust Palliation

The origin of dust is instability of surface soil. The objective of dust control is, thus, soil stabilization. Soil stabilization for dust control is confined to that part of the soil that can be disturbed by wind, water, and traffic. These are the mechanical forces that bear down on the soil surface and attack soil stability while the soil is at rest. Soil stabilization for dust control consequently involves only the upper few inches of the soil. Dust consists of dislodged soil particles suspended in the air. Water reportedly increases the susceptibility of soil to dustiness after drying out (4). In contrast, incorporation of nonfugitive cementing agents, such as liquid petroleum residue, into soil imparts cohesiveness to the soil and reduces the fines. Repeated applications of treating agents that contain such petroleum residue, etc., which accumulate in the soil, increase the abrasion resistance, particularly if the oils have low evaporation and good aging characteristics (i.e., remain tacky for an extended period of time).

Based on field observations, the important properties for dust palliatives are as follows (1):

1. To prevent particles from going airborne, the dust-sized particles must be made to cohere either to themselves or to larger particles due to the capillarity or cohesion imparted by the dust-palliative residue.
2. To resist wear by traffic, there must be an intimate mixture of soil and dust palliative to a depth of 0.5-1 in. This may be a result of product penetration or blade mixing. Penetration is a function of product viscosity, soil gradation, clay content, soil density, and amount of residue applied. Blade mixing must be used if the product will not penetrate.
3. For useful residue to remain on the road, the product must not evaporate completely. Once the water or cutter evaporates, a useful residue should remain. Further, the useful residue should not leach out due to rainfall.
4. To remain effective, a product should resist aging.

The above properties lend themselves not only to petroleum-based dust palliatives but also to lignins and salts.

Types of Dust-Abatement Systems

Two types of systems are normally used to abate dust: penetrating products or mixed-in-place products. The primary factor that differentiates the systems is the ability of the product to penetrate.

The following sections discuss the properties and test methods in more detail.

Penetration

To obtain an intimate mixture of soil and dust palliative without blade mixing, the dust palliative must be able to penetrate the road surface. To evaluate penetration, one should consider both rate and depth of penetration. Penetration rate is important to the users of the treated road because, if the fresh product remains on the surface of the road, it can be picked up by the tires of vehicles and distributed on the sides of the vehicles. Depth of penetration is important from a mechanical standpoint in that an intimate mixture of oil and aggregate will probably resist wear better than if a scab is formed on top of the road and then subjected to traffic.

If a product will not penetrate in the laboratory, then it will probably have to be road mixed, as in the case of CSS-1 and/or DO-8. When the asphalt emulsions are used as a spray-on dust palliative, the asphalt particles tend to be filtered out of the emulsion and left on the surface. The asphalt itself will not penetrate due to the size of the particles and their high viscosity.

Penetration may be evaluated by using the cone penetration test. Dust palliative is introduced into a conical depression in a molded soil briquet. The rate and depth of penetration are measured. A good gage of whether a product will penetrate is to require a 0.39-in minimum depth of penetration within 1000 s (Figure 2).

Evaporation and Distillation

Immediately after a dust palliative is applied, the process of evaporation begins. Water or cutter stock introduced into the dust palliative as a carrier will eventually evaporate, which leaves a residue that, it is hoped, provides some degree of dust abatement. The rate of evaporation depends on the type and amount of carrier (water and/or cutter stock). It is necessary to determine in the laboratory the following:

1. Amount of residue: This can be correlated to a residue determined after distillation to a specified temperature for a specified period of time, for example, 325°F for 3 h or distillation to 680°F.
2. Constituents of distillates: This should be oil and/or water. By collecting the distillate and condensing it, the amount of water present can be determined as well as the amount of low-boiling-range petroleum carrier. These are determined volumetrically by collecting the condensed vapors in a graduated cylinder. The oil and water will form two distinct phases. This allows a means to monitor the water content of the dust palliative and to determine the amount of low-boiling-range petroleum constituents for specification compliance.
3. Rate of evaporation: The rate of evaporation of the diluent or product will affect the depth of penetration and the useful life of the treatment. The rate of evaporation may be determined by placing a known amount of product in a petrie dish and placing the dish in a convection oven. By measuring the weight loss over time, the rate of evaporation may be determined (Figure 3).

Water Resistance (Leaching)

If a dust-abated roadway is subjected to intermittent rainfall, it is important that the residue that remains on the road resists leaching. This is important from two standpoints. The first is mechanical; that is, if the residue is leached out of the road surface, it cannot provide dust abatement. The second is environmental. Because dust palliatives may contain environmentally unacceptable constituents (e.g., heavy metals), there are potentially harmful conditions that could arise if these compounds leach into the ecosystem. The impacts of these toxic constituents have been recently studied by the California Department of Health Services (3).

To test if leaching is an obvious problem, a residue-sand mixture is placed in a test tube of distilled water and agitated. By noting any change of coloration or conductivity, the possibility of leaching may be determined.

Cohesion or Abrasion Resistance

Basically, there are two ways to prevent dust-sized particles from going or staying airborne:

1. Agglomerate dust-sized particles into larger particles that will not remain suspended in air [i.e., into particles with a diameter of more than 0.003 in (retained on a No. 200 sieve)], or
2. Bind dust-sized particles to a mat to prevent them from going airborne at all.

A successful dust palliative provides the necessary cohesion to achieve either of the above. This may be accomplished by either apparent cohesion caused by capillarity or by actual cohesion provided by the residue gluing the particles together. It is also important for the residue that remains on the road to have the ability to reglue particles that have been broken apart by the action of traffic. It is not sufficient that the residue bind particles together once and not have the ability to rebind. To do this, the residue must be able to remain soft, that is, not become brittle. This would suggest the need for a residue of medium viscosity to be able to adapt to newly formed fines.

The abrasion resistance of a dust-palliative residue may be determined by the modified-pellet-abrasion (MPA) test. By abrading a sand-residue pellet in a jar mill, the resistance to abrasion is determined. By varying the residue content, the change in abrasion resistance is determined. The abrasion resistance is very sensitive to the residue content within a very narrow range of residue contents (Figure 4).

Aging Resistance

For a dust-palliative residue to have a lasting effect, it must resist aging due to environmental conditions (oxygen, heat, etc.). Aging causes petroleum-based products to become hard and brittle, thus reducing their useful life span. As dust oils disperse into the aggregate with time and traffic, more surface area of the dust oil is exposed to the environment, which accelerates the aging process. Dust oils should be able to resist aging. Aging resistance may be evaluated with the aged-pellet-abrasion test.

SELECTION AND EVALUATION SYSTEM

This section presents procedures to select the type and amount of dust-abatement material for a given situation and to perform cost and energy analyses for evaluating the various dust products. Figure 5 outlines the approach to be followed.

Select Type of Palliative

Several factors need to be considered in the selection of the type of dust palliative. The most important factors include

1. Soil gradation: density or in-situ permeability,
2. Climate: dry or wet, and
3. Traffic: light versus heavy.

Soil type and density (more than the other factors) affect the rate and amount of penetration for a given palliative. In all instances, it is desirable to attain a 0.5- to 1-in penetration. Most products (with the exception of CSS-1) will penetrate and coat most soils if they have been loosened by scarification. For surfaces that have not been scarified, only those products with low viscosities (e.g., DO-1 through DO-4, DO-6, Coherex, and lignin) will penetrate. As a general rule of thumb, the

Figure 2. Cone penetration test.

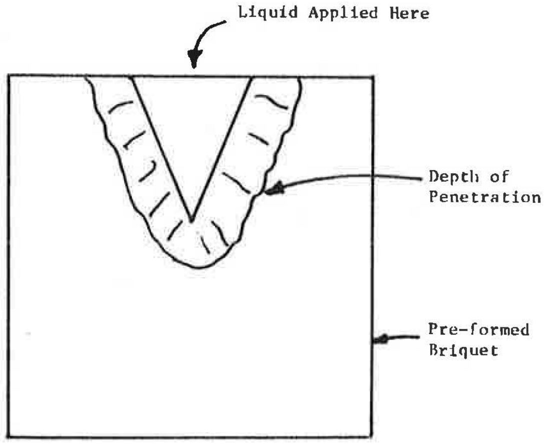


Figure 3. Rate of evaporation of dust palliatives at 140°F.

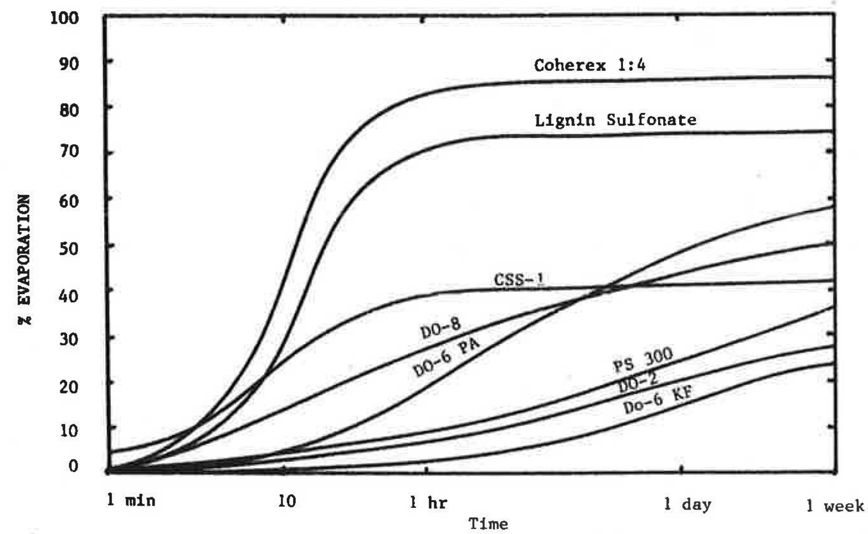


Figure 4. Pellet residue content versus pellet abrasion loss.

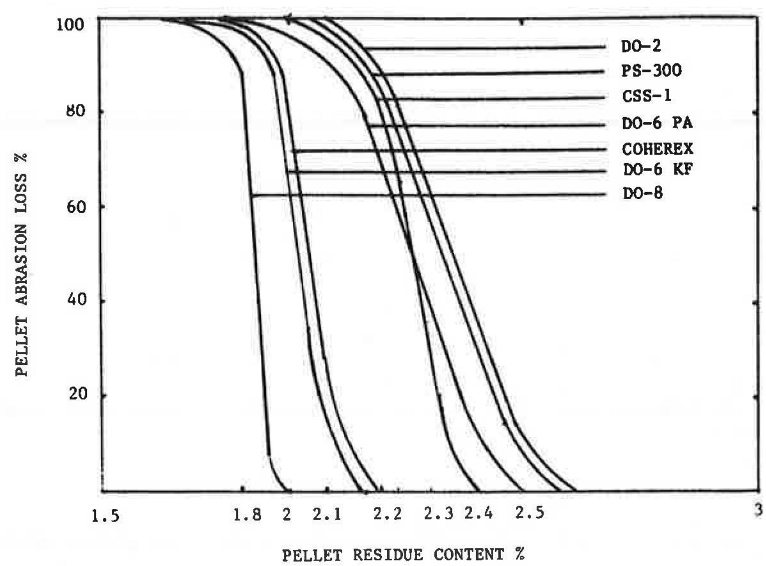
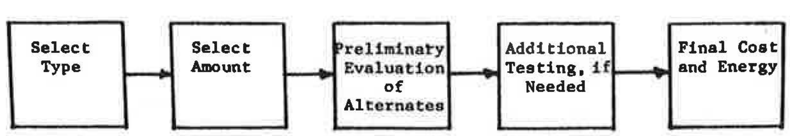


Figure 5. Approach to select type and amount of dust-abatement material.



following appear applicable for penetration treatment:

Aggregate Surface	Recommended Type of Palliative
Clean, open-graded rock (<2% minus No. 200)	CSS-1, DO-6, DO-8
Intermediate-graded rock (2-6% minus No. 200)	DO-6PA, DO-8
Dense-graded rock (>6% minus No. 200 without scarification)	Water, DO-1, DO-2, DO-4, DO-6KF, salts, Coherex, lignin sulfonates
Dense-graded rock with scarification	DO-1, DO-2, DO-4, DO-6's, DO-8, salts, Coherex, lignin sulfonates
Volcanic cinders or pumice (with scarification)	DO-2, DO-6's, Coherex, lignin sulfonates
Mt. St. Helen's volcanic ash	DO-4, Coherex, lignin sulfonates

Typically CSS-1, DO-8, and salts (in solid form) are recommended for mixed-in-place treatments. Products should be mixed in place when satisfactory penetration cannot be achieved.

Selection of Application Rates

Application rates can be determined based on past experience or from laboratory tests. Based on past experience, the application rates should generally be in the following ranges:

Product	Recommended Application Rate (gal/yd²)
Arcadias (DO-1, 2, 3)	0.2-0.5
DO-4	0.2-0.5
DO-6PA	0.2-0.5
DO-8	0.2-0.5
Coherex	1-1.5
CSS-1	0.2-0.5
Lignin sulfonate	0.2-0.5
ESI-Duster	0.2
Water	0.5

[Note that Coherex is applied at 4 parts H_2O and 1 part concentrate, lignin sulfonate is applied as a concentrate with 50 percent solids, and ESI-Duster is applied at 50-lb/1000-gal H_2O. The recommended application rate for salts is 0.5-2.5 lb/yd² (dry).]

Langdon (1) has developed a laboratory approach for calculating the quantity of dust-abatement material. This approach is currently limited to petroleum products. The method relies on the MPA test to estimate the residue needed to provide adequate cohesion. Laboratory tests indicate that the residue content at 20 percent weight loss correlated with residue contents measured from field test selections that performed well. Approximate design values for residue content are as follows:

Product	MPA (% residual asphalt)	Application Rate (gal/yd² for 0.75-in depth)
DO-1, 2, 3	2.5	0.25
DO-4	2.5	0.20
DO-6PA	2.4	0.25
DO-6KF	2.1	0.2
DO-8	1.9	0.35
CSS-1	2.3	0.3
Coherex	2.1	1.4

As indicated, these values fall within the recommended ranges based on past experience. It should also be noted that these values were developed by using a standard soil (5 percent dixie clay and 95 percent Ottawa sand). It is recommended that these values be used as a first estimate. Further testing can be performed with the soil to be treated. For the determined MPA, Figure 6 can be used to estimate the residual asphalt application rate to ensure good cohesion (note, this chart is not applicable to cinders). Figure 7 can be used to determine the product application rate. For the products available, the percentage of residue can be assumed as follows:

Product	Residue (%)
DO-1, 2, 3	75
DO-4	90
DO-6's	60
DO-8	50
CSS-1	60
Coherex	12

Preliminary Selection Evaluation of Alternatives

Once the types and amount of each palliative have been determined, a preliminary cost and energy analysis is conducted. Traffic and climate both can affect the rate at which palliatives wear out. Langdon (1) determined from test roads east and west of the Cascade mountain range that the effective life of a dust palliative may be determined as follows:

$$\text{Life (vehicles)} = 1040 + 1957\ \text{residue} - \log\ \text{viscosity} \qquad (1)$$

where

Life = effective life to cause an environmental nuisance [photo comparison method (PCM) rating (1)],
Residue = residue applied (gal/yd²), and
Log viscosity = base 10 logarithm of the kinematic viscosity of the residue measured at 85°F.

The coefficient of determination for this relation is equal to 0.917. Figure 8 is a graphic display of the above equation. For viscosity, if data are not available, assume the following:

Product	Kinematic Viscosity of Residue at 85°F (cSt)
DO-1	<1 000
DO-2	5 000
DO-4	<1 000
DO-6PA	2 000
DO-6KF	2 000
DO-8	4 500
CSS-1	100 000
Coherex	4 000

It should be emphasized that this relation is based on the best data available. The relation estimates life in vehicles where the traffic for the tests was estimated to be 50 percent administrative and recreational and 50 percent logging (heavy trucks).

To estimate the cost of and energy in dust-abatement materials, one then needs to know the application rate of the product, the effective life of the product, the type and extent of road preparation, and user traffic.

In all energy/cost analyses, one should evaluate the following alternatives: traffic control (reduced speed, etc.), watering, and dust-abatement products.

Figure 6. MPA versus residue application rate.

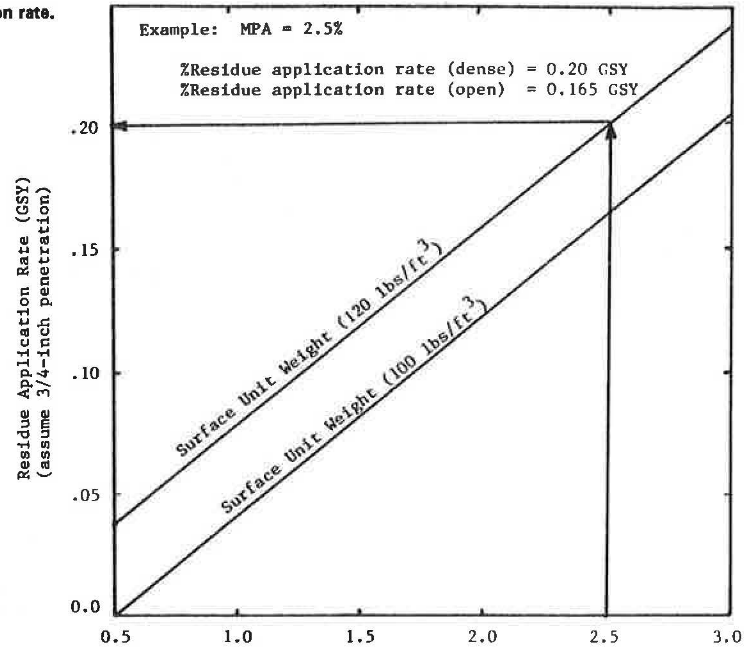
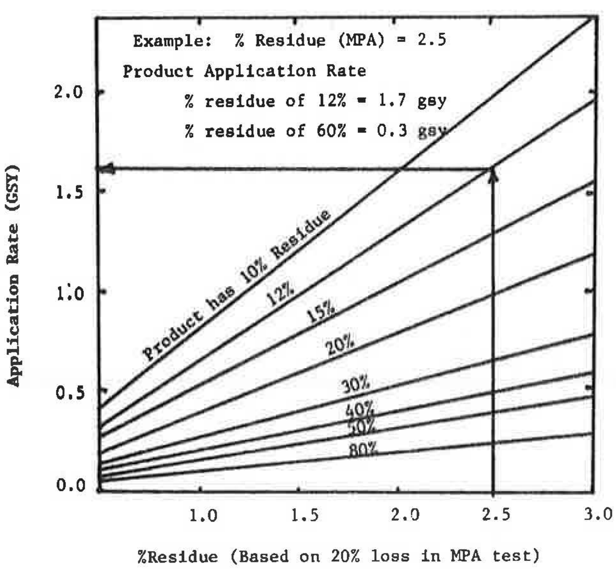


Figure 7. Percent residue (MPA) versus product application rate.



CONSTRUCTION GUIDES

Construction procedures vary depending on whether the abatement material is of a penetrating type or not. Much of what is reported below comes from the Forest Service Standard Specifications for Construction of Roads and Bridges (5).

Penetrating Abatement Materials

Dust palliatives should be applied only when the surface to be treated contains sufficient moisture for penetration and uniform distribution. For petroleum products, the temperature should normally be more than 50°F.

Equipment should consist of a motor patrol for scarifying, a water truck, and a distributor truck. The road surface should be watered and shaped before application of the dust-palliative treatment. The upper 0.5-1 in should be loose to allow for penetration.

Application rates should be determined as previously discussed. Uniform distribution should be obtained over the entire surface. Overlapping or skips between spread section should be corrected. Excess application or spillage should be covered with a blotter material.

Traffic should not be permitted on the dust-abated areas until the treatment has penetrated and cured enough to prevent excessive pickup under traffic. Satisfactory compaction can normally be achieved by user traffic.

Mix in Place

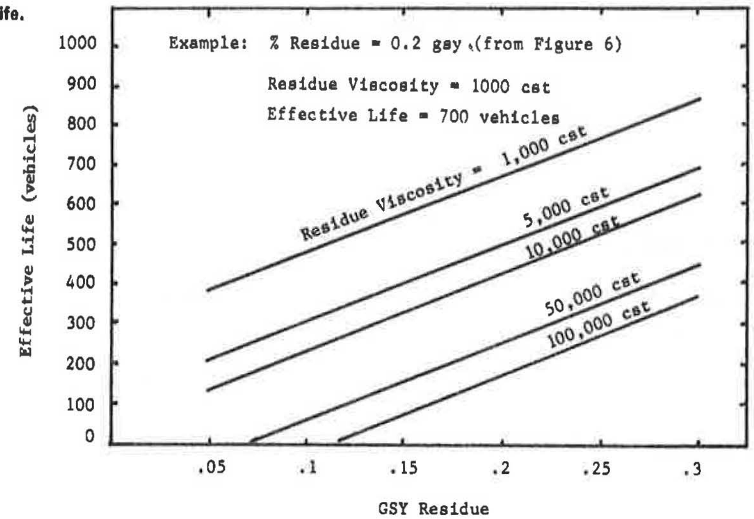
Dust palliatives should be applied only when the surface to be treated contains sufficient moisture for penetration and uniform distribution. CSS-1 normally requires mixing and DO-8 may require mixing. The use of these products should be restricted to temperatures greater than 50°F.

Equipment should consist of a motor patrol for scarifying and mixing, a water truck, and a distributor truck. The road surface should be watered and shaped before application of the dust oil. The upper 1-2 in should be loosened to allow for blade mixing. The minimum depth of road mixing is twice the maximum aggregate size.

Uniform distribution should be obtained over the entire surface. At least two passes with the motor patrol should be employed to obtain mixing. The goal is to obtain a uniform mixture in the top 1-2 in.

Traffic should not be permitted on the dust-abated areas until the mix has cured enough to prevent excessive pickup under traffic. Satisfactory compaction can normally be achieved by user traffic.

Figure 8. Residue application rate versus effective life.



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Recycling Bituminous Concrete Through Use in Cement-Treated Base: Case Study, Fredonia Streets

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The reconstruction of a low-volume road through Fredonia, Arizona, was the first pavement structure constructed under contract to the Arizona Department of Transportation (ADOT) that incorporated an old road base, including ground bituminous concrete, into a cement-treated-base (CTB) design. The shortage of nearby suitable road-base material resulted in the consideration of stabilization of the existing pavement structure. If cement stabilization was to be used, ADOT experience indicated that an asphalt-rubber stress-absorbing membrane interlayer would be required to inhibit reflective cracking through the asphalt surface. Three different structural sections were constructed based on varying soil types and availability of recyclable road base. On this particular project, the use of a CTB that incorporated reprocessed bituminous concrete and aggregate base from the previous pavement structure saved ADOT approximately $120 000. This savings is based on a structurally equivalent pavement that consisted of full-depth asphaltic concrete and costs based on the contractors' bid prices for this item on this job. An additional consideration that made this alternative attractive was the simplicity of construction techniques. It is believed that cement stabilization of old, recyclable pavements will prove to be a low-cost, high-strength alternative to thick asphalt concrete sections when aggregate availability is a problem.

In many rural areas of Arizona, the cost of roadway development is often escalated by the lack of accessible quality material. Fredonia is one such area. For economic reasons, a design was developed that recycled bituminous concrete through use in a cement-treated-base (CTB) mixture. The pavement structures consisted of either 6 or 8 in of CTB covered by 2 or 6 in of asphalt concrete (AC), respectively, both topped by 0.5 in of asphalt concrete friction course (ACFC). Based on historical evaluations, an asphalt-rubber stress-absorbing membrane interlayer (SAMI) was incorporated into this system between the top of the CTB and the bottom of the AC.

BACKGROUND

The decision to use CTB on Fredonia streets was influenced by the performance and evaluation of existing roadways constructed with soil-cement. During the summer of 1977, a section of AZ-169 was constructed by using soil-cement. Construction was efficient and economical, and an evaluation after five years of service has shown it to be struc-