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Effects of Asphalt on Some Phases of Soil Structure and Erodibility by Wind[1]

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ABSTRACT

A cut-back asphalt and an asphalt-in-water emulsion were tested for improving soil structure and controlling erosion of soil by wind. The materials applied as fine spray at rates up to 400 gallons per acre, on the basis of undiluted material, produced a film which initially was completely effective in holding various soils against wind. The finer the spray and the more dilute the solution or suspension, the more uniform and stable was the film. The film was effective only for about 2 weeks on clay soil and for at least 2 months on sand and loamy sand.

The film was generally porous and took in rainwater readily. Germination and emergence of wheat, grass, and legume seeds were unaffected by the asphalt film.

Asphalt mixed with soil produced a high degree of soil aggregation in both wet and dry state and decreased erodibility by wind, but only for about 2 years. After this period, the treated soil became progressively more granulated and more erodible by wind but continued to have a substantially greater proportion of water-stable aggregates and to be much more permeable by water. Changes in physical properties of asphaltic cement in soil and its relationship to soil structure and erodibility were recorded and explained. Cement added to soil, it was concluded, will be effective against wind erosion only so long as its sticky property is maintained.

A CUT-BACK asphalt and asphalt-in-water emulsion were sprayed at various rates on the surface of the ground or mixed into the soil. The cut-back asphalt is a commercial liquid asphalt thinned by the addition of lighter oils. The asphalt-in-water emulsion is a petroleum product commercially available also. Three types of tests were conducted to determine (a) the effectiveness and stability of asphalt films against erosion by wind when the asphalt was sprayed on the surface of the ground, (b) the effect of the films on seed germination, and (c) the effects of asphalt on structural characteristics, erodibility, and growth of crops when the asphalt was mixed into the soil.

Asphalt has been used to a limited extent in erosion control. Myers and Throckmorton (5) reported that seedlings of grasses and legumes had little difficulty emerging through a surface coating of asphalt applied at rates of 1/2 and 1 gallon per square yard. The coating was permeable and gave reasonable protection against erosion by water. They stated that road oil was used by the Soil Conservation Service in the 1930's to control sand dunes in the vicinity of Caddoa Dam in Colorado.

Procedure

ASPHALT SPRAYED ON TOP OF THE GROUND

In initial experiments of 1949, asphalt-in-water emulsion was sprayed with a knapsack and a paint sprayer at various rates. The sprayed soil was kept in trays 5 feet long, 8 inches wide, and 2 inches deep with bottoms composed of a fine brass screen to allow for percolation of rainwater. The trays of soil were kept in the field and covered with a 1/4-inch screen to prevent any erosion that might otherwise occur. Periodically the trays of soil were brought into the laboratory and exposed to erosive winds in a laboratory wind tunnel (7).

A greenhouse experiment was conducted to determine what effects, if any, asphalt films might have on seed germination, emergence, and growth of plants. The crops tested were sweetclover, alfalfa, winter wheat, and bromegrass. Two rows of 100 seeds each were planted in 18- by 20-inch rust-proof metal trays, 2 1/2 inches deep. Wheat seeds were planted about 1/2 inch deep and all the others about 1/8 inch deep. The soil surface was then sprayed with asphalt-in-water emulsion at a rate of 100 and 200 gallons per acre diluted with an equal amount of water. The numbers of seedlings in the treated and untreated trays were recorded at periodic intervals until wheat was about 5 inches high, brome was 2 1/2 inches, and alfalfa and sweetclover 1 1/2 inches high. Tests were discontinued 15 days after planting.

In 1950, tests were carried out on substantial areas in the field. The first problem was to assemble suitable power sprayers for field use. It soon became evident that the type of sprayer to be used depended on the type of asphalt material on hand. Since the object was to test the value of two types of asphalt material, two different types of sprayers were assembled.

The cut-back liquid asphalt was sprayed using a gear pressure pump and spray nozzles mounted on a horizontal boom. The nozzles had openings 2 mm. in diameter. The unheated cut-back asphalt had to be diluted with 1 part diesel fuel or solvent to 3 parts of liquid asphalt for proper spraying under a pressure of 35 pounds. Dilution would have been unnecessary if the asphalt material had been heated.

The unheated asphalt-in-water emulsion could not be used in a gear pump. The water was squeezed out, leaving a heavy gum which hung in the gears and clogged the working parts. The rubber-paddle pump gave similar trouble. It was necessary, therefore, to spray the asphalt emulsion using an air pump and a pressure tank. During the operation, the air pressure of 35 pounds was applied to the body of the emulsion in the tank. The nozzles were same as in the first outfit.

A sediment bulb and a metal screen with 0.42 mm. openings placed ahead of the nozzles were indispensable in spraying asphalt-in-water emulsion. As obtained commercially, the emulsion contains bits of solid matter which soon clog the nozzles unless a filter such as this is used.

The asphalt-in-water emulsion, as obtained commercially, contains about 50% asphalt and 50% water by weight. When sprayed unheated, this material had to be diluted with at least an equal volume of water.

ASPHALT-IN-WATER EMULSION MIXED INTO THE SOIL

The emulsion in amounts containing up to 12% of asphalt was mixed with 10-pound duplicated samples of Keith silt loam. The samples were placed in 10-inch square, porous-bottomed trays in the field and covered with 1/4-inch screen to protect the soil from erosion by wind. Analyses of some structural characteristics and erodibility of soil by wind were made periodically during a 5-year period after treatment. These analyses included duplicated determinations of the size-distribution of water-stable aggregates by the method of Yoder (6), the size-distribution of dry aggregates by the method of Chepil and Bisal (2), and permeability of screened portions of the samples by the method of Fireman (4). Soil erodibility by wind was computed from the proportion of erodible fraction contained in the soil (3).

On two occasions during the 5-year period the samples were transferred into earthenware pots in the greenhouse and planted uniformly to corn, oats, and sorghum. Yields of oven-dry forage were determined 2 months after seeding. The soil was returned to the trays in the field after a crop was removed.

Effects of Asphalt Sprayed on Top of the Ground

Cut-back liquid asphalt applied as fine spray at rates up to 200 gallons per acre on the basis of undiluted

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material produced a film which, immediately after spraying, was completely effective in holding different soils against wind. In some cases as little as 100 gallons per acre of cut-back asphalt was sufficient to protect the soil against wind. Asphalt-in-water emulsion, on the other hand, required about twice those amounts for equal effectiveness, principally because the unheated emulsion could not be applied in as fine a spray as the unheated cut-back asphalt. A coarse spray nozzle at least 1 mm. in diameter had to be used for the asphalt emulsion to prevent clogging. Even then it was necessary to pass the diluted emulsion through a 0.25 mm. or a 0.42 mm. sieve. This was necessary to remove bits of asphalt present in the emulsion. Screening after dilution was possible in ratios down to 1 part of emulsion to 4 parts of water without any detrimental effects to the stability of the emulsion. Dilution was necessary to produce a uniform and more stable film. For equal amounts of emulsion, porosity of the film decreased with increased dilution. The depth of penetration and stability of the film, on the other hand, increased with increased dilution.

The stability of the film varied also with the nature of the soil. The film on clay soil began to show definite signs of disintegration and loss of resistance to wind 2 weeks after the application. On dune sand and loamy sand the film was virtually intact 2 months after the application, but had disintegrated completely on clay soil. The disintegration apparently was due to the relatively high degree of expansion and contraction of clay under wetting and drying conditions in the field.

The asphalt-in-water emulsion sprayed at 100 and 200 gallons per acre did not have an appreciable effect on the emergence of seedlings, or on the growth of seedlings after emergence. Germination was not affected by the asphalt films. A slight yellowing of wheat was noticed 5 days after planting, but the discoloration disappeared shortly afterwards. Fifteen days after planting, the crops in the treated plots appeared actually greener and more vigorous than in the non-treated plots. The treated soils did not dry up so readily, evidently on account of the decreased porosity of the surface.

The emulsion sprayed at the rate of 100 gallons per acre of 50:50 dilution, produced films that were quite porous. Water ran into the soil through the film quite freely. The film was thin and parts of it—perhaps 5% of the total area—floated up and off with the water when water was poured on the surface. The same rate of emulsion diluted with 4 parts of water to 1 of asphalt emulsion produced a film that was much less porous. Several days after the application, the film cracked and facilitated the percolation of water into the soil.

The film produced by 400 gallons per acre of a mixture of equal parts of emulsion and water (100 gallons of asphalt in 300 gallons of water) was about half as porous as that formed by the same mixture sprayed at the rate of 200 gallons per acre. The mixture diluted further to 100 gallons of asphalt in 500 gallons of water per acre produced a film virtually impervious to water. However, in a day or two, some cracks in the film occurred and these facilitated the intake of water. In no case did water stand on the surface for more than 5 minutes after application of amounts necessary to keep the soil in a moistened condition.

In one field trial, the cut-back asphalt was sprayed over a newly-worked outlet ditch at the rate of 200 gallons per acre on basis of undiluted material. This rate of application did not prevent the soil from washing down the banks when a heavy rain fell about a week later. It was estimated that at least 750 gallons per acre of this material would be required for a satisfactory protective cover. This rate is much higher than the effective rate required to control erosion of different soils by wind.

In another series of experiments, the asphalt-in-water emulsion was sprayed at different rates on level ground. When the 2-mm. nozzle openings and the unheated material were used, it was estimated that about 400 gallons per acre over highly erodible sandy loam were necessary for complete protection against wind. The amount of emulsion required in these cases was about twice as great as the amount required for the same kind of soil material where the emulsion was strained and the 1-mm. openings and a higher pressure were used. It was evident that the coarser the spray, the greater is the amount of emulsion required for equal effectiveness of the film against wind. Germination and growth of oats sown just before treatment were unaffected by the asphalt film.

Effects of Asphalt-in-Water Emulsion Mixed into the Soil

The asphalt caused a high degree of soil aggregation in the dry state and decreased erodibility by wind for at least 18 months after treatment (table 1). Then the trends reversed. The reversal was even more pronounced 5 years than 3 years after treatment. Thus, 3 years after treatment, 6% of asphalt increased the proportion of dry erodible fraction less than 0.84 mm. in diameter from 31 to 47%, but 5 years after treatment it increased the erodible fraction from 33 to 69%. Furthermore, 3 years after treatment the 6% rate of application increased the erodibility by wind from 0.4 to 1.5 tons per acre, but 5 years after treatment the same rate of application increased the erodibility from 0.5 to 9.0 tons per acre, as measured by the differences from the untreated soil. From the data available it is impossible to forecast in what direction the trends will continue.

The effects of asphalt on the status of water-stable aggregates followed an altogether different pattern. The proportion of water-stable aggregates increased proportionally with the amount of asphalt added. This general effect has prevailed to the present time, i.e., 5 years after treatment. The proportion of coarse water-stable aggregates formed by asphalt in any given treatment diminished slightly during the 5-year period, but the reduction was not significant. The degree of aggregation in a wet state has not changed hand in hand with the degree of aggregation in a dry state or with the erodibility of soil by wind. The water-stable aggregates too coarse to be blown by wind (greater than 0.84 mm.) no doubt tended to reduce erodibility, but these coarse aggregates had only a minor influence on the state of dry soil structure and erodibility by wind.

Yields of corn and oats sown 6 months after treatment decreased directly with the amount of asphalt

Table 1.—Average effects of asphalt-in-water emulsion on soil structural characteristics and erodibility by wind. (Asphalt was mixed thoroughly with Keith silt loam.)

Amount of asphalt added (by weight)	Water-stable aggregates			Dry aggregates			Erodibility by wind
	>0.84 mm.	0.84–0.02 mm.	<0.02 mm.	>6.4 mm.	6.4–0.84 mm.	<0.84 mm.	
%	%	%	%	%	%	%	tons/acre
				4 months after treatment			
0 (check)	2	75	23	40	24	36	0.6
3	22	62	16	47	26	27	0.2
6	32*	56	12	37	36	27	0.2
12	52**	40	8	43	42	15**	0.05*
				18 months after treatment			
0 (check)	4	73	23	44	22	34	0.5
3	26	62	12	48	27	25	0.2
6	46**	41	13	37	37	26	0.2
12	66**	30	4	35	46	19*	0.1
				3 years after treatment			
0 (check)	1	72	27	53	15	32	0.4
3	16	64	20	31	29	40	0.9
6	26*	60	14	16	37	47*	1.5**
12	46**	42	12	21	46	33	0.4
				5 years after treatment			
0 (check)	1	83	16	52	14	34	0.5
3	14	75	11	35	14	51*	1.9**
6	23	69	8	7	24	69**	9.0**
12	41**	53	6	10	39	51**	2.1**

*Significant difference at 5% level, compared with check.
**Significant difference at 1% level, compared with check.
Analysis of variance of individual data was determined only for water-stable aggregates >0.84 mm., dry aggregates <0.84 mm. and erodibility.

applied (table 2). Commercial fertilizers containing N, P, and K were added, but these failed to bring the yields of the treated soil up to those of the untreated. Suppression of growth on the treated soil was probably due to the presence of some toxic element in the asphalt rather than to the lack of plant nutrients. However, these effects were only temporary. Five years later, sorghum grew as well on the treated as on the untreated soil (table 2).

Soil treated with asphalt 5 years previously was considerably more permeable than the untreated soil. Permeability increased directly with the amount of asphalt applied (table 3). Thus, a 3-, 6-, and 12% rate of application increased soil permeability by about 25, 75, and 250%, respectively.

Table 2.—Effects of asphalt-in-water emulsion on yield of crops in the greenhouse.

Amount of asphalt added (by weight)	Yields of dry forage*		
	6 months after treatment		5 years after treatment
	Corn	Oats	Sorghum
%	tons/acre	tons/acre	tons/acre
0 (check)	7.70	3.67	1.02
3	5.52	3.22	0.81
6	4.82	2.95	0.98
12	3.56	0.83	1.05

*N, P, K at 100, 200, and 100 pounds per acre, respectively, were added to corn and oat crops, but no fertilizer was applied to sorghum. Amount of soil available for growth of corn and oats was 8 pounds and for sorghum 3.3 pounds in each duplicated sample.

Table 3.—Effects of asphalt-in-water emulsion on soil permeability 5 years after treatment.

Amount of asphalt added (by weight)	Permeability	
	Water/hour 1st hour	Water/hour 7th hour
%	inches	inches
0 (check)	1.35	1.09
3	1.81	1.27
6	2.41	1.91
12	4.38	4.05

Discussion and Conclusions

Under the conditions of these experiments, from 100 to 200 gallons of asphalt per acre resulted in the protection of highly erodible soil material against wind. The finer the spray the better was the surface coverage, and a smaller amount of asphalt was required. Both the cut-back and the emulsion were applied effectively. Dilution of either of these materials decreased the porosity but increased the depth of penetration and stability of the film. The actual amount of dilution required, if any, would depend on soil and climatic conditions. In areas of high rainfall, a thin, porous film which allows the rainwater to percolate readily would be better than a dense film. The increased percolation, however, should not be exchanged for a decrease of stability of the film if the primary object is to protect the soil against wind.

A thin asphalt film disintegrated most rapidly on clay soil, less readily on silt loam, and much less readily on loamy sand. The data indicate that on clay soil, the film usually loses its effectiveness against wind in about 2 weeks, but is effective much longer on coarser textured soils. Under favorable conditions for germination 2 weeks might be sufficient for the surface to become covered with enough vegetative growth to prevent erosion by wind. Under prolonged unfavorable conditions for germinations, however, application of asphalt films on clay soil might not be fully effective. On highly erodible sandy soil and on extremely erodible dune sand, a 200-gallon-per-acre rate of cut-back asphalt or 400-gallon-per-acre of emulsion was entirely effective for at least 2 months after the application. Rates higher than these appear to be unnecessary on smooth, level ground if the material is applied in very fine spray. The rate might have to be increased for crests of dunes where wind velocity is higher than over level ground. Irrespective of the rate of application, vigilance must be exercised until such time as the ground is covered with vegetation. Insects and animals, such as rodents and rabbits, cause injury to the film. If considerable injury occurs before vegetation is established, the land might have to be resprayed, at least in areas where such injuries will cause erosion of soil by wind.

The influence of asphalt on soil structure and erodibility with time after treatment seems to follow the same general pattern as that produced by the addition of vegetative matter (1). Initially, both asphalt and decomposing organic matter contain sticky substances which produce a soil structure resistant to erosion by wind and water. Gradually, both asphalt and products of decomposition of organic matter lose their sticky property and become hard and brittle. Mechanical forces of tillage and differential expansion and contraction of the soil by wetting and drying and freezing and thawing, cause the hardened cements to break up and the soil body to disintegrate again to discrete particles and aggregates. Many of the resultant aggregates differ from the original in that they are held together by a hardened, water-insoluble cement. These aggregates are essentially water-stable. They form a soil that is highly permeable to water and, consequently, comparatively resistant to water erosion. Unfortunately, the aggregates are too small to resist erosion by wind.

To resist wind erosion permanently, therefore, the cement added to soil must be able to maintain its sticky property indefinitely.

Literature Cited

1. Canada Department of Agriculture. Soil moisture, wind erosion, and fertility of some Canadian Prairie soils. Soil Research Laboratory, Swift Current, Sask., Can. Tech. Bull. 71 (1949).
2. Chepil, W. S., and Bisal, F. A rotary sieve method of determining the size-distribution of soil clods. Soil Sci. 56: 95–100 (1943).
3. ———, *et al.* Field study of wind erosion in Western Texas. (To be published by U.S.D.A., Soil Conserv. Serv. in TP series.)
4. Fireman, Milton. Permeability measurements on disturbed soil samples. Soil Sci. 58:337–353 (1944).
5. Myers, H. E., and Throckmorton, R. I. Some experiences with asphalt in the establishment of grasses and legumes for erosion control. Soil Sci. Soc. Amer. Proc. (1941) 6:459–461 (1942).
6. Yoder, R. E. A direct method of aggregate analysis and a study of the physical nature of erosion losses. Jour. Amer. Soc. Agron. 28:337–351 (1936).
7. Zingg, A. W., and Chepil, W. S. Aerodynamics of wind erosion. Agr. Engin. 31:279–282, 284 (1950).