USE OF TAR IN BASE STABILIZATION

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SYNOPSIS

The activities of the Indiana maintenance forces in constructing bases with a 55-80 viscosity tar are described by Mr. Schafer. Costs of this work varied from $0.21 to $0.37 per sq. yd. The compacted bases were 4½ to 5 in. deep and 18 ft. wide. It is estimated that under ideal conditions, 75 to 80 per cent of the cost will be for materials, that is, tar and chips; 5 to 10 per cent labor; and 16 to 20 per cent for equipment. Tack coat should be provided immediately after compacting to provide a temporary wearing course. This should be followed in about 10 days with a seal coat for the wearing surface.

Mr. Tilley describes Nebraska methods for stabilization with tar. A mix of 40 per cent selected soil, 60 per cent of coarse sand combined with 4 per cent of tar (RT3) was found to be an economical and stable mixture. Traveling pugmills were used and compaction secured with numerous pieces of equipment. It was found that after the moisture content of the mix has been reduced to about 6 per cent, the base was impermeable. A surface treatment of one-third of a gallon of RT 10 tar and 35 lb. of sand gravel per sq. yd. was applied after about a week.

Mr. Loughborough emphasized the careful consideration that must be given to the type of soil to be stabilized. He described two recently completed Virginia projects on which both tar and asphalt were used to stabilize a sand clay soil with a PI of 4.5. Wearing courses were also applied. Total cost of the construction was about $5300 per mile. Cost of the base stabilization was about $2900 per mile for the tar and $3250 for the asphalt.

West Virginia practice on 32 miles of gravel-soil-bitumen stabilization was described by Mr. Miller. Material from berms and ditches was added to material already on a 15-year old gravel road and mixed in a traveling pugmill with a cutback asphalt, asphalt emulsion, and tar as the binding or waterproofing agent. The cost of the stabilization with tar, done by contract, was about $3900 per mile or $0.37 per sq. yd.

INTRODUCTION

Loughborough: Not always, but usually, soils used for surfacing are found in low-lying or rolling sections of the country where grading is not heavy and quite often drainage is poor. Under such conditions a wide roadbed section should be constructed, with preferably a minimum width of 50 ft., sloping gradually from the ditch line to the crown of the road, with the slope of the shoulder flat enough to allow a car to go off on it in safety, and with the ditch line well below the bottom of the subgrade. Bringing the material in from the sides puts the roadbed higher than the surrounding ground, provides proper drainage and eliminates borrow, and although some failures can be expected on low cost surfaces these can be lessened to quite an extent if the foundation on which they are placed is properly drained and compacted. The ideal method although difficult to arrange because of the public demand for immediate hard surfacing, is to construct the roadbed and let it be subjected to traffic for a year or more before placing the surfacing.

Even a roadbed constructed by methods less exacting than those now required generally and put in use for a year or more before surfacing is ofttimes in better condition than one which has been constructed by the most careful methods and the surfacing material immediately applied. Many benefits accrue, not only from compaction by time and weather, but by enabling the engineer to find and correct the weak places before the final surface is placed.

Schafer: Because of limited maintenance funds, a low cost all weather road would be a solution of the problem. If it is possible to use all the materials available on the surface and add only an admixture, the result should be reasonable in cost.

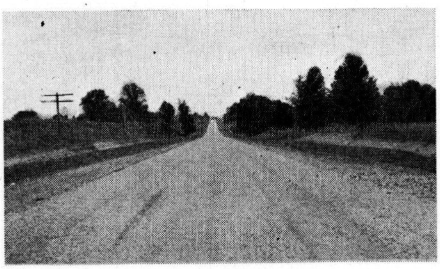

Figure 1. Loose Aggregate Surface Before Stabilization

Indiana has built stabilized bases for several years by using admixtures and new materials. This is satisfactory for new construction but is impractical and too expensive as a maintenance operation.

Tilley: Due to extensive mileage of low-revenue roads and the wide variance in the type of natural road-building soils, it has been necessary for the State of Nebraska to develop several types of low cost base courses and surfaces. The design and construction of the clay-gravel type of stabilized soil base courses and stabilized bituminous sand have been reported elsewhere.[1] The first stabilized soil base course in Nebraska using tar as the stabilizing agent was constructed in 1939 as an experimental project.

[1] "Stabilized Soil Base," Third Annual Montana Bituminous Conference, and "Stabilized Bituminous Sand," Eleventh National Asphalt Paving Conference.

LOCATION AND DESCRIPTION OF PROJECTS

Miller: During the 1939 construction season the West Virginia State Road Commission contracted 32 miles of gravel-soil-bitumen stabilized base course. Asphalt cutback, asphalt emulsion and tar cutback were used as the binding or waterproofing medium. The plan section provided for 5 in. compacted uniform thickness—18 ft. width.

The roadway to be stabilized was a traffic bound gravel surface constructed approximately 15 years ago. The average depth of gravel was $3\frac{1}{2}$ in. varying from 2 to $5\frac{1}{2}$ in. The original depth was 6 in. Suitable material secured from the berms and ditches was incorporated with the existing gravel surface to obtain the required depth.

The gravel-soil mixture during construction showed the following analysis:

Passing $1\frac{1}{2}$ in. sieve, %	99–100
Passing No. 4 sieve, %	30– 70
Passing No. 200 sieve, %	10– 35
Silt, %	6– 24
Clay, %	7– 17
Colloids, %	2– 9
Liquid Limit	19– 33
Plastic Index	0– 15

The subgrade varied from a clay loam to clay—B.P.R. Classification A-4 and A-7.

The bitumen and water content required for waterproofing and to obtain maximum density of the soil-gravel mixture was determined in the laboratory by means of the cell test apparatus, extrusion test, capillary and absorption tests and freezing and thawing. It was not deemed feasible to apply formulae for bitumen determination such as is used in the western States due to the high 200 mesh and colloidal content.

Schafer: In the spring of 1939, three roads in Indiana were selected for stabilizing those materials which were in place. Road No. 1 was 3.65 miles long, part of which was traffic bound aggregate surface on new locations and the other was old county road which had been widened. The aggregate varied from 1 to 4 in. in depth and the subgrade was sandy loam and clay. Several base failures had occurred in this surface. Road No. 2 was 6.5 miles long and consisted of a traffic bound aggregate surface approximately 4 in. deep with a normal clay subgrade. The only soil in the aggregate was that which had been forced upward from the subgrade by traffic. Failures had also occurred in this surface. Road No. 3 was 8 miles long and had a 3-in. aggregate surface. There was a normal amount of what is called black "gumbo" clay present in the subgrade. Failures had also occurred in this surface.

Tilley: The experimental project is located on Highway No. 33 beginning at Crete, Nebraska and extending east 4.4 miles. This road carries considerable truck and passenger traffic. The region through which it passes is a glacial area covered with a mantle of loess soils. The soils are primarily silty clays and silty clay loams which have rather high shrinkage factors and are extremely unstable during wet weather. The stabilized base course was designed to provide a 24-ft. surface on the 30-ft. roadway. The first 2.8 miles was to be 5 in. in depth and the next 1.6 miles, 4 in.

DESIGN

Loughborough: Soils and other local surfacing materials are now generally required to meet certain definite specifications, and this has brought about a great improvement in their use and has eliminated many unsatisfactory materials heretofore selected by visual inspection. However, there are certain materials which, failing to meet the general specifications, under certain conditions give good results, and where it is a known fact that such materials have been used satisfactorily and the cost of admixtures of material to bring them up to specifications would be high it would seem only reasonable to set up specifications for those particular materials and allow them to be used. This is of especial significance, because in many States the increasing scarcity of suitable soils is becoming a serious problem. In some localities, soils have been first taken to build a road, then to maintain it for some years as an untreated road, then, finally, to rebuild it. This continuous stripping of top-soil soon depletes the supply and makes all the more important the careful consideration and study of methods whereby the depth of soil necessary to give satisfactory results can be reduced.

Tilley: On the Nebraska project the quantities of coarse sand and selected soil were proportioned so that the final mixture would have about 30 per cent through the No. 200 sieve. The gradations of the materials were such that approximately 60 per cent coarse sand and 40 per cent selected soil were used. The liquid limit of the mix was about 17 and the plastic limit about 12. A density-moisture test run on the material mixed with tar showed that the mix had an "optimum" moisture content of about nine per cent and a maximum dry weight of about 120 lb. per cu. ft. including the tar. Preliminary laboratory tests showed that 4 per cent tar, RT-3 by dry weight, was necessary to stabilize the coarse sand—soil mixture. These tests also indicated that thorough mixing could be accomplished with the moisture content ranging from 8 to 12 per cent and also from 16 to 20 per cent. The material appeared to be practically impossible to mix at moisture contents of from 12 to 16 per cent. The range from 8 per cent to 12 per cent was selected because material mixed at the higher moisture contents would have required considerable drying before it could have been laid down and compacted.

CONSTRUCTION METHODS

Miller: *Preparation of Windrow—Equipment:* Two Adams motor patrol graders with 12 ft. blades, 1 York Master Workman scarifier and International 40 Tractor, one Killefer Twin-24 in. disk-harrow and one dump body truck part time.

Labor: Two common laborers, four skilled laborers and one grade foreman.

One motor patrol was used the greater part of the time in maintaining the gravel surface and reclaiming and spreading suitable material from the berms and ditches. All material that possibly could be was reclaimed in order that the existing surface would be disturbed as little as possible. All loose material on the surface, together with the reclaimed material, was bladed well onto the shoulders on both sides of the road. The cubical content of the material in the two windrows thus formed was estimated. Additional soil-gravel was loosened from the roadway proper to secure the requisite amount for the 5-in. compacted depth. All the loose material was combined on the shoulders. The exposed subgrade was then dressed to crown and grade and checked with crown board and straight edge. The two windrows were combined to form one large one which was located approximately four ft. off the center line in order to facilitate the movement of traffic. Moisture content, and weight in pounds per cubic foot were determined. The estimated quantity of dry material required to give a 5-in. compacted depth was 1,050 lb. per lineal foot of 18-ft. roadway. From these data the required size of windrow was estimated. A large pair of calipers was used to determine the size of windrow as the contractor was unable to obtain a metering box for a windrow of this size. The cross section of the windrow varied from 9½ to 15 sq. ft. depending on the moisture content, grading and additional material required for widening. Several points of interest may be here emphasized on windrow construction. A York Master Workman was used to loosen the existing gravel surface course. The York machine also had a rake attachment for removing oversize aggregate. Due probably to the large amount of loose material this attachment was practically useless and the oversize material was removed by hand. The disk-harrow was not used often as the fine fraction pulverized very readily when manipulated with the blade. Where an excessive amount of soil fines or a deficiency in gravel existed the contractor was required to carry forward sufficient material to correct this condition. The extra material was obtained by increasing the size of the windrow where an excess of gravel existed, running this material through the traveling mix plant and discharging through the overflow chute into a waiting truck. Whenever a deficiency existed in the windrow additional material was obtained from the shoulder and the Barber-Green overflow. The quantity of material in the windrow was held within 5 per cent of the estimated amount. The lineal feet of windrow prepared was limited to one day's run as the undisturbed material protected the subgrade from drying out and also allowed a quick run-off in case of rain. Approximately 14 hours were required to construct 2,500 and 3,000 ft. of completed windrow with this equipment.

Combining Soil, Gravel, Tar and Water—Equipment: Barber-Green traveling mix plant, water storage tank and pump mounted on a trailer which was attached to the Barber-Green, water pump at the source of supply, two tar distributors—800-gal. capacity each, one 2,600-gal. tar trailer truck, one steam boiler mounted on truck, one 6,000-gal. storage tank and two water trucks.

Labor: Six truck drivers, 2 Barber-Green operators and one common laborer.

Tar Delivery: The tar was heated in the tank car by means of a portable steam boiler. The 2,600-gal. trailer truck transported the tar to the 6,000-gal. storage tank which was located conveniently on the project. The two 800-gal. tar distributors transported the tar from the storage tank to a 700-gal. storage tank on the Barber-Green.

Water Delivery: Three trucks equipped with pumps were required on the first twelve miles of base course construction. The water was supplied by means of two trucks on the remainder of the project by using one large pump at the source of supply and one pump for unloading mounted on the trailer truck.

Mixing: The windrowed material was picked up by the Barber-Green by means of a screw and bucket conveyor which emptied into a storage bin of approximately one cubic yard capacity. The material from the storage bin flowed through an adjustable gate onto a belt conveyor and then into the pug-mill. The amount of material passing through the gate varied with the moisture content and grading of the aggregate. To overcome this discrepancy the windrow was prepared accurately and the gate left full open except where the windrow contained extra material for widening. Where the windrow contained extra material the gate was adjusted to carry the normal amount of aggregate. The forward speed of the plant then was adjusted as required to maintain a constant supply of material in the storage bin. Following this procedure it was possible to change from a windrow of 9.5 to 15 cu. ft. per ft. without stopping the pug-mill.

The tar pump and pug-mill were driven by a motor running at constant speed. The tar was delivered therefore at a constant rate which could be altered only by changing the tar pump gear ratio. The rate at which the tar was delivered and the forward speed of the machine determined the quantity of tar in the finished mixture. Slight variations in the quantity of tar could be obtained by decreasing or increasing the speed of the traveling motor. Major variations could be obtained only by changing the traveling motor gear ratio or both the tar pump and traveling motor gear ratio.

The water was delivered to the pug-mill by means of a pump mounted on the mixer. The quantity of water delivered was controlled manually.

The percentage of tar required in the mix was determined in the laboratory on the soil fines passing the No. 4 sieve having a plastic index of 0 and 15. No allowance was made for bitumen on the coarse material retained on the No. 4 sieve. The average amount of tar required was 5 per cent or approximately 5.0 gal. per lineal foot of windrow. The quantity of water and the gradation of the aggregate were the only two variables that needed to be considered as the rate at which the tar and the soil aggregate were delivered to the mixer was already established. The grading of the aggregate was determined by sampling the windrow where any change in color or texture was noted. This method of sampling was found to be far more effective than obtaining samples at regular intervals. The tar required was calculated for each change in gradation. The inspector at the mixer was then given a tabulation showing the number of gallons of tar required per running foot between designated stations. The travel-motor was usually flexible enough to make a full day's run without changing the gear ratio on the tar pump or traveling motor. Incidentally, it required approximately 30 min. to make a change in the pump sprocket or the gear ratio of the traveling motor. For this reason the rate of tar delivery was set usually at an assumed maximum for the day's run. The average rate of travel was 5.2 lin. ft. per min. The amount of water required could be estimated closely and was controlled by visual inspection. The moisture content of the mix was carried slightly above the optimum. Keeping the moisture above optimum insured partial evaporation of the light oils when the mix was aired, before spreading and compacting. Moisture content of the windrow during the month of May varied from 1.8 to 6.0 per cent with an average of 2.5 per cent. During the month of August the moisture in the windrow varied from 0.6 to 6.7 with an average of 2.3 per cent. The average amount of water added at the mixer was 5.5 gal. Grade TM-2 tar was used but without much success, as the soil fines were not coated nearly so well as when using TM-1. The maximum length of windrow mixed in one 14-hour day was 4050 ft. The writer was well pleased with the mixing results obtained with the traveling mix plant.

Spreading, Compacting and Finishing—Equipment: One motor patrol with 12-ft. blade, 2 pairs of sheepsfoot rollers, 1 rubber-tired roller, 1 7-ton flat wheeled roller, 1 International rubber-tired tractor and 1 International Trac-Tractor with street plates.

Labor: One foreman, 4 equipment operators and 1 common laborer.

Although the plans call for a uniform cross section 18 ft. wide, it was found advisable shortly after the project was started to increase the width slightly over 18 ft. in order to accomodate a full 18-ft. width wearing surface. The first operation, therefore, before spreading the windrow was to blade all loose material from the roadway. Stakes were then set 10 ft. off the centerline as a guide to the blade operator. A shallow trench was cut 6 in. inside the stake line running from 1 to 1½ in. deep tapering off to zero within 6 in. Spreading and leveling were started as soon as possible. The mixture was then aired to decrease the moisture and light oil content. A tractor-drawn Lakewood rooter was found to be much more efficient than the disk-harrow for this purpose. This operation was followed by using the two sheepsfoot rollers and blading until 1 to 1½ in. of loose material remained on the surface. The sheepsfoot roller was then replaced with the rubber tired roller. Blading and rolling continued until the surface was bound firm and smooth. The flat-wheeler roller gave a final smooth finish to the surface.

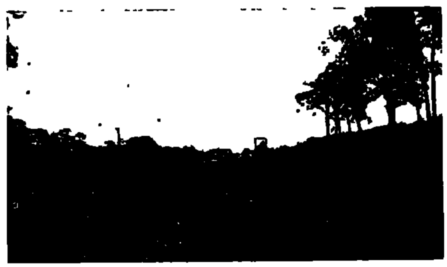

Figure 2. Mixing Process About Half Complete. Indiana

Schafer: The construction methods were practically the same for roads No. 2 and 3, and a small part of road No. 1. Stabilization construction was started by scarifying the surface its entire width to a depth of from 4 to 4½ in. This was accomplished by using power graders and a 10 ft. grader equipped with a scarifier attachment and pulled by a 75 H.P. tractor. The power graders next pulverized the material by moving it back and forth over the surface, finally windrowing it at each edge of the proposed base. No lumps larger than ½ in. in diameter were permitted in the mix. The windrowed material consisting of aggregate and subgrade soil was then bladed onto the road bed in three operations, each operation constructing a lift composed of approximately one-third the material. One-third of the total proposed application of tar and enough water to make the mixture work well was applied to each lift. The total bitumen applied was approximately 0.9 gal. per sq. yd. or 2 per cent by weight of 55-80 (Engler at 40° C) viscosity tar.

After the tar had been applied and all the loose material had been bladed onto the roadbed, the entire mixture was windrowed to the center of the road. At this point a thickened edge was made by cutting a 2 by 36 in. wedge from the subgrade. The material from this wedge was then incorporated with that in the windrow. The entire windrow was then mixed until the tar was uniformly distributed through the mass. Power graders were used for the mixing because the curved blades mix the material in a rolling movement. Motor graders were also used because the entire depth of the material was moved at one time preventing segregation.

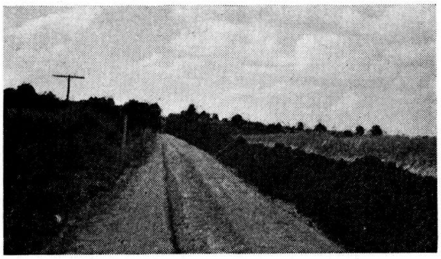

Figure 3. View Showing Thickened Edge Construction of Subgrade

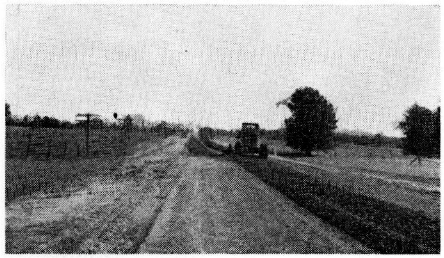

Figure 4. Power Graders Moving Windrows Across the Road, Indiana

After the mixing operation was complete, the materials were again windrowed on each edge of the roadbed. The windrowed material was again evenly bladed onto the roadbed in three equal lifts and each lift compacted by means of rubber tired equipment including a rubber tired roller. A sheepsfoot roller does not work satisfactorily because of the mechanical bond in the mixture. For satisfactory results, kneeding action was required and secured by the use of rubber tired equipment. The last rolling operation was the compaction of a small amount of loose material on the surface with standard 10-ton 3-wheel rollers.

After the mixed materials had been compacted, a tack coat of 0.2 gal. per sq. yd. of the same grade of tar as that used in the mix and 10 lb. of chips per sq. yd. were applied to the surface and rolled. Traffic was permitted to use the surface for ten days and a seal coat was then applied. The seal coat consisted of a 0.2 gal. application of tar and 18 lb. of small chips which were slightly mixed and rolled. To this was applied 0.13 gal. of tar per sq. yd. and enough small chips to get a uniformly tight surface. The surface was then given a final rolling. The tar used for the seal had a float test at 32° C of from 120 to 180 sec.

Road No. 1 was constructed practically the same as roads 2 and 3 except 3.07 miles which were mixed with a traveling plant but spread with motor graders. The bitumen content in the mix of this road varied from 2 to 3 per cent of tar by weight. The average application was 2.5 per cent. This variation in bitumen content was made to take care of the varying amount of fine materials present in the mix.

Moisture tests were not made on any of these projects; however, it was estimated that the total moisture content before mixing was approximately 10 per cent. This deduction was made by estimating the moisture present in the original windrow plus the known amount of water which was added.

On all projects it was necessary to cure the mixture by manipulation which permitted a certain amount of water to leave the mix before it was compacted. Two small areas on one road were not cured sufficiently and these failed. These places were scarified, aerated, again compacted, and sealed. It is estimated that about 4 per cent is the proper moisture content for good compaction.

The sieve analysis of the materials which were in place on the three projects showed a variation of from 18.8 to 91.1 per cent passing the No. 10 screen and from 7.1 to 56.8 per cent passing the No. 200 screen. An examination of the stabilized material showed the particles retained on the No. 10 screen to be practically uncoated while those passing were well coated.

Tilley: The first construction operation to be performed was hauling and placing the coarse sand. This material was obtained from the waste sand pile of an old gravel pit. It was loaded into 4-cu. yd. trucks by means of a $\frac{3}{4}$-cu. yd. dragline and taken an average haul-distance of about five miles. The coarse sand was windrowed on one side of the roadway and the selected soil was placed in a separate windrow.

The selected soil was obtained from local pits adjacent to the project and the average haul distance was a little over one mile. The soil was partially pulverized in the pit by means of farm discs, harrows and tillers and then windrowed with a 12-ft. grader blade. The material was loaded into 4-cu. yd. trucks with two Schinck loaders, a device having a loading arrangement mounted on the front of McCormick-Deering Farmall tractors. The pulverizing was completed on the road by means of the Seaman tiller, a small flat roller and an auto patrol.

The pulverized soil was then placed in a windrow near the center of the road and the coarse sand brought over and placed on the windrow of soil so that both materials formed a single windrow in the center of the roadway. This was the most desirable position from a standpoint of the mixing operation which was to follow and also the grade was better protected in case of rain.

The next operation was to mix the materials in the windrow and apply the

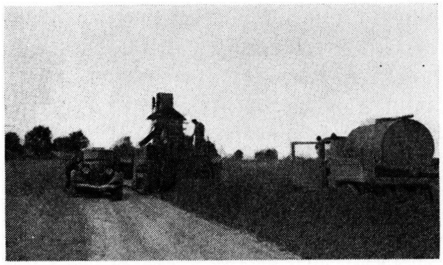

Figure 5. Traveling Plant Discharges Mixed Material in Windrow in Center of Roadbed. Indiana.

tar to the mixed aggregate. This was done by means of a Barber-Greene traveling plant mixer. The mixer took the material from the windrow, mixed it and elevated it into a pugmill at the rear of the machine. The tar and water were added in the pugmill and the mixed material was placed in a windrow at the rear of the mixer ready for the lay-down operations.

The tar was heated to about 145° F. and pumped from tank cars into relay tanks by means of a Cleaver Brooks heater. Two trucks having 1,000-gal. tanks were used to haul the tar to the mixer. These relays hooked on to the mixer and the tar was pumped into a storage tank. The tar was pumped through nozzles into the pugmill by means of a positive displacement pump.

The water was hauled to the mixer with two 1,000-gal. relays and pumped into a trailer storage tank which was hooked on to the mixer. The water was pumped from the storage tank through a meter and into spray bars mounted over the pugmill, the flow being regulated by means of a hand valve.

The purpose of the water was twofold, first to assist in thorough distribution of the tar and second to aid in compaction. The consistency of the material as it came from the pugmill was kept just below the plastic limit. This could be checked with very little experience by compressing the material between the fingers. The moisture content of the mix was about 9 per cent. The amount of moisture required for compaction was about 9 per cent. When the mix reached a moisture content greater than about 12 per cent, the material became so stiff in the pugmill that mixing was impossible.

The traveling plant mixer was operated 24 hours a day, traveling at the rate of one station in 25 minutes on the 4 in. section and one station in 30 minutes on the 5 in. section.

After a mile of the windrow had been mixed the lay-down operations were started. This required 2 auto patrols, 2 sets of dual drum sheepsfoot rollers pulled by 40 h.p. crawler-type tractors, 1 pneumatic-tired roller and 1 flat roller pulled by rubber-tired farm tractors, and 1 distributor for applying water.

The first operation was to move the windrow from its original position to one side of the road. Next, the base was wetted and material laid on the surface not occupied by the windrow and over to a line of stakes which had been set for the outer edge of the base course. The remaining part of the windrow was moved from its position, the base wetted where the windrow had been, and the material laid to the other stake line. An auto patrol with a shoe on the outer edge of the mold board was used to cut the material back from the outside to form the edge and shoulder line of the base course. The base course was then shaped to the approximate cross-section leaving the material in place but not compacted. It usually took about 3 to 4 hours to reach this stage of the lay-down.

The sheepsfoot rollers, loaded to about 230 lb. per sheepsfoot, were started along one edge and lapped systematically towards the center and the operation continued until the feet were within 2 in. of the surface. Then a patrol was used to maintain a fair size windrow over the surface and keep the top to the desired cross-section while the sheepsfoot rollers continued until they were within about an inch of the top. They were then removed, having been in operation from 2 to 3 hours, depending on the moisture content of the material.

When the sheepsfoot rollers were removed, the auto patrol still had its maintenance windrow but usually by this time the material was getting rather dry and it was necessary to apply water to the surface to keep it in a workable condition. The maintenance windrow was then distributed on the surface as the patrol completed the final shaping. The pneumatic-tired roller, with 45 lb. per sq. in. air pressure in the tires, was then started and it continued rolling for two or three hours until the surface was well compacted. It was necessary at times to use light applications of water during this rolling operation.

The following day a flat roller, with a load of 150 lb. per sq. in., was used to compact the surface. About 5 or 6 hours flat rolling was necessary to compact and maintain the shape of the surface while the moisture content was being reduced to a point where the base course was stable under traffic.

It was found that, if for any reason the moisture content reached a percentage greater than about eleven, the surface could not be finished until the moisture content was reduced to a point where the material was stable. In this case, it was necessary to wet the surface and blade with an auto patrol, finishing with pneumatic and flat rollers.

During the period between the lay-down operations and the application of the prime coat, it was necessary to use light applications of water to aid in reducing the moisture in the base course. For a few days after the lay-down, applications of water made the surface soft and it could be bladed, but after about five days, or when the moisture content in the upper part had dried to 5 or 6 per cent, the applied water did not affect the surface. Also, it was noticeable that after about a week the surface became friable and would dust and ravel.

In about a week's time the base course had dried sufficiently to permit application of the prime coat. RT-3 tar, the same as was used in the mix, was applied at the rate of 0.3 gal. per sq. yd. by means of distributors with 12 ft. spray bars. Traffic was kept off the surface for the first two days after the prime coat was applied.

Usually, on the third day after the prime coat was applied, the surface was in condition for the armor coat. The armor coat consisted of 0.35 gal. of RT-10 tar per sq. yd. and 35 lb. of sand-gravel per sq. yd. The tar heated to a temperature of 250° F. was sprayed on the surface with a distributor. Half of the road was covered at a time. The sand gravel was hauled to the project in dump trucks and applied with a spreader box which was attached to the rear end of the truck. It was necessary for the trucks to back up so that the aggregate was spread ahead of the wheels of both the spreader and the truck. The spreader covered a third of the road at a time so three trips had to be made with the spreader. Application of the tar was regulated so that the tar was never very far ahead of the sand gravel. A drag consisting of a number of wire brushes fastened on to a wooden frame was dragged over the surface to distribute the aggregate evenly. This was followed by a flat roller. It was necessary to maintain the surface of the road with the drag broom and roller for three days after the application of the armor coat.

When the maintenance on the armor coat had been completed, soil was hauled in and the shoulders of the grade were built up level with the top of the finished surface.

COST DATA

Loughborough: The essential data and the cost of a tar base in Virginia constructed during 1939 are:

Length: 2.75 miles.
Width of base: 20 ft. Depth of base: 6 in.
Type of soil: Sand clay with plasticity index of 4.5.
Bitumen used: RT-5.
Quantity: 2.7 gal. per sq. yd.
Seal coat: 0.25 gal. RT-7 and 25 lb. sand per sq. yd.
Wearing course: 0.25 gal. RT-7 and 25 lb. No. 9 chips.
Approximately 2 in. of coarse sand added to road before being stabilized.
Cost:

6 in. base per sq. yd.	$0.25
Seal and wearing course	0.12
Sand admixture	0.07
Total cost per sq. yd.	$0.44

Miller: The contract unit price for completed stabilization in West Virginia was 37 cents per sq. yd. or $3900 per mile. Total cost which includes shoulders and ditches and 55 lb. wearing surface was $5700 per mile.

The maximum length of roadway that could be completed in one day (14 hours) was 4000 ft. Approximate time required for the various operations on 1000 ft. of roadway:

	Hr.	Min.
Cutting thickened edge and removing loose material	..	20
Spreading and leveling	..	60
Aerating	..	60
Sheepsfooting	3	45
Rubber-tired rolling	2	..
Flat-wheeled rolling	1	..

Schafer: The costs for the three projects in Indiana were as follows:

	No. 1	No. 2	No. 3
Stabilized base per mile (18 ft. wide)	$3,276.72	$1,700.37	$1,874.70
Stabilized base per sq. yd. (18 ft. wide)	0.310	0.161	0.158
Seal per mile (18 ft. wide)	624.11	486.00	1,167.30
Seal per sq. yd. (18 ft. wide)	0.059	0.046	0.099
Total cost per mile (18 ft. wide)	3,900.83	2,186 37	3,042.00
Total cost per sq. yd. (18 ft. wide)	0.369	0.207	0.257

The equipment, labor, and materials costs were as follows:

	No. 1		No. 2		No. 3	
	Cost	% of Total	Cost	% of Total	Cost	% of Total
Equipment Per mile (18 ft. wide)	$1,416.42	36	$ 315.63	14	$ 638.72	21
Labor Per mile (18 ft. wide)	338 10	9	155.65	7	439.53	14
Material Per mile (18 ft. wide)	2,146.31	55	1,715 09	79	1,963 75	65
Total	$3,900.83	100	$2,186 37	100	$3,042.00	100

The equipment costs for road No. 1 were high because a traveling plant was used for the mixing. This plant was rented and the costs might have been less if the department had owned the machine. The materials also required much additional manipulation because of heavy rains.

Road No. 2 was an ideal project because the equipment was well balanced and the weather was satisfactory. This project was started on June 14 and the stabilized base work was completed June 27, which is a period of 11 working days. The seal coat was completed July 5.

The equipment used on this project was as follows:

1 75 H.P. crawler tractor.
1 10 ft. blade grader with scarifier attachment.
2 Tandem driven power graders with scarifiers.
2 10-ton 3-wheel rollers.
2 850 gallon bituminous distributors.
1 multiple blade maintainer (for surface seal only).
6 2½ cu. yd. dump body trucks as needed.

Road No. 3 received a surface treatment while a light seal coat was applied to roads Nos. 1 and 2. The equipment costs of this project were comparatively high because of insufficient heavy equipment which could scarify the surface. This unbalanced the entire procedure. Heavy rains also caused additional manipulation in the preparation of the materials.

Tilley: The contract cost for the 4 in. base course in Nebraska without prime coat or armor coat was approximately $6,300.00 per mile, and for the 5 in., it was approximately $7,600.00 per mile. The prime coat and armor coat cost was approximately $1,700.00 per mile.

The cost of the shouldering is not available at this time since it is in the process of being completed.

The total approximate cost of the tar stabilized soil base course with the wearing course of prime coat and armor coat was $8,000.00 for the 4 in. course and $9,300.00 for the 5 in.

SUMMARY

Schafer:

1. For proper workability approximately 10 per cent of moisture should be

present in the mix. The manipulation costs will be increased materially if the moisture content is too high or too low. Low moisture content requires additional mixing to get proper coating of the particles. High moisture content does not affect the coating of the particles but does require additional manipulation to permit the escape of moisture.

2. The stabilized base must not be sealed with too much moisture in the mixture. It is recommended that two weeks elapse between the tack coat application and the seal coat. This permits the appearance of any failures which are due to excess moisture.

3. If excess moisture failures do appear after the seal coat is applied, the base should be scarified and aerated, again compacted, and sealed.

4. A tack coat must be applied immediately after the compaction of the base is complete and before it is used by traffic. The tack coat penetrates the loose material on the surface and provides a temporary wearing surface. The stabilized base should never be used as a wearing surface.

5. The stabilized base can be used as the first step in stage construction. The application of a seal coat provides a cheap wearing surface; a high type surface may be secured by adding a binder course and a wearing course. This stage construction would permit the improvement of a large number of miles where few miles could be constructed if the entire improvement was made in a single season.

6. The length of the working season can be increased because of the low temperature at which the work can be prosecuted.

7. The cost for this type of improvement is very reasonable because those materials which are already present in the surface and subgrade do not have to be purchased. The only expenditures are for bituminous material, chipping aggregate, labor, and equipment.

8. The stabilized base is composed of practically uncoated large aggregate particles completely surrounded by well coated fine particles. The rubbing or grinding action which the fine particles have on the large particles during the mixing period is a reason for the lack of coating on the large particles.

9. Periodic inspections have been made of the three stabilization projects in Indiana. All have satisfactory riding qualities and their surfaces are in excellent condition. Base failures which occurred before the improvement, have failed to reoccur after the improvement. The cost of this type of construction is reasonable and the results to date are very satisfactory.

Tilley: Since the completed road has been in service only a short time, it is impossible as yet to make any conclusions as to the lasting durability of this type of construction, but it is possible to mention a few items that are worthy of consideration in future designs and construction involving tar stabilized soil as a base course.

Trenching the mat would eliminate the trouble that was experienced in holding and compacting the edges of the mat. In any design, however, provision should be made to protect the edges of the mat since they will become very dry and will break away readily.

The moisture content for mixing should be kept in the range between the "optimum" moisture as determined by the Procter density test and the plastic limit of the mix, preferably nearer the "optimum" moisture content. Higher moisture contents are undesirable from the standpoint of the extra manipulation required to dry the material, because of difficulty in compacting the material, and because of damage that might be done to the subgrade due to the wet material.

The material should be laid down not

later than a day or two after mixing has been completed for best results and ease in handling.

The sheepsfoot rollers should not be brought up closer than about one inch from the surface.

Excess moisture in the lower part of the base course penetrated into the subgrade even after the prime coat was applied.

The completed road has a base course with a density higher than the maximum Procter density; it appears to be impervious to water and the surface has good riding qualities. Therefore, it might be said as a conclusion to the above experience that stabilizing base courses with a small percentage of tar has possibilities that are worthy of further consideration.