are not properly replaced and witnessed. Then, when occasion arises to find the corner again, a good highway may be materially damaged and hours of valuable time spent in trying to find it. Sometimes the surveyor and the construction engineer are one and the same person. In saying this I am speaking with a very guilty conscience. Not only are county surveyors guilty of this neglect, but state highway engineers are also guilty. When state highways are constructed in a county, complete field notes of corners, relocated and established, should be transmitted to the county surveyor's office. Such corners are frequently of vital importance to the interested persons.

LOW-COST STABILIZED SURFACES

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One of the problems of the highway engineer is that of developing a satisfactory low-cost road surface to take the place of the ordinary gravel road, which is unsatisfactory for modern traffic and expensive to maintain. To meet the requirements, this intermediate type should be moderate in both initial and maintenance cost.

There is a large mileage of gravel-surfaced county roads, as well as some state trunk lines carrying a moderate amount of traffic, which can not be paved within a reasonable time because of a lack of the necessary funds. In some instances, the type or volume of traffic would not warrant the construction of a high-type pavement. Development of a method of improving these roads by building up and stabilizing the existing surface, thus salvaging the large investment already made in gravel roads, is desirable from an economic standpoint.

Various bituminous materials as well as calcium and sodium chlorides are being used in stabilization work. Our work in Livingston County has been mainly surface stabilization with the use of bituminous materials, such as slow-curing asphaltic oil, medium-curing cut-back asphalts, and tar mixed on the road with a densely graded, local, bank-run gravel. Thus far, we have built the surface on an ordinary gravel base without any special treatment to stabilize the base. We would prefer to build a bituminous surface on a well-stabilized base but our road funds are limited and our roads are carrying the traffic without excessive maintenance cost. To meet future conditions, there is the following possibility in connection with our slow-curing oil surfacing. If and when traffic increases to the extent that the base is inadequate and maintenance cost becomes excessive, we can scarify the oil mat and a sufficient depth of the base and mix in enough new oil or other bituminous material to provide a stabilized base on which a new wearing-surface can be laid. The roads we have surfaced carry

traffic of about 300 to 800 vehicles a day. In 1935 we built three miles of oil-gravel road for the General Motors Proving Ground. These roads carry heavy traffic and are standing up very well.

The bituminous materials used are slow-curing, 70-80% asphaltic oil meeting the Asphalt Institute specification SC-3, medium-curing, cut-back asphalt MC-2, and 28-35 viscosity tar. When using slow-curing oil, we build the surfacing three inches thick, loose measure, whereas with cut-back or tar, it is 2½ inches thick. We do not think it advisable to build too thin a surface on a gravel base.

METHODS OF CONSTRUCTION

The existing gravel road is first bladed to true up the surface and remove corrugations. The loose material is scraped into a windrow in the center of the road. The number of cubic feet of aggregate required per linear foot of road is computed, and enough new gravel is added to the windrow of salvaged material to make the correct total. This is done by metering the material through an adjustable proportioning device designed by the writer, which straddles the windrow of salvaged material. (Fig. 1). The opening in the rear of the proportioner

Fig. 1. Combining old and new aggregate into a uniform windrow by use of the "Proportioner".

is adjusted to correspond with the cross-sectional area of the bituminous surfacing under construction. Each truck is hitched to the proportioner and pulls it forward as the load is being dumped and the new and old aggregates are combined into a uniform, flat-topped windrow. (Fig. 2). This

method assures a uniform quantity of aggregate on the road and makes the control of the percentage of bituminous material in the mix an easy matter.

Fig. 2. Use of "Proportioner" in placing and measuring aggregate for road-mix.

Aggregate. We produce our own aggregate from local pits with portable screening and loading equipment. A bucket-type loader equipped with a 2′ x 6′ single-deck, vibratory screen used in conjunction with a drag line makes an efficient outfit for this work. The use of densely graded aggregate is very necessary in this type of road surfacing, and we take particular pains to get a material that has a good gradation of the various sizes of gravel and sand from one inch down to the finest sand. Most commercial gravel companies can produce a satisfactory material.

Since there is usually a deficiency of 100- and 200-mesh material in the gravel, we provide this by adding from 5 to 7 per cent of the finest bank sand obtainable locally. This material is usually added to the windrow of gravel on the road, and, as it fills in the voids in the coarser material when mixed, the total volume of aggregate is not changed. If suitable filler material cannot be found locally, it must be shipped in, as it is a very necessary part of the aggregate. Limestone dust makes a suitable filler.

Aggregate meeting the following specification for grading is considered satisfactory:

Passing one-inch screen	100%
Passing ¼-inch screen	60 - 80%
Passing 10-mesh sieve	40 - 60%
Passing 40-mesh sieve	20 - 40%
Passing 100-mesh sieve	8 - 10%
Passing 200-mesh sieve	5 - 8%

Bituminous Material. The moisture content of the aggregate should be reduced as much as possible before the application of the bituminous material. This is done by spreading out the windrow of gravel and disking it for a day or so to permit evaporation. The bituminous material is applied with a pressure distributor at the rate of one-half gallon per square yard for each application. We prefer to use a half gallon per application instead of a greater amount because there is a better opportunity to compensate for errors by making allowance in subsequent applications. When using slow curing asphaltic oil as a binder, we use 0.52 gallons per square yard per inch depth of aggregate, or 1.56 gallons for a three-inch depth, which is about 5% by weight. We have found by experience that this is the correct amount to use with our aggregate. It makes a surface that will not ravel, and yet the mat has enough stability so that it will not corrugate. We heat the bituminous material to about 165° before applying it.

The following formula for computing the correct percentage of oil for various gradations of aggregate has been quite extensively used, and we occasionally use it as a check on our work:

P=0.02A plus 0.045B plus 0.18C

Where A=percentage of aggregate retained on No. 10 sieve
B=percentage of aggregate passing No. 10 sieve and retained on No. 200 sieve
C=percentage of aggregate passing No. 200 sieve

Particular care should be taken to get the correct amount of oil in the mix and uniformly distributed, because fat or lean spots are almost certain to cause trouble. When using medium-curing cut-back or tar instead of slow-curing oil in the mix, we use 0.6 gallon per square yard per inch of aggregate.

Mixing. Each application of oil is mixed into the aggregate by a three-section disk drawn by a small track-type tractor which follows closely behind the distributor. Various types of mixing equipment are available, including multiple-blade mixers and traveling plants, which are being widely used. We are using power graders on our work, and they are satisfactory although slower than the other types of equipment. The more rapid the mixing operation, the more necessary it is to have

the aggregate dry in the beginning. Wet weather of course delays the work and increases the cost of mixing.

When the bituminous material has all been applied and disked in, the aggregate is put into a windrow and bladed back and forth across the road until thoroughly mixed. It is important that mixing be continued until the whole mass is uniform in consistency and black in color. Exposure to the air and sunlight has a beneficial effect on the mix, in addition to drying out the moisture, and money spent on further mixing after the aggregate is all well coated is not wasted. We do not prime the base when using slow-curing oil. Unless the prime material penetrates thoroughly into the base, there is a chance that part of it will be absorbed upward into the mat and cause a fat mix.

After the mixing operation is finished, a thickened edge is provided for by making a triangular cut with the grader blade reversed to throw the excavated base material outward. This cut is about two inches deep at the outer edge and feathers out about two feet in from the edge. The mixture is then spread out with the graders. We find that we get a much straighter edge by carrying a little excess material to the edge of the channel and leaving it in a small windrow to be pulled in when the spreading is nearly finished. The road is then opened to traffic and bladed lightly for two or three days while traffic partially compacts the surface, after which it is rolled with a seven-ton tandem roller. When cut-back or tar is used in the mix, the rolling is done immediately after spreading or on the following day.

For a seal we use a light application consisting of one fourth gallon emulsion or cut-back covered with about 15 pounds of 0.10″ to 0.25″ birdseye gravel or chips. We prefer a light seal on the slow-curing oil surface because it will be easier to break up if we should want to scarify and remix the whole mat in later years. Thus far, less than one half of our roads have been sealed.

COSTS

Our construction cost for slow-curing oil-mix surfacing twenty feet wide and 2½ inches compacted depth, averages, without a seal coat, about $1800.00 per mile, or about fifteen cents per square yard. This includes labor, equipment rental, and materials, with slow-curing oil costing about 5¼ cents per gallon and gravel 15 cents per cubic yard in the bank. The cost of screening, loading, and hauling gravel is about 50c-60c per cubic yard for a four-mile average haul. The cost of the surface, using cut-back asphalt or tar, is correspondingly higher, depending on the cost of the bituminous material.

MAINTENANCE

The major part of the maintenance work consists of patching spots that fail because of frost boils or weak places in the base. These are usually excavated to a depth of six or eight inches and filled in with oil-gravel mix. In case of bad frost heaves, we excavate the silty material to a depth of about two feet and back-fill with gravel before making the surface patch. During construction operations, we pick up about thirty cubic yards of oil-gravel mix from each mile of road before it is spread, and put it into stock piles. This usually supplies enough patching mixture for several years. The annual cost of patching averages less than thirty dollars per mile for roads that have been built from one to six years.

In general we prefer the slow-curing oil to the other bituminous materials. The mat is much more flexible and better able to withstand the frost heaves without breaking up in the spring. Another reason is that almost any of the low-cost bituminous surfaces become more or less out of shape from heaving, settling, and patching after a period of years and that there is a definite satisfaction in the knowledge that a surface can be scarified and remixed at nominal cost and made as good as new. The medium-curing cut-back and tar mixes have some advantage in that they are damaged less by tractor lugs and the like and when laid on a firm, well-drained base have been entirely satisfactory. We have built cut-back asphalt type of surface principally in the residence section of towns and villages in our county.

The construction of this low-cost type of surface should have just as careful supervision as would be given in the building of a higher type of road. The base should be as thoroughly drained as possible, and pockets of silt, if present, should be removed by excavating and back-filling with good material. The gradation of the aggregate, particularly that of the fraction which passes the ten-mesh sieve, is very important, because the stability and bitumen capacity of the aggregate itself is mainly dependent on the gradation and quantity of this finer material. Lack of sufficient fines and use of too much bitumen are almost certain to cause trouble later on. Careful proportioning of the aggregate and bitumen so as to have the correct percentage of the latter in the mix is very necessary. It is better to have the mix a trifle lean than too rich, especially where the roadbed is not too well drained, as the absorption of moisture from the base may cause the surface to corrugate if the maximum amount of bitumen is used. This type of surfacing has been very satisfactory in our county, and our experience has proved that the saving in maintenance cost as compared with gravel road maintenance is sufficient to pay for the cost of the surfacing in five years or less.

CLAY-CHLORIDE STABILIZATION

Our experience with clay-chloride stabilization has been quite limited. During the past summer, we stabilized eleven miles of gravel road, adding two inches of new gravel. The materials were mixed on the road without detouring traffic, and we experienced some difficulties from extremely dry weather. About 20,000 gallons of water per mile were used to compact the surface. The plasticity index was kept low to avoid a muddy surface during rainy weather and because it is intended as a base for a bituminous surface. The cost of this work was about $1300.00 per mile. While this type of stabilization has been quite extensively used as a road surface, the trend at present is toward its use as a base for a bituminous surface rather than as a finished road.

GETTING THE MOST OUT OF THE GOVERNMENT SECONDARY ROAD PROGRAM

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As an opening statement I will quote from the Report of the Chief of the Bureau of Public Roads, 1936:

"One of the major efforts of the Federal Government to relieve unemployment through a large-scale road-construction program began with an authorization of $400,000,000 as a direct grant to the States by the National Industrial Recovery Act of June 16, 1933. One year later the Hayden-Cartwright Act of June 18, 1934, authorized a supplementary $200,000,000. These funds are known as the 1934 and 1935 Public Works highway funds. The Hayden-Cartwright Act also provided $125,000,000 as Federal aid to the States in each of the fiscal years 1936 and 1937. The emergency program was continued by allocations of $200,000,000 for highways and $200,000,000 for grade-crossing work, as direct grants to the States made from funds provided by the Emergency Relief Appropriation Act of April 8, 1935. These various acts also provided lesser amounts for the improvement of highways in national parks, national forests, public lands, and other Federal areas.

"The work of highway construction carried out under these several acts had resulted, at the end of the last fiscal year, in the construction of 38,220 miles of road at a total cost of $636,622,561, of which $571,276,033 was paid by the Federal Government, and there were under construction, or approved for construction, 17,862 miles additional, involving an estimated total cost of $357,283,044, of which $270,336,054 was Federal funds. The remaining Federal funds, available for new projects, including Federal aid for the fiscal year 1937,