

received may be from \$1.40 to \$3.00 per linear foot of roadway. The amount of filling material needed below the top of the muck line will vary from 25% to 100% of the amount required if all muck were entirely removed and the fill allowed to take a 1½-to-1 slope. If extreme depths or unusual conditions are encountered, full allowance should be made for them in estimating the costs and determining the economics of location and construction. The consistency, nature, and depth of muck seem to cause the percentage required to vary. Indications are that the slope of the underlying foundation material has considerable to do with the amount required, and the kind of filling material also probably has its effect. The cost of the construction, maintenance of detours, etc., which lie above the ground, can be determined without difficulty and in the usual way as for any other construction work.

### **BLACK TOP ROADS**

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Black top roads, as ordinarily considered by the public, include many types, such as oil mats, light and heavy mulch, retread, bituminous macadam, rock asphalt wearing surface, bituminous concrete, or sheet asphalt. Ordinarily the public does not differentiate between the cheaper mats and the higher types. In most of the criticisms of failures in these types of roads the public fails to take into account the cost. Ordinarily, if the proper selection of materials and bitumen is made, we get what we pay for. We cannot expect a very light surface mat to stand up under heavy truck traffic.

In selecting types to economize properly, the one in charge should consider several items, namely: the stability of the surface he proposes to mat, the amount and kind of traffic, the probable traffic demands for the next few years, the availability of materials, and any other agencies contributing to the lasting quality or destruction of the road. Light traffic can be economically carried over the lighter mats, but where heavy truck traffic prevails, such light mats are soon disintegrated; and, for this reason, it would pay to construct the heavier wearing course where such improvement is considered. I will describe briefly some of the methods we have used in the past few years on the various so-called black top roads.

#### **Road Oil Mat**

When traffic on a road is not heavy enough to justify a high-type pavement yet warrants the construction of some

type of surface that will alleviate the dust nuisance and furnish for most of the year a paved road, we have built road oil mats. Ordinarily it is easier to secure good results by constructing this mat over a period of 2 years, during the first year applying an oil palliative, and during the second year producing the mat. However, if it is necessary, a very satisfactory mat can be produced the first year. Last year we built several miles of road oil mat; and while we expected this light mat to show some failures during the winter season, yet to my knowledge we have had no failure thus far.

In road oil mat construction in our territory we have added to the old gravel or stone surface from 500 to 550 cubic yards of good maintenance gravel or stone, in most cases holding the maximum size to 1 inch. Two or more applications of road oil have been applied totaling about 1 gallon per square yard. The first application of road oil meets our specification A-60, and the subsequent application, A-70.

The chief objection on the part of the general public to oil roads is the spattering of fresh oil on their machines. A certain amount of this is unavoidable. Some study has been given to this item and experiments were carried on this last year which tend to shorten the curing period of road oil materially.

### Mulch Retread

Mulch retreads may be built in varying thicknesses and here again you get about what you pay for. Upon the surface which has been stabilized and leveled by maintenance, a good grade of maintenance aggregate is spread to the thickness of the desired mat (ordinarily 1 inch to 2½ inches). An application of bituminous material of such consistency that it will lend itself to mixing, from .3 to .6 gallon per square yard, is then made, varying with the amount of aggregate, and thoroughly mixed by use of a blade grader.

It is well to prime the old base with an application of ½ gallon of road oil per square yard before putting on the aggregate. If this is not done, the aggregate and bitumen should be bladed to one side and the bare surface given a light application of bituminous material and then the mixture bladed back onto it and spread. The use of a long-base grader aids materially in securing a smooth riding surface. After the mixture has been spread over the surface, it should be allowed to cure until the bituminous material becomes tacky and then should be thoroughly rolled. The surface should then be given a light surface treatment varying in quantity from .15 to .25 gallon per square yard and an application of covering material from 10 to 25 pounds per square yard depending upon the amount of voids remaining in the surface. The surface should again be rolled and opened to traffic.

The heavier mulch tops are built in very much the same

manner as described above except that the quantities of materials are increased in proportion to the thickness of the mat desired and the size of the aggregate is increased with the depth of the mat. A spike-tooth harrow may be used to advantage in mixing the aggregate and bituminous material in the thicker course. This method is not practical for use in mats of greater thickness than about  $2\frac{1}{2}$  inches. In our territory we have added to the old surface 700 to 1000 cubic yards of well graded aggregate using 1 gallon to 1.2 gallons per square yard of bituminous material.

### **Heavy Retreads**

Upon a base which has been stabilized and leveled by long-base drags under maintenance and upon which it is decided to place a heavy retread top, we have adopted the practice of priming the base with about  $\frac{1}{2}$  gallon of road oil, Indiana State Highway Commission specification A-70. Road oil A-70 contains 70 to 85% asphalt and has a viscosity from 10 to 45 at  $60^{\circ}$  C. This road oil mats any loose material that may be on the old surface and also aids in intercepting capillary moisture. Upon this primed base is spread 3 to 5 inches of No. 2 crushed stone ( $2\frac{1}{2}$  inches to  $1\frac{1}{2}$  inches). This stone may be leveled by use of a long-base grader. I encourage mechanical leveling. This stone is then given an application of approximately  $\frac{1}{2}$  gallon of tar TM or liquid asphalt CB. The bituminous material and stone are then thoroughly mixed by use of a spike-toothed harrow having teeth extending approximately 6 inches below the frame, or long enough to extend through the layer of stone. This freshly harrowed mixture is then leveled with a long grader and rolled until the stone is keyed and the surface is stable. Better results can be secured if the major portion of the rolling is done when the bituminous material is tacky. The surface is then given an application from .3 to .5 gallon per square yard of asphalt CB or tar TM and again rolled.

Any depressions are then patched out with bituminous-coated stone of the same size as that used in this course ( $2\frac{1}{2}$  inches to  $1\frac{1}{2}$  inches), and the patches are thoroughly rolled. Covering material is then spread over the surface in sufficient amount to fill the voids and is brushed over the surface until it is uniformly distributed and all the voids are filled. A very satisfactory method that has been used is that of dragging an old rug or carpet behind a light car. This seems to place the covering material in the voids very satisfactorily. This covering material is our grade No. 4 crushed stone, size 1 inch to  $\frac{5}{8}$  inch. The surface is then given an application of asphalt CB or tar TH at the rate of approximately .3 gallon per square yard and dragged with a long-base drag or planer, and the surface is again thoroughly rolled. Next a surface treatment

of approximately .2 gallon per square yard asphalt CB or tar TH is applied, covered with about 50 tons of covering material per mile, dragged with a long-base drag or maintainer, rolled lightly, and opened to traffic.

In some 30 miles of heavy retread 20 feet wide and 3 to 3½ inches compacted thickness built in our territory during 1929 and 1930, we used 2000 to 2300 tons of aggregate and 17,000 to 18,000 gallons of bituminous material, with 3 to 3½ per cent of bitumen by weight, per mile. The cost of this high type of retread *surface only* was from \$6500 to \$7500 per mile. On one section of road built in 1930 just under 3 per cent of bituminous material by weight was used in the construction, and this particular road showed slight signs of ravel in the early winter. While it does not show signs of absolute failure, it does indicate that approximately 3 per cent of bitumen by weight is as low as possible to insure stability in this type of construction. It has been our policy to use only enough bitumen to prevent ravel. In so doing we have gotten away from the fat surface and the tendency to push and shove which has prevailed in bituminous surface built with a too large per cent of bitumen. We have also encouraged the use of large aggregate, as the combination of fine aggregate and a high per cent of bitumen invariably forms a road surface which will push and shove or distort under traffic.

### Bituminous Macadam

The bituminous macadam top course is placed upon a surface which has been well stabilized by maintenance with the addition of extra aggregate, or the addition of a light water-bound macadam base course. The base should be primed with road oil as previously described under retread. On this base is uniformly spread coarse aggregate No. 1 crushed stone size 4½ inches to 2½ inches. This coarse aggregate is spread with spreader boxes drawn between carefully set berm boards which are brought to a true line and grade as established on the ground by the engineer. This coarse aggregate should be harrowed if it is not uniform in size and should be carefully leveled by hand. The surface should then be lightly keyed by rolling and new aggregate should be added to any depressions to bring the surface to a uniform crown grade. The aggregate is then given an application of approximately 1 gallon per square yard of asphalt A-2 or tar Tp-6 and then rolled. Any depression showing in the surface after this rolling should be patched out with No. 2 coated stone, and a small amount of covering material should then be broomed over the surface and a seal coat of approximately .4 gallon per square yard asphalt CB or tar TH given. A light amount of covering material is uniformly spread over the surface and again thoroughly rolled. The surface is then given a surface treatment

with asphalt CB or tar TM at the rate of approximately .25 gallon per square yard and covering material applied. This covering material is then dragged with a long-base drag or planer. The surface is again rolled and opened to traffic.

In this type of construction in our territory the following amounts of materials have been used per mile on 18 foot pavements: 1800 to 2000 tons of aggregate (bituminous macadam course only); 2000 to 2200 tons of aggregate in waterbound base course; and 18,000 to 22,000 gallons of bituminous material containing from 4½ to 8% of bitumen by weight. There is very little difference between some of our heavy retread tops and a bituminous macadam top, the cost per mile being practically the same.

The principal objection of the traveling public to bituminous macadam or retread surfaces has been to driving motor vehicles through freshly applied surface treatments, necessary from time to time in the course of maintenance. This objection has been minimized by the selection of bituminous surface-treating materials that cure in much less time than the old surface-treating materials. Also the method of applying covering material in small quantities, dragging the surface, then applying more covering material, then rolling the surface, has considerably reduced the time the road is sloppy from such treatments.

### **Rock Asphalt Wearing Course on Bituminous Macadam**

Bituminous macadam to receive a rock asphalt wearing course is built in the usual way except that the surface treatment is omitted, the seal coat may be reduced to about .25 gallon per square yard, and the amount of covering material reduced to just enough to fill the voids. This leaves the surface which is to receive the rock asphalt much more open than would be permitted on a bituminous macadam surface ready to go into service. Upon this newly built bituminous macadam, rock asphalt is spread at the rate of 80 pounds per square yard to give a ¾-inch thickness compacted, or about 100 pounds per square yard for 1-inch thickness. This rock asphalt is carefully leveled by the use of lutes riding on metal strips which gauge the depth of this loose course. The rock asphalt is then rolled lightly, thoroughly planed with a long-base drag or planer until a smooth and uniform surface prevails, and then rolled and opened to traffic.

In this type of construction in our territory about 1800 tons of aggregate, from 12,000 to 13,000 gallons of bituminous material, and the amount of rock asphalt as stated above for the thickness desired, are used per mile.

Because of age and increased heavy traffic, many of our hard surface roads have failed badly within the last few years. Correction of the resulting irregular riding surfaces and ex-

cessive maintenance cost due to such failure have become necessary. We have experimented with several types of bituminous mixtures in resurfacing and have obtained much better results where a type of not less than  $2\frac{1}{2}$  or 3 inches in thickness was adopted. A course of less thickness does not provide sufficient load distribution nor does it permit removal of all the irregularities of the old surface. As a result, the old pavement continues to fail under the light resurfacing whereas it has not done so under the thicker course. A very satisfactory treatment of this problem is the use of a rock asphalt wearing course on bituminous macadam placed on the old hard surface base.

To obtain the best results in using the various bituminous surfaces, the following are salient points to be considered:

1. Proper line and grade cross-section, stability of the old base, and drainage.
2. Smoothing of old base with long-base drag or planer so that the top course will be practically uniform in thickness.
3. Careful selection of the proper type of resurfacing to be used considering the strength of the old road which is to be resurfaced.
4. Careful selection and inspection of materials.
5. Holding bitumen content to a minimum, using only enough to prevent raveling.
6. Mechanical leveling, which will produce ordinarily a smoother riding surface at less cost than the old method of hand leveling.
7. Sufficient rolling. Insufficient rolling has been one cause of failure in bituminous macadam and retread types. Too much rolling is impossible when the bituminous material is in the proper stage of curing.
8. Careful watch of the details of construction. These details often are the difference between mediocre and extra good results.
9. Proper maintenance as in all other types of pavements.

Bituminous types of pavement lend themselves readily to development by stages. The lighter and cheaper oil mats which will carry the traffic satisfactorily on a secondary road may be used as a base for a retread as the road develops into a more important thoroughfare. The retread then may be used, when traffic demands, as a base for a heavy retread or bituminous macadam, which, if deemed necessary, can be surfaced with a rock asphalt wearing course at any time. In such stage construction one has kept the capital investment to a minimum with traffic demands and has arrived in the final stages with a high-type pavement without the outlay of a large sum of money before it is needed, and at a total cost in most cases less than the cost of other types of pavement plus its maintenance and interest on capital investment over a

similar period. Another feature that is interesting is that most bituminous roads become better under maintenance. Further, a large number of people can be satisfactorily served with a fixed yearly revenue by using, where practical, some of the light bituminous surfaces.

## DESIGN FEATURES OF CITY PAVEMENTS

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By request, this paper is confined to a discussion of design features in concrete pavements for city use. It is obvious that design features of pavements, as of any engineering structure, vary with the use. Treatment of this subject logically will deal with a number of broad general situations affecting that use. Design features will vary according to the location of the improvements, whether in an area that is devoted to residential or business purposes. The design will be influenced by existing conditions, i. e., if in an area fully, or nearly completely occupied by residences or business houses, or in an area untouched by previous improvements and wholly undeveloped.

### Design of Profiles

When a pavement is laid in an area in which building grades of existing structures wholly determine the design of profile, the engineer has little opportunity of producing grades that serve any greater purpose than simple utility. His opportunity of designing a profile that is pleasing to the eye of the observer is limited and circumscribed in many cases by the existing building grades which have come into existence at random without any conscious effort at planning. The result, as it relates to the appearance of the profile, is often anything but pleasing.

When designing profiles in an area unhampered by existing structures, as in a new subdivision, the engineer should by all means exercise his artistic sense in order to produce a pavement profile that does not destroy the natural features of the property and landscape. In areas of irregular and rolling topography, particularly in residential areas, paving profiles should follow the topography of the land, preserving, in so far as it is possible, those natural features which are prized by every prospective purchaser as a natural asset. Sharp vertical deflections in the grade lines should without exception be avoided. Vertical curves should be employed at every point