REPORT OF COMMITTEE ON MAINTENANCE

B C TINEY, *Chairman*

Maintenance Engineer, Michigan State Highway Department

The Maintenance Committee undertook during 1929 the study of two subjects, namely:

Maintenance Equipment
Bituminous Surface Treatments and Toppings

MAINTENANCE EQUIPMENT

The subject "Maintenance Equipment" may be summarized under the following headings:

1. Specifications
2. Methods of Purchase
3. History of Development
4. Rental Rates

1. SPECIFICATIONS

An analysis of the specifications which the various State Highway Departments furnish to bidders on equipment, indicates that an attempt is made to cover the essential features of the equipment but to leave the specifications sufficiently general to encourage competitive bidding. Further study of equipment specifications is thought desirable, with a view to developing information on the various features of each type of equipment.

2. METHODS OF PURCHASE

The committee has made a preliminary study with a view to standardizing the form in which information on equipment is submitted by bidders Further work on this phase of equipment purchase is contemplated for the coming year. An extensive investigation of methods of purchasing equipment has been made by a joint committee of the American Association of State Highway Officials and the American Road Builders' Association, the results of which will be reported in the publications of these associations.

3. History of Development

The committee has made a study of the development of maintenance equipment It is expected that further work will lead to improvements in design and suggestions for research

4 Rental Rates

The determination of rental rates for state-owned maintenance equipment does not involve the same consideration as the determination of rates for privately-owned equipment used for construction purposes

In fixing rental rates for state-owned maintenance equipment the following charges should be considered: (1) Depreciation; (2) interest on investment, (3) major or shop repairs; (4) minor or field repairs, (5) storage, incidentals, and equipment overhead, (6) insurance Taxes would not be charged against this class of equipment as would be required witht privately-owned equipment

In general, state-owned maintenance equipment will be used throughout its economical life whereas in the case of privately-owned equipment the necessity for replacement occasioned by frequent changes of specifications for contract jobs will result in the disposal of partly worn-out equipment at commercial prices which are almost invariably less than the economic value of such equipment This makes for a higher rate of depreciation with a resultant increase in the amount of rental charged.

Rental rates should be sufficient to cover, during the economical life of equipment, the initial cost plus other charges as indicated above. The Associated General Contractors use a schedule of rental rates for construction equipment which has been adopted by some of the states for use in connection with maintenance equipment. It is believed that construction equipment receives harder usage than maintenance equipment and consequently should have a higher rental rate applied

Michigan uses rental rates derived from the use of the following formula.

$$R = \frac{I + (D \times O) + (O \times M \times N),}{E}$$

and

$$C = \frac{R}{O},$$

where

R = daily rental
O = original value

N = life of equipment in years
E = No days equipment used during life
M = per cent per year of original value necessary for maintenance (repairs and renewals)
I = interest on $\frac{1}{2}$ original value at 5 per cent for N years
D = per cent of depreciation of original value at the end of N years
C = coefficient by which original value can be multiplied to get daily rental

This formula does not take into consideration charges covering storage, incidentals, equipment overhead, and insurance. Unless accurate data has been kept for several years it becomes necessary to assign more or less arbitrary values to N, E, M and D Coefficients have been revised from time to time when it has been found that values assigned to N, E, M or D were incorrect.

West Virginia uses the Associated General Contractors schedule of rental rates Cost records indicate that the rates are somewhat high.

Rhode Island determines rental rates for the current year through an equalization of the average operating cost for the previous year

Pennsylvania has established a fixed daily rental for each day the equipment is in use This rental rate, in addition to providing for all operating and repair expenses, covers fixed charges, such as. depreciation, storage and insurance

The U S Bureau of Public Roads, Division of Construction, makes a monthly charge of 4 per cent of the last inventory value of a piece of equipment When the project has been completed or at the end of the construction season an adjustment in rentals is made as follows: The equipment is appraised and the difference between the appraised value and the value when the equipment was assigned to the job, plus the cost of needed repairs, the cost of Equipment Depot repair and replacement charges during the construction season and the cost of warehousing, shall constitute the total rental charge against the project.

California rentals are based on upkeep and replacement. Obsolescence has been found to be an important factor in determining rental rates Some equipment is charged on a monthly basis but the majority of equipment is placed on a daily or shift basis with a minimum of ten days' rental per month regardless of use. In the establishing of rates of rental an effort is made to make each district self-

supporting, consequently if the rates used show a profit, the excess is returned to the district in which it was collected

Necessity for Rental Rates. Depreciation, interest and the cost of maintaining equipment is obviously a charge against the project upon which the equipment is used Any maintenance cost data which ignore the item of equipment rental do not give true cost information, and such data are useless for the purpose of comparison California reports that 32 per cent of the total cost of maintenance is due to equipment rental This figure checks rather closely with somewhat limited Michigan information It is approximately correct to say that one-third of maintenance costs are chargeable to equipment rental, hence maintenance organizations that disregard rental charges are only reporting two-thirds of the actual cost

BITUMINOUS SURFACE TREATMENTS AND TOPPINGS

The Committee Report may be summarized under the following headings:

1 Oiling of Earth Roads.
2 Use of Dust Palliative Oils on Gravel, Traffic-Bound Macadam, or other low type Metalled Surfaces.
3 Bituminous Mat Surface Treatments
4 Bituminous Retread and other Mixed-in-Place Types.
5 Penetration Macadam and Similar Types
6 Hot-Mixed Asphaltic Surface Courses

1 Oiling of Earth Roads

Illinois Practice Oiling of earth roads has been practiced extensively on county and township highways in Illinois Reports on this work indicate that a firm subgrade and well compacted surface are necessary to successful treatment. The type of oil most favored is a medium semi-asphaltic oil, which requires heating for application A season's treatment consists of three or four applications of $\frac{1}{4}$ gallon each, at a cost of $450 00 to $600 00 per mile 16 feet wide. These treatments are described as being satisfactory for moderate traffic, being dustless and unaffected by rains during a greater part of the season They are not suitable where any large portion of the traffic consists of horse-drawn vehicles, farm tractors with lugs, or heavy trucks The treatments tend to break up during the winter thaws, and the value of the oil is largely lost, necessitating, as a rule, a complete new treatment each year.

California Practice The use of light oil as a dust layer was begun in Los Angeles County as early as 1898 It is considered to have a very definite field in the maintenance of earth roads under daily traffic of 200 to 300 vehicles Two or three applications are made per season, at the rate of ¼ gallon per square yard for each application Subsequent maintenance consists of blading and scarifying any portions which become rough The cost of this work is given as $200.00 to $250 00 per mile of 18 foot road per ¼ gallon application

Pennsylvania Practice. Oiling of earth roads is considered as being essentially a dust preventative, although the oiled surface with its characteristic of shedding water, is of value in increasing the bearing power of the road. Treatment is temporary and only effective for a few weeks. Practice is to make first application in June, and another application the latter part of August Each application is about 0.2 of a gallon per square yard The road surface should be well drained and dragged to acceptable cross section just prior to application of oil. Oil is applied with pressure distributor and the cost is 6 3 to 6 6 cents per gallon, applied The annual cost of oiling earth roads varies from $300 00 to $350 00 per mile

The U S. Bureau of Public Roads Reports as Follows The use of a light dust palliative oil on well compacted earth roads is indicated The oil may be applied without heating, but application should preferably be made by means of a pressure distributor, at the rate of ⅛ to ¼ gallon per square yard Frequency of applications to lay the dust successfully through an entire season, will depend upon traffic and climatic conditions, one application may prove sufficient, but three or four may be needed

The Oil Processing of Earth Roads is carried on quite extensively in the West, but is successful so to speak only where the traffic is light and soil conditions favorable Sections of road are often selected for this treatment where arid or semi-arid climate exists, or where more expensive types of surfaces are prohibitive. The basic soil should not contain any noticeable amount of coarse gravel or more than 20 per cent clay Fine gravel or sandy soils are considered the more suitable Satisfactory results are usually experienced where practically all of the soil material passes a ¾-inch screen, with the main portions passing a No 10 sieve. The material passing the No 10 sieve should range from this size to a small percentage passing a 200-mesh sieve The roadbeds treated vary in thickness after completion from four to eight inches and carry an average of prob-

ably 7 to 8 per cent bituminous material. Fuel oil containing 60 to 70 per cent asphalt with a penetration around 80 is used in the West at times and is heated to temperature ranging from 100° to 200° F. A fuel oil higher in asphaltic content, however, is often used, as is tar and cutback material. The oil can be spread either from gravity or pressure distributors, but the latter is preferred.

2 The Use of Dust Palliative Oils on Gravel, Traffic-Bound Macadam, or Other Low Type Metalled Surfaces

Indiana Practice. Indiana has treated approximately 350 miles of gravel road with a dust palliative oil during the past season The cost of this work is about $400 00 per mile for two treatments. The purpose is to saturate the top layer of the gravel with light oil that will hold the dust without forming a mat on the surface On the road surface, before treatment, there should be about a one-inch layer of maintenance gravel, slag, or hard stone, which aggregate should be clean and free from clay and silt The road surface should be smooth and free from holes before the oil is applied The practice consists in first scraping all loose gravel to the side of the road, then applying the oil to the road, and then scraping the loose material back over the road The first application of oil consists usually of about ½ gallon per square yard A second very light application of ⅛ gallon per square yard may be applied as soon as dust begins to be in evidence

The U. S Bureau of Public Roads reports the use of dust palliative oils on macadam, shell and gravel roads Cold application oils are applied with pressure distributors at the rate of ⅛ to ¼ gallon per square yard From one to four applications may be necessary per season, depending on traffic and climatic conditions

Michigan Practice Light asphaltic oil has been used to a rather limited extent during the past few years as a dust palliative on gravel roads in Michigan The oil used conforms to the following specification·

The asphaltic oil shall be homogeneous, free from water, and shall meet the following requirements

(a) Specific gravity, 25°/25° C (77°/77° F)—not less than	0 900
(b) Flash point, not less than	80° C = 176° F
(c) Specific viscosity (Engler, 50 cc at 25° C)	15 to 30
(d) Loss on heating at 163° C, 20 gm, 5 hrs, not over	30 per cent
(e) Total Bitumen, not less than	99 8 per cent

Note—This oil does not require heating for application

Application was made by means of a pressure distributor at the rate of approximately 1/5 gallon per square yard for the initial application early in the summer, and this was followed, after an interval of from four to six weeks, with a second application of about 1/8 gallon per square yard The ideal condition for application of this treatment is to have a thin coating of gravel, ranging in size from 1/2 to 1/8 inches, uniformly distributed over the surface. The use of this oil does not contemplate the formation of a mat, and in fact, every effort is made to avoid forming a mat. Subsequent maintenance is conducted with patrol graders which float the thin cover of loose material daily and do the necessary cutting of the surface to eliminate chatter-bumps The two applications mentioned are usually sufficient for satisfactory dust laying over a period of approximately three months The relation between the amount of oil applied and the amount of loose gravel on the road surface is important, and an excess of oil will result in a glazed surface which soon becomes very rough under traffic The results which may be obtained with light oil treatments are comparable to those which may be obtained with calcium chloride The cost of these treatments has varied between $300 00 and $400 00 per mile per season

3 Bituminous Mat Surface Treatments

Rhode Island Practice The use of a 45 per cent cutback asphaltic oil in surface treating old waterbound macadam or gravel roads is reported The treatment consists of 1/3 gallon of asphaltic oil per square yard, covered with 8 to 10 pounds of clean, sharp sand Two to three weeks after treatment, the surface is gone over with a light planer which removes material from the high spots and deposits it in the holes where it is compacted by traffic The average cost per mile of this treatment for 1929 is reported as $562 20 This type of treatment is applied on roads which are from ten to twenty-five years old

A process in Rhode Island is also reported indicating that earth roads are covered with a four to six inch compacted course of gravel and then treated with 3/4 gallon per square yard of cold application tar in two applications. This is followed after an interval of from six to eight weeks, with an additional seal coat of 1/4 to 1/3 gallon per square yard of a 65 per cent to 85 per cent asphaltic oil, and covered with clean, sharp sand, or stone chips The cost of this process is indicated from $3000 00 to $5000 00 per mile Such roads are reported to be carrying from 8000 to 9000 vehicles per day with vehicular weights up to 28,000 pounds

Pennsylvania Practice Bituminous Surface Treated Oil Bound Macadam. Oil bound macadam is constructed by placing about two inches of ¾ to ⅛-inch stone over prepared base, which may be either slag, gravel or stone Upon the stone so spread, there is applied about ¾ of a gallon of bituminous material, in two applications. It is necessary to surface treat the roads so constructed oftener than the heavier type bituminous surface treated macadam That is, the oil bound macadam should be treated every two years with about ¼ of a gallon of bituminous material to the square yard and about 25 pounds of chips. The cover material ranges in size from ⅝ inch to 1¼ inches

Pennsylvania Practice Bituminous Surface Treated Macadam Bituminous surface treated macadam consists of a waterbound macadam sealed with a bituminous surface treatment The initial surface treatment is made immediately following construction and thereafter treatments are required approximately every three years At the time of construction the macadam is bound with screenings and water and is opened to traffic for a short time The road is allowed to cure under traffic for one to three weeks until the excess screenings are worn off, then a treatment is given using 0 3 of a gallon bituminous material per square yard, which is not covered After this material has penetrated, a second application of 0 2 of a gallon per square yard is given and is covered with approximately 25 pounds of commercial ¾-inch stone ranging in size from ⅝ to 1¼ inches The successive treatments comprise applications each of ¼ gallons per square yard of bitumen and covering of 25 pounds per square yard of commercial ¾-inch stone.

Indiana Practice Indiana treats, each year, several hundred miles of bituminous macadam roads, treatments being applied generally about every other year Cover material on these treatments is dragged to increase the smoothness of the road In treating new waterbound macadam roads, Indiana has used to some extent two applications of liquid asphalt at the rate of approximately ¼ gallon per square yard each

West Virginia Practice West Virginia is continuing the work of placing asphaltic surface treatments on shale and gravel roads This form of maintenance is regarded as successful on these types.

The U S Bureau of Public Roads Reports as Follows A light oil surface treatment of crushed rock or gravel traffic-bound macadam consists of impregnating the upper portions of the consolidated metalling with a light fuel oil The roadbed is first thoroughly cleaned with brooms to remove all loose material and expose a firm

pitted surface Light oil is applied under pressure at the rate of 0.2 of a gallon per square yard and left to penetrate Two or three days may be required for satisfactory penetration during which time the road should be closed to traffic, and at this stage any minor imperfections in the surface may be repaired with a lean mixture of oil and suitable aggregate A second application of oil, at the rate of 0 2 of a gallon per square yard is then applied and allowed to penetrate for several days without traffic Stone chips in the amount of 10 to 25 pounds per square yard, depending upon the viscosity of the oil, are then applied

Road oils, heated or cold, are used in forming thin wearing mats or carpets on macadam pavements which may be maintained or built up by subsequent treatments as desired Successful treatments of this class require that the road surfaces shall be in good state of repair, well consolidated, free from holes or depressions, and must be thoroughly swept for the removal of dust and detritus before the applications are made Newly constructed pavements should be permitted to thoroughly consolidate under traffic before the oil is applied The oils may be applied either cold or hot according to the class selected, and the initial applications should be made by means of pressure distributors at the rate of from one-third to one-half gallon per square yard It should then be covered with a uniform layer of dustless broken stone, all of which will pass the $\frac{1}{2}$ or $\frac{3}{4}$-inch laboratory screen, or with pea gravel, which will pass a $\frac{1}{2}$-inch laboratory screen in an amount just sufficient to absorb the bitumen and prevent the surface from picking up under traffic Subsequent applications may be by a pressure distributor or by brooming the oil uniformly over the road surface From 0 1 to 0 2 gallon will usually prove sufficient, and this should be covered with coarse sand or stone chips which will pass a one-inch laboratory screen

When hot oil is used it should be heated to a temperature of 200° F to 250° F To secure best results the treatments should be applied in the early summer except in localities where snow and freezing weather are not found Under favorable conditions the cold treatment should last throughout an entire season, while the hot application method should last for several years with the necessary occasional patching.

Michigan Practice Waterbound macadam roads are surface treated by first sweeping the surface to an exposure of larger stone, and then making two applications of approximately $\frac{1}{4}$ gallon per square yard each, using, in general, a cold application surface treat-

ment tar Stone chips, or pea gravel, in the amount of approximately 20 pounds per square yard, are used as a cover on the second application Gravel roads are treated in practically the same manner, being prepared in the early spring by shaping to proper cross section with a heavy grader and possibly scarifying some portions Proper drainage and subgrade conditions are very essential in the successful surface treating of gravel roads Tars are preferred for initial applications on either macadam or gravel roads, but asphalts have been successfully used in treatments other than first year treatments Hot application materials are also considered preferable, excepting for initial treatments, as it is believed that there is less inconvenience to traffic where hot application materials are used

California and Oregon Practice Bituminous surface treatments are applied to tightly bound crushed gravel and rock, or screened gravel roads Asphaltic oil heated to a temperature of 150 to 200° F. is applied with a pressure distributor. The road surface is prepared by sweeping with a revolving broom until the dust is removed and the imbedded rock exposed The first application is made at the rate of $\frac{1}{4}$ gallon per square yard, and is allowed to penetrate for a period of from 6 to 24 hours The second application of $\frac{1}{4}$ gallon per square yard is then made, and this is covered with an application of stone chips or pea gravel, from $\frac{3}{4}$ to $\frac{1}{8}$ inch in size Proper drainage and subgrade conditions are considered very important in this work. Subsequent maintenance consists of skin patching in the shallow holes, or the use of cold-patch mixtures

4 Bituminous Retread and Other Mixed-in-Place Types

Indiana Practice Bituminous retread top, as constructed in Indiana, consists of placing a course of stone, two to four inches in thickness, on a prepared gravel, or macadam, base This stone may range in size up to $2\frac{1}{2}$ inches It is first shaped with a grader and rolled to proper cross section The first application of bituminous material is applied and allowed to cure, after which the surface is rolled and any inequalities corrected by use of a grader. The second application of bituminous material is then applied and allowed to cure, after which the surface is again rolled. An application of stone chips is then placed on the surface and thoroughly broomed into the voids A third application of bituminous material is then placed, a covering of stone chips added, and the surface thoroughly dragged with a long base drag or planer The surface is then given a final

rolling and is opened to traffic. An additional seal coat of bituminous material may be necessary at a little later date if the surface appears to be too open

Michigan Practice Retread tops, two inches in thickness, are constructed in Michigan on gravel or macadam bases, according to the following method; the gravel or macadam base, if it has not been previously surface treated, is given a prime coat of bitumen at the rate of about $\frac{1}{4}$ gallon per square yard Stone, ranging in size from $\frac{5}{8}$ to $1\frac{1}{4}$ inches, is placed on the prepared base to such depth as will compact to approximately two inches This aggregate is then brought to proper cross section with graders and is given an application of about $\frac{3}{4}$ of a gallon per square yard of bitumen The stone is then bladed back and forth across the road during the time the bituminous material is setting up This blading process is continued until the stone is thoroughly coated with bitumen, at which time the mixture is bladed to proper cross section and rolled A seal coat of about $\frac{1}{4}$ gallon per square yard is then applied, followed by an application of stone chips and additional rolling The cost of this method is approximately 50 cents per square yard for two-inch thickness

West Virginia Practice. A two-mile section of retread on a gravel base has been placed in West Virginia and this surface has given satisfactory service for three years under a rather heavy truck traffic

The U S Bureau of Public Roads reports the following general procedure in the construction of retread without use of a roller:

1 Scarify and reshape old base, adding additional stone if necessary, or merely sweep base clean of dust and dirt, if it is of proper cross section and grade and well solidified
2. Spread layer of stone about 2 inches thick (use $\frac{3}{4}$ to $1\frac{1}{2}$-inch stone).
3 Treat with 0 5 to 0 75 gallons per square yard of bitumen
4 Blade surface to proper cross section
5 Continue blading to maintain desired cross section until the surface begins to set.
6 At the end of four or five days after the surface has set, apply about $\frac{1}{4}$ gallon of bitumen followed by light cover of stone chips Traffic is permitted to operate continuously during the entire construction.

The U. S Bureau of Public Roads reports the following practice in a mid-western state on the construction of retread, using a roller:

1 Scarify and reshape old base if necessary or merely sweep it clean of dust and dirt.

2. Spread layer of stone to the desired thickness (2, 2½ or 3 inch loose, use 1¼-2 inch stone) (1 inch loose, use ¾ to 1¼ inch stone).
3. Roll stone lightly.
4. Apply first treatment of bitumen (about 0.4 gallon per square yard).
5. Blade immediately, only disturbing top layer.
6. Roll immediately after blading and again after two days.
7. Fill surface voids with stone chips applied sparingly.
8. Apply light treatment of bitumen after first treatment has set (about 0 2 gallon per square yard).
9. Drag surface, preferably with light drag.
10. Roll chips into surface after dragging.
11. In about two weeks apply still lighter coat of bitumen (about 0 15 gallon per square yard).
12. Cover sparingly with chips and roll thoroughly.

The thickness of layer and size and quality of the stone used, as well as the quantities of bitumen applied, will necessarily vary under different traffic and other pertinent conditions.

There are numerous procedures followed in the processing of mixed-in-place roadbeds, one method consists essentially of scarifying, shaping and pulverizing the old surface after which the bituminous material is applied in one or more applications by means of gravity or pressure distributors The surface is disced slightly after each application This, as a rule, proves valuable in preventing loss of the light constituents of the bituminous material Mixing is carried on by means of the blade grader, the procedure being to carry the treated material from one side of the road to the other This process is continued until a uniform mixture is secured, after which the material is evenly spread, shaped and allowed to compact under traffic.

While processing the existing surface of roadways is at times successful, it should be avoided provided sufficient funds are available to build up a new course for treatment. Working direct on the existing surface necessitates breaking up the wearing surface or natural crust, uncovering at times unstable areas which fail after the mixed course is formed. For this reason it is best to leave the crust formed on the traveled way undisturbed where possible, and spread for mixing purposes a layer of the best material at hand

California Practice Description is given of a mixed-in-place treatment which is usually applied to a base which is metalled either

with crushed rock or gravel, the binder of which is deficient in cementing qualities The base is scarified to a uniform depth of three to four inches, and then harrowed A fuel oil heated to 150 to 200° F. is then applied with a pressure distributor at the rate of approximately 1½ gallons per square yard. The road is then harrowed, after which oil is mixed with the aggregate by blading the mixture back and forth across the road This mixing is continued until the aggregate is quite thoroughly coated, after which it is bladed to proper cross section and opened to traffic. Dragging is continued over a period of about seven days to eliminate any ruts which may be produced by traffic Obstructions are placed in the middle of the roadway to force traffic to use the edges in order to thoroughly compact them.

5. Penetration Macadam and Similar Types

West Virginia Practice A modified type of bituminous macadam called "Puddle Macadam" is constructed in West Virginia The method consists of placing a four-inch course of stone on a prepared base and rolling same just enough to shape and compact the loose stone, but not enough to crush or break the stone. Stone screenings and dust are then spread over the surface to a depth of about ¼ of an inch over the top of the stone, and this is then rolled and dust added where necessary until no movement is discernible under the roller. The surface is then swept clean of any surplus screenings or dust, and an application of cold tar is made at the rate of one gallon per square yard A cover of stone chips is then added and the surface is again rolled Traffic uses the road at all times except for a few minutes when the bituminous material is being poured and the cover coat applied

Pennsylvania Practice Bituminous Penetration Macadam. In the construction of bituminous penetration macadam, the aggregate used for the lower course is stone ranging in size from 1¼ to 2¾-inch, and an application of 1 85 gallons per square yard of asphaltic oil is given. Then a covering of 60 pounds per square yard of commercial ¾-inch stone, which is followed by a treatment of 0.3 of a gallon per square yard of asphaltic oil. After this treatment has penetrated sufficiently, an application of 0 35 gallon of bituminous material is given and covered with 30 pounds per square yard of ⅛ to ⅝-inch chips

In the final application of 0 35 gallons per square yard, tar is used instead of asphalt in order to improve tractive quality of sur-

face. Penetration macadams require successive treatments at four or five-year intervals after construction These treatments of bituminous penetration macadam are the same as successive treatments of bituminous surface treated macadam and oil bound macadam.

Michigan Practice. Bituminous macadam by the penetration method A 3-inch course of stone ranging in size from ½ to 3 inches is placed on a prepared macadam base, and spread uniformly to proper cross section The stone is then thoroughly rolled and irregularities corrected during the process of rolling. Hot bituminous material is then applied with a pressure distributor at the rate of 0 7 to 0 8 of a gallon per square yard, per inch of thickness Coarse chips are then applied and thoroughly broomed into the voids The surface is then thoroughly rolled and a seal coat of bitumen applied at the rate of ¼ to ½ gallon per square yard This is followed by a cover of fine chips and additional rolling. A second seal coat of about ¼ gallon per square yard is applied, preferably a few months after the road has been placed under traffic Fine chips are used to cover the second seal coat

California Practice A type of surface course called "Armor Coat" is used in California This treatment consists of two separate applications of heavy asphaltic road oil on an adequately metalled and traffic-bound base, following a prime coat of light fuel oil The roadway is first swept with a power broom until the dust has been removed and the imbedded stone exposed after which the prime coat is applied and allowed to thoroughly penetrate the base The first application of asphaltic road oil is then made at the rate of 0 2 to 0 25 gallons per square yard and is followed with an application of 30 to 40 pounds of stone chips per square yard The surface is then rolled with a six-ton roller The surface is again swept and a second application of asphaltic oil is placed at the rate of 0 2 of a gallon per square yard Thirty to thirty-five pounds of stone chips per square yard are then applied and the surface rolled The result is a non-skid surface, which is successfully carrying traffic up to 2000 vehicles per day. The cost of the treatment is reported as approximately 20 cents per square yard

Oregon Practice A so-called "Multiple Lift" type of surface is used to some extent in Oregon It consists of light courses of 1½ to ¾-inch crushed rock, oiled and rolled, which, after the desired thickness has been secured is oiled and sealed with stone chips The oil is first applied and after covering with stone, is levelled with a

blade grader and then rolled Each lift is complete in itself, with the exception of the seal coat, and the use of the blade grader insures a very smooth job

Indiana Practice Indiana reports constructing in 1929 more than 100 miles of rock asphalt surface on penetration macadam Standard penetration macadam is built on any suitable base, using only $1\frac{1}{4}$ gallons of bituminous material per square yard for $4\frac{3}{4}$-inch depth of loose aggregate This leaves a very lean, open surface, on which is placed from 80 to 100 pounds of rock asphalt per square yard By a suitable levelling and planing process, the surface is made very smooth and uniform The service record of this type of surface does not extend over a sufficient period of time to draw definite conclusions on maintenance upkeep, but there is every indication that, under normal traffic, the maintenance cost will be very reasonable Tractors with lugs, and heavy horse-drawn traffic, damage this type during the warm season, and it should not be constructed where such traffic is heavy.

6 Hot Mixed Asphaltic Surface Courses

Michigan Practice During the past six years Michigan has laid approximately 113 miles of 18-foot width asphaltic surfaces on gravel and macadam bases This work consists of stone filled sheet asphalt laid to a depth of 2 inches, and of sheet asphalt laid to a depth of $1\frac{1}{2}$ inches The original gravel or macadam base is widened where necessary with gravel, crushed stone, or slag, and given a prime coat of bitumen applied at the rate of about $\frac{1}{4}$ gallon per square yard A black base mixture is then placed and rolled for the purpose of eliminating high crown, or any irregularities in the base, as well as to strengthen the base. The top course of sheet asphalt, or asphaltic concrete, is then placed and rolled The average cost of top course for five years' work is $1.04 per square yard The average cost per mile of this construction, including shoulder work, is $17,300 00 Work is performed with state-owned asphalt plant and force account organization