HIGHWAY RESEARCH BOARD
DIVISION OF ENGINEERING AND INDUSTRIAL RESEARCH
NATIONAL RESEARCH COUNCIL

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Wartime Road Problems

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No. 10

SALVAGING OLD HIGH TYPE FLEXIBLE PAVEMENTS

HIGHWAY RESEARCH BOARD
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HIGHWAY RESEARCH BOARD

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Wartime Road Problems

There are two major wartime road responsibilities; to keep the traffic essential to the war effort moving, and to carry the existing roads through the war period in as good condition as possible. Discharge of these responsibilities entails consideration of many new factors in view of the limitations on time, money, labor, equipment and use of critical materials imposed by the exigencies of the national situation. Obviously, changing emphasis from devising better and more economical methods to a program, within the wartime limitations of wartime traffic movement and conservation of the existing roads confronts highway engineers with many new problems and new aspects of old problems.

The Highway Research Board believes that it can be helpful by aiding in disseminating in usable form the best available information on those phases of highway technology in which common practice has not become established or in which practice must be modified during the war. To this end a series of bulletins on WARTIME ROAD PROBLEMS will be prepared by qualified committees and published by the Highway Research Board. Recommendations in this series of bulletins are based upon wartime restrictions and needs and are only intended for use as guides during the periods in which these conditions prevail.

This program has been endorsed by the Executive Committee of the American Association of State Highway Officials.

Suggestions for suitable subjects will be welcomed.

The following report on salvaging old high-type pavements is of immediate importance. The recommendations, however, are general and need not be restricted to wartime practice as they apply whenever the described conditions prevail.

TABLE I. PRINCIPAL USES OF VARIOUS GRADES OF TARS AND ASPHALTS

Usually for any particular project, any one of two or more different grades of bituminous materials may be used with satisfactory results. Howeve, this is not always true as the kind of aggregate may dictate the particular grade of bituminous material that will give best results. Generally the heaviest grade of liquid asphalt that can be readily incorporated with the aggregate being used and which produces a mix that can be readily and uniformly spread will result in the most service for the money expended.

Frequently, on account of its slower drying character, MC material of one number higher grade than RC used on similar work would be used on road mix or cold plant mix construction.

CLASS OF WORK	GRADE OF BITUMEN: Slow Curing Road Oils						Medium Curing Cutback Asphalts						Rapid Curing Cutback Asphalts						Emulsified Asphalts						Tars														AC-Asphalt Cements Penetration							
	SC 0	SC 1	SC 2	SC 3	SC 4	SC 5	MC 0	MC 1	MC 2	MC 3	MC 4	MC 5	RC 0	RC 1	RC 2	RC 3	RC 4	RC 5	RS 1	MS 1	MS 2	MS 3	SS 1	SS 2	RT 1	RT 2	RT 3	RT 4	RT 5	RT 6	RT 7	RT 8	RT 9	RT 10	RT 11	RT 12	RT CB 5	RT CB 6	50 60	60 70	70 85	85 100	100 120	120 150	150 200	200 300
1. DUST PALLIATIVE, on dirt or dirty aggregate	X	X	X	–	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X(1)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2. SOIL STABILIZATION, base	–	–	–	–	–	–	–	–	X	–	–	–	–	–	X	–	–	–	–	–	–	–	–	X	X	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3. BLOTTER OR MULCH TREATMENT, excess of fines	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X(1)	–	–	–	–	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4. PRIMING																																														
a. Tightly bonded surface	–	–	–	–	–	–	X	X	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
b. Loosely bonded fine agg. surface	–	–	–	–	–	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	X(1)	–	–	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
c. Loosely bonded coarse agg surface	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5. TACK COAT																																														
a. Bituminous Surface	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	–	–	–	X	–	–	–	–	–	–	–	–	–	–	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–
b. Brick and Concrete	–	–	–	–	–	–	–	–	X	–	–	–	–	–	X	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–
6. SURFACE TREATMENT, seal or skin																																														
a. With or without light sand cover	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	X	–	–	–	–	–	–	–	–	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
b. Coarse sand cover	–	–	–	–	–	–	–	–	X	–	–	–	–	X	X	–	–	–	X	–	–	–	–	–	–	–	–	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
c. Clean ¼-in. aggregate cover	–	–	–	–	–	–	–	–	X	X	–	–	–	X	X	–	–	–	X	–	–	–	–	–	–	–	–	–	–	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–
d. Clean ½-in. aggregate cover	–	–	–	–	–	–	–	–	–	X	X	–	–	–	X	X	–	–	X	–	–	–	–	–	–	–	–	–	–	–	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	
e. Clean ⅝-in. aggregate cover	–	–	–	–	–	–	–	–	–	X	X	X	–	–	–	X	X	–	X	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	–	–	–	–	–	–	–	–	–	–	–	X
f. Clean ¾-in. aggregate cover	–	–	–	–	–	–	–	–	–	–	X	X	–	–	–	–	X	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	X	X	X	–	–	–	–	–	–	–	–	X	X	–
g. Graded gravel aggregate	–	–	–	–	–	–	–	–	X	X	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–
h. Gravel mulch	–	–	X	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	X(1)	–	–	–	–	–	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7. DRAGGED LEVELING COURSE																																														
a. Open graded aggregate	–	–	–	–	–	–	–	–	–	X	X	–	–	–	–	X	–	–	–	X	X	–	–	–	–	–	–	–	–	X	X	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–
b. Dense graded aggregate	–	–	–	–	–	–	–	–	X	X	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	–	–	–	X	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–

(1) Emulsified asphalt to be diluted, 3 parts emulsion to 9 parts water.

TABLE I—*Continued*

8. ROAD MIX						
a. Open graded aggregate						
1. Sand	– – – – – –	– – – X – –	– X X – – –	– X – – – –	– – – – – X X – – – – – – –	– – – – – – – –
2. Max. dia. 1", high percent passing 10 mesh	– – – – – –	– – – X – –	– – – – – –	– – – – – –	– – – – – X X X – – – – – –	– – – – – – – –
3. Macadam aggregate	– – – – – –	– – – – – –	– – X X – –	– X – – – –	– – – – – – X X X X – – – –	– – – – – – – –
b. Dense graded aggregate	– – – – – –	– – – – – –	– – – – – –	– – – – – –	– – – – – – – – – – – – – –	– – – – – – – –
1. High percent passing 200 mesh	– – X X – –	– – X – – –	– – – – – –	– – – – – –	– – – – – X X X – – – – – –	– – – – – – – –
2. Max. dia 1", medium passing 200 mesh	– – – X – –	– – X X – –	– – – – – –	– – – – – –	– – – – – – X X X – – – – –	– – – – – – – –
9. BITUMINOUS (HOT PENETRATION) MACADAM						
a. Warm climates	– – – – – –	– – – – – –	– – – – – –	– – – – – –	– – – – – – – – – – – X – –	– – – X – – – –
b. Northern climates, summer	– – – – – –	– – – – – –	– – – – – –	– – – – – –	– – – – – – – – – – – X – –	– – – X X X – –
c. Northern climates, cool weather	– – – – – –	– – – – – –	– – – – – –	– – – – – –	– – – – – – – – – – X X – –	– – – X X X – –
10. COLD PENETRATION MACADAM	– – – – – –	– – – – – –	– – – – – X[3]	X – – – – –	– – – X X X – – – – – – – –	– – – – – – – –
11. SEAL COAT, new construction	– – – – – –	– – – – X X	– – – X X X	X – – – – –	– – – – – X X X X X X – – –	– – – X X X – –
12. COLD PATCH						
a. Open graded aggregate	– – – – – –	– – – X X –	– – X – – –	– – – X – –	– – – – – – – – – – – – X X	– – – – – – – –
b. Dense graded aggregate	– – – – X X	– – X X – –	– – – – – –	– – – – – –	– – – – – – – – – – – – X X	– – – – – – – –
13. PLANT MIX, COLD LAID						
a. Open graded aggregate						
1. Sand	– – – – – –	– – – – – –	– – X X – –	– – – – – –	– – – – – – – X X X – – – –	– – – – – – – –
2. Max. dia. 1", high percent passing 10 mesh	– – – – – –	– – – – – X	– – – X – –	– – X – – –	– – – – – – – X X X – – – –	– – – – – – – –
3. Macadam aggregate	– – – – – –	– – – – – –	– – – – X X	– – – X – –	– – – – – – – – X X X – – –	– – – – – – – –
4. Macadam aggregate, liquefier type	– – – – – –	– – – – – –	– – – – – –	– – – – – –	– – – – – – – – – – – – – –	– – – X – – – –
b. Dense graded aggregate						
1. High percent passing 200 mesh	– – – – X X	– – – X X –	– – – – – –	– – – – X –	– – – – – – X X X – – – – –	– – – – – – – –
2. Max. dia. 1", medium pct. passing 200 mesh	– – – – – –	– – – – X X	– – – – – –	– – – – X –	– – – – – – X X – – – – – –	– – – – – – – –
c. Primer to be followed with soft AC	– – – – – –	X – – – – –	– – – – – –	– – – – – –	– – – – – – – – – – – – – –	– – – – – – – –
14. PLANT MIX, HOT LAID						
a. Sheet asphalt	– – – – – –	– – – – – –	– – – – – –	– – – – – –	– – – – – – – – – – – – – –	X X X X – – – –
b. Bituminous concrete	– – – – – –	– – – – – –	– – – – – –	– – – – – –	– – – – – – – – – – X X – –	X X X X X X – –
c. Medium hot, Class F	– – – – – –	– – – – – X	– – – – – X	– – – – – –	– – – – – – X X X X – – – X	– – – – – – – –
d. Medium hot, oil-aggregate	– – – – X X	– – – – – –	– – – – – –	– – – – – –	– – – – – – – – – – – – – –	– – – – – – – –
15. CRACK FILLER	– – – – – –	– – – – – –	– – – – X X	X – – – – X[2]	– – – – – – – – – – X X – X	X X X X – – – –

(2) To be mixed with sand but producing a flowable mix. (3) Modified type penetration macadam, RC-3 applied hot.

SALVAGING OLD HIGH-TYPE FLEXIBLE PAVEMENTS

High type flexible pavements are those flexible pavements which cannot be readily scarified to mix the surface and base material. They include bituminous concrete, sheet asphalt, penetration macadam and the heavier surfaces of the road mix type.

It is important that repairs be made promptly to stop rapid spreading of disintegrating areas, to reduce the total amount of repair material required; and to save tires which may be seriously damaged by the sharp edges of potholes. Labor costs generally will be reduced by prompt repair work.

Four methods of salvaging old high-type flexible pavements are presented:

1. Patching.
2. Temporary Maintenance, Repairs and Resurfacing of Pavements Awaiting Deferred Construction.
3. Substantial Resurfacing where Reconstruction is not Anticipated.
4. Widening.

The method which should be followed on any particular road will be determined principally by the condition of the highway, availability of materials and labor, nature and amount of traffic, present grade and alignment and the predicted use of the highway in future years. As long as the country is at war it will be desirable as far as practical to use Methods 1 or 2. However, to prevent serious damage to important roads which serve heavy traffic, substantial resurfacing and sometimes widening as described under Methods 3 and 4 should not be delayed too long. Serious breaking down of the old road would materially reduce its future value as a base.

TERMINOLOGY AND REFERENCE CITATIONS

Bituminous Materials

AC—Asphalt Cement: Classified according to penetration ranging from 0 to 300. Standard grades are AC, 40–50; AC, 50–60; AC 60–70; AC, 70–85; AC, 85–100; AC, 100–120; AC, 120–150; AC, 150–200; AC, 200–300. Asphalt cements should comply with Federal Specification SS-A-706 b.[1]

RC—Rapid Curing Cutback (AC plus highly volatile distillate): grades RC – 0 to RC – 5.

MC—Medium Curing Cutback (AC plus medium volatile distillate): grades MC – 0 to MC – 5.

RC and MC Cutback asphalts should comply with one of the following specifications:

Federal Specification SS – A-671a
American Association of State Highway Officials Specification M81 – 42, M82 – 42
American Society for Testing Materials Tentative Specifications D597 – 40T, D598 – 40T
Specifications of the Asphalt Institute

SC—Slow Curing Liquid Asphaltic Material (sometimes called road oil)[2] (Residual oil or AC plus low-volatile distillate): grades SC – 0 to SC – 5. Slow Curing Road Oils should comply with the specifications of the Asphalt Institute.

RS—MS—SS—Emulsified Asphalts (AC plus water plus emulsifying agent): rapid setting, grade RS-1; medium setting, grades MS-1 to MS-3; slow setting, grades SS-1 to SS-2. Emulsified Asphalts should comply with the Specifications of the Asphalt Institute.

RT—Road Tar: grades RT-1 to RT-12

RTCB—Tar Cutback: grades RTCB-5 and RTCB-6.

Tars should comply with one of the following specifications:

American Association of State Highway Officials Specifications M52 – 42
American Society for Testing Materials Tentative Specification D490 – 43 T

Table 1 gives the appropriate uses of various grades of tars and asphalts.

[1] Specifications are obtainable as follows:
Federal, Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
American Association of State Highway Officials, National Press Building, Washington 4, D. C.
The Asphalt Institute, 801 Second Avenue, New York 17, N. Y.
American Society for Testing Materials, 260 S. Broad Street, Philadelphia, Pa.

[2] At this date (April 1945) the use of road oil is unrestricted except in the States of Washington, Oregon, California, Nevada and Arizona.

Aggregates

Numbers indicating sizes of aggregate refer to Simplified Practice Recommendation R163 – 39 prepared under the direction of the National Bureau of Standards.[3]

The term "local aggregate" refers to local materials unprocessed or but lightly processed, such as bank or creek gravel, field stone picked up from fields or creeks, crusher run stone or gravel wherein the stone or gravel is run through the crusher to reduce the over-size but is not screened.

METHOD 1. PATCHING

Thorough patching of a pavement is warranted when defects, due to surface or base failures have developed although a substantial part may be in good condition. This subject is treated under the following subdivisions: Preparing for the Patch, Paint Patching, Patching with Premixed Material, Patching Mixtures, Methods of Making Patching Mixtures, Patching with Road Mix, and Cold Weather Patching.

Preparing for the Patch

Two conditions of the old surface will be considered: (1) where the old pavement can be used as a base for the patching material and (2) where it is necessary to dig out and reconstruct the base.

Where the Old Pavement Is Suitable as a Base

Patches may have feather edges (wedge shape) or vertical edges. Feather edge patches may be very satisfactory in hot weather, especially where the old surface shows rich in bitumen. In cold weather and when the old surface shows an absence of bitumen vertical edges are preferable. For a feather edge patch, the old surface is simply cleaned of all loose or caked dirt and foreign material. The vertical edge patch requires cutting out some of the old pavement to form the required edge. A paving breaker operated by air pressure is a suitable tool for cutting the vertical edge and removing the old surface to the required depth.

Heating and raking off the old surface preparatory to patching a sheet asphalt pavement is a successful method. At the places where the old pavement is cracked, disintegrated or irregular, it is warmed with a surface heater and raked off to a depth of $\frac{3}{4}$ in. to $1\frac{1}{4}$ in., care being taken to remove all burned material. Reheating and raking two or more times may be required to remove high spots. The heated material thus raked off is sometimes used to fill holes in alleys or little used streets, and either lightly tamped or compacted under traffic. This heating method may be used also on an old fine-graded bituminous concrete pavement but it is not satisfactory with the coarse graded type.

Where the patch is to be less than 2 in. thick, a thin paint coat of bitumen should be applied to guarantee the proper union of the old surface and the patching material. The bitumen may be sprayed on the surface or applied with a brush. This paint coat is most necessary on the edges of the area to be patched, whether of the feather or vertical edge type. For this paint coat a number of grades of bitumen are satisfactory. RC-2, RC-3, RT-5, RS-1 or MC-5 may be used. An asphalt cement of 85 to 100 or 100 to 120 penetration is satisfactory when thinly spread hot. Before RS-1 is applied, the surface should be dampened with water (no pools). If a light grade of bitumen is used, it should be allowed sufficient time to become tacky before the patching material is placed. It is desirable that all the surface be uniformly coated and important that no excess of bitumen be used. While the condition of the old surface will determine the amount of paint coat required, usually 0.2 gal. per sq. yd. of bitumen will be the maximum. An excess may make difficulty later through being absorbed in the patching mixture, thus causing it to become unduly soft.

Digging Out and Replacing Foundation Material

This class of repair is needed where the base has failed badly in spots but the adjacent pavement is holding well. In preparing for patching at such places, it is advisable to excavate the soil to a greater depth

[3] Obtainable from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

by 4 in. or more, than that of the old foundation which failed. Pockets of soft, unstable base soil should be replaced with stable material.

Poor drainage, accompanied by wet weather springs, often will be recognized as the cause of base failure. If so, before the patches are made, drainage should be provided by perforated pipe, sewer pipe or French drains leading into the side ditches or other drainage outlets in order to lower the ground water level. On plastic clay soil it is most important to provide drainage from the base material through the shoulders to the side ditches. Drains are particularly required at the bottom of or along grades where water seeps from outcrops of

FIG. 1.—Compacting base aggregate with a gas vibrator in a patch too small to roll.

horizontal strata of rock, shale, or other impervious soil.

On clay foundation soil, 1½ to 2½ in. of fine aggregate, preferably crushed stone or slag screenings, should be spread before the base course aggregate is placed for the patch foundation. This prevents the saturated clay soil from being forced up into the coarse aggregate and weakening the base structure. Upon this fine aggregate is placed coarse aggregate, well compacted in layers not exceeding 4 in. thick and properly filled with screenings. It may be desirable to compact the base material with an air hammer or vibrator when patches are too small for rolling of the foundation courses. Where the amount of patching material required is small, the base course may be a bituminous mixture which, when properly tamped, is a better guarantee against future settlement than uncoated aggregate. On the base is placed a new bituminous top which may consist of one of the mixtures described under *Patching Mixtures*. Frequently the broken-up old pavement may be used satisfactorily as a part of the base aggregate.

Paint Patching

Paint patching (sometimes called skin patching) consists of painting the dry surface of a depression or disintegrated area with bituminous material (RC-2, RC-3, MC-5, RS-1, RTCB-6, RT-5 or AC 85–100) and covering with aggregate. (A paint patch is only a miniature surface treatment

FIG. 2.—Making a paint patch; bitumen applied from a hose is spread with a broom, covered with fine aggregate and rolled.

of the skin or seal coat type described in Method 2.) Where the patch is to be subjected promptly to heavy traffic, it is desirable to use the heavier grades of bitumen, which will prevent the aggregate from being displaced and the bitumen from splashing.

The size of aggregate will depend upon the grade and amount of bitumen, coarser aggregate being used on the heavier grades of bitumen. To cover 0.3 gal. per sq. yd. of MC-5, MC-4, RC-4, RT-8, or a soft AC, No. 6 (¾ to ⅜ in.) aggregate generally will be satisfactory. As a covering for 0.25 gal. per sq. yd. of RC-2, RC-3, MC-3, RS-1 or RT-6, No. 7 (½ in. to No. 4) aggregate is suitable. On 0.2 gal. per sq. yd. of RT-3, RC-1, MC-2 or MS-2, No. 9 (¼ in. to No. 8) aggregate or coarse sand may be appropriate. A slightly coarser aggregate can be

used with a heavy treatment than with a light treatment.

While the quantity of bitumen to apply will vary with the roughness of the old surface as well as the grade of bitumen, ordinarily 0.25 gal. per sq. yd. may serve as the basis for estimating. The quantity of aggregate covering generally will average about 10 lb. of stone or gravel per sq. yd. per 0.1 gal. of bitumen. However, this will vary with the different specific gravities and the variable absorptive properties of different aggregates. A little experience will show the proper amount of any grade of bitumen for the particular grade of aggregate being used. It is important that all the aggregate covering (which should be dry) that will be held by the bitumen, be used. Any appreciable surplus beyond this will be wasted. If the work is properly handled, fat spots will not develop.

The bituminous material may be applied by hand brushing or by spraying from a pressure tank. Such a tank may be a 500-gal. or larger tank of an ordinary distributor, or a smaller tank (200- to 400-gal.) on a 2- or 4-wheel trailer from which the bitumen is pumped through the hose and nozzle.

Promptly after application, the aggregate should be spread uniformly and rolled. Aggregate should be broomed, if necessary, to produce uniform distribution. Although a 5- to 10-ton roller will be desirable, use of a smaller roller, sometimes called a patch roller, may slightly reduce the cost of this work if the amount is small or in isolated locations. Prompt pressing of the aggregate into the bitumen, if a heavy grade of bitumen is used, is most important. Sometimes a small damp spot will hold up the work. Wet areas can be quickly dried with a pressure burner or by burning a small amount of gasoline on the damp surface.

If it is desirable to build up thickness to correct a fairly deep depression or to correct a weak base, a double or triple treatment may be used. In double applications, a smaller sized aggregate should be used on the second treatment. If three treatments are used, the aggregate covering on the third application of bitumen may be $\frac{3}{8}$ in. maximum size or a coarse sand. With these successive treatments, however, the general rule of using all the aggregate the bitumen will retain still holds. The aggregate covering on each application should be compacted by tamping or rolling.

Patching With Premixed Material

Patches with premixed material may be made feather edge or vertical edge, the latter being preferable on heavily traveled pavements. Premixed material may be of one of the classes described under *Patching Mixtures*.

The patching mixture should be spread and tamped or rolled in layers $\frac{3}{4}$ in. to 2 in. thick. Thin courses generally compact better, and hence give greater stability. If placed in more than one layer, the patching mixture just under the top course is frequently referred to as the binder course and

FIG. 3.—Warming an old surface to make a feather edge joint at junction with new pavement.

may be made of coarser aggregate than the top, which should be a dense mix. Frequently however, all courses are made of the top course mixture. The small additional cost of the top course mixture may be less than the extra expense of providing two mixtures of different grading.

On small areas where it is not practicable to roll the bottom courses, an air hammer or vibrator may be used very effectively in lieu of a hand tamper. The required amount of hand tamping may be reduced by passing a truck wheel back and forth over the patch. It is always desirable to roll the top course to provide a smooth surface even though the patch is too small for rolling of the base course.

In secondary road patching sometimes it will be more practical to place the bituminous top course of the patch after the base

of untreated aggregate has been compacted under traffic. In this case a temporary surface may be placed on the newly constructed base to protect it. Temporary surfaces can be made by using base or binder course bituminous mixtures or a readily workable mix such as Class B[4] (using SC-4). After compaction under traffic for some time, the temporary top is removed and the permanent top placed. If necessary the temporary surface may be heated with an oil burner and raked off. This will leave a good surface to which the new bituminous top course will readily adhere.

When fully compacted, the surface of a vertical edge patch should be just slightly higher than the adjacent pavement in order that maximum density of the patching mix-

FIG. 4.—A patched area in a pavement filled to top with binder is being allowed to compact under traffic before top course is placed.

ture may be assured. Proper compaction of both the base and top courses is a big factor in contributing to the permanence of the patch. This compaction is greatly aided if the patching mixture is in the state of cooling or curing which produces a slightly sticky mixture that will "stay put" when tamped or rolled into place.

A mixture of the proper consistency, of the cold or semi-cold type, can be made by using the right grade of bitumen to fit the weather conditions or by properly aerating or aging the mixture to a suitably cured stage. An MC-5 or RTCB-6 mix will be suitable for use in hot weather immediately after mixing while an MC-3 or RTCB-5 mix will be best if allowed to cure some time before using. On the other hand an MC-3 or RTCB-5 mix could be used immediately after mixing in cold weather.

Patching Mixtures

Patching mixtures may be either cold mix or hot mix. A cold mix type is workable when cold but does not necessarily have to be mixed cold. The hot mix type is laid and rolled while hot. The term "semi-cold" is sometimes applied to a mix that is heated only moderately and that must be used before it reaches atmospheric temperature except in the hottest weather.

In most patching mixtures the best results will be secured with dry aggregates. Too often the use of a wet aggregate has reduced the life of the patch. Although for use with emulsions, surface dampness of the aggregate is desirable (and with some emulsions necessary), a large amount of internal moisture in the aggregate may be detrimental. During the dry summer months, a sun-dried aggregate often will be satisfactory, but for continuous operation means of artificially drying the aggregate is necessary. Small portable driers are available for this purpose.

The maximum size of aggregate in a patching mixture should not be greater than two-thirds the thickness of the course to be laid. However, it is not always practicable to comply with this rule when feather edge patches are made, because of the varying depth of the depression to be filled. The use of a heavy roller crushes the coarser particles to a considerable extent at the feather edge of a patch, thus reducing the over-size pieces of aggregate. For average conditions, $\frac{3}{4}$ in. maximum size aggregate is very satisfactory for much patchwork. However, if many of the patches are shallow and securing a smooth surface is a factor, $\frac{1}{2}$ in. or even $\frac{3}{8}$ in. maximum size will be more satisfactory. A coarser aggregate for the bottom courses of deep patches is desirable but several layers of the top course mix will be satisfactory. Coarser aggregate in the bottom courses should cost less but when only small quantities are required, it may be more economical to use one gradation for all courses. On residential streets or important highways it may be desirable to match the appearance of the old pavement as nearly as possible by selecting an

[4] See page 11 and Appendix.

aggregate of approximately the same size as that in the surface course of the pavement.

Each layer of cold mix patching mixtures should be allowed to cure before the next layer is added.

For stability, gradation of aggregates and amount of bitumen are as important in a patching mixture as in one for a new pavement. A good mix will usually stay put but if carelessly placed the patch may be rough. If the ingredients have not been properly proportioned the patch may shove, roll or ravel and it may be short lived. If possible a testing laboratory or an engineer experienced in this work should be consulted in proportioning the patching mixture. It is particularly important to avoid the use of too much bitumen.

Mixtures suitable for patching, classified according to the general classification of paving mixtures of the Public Roads Administration are as follows: (Typical specifications for the classes and types described, briefed from Public Roads Administration Specifications, are given in the Appendix.)

Class B, Type B-2a, *Dense Graded Plant Mixtures Using Slow Curing Liquid Asphalts:* See Appendix "Paving Mixture for Dense Graded Plant Mix Surface Course (Slow-curing Liquid Asphalt)." In addition to the aggregates given in this specification, blast furnace slag complying with the requirements for aggregates of the specification is suitable for use in patching. In addition to the bituminous materials given in the specification asphalt cut-back MC-2 may be used. The aggregate should be dense graded and dried to not over 1 per cent moisture. The SC-4 and MC-2 mixtures are quite workable and may be stored for many months. The mixtures are satisfactory on secondary roads and may be the most economical for temporary patching on heavily traveled surfaces. The workability of mixes using these grades of bitumen makes them suitable for certain winter patching.

Class F, Type F-1, *Dense Graded Plant Mixtures Using Tars, Emulsions and Medium Curing Cutback Asphalts:* See Appendix, "Paving Mixture for Type F-1 Dense Graded Plant Mix Surface Course." In addition to the aggregates given in this specification blast furnace slag complying with the requirements for aggregates of the specification is suitable for use in patching. Tar cutcacks RTCB-5 and 6 may also be used in addition to the bituminous binders given in this specification; their use, however, tends to be restricted to patching ralatively small areas.

This class stiffens fairly rapidly but is capable of storage for several weeks during hot summer weather. For winter patching MC-4, MC-3 or RTCB-5 is suitable. The workability of a stockpile of patching mixture made with cutbacks may be prolonged by covering the pile with a tarpaulin or roofing paper to retard evaporation of volatile constituents. A stockpile of MC mixture may be kept workable through the winter by several spray treatments of MC-1 or SC-3 material, each treatment being followed by a covering of sand. The crust thus formed on the surface may be broken up and mixed with the workable material in the interior when the pile is used.

Mixtures under this subdivision of Class F may be made the same as Class I, but the bitumen is not heated to such high temperatures. The temperature of the aggregate should not be over 225 F. when it is to be mixed with MC asphalt and 135 F. when mixed with the tar. The aggregate should be heated enough to dry it to less than 2 per cent moisture.

Class F, Type F-2 (*Open Graded*), *Using Tars, Emulsions and Rapid Curing Cutback Asphalts:* See Appendix, "Paving Mixture for Type F-2 Open Graded Plant Mix Surface Course." Mixtures in this subdivision of Class F set up within 6 to 20 hr. and hence cannot be stocked long. Such a mixture may be desirable when the patch is to be used immediately. An open graded aggregate practically all retained on the $\frac{1}{8}$ in. sieve must be used. For use with the emulsified asphalt, the aggregate need not be heated. Although the aggregate for an emulsified asphalt mix frequently need not be dried, it should not contain an excess of moisture. It may be necessary to dampen the surface of the aggregate, if too dry, before the emulsion is added.

Class H, Type H-1, *Open Graded Bituminous Concrete:* In this class only the liquefier type is included. See Appendix, "Paving Mixture for Type H-1 Liquefier

Asphalt Pavement." In addition to aggregates given in this specification crushed gravel, of which at least 75 per cent of the particles have one fractured face and which otherwise comply with the specification for aggregate, is suitable for use in patching. This mixture is made of an open graded aggregate and 85–100 penetration asphalt cement with just sufficient liquefier (0.2 to 1.5 per cent naphtha according to air temperature and time of curing when being used) to preserve its workability. The aggregate should be dried and cooled to about 100 F.; the liquefier should then be added and after that the hot AC. It should be placed in comparatively thin courses (preferably not over 1½ in.) to let the liquefier pass out. In cold weather the mix may be hauled in insulated trucks and used warm before it hardens. Ordinarily, each layer of this type of mixture must be allowed to cure before the next layer is placed. The least amount of distillate that will allow the mix to be properly spread is desirable.

Class I, *Dense Graded Bituminous Concrete:* Of the several types in this class, the following three are often used.

Type I-3a, Cold Laid Tar Concrete: See Appendix, "Paving Mixture for Type I-3a Tar Concrete Pavement (Cold Laid)". This type is made of tar RT-8, RT-9 or RT-10 and an open graded aggregate. The temperature of the aggregate should not be above 135 F. at time of mixing.

Type I-1, Hot Asphalt Concrete: See Appendix, "Paving Mixture for Type I-1 Hot Asphalt Concrete Pavement." This type which is made of heated aggregate and hot asphalt cement must be laid and spread at 225 to 300 F. and rolled while hot as it becomes unworkable on cooling. A fairly dense graded aggregate with 2 to 8 per cent passing a No. 200 sieve, is desirable. Although any standard hot mix bituminous concrete may be used, it is best not to use the lower penetration asphalts. Because of their greater workability, softer asphalts, even up to 150 penetration, frequently will be desired. With the softer asphalt cements, feather edge patches can be satisfactorily made with the fine graded aggregate type.

Type I-3b, Hot Laid Tar Concrete: See Appendix, "Paving Mixture for Type I-3b Tar Concrete Pavement (Hot Laid)." This type is made of tar RT-10, RT-11 or RT-12. The temperature of the aggregate should be from 150 to 255 F. at time of mixing.

Class J. *Sheet Asphalt:* While any of the various plant asphalt mixes may be used for patching, a mix that will produce a patch similar in appearance and durability to that of the adjacent surface is preferable. For this reason Class J should be used in patching old sheet asphalt pavements, whenever it is practicable to secure the sheet asphalt mix. A dense graded bituminous concrete Class I, Hot Mix, is the best substitute for sheet asphalt when the latter cannot be readily secured. In warm weather thin courses of sheet mix, made with 85–100 penetration AC, can be satisfactorily used in feather edge patches. In making a sheet asphalt mixture for patching when only small quantities are taken from the plant at a time, care must be taken not to overheat or mix it unduly long as either will harden the asphalt.

Making Patching Mixtures

For thoroughness and uniformity of mix, it is desirable that patching mixtures be made in a pugmill or similar type of mixer. When such a mixer is not available, it is best to use one of the more workable mixes with open graded aggregate such as Class B, Class F or Class H, which can be mixed in a concrete mixer. Where a plant mix cannot be secured, a practical way of making the Class B or F types is to spread the aggregate on an abandoned piece of pavement, apply the bituminous material from a distributor and do the mixing with a motor grader. After mixing, the material is loaded and hauled to the road for immediate use or to a stockpile.

Road Mix Patches

On light traffic roads, patches about 50 ft. or more long may be made on the whole or half width of the surface by road mixing. Such a patch may be needed to cover a large area that is failing as the result of a weak base or disintegrating top, or both.

The old surface is first sprayed with about 0.15 gal. per sq. yd. of RC-2, RC-3, MC-3, RT-6, RT-7 or MS-1. On this tack

coat aggregate is spread 1 to 3 in. deep. The maximum size of the aggregate should not exceed 1¼ in. or two-thirds of the depth of the finished course, whichever is smaller. The aggregate is then sprayed with the bituminous material being used.

The aggregate and bitumen are mixed as for an ordinary road mix surface. It is desirable not to use too slow setting bituminous material as this work is usually done without closing the road to traffic.

This method is a contracted form of the resurfacing with road mix described under Method 2. Because it is not always practicable to use a dense graded aggregate, a choke and seal coat may be necessary. Frequently such patching precedes a general surface treatment or resurfacing of the whole road. If the patches have a much more open texture than the adjacent surface, they should be pre-sealed or choked with suitably sized aggregate before the over-all surface treatment is applied.

Cold Weather Patching

While cold weather patching is to be avoided as much as possible, it sometimes becomes necessary when small potholes have developed during winter thawing periods. If neglected, these holes may become very objectionable. Patches can be made successfully during cold weather (air temperature 20 to 45 F. above zero).

FIG. 5.—Winter patching—drying damp hole preparatory to filling with bituminous mixture.

The surface of the depression or hole to be patched is first dried with a blow torch, oil burner, or other source of heat. After raking off any burned material, the patching mixture is promptly spread and tamped or rolled. Hot mix, or a cold mix type that has been warmed, should be used for this winter patching. In cold weather the heated material may be hauled in insulated truck beds as far as 25 miles if well covered. If the mix becomes chilled, a burner may be directed lightly against a portion of it, care being taken not to burn it. If the RC type of mix is used, special care should be taken to guard against fire in heating the mix with an open flame if the mix has just recently been made.

Although a patch made in this matter may be as satisfactory as one made in summer weather, it will cost considerably more.

METHOD 2. TEMPORARY MAINTENANCE REPAIRS AND RESURFACING OF PAVEMENTS AWAITING DEFERRED CONSTRUCTION

When the existing surface is for only temporary use, maintenance work should be done at the least expenditure that will keep the pavement in suitable condition until the new pavement is built. Temporary patches followed sometimes by surface treatments or light road mixes are appropriate. Shoulders should be kept safe for traffic. A sudden increase in traffic may sometimes require temporary widening of the traveled surface by the use of local aggregates. The condition of the road, its importance to traffic, and the amount of traffic will determine whether temporary patches, surface treatment or road mix should be used.

Temporary Patches

For the top course on temporary patches, almost any available bituminous mixture may be used. It may be economical to use a readily workable mixture, such as Class B. While not as permanent as some other patching materials, such mixtures generally cost less. They are easily spread and compacted and readily conform to a feather edge. However, where patching material of a better type is available, it may be more economical to use it than to prepare a small quantity of a special mix.

In order to keep costs down, temporary patches should be made feather edged without cutting out any of the old pavement.

For temporary use of the pavement, digging out and replacing the base ordinarily will not be justified. Building up rather than digging down to gain strength will cost less if an appreciable area is involved. Even in making more permanent patches this principle can frequently be used to advantage. However, holes through the pavement should be cleaned and filled with coarse aggregate, well tamped and filled with screenings. This base may then be topped with one of the bituminous patching mixtures treated in Method 1. If the hole is not entirely through the base, frequently it will be cheaper to fill it with layers of the bituminous patching mixture than to use uncoated aggregate. Traffic will aid in compacting the bottom layers if allowed to run on them before the next or top layer is applied.

Frequently for temporary patching, the heavy paint patches described in Method 1 will serve satisfactorily for a year or more and will be the lowest cost shallow patches that can be made. Several layers may be placed if required by the depth of the depression.

After the holes have been patched, if the general condition of the pavement indicates serious weakness or prospective disintegration during its expected life, a surface treatment or thin road mix will be the next step.

Surface Treatments

Surface treatments (sometimes called skin or seal treatments) will cover the patches and delay further disintegration of the old surface. Such a skin treatment may consist of 0.2 to 0.3 gal. per sq. yd. of an MC-5 or RC-3 asphalt or RT-9 tar covered with No. 7 ($\frac{1}{2}$-in. to No. 4) aggregate. MC-4 may be used instead of MC-5 in cold weather. The aggregate may be either crushed stone, slag or gravel at a rate of about 10 lb. to 0.1 gal. of bitumen. The exact amount will vary with different aggregates. All the aggregate that the bitumen will hold should be applied, but no more, as an excess will act as an abrasive under traffic and remove some of the aggregate that has adhered. After the aggregate is placed, it should be lightly broom dragged and rolled. The broom dragging is intended only to spread the aggregate uniformly and should not be intense enough to disturb the aggregate that is stuck to the bitumen. If a chip spreader is available its use may obviate the need for broom dragging if a uniform spread of chips is secured. With heavy grades of bitumen such as MC-5 or RT-9, it is important that the aggregate be spread and rolled promptly after application of the bitumen, particularly in cool weather.

Later, under traffic, if insufficient aggregate is manifest, as much more as will adhere should be added from time to time. Never should a surface be allowed to remain over-rich in bitumen, as such surfaces may become slippery. For a final covering, to correct a too rich surface, a comparatively fine graded aggregate may be used. Crushed slag No. 10 (No. 0 to 4) is excellent for this purpose as it has high absorption and will readily dry up the excess bitumen and produce a non-skid surface. Fine crushed stone, gravel or coarse sand also will be satisfactory for this "mopping up" work. If the surface treatment is applied during hot weather, there will be less need for applying additional aggregate after construction is completed.

Where only slight weakness of the surface prevails, a lower cost (but more temporary) surface treatment may be made with RC-2, MC-3 or RT-4 with No. 9 (No. 4 sieve to No. 16) aggregate or coarse sand covering, using 0.15 to 0.20 gal. of the bituminous material and 10 to 20 lb. per sq. yd. of aggregate. When these softer grades of bitumen are used, all but slow speed traffic should be kept off the surface until the bitumen is sufficiently dry to prevent the aggregate from being seriously displaced.

A temporary method of reclaiming an old badly cracked sheet asphalt pavement consists of an application of 0.25 gal. per sq. yd. of 150-200 penetration asphalt (heated to 350 to 380 F.) covered with 20 to 25 lb. per sq. yd. of warm precoated concrete sand. The sand is heated to about 225 F. and coated in a pugmill with 1 per cent (by weight) of MC-2. After spreading, the sand is broom dragged, rolled once and opened to traffic. Additional applications of warm precoated sand are dragged over the surface for three days while the road is

under traffic. All the sand that will be absorbed must be applied. The kneading action of the pneumatic tire traffic is a necessary part of this process. The use of precoated sand prevents dusting during the operation and aids in its absorption into the asphalt, thus reducing "whip-off" by traffic. This method thoroughly fills the cracks so that they do not open as readily as under the ordinary surface treatment. Before the surface treatment is applied, any shallow holes and wide cracks are filled with sheet asphalt mix which is tamped or rolled. This filling will stop the rocking of loose pieces of the old pavement. This class of surface treatment can be done satisfactorily only during warm weather.

Road Mix

If there are reasons for smoothing and strengthening the old surface as well as thoroughly sealing all cracks, a thin road mix will be more satisfactory than the skin or seal treatment. Also, an over-all weak base can be strengthened temporarily at reasonable cost by the use of a road mix.

For this work a tack coat of about 0.15 gal. per sq. yd. of RC-3, MC-3, MC-5 or RT-8 to RT-9 is applied. The aggregate is then spread uniformly upon this tack coat and additional bitumen applied and intimately mixed in two or more applications. The mix may be made in one or more lifts. About 125 lb. per sq. yd. of aggregate is the most that should be placed in one lift. After the final mixing, the mixture is spread to an even surface and compacted thoroughly by rolling. Most of the rolling should be done when the bitumen is at such stage of drying that the aggregate will be compacted to its maximum density.

FIG. 6.—Making a road mix of open graded aggregate and a heavy bitumen by once over with the mixing machinery, etc.

The MC-3 is used with a dense graded aggregate containing 5 to 10 per cent through the No. 200 sieve. The RC-3 must be used with an open graded aggregate containing not over 5 per cent through the No. 8 sieve and will require a seal coat usually of 0.25 to 0.3 gal. per sq. yd. and 15 to 25 lb. of No. 8 ($\frac{3}{8}$-in. to No. 8) covering aggregate. It is preferable that the maximum size of aggregate used in any mix should be no greater than two-thirds of the average thickness of the course.

In places where it is necessary to open a road as soon as possible, a bitumen as heavy as MC-5 or RT-10 with a hurried operation of the mixing machinery may be used. One-half of the road is surfaced at a time. With these heavy bitumens the rolling and application of the seal coat may be done the same day. With the lighter grades of bitumen several days' curing may be required before the road can be completed and opened to traffic.

If a mixing plant is available, it will sometimes be more practical to use a workable plant mix than the road mix. A Class B, Class F or Class H mixture may be spread from a truck, scraped into the depressions, leveled with a motor grader and compacted by rolling. A plant mix may be spread over the entire surface after this patch work has been done.

Shoulder Maintenance and Temporary Widening

Sometimes roads awaiting the construction of a new pavement are required to carry a sudden increase of traffic, and shoulder ruts paralleling the pavement develop. Such ruts can be filled with local aggregate, either bank gravel, crusher run stone or slag. With an occasional dragging, they may be kept in a safe condition. The aggregate should be well compacted. This may be done by regulated slow speed truck traffic and systematic dragging or by rolling. A standard 3-wheel roller or a trench roller may be used for this purpose. In dry weather, sprinkling in conjunction with the compacting may be necessary. For temporary purposes bituminous mixtures may not be justified, but the use of chlorides of

calcium or sodium will assist in the maintenance by holding moisture in the aggregate. However, for a season's or several years' use, it may be economical to use a bituminous mixture, particularly to fill the bad ruts which repeatedly form on grades where the erosion of storm water soon turns a small wheel track into a large and dangerous rut. A bituminous surface treatment, using from 0.3 to 0.5 gal. per sq. yd. of MC-3, SC-3 or RT-4 will be effective on the aggregate shoulders at low cost. The ruts may be filled with the road mix by dragging. In refilling ruts, use of a plant mix with good workability may be justified. Although rolling, particularly on the plant mix, is desirable, the loose aggregate may be fairly well compacted by traffic.

METHOD 3. SUBSTANTIAL RESURFACING WHERE RECONSTRUCTION IS NOT ANTICIPATED

Either because of natural wear or increased loads, or both, an old road at times must be reconditioned and strengthened. Surface treatment, road mix, penetration macadam or plant mix may be used. The strength of the old pavement and availability of different aggregates and machinery will govern selection of the method to be followed.

If the old road is strong enough and merely shows a slight roughness or a dry surface with incipient disintegration, a seal coat may be sufficient. If the pavement has an adequate base but has undulations that a road mix will correct, this may be the practical type to use.

If the pavement must be made appreciably stronger, additional thickness will be required. For moderate traffic, a road mix or penetration macadam may be satisfactory. Plant mix can be better controlled and is more uniform in character. Modern machinery has been developed for spreading and compacting the plant mix to a smooth riding surface. A hot plant mix type allows use of the pavement as soon as the mix is laid and rolled.

Long undulations with deep depressions should be corrected with a plant mix material properly spread and rolled before the over-all surface course of any type is placed. Also, before the new surface is constructed, the old road should be thoroughly patched with substantial bituminous mixtures as given in Method 1. Feather edge patches may generally be used as cutting out is necessary only where the base is too weak to carry the load with the added resurfacing. Any excessively rich spots found in patches previously made should be removed. For patching the depressions in the old surface and for the top course of replaced base areas, the same binder or top course mixture as for the new surface may be used.

It is most economical to resurface before the old pavement has failed to a point where it is greatly weakened and requires extensive patching.

Surface treatment: For this type of surface, a single seal treatment as in Method 2 may be used.

Road Mix (suitable for moderate traffic roads): This type may be used for increasing strength and for leveling a rough surface with comparatively long undulations. The longer the base of the drag or machine used in mixing and leveling, the smoother will be the riding surface produced. The thickness of the course should be such as to provide the necessary strength. Details of the road mix type are found in Method 2. Due to the length of time the construction of this type interferes with traffic, it is poorly adapted to use on a heavily traveled road.

Penetration Macadam: A penetration macadam course from $2\frac{1}{2}$ to $3\frac{1}{2}$ in. thick may be economical if good aggregates for this class of work are available. This type consists of coarse aggregate spread on the surface, penetrated with bitumen, bound with key stone and sealed with bitumen covered with pea stone.

The aggregate should be crushed stone, crushed slag or crushed gravel in which 75 per cent (by weight of the particles) have been crushed. The coarse aggregate should range from 1-in. to $2\frac{1}{2}$ in. in size; key stone from No. 4 sieve to $\frac{3}{4}$ in.; and the pea stone, from No. 8 sieve to $\frac{5}{8}$ in. The bituminous material should be one of the grades specified for penetration macadam in Table 1.

The coarse aggregate is spread to a

smooth surface and lightly rolled with a three-wheel roller weighing not less than 10 tons and the bitumiuous material is then applied uniformly with a distributor. While the bitumen is still warm, the course is again rolled, if necessary with application of just enough oil or water to the wheels of the roller to prevent the bitumen from sticking to them. Sufficient key stone is then spread and broomed over the surface to fill the surface voids and the surface again rolled. Some pea stone may be used in this operation to fill the smaller voids not filled by the key stone. Filling voids with stone and rolling is continued until the surface is thoroughly bonded and compacted but not entirely closed. Care should be taken not to over-fill nor over-roll soft stone. A seal coat of bituminous material is then applied at the rate of 0.35 to 0.4 gal. per sq. yd., covered with pea stone and rolled.

The total amount of bitumen required will depend upon the thickness of the course and the hardness of the stone. It will vary from 0.6 gal. per sq. yd. per inch of depth for soft stone to 1 gal. for trap or other hard rock. The bitumen may be applied in more than two applications, using key or pea stone and rolling after each application.

Plant Mix (desirable on heavily traveled roads): A hot mix laid with a modern paving machine is the best and most satisfactory resurfacing for many old bituminous high type roads. Because of its density a comparatively thin layer will greatly increase the carrying capacity of the road.

FIG. 7.—Spreading 1½ in. plant mix bituminous concrete on an old bituminous road with a paving machine to level and strengthen the old surface.

The hot mix bituminous concrete is usable by traffic as soon as laid and rolled under average conditions, which is often an important factor in its selection. The cold mix type can be used satisfactorily on roads and streets that may be closed to high speed traffic long enough for the mix to cure properly. Under certain weather conditions and type of mix, this may be a short period.

Since the resurfacing is intended to level an old surface as well as increase its strength, the work should be done so as to provide the maximum leveling effect. A single course of 1½ in. is used quite extensively in resurfacing old bituminous roads that are fairly level and do not require materially greater additional strength. Where 2-in. or more of additional thickness is required, it will usually be desirable to place it in two courses, the first a leveling course with a minimum thickness of ¾ in. and the second a uniform depth top course. Where the old road is very irregular, sometimes a preliminary "scratch course," intended to fill all the bigger depressions without leaving any material on the rest of the surface, is placed.

A somewhat modern development is the use of a plant mix resurfacing course about ¾ in. thick as a substitute for the ordinary surface treatment or road mix in maintaining heavily traveled important highways. In this single thin course, MC-5, RC-5, RT-8 to RT-12 or comparatively soft AC (85 to 100 or 100 to 120 penetration) may be used. Hard asphalt cements would not be satisfactory for such thin courses. It is also necessary that thin plant mix courses be laid during warm weather.

In resurfacing with plant mix, the old road generally is first given a tack coat of 0.1 to 0.15 gal. per sq. yd. of bitumen. It is most important that no excess of bitumen be used. Sometimes in resurfacing old bituminous roads that are already rich in bitumen, this tack coat is reduced to a mere "fog" treatment sufficient only to absorb the small particles of dust that may be on the surface. Where the old surface is generally rich in bitumen, the tack coat may be omitted during hot weather in laying hot mix as thick as 1½ in. In fact there may be "fat" spots where patching has been done

in former years that should be dug out and replaced with plant mix before resurfacing.

Special attention to three features is required to secure proper construction of plant mix surfaces.

(1) The joint between two spreads of a course should be staggered so that it does not come just above a joint in a course below.

(2) A slight excess of the mix should be used at the junction of two spreads to prevent a depression or a low density area which might develop into a defect at the joint in later years.

(3) The mixture must be rolled at the right stage of cooling or curing so as to secure the greatest practicable density. Over-rolling when the mix is too hot or too cold may cause cracks. Rolling delayed until the mix is too stiff will produce a surface lacking in density and subject to water absorption.

METHOD 4. WIDENING

Modern speed and increased traffic require that many old pavements be widened. In widening roads with satisfactory grade and alignment, the work should be done with as good materials and as carefully as the original construction.

A trench is excavated along the side of the old pavement wide and deep enough for the additional pavement. Special scarifiers and grader blades have been developed to

FIG. 8.—Excavating the narrow trench along the old pavement with specially designed grader blade, etc.

do this excavating at low cost. The depth of excavation will vary with the nature of the soil but should be as great or greater than the thickness of the old pavement.

Base Course

The base usually consists of one or more layers of aggregate to provide stability and to distribute the loads. If local aggregates are used in the base, an aggregate course, principally of crushed or other angular particles just underneath the bituminous top will usually be justified because of its greater stability.

On clay soil if the local aggregate is not well graded it is best to make the first layer of stone or slag screenings 1½ to 2-in. deep. The base is then built up of suitable layers.

A granular stabilized base, as described in Wartime Problems No. 5, Granular Stabilized Roads, of the Highway Research Board would also be satisfactory.

The base should be well compacted. In lieu of thorough tamping or rolling compaction may be secured by allowing traffic to

FIG. 9.—Rolling base course in widened strip with trench roller.

use the widened base for several months before the bituminous top is placed. This method is not desirable on a heavily traveled road.

Top Course

For the top course a bituminous plant mix of the type and composition generally used on roads or streets of the class involved should be used. In the absence of specifications for such mixtures, one of the typical specifications given in the Appendix may be used.

The top course of the widened base should be completed ¼ in. higher than the edge of the adjacent pavement but should otherwise conform to the crown and elevation of the old pavement.

Due to the difficulty and time required to compact thoroughly a widened base of untreated aggregate or penetration macadam, some engineers, on narrow strip widening, have built the entire thickness of several courses of hot mix. The layers of hot mix have the advantage of immediately taking almost their full compaction when properly rolled while hot, thus reducing to a minimum the possibility of future settlement. The edges of the old pavement should be picked and scraped clean of all dirt and loose material and given a paint coat of bitumen to secure good adhesion of the new bituminous mixture.

Commercial trench rollers are made for rolling the narrow strips of widened base. Also special spreading boxes have been developed for spreading the different layers of aggregate and mixtures.

Where a high crown in the old road is to be reduced, the hot mix top course of the widened strip is extended in a wedge shape (feather edge) out upon the old pavement. Often if a new overall top is not to be placed immediately, the whole width is given a surface treatment to aid in further sealing the old and new portions and to produce a uniform appearance.

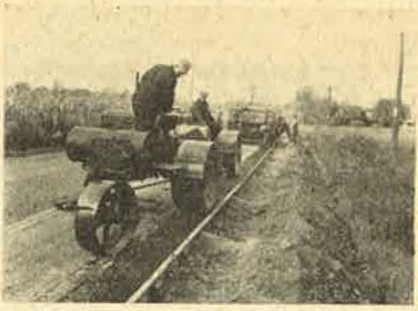

FIG. 10.—Spreading plant mix bituminous concrete in the trench (in distance) and compacting it with trench rollers.

Resurfacing is often combined with widening, in which case one or more layers of the resurfacing, as given in Method 3 are placed over the full width of widened pavement. Various combinations of different thicknesses of courses are used to fit the width, crown, roughness and strength of the old road being salvaged.

APPENDIX

TYPICAL SPECIFICATIONS FOR BITUMINOUS PAVING MIXTURES BRIEFED FROM PUBLIC ROADS ADMINISTRATION SPECIFICATIONS

The following paving mixtures are selected as suitable for salvage work. They are classified under the Public Roads Administration classification as Classes B, F (two illustrations), H and I (three illustrations), taken in that order.

Paving Mixture for Type B-2a Dense Graded Plant Mix Surface Course (Slow-curing Liquid Asphalt)

Description: The paving mixture shall be composed of aggregate, naturally or artificially graded to provide the density required, and the slow curing binder prescribed, the two mixed in a central plant ready for delivery to the road job.

Determination of Percentage of Bituminous Material: The amount of bituminous material, by weight, to be added to the aggregate shall be between 3½ and 7 per cent of the weight of the dry aggregate. The exact percentage to be used shall be fixed by the engineer on the basis of preliminary laboratory tests and field sieve analyses of the aggregate furnished.

Aggregate: For the grading of the aggregate, selection shall be made from Table 1. Aggregate shall be so graded within the limits given in Table 1 that at least 10 per cent of the total aggregate shall pass a No. 4 sieve and be retained on a No. 10 sieve.

The aggregate shall consist of gravel (crushed to size as necessary) or crushed stone, in either case composed of hard, durable pebbles or stone fragments, and a filler of finely crushed stone, sand or other finely divided mineral matter. The portion of the material retained on a No. 4 sieve shall be known as coarse aggregate, and that portion passing a No. 4 sieve shall be known as filler.

The coarse aggregate shall have a per cent of wear of not more than 50 at 500 revolutions, as determined by A.A.S.H.O Method T-96.

For all gradings, that portion of the filler, including any blended filler, passing a No. 40 sieve shall have a plasticity index of not more than 6 as determined by A.A.S.H.O. Method T-91.

The aggregate shall be of such nature that a thorough coating of the bituminous material to be used in the work applied to it will not slough off upon contact with water. The bituminized aggregate shall have a swell of not more than 1.5 per cent, as determined by Method 1 of A.A.S.H.O. Method T-101.

Additional Filler for Blending: Additional filler for blending with aggregate at the mixing plant, if needed, shall be obtained from sources approved by the engineer. The material for such purpose shall be free from lumps, and shall not contain more than 15 per cent of material retained on a No. 4 sieve.

Bituminous Material: The bituminous material shall be slow-curing liquid asphalt, grade SC-4 or SC-5.

Paving Mixture for Type F-1 Dense Graded Plant Mix Surface Course

Description: The paving mixture shall be composed of aggregate, naturally or artificially graded to provide the density required, and the bituminous material prescribed, the two mixed in a central plant ready for delivery to the road job. The mixture may be placed in two courses, a binder or leveling course and a wearing course. The binder or leveling course shall be rolled, finished and cured before placing the wearing course.

Determination of Percentage of Bitumi-

nous Material: The amount of bituminous material, by weight, to be added to the aggregate shall be between 3½ and 7 per cent of the weight of the dry aggregate. The exact percentage to be used shall be fixed by the engineer on the basis of preliminary laboratory tests and field sieve analyses of the aggregate furnished.

Aggregate: For the grading of the aggregate, selection shall be made from Table 2. Aggregate shall be so graded within the limits given in Table 2 that at least 10 per cent of the total aggregate shall pass a No. 4 sieve and be retained on a No. 10 sieve.

TABLE 1

Sieve Designation	Percentages by weight passing square mesh sieves			
	Grading 1	Grading 2	Grading 3	Grading 4
¾-inch	100	100		
½-inch			100	100
No. 4	50-70	55-75	55-75	60-80
No. 10	35-55	40-60	40-60	45-65
No. 200	5-10	5-12	5-10	5-12

TABLE 2

Sieve Designation	Percentages by weight passing square mesh sieves	
	Grading 1	Grading 2
¾-inch	100	
½-inch		100
No. 4	35-50	40-55
No. 10	25-40	30-45
No. 200	2-7	2-7

The aggregate shall consist of crushed gravel or crushed stone, in either case composed of hard, durable pebbles or stone fragments, and a filler of finely crushed stone, sand or other finely divided mineral matter. The portion of the material retained on a No. 4 sieve shall be known as coarse aggregate and that portion passing a No. 4 sieve shall be known as filler.

The coarse aggregate shall have a per cent of wear of not more than 50 at 500 revolutions, as determined by A.A.S.H.O. Method T-96.

If crushed gravel is used, not less than 50 per cent by weight of the coarse aggregate particles shall be particles having at least one fractured face.

For all gradings, that portion of the filler, including any blended filler, passing a No. 40 sieve shall have a plasticity index of not more than 6, as determined by A.A.S.H.O. Method T-91.

The aggregate shall be of such nature that a thorough coating of the bituminous material to be used in the work applied to it will not slough off upon contact with water. The bituminized aggregate shall have a swell of not more than 1.5 per cent as determined by Method 1 of A.A.S.H.O. Method T-101.

Additional Filler for Blending: Additional filler for blending with the aggregate at the mixing plant, if needed, shall be obtained from sources approved by the engineer. The material for such purpose shall be free from lumps, and shall not contain more than 15 per cent of material retained on a No. 4 sieve.

Bituminous Materials: The bituminous material shall be one of the following: medium-curing cutback asphalt, grade MC-3, MC-4 or MC-5; emulsified asphalt, grade SS-1; or tar, grades RT-7 to RT-12.

Paving Mixture for Type F-2 Open Graded Plant Mix Surface Course

Description: The paving mixture shall be composed of aggregate and the bituminous material prescribed, the two mixed in a central plant ready for delivery to the road job.

Determination of Percentage of Bituminous Material: The amount of bituminous material to be added to the aggregate shall be set by the engineer and shall be between 3 and 5 per cent, by weight, of the aggregate. The minimum amount of bituminous material used shall be within the above limits and shall be such that the amount of bitumen in the residue left on the stone will not be less than 2.75 per cent, by weight, of the aggregate.

Aggregate: For the grading of the aggregate, selection shall be made from Table 3. Aggregate shall be crushed gravel, crushed stone, or crushed slag. The aggregate shall consist of clean, tough, durable fragments, free from an excess of flat elongated, soft or disintegrated pieces,

dust or other objectionable matter and shall have a per cent of wear of not more than 40 at 500 revolutions, as determined by A.A.S.H.O. Method T-96.

Crushed gravel shall consist of the product obtained by crushing and screening gravel that has first been screened in such a manner that not less than 90 per cent of the material for crushing, when tested by laboratory methods, is retained on a sieve having 1½-inch square openings.

Aggregate shall be of such nature that a thorough coating of the bituminous material to be used in the work applied to it will not slough off upon contact with water.

Bituminous Material: The bituminous material shall be rapid-curing cut-back asphalt, grade RC-3, RC-4, or RC-5, emulsified asphalt, grade RS-1 or MS-2, or tar, grades RT-7 to RT-12.

TABLE 3

Sieve Designation	Percentages by weight passing square mesh sieves	
	Grading 1	Grading 2
1-inch	100	
¾-inch	90–100	
½-inch		100
⅜-inch	30–65	85–100
No. 4	5–25	10–30
No. 8	0–5	0–10

Paving Mixture for Type H-1 Liquefier Asphalt Pavement

Description of Pavement: The pavement shall consist of cold-laid bituminous concrete constructed on the prepared subgrade in two courses, a bottom or leveling course that is a continuous mat but not necessarily of uniform thickness, and a wearing course that is of uniform thickness. The bottom course should have a thickness of approximately three-fourths of the total pavement thickness and not less than the maximum size of the aggregate used. The pavement shall be dressed off with a light coat of top dressing.

The cold-laid bituminous concrete shall be composed of a mixture of Mineral Aggregate, Bituminous Material, and certain Admixtures.

General Composition of Mixtures: The mineral aggregate shall meet the grading requirements of Table 4 for "Bottom Course" or "Wearing Course" as the case may be. To such aggregate (considered as 100 per cent) shall be added bitumen, and admixtures of liquefier and hydrated lime within the percentage limits in Table 4.

Mineral Aggregate: Mineral aggregate shall be crushed stone, excluding all but fractured particles, or crushed slag. The aggregate shall consist of clean, tough, durable fragments, free from an excess of flat, elongated, soft or disintegrated pieces, dirt or other objectionable matter and shall have a percentage of wear of not more than 40 at 500 revolutions, as determined by A.A.S.H.O. Method T-96. Aggregate shall be of such nature that a thorough coating of the bituminous material to be used in the work, when applied to the aggregate, will not slough off upon contact with water.

TABLE 4

Sieve Designation	Percentages by weight passing square mesh sieves	
	Bottom Course	Wearing Course
1½-inch	95–100	
½-inch	10–35	95–100
No. 4	4–16	15–40
No. 8		10–25
No. 20		5–15
Liquefier, per cent	0.2–1.2	0.2–1.5
Hydrated lime, per cent	0.4–1.0	0.5–1.0
Bitumen (Sol. CS_2), per cent	3.5–6.0	5.0–7.0

Bituminous Material: The bituminous material shall be an asphalt cement of penetration grade 85–100.

Admixtures: Admixtures shall consist of petroleum naphtha liquefier and hydrated lime.

Top Dressing: The material for top dressing shall consist of dry sand or stone screenings so graded that 95 to 100 per cent passes a No. 4 sieve and 0 to 40 per cent passes a No. 50 sieve.

Plant and Equipment: The mixture should be procured from a producer using a standard plant. The plant shall include equipment for drying, screening, cooling and storing aggregates (at least three compartment storage of appropriate aggregate fractions); tanks for storage and heating of bituminous material; equipment for proportioning mixture ingredients; and a twin pugmill mixer.

Paving Mixture for Type I-3a Tar Concrete Pavement (Cold-Laid)

Description of Pavement: The pavement shall consist of cold-laid tar concrete constructed on the prepared subgrade in two courses, a bottom or leveling course that is a continuous mat, but not necessarily of uniform thickness, and a wearing course of uniform thickness. The bottom course shall have a thickness of approximately three-fourths of the total pavement thickness and nor less than the maximum size of the aggregate used.

The cold-laid tar concrete shall be composed of a mixture of Coarse Mineral Aggregate, Fine Mineral Aggregate and (if required to meet the prescribed grading) Mineral Filler with Tar.

TABLE 5

Sieve Designation	Percentages by weight passing square mesh sieves	
	Bottom Course	Wearing Course
1½-inch	100	
1-inch	20–60	100
½-inch		85–100
No. 4	5–20	40–75
No. 8	0–5	25–55
No. 20		15–35
No. 200		0–8
Bitumen (Sol. CS_2), per cent.	3.0–6.5	6.0–10.0

General Composition of Mixtures: The mineral aggregate shall meet the grading requirements of Table 5 for "Bottom Course" or "Wearing Course" as the case may be and the fraction retained between any two consecutive sieves shall be not less than 4 per cent of the total. To such aggregate, tar shall be added in such amount that the bitumen content of each course will constitute a percentage (of the mineral aggregate considered as 100 per cent) falling within the respective percentage limits set forth in Table 5.

Coarse Mineral Aggregate: The portion of the aggregate retained on a No. 4 sieve shall be known as coarse aggregate and shall be crushed stone, crushed slag, or crushed gravel. The coarse aggregate shall consist of clean, tough, durable fragments, free from an excess of flat, elongated, soft or disintegrated pieces, dirt or other objectionable matter and shall have a percentage of wear of not more than 40 at 500 revolutions as determined by A.A.S.H.O. Method T-96.

If crushed gravel is used, not less than 50 per cent by weight of the course aggregate particles shall be particles having at least one fractured face.

Fine Mineral Aggregate: The portion of the aggregate passing a No. 4 sieve shall be known as fine aggregate and shall consist of sand (or a blend of sand and stone screenings) composed of clean, tough, rough surfaced and angular grains.

Mineral Filler: The mineral filler shall consist of limestone dust, dolomite dust, or portland cement and shall be free from foreign or other objectionable material. It shall be dry and free from lumps and shall be so graded that 100 per cent will pass a No. 30 sieve and 65–100 per cent will pass a No. 200 sieve.

Bituminous Material: The bituminous material shall be tar, grade RT-8, RT-9, or RT-10.

Plant and Equipment: The mixture should be procured from a producer using a standard plant. The plant shall include equipment for drying, screening, cooling, and storing aggregates (at least three compartment storage of appropriate aggregate fractions); tanks for storage and heating of bituminous material; equipment for proportioning mixture ingredients; and a twin pugmill mixer.

Skin or Seal Treatment: When the gradation of mineral aggregate in the top course mixture falls below the middle of the limits given in Table 5, the surface of the pavement shall be given a treatment of hot tar and fine aggregate. The treatment shall be applied after the pavement has been consolidated by traffic not less than 30 nor more than 60 days. The treatment shall consist of 0.15 to 0.25 gallons of tar per square yard heated to a temperature of 150° to 225°F. uniformly applied to the surface of the pavement and immediately covered with 6 to 10 pounds per square yard of fine aggregate.

Tar shall be grade RT-9 or RT-10 and fine aggregate shall be fine mineral aggregate as described above, so graded that all

shall pass a No. 4 sieve and not less than 75 per cent shall pass a No. 8 sieve.

Paving Mixture for Type I-1 Hot Asphalt Concrete Pavement

Description of Pavement: The pavement shall consist of hot-laid bituminous concrete constructed on the prepared subgrade. The course shall have a thickness not less than the maximum size of the aggregate used.

The bituminous concrete shall be composed of a mixture of Coarse Mineral Aggregate, Fine Mineral Aggregate, and Mineral Filler, with Asphalt Cement. Mineral filler shall be considered to include any mineral dust naturally present in the bituminous material.

TABLE 6

Sieve Designation	Percentages by weight passing square mesh sieves	
	Grading 1	Grading 2
1-inch	100	
¾-inch		100
⅜-inch	55–95	86–100
No. 4	28–50	55–67
No. 10	22–44	40–54
No. 20	17–37	
No. 40	12–31	22–31
No. 80	8–18	12–20
No. 200	4–8	4–8
Bitumen (Sol. CS_2), per cent	5.5–8	6–8.5

General Composition of Mixtures: The composition of the bituminous concrete shall meet the requirements of grading 1 or grading 2 in Table 6, whichever is selected. The several mineral constituents for the bituminous concrete shall be so sized and graded and shall be combined in such proportions that the resulting composite blend will meet the respective requirements of grading 1 or grading 2, which is selected from Table 6, and the fraction retained between any two consecutive sieves will be not less than 4 per cent of the total, and at least one-half of the fraction passing the No. 200 sieve shall be mineral filler. To such composite blended aggregate (considered as 100 per cent) shall be added bitumen within the percentage limits set forth under the grading selected.

Coarse Mineral Aggregate: The portion of the aggregate retained on a No. 4 sieve shall be known as coarse aggregate and shall be crushed stone, crushed slag, or crushed gravel. The coarse aggregate shall consist of clean, tough, durable fragments, free from an excess of flat, elongated, soft or disintegrated pieces, dirt or other objectionable matter and shall have a per cent of wear of not more than 40 at 500 revolutions, as determined by A.A.S.H.O. Method T-96.

If crushed gravel is used, not less than 50 per cent by weight of the course aggregate particles shall be particles having at least one fractured face.

Aggregate shall be of such nature that a thorough coating of the bituminous material to be used in the work, when applied to the aggregate, will not slough off upon contact with water.

TABLE 7

Sieve Designation	Percentages by weight passing square mesh sieves
	Surface course
1-inch	100
¾-inch	85–100
⅜-inch	60–85
No. 4	40–70
No. 8	25–55
No. 40	10–25
No. 100	5–15
No. 200	0–8
Bitumen (Sol. CS_2), per cent	6.0–10

Fine Mineral Aggregate: The portion of the aggregate passing a No. 4 sieve shall be known as fine aggregate and shall consist of sand or a blend of sand and stone screenings, composed of clean, tough, rough surfaced, and angular grains.

Mineral Filler: The mineral filler shall consist of limestone dust, dolomite dust, or portland cement and shall be free from foreign or other objectionable material. It shall be dry and free from lumps and shall be so graded that 100 per cent passes a No. 30 sieve and 65–100 per cent passes a No. 200 sieve.

Bituminous Material: The bituminous material shall be asphalt cement of penetration grade 50–60, 60–70, 70–85, or 85–100.

Plant and Equipment: The mixture should be procured from a producer using a

standard plant. The plant shall include equipment for drying, screening and storing aggregates (at least three compartment storage of appropriate aggregate fractions); tanks for storage and heating of bituminous materials; equipment for proportioning mixture ingredients; and a twin pugmill mixer.

Paving Mixture for Type I-3b Tar Concrete Pavement (Hot Laid)

Description of Pavement: The pavement shall consist of hot-laid tar concrete constructed on the prepared subgrade. The course shall have a thickness not less than the maximum size of the aggregate used.

The tar concrete shall be composed of a mixture of Coarse Mineral Aggregate, Fine Mineral Aggregate, and (if required to meet the prescribed grading) Mineral Filler with Tar.

General Composition of Mixtures: The several mineral constituents for the tar concrete shall be so sized and graded and shall be combined in such proportions that the resulting composite blend will meet the grading requirements of Table 7, and the fraction retained between any two consecutive sieves will be not less than 4 per cent of the total. To such composite blended aggregate tar shall be added in such amount that the bitumen content will constitute a percentage (of the mineral aggregate considered as 100 per cent) falling within the limits of Table 7.

Coarse Mineral Aggregate: The portion of the aggregate retained on a No. 4 sieve shall be known as coarse aggregate and shall be crushed stone, crushed slag, or crushed gravel. The coarse aggregate shall consist of clean, tough, durable fragments, free from an excess of flat, elongated, soft or disintegrated pieces, dirt or other objectionable matter and shall have a per cent of wear of not more than 40 at 500 revolutions, as determined by A.A.S.H.O. Method T-96.

If crushed gravel is used, not less than 50 per cent by weight of the coarse aggregate particles shall be particles having at least one fractured face.

Fine Mineral Aggregate: The portion of the aggregate passing a No. 4 sieve shall be known as fine aggregate and shall consist of sand (or a blend of sand and stone screenings), composed of clean, tough, rough surfaced, and angular grains.

Mineral Filler: The mineral filler shall consist of limestone dust, dolomite dust, or portland cement and shall be free from foreign or other objectionable material. It shall be dry and free from lumps and shall be so graded that 100 per cent passes a No. 30 sieve and 65–100 per cent passes a No. 200 sieve.

Bituminous Material: The bituminous material shall be tar, grade RT-10, RT-11, RT-12.

Plant and Equipment: The mixture should be procured from a producer using a standard plant. The plant shall include equipment for drying, screening and storing aggregates (at least three compartment storage of appropriate aggregate fractions); tanks for storage and heating of bituminous materials; equipment for proportioning mixture ingredients; and a twin pugmill mixer.

Skin or Seal Treatment: The surface of the pavement shall be given a treatment of hot tar and fine aggregate after the pavement has been consolidated by traffic for not less than 30 days nor more than 60 days. The treatment shall consist of 0.15 to 0.30 gallons of tar per square yard heated to a temperature of 150°F. to 225°F. uniformly applied to the surface of the pavement and immediately covered with 6 to 12 pounds per square yard of fine aggregate.

Tar shall be grade RT-9 or RT-10 and fine aggregate shall be fine mineral aggregate as described above, so graded that all shall pass a No. 4 sieve and not less than 75 per cent shall pass a No. 8 sieve.