hours of equipment usage, quantities of materials received, used and on hand, maintenance cost records, etc.

Skilled Laborer
: One who through special training or experience has become proficient in such a trade as carpenter, painter, mason, plumber, or such work as patrolman helper, bridge repair man, truck driver, etc

Common Laborer
: One who performs manual labor

Note In the foregoing definitions of titles of maintenance personnel, the first subdivision in the State for supervision purposes is called a division, the second subdivision is called a district

Additional Definitions of Titles of Key Personnel Other Than Maintenance

Project Engineer
: One who has charge in the field of one or more highway construction projects under the general supervision of a Division Construction Engineer and/or a Division Engineer.

Chief of Survey Party
: One who has charge in the field of a highway survey party with some latitude for exercising individual judgment but under the general supervision of an Assistant Division Engineer and/or a Division Engineer.

Plans Designer
: One who designs highway construction plans, such as laying grade line, preparing intersection layouts, determining sizes and lengths of drainage structures except bridges, preparing construction estimates, etc —all under the direct supervision of a Chief Designer

Bridge Designer
: One who designs highway bridges under the direct supervision of a Chief Bridge Designer

Chief Clerk
: One who has a knowledge of modern office methods, procedures and equipment, business arithmetic and business english, and supervises a large group of clerical employees, engaged in performing important clerical work.

PROGRESS REPORT OF COMMITTEE ON HIGHWAY MAINTENANCE COSTS AND OPERATING METHODS

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SYNOPSIS

In an effort to arrive at comparative costs, field maintenance engineers of the Public Roads Administraiton were asked to secure from State highway departments such data for individual maintenance operations on portland cement concrete pavements as were readily available. A description was also requested of the materials and practices on the operations studied This progress report furnishes the results of the survey and also an analysis of costs on: (1) filling joints and cracks, (2) patching concrete pavements with bituminous materials, (3) patching concrete pavements with concrete, (4) drilling holes and materials for mud-jacking operations, (5) shoulder maintenance, (6) clearing and shaping of drainage ditches, and (7) painting of center-line traffic stripes.

The performance of road maintenance to preserve the nation's streets and highways cost $659,000,000 in 1941, the last year of normal operations before the war. This sum represented the annual cost of all road maintenance operations throughout the United States. Analysis of maintenance performance over a period of years on representative road sections discloses that on the average 45 per cent of the expenditures is made for direct labor, 21 per cent for materials, 25 per cent for equipment and 9 per cent for overhead.

Total expenditures for 1942 and subsequent years reflect only a partial performance of necessary highway maintenance due to manpower, equipment and material limitations. The 1941 cost of maintenance is, therefore, to be considered the minimum expenditure to meet present requirements. A general uptrend of prices and the essential work of overcoming the accumulation of deferred maintenance work will be contributing factors in making additional expenditures.

The expenditure of nearly three quarters of a billion dollars on maintenance operations per year emphasizes the need for revaluing in the post-war years the repair practices used to arrive at common results and the selection of the most efficient methods. Such selections should be based on comparisons between States of unit costs, analysis of the maintenance operations and an appraisal of the effectiveness and durability of the work performed.

As a beginning, in an effort to arrive at comparative costs, field maintenance engineers of the Public Roads Administration were asked to secure from State highway departments such data for individual maintenance operations on portland cement concrete pavements as were readily available. A description was also requested of the materials and practices on the operations studied. This progress report furnishes the results of the survey and also an analysis of costs on several other maintenance operations

Only 17 of the 48 States had cost analyses readily available for specific maintenance operations on concrete pavements In these reports there was a lack of uniformity in the units used in cost analysis. The data presented in this report should focus attention on the need for adoption of uniform cost units for maintenance operations and encourage maintenance organizations to compare their unit costs with those of other organizations. It will permit maintenance engineers who develop unit costs during 1946 to compare their costs with those in this report for a determination as to whether economy in method is being achieved

All 48 States were requested to supply costs and descriptions of methods for:

(a) Joint and crack filling,
(b) Patching concrete with bituminous material,
(c) Patching concrete with concrete,
(d) Mud-jacking operations

Of the 17 States which responded with data, eight submitted costs on item (a), seven had costs on item (b), seven had costs on item (c), and five had costs on item (d). Only one State submitted costs on all four items

JOINT AND CRACK FILLING

Data submitted by the eight States for joint and crack filling disclosed a wide variation in unit costs—the lowest being $8 64 per road mile and the highest $138 89. Unit costs of this item on the basis of length of joints and cracks would have furnished a more accurate comparison but these were available in only a few instances The complete tabulation of costs submitted by the eight highway departments are as follows:

	Cost per road mile
(1)	$50 to $85
(2)	25.00
(3)	138 89
(4)	33 96
(5)	39.13
(6)	8.64 (machine method)
	15 90 (hand method)
(7)	32 77
(8)	35.00 (pavements up to ten years old)
	60 00 (pavements ten years and older)

(1) The cost of $50 to $85 per mile varies with the number of pavement joints and cracks per mile of road. The cost per lineal foot of joint and crack filling varied from ½ to ⅝ cents The material used was a mixture of 30 per cent 90–95 (SC6) and 70 per cent of 31–40 penetration air-blown asphalt The filler was heated to a temperature of 300–325 F and poured into the joints and cracks through metal cones A crew of from four to six men was generally used for the work.

(2) The cost of $25 per mile for joint and crack filling was an average based on work performed on 761 miles of concrete pavement. Material used for the filling consisted of an 85–100 penetration asphalt cement mixed with 15 to 25 per cent by weight of mineral filler Loose material in joints was removed before filling Cost per lineal foot of filling was not available

(3) The $138 89 cost per mile was an average on eight sections of pavement totaling 112 miles The asphalt-mineral filler used

in this work consisted of a 50 to 60 per cent homogeneous mixture of mineral with an asphalt having a penetration of 50–65

(4) The cost of $33 96 per mile was reported by the fourth State as an average on 221 miles of pavement. The description of the filler was briefly reported as an asphaltic cold patch material

(5) The cost of $39.13 per mile was the average cost of joint and crack filling on 6,034 miles of concrete pavement The asphalt filler had a 50–60 penetration and was poured at a temperature of not less than 225 nor more than 275 F

(6) The cost per mile of $8 64 and $15 90 are average costs reported from records kept on machine pouring and hand pouring methods, respectively. Savings of about 25 per cent in material with practically no waste and neater work were reported as being accomplished with smaller operating crews when crack filling machines were employed. The material used was an asphalt of 85–130 penetration in which was incorporated 15–25 per cent by weight of mineral flour of such fineness that no appreciable separation of the mixture occurred while being maintained in a liquid state The material was heated for proper thinning in preparation for the pouring in cracks but not to exceed 375 F Cost per lineal foot of filling was not available

(7) The cost of $32 77 per road mile was based on records kept on eight projects totaling 97 miles of pavement located within one maintenance district. The cost included $20 79 for labor and equipment rental and $11 98 for material. Filling was estimated to cost one third of a cent per foot of joint or crack The material used was asphalt crack filler of a 100–120 penetration

(8) The cost of $35 per mile was based on pavements up to ten years of age, while the $60 cost was based on pavements over ten years old The cost per lineal foot of crack or joint was estimated to be one fourth of a cent

Two types of joint filler were used, one being RC-5 having a penetration of 80–120 and the other conforming to the A A S H O specification M-18

PATCHING CONCRETE WITH BITUMINOUS MATERIAL

Costs reported by the seven States for bituminous patching ranged from $0 25 to $1 per square yard Costs were also reported on a per mile basis

The lowest cost per square yard reported for bituminous patching resulted from the use of a penetration type emulsion. Fine or medium screenings were used on shallow patches and ⅜- or ½-inch crushed rock on deeper patching. In performing the work the area to be patched was first broomed, a light tack coat of emulsion applied and enough crushed rock or screenings spread to bring the depression to grade An application of ⅛ to ¼ gal of emulsion per square yard was then applied, followed by sanding and rolling.

No indication was given as to the method or materials used in the patching work which cost $1 per square yard, other than that patches were of an oil mulch type

Two reports on a per mile basis indicated costs of $25 12 and $99 09—the former being based on 221 miles and the latter on 6,832 miles of highways. The method and materials used were not described for the lower cost Asphalt cutback, asphalt emulsion and plant mixed bituminous concrete were the materials used for the patching work costing $99 09 per mile

PATCHING WITH PORTLAND CEMENT CONCRETE

Reports from five States show a range in costs for patching with concrete from $4 to $6.70 per square yard.

Data compiled by one State on replacing 19,952 square yards of concrete by State forces disclosed a unit cost of $5 14 per square yard. Similar work by contract in replacing 1,309 square yards cost $6 70 per square yard. The concrete mix was 1:1½:2 (by volume) using 1½-inch coarse aggregate and a 1 3 mix when using 50-50 pit-run aggregate The concrete was mixed for two minutes and consolidated by mechanical vibrator. Work was confined to half of the slab width and all patches were permitted to cure for 24 hr. under the protection of burlap.

In another State 43,959 sq. yd. of concrete replacement was completed at an average cost of $4 68 per square yard. Three methods were employed on this work. Part of the concrete was hauled as dry batch and mixed at the site, part was mixed at a central plant and hauled as wet batch and part was proportioned at a central plant and hauled in transit mixers. Practically all mixing and

proportioning were performed by State forces, although in a few instances ready-mixed concrete was purchased from a commercial firm which made delivery.

Cost data kept on concrete replacement work performed during 1944 and 1945 in a mid-western State was summarized as follows:

Patch not more than 5 square yards in one lane	$6.00 per sq. yd.
Patch over 5 and less than 15 square yards in one lane	5.25 per sq. yd.
Patch over 15 and less than 40 yards in one lane	4.90 per sq. yd.
Patch over 40 square yards	4.78 per sq. yd.

These costs include removal of old pavement and storing debris within two miles of the site, curing, and maintenance of barricades, signs and lights, but do not include reinforcing, renewal of subgrade or dowels. The concrete used was of a sand-gravel mix with seven sacks of cement per cubic yard.

Another State reported that 3,316 sq. yds. of concrete were removed and replaced at a cost of $5 02 per sq. yd. Similar work by maintenance contract has averaged $5.50 per sq. yd.

The remaining unit cost of $4 per square yard was obtained from data kept by a western State on 18-ft. pavements over 10 yr. old. This cost is an average figure for replacing pavements of 6- to 9-in. thickness. The cost of breaking old concrete which was included in the $4 unit cost averaged $1 per sq. yd.

Unit costs were not available for placing shallow concrete patches and only one State reported using this type of patch. In the method described, all disintegrated concrete was removed and a solution of one part hydrochloric acid and four parts water was brushed onto the concrete. After 5 min. the solution was flushed off with water and a mix of neat cement was brushed onto the surface of the old concrete. The concrete patch was then laid. The mix consisted of one part air-entrained (vinsol resin) cement, two parts sand and three parts trap rock In very shallow patching ½-in. trap rock was used for aggregate In deeper patching the coarse aggregate was made up of 60 per cent of 1½ in stone and 20 per cent of ½-in. stone.

MUD-JACKING OPERATIONS

Of five States reporting mud-jacking costs, two were based on the square yards of surface raised to normal level, one was on a per mile of road basis, one was on per cubic yard of material and one on per gallon of material placed under the surface.

One State employs two mud-jacking crews to repair all concrete pavement settlements within the State. The annual cost for work is about $25,000 for the 761 miles of pavement. In mud-jacking, special attention is given to settlements of recently laid concrete but no lifting is performed unless the settlement exceeds 2 in. The amount that slabs have been raised varied from 2 to 8 in. The cost varied from about $1 to $4 per sq yd. depending upon the amount of lift In 1942 the average lift was 3 in. and in 1943 it was 5 in., the costs being $1 58 and $2 56 per sq. yd, respectively The aggregate used in the slurry mix was earth which would hold water under pressure of 500 lb per sq. in., such as loam, topsoil, hardpan or clay. Materials were required to pass a ⅜-in. mesh screen and contain not more than 5 per cent of sand. Two sacks of cement per cubic yard were used in the mix and additional cement was added where the subgrade was wet.

Mud-jacking costs kept in repairing 50 miles of concrete pavement in another State indicated an average cost per mile of $117 61. More detailed data relative to the extent of the operations were not available

The cost of treating 21,200 sq. yd. of concrete pavement in one of the eastern States averaged $0 24 per sq. yd. A slurry of topsoil, cement, water and asphalt was used, the total amounts being 105 cu. yd of topsoil, 275 sacks of cement and 300 gal of asphalt. Approximately 1,800 holes were required for the treatment The crew consisted of seven men.

A central State reported that during 1944 a total of 9,455 cu. yd. of material were placed under pavements as preventive and corrective work at an average cost of $9.24 per cu. yd. Usually no attempt was made to raise the pavement from its settled position. It is the policy in the State merely to fill the voids under the slab to reduce deflection and then restore riding qualities with a bituminous top course. Mud-jacking work was performed by an eight-man crew consisting of a foreman, mud-jack operator, nozzle operator, truck driver, flagman and three laborers. Such a crew has pumped as much as 28 cu.

yd. of slurry in a 10-hr. day. The slurry used was a mixture of topsoil, cement and water in the proportions of four sacks of cement per cubic yard of soil with 50 to 55 per cent water. Holes were drilled with a pneumatic hammer using a 1¼-in. bit although 1½- or 2-in. bits were also used to permit use of a larger nozzle opening where selected soil was not available. The cost for drilling these holes was estimated at 7 to 10 cents each.

In several States, liquid asphalt was used under the pavement in place of a slurry to reduce pumping action of slabs. Good results have been reported with a low penetration asphalt having a high melting point. The contract price for this type of work in one State was reported to be 12½ cents per gallon of asphalt pumped and 23 cents per hole for drilling

SHOULDERS

The availability of unit costs on shoulder maintenance is also limited.

The highway departments were questioned by field maintenance engineers of the Public Roads Administration on the maintenance of shoulders, especially turf While an average cost per mile of shqulder maintenance was frequently available, it was not identified with a specific type of shoulder or broken down for the various operations so as to be used in comparisons between States.

The following is the cost per mile in one eastern State for maintaining 8-ft. turf shoulders:

	Cost per mile
Mowing (48 swath miles at $0.41. This includes two round trips per mowing performed twice a month during the growing season or for approximately six months)	$19.68
Machining or rolling high places to keep good drainage (each year)	50 00
Patching and reseeding (each year)	25.00
Total annual cost per mile	$94.68

A general average cost per mile for maintaining three types of shoulders in a northwestern State was reported as follows:

	Cost per mile
Earth	$50
Turf	52
Crushed rock	69

Although there is a wide variation in the cost of maintaining individual projects in the State, it was noted that where the pavement was of sufficient width to eliminate the formation of edge ruts, the cost of maintaining crushed rock shoulders was low The shoulders on one portion of a route carrying a heavy volume of traffic was kept in a very satisfactory condition with only four or five bladings a year at a cost of $25 per mile.

DRAINAGE DITCHES

Developments in machines for loading material trimmed from ditches and shoulders are lowering the cost of drainage maintenance. The following is a detail analysis of operations in a western State in which 61.9 miles of ditches were cleaned and reshaped in 15 days There were 4,714 cu yd. of materials moved and the total cost of the work was $3,030. This resulted in a cost of $48 96 per mile or $0 64 per cu yd. of material moved. Average costs of similar operations by hand methods were reported as $0 90 to $1 per cubic yard.

Cost Analysis for Machine Method of Cleaning and Reshaping Ditches

Items	Dollars
Labor	$1,619 40
Medical attention and industrial insurance	42.05
Rental of State equipment	878 14
Rental of loading equipment	280.00
Provisions and supplies	210 83
Total	$3,030 42

Equipment Used	Rental Rate Per Day
1—F.W D. truck	$16 00
1—Pull grader	10.00
1—Motor grader	8 00
2—Trucks	6.00 each
2—Trucks	5.00 each
1—Pickup	3.25
1—Loader	20.00

CENTER-LINE TRAFFIC STRIPE

The unit cost of maintaining a continuous center traffic line was reported as substantially higher than for a broken line. One northeastern State painted a line 15 ft long with an interval of 25 ft. Ten gallons of paint were required per mile for a continuous line 4 in. wide while only 4 gal of paint were required for the 4-in. broken line. Cost of the broken line, including cost of paint, labor and rental of equipment, was 45 per cent of the cost of the continuous center-line stripe.

A Pacific coast State reported that substitution of a broken line for a continuous line saved the State $90,000 in one year. The saving became available for other needed maintenance work. This well illustrates the value of unit cost comparisons of maintenance operations as a basis for developing efficiency in repairing practices and effecting reductions in expenditures

CONCLUSIONS

1 Maintenance expenditures in the United States of six tenths of a billion dollars per year on highways, roads and streets are of such magnitude as to emphasize the need of revaluing present maintenance practices, materials and equipment used to insure the highest degree of economy and efficiency.

2. Comparisons are now hampered by a lack of uniformity in units of measure in maintenance cost keeping.

3 Comparing costs on a lineal foot basis of filling joints and cracks in concrete pavements develops the range of costs as from ½ to ⅝ cents per lin ft There is an indication that with increase in age beyond 10 yr. the costs per mile increase quite noticeably in the maintenance of joints and cracks There are also indications that machine methods are quite markedly more economical than hand operations, possibly permitting a saving of 50 per cent

4 The patching of concrete pavements with bituminous materials costs from $0.25 to $1 per sq yd There are no satisfactory data as to the life of the patches.

5 The cost of patching concrete with concrete ranges from $4 to $6 70 per sq yd. Work performed by State forces cost from 80 to 90 per cent of the cost by contract There are indications that the cost per square yard of concrete patch decreases with the increase in size of the patch

6. The cost of drilling holes in concrete pavement for mud-jacking ranges from $0 07 to $0 23 per hole. Information on the cost of slurry, including pumping under the pavement, is meager; probably it is in the neighborhood of $10 per cu. yd Information on the cost of pumping asphaltic mixtures under the pavement is also meager but is probably around $0 12 per gallon.

7. The reports on shoulder maintenance are not conclusive but costs vary with the type and the width of shoulders As an illustration, one State reports the cost of maintenance of 8-ft turf shoulders as approximately $94 per mile This includes $19 for mowing, $50 for machining or rolling high places, and $25 for patching and seeding. The maintenance of crushed rock shoulders seems to be generally the most economical, ranging from $25 to $70 per mile

8 Cleaning and shaping of drainage ditches, as would be expected, is reported to be more economical by machine methods than by hand methods. Useful comparisons can be made only when data are available on maintenance of ditches of similar design and in similar soils

9 Cost of repainting of center-line traffic stripes indicates economy in the use of the broken center line in lieu of the continuous line One State indicates a saving of 55 per cent

10. An analysis of maintenance expenditures over a period of years on representative sections of road discloses that on the average, 45 per cent of the expenditures are made for direct labor, 21 per cent for materials, 25 per cent for equipment, and 9 per cent for overhead.