EXPOSURE CABINET FOR TESTING EFFICIENCY OF COTTON MATS
IN PROTECTING CONCRETE WHILE CURING

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COTTON MATS FOR CURING CONCRETE

REPORT OF TESTS TO DETERMINE THE EFFICIENCY OF COTTON MATS OF VARIOUS THICKNESSES FOR THE PROTECTION OF CONCRETE WHILE CURING

Prepared by the Division of Tests, United States Bureau of Public Roads

THE IMPORTANCE of minimizing temperature changes within concrete, especially during the early curing period, is well recognized. In connection with this problem the possibility of utilizing the heat insulating properties of mats made up of several plies of raw cotton separated by loosely woven cotton cloth has been suggested and samples of cotton mats containing 3, 6, and 9 plies of cotton were submitted for test purposes by the Texas State Highway Department. These mats measured approximately 1, 2, and 3 inches in thickness, respectively. Figure 1 gives a general idea of the construction of the mats and also shows the number of plies of cotton in each mat as received. The dry mats showed the following average weights per square foot:

	Pounds
3 ply	0. 7
6 ply	1. 2
9 ply	1. 7

Tests were conducted by the Bureau at the Arlington Experimental Farm to determine the efficiency of these mats for curing concrete. These tests involved two separate investigations, one a study of the heat insulating value of the mats when applied to a concrete surface and the other the ability of the mats to retain moisture within the concrete and thus promote efficient curing.

TEMPERATURE TESTS

First series.—In order to determine the relative protection from heat absorbed from the sun's rays afforded to concrete pavement slabs by the cotton mats, tests were conducted in which the surface temperatures of small concrete slabs covered with these and other materials and exposed to the rays of the sun were measured over the daily temperature cycle.

Six concrete slabs each 2 feet square and 6 inches thick were constructed for the tests, a typical paving mixture being used. In the upper face of each slab,

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at the midpoint and one fourth inch below the surface, a copper-constantan thermocouple was installed to indicate the surface temperature of the concrete during the tests. Three of these slabs were covered with sections of the three thicknesses of cotton mats, while for comparison the other three were covered as follows: No cover, double burlap, and a bituminous cutback coating.

To produce a greater temperature range in the air surrounding the specimens than would be possible out of doors at the time of year at which the tests were made, thus simulating summer conditions, an insulated box with a glass cover, similar to a horticultural cold-frame, was constructed. The walls of the box were 6 inches thick and filled with sawdust. The box was inclined toward the sun at an angle such that the sun's rays passing through the glass cover fell normally upon the surface of the specimens. The appearance of this box and the arrangement of the specimens in it are shown in the cover picture of this issue and in figures 2 and 3.

The first observations were made on March 28, 1933, the slabs being 2 weeks old. The evening before the observations were begun the double burlap covering and the three cotton mats were removed from the frame, laid on the ground, and sprinkled with a hose for 5 minutes. The burlap became saturated at once; but the natural oils in the cotton fiber made the mats very water-repellent, and apparently only a small amount of moisture was absorbed during the prolonged sprinkling. The mats were placed on the concrete with the wetted side up, and the box closed up immediately. Temperature readings were begun before daylight the next morning and were continued throughout the day until after dark. These observations included the temperature in the concrete of each of the

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COTTON MATS EFFECTIVE IN HEAT INSULATION AND CURING OF CONCRETE

Experimental determination of the efficiency of cotton mats as a substitute for wet burlap in the curing of concrete reveals the following facts:

1. Cotton mats were proved effective in providing insulation from the heat of the sun's rays. Under the conditions of the tests, the 24-hour temperature range under cotton mats was approximately 35 percent of that which occurred in uncovered concrete and about 60 percent of that in concrete covered with wet burlap.

2. The insulating properties of various thicknesses of mat (ranging from 1-ply, about one third inch thick, to 9-ply, about 3 inches thick) appeared to be about the same.

3. Modulus of rupture tests showed that cotton mats, wet once and placed with the wetted side on the concrete, were as effective in curing as was double-thickness burlap kept continuously wet, the curing period in both cases being 3 days.

4. Cotton mats applied dry proved less effective in curing than wet mats or wet burlap, the specimens developing about 88 percent of the strength of those cured by the other two methods.

5. The various thicknesses of mat used appeared to be equally effective as curing agents for concrete.

six slabs, the air temperature within the box as indicated by a shaded thermocouple, and the air temperature outside the box, also measured in the shade. All of the data obtained in this first series of observations are shown in figure 4, while in figure 5 the ranges from maximum to minimum temperature for the air within the box, the bare concrete, and the slabs covered with the double burlap and the three thicknesses of cotton mat are given.

Following this test all covering materials were thoroughly dried for several days, and on April 3, 1933, the tests were repeated with all materials assembled in a dry condition. The data from these observations are shown in figure 6 and figure 7.

It will be noted in an examination of the data that the cotton mats were very effective in reducing the temperature range to which the concrete under them was subjected and that the difference in effect between the three thicknesses used was small. The temperature
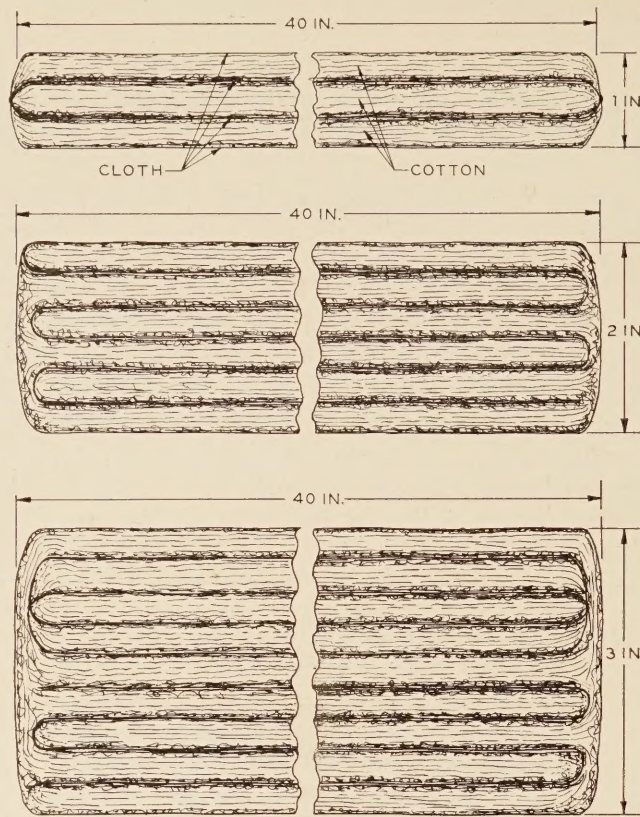
FIGURE 1.—STRUCTURE OF COTTON MATS.

range under the cotton mats was approximately 35 percent of that of the bare concrete and about 60 percent of that of the concrete covered with a double layer of burlap.

The possibility of making use of the cotton mats for the protection against freezing of concrete exposed to sudden drops in temperature is recognized, and a series of laboratory tests is being initiated to investigate their value for this purpose.

The heat-absorbent properties of the black surface obtained with the bituminous coating is evident in these data. It will be noted that there is relatively little difference between the temperature of the bare concrete and that of the slab coated with bitumen, considerably less than has been found in other previous tests. This was thought to be due to the fact that the concrete was unusually dark in color because the cement employed was a very dark blue-gray, in fact almost black, and raised an interesting
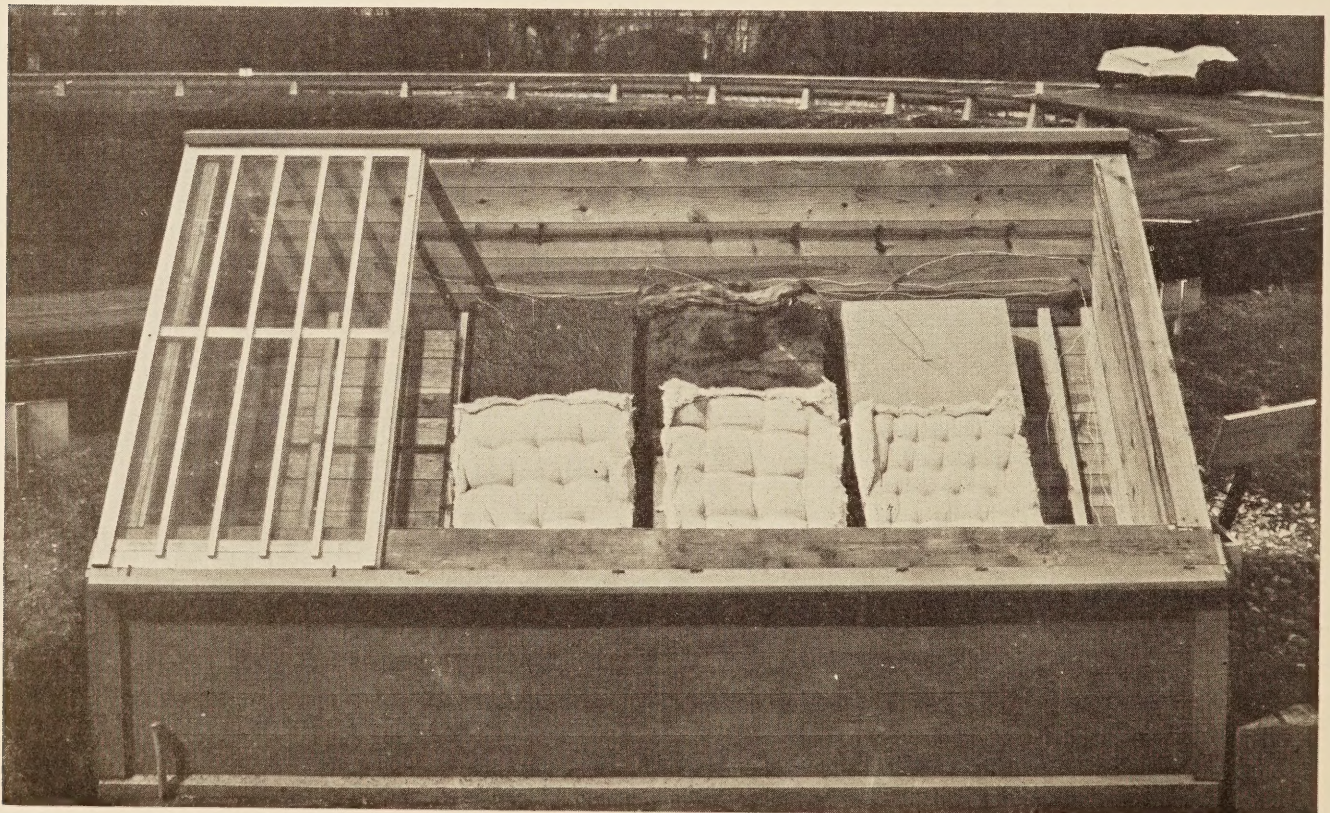
FIGURE 2.—EXPOSURE CABINET OPENED TO SHOW ARRANGEMENT OF TEST SLABS.

FIGURE 3.—COTTON MATS LIFTED TO SHOW RELATIVE THICKNESS OF EACH.

question as to the effect of cement color on the heat absorption of concrete pavements. Some data on this point appear later in the report.

Taking the mean temperature of the bare concrete slab as a base and comparing with it the mean temperature of the burlap-covered slab and the mean temperature of the group of three slabs which were covered with cotton mats, we find the following relations:

Covering	Decrease in temperature below that of bare concrete
	°F.
Double burlap (damp)	12
Cotton mats (damp)	22
Double burlap (dry)	7
Cotton mats (dry)	19

This comparison gives a good idea of the relative protection from the sun's rays afforded by the burlap and the cotton mats, brings out the temperature-lowering effect of moisture evaporation, and shows that even when thoroughly dry the cotton mat provides a very definite thermal protection for the slab.

The fact that there was so little difference in the temperature of the slabs under the three thicknesses of cotton suggested that mats having less than three plies of cotton might be effective.

FIGURE 4.—EFFECT OF VARIOUS SURFACE COVERINGS ON THE TEMPERATURE OF CONCRETE EXPOSED TO THE SUN'S RAYS; TESTS MADE MARCH 28, 1933.

FIGURE 5.—TWENTY-FOUR-HOUR RANGE IN TEMPERATURE OF CONCRETE COVERED WITH VARIOUS MATERIALS AND EXPOSED TO THE SUN'S RAYS; TESTS MADE MARCH 28, 1933.

It is apparent that the exposure cabinet functioned as intended, increasing the air temperature range about 50 percent and creating maximum air temperatures (in the shade) of approximately 90° F., at a time when such temperature conditions could not be even approached out of doors.

Second series.—Because of the opportunity which was afforded to obtain additional data on this important subject and to answer certain questions which had been raised by the first series of observations, additional temperature tests were made. The procedure followed was essentially the same as that previously used, and the points investigated were:

(*a*) The effect of placing the wetted side of the cotton mats down, in contact with the concrete, instead of up.

(*b*) The effect of using fewer plies of cotton in the mats.

(*c*) The effect of the color of the cement on the temperature of the concrete.

(*d*) The effect of certain other coverings.

The first series of temperature tests were made with the wetted side of the cotton mats up, as would be the case if the mats were placed on the road slab and then sprinkled with a hose. The question arose as to whether the insulating effect of the mats would be different were they wet on the lower surface only. In the tests which were made to determine the answer to

this question, the temperatures of slabs covered with 1-, 2-, 3-, 6-, and 9-ply cotton mats with the wetted side both up and down were observed over a complete daily cycle in comparison with the temperature of a bare slab. The 24-hour range for each of these is shown in table 1, expressed as a percentage of the range of the bare concrete slab.

TABLE 1.—*24-hour ranges of temperatures in concrete covered with cotton mats of various thicknesses, and in bare concrete*

Covering	24-hour range	
	Wet side up	Wet side down
	Percent	*Percent*
Bare	[1] 100	[1] 100
1-ply cotton mat	40	38
2-ply cotton mat	30	30
3-ply cotton mat	35	35
6-ply cotton mat	30	37
9-ply cotton mat	32	36

[1] Bare concrete slab dry in both cases.

These data indicate that the position of the wetted surface does not appreciably affect the daily temperature range of the concrete.

Under conditions of low humidity it is probable that, if the upper surface of the mat were wet, evaporation would lower somewhat the mean temperature below the mat. In these tests the exposure cabinet was closed and evaporation was limited, so that it was not to be expected that a difference in mean temperature would
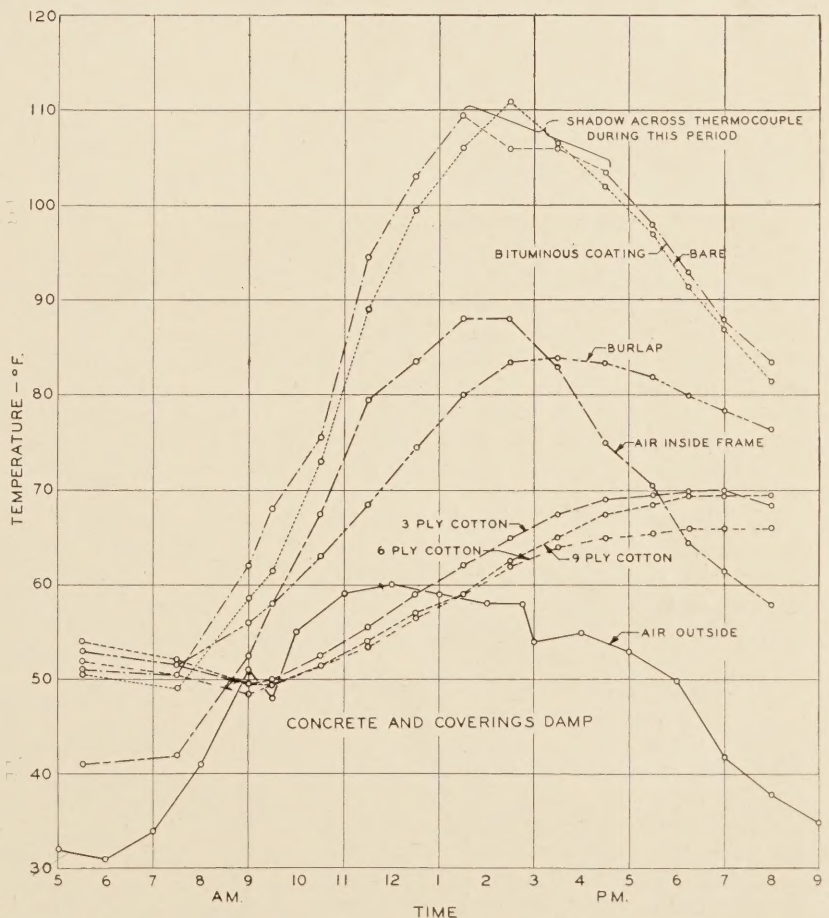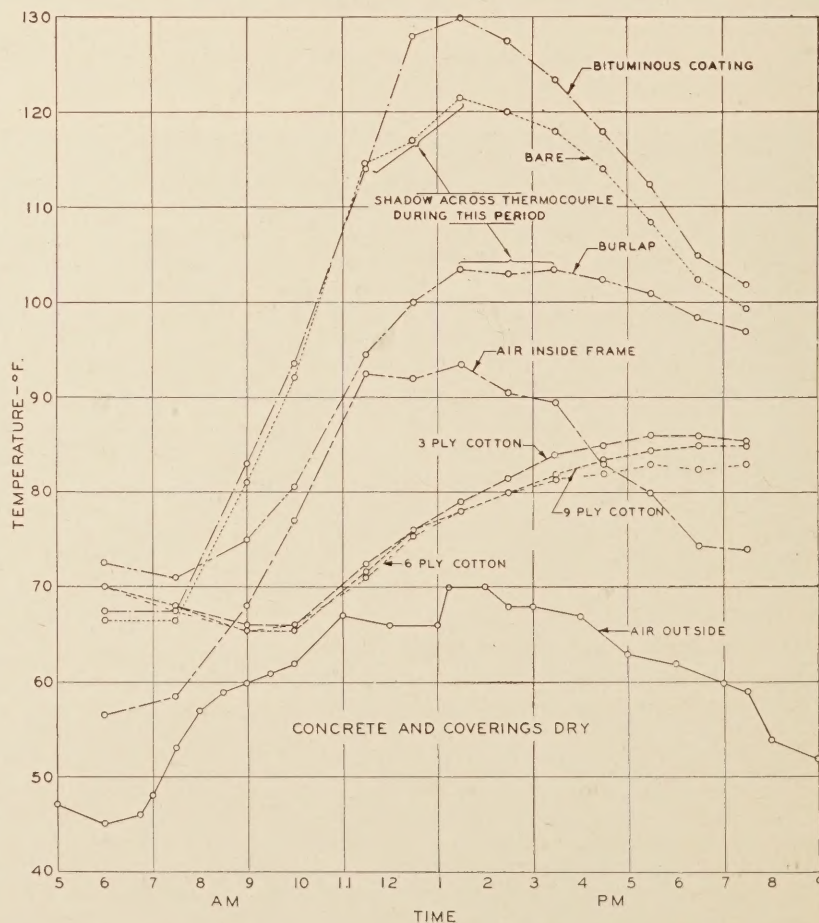

FIGURE 6.—EFFECT OF VARIOUS SURFACE COVERINGS ON THE TEMPERATURE OF CONCRETE EXPOSED TO THE SUN'S RAYS; TESTS MADE APRIL 3, 1933.
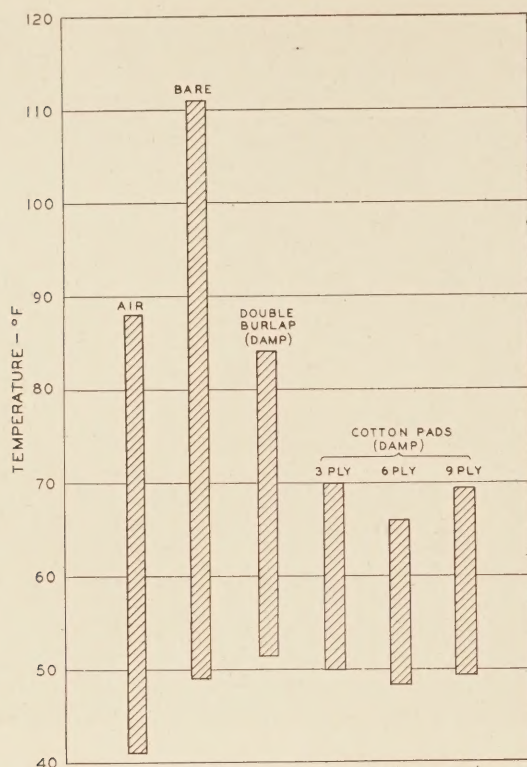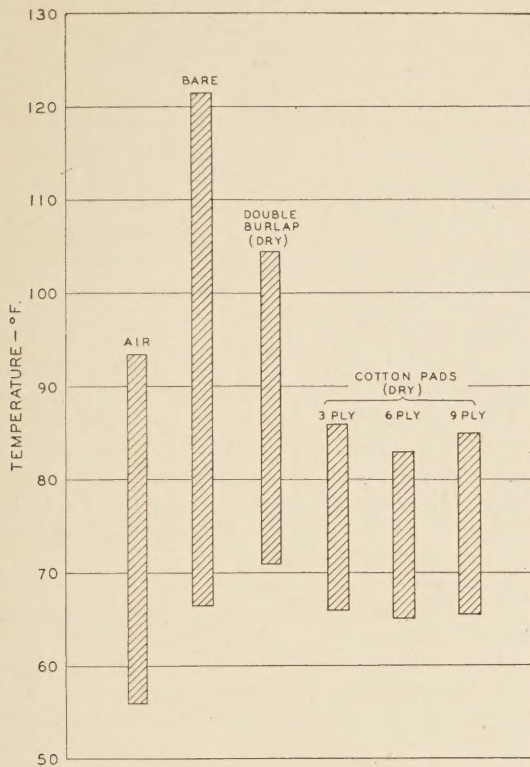
FIGURE 7.—TWENTY-FOUR-HOUR RANGE IN TEMPERATURE OF CONCRETE COVERED WITH VARIOUS MATERIALS AND EXPOSED TO THE SUN'S RAYS; TESTS MADE APRIL 3, 1933.

be found. Actually the mean temperature of the covered slabs was approximately 80 percent of that of the bare slabs, irrespective of the position of the wetted surface of the covering mats.

SINGLE-PLY COTTON MAT PROTECTS FROM SUN'S RAYS

Two new mats were made containing 1 and 2 plies of cotton, respectively, but otherwise identical to the 3-, 6-, and 9-ply mats used in the first tests. The temperature ranges for slabs covered with 1-, 2-, and 3-ply cotton mats over a 24-hour cycle compared with that of a bare slab are shown in figure 8. These data indicate that, so far as heat absorbed from the sun's rays is concerned, even a single ply of cotton offers effective protection. The difference in the insulating value of the various thicknesses of cotton mat is not shown to the best advantage under rapidly changing temperature conditions such as those to which a concrete slab is ordinarily exposed. While the additional insulation offered by the thicker mats creates a time-lag effect which is perceptible in all of the data, it would be more marked if the time during which the temperature cycle occurred were greater.

EFFECT OF COLOR OF CEMENT STUDIED

Mention was made in the report of the first series of tests of the fact that the cement used in the construction of the test slabs was of an unusually dark blue-gray or black color, and it was suggested that this dark color might affect the heat absorption by the concrete. Two duplicate slabs were constructed identical in every way except as to the color of the cement. In one a pure white and in the other a light gray portland cement were used. Because of the influence of the colors of the aggregate the resulting color was about the same in both of these slabs. However, both were considerably

lighter in color than the first specimens made. The slabs containing the three cements when exposed to the sun (without a glass cover) showed the following temperature range:

Color of cement	24-hour temperature range	
	May 2	May 19
	°F.	°F.
White	79–98	51–92
Light gray	80–98	52–92
Dark blue-gray	78–110	52–106

Under the very moderate conditions which prevailed at the time of these observations the concrete containing the dark-colored cement reached a maximum temperature 12° to 14° F. above that of the concrete containing the light-colored cements. Since all three reached the same minimum temperature this difference of 12° to 14° in the maximum value also represents the difference in the 24-hour temperature range between slabs made with light and those made with dark-colored cement, under the conditions which obtained at the time of these tests.
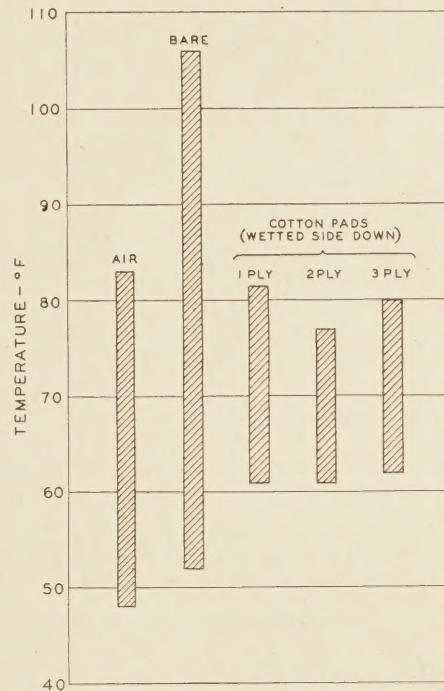
FIGURE 8.—TWENTY-FOUR-HOUR RANGE IN TEMPERATURE OF CONCRETE COVERED WITH 1-, 2-, AND 3-PLY COTTON MATS AND EXPOSED TO THE SUN'S RAYS; TESTS MADE MAY 19, 1933.

COTTON CLOTH AND WHITEWASH TRIED

Because of the opportunity afforded, observations were made of the effect on slab temperature of two other coverings which are of interest. One of these was a relatively thin white cotton cloth laid directly on the surface of the concrete in a dry state, thus representing the limiting condition in the reduction in thickness of the cotton mats. The other was a whitewash coating given the bituminous coated slab. The tests of these coverings were made in the exposure cabinet under glass.

The 24-hour temperature range for these two specimens is compared with the range for the bare slab and

one covered with a 3-ply cotton mat in figure 9. The range of the slab covered with the 3-ply cotton mat is shown to be 10° F., or 20 percent less than that of the specimen covered with the cotton cloth; 21° F., or 35 percent less than that of the bituminous coated white-washed slab; and 34° F., or 47 percent less than that of the bare concrete slab.
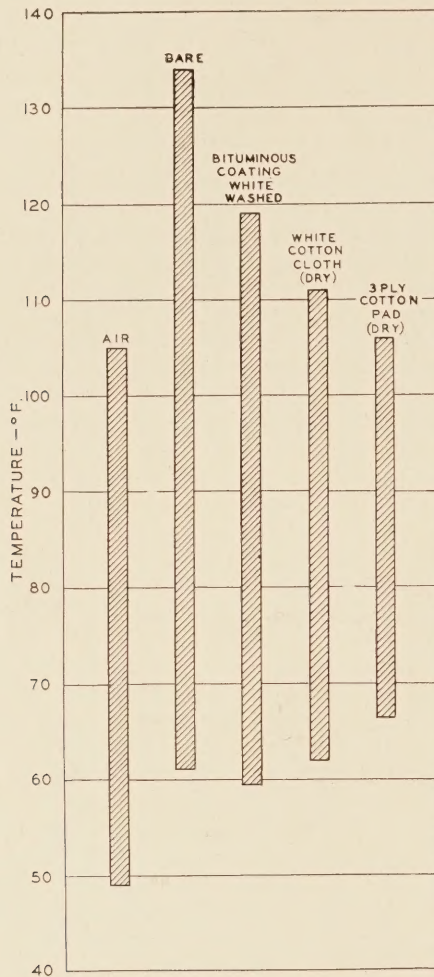
FIGURE 9.—TWENTY-FOUR-HOUR RANGE IN TEMPERATURE OF CONCRETE COVERED WITH VARIOUS MATERIALS AND EXPOSED TO THE SUN'S RAYS; TESTS MADE APRIL 24, 1933.

TESTS FOR STRENGTH AND MOISTURE LOSS

First series.—This portion of the report presents the results of a series of tests made to determine the flexural strength at 28 days of mortar specimens cured for 3 days under 3-ply, 6-ply, and 9-ply cotton mat, as compared with the strength developed by specimens cured with a double thickness of burlap kept wet during the same period. Measurements to determine the rate of moisture loss occurring under the various coverings were also taken.

The following methods of retaining moisture were studied:

> Double thickness of burlap, kept wet 3 days.
> Double thickness of burlap, wet once when applied.
> Three-ply cotton mat, wet on one side when applied.
> Six-ply cotton mat, wet on one side when applied.
> Nine-ply cotton mat, wet on one side when applied.
> Three-ply cotton mat, dry when applied.
> Six-ply cotton mat, dry when applied.
> Nine-ply cotton mat, dry when applied.

TEST PROCEDURE DESCRIBED

Test specimens consisted of mortar mixed in the proportion of 1 part cement to 2 parts sand by weight, with 14 percent water. This produced a mortar of such consistency that a film of free water showed on the surface of the specimens shortly after molding. The specimens were approximately 11 inches in length by 6½ inches in width by 2 inches in thickness and were molded in water-tight pans of sufficient depth to take the specimen and the curing mat. Mats were applied after the specimens had been exposed to the air of the laboratory for approximately 2½ hours after molding.

All of the curing mats except the double thickness of burlap, kept wet 3 days, were cut to fit the pans and the edges sealed with paraffin to prevent moisture loss except through the top. In the case of the wet burlap the covering material was cut longer than the specimen and the free end was immersed in water. This provided an ideal curing condition for the 3-day period. The results of the tests made with this mat are used as the standard of comparison.

The mats which were applied wet were thoroughly sprinkled with water on one side immediately prior to application. They were applied with the wet side down. The same comments as regards the penetration of moisture into the mats which were given in connection with the discussion of the temperature tests apply in this case also.

At the end of 72 hours (3 days) the curing mats were removed. The specimens were weighed and then allowed to remain in the pans with the surface exposed to the air of the laboratory until the age of 26 days. They were then removed from the pans, immersed in water for 2 days and tested for flexural strength on a 9-inch span with the load applied at the center of the span. The slabs were tested in the flat position, with the upper surface (as cast) in tension. Changes in moisture were obtained by weighing the specimens at the end of 3, 10, 20, and 26 days, as well as immediately before testing at 28 days.

Three rounds of tests were run, eight specimens to each round, making a total of 24 specimens.

The results of these tests are given in tables 2 and 3 and in figures 10, 11, and 12.

Table 2 gives the percentage of moisture retained by each specimen at 3, 10, 20, 26, and 28 days, as compared with the original water content. Average results for the three rounds are shown graphically in figure 10. Figure 11 gives the 3-day test data in bar diagram form to facilitate comparisons with the strength data.

The results of the individual strength tests are shown in table 3, with the average results expressed also as percentages of the strength developed by the use of the double thickness of burlap kept wet 3 days.

RESULTS OF TESTS DISCUSSED

In figure 10 the moisture content of each group of specimens at 3, 10, 20, 26, and 28 days is shown. In plotting the values in this figure as well as in figures 11 and 12, the three rounds of tests have been averaged. In figure 10 the results have been further averaged so as to give for each condition of curing the average value for the three thicknesses of cotton. This was done because the individual points were so close that they could not be very well plotted separately.

From figure 10 the effectiveness of each of the curing mats is immediately apparent. For instance, at the

TABLE 2.—*Percentage of original water content of specimens at ages indicated (3-, 6-, and 9-ply mats)* [1]

Curing method	Specimen no.	Percentage of original water content at age of—				
		3 days	10 days	20 days	26 days	28 days
Burlap, kept wet 3 days	1	101.4	90.4	87.6	86.8	97.5
	2	98.1	88.4	85.3	84.9	93.8
	3	100.4	90.2	87.3	86.1	95.6
Average		100.0	89.7	86.7	85.9	95.6
Burlap, wet when applied	1	86.5	82.1	79.6	78.9	99.9
	2	84.7	82.0	79.4	78.7	92.5
	3	89.2	85.1	82.5	81.5	100.6
Average		86.8	83.1	80.5	79.7	97.7
3-ply mat, wet when applied	1	102.5	91.7	88.5	87.6	98.5
	2	99.6	90.0	87.1	86.4	95.4
	3	100.5	90.7	87.8	86.6	95.7
Average		100.9	90.8	87.8	86.9	96.5
6-ply mat, wet when applied	1	100.3	90.3	87.0	86.2	96.4
	2	100.7	91.0	87.8	87.2	96.8
	3	102.4	92.0	88.6	87.4	97.4
Average		101.1	91.1	87.8	86.9	96.9
9-ply mat, wet when applied	1	100.6	91.1	88.3	87.4	97.2
	2	99.0	90.0	87.0	86.4	95.1
	3	101.2	91.4	88.3	87.0	96.7
Average		100.3	90.8	87.9	86.9	96.3
3-ply mat, dry when applied	1	92.7	86.4	83.5	82.9	101.9
	2	91.1	85.8	83.1	82.2	93.3
	3	92.0	86.5	83.5	82.3	97.6
Average		91.9	86.2	83.4	82.5	97.6
6-ply mat, dry when applied	1	93.1	86.4	83.9	83.1	98.5
	2	91.3	86.0	83.0	82.7	95.2
	3	92.7	87.5	84.7	83.3	96.9
Average		92.4	86.6	83.9	83.0	96.9
9-ply mat, dry when applied	1	93.5	86.8	83.9	82.8	96.2
	2	92.2	86.8	83.9	83.0	100.0
	3	93.0	86.9	83.9	83.0	94.8
Average		92.9	86.8	83.9	82.9	97.0

[1] Curing agents removed at end of 3 days, and specimens cured from 3 to 26 days in laboratory air. Specimens immersed in water at end of 26 days.

TABLE 3.—*Results of tests for flexural strength at the age of 28 days (3-, 6-, and 9-ply mats)*

Curing method	Modulus of rupture, in pounds per square inch				Strength ratio [1]
	(1)	(2)	(3)	Average	
Burlap, kept wet 3 days	904	893	948	915	1.00
Burlap, wet when applied		814	801	808	.88
3-ply mat, wet when applied	917	988	904	936	1.02
6-ply mat, wet when applied	910	919	919	916	1.00
9-ply mat, wet when applied	926	934	902	921	1.01
3-ply mat, dry when applied	808	919	756	828	.90
6-ply mat, dry when applied	783	776	820	793	.87
9-ply mat, dry when applied	841	799	812	817	.89

[1] Percentage of strength developed by double burlap kept wet 3 days.

end of the 3-day curing period the specimens cured under burlap which was kept wet and those cured under cotton which was wet once before being applied showed moisture contents of at least 100 percent of the original mixing water. This applies to all three thicknesses of cotton mat. In view of the fact that some of the original mixing water was lost during the 2½ hours before the mats were applied, this means that the specimens actually took up water from the mats during the 3-day curing period. The burlap which was wet when applied but which was not subsequently wet was the least effective in retaining moisture, the specimens at 3 days retaining but 87 percent of the original mixing water. The mats which were applied dry gave intermediate results, the average for the three thicknesses
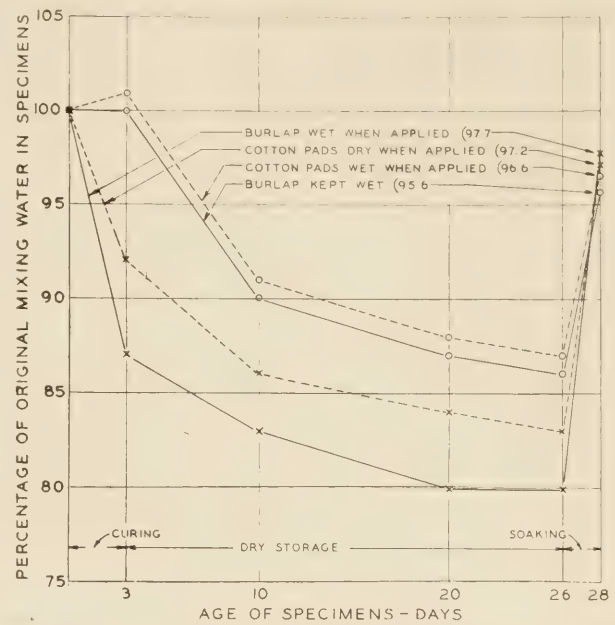
FIGURE 10.—COMPARATIVE MOISTURE CONTENTS OF MORTAR SPECIMENS CURED UNDER BURLAP AND COTTON.

being 92 percent. The relative order of moisture loss is the same for the entire dry-storage period, the specimens continuing to lose moisture up to 26 days. However, at 28 days, after 2 days immersion in water, it was found that the relative order of moisture loss had been reversed, both the specimens cured under burlap wet when applied and those cured under the dry mats showing slightly higher moisture contents than the specimens cured under burlap kept wet and the mats which were wet when applied. This is an indication of the greater curing efficiency of the wet cotton mats which resulted in somewhat denser specimens, lower moisture loss at 26 days, and less gain in weight between 26 and 28 days.

Figure 11 shows the relative moisture losses at 3 days in bar diagram form. Here the values for the three thicknesses of mat are shown separately. The arrangement of this chart affords a good opportunity to study the relative order of values as compared with the burlap which was kept wet for 3 days and which is considered as the standard for comparison.

Figure 12 shows the flexural strength at 28 days for each curing condition plotted as a percentage of the flexural strength of the standard cured specimens (burlap kept wet 3 days). The order of values agrees very well with the percentage of moisture retained in the specimens at the end of the 3-day curing period, indicating a rather definite relation between strength and the amount of curing received during the first 3 days.

These data indicate that, from the standpoint of strength, the 3-ply, 6-ply, and 9-ply cotton mats, if wet when applied, are as effective from the standpoint of curing as a double thickness of burlap kept wet for 3 days. Furthermore, all three thicknesses give comparable results insofar as strength is concerned. The results also indicate that curing with mats applied dry is not as effective as when the mats are wet before being applied. The dry mats developed only 88 percent of the strength attained when they were applied wet, which was about the same relative strength as that obtained with burlap wet once when applied.

Second series.—In view of the fact that the 3-ply mats gave as good results from the standpoint of moisture
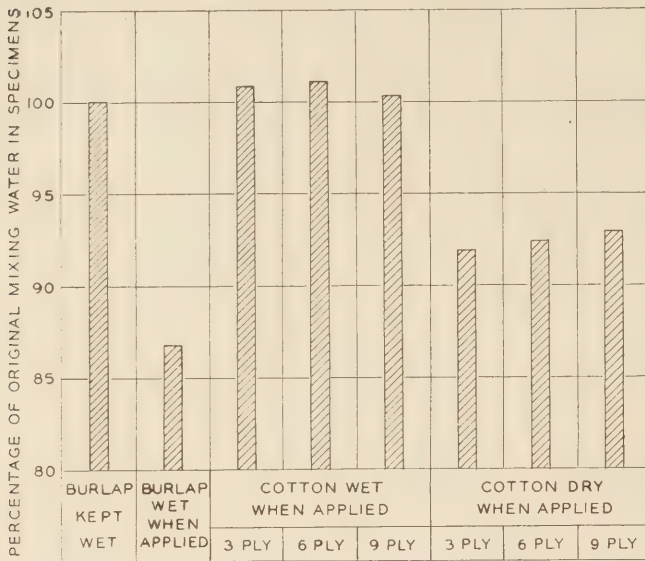
FIGURE 11.—COMPARATIVE MOISTURE CONTENTS OF MORTAR SPECIMENS AFTER 3 DAYS' CURING UNDER BURLAP AND COTTON; FIRST SERIES

FIGURE 13.—COMPARATIVE MOISTURE CONTENTS OF MORTAR SPECIMENS AFTER 3 DAYS' CURING UNDER BURLAP AND COTTON; SECOND SERIES.

FIGURE 12.—COMPARATIVE STRENGTHS OF MORTAR SPECIMENS CURED UNDER BURLAP AND COTTON; FIRST SERIES
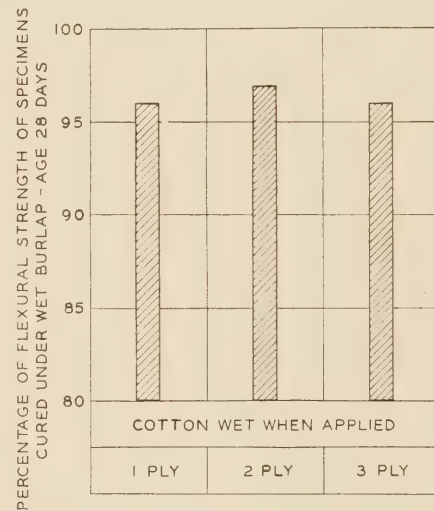
FIGURE 14.—COMPARATIVE STRENGTHS OF MORTAR SPECIMENS CURED UNDER BURLAP AND COTTON; SECOND SERIES

retention and strength as the 6- and 9-ply mats, it was decided to repeat the tests, using mats made up of 1 and 2 plies of cotton. In order to tie in the results with the previous work, tests of the 3-ply mat as well as the double burlap, kept wet 3 days, were repeated. The same test procedures were followed throughout the supplementary series, the only variation being the thickness of the mats.

The results of these further tests are shown in tables 4 and 5 and in figures 13 and 14.

Table 4 gives the percentages of moisture retained by the cotton mats at the various test periods. Comparison with table 2 will show that the values are almost identical with the corresponding values for the 3-, 6-, and 9-ply mats shown in table 2. This indicates quite definitely that the 1- and 2-ply mats are just as effective in retaining water as the 3-ply and thicker mats, within the limits of these tests.

In table 5 the flexural strengths of mortar specimens cured under 1-, 2-, and 3-ply mats, as well as under burlap kept wet 3 days, are shown, together with the strength ratios of the cotton-cured specimens in terms of the strength developed by the burlap cure. The three thicknesses, it will be noted, all show substantially the same efficiency—that is, either 96 or 97 percent of wet burlap. Reference to table 3 will show that, in the initial series of tests, the 3-ply mats as well as the 6- and the 9-ply showed about 100 percent of the burlap cure. Dry mats, on the other hand, only gave about 90 percent of the standard. The slightly lower ratio shown by the 3-ply mats in the second series (table 5) is probably due to the somewhat high strength developed by the burlap-cured standard of comparison as compared to the strength obtained in the first series (table 3). The fact that, in each group, the strengths of the wet mats of different thicknesses are substantially the same leads to the conclusion that for all practical purposes the 1- and 2-ply mats are just as effective as

AN INDEX OF THE COST OF HIGHWAY CONSTRUCTION

Reported by J. L. Harrison, Senior Highway Engineer, Division of Management, United States Bureau of Public Roads

IN ORDER to place a comprehensive statement of the relative purchasing power from year to year of the funds made available for highway construction at the disposal of those responsible for the determination of policy in this field, and of others who may be interested, the division of management of the Bureau of Public Roads has prepared indexes of such construction. These indexes are shown in figures 1 and 2.

The indexes given in figure 1 show the trend in unit prices for excavation, surfacing, and structures over the period from 1922 to 1933 and a similar price trend for a "composite mile" of road. Figure 2 gives the trend of the usage index and the cost index for a mile of road for the years from 1923 to 1931, as well as the price trend for the composite mile.

It is well known that the quantities of materials and the amount of work required to build a mile of road have gradually increased during the last dozen years. The usage index shows this trend. Since the price index is based on the same quantities of excavation, surfacing, and structures for each year, it does not give a true picture of the variation in the cost of road construction. The cost index takes usage into account, and therefore shows the trend in actual cost per mile.

In the determination of these indexes it was necessary to select the unit in which values are to be expressed, the classes of work to be included, the weight to be given to each, and a reference base period. It was decided that the index figure should be developed on the basis of a composite mile of highway and that the classes of work to be included and the weights for each should be as follows:

Common excavation	cubic yards	17, 491
Pavement	square yards	3, 726
Reinforcing steel	pounds	16, 000
Structural steel	do	4, 325
Structural concrete	cubic yards	68

The advantage of a base made up in this way lies in the fact that it measures trends by means of items that are so widely and so frequently used that regional trends in price as well as national trends can be determined with a reasonable degree of accuracy, even on a quarterly basis.

It was decided to use the fiscal years 1925 to 1929, inclusive, as the base period. This is an arbitrary selection, though it produces weightings that, as an expression of usage of materials, are about intermediate between the weightings that would result if the usage of 1922 or the usage of 1931 had governed. A 5-year base period was used in order more accurately to reflect the influence of the various States on both prices and quantities.

The index figures here shown were developed on the basis of the average cost of 1 mile of highway composed of units of grading, surfacing, and structures in the same ratios of use as were found in the highway construction program for the years comprising the base period.

CHANGES IN CONSTRUCTION PRACTICE MAKE DETERMINATION OF INDEXES DIFFICULT

In the presentation of the relative purchasing power from year to year of the money expended in any field, a fixed base from which to measure this purchasing power is the first essential. Actually this requirement cannot be met fully, for in every field of human endeavor—though the physical standards of measurement as applied to the commodities used in this field remain constant—the methods and practices by which those selected for use as a base are produced change constantly, often radically. This is particularly true in the highway field where the development which has taken place during the past 10 years has been both extensive and far-reaching.

This is a condition by no means confined to the highway field. It is, for instance, perfectly apparent that an average pair of shoes is not the same thing today that it was 20 years ago. Though it is equally true, it is not so apparent that even a pound of the leather out of which these shoes are made is a different thing now from what it was then. The processes by which it is produced have changed, and many of the chemicals used in its treatment have been modified, at least as to the methods by which they are prepared.

Any number of additional illustrations of this situation could be given but to no very valuable purpose, for such illustrations would merely add emphasis to the statement already made that, even though the apparent physical aspects of the commodities which are selected

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INDEXES SHOW TREND IN COST OF HIGHWAY CONSTRUCTION

The results of this study show that unit prices for highway excavation, surfacing, and structures declined steadily from 1923 to the second quarter of 1932. Since that date a definite upturn in unit prices has been noted. The combined effect of these trends is shown in the index of the cost of a composite mile of highway, which is based on the assumption of equal quantities of excavation, surfacing, and structures per mile in each year. The price index curves are shown in figure 1.

The quantities of work and materials required per mile of highway have increased almost continuously during the years from 1923 to 1931. The variation of the usage index, which gives the trend in the cost of a composite mile of highway, on the assumption of constant unit prices, is shown in figure 2.

The cost index, which takes into account both the decline in unit prices paid for excavation, surfacing, and structures and the increasing quantities of these items used per mile, is also shown in figure 2. Between 1926 and 1930 the cost trend was upward. In 1931 the decline in price levels was felt sufficiently to cause a drop in the cost index as compared with that of the previous year.

FIGURE 1.—PRICE TREND IN HIGHWAY CONSTRUCTION FROM 1922 TO 1933. AVERAGES FOR 1925 TO 1929 TAKEN AS BASE.

as a base from which to measure changes in the purchasing power of money remain the same, these commodities are not thereby insured a constant internal composition or constancy as to the methods, processes, and practices by which they are created. Insofar as either their internal composition or the methods by which they are created are altered, they necessarily fall short of forming an absolutely fixed base. However, in an age that has been marked by rapid changes in the materials in common use, to say nothing of changes in the methods and practices used in combining them or the machines used in making them, the multiplicity of these changes precludes the possibility of constructing any base which altogether avoids them and so remains, in fact, fully constant over extended periods of time.

power of the money spent in the highway field, and it is believed that a substantially accurate indication of the relative purchasing power of the money used in it results.

In further comment in regard to this matter it may be remarked that if, in fact, the relative purchasing power of the money spent on highway construction differs from the purchasing power as indicated by the index, there is every reason for believing it to be slightly greater than as shown. This statement is based on the fact that the majority of the changes which have taken place in the composition of the units that have been used in establishing the index is in the direction of improved quality or increased quantity, or of both. As these factors tend to produce extra cost—seldom to
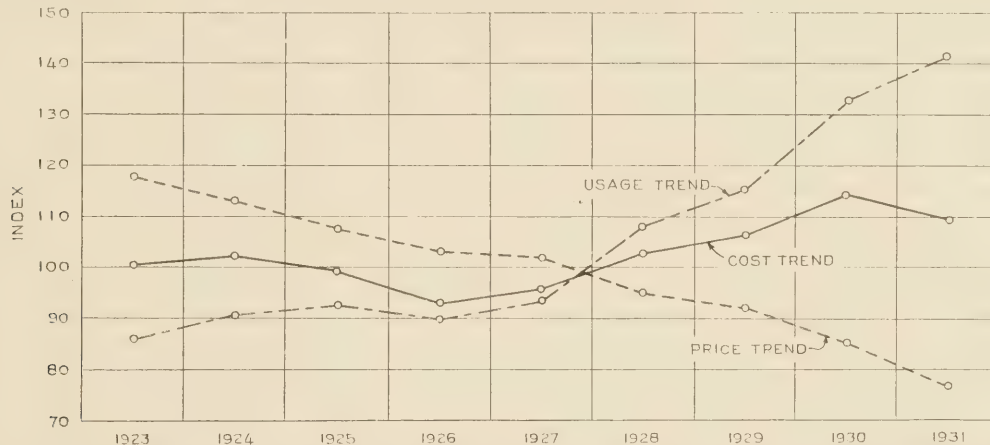
FIGURE 2.—VARIATION IN INDEXES OF HIGHWAY CONSTRUCTION COST FROM 1923 TO 1931. PRICE INDEX SHOWS TREND IN COST OF COMPOSITE MILE COMPOSED OF SAME QUANTITIES OF EXCAVATION, SURFACING, AND STRUCTURES IN EACH YEAR. USAGE INDEX SHOWS TREND IN QUANTITIES OF EXCAVATION, SURFACING, AND STRUCTURES USED PER MILE IN EACH YEAR. COST INDEX, TAKING ACCOUNT OF USAGE, SHOWS TREND IN ACTUAL COST PER MILE. AVERAGES FOR 1925 TO 1929 TAKEN AS BASE.

In the highway field this difficulty must be faced in a somewhat more aggravated form than in other fields, since, in addition to the numerous internal changes which have taken place in the great bulk of the commodities used in constructing highways there have been numerous changes in the physical form of the units by which highway work is measured, more particularly in the paving field. To illustrate, in concrete paving construction the standard unit of measurement is the square yard of finished pavement, but the only fixed thing about this unit is its finished area. The specifications that govern the selection of all of the materials entering into the composition of the completed unit are subject to frequent changes, usually minor, it is true, but nevertheless changes. The proportions in which these materials are used, the amount of manipulation that is required, the exactness with which the surface must be finished, finally even the thickness of the pavement— all change from time to time.

Admittedly, this is rather an extreme example of the instability of what, in theory, should be stable units, and it cannot be denied that this sort of instability subtracts something from the authority of any conclusions index figures would otherwise appear to justify. But no better means of measuring relative prices or their reciprocal, the relative purchasing power of money, is available than is offered by the commodities with which an industry deals, and no better measure of them is to be had than the units on which business transactions are based. These units have therefore been used in developing an index to show the relative purchasing

subtract from the cost—it should be, and probably is, true that when the purchasing power of money is rising their effect is to show somewhat less of a rise than actually takes place, and that when the purchasing power of money is falling their effect is to accentuate the fall. In short, the effect of these factors has been a little to understate rather than to overstate the relative purchasing power of the money used in the highway field.

WEIGHTING THE INFLUENCE OF UNITS

Under some circumstances an index figure that is based on unweighted prices appears to yield results which prove entirely satisfactory; but in the highway field an index developed in this way would be open to the objection that so much more of some kinds of material, such as concrete, is used than of others, such as steel, that unless the amount used is considered, the index is likely to give an unreliable indication of relative purchasing power, for changes in price seldom affect all commodities in the same degree. It is not uncommon for some commodities to rise in price at the same time that others are falling. Then, too, freight charges, which are a large factor in the cost of some types of construction, are an almost negligible factor in the cost of others.

To illustrate these points: If, during the base period and during a succeeding year, prices on four items have been as follows, the use of the unit price alone indicates a rise in the index number—that is, a drop in the purchasing power of the money expended.

	Base period	Another year
Concrete pavement	$2.00	$1.90
Brick pavement	3.50	4.00
Macadam surfacing	1.00	1.15
Gravel surfacing	.50	.40
Total	7.00	7.45
Index number	100.0	106.4

If, instead of unweighted prices, a weighting based on use is introduced, the result may be quite different, as the following illustration (weightings assumed) will indicate.

	Weighting	Base year		Another year	
		Unit price	Total	Unit price	Total
Concrete pavement	10	$2.00	$20.00	$1.90	$19.00
Brick pavement	1	3.50	3.50	4.00	4.00
Macadam surfacing	2	1.00	2.00	1.15	2.30
Gravel surfacing	12	.50	6.00	.40	4.80
Total			31.50		30.10
Index number			100.0		95.5

Where the number of units on which an index is based is large, and more particularly when the index is based on a wide variety of commodities, the unweighted index is perhaps as reliable as the weighted index; but in a restricted field from which it is necessary to select a limited number of items, weighted figures appear likely to yield more reliable results if reasonably accurate weightings can be given to the units selected.

In theory the weighted figures and the unweighted figures are about equally responsive to general price movements. Periods of inflation and deflation tend to affect all commodities about alike, and their effect should be made about equally apparent by both styles of index figures. The same should be true of any general alteration in wage levels. But when it comes to the matter of reflecting the effect on cost of such factors as overproduction, underproduction, more complete mechanization, and improved efficiency, index figures based on weighted prices have a distinct advantage.

Changes in mechanical devices or in processes and improvements in efficiency—to say nothing of overproduction or underproduction—cause radical changes in price. In a restricted field the full effect of changes of this sort may easily be overlooked unless weighted figures are used in developing the index; for each change of this sort is likely to be of limited application, with the result that while in a broad field it has only a limited effect, in a narrow field it may have either a powerful effect or almost no effect at all—the result depending on whether commodities of major or of minor importance in that field are affected. For these reasons it has been thought wise to use weightings in preparing indexes for the highway construction field.

COMPOSITE MILE TAKEN AS BASIS FOR WEIGHTING

If weighted figures are to be used, a basis for the weightings must be determined. After some study it was decided that a composite mile of highway—that is, a mile in which the total yardage of surfacing is appropriately distributed among the various types commonly used, and to which average amounts of grading, structural concrete, and steel have been assigned—would be used as the underlying basis for all weightings. The Bureau's records (compiled from reports of State authorities) of State highway mileage built during the years from 1923 to 1931, inclusive, were used to determine the component types of surfacing entering into the composite mile of pavement.

On the other hand, while the Bureau has satisfactory statistics covering such matters as the mileage of work completed on the State highway systems and the types laid down, no records of such matters as the yardage of excavation handled, the yardage of concrete used in structures, etc., are available except for the work in which the Federal Government has participated. The lack of information of this sort effectively prevented the development of weightings wholly based on the general State highway practice. Careful consideration of these matters led to the conclusion that a satisfactory result might be attained if the composition of the composite mile of pavement were based on average usage in construction work on the State highway systems, and the amounts of the correlated items (grading, structural concrete, and steel) were based on the Bureau's experience on Federal-aid construction.

The propriety of determining the composition of the base in this way necessarily depends on an assumption that practices in the State highway field, taken as a whole, are substantially the same as prevail in the somewhat more restricted field in which Federal aid is applied. That they must be is apparent from the fact that governing specifications are the same in both fields and that design is by the same organizations.

To further emphasize the correctness of this assumption, one has but to remark the fact that as he travels today he finds nothing that will afford any indication as to whether Federal aid was used on the highway at the particular point where he happens to be or whether it is a part of the broader field the State has covered without Federal assistance.

As a result of this decision, the following items were selected for inclusion in the base for these indexes. Their further adjustment and the weightings assigned to them are considered in subsequent paragraphs.

From the Bureau's Federal-aid records:
    Excavation:
        Common
        Unclassified
        Rock
    Structures:
        Reinforcing steel
        Structural steel
        Structural concrete, class A
        Structural concrete, class B
        Structural concrete, class C

From statistics on State highway mileage:
    Pavement:
        Gravel and sand-clay
        Macadam
        Bituminous macadam
        Bituminous concrete
        Portland cement concrete
        Brick

These items cover somewhat more than 90 percent of the total cost of highway construction. Therefore, though their number is not great, it would appear to be adequate. The items not used involve the use of about the same basic commodities, manufacturing processes, transportation problems, and the same classes of labor which were involved in the items used. To include them would complicate the calculations but would neither clarify nor improve the result.

MINOR ITEMS CONVERTED INTO EQUIVALENT AMOUNTS OF MORE IMPORTANT ITEMS

The various items that enter into a composite mile of pavement and the quantity of each to be used having been determined, a question naturally arises as to the distribution of these items—that is, are they universally and frequently used, or are some or perhaps most of them used locally or regionally and infrequently? If the latter is the case, can substantial accuracy be obtained if the items which are used locally or regionally, and on the whole infrequently, are converted into an equivalent amount of items more widely used but likely to show similar price trends?

In answer to the first question, it has been found that of the three grading items common excavation is widely used; unclassified excavation is considerably used but in many States not used at all; and rock excavation, though widely used, is not so frequently used as might be supposed. All of these items involve about the same construction practices and show a similar price trend. In general, the price of unclassified excavation is about one and a half times the price of common excavation, while the cost of rock excavation tends to run about three times the cost of common.

Under surfacing items, examination indicates that gravel, sand-clay, and topsoil are local in their general aspects, generate little freight, and in construction methods as well as in the nature of equipment used are similar to grading operations. On this account the natural conversion of gravel, sand-clay, and topsoil surfacing is into units of common excavation. As macadam and bituminous macadam occupy a middle ground, macadam has been converted into grading units and bituminous macadam into concrete pavement, the latter type having been selected for the conversion of all of the higher types of pavement. These conversions are shown in table 8.

In this way the 3 grading items and the 6 paving items indicated above are reduced to 2 items, common excavation and concrete pavement, the weightings of these 2 items being altered to reflect the influence of the various items that have been dropped. For similar reasons structural concrete, classes B and C, were merged with structural concrete, class A.

The determination of the primary weightings is discussed in succeeding paragraphs, the purpose being to indicate the methods that have been used in working out these weightings.

Excavation.—After it had been determined that the primary weightings should be based on 1 composite mile of highway, that the years 1925 to 1929 should be used as the base period, and that the units should be those already noted, the first problem that required solution was the amount of excavation (grading) to be assigned to this composite mile.

Three conditions required evaluation: First, under the Bureau's policy of encouraging stage construction, a considerable mileage of road is graded during one construction season and surfaced during some subsequent construction season. During the earlier years in which Federal aid was granted for highway construction, this policy resulted in a rapid statistical accumulation of graded and drained but unsurfaced mileage. Though this policy has not changed, the rate at which graded and drained roads are surfaced is more nearly in harmony with the rate at which new grading and draining is done.

The second condition to be evaluated is the importance of the apparent accumulation of graded and drained but unsurfaced mileage. In all probability this is at least largely a statistical accumulation, arising from the fact that graded and drained mileage often is surfaced by the States without the assistance of Federal aid, and therefore without subtraction from the Bureau's recorded accumulation of unsurfaced mileage. In the same way Federal aid is often used in surfacing roads which have been graded and drained without the assistance of Federal aid.

There is, of course, a large mileage on which both the grading and draining and the surfacing are done at the same time. On account of this situation, which for various reasons does not lend itself to a more exact solution, it was decided that the whole amount of the grading done during the base period would be allocated to the mileage surfaced during that period. This is, in effect, an assumption—reasonably accurate, we believe—that in the present advanced stage of our construction program partially completed highways are being advanced toward completion at about the same rate that partially completed mileage is being created.

The third condition that has to be evaluated arises from the fact that the Bureau's accumulation of bid-price data is not quite as complete as its data on mileage of work completed. There are several reasons for this. The first is that it would be a very complex statistical problem to so adjust the number of units entering into the Bureau's bid-price data on any class of work that at the end of the year these units would total to an exact agreement with the mileage of pavement built. As such an agreement would add nothing to the value of the bid-price data, as now obtained, no effort has been made to bring about such an agreement.

A second and perhaps even more important reason for the fact that the quantities on which bid prices have been obtained differ from those indicated by the mileage constructed is found in the fact that the preliminary estimates of quantities on which bids are taken commonly differ somewhat from the quantities actually handled. Finally, it is probable that the Bureau's bid-price data does not include quite all of the projects on which work has been done.

Structures.—The development of a highway system always requires the erection of a good many structures, principally bridges and culverts. In the development of this system of index figures the structural field is covered by the inclusion of the following items: Reinforcing steel, structural steel, and structural concrete. There are many other items, such as pipe (concrete, cast iron, corrugated iron, terra cotta), excavation of various grades, special work on handrails, etc., that this list does not include; but it does include the items of greatest importance. Most of the excluded items are, in nature, quite similar to those that are included.

Reinforcing steel.—Reinforcing steel is a component part of reinforced concrete pavement and of structural concrete, class A. It may or may not be used in structural concrete, classes B and C, depending entirely on design policy and its application to specific cases. On this account, as a matter of theory, reinforcing steel should not appear as a separate item in the list on which the index is based. In practice, however, though some States include reinforcing steel in such items as class A concrete, more call for separate bids on steel, these bids including the cost of handling the steel and placing it in the finished work.

Bids taken in this way may not indicate whether the steel is to be used in the pavement or in the structure. On this account, although shown as an item in the

structural list, a part of the total is in the nature of a correction of deficiencies in the amount included in the assigned yardage of reinforced concrete pavement. In view of the fact that some of the steel known to be used is not included in the recorded quantities, the reinforcing steel component in the base was taken as 16,000 pounds, an increase of 69 percent over the average quantities reported for the base years 1925 to 1929. The resulting adjustments are shown in table 12.

CORRECTION FACTORS APPLIED TO QUANTITIES USED IN DETERMINING UNIT BID PRICES

The fact that the mileage of pavement constructed and the number of units of grading and other items on which average bid prices have been recorded are not in agreement has made it necessary to use a correction factor. To obtain this factor it has been assumed that the processes by which the quantities used in developing unit bid prices are accumulated result in a uniform rate of underestimate applicable to all of the items listed (except surfacing items based on tables of State highway mileage).

As concrete pavement appears to offer the best basis for determining the correction factors, it has been used. The Bureau's records of the mileage of concrete roads on which Federal-aid funds have been used are complete and accurate. To convert the known mileage into an equivalent yardage involves a knowledge of average widths. The division of design has made several excellent studies touching on this matter. From the data given in these studies and from other known facts, it appears that during the period covered by these indexes the average width of the pavements built has increased pretty uniformly at the rate of about 0.3 foot per year to the currently prevailing average of 20 feet. On this basis, the recorded mileage of concrete pavement has been converted into an equivalent yardage, and with this yardage as a base the correction factors to be applied to the grading and other items used in the composite mile (except surfacing) have been computed. The details of the development of the correction factors are given in table 1.

TABLE 1.—*Factors for adjusting reported quantities*

Year	Miles of concrete pavement built [1]	Width of slab, in feet	Square yards per mile	Square yards of concrete pavement [2]	Square yards of concrete pavement reported [3]	Correction factor
1923	1,440.3	17.6	10,325	14,871,097	16,492,245	90.17
1924	1,667.9	17.9	10,501	17,514,618	18,750,167	93.41
1925	2,806.4	18.2	10,677	29,963,933	20,713,140	144.66
1926	2,660.0	[4] 18.5	10,853	28,868,980	24,600,841	117.35
1927	2,284.1	18.8	11,029	25,191,339	23,548,060	106.98
1928	3,114.6	[4] 19.1	11,205	34,899,093	34,415,209	101.41
1929	3,131.3	19.4	11,381	35,637,325	26,402,583	134.98
1930	3,170.3	19.7	11,557	36,639,157	26,118,498	140.28
1931	4,540.7	[4] 20.0	11,733	53,276,033	46,845,087	113.73

[1] From Federal-aid records.
[2] Total miles multiplied by square yards per mile.
[3] Bid-price records.
[4] Widths for these 3 years obtained from tables compiled by the division of design. From these figures the width was assumed to have changed 0.3 foot per year.

The adjusted quantities (except surfacing) and the quantities per surfaced mile are shown in tables 2 and 3.

TABLE 3.—*Quantities of construction items per surfaced mile*

Year	Mileage surfaced [1]	Excavation	Reinforcing steel	Structural steel	Structural concrete
		Cubic yards	*Pounds*	*Pounds*	*Cubic yards*
1923	6,949.3	8,068	5,491	2,297	53
1924	7,004.7	8,364	7,329	2,258	67
1925	9,217.8	9,238	8,044	4,718	64
1926	8,427.6	11,068	8,334	3,629	68
1927	7,072.9	10,960	7,566	3,301	64
1928	7,917.6	12,545	10,114	4,953	65
1929	7,049.2	17,028	13,329	5,024	81
1930	6,676.4	18,946	15,905	7,750	122
1931	9,061.0	22,361	18,214	12,216	141

[1] From Federal-aid records.

Further adjustment in the quantities of reinforcing steel was made in the following manner. In table 3 we find the average quantities per mile (after application of the correction factor) to be as follows:

	Pounds
1925	8,044
1926	8,334
1927	7,566
1928	10,114
1929	13,329
Total	47,387
Average	9,477

As stated previously, the quantity of reinforcing steel was increased to 16,000 pounds to account for deficiencies in the reported amounts. The adjustment factor used was $\frac{16,000}{9,477} = 1.6883$. The adjusted quantities are shown in table 4.

TABLE 4.—*Adjustment of quantities of reinforcing steel*

Year	Quantity of reinforcing steel	Adjustment factor	Adjusted quantity
	Pounds		*Pounds*
1923	5,491	1.6883	9,270
1924	7,329	1.6883	12,374
1925	8,044	1.6883	13,581
1926	8,334	1.6883	14,070
1927	7,566	1.6883	12,773
1928	10,114	1.6883	17,075
1929	13,329	1.6883	22,503
1930	15,905	1.6883	26,852
1931	18,214	1.6883	30,751

QUANTITIES OF PAVEMENT TYPES IN COMPOSITE MILE BASED ON REPORTS OF STATE HIGHWAY MILEAGE BUILT

The composition of the composite mile of pavement is based on mileage tables prepared by the division of highway transport, from reports of State authorities.

TABLE 2.—*Adjusted quantities of construction items, based on quantities shown in bid-price tables*

Year	Correction factor	Combined excavation		Reinforcing steel		Structural steel		Structural concrete	
		Reported	Adjusted	Reported	Adjusted	Reported	Adjusted	Reported	Adjusted
		Cubic yards	*Cubic yards*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Cubic yards*	*Cubic yards*
1923	90.17	62,178,407	56,066,270	42,318,786	38,158,849	17,702,791	15,962,607	408,798	368,613
1924	93.41	62,720,726	58,587,430	54,960,417	51,338,526	16,934,807	15,818,803	498,819	465,947
1925	144.66	58,862,196	85,150,053	51,253,859	74,143,832	30,066,422	43,494,086	405,029	585,915
1926	117.35	79,483,545	93,273,940	59,852,629	70,237,060	26,058,778	30,579,976	488,814	573,623
1927	106.98	72,462,022	77,519,871	50,020,271	53,511,686	21,823,280	23,346,545	420,582	449,939
1928	101.41	97,941,791	99,322,770	78,963,647	80,077,034	38,668,944	39,214,176	509,860	517,049
1929	134.98	88,925,066	120,031,054	69,609,347	93,958,697	26,238,148	35,416,252	421,084	568,379
1930	140.28	90,169,860	126,490,280	75,695,757	106,186,008	36,884,909	51,742,150	581,439	815,643
1931	113.73	178,155,572	202,616,332	145,113,073	165,037,098	97,326,093	110,688,966	1,126,279	1,280,917

The reported mileage of State highways completed is shown for the years 1923 to 1931 in table 5.

In this and in subsequent tables the classification of road types is simplified. Under gravel are included sand-clay and topsoil roads, as well as treated and untreated surfaces; water-bound macadam includes both treated and untreated surfaces; bituminous concrete includes sheet asphalt; and under brick is included all block pavement.

TABLE 5.—*Reported mileage of State highways completed in the years from 1923 to 1931, compiled from reports of State authorities*

Year	Graded and drained	Gravel[1]	Water-bound macadam[2]	Bitumi-nous macadam	Bitumi-nous concrete[3]	Portland cement concrete	Brick and other block pavement[4]	Total	Total mileage surfaced
	Miles	Miles	Miles	Miles	Miles	Miles	Miles	Miles	Miles
1923	5,814	7,852	1,017	990	511	3,878	235	20,297	14,483
1924	5,957	9,045	1,467	997	684	4,851	164	23,164	17,207
1925	5,316	10,005	1,144	1,000	565	4,975	146	23,152	17,836
1926	7,060	12,272	1,088	1,132	460	4,403	137	26,552	19,492
1927	7,151	11,132	1,707	1,105	501	5,058	69	26,723	19,572
1928	8,675	10,823	1,006	1,979	598	6,055	116	29,252	20,577
1929	7,451	14,582	1,642	1,200	556	6,991	100	32,522	25,071
1930	7,813	15,306	1,371	1,276	697	8,651	163	35,277	27,464
1931	10,095	20,573	1,453	1,939	749	9,664	161	44,634	34,539

[1] Includes sand-clay and topsoil.
[2] Includes treated and untreated macadam.
[3] Includes sheet asphalt.
[4] Includes all block pavements.

Table 6 gives the percentage distribution of the surfaced mileage by types.

TABLE 6.—*Percentage distribution of State highway mileage surfaced in the years from 1923 to 1931*

Year	Gravel	Water-bound macadam	Bitumi-nous macadam	Bitumi-nous concrete	Portland cement concrete	Brick	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1923	54.22	7.02	6.84	3.53	26.77	1.62	100.00
1924	52.56	8.52	5.79	3.98	28.19	.96	100.00
1925	56.10	6.41	5.61	3.17	27.89	.82	100.00
1926	62.96	5.58	5.81	2.36	22.59	.70	100.00
1927	56.88	8.72	5.65	2.56	25.84	.35	100.00
1928	52.60	4.89	9.62	2.90	29.43	.56	100.00
1929	58.16	6.55	4.79	2.22	27.88	.40	100.00
1930	55.73	4.99	4.65	2.54	31.50	.59	100.00
1931	59.56	4.21	5.61	2.17	27.98	.47	100.00

The conversion of these percentages into the yardage in the composite mile assignable to each type is shown in table 7. It will be observed that the surfaced yardage in the composite mile varies from year to year, as indicated in a preceding paragraph.

TABLE 7.—*Square yards per surfaced mile assignable to each type of surfacing*

Year	Total	Gravel	Water-bound macadam	Bitumi-nous macadam	Bitumi-nous concrete	Port-land cement concrete	Brick
	Sq. yd.	Sq. yd.	Sq. yd.	Sq. yd.	Sq. yd.	Sq. yd.	Sq. yd.
1923	10,325	5,598	725	796	365	2,764	167
1924	10,501	5,519	895	608	418	2,960	101
1925	10,677	5,990	684	599	338	2,978	88
1926	10,853	6,833	606	630	256	2,452	76
1927	11,029	6,273	962	623	282	2,850	39
1928	11,205	5,894	548	1,078	325	3,297	63
1929	11,381	6,619	745	545	253	3,173	46
1930	11,557	6,441	577	537	294	3,640	68
1931	11,733	6,988	494	658	255	3,283	55

For reasons previously explained, gravel and water-bound macadam have been converted into an equivalent yardage of excavation. Similarly, bituminous macadam, bituminous concrete, and brick have been converted into an equivalent yardage of concrete surfacing. The details of these conversions are shown in table 8.

TABLE 8.—*Equivalent quantities of excavation and pavement*

Year	Equivalent excavation in cubic yards		Equivalent portland cement concrete pavement in square yards			
	Gravel (0.6871)[1]	Water-bound macadam (1.3818)[1]	Bitumi-nous macadam (0.6423)[1]	Bitumi-nous concrete (0.8405)[1]	Brick (1.3581)[1]	Portland cement concrete
1923	3,846	1,002	453	307	227	2,764
1924	3,792	1,237	391	351	137	2,960
1925	4,116	945	385	284	120	2,978
1926	4,695	837	405	215	103	2,452
1927	4,310	1,329	400	237	53	2,850
1928	4,050	757	692	273	86	3,297
1929	4,548	1,029	350	213	62	3,173
1930	4,426	797	345	247	92	3,640
1931	4,801	683	423	214	75	3,283

[1] Conversion factor.

The adjustments were made by applying the ratios of the base prices as used in the computation of the price trend. These ratios were as follows:

Gravel to excavation:

$$\frac{0.235}{0.342} = 0.6871$$

Water-bound macadam to crushed stone (2,350 cubic yards of crushed stone per mile):

$$\frac{2,350}{10,560} = 0.2225$$

Crushed stone to excavation:

$$\frac{2.124}{0.342} = 6.2105$$

Water-bound macadam to excavation:

$$6.2105 \times 0.2225 = 1.3818$$

Bituminous macadam to portland cement concrete:

$$\frac{1.426}{2.220} = 0.6423$$

Bituminous concrete to portland cement concrete:

$$\frac{1.866}{2.220} = 0.8405$$

Brick to portland cement concrete:

$$\frac{3.015}{2.220} = 1.3581$$

As the result of these operations, the final quantities per surfaced mile are as shown in table 9.

TABLE 9.—*Final quantities per surfaced mile*

Year	Excavation in cubic yards				Pavement in square yards					Structures		
	From excavation	From gravel	From water-bound macadam	Total excavation	From bituminous macadam	From bituminous concrete	From brick	From Portland cement concrete	Total pavement	Reinforcing steel	Structural steel	Structural concrete
										Pounds	Pounds	Cubic yards
1923	8,068	3,846	1,002	12,916	453	307	227	2,764	3,751	9,270	2,297	53
1924	8,364	3,792	1,237	13,393	391	351	137	2,960	3,839	12,374	2,258	67
1925	9,238	4,116	945	14,299	385	284	120	2,978	3,767	13,581	4,718	64
1926	11,068	4,695	837	16,600	405	215	103	2,452	3,175	14,070	3,629	68
1927	10,960	4,310	1,329	16,599	400	237	53	2,850	3,540	12,773	3,301	64
1928	12,545	4,050	757	17,352	692	273	86	3,297	4,348	17,075	4,953	65
1929	17,028	4,548	1,029	22,605	350	213	62	3,173	3,798	22,503	5,024	81
1930	18,946	4,426	797	24,169	345	247	92	3,640	4,324	26,852	7,750	122
1931	22,361	4,801	683	27,845	423	214	75	3,283	3,995	30,751	12,216	141

TABLE 10.—*Adjusted average bid prices for common excavation* [1]

State	Base quantities	National weighting	1922 Bid price	1922 W	1923 Bid price	1923 W	1924 Bid price	1924 W	1925 Bid price	1925 W	1926 Bid price	1926 W	1927 Bid price	1927 W	1928 Bid price	1928 W	1929 Bid price	1929 W	1930 Bid price	1930 W
	Cubic yards																			
New England	8,672,136	0.022																		
Maine	1,237,391	.003	$1.23	0.0037	$1.52	0.0046	$1.23	0.0037	$1.18	0.0035	$1.07	0.0032	$1.00	0.0030	$1.02	0.0031	$0.81	0.0024	$0.65	0.0019
New Hampshire	620,590	.002	1.02	.0020	1.47	.0029	1.32	.0026	.99	.0020	1.17	.0023	.93	.0019	.91	.0018	.65	.0013	.51	.0010
Vermont	1,371,532	.003	1.01	.0030	1.28	.0038	1.29	.0039	1.19	.0036	1.20	.0036	1.04	.0031	.93	.0028	.73	.0022	.69	.0021
Massachusetts	2,703,415	.007	.92	.0064	1.32	.0092	1.19	.0083	1.12	.0078	.81	.0057	.72	.0050	.77	.0054	.77	.0054	.48	.0034
Rhode Island	1,136,757	.003	.95	.0028	1.28	.0038	1.00	.0030	.92	.0028	.90	.0027	.84	.0025	.50	.0015	.42	.0013	.42	.0013
Connecticut	1,602,451	.004	.93	.0037	1.25	.0050	1.21	.0048	1.17	.0047	.75	.0030	.85	.0034	.89	.0036	.73	.0029	.59	.0024
Middle Atlantic	46,955,531	.118																		
New York	20,083,395	.051	.91	.0309	.87	.0296	.92	.0313	.84	.0286	.93	.0316	.66	.0224	.64	.0218	.53	.0180	.54	.0184
New Jersey	4,515,264	.011	1.36	.0150	1.52	.0167	1.54	.0169	1.22	.0134	1.04	.0114	.82	.0090	.84	.0092	.56	.0062	.65	.0071
Pennsylvania	22,356,872	.056	1.10	.0407	1.38	.0511	1.33	.0492	1.16	.0429	.88	.0326	.99	.0366	.79	.0292	.75	.0277	.77	.0285
East North Central	39,897,012	.100																		
Ohio	10,498,485	.026	.65	.0169	.53	.0138	.59	.0153	.56	.0146	.56	.0146	.46	.0120	.49	.0127	.48	.0125	.45	.0117
Indiana	4,889,953	012	.52	.0062	.50	.0060	.33	.0040	.49	.0059	.40	.0048	.43	.0052	.41	.0049	.40	.0048	.38	.0046
Illinois	5,731,257	.014	.43	.0060	.48	.0067	.41	.0057	.44	.0062	.40	6056	45	.0063	.41	.0057	.50	.0070	.34	.0048
Michigan	6,962,724	.018	47	.0085	.59	.0106	.51	.0092	.46	.0083	.45	.0081	.44	.0079	.42	.0076	.38	.0068	.30	.0054
Wisconsin	11,814,593	.030	.40	.0120	.57	.0171	.42	.0126	.46	.0138	.42	.0126	.48	.0144	.44	.0132	.40	.0120	.33	.0099
West North Central	103,605,082	.261																		
Minnesota	23,505,790	.059	.31	.0183	.31	.0183	.26	.0153	.25	.0147	.26	.0153	.27	.0159	.25	.0147	.25	.0147	.31	.0183
Iowa	9,209,728	.023	.27	.0062	.29	.0067	.29	.0067	.23	.0053	.28	.0064	.43	.0099	.36	.0083	.32	.0074	.40	.0092
Missouri	10,298,517	.026	.34	.0088	.33	.0086	.35	.0091	.38	.0099	.30	.0078	.32	.0083	.31	.0081	.36	.0094	.34	.0088
North Dakota	16,816,188	.042	.27	.0113	.31	.0130	.27	.0113	.28	.0118	.31	.0130	.30	.0126	.29	.0122	.25	.0105	.23	.0097
South Dakota	13,023,156	.033	.25	.0082	.28	.0092	.25	.0082	.21	.0069	.21	.0069	.20	.0066	.21	.0069	.19	.0063	.18	.0059
Nebraska	17,716,058	.045	.25	.0112	.46	.0207	.24	.0108	.23	.0103	.20	.0090	.19	.0085	.18	.0081	.19	.0085	.16	.0072
Kansas	13,035,645	.033	.42	.0139	.39	.0129	.39	.0129	.33	.0109	.30	.0099	.27	.0089	.26	.0086	.27	.0089	.22	.0073
South Atlantic	25,570,554	.064																		
Delaware	563,300	.001	.83	.0008	1.24	.0012	1.27	.0013	1.53	.0015	.75	.0007	.64	.0006	.59	.0006	.64	.0006	.63	.0006
Maryland	324,700	.001	.72	.0007	.89	.0009	.85	.0008	1.02	.0010	.74	.0007	.63	.0006	.67	.0007	.57	.0006	.30	.0003
Virginia	3,000,533	.007	.49	.0024	.57	.0028	.44	.0022	.65	.0032	.50	.0025	.41	.0020	.40	.0020	.71	.0035	.43	.0021
West Virginia	5,669,135	.014	.71	.0064	.67	.0060	.49	.0044	.69	.0062	.56	.0050	.50	.0045	.51	.0046	.50	.0045	.48	.0043
North Carolina	3,896,910	.010	.81	.0081	.48	.0048	.53	.0053	.55	.0055	.49	.0049	.38	.0038	.33	.0033	.32	.0032	.29	.0029
South Carolina	5,211,802	.013	.27	.0035	.29	.0038	.32	.0042	.39	.0051	.31	.0040	.33	.0043	.31	.0040	.29	.0038	.32	.0042
Georgia	5,024,754	.013	.23	.0030	.31	.0040	.34	.0044	.36	.0047	.35	.0045	.29	.0038	.31	.0040	.30	.0039	.29	.0038
Florida	1,879,420	.005	.36	.0018	.58	.0029	.53	.0026	.56	.0028	.48	.0024	.37	.0018	.33	.0016	.32	.0016	.31	.0015
East South Central	37,814,702	.095																		
Kentucky	13,903,434	.035	.41	.0143	.50	.0175	.42	.0147	.36	.0126	.34	.0119	.38	.0133	.41	.0143	.36	.0126	.38	.0133
Tennessee	6,486,454	.016	.37	.0059	.30	.0048	.44	.0070	.36	.0058	.38	.0061	.33	.0053	.44	.0070	.33	.0053	.34	.0054
Alabama	12,596,256	.032	.28	.0090	.32	.0102	.30	.0096	.28	.0090	.31	.0099	.29	.0093	.27	.0086	.27	.0086	.25	.0080
Mississippi	4,828,558	.012	.26	.0031	.29	.0035	.28	.0034	.33	.0040	.30	.0036	.28	.0034	.28	.0034	.26	.0031	.26	.0031
West South Central	36,011,743	.091																		
Arkansas	6,605,424	.017	.21	.0036	.62	.0105	.48	.0082	.23	.0039	.26	.0044	.29	.0049	.27	.0046	.25	.0042	.22	.0037
Louisiana	5,662,812	.014	.28	.0039	.24	.0034	.36	.0050	.19	.0027	.52	.0073	.18	.0025	.23	.0032	.27	.0038	.26	.0036
Oklahoma	2,055,775	.005	.26	.0013	.27	.0013	.27	.0013	.16	.0008	.26	.0013	.24	.0012	.24	.0012	.23	.0011	.23	.0011
Texas	21,687,732	.055	.16	.0088	.17	.0093	.19	.0104	.19	.0104	.21	.0115	.18	.0099	.17	.0093	.18	.0099	.19	.0104
Mountain	59,477,256	.149																		
Montana	23,225,283	.056	.24	.0134	.37	.0207	.28	.0157	.24	.0134	.25	.0140	.29	.0162	.25	.0140	.24	.0134	.29	.0162
Idaho	3,602,469	.009	.28	.0025	.33	.0030	.33	.0030	.28	.0025	.25	.0022	.32	.0029	.32	.0029	.29	.0026	.25	.0022
Wyoming	9,009,288	.023	.20	.0046	.23	.0053	.29	.0067	.23	.0053	.20	.0046	.21	.0048	.23	.0053	.21	.0048	.21	.0048
Colorado	7,355,863	.019	.27	.0051	.33	.0063	.39	.0074	.29	.0055	.32	.0061	.27	.0051	.31	.0059	.33	.0063	.20	.0038
New Mexico	3,839,591	.010	.28	.0028	.29	.0029	.31	.0031	.40	.0040	.27	.0027	.19	.0019	.23	.0023	.20	.0020	.21	.0021
Arizona	3,092,928	.008	.95	.0047	1.10	.0055	1.11	.0055	.79	.0039	.35	.0017	.70	.0035	.50	.0025	.41	.0020	.67	.0033
Utah	3,570,442	.009	.39	.0035	.45	.0040	.42	.0038	.25	.0022	.31	.0028	.34	.0031	.36	.0032	.33	.0030	.26	.0023
Nevada	5,781,392	.015	.71	.0071	.74	.0074	.74	.0074	.53	.0053	.44	.0044	.50	.0050	.26	.0026	.35	.0035	.34	.0034
Pacific	39,670,604	.100																		
Washington	11,907,165	.030	.45	.0135	.48	.0144	.41	.0123	.38	.0114	.29	.0087	.36	.0108	.38	.0114	.34	.0102	.25	.0075
Oregon	8,377,200	.021	.37	.0078	.37	.0078	.35	.0073	.42	.0088	.37	.0078	.27	.0057	.40	.0084	.34	.0071	.27	.0057
California	19,386,239	.049	.75	.0247	1.03	.0340	.82	.0271	.50	.0165	.55	.0181	.57	.0188	.51	.0168	.43	.0142	.45	.0148
United States	397,674,620	1.000		.4020		.4685		.4289		.3859		.3639		.3524		.3371		.3156		.3033

[1] Unclassified excavation predominates in New York, Pennsylvania, West Virginia, Virginia, Arizona, Nevada, and California, and the bid prices shown for these States are for unclassified excavation. In order to convert these prices into equivalent common excavation, the weighting values were correspondingly adjusted. The resultant weighting values for these States as used in this table are as follows: New York, 0.034; Pennsylvania, 0.037; Virginia, 0.005; West Virginia, 0.009; Arizona, 0.005; Nevada, 0.010: California, 0.033.

BID PRICES ON FEDERAL-AID WORK USED IN COMPUTATION OF PRICE INDEX

The final step in the preparation of index numbers involves the application of prices to the quantities selected as a base. All prices are from the Bureau's records of bid prices, which prior to October 1931 cover Federal-aid construction only. Since that date, prices on State work have been available and are included in the averages.

Throughout the highway construction field variations in the controlling specifications cause prices to vary considerably from State to State. In a general way prices of materials and labor are higher in the North than they are in the South; but as work can be carried on throughout the whole of the year in the South while it can be satisfactorily handled in the North only during the warmer months, the regional volume of work awarded is not uniform from month to month. Neither does the influence of these two very general regions on the amount awarded remain constant.

To avoid the effect of these and of other causes which produce variations in a given region during a given time,

TABLE 10.—*Adjusted average bid prices for common excavation*—Continued

State	Base quantities	National weighting	1931 First quarter Bid price	W	Second quarter Bid price	W	Third quarter Bid price	W	Fourth quarter Bid price	W	1932 First quarter Bid price	W	Second quarter Bid price	W	Third quarter Bid price	W	Fourth quarter Bid price	W	1933 First quarter Bid price	W
	Cubic yards																			
New England	8,672,136	0.022																		
Maine	1,237,391	.003	$0.35	0.0010	$0.55	0.0016	$0.48	0.0014	$0.35	0.0010	$0.31	0.0009	$0.43	0.0013	$0.41	0.0012	$0.41	0.0012	$0.41	0.0012
New Hampshire	620,590	.002	.48	.0010	.33	.0007	.40	.0008	.29	.0006	.26	.0005	.32	.0006	.25	.0005	.29	.0006	.46	.0009
Vermont	1,371,532	.003	.57	.0017	.47	.0014	.44	.0013	.32	.0010	.28	.0008	.33	.0010	.20	.0006	.21	.0006	.21	.0006
Massachusetts	2,703,415	.007	.49	.0034	.43	.0030	.30	.0021	.27	.0019	.24	.0017	.20	.0014	.20	.0014	.19	.0013	.26	.0018
Rhode Island	1,136,757	.003	.35	.0010	.25	.0007	.25	.0007	.22	.0007	.20	.0006	.23	.0007	.13	.0004	.15	.0004	.33	.0010
Connecticut	1,602,451	.004	.52	.0021	.50	.0020	.70	.0028	.40	.0016	.36	.0014	.42	.0017	.25	.0010	.31	.0012	.38	.0015
Middle Atlantic	46,955,531	.118																		
New York	20,083,395	.051	.40	.0136	.38	.0129	.35	.0119	.50	.0170	.29	.0099	.24	.0082	.23	.0078	.26	.0088	.30	.0102
New Jersey	4,515,264	.011	.65	.0071	.23	.0025	.22	.0024	.22	.0024	.20	.0022	.16	.0018	.27	.0030	.20	.0022	.20	.0022
Pennsylvania	22,356,872	.056	1.75	.0647	1.39	.0514	.71	.0263	.30	.0111	.45	.0166	.35	.0129	.34	.0126	.36	.0133	.37	.0137
East North Central	39,897,012	.100																		
Ohio	10,498,385	.026	.30	.0078	.32	.0083	.34	.0088	.26	.0068	.35	.0091	.17	.0044	.17	.0044	.16	.0042	.18	.0047
Indiana	4,889,953	.012	.29	.0035	.30	.0036	.27	.0032	.24	.0029	.22	.0026	.21	.0025	.20	.0024	.21	.0025	.22	.0026
Illinois	5,731,257	.014	.32	.0045	.30	.0042	.28	.0039	.21	.0029	.23	.0032	.21	.0029	.24	.0034	.23	.0032	.22	.0031
Michigan	6,962,724	.018	.27	.0049	.25	.0045	.20	.0036	.25	.0045	.21	.0038	.21	.0038	.19	.0034	.21	.0038	.21	.0038
Wisconsin	11,814,593	.030	.31	.0093	.30	.0090	.26	.0078	.90	.0270	.31	.0093	.22	.0066	.22	.0066	.18	.0054	.27	.0081
West North Central	103,605,082	.261																		
Minnesota	23,505,790	.059	.18	.0106	.20	.0118	.46	.0271	.36	.0212	.17	.0100	.15	.0088	.12	.0071	.15	.0088	.14	.0083
Iowa	9,209,728	.023	.33	.0076	.31	.0071	.31	.0071	.20	.0046	.14	.0032	.12	.0028	.14	.0032	.10	.0023	.10	.0023
Missouri	10,298,517	.026	.35	.0091	.28	.0073	.24	.0062	.24	.0062	.19	.0049	.20	.0052	.20	.0052	.22	.0057	.20	.0052
North Dakota	16,816,188	.042	.20	.0084	.21	.0088	.20	.0084	.15	.0063	.13	.0055	.13	.0055	.15	.0063	.16	.0067	.15	.0063
South Dakota	13,023,156	.033	.17	.0056	.19	.0063	.19	.0063	.11	.0036	.12	.0040	.11	.0036	.13	.0043	.15	.0049	.13	.0043
Nebraska	17,716,058	.045	.16	.0072	.18	.0081	.19	.0085	.16	.0072	.15	.0067	.14	.0063	.14	.0063	.15	.0067	.14	.0063
Kansas	13,035,645	.033	.20	.0066	.20	.0066	.20	.0066	.16	.0053	.14	.0046	.14	.0046	.15	.0049	.13	.0043	.15	.0049
South Atlantic	25,570,554	.064																		
Delaware	563,300	.001	.44	.0004	.52	.0005	.66	.0007	.40	.0004	.29	.0003	.21	.0002	.17	.0002	.40	.0004	.40	.0004
Maryland	324,700	.001	.52	.0005	.43	.0004	.54	.0005	.23	.0002	.17	.0002	.20	.0002	.19	.0002	.22	.0002	.28	.0003
Virginia	3,000,533	.007	.45	.0022	.58	.0029	.46	.0023	.31	.0015	.21	.0010	.19	.0009	.31	.0015	.30	.0015	.28	.0014
West Virginia	5,669,135	.014	.36	.0032	.36	.0032	.33	.0030	.23	.0021	.39	.0035	.25	.0022	.24	.0022	.31	.0028	.28	.0025
North Carolina	3,896,910	.010	.37	.0037	.30	.0030	.24	.0024	.37	.0037	.35	.0035	.18	.0018	.24	.0024	.32	.0032	.30	.0030
South Carolina	5,211,802	.013	.36	.0047	.33	.0043	.42	.0055	.24	.0031	.17	.0022	.27	.0035	.22	.0029	.25	.0032	.27	.0035
Georgia	5,024,754	.013	.27	.0035	.25	.0032	.24	.0031	.20	.0026	.13	.0017	.17	.0022	.12	.0016	.22	.0029	.30	.0039
Florida	1,879,420	.005	.33	.0016	.31	.0015	1.00	.0050	.68	.0034	.22	.0011	.26	.0013	.33	.0016	.29	.0014	.39	.0019
East South Central	37,814,702	.095																		
Kentucky	13,903,434	.035	.29	.0101	.27	.0094	.26	.0091	.17	.0059	.14	.0049	.22	.0077	.19	.0066	.17	.0059	.18	.0063
Tennessee	6,486,454	.016	.41	.0066	.30	.0048	.50	.0080	.26	.0042	.21	.0034	.19	.0030	.26	.0042	.23	.0037	.30	.0048
Alabama	12,596,256	.032	.20	.0064	.24	.0077	.29	.0093	.18	.0058	.15	.0048	.16	.0051	.26	.0083	.20	.0064	.25	.0080
Mississippi	4,828,558	.012	.23	.0028	.23	.0028	.24	.0029	.19	.0023	.16	.0019	.15	.0018	.18	.0022	.21	.0025	.21	.0025
West South Central	36,011,743	.091																		
Arkansas	6,605,424	.017	.24	.0041	.24	.0041	.15	.0025	.13	.0022	.11	.0019	.11	.0019	.14	.0024	.25	.0042	.18	.0031
Louisiana	5,662,812	.014	.25	.0035	.22	.0031	.18	.0025	.18	.0025	.15	.0021	.17	.0024	.21	.0029	.17	.0024	.21	.0029
Oklahoma	2,055,775	.005	.22	.0011	.18	.0009	.18	.0009	.14	.0007	.12	.0006	.10	.0005	.13	.0006	.13	.0006	.14	.0007
Texas	21,687,732	.055	.18	.0099	.14	.0077	.14	.0077	.12	.0066	.10	.0055	.10	.0055	.12	.0066	.14	.0077	.21	.0115
Mountain	59,477,256	.149																		
Montana	23,225,283	.056	.22	.0123	.31	.0174	.21	.0118	.15	.0084	.12	.0067	.14	.0078	.31	.0174	.26	.0146	.20	.0112
Idaho	3,602,469	.009	.20	.0018	.25	.0022	.27	.0024	.16	.0014	.19	.0017	.23	.0021	.26	.0023	.20	.0018	.36	.0032
Wyoming	9,009,288	.023	.22	.0051	.20	.0046	.18	.0041	.16	.0037	.15	.0034	.16	.0037	.17	.0039	.17	.0039	.16	.0037
Colorado	7,355,863	.019	.15	.0028	.17	.0032	.18	.0034	.33	.0063	.14	.0027	.18	.0034	.20	.0038	.16	.0030	.14	.0027
New Mexico	3,839,591	.010	.29	.0029	.27	.0027	.25	.0025	.14	.0014	.11	.0011	.17	.0017	.26	.0026	.19	.0019	.20	.0020
Arizona	3,092,928	.008	.27	.0013	.52	.0026	.59	.0029	.48	.0024	.31	.0015	.35	.0017	.51	.0025	.47	.0023	.64	.0032
Utah	3,570,442	.009	.23	.0021	.21	.0019	.42	.0038	.17	.0015	.15	.0013	.14	.0013	.13	.0012	.15	.0013	.21	.0019
Nevada	5,781,392	.015	.24	.0024	.62	.0062	.33	.0033	.16	.0016	.20	.0020	.23	.0023	.23	.0023	.32	.0032	.35	.0035
Pacific	39,670,604	.100																		
Washington	11,907,165	.030	.22	.0066	.28	.0084	.26	.0078	.20	.0060	.23	.0069	.21	.0063	.27	.0081	.19	.0057	.14	.0042
Oregon	8,377,200	.021	.20	.0042	.46	.0097	.27	.0057	.22	.0046	.24	.0050	.24	.0050	.25	.0052	.20	.0042	.34	.0071
California	19,386,239	.049	.31	.0102	.30	.0099	.28	.0092	.24	.0079	.25	.0082	.27	.0089	.30	.0099	.35	.0115	.24	.0079
United States	397,674,620	1.000		.2967		.2901		.2695		.2282		.1806		.1710		.1916		.1905		.2003

the influence of each State has been weighted. To obtain these weightings the whole amount of work performed on Federal-aid projects on each of the selected items during the base period was ascertained for each State. This amount was then reduced to a percentage assignable to each of the States where work of this kind was done. These percentages are used as indicating the average influence of the various States in determining the average price at which the item in question is produced. For any period the national average price is, then, the sum of the products obtained by multiplying each average State price (as determined from the Bureau's records of bid prices) by the corresponding State influence rating.

It seldom happens that during a given quarter every State awards enough highway work so that all States report prices on every one of the items used in this index. There are, of course, several ways in which this deficiency can be adjusted. These need no discussion here. Suffice it to say that for this index the practice has been adopted of using estimated prices based on regional experience wherever prices are missing. Thus, if of several States in a geographic division there is one for which no new price is of record, but those

reporting show an average drop in price of 3 percent, the missing price is supplied at 97 percent of the price shown for the preceding quarter. If no prices are received from a geographic division or if too small percentage of the States report new prices, the last reported prices are used as the current prices.

Table 10 shows the prices on common excavation as calculated in this way. The columns headed "W" in this table give for each year the product of the average bid price in a given State times the national weighting of that State. As stated previously, the sum of these products, given at the foot of the column, is the average bid price for the year.

Base quantities and base prices are shown in table 11. The prices used in computing the base are the arithmetical average of the prices shown by years for the base period.

THE PRICE INDEX

The final computation of the price index is shown in table 12. The composite mile on which the price index is based is composed of the average quantities of excavation, pavement, reinforcing steel, structural steel, and structural concrete determined for the base years 1925 to 1929, and shown in table 11. In table 12 the average bid price for each item in each year is shown. Under the heading "Amount" is given the cost of the average (base) quantity of each item at the prevailing bid price of the year. The subindexes are proportional to these amounts, index value 100 being based on the average bid prices for the base years, as given in table 11. Similarly, under the heading "Composite mile" the total amounts and the corresponding indexes are given for each year. The variation of these price indexes is shown in graphical form in figure 1.

THE USAGE INDEX

A usage index differs from a price index in that it shows the effect of changing usage rather than changing price. This is done by applying fixed prices—in this case, those of the base period—to the varying quantities of the several items of which the base is composed, the result being to show how cost would have varied from year to year on account of changing usage if prices had remained constant.

In the highway field usage has changed a great deal since the first year (1923) for which figures are available. There probably has been some change in pavement thickness during this period, but as this change is believed to have been small and as no analysis of the amount of it has ever been attempted it is included in none of the usage calculations.

TABLE 11.—*Average quantities and prices for the years 1925 to 1929, used as base for computation of indexes*

Year	Excavation		Pavement		Reinforcing steel		Structural steel		Structural concrete	
	Quantity	Price per cubic yard	Quantity	Price per square yard	Quantity	Price per pound	Quantity	Price per pound	Quantity	Price per cubic yard
	Cu. yds.		Sq. yds.		Lbs.		Lbs.		Cu. yds.	
1925	14,299	$0.386	3,767	$2.360	13,581	$0.0565	4,718	$0.0667	64	$22.534
1926	16,600	.364	3,175	2.286	14,070	.0534	3,629	.0736	68	22.760
1927	16,599	.352	3,540	2.291	12,773	.0510	3,301	.0707	64	22.647
1928	17,352	.337	4,348	2.096	17,075	.0492	4,953	.0671	65	21.216
1929	22,605	.316	3,798	2.055	22,503	.0481	5,024	.0591	81	21.582
Total	87,455	1.755	18,628	11.088	80,002	.2582	21,625	.3372	342	110.739
Average	17,491	.351	3,726	2.218	16,000	.0516	4,325	.0674	68	22.148

TABLE 12.—*Price trend in highway construction*

Year	Excavation [1] (17,491 cubic yards)			Pavement [2] (3,726 square yards)			Structures										Composite mile	
							Reinforcing steel (16,000 pounds)		Structural steel (4,325 pounds)		Structural concrete (68 cubic yards)		Combined					
	Bid price [3]	Amount	Sub-index	Bid price [3]	Amount	Sub-index	Bid price [3]	Amount	Bid price [3]	Amount	Bid price [3]	Amount	Amount	Sub-index		Total amount	Index
Base period, 1925 to 1929	$0.35	$6,139	100.0	$2.22	$8,264	100.0	$0.052	$826	$0.067	$291	$22.15	$1,506	$2,623	100.0		$17,026	100.0
1922	.40	7,031	114.5	2.28	8,488	102.7	.050	800	.074	321	20.18	1,372	2,493	95.1		18,012	105.8
1923	.47	8,186	133.3	2.43	9,047	109.5	.057	920	.078	338	23.37	1,589	2,847	108.6		20,080	117.9
1924	.43	7,504	122.2	2.40	8,950	108.3	.057	920	.077	333	22.91	1,558	2,811	107.2		19,265	113.1
1925	.39	6,751	110.0	2.36	8,793	106.4	.056	904	.067	288	22.53	1,532	2,724	103.9		18,268	107.3
1926	.36	6,367	103.7	2.29	8,518	103.1	.053	854	.074	318	22.76	1,548	2,720	103.7		17,605	103.4
1927	.35	6,157	100.3	2.29	8,536	103.3	.051	816	.071	306	22.65	1,540	2,662	101.5		17,355	101.9
1928	.34	5,894	96.0	2.10	7,810	94.5	.049	787	.067	290	21.22	1,443	2,520	96.1		16,224	95.3
1929	.32	5,527	90.0	2.05	7,657	92.7	.048	770	.059	256	21.58	1,468	2,494	95.0		15,678	92.1
1930	.30	5,300	86.3	1.86	6,949	84.1	.045	715	.061	264	20.08	1,365	2,344	89.4		14,593	85.7
1931																	
First quarter	.30	5,195	84.6	1.79	6,666	80.7	.042	672	.055	240	18.90	1,285	2,197	83.7		14,058	82.6
Second quarter	.29	5,072	82.6	1.77	6,580	79.6	.041	658	.051	219	18.48	1,257	2,134	81.3		13,786	81.0
Third quarter	.27	4,705	76.6	1.59	5,924	71.7	.040	634	.052	224	17.49	1,189	2,047	78.0		12,676	74.4
Fourth quarter	.23	3,988	65.0	1.56	5,809	70.3	.037	594	.056	241	17.22	1,171	2,009	76.6		11,806	69.3
1932																	
First quarter	.18	3,166	51.6	1.52	5,656	68.4	.036	571	.049	211	15.22	1,035	1,817	69.3		10,639	62.5
Second quarter	.17	2,991	48.7	1.47	5,481	66.3	.034	538	.045	197	14.98	1,019	1,754	66.8		10,226	60.1
Third quarter	.19	3,358	54.7	1.35	5,045	61.0	.033	526	.043	184	14.82	1,008	1,718	65.5		10,121	59.4
Fourth quarter	.19	3,323	54.1	1.44	5,377	65.1	.033	528	.048	208	16.28	1,107	1,843	70.3		10,543	61.9
1933																	
First quarter	.20	3,498	57.0	1.49	5,552	67.2	.032	506	.043	187	15.44	1,050	1,743	66.4		10,793	63.4

[1] Common excavation plus other items expressed as equivalent common excavation. (See p. 85 and table 8.)
[2] Portland cement concrete plus other items expressed as equivalent portland cement concrete. (See p. 85 and table 8.)
[3] Indexes and totals were calculated with the bid prices carried to 1 more decimal place than that to which they are shown in this table.

TABLE 13.—*Usage trend in highway construction*

| Year | Excavation [1] ($0.351 per cubic yard) | | | Pavement [2] ($2.218 per square yard) | | | Structural | | | | | | | | Composite mile | |
| | | | | | | | Reinforcing steel ($0.0516 per pound) | | Structural steel ($0.0674 per pound) | | Structural concrete ($22.148 per cubic yard) | | Combined | | | |
	Quantities	Amount	Sub-index	Quantities	Amount	Sub-index	Quantities	Amount	Quantities	Amount	Quantities	Amount	Amount	Sub-index	Total amount	Index
Base period, 1925 to 1929	17,491	$6,139	100.0	3,726	$8,264	100.0	16,000	$826	4,325	$291	68	$1,506	$2,623	100.0	$17,026	100.0
1923	12,916	4,533	73.8	3,751	8,320	100.7	9,270	478	2,297	155	53	1,174	1,807	68.9	14,660	86.1
1924	13,393	4,701	76.6	3,839	8,515	103.0	12,374	638	2,258	152	67	1,484	2,274	86.7	15,490	91.0
1925	14,299	5,019	81.7	3,767	8,355	101.1	13,581	701	4,718	318	64	1,417	2,436	92.9	15,810	92.9
1926	16,600	5,827	94.9	3,175	7,042	85.2	14,070	726	3,629	245	68	1,506	2,477	94.4	15,346	90.1
1927	16,599	5,826	94.9	3,540	7,852	95.0	12,773	659	3,301	222	64	1,417	2,298	87.6	15,976	93.8
1928	17,352	6,091	99.2	4,348	9,644	116.7	17,075	881	4,953	334	65	1,440	2,655	101.2	18,390	108.0
1929	22,605	7,934	129.2	3,798	8,424	101.9	22,503	1,161	5,024	339	81	1,794	3,294	125.6	19,652	115.4
1930	24,169	8,483	138.2	4,324	9,591	116.0	26,852	1,386	7,750	522	122	2,702	4,610	175.7	22,684	133.2
1931	27,845	9,774	159.2	3,995	8,861	107.2	30,751	1,587	12,216	823	141	3,123	5,533	210.9	24,168	141.9

[1] Common excavation plus other items expressed as equivalent common excavation. (See p. 85 and table 8.)
[2] Portland cement concrete plus other pavement items expressed as equivalent Portland cement concrete. (See p. 85 and table 8.)

As noted in a previous paragraph, the average width of the surfacing has increased rather steadily at the rate of about 0.3 foot per year. This has affected excavation quantities and structural quantities, as well as surfacing quantities.

The amount of excavation handled per mile of highway constructed has been further increased by the use of wider shoulders and lighter side slopes. Fifteen years ago 16-foot pavement and 3-foot shoulders, giving an embankment width of 22 feet, were common. Today 20-foot pavement and 6-foot shoulders, giving an embankment width of 32 feet are almost as common, with wider shoulders not infrequently used.

Finally, as compared to the conditions prevailing even 10 years ago, there is a marked tendency to hold to improved standards of both alinement and grade even where this policy requires a great deal of heavy grading. Again the necessary result is increased quantities. In the light of these conditions, the fact that the excavation handled per mile of highway built has more than doubled during the period covered by this index is not surprising.

In the structural field the situation is similar. Pavements have increased in width, and this has forced a corresponding increase in the width of bridges and in the length of culverts. Formerly both were governed quite largely by the width of the surfacing. In more recent years there has been a tendency to make bridges wider than the surfaced roadway. There has also been a marked tendency to make culverts at least as long as the width of the embankment (surfacing plus shoulders). As a result of these changes the structural quantities used per mile of highway constructed have also more than doubled.

TABLE 14.—*Cost trend in highway construction*

| Year | Excavation [1] | | | | Pavement [2] | | | |
	Bid price [3]	Quantity	Amount	Subindex	Bid price [3]	Quantity	Amount	Subindex
Base period, 1925 to 1929	$0.35	*Cubic yards* 17,491	$6,139	100.0	$2.22	*Square yards* 3,726	$8,264	100.0
1923	.47	12,916	6,045	98.5	2.43	3,751	9,107	110.2
1924	.43	13,393	5,746	93.6	2.40	3,839	9,221	111.6
1925	.39	14,299	5,519	89.9	2.36	3,767	8,890	107.6
1926	.36	16,600	6,042	98.4	2.29	3,175	7,258	87.8
1927	.35	16,599	5,843	95.2	2.29	3,540	8,110	98.1
1928	.34	17,352	5,848	95.2	2.10	4,348	9,113	110.3
1929	.32	22,605	7,143	116.4	2.05	3,798	7,805	94.4
1930	.30	24,169	7,323	119.3	1.86	4,324	8,064	97.6
1931	.27	27,845	7,546	122.9	1.68	3,995	6,696	81.0

| Year | Structures | | | | | | | | | | | Composite mile | |
| | Reinforcing steel | | | Structural steel | | | Structural concrete | | | Combined | | | |
	Bid price [3]	Quantity	Amount	Bid price [3]	Quantity	Amount	Bid price [3]	Quantity	Amount	Amount	Sub-index	Amount	Index
Base period 1925 to 1929	$0.052	*Pounds* 16,000	$826	$0.067	*Pounds* 4,325	$291	$22.15	*Cu. yds.* 68	$1,506	$2,623	100.0	$17,026	100.0
1923	.057	9,270	533	.078	2,297	180	23.37	53	1,239	1,952	74.4	17,104	100.5
1924	.057	12,374	711	.077	2,258	174	22.91	67	1,535	2,420	92.3	17,387	102.1
1925	.056	13,581	767	.067	4,718	315	22.53	64	1,442	2,524	96.2	16,933	99.5
1926	.053	14,070	751	.074	3,629	267	22.76	68	1,548	2,566	97.8	15,866	93.2
1927	.051	12,773	651	.071	3,301	233	22.65	64	1,449	2,333	89.0	16,286	95.7
1928	.049	17,075	840	.067	4,953	332	21.22	65	1,379	2,551	97.3	17,512	102.9
1929	.048	22,503	1,082	.059	5,024	297	21.58	81	1,748	3,127	119.2	18,075	106.2
1930	.045	26,852	1,200	.061	7,750	473	20.08	122	2,449	4,122	157.2	19,509	114.6
1931	.040	30,751	1,227	.054	12,216	655	18.02	141	2,541	4,423	168.6	18,665	109.6

[1] Common excavation plus other items expressed as equivalent common excavation. (See p. 85 and table 8.)
[2] Portland cement concrete plus other items expressed as equivalent portland cement concrete. (See p. 85 and table 8.)
[3] Indexes and totals were calculated with the bid prices carried to one more decimal place than that to which they are shown in this table.

The effect of these and of other influences which have affected highway design is shown in the index of highway usage which is given in graphical form in figure 2 and in statistical form in table 13.

THE INDEX OF HIGHWAY COST

The cost at which highways are built integrates changes in price and changes in usage. In the highway field the number of units handled in building a mile of finished pavement has been increasing steadily. The price at which these units have been handled has been falling. Cost has remained relatively uniform. The cost index is obtained by applying the annual average quantities handled to the average annual price at which they were handled. In graphical form this index is shown in figure 2. In tabular form it is shown in table 14.

the 3-, 6- and 9-ply mats. This conclusion is verified by a consideration of the relative moisture losses sustained, as shown in tables 2 and 4. It has been shown that, for the mats which were wet when applied, the amount of moisture is virtually the same, regardless of the thickness of the mat.

TEST RESULTS SHOW EFFICIENCY OF MATS IN HEAT INSULATION AND CURING

The conclusions drawn from this investigation are necessarily qualified by the fact that the tests were made with small laboratory samples, rather than in the field. The indications are as follows:

1. Cotton mats were effective for heat insulation. Under the conditions of these tests, the 24-hour temperature range under the cotton mats was approximately 35 percent of that which occurred in uncovered concrete and about 60 percent of that which occurred in concrete covered with wet burlap.

2. The insulating properties of the various thicknesses of mat (ranging from 1-ply, about one-third inch thick, to 9-ply, about 3 inches thick) against heat absorbed from the rays of the sun, appeared to be about the same.

3. From the standpoint of strength the cotton mats which were wet once and received no further wetting were as effective in curing as was double-thickness burlap kept wet continuously, the curing period in both cases being 3 days.

4. The cotton mats applied dry were not as effective for curing as were the wet mats or the wet burlap. Specimens cured with dry mats developed about 88 percent of the strength developed by specimens cured under wet mats or under wet burlap kept continuously wet.

5. The various thicknesses of mat appeared to be equally effective as curing agents for concrete.

TABLE 4.—*Percentage of original water content of specimens at ages indicated (1-, 2-, and 3-ply mats)* [1]

| Curing method | Specimen no. | Percentage of original water content at age of— | | | | |
		3 days	10 days	20 days	26 days	28 days
Burlap, kept wet 3 days	1	101.9	90.2	87.9	87.2	97.1
	2	99.8	89.5	87.4	86.4	95.4
	3	101.1	90.1	88.3	87.2	95.9
Average		100.9	89.9	87.9	86.9	96.1
1-ply mat, wet when applied	1	101.1	90.8	87.7	87.2	97.6
	2	97.3	89.1	86.9	85.9	96.5
	3	98.9	90.4	88.7	87.6	97.4
Average		99.1	90.1	87.8	86.9	97.2
2-ply mat, wet when applied	1	101.7	90.3	87.4	86.6	97.5
	2	99.8	89.4	87.5	86.2	96.5
	3	101.6	90.8	89.1	87.7	97.3
Average		101.0	90.2	88.0	86.8	97.1
3-ply mat, wet when applied	1	100.4	88.7	86.3	85.2	95.8
	2	101.7	91.2	88.8	87.5	98.1
	3	100.7	90.3	88.4	87.0	96.7
Average		100.9	90.1	87.8	86.6	96.9

[1] Curing agents removed at end of 3 days, and specimens cured from 3 to 26 days in laboratory air. Specimens immersed in water at end of 26 days.

TABLE 5.—*Results of tests for flexural strength at the age of 28 days (1-, 2-, and 3-ply mats)*

| Curing method | Modulus of rupture in pounds per square inch | | | | Strength ratio [1] |
	1	2	3	Average	
Burlap, kept wet 3 days	958	1,009	902	956	1.00
1-ply mat, wet when applied	934	896	931	920	.96
2-ply mat, wet when applied	853	962	962	926	.97
3-ply mat, wet when applied	918	880	954	917	.96

[1] Strength developed by double burlap kept wet 3 days taken as standard.

CORRECTIONS

Vol. 14, No. 2, April 1933.—In the article entitled, "The Wisconsin Financial Survey", page 31, in right-hand middle panel of figure: "Vehicle-miles in millions" should read, "Vehicle-miles in billions."

Vol. 14, No. 3, May 1933.—In the article entitled, "The Illinois Financial Survey", page 47, in upper left-hand panel of figure: "Other imposts" should read "all imposts."

ROAD PUBLICATIONS of the BUREAU OF PUBLIC ROADS

Any of the following publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D.C. As his office is not connected with the Department and as the Department does not sell publications, please send no remittance to the United States Department of Agriculture.

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Report of the Chief of the Bureau of Public Roads, 1927. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1928. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1929. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1931. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1932. 10 cents.

DEPARTMENT BULLETINS

No. 136D . . Highway Bonds. 20 cents.

No. 347D . . Methods for the Determination of the Physical Properties of Road-Building Rock. 10 cents.

No. 532D . . The Expansion and Contraction of Concrete and Concrete Roads. 10 cents.

No. 583D . . Reports on Experimental Convict Road Camp, Fulton County, Ga. 25 cents.

No. 660D . . Highway Cost Keeping. 10 cents.

No. 1279D . . Rural Highway Mileage, Income, and Expenditures, 1921 and 1922. 15 cents.

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No. 55T . . Highway Bridge Surveys. 20 cents.

No. 265T . . Electrical Equipment on Movable Bridges. 35 cents.

MISCELLANEOUS CIRCULARS

No. 62MC . . Standards Governing Plans, Specifications, Contract Forms, and Estimates for Federal-Aid Highway Projects. 5 cents.

No. 93MC . . Direct Production Costs of Broken Stone. 25 cents.

No. 109MC . . Federal Legislation and Regulations Relating to the Improvement of Federal-Aid Roads and National-Forest Roads and Trails, Flood Relief, and Miscellaneous Matters. 10 cents.

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Reports on Subgrade Soil Studies. 40 cents.

Single copies of the following publications may be obtained from the Bureau of Public Roads upon request. They cannot be purchased from the Superintendent of Documents.

SEPARATE REPRINT FROM THE YEARBOOK

No. 1036Y . . Road Work on Farm Outlets Needs Skill and Right Equipment.

TRANSPORTATION SURVEY REPORTS

Report of a Survey of Transportation on the State Highway System of Ohio (1927).

Report of a Survey of Transportation on the State Highways of Vermont (1927).

Report of a Survey of Transportation on the State Highways of New Hampshire (1927).

Report of a Plan of Highway Improvement in the Regional Area of Cleveland, Ohio (1928).

Report of a Survey of Transportation on the State Highways of Pennsylvania (1928).

Report of a Survey of Traffic on the Federal-Aid Highway Systems of Eleven Western States (1930).

A complete list of the publications of the Bureau of Public Roads, classified according to subject and including the more important articles in PUBLIC ROADS may be obtained upon request addressed to the U.S. Bureau of Public Roads, Willard Building, Washington, D.C.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

CURRENT STATUS OF FEDERAL-AID ROAD CONSTRUCTION

AS OF

JUNE 30, 1933

STATE	COMPLETED MILEAGE	UNDER CONSTRUCTION						APPROVED FOR CONSTRUCTION					BALANCE OF FEDERAL-AID FUNDS AVAILABLE FOR NEW PROJECTS
		Estimated total cost	Federal aid allotted	Percentage completed	MILEAGE Initial	MILEAGE Stage[1]	MILEAGE Total	Estimated total cost	Federal aid allotted	MILEAGE Initial	MILEAGE Stage[1]	MILEAGE Total	
		$	$					$	$				$
Alabama	2,944.3	5,032,976.50	2,516,488.13	75	131.2	110.3	241.5						3,199,828.75
Arizona	1,270.4	2,884,355.53	1,355,008.46	72	68.0	126.7	194.7	43,050.08	27,982.56		5.9	5.9	1,610.68
Arkansas	1,932.8	4,613,104.71	2,192,025.82	72	130.6	89.0	219.6	1,187,545.23	593,772.55	102.1	15.7	117.8	663,844.66
California	2,500.1	7,629,209.24	1,665,804.03	81	130.4	55.1	185.5	73,760.44	17,153.65	.9	2.0	2.9	117,095.88
Colorado	1,863.7	2,900,175.57	1,330,286.76	79	116.6	19.1	135.7						269,439.58
Connecticut	296.8	4,110,880.78	1,695,978.21	80	43.7	5.3	49.0	394,215.58	177,396.94	27.9	.2	28.1	185,167.11
Delaware	381.1	755,181.00	150,125.44	93	23.6	15.9	39.5						989,164.32
Florida	661.1	6,609,972.32	3,168,669.14	81	112.4		172.4						
Georgia	3,238.8	4,303,700.67	1,748,672.41	87	107.4	180.6	288.0						100,536.93
Idaho	1,592.4	2,354,542.60	841,030.70	79	90.6	113.9	204.5	81,908.25	44,788.31	6.2	3.4	9.6	73,920.51
Illinois	3,110.9	20,162,768.27	7,703,139.50	76	617.0	60.6	677.6	716,775.42	311,902.26	27.0		27.0	95,967.25
Indiana	2,109.4	7,139,311.52	2,773,730.55	88	228.3	20.7	249.0	1,372,003.25	133,528.13	65.0	5.3	70.3	209,145.99
Iowa	3,540.0	5,321,273.39	803,331.76	96	261.1	38.5	299.6	163,196.62	75,935.47	8.6	3.1	11.7	59,251.82
Kansas	4,052.9	3,498,351.61	1,032,386.15	70	190.3	61.0	251.3						153,217.33
Kentucky	1,933.6	4,024,383.53	1,395,480.17	73	159.6	122.0	281.6	283,561.74	126,216.05	10.7	13.9	24.6	48,791.33
Louisiana	1,619.6	6,392,245.96	2,785,921.90	68	42.4	24.8	67.1						76,304.51
Maine	823.0	2,203,423.77	508,213.51	74	66.4	.3	66.7	38,958.62	3,989.09		1.9	1.9	
Maryland	872.7	965,442.17	99,880.77	57	33.3	1.5	34.8	251,758.25	25,648.82	5.4		5.4	
Massachusetts	875.9	4,115,901.96	972,218.48	74	57.2	4.9	62.1						351,632.06
Michigan	2,339.2	6,674,228.20	2,567,439.95	74	283.9	97.1	381.0	602,750.00	196,440.00	39.3	.5	40.1	175,723.01
Minnesota	4,309.6	34,768,398.82	202,728.91	96	150.9	139.9	290.8						34,304.16
Mississippi	1,863.8	6,193,724.28	3,072,313.77	66	185.3	97.9	283.2	250,653.30	125,326.62	11.6	4.2	15.8	2,952,041.86
Missouri	3,233.2	4,351,270.58	737,807.32	47	173.8	17.0	190.8	445,829.85	91,623.60	13.1	16.6	29.7	8,827.28
Montana	2,973.2	5,616,576.61	3,142,856.07	76	405.9	255.8	661.7	57,325.91	32,350.96		12.0	12.0	401,817.97
Nebraska	4,259.7	6,234,000.11	2,913,882.72	88	156.3	159.9	316.2						49,318.84
Nevada	1,352.1	1,975,857.64	721,167.78	91	38.7	127.5	166.2						117,662.21
New Hampshire	448.8	563,304.16	232,591.90	75	12.5	.5	13.0	85,798.47	36,415.44	1.6	.7	2.3	64,377.21
New Jersey	637.9	5,309,569.73	1,735,318.97	87	55.7		55.7						109,558.29
New Mexico	2,300.9	2,532,793.19	975,113.25	96	127.9	103.5	231.4	111,736.03	44,694.41		5.1	5.1	85,464.22
New York	3,516.6	18,271,330.05	5,611,850.00	55	479.1	32.0	511.1						355,781.37
North Carolina	2,358.8	5,040,679.02	2,518,674.96	75	513.8	28.1	541.9	324,785.47	162,392.71	43.4		43.7	977,044.05
North Dakota	5,432.1	3,495,612.32	1,451,921.71	51	237.3	410.3	647.6	299,625.98	123,677.17	22.8	73.5	96.3	416,198.04
Ohio	3,057.9	8,085,323.09	2,179,738.01	78	177.5	52.3	229.8	76,364.00	123,361.08	1.3	3.3	4.6	190,835.32
Oklahoma	2,502.2	3,951,579.57	1,210,680.90	84	191.3	74.7	266.0	528,539.65	105,707.88	38.2		38.2	433,937.87
Oregon	1,630.5	4,104,798.63	1,640,267.03	77	106.6	74.4	181.0	59,172.74	26,004.62	1.7	1.6	3.3	56,880.55
Pennsylvania	3,276.8	10,077,698.86	2,532,150.15	68	348.7	14.0	362.7						53,641.77
Rhode Island	271.7	1,013,905.12	318,007.01	72	22.5	4.5	27.0						70,834.03
South Carolina	1,962.5	3,413,612.84	1,277,642.73	85	161.2	154.7	315.9	278,850.45	120,075.71	20.3	29.1	49.4	12,443.92
South Dakota	4,305.3	3,155,055.66	1,288,695.86	78	249.4	201.7	451.1						169,101.27
Tennessee	1,723.5	4,645,392.30	2,321,975.19	72	159.6	40.8	200.4	719,256.12	250,336.03	40.8	18.3	59.1	576,790.79
Texas	8,113.8	15,549,620.20	5,086,325.25	76	551.2	502.8	1,054.0	259,868.69	111,261.16	24.7	12.4	37.1	49,990.22
Utah	1,286.3	1,877,602.57	774,640.08	84	121.8	36.3	158.1						
Vermont	393.8	366,965.01	43,473.80	83	18.6		18.6	201,384.63	43,000.00	7.6	6.5	14.1	151.97
Virginia	1,994.3	4,026,229.27	1,817,348.27	80	179.6	52.7	232.3	35,537.10	17,765.54	2.3		2.3	194,541.87
Washington	1,330.7	3,045,261.29	916,420.63	76	109.6	9.7	119.3						59,732.72
West Virginia	925.6	3,071,207.15	1,256,848.11	83	113.8	8.1	121.9	52,061.50	21,500.00				49,516.08
Wisconsin	2,760.1	5,384,047.69	966,926.70	78	136.3	101.9	238.2						265,183.36
Wyoming	2,179.8	2,606,875.23	859,481.92	89	215.7	137.9	353.6				.9	.9	151,122.56
Hawaii	109.4	1,687,095.81	1,138,158.71	62	36.9		36.9						514,689.68
TOTALS	107,868.8	242,106,796.30	86,140,857.55	75	6,397.4	5,986.2	12,383.6	8,996,253.34	3,067,251.80	522.5	236.7	759.2	15,190,331.20
Construction completed		176,248,000	64,944,000										
Balance uncompleted		65,859,000	21,197,000										

[1]The term stage construction refers to additional work done on projects previously improved with Federal aid. In general, such additional work consists of the construction of a surface of higher type than was provided in the initial improvement.