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BUREAU OF PUBLIC ROADS

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BUREAU OF PUBLIC ROADS

D. M. BEACH, *Editor*

Volume 19, No. 8 October 1938

The reports of research published in this magazine are necessarily qualified by the conditions of the tests from which the data are obtained. Whenever it is deemed possible to do so, generalizations are drawn from the results of the tests; and, unless this is done, the conclusions formulated must be considered as specifically pertinent only to described conditions.

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THE EFFECT OF USING A BLEND OF PORTLAND AND NATURAL CEMENT ON THE PHYSICAL PROPERTIES OF MORTAR AND CONCRETE [1]

BY THE DIVISION OF TESTS, BUREAU OF PUBLIC ROADS

Reported by W. F. KELLERMANN, Associate Materials Engineer, and D. G. RUNNER, Assistant Materials Engineer

WITHIN the last few years considerable scaling of concrete pavements has resulted from the use of chemical salts in ice treatment in the Northern States. In an effort to combat this condition the New York State highway department began about 4 years ago to experiment with a blend of portland and natural cement for concrete pavement construction.

Preliminary tests made in the laboratory of the New York Department of Public Works indicated that concretes containing blends of portland and natural cements had greater resistance to alternate freezing and thawing in a solution of calcium chloride than had concretes containing only portland cement. These preliminary laboratory experiments were followed by the construction of a number of experimental sections of actual pavements, using portland cements of various chemical compositions and two natural cements, both made in New York State and both readily available commercially.

The Bureau of Public Roads became interested in this work not only from the technical viewpoint but also because of a request from the Division of Highways of the New York Department of Public Works for permission to conduct certain of its field experiments on pavements financed either wholly or in part with Federal funds. It was felt that before approving the use of blended cements on any extended mileage of highway very definite information should be obtained regarding their effect on other essential qualities, such as strength volume change, etc., and, furthermore, that these tests should be made in the laboratory under closely controlled conditions.

This paper reports the results of such a study as well as the results of a series of freezing and thawing tests on specimens taken from certain of the experimental pavements referred to above. The data on laboratory fabricated specimens are presented in two sections, the first dealing with tests of mortars, and the second with concretes. The results of freezing tests on concrete cores are discussed in a third section.

Tests on the mortar specimens included determinations of crushing strength, flexural strength, absorption, density, durability, and volume change. Two portland cements, differing considerably in chemical composition, and two sands of widely different mineral composition were used in this portion of the investigation. Tests on concrete specimens fabricated in the laboratory included determinations of crushing strength, flexural strength, and modulus of elasticity, using the same two portland cements with local fine and coarse aggregate. One brand of natural cement was used in all specimens fabricated in the laboratory.

The freezing tests discussed in the third part of the report were made on cores taken from four of the experimental concrete pavements. Two natural cements as well as portland cements conforming to four different classifications as to compound composition were used in these roads. Core specimens were taken from sections in which straight portland cement was used as well as from sections containing blends in the proportion of 6 parts of portland cement to 1 part of natural cement, and 5 parts of portland cement to 2 parts of natural cement, by weight. These specimens were subjected to alternate freezing and thawing in water and in a 10 percent solution of commercial calcium chloride.

REPRESENTATIVE MATERIALS USED IN LABORATORY FABRICATED SPECIMENS

The two portland cements included one brand from the Hudson River Valley region, designated as cement A, and one from the Lehigh Valley of Pennsylvania, designated as cement B. Both cements satisfactorily met the requirements for portland cement of the American Society for Testing Materials. The natural cement represented material produced in the northeastern part of the United States and is typical of the old type produced in vertical kilns. The fineness as determined by the Wagner turbidimeter was about the same for both portland cements, but the natural cement had a fineness more nearly corresponding to that of high-early-strength cement. The results of the physical and chemical tests on the three cements are shown in table 1.

Three concrete sands were used in the investigation. Sands A and C were composed essentially of quartz, and sand B consisted essentially of shale and quartz particles with appreciable amounts of limestone, slate, and sandstone. The sieve analyses and physical properties of the three sands and the coarse aggregate used in the tests are given in table 2. The coarse aggregate used in the laboratory fabricated concrete specimens was a limestone of known satisfactory quality and graded uniformly from No. 4- to 1½-inch material.

For the various tests on mortars, each portland cement and blend was used with each sand. Specimens were made using 100 percent portland cement and using two blends, one in which 14 percent and the other in which 28 percent by weight of portland cement was replaced by natural cement. These values correspond to the percentages of natural cement used in the New York experimental roads, which were of the order of 1 sack or 2 sacks in a 7-sack batch, or 14 and 28 percent, respectively.

For each of the portland cements, a sufficient quantity of water was added to the straight portland cement-sand A mixture to give a flow of approximately 90 on

[1] Paper presented at the forty-first annual meeting of the American Society for Testing Materials, Atlantic City, N. J., 1938.

TABLE 1.—*Properties of cements used in laboratory fabricated specimens*

PHYSICAL PROPERTIES

Item	Cement A	Cement B	Natural cement
Apparent specific gravity	3.14	3.11	3.00
Specific surface, cm²/gm	1,730	1,805	2,680
Percent retained on No. 200 sieve	7.1	9.6	10.5
Normal consistency, percent	23.7	24.0	26.0
Time of set, hours:			
Initial	3.3	2.9	1.1
Final	5.1	4.9	1.8
Tensile strength, lb. per sq. in.:			
7 days	380	370	50
28 days	445	445	150

CHEMICAL ANALYSES

Oxides	Percent	Percent	Percent
Silica	22.41	20.80	24.91
Alumina	4.78	6.47	9.65
Iron	3.72	2.38	
Lime	64.55	63.22	33.93
Magnesia	1.15	3.45	19.92
Sulphuric anhydride	1.72	1.77	1.42
Loss on ignition	1.37	1.47	8.55

COMPUTED COMPOUND COMPOSITIONS

Compounds			
Tricalcium silicate	50	47	----------
Dicalcium silicate	26	25	----------
Tricalcium aluminate	6	13	----------
Tetracalcium alumino-ferrite	11	7	----------

TABLE 2.—*Properties of aggregates*

SIEVE ANALYSES OF FINE AGGREGATES

Total retained on—	Sand A	Sand B	Sand C
3/8-inch sieve	0	0	0
No. 4 sieve	2	4	7
No. 8 sieve	11	21	24
No. 16 sieve	27	45	39
No. 30 sieve	49	67	53
No. 50 sieve	84	87	86
No. 100 sieve	97	95	97
Fineness modulus	2.70	3.19	3.06

PHYSICAL PROPERTIES

Item	Sand A	Sand B	Sand C	Coarse aggregate
Absorption, percent	0.3	2.2	0.9	0.32
Organic matter	(1)	(1)	(1)	----------
Decantation loss, percent	1.4	2.5	1.5	----------
Compressive strength ratio:				
7 days	140	123	121	----------
28 days	130	124	121	----------
Percentage of wear, Deval	----------	----------	----------	3.0

[1] Satisfactory.

the 10-inch flow table. The same quantity of water was then used in all other mixtures containing this cement. This resulted in slightly lower flows (drier mortars) for the mixtures containing sand B and also somewhat lower flows for the mixtures containing natural cement. All mixtures, however, were plastic and workable, insofar as could be determined when fabricating the test specimens. The consistencies of the various mixes, as determined by the use of the 10-inch flow table, are shown in table 3.

An outline of the various tests made on the mortar specimens follows.

1. Determinations of crushing and flexural strengths of 2-inch cubes and 2- by 3- by 18-inch beams, using a mix of 1:2 by weight. Specimens were cured continuously in water at 70° F., and broken at ages of 7, 28, 90, 180, and 360 days. Duplicate sets of specimens were cured in air (with 7 days initial water cure) and broken at 28, 90, 180, and 360 days. Beam specimens were broken as cantilevers, using portions of the same beam for tests at various ages.

2. Determinations of tensile strength of briquets containing standard Ottawa sand in a 1:3 mix by weight. Specimens were broken at 7 and 28 days.

3. Tests for volume change on 2- by 3- by 18-inch beams, using a 1:2 mix by weight. One set of specimens was stored in air for 120 days, the other continuously in water at 70° F. for 180 days. As a supplementary portion of this phase of the work, after 180 days of water storage the beams were frozen and thawed for 6 cycles, dried at 120° F. for 4 days, and resaturated in water at 70° F. for 3 days, after which the freezing and thawing cycle was again repeated. In this test measurements of length were made at the conclusion of each 3-day resaturation period. The linear comparator used in all measurements of volume change is shown in figure 1.

4. Miscellaneous tests included absorption and bulk specific gravity tests on 2- by 4-inch cylinders of 1:2 mortar, sodium sulphate soundness tests on 1- by 1- by 6-inch bars, using a mix of 1:5 by weight of Ottawa sand, and autoclave tests on 1- by 1- by 10-inch neat cement bars.

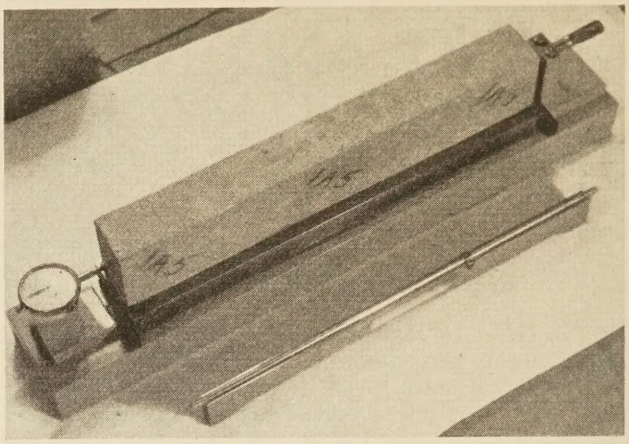

FIGURE 1.—HORIZONTAL COMPARATOR USED IN MEASURING LENGTH CHANGE OF MORTAR BEAMS.

TABLE 3.—*Consistencies of mortars as determined by the 10-inch flow table*

MIXTURES CONTAINING SAND A

Percentage of portland cement replaced by natural cement	Cement A		Cement B	
	Beams	Cubes	Beams	Cubes
0	91	93	93	93
14	87	90	90	89
28	83	83	88	85
MIXTURES CONTAINING SAND B				
0	83	83	85	85
14	79	76	82	80
28	74	70	79	78

USE OF BLENDED CEMENTS DECREASED STRENGTH OF MORTARS

The results obtained in the strength tests of mortars are given in tables 4 to 7, inclusive, and are shown graphically in figures 2 to 5 inclusive. In the figures, the values have been plotted so as to show on the left the average results for the two sands with each cement and on the right the average results for the two cements with each sand.

Table 4 and figure 2 give the results of crushing tests on specimens continuously water cured. When the results are averaged as in the figure it will be seen that, for each combination of materials, the straight portland cement mixes developed the greatest strengths

TABLE 4.—*Crushing strengths of 2-inch mortar cubes, mix 1:2 by weight, water cured*

Percentage of portland cement replaced by natural cement	7 days		28 days		90 days		180 days		360 days	
	Lb. per sq. in.[1]	*Per-cent*[2]	*Lb. per sq. in.*[1]	*Per-cent*[2]	*Lb. per sq. in.*[1]	*Per-cent*[2]	*Lb. per sq. in.*[1]	*Per-cent*[2]	*Lb. per sq. in.*[1]	*Per-cent*[2]
CEMENT A—SAND A										
0	6,180	100	8,570	100	9,625	100	9,910	100	9,990	100
14	5,805	94	7,360	86	8,580	89	9,005	91	9,320	93
28	4,620	75	6,105	71	7,255	75	7,595	77	8,290	83
CEMENT A—SAND B										
0	5,000	100	6,975	100	8,280	100	9,125	100	9,645	100
14	5,010	100	6,555	94	7,740	94	8,270	91	9,245	96
28	4,430	89	5,845	84	7,190	87	7,880	86	8,660	90
CEMENT B—SAND A										
0	6,400	100	8,375	100	9,825	100	9,665	100	9,355	100
14	5,090	80	6,710	80	8,165	83	8,695	90	8,620	92
28	4,130	65	5,420	65	6,920	70	7,175	74	7,490	80
CEMENT B—SAND B										
0	5,015	100	6,815	100	7,840	100	8,620	100	8,980	100
14	4,745	95	6,140	90	7,345	94	7,725	90	8,590	96
28	3,930	78	5,215	77	6,645	85	7,120	83	7,735	86

[1] Each value is the average of 15 tests.
[2] Figures indicate percentage of the strength of 100 percent portland cement mixes.

TABLE 5.—*Crushing strengths of 2-inch mortar cubes, mix 1:2 by weight, air cured after 7-day initial water cure*

Percentage of portland cement replaced by natural cement	28 days		90 days		180 days		360 days	
	Lb. per sq. in.[1]	*Percent*[2]	*Lb. per sq. in.*[1]	*Percent*[2]	*Lb. per sq. in.*[1]	*Percent*[2]	*Lb. per sq. in.*[1]	*Percent*[2]
CEMENT A—SAND A								
0	8,825	100	8,870	100	8,715	100	9,085	100
14	8,155	92	8,550	96	8,535	98	8,865	98
28	6,895	78	7,335	83	7,540	87	7,870	87
CEMENT A—SAND B								
0	7,205	100	7,555	100	7,870	100	7,105	100
14	7,170	100	7,470	99	7,780	99	6,885	97
28	6,540	91	7,100	94	7,210	92	6,295	89
CEMENT B—SAND A								
0	8,755	100	8,975	100	9,040	100	8,765	100
14	7,530	86	7,980	89	8,255	91	8,175	93
28	6,290	72	6,705	75	7,065	78	6,920	79
CEMENT B—SAND B								
0	7,040	100	7,425	100	7,670	100	7,195	100
14	6,700	95	6,895	93	7,465	97	6,525	91
28	5,495	78	5,505	74	5,825	76	6,040	84

[1] Each value is the average of 15 tests.
[2] Figures indicate percentage of the strength of 100 percent portland cement mixes.

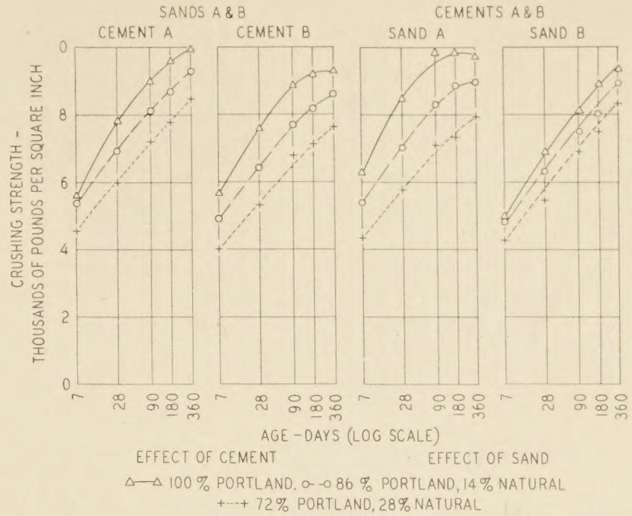

FIGURE 2.—EFFECT OF BLENDING PORTLAND AND NATURAL CEMENT ON THE CRUSHING STRENGTH OF 2-INCH MORTAR CUBES CURED IN WATER.

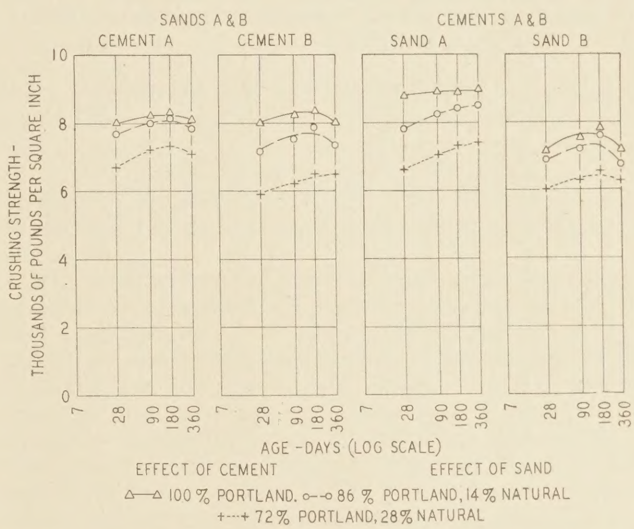

FIGURE 3.—EFFECT OF BLENDING PORTLAND AND NATURAL CEMENT ON THE CRUSHING STRENGTH OF 2-INCH MORTAR CUBES CURED IN AIR.

at all ages. With the exception of the 180- and 360-day values for the straight portland cement mortar in which sand A was used with cements A and B, all mortars exhibited gain in strength from the 7- up to the 360-day periods.

In the left hand portion of figure 2 it may be seen that mortars containing cement A had slightly greater strengths than those containing cement B. The right hand portion of this figure shows the effect of using different sands. In the unblended mix, as well as in the mortar containing 14 percent of natural cement, specimens containing sand A showed greater strengths at all ages. However, in the mixes containing 28 percent of natural cement, the strengths were about the same. In other words, replacing portland cement with natural cement seemed to affect the strength of mortars made with sand A much more than those made with sand B.

The values obtained on air-cured, 2-inch cubes (after 7 days of initial water storage) are given in table 5 and in figure 3. The average values given in the figures

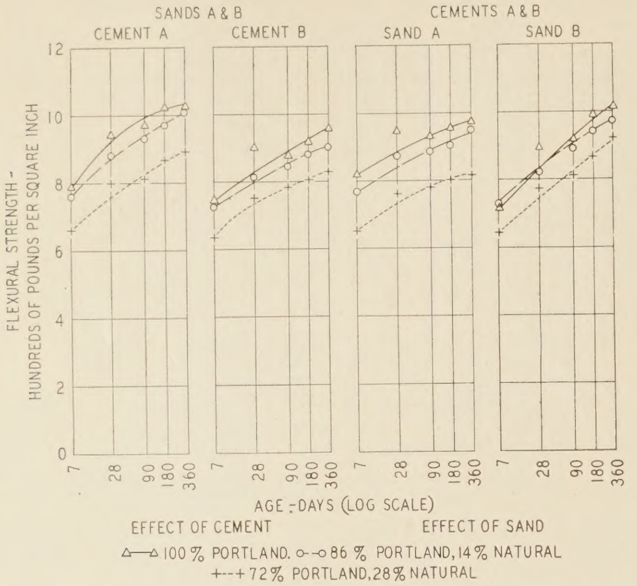

FIGURE 4.—EFFECT OF BLENDING PORTLAND AND NATURAL CEMENT ON FLEXURAL STRENGTH OF 18-INCH MORTAR BEAMS CURED IN WATER.

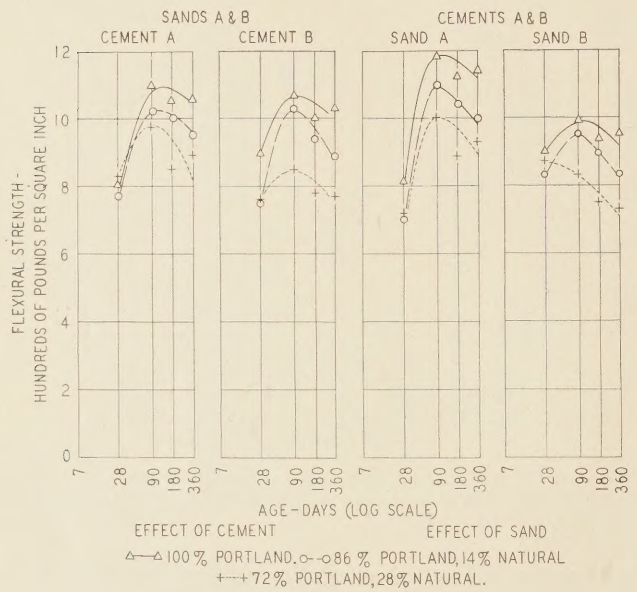

FIGURE 5.—EFFECT OF BLENDING PORTLAND AND NATURAL CEMENT ON FLEXURAL STRENGTH OF 18-INCH MORTAR BEAMS CURED IN AIR.

show, in all cases, higher strengths for the mixes containing straight portland cement. Comparing figures 2 and 3 it will be noted that the specimens moist-cured 7 days and air-dried for 21 days were in general higher in strength than those cured continuously in water for 28 days. Further air storage, however, resulted in only slight gain in strength at 90 days, with little or no gain thereafter.

Figure 3 shows the effect of the cement and sand upon the crushing strength of the air-dried specimens. Specimens containing cement A exhibited slightly greater strengths in the blends, with the unblended mortars having about the same strength at all ages. Specimens containing sand A showed definitely higher strengths throughout. The most interesting point in connection with this figure is the decrease in strength

TABLE 6.—*Flexural strengths of 18-inch mortar beams, mix 1:2 by weight, water cured*

Percentage of portland cement replaced by natural cement	7 days		28 days		90 days		180 days		360 days	
	Lb. per sq. in.[1]	*Per-cent*[2]	*Lb. per sq. in.*[1]	*Per-cent*[2]	*Lb. per sq. in.*[1]	*Per-cent*[2]	*Lb. per sq. in.*[1]	*Per-cent*[2]	*Lb. per sq. in.*[1]	*Per-cent*[2]
CEMENT A—SAND A										
0	850	100	995	100	970	100	1,010	100	1,030	100
14	770	91	905	91	940	97	945	94	995	97
28	660	78	780	78	795	82	825	82	880	85
CEMENT A—SAND B										
0	735	100	900	100	965	100	1,045	100	1,025	100
14	755	103	860	96	920	95	985	94	1,055	103
28	660	90	820	91	835	87	915	88	915	89
CEMENT B—SAND A										
0	790	100	905	100	885	100	900	100	915	100
14	760	96	845	93	835	94	865	96	915	100
28	650	82	745	82	765	86	790	88	760	83
CEMENT B—SAND B										
0	700	100	890	100	870	100	930	100	1,000	100
14	700	100	795	89	865	99	895	96	885	89
28	625	89	745	84	800	92	820	88	910	91

[1] Each value is the average of 5 tests.
[2] Figures indicate percentage of the strength of 100 percent portland cement mixes.

TABLE 7.—*Flexural strengths of 18-inch mortar beams, mix 1:2 by weight, air cured*

Percentage of portland cement replaced by natural cement	28 days		90 days		180 days		360 days	
	Lb. per sq. in.[1]	*Percent*[2]	*Lb. per sq. in.*[1]	*Percent*[2]	*Lb. per sq. in.*[1]	*Percent*[2]	*Lb. per sq. in.*[1]	*Percent*[2]
CEMENT A—SAND A								
0	720	100	1,195	100	1,140	100	1,180	100
14	680	94	1,110	93	1,070	94	1,035	88
28	725	100	1,085	91	915	80	970	82
CEMENT A—SAND B								
0	885	100	1,005	100	950	100	935	100
14	865	98	930	93	920	97	875	94
28	930	105	850	85	795	84	805	86
CEMENT B—SAND A								
0	905	100	1,165	100	1,095	100	1,100	100
14	700	77	1,080	93	1,015	93	970	88
28	710	79	905	78	855	78	880	80
CEMENT B—SAND B								
0	900	100	970	100	915	100	975	100
14	800	89	970	100	860	94	800	82
28	810	90	810	83	705	77	655	67

[1] Each value is the average of 5 tests.
[2] Figures indicate percentage of the strength of the 100 percent portland cement mixes.

caused by the replacement of 28 percent of the portland cement with natural cement. The strengths obtained with this combination ran about 1,000 to 2,000 pounds per square inch lower than those of the straight portland cement mixes for the different cements and sands.

The effect of blending portland and natural cement upon the flexural strength of water-cured mortar beams is shown in table 6 and in figure 4. It will be noted that when the results are averaged as in figure 4, for

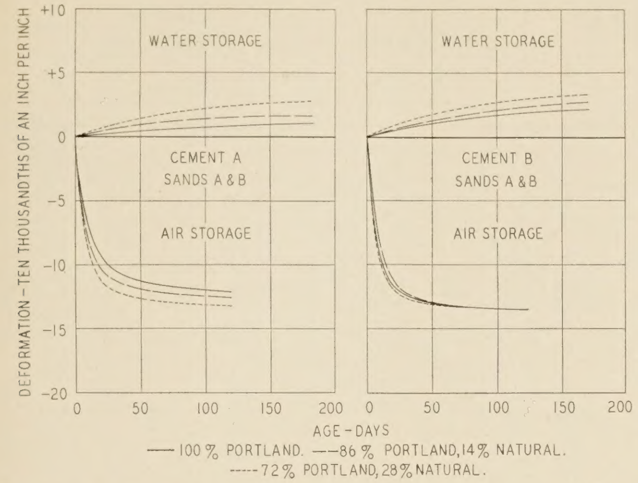

FIGURE 6.—EFFECT OF BLENDING PORTLAND AND NATURAL CEMENT ON VOLUME CHANGE OF 18-INCH MORTAR BEAMS.

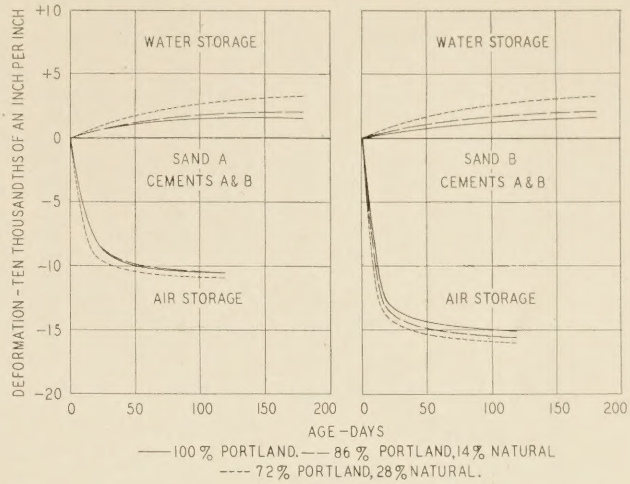

FIGURE 7.—EFFECT OF BLENDING PORTLAND AND NATURAL CEMENT ON VOLUME CHANGE OF 18-INCH MORTAR BEAMS.

each combination of materials, the straight portland cement mixes, with a single exception, produced the greatest strengths at all ages. As in the water-cured compression specimens, the gain in strength with age was fairly uniform. However, the reduction in strength caused by blending was not proportional to the amount of natural cement used, the 28-percent replacement causing a proportionately greater reduction than the 14-percent replacement. Cement A in general produced greater strengths for all combinations of materials than did cement B.

The results of flexure tests on air-cured beams are given in table 7 and in figure 5. It will be observed that here also for each combination of materials, with a single exception, the straight portland cement mixes produced the greatest strengths at all ages. With few exceptions the highest strengths were obtained at 90 days, all mixes showing retrogression after that period. In every case the strengths at 90 days were higher than those of the corresponding water-cured specimens.

The effect of blending portland and natural cement upon volume change of 18-inch mortar beams in continuous water storage is shown graphically in the upper portion of figures 6 and 7. The changes are shown in 0.0001 inch per inch at the ages indicated on the abscissas. It will be noted from the figures that blends containing 28 percent of natural cement had the greatest expansion at 180 days, and that the straight portland cement mixes for all combinations exhibited the least expansion. It is of interest to note (fig. 6) that specimens containing cement B had slightly greater expansions for both blended and unblended mixtures than those containing cement A. However, as will be seen from figure 7, changing the sand had very little effect upon volume change.

MORTAR BEAMS SUBJECTED TO ACCELERATED WEATHERING TESTS

Volume changes resulting from continuous air storage are shown in the lower portions of figures 6 and 7. The treatment of these beams consisted of storage for 24 hours in the moist closet, at the end of which time an initial reading was taken, followed by continued storage in laboratory air. During the period from 90 to 120 days the beams were placed in a cabinet in which the air was dried with calcium chloride to decrease further the amount of moisture in the specimens. As expected, all beams showed slightly increased shrinkage during this period.

Beams containing sands A and B and cement A had approximately the same amount of shrinkage as those containing cement B (fig. 6). However, specimens containing cements A and B and sand B had shrinkages at 120 days about 50 percent greater than those containing sand A (fig. 7). The figures show that although the initial shrinkage was somewhat greater in specimens containing the blended cements, the total shrinkage at the end of 120 days of continuous air storage was about the same.

The mortar beams from the continuous water storage series were measured for length at the end of 180 days, and then subjected to 15 rounds of the following accelerated weathering treatment. Each round required 13 days for completion and consisted of 6 cycles of freezing and thawing, each 24 hours in duration, followed by drying for 4 days in an electric oven at 120° F., and resaturation for 3 days in water at 70° F. Readings were taken on each beam at the end of the resaturation period and were discontinued at the end of the fifteenth round, at which time surface disintegration of the specimens had progressed to a point which affected the accuracy of the readings because of loosening of the gage points. Unit length changes at the end of the first, third, sixth, ninth, twelfth, and fifteenth rounds are shown in figures 8 and 9. Here the data have been averaged in the same manner as in the previous figures so as to bring out the effect of variations in the cement and sand.

Several points in connection with these figures are of interest. In the first place, all specimens showed an initial contraction followed by expansion up to the fifteenth round. The amount of initial contraction seemed to have been affected greatly by the combination of materials used, being greatest for the combinations involving cement A with the two sands (fig. 8) and sand B with the two cements (fig. 9). The combinations involving sand A with cements A and B showed very little initial contraction. This effect may have resulted from the drying cycle which was introduced. Drying at 120° F. for 4 days undoubtedly induced high shrinkage in the cement paste, subjecting the particles of aggregate to high compressive stress. It is possible that the difference in the ability of the sands to resist this stress without permanent deforma-

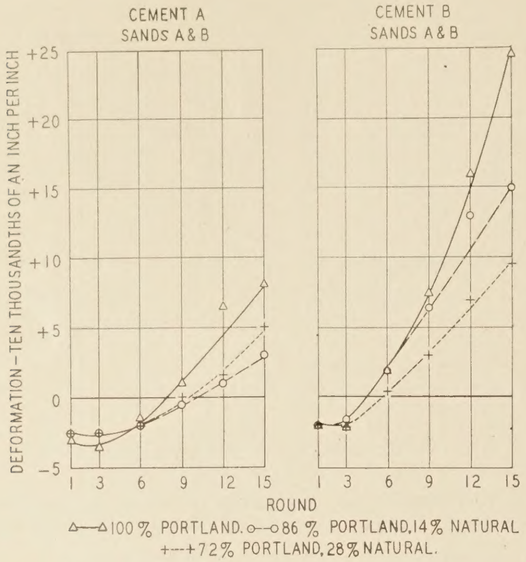

FIGURE 8.—EFFECT OF FREEZING AND THAWING, FOLLOWED BY DRYING, COOLING, AND RESATURATION ON VOLUME CHANGE OF MORTAR BEAMS.

tion may have accounted for the residual shrinkage observed in the specimens containing sand B, which was composed of comparatively low-strength material. The quartz particles composing sand A may have possessed sufficient strength to resist the shrinkage stresses without permanent deformation, so that the specimens when resaturated returned practically to their original length. The accumulated effect of this action may account also for the relatively small expansions which were observed for specimens containing sand B as compared to the expansions shown by specimens containing sand A.

It will be observed also that, without exception, specimens containing the blended cement showed lower expansions than the corresponding specimens containing only portland cement. It is usually assumed, insofar as expansion is concerned, that repeated freezing and thawing produces a gradually expanding paste, resulting in the eventual disintegration of the specimen. On this basis, the use of the blended cements may be considered beneficial. However, visual examination of the specimens as the test proceeded failed to reveal any consistent difference in appearance at any stage between the specimens containing the blended cements and those containing the straight portland cement. So far as could be determined by visual inspection of the surface, all of the specimens failed at about the same rate. All were badly exfoliated or surface pitted by the end of the fifteenth round and apparently possessed little strength.

BLENDING INCREASED RESISTANCE OF MORTARS TO SULPHATE ACTION

The effect of replacements with natural cement on the tensile strength of 1:3 Ottawa sand briquets is shown in table 8. It is of interest to note that, for both cements at 28 days, the specimens containing 14 percent of natural cement had very nearly the same strengths as the straight portland cement mortars. The strengths at 28 days of specimens containing 28 percent of natural cement were approximately 90 percent of the strengths of the straight portland cement mortars.

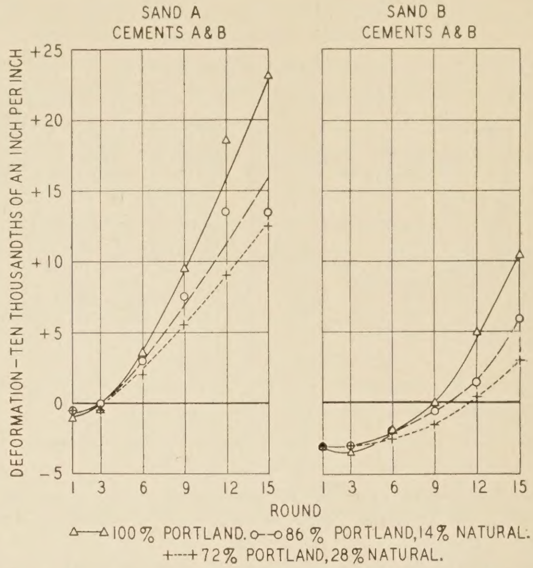

FIGURE 9.—EFFECT OF FREEZING AND THAWING, FOLLOWED BY DRYING, COOLING, AND RESATURATION ON VOLUME CHANGE OF MORTAR BEAMS.

TABLE 8.—*Tensile strengths of briquets, mix 1:3, standard Ottawa sand*

Percentage of portland cement replaced by natural cement	Cement A				Cement B			
	7 days		28 days		7 days		28 days	
	Lb. per sq. in.[1]	*Percent*[2]	*Lb. per sq. in.*[1]	*Percent*[2]	*Lb. per sq. in.*[1]	*Percent*[2]	*Lb. per sq. in.*[1]	*Percent*[2]
0	390	100	455	100	390	100	450	100
14	370	95	450	99	360	92	440	98
28	345	88	405	89	330	85	405	90

[1] Each value is the average of 15 tests.
[2] Figures indicate percentage of the strength of 100 percent portland cement mixes.

The effect of blending the cements upon the bulk specific gravity and absorption of mortar specimens is shown in table 9. Cylinders 2 inches by 4 inches in size of 1:2 mortar, after 24 hours in moist air, were stored in water at 70° F. and the bulk specific gravity and absorption determined after 7 and 28 days by first determining the saturated-surface dry weights of the specimens in air and in water and then drying to constant weight. It will be observed that blending with natural cement lowered the bulk specific gravity and increased the absorption in all cases. The decrease in density which is indicated by these tests may have been the result of a slight increase in the air voids brought about by the use of natural cement. Other tests have indicated that air voids in concrete are increased somewhat by using blends.

Bars 1 by 1 by 6 inches long, using a 1:5 standard Ottawa sand mortar, and with 0, 14, and 28 percent of the portland cement replaced with natural cement, were fabricated and stored for 6 days in water at 70° F. At the end of this period the bars were measured for length and then immersed in a 10-percent solution of sodium sulphate. After 21 days of continuous storage in this solution at 70° F., they were again measured for length. The amount of expansion was read to 0.001 inch. The results are shown in figure 10 (left panel). Each value is the average of three tests. It will be noted that specimens containing cement B showed greater expansion in all cases than those con-

TABLE 9.—*Bulk specific gravity and absorption of 2 by 4-inch mortar cylinders, mix 1:2 by weight, water cured*

Percentage of portland cement replaced by natural cement	Bulk specific gravity [1]				Percentage absorption [1]			
	7 days		28 days		7 days		28 days	
		Percent [2]		*Percent* [2]		*Percent* [2]		*Percent* [2]
CEMENT A—SAND A								
0	2.10	100	2.12	100	9.52	100	9.23	100
14	2.07	99	2.09	99	9.89	104	10.01	108
28	2.03	97	2.04	96	10.32	108	10.59	115
CEMENT A—SAND B								
0	2.09	100	2.10	100	10.49	100	10.32	100
14	2.07	99	2.08	99	10.84	103	10.73	104
28	2.04	98	2.05	98	11.34	108	11.19	108
CEMENT B—SAND A								
0	2.07	100	2.11	100	10.03	100	9.98	100
14	2.05	99	2.06	98	10.66	106	10.62	106
28	2.02	98	2.02	96	11.27	112	11.40	114
CEMENT B—SAND B								
0	2.09	100	2.07	100	10.95	100	10.76	100
14	2.04	98	2.06	100	11.34	104	11.11	103
28	2.01	96	2.04	99	11.73	107	11.57	108

[1] Each value is the average of 3 tests.
[2] Figures indicate percentage of the corresponding values for 100 percent portland cement mixes.

taining cement A, and also that blending with natural cement reduced the amount of expansion in both cases. These tests seem to indicate that blending with natural cement increases resistance to the action of sodium sulphate solutions.

The expansions of neat cement bars exposed for 3 hours at 420° F. in the autoclave are shown in the right panel of figure 10. In both cases, the replacement of 14 and 28 percent of portland cement by natural cement resulted in increased expansion. It will be noted, however, that cement B, unblended, showed considerably greater expansion than cement A with a 28 percent replacement of natural cement. The relatively high expansions shown by cement B may possibly be associated with the higher magnesia and greater C_3A content of this cement. (See table 1.)

The same two portland cements and the same natural cement that were used in the mortar tests were combined with a local fine and coarse aggregate in fabricating the concrete specimens. The characteristics of the aggregates are shown in table 2. Sand C was used in the concrete tests. The coarse aggregate was uniformly graded from No. 4 to 1½-inch. Two blends were used, one with 14 percent and the other with 28 percent of natural cement as in the mortar tests.

A typical concrete paving mix containing 6 sacks of cement per cubic yard with sufficient water for a 2½-inch slump was used. This resulted in a net water-cement ratio by volume of approximately 0.75.

Although the tests made on the mortars showed that the consistency of the mix was affected somewhat by the substitution of natural cement for portland cement, the slump of the concrete containing the blends was the same as that obtained with the straight portland cement. However, in manipulating the concrete it was found that the blended cement mixtures had a stickiness which was not apparent in mixtures containing the straight portland cement.

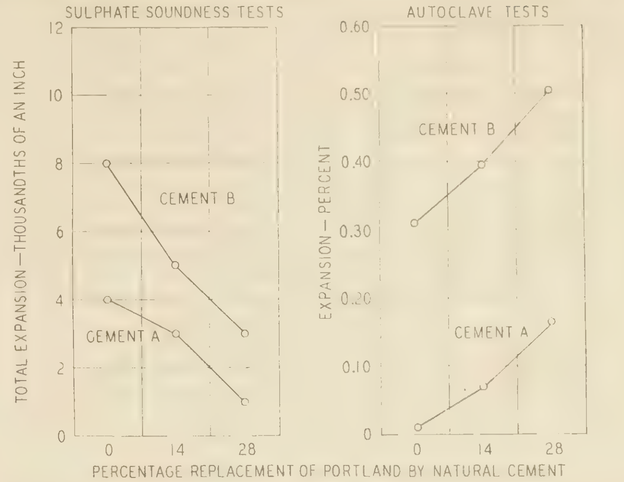

FIGURE 10.—EFFECT OF BLENDING PORTLAND AND NATURAL CEMENT UPON VOLUME CHANGE IN SULPHATE SOLUTION AND IN THE AUTOCLAVE.

USE OF BLENDED CEMENTS SLIGHTLY DECREASED STRENGTH OF CONCRETE

Flexure tests were made on beams 6 by 6 by 21 inches in size, loaded at the third points of an 18-inch span. Compression tests as well as measurements for modulus of elasticity, using a Martens extensometer, were made on 6-inch by 12-inch cylinders. Five specimens were made for each test condition and tests were made at 7, 28, 90, 180, and 360 days. All specimens were stored continuously in moist air at 70° F. until tested.

The results of the tests for strength and modulus of elasticity on laboratory fabricated concrete specimens are shown in table 10 and are shown graphically in figure 11.

Referring to the data for cement A (table 10 and left panel of fig. 11), it will be observed that there was a gradual increase in crushing strength with age for specimens containing the unblended as well as the blended cement. Blending with natural cement decreased the average strength at all ages about 1 percent in the specimens containing 14 percent of natural cement and about 8 percent in the specimens containing 28 percent of natural cement. Similar data for cement B are shown in the next panel to the right. In the specimens containing straight portland cement it will be observed that the same order of strengths was obtained as with cement A. However, in specimens with the blended cements as compared to the specimens with straight portland cement, the reduction in strength was more marked, the corresponding figures being 7 percent for the 14 percent blend and 17 percent for the 28 percent blend.

It is interesting to observe that specimens containing the 14 percent blend for both cements A and B exhibited higher strengths at 360 days than the corresponding straight portland cement specimens. This was due to the fact that the straight portland cement concretes showed no increase in strength beyond the 180-day period for cement A, while for cement B no increase was observed after the 90-day period. On the other hand, the concrete containing the blended cements showed a fairly uniform increase in strength up to 360 days.

Flexural strengths of the concrete specimens are shown also in table 10 and are plotted in the two center panels of figure 11. For each cement the specimens containing the 14 percent blend had strengths com-

TABLE 10.—*Effect of blending portland and natural cements on crushing and flexural strengths and modulus of elasticity*

Percentage of portland cement replaced by natural cement	Test results at age indicated [1]									
	7 days		28 days		90 days		180 days		360 days	
CRUSHING STRENGTH—CEMENT A										
	Lb. per sq. in.	*Percent* [2]	*Lb. per sq. in.*	*Percent* [2]	*Lb. per sq. in.*	*Percent* [2]	*Lb. per sq. in.*	*Percent* [2]	*Lb. per sq. in.*	*Percent* [2]
0	3,730	100	5,510	100	6,190	100	6,650	100	6,660	100
14	3,860	103	5,270	96	6,010	97	6,470	97	6,830	103
28	3,430	92	4,750	86	5,870	95	6,080	91	6,480	97
MODULUS OF RUPTURE—CEMENT A										
0	600	100	683	100	777	100	858	100	831	100
14	612	102	697	102	777	100	845	98	857	103
28	542	90	631	92	742	95	801	93	853	103
MODULUS OF ELASTICITY—CEMENT A										
	1,000 lb. per sq. in.		*1,000 lb. per sq. in.*		*1,000 lb. per sq. in.*		*1,000 lb. per sq. in.*		*1,000 lb. per sq. in.*	
0	5,272	100	6,047	100	6,490	100	6,785	100	7,102	100
14	5,170	98	5,947	98	6,670	103	6,735	99	7,432	105
28	5,312	101	5,557	92	6,268	97	6,285	93	6,628	93
CRUSHING STRENGTH—CEMENT B										
	Lb. per sq. in.		*Lb. per sq. in.*		*Lb. per sq. in.*		*Lb. per sq. in.*		*Lb. per sq. in.*	
0	3,990	100	5,640	100	6,450	100	6,310	100	6,480	100
14	3,700	93	5,000	89	5,760	89	5,960	94	6,530	101
28	3,190	80	4,330	77	5,250	81	5,670	90	5,730	88
MODULUS OF RUPTURE—CEMENT B										
0	620	100	677	100	781	100	783	100	821	100
14	577	93	698	103	753	96	820	105	859	105
28	542	87	580	86	716	92	801	102	788	96
MODULUS OF ELASTICITY—CEMENT B										
	1,000 lb. per sq. in.		*1,000 lb. per sq. in.*		*1,000 lb. per sq. in.*		*1,000 lb. per sq. in.*		*1,000 lb. per sq. in.*	
0	5,225	100	6,083	100	6,420	100	6,638	100	6,970	100
14	5,065	97	5,810	96	6,178	96	6,465	97	7,070	101
28	5,030	96	5,623	92	6,018	94	6,330	95	6,408	92

[1] Each value for crushing strength and modulus of rupture is the average of 5 tests. Each value for modulus of elasticity is the average of 4 tests.
[2] Figures indicate percentage of the strength of 100 percent portland cement mixes.

parable to those obtained with the straight portland cement specimens. Specimens with the 28 percent blend had strengths that averaged about 95 percent of those of the straight portland cement specimens. It is to be observed also that for both portland cements the blended cement concrete showed higher strength ratios in flexure than in compression.

Results of tests for modulus of elasticity are shown in the two right panels of figure 11. These results are also included in table 10. Here again the addition of the natural cement is reflected in the somewhat lower values obtained with specimens containing the blended cements.

In general, it may be said that the values obtained in flexure and modulus of elasticity for the specimens containing the 28 percent blend were about 95 percent of those obtained for the specimens containing the straight portland cements. The strength ratios of specimens in compression were not the same for both cements, specimens containing cement B giving an average ratio of 83 percent, which was about 10 percent lower than that obtained for specimens containing cement A. Comparing the results of tests on concrete specimens with the corresponding results of tests on mortar specimens, it will be observed that replacement with the natural cement had a much greater effect on mortar strength than on concrete strength. This would, of course, be expected because of the higher cement content in the mortar specimens.

FREEZING AND THAWING TESTS MADE ON PAVEMENT CORES

The results of freezing and thawing tests on cores taken from four experimental projects in New York State are given in this portion of the report. On each of these projects specimens of straight portland cement concrete and blended cement concrete were taken from sections containing cement conforming to each of the four classifications as to compound composition given in table 11.

Natural cement of the brand used in the laboratory tests already described was used on two of the projects. The other two contained natural cement from another mill in New York State. A 6:1 blend was used on two of the projects, a 5:2 blend on the other two.

TABLE 11.—*Classification of four cements as to compound composition*

Specification designation	Tricalcium aluminate C_3A (percent)	Tricalcium silicate C_3S (percent)
935	Not over 9	Not over 35.
950	Not over 9	Between 48 and 52.
1439	Not less than 14	Not over 39.
1450	Not less than 14	Between 48 and 52.

This portion of the work was done for the purpose of testing specimens of concrete which had been subjected to the usual field manipulation during placing in order to study the effects of the "bleeding" or "water-gain" which frequently occurs during the finishing operation. This action results in the accumulation of an excess amount of water in the top surface of the pavement, leaving a weak, porous layer which is lacking in resistance to the disintegrating effects of ice and chemical salts.

In a preliminary series of freezing and thawing tests made on full depth cores it was found that disintegration was confined almost entirely to the top 2 inches of the specimen. Because of this, and also to facilitate performance of the test, it was decided to study the effect of the blend by testing the upper portion of the concrete only. Disks 2 inches thick were sawed from the tops of the cores. One set of these disks was alternately frozen and thawed in a 10 percent solution of calcium chloride, the other set in plain water. In addition, a few tests were made to determine the resistance of similar disks sawed from the lower surface of the cores.

It was found desirable in this work to use a minimum amount of the chloride solution and to freeze rapidly in order to keep the solution from separating into layers of different density. This was accomplished by using close-fitting containers and immersing these containers in the brine solution of the refrigerator. The minimum temperature obtained was approximately −10° F., one complete cycle of freezing and thawing being performed each day. The time required to lower the temperature of the specimen to this minimum was approximately 10 hours. The calcium chloride solution was changed after 10 cycles of freezing and thawing. These time-temperature relations applied to freezing both in chloride and in water.

Periodic examinations were made of the specimens, this examination consisting of weight loss determina-

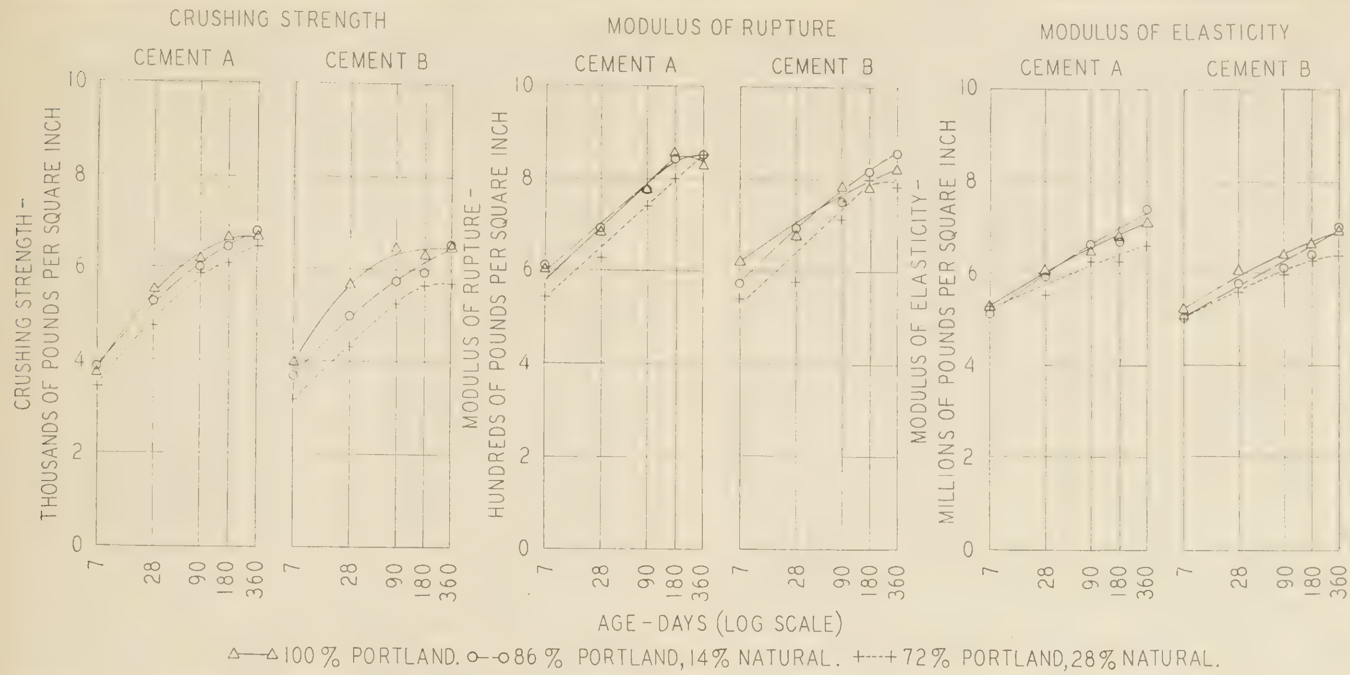

FIGURE 11.—EFFECT OF BLENDING PORTLAND AND NATURAL CEMENT ON STRENGTH AND MODULUS OF ELASTICITY OF CONCRETE.

tions and visual inspections. It was found that the weight losses of the 2-inch disks were meaningless. For instance, a specimen which had not lost more than 2 percent in weight would become unsound and disintegrate. While some scaling of the surface developed, unsoundness in general was caused by failure of the bond between the cement and aggregate, resulting in the eventual disintegration of the entire specimen.

For each project and for each type of freezing there were two groups of 8 specimens each. In one group there were 4 pairs of specimens containing straight portland cement and 4 pairs containing the same portland cements blended with natural cement in the proportion of either 6:1 or 5:2. The 4 pairs of specimens in each group represented concrete containing the 4 classes of portland cement mentioned above.

In order to evaluate the resistance to freezing and thawing, the individual specimens were examined at various intervals and rated in accordance with their appearance and ring when struck with a hammer. A specimen which was entirely sound was given a rating of 12½. An unsound specimen was rated at 2½, while a specimen which appeared to be between these two conditions was considered as questionable and was given a rating of 7½. Any specimen which had disintegrated was given a rating of zero. If all of the specimens of a particular group were sound the rating would be 100. On the other hand, if all of the specimens were disintegrated, the rating would be zero. By this method of rating, the results obtained with the four cements used on each project were averaged for comparison with the results obtained with the same portland cements blended with natural cement. This procedure was decided upon after a study of the individual results had failed to reveal any consistent relation between the composition of the portland cement and its resistance to freezing and thawing either when used straight or when blended. With a few exceptions, concrete made from portland cements conforming to the various composition classifications, when used on a given job, behaved about alike insofar as resistance to freezing and thawing was concerned.

BLENDED SPECIMENS MOST RESISTANT TO FREEZING IN CALCIUM CHLORIDE SOLUTION AND WATER

The ratings of the several groups of specimens after 35 alternations in a 10-percent solution of calcium chloride as well as the corresponding ratings when frozen in water for various periods up to 150 alternations, are given in table 12. The appearance of each individual specimen at the end of 35 alternations in calcium

TABLE 12.—*Resistance of core specimens to freezing and thawing*

Blend [1]	Rating [2] at number of freezing and thawing cycles indicated					
	35 cycles in calcium chloride	35 cycles in water	50 cycles in water	75 cycles in water	100 cycles in water	150 cycles in water
PROJECT A						
7-O	0	15	10	0	0	0
6-1G	90	95	90	90	90	90
PROJECT B						
7-O	25	50	30	25	25	25
5-2G	100	100	100	100	100	100
PROJECT C						
7-O	40	30	5	[3] 0	0	0
6-1H	15	25	10	[4] 0	0	0
PROJECT D						
7-O	0	10	5	0	0	0
5-2H	55	65	55	30	30	25

[1] Figures indicate the number of sacks of portland and natural cement in a 7-sack batch; letters refer to the brand of natural cement.
[2] Rating of 100 indicates all 8 specimens sound; rating of 0 indicates all 8 specimens disintegrated.
[3] At 65 alternations.
[4] At 60 alternations.

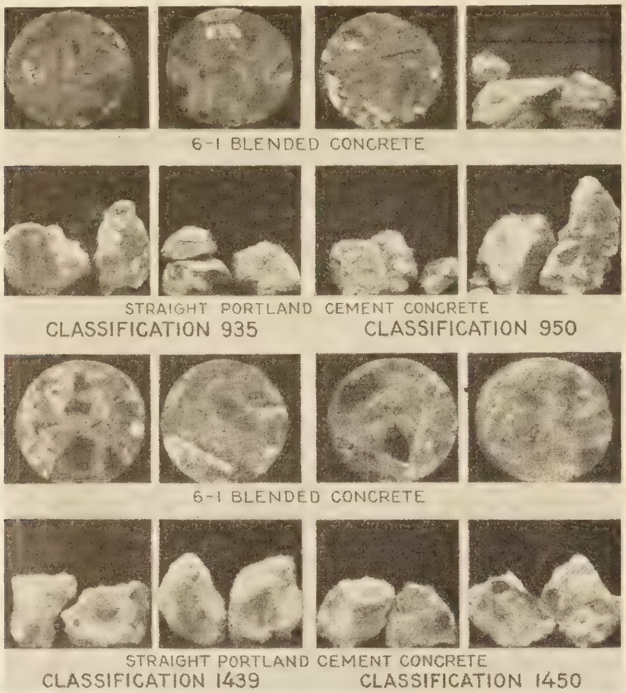

Figure 12.—Project A. Appearance of Blended and Straight Portland Cement Concrete Specimens after 35 Alternations of Freezing and Thawing in a 10 Percent Solution of Calcium Chloride.

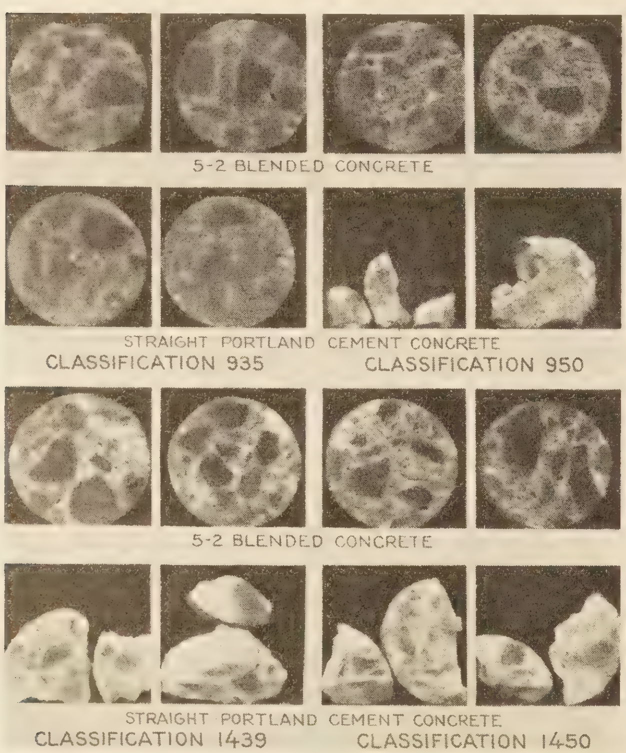

Figure 13.—Project B. Appearance of Blended and Straight Portland Cement Concrete Specimens after 35 Alternations of Freezing and Thawing in a 10 Percent Solution of Calcium Chloride.

chloride and at the end of 50 alternations in water is shown in figures 12 to 19 inclusive. In each of these figures the specimens are arranged as follows: The four specimens shown in the upper left quadrant contain

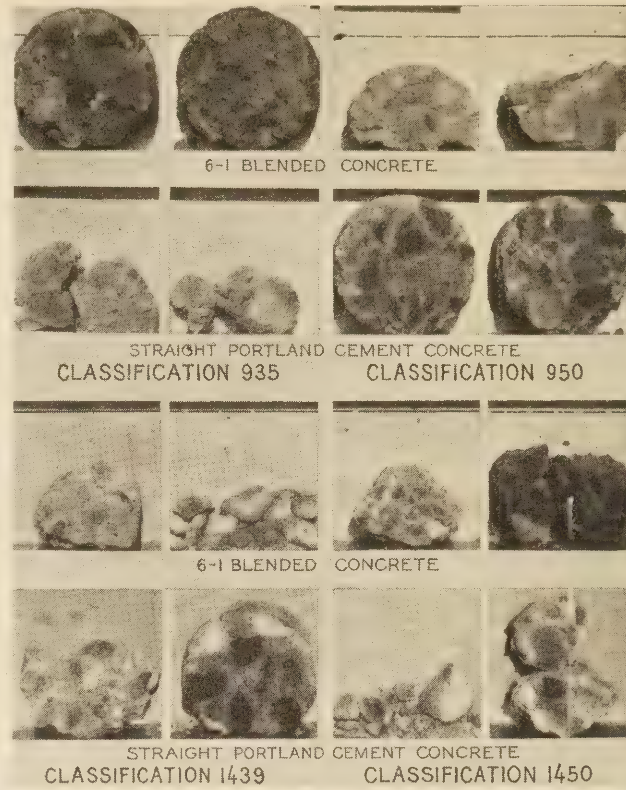

Figure 14.—Project C. Appearance of Blended and Straight Portland Cement Concrete Specimens after 35 Alternations of Freezing and Thawing in a 10 Percent Solution of Calcium Chloride.

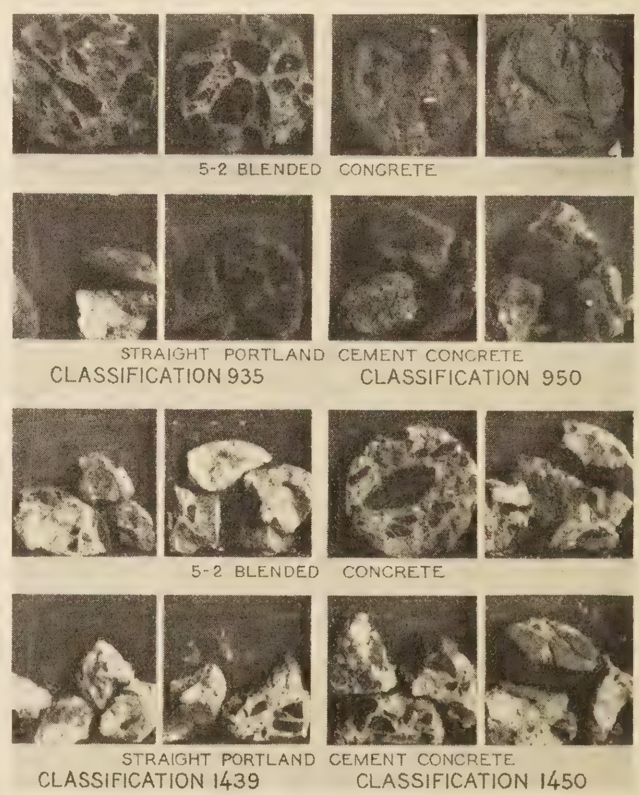

Figure 15.—Project D. Appearance of Blended and Straight Portland Cement Concrete Specimens after 35 Alternations of Freezing and Thawing in a 10 Percent Solution of Calcium Chloride.

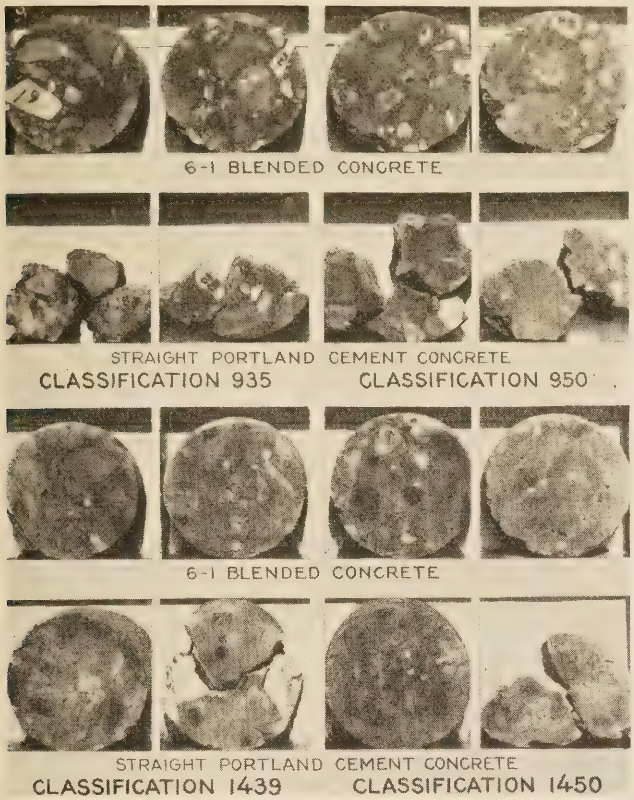

Figure 16.—Project A. Appearance of Blended and Straight Portland Cement Concrete Specimens after 50 Alternations of Freezing and Thawing in Water.

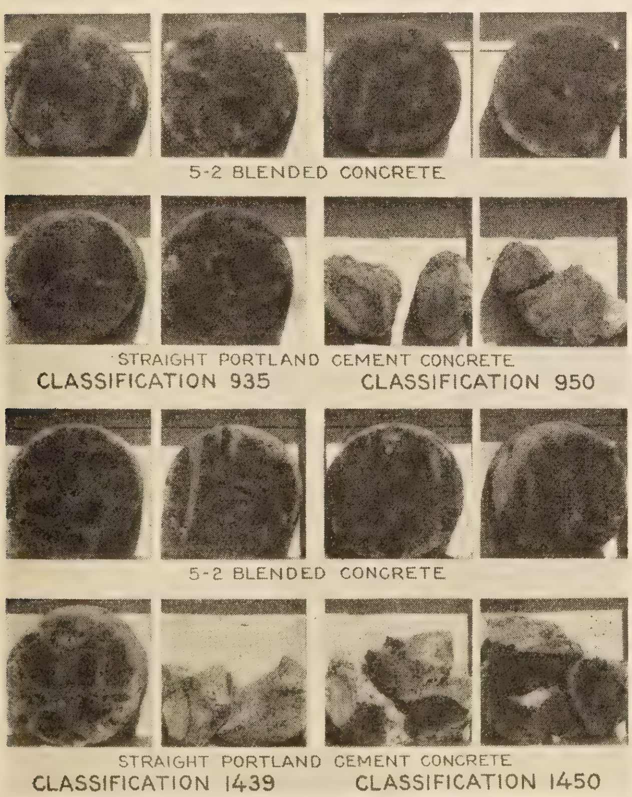

Figure 17.—Project B. Appearance of Blended and Straight Portland Cement Concrete Specimens after 50 Alternations of Freezing and Thawing in Water.

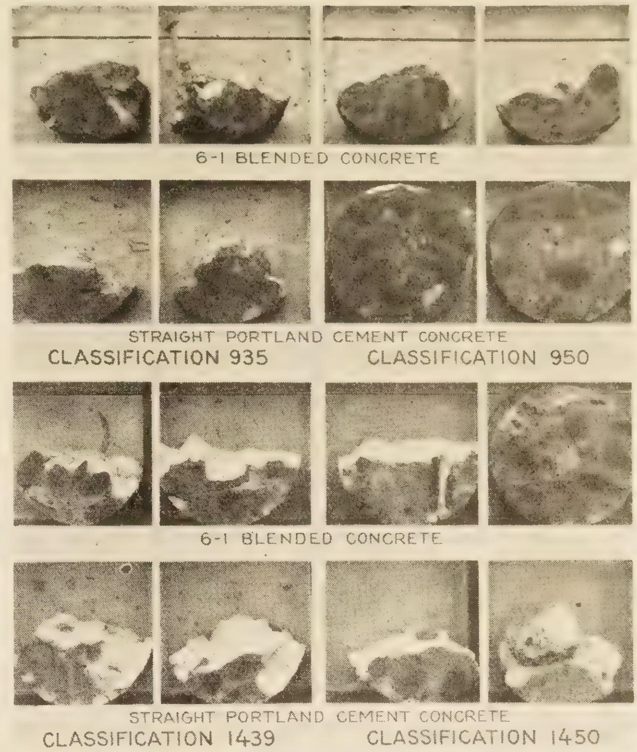

Figure 18.—Project C. Appearance of Blended and Straight Portland Cement Concrete Specimens after 50 Alternations of Freezing and Thawing in Water.

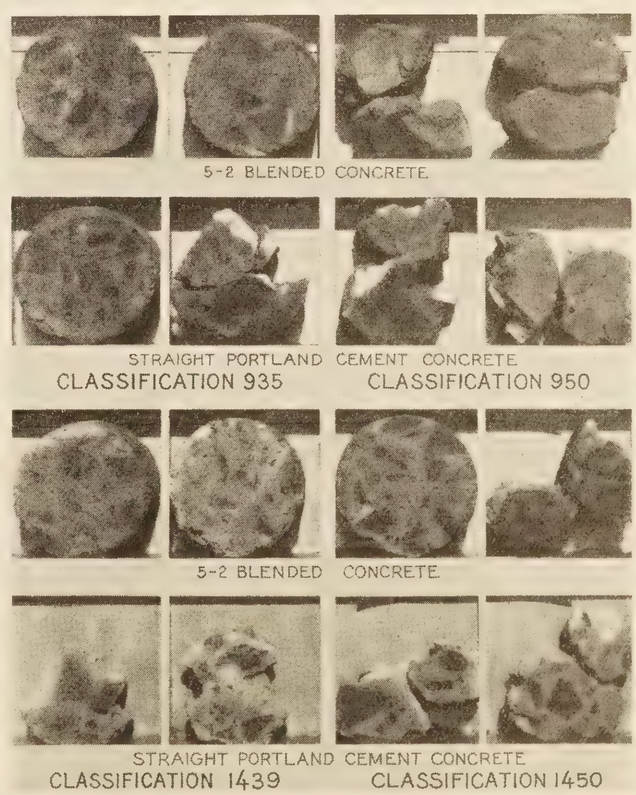

Figure 19.—Project D. Appearance of Blended and Straight Portland Cement Concrete Specimens after 50 Alternations of Freezing and Thawing in Water.

portland cement conforming to New York State specification classification 935, the two specimens in the top row containing the blended cement and the two specimens in the second row the straight portland cement. Similarly, the four specimens in the upper right quadrant contain cement conforming to the 950 classification, those in the lower left quadrant the 1439 cement, and those in the lower right quadrant the 1450 cement.

Referring to table 12 and to figures 12 to 15, inclusive, it will be noted that the use of the blend resulted in a marked increase in resistance to freezing in calcium chloride in Projects A and B, some improvement in Project D and no improvement in Project C. Projects A and B contained natural cement G in the blend, whereas natural cement H was used in Projects C and D.

A study of the individual results shows that in Project A all eight of the straight portland cement specimens disintegrated, while seven of the blended cement specimens remained sound. In Project B, six of the eight straight portland cement specimens disintegrated, whereas all eight of the blended specimens remained sound. In Project C five of the unblended specimens disintegrated as compared to six of the specimens containing the blended cement. In Project D all eight of the unblended specimens disintegrated, whereas three of the blended specimens disintegrated and one was unsound.

The comparative effect of freezing in calcium chloride and in water may be noted by comparing the ratings at 35 alternations as shown in the second and third columns of table 12. It will be observed that in Projects A and B the action in water was less severe than in calcium chloride. However, in Projects C and D the amount of disintegration was about the same for freezing in both liquids. The comparatively low resistance of Projects C and D to freezing in water would indicate that the quality of the concrete was inferior to that in Projects A and B.

Study of the comparative behavior of the various specimens when frozen in water for periods beyond 35 cycles may also be made by referring to table 12. In Projects A and B, virtually the same resistance is shown for the blended cements when frozen in water up to 150 cycles as was indicated when the specimens were frozen in calcium chloride for 35 cycles. However, it will be observed that the straight portland cement concrete in Project B was considerably more resistant to freezing and thawing in water at periods beyond 35 cycles than was the concrete in Project A. The concrete in Project C appeared to be definitely inferior, all specimens in both the straight portland and the blend having disintegrated at either 60 or 65 cycles. In Project D the behavior of the straight portland cement concrete specimens also indicated comparatively inferior concrete as compared to Projects A and B. However, the blended specimens from Project D were considerably more resistant than those containing straight portland cement although, as indicated above, the improvement was not as marked as in Projects A and B.

BLENDING FOUND TO INCREASE DURABILITY BY REDUCING BLEEDING

The comparative resistance of the individual specimens when frozen in water may be studied by referring to figure 20, which shows for each test disk the number of cycles at which the various stages of unsoundness were observed. Thus, for Project A, cement classification 1439, the figure shows that of the two unblended cement specimens, one developed questionable soundness at 50 alternations, became definitely unsound at 60, and disintegrated at 75. The other specimen was questionable at 20 alternations and disintegrated at 25. The two blended specimens were sound at 150 alternations. It will be observed that there is no consistent relation between composition of cement and resistance to freezing. This has already been commented upon and would appear to justify the method of rating the groups as a whole as shown in table 12.

An interesting feature of figure 20 is the close agreement which was observed in general between the behavior of the two specimens representing a given concrete. In many cases, failure progressed at almost an identical rate. The figure also shows the comparatively low resistance offered by the blended cement specimens from Projects C and D. Whether this was caused by the fact that natural cement H was used or by the fact that the concrete in these projects appeared, in general, to be of poorer quality than the concrete used in Projects A and B was not determined definitely. The fact remains, however, that the use of natural cement H did not improve the concrete in Project C at all and that while some improvement was shown for Project D, the results were not so positive as those indicated for Projects A and B, in both of which natural cement G was used.

Although there will be no extended discussion of the action of the blended cement concrete as compared to concrete containing only portland cement, there were certain physical differences noted in the concrete at the time the specimens were fabricated which will be discussed briefly. It has been observed in the field that there is less bleeding or water gain in concrete made with the blended cement than there is when portland cement is used alone. This observation led to a short laboratory investigation, the purpose of which was to determine the amount of water accumulating on the top of the fabricated specimens.

The concrete was proportioned in accordance with New York State highway specifications and contained approximately 6.3 sacks of cement per cubic yard. A slump of 2½ inches was used, requiring a water-cement ratio of 0.70.

Test specimens consisted of 6- by 6- by 21-inch beams molded in the usual way. After molding, the tops of the specimens were exposed to the laboratory air. Two specimens were made using 100 percent portland cement, two using a blend of 86 percent portland cement and 14 percent natural cement, and two using 72 percent portland cement and 28 percent natural cement.

At stated intervals after molding, the water which had accumulated at the top was carefully removed. The total water removed at the end of 2½ hours is shown in table 13, expressed as a percentage of the free water going into the concrete. This table also gives the results of a second test made several days later, showing the total water removed at the end of 4 hours.

From the results shown in the table it is evident that the substitution of natural cement for portland cement was effective in reducing bleeding. As will be noted, the bleeding was reduced as the amount of natural cement was increased, a replacement of 28 percent resulting in a reduction of more than one-half. Assuming that bleeding leaves the upper layer of concrete porous and weak as compared to the lower structure, it is apparent that the use of materials or methods of manipulation which will reduce bleeding should prove beneficial.

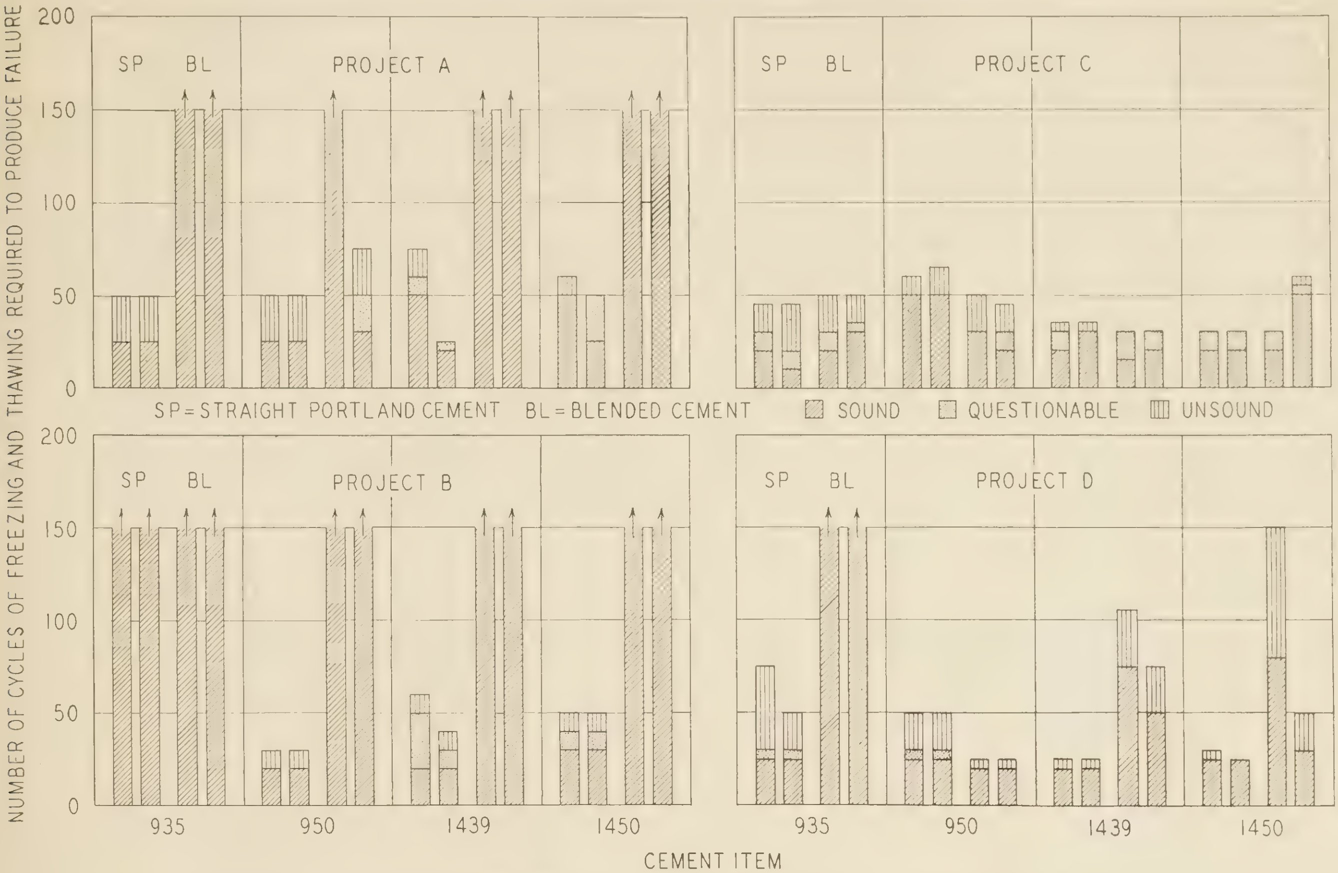

FIGURE 20.—EFFECT OF FREEZING AND THAWING CONCRETE CORE SPECIMENS IN WATER.

TABLE 13.—*Water removed from tops of 6 by 6 by 21-inch beam specimens in bleeding tests*

Cement blend		Water removed from specimens [1]	
Portland	Natural cement G	First test	Second test
	Percent	*Percent*	*Percent*
100 percent	0	7.6	7.4
86 percent	14	4.6	4.8
72 percent	28	3.5	2.9

[1] Based on total free water in concrete.

Data have been presented to show how the substitution of natural cement for portland cement materially increased the resistance to frost action of the top portions of the drilled cores.

In order to determine what effect water travel or bleeding has on durability, 2-inch disks were cut from the tops and also the bottoms of 9 identical cores and alternately frozen and thawed in a 10-percent calcium chloride solution until failure occurred. It was found that the average number of alternations required to produce failure was 20 for the tops of the cores and 35 for the bottoms, a difference of 15 alternations. All of the specimens were taken from Projects A and B and represented five different portland cements, none of which was blended with natural cement.

SUMMARY OF RESULTS

In the summary given below reference to a 1- or 2-sack replacement of portland cement by natural cement corresponds to a 14 or 28 percent replacement by weight, respectively. The values for strength are the averages of results of tests at all ages at which determinations were made.

A. The results of tests on specimens fabricated in the laboratory indicate that replacing a portion of the portland cement with natural cement:

1. Reduced the average crushing strength of 1:2 mortar specimens 7 percent for the 1-sack replacement and 19 percent for the 2-sack replacement (figs. 2 and 3).
2. Reduced the average flexural strength of 1:2 mortar specimens 6 percent for the 1-sack replacement and 15 percent for the 2-sack replacement (figs. 4 and 5).
3. Increased expansion of 1:2 mortar bars under continuous water storage up to 180 days (figs. 6 and 7).
4. Slightly increased contraction of 1:2 mortar bars under air storage conditions up to 120 days (figs. 6 and 7).
5. Considerably reduced the expansion of 1:2 mortar bars caused by repeated freezing and thawing, followed by heating, cooling and resaturation (figs. 8 and 9).
6. Decreased the bulk specific gravity and increased the water absorption of 1:2 mortar specimens (table 9).
7. Reduced the expansion of 1:5 mortar bars when subjected to the action of a 10-percent sulphate solution (fig. 10).
8. Increased the expansion of neat cement bars when subjected to the autoclave test at 420° F. for 3 hours (fig. 10).

9. Reduced the average crushing strength of concrete specimens containing 6 sacks of cement per cubic yard of concrete, 4 percent for the 1-sack replacement and 12 percent for the 2-sack replacement (fig. 11).

10. Increased the average flexural strength of concrete specimens containing 6 sacks of cement per cubic yard of concrete 1 percent for the 1-sack replacement and reduced the flexural strength 6 percent for the 2-sack replacement (fig. 11).

11. Decreased the average modulus of elasticity of concrete specimens containing 6 sacks of cement per cubic yard of concrete 1 percent for the 1-sack replacement and 5 percent for the 2-sack replacement (fig. 11).

B. The results of tests on cores taken from concrete pavements indicate that replacing a portion of the portland cement with natural cement considerably increased the resistance of the surface of the concrete to freezing and thawing in water and in a 10-percent solution of calcium chloride (table 12 and fig. 20).

In the tests covered by the above statement greater improvement in resistance was obtained by the use of natural cement G than by the use of natural cement H.

CONCLUSIONS

These tests indicate that, although the crushing and flexural strength of pavement concrete may be slightly reduced by the replacement of 14 or 28 percent of the portland cement with natural cement G, the resistance of the pavement surface to alternate freezing and thawing will be materially increased. No laboratory tests were made using natural cement H and tests of field specimens indicate that natural cement H did not improve the resistance of the concrete to the same extent as natural cement G.

HIGHWAY RESEARCH BOARD TO MEET SOON

The Eighteenth Annual Meeting of the Highway Research Board of the National Research Council will be held in Washington, D. C., Monday, November 28, to Friday, December 2, 1938. Reports on highway research investigations will be presented, and the formal meetings of the Board will be interspersed with open meetings for informal discussion of pertinent topics. A program of reports is to be announced by the Board in the near future.

DISPOSITION OF STATE MOTOR-FUEL TAX RECEIPTS, 1937

[Compiled for calendar year from reports of State authorities]

State	Net total receipts of calendar year	Adjustments to undistributed funds etc.[1]	Tax on aviation gasoline deducted	Net total funds distributed[2]	Expenses of collection and administration	For other administrative purposes[3]	For State highway purposes: Construction, maintenance, and administration[4]	For State highway purposes: State highway police	Service of State highway obligations: State highway bonds and notes	Service of State highway obligations: State assumed local obligations[5]	Service of State highway obligations: Total	Total for State highway purposes	For local roads and streets[6]: For work on county and local roads[4]	For local roads and streets: For work on city streets[7]	For local roads and streets: Service of local highway obligations	For local roads and streets: Total	For other highway purposes (park and forest roads, etc.)	For nonhighway purposes: To general funds[8]: Inspection fees, dealers licenses, etc.	To general funds: Motor-fuel tax	For relief of unemployment or destitution	For education	For other specific purposes[9]	Total
	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars
Alabama	13,350	61		13,411	82	56	4,195		2,392		2,392	6,587	6,686			6,686							
Arizona	4,333			4,333	96		2,829	104				2,933	*1,297			1,297						7	7
Arkansas	9,962			9,962	348	3	2,251		4,440	2,111	6,551	8,802	623		104	727		82					82
California	46,624	−1,205		45,419	168		26,373					26,373	*15,283	3,595		18,878							
Colorado	7,431	−30		7,401	89	23	4,528	236	570		570	5,334	1,955			1,955							
Connecticut	9,496	−209		9,287	51		7,406			1,830	1,830	9,236											
Delaware	2,034			2,034	11		[4] 1,364	133	41	329	370	1,867	([4])	13		13	138					5	5
Florida	22,466	16		22,482	24	395	9,123	39		3,300	3,300	12,462	103	38	6,293	6,434			2,542		604	21	3,167
Georgia	19,550			19,550	600		10,170			2,399	2,399	12,569	3,142			3,142					3,239		3,239
Idaho	4,037	43	6	4,074	15		4,056	3				4,059											
Illinois	36,266	42		36,308	353	261	11,836					11,836	*8,412	*7,970		16,382		168		4,409	2,899		7,476
Indiana	23,497	2,957		26,454	91	92	14,355					14,355	9,208	2,290		11,498		418					418
Iowa	13,047	55		13,102	81	23	3,921			3,269	3,269	7,190	*5,808			5,808							
Kansas	10,236	4		10,240	337	106	6,317	72	238	689	927	7,316	2,481			2,481							
Kentucky	12,671	46		12,717	48		12,461	153				12,614	55			55							
Louisiana	16,000	−3		15,997	87	74	1,100	87	7,521		7,521	8,708		262		262				4,622	1,122	1,122	6,866
Maine	5,550			5,550	19		3,364	165	1,443		1,443	4,972	559			559							
Maryland	9,857	13		9,870	34		3,929		[10] 1,456		1,456	5,385	930	2,786	735	4,451							
Massachusetts	19,836			19,836	50		5,145	247	[11] 2,292		2,292	7,684	2,933		[11] 345	3,278	[11] 833		6,600	[11] 1,391			7,991
Michigan	29,430	127	50	29,507	253		19,699		3,000		3,000	22,699	*6,550			6,550		5					5
Minnesota	15,493			15,493	49	100	10,051	144				10,195	*5,098			5,098		51					51
Mississippi	10,222	7		10,229	91		2,818	38	2,562		2,562	5,418	*4,267			4,267	453						
Missouri	11,217			11,217	55	51	6,913	205	3,919		3,919	11,037						74					74
Montana	4,581	68		4,649	19		4,064		566		566	4,630											
Nebraska	11,030		25	11,005	105		6,327					6,327	*3,020	331		3,351				1,222			1,222
Nevada	1,177			1,177	4		1,135	29		9	9	1,173											
New Hampshire	3,286	1		3,287	([12])		2,012	40	825		825	2,877	245		[13] 152	397	13						
New Jersey	21,593	193		21,786	148		1,614		7,633		7,633	9,247	3,443		557	4,000	68			6,322	1,238	763	8,323
New Mexico	4,022	−25		3,997	90	2	2,302		1,603		1,603	3,905											
New York [14]	61,915	−4,408		57,507	97		8,808	488	3,715		3,715	13,011	*8,545	1,680		10,225	2,081		32,093				32,093
North Carolina	23,393	−26		23,367	([15])	55	[4] 14,216	449	6,907	346	7,253	21,918	([4])					877	500			17	1,394
North Dakota	2,935	−133		2,802	12	61	1,621		189		189	1,810	905			905			14				14
Ohio	[16] 46,538	485		47,023	156		19,329					19,329	8,707	6,814		15,521					12,017		12,017
Oklahoma	13,772	−298		13,474	359		7,905					7,905	*3,352			3,352		4				1,854	1,858
Oregon	9,801	25	8	9,818	37		5,258	236	2,733		2,733	8,227	*1,467			1,467	33		51				54
Pennsylvania	55,720	[17] 8,100		63,820	298		37,889	1,246	2,973		2,973	42,108	*7,032	238		7,270	52			13,854		238	14,092
Rhode Island [14]	3,094	24		3,118	22		1,548	79	150		150	1,777	229			229	16		1,074				1,074
South Carolina	11,135	9	31	11,113	[18] 39	[18] 11	4,620		1,523	2,924	4,447	9,067	*1,812			1,812		184					184
South Dakota	4,155	343	3	4,495	49	46	2,661	3				2,664					36	38				1,662	1,700
Tennessee	18,938	−676	39	18,223	179	93	2,458		6,815	1,211	8,026	10,484	5,041			5,041		981				1,445	2,426
Texas	41,678	−52		41,626	642		20,492			10,246	10,246	30,738									10,246		10,246
Utah	3,424	69	36	3,457	12		3,312	133				3,445											
Vermont	2,323	183		2,506	3		1,291		310		310	1,601			897	897	5						
Virginia	16,122	37		16,159	([15])	47	[4] 15,318		518		518	15,836	[4] 267			267						9	9
Washington	15,282			15,282	26		5,951		[11] 119	52	171	6,122	*6,482	1,550	[11] 97	8,129				[11] 1,005			1,005
West Virginia	8,496			8,496	11		[4] 4,066		4,419		4,419	8,485	([4])										
Wisconsin	19,751	400		20,151	72	214	9,717			2,584	2,584	12,301	4,419	699		5,118	142		2,304				2,304
Wyoming	2,500		33	2,467	13		1,679	47	112		112	1,838	616			616							
District of Columbia	2,732			2,732	([19])									2,724		2,724		8					8
Total	761,998	6,243	231	768,010	5,425	1,713	359,797	4,376	70,984	31,299	102,283	466,456	130,972	30,990	9,180	171,142	3,870	2,890	45,181	32,825	31,365	7,143	119,404

[1] Amounts distributed during the calendar year often differ from actual collections because of undistributed funds and lag between accounts of collecting and expending agencies.

[2] In many States the proceeds of highway user taxes are placed in a common fund from which a distribution is made. The amounts so distributed have been prorated in proportion to the receipts not otherwise dedicated. See the following tables.

[3] Where reported separately from collection expenses, funds allotted for motor-fuel inspection, administration of motor vehicle department, and regulation of motor vehicles are shown in this column.

[4] The following allotments for construction and maintenance of county roads under State control are included in State highway purposes: Delaware, $259,000; North Carolina, $7,499,000; Virginia, $7,000,000; West Virginia, $1,231,000.

[5] Reimbursement to local units of Government for amounts spent on roads now on State system.

[6] In States indicated by star (*) law provides that these funds may also be used for service of local highway obligations. Amounts so used not reported separately. In Colorado funds may be used on both State and local roads.

[7] This column shows specific allotments for city streets. Where reported separately, funds alloted for urban extensions of State highway system are included in allotments for State highway purposes.

[8] To State general funds except in Wisconsin, where amount went to towns, cities, and villages in lieu of personal property taxes formerly imposed on motor vehicles. Allocations to local general funds may have been used in part for highways, but such amounts not reported.

[9] For the following purposes: Arizona, irrigation engineering expenses; Delaware, beach protection; Florida, aviation; Louisiana, harbor improvement; New Jersey, service of institutional construction bonds, $520,000, and Department of Commerce and Aviation, $243,000; North Carolina, State probation commission; Oklahoma, service of general State debt; Pennsylvania, aircraft landing fields, $214,000, and cooperative work other departments, $24,000; South Dakota, payment on real estate bonds; Tennessee, debt service on nonhighway bonds; Virginia, aviation.

[10] Legislative restorations from proceeds of sale of general State bonds were applied to debt service payments, thus reducing amounts necessary from current revenue.

[11] Includes debt service charges on emergency relief bond issues prorated in proportion to use of proceeds for State highway, local road, other highway, and nonhighway purposes.

[12] Paid out of motor-vehicle revenue, $3,000. See the following table.

[13] Service of highway relief bonds, a State obligation incurred for improvement of local roads.

[14] Appropriations for highway purposes out of State general fund have been credited against payments of motor-fuel tax and motor-vehicle fees to the general fund and prorated in proportion to net receipts not otherwise dedicated.

[15] Included in cost of collecting motor-vehicle revenue. See the following table.

[16] Tax of $662,000 on non-motor-vehicle fuels not included.

[17] Amounts previously loaned to general fund for relief purposes entirely repaid during 1937.

[18] Estimated from fiscal-year appropriations.

[19] Paid out of general revenue. Amount not reported.

DISPOSITION OF STATE MOTOR-VEHICLE RECEIPTS, 1937

[Compiled for calendar year from reports of State authorities]

State	Net total receipts of calendar year	Adjustments due to undistributed funds, etc.[1]	Net total funds distributed [2]	Expenses of collection and administration [3]	For other administrative purposes [4]	For State highway purposes: Construction, maintenance, and administration [5]	For State highway purposes: State highway police	For State highway purposes: Service of State highway obligations: State highway bonds and notes	For State highway purposes: Service of State highway obligations: State-assumed local obligations [6]	For State highway purposes: Service of State highway obligations: Total	For State highway purposes: Total for State highway purposes	For local roads and streets [7]: For work on county and local roads [5]	For local roads and streets [7]: For work on city streets [8]	For local roads and streets [7]: Service of local highway obligations	For local roads and streets [7]: Total	For other highway purposes (park and forest roads, etc.)	For nonhighway purposes: To general funds [9]	For nonhighway purposes: For relief of unemployment or destitution	For nonhighway purposes: For education	For nonhighway purposes: For other specific purposes [10]	For nonhighway purposes: Total
	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars
Alabama	4,439	135	4,574	484		2,085	406	835		835	3,326						764				764
Arizona	1,143		1,143	235		876	32				908										
Arkansas	3,241		3,241	101		770	130	1,518	722	2,240	3,140										
California	24,003	1,069	25,072	3,028	145	3,744	2,641	3,964		3,964	10,349	*3,794			3,794		7,756				7,756
Colorado	2,603	5	2,608	466	55	898	49	119		119	1,066	1,021			1,021						
Connecticut	6,691	−407	6,284	1,124		1,501	325		371	371	2,197	2,963			2,963						
Delaware	1,202	75	1,277	104		[5] 790	77	24	191	215	1,082	([5])	8		8	80				3	3
Florida	6,196		6,196	464	224														5,508		5,508
Georgia	2,368		2,368	264		941	320		222	222	1,483	621			621						
Idaho	2,498	−25	2,473	71		289	101				390	*2,012			2,012						
Illinois	21,430	422	21,852	831	361	8,907	1,436	8,837	382	9,219	19,562	891			891		207				207
Indiana	9,827	29	9,856	931		3,907	446				4,353	1,561	390		1,951		2,621				2,621
Iowa	11,918	67	11,985	1,387		5,780			4,818	4,818	10,598										
Kansas	4,537	−260	4,277	709		2,301	26	86	251	337	2,664	904			904						
Kentucky	5,125	−4	5,121	469	26	2,174	27				2,201	600			600		1,825				1,825
Louisiana	4,710	−201	4,509	73		2,946	325	447		447	3,718		718		718						
Maine	3,865	−1	3,864	151		2,259	110	969		969	3,338	375			375						
Maryland	5,577	−1,006	4,571	522	56	1,694	378	[11] 1,107		1,107	3,179		814		814						
Massachusetts	6,875	213	7,088	1,580	35	2,136	103	[12] 951		951	3,190	1,217		[12] 143	1,360	[12] 346		[12] 577			577
Michigan	22,085	−209	21,876	1,700		455	321				776	*19,129			19,129		271				271
Minnesota	8,867	35	8,902	428		4,214	137	1,748	2,261	4,009	8,360						114				114
Mississippi	2,248	−11	2,237	108		212					212	*1,917			1,917						
Missouri	9,638	−10	9,628	615		5,645	168	3,200		3,200	9,013										
Montana	1,532	95	1,627	73			159				159	1,354	41		1,395						
Nebraska	2,603	−159	2,444	201	21	657	75				732	1,482			1,482		8				8
Nevada	282		282	25		166	4	87		87	257										
New Hampshire	2,347	56	2,403	126	3	1,770	139	4		4	1,913	216		[13] 133	349	12					
New Jersey	19,271	−23	19,248	1,767		3,897					3,897	5,794		1,345	7,139	164		6,281			6,281
New Mexico	1,544	176	1,720	93	114	599	114				713	218			218		582				582
New York [14]	52,901	−288	52,613	2,736	176	15,279	847	6,445		6,445	22,571	*10,692	4,949		15,641	3,609	7,880				7,880
North Carolina	8,855	−637	8,218	446		[5] 5,041	159	2,449	123	2,572	7,772	([5])									
North Dakota	1,581	−19	1,562	130	22	632	121	62		62	815	595			595						
Ohio	25,635	1,284	26,919	1,403		6,273	501				6,774	*13,836	4,532		18,368					374	374
Oklahoma	5,584	8	5,592	930	180	1,603	294				1,897	*2,585			2,585						
Oregon	3,378	19	3,397	460		1,579	71	821		821	2,471	*440			440	10	16				16
Pennsylvania	38,332	[15] 10,788	49,120	1,990		41,882	1,377	3,287		3,287	46,546		262		262	58				264	264
Rhode Island [14]	2,790	69	2,859	258		1,300	67	126		126	1,493	193			193	13	902				902
South Carolina	1,690		1,690	142		645	282	213	408	621	1,548										
South Dakota	1,650	−2	1,648	77	4	322					322	1,242			1,242	3					
Tennessee	4,233	8	4,241	261		3,537	443				3,980										
Texas	19,684	25	19,709	993	320	6,282	443				6,725	*11,671			11,671						
Utah	1,049	−241	808	123	12		11	592		592	603						70				70
Vermont	2,410	175	2,585	87		1,239	94	298		298	1,631			862	862	5					
Virginia	6,153	−2	6,151	595		4,976	205	375		375	5,556										
Washington	4,402	52	4,454	347		2,604	1,490				4,094	13			13						
West Virginia	6,162		6,162	216		[5] 2,845	10	3,091		3,091	5,946	([5])									
Wisconsin	12,984	−506	12,478	771	32	5,707			1,518	1,518	7,225	2,596	410		3,006	83	1,358				1,358
Wyoming	597	−4	593	4		411	12	166		166	589										
District of Columbia	878	−2	876	86	75												715				715
Total	399,613	10,788	410,401	30,188	1,861	163,770	14,476	41,821	11,267	53,088	231,334	89,932	12,124	2,483	104,539	4,383	25,089	6,858	5,508	641	38,096

[1] Amounts distributed during the calendar year often differ from actual collections because of undistributed funds and lag between accounts of collecting and expending agencies.
[2] In many States the proceeds of highway user taxes are placed in a common fund from which a distribution is made. The amounts so distributed have been prorated in proportion to the receipts not otherwise dedicated. See tables that precede and follow this table.
[3] Collection expenses in many States include service charges deducted by county and local collectors.
[4] Where reported separately from collection expenses, funds allotted for collection of motor-fuel tax, payments to auto theft fund, and miscellaneous expenses of motor-vehicle regulation are shown in this column.
[5] The following allotments for construction and maintenance of county roads under State control are included in State highway purposes: Delaware, $150,000; North Carolina, $2,659,000; West Virginia, $863,000.
[6] Reimbursement to local units of government for amounts spent on roads now on State system.
[7] In States indicated by star (*) law provides that these funds may also be used for service of local highway obligations. Amounts so used not reported separately. In Colorado funds may be used on both State and local roads.
[8] This column shows specific allotments for city streets. Where reported separately, funds allotted for urban extensions of State highway system are included in allotments for State highway purposes.
[9] To State general funds except in the following States: Alabama, county and municipal general funds; California, general funds of counties and cities, $3,821,000; New Mexico, county general funds, $364,000; Wisconsin, towns, cities, and villages in lieu of personal property tax formerly imposed on motor vehicles, $1,353,000. Allocations to local general funds may have been used in part for highways, but such amounts not reported.
[10] For the following purposes: Delaware, beach protection; Ohio, hospitalization of indigent persons injured in motor-vehicle accidents; Pennsylvania, aircraft landing fields, $237,000, and cooperative work other departments, $27,000.
[11] Legislative restorations from proceeds of sale of general State bonds were applied to debt service payments, thus reducing amounts necessary from current revenue.
[12] Includes debt service charges on emergency relief bond issues prorated in proportion to use of proceeds for State highway, local road, other highway, and nonhighway purposes.
[13] Service of highway relief bonds, a State obligation incurred for improvement of local roads.
[14] Appropriations for highway purposes out of State general fund have been credited against payments of motor-fuel tax and motor-vehicle fees to the general fund and prorated in proportion to net receipts not otherwise dedicated.
[15] Amounts previously loaned to general fund for relief purposes entirely repaid during 1937

DISPOSITION OF STATE MOTOR-CARRIER TAX RECEIPTS, 1937

[Compiled for calendar year from reports of State authorities]

State	Net total receipts of calendar year	Adjustments due to undistributed funds, etc.[1]	Net total funds distributed [2]	Expenses of collection and administration	For State highway purposes: Construction, maintenance, and administration [3]	For State highway purposes: State highway police	Service of State highway obligations: State highway bonds and notes	Service of State highway obligations: State-assumed local obligations [4]	Service of State highway obligations: Total	Total for State highway purposes	For local roads and streets [5]: For work on county and local roads [3]	For local roads and streets: For work on city streets [6]	For local roads and streets: Service of local highway obligations	For local roads and streets: Total	For other highway purposes (park and forest roads, etc.)	For nonhighway purposes: To general funds	For nonhighway purposes: For relief of unemployment or destitution	For nonhighway purposes: For education	For nonhighway purposes: Total
	1,000 dollars	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*	*1,000 dollars*
Alabama	216	1	217	58	159					159									
Arizona	162	−2	160	13	142	5				147									
Arkansas	2		2		2					2									
California	3,048	−41	3,007	544	46					46	16			16		2,401			2,401
Colorado	621	21	642	98	238	13	31		31	282	262			262					
Connecticut	211	−15	196		88			22	22	110	86			86					
Delaware	(7)																		
Florida	262	−4	258	32							10		210	220				6	6
Georgia	155	226	381	111	218			52	52	270									
Idaho	106	37	143	30	81	32				113									
Illinois	(7)																		
Indiana	682	−148	534	134	400					400									
Iowa	537		537	135							*402			402					
Kansas	1,163		1,163	281	549	38	20	60	80	667	215			215					
Kentucky	394	85	479	57	415	5				420	2			2					
Louisiana	3		3	3															
Maine	22	−4	18	18															
Maryland	(8)																		
Massachusetts	55		55	55															
Michigan	403	−58	345	197	148					148									
Minnesota	23		23	23															
Mississippi	158		158	4							*154			154					
Missouri	521	411	932	79	497	15	281		281	793	60			60					
Montana	46	−11	35	35															
Nebraska	27		27	27															
Nevada	198		198	12	181	5				186									
New Hampshire	4		4	4															
New Jersey	91	−7	84		22					22	19		7	26	1		35		35
New Mexico	153	−9	144	34	104	6				110									
New York	(7)																		
North Carolina	251	−18	233	1	[3] 151	4	73	4	77	232	(3)								
North Dakota	23	10	33	23	10					10									
Ohio	492	214	706	108	571					571	27			27					
Oklahoma	1,271	−5	1,266	91	843					843	332			332					
Oregon	1,094	−36	1,058	211	443	43	230		230	716	*124			124	2	5			5
Pennsylvania	8		8		8					8									
Rhode Island	9		9	9															
South Carolina	189	−54	135	32	93					93		10		10					
South Dakota	484	−15	469	41	423					423					5				
Tennessee	369	2	371	69	234					234						68			68
Texas	109		109	102	7					7									
Utah	113	−15	98	11	81					81						6			6
Vermont	(7)																		
Virginia	200	−3	197	26	135		10		10	145						26			26
Washington	245		245	245															
West Virginia	91		91		36		55		55	91									
Wisconsin	1,559	−56	1,503	356												1,147			1,147
Wyoming	227	−1	226	33	188	5				193									
District of Columbia	219		219													219			219
Total	16,216	505	16,721	3,342	6,513	171	700	138	838	7,522	1,709	10	217	1,936	8	3,872	35	6	3,913

[1] Amounts distributed during the calendar year often differ from actual collections because of undistributed funds and lag between accounts of collecting and expending agencies.

[2] In many States the proceeds of highway user taxes are placed in a common fund from which a distribution is made. The amounts so distributed have been prorated in proportion to the receipts not otherwise dedicated. See 2 preceding tables.

[3] Approximately $80,000 allotted for use on county roads under State control in North Carolina included in State highway purposes.

[4] Reimbursement to local units of Government for amounts spent on roads now on State system.

[5] In States indicated by star (*) law provides that these funds may also be used for service of local highway obligations. Amounts so used not reported separately. In Colorado funds may be used on both State and local roads.

[6] This column shows specific allotments for city streets. Where reported separately, funds allotted for urban extensions of State highway system are included in allotments for State highway purposes.

[7] No special taxes on motor carriers reported.

[8] Ton-mile and passenger-mile taxes paid by motor carriers in lieu of registration fees included in motor-vehicle receipts, preceding table.

DISPOSITION OF RECEIPTS FROM STATE IMPOSTS ON HIGHWAY USERS, 1937

[Compiled for calendar year from reports of State authorities]

State	Net total receipts of calendar year [1]	Adjustments due to undistributed funds etc. [2]	Tax on aviation gasoline deducted	Net total funds distributed	Expenses of collection and administration [3]	For State highway purposes						For local roads and streets [6]				For other highway purposes (park and forest roads, etc.)	For nonhighway purposes					
								Service of State highway obligations									To general funds [8]					
						Construction, maintenance, and administration [4]	State highway police	State highway bonds and notes	State-assumed local obligations [5]	Total	Total for State highway purposes	For work on county and local roads [4]	For work on city streets [7]	Service of local highway obligations	Total		Motor-fuel inspection fees, dealers' licenses, etc.	All other highway user imposts	For relief of unemployment or destitution	For education	For other specific purposes [9]	Total
	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars	1,000 dollars
Alabama	18,005	197		18,202	680	6,439	406	3,227		3,227	10,072	6,686			6,686			764				764
Arizona	5,638	−2		5,636	344	3,847	141				3,988	*1,297			1,297						7	7
Arkansas	13,205			13,205	452	3,023	130	5,958	2,833	8,791	11,944	623		104	727		82					82
California	73,675	−177		73,498	3,885	30,163	2,641	3,964		3,964	36,768	*19,093	3,595		22,688			10,157				10,157
Colorado	10,655	−4		10,651	731	5,664	298	720		720	6,682	3,238			3,238							
Connecticut	16,398	−631		15,767	1,175	8,995	325		2,223	2,223	11,543	3,049			3,049							
Delaware	3,236	75		3,311	115	[4] 2,154	210	65	520	585	2,949	([4])	21		21	218					8	8
Florida	28,924	12		28,936	1,139	9,123	39		3,300	3,300	12,462	113	38	6,503	6,654			2,542		6,118	21	8,681
Georgia	22,073	226		22,299	975	11,329	320		2,673	2,673	14,322	3,763			3,763					3,239		3,239
Idaho	6,641	55	6	6,690	116	4,426	136				4,562	*2,012			2,012							
Illinois	57,696	464		58,160	1,806	20,743	1,436	8,837	382	9,219	31,398	*9,303	*7,970		17,273		168	207	4,409	2,899		7,683
Indiana	34,006	2,838		36,844	1,248	18,662	446				19,108	10,769	2,680		13,449		418	2,621				3,039
Iowa	25,502	122		25,624	1,626	9,701			8,087	8,087	17,788	*6,210			6,210							
Kansas	15,936	−256		15,680	1,433	9,167	136	344	1,000	1,344	10,647	3,600			3,600							
Kentucky	18,190	127		18,317	600	15,050	185				15,235	657			657			1,825				1,825
Louisiana	20,713	−204		20,509	237	4,046	412	7,968		7,968	12,426		980		980				4,622	1,122	1,122	6,866
Maine	9,437	−5		9,432	188	5,623	275	2,412		2,412	8,310	934			934							
Maryland	15,434	−993		14,441	612	5,623	378	[10] 2,563		2,563	8,564	930	3,600	735	5,265							
Massachusetts	26,766	213		26,979	1,720	7,281	350	[11] 3,243		3,243	10,874	4,150		[11] 488	4,638	[11] 1,179		6,600	[11] 1,968			8,568
Michigan	51,918	−140	50	51,728	2,150	20,302	321	3,000		3,000	23,623	*25,679			25,679		5	271				276
Minnesota	24,383	35		24,418	600	14,265	281	1,748	2,261	4,009	18,555	*5,098			5,098		51	114				165
Mississippi	12,628	−4		12,624	203	3,030	38	2,562		2,562	5,630	*6,338			6,338	453						
Missouri	21,376	401		21,777	800	13,055	388	7,400		7,400	20,843	60			60		74					74
Montana	6,159	152		6,311	127	4,064	159	566		566	4,789	1,354	41		1,395							
Nebraska	13,660	−159	25	13,476	354	6,984	75				7,059	*4,502	331		4,833			8	1,222			1,230
Nevada	1,657			1,657	41	1,482	38	87	9	96	1,616											
New Hampshire	5,637	57		5,694	133	3,782	179	829		829	4,790	461		[12] 285	746	25						
New Jersey	40,955	163		41,118	1,915	5,533		7,633		7,633	13,166	9,256		1,909	11,165	233			12,638	1,238	763	14,639
New Mexico	5,719	142		5,861	333	3,005	120	1,603		1,603	4,728	218			218			582				582
New York [13]	114,816	−4,696		110,120	3,009	24,087	1,335	10,160		10,160	35,582	*19,237	6,629		25,866	5,690		39,973				39,973
North Carolina	32,499	−681		31,818	502	[4] 19,408	612	9,429	473	9,902	29,922	([4])					877	500			17	1,394
North Dakota	4,539	−142		4,397	248	2,263	121	251		251	2,635	1,500			1,500			14				14
Ohio	72,665	1,983		74,648	1,667	26,173	501				26,674	*22,570	11,346		33,916					12,017	374	12,391
Oklahoma	20,627	−295		20,332	1,560	10,351	294				10,645	*6,269			6,269		4				1,854	1,858
Oregon	14,273	8	8	14,273	708	7,280	350	3,784		3,784	11,414	*2,031			2,031	45		75				75
Pennsylvania	94,060	[14] 18,888		112,948	2,288	79,779	2,623	6,260		6,260	88,662	*7,032	500		7,532	110			13,854		502	14,356
Rhode Island [13]	5,893	93		5,986	289	2,848	146	276		276	3,270	422			422	29		1,976				1,976
South Carolina	13,014	−45	31	12,938	224	5,358	282	1,736	3,332	5,068	10,708	*1,812	10		1,822		184					184
South Dakota	6,289	326	3	6,612	217	3,406	3				3,409	1,242			1,242	44	38				1,662	1,700
Tennessee	23,540	−666	39	22,835	602	6,229	443	6,815	1,211	8,026	14,698	5,041			5,041		981	68			1,445	2,494
Texas	61,471	−27		61,444	2,057	26,781	443		10,246	10,246	37,470	*11,671			11,671					10,246		10,246
Utah	4,586	−187	36	4,363	158	3,393	144	592		592	4,129							76				76
Vermont	4,733	358		5,091	90	2,530	94	608		608	3,232			1,759	1,759	10						
Virginia	22,475	32		22,507	668	[4] 20,429	205	903		903	21,537	[4] 267			267			26			9	35
Washington	19,929	52		19,981	618	8,555	1,490	[11] 119	52	171	10,216	*6,495	1,550	[11] 97	8,142				[11] 1,005			1,005
West Virginia	14,749			14,749	227	[4] 6,947	10	7,565		7,565	14,522	([4])										
Wisconsin	34,294	−162		34,132	1,448	15,424			4,102	4,102	19,526	7,015	1,109		8,124	225		4,809				4,809
Wyoming	3,324	−5	33	3,286	50	2,278	64	278		278	2,620	616			616							
District of Columbia	3,829	−2		3,827	161								2,724		2,724		8	934				942
Total	1,177,827	17,536	231	1,195,132	42,529	530,080	19,023	113,505	42,704	156,209	705,312	222,613	43,124	11,880	277,617	8,261	2,890	74,142	39,718	36,879	7,784	161,413

[1] Includes receipts from motor-fuel taxes, motor-vehicle fees and fines, and special imposts on motor vehicles operated for hire (motor-carrier taxes). See preceding tables, which give distribution of receipts separately.

[2] Amounts distributed during the calendar year often differ from actual collections because of undistributed funds and lag between accounts of collecting and expending agencies.

[3] Includes expenses of collection and administration of motor-fuel tax, motor-vehicle fees, and motor-carrier taxes, and miscellaneous expenses of motor-vehicle regulation.

[4] The following allotments for construction and maintenance of county roads under State control are included in State highway purposes: Delaware, $409,000; North Carolina, $10,238,000; Virginia, $7,000,000; West Virginia, $2,094,000.

[5] Reimbursement to local units of government for amounts spent on roads now on State system.

[6] In States indicated by star (*) law provides that these funds may also be used for service of local highway obligations. Amounts so used not reported separately. In Colorado funds may be used on both State and local roads.

[7] This column shows specific allotments for city streets. Where reported separately, funds allotted for urban extensions of State highway system are included in allotments for State highway purposes.

[8] To State general funds except in the following States: Alabama, county and municipal general funds; California, general funds of counties and cities, $3,821,000; New Mexico, county general funds, $364,000; Wisconsin, towns, cities, and villages in lieu of personal property tax formerly imposed on motor vehicles, $3,657,000. Allocations to local general funds may have been used in part for highways, but such amounts not reported.

[9] For the following purposes: Arizona, irrigation engineering expenses; Delaware, beach protection; Florida, aviation; Louisiana, harbor improvement; New Jersey, service of institutional construction bonds, $520,000, and Department of Commerce and Navigation, $243,000; North Carolina, State probation commission; Ohio, hospitalization of indigent persons injured in motor-vehicle accidents; Oklahoma, service of general State debt; Pennsylvania, aircraft landing fields, $451,000, and cooperative work other departments, $51,000; South Dakota, payments on real estate bonds; Tennessee, debt service on nonhighway bonds; Virginia, aviation.

[10] Legislative restorations from proceeds of sale of general State bonds were applied to debt service payments, thus reducing amounts necessary from current revenue.

[11] Includes debt service charges on emergency relief bond issues prorated in proportion to use of proceeds for State highway, local road, other highway, and nonhighway purposes.

[12] Service of highway relief bonds, a State obligation incurred for improvement of local roads.

[13] Appropriations for highway purposes out of State general fund have been credited against payments of motor-fuel tax and motor-vehicle fees to the general fund and prorated in proportion to net receipts not otherwise dedicated.

[14] Amounts previously loaned to general fund for relief purposes entirely repaid during 1937.

STATUS OF FEDERAL-AID HIGHWAY PROJECTS

AS OF SEPTEMBER 30, 1938

STATE	COMPLETED DURING CURRENT FISCAL YEAR			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	
Alabama	$ 1,659,461	$ 735,930	17.6	$ 8,126,378	$ 4,053,960	344.6	$ 2,176,494	$ 1,085,955	94.4	$ 2,875,596
Arizona	988,010	787,011	69.3	1,289,778	941,811	44.2	194,821	120,880	4.3	1,451,953
Arkansas	541,415	539,727	63.1	1,733,621	1,730,820	111.3	1,632,270	1,630,454	97.6	1,063,230
California	2,950,086	1,547,565	73.9	10,179,207	5,360,556	181.0	2,137,333	1,140,456	49.6	1,808,453
Colorado	1,466,214	806,752	64.1	2,917,207	1,605,878	73.3	920,810	511,980	31.5	1,794.558
Connecticut				1,350,040	660,511	14.7	244,930	120,990	2.0	1,536,794
Delaware	75,320	37,660		1,010,202	500,965	23.5	231,920	115,910	.2	1,184,277
Florida	480,110	240,055	15.1	3,787,138	1,893,569	79.7	468,000	234,000	.3	2,981,176
Georgia	2,807,740	1,398,558	147.4	5,981,044	2,990,522	277.9	768,970	384,485	45.1	5,527,478
Idaho	1,299,877	775,218	116.6	1,830,239	1,088,878	111.4				1,134,504
Illinois	1,782,500	908,384	48.7	11,668,268	5,832,370	262.2	3,149,550	1,574,774	91.8	2,328,326
Indiana	2,035,190	1,017,595	55.5	4,891,291	2,445,645	109.0	1,793,604	896,672	36.1	2,350,710
Iowa	2,649,293	1,232,519	81.0	7,195,830	3,242,183	237.9	1,763,024	827,300	57.2	349,747
Kansas	2,117,710	1,058,754	104.9	5,045,834	2,479,217	678.3	3,602,952	1,800,473	191.5	2,955,696
Kentucky	2,229,306	1,101,911	88.4	5,150,474	2,575,237	146.5	1,520,780	760,390	45.4	2,073,578
Louisiana	496,596	248,267	15.8	12,060,405	2,403,818	52.8	1,648,572	721,592	28.6	2,347,042
Maine	1,911,860	955,864	45.6	1,792,486	891,888	34.7	435,005	217,501	10.3	230,174
Maryland	308,000	154,000	5.3	1,891,567	944,021	29.0	1,688,981	820,830	28.3	1,670,916
Massachusetts	567,951	283,974	3.8	2,644,499	1,322,246	13.5	855,151	425,990	8.9	2,316,555
Michigan	2,790,200	1,395,100	86.6	6,481,208	3,168,694	124.2	1,736,469	863,322	40.5	1,713,365
Minnesota	567,280	256,994	10.5	7,088,576	3,528,072	345.5	2,123,524	1,053,619	103.4	1,924,238
Mississippi	759,208	352,662	31.9	8,326,480	3,205,471	368.9	1,409,600	351,970	71.1	3,115,942
Missouri	2,018,904	1,004,195	65.1	3,985,170	1,950,258	101.3	4,096,238	1,778,114	159.4	3,370,342
Montana	1,383,975	778,153	69.4	674,888	379,264	19.4	317,839	178,783	11.0	4,363,986
Nebraska	2,097,633	1,048,733	248.7	6,178,086	3,079,442	457.8	2,070,308	401,601	52.3	2,553,158
Nevada	1,080,635	936,162	106.1	623,465	534,727	75.2	468,897	406,166	8.2	1,217,185
New Hampshire	711,007	351,969	19.8	558,750	278,256	4.9	143,230	71,614	1.5	1,138,227
New Jersey				3,028,331	1,511,228	21.7	305,990	152,370	3.3	2,537,873
New Mexico	1,157,176	705,751	145.4	1,884,391	1,249,455	119.5	210,862	128,604	6.6	798,787
New York	4,890,956	2,398,750	105.1	14,251,023	7,037,212	238.6	2,024,030	982,665	25.0	2,817,777
North Carolina	2,642,358	1,304,224	136.1	6,837,996	3,304,827	328.2	1,769,590	873,470	95.0	1,933,713
North Dakota	509,340	460,000	50.2	2,889,891	2,643,078	212.0	136,652	73,189	10.2	3,567,977
Ohio	2,098,470	1,047,200	28.9	8,541,422	4,242,300	89.8	5,579,690	2,772,519	49.6	5,846,598
Oklahoma	2,390,057	1,259,286	81.8	5,266,416	2,748,303	185.5	1,401,390	744,465	58.6	2,656,311
Oregon	1,240,688	707,212	49.2	1,747,565	1,058,367	47.5	425,782	259,860	56.7	1,982,244
Pennsylvania	4,465,212	2,230,026	74.9	5,563,978	2,759,958	78.3	6,560,257	3,261,179	60.0	2,672,558
Rhode Island	202,800	101,400	1.7	939,242	469,621	14.3	287,710	143,855	2.1	1,028,924
South Carolina	2,730,437	1,209,193	152.5	3,370,242	1,503,432	125.8	2,003,011	900,100	56.7	1,165,475
South Dakota	611,862	353,755	73.9	4,089,492	2,261,560	384.5	1,580,520	872,770	117.3	2,720,117
Tennessee	1,623,080	811,540	56.0	4,868,714	2,434,357	128.5	868,860	433,930	15.4	4,310,972
Texas	6,823,031	3,387,715	440.9	10,183,495	5,046,449	509.9	4,263,605	1,886,002	212.5	6,275,668
Utah	725,860	521,130	102.4	1,613,295	1,146,535	55.2	354,730	251,750	10.0	894,864
Vermont	819,759	364,476	23.3	971,790	461,233	25.7	328,570	164,095	5.3	148,696
Virginia	2,594,411	1,296,500	86.2	4,646,135	2,320,402	157.1	1,510,354	752,827	40.0	688,815
Washington	2,249,597	1,183,100	46.2	3,138,123	1,644,159	45.8	804,454	423,000	13.5	828,161
West Virginia	703,299	518,649	26.0	1,910,644	1,203,321	57.3	708,719	342,923	9.8	2,176,030
Wisconsin	2,439,158	1,181,453	72.0	6,856,365	3,187,350	206.9	987,244	479,920	28.8	1,551,246
Wyoming	1,163,657	715,911	140.0	1,377,252	845,491	154.6	238,950	147,620	24.8	670,022
District of Columbia										
Hawaii	369,705	184,853	6.6	1,270,235	626,047	20.4	28,450	11,865	.3	1,202,411
Puerto Rico				1,128,739	562,390	20.5	28,590	14,245	1.9	657,740
TOTALS	80,226,394	41,895,836	3,553.5	220,836,907	109,355,354	7,550.3	70,007,282	34,569,044	2,173.9	106,510,185

STATUS OF FEDERAL-AID SECONDARY OR FEEDER ROAD PROJECTS

AS OF SEPTEMBER 30, 1938

STATE	Completed during current fiscal year: Estimated Total Cost	Completed during current fiscal year: Federal Aid	Completed during current fiscal year: Miles	Under construction: Estimated Total Cost	Under construction: Federal Aid	Under construction: Miles	Approved for construction: Estimated Total Cost	Approved for construction: Federal Aid	Approved for construction: Miles	Balance of funds available for programmed projects
Alabama				$ 562,000	$ 280,700	37.8	$ 82,605	$ 40,200	6.2	$ 732,072
Arizona	$ 281,361	$ 187,459	18.6	45,324	27,889	2.0	76,142	45,177	4.7	395,957
Arkansas				19,426	12,863		107,411	107,356	12.6	743,889
California	392,268	226,045	34.8	1,228,447	670,195	62.6	421,417	230,347	33.8	720,639
Colorado	425,450	236,550	31.6	417,036	230,283	19.5	88,360	32,000	4.8	422,735
Connecticut				57,470	28,735	1.2	29,410	14,510	.3	275,033
Delaware							103,704	51,852	16.9	195,023
Florida				20,122	10,061		105,900	52,950	.7	611,841
Georgia	129,837	63,897	17.6	498,260	249,130	58.4	256,080	128,040	37.1	817,655
Idaho	243,115	110,501	39.8	229,211	97,855	14.7	35,697	17,955	2.3	247,261
Illinois	553,000	276,500	44.7	1,672,992	782,496	125.2	648,400	324,200	43.7	643,719
Indiana	56,600	24,600	9.2	772,700	334,350	76.9	1,059,148	516,702	97.1	366,786
Iowa										1,298,449
Kansas	43,670	21,835	.5	67,822	33,911	7.6	268,154	134,076	48.4	1,129,149
Kentucky	309,086	104,551	52.0	630,278	186,311	50.4	1,262,037	335,098	94.9	188,466
Louisiana				155,231	72,985	11.6	878,653	371,430	75.4	279,721
Maine	174,400	87,200	11.0	327,126	163,563	19.7	138,600	63,433	6.0	14,377
Maryland				6,264	3,132		84,800	29,605	8.7	379,739
Massachusetts				5,300	2,650		143,050	71,315	2.4	572,435
Michigan				616,866	308,433	46.1	305,290	152,645	25.8	1,074,461
Minnesota	130,131	61,694	21.3	321,169	151,900	24.9	318,140	158,740	40.0	1,007,246
Mississippi				104,800	52,400	4.0	194,200	97,100	19.8	739,427
Missouri	224,357	111,427	34.3	231,370	115,290	15.3	616,650	225,705	84.1	612,827
Montana				13,983	7,865					1,027,170
Nebraska	149,082	74,541	21.6	451,070	225,535	72.9	247,552	120,556	47.4	575,420
Nevada	228,041	194,840	30.8	119,166	100,152	32.7	94,427	81,932	22.1	117,369
New Hampshire	97,426	48,277	1.7	111,335	55,301	2.8	39,820	19,880	1.5	123,417
New Jersey				123,040	61,520	2.4	223,920	103,630	2.7	507,623
New Mexico	289,750	176,717	14.4	327,188	190,070	22.5	299,156	162,318	15.2	277,667
New York	1,484,731	739,812	102.8	1,420,300	692,550	94.6	1,101,600	469,450	42.2	458,403
North Carolina	54,380	27,190	10.1	1,004,664	502,310	97.0	293,440	136,520	19.6	415,835
North Dakota				106,900	57,253	26.8	91,100	48,792	16.2	681,207
Ohio				184,400	92,200	3.8	60,600	29,750	1.8	1,709,691
Oklahoma	12,200	6,491		396,738	209,979	34.2	449,030	215,734	29.9	752,711
Oregon	279,315	169,410	44.7	152,117	92,122	9.3	60,504	28,000	6.6	463,622
Pennsylvania	758,719	369,060	54.8	1,201,117	581,021	73.0	1,347,074	654,837	72.8	510,970
Rhode Island	66,840	33,420	3.5	68,848	34,424	2.6	187,830	93,915	3.1	26,132
South Carolina	50,120	22,700	6.6	752,519	319,662	84.9	482,027	191,400	46.6	144,918
South Dakota				11,300	6,250					816,436
Tennessee	53,200	26,600	1.3	400,886	184,973	23.4	275,920	101,810	14.6	746,107
Texas	690,705	313,110	122.6	2,070,709	919,140	220.8	734,944	306,775	111.0	1,585,744
Utah	226,240	125,370	28.1	372,398	177,140	24.8	170,330	75,400	26.9	172,460
Vermont	163,580	71,150	9.7	101,376	49,153	4.8	114,700	56,200	3.8	33,093
Virginia	255,430	125,500	28.8	728,647	315,041	53.1	243,230	113,931	20.6	337,527
Washington	266,218	139,900	19.9	310,853	163,278	42.2	395,197	208,000	24.6	219,378
West Virginia	28,900	14,450	1.4	215,150	107,575	20.0	122,300	61,150	6.2	366,499
Wisconsin	46,947	23,405	1.4	924,481	441,190	38.5	252,117	115,380	14.4	632,253
Wyoming	290,340	179,400	33.7	333,680	206,180	20.9	124,440	76,890	14.0	122,723
District of Columbia										
Hawaii				56,250	28,125	2.4				218,750
Puerto Rico				244,000	121,950	13.7	35,610	17,455	1.5	107,470
TOTALS	8,455,439	4,393,602	853.3	20,192,329	9,757,091	1,602.0	14,670,716	6,690,141	1,231.0	26,619,502

U. S. GOVERNMENT PRINTING OFFICE: 1938

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.

ANNUAL REPORTS

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

Report of the Chief of the Bureau of Public Roads, 1933. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1934. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1935. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1936. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1937. 10 cents.

HOUSE DOCUMENT NO. 462

Part 1 . . . Nonuniformity of State Motor-Vehicle Traffic Laws. 15 cents.

Part 2 . . . Skilled Investigation at the Scene of the Accident Needed to Develop Causes. 10 cents.

Part 3 . . . Inadequacy of State Motor-Vehicle Accident Reporting. 10 cents.

Part 4 . . . Official Inspection of Vehicles. 10 cents.

Part 5 . . . Case Histories of Fatal Highway Accidents. 10 cents.

Part 6 . . . The Accident-Prone Driver. 10 cents.

MISCELLANEOUS PUBLICATIONS

No. 76MP . . The Results of Physical Tests of Road-Building Rock. 10 cents.

No. 191MP . . Roadside Improvement. 10 cents.

No. 272MP . . Construction of Private Driveways. 10 cents.

No. 279MP . . Bibliography on Highway Lighting. 5 cents.

Highway Accidents. 10 cents.

The Taxation of Motor Vehicles in 1932. 35 cents.

Guides to Traffic Safety. 10 cents.

Federal Legislation and Rules and Regulations Relating to Highway Construction. 15 cents.

An Economic and Statistical Analysis of Highway-Construction Expenditures. 15 cents.

Highway Bond Calculations. 10 cents.

DEPARTMENT BULLETINS

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

No. 1486D . . Highway Bridge Location. 15 cents.

TECHNICAL BULLETINS

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

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

MISCELLANEOUS PUBLICATIONS

No. 296MP . . . Bibliography on Highway Safety.

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).

UNIFORM VEHICLE CODE

Act I.—Uniform Motor Vehicle Administration, Registration, Certificate of Title, and Antitheft Act.

Act II.—Uniform Motor Vehicle Operators' and Chauffeurs' License Act.

Act III.—Uniform Motor Vehicle Civil Liability Act.

Act IV.—Uniform Motor Vehicle Safety Responsibility Act.

Act V.—Uniform Act Regulating Traffic on Highways.

Model Traffic Ordinances.

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.

STATUS OF FEDERAL-AID GRADE CROSSING PROJECTS

AS OF SEPTEMBER 30, 1938

STATE	COMPLETED DURING CURRENT FISCAL YEAR					UNDER CONSTRUCTION					APPROVED FOR CONSTRUCTION					BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
			NUMBER					NUMBER					NUMBER			
	Estimated Total Cost	Federal Aid	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	Estimated Total Cost	Federal Aid	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	Estimated Total Cost	Federal Aid	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	
Alabama	$ 153,610	$ 153,610	4		4	$ 502,248	$ 501,224	5			$ 548,900	$ 548,400	6		3	$ 782,285
Arizona						9,452	9,452									620,761
Arkansas						425,535	424,296	10			209,841	209,472	4			1,125,001
California	366,760	366,760		2		1,086,983	1,086,408	5	2		326,626	317,154	3			1,929,887
Colorado	17,980	17,979	1		1	71,588	71,588	1			25,042	21,282			10	1,177,463
Connecticut																844,490
Delaware											77,270	77,270			23	416,480
Florida						10,616	10,616				391,900	391,900	3			1,003,281
Georgia						18,346	18,346				362,690	362,690	6			2,036,351
Idaho	87,825	87,652	1			12,342	12,342				250,314	250,314	6			472,562
Illinois	186,500	186,500	1		1	1,544,675	1,544,675	5	2		660,230	660,230	6		60	2,813,238
Indiana	314,886	228,900	1	3		555,600	528,700	4	2		689,780	689,780	1	1	89	966,769
Iowa	527,765	498,900	4		9	694,219	653,600	7	1	5	48,001	44,400		2	7	1,365,724
Kansas	326,940	326,940	7		4	506,321	506,321	6			360,123	360,123	6		7	1,381,124
Kentucky	145,000	145,000	1			51,100	51,100	1			548,746	548,746	5	2	31	1,069,199
Louisiana						225,285	196,478	3			248,872	248,090	9			1,132,503
Maine	48,590	48,590	2			327,315	327,315	3	2		2,610	2,610			1	312,688
Maryland						64,586	64,586	1								962,247
Massachusetts						122,260	118,859		2		279,660	279,550	1	1		1,514,879
Michigan	393,000	393,000	5	1	7	912,458	912,458	6		38	238,600	238,600	3	1		1,741,127
Minnesota	40,218	40,218		1	1	770,180	770,180	3	5							1,614,049
Mississippi						355,700	355,700	4			363,800	363,800	3			864,651
Missouri	128,120	128,120	2	1		223,970	223,970	2			380,320	380,320	2			2,292,843
Montana	248,112	243,230	3			569,521	569,521	5								511,720
Nebraska	29,220	29,220	1			296,443	296,443	12			497,755	497,755	5		28	940,992
Nevada	97,187	97,187		2	2						57,561	57,561		1	2	303,893
New Hampshire	61,732	61,425		1		7,406	7,406				86,081	86,022	5			338,897
New Jersey						210,005	204,778	2	1		130,800	130,800		1	2	1,634,678
New Mexico						200,118	200,118	4	1		128,355	128,355	3			523,018
New York	141,400	141,400		1	2	2,472,972	2,417,071	9	7		214,000	183,150		2		4,028,308
North Carolina	73,550	73,550		1		470,810	470,810	5	1		608,330	575,630	3	4	11	1,324,404
North Dakota						606,278	606,278	2	2							972,943
Ohio						103,830	103,830	2			465,700	465,700	5			3,659,638
Oklahoma						17,343	17,343				52,075	52,075			14	2,212,091
Oregon	95,263	94,614		2		220,687	220,687	1			51,075	51,075				608,955
Pennsylvania	138,043	122,837	1			161,073	161,073	1			200,021	191,000	1			5,257,625
Rhode Island						314,484	314,484	1	2		20,535	20,535		1		158,731
South Carolina						86,379	63,593	1	2		272,740	222,140	12		34	1,203,369
South Dakota	7,530	7,530			2	316,708	314,568	2	2	7	105,850	105,850	5		1	891,343
Tennessee						14,381	14,381				87,380	87,380		2	1	1,790,272
Texas	36,660	35,990	2			928,672	928,672	8	2		389,767	389,155	5	1		3,987,972
Utah	1,760	1,760			1	142,818	142,818	4			5,319	5,319			3	423,166
Vermont	202,882	197,882	6	1		27,454	27,454		1		24,470	24,470			9	230,321
Virginia	245,670	245,670	12	1		241,018	241,018	3	1		304,555	304,555	3		8	1,004,787
Washington	149,718	147,618	1	2	2	613,457	613,457	7	2		31,117	31,117			7	591,609
West Virginia	120,100	119,080	1			291,909	291,909	3			60,870	60,870	2		5	852,239
Wisconsin	100,586	100,586	1			1,110,736	1,068,297	10			210,283	155,538	1			1,149,088
Wyoming						161,544	161,544		2	1	12,410	12,410			5	502,776
District of Columbia											34,262	34,262		1		291,169
Hawaii						33,230	33,230	1			152,570	152,570	2	1		307,950
Puerto Rico						110,940	110,390	3			116,096	115,440	1			504,470
TOTALS	4,486,607	4,341,748	57	19	36	18,220,995	17,989,387	152	42	51	10,333,302	10,135,465	117	21	361	64,646,026