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SOIL TESTS USEFUL IN DETERMINING QUALITY OF CALICHE

Reported by H. S. GILLETTE, Materials Engineer, District 6, Bureau of Public Roads

THE TERM "CALICHE", as used in the United States, is applied to a group of formations consisting principally of calcium carbonate and silica but containing some alumina, iron and magnesium carbonate. Formations occur locally, in relatively thin beds in solid or powdered form, but usually consist of clays and sands more or less thoroughly cemented by calcium carbonate, or of gravels or breccia so cemented, into caliche conglomerate.

They have been found and developed as road material,[1] in extensive areas of the semiarid regions of the southwest, notably in Arizona, New Mexico, northwestern Oklahoma, and western and southern Texas.

They are frequently described as being both calcareous and siliceous. The latter term arises apparently from chemical analyses which do not distinguish the cementing material from the chemical content of siliceous particles of clays or sands which form the base for cementation. However, one deposit in Texas is reported definitely as having silica alone as the cementing material.

The caliches of the United States are not related, unless in general appearance, to the nitrate deposits of Chile, to which the term caliche was originally applied.

Geologically, our caliches are superficial formations, varying from beds of incoherent powder to those of very considerable hardness and a corresponding high degree of cementation. They have limited continuity and are local in extent, but are of widespread occurrence. They vary in thickness from a few inches to 60 feet or more. Occasionally they are surface deposits, exposed by the erosion of wind or water, or, quite rarely, are products of evaporation of standing bodies of water. Their origin has been carefully studied and described by J. F. Breazeale and H. V. Smith.[2]

Most caliches have been formed at various depths beneath the surface and originate probably through evaporation of ascending or descending waters, the former frequently being the result of capillarity.

The following conclusions are from the bulletin cited:

1. Caliche, wherever found in Arizona, was formed by the solution, transportation, and precipitation of calcium carbonate.
2. Water, when charged with carbon dioxide, dissolves calcium carbonate and forms calcium bicarbonate. The calcium bicarbonate is carried in solution and is precipitated as calcium carbonate, or caliche, when the water is evaporated, or when there is a relief in pressure, which drives off carbon dioxide.
3. Caliche strata may be formed beneath the surface of a soil, either by the evaporation of descending surface water or by the evaporation of ascending ground water.
4. Caliche may be formed in a soil by means of plant roots. Plants growing upon the surface absorb soil water for transpiration purposes, and the calcium carbonate that is dissolved in the soil solution is precipitated as caliche.
5. As long as they are permeable to water, caliche strata will move downward in a soil as fast as erosion removes the upper soil surface.
6. Caliche probably is formed upon the surface of a soil by the evaporation of surface or flood water. The formation under such conditions is hastened by the presence of algae and other water plants.

CALICHES VARY IN CHARACTERISTICS

Generally, caliche is white in color. In specific instances, however, this white color may blend to a light pink, a light purplish red, a dark gray, a light brown, or a light ocher-yellow color. Usually, however, these colors bleach out under the effect of moisture and climate when left for any length of time on the surface.

The chemical constituents of caliche vary considerably. This is because the composition of a deposit depends upon the type of material in which precipitation took place, or upon the chemical nature of the salts in the ground water solution, or both. In Texas, the caliches in which silica or calcium carbonate is the predominating constituent are the ones most widely distributed and, by reason of this widespread distribution, are the ones more largely used. However, other caliches, of a different type from a chemical standpoint, are available in restricted areas.

Outside of Texas there are materials, locally defined as caliche, with other cementing mediums. In the Imperial Valley of California a so-called deposit of "caliche" occurs which consists of a gravel conglomerate cemented with sodium chloride. In Chile the so-called caliches are cemented with sodium nitrate—the Chilean saltpeter of commerce.

Caliches used in highway construction may be classified under three general types, according to hardness:

1. *Flourlike caliche*.—This type consists of a fine sand loosely cemented with a fine impalpable powder which, according to chemical analyses, is composed principally of silica or calcium carbonate. Such caliche may be handled or loaded in the pit without plowing or mechanical breaking of any kind. It may be scraped to a loading platform; may be loaded into wagons or trucks with an elevating grader; or may be loaded into wagons or trucks by laborers with shovels without previous mechanical manipulation.

2. *Semihard caliche*.—This type consists of cemented areas interspersed with the flourlike caliche. Beds of this nature have to be broken up with a hard steel plow or hard steel rooter before the material can be loaded into trucks or wagons. Formations can be broken up and loaded with a steam shovel. When placed on the subgrade of a road the large and semihard lumps usually have to be broken up with mauls or hammers.

3. *Hard caliche*.—This type consists of well-cemented strata or conglomerate areas that have to be blasted with powder or dynamite, and broken into lumps of variable size before the material can be loaded from the pit. Usually it must be run through a crusher before it can be used.

The thickness of overburden on these formations varies with the nature of the terrain and presumably with the previous geological history of the locality where it was formed.

[1] See Caliche as a Surfacing Material, by L. C. Campbell, Western Highways Builder, April 1929. A number of articles on this subject have been published in highway journals of the Southwestern States, and in other technical magazines. A partial bibliography is appended to the report of J. F. Breazeale and H. V. Smith, cited below.

[2] Bulletin No. 131 of the Agricultural Experiment Station, College of Agriculture, University of Arizona.

CALICHE DEPOSITS IN TEXAS DESCRIBED

In Live Oak County there is a deposit of flourlike or fine, loosely bound caliche situated at the lower point of a sloping terrain. This deposit has a very thin overburden of disintegrated material locally called soft limestone, the thickness of which is approximately 8 inches. The flourlike caliche can be loaded with an elevating grader without plowing. The pit is 20 or more feet in depth, 200 to 300 feet wide, and approximately 1,100 feet long and can be extended in length, width, and depth.

About 50 miles south of this location in Duvall County test holes have indicated a similar formation several square miles in area on rolling terrain. The only difference noted in this area is a variation in the amount of overburden. Here it varies in thickness from a few inches to 3 feet.

This same type of flourlike caliche occurs in west Texas in Throckmorton County on the surface of the rolling prairies. This formation, however, is shallow in depth, usually ranging from 3 to 7 feet, and is underlain by instead of covered by a disintegrated limestone formation. While in some areas there is no overburden, in others topsoil occurs from 6 to 18 inches in depth. Pits of a similar nature exist in southeast Texas, particularly in Kerr and Gillespie Counties.

Semihard caliche formations occur in numerous areas in Texas. A typical example is the Realitos pit in Duvall County. This pit is over 1,500 feet long, 500 to 800 feet wide, and from 3 to 25 feet in depth. Although some blasting had to be resorted to, nearly all material has been taken out with a large steam shovel without blasting. Material found in this pit consists mainly of large cemented areas and conglomerate strata in the interstices of which is fine flourlike material.

Hard caliche beds occur in a great many west Texas areas and, in some instances, in south Texas. They usually consist of stratified layers and conglomerate beds very firmly bound together with a cementing medium. In all instances the caliche has to be blasted before it can be excavated and has to be run through a crusher and broken into small sizes before being used for highway construction.

The use of caliche for highway construction in Texas has been one of necessity. There are a great many areas in the State, some distance from railroads, where other road materials are scarce or wholly absent. Long and expensive railroad hauls prohibited the use of shipped-in materials and the local caliches were developed for use. The construction methods used in building caliche bases and the tests used to determine the quality of the materials have been developed gradually over a period of years.

The first instance of its use on any considerable mileage of Federal-aid highway work was in Hidalgo County in 1920. Since caliche is confined to a more or less localized area, it had not received the widespread attention in road building literature that had been accorded most materials of construction, and as a consequence no special methods of testing this class of road material had been developed. Therefore, some method of testing had to be devised.

STUDIES MADE TO DEVELOP BETTER TESTS FOR CALICHE

Since tests for determining the cementing value and slaking time had been used for a number of years as a means of determining the quality of binders such as rock dust resulting from crushing, and since calcareous binders approached the composition and character of caliches, it was thought at the outset that these tests could be applied to caliches and used to differentiate between caliches of inferior quality and those of good quality. These methods were used for a number of years for control of caliche materials in Texas.

Within the last two years, however, the chemical composition and physical characteristics as disclosed by the routine subgrade tests of the Bureau of Public Roads have been investigated as a means for determining the probable performance of caliche as a road material.

Chemical analyses disclose the percentages of silica, alumina and iron oxide, calcium carbonate, magnesium carbonate, and ignition loss. The routine subgrade soil tests disclose the grading and constants as follows: Liquid limit, plasticity index, shrinkage limit, shrinkage ratio, centrifuge moisture equivalent, field moisture equivalent, and either the volumetric change or the lineal shrinkage.

The significance of these physical tests and the procedures for making them have been discussed in detail in PUBLIC ROADS.[3]

TABLE 1.—*Results of chemical analyses and physical tests of samples of caliche*

Sample no.	Chemical analyses					Physical tests	
	Silica	Alumina and iron oxide	Calcium carbonate	Magnesium carbonate	Ignition loss	Cementing value	Slaking value
	Percent	*Percent*	*Percent*	*Percent*	*Percent*		*Minutes*
GROUP 1							
1	36.30	4.75	52.60	3.71	2.00	335	15
2	15.65	4.55	73.03	1.17	4.96	92	25
3	12.70	2.20	82.32	1.14	1.25	99	10
4	32.40	5.70	55.70	1.97	4.10	147	15
5	54.05	4.80	35.26	2.54	2.81	342	60+
6	13.90	2.60	80.54	2.50		442	60+
7	9.40	1.95	84.20	3.26	1.07	101	60+
8	18.80	7.85	71.43	1.17	0.95	95	25
9	51.00	8.00	35.89	1.78	3.00	384	30
10	32.15	8.75	55.00	1.55	1.90	249	20
11	10.25	4.20	80.54	1.17	2.60	119	40
12	22.80	10.30	60.18	1.48	2.50	98	20
13	16.50	6.05	71.52	2.95	1.85	120	25
14	26.20	7.25	59.91	1.48	4.62	156	30
GROUP 2							
15	47.30	11.20	34.11	1.78	4.76	294	15
16	47.10	7.90	37.68	3.33	3.44	500+	60+
17	6.00	1.00	90.36	2.59		104	60+
18	60.80	7.45	19.73	8.71	1.70	203	8
19	18.20	2.95	72.50	3.26	2.50	287	45
GROUP 3							
20	66.45	7.50	17.23	3.30	3.45	500+	58
21	75.00	9.60	7.68	2.46	3.35	500+	17
22	51.20	6.35	34.73	2.61	3.20	500+	25
GROUP 4							
23	57.90	5.60	25.00	10.07	1.05	467	17
24	28.10	8.40	56.25	1.55	4.05	500+	60+
25	34.70	7.50	50.57	3.40	3.65	441	9
26	42.10	5.50	44.64	4.77	1.57	464	23
27	53.40	17.80	17.77	2.12	8.07	311	15
28	40.05	9.75	45.00	3.03	2.07	288	28
29	36.40	10.20	43.21	3.03	5.91	480	6
30	78.00	11.50	1.43	1.29	6.55	163	4

[3] See PUBLIC ROADS, vol. 12, nos. 4, 5, and 7.

The routine tests are supplemented by the flocculation test, which is being investigated for use as a substitute for certain of the routine tests in the examination of particular materials, of which caliche is one. It furnishes information on the maximum porosity of sediments and the presence of colloidal gels. The maximum porosity is disclosed by a voids ratio termed the flocculation factor or a corresponding moisture content termed the flocculation limit.

The flocculation factor is defined as the ratio of pores to solids in a sediment formed in 24 hours from a mixture of 5 cc absolute volume of powdered soil solids thoroughly dispersed in 39 cc of distilled water and 1 cc of chemical deflocculent.[4] The quantity of gel present is indicated by type numbers discussed later in this report.

In order to determine the relative efficiency of the various methods of tests for identifying caliches for road building purposes a number of samples representative of both good and undesirable caliches were obtained from roads and pits in various parts of Texas and tested in the Bureau laboratory at the Arlington Experiment Station.

All the samples which could be definitely classified as good or poor base material, according to the performance of the roads in which they were used, were divided into four groups, the first two groups representing the satisfactory caliches, and the third and fourth groups representing the unsatisfactory materials. All the samples represented material in the base courses of roads that had been in service from 3 to 13 years. The chemical analyses and results of the cementing and slaking value tests are shown in table 1. The results of the subgrade soil tests are shown in table 2.

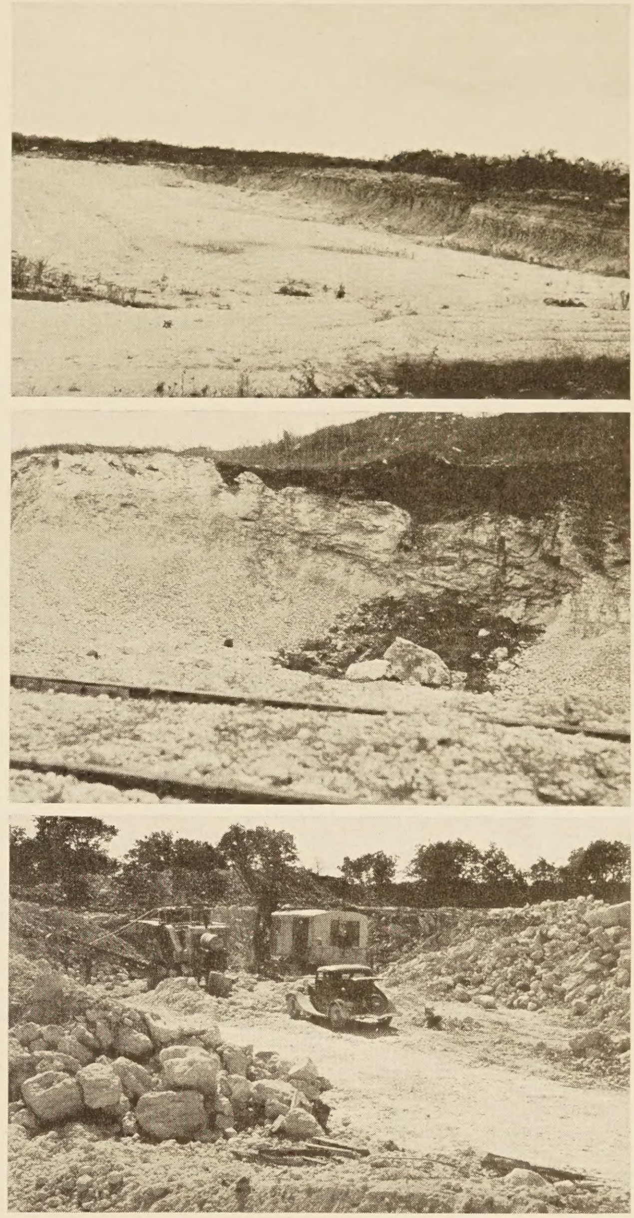
HARD AND SEMIHARD CALICHES GAVE BEST SERVICE

Group 1.—All samples of group 1, except no. 6, were taken from roads in west Texas which have been in use from 3 to 8 years. Each sample was from a base course of 6 or 8 inches compacted depth. These base courses were topped with an asphaltic surface from 1 to 2 inches in depth. All surfacing courses were in excellent condition. One significant feature of this group is that practically all the materials are from pits of hard caliche where most of the material had to be blasted. This, in itself, tended to keep the amount of fine material or binder within safe limits.

In samples, as removed from existing bases, the major amount of material is larger than 2 millimeters in size with a minor amount of excellent binder material containing sufficient cohesive material to thoroughly bind the coarse particles firmly together without detrimental volumetric change. This is not shown in table 2 since in preparing the samples for testing a rubber-covered pestle was used to break down lumps of material.

Group 2.—These materials were collected in south Texas, except sample no. 19, which was from west Texas. The samples were from roads that had been used from 7 to 13 years. All the materials used in these roads were from deposits of semihard caliches which had to be plowed for the most part before excavating. In some few instances strata had to be blasted. All the caliche bases were topped with an asphaltic surface course and in 1933 were in satisfactory condition. The materials of this group will be discussed singly.

[4] See Proceedings of Twelfth Annual Meeting of the Highway Research Board, p. 162.



DEPOSITS OF FLOURLIKE, SEMIHARD AND HARD CALICHE IN TEXAS.

Sample 15 was taken from a road constructed in 1926. The base course had a compacted depth of 8 inches and was constructed in two layers. The bottom layer was wetted, rolled until thoroughly compacted and permitted to set up before the second course was placed. The same method was used in constructing the second course. Previous to constructing the top course, the base course was bladed even and smooth. This is an important step in preparing caliche bases for top courses, particularly where the traffic is heavy. A major portion of the material, as placed in the road, was above the 2 mm sieve with very little binder. This caliche base was topped with a ¾-inch Uvalde rock asphalt surface course and in 1933 was in excellent condition.

Sample 16 is from a road built in 1927 with semihard caliche containing a high proportion of lumps larger than the 2 mm sieve. The caliche was excavated

TABLE 2.—*Results of soil tests performed on samples of caliche*

Sample no.	Mechanical analyses							Physical characteristics of material passing no. 40 sieve						Volumetric change	Flocculation test	
	Particles larger than 2 mm	Particles smaller than 2 mm						Liquid limit	Plasticity index	Shrinkage limit	Shrinkage ratio	Moisture equivalent			Flocculation factor	Type
		2.0 to 0.25 mm	0.25 to 0.05 mm	0.05 to 0.005 mm	Smaller than 0.005 mm	Smaller than 0.001 mm	Passing no. 40 sieve					Centrifuge	Field			
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*		*Percent*		*Percent*	*Percent*	*Percent*		
GROUP 1																
1	0	25	30±	[1]	[1]	[1]	[1]	33	0	40	1.3	25	37	0	1.7	1
2	0	39	20	25	16	8	73	20	3	25	1.6	19	21	0	1.7	1
3	0	31	24	29	16	5	80	22	4	21	1.7	18	21	0	1.3	2
4	0	24	38±	[1]	[1]	[1]	[1]	21	5	21	1.7	15	20	0	1.6	1
5	0	26	41	17	16	8	89	24	6	22	1.6	19	23	2	1.3	2
6	0	44	26	18	12	3	67	25	6	33	1.4	19	26	0	1.2	1
7	0	28	18	27	27	9	82	26	6	22	1.7	20	24	3	1.4	2
8	55	22	22	27	29	9	86	26	6	24	1.6	25	23	0	1.6	2
9	28	16	47	20	17	8	91	26	7	25	1.6	18	22	0	1.3	2
10	0	17	23	38	22	6	92	25	8	21	1.7	21	21	0	1.4	2
11	0	22	23	29	26	10	86	26	8	20	1.7	24	23	5	1.5	2
12	0	17	25	28	30	15	92	27	10	18	1.8	24	20	4	1.7	2
13	0	14	20	28	38	9	92	31	13	18	1.8	24	24	11	1.9	1
14	49	20	17	35	28	10	87	36	14	26	1.6	32	31	8	2.2	2
GROUP 2																
15	0	11	42	27	20	10	95	30	8	27	1.5	19	30	5	1.7	2
16	0	19	33	29	19	8	89	34	10	28	1.5	33	31	5	1.7	2
17	0	19	9	53	19	5	88	31	11	19	1.7	28	27	14	1.6	2
18	0	18	50	19	13	7	94	35	12	27	1.6	29	35	13	2.5	3
19	0	6	13	53	28	6	98	38	13	27	1.6	22	34	11	2.0	2
GROUP 3																
20	0	15	53	10	22	14	93	33	17	19	1.7	[2] 80	21	3	7.5	5
21	0	8	64	5	23	17	98	36	21	21	1.7	[2] 88	23	3	7.8	5
22	0	16	40	22	22	13	92	37	23	19	1.7	[2] 77	24	8	6.8	5
GROUP 4																
23	0	18	50	16	16	8	90	40	15	29	1.5	35	35	9	2.8	3
24	0	6	9	35	50	14	97	36	17	24	1.6	31	26	3	1.8	3
25	0	18	28	34	20	8	90	40	18	24	1.6	27	30	10	3.0	4
26	0	4	37	30	29	10	98	46	26	23	1.6	32	34	18	4.7	4
27	0	11	40	19	30	14	93	43	27	15	1.8	27	26	20	3.1	1
28	0	5	28	38	29	11	98	46	28	17	1.7	25	28	19	3.3	1
29	0	12	25	44	19	8	94	52	29	23	1.6	29	32	14	4.0	4
30	0	9	53	6	32	28	99	49	33	20	1.7	29	24	7	7.8	5

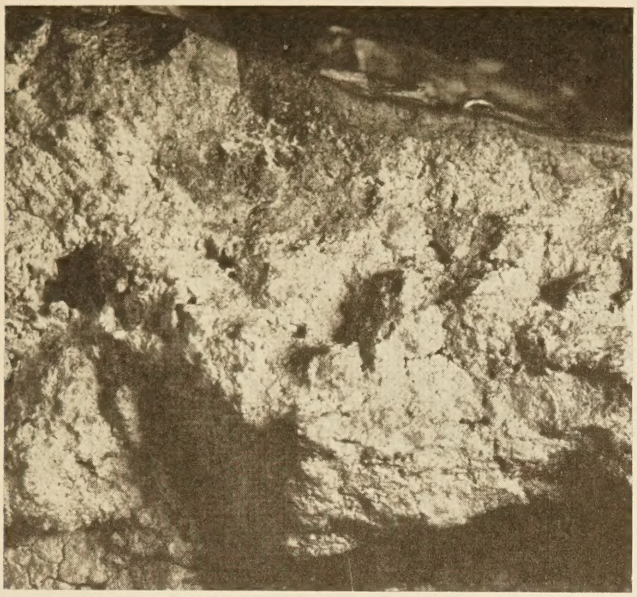
[1] Flocculated.
[2] Waterlogged.

with a steam shovel and as placed in the road, did not contain an excessive amount of binder.

Samples 17 and 18 are considered together as they were taken from the same highway about 5 miles apart. The road was built in 1920 with caliches of the semihard variety. While some strata had to be blasted with dynamite most of the material was plowed and loaded. An 8-inch compacted base was surfaced with 1-inch of Uvalde rock asphalt. About 1924 the surface was given a light treatment of liquid asphalt. The condition of the surface in 1933 was satisfactory, although some maintenance of edges had been necessary. This road is in a semiarid country; the grades provide excellent drainage and the subgrade is a sand. The temperature very rarely falls lower than 40° F. It is doubtful if this material would be satisfactory for use with a large amount of binder, in regions of heavy rainfall, frosts, and poor drainage or without a thoroughly sealed surface course.

The material represented by sample 19 has an interesting history. The road was built in 1926 when the cementing value and slaking tests were specified as the criteria for quality. At that time very little was known locally about soil physics. The road was in west Texas where caliches are mostly pure white. After the contract was let for the construction of the road, the caliche pit was opened and the material found was of a light pink color instead of white. This was the first pit of pink caliche found in west Texas. Its quality was questioned and considerable concern felt about using it. However, tests were made and the material met the specification requirements as to cementing value and slaking. There were no other pits close at hand and the material was finally used. It is a semihard caliche. Some of the strata had to be blasted, but most of the material was plowed with a tractor.

A base course, 8 inches in compacted depth, was placed late in the fall and allowed to go through one winter without a surfacing course. During wet winter weather the surface became slippery and mucky. In the following summer, after the caliche had dried out and set, it was surfaced with a 2½-inch penetration course with a surface seal coat of liquid asphalt. The seal coat was entirely successful in completely sealing the surface. The grades on this road provide good drainage. At the time of inspection in 1933 this road was in excellent condition.



A Sample of Caliche.

Group 3.—The road from which these samples were taken is in extreme south Texas in a semiarid territory. It was built about 1925 or 1926. Tests of the materials at that time disclosed very high cementation and acceptable slaking properties.

The material was laid to form a base course 6 inches in compacted depth. For 3 years this base course carried traffic without being surfaced. Surface evaporation caused the material to set hard and it gave satisfactory service under traffic. At the end of 3 years the base was surfaced with 1 inch of Uvalde rock asphalt. The rock-asphalt surfacing failed completely in less than a year and had to be removed. This history indicates that caliches of high plasticity, when used in arid regions of high temperatures, with provision for adequate surface evaporation, will set hard and provide good traffic service for up to about 800 vehicles per day. Such caliches may be totally unsatisfactory as bases for a bituminous surfacing. The surfacing prevents evaporation of moisture from the caliche. High capillarity produces considerable water which, if not removed by evaporation, causes loss of stability.

Group 4.—All materials in this group are unsatisfactory caliches. All of the samples were taken from complete failures. Samples of these materials taken from bases beneath asphaltic top courses show high moisture contents and soft cheeselike consistencies with very little stability. In one instance this type of caliche gave reasonably satisfactory traffic service for light traffic during one summer previous to placing the bituminous surface. However, they all failed as a base course for bituminous surfacing.

CHEMICAL ANALYSES AND TESTS OF CEMENTING VALUE NOT SIGNIFICANT

The results of the tests for cementing value show a lack of correlation between test results and field behavior. There is some indication that the better caliches have a lower cementing value and a higher slaking time than the poor materials, but the relations between tests results and field service, in general, are too erratic to be of value.

The chemical analyses illustrate the variable chemical composition of caliches, and also demonstrate the inadequacy of a chemical analysis as a basis for differentiating between the good and poor varieties of caliche. There is dissimilarity in the chemical composition of caliches within the various groups, and also frequent similarity in the compositions of good and poor caliches as, for example, between nos. 14 and 24 and nos. 9 and 22. In general, the better caliches contain more calcium carbonate than the unsatisfactory varieties, but numerous exceptions to this general rule render the chemical analysis ineffective for definitely identifying the satisfactory materials.

GOOD CALICHES HAVE LOW PLASTICITY

In developing a routine procedure for testing soils it has been the aim to develop a sufficient number of tests, varied in character, as to make possible the identification of all the soils apt to be encountered in highway construction. However, in the testing of special surfacing and base course materials, such as limerock, caliche, shale, disintegrated granite and the like, the tests may be limited to those which disclose the particular characteristics upon which the performance of the material depends. These dominating characteristics, as well as the tests which disclose them, may be learned from the results of all the routine tests performed on a sufficient number of samples.

To illustrate, the results shown in table 2 and averaged in table 3 show that the undesirable caliches have higher liquid limits and plasticity indexes than the good materials. The tests for field moisture equivalent, shrinkage limit, volumetric change, and centrifuge moisture equivalent (except in the case of waterlogged materials) do not show consistent differences between good and poor caliches. The poor caliches appear to differ from the good ones mainly in having higher plasticity. Shrinkage as indicated by either the volumetric change or its related constant, lineal shrinkage, seems to be a minor factor in contributing to failure.

Table 3.—*Average results of subgrade soil tests*

Group	Liquid limit	Plasticity index	Shrinkage limit	Centrifuge moisture equivalent	Field moisture equivalent	Volumetric change	Flocculation factor
	Percent		*Percent*	*Percent*	*Percent*	*Percent*	
1	26	7	24	22	24	2	1.6
2	34	11	26	26	31	10	1.9
3	35	20	20	82	23	5	7.4
4	44	24	22	29	29	12	3.8

Considering the test results it seems that a plasticity index less than 15 is sufficient to indicate a caliche satisfactory for road purposes, and that a plasticity index exceeding 15 denotes a material which may prove troublesome. As a supplementary requirement for indicating good caliche the flocculation factor might be limited to 2.5. However, it is possible that either semiarid climate or good drainage may have contributed to the satisfactory performance of several of the caliches represented by the samples with the higher plasticity indexes in group 2. Until more is learned concerning the matter it may be advisable to use caliches with plasticity indexes of, say, 10 to 15 only in fairly dry climates and where subgrade drainage conditions are favorable. In this case flocculation factors up to and including 1.7 would designate materials suitable under general conditions and factors up to and including 2.5 would denote caliches suitable under favorable conditions.

SILICA GEL MAY BE DISTINGUISHING FEATURE OF CALICHE PERFORMANCE

The flocculation factor, resulting from the flocculation test, is useful but the test may serve a more important purpose in disclosing the properties of caliche by indicating the presence or absence of a silica gel.

Sediments of caliches may be of five different types, as follows:

Type 1: No gel, with a clear suspending medium above the sediment.

Type 2: Little or no gel, with a cloudy suspending medium above the sediment.

Type 3: Well defined gel, not exceeding about 5 cc in volume; suspending medium clear.

Type 4: Heavy gel, 5 to 15 cc in volume, suspending medium clear.

Type 5: Very heavy gel exceeding 15 cc in volume, suspending medium clear.

Types 1, 3, and 5 are shown in the illustration.

From table 2 it can be seen that with but one exception the good caliches, groups 1 and 2, contain little or no gel. Those of group 3 are highly colloidal, as indicated by very heavy gels. This is undoubtedly responsible for the waterlogging in the test for centrifuge moisture equivalent. Oddly enough, however, these gels do not increase the plasticity to the extent which would be expected from the increase in the moisture equivalent.

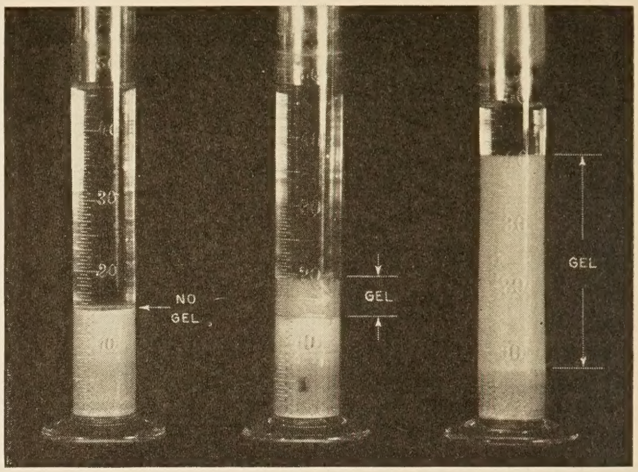
That the gel, in itself, is not responsible for the high flocculation factors is indicated by the tests on the group 4 samples. Samples 27 and 28, with flocculation factors above 3, have no gel whatever. This indicates that while the presence of a heavy gel may be responsible, in part, for high flocculation factors, as in the case of the group 3 samples, the absence of gel does not necessarily indicate a low flocculation factor.

The gel occurring in caliches is, to all appearances, the same as that produced by the bentonite colloids, which act as emulsifying agents on bituminous materials. Consequently, this silica gel, acting as an emulsifying agent, may be responsible for the failures of processed surfaces and thin bituminous surfaces on caliche bases. Except for the presence of this gel, the soil tests disclose no reason for such failures on caliches.

This leads to the general indications (1) that caliches with plasticity indexes less than about 10, with flocculation factors not exceeding 1.7, and without the gel-producing colloids should prove satisfactory as bases for thin bituminous surface treatments under average moisture conditions; (2) that caliches with plasticity indexes of 10 to 15, flocculation factors not exceeding 2.5 and without colloidal gel, should prove satisfactory for thin bituminous surfaces in semiarid or well-drained locations; and (3) the better grade materials, even with a considerable amount of gel, may prove satisfactory as bases for the thicker bituminous surfaces.

SUMMARY

The information available relative to the use of caliche suggests the following conclusions:



Types 1, 3, and 5 of Caliche Sediments.

1. The stability of caliche base courses for bituminous surfacing depends upon the quality and quantity of the fine binder material (passing the no. 40 sieve) contained in the total volume of material in place.

2. The quality of the binder depends on the geologic origin of the material. The quality can be determined by the standard physical soil tests developed by the Bureau of Public Roads. Study of soil constants derived by subjecting caliches which have given various degrees of road service to this standard series of tests makes possible the establishing of suitable limiting test values.

The quantity of fine soil binder (material passing no. 40 sieve) depends on the nature of the caliche deposit and on the mechanical appliances and methods used in excavating and handling.

3. The hard and semihard caliches are the best materials since they are most likely to contain a desirable quantity and quality of fine binder material.

4. Flourlike or very fine caliches may be used under favorable conditions. However, they generally contain an excessive amount of very fine clay and colloidal material. Such fine material will bind and set when properly manipulated, but the completed road has very high capillary action. Material of this kind should be thoroughly investigated before being used.

5. In regions of sparse rainfall, freedom from frost or snow, and good surface drainage, caliches with high colloidal content, as evidenced by high liquid limits, high plasticity indexes and colloidal gels, may be successfully used to carry light traffic without surface covering. This type of caliche will prove unsatisfactory if a surface covering, which prevents evaporation of capillary moisture, is placed on top of it or if it is placed without providing good drainage.

6. The minimum depth of compacted base course that will give good service, as deduced from records of roads that have been built for 5 or more years, is 8 inches.

7. Base courses in excess of 4 inches compacted depth will give better service if built in two courses. The base course material should be thoroughly compacted from the subgrade upward.

TRAFFIC ON STATE AND COUNTY ROADS OF INDIANA

A DIGEST OF A REPORT BY THE STATE HIGHWAY COMMISSION OF INDIANA [1]

THE present State highway system has been developed since 1920 with funds derived principally from automobile license fees, a gasoline tax, and Federal aid. The county system, the intensive development of which began with the enactment of the State's famous "Three Mile Gravel Road Law" in 1905, was paid for almost entirely with the proceeds of county and township bond issues. The issuance of State bonds is prohibited in the Indiana constitution. There are 2.14 miles of road in the State for each square mile of area, a figure exceeded only in Massachusetts and Connecticut. The mileage of surfaced roads is greater than that of any other State, there being a total of 59,085, of which 8,450 are dustless, including 5,536 miles of pavement. There are 50,635 miles of untreated gravel and water-bound macadam. Most of the pavement is on the State system. Table 1 gives a detailed summary of the various types of surfaces on the State highway system.

The unusual facilities for traveling throughout the year provided by the extensive county road system result in a narrower range of seasonal changes in traffic density than is found in other parts of the Middle West. The topography of the State is faily uniform, there being no mountains and only limited areas of marsh lands where construction is difficult. Indianapolis, with a population of about 400,000 is the largest city. Farming and manufacturing are about of equal importance in the State's economic life. The 1930 population was 3,238,503 of which 55.5 percent was classified as urban and 44.5 percent as rural.

TABLE 1.—*Miles of different types of surfaces on the State highway system, 1932*

Type of surface	Miles	Accumulated total, miles
Brick	106.96	106.96
Cement concrete	3,356.25	3,463.21
Rock asphalt	360.60	3,823.81
Bituminous concrete	52.17	3,875.98
Bituminous macadam	209.84	4,085.82
Surface-treated waterbound macadam	46.26	4,132.08
Bituminous retread	304.87	4,436.95
Bituminous mulch top	437.73	4,874.68
Road-oil mat top	1,766.16	6,640.84
Oil-treated surface	103.48	6,744.32
Stone	507.52	7,251.84
Gravel	863.63	8,115.47
Earth	28.09	8,143.56
Torn up for construction	197.35	8,340.91
Miscellaneous	81.72	8,422.63

SURVEY MADE ACCORDING TO ACCEPTED METHODS

The survey was undertaken to obtain information concerning the volume and kind of traffic on the various classes of highways as a basis for properly classifying highways and controlling expenditures upon them.

The methods of the survey were in accordance with principles which have been developed in a number of State-wide surveys and which are accepted as yielding satisfactory results. Traffic counts were made at 1,016 stations on the State system and data were collected at 525 points on county roads in 21 selected townships in 11 counties representing different conditions throughout the State. For certain classes of data intensive studies were made at a number of representative points and factors determined which were applied to other points of like character. The survey covered a 1-year period beginning in May 1932.

HEAVIEST TRAFFIC FOUND ON U. S. ROUTES

The 8,423 miles of State roads covered by the report do not include the 451 miles of State routes in cities with a population over 3,500 which were not maintained by the State. The Federal-aid highways included in the State system aggregated 4,923 miles.

During the year of the survey there was a motor vehicle movement on the State highways of approximately 6,890,200 vehicle-miles per day. On the county roads the figure was 3,483,953. The relative use of the Federal-aid systems and the United States routes is shown in table 2.

The daily volume of traffic on different parts of the State system varied widely. The number of motor vehicles per average 24-hour day ranged from 18,881 at the junction of routes U S 41 and U S 12 and U S 20 near Chicago, Ill., to a minimum of less than 100 vehicles on some unimproved sections recently added to the system. The average for the entire 8,423 miles was 818 vehicles per day. On county roads the average was 50.6 and the range was between a maximum of 3,943 and a minimum of 2.2.

TABLE 2.—*Average daily traffic on different route classifications of the State highway system*

	Highway mileage	Percent of State highway system	Average daily vehicle-miles	Percent of total vehicle-miles
Primary Federal-aid system	1,830	21.7	3,149,652	45.7
Secondary Federal-aid system	3,093	36.7	2,305,816	33.5
Other State roads	3,500	41.6	1,434,732	20.8
Total State system	8,423	100.0	6,890,200	100.0
US routes	1,933	22.9	3,194,545	46.5

The largest volume of traffic of both passenger cars and trucks is found in the areas adjacent to large centers of urban population and on the main traffic routes. The picture of the traffic flow in the Indianapolis area (as shown by maps accompanying the full report) is a striking example of the urban influence. The flow on all the roads increases as the city is approached. The den-

[1] The work was executed under the direction of F. A. Henning and W. F. Milner, engineers, and L. E. Freeman, statistician, for the State Highway Commission. The advice and assistance of the United States Bureau of Public Roads was had in planning the survey and supervision was furnished in part by the bureau in collecting field data. The complete report has been published by the State Highway Commission of Indiana.

sity lines, on the maps, for U S 40 between Indianapolis and Terre Haute and for U S 52 between Indianapolis and Lafayette show the characteristic maximum on these sections near the urban areas and the minimum midway between the cities.

The most striking example of the combination of the influence of urban traffic and through traffic is in the Calumet region and on U S routes 12 and 50 skirting Lake Michigan. The heavy traffic in this section is the result of a large population within the area itself, its proximity to Chicago, and the junction of several important through routes. The 28 miles of U S 12 outside of cities carries an average daily traffic of 4,509. From Gary to Elkhart, a distance of 63 miles, there is an average flow of 3,061 vehicles per day. The principal through routes, in general, are those designated as U S highways, of which the most important are U S 12, 20, 30, 31, 40, 41, and 52.

The mileage of State highways carrying various densities of total traffic and of truck traffic is shown in figures 1 and 2.

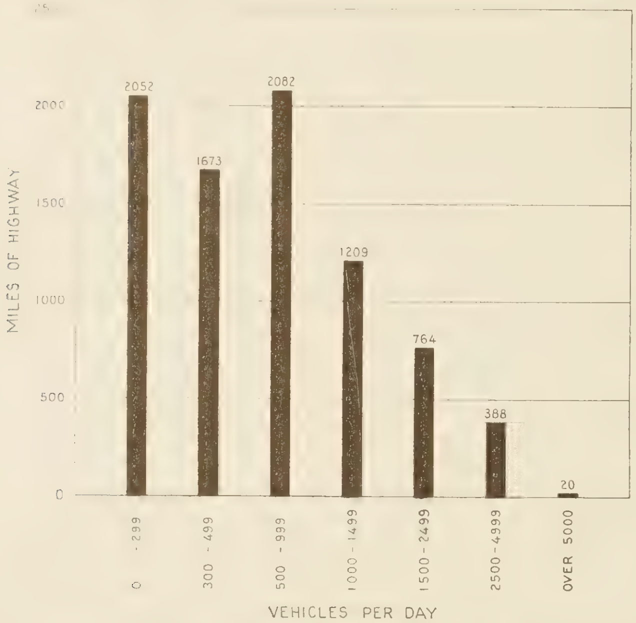


FIGURE 1.—STATE HIGHWAY MILEAGE CLASSIFICATION ACCORDING TO TRAFFIC DENSITY.

AUGUST FOUND TO BE MONTH OF HEAVIEST TRAFFIC

The seasonal variation in traffic is shown in figure 3, which is based on counts at 102 control stations. The bars represent the average traffic during each month as a percentage of the average monthly total traffic. Passenger-car traffic shows a greater variation than truck traffic. Maximum passenger-car traffic was in August and the minimum in March, with a ratio between the two of 1.56. For trucks the high and low months were August and February, with a ratio between them of 1.20.

Figure 4 shows the variation in traffic on different days of the week. Volumes of traffic are expressed as percentages of total traffic on the average week day (average for Monday to Friday, inclusive). Figures 3 and 4 are based on traffic on State highways only. It was found that the increase in traffic on Sunday was greater on local roads than on main routes, probably because of the desire of some pleasure drivers to avoid heavy traffic. Table 3 shows variations between week-day traffic and Saturday and Sunday traffic.

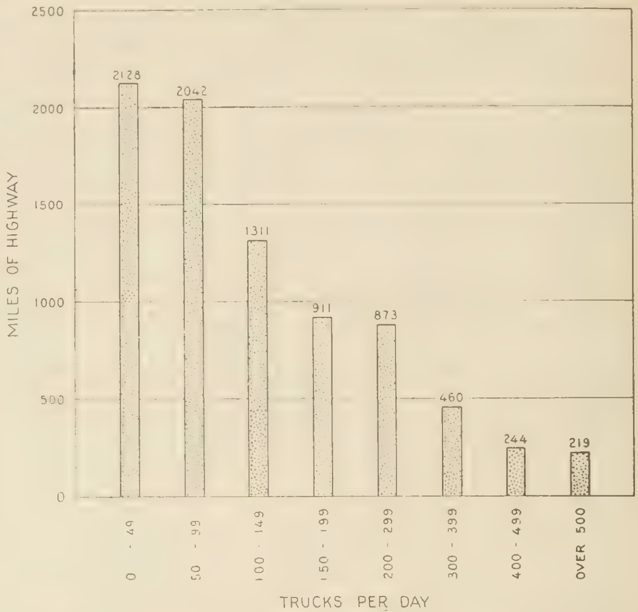


FIGURE 2.—STATE HIGHWAY MILEAGE CLASSIFICATION ACCORDING TO TRUCK DENSITY.

TABLE 3.—*Average Saturday and Sunday traffic as percentages of average week-day traffic*

	Average week-day flow	Saturday flow	Sunday flow
	Percent	*Percent*	*Percent*
Passenger cars	100	121	167
Trucks	100	81	41
Total	100	113	142

HEAVY TRUCK TRAFFIC CONFINED LARGELY TO PRINCIPAL ROUTES

Motor-truck traffic is 16.9 percent of the total traffic on State highways and 16.3 percent of the total on county roads. In the density counts busses were counted as trucks. However, early in the survey, a check was made on the relative number of busses to trucks and to total vehicles. This count showed that the bus flow was less than 1 percent of the total flow and approximately 4 percent of the truck flow.

It is highly significant that the percentage of truck traffic in Indiana is practically the same on State and county roads and still more significant that the percentage of heavy trucks on county roads, as determined by inspection, is approximately half that of heavy trucks on State roads. It was found during the summer of 1933 that 47 percent of the trucks passing the survey stations on State roads during daylight hours were either equipped with dual tires or were obviously large and heavy. This figure includes busses. On county roads the proportion of similar heavy vehicles was 26 percent. Dual tire equipment is principally used on vehicles which may be roughly classified as heavy. No classification by tonnage was attempted.

The average daily traffic flow map published in the full report shows that the number of miles of State roads that averaged over 200 trucks per day are comparatively few. In figure 2 the mileage of the State highway system is classified according to several truck-density classes. The number of trucks per average 24-hour day varied from 3,790 at the junction of routes U S 41 and U S 12 and 20 northwest of Whiting to less

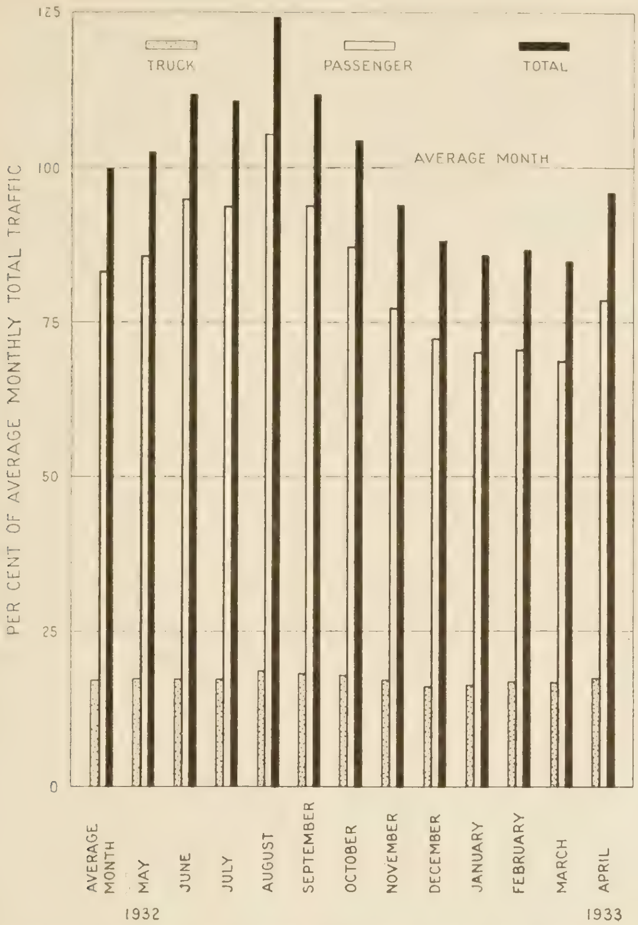


FIGURE 3.—DAILY VARIATION OF TRAFFIC ON STATE HIGHWAYS. TOTAL TRAFFIC ON AVERAGE WEEK DAY (MONDAY TO FRIDAY) IS TAKEN AS 100 PERCENT.

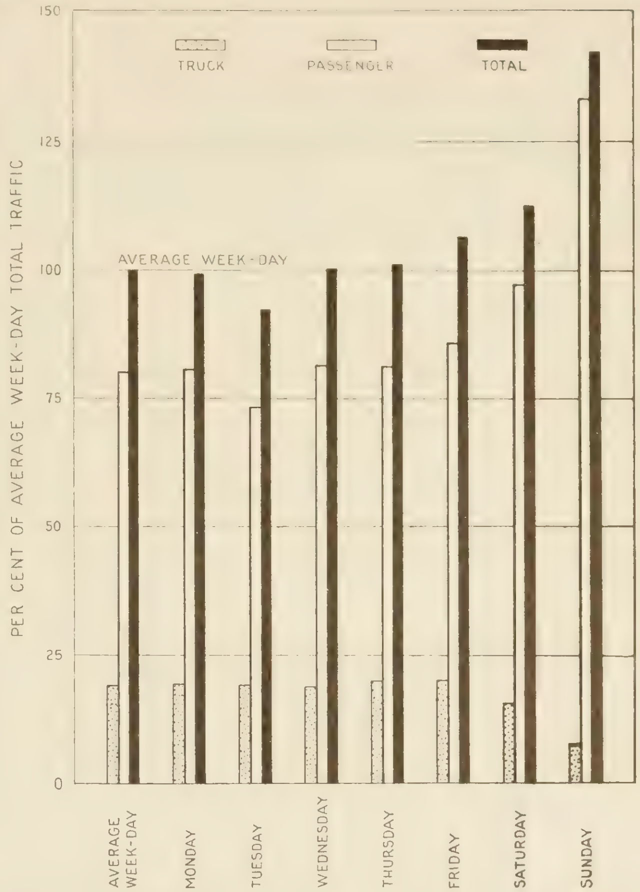


FIGURE 4.—MONTHLY VARIATION OF TRAFFIC ON STATE HIGHWAYS.

than 10 on some of the unimproved sections of the State system. On the county roads the maximum on the average day was 726 and the minimum none.

Table 4 gives the average truck flow on the principal truck routes. The decrease in this traffic on Saturdays and Sundays brings the average flow below the flow on a week day.

TABLE 4.—*Average daily truck flow on the principal truck routes*

Route	Length in miles	Average trucks per day
U S 12—Michigan Line to Illinois Line	28	996
U S 40—Indianapolis to Illinois Line	68	775
U S 40—Indianapolis to Ohio Line	61	445
U S 31—Michigan Line to Louisville	241	356
U S 20—Gary to Elkhart	63	473
U S 20—Elkhart to Ohio Line	60	220
U S 52 and U S 41—Indianapolis to Hammond	151	384
U S 41—Terre Haute to Ohio River	103	327
67-9-U S 24—Indianapolis to Fort Wayne	102	324
U S 30—Illinois Line to Ohio Line	143	255

TRAFFIC ON STATE HIGHWAYS DIFFERED GREATLY FROM THAT ON COUNTY ROADS

Upon analysis of field data it was found that traffic characteristics in Lake County, in the Chicago metropolitan area, differed so widely, in many respects, from those in the other 10 counties that a separate study of them would be required. Tables 5 and 6 show the major characteristics developed for the State as a whole and for Lake County alone. The various items are grouped for convenient comparison and each group represents 100 percent of the traffic. Direct comparison of State road and county road traffic can be made easily. In table 6 for Lake County the first column shows data relative to the State highways; the second, county roads in the northern portion of the county which lies within the Chicago metropolitan area; the third, the entire county road system. Many of the roads in North and Calumet townships are really city streets under the jurisdiction of county authorities. They carry a large volume of traffic and more elaborate studies than those undertaken in this survey will be required to give an adequate picture of them.

All comparisons in the second, seventh, eighth, and ninth groups in both tables are based on 24-hour traffic flow, but the remainder are based on the flow in the daylight period, during which observations were taken and for which no night factors were available. Survey figures show that foreign traffic maintained its percentage with reasonable uniformity throughout the night and indicate that the percentage of city-owned vehicles was greater on the State highways at night and less on county roads, and it may be worth while to bear this in mind in considering the 12-hour characteristics shown in the table. Seasonal variations in the characteristics listed were not great, except in resort areas and on roads near recreation centers and in items which constituted very small percentages of the total traffic.

It is apparent from the figures in table 5 that the State road system has distinctly different traffic characteristics from those found on the county-road system.

Table 5.—Composition of traffic—all roads

	Vehicle-miles		
	Percent on State roads	Percent on county roads	Percent on combined systems
1. Indiana-owned vehicles	82.5	96.6	87.2
All other vehicles	17.5	3.4	12.8
Total	100.0	100.0	100.0
2. Passenger cars	83.1	83.7	83.3
Trucks	16.2	16.1	16.2
Busses	.7	.2	.5
Total	100.0	100.0	100.0
3. City vehicles	62.5	33.4	52.8
Farm vehicles	18.4	43.7	26.8
Village vehicles	19.1	22.9	20.4
Total	100.0	100.0	100.0
4. Vehicles traveling to or from points in the township	33.0	71.3	45.8
Vehicles traveling to or from points in the county outside the township	36.7	22.5	31.9
Vehicles traveling to or from points in the State outside the county	22.5	6.0	17.0
Vehicles traveling between points in other States (trans-State)	7.8	.2	5.3
Total	100.0	100.0	100.0
5. Vehicles traveling from city to city	43.5	12.5	33.2
Vehicles traveling from city to country	20.3	17.1	19.2
Vehicles traveling from country to city	19.3	14.7	17.8
Vehicles traveling between points in the country	16.9	55.7	29.8
Total	100.0	100.0	100.0
6. Vehicles traveling within the State (intra-State)	77.9	96.9	84.2
Vehicles traveling between points in Indiana and points in other States (inter-State)	14.3	2.9	10.5
Vehicles crossing the State (trans-State)	7.8	.2	5.3
Total	100.0	100.0	100.0
7. Indiana passenger cars	67.2	80.6	71.7
Foreign passenger cars	15.9	3.1	11.6
Indiana trucks	14.6	15.8	15.0
Foreign trucks	1.6	.3	1.2
Indiana busses	.7	.2	.5
Foreign busses			
Total	100.0	100.0	100.0
8. Passengers cars owned in the county	37.9	60.8	45.6
Passenger cars owned in the State, outside the county	29.3	19.8	26.1
Passenger cars owned in other States or countries	15.9	3.1	11.6
Trucks owned in the county	7.5	11.4	8.8
Trucks owned in the State, outside the county	7.1	4.4	6.2
Trucks owned in other States or countries	1.6	.3	1.2
Busses owned in the county	.3	.1	.2
Busses owned in the State, outside the county	.4	.1	.3
Busses owned in other States or countries			
Total	100.0	100.0	100.0
9. County-owned vehicles	45.7	72.3	54.6
State-owned vehicles	36.8	24.3	32.6
Foreign vehicles	17.5	3.4	12.8
Total	100.0	100.0	100.0

Table 6.—Composition of traffic—Lake County roads

	Vehicle-miles		
	Percent on State roads	Percent on county roads [1]	Percent on county roads [2]
1. Indiana owned vehicles	53.3	85.7	86.8
All other vehicles	46.7	14.3	13.2
Total	100.0	100.0	100.0
2. Passenger cars	85.0	86.0	85.9
Trucks	14.0	12.6	12.9
Busses	1.0	1.4	1.2
Total	100.0	100.0	100.0
3. City vehicles	85.9	89.2	83.9
Farm vehicles	5.6	3.0	6.4
Village vehicles	8.5	7.8	9.7
Total	100.0	100.0	100.0
4. Vehicles traveling to or from points in the township	31.0	84.4	82.7
Vehicles traveling to or from points in the county outside the township	23.9	10.9	12.2
Vehicles traveling to or from points in the State outside the county	28.4	2.7	3.3
Vehicles traveling between points in other States (trans-State)	16.7	2.0	1.8
Total	100.0	100.0	100.0
5. Vehicles traveling from city to city	72.8	79.7	72.3
Vehicles traveling from city to country	12.8	9.2	10.7
Vehicles traveling from country to city	8.9	7.5	8.7
Vehicles traveling between points in the country	5.5	3.6	8.3
Total	100.0	100.0	100.0
6. Vehicles traveling within the State (intra-State)	36.6	83.4	85.0
Vehicles traveling between points in Indiana and points in other States (inter-State)	46.7	14.6	13.2
Vehicles crossing the State (trans-State)	16.7	2.0	1.8
Total	100.0	100.0	100.0
7. Indiana passenger cars	42.9	73.7	74.5
Foreign passenger cars	42.1	12.3	11.4
Indiana trucks	9.6	10.6	11.1
Foreign trucks	4.4	2.0	1.8
Indiana busses	.8	1.4	1.2
Foreign busses	.2		
Total	100.0	100.0	100.0
8. Passenger cars owned in the county	32.0	70.6	68.2
Passenger cars owned in the State, outside the county	10.9	3.1	6.3
Passenger cars owned in other States or countries	42.1	12.3	11.4
Trucks owned in the county	5.9	9.6	9.5
Trucks owned in the State, outside the county	3.7	1.0	1.6
Trucks owned in other States or countries	4.4	2.0	1.8
Busses owned in the county	.4	1.3	1.1
Busses owned in the State, outside the county	.4	.1	.1
Busses owned in other States or countries	.2		
Total	100.0	100.0	100.0
9. County-owned vehicles	38.3	81.5	78.8
State-owned vehicles	15.0	4.2	8.0
Foreign vehicles	46.7	14.3	13.2
Total	100.0	100.0	100.0

[1] In Calumet and north townships only.
[2] In all townships.

The figures for the different sections of the individual roads included in the averages shown in the table indicate that extreme variations from these averages may be found on a single road. For instance, most of the characteristics found on U S 31 in Marion County are quite different from those in Scott County. Centers of population, proximity to the State border or location in a highly developed resort area will cause changes in the composition of the traffic which will make the figures for certain sections of almost any State road either greater or less than similar figures for the average county road. Likewise, many of the county road characteristics shown in the table vary widely between the different counties in which the survey was conducted, although the percentages of foreign vehicles and of trucks are fairly uniform. Individual county roads can be compared with the State road figures shown only when full consideration is given to every detail of their geographical locations. In making such comparisons it must be remembered that the average State road carries 16 times as much traffic as the average county road, and that even though a certain county road shows a higher percentage of foreign or nonlocal traffic than the average State road the volume of such traffic may be practically negligible. The possibility of a material increase in these two items following the inclusion of a road in the State system must be studied.

The relative use of the roads by local and nonlocal vehicles is perhaps the most important comparison of the various traffic elements that can be made from the tables. In this survey if a vehicle either began or ended its trip in a certain place it was counted as local to that place. The first item in group 4 of either table is local traffic in the average township. The second item is traffic found crossing the township but local to the county in which the township is located. The sum of items 1 and 2 is the amount of traffic local to the entire county. The third item is traffic crossing both township and county coming from or going to points within the State and is called State traffic. Vehicles in the fourth item cross the State from border to border, passing through the county and the township. Thus the entire average vehicular movement is divided into "township", "county", "State", and "trans-State" traffic. The figures in table 5 indicate that the State highways carry an average of 33 percent township traffic, while the county roads carry 71.3 percent. Combined township and county traffic on the State highways is 69.7 percent of the total and on county roads 93.8 percent. Other comparisons are easily made from the tables themselves. The figures are averages for the entire State and vary materially between urban and rural areas.

By combining township and county figures in the fourth group and comparing them with the combined figures for county-owned cars in the last group we find that about 46 percent of the traffic on the State roads originates in the local county while about 24 percent additional has its destination there, having come from somewhere else. These same figures for the county roads are approximately 72 percent and 22 percent. The remainder of the traffic in each case moved entirely across the county. In this method of comparison, location of ownership denotes origin. In other words, the "origin or destination" method indicates that about 70 percent of the State highway traffic and 94 percent of the county road traffic is local to the county in which a road lies, while the "origin only" method indicates 46 percent and 72 percent, respectively, for these two items. "Origin only" figures for the townships are not available.

In this survey municipalities with 2,500 or more population were classed as cities. Automobile license registration figures in 1932 showed that 54.3 percent of all vehicles were owned in cities, 26.6 percent on farms, and 19.1 percent in villages or towns. Traffic on State roads was found to consist of 62.5 percent city vehicles, 18.4 percent farm, and 19.1 percent village. On the county roads, farm and village vehicles aggregated 66.6 percent. On the combined systems city vehicles constituted 52.8 percent of the traffic. Vehicles traveling from city to city, and city to country accounted for 63.8 percent of the State highway traffic, which is almost the same as the percentage of city-owned vehicles found on these roads. The movement between points in the country and from the country to the city on the county roads was 70.4 percent, which may be compared to the 66.6 percent of farm and village vehicles found on these roads. Figures in the table showing a slightly greater movement from city to country than in the opposite direction indicate that some of the heavy pleasure traffic starting from the cities during daylight hours did not return until after the counting stations were closed for the night or that they returned by different routes.

Trucks and busses were the only commercial vehicles segregated in the survey. Under the Indiana law busses used exclusively for carrying children to and from school are classed as trucks and carry truck license plates. While there are approximately 7,000 such vehicles in use they are very light, frequently mounted on passenger-car chassis, and travel an average of only 3,200 miles a year each.

The average mile of the State highway system carried 818 vehicles of all types a day; 680 of these were passenger cars, 132 were trucks and 6 were busses. On the county system these figures were 42.4, 8.1, and 0.1, making a total of 50.6 vehicles per day.

Bus registrations in the State amounted to only 878, and these few together with those registered in other States accounted for the flow shown above. On the State roads approximately 1 bus in each 7 is foreign. Out of each 13 trucks 1 is foreign, and 1 in each group of 7 passenger cars is of foreign registration. Foreign traffic on the county roads is very light (3.4 percent). Although there is hardly any bus traffic on the county roads it is interesting to note that the ratio of passenger cars to trucks and busses is practically the same on State and county roads. Foreign trucks are found to furnish 1.5 percent of the total State traffic on State roads, while foreign busses account for less than one-tenth of 1 percent. The total truck traffic is 16.9 percent. In other words, one-eleventh of the truck traffic, including busses, is of foreign registration.

COUNTY ROADS DO NOT EARN MAINTENANCE COSTS

Between May 1, 1932, and April 30, 1933, the net revenue from the 4-cent gasoline tax earned on all rural roads was $10,656,867. Of this total 66.5 percent, or $7,081,766, was earned on State roads and 33.5 percent, or $3,575,101, on county roads. These figures are based on an estimated gasoline consumption by passenger cars of 15 miles per gallon and 11¼ miles per gallon by trucks, which are the figures used by the Bureau of Public Roads in its report on the Survey of the Eleven Western States. No evidence has been produced since the publication of that report to justify a revision of these figures, although all available pertinent data have been studied. Some interesting light is thrown on this

(Continued on p. 250)

TABLE 7.—*Relative gasoline tax earnings on the State road and county road systems during the period of the survey, May 1, 1932, to Apr. 30, 1933*

		Passenger		Truck		Total		
			Percent of total		Percent of total		Percent of total	Percent of grand total
State roads	Daily vehicle-miles	5,727,296	83.1	1,162,904	16.9	6,890,200	100	
	Yearly earnings	$5,574,568	78.7	$1,509,217	21.3	$7,081,766	100	66.5
County roads	Daily vehicle-miles	2,916,676	83.7	567,277	16.3	3,483,953	100	
	Yearly earnings	$2,838,888	79.4	$736,213	20.6	$3,575,101	100	33.5
	Grand total—earnings					$10,656,867		100.0

EFFECT OF TEMPERATURE AND MOISTURE CONTENT ON THE FLEXURAL STRENGTH OF PORTLAND CEMENT MORTAR

BY THE DIVISION OF TESTS, BUREAU OF PUBLIC ROADS

Reported by D. O. WOOLF, Associate Materials Engineer, and K. F. SHIPPEY, Junior Highway Engineer

IN A REPORT on the effect of steel reinforcement in concrete pavements which was presented at the 1931 meeting of the Highway Research Board,[1] several theoretical considerations of the effect of change in moisture content and temperature on the flexural strength of concrete were advanced. It was stated that while both a lowering of temperature and a decrease in moisture content will cause a concrete slab to shorten in linear dimensions, these two effects may have opposite reactions on the flexural strength. When shrinkage occurs due to loss of moisture, the cement is placed under compression by the surface tension of the "solidified" water, and the modulus of rupture will be increased. Filling the pores of the mortar with water subsequent to drying reduces the capillary pressure to zero and causes the mortar to swell and the flexural strength to diminish. On the other hand, a decrease in temperature of rigid concrete causes molecular consolidation, the inert particles become smaller in diameter and the glue bands of the cementing material tend to shorten. This causes the linear dimensions of the slab to diminish and the glue bands to become stretched in effect and thus be placed in tension. This, in theory, should reduce the modulus of rupture.

This theoretical conception of the effect of temperature on the modulus of rupture was supported by the results of a series of tests of concrete made under field conditions. Since accurate control of temperature and moisture is quite difficult in the field, it was decided to make a series of tests under laboratory conditions to check the effect of temperature and moisture on the strength of mortar.

Several years ago a short series of tests to determine the effect of moisture content on the strength of mortar was made, using tension, compression and flexure specimens.[2] After 6 months' curing in water, a portion of each set of specimens was dried in warm air for 2 days and then tested. The remainder of the specimens were tested wet. The following results were found:

Mortar strength, pounds per square inch

Test	Wet	Air dry
Tension	530	380
Compression	6,215	7,145
Flexure	675	445

These results do not agree with the theories advanced. However, it is now believed that lack of agreement is the result of the air-dried specimens not being thoroughly dry and that when tested they still contained an appreciable quantity of water. Subsequent tests have indicated the correctness of this conclusion.

Following these tests a set of seven 2- by 3- by 18-inch mortar beams of 1:3 mix with Potomac River sand was tested at an age of 2 years to determine the effect of moisture content on the flexural strength. After each beam had been tested in a saturated condition, the beams were oven dried at 105° C. to constant weight and tested dry. As shown in table 1, the wet beams developed a flexural strength averaging 750 pounds per square inch. The average strength of the dry beams was 1,065 pounds per square inch, or 142 percent of the strength of the wet beams. These tests demonstrated that the moisture content had an appreciable effect on the flexural strength.

To determine the effect of both temperature and moisture, three series of mortar beams were prepared, using a 1:2 mix by weight of stock cement and Potomac River sand with a water-cement ratio of 0.68 by volume. Each series consisted of 6 beams 2 by 3 by 16 inches, and 6 beams 2 by 3 by 12 inches. Two other beams of the same proportions and consistency were cast with thermocouples and a thermometer placed in them. It was the intention to use these beams as temperature control specimens for the test beams. After one day in moist air, the beams were removed from the molds and stored in water at a temperature of 70° F. At an age of 28 days, half of the beams were dried in an oven at a temperature of 150°±5° F. for a period of 7 days, in which time they attained a constant weight.[3] All beams were tested at an age of 35 days.

TABLE 1.—*Moduli of rupture of mortar beams tested in flexure at age of approximately 2 years with specimens at room temperature*

Beam	Beams wet			Beams oven-dried to constant weight			Increase in strength
	1	2	Average	1	2	Average	
	Pounds per square inch	*Pounds per square inch*	*Pounds per square inch*	*Pounds per square inch*	*Pounds per square inch*	*Pounds per square inch*	*Percent*
1	827		827	1,140	1,101	1,120	136
2	702		702	1,082	999	1,040	148
3	685		685	1,136	1,155	1,146	167
4	664		664	1,123		1,123	169
5	853		853	1,026		1,026	120
6	762		762	988		988	130
7	746	756	751	1,009		1,009	134
Average			750			1,065	142

Prior to the tests, investigations of the rate of heating or cooling of mortar beams were made to determine the time required to bring a test beam to the desired temperature. For this purpose, a surplus beam of unknown age was fitted with a thermocouple and thermometer. The beam was subjected to all the heating

[1] Functions of Steel Reinforcement in Concrete Pavements and Pavement Bases, by C. A. Hogentogler, E. A. Willis, and F. A. Robeson, Proceedings, Highway Research Board, vol. 11, pt. 1.

[2] Effect of Moisture Content on the Strength of Cement Mortar Specimens, by D. O. Woolf and Baxter Smith, PUBLIC ROADS, August 1929.

[3] Loss of 1 gram (0.03 percent) or less in 24 hours' heating.

and cooling treatments proposed for use in the test, and time-temperature records obtained. It was found in this preliminary treatment that the thermometer reading usually showed a lag of 2° or 3° F. behind that obtained with the thermocouple. Some difficulty was experienced, however, in making thermocouple readings because of vibration of the galvanometer mirror. While the thermocouple was believed to give more accurate determinations of temperature, it was decided to use thermometer readings in the proposed tests.

FIRST SERIES OF TESTS INCONCLUSIVE

Tests were made of the flexural strength of beams at temperatures of 40°, 70°, and 100° F., in both oven-dried and saturated conditions. One long and one short beam were tested on each of 3 days for each of the 6 conditions of temperature and moisture. In most cases, 15 breaks were made under each test condition. Some specimens failed by shear at the ends because of uneven surfaces, and such breaks were discarded. After each test, the dimensions of the beam at the plane of failure and the length of the lever arm to the plane of failure were measured, and the modulus of rupture computed. The cantilever machine used has been described in Public Roads for May 1928. A 36-inch lever arm was used rather than the 18-inch arm used in the first work with the machine.

In the preliminary series of time-temperature tests, it was found that it was necessary to allow for a change of 10° F. in the temperature of the beam while in the testing machine, in making tests at 40° and 100° F. The beams for the low-temperature tests were cooled to freezing temperature before being placed in the testing machine, a bath of melting ice being used for the wet specimens, and the dry specimens being cooled by electric refrigeration. Wet specimens for testing at 100° F. were heated in water to 110° F. before being placed in the testing machine. Dry specimens for testing at 100° F. were oven heated to 150° F. and cooled in room air to 110° F. before being placed in the machine. The wet beams tested at 70° F. were taken direct from the laboratory storage water, while the dry beams were cooled from 150° to 70° F. in room air before testing.

The temperature of the test specimen at the moment of failure was obtained by subjecting the thermometer equipped control beam to the same temperature treatment as was given the test specimen. When the test beam was placed in the testing machine, the control beam was placed beside it, and the test was made when the control beam reached the desired temperature.

Upon the completion of this series of tests it was observed that the individual test results at a given temperature were not always concordant, especially in the case of the beams tested in a dry condition.

An inspection of the average results also showed a much smaller difference in strength, due to moisture condition at time of test, than had been indicated by the 2-year tests previously noted. It was felt that this might be due to the proportionately greater amount of water-curing given the wet beams (35 days as compared with 28 days for the beams tested dry). This would introduce an error which might be corrected, in part, by increasing the wet-storage period. It was therefore decided to repeat the test, using the same materials, proportions, and water-cement ratio but to give all beams a preliminary curing of 90 days in water instead of 28 days as in the former series. In this second series of tests, six 2- by 3- by 16-inch beams were prepared on each of 12 days and stored for 90 days. Three of each set of six beams prepared on 1 day were then removed from storage and dried to constant weight at a temperature of 150°±5° F. The remaining specimens were continued in water storage. At an age of 103 days both wet and dry beams were tested for flexural strength at temperatures of 40°, 70°, and 100° F., using the same methods as given above.

SECOND SERIES OF TESTS SHOWS IMPORTANCE OF CONTROL OF MOISTURE AND TEMPERATURE IN TESTING

The results of the two series of tests are given in tables 2 and 3, and in figure 1. In all cases, increase in temperature resulted in lowering the flexural strength of the mortar. This is more marked in the tests of the wet beams, and here a greater reduction in strength was found with increase in temperature from 70° to 100° F. than from 40° to 70° F. At an age of 35 days, the dry specimens tested at a temperature of 40° F. developed only 94 percent of the strength of the wet beams, but at 100° F. the dry beams had a strength of 118 percent of that of the wet beams. At 70° F. the dry and wet beams had practically the same strength.

At an age of 103 days, the strengths of the dry beams greatly exceeded the strengths of the wet beams at all temperatures. At 40° F. the dry beams were 144 percent stronger; at 70° F., 145 percent stronger; and at 100° F., 195 percent stronger. It will be recalled that in the tests made at 2 years, the flexural strengths of the dry beams tested at 70° F. averaged 142 percent of the strengths of the wet beams. It is apparent that the time of curing has a considerable effect on the ratio of flexural strength of wet and dry beams tested at the age of 35 days. In this case, the wet beams were cured in water for 35 days but the dry specimens had only 28 days' water-curing, followed by heating. This treatment probably affected the strengths of the dry specimens adversely.

It is interesting to note that, insofar as the effect of temperatures of specimens at time of test is concerned, these tests verify the results obtained several years ago by Parkinson, Finch, and Hoff, of the University of Texas [4] which indicated quite definitely that the

[4] Relation Between Strength of Portland Cement Mortar and Its Temperature at Time of Test, University of Texas Bulletin no. 2825, July 1, 1928.

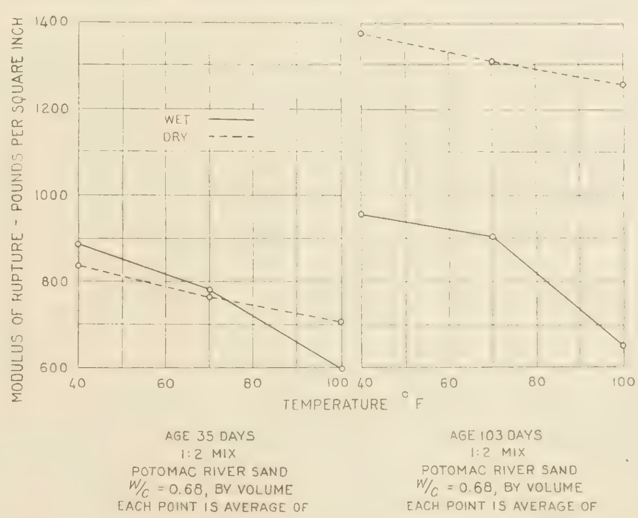


Figure 1.—Effect of Temperature and Moisture Conditions at Time of Test on Flexural Strength of Portland Cement Mortar.

TABLE 2.—*Moduli of rupture of mortar beams tested in flexure at age of 35 days and at various temperatures at time of test*

Beams, dry			Beams, wet		
40° F.	70° F.	100° F.	40° F.	70° F.	100° F.
Pounds per square inch	*Pounds per square inch*	*Pounds per square inch*	*Pounds per square inch*	*Pounds per square inch*	*Pounds per square inch*
726	672	590	897	788	575
862	740	614	852	785	689
828	705	607	900	765	635
816	744	570	797	784	552
731	734	811	817	777	622
965	677	787	838	797	520
749	771	678	850	827	565
829	891	900	989	676	586
849	877	928	811	802	655
788	840	691	929	818	585
851	750	750	966	820	599
836	847	595	986	741	606
890	710	654	886	770	571
994	621			758	601
	918			774	624
Av. 837	767	706	886	778	599

strength of mortar specimens tested in a wet condition is decreased as the temperature at the time of test is increased.

It should be noted that these observations were made on mortars using a single cement and a single sand and with one proportion. It is possible that the use of other materials and proportions might have indicated somewhat different relations.

The following conclusions appear to be warranted by the results obtained in these tests:

1. Increase in temperature of mortar beams at time of test results in a reduction of the flexural strength.

2. The effect of the temperature of a mortar beam at time of test on the flexural strength is more pronounced in the case of beams tested in a wet condition than with oven-dried beams.

3. In these tests, the flexural strength of mortar beams tested in a wet condition appeared to be affected to a greater extent by a change in temperature from 70° to 100° F. than from 40° to 70° F.

4. Mortar beams tested in a dry condition show a uniform reduction in flexural strength with increase in temperature from 40° to 100° F.

5. Mortar beams tested in a dry condition develop higher flexural strength than beams tested in a wet

TABLE 3.—*Moduli of rupture of mortar beams tested in flexure at age of 103 days and at various temperatures at time of test*

Beams, dry			Beams, wet		
40° F.	70° F.	100° F.	40° F.	70° F.	100° F.
Pounds per square inch	*Pounds per square inch*	*Pounds per square inch*	*Pounds per square inch*	*Pounds per square inch*	*Pounds per square inch*
1,489	1,294	1,310	994	938	662
1,416	1,399	1,399	1,017	873	599
1,392	1,391	1,310	1,004	940	630
1,365	1,134	1,194	1,020	996	631
1,419	1,041	963	975	861	688
1,237	1,255	1,143	908	935	677
1,223	1,164		932	920	570
1,238			1,036	928	596
1,279	1,122		948	870	
1,364	1,366	1,373	987	924	615
1,337	1,524	1,342	975	978	615
1,428	1,400	1,204	981	876	649
1,458	1,396	1,353	995	935	627
1,389	1,375	1,345	904	860	688
1,460	1,368	1,374	998	933	729
1,469	1,274	1,339	1,023	1,000	708
1,395	1,289	1,206	979	913	639
1,364	1,384	1,330	984	925	717
1,342	1,356	1,300	921	894	623
1,465	1,274	1,265	927	858	654
1,360	1,277	1,304	935	856	596
1,373	1,314	1,254	891	842	636
1,404	1,381	1,257	916	888	689
1,386	1,342	1,268	963	924	649
1,372	1,317	1,293	933	884	624
1,446	1,317	1,246	897	805	632
1,399	1,346	1,230	927	811	612
1,339	1,262	1,268	943	937	701
1,381	1,247	1,161	923	848	618
1,391	1,381	1,221	956	865	657
1,318	1,257	1,277	972	936	594
1,304	1,260	1,152	892	911	664
1,423	1,306	1,199	1,001	911	573
1,404	1,332	1,194	923	883	699
1,429	1,345	1,290	990	915	
1,369	1,339	1,171	858	878	696
Av. 1,379	1,309	1,259	956	901	646

condition provided duplication in curing conditions has been attained.

These tests point to the necessity of closely controlling both the temperature and the moisture condition of concrete specimens for flexure tests at the time of test.

Because of the comparative ease with which saturation of specimen can be insured it is recommended that all flexure tests be made with saturated specimens. In view of the fact that a temperature of 70° F. is commonly used and can be quite conveniently controlled, it is recommended that this temperature plus or minus 5° F. be established as a standard temperature for testing.

TRAFFIC ON ROADS OF INDIANA

(Continued from p. 247)

subject by the results of an analysis of the registration figures in Indiana made during the period of the survey. It was found that 42 percent of all trucks had a capacity of less than 1 ton, 91.8 percent had a capacity of less than 2 tons, and an additional 5.3 percent were rated at less than 3½ tons. Very heavy vehicles with high rates of gasoline consumption constituted only 2.9 percent of the total registration.

Proportioned on the same basis registration fee earnings on the rural roads during the period of the survey amounted to $3,821,306. Of this amount the State roads earned $2,539,841 and the county roads earned $1,281,465.

The net total earnings from the two sources just mentioned were $14,478,173. Table 7 shows the daily vehicle-miles of travel on each system, separated as to trucks and busses, and the relative gasoline-tax earnings in each case. From these figures we find that in gasoline tax and automobile license fees the average State road earns $1.40 annually for each daily vehicle-mile of travel (365 vehicle-miles in a year) and the average county road earns $1.39. On this basis it is evident from figure 1 that a considerable mileage of State roads is not earning maintenance charges, which averaged $411 per mile in 1932, but the average earnings per mile on the State system are $1,145.20. The average earnings on the county system are $70.33 per mile, which indicates that the county system as a whole does not earn its cost of maintenance, which, in 1931, was approximately $187 per mile.

CURRENT STATUS OF UNITED STATES PUBLIC WORKS ROAD CONSTRUCTION

AS PROVIDED BY SECTION 204 OF THE NATIONAL INDUSTRIAL RECOVERY ACT (1934 FUNDS) AND BY THE ACT OF JUNE 18, 1934 (1935 FUNDS)

CLASS 1.—PROJECTS ON THE FEDERAL-AID HIGHWAY SYSTEM OUTSIDE OF MUNICIPALITIES

AS OF NOVEMBER 30, 1934

STATE	APPORTIONMENTS		COMPLETED				UNDER CONSTRUCTION				APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS	
	Sec. 204 of the Act of June 16, 1933 (1934 Fund)	Act of June 18, 1934 (1935 Fund)	Total Cost	1934 Public Works Funds	1935 Public Works Funds	Mileage	Estimated Total Cost	1934 Public Works Funds	1935 Public Works Funds	Mileage	1934 Public Works Funds	1935 Public Works Funds	Mileage	1934 Public Works Funds	1935 Public Works Funds
Alabama	$ 3,947,753	$ 2,129,921	$ 4,385,124	$ 2,396,205	$ 35,889	237.6	$ 2,636,193	$ 1,357,286	$ 158,342	171.8	$ 58,042	$ 416,749	29.6	$ 136,220	$ 1,518,940
Arizona	3,878,555	1,338,712	4,307,361	3,718,223		284.2	746,769	96,741	648,668	51.0	4,655	72,904	3.1	58,935	617,140
Arkansas	3,374,167	1,714,000	2,003,051	1,604,863		97.6	1,769,519	1,598,375		76.1	72,616	578,945	23.4	98,314	1,135,055
California	7,912,928	3,713,643	7,164,849	5,384,201		241.8	4,957,185	2,517,283	826,645	85.8		195,800	11.7	11,445	2,691,198
Colorado	3,437,265	2,424,504	3,196,462	3,180,459		141.3	1,875,425	213,641	1,538,075	92.9		183,131	7.0	43,164	703,298
Connecticut	1,404,213	607,500	565,723	565,723		10.7	1,507,276	837,905	498,023	25.5	584	12,499			96,978
Delaware	892,544	461,697	876,080	873,987		18.0	467,709		452,532	10.7				18,557	9,166
Florida	2,519,010	1,330,672	2,817,619	2,088,980		103.4	601,207	339,123	147,473	16.9	58,425	251,540	10.9	32,483	931,658
Georgia	5,045,592	2,556,745	2,926,354	2,903,506		203.3	1,584,204	1,440,059		90.5	296,788	139,839	20.8	405,240	2,416,906
Idaho	2,166,858	1,131,910	2,068,131	1,986,705	14,243	177.9	557,239	150,095	374,630	23.7		67,364	10.6	30,058	675,673
Illinois	4,468,247	3,060,041	1,259,508	1,258,271		26.6	3,266,271	3,058,345	194,944	35.2	151,631	232,610	5.5		2,632,486
Indiana	5,018,921	2,843,478	1,788,127	1,781,926		65.9	2,571,542	2,570,855		69.1	451,103	110,100	17.4	215,037	2,733,378
Iowa	5,027,830	2,217,361	4,636,791	4,456,051		240.5	1,944,999	543,650	1,239,017	146.1		523,480	30.2	28,129	454,864
Kansas	5,044,802	2,558,837	4,923,320	4,772,059	35,977	408.3	1,404,395	211,063	1,037,656	187.0		659,894	92.6	61,680	825,311
Kentucky	3,751,605	1,527,324	3,217,161	3,060,734		227.7	885,248	575,203	192,298	50.2	94,933	254,506	32.0	20,735	1,080,520
Louisiana	2,681,152	1,380,419	1,507,997	1,506,764		60.7	1,873,744	1,141,619	225,474	24.7	12,232	215,695	.7	20,537	939,250
Maine	1,617,560	793,644	1,302,743	1,277,647		43.1	776,514	241,619	524,425	12.7		236,028	7.8	98,294	33,191
Maryland	1,782,263	289,610	527,930	518,282		10.5	1,031,803	925,217	106,586	20.2	204,764	13,660	4.3	134,001	169,363
Massachusetts	1,101,716	1,632,874	1,157,821	868,570		32.5	261,099	157,399		5.2		749,709	9.9	75,747	883,165
Michigan	6,113,389	3,226,284	3,802,535	3,786,680		173.5	3,004,525	2,303,250	652,275	121.0		567,575	21.0	23,459	2,006,434
Minnesota	4,561,011	2,642,244	5,295,204	4,143,865	1,067,676	801.7	1,046,730	383,615	590,115	149.0		439,623	62.5	33,532	524,829
Mississippi	3,489,337	2,301,148	2,514,890	1,348,075		138.3	3,505,643	1,762,606	300,907	176.2	139,940	375,549	38.6	238,716	1,624,692
Missouri	5,237,532	2,778,183	4,431,303	3,904,174		179.8	2,236,040	1,027,297	1,003,292	67.3	293,639	437,066	13.8	12,423	1,337,824
Montana	4,463,849	2,714,208	5,102,182	4,415,927	109,308	384.1	1,445,667	15,129	1,298,099	171.3		606,677	39.2	32,792	700,124
Nebraska	3,914,481	1,982,182	4,408,564	3,330,588		306.7	1,960,839	578,887	927,171	114.5		158,335	18.2	5,006	896,676
Nevada	2,909,387	1,350,356	2,717,093	2,669,838		259.1	571,715	133,064	438,651	48.3		347,370	62.2	106,485	564,334
New Hampshire	725,739	484,731	656,678	641,338		10.8	322,315	79,019	228,130	7.7		224,470	4.6	5,362	32,131
New Jersey	3,099,371	951,379	1,694,514	1,674,982		31.8	1,454,171	1,314,704		15.4	97,912	106,716	2.7	11,772	844,664
New Mexico	2,846,648	1,676,769	2,924,494	2,780,565		274.2	1,058,548	18,762	1,039,786	102.5		98,724	7.3	47,322	538,258
New York	10,465,672	2,872,521	8,074,884	7,181,395	11,000	174.9	8,996,468	3,283,803	2,110,200	159.6		139,406	18.3	474	611,915
North Carolina	4,761,147	2,040,068	3,972,434	3,345,600	6,884	529.8	1,464,974	726,891	298,860	148.6	270,989	11,441	17.7	417,667	1,722,884
North Dakota	2,902,224	1,469,484	2,977,675	2,588,455	16,672	958.4	435,864	188,435	138,626	109.1	29,897	392,618	215.2	95,436	921,567
Ohio	7,277,758	3,539,255	7,301,586	6,976,134		189.6	627,980	154,648	364,820	12.5		1,788,280	38.3	146,976	1,386,156
Oklahoma	4,608,399	2,342,590	3,433,619	3,378,528		268.2	939,899	933,664		35.7	181,001	1,003,496	60.3	115,207	1,339,094
Oregon	3,053,448	1,548,906	3,254,723	2,961,134		182.2	1,156,077	59,497	981,835	48.1		64,097	.4	32,817	502,974
Pennsylvania	6,691,194	4,554,082	4,287,464	4,176,066	17,389	107.8	4,305,941	2,422,183	1,624,775	59.9	10,865	1,133,576	27.5	82,079	1,778,341
Rhode Island	979,367	464,572	996,030	933,162		20.5	215,718		215,718	6.7	46,205	245,737	4.8		3,117
South Carolina	2,729,583	1,385,477	1,119,787	1,116,913		103.0	1,697,875	1,571,817	109,624	143.0	14,500	312,276	22.4	26,353	963,577
South Dakota	3,005,739	1,523,821	2,440,936	2,137,065		407.9	957,342	796,375		133.6	72,299	528,721	164.1		995,101
Tennessee	4,246,309	2,105,453	3,598,645	2,997,623		140.3	1,223,987	969,926	254,061	51.5	216,035	608,058	26.1	62,725	1,243,335
Texas	11,586,643	6,145,627	10,046,798	9,540,155		893.9	2,140,695	1,923,516	156,017	134.3		2,365,325	181.8	124,972	3,624,285
Utah	2,374,205	1,066,345	2,348,442	2,160,784	129,000	204.0	951,029	173,572	538,600	83.3		23,242	2.7	39,849	375,503
Vermont	928,184	466,042	849,889	807,290	10,073	42.7	386,497	116,745	251,974	17.5		25,648	1.4	4,148	178,348
Virginia	3,708,379	1,882,693	3,245,396	3,133,495		143.0	471,669	291,573	68,207	14.6	26,480	1,093,483	44.7	256,830	721,093
Washington	3,057,934	1,553,206	2,582,025	2,573,154		94.8	1,000,038	436,929	563,109	24.2	1,485	228,973	7.1	46,366	761,125
West Virginia	2,013,405	1,140,167	1,675,847	1,666,732		61.3	817,613	326,365	474,356	29.9		208,412	7.4	20,308	457,400
Wisconsin	4,615,429	1,865,947	4,448,696	4,332,834	500	213.1	617,438	245,430	327,698	35.9		169,957	7.8	37,165	1,367,792
Wyoming	2,250,663	1,692,907	2,320,877	2,025,467	67,583	468.2	959,381	193,976	738,663	118.5		174,243	45.6	31,220	712,418
District of Columbia															
Hawaii	1,683,956	598,778	254,428	178,070		10.9	1,766,159	1,437,846		28.1	66,000		.7	2,040	598,778
TOTALS	185,375,363	94,078,317	153,409,790	137,109,244	1,542,194	10,406.1	78,457,178	41,845,002	23,860,357	3,563.1	2,873,020	18,793,547	1,481.9	3,548,097	49,882,219

CURRENT STATUS OF UNITED STATES PUBLIC WORKS ROAD CONSTRUCTION

AS PROVIDED BY SECTION 204 OF THE NATIONAL INDUSTRIAL RECOVERY ACT (1934 FUNDS) AND BY THE ACT OF JUNE 18, 1934 (1935 FUNDS)

CLASS 2.—PROJECTS ON EXTENSIONS OF THE FEDERAL-AID HIGHWAY SYSTEM INTO AND THROUGH MUNICIPALITIES

AS OF NOVEMBER 30, 1934

STATE	APPORTIONMENTS		COMPLETED				UNDER CONSTRUCTION				APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS	
	Sec. 204 of the Act of June 16, 1933 (1934 Fund)	Act of June 18, 1934 (1935 Fund)	Total Cost	1934 Public Works Funds	1935 Public Works Funds	Mileage	Estimated Total Cost	1934 Public Works Funds	1935 Public Works Funds	Mileage	1934 Public Works Funds	1935 Public Works Funds	Mileage	1934 Public Works Funds	1935 Public Works Funds
Alabama	$ 2,389,928	$ 1,064,961	$ 783,134	$ 783,134	$	19.9	$ 1,388,494	$ 1,388,494	$	41.8	$ 47,630	$ 73,007	4.0	$ 170,670	$ 991,953
Arizona	807,982	305,191	522,097	514,133	6,592	12.7	145,384	105,818	30,635	2.0	129,322	2,709	.2	58,710	265,254
Arkansas	1,889,534	857,025	1,106,233	1,017,847		30.4	783,565	756,485		13.3	115,201	17,857	1.9		839,168
California	4,213,986	2,219,360	3,816,831	3,332,266		45.7	1,145,268	863,848	50,000	7.5		217,500	2.3	17,872	1,951,860
Colorado	1,718,633	190,000	1,762,843	1,712,885		35.2	19,122		19,122	1.8		170,878	2.0	5,748	
Connecticut	802,407	426,500	806,490	802,407		10.2	6,892		6,892			155,920	1.2		263,687
Delaware	477,680	230,849	356,021	347,740		6.4	172,485	118,305	54,180	1.5	4,919			6,717	176,669
Florida	1,410,008	665,336	909,627	670,710		10.4	724,947	724,947		8.1	7,721	79,475	2.1	6,629	585,861
Georgia	2,724,620	1,278,373	1,021,094	1,020,089		44.4	813,472	813,472		21.4	448,889		6.3	442,170	1,278,373
Idaho	1,197,829	321,126	838,439	799,742	2,643	19.2	390,046	367,764	22,282	1.6		2,733	.2	30,323	293,468
Illinois	7,692,483	2,515,835	5,159,256	5,111,073		56.1	2,268,824	2,268,824		14.5	185,253	213,466	3.4	127,333	2,302,369
Indiana	4,416,651	2,035,585	1,899,127	1,894,263		45.8	1,909,783	1,909,783		23.6	432,006	13,156	3.9	180,599	2,022,429
Iowa	2,614,472	1,311,000	1,676,770	1,583,614	2,680	49.0	967,446	884,858	38,273	11.1	146,000	169,505	7.5		1,100,542
Kansas	2,522,401	1,279,419	2,025,212	2,005,723	896	36.3	809,403	453,792	210,758	5.3	32,129	199,290	5.1	30,758	868,476
Kentucky	1,927,828	954,578	1,053,632	1,035,277		23.1	814,016	688,899	120,789	9.5	63,000	160,649	4.4	140,653	673,140
Louisiana	1,748,577	744,560	586,072	586,072		13.4	909,501	861,674	21,233	13.7	118,177		2.1	182,653	723,327
Maine	909,878	490,045	804,324	801,222		16.4	38,606	38,606		.4		58,848	.1	70,050	431,197
Maryland	891,132	452,514	296,278	292,128		3.1	1,003,656	190,135		1.4				408,869	452,515
Massachusetts	5,007,199	847,600	1,039,670	998,126		6.6	3,914,353	3,889,377		10.0		194,042	1.6	119,696	653,557
Michigan	3,438,781	1,613,142	2,049,059	2,040,697		34.2	1,803,723	1,391,623	399,600	12.0	6,461	330,600	1.5		882,942
Minnesota	3,719,143	1,421,494	3,127,348	2,954,560	144,685	104.7	489,811	225,210	256,401	12.3		37,531	5.7	539,373	982,877
Mississippi	1,744,669	885,057	524,869	512,409		18.5	671,990	608,966	63,024	24.1	275,321	55,146	7.7	347,973	766,887
Missouri	4,019,501	1,543,435	2,119,202	1,969,238		48.6	1,681,082	1,512,454	144,128	12.6	119,164	325,731	2.7	418,644	1,073,577
Montana	1,115,962	113,092	1,066,829	1,066,829		32.4	66,727	34,716	7,458	4.6	8,796	28,207	3.2	5,621	77,427
Nebraska	1,957,240	991,091	992,042	961,073	19,792	26.6	1,111,514	945,184	166,330	10.7		248,692	4.0	50,983	556,277
Nevada	500,051	100,000	504,552	481,548		8.8						1,000		18,504	99,000
New Hampshire	706,640	242,366	682,527	680,010		15.6	168,358		168,358	3.1		9,220	.3	26,630	64,788
New Jersey	3,190,118	1,809,500	1,560,965	1,486,604		10.6	1,665,825	1,611,692		12.2		399,314	4.2	91,822	1,410,186
New Mexico	1,674,158	529,506	1,286,002	1,286,002		29.8	469,687	286,479	183,208	10.4		60,330	1.7	101,677	285,969
New York	8,255,661	4,203,000	4,777,109	4,594,395		46.4	4,523,356	3,649,256	539,900	21.9		2,048,650	13.0	12,010	1,614,450
North Carolina	2,380,573	1,210,236	1,782,121	1,766,962	13,035	69.1	376,392	335,266	20,407	11.3	186,092	38,257	2.9	92,252	1,138,537
North Dakota	1,451,112	734,741	981,073	979,094		41.0	175,825	175,825		8.6	277,925	139,336	13.9	18,268	595,406
Ohio	4,335,686	2,359,504	4,382,141	3,898,898		54.7	453,230	398,438	23,000	4.8		818,500	12.6	38,349	1,518,003
Oklahoma	2,304,200	1,171,295	1,594,042	1,574,749		35.2	515,219	514,439		9.7	181,674	115,037	4.3	33,337	1,056,258
Oregon	1,526,724	774,454	1,361,445	1,343,930		25.7	127,593	127,593		2.1	30,841	170,887	3.0	24,360	603,567
Pennsylvania	4,854,988	2,397,703	3,009,010	2,913,789	19,191	50.3	1,871,120	1,708,433	148,793	13.1	193,049	687,680	14.4	39,717	1,542,039
Rhode Island	579,625	255,000	388,193	387,294		6.4	148,206	148,206		1.0				44,125	255,000
South Carolina	1,364,791	692,738	658,144	657,739		20.7	534,349	530,205	4,144	21.8	68,277		1.3	108,571	688,594
South Dakota	1,502,870	761,911	1,132,468	1,132,467		36.9	26,589	26,589		3.5	70,474	29,715	5.1	273,340	732,196
Tennessee	2,123,155	1,121,790	1,498,066	1,492,270		22.5	528,156	491,517	36,639	4.7	118,335	112,621	2.3	21,034	972,529
Texas	6,642,863	3,072,813	3,559,032	3,455,831		96.4	3,010,673	2,784,120		21.1	126,752	44,845	5.6	276,161	3,027,968
Utah	771,826	533,173	692,893	643,814	20,000	17.2	133,237	8,700	116,900	4.9		231,000	6.3	119,312	165,273
Vermont	500,509	240,611	467,259	441,585		12.9	58,924	58,924		1.7		55,000	1.2		185,611
Virginia	2,008,458	941,347	1,255,850	1,228,247		24.1	768,298	476,750	91,957	2.8		150,192	3.6	303,461	699,199
Washington	1,977,260	776,603	1,950,761	1,933,450		32.4	125,116		125,116	3.5		267,958	6.6	43,810	383,529
West Virginia	1,342,270	570,085	631,176	631,176		11.1	718,804	669,205	25,253	10.3	10,795		.1	31,094	544,832
Wisconsin	2,684,067	1,293,455	2,537,584	2,479,515	15,000	52.3	168,329	116,630	51,699	2.7		168,456	4.1	87,922	1,058,299
Wyoming	1,125,332	22,877	1,029,287	1,028,703		22.3	103,839	96,629	6,629	2.6					16,248
District of Columbia	968,235	243,460	725,952	704,305	21,647	4.7	457,597	250,164	207,433	2.0				13,765	14,381
Hawaii															
TOTALS	116,129,696	50,815,336	74,790,151	72,035,634	266,161	1,496.4	41,178,832	35,508,294	3,360,541	444.6	3,404,203	8,302,940	179.6	5,181,565	38,885,694

CURRENT STATUS OF UNITED STATES PUBLIC WORKS ROAD CONSTRUCTION

AS PROVIDED BY SECTION 204 OF THE NATIONAL INDUSTRIAL RECOVERY ACT (1934 FUNDS) AND BY THE ACT OF JUNE 18, 1934 (1935 FUNDS)

CLASS 3.—PROJECTS ON SECONDARY OR FEEDER ROADS

AS OF NOVEMBER 30, 1934

STATE	APPORTIONMENTS		COMPLETED				UNDER CONSTRUCTION				APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS	
	Sec. 204 of the Act of June 16, 1933 (1934 Fund)	Act of June 18, 1934 (1935 Fund)	Total Cost	1934 Public Works Funds	1935 Public Works Funds	Mileage	Estimated Total Cost	1934 Public Works Funds	1935 Public Works Funds	Mileage	1934 Public Works Funds	1935 Public Works Funds	Mileage	1934 Public Works Funds	1935 Public Works Funds
Alabama	$ 2,032,452	$ 1,064,960	$ 286,761	$ 286,761		15.9	$ 1,587,551	$ 1,587,551		119.7	$ 123,547	$ 329,881	32.0	$ 34,594	$ 735,080
Arizona	525,423	998,032	530,237	517,610		42.3	155,442		$ 139,878	14.5				7,813	858,154
Arkansas	1,484,634	857,024	660,891	659,906		111.3	606,496	601,497		46.3	121,457		3.4	101,773	857,024
California	3,480,440	1,999,203	2,742,860	2,285,839		124.4	1,208,714	1,023,893		54.2	170,709	310,056	13.9		1,689,147
Colorado	1,718,632	871,502	1,625,390	1,579,665		152.8	882,977	110,000	313,313	176.6		103,011	4.1	28,967	455,178
Connecticut	659,120	420,868					885,812	659,120	220,896	19.0					199,972
Delaware	448,864	230,849	202,680	202,680		9.1	276,342	81,450	194,892	48.0	164,733		2.5		35,957
Florida	1,302,816	665,335	1,261,443	1,258,850		74.8	214,156	19,244	194,912	6.3		130,626	5.1	24,722	339,798
Georgia	2,320,973	1,278,373	939,916	938,662		80.9	726,238	726,238		52.0	320,644		18.8	335,428	1,278,373
Idaho	1,121,562	824,450	1,085,506	1,003,679		129.4	549,094	117,819	396,544	63.4		140,363	13.0	64	287,543
Illinois	5,410,040	3,345,525	1,617,971	1,614,813		112.5	4,131,873	3,653,043	478,830	237.9	126,849	1,332,064	71.6	15,335	1,534,631
Indiana	602,271	209,900	251,310	251,310		23.2	347,461	347,461		53.6	3,500	102,591	9.9		107,309
Iowa	2,413,358	1,590,000	1,822,220	1,732,496	15,800	246.5	1,200,039	598,250	444,250	198.6	38,200	559,450	151.9	44,412	570,500
Kansas	2,522,401	1,279,419	1,771,695	1,763,703	5,563	147.0	1,060,414	753,181	307,233	105.8		520,275	31.0	5,517	446,347
Kentucky	1,837,926	1,336,409	1,762,463	1,730,098		205.9	512,927	85,833	410,374	49.2		285,853	39.6	21,995	640,182
Louisiana	1,398,862	838,953	596,741	596,462		30.3	677,249	677,249		29.1		14,741	.8	125,152	824,212
Maine	842,479	427,897	965,702	828,744	60,730	83.4	343,050	5,000	330,153	29.5		16,994	.7	8,735	20,020
Maryland	891,132	1,067,934	613,642	613,642		47.5	469,717	252,997	202,793	25.9	20,419	76,222	6.9	4,073	788,919
Massachusetts	488,185	870,000	469,741	469,741		15.2								18,444	870,000
Michigan	3,184,057	1,613,142	2,322,280	2,322,280		165.7	1,133,550	861,777	238,200	64.0		384,200	14.3		990,742
Minnesota	2,376,415	1,361,813	2,148,243	2,120,326	27,917	205.8	709,191	242,241	303,051	108.5		239,952	27.1	13,848	790,894
Mississippi	1,744,669	354,022	54,182	54,182		9.2	1,394,146	1,394,146		138.8	132,896		11.4	163,445	354,023
Missouri	2,923,273	1,852,122	2,722,227	2,615,655	44,922	515.6	659,932	212,571	447,361	191.2	4,361	616,646	133.9	90,686	743,192
Montana	1,859,937	942,434	1,845,330	1,834,423		226.1	48,525		48,525			283,705	27.9	25,514	610,203
Nebraska	1,957,240	991,091	1,296,979	1,287,084	7,824	209.2	1,090,225	645,990	443,985	176.1		199,257	63.2	24,166	340,025
Nevada	1,136,479	852,000	1,124,565	1,028,658	75,273	133.3	253,557	72,661	130,528	22.3		89,858	16.2	35,160	556,342
New Hampshire	477,460	242,365	412,780	371,791		22.1	169,678	105,172	63,942	7.5		68,066	3.3	497	110,357
New Jersey	56,550	460,000	56,528	55,098		.5								1,452	460,000
New Mexico	1,272,129	735,425	1,185,770	1,185,770		206.6	154,040	75,664	78,376	26.1		39,214	5.6	10,695	617,834
New York	3,608,768	4,252,400	3,085,376	2,919,351	4,200	81.1	3,334,300	676,975	1,690,600	112.7		1,413,740	114.0	12,442	1,143,860
North Carolina	2,380,573	1,590,637	1,832,167	1,831,389		193.5	632,359	475,544	156,815	57.9		445,677	53.7	73,639	988,145
North Dakota	1,451,112	734,742	819,429	819,429		261.6	321,441	321,441		91.8	114,141	20,647	52.0	196,102	714,095
Ohio	3,871,148	1,966,253	3,799,695	3,545,417		291.2	622,270	323,903	240,500	60.1		263,400	40.7	1,828	1,462,353
Oklahoma	2,304,199	1,171,295	998,064	980,096		147.4	1,362,330	1,295,833		128.2	5,479	273,084	9.7	22,792	898,211
Oregon	1,526,724	774,454	1,469,447	1,270,753	13,322	104.7	651,721	246,968	380,788	33.7		84,987	12.2	9,003	295,358
Pennsylvania	7,344,822	2,639,003	5,487,926	5,356,085		464.3	3,124,285	1,983,112	1,133,199	270.2	5,625	852,620	27.8		653,184
Rhode Island	439,716	295,000	350,421	348,280		28.6	60,357	60,357		4.5				31,080	295,000
South Carolina	1,364,791	692,739	820,981	820,981		87.5	521,500	472,524	48,976	64.1		398,542	37.4	71,286	245,221
South Dakota	1,502,870	761,911	1,064,542	1,064,529		309.5	431,493	387,964	43,529	117.7	34,544		28.3	15,833	718,381
Tennessee	2,123,155	1,075,748	1,217,153	1,195,620		102.4	948,186	861,645	86,541	52.8		312,381	17.2	65,890	676,826
Texas	6,012,518	3,072,813	5,482,785	5,091,029		714.4	902,898	874,074		52.3		672,608	38.0	47,416	2,400,205
Utah	1,048,677	533,173	1,025,455	903,620	37,500	161.2	335,149	132,945	160,300	59.6		35,000	5.3	12,112	300,373
Vermont	438,880	241,354	376,609	363,822		29.4	192,477	75,058	104,976	14.3		72,291	5.5		64,088
Virginia	1,699,920	941,347	1,403,970	1,362,039		199.4	349,903	278,139	43,015	18.0	11,450	60,496	2.9	48,291	837,835
Washington	1,080,673	776,603	932,259	915,000		60.4	277,170	163,455	113,715	11.8		446,158	35.0	2,218	216,730
West Virginia	1,118,559	570,083	536,043	528,965		28.2	532,022	506,887		28.9	48,468		.1	34,238	570,083
Wisconsin	2,425,385	1,782,435	2,340,560	2,169,244	40,000	170.4	408,513	155,767	142,852	9.6	82,822	246,829	11.8	17,553	1,352,754
Wyoming	1,125,332	571,928	1,081,608	1,064,346		148.4	90,037		90,035	12.3		193,656	28.7	60,985	288,237
District of Columbia	950,234	730,382	931,582	931,582		7.7	238,535		238,535	2.6		312,510	1.8	18,652	179,336
Hawaii	187,106	351,000					177,718	177,718		4.9				9,388	351,000
TOTALS	92,494,941	55,106,347	67,432,125	64,691,505	333,051	6,937.8	36,963,060	24,380,357	10,062,412	3,272.1	1,529,844	11,947,651	1,230.2	1,893,235	32,763,233

CURRENT STATUS OF UNITED STATES PUBLIC WORKS ROAD CONSTRUCTION

AS PROVIDED BY SECTION 204 OF THE NATIONAL INDUSTRIAL RECOVERY ACT (1934 FUNDS) AND BY THE ACT OF JUNE 18, 1934 (1935 FUNDS)

SUMMARY OF CLASSES 1, 2, AND 3.

AS OF NOVEMBER 30, 1934

STATE	APPORTIONMENTS		COMPLETED				UNDER CONSTRUCTION				APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS	
	Sec. 204 of the Act of June 16, 1933 (1934 Fund)	Act of June 18, 1934 (1935 Fund)	Total Cost	1934 Public Works Funds	1935 Public Works Funds	Mileage	Estimated Total Cost	1934 Public Works Funds	1935 Public Works Funds	Mileage	1934 Public Works Funds	1935 Public Works Funds	Mileage	1934 Public Works Funds	1935 Public Works Funds
Alabama	$ 8,370,133	$ 4,259,842	$ 5,455,019	$ 3,466,100	$ 35,889	273.4	$ 5;612,237	$ 4,333,331	$ 158,342	333.3	$ 229,219	$ 819,637	65.7	$ 341,484	$ 3,245,973
Arizona	5,211,960	2,641,935	5,359,695	4,749,966	6,592	339.2	1,047,595	202,559	819,181	67.5	133,977	75,613	3.3	125,458	1,740,548
Arkansas	6,748,335	3,428,049	3,770,175	3,282,616		239.3	3,159,581	2,956,357		135.7	309,275	596,802	28.7	200,087	2,831,247
California	15,607,354	7,932,206	13,724,540	11,002,306		411.9	7,311,167	4,405,023	876,645	147.5	170,708	723,356	27.9	29,317	6,332,205
Colorado	6,874,530	3,486,006	6,584,695	6,473,009		329.4	2,777,524	323,642	1,870,511	271.3		457,019	13.1	77,879	1,158,476
Connecticut	2,865,740	1,454,868	1,372,214	1,368,130		20.9	2,399,980	1,497,025	725,811	44.6	584	168,419	1.2		560,637
Delaware	1,819,088	923,395	1,434,781	1,424,406		33.5	916,536	199,755	701,603	60.3	169,652		2.5	25,274	221,792
Florida	5,231,834	2,661,343	4,988,689	4,018,540		188.5	1,540,310	1,083,313	342,386	31.3	66,146	461,641	18.1	63,834	1,857,317
Georgia	10,091,185	5,113,491	4,887,364	4,862,257		328.5	3,123,914	2,979,769		163.9	1,066,321	139,839	45.8	1,182,838	4,973,652
Idaho	4,486,249	2,277,486	3,992,077	3,790,126	16,886	326.5	1,496,380	635,678	793,456	88.7		210,460	23.8	60,445	1,256,684
Illinois	17,570,770	8,921,401	8,036,735	7,984,158		195.3	9,666,968	8,980,211	673,775	287.6	463,733	1,778,140	80.5	142,668	6,469,486
Indiana	10,037,843	5,088,963	3,938,563	3,927,499		134.8	4,828,786	4,828,099		146.3	886,609	225,847	31.2	395,636	4,863,116
Iowa	10,055,660	5,118,361	8,135,781	7,772,161	18,480	536.0	4,112,484	2,026,758	1,721,540	355.9	184,200	1,252,435	189.6	72,541	2,125,906
Kansas	10,089,604	5,117,675	8,720,227	8,541,485	42,436	591.6	3,274,213	1,418,036	1,555,647	298.2	32,129	1,379,459	128.6	97,955	2,140,134
Kentucky	7,517,359	3,818,311	6,033,256	5,826,108		456.8	2,212,191	1,349,934	723,461	109.0	157,933	701,008	76.0	183,383	2,393,842
Louisiana	5,828,591	2,963,932	2,690,811	2,689,298		104.5	3,460,494	2,680,542	246,707	67.4	130,409	230,436	3.5	328,342	2,486,789
Maine	3,369,917	1,711,586	3,072,769	2,907,613	60,730	142.9	1,158,170	285,225	854,577	42.6		311,870	8.6	177,079	484,408
Maryland	3,564,527	1,810,058	1,437,851	1,424,052		61.1	2,505,175	1,368,349	309,380	47.6	225,183	89,882	11.2	546,943	1,410,797
Massachusetts	6,597,100	3,350,474	2,667,233	2,336,437		54.3	4,175,452	4,046,776		15.2		943,752	11.5	213,887	2,406,722
Michigan	12,736,227	6,452,568	8,173,874	8,149,657		373.4	5,941,798	4,556,650	1,290,075	197.1	6,461	1,282,375	36.9	23,459	3,880,118
Minnesota	10,656,569	5,425,551	10,570,794	9,218,751	1,260,278	1,112.2	2,245,733	851,066	1,149,567	269.7		717,106	95.2	586,753	2,298,600
Mississippi	6,978,675	3,540,227	3,093,940	1,914,667		166.0	5,571,779	3,765,717	363,931	339.1	548,157	430,695	57.7	750,134	2,745,602
Missouri	12,180,306	6,173,740	9,272,732	8,489,067	44,923	743.9	4,577,055	2,752,323	1,594,782	271.2	417,164	1,379,442	150.4	521,753	3,154,593
Montana	7,439,748	3,769,734	8,014,341	7,317,179	109,308	642.6	1,560,920	49,846	1,354,082	175.9	8,796	918,590	70.2	63,927	1,387,754
Nebraska	7,828,961	3,964,364	6,697,585	5,578,744	27,616	542.5	4,162,578	2,170,061	1,537,485	301.3		606,284	85.4	80,155	1,792,978
Nevada	4,545,917	2,302,356	4,346,210	4,180,044	75,273	401.2	825,272	205,725	569,179	70.6		438,228	78.3	160,149	1,219,676
New Hampshire	1,909,839	969,462	1,751,985	1,693,139		48.5	660,351	184,191	460,430	18.3		301,755	8.2	32,509	207,276
New Jersey	6,346,039	3,220,879	3,312,007	3,216,685		42.9	3,119,995	2,926,396		27.5	97,912	506,030	6.9	105,046	2,714,850
New Mexico	5,792,935	2,941,700	5,396,265	5,252,336		510.5	1,682,275	380,905	1,301,370	139.1		198,269	14.6	159,694	1,442,061
New York	22,330,101	11,327,921	15,937,369	14,695,140	15,200	302.3	16,854,124	7,610,034	4,340,700	294.1		3,601,796	145.3	24,926	3,370,225
North Carolina	9,522,293	4,840,941	7,586,721	6,943,951	19,918	792.4	2,473,725	1,537,702	476,082	217.8	457,081	495,375	74.3	583,558	3,849,566
North Dakota	5,804,448	2,938,967	4,778,178	4,386,979	16,672	1,261.0	933,130	685,701	138,626	209.5	421,962	552,601	281.2	309,806	2,231,068
Ohio	15,484,592	7,865,012	15,483,422	14,420,449		535.6	1,703,480	876,989	628,320	77.4		2,870,180	91.6	187,153	4,366,512
Oklahoma	9,216,798	4,685,180	6,025,725	5,933,373		450.7	2,817,448	2,743,936		173.6	368,153	1,391,617	74.3	171,336	3,293,563
Oregon	6,106,896	3,097,814	6,085,614	5,575,817	13,322	312.6	1,935,391	434,058	1,362,623	83.9	30,841	319,971	15.6	66,180	1,401,899
Pennsylvania	18,891,004	9,590,788	12,784,401	12,445,939	36,580	622.4	9,301,346	6,113,729	2,906,767	343.2	209,540	2,673,877	69.7	121,796	3,973,564
Rhode Island	1,998,708	1,014,572	1,734,643	1,668,736		55.6	424,280	208,562	215,718	12.2	46,205	245,737	4.8	75,205	553,117
South Carolina	5,459,165	2,770,954	2,598,912	2,595,632		211.2	2,753,725	2,574,547	162,744	229.0	82,777	710,818	61.0	206,210	1,897,392
South Dakota	6,011,479	3,047,643	4,637,945	4,334,061		754.3	1,415,424	1,210,928	43,529	254.8	177,318	558,436	197.5	289,173	2,445,678
Tennessee	8,492,619	4,302,991	6,313,864	5,685,513		265.2	2,700,328	2,323,087	377,241	108.9	334,370	1,033,060	45.7	149,649	2,892,690
Texas	24,244,024	12,291,253	19,088,615	18,087,015		1,704.7	6,054,266	5,581,709	156,017	207.7	126,752	3,082,778	225.4	448,549	9,052,458
Utah	4,194,708	2,132,691	4,066,790	3,708,218	186,500	382.4	1,419,415	315,217	815,800	147.8		289,242	14.3	171,273	841,149
Vermont	1,867,573	948,007	1,693,757	1,612,697	10,073	85.0	637,898	250,728	356,949	33.4		152,938	8.2	4,148	428,047
Virginia	7,416,757	3,765,387	5,905,216	5,723,782		366.6	1,589,870	1,046,462	203,179	35.3	37,930	1,304,171	51.3	608,582	2,258,037
Washington	6,115,867	3,106,412	5,465,044	5,421,605		187.6	1,402,324	600,384	801,940	39.5	1,485	943,088	48.8	92,394	1,361,384
West Virginia	4,474,234	2,280,335	2,843,066	2,826,873		100.5	2,068,438	1,502,458	499,608	69.0	59,263	208,412	7.5	85,640	1,572,315
Wisconsin	9,724,881	4,941,837	9,326,841	8,981,593	55,500	435.8	1,194,281	517,827	522,249	48.2	82,822	585,243	23.8	142,640	3,778,845
Wyoming	4,501,327	2,287,712	4,431,772	4,118,516	67,583	639.0	1,153,256	290,605	835,327	133.3		367,899	74.3	92,205	1,016,903
District of Columbia	1,918,469	973,842	1,657,535	1,635,888	21,647	12.4	696,132	250,164	445,968	4.6		312,510	1.8	32,417	193,717
Hawaii	1,871,062	949,778	254,428	178,070		10.9	1,943,876	1,615,564		32.9	66,000		.7	11,428	949,778
TOTALS	394,000,000	200,000,000	295,632,066	273,836,383	2,141,406	18,840.3	156,599,070	101,733,653	37,283,310	7,279.8	7,807,067	39,044,138	2,891.7	10,622,897	121,531,146