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U. S. DEPARTMENT OF AGRICULTURE

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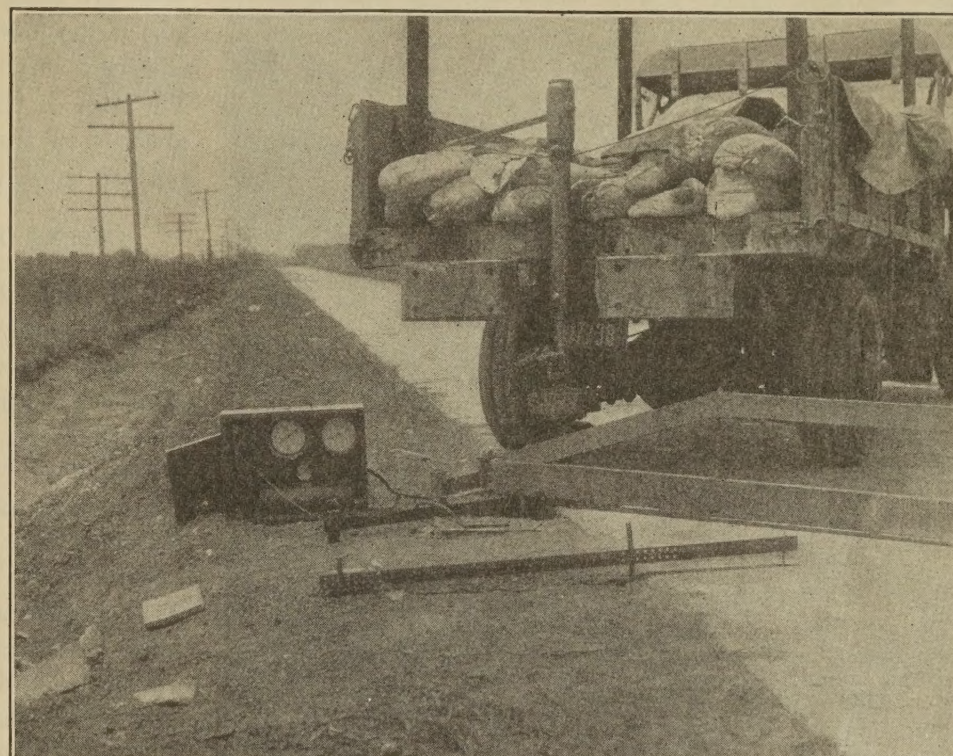
PRELIMINARY REPORT ON THE BATES EXPERIMENTAL ROAD.

By CLIFFORD OLDER, Chief Engineer, and H. F. CLEMMER, Engineer of Tests, Illinois Highway Department.

THE Bates experimental road which has been constructed by the division of highways, Illinois department of public works and buildings, in cooperation with the United States Bureau of Public Roads, has for its purposes: First, the determination, in so far as possible, of the resistance of the various kinds and types of pavements to heavy motor-truck traffic; and, second, the securing of such data and information as will enable the highway engineer to attempt the design of road surfaces with some degree of confidence and accuracy. There can be no question as to the need for such information. In fact, the proper expenditure of the large sums available for highway work in the United States to-day is dependent upon securing it.

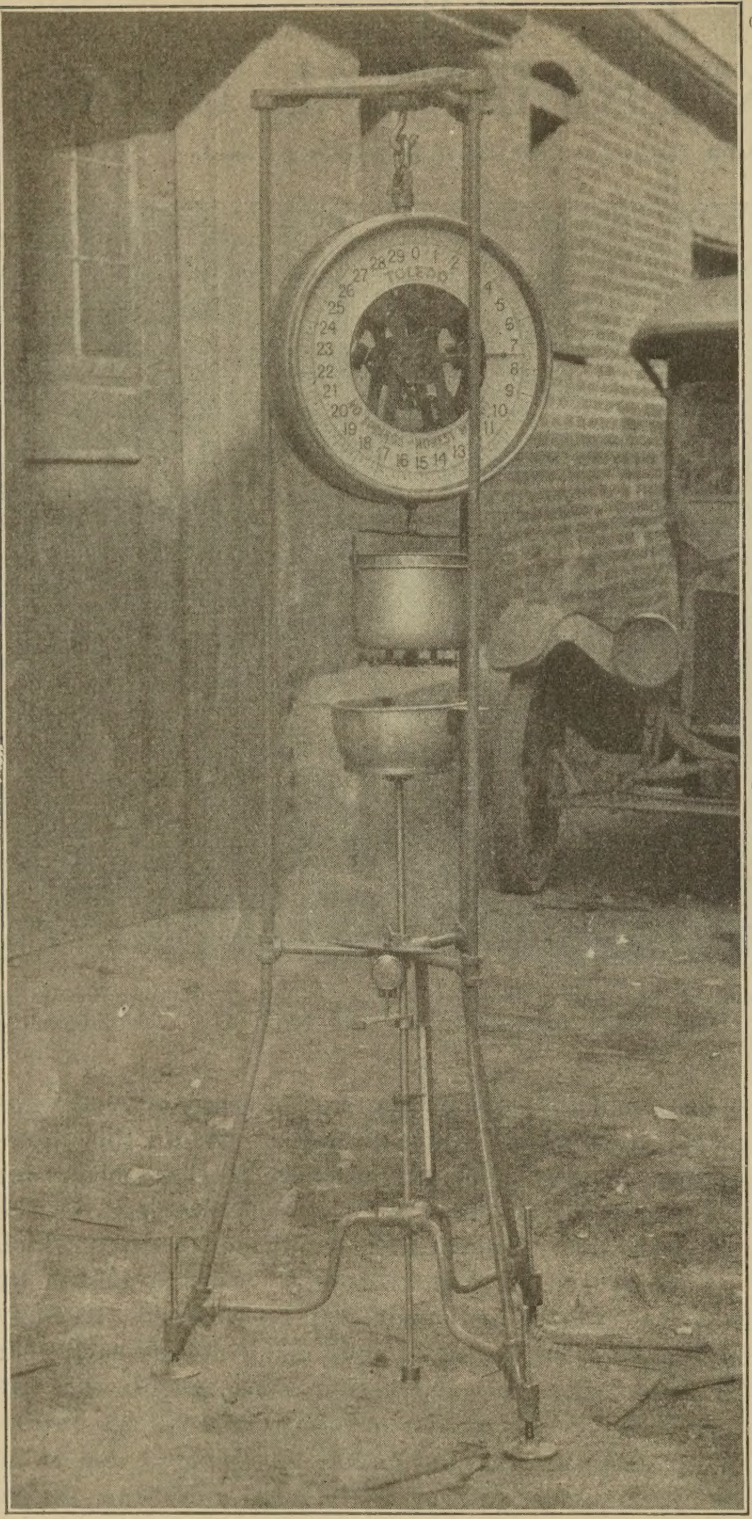


SET-UP FOR OBTAINING INFORMATION ON DEFLECTION OF PAVEMENT, SHOWING METHOD OF LOADING, AMES DIAL SUPPORTS AND APPARATUS FOR READING PRESSURE CELLS.

Of course, the ultimate aim of all highway research and investigation is to secure such information as is necessary for the comprehensive design of roads. Although extensive work along these lines has been carried on by the various highway agencies throughout the country for some time, the problems to be solved cover such a large field that it will probably be some time before the data can be so correlated as to be of material assistance to the engineer. Because of this fact, and also because of the immediate need for information necessary for the proper selection of pavements, it was considered that the quickest and best way of securing such information was to construct a road comprised of sections representing the various kinds of pavements and types of construction now in use or advocated, and submit this road to traffic of the character that must be resisted by our present-day highways. This is the principal reason for the construction of the Bates road.

After the proper time has been allowed for the road to season it is planned to subject it to a rigidly controlled truck traffic. The trucks are to be carefully weighed, and the weights will be gradually increased from a light load to one 50 per cent greater than that allowed by the present Illinois highway laws. The number and weight of loads required to produce failure in the various sections will then be an index of the behavior of the various types of pavements when subjected to different kinds of traffic. While this information in itself will not contribute to that needed for the design of pavements, it is, nevertheless, of the utmost value. Knowing the conditions of traffic which are to be accommodated, it will afford a means by which a proper pavement can be selected. It may also lead to the saving of millions of dollars each year by preventing the construction of pavements that are found to be incapable of resisting modern traffic. While this information should be of particular value to all engineers dealing with such conditions as are found in the corn-belt area of Illinois, it should also be of considerable value to every one interested in the proper construction of roads.

For the future design of roads it is necessary to go further and determine as well as possible why certain pavements fail and also why other types satisfactorily resist forces produced by traffic or other agencies. The Bates road furnishes an unparalleled opportunity for such study because of the fact that considerable time is available for the taking of observations in the absence of traffic. Owing to the fact that every road carries traffic, it has been more or less impossible up



PENETRATION MACHINE.

to the present time to determine just what effect is produced by climatic conditions. It is therefore proposed to make a comprehensive investigation of the behavior of the various sections in the absence of traffic, paying special attention to the effects of temperature and moisture on both the surface and the subgrade, both with and without artificial loading. This study will be divided in two distinct parts. First, the effect of temperature upon the surface itself; and, second, the effect of temperature and moisture on the subgrade.

The so-called subgrade failure which is so widely discussed at present is in most cases not a subgrade failure at all. Generally it is a surface failure which occurs because the pavement is laid without a proper knowledge of the behavior of the subgrade. No pavement can be designed properly until the conditions of support offered by the subgrade at all times of the year are determined, and these conditions of support are dependent not only upon the behavior of the subgrade but also upon the action of the pavement. The aim of the investigational work carried on in the absence of traffic on the Bates Road is to secure information upon the above conditions and their effects.

TYPES OF PAVEMENT TO BE INVESTIGATED.

The Bates Road, which was selected for the experiments, is laid out on a relocation 2½ miles long, extending east and west and parallel to the Wabash Railroad, about 12 miles southwest of Springfield, Ill. The fact that the road lies on a new location and that the old road will accommodate traffic for any reasonable period permits the closing of the test road to all but the carefully controlled test traffic which is to be applied to it. There are no curves in the alignment. The grades vary from zero to four-tenths of 1 per cent with an average grade of one-tenth of 1 per cent, the maximum and minimum grades extending over very short distances. The subgrade soil is uniformly a brown silt loam, except for two small stretches where it more nearly approaches gumbo.

The road is surfaced with 7 general types of pavements as follows:

1. Portland cement concrete.
2. Three and four inch lug brick constructed monolithic with a Portland cement concrete base.
3. Three and four inch lug brick constructed semimonolithic with a Portland cement concrete base.
4. Three and four inch bituminous-filled lug and lugless brick on Portland cement concrete base.
5. Three and four inch bituminous-filled lug and lugless brick on macadam base.
6. Asphaltic concrete with and without binder course on Portland cement concrete base.
7. Asphaltic concrete with and without binder course on macadam base.

The series of test sections for each type or design cover all reasonable variations in strength that might be expected to give any degree of satisfaction under heavy traffic. Each series begins with a section roughly estimated to be equivalent in strength to 4 inches of concrete and increases to the approximate equivalent of 9 inches of concrete. In comparing the strength of concrete pavements with other types, the following assumptions were made:

1. That a brick pavement constructed monolithic or semimonolithic with concrete base has a strength equal to that of a concrete pavement of the same thickness and of the

same quality of concrete as that used in the monolithic brick base.

2. That bituminous-filled brick on a concrete base has a strength equal to that of a concrete slab having a thickness equal to that of the base plus one-half of the thickness of the brick surface.
3. That bituminous concrete surfaces of 2-inch wearing course, or 1½-inch wearing course with 1½-inch binder course, have strength equal to 1 inch of concrete.

Table No. 1 furnishes a detailed description of the various types of pavements with their location in the road.

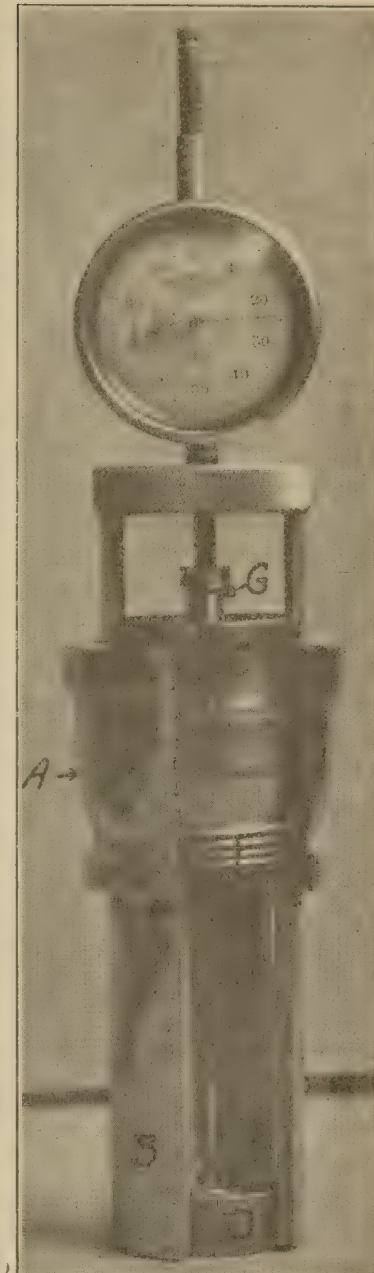
SUBGRADE TESTED BEFORE LAYING PAVEMENTS.

In order that the department might have absolute control over all construction, it was deemed best to do the work with the department's forces rather than by contract. Actual work was begun on June 7, 1920, when grading and culvert construction were started, but it was not until August 2 that the first concrete surface was poured.

Since the experiment is essentially a comparison of the strengths of the various pavement sections, and since the strengths are affected by subgrade conditions, every effort was made to secure uniform subgrade throughout. To accomplish this the road was first rough graded to somewhere near the correct elevation. The whole area of the subgrade, including an additional foot of width on each side of the pavement, was then plowed to a depth of 6 inches, harrowed, and rolled with a three-wheel, 10-ton roller, the roller making not more than two trips over any area. After the side forms had been set to line and grade, the subgrade was carefully finished by hand, and a wooden template riding on the side forms was used to guide the finishing. For the purpose of determining the uniformity of the subgrade under each of the 63 sections comprising the road, observations were made for moisture content and bearing power of soil under both static and impact loads at points 25 feet apart along the center of the roadway. These observations were made immediately before pouring of the concrete. In addition, samples of the subgrade, secured from different points along the road, were sent to the United States Bureau of Public Roads for soil analysis and laboratory determinations of bearing power.

SURFACING MATERIALS CAREFULLY TESTED.

During the construction of the pavements notes were taken daily on all conditions that were thought to affect the setting and curing of the road sections. The condition of the subgrade in the morning, especially after rains, was reported, and any change in the weather during the day as well. The consistency of the concrete at different times, with an average for the day, and the presence of water in the aggregates that would effect the consistency were made part of the record. All mechanical delays caused by the mixer, tamper, and finisher were noted, and where hand finishing was necessary the fact was recorded. Other data pertinent to the specimens, as the proportions of the mix, a description of the type of pavement represented, and brief mention of the character of the aggregate and cement used, were recorded.



ILLINOIS SUBGRADE TESTING CYLINDER.

All materials used in the construction were carefully sampled and tested to determine their physical characteristics, and in addition, test specimens of the concrete and other pavement types were made up from the materials entering into the pavement.

On each 200-foot section of concrete pavement or base the following test specimens were prepared: Three slabs for determination of transverse strength; 9 cylinders for compression strength test; and 3 slump test specimens. In order to duplicate as nearly as possible the actual conditions of construction, concrete for these specimens was taken from batches during the run of the day's work. When the pavement forms were ready for filling, samples of the aggregates were taken from the loaded wheelbarrows for the batch selected, a cement sample was taken from the skip of the mixing plant, and the temperature of the feed water was determined. At the discharge of the batch, the boom was swung to the special mixing board and an amount of material sufficient for one slab, three cylinders, and the slump test was deposited. The boom was then returned to the road and the balance of the batch dumped on the subgrade. After initial tamping a shovel full of this concrete was placed in a bucket of water for a wash-mix sample. This wash-mix sample, which is merely the concrete with the cement removed, was taken as a check to determine whether the concrete as mixed actually embodied all the requirements of the mix for that particular section. The sample is prepared in the field by washing the shovel full of concrete in water a number of times, and screening over a 100-mesh sieve to remove the cement. While it is not possible to remove all the cement particles, nor to prevent the loss of some fine sand, the discrepancy may be considered negligible. The value of this form of sample would lie not so much in the individual analysis but rather in the average of a large number of samples.

The transverse slabs were prepared in steel forms with inside measurements of 8 by 12 by 30 inches, while the compression cylinders were made in field forms of parafined strawboard, giving a specimen 6 inches in diameter and 12 inches in height. The specimens were made up as rapidly as possible, rarely more than 20 minutes being required to complete the slab and 3 cylinders. In order to eliminate the personal factor the labor of preparing the specimens was divided so that one man ran the slump test for every batch, a second man did all the tamping, a third the finishing, etc., for every specimen.

The test pieces were removed from their forms on the following day, marked with serial number, date, and station, and then placed, one slab with three cylinders, at the edge of the pavement opposite the section they represented. If the pavement was being cured by ponding, the specimens were covered with water for the same period as the sections of the road they represented. In other cases moist earth was used as a covering where that method of curing was employed on the road. Record was made of the time of moving the specimens and whatever conditions affected the pavement were simulated in the treatment of the specimens. Thus, if on a hot morning the pavement was protected from the sun by canvas, then the test pieces were given the same treatment. Wherever possible the cylinders were cured in water for 28 days.

It is planned to leave the concrete slabs buried in the road shoulders until the section represented is tested by artificial traffic. The slab will at that time be removed to the laboratory and broken on a Riehle testing machine to determine the maximum transverse strength. The slabs are for the most part of Portland cement concrete, varying only in mix and aggregates with the sections they accompany. In special sections test pieces were made so as to incorporate the features of the pavement, as monolithic brick, concrete with mesh reinforcing, concrete with an addition of calcium chloride, or concrete with asphaltic concrete surface.

One of the 3 cylinders buried with each slab is broken in the laboratory for maximum compression strength when 4 months old, the second after a period of 8 months, and the third will be broken with the transverse slab at the time of testing the road.

The construction of all the pavement sections is now completed. The preliminary subgrade tests have been made, and the pavement test specimens are being tested at the appointed periods. The pavements are now under observation to determine the effect of temperature and moisture in the absence of traffic, and the next step will lead to the tests under traffic.

THE BEARING POWER OF THE SUBGRADE.

In the study of bearing power of the subgrade an attempt was made to compare the bearing power of the soils under impact as well as static loads. Comparison of the bearing power just before the pavement was laid and at various times after pouring the concrete was also attempted. The points at which the bearing power determinations were made were located 20 feet apart along the center line of the road on the completed subgrade, and after the pavements were laid the determinations were made through the testing cylinders which will be described later.

The impact determinations were made with the Goldbeck apparatus shown in the photograph on page 9. The apparatus consists of a steel footing 7 square inches in base area into which is fitted a ½-inch steel rod about 3½ feet long. On the rod, fitted loosely so that it can be dropped from any height, is a steel cylinder of 10 pounds weight. The impact can be varied by dropping this weight from different heights. The depth of penetration is measured from a string stretched tightly between two steel rods driven firmly into the ground and set 2 feet apart. On this string, which just clears the side of the rod, is suspended a small level. After any number of drops of the weight

TABLE I.—*Detailed descriptions, by sections, of materials and construction used on the Bates Experimental Road.*

LUG AND LUGLESS BRICK, BITUMINOUS FILLER, MACADAM BASE.

Number of section.	Length.	Thickness of brick.	Cushion.	Base course. Thickness.	Base course. Coarse aggregate.	Total thickness of pavement.	Remarks.
	Feet.			Ins.		Ins.	
1A	100	3-inch lug	2-inch sand	4	Crushed limestone.	9	1-course base.
1B	100	3-inch lugless	do	4			
2	100	4-inch lug	do	4	do	10	Do.
3	100	4-inch lugless	do	4	do	10	Do.
4	100	4-inch lug	1-inch mastic	8	do	13	2-course base.
5	100	3-inch lugless	2-inch mastic	8	do	13	Do.

ASPHALTIC CONCRETE, MACADAM OR NOVACULITE BASE.

Number of section.	Length.	Wearing course.	Base course.	Total thickness of pavement.	Remarks.
	Feet.			Inches.	
6	200	2-inch Topeka	10-inch macadam [1]	12	2-course base.
7	200	do	8-inch macadam [1]	10	Do.
8	200	1½-inch Topeka; 1½-inch binder	5-inch macadam [1]	8	1-course base.
9	200	2-inch Topeka	6-inch macadam [1]	8	Do.
10	200	do	4-inch novaculite	6	Do.
11	200	do	4-inch macadam [1]	6	Do.

[1] The coarse aggregate for the macadam base is crushed limestone.

Table 1.—*Detailed descriptions, by sections, of materials and construction used on the Bates Experimental Road*—Continued.

ASPHALTIC CONCRETE, PORTLAND CEMENT CONCRETE BASE, 6-INCH CURBS.

Number of section.	Length.	Wearing course.	Base course.			Total thickness pavement.	Remarks.
			Thickness.	Coarse aggregate.	Mix.		
	Feet.		*Ins.*			*Ins.*	
12A	200	2-inch Topeka.	4	Crushed limestone.	1-3-5	6	None.
12B	25	.....do	5	.....do	1-3-5	7	Do.
13	200	1½-inch Topeka; 1½-inch binder.	4	.....do	1-3-5	7	Do.
14	200	2-inch Topeka.	4	.....do	1-2-3½	6	Do.
15	200	1½-inch Topeka; 1½-inch binder.	4	.....do	1-2-3½	7	Do.
16	200	2-inch Topeka.	5	.....do	1-3-5	7	Do.
17	200	2-inch Topeka.	5	Crushed limestone.	1-2-3½	7	None.
18	200	1½-inch Topeka; 1½-inch binder.	5	.....do	1-2-3½	8	Do.
19	200	2-inch Topeka.	6	.....do	1-3-5	8	Do.
20	200	.....do	6	.....do	1-2-3½	8	Do.
21	200	.....do	7	.....do	1-2-3½	9	Do.
22	200	1½-inch binder; 1½-inch Topeka	8	.....do	1-2-3½	11	Do.

LUG AND LUGLESS BRICK, BITUMINOUS FILLER, PORTLAND CEMENT CONCRETE BASE, 6-INCH CURBS.

Number of section.	Length of section.	Thickness of brick.	Cushion.	Base course.			Total thickness of pavement.	Remarks.
				Thickness.	Coarse aggregate.	Mix.		
	Feet.			*Inches.*			*Inches.*	
23A	100	3-inch lug	1-inch sand	6½	Crushed limestone	1-2-3½	10½	None.
23B	100	3-inch lugless	.....do	6½		1-2-3½	10½	Do.
24	100	3-inch lug	.....do	5½	.....do	1-2-3½	9½	Do.
25	100	3-inch lugless	1-inch mastic	5½	.....do	1-2-3½	9½	Do.
26A	100	4-inch lug	1-inch sand	4	.....do	1-2-3½	9	Do.
26B	100	4-inch lugless	.....do	4	.....do	1-2-3½	9	Do.
27	100	3-inch lug	.....do	4½	.....do	1-2-3½	8½	Do.
28	100	3-inch lugless	.....do	4½	.....do	1-2-3½	8½	Do.
29A	100	3-inch lug	.....do	4½	.....do	1-3-5	8½	Do.
29B	75	3-inch lugless	.....do	4½	.....do	1-3-5	8½	Do.
30	125	3-inch lug	.....do	3½	.....do	1-2-3½	7½	Do.
31	100	3-inch lugless	1-inch sand-cement	3½	.....do	1-2-3½	7½	Do.
32A	100	3-inch lug	1-inch sand	3½	.....do	1-3-5	7½	Do.
32B	100	3-inch lugless	.....do	3½	.....do	1-3-5	7½	Do.

LUG BRICK, MONOLITHIC AND SEMIMONOLITHIC, PORTLAND CEMENT CONCRETE BASE.

Number of section.	Length of section.	Thickness of brick.	Type.	Base course.			Total thickness pavement.	Remarks.
				Thickness.	Coarse aggregate.	Mix.		
	Feet.			*Inches.*			*Inches.*	
33	200	3	Monolithic	2	Crushed limestone	1-2-3½	5	
34A	200	3	Semimonolithic	2	.....do	1-2-3½	5¾	¾-inch sand-cement bed.
34B	50	(1)	(1)	(1)	(1)	(1)	6	
35	200	4	Monolithic	2	Crushed limestone	1-2-3½	6	
36	200	3	.....do	3	.....do	1-3-5	6	
37	200	3	.....do	3	.....do	1-2-3½	6	
38	200	4	.....do	3	.....do	1-2-3½	7	
39	200	4	.....do	4	.....do	1-3-5	8	

[1] Portland cement, standard design.

PORTLAND CEMENT CONCRETE.

Number of section.	Length.	Thickness.	Coarse aggregate.	Mix.	Special features.
	Feet.	*Inches.*			
40	200	9	Crushed limestone	1-2-3½	None.
41	150	8	.....do	1-2-3½	Transverse dividing planes every 25 feet. Longitudinal dividing planes full length of section.[1]
42	150	8	.....do	1-2-3½	None.
43	150	7	.....do	1-2-3½	Transverse dividing planes every 25 feet. Longitudinal dividing planes full length of section.[1]
44	150	7	.....do	1-2-3½	None.
45	100	6	.....do	1-2-3½	Transverse dividing planes every 25 feet. Longitudinal dividing planes full length of section.[1] Pavement reinforced with circumferential reinforcing in 25 by 9 foot sections.[2]
46	100	6	.....do	1-2-3½	Transverse dividing planes every 25 feet. Longitudinal dividing planes full length of section.[1] Pavement reinforced with circumferential reinforcing in 25 by 18 foot sections. Transverse rods passed through longitudinal dividing plane. No longitudinal rods adjacent to longitudinal dividing plane.
47	100	6	Crushed limestone	1-2-3½	Transverse dividing planes every 25 feet. No longitudinal dividing plane.[1] Pavement reinforced with circumferential reinforcing in 25 by 18 foot sections.[2]
48	100	5	.....do	1-2-3½	Special features same as section 45.
49	100	5	.....do	1-2-3½	Special features same as section 46.
50	100	5	.....do	1-2-3½	Special features same as section 47.
51	100	6	.....do	1-2-3½	Wire mesh reinforcing used.[3]
52	200	6	.....do	1-2-3½	None.
53	100	5	.....do	1-2-3½	Wire mesh reinforcing used.[3]
54	200	5	.....do	1-2-3½	None.
55	200	5	Gravel	1-2-3½	Do.
56	200	5	Crushed limestone	1-2-3½	4 per cent calcium chloride incorporated in 125 feet; 2½ per cent calcium chloride used in 75 feet.
57	200	5	.....do	1-2-3½	Cemite cement used.
58	200	[4] 4; [5] 4	.....do	1-2-3½	4-inch rolled stone base course.
59	200	4	.....do	1-2-3½	Cemite cement used.
60	200	4	.....do	1-2-3½	2½ per cent clacium chloride incorporated.
61A	100	4	.....do	1-2-3½	Hydrated lime 7½ per cent.
61B	100	4	.....do	1-2-3½	None.
62	200	4	.....do	1-2-3½	Standard section.
63A	150	7	Gravel	1-2-3½	None.
63B	50	7	Crushed limestone	1-2-3½	Do.

[1] Transverse and longitudinal dividing planes were formed by setting on edge strips of horizontally corrugated galvanized iron. The strips were 6 feet long and had a width 1 inch less than the thickness of the pavement. The width of the corrugations was 3 inches; the depth 1 inch. The metal was 16 gauge and the weight of galvanizing was 2 ounces per square foot.

[2] All bar reinforcing consisted of three-quarter inch round deformed bars placed 2 inches from the top of the slab and 6 inches in from the edges of the section with a 3-inch lap at intersections.

[3] The wire mesh reinforcing weighed approximately 45 pounds per 100 square feet. The total effective longitudinal sectional area in square inches per foot of width was 0.093 and the sectional area of the longitudinals in square inches per foot of width was 0.087.

[4] Concrete.

[5] Stone.

CONCRETE SLABS USED FOR OBTAINING INFORMATION ON BEARING POWER OF SOIL.

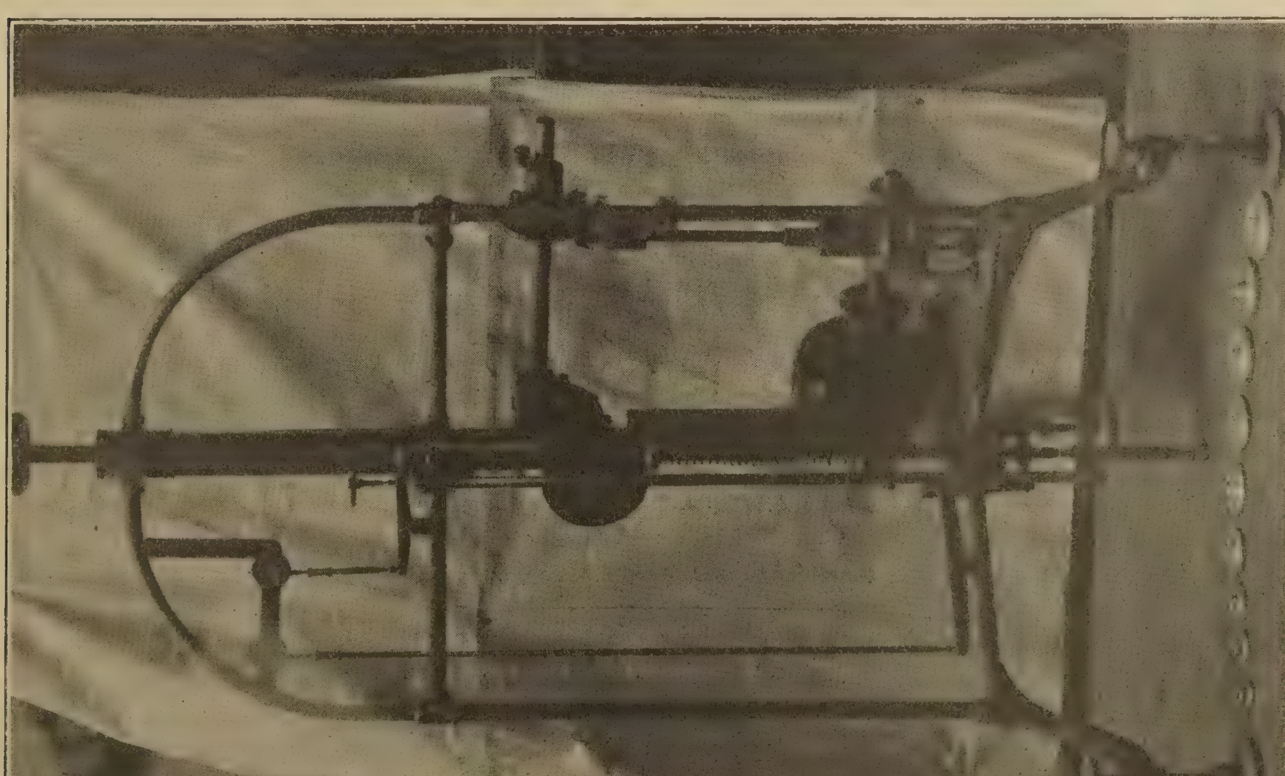
the distances are measured from the string to a given point on the rod with a 6-inch engineer's scale, and are recorded to one one hundredth of an inch.

A special apparatus for making the static-load determinations has been designed by the Illinois highway division. As shown in the illustration on page 4, this apparatus consists of a three-legged iron pipe frame from which is suspended a Toledo automatic hanging scale supporting a pail which contains about 30 pounds of shot. The load is applied to the subgrade by means of a ½-inch steel rod terminating in a shoe ½ inch in diameter on the bottom tapered back to ⅜ inch, ⅛ inch above the bottom. On the top of this rod is a pan which receives the shot from the pail which hangs on the scale, described above. An Ames dial, connected to the frame, with its plunger resting on the support attached to the ½-inch rod, measures the depth of penetration as well as any upward movement of the rod due to elasticity of the soil. A thumb screw set in the frame enables the operator to stop the rod at will. At the 20-foot distances on the center line of the road an initial reading was taken with the footing resting on the subgrade without any load, after which the shot was released and readings were taken for total loads of 10, 20, and 30 pounds. Additional readings were taken for 2 minutes at intervals of 30 seconds under the 30-pound load. The load was then removed and the upward movement of the rod, due to the elasticity of the soil, was measured. The 30-pound load delivered a weight of 150 pounds per square inch to the subgrade. To determine the bearing power after the pavement had been laid, measurements of the penetration under static load were taken through the testing cylinders set in the pavement as well as at points 50 feet apart along the edge of the pavement. For making these observations the static bearing power apparatus was used, with a shoe 1 square inch in area attached. This shoe was used to bring the range of pressure delivered to the subgrade to from 3 to 30 instead of 15 to 150 pounds per square inch. In these observations special attention was paid to time of recovery of the soil after the pressure was removed.

INVESTIGATIONS OF THE BEHAVIOR OF SOILS WHEN SUBJECT TO REPEATED LOADS.

In addition to the observations made for determining the bearing power of the subgrade when subjected to static and impact loads, it is desired to know the effect produced by a load application which more nearly approximates the actual conditions brought to the subgrade when a truck wheel passes over a rigid surface. In this case the load is not, in the strictest sense, a static load, and when the road surface is very smooth there is possibly very little impact. The actual force delivered to the subgrade starts at zero when the influence of the load is first carried through the slab, becomes a maximum when the load is directly over a given point and again diminishes to zero after the wheel has passed some distance beyond the point. From observations made November, 1920, on 7-inch surfaces it was indicated that the influence of an 8,000-pound wheel load was felt through a distance of 17 feet on each side of the wheel. This would mean that the pressure produced at any point by a truck running at a moderate rate of speed would increase from zero to the maximum pressure in about one second, and decrease from the maximum to zero in the next second. The repeating load machine, which is shown in the illustration on page 9, was designed to approximate the above condition. The apparatus consists of a pipe frame in which is mounted a cam and spring for producing pressure and a plunger through which this pressure is delivered to the soil. The cam is driven by a one-sixteenth horsepower motor to which power is supplied by a generator set, which is carried in a motor truck. By means of a scale along which a pointer on the spring moves, any desired pressure is registered. The cam revolves at a rate which will produce 10 applications per minute. The movement of the plunger, which is identical with the movement of the soil under the pressure, is shown by an Ames dial. A second Ames dial is used to regulate the machine so as to keep the pressure constant. The different footings, as shown in the illustration, range in area from 1 to 10 square inches. The effect produced upon a soil by these repeated loadings is assumed to be very much like that produced upon a subgrade when a number of trucks travel over a rigid surface. It is supposed therefore that the behavior of the soil under the plunger will be

GOLDBECK IMPACT SUBGRADE DETERMINATOR.



ILLINOIS REPEATING LOAD DETERMINATOR.

METHOD OF OBTAINING DEFLECTION AND DEFORMATION OF PAVEMENT UNDER LOAD WHEN SUBGRADE HAS BEEN REMOVED.

very much like that of the subgrade under a load. By means of this apparatus the data can be secured on the action of the soils of different densities and moisture contents when subject to repeated loads. To obtain some light on the effect of applying loads on areas of different sizes the different footings are used. These footings are loaded from 10 to 50 pounds per square inch, the loads being varied by means of an adjusting screw at the top of the frame.

In addition to the above-described devices for obtaining information on bearing power of subgrades, observations are also being made on the effect of loads applied to concrete slabs 3 feet in diameter. These slabs are placed on the shoulders directly opposite the pavement sections on which it is proposed to run a series of slab deformation and deflection tests. These circular slabs are subjected to repeated loads of such magnitude as to deliver 10 pounds per square inch pressure to the subgrade and the resulting permanent and temporary settlements are observed by means of Ames dials. The load is applied by a jack placed under the rear of a loaded truck. Information is being secured under conditions of subgrade ranging from normally dry to artificially saturated, the saturated condition being effected by keeping small ditches, around the sides of the slabs, filled with water.

ILLINOIS SUBGRADE TESTING CYLINDER.

The special subgrade testing cylinder, shown on page 5, has been designed for study of the relative movements of the slab and subgrade. When the last of the cylinders have been set there will be approximately 800 of them in use. They consist of a 1½ by 1¼ inch black iron reducer (A), a short length of 1¼-inch black iron pipe (B), a ½ by 1¼ inch brass disk (D), a short sleeve of 1-inch black iron pipe (E), and a special ¼ by 1¼ inch brass bearing plug (F). Reducer (A) is flush with top of the pavement and disk (D) rests freely on the subgrade. The lengths of the pipe (B) and sleeve (E) vary with the thickness of the pavement in which the cylinders are used.

In the concrete sections these cylinders were installed when the pavement was constructed. In the bituminous concrete and brick pavements they were installed after construction of the pavement by boring holes with a Calyx core drill and grouting around them with care so as to assure satisfactory contact with the adjacent pavement.

The brass bearing disk (D) follows the downward movement of the pavement and the upward movement of the subgrade so that any separation between the subgrade and the bottom of the pavement due either to rutting caused by traffic or occasioned by moisture or frost conditions can be learned by measurements taken from this plug.

The device for reading the change in position of the bearing plug in relation to the pavement is shown very clearly in the illustration. It consists of an Ames dial fastened in a support (C) which rests on the stationary brass disk (F) and a rod (G) which fits into a small circular depression in the center of the bearing plug (D).

The difference between initial readings taken as soon as possible after the testing cylinders are placed and readings taken at subsequent times shows any change in position between the subgrade and the pavement.

These bearing plugs can also be used to obtain data on bearing power of subgrade by loading them with with the plunger of the static bearing power determinator.

By removing the brass bearing plug and iron sleeve, these cylinders afford an excellent means of obtaining subgrade samples for moisture content determination. Also the brass bearing plugs in the cylinders give excellent points for taking precise levels so that the amount of heaving or settling can be determined.

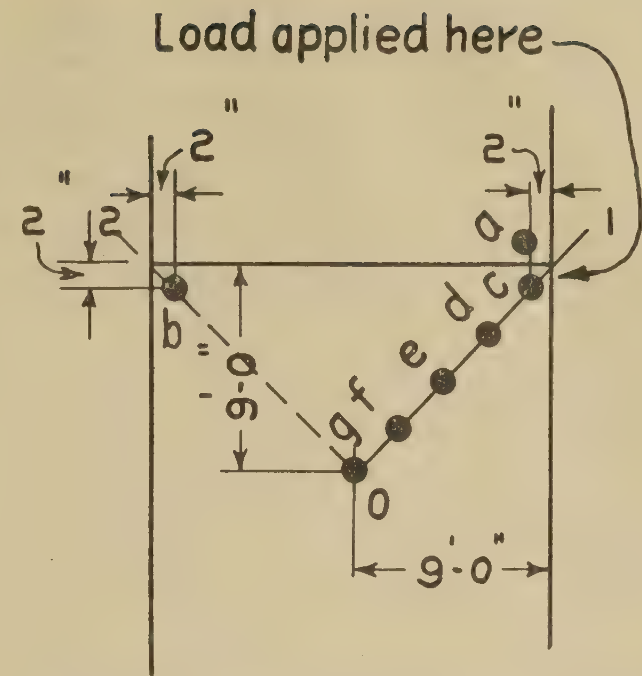
The testing cylinders are set in rows of 3 and 5 across the pavement, the rows being 25 feet apart. When 5 cylinders are set in a row they are placed in the center, at the quarter points, and 18 inches from the edges, and when 3 are used, the ones at the quarter points are omitted.

PRECISE LEVELS ON PAVEMENT.

Bench marks, made by driving a 3-inch iron pipe 4 feet long approximately 3½ feet under the ground, were established every 600 feet along the road. The inner core of the earth was then reamed out with a large auger, and a 1-inch square rod 6 feet long was driven through the pipe, thus allowing the rod to penetrate the ground below the pipe for a distance of at least 2 feet. Small holes were then drilled in the top of the 1-inch rod and a cap was placed on the 3-inch pipe. Small holes were drilled in the inner brass plug of the subgrade cylinders in order to provide permanent points for taking levels on the pavement. Three cylinders were used at every level station, the cylinders taken being those at the two edges of the pavement and center. The level stations were approximately 75 feet apart. An ordinary Beckman Wye level was used together with a New York level rod reading to 0.001 of a foot. The rod was plumbed for all readings by means of a small rod level. Since the level points consisted of small holes it was necessary to equip the rod with an attachment whereby the zero point of the rod might rest in the small hole. Therefore a small steel rod about 2 inches long, rounded at the end, was attached to the bottom of the level rod. Levels were taken over the pavement points about once every week and at such additional times as it was deemed advisable due to temperature and weather changes.

DETERMINATION OF MOISTURE CONTENT.

For the purpose of obtaining data on the effect of moisture content on the bearing power of soils, samples were taken from the subgrade for moisture content determination at every location where observations for bearing power were made. These samples were inclosed in sealed cans and weighed immediately upon reaching the laboratory. It was first attempted to weigh the sample in the field, but owing to difficulties encountered this method was abandoned after one trial. Ordinarily the weight of one sample was between 300 and 400 grams. Before the sample was placed in the oven the soil was broken into small pieces. The oven was an ordinary gas oven with thermometer attached, except that in later determinations an electric furnace was used. After heating, in many cases, small and very hard lumps were found; when these were broken and inspected it was to be seen that all the moisture had not been driven from the sample. When such conditions were found a second heating showed considerable loss and a third and fourth heating were often needed. As a rule when a moisture content of between 12 and 17 per cent was obtained, two dryings were all that was necessary to give a constant weight. The temperature of the ovens was kept constant between 100° and 110° C. If the temperature was allowed to rise above 110° and permitted to remain for any length of time, a certain amount of



SKETCH SHOWING LOCATION OF OBSERVATION POINTS ON EACH SLAB.

organic matter was apt to be driven off, thereby introducing an error into the determination. The samples were heated for a period of from 6 to 12 hours and even longer, but 12 hours seemed to be the best length of time for heating.

THE STUDY OF THE SUBGRADE BY MEANS OF SOIL PRESSURE CELLS.

The Goldbeck soil pressure cells provide a very convenient means for measurement of pressure in inaccessible places, such as road surfaces against subgrades. Twenty-six of the cells have been installed in the Bates road. For further information regarding this apparatus see "The Distribution of Pressure Through Earth Fills," by A. T. Goldbeck, Proc. A. S. T. M., 1917.

TESTS OF SURFACE BEHAVIOR DUE TO CLIMATIC CHANGES.

Preliminary to the testing of the road by means of loaded motor trucks information is being sought on (1) the behavior of the various kinds of surfaces when subjected to climatic changes, repeated loads and different subgrade support, and (2) the distribution of loads across joints and through pavement sections of different thicknesses and types.

For obtaining data on deflection of the various sections when subjected to different temperatures as well as to repeated loads, 8 Ames dials are set on any slab, as shown in the illustration on this page. The following procedure is used in each case. The dials *a* and *b* are independently supported while *c*, *d*, *e*, *f*, and *g* are set in a beam which rests on two supports, one placed on the shoulder and the other placed on the subgrade through a hole in the center of the slab. Two ther-

(Continued on page 22.)

U. S. SUPREME COURT UPHOLDS STATE TAXATION OF GASOLINE

By W. J. O'LEARY, Assistant in Road Management, Bureau of Public Roads.

A TAX on gasoline for the purpose of raising road revenues is now imposed in at least 11 States, as follows:

State.	Amount of tax.	Law authorizing tax.
Arizona	1 cent per gallon	Chap. 116, Session Laws of 1921, approved Mar. 17, 1921.
Arkansas	do	Act 606, Laws of 1921.
Colorado	do	Chap. 168, Laws of 1919.
Georgia	do	Act approved Aug. 10, 1921.
Kentucky	do	Chap. 93, Laws of 1920.
New Mexico	do	Act approved Mar. 10, 1921.
North Carolina	do	State Road Law, approved Mar. 3, 1921.
Oregon	2 cents per gallon	Chap. 159, Laws of 1919, and Chap. 412, Laws of 1921.
Pennsylvania	1 cent per gallon	Act 368, approved May 20, 1921; effective Sept. 1, 1921.
South Dakota	do	Chap. 292, Laws of 1921, effective Jan. 1922.
Washington	do	Chap. 173, Laws of 1921.

The new constitution of Louisiana adopted by the constitutional convention June 18, 1921, provides that the legislature shall levy, in addition to other enumerated taxes, an annual tax on the sale of gasoline of not to exceed 2 cents per gallon, the proceeds of which are to be placed to the credit of the general highway fund.

It is reported that the 1921 session of the Florida Legislature passed a law taxing gasoline. No copy of the statute has been received up to the time of this writing, however, and the report can not be verified.

Some concern has been manifested by the officials charged with the enforcement of these laws as to their validity both under the State and Federal Constitutions. This point has been definitely settled by the United States Supreme Court in a suit brought by certain refining companies against the New Mexico law. The first case was decided April 19, 1920, and is known as Askren *v.* Continental Oil Co., reported in volume 252, page 444, United States Reports.

It appears that chapter 93 of the session laws of New Mexico for 1919 provided for an excise tax of 2 cents per gallon upon the sale or use of gasoline and a license tax of $50 per annum to be paid by distributors and $5 per annum by retail dealers therein. Suit was brought in the United States district court for the district of New Mexico by the Continental Oil Co., Sinclair Refining Co., and the Texas Co. for a temporary injunction to restrain the State from enforcing the provisions of the law. The temporary injunction was granted and a direct appeal was taken to the Supreme Court of the United States.

The New Mexico act defined a distributor as: "Every person, corporation, firm, copartnership, and association who sells gasoline from tank cars, barrels, or packages not purchased from a licensed distributor of gasoline in this State." The definition of retail dealer was given as: "A person, other than a distributor of gasoline, who sells gasoline in quantities of 50 gallons or less."

Failure to comply with the act was made punishable by fine and forfeiture of license. The taxes collected under the law, after paying the salaries and expenses of the inspectors, were to be credited to the State road fund.

The oil companies conduct two classes of business, (1) shipping into the State in tank cars and in barrels and packages containing not less than two 5-gallon cans, selling the contents in the State of New Mexico in the original, unbroken tanks, barrels, and packages; (2) shipping into the State in tank cars and selling gasoline from tank cars, barrels, and packages in such quantities as the purchaser requires. As to the first class of business the Supreme Court held that the tax upon the sale of gasoline brought into the State in tank cars or original packages and thus sold is beyond the taxing power of the State; that the direct and necessary effect of such legislation was to impose a burden upon interstate commerce and was a violation of the Federal Constitution, as it provided for fees in excess of the cost of inspection. As to selling gasoline in retail quantities to suit the purchaser the court held that a business of this sort, although the gasoline is brought into the State in interstate commerce, is properly taxable under the laws of the State; but as it was impossible from the bill to determine the relative importance of this part of the oil companies' business as compared with that which is nontaxable, it reserved judgment upon the question whether the act was separable and capable of being sustained so far as it imposed a tax upon business legitimately taxable. This point, however, was decided by the Supreme Court June 6, 1921, when the question was finally presented in the case of Harry S. Bowman, attorney general of the State of New Mexico, *v.* The Continental Oil Co.

The amended bill of the Continental Oil Co. showed that in addition to buying and selling gasoline it used gasoline at each of its 37 distributing stations in New Mexico in the operation of its automobile tank wagons and otherwise; that under the terms of the New Mexico act it was prohibited from using this gasoline except upon the payment of the excise tax of 2 cents per gallon therefor. The company urged that such a tax was void under section 1 of article 8 of the State constitution because not levied in proportion to the value of the gasoline; that the imposition of the tax denied the company the equal protection of the laws

(Continued on page 23.)

9,245,195 MOTOR CARS AND TRUCKS REGISTERED FIRST SIX MONTHS, 1921.

By ANDREW P. ANDERSON, Highway Engineer, Bureau of Public Roads.

A TOTAL of 9,245,195 passenger cars, trucks and commercial vehicles and also 28,114 trailers and 177,234 motor cycles were registered in the 48 States and the District of Columbia, during the six months, January 1 to July 1, 1921. As a result of these registrations and the licensing of chauffeurs, operators, etc., the several States collected during this period a total gross revenue amounting to $108,213,165.33.

While the present registration figures are not fairly comparable with those for the year 1920, it is interesting to note that on July 1 of this year there had been registered 13,244 more cars, but 61,868 less motor cycles, than were registered during the entire year 1920. Of the several States 21 already show an increase over and above the total registrations for 1920, while only 12 States show a decrease of more than 5,000 cars each. This decrease is probably due in part to leniency in enforcing the registration provisions during the present financial depression and in part to the fact that not a few people owning cars or trucks have found it financially impossible or inadvisable to operate these vehicles and have let them remain in the garage.

At the present time every State requires an annual registration of all passenger cars, trucks or commercial vehicles and motor cycles before they can be used on the public roads. Minnesota, the last State to require annual registration, passed such an act this year which became effective on April 15.

The total registration revenues collected in 1920 amounted to $102,546,212.25. The registration revenues collected to July 1 of this year amounted to $108,213,165.33, an increase of $5,666,953.08 over those collected for the entire year 1920. Of the 1920 registration revenues a grand total of $97,671,742.10, or 95 per cent of the gross receipts, was available for road work. Of the registration revenues collected during the first six months of this year $101,793,416, or 94 per cent of the gross receipts, is available for road work, either by the State highway departments or the local road officials. This apparent percentage decrease is due to the fact that in some States the funds do not become available until the close of the year. Of the total devoted to road work in 1920, 79 per cent was expended by or under the supervision of the State highway departments. During the first 6 months of 1921 this proportion had increased to 81 per cent.

TWELVE STATES HAVE PROVIDED FOR A TAX ON GASOLINE.

The motor vehicle has also proved to be an indirect source of road revenues in a large number of States. Prior to this year, Colorado, Kentucky, New Mexico, and Oregon had levied a tax on gasoline. During the present year the States of Arkansas, Arizona, Georgia, North Carolina, Pennsylvania, South Dakota, and Washington have passed a gasoline tax, while other States have the question of passing such a tax under consideration. The State of Louisiana has written such a measure into its new constitution.

Only 13 States gave definite information as to the sizes of the trucks and commercial cars registered during the six months. These data are given in Table 1. They are, however, not directly comparable due to the following reasons: So far as legislative registration enactments are concerned there is as yet no universally accepted standard as to what constitutes a motor truck. In some States all motor cars are registered on the same basis; in others only cars having solid tires are classed as trucks, while in others all motor vehicles used for carrying freight or merchandise of any kind whatever, are classed as trucks. Even those States which provide for a separate registration for motor trucks do not employ the same basis for designating the size of the vehicle. Some States use the total weight of the loaded vehicle, others the weight of the unloaded vehicle or the weight of the chassis, and still others use such indefinite bases as the horsepower, or the cost of the vehicle.

It is interesting to note, however, that of the 10 States reporting a total of 91,488 truck and commercial car registrations based on rated carrying capacity, 46.8 per cent were 1 ton or less, 48.2 per cent were between 1 and 3 ton, 4.6 per cent between 3 and 5 ton, and only 0.4 of a per cent over 5-ton capacity. Two

TABLE 1.—*Truck and commercial car registration by sizes.*

State.	Carrying capacity in tons.							Total registrations.
	1 ton or less.	1 to 3.	3 to 5.	5 to 8.	8 to 10.	10 to 12½.	12½ tons or over.	
Alabama	3,808	4,471	363	....	....	....	....	8,642
Arizona	2,880	533	60	2	....	....	....	3,475
Connecticut[1]	([2])	21,298	2,001	272	....	....	....	23,571
Maine	4,146	635	287	1	....	....	....	5,069
Minnesota[3]	9,000	4,000	....	....	....	....	....	13,000
Nebraska[4]	12,000	3,000	998	....	....	....	....	15,998
New Jersey[4]	14,549	10,268	4,745	2,948	564	....	....	34,074
New Mexico	844	281	52	1	....	....	....	1,178
Pennsylvania[5]	([2])	42,095	9,122	286	....	....	....	51,503
South Carolina	4,760	1,749	63	....	....	....	....	6,572
South Dakota[1]	([2])	[6] 7,742	[7] 64	....	....	....	....	7,806
Vermont	2,474	549	55	3	1	....	3	3,085
Wisconsin	14,965	2,899	[8] 1,235	....	....	....	....	19,099
Total	69,426	100,520	19,045	3,513	565	....	3	193,072

[1] Data for year 1920.
[2] Included in column "1 to 3."
[3] Data approximate.
[4] Distribution based on total loaded weight.
[5] Distribution based on weight of chassis.
[6] Two tons and less.
[7] Between 2 and 5 ton.
[8] Three ton and over.

TABLE 2.—*Motor-vehicle registrations and revenues, Jan. 1 to July 1, 1921.*

State.	Total car and truck registrations.	Passenger cars.	Trucks and commercial cars.	Taxis and busses.	Trailers.	Motor cycles.	Reregistrations or transfers.	Owners' and chauffeurs' licenses.	Manufacturers' and dealers' licenses.	Total gross motor-vehicle registration and license revenues.	Motor-vehicle revenues available for road work.	
											By or under State highway department.	Under direction of local authorities.
Alabama	78,761	66,252	8,867	3,642	...	778	...	4,544	1,350	$897,378.67	$874,663.27	...
Arizona	30,175	[1] 26,328	[2] 3,475	372	...	376	743	31,045	219	187,434.75	187,434.75	...
Arkansas	58,676	58,287	[3] 389	...	8	136	261	242	397	615,000.00	187,500.00	$430,500.00
California	588,863	557,231	31,632	...	2,661	15,161	90,840	801,515	2,475	6,215,936.82	2,706,652.28	2,706,652.28
Colorado	119,867	112,783	7,804	...	38	2,103	4,124	118,119	2,176	789,080.47	357,138.42	357,138.42
Connecticut	114,643	93,548	[4] 21,095	...	...	2,759	9,878	132,248	695	1,876,444.58	1,876,444.58	...
Delaware	18,800	18,800	(5)	...	56	500	...	21,416	564	338,804.00	338,804.00	...
District of Columbia	42.377	[6] 35,654	[7] 5,448	1,275	...	2,487	...	16,972	...	298,404.25	...	...
Florida	89,795	76,323	13,345	127	(8)	1,153	1,713	2,236	699	701,589.00	96,273.22	545,151.51
Georgia	118,652	118,652	(5)	...	...	1,023	238	3,739	618	1,598,355.30	1,598,355.30	...
Idaho	46,035	46,035	(5)	...	...	750	...	46,663	348	[9] 726,404.25	145,280.85	508,482.97
Illinois	580,345	512,541	67,804	...	...	7,243	...	61,027	6,511	6,238,326.70	6,221,282.05	...
Indiana	344,890	309,450	35,440	...	1,401	5,739	10,002	7,170	1,379	2,151,543.00	2,151,543.00	...
Iowa	435,356	[10] 407,084	28,272	...	313	3,406	108,000	6,790	1,687	7,343,051.32	6,792,326.00	...
Kansas	287,393	267,933	19,460	...	...	3,398	10,045	287,393	2,166	1,430,180.50	...	1,275,453.00
Kentucky	103,493	94,414	9,079	...	...	1,034	...	7,680	700	1,672,587.25	1,672,587.25	...
Louisiana *	71,000	64,000	7,000	...	...	490	...	...	...	426,000.00	...	383,000.00
Maine	66,133	57,874	8,259	...	...	1,172	3,252	82,013	712	865,688.75	658,018.75	...
Maryland	132,273	122,550	9,472	251	195	[11] 4,062	5,648	27,621	3,016	2,031,535.86	1,422,075.00	...
Massachusetts	300,027	250,778	49,249	...	401	10,013	...	204,399	1,758	3,842,593.25	[12] 1,858,250.00	...
Michigan	426,460	[13] 382,432	[14] 44,028	...	3,382	5,252	17,002	56,349	1,680	5,963,228.16	2,883,004.15	2,883,003.31
Minnesota	283,000	[15] 270,000	13,000	...	7,684	3,000	...	1,700	1,350	4,795,526.00	4,795,526.00	...
Mississippi *	56,114	48,100	8,014	...	...	122	...	...	...	700,000.00	650,000.00	...
Missouri	305,802	[16] 305,802	(5)	...	...	3,081	8,464	327,201	2,045	2,236,392.00	2,236,392.00	...
Montana	51,500	51,500	(5)	...	...	373	208	453	255	530,617.50	238,777.87	238,777.87
Nebraska	215,909	199,861	16,048	...	232	1,419	7,072	...	2,193	2,652,933.98	1,920,060.96	640,020.32
Nevada	8,688	8,688	(5)	...	...	104	...	...	73	96,548.85	95,798.85	750.00
New Hampshire	37,170	37,170	(5)	...	...	1,919	...	34,400	270	540,967.14	508,328.64	...
New Jersey	237,339	214,940	22,399	...	759	8,295	...	295,008	2,853	3,464,938.85	3,194,938.85	...
New Mexico	19,661	18,483	1,178	...	...	152	500	...	...	183,173.72	178,592.74	...
New York *	675,530	505,642	144,888	25,000	4,000	22,580	(5)	...	...	9,000,000.00	6,750,000.00	2,250,000.00
North Carolina	147,910	133,846	14,064	...	(8)	1,534	...	...	1,116	1,680,000.00	1,680,000.00	...
North Dakota	86,310	84,942	1,368	...	...	676	3,419	...	...	632,241.00	176,120.50	176,120.50
Ohio	628,283	[17] 547,000	77,000	4,283	4,775	[18] 23,300	...	...	5,837	[19] 6,000,000.00	3,000,000.00	3,000,000.00
Oklahoma	177,300	168,300	9,000	...	...	628	...	...	772	2,130,992.50	[20] 1,924,546.75	...
Oregon	102,274	102,274	(5)	...	...	2,486	8,889	29,747	489	2,153,843.75	1,500,000.00	500,000.00
Pennsylvania	609,268	557,765	51,503	...	1,560	18,174	38,117	237,505	13,547	8,387,106.05	8,387,106.05	...
Rhode Island	46,574	37,676	8,898	...	16	1,524	...	33,230	...	604,654.00	574,654.00	...
South Carolina	82,447	[21] 75,875	6,572	...	44	643	698	...	649	703,655.52	562,924.41	...
South Dakota	117,800	110,000	7,800	...	...	750	2,410	...	1,000	750,000.00	...	680,000.00
Tennessee	98,924	86,610	12,314	...	...	845	2,064	...	449	1,203,944.08	1,168,610.36	584,305.17
Texas	412,332	[22] 412,332	(5)	...	...	3,219	71,851	12,507	2,030	3,423,802.29	1,671,669.16	1,670,751.57
Utah	41,136	35,730	5,406	...	...	792	...	42,827	186	385,053.05	355,194.55	...
Vermont	32,871	29,786	3,085	...	(8)	847	1,812	40,025	245	594,562.55	572,733.72	...
Virginia	124,000	110,000	14,000	...	...	1,800	5,000	4,500	3,000	1,800,000.00	1,700,000.00	...
Washington	162,287	136,205	23,374	2,708	577	2,924	4,654	...	812	2,642,831.51	2,518,131.51	...
West Virginia	91,204	78,002	[23] 13,202	...	...	1,220	...	9,617	1,092	1,076,279.86	1,076,279.86	...
Wisconsin	315,864	296,765	19,099	...	...	5,505	8,000	...	2,040	3,373,000.00	2,429,066.39	809,688.79
Wyoming	23,684	21,184	2,500	...	12	287	200	...	204	260,534.25	260,534.25	...
Total	9,245,195	8,363,427	844,110	37,658	28,114	177,234	425,104	2,996,901	69,657	108,213,165.33	82,153,620.29	19,639,795.71

[1] Does not include 109 nonresident passenger cars.
[2] Does not include 6 nonresident motor trucks.
[3] Registration became effective May 1, 1921.
[4] Includes motor busses and trailers.
[5] Included under passenger cars.
[6] Does not include 16,979 nonresident passenger cars.
[7] Does not include 1,528 nonresident motor trucks.
[8] Included under motor trucks.
[9] To June 1.
[10] Does not include 821 nonresident passenger cars.
[11] Does not include 2,053 motor bicycles and side cars.
[12] Appropriations made annually by legislature.
* Estimated.
[13] Does not include 198 nonresident passenger cars.
[14] Does not include 216 nonresident motor trucks.
[15] Does not include 200 nonresident passenger cars.
[16] Does not include 268 nonresident passenger cars.
[17] Does not include 82,798 nonresident passenger cars.
[18] Includes side cars.
[19] Approximate.
[20] Distributed under counties but expended under supervision of State highway department.
[21] Does not include 50 nonresident passenger cars.
[22] Does not include 339 nonresident passenger cars.
[23] Includes taxis, busses, and trailers.

States having a total of 50,072 truck and commercial car registrations based on the total loaded weight of the vehicle show the following grouping: One ton or less, 53 per cent; 1 to 3 ton, 29 per cent; 3 to 5 ton, 11 per cent; 5 to 8 ton, 6 per cent; and above 8 ton, only 1 per cent. One State having a total of 51,503 truck registrations based on weight of chassis shows the following grouping: Between 1 and 3 ton, 81.8 per cent, between 3 and 5 ton, 17.7 per cent, and only 0.5 of a per cent over 5 ton.

The registration of passenger cars, motor trucks, and commercial vehicles, taxis and busses, trailers, motor cycles, reregistrations and transfers, owners' and chauffeurs' licenses, manufacturers' and dealers' licenses, total gross revenues and also the portion of these revenues available for road work by or under the several State highway departments and local road officials, respectively, are given in Table I. Nine States still fail to segregate their registration data so as to show the number of trucks or commercial cars within their borders. Only 7 States and the District of Columbia reported the number of taxis and busses, and only 19 States had any data as to the number of trailers.

MARYLAND'S ROAD ACCIDENT MAP SHOWS GREAT DANGER OF SPEED.

By HARRY D. WILLIAR, Jr., Assistant Chief Engineer, Maryland State Roads Commission.

THE MARYLAND RECORDS SHOW THAT FEWER ACCIDENTS OCCUR ON THE CURVED ROAD AT THE RIGHT THAN ON THE STRAIGHT ROAD AT THE LEFT.

DURING the past 3 months 94 accidents have occurred on the State roads of Maryland, 14 of which have involved loss of life, according to reports received from its patrolmen by the Maryland State roads commission. Few of these accidents have been due to faulty construction or location of the roads; and the 20 cases in which a highway condition is given as the immediate cause of the trouble were caused by wet surfaces. In these cases the failure of motorists to exercise ordinary precaution undoubtedly played a large part.

The State roads commission has determined to learn for itself the cause of the many accidents which occur on its roads. If any of them are due to defects in road design or location, the commission wants to know it so that the proper corrective measures may be applied. To this end it has put into effect a plan which will bring to the desk of the chief engineer a report on every accident that occurs on any part of the State system.

Each patrolman is furnished with report blanks which, when properly filled out, make it possible to locate and study the exact spot where each accident occurs. The reports also contain complete information in regard to the nature of the accidents, how they occur, whether or not they result fatally, the number of persons killed and injured, and the license numbers of the vehicle or vehicles involved. On the reverse side of the report blank four simple diagrams of typical road sections are printed. The sections represented, as shown in the illustrations, are a length of tangent, a single curve, a reverse curve, and a cross-roads intersection. The patrolman is required to indicate the exact location of the accident on the appropriate diagram and give the distance of the point from the nearest town.

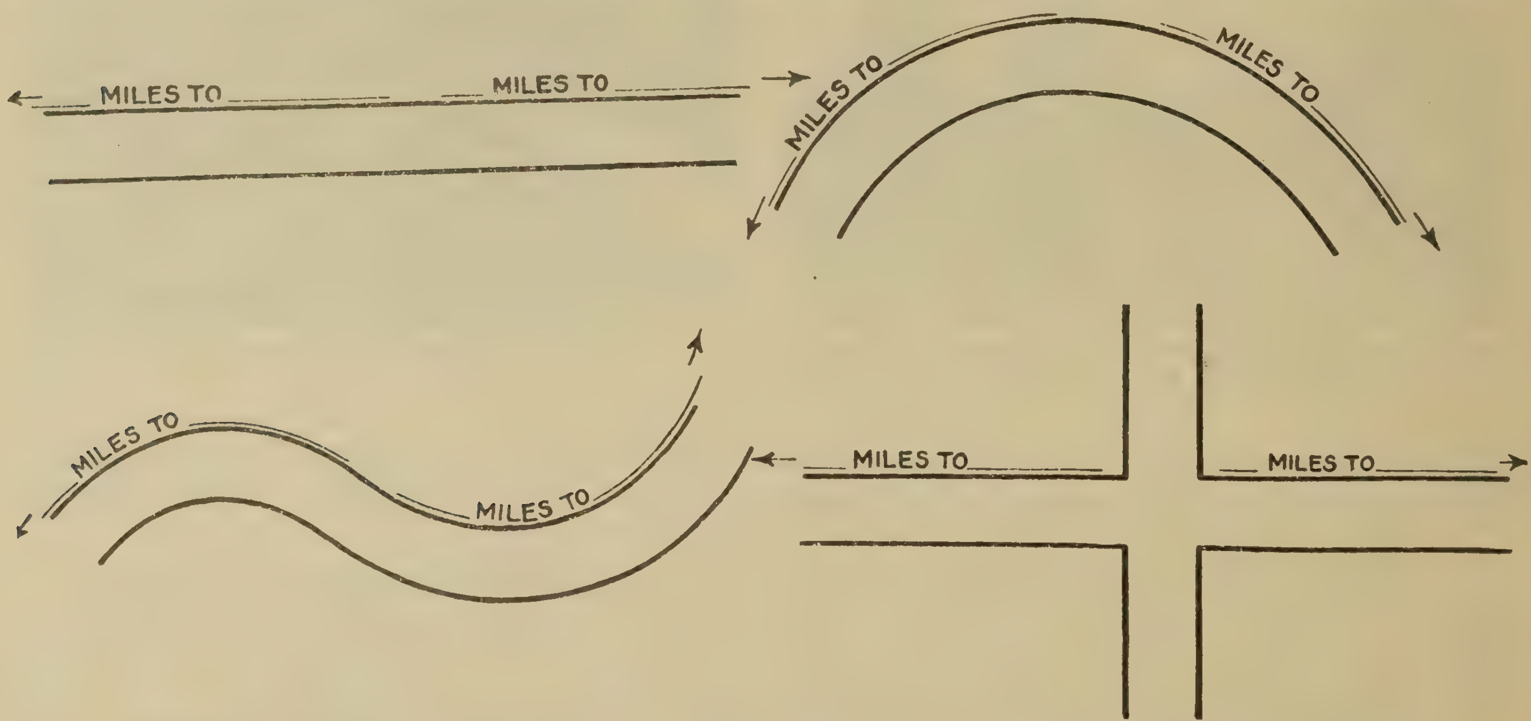
FEW ACCIDENTS CAUSED BY THE ROADS.

The reports received daily from all over the State are recorded on a large map of the road system by the use of colored tacks, each color representing one kind of accident. Although the record has been kept only a few months the map has already brought to light some most interesting and unsuspected facts. From the reports that are received it is possible in the large majority of cases to determine which is at fault—the road or the driver.

Few accidents are attributed to the road, but where the report leaves a question as to the cause, the location is immediately examined and, where any condition is found to exist which might possibly have contributed to the trouble it is rectified at once to prevent a repetition. Different locations require different treatment. For example, it may be shown that additional width is needed, or that a curve requires banking, that a tree or other obstruction interferes with the vision and should be removed, that a guard rail should be constructed, or a warning sign placed in a different location. While such changes are made when the reports indicate the need, the records thus far disclose few cases in which the highway defect would have caused an accident if the vehicle operator had been careful.

One of the interesting developments is that the largest number of accidents have occurred at the places that have always been considered safe, while the sections of road which have been commonly regarded as extremely dangerous are proving to be relatively free from accidents. It is particularly noticeable that in western Maryland, where the State highway crosses the Blue Ridge, and where the grades are necessarily steep and the curves sharp, there have been but 8 accidents in three months, none of which has resulted fatally. On other roads where numerous curves constitute what might be considered a decided hazard the accidents have been few and not serious. Rather strangely also the accidents have been fewest where the traffic density is greatest. Thus on all the roads radiating from Baltimore highway in the whole road system are so free of any features which might be considered as dangerous. Yet the three-months record of this road is 16 accidents, 3 of which were fatal. Similarly, on the Baltimore-Washington road, with all apparent danger spots removed, the record covering the same period shows that there has been 1 accident for every 4 miles of road.

There seems to be only one answer to account for these hitherto unsuspected conditions. It is that even the less careful motorists drive cautiously in the presence of recognized dangers, such as steep grades, sharp



DIAGRAMS OF TYPICAL ROAD SECTIONS ON WHICH PATROLMEN INDICATE THE LOCATION OF ACCIDENTS.

the three-months record shows only 7 accidents within 10 miles of the city, while in a similar zone around the town of Frederick twice as many smash-ups occurred in the same length of time. Even the railway grade crossing, generally considered one of the most menacing of highway evils, has proved to be far from the most important cause of fatal accidents.

THE HIGH PRICE PAID FOR SPEED.

The outstanding fact brought to light by the three-months record is that the vast majority of the disasters that overtake motorists are brought upon themselves by their own recklessness, and 90 per cent are due to just one cause—speeding. On the National Pike, between Baltimore and Frederick, there are 48 miles of the straightest road in the State. Few stretches of curves, grade crossings, etc., while the absence of such dangerous features gives the driver a sense of security which prompts him to take a chance and yield to the well-nigh universal passion for speed.

The accidents which have occurred on the State highways during the three months, May to July, inclusive, may be classified as follows:

Violation of motor law, 60; 10 fatal.

Wet road, 20; 4 fatal.

Car trouble, 14; none fatal.

The 14 fatalities may be classified as follows:

Failure to heed warning at railway crossing	2
Speeding	4
Driving on wrong side of road	4
Reckless driving	4
	14

THE FIELD OF HIGHWAY RESEARCH.

By W. K. HATT, Director, Highway Research Committee, Division of Engineering, National Research Council.

IT IS not too much to say that the situation in respect to highway transport is critical, and that unless those interested in its development settle upon a basis of fact the numerous problems that remain to be solved there is danger that the public may interrupt what progress has been made, because of a general feeling of insecurity. We must at least learn the answers to the physical problems of road design and the economic problems of service cost before we can be sure we are wisely investing the money which is now so freely given by a trusting public. What is needed is research—conscientious, intensive, comprehensive research by all agencies and individuals that can be induced to take an active interest.

Realizing the need, the Bureau of Public Roads, the United States Army, the State highway commissions, and many of the universities and industrial organizations are actively at work, each upon the problems that seem to it most important, and all with the earnest desire to put highway construction upon a scientific basis. Their efforts are yielding valuable fruits, but there is danger that their resources may not be applied so as to bring about the maximum result. Through lack of coordination two or more of them may devote their efforts to the solution of the same problem, while other equally important problems remain untouched.

It is for the purpose of coordinating the work of such agencies and to induce other organizations to bear a part, that the Advisory Board on Highway Research of the National Research Council has been organized in cooperation with the Engineering Foundation. This board is composed of representatives of engineering, operating, and industrial organizations, Federal departments, and the Association of State Highway Officials. The board will not engage in research directly, but will act merely as a coordinating agency.

Believing that a comprehensive and logical assemblage of the problems will be helpful, the writer has been endeavoring to set down upon a simple chart all the elements of the highway transport situation in their proper relations, including the factors of engineering, economics, administration, and finance. In so doing he has been impressed with the number of figures that are seen but dimly in the picture and with the large section of the field that is blank. The following are only a few of the questions which can not be completely answered:

The transport unit:

(1) What is the economical highway-truck unit for each of the several uses—e. g., intercity, farm-to-market? What is the cost of transport arising from vehicle and from road?

(2) What is the relation of this economical unit to other systems of transport—e. g., electric and steam—in a unified system?

(3) To what extent, as a matter of public policy, should any transport unit be indirectly subsidized?

(4) What traffic regulations should be imposed on such economical unit? What fees should be charged for service rendered to the vehicle by the road?

(5) What should be the proportion of the total traffic supplied by such economical unit to justify a special design of road for it?

(6) What prediction can be made of future changes in general traffic and what is the influence of these on the economics of the present situation?

(7) How should passenger traffic over the highway be evaluated?

The road:

(1) What type of road paving should be selected for a specified transport unit?

(2) If the road can not be economically fitted to the truck-transport unit, can the latter be modified in design to fit the road?

(3) How should the design of the road and paving be modified to meet changing conditions of subgrade, climate, etc.? How shall subsoils be improved?

(4) What sum of money is the locating engineer justified in spending to avoid increase in distance, curvature, rise and fall, maximum grade, maximum curve?

(5) What system of maintenance and organization is best fitted for types of roads differing in traffic, in materials, and in climate?

(6) What is the capacity of a road of given width for any particular type of vehicle as expressed in vehicles per hour, ton-miles per year, etc.? What is the appropriate unit for expressing traffic for various purposes?

(7) (In construction many questions arise in selection, production, and economical use of materials, standardization, and regulation.)

(8) How may the volumetric changes in roads be overcome?

(9) What is the economical life of various types of roads—that is, when do maintenance charges exceed earning value?

Administration:

(1) What should be the policy in control of truck and bus transportation systems, terminals, routing, etc.?

(2) What police regulations should control use of roads?

(3) What is the best administrative and executive organization for administration and operation of roads?

(4) What principles should govern the selection of a system of roads in its various parts, as influenced by interstate, intrastate, county, local traffic, etc.?

Financing:

(1) What should be the method of financing construction and maintenance of roads? What portions of the cost should be paid from long term bonds, and what from current funds? What form of bonds should be issued and how create a market for them?

(2) What should be the relation between the life of the bonds and the economic life of the road?

(3) To what extent do social betterment, military use, i. e., social value, and other imponderables enter into highway policy?

(4) What should be the distribution of costs as between Federal, State, county, township, property benefited, the user and other units?

(5) How shall the future maintenance charges on completed road systems be met? Shall the user pay all of these?

(6) How shall safety be insured on the roads?

The chart reproduced in Table I is devised to indicate the field of research and to divide it into subfields from which data must be sought by research to produce the answers to these and other equally important questions.

Some of the studies that should be made at once are as follows:

(1) To develop a traffic census blank. The problem here is to develop a traffic classification, to define the purpose of the census and to standardize various forms and instructions.

(2) In order to determine the cost of transport a statistical table must be made that notes all of the elements of cost; sometimes only a few of these are reported.

(3) To study the operating costs of elements entering into location of highways, such as distance, grade, curvature.

(4) To study the character of the highway loads produced by the vehicle.

(5) To study design of vehicles with a view to lessening their destructive effects on the road.

(6) To study supporting power and improvement of subgrades and the relations to design of paving.

(7) To study resistance of concrete slabs to alternate stresses and to surface loads.

(8) To study proportioning and use of bituminous materials.

(9) To study bonding of brick surfaces.

(10) To study volume changes and the means of meeting them.

(11) To study operations of concrete mixers.

(12) To study the organization and economics of construction plants.

(13) To study sand-clay, top-soil and gravel roads.

(14) To study cellular and other new types of paving.

Replies to these questions are wanting or are indefinite. The function of research is to assemble well authenticated data upon the basis of which a reasonable judgment may be rendered.

TABLE I.—*The field of highway research.*

I. Economics (data for economic survey and study of project).	II. Operation.	III. Design (road).	IV. Design (vehicles) as related to road).	V. Construction.
1. Traffic studies (regional): A. Distribution in region. B. Character (traffic blank)— Vehicle. Weight and distribution. Speed. Tire (condition). Commodity. Length haul. C. Method of expressing unit of traffic. D. Predicted changes. E. Other traffic on steam and electric roads. F. Central sources of traffic. 2. Community needs: Systems of roads in classes for industries, etc. Intangibles. 3. Cost of transport: Capital cost— Road. Vehicle. Fixed charges. Overhead. Operation— Maintenance. Routine. Replacement on road. on vehicle. Equivalent units, x—auto= y—ton truck, etc. (economic life). 4. Economics of location: Cost of distance— Rise and fall. Curvature. Ruling grade. Ruling curve. 5. Financing: Bonds. Taxes. Fees, etc. 6. Highway valuation: Increment of land values.	1. Control of traffic. Routing. Terminals. Franchises. Police regulations. 2. Accident insurance. 3. Planning systems of transport: Financing. Environment. Relation to other transport organization. 4. Distribution of costs: Traffic. Property. Political units. 5. Maintenance systems. 6. Maintenance machinery. 7. Maintenance methods: Routine. Replacement. Snow removal, etc. 8. Trail marking. 9. Cost accounting. 10. Safety.	1. Subsoil studies: Properties— Physical. Mechanical. Chemical. Drainage. Supporting power. Improvement by treatment. Effect of road deformations. Effect of climate. Distribution of pressure. 2. Base course: Character, type— Thickness. Materials. Cross section. 3. Surface: Character. Thickness. Materials. Cross section. Wear by traffic. Wear by elements. Impact of traffic. Tractive resistance. Wear of tire. Wear of vehicle. Dusting. Influence of locality. 4. Cross section: Width. Crown. Shoulders. Ditches. 5. Loads: Static. Impact. Surface, integral, as effected by design of vehicle. 6. Design of integral slab: Strength and stiffness of— Solid. Precast. Cellular. 7. Volume changes: Joints. Shoving. Corrugations. 8. Reinforcing: Theory of. Amount. Kind. Distribution. Direction.	1. Design of vehicle: Power gear ratio. Braking, etc. Effect on loads— Sprung. Unsprung. Distribution. 2. Economy of operation and maintenance (see Automotive industry): Economic limit of size of truck in various situations. Cost of truck transport (schedule of elements). Economic limit of haul. Cost of accounting. 3. Surface: Tractive effort. Wear on tires. Loads. Maintenance of vehicle. 4. Alignment: Curves (speed). Grades. 5. Cross section: Width. Crown. 6. Safety.	1. Materials: Bituminous. Nonbituminous. Fundamental mechanical properties. Methods of test. Standard tests. Specification. Preparation and treatment. (See Special list.) Proportioning. 2. Mixing: Efficiency of mixer. Central mixing plants. 3. Placing. 4. Methods of testing roads: Instrument. Cores. 5. Design of experimental roads. 6. Drainage (and drainage structures). 7. Impact on bridges (see design). 8. Reinforcing handling and placing. 9. Inspection. 10. Plant design and control. 11. Cost accounting. 12. Construction contracts.

This list of research studies applies to all classes of roads—brick, concrete, bituminous, macadam, sand-clay, gravel, etc.

THE NEED FOR TREE PLANTING ALONG THE PUBLIC HIGHWAYS.

By F. W. BESLEY, State Forester of Maryland.

A WELL-SHADED ROADWAY NEAR COLLEGE PARK, MD.

VAST sums of money have been spent in recent years in constructing improved highways through the various States, resulting in some magnificent highway systems. In their desire to construct the most miles of good roads at the lowest cost, the engineers have given little or no attention to beautifying the roadsides. In fact, this is generally regarded by the road engineers as an entirely separate project. There has developed, however, in recent years, a strong sentiment in favor of carrying this good work further than the actual building of highways and looking to the importance of making them more attractive by the planting of shade trees. Some States have enacted laws authorizing such work, but in most cases it is left to the initiative of the local communities, with little or no financial support from the State. Consequently, little in the way of systematic work has been done.

Many of the trees were removed from the highways prior to the time improved surfaced roads were regarded as so necessary an adjunct in our transportation system. When the era of good roads swept in, and the need of wide improved highways to accommodate the increasing automobile traffic became apparent, most of the remaining native tree growth along the roads was cut down. Some of this destruction was made necessary by the widening of the roads and the grading operations, but many of the trees were needlessly sacrificed. Since that time a reaction has set in, demanding shade trees along these improved highways to make travel more comfortable and the roadsides more attractive in appearance. What is needed now is systematic tree planting along all roadsides where grades and road lines are permanently established.

OBSTACLES TO PLANTING.

In undertaking the planting of trees along the highways, there are certain conditions peculiar to the work that must be given due consideration before any plan of planting will succeed. In the first place, traffic conditions—both the present and the probable future conditions—must be given proper weight. This means that in planting, sufficient room must be allowed for widening the roadway to carry the traffic safely for the next 50 years. On the main highways this generally means that the trees should not be planted closer than 25 feet from the center of the surfaced roadway. On subordinate roads it may be practicable to plant them a little closer to the center, although the 50-foot spacing should be observed as far as possible. This permits of a reasonably wide road surface and the necessary room for drainage. Frequently the established right of way of the road is less than 50 feet in width, in which case complications may arise in dealing with the landowners along the highway. This has been found to be a source of considerable difficulty. Where the road is simply a right of way for public travel and the fee in the land rests with the adjoining owner, the planting of trees may be entirely prevented by such owners. Furthermore, if the trees are not planted within the right of way of the highway, they can not be fully protected, which presents further difficulty.

The chief opposition to tree planting comes from farmers. They object to the planting of trees along the highways adjacent to their fields because of the effect of the trees in shading the ground and in extracting moisture and soil fertility from the surface under and adjacent to the trees. While this is true of many varieties of trees, there are others, such as the locust, walnut, persimmon and coffee trees which interfere with cultivated crops to a very small extent only, if at all. The proper selection of trees for the different conditions and localities would, it is believed, overcome this objection.

Another obstacle advanced against tree planting is the existence of pole lines along the highways, carrying

THE BALTIMORE-WASHINGTON BOULEVARD—A SHADELESS ROADWAY.

telephone, telegraph, and electric-light wires. Trees planted along the highway will come in contact with these wires in a few years, and from that time on there will be a conflict of interest, in which either the trees or the wires must give way. Where the road is wide enough it may be possible to plant the trees a sufficient distance from the wires, so that they may be trained above them. Where this is not possible the wires may be carried through the trees in cables, without serious injury to the trees, as is being done in many of the smaller cities. Eventually, the wires may be carried in underground conduits, as is being done in the case of some of our long-distance telephone and telegraph lines, or they may be carried on poles erected on private rights of way outside of the roadway. If we want trees along the highways, and our desire is sufficiently strong, we will have them, and such obstacles as the pole lines will be removed. There should be a general recognition of the principle that the planting of trees along the highways is part of the improvement of the highway, required for comfortable travel and a pleasing outlook. The objections mentioned are not by any means insurmountable.

PUBLIC INTEREST AWAKENED.

The real obstacle that has prevented earlier attention to the condition of our roadsides has been the lack of a public appreciation of the aesthetic and practical advantages of shade trees. As a consequence the necessary funds are lacking to carry on the work of planting. There is great hope that this condition will soon be corrected and that an awakened public interest will lead to the appropriation of the money that is needed. Perhaps no one factor has contributed more to this awakening than the influence of the thousands of men who went to France and witnessed the splendid work the French have done in beautifying their highways.

To follow the example that the French have set for us, however, we shall need more than money. That is the first need; but equally important is the necessity for the creation of a State agency to plan and supervise the planting. Without such an agency the development of a uniform plan for the State will be difficult, if not entirely impossible. Some of the States have already provided the money and others have created the machinery for the planting, but it so happens that none has given the necessary attention to both requirements. The State of Maryland has enacted most advanced legislation for the protection of trees along its highways, and has established legislative framework for highway planting, but unfortunately the lack of an appropriation has greatly limited the work that could be done. New Jersey, Massachusetts, Pennsylvania,[1] New York, Illinois, and a number of other States have enacted legislation providing for the planting of trees, but the work heretofore has been left almost entirely to the local units of government, so that no general planting system has been worked out. The experience of these States indicates that no great advance will be made until both the money and the centralized machinery for State-wide planting are provided.

ROADSIDE TREES AS MEMORIALS.

For a part of the money needed we can undoubtedly look to the many patriotic organizations, such as the Daughters of the American Revolution, the Grand Army of the Republic, and the American Legion. No memorial to our fallen heroes and to those who served the colors in our wars could be more fitting and more beautiful than avenues of trees along our highways. In Maryland it has been proposed to honor in this way not only those who gave their lives in the World War, but also each son of the State who answered the country's call for service on the fields of France. If the plan is carried out as it has been proposed there will eventually be one tree which will be named for each man and woman who served in the Army or the Navy and the Red Cross and other auxiliary organizations as well.

Many of our towns have found that a tree-lined road gives the traveler a wonderfully good impression of the good taste and public spirit of their citizens, and they will undoubtedly be willing to raise a part of the cost of the planting along their main approaches.

With an almost endless variety of trees from which to select, there is a kind of tree for every place, and there is no condition of soil in which some tree will not grow and thrive. We have most abundant resources to draw upon, and with the rapidly growing public sentiment in favor of the work, roadside tree planting is destined to move forward rapidly within the next 10 years.

[1] Recent information from Pennsylvania indicates that this condition is about to be corrected in that State through the cooperation of the State highway and forestry departments, which together have worked out a comprehensive plan of planting.

THE EFFECT OF TAX LIMITS ON COUNTY AND MUNICIPAL BONDS

By CHESTER B. MASSLICH, of the New York Bar.

IT is not always the size or wealth of a county or city which determines the salability of its bonds. And among the factors that determine the salability of municipal bonds, including in that term bonds of counties and taxing districts as well as of cities and towns, none is more important than a provision for unlimited taxes for their payment. The difficulties met with in marketing many public securities can be traced directly to a tax limitation.

A few years ago, when the demand for public securities was greater than the supply, less attention was paid by investors to the unfavorable features of many of these bonds. In these latter days, with billions of Liberty bonds outstanding, and a demand for money that can not be supplied, discrimination has come to be used in the selection of investments, and this discrimination has directly affected municipal bonds that are not protected by an unlimited tax provision.

Tax limitations for current expenses and for permanent improvements are a necessary protection against burdensome taxation, but tax limitations affecting the payment of a debt legally created are utterly illogical. The taxpayer can be protected against an excessive public debt by a constitutional or statutory limitation upon the amount of the debt which may be legally created. Many States have such debt limitations in their constitutions and many others have fixed them by statute. These limitations protect the bondholder as well as the taxpayer, but there is no greater unwisdom than to limit the amount of the tax which may be collected to pay a debt lawfully created.

So vital has this appeared to lawmakers that a dozen or more of the States of the Union have written into their constitutions a mandatory requirement that no debt shall be created by any political subdivision unless then or theretofore provision shall have been made for the levy of a sufficient tax for its payment. In many of the other States statutory authority is given to levy a sufficient tax, but there are still many States in which the amount that can be levied annually to pay bonds is limited.

The number of these latter States is being gradually reduced. In some of them, where special and private acts are still permitted, the tax limitations of general laws are being set aside as to particular districts and localities.

The haphazard nature of these tax laws is well illustrated in the State of Florida, where the constitution imposes no limit upon taxes for county bonds for any county purpose, but fixes the maximum annual rate for school district bonds at 5 mills on the dollar. As a result, Florida counties can sell bonds even in excessive amounts, while school districts suffer from their inability to borrow small sums.

NORTH CAROLINA HAS REMOVED LIMITATION.

North Carolina is one of the States which have seen the error of limits upon bond taxes. With few exceptions, all the general and special laws passed in that State in recent years granting authority for bond issues, have expressly provided that the tax for their payment shall be unlimited. South Carolina has followed the same new policy. Georgia has long since removed all limits upon bond taxes by constitutional enactments which make mandatory a sufficient levy without any limit whatever, and as a result the bonds of Georgia counties and municipalities find a ready sale. Georgia's taxpayers have not suffered, for the same section of the constitution which requires the unlimited tax puts a rigid limit upon the amount of lawful debt that may be created.

Across the line from Georgia, Alabama still labors under a constitutional limit of bond taxes, with the result that investors pay little attention to public securities coming from that State.

It must be remembered that a tax limit which appears to be sufficient at the time of the issuance of a public security, may presently become insufficient. Alabama has had exactly that experience. Assessed valuations change from year to year. Sometimes they change because property values have increased or decreased, but in many States they have changed by fiat of the legislature, which has established a different basis of taxation and a different ratio between actual values and assessed values. Investors are well acquainted with the fact that these changes have sometimes been made on a downward scale. In Kentucky, where a constitutional limitation of bond taxes still prevails, a school district issued a comparatively small amount of bonds when its assessed valuation was about $1,500,000. Long before those bonds fell due, it became unprofitable further to develop the natural resources that had given the district its prosperity, and the assessed valuation fell to about $375,000. The 50-cent tax rate allowed by the State constitution would no longer produce the amount necessary to pay the interest and provide for a sinking fund, and the bondholders were compelled to compromise. Many such illustrations can be given in many States. In one prosperous Alabama city, where no question was raised as to the legality of any bonds it had issued, the authorities were able to effect a compromise which gave the bondholders new bonds at half the face value of the outstanding bonds and at only 3 per cent interest. Only one bond issue of that city escaped the general disaster, through the fact that it constituted a lien upon public property, and the bondholders took possession of that property under order of the United States courts.

INSURANCE COMPANIES THE HEAVIEST BUYERS.

The great insurance companies are among the heaviest investors in municipal securities. Long experience has taught them wisdom in these investments. Their attitude on the tax limit question may be illustrated by an occurrence within the past year. A syndicate of investment houses had purchased an issue of $2,000,000 bonds of a prominent city with a population of over 75,000 and contracted to sell this issue to four of the large insurance companies. One after the other, all acting independently, the counsel of these four companies raised the objection that there was a limitation upon the amount of tax the city might legally levy for the payment of the bonds. Three of the counsel were finally persuaded that the limitation had been repealed and their companies accordingly accepted the bonds. But the counsel of the largest of the four companies was unable to resolve his doubt as to whether the limit had been repealed, and accordingly declined to accept the bonds. And yet that city has a perfect record of prompt payment of principal and interest of its indebtedness.

INVESTORS REMEMBER DEFAULTS.

An innocent purchaser of public securities is protected by the courts from many irregularities in their issuance. He is never protected against the evil consequences of a tax limit. There are communities in the United States which, abhorring the very thought of repudiation, have nevertheless been compelled to repudiate and compromise because the maximum limits of taxes they were permitted to levy have not been sufficient to meet their debts. One of the greatest American cities suffered that dishonor, but rose in its might and demanded and obtained a constitutional amendment for itself alone, empowering it to levy sufficient taxes to pay its creditors. It was many years however, before it could outlive the effects of that dishonor. The laws permitting investment of funds of savings banks in New York and the various New England States, make it a condition of such investments that no default shall have occurred within a given long period. Investors remember these defaults. They are sensible of the reasons why the defaults occurred and they are not anxious again to put themselves into a position which makes the payment of their bonds dependent upon the continued prosperity of the city or county which issued them.

Perhaps the worst form of tax limitation is the general limitation which fixes the maximum rate of annual tax for all purposes. If the amount raised by such a tax is insufficient to pay running municipal expenses and also the principal and interest of outstanding bonds, the courts hold that the payment of running expense comes first, and that the creditors can have no part of the taxes which the municipal authorities in their discretion choose to apply to those expenses. In other words, the maintenance of the life of a municipality is its first duty and the courts will not disturb the judgment of its governing body as to the amount necessary for maintenance.

There are many laws on the statute books to-day which fix so high a limit upon the amount of bonds which may be issued, and so low a limit upon the amount of taxes that may be levied to pay them, that it is a foregone conclusion that the bonds will not be enforcible if the entire amount allowed by law be issued.

Those who are interested in the building up of communities by road construction should see to it that their representatives in the legislature become acquainted with the conditions that will enable money to be borrowed for those purposes, and especially with the primary condition, now in almost universal demand by investors, that all tax limitations for the payment of municipal bonds be repealed.

(Continued from page 11.)

mometers are used, one for recording the air temperature and the other for obtaining the temperature of the concrete. Four sets of observations are made on each slab. In the first set of observations, which is made for determining the effects of change of temperature only, readings are taken on the thermometers and dials every half hour for 12 hours. In the second set of observations, taken for the purpose of determining the deflection caused by loads applied to the corners of the slabs, readings are taken for 24 hours at half-hour intervals. From 4,000 to 6,000 pounds is applied at the corner every hour. A reading is taken and the load is immediately released. One-half hour later a reading is taken without the load. The results obtained already show that the measurement of the load deflection would be futile without the determinations of temperature changes, because the warping of the surface due to temperature variations greatly exceeds the deflection under the loads applied.

For the purpose of securing some idea of the effect of the supporting power of the subgrade on the deflection of the slab after the 24-hour run the subgrade is excavated under the corner and several observations are made to determine the difference in the deflection of the slab when supported and when not supported by the subgrade. During the loading tests, a strain gauge is set along the diagonal for the purpose of securing some idea of the deflection of the upper surface. For the first 12 hours of the loading run, the dials are set along

(Concluded on page 24.)

FEDERAL-AID ALLOWANCES

PROJECT STATEMENTS APPROVED IN JULY, 1921.

State.	Project No.	County.	Length.	Type of construction.	Date approved.	Total estimated cost.	Federal aid.
Arizona	46	Maricopa		Concrete	July 22	[1] $77,330.69	[1] $38,665.34
Arkansas	93	Crittenden	[2] 5.260	Gravel and concrete	July 25	[2] 35,518.72	[2] 75,000.00
Kansas	85	Wyandotte	2.050	Concrete, brick, or asphalt	July 26	84,535.00	30,000.00
Kentucky	34	Webster	[2] 8.140	Earth	July 22	[2] 32,594.63	[2] 16,297.32
	46	Hancock		do	July 25	[1] 51,700.00	[1] 25,850.00
	49	Madison	7.000	Rock asphalt	July 22	265,265.00	132,632.50
	63	Clark	9.590	do	do	381,714.85	190,857.42
Maine	2	Prince George	[2] .290	Concrete	July 6	[2] 36,343.97	[2] 3,634.39
Massachusetts	62	Essex	6.522	Concrete and bituminous macadam	July 1	522,104.00	152,440.00
Michigan	46	Charlevoix	[1] 3.213	Gravel	July 25	[1] 70,640.35	[1] 35,320.18
Mississippi	113	Noxubee	3.500	do	July 26	62,416.20	31,416.20
New Mexico	67	Taos	10.020	do	July 25	50,077.50	25,038.75
	79	Colfax	33.200	Earth	July 28	71,269.00	35,634.50
New York	127	Schoharie	4.500	Bituminous macadam or concrete	July 22	180,000.00	90,000.00
	129	Monroe	4.390	Bituminous macadam	July 13	104,000.00	52,000.00
	131	Orleans	3.700	do	July 27	210,900.00	73,815.00
	133	Hamilton	1.630	do	July 9	36,500.00	18,250.00
	134	Steuben	6.470	do	July 6	143,000.00	71,500.00
	136	Wyoming	2.650	do	July 13	71,300.00	35,650.00
	141	Cattaraugus	2.910	do	July 6	91,300.00	45,650.00
	144	Monroe	3.370	do	July 13	93,869.60	46,934.80
	146	Ontario	4.040	Concrete	July 6	160,675.90	80,387.95
	150	Westchester	1.280	do	July 13	49,600.00	16,120.00
	151	do	3.880	do	July 11	163,900.00	53,267.50
	152	Putnam	1.360	Bituminous macadam	July 13	27,500.00	13,750.00
	156	Oneida	4.550	Concrete	do	146,900.00	73,450.00
	161	Ulster	1.760	do	July 6	70,400.00	35,200.00
	162	Yates	2.000	Bituminous macadam	July 13	32,600.00	16,300.00
	163	Tioga	6.770	Concrete slab	do	270,800.00	135,400.00
	164	Jefferson	4.870	Concrete	July 6	175,000.00	87,500.00
	165	Orange	2.000	Bituminous macadam, or concrete	July 11	80,000.00	40,000.00
	166	Lewis	2.680	Concrete	July 13	80,000.00	40,000.00
	167	Rensselaer	1.100	Bituminous macadam	do	43,700.00	21,850.00
Oklahoma	25	Kingfisher	[2] 1.656	Concrete	July 25	[2] 201,440.19	[2] 53,339.02
Pennsylvania	101	Clarion-Jefferson	7.421	do	do	579,185.47	148,420.00
	102	Crawford	3.526	Concrete and brick	July 6	286,456.22	70,520.00
	103	Columbia	3.691	Concrete	July 26	224,683.52	73,820.00
	104	McKean	6.098	do	July 6	426,071.69	121,960.00
	106	Northumberland	4.946	do	do	307,371.07	98,920.00
	107	Somerset	3.610	do	do	218,107.72	73,200.00
	112	Clearfield	6.197	do	July 8	434,608.73	123,940.00
South Carolina	26	Saluda	9.980	Top-soil	July 26	36,867.73	18,433.86
	89	Kershaw	21.069	Sand-clay	do	158,829.05	79,414.52
	122	Dorchester	.606	Bridge and sand-clay	do	31,614.62	15,807.31
	128	Greenville	1.364	Concrete, asphalt	do	53,065.07	26,532.53
	132	Greenwood	.264	Concrete	do	10,198.65	2,000.00
Tennessee	83	Marshall	(3)		July 26	87,181.49	43,590.74
Texas	179	Ellis		Gravel, surface-treated	July 22	[2] 22,462.88	
	185	Comanche	18.000	Gravel	July 6	221,874.48	50,000.00
	248	Calhoun	11.500	Shell	do	88,000.00	44,000.00
	252	Galveston	(3)		do	7,805.07	13,405.07
Virginia	114	Southampton	4.710	Concrete	July 22	150,075.75	75,037.87
Washington	86	Skamania	.910	Earth and bridge	July 6	41,999.10	15,000.00
	87	Okanogan	(3)		do	61,243.82	25,000.00
Wisconsin	175	Sauk	3.000	Gravel	July 26	70,873.00	22,000.00
	192	Clark	1.350	do	do	20,307.21	9,000.00

[1] Revised statement; amounts given are decreases over those in the original statement.
[2] Revised statement; amounts given are increases over those in the original statement.
[3] Bridge.

(Continued from page 12.)

and amounted to a taking of its property without due process of law in contravention of the fourteenth amendment to the Federal Constitution, and, further, was in violation of the commerce clause of the Constitution.

It was developed that the business of the company for the years 1918 to 1920 amounted to 94.5 per cent in bulk or from broken packages and 5.5 per cent was sold in original barrels, packages, or tank cars. In addition the company consumed 8 per cent of its total sales in the conduct of its own business. The court held that the excise tax upon the use of gasoline by the company at its distributing stations as well as upon its sale in domestic trade did not infringe its right under the Federal Constitution. It also decided that such a tax did not violate the provisions of section 1 of article 8 of the State constitution, which reads: "Taxes levied upon tangible property shall be in proportion to the value thereof and taxes shall be equal and uniform upon subjects of taxation of the same class." The Supreme Court held that a tax upon the "sale or use of gasoline sold or used" in the State is not *property* taxation, but in effect, as in name, an *excise* tax; and since the tax operated "impartially upon all, and with territorial uniformity throughout the State," deemed it "equal and uniform upon subjects of taxation of the same class."

The question of the severability of the annual license tax of $50 for each distributing station was decided against the State as the subject taxed was not in its nature divisible, as in the case of an excise tax. The provisions of the New Mexico statute were declared not capable of separation so as to confine them to domestic trade, leaving interstate commerce

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the diagonal 0–1, and for the second 12 hours along the diagonal 0–2. This work is carried on by a corps of engineers divided into three shifts each working 8 hours so that continuous readings are made day and night.

For determining the distribution of loads across joints and through pavement slabs of different thicknesses and types, soil pressure cells are placed under corners and centers of the slabs, and two Ames dials are set—one on each side of the joint about 2 inches from the edge of the pavement. A thermometer is supplied for registering air temperature. After the apparatus has been set up a loaded truck is brought slowly toward the point with its outer wheel about 6 inches from the edge of the pavement. The truck is stopped as soon as the dials give the first indication of the deflection of the pavement. Readings on the dials and the pressure cells are then taken, stopping the truck every 2 feet to the joint and every 2 feet beyond the joint till the dials again indicate that the truck is so far away as to cause no deflection. Because of the warping action of the slab and the temperature change these readings are made at night as well as day, the daylight readings being taken between 9 a. m. and 4 p. m., and the second set the same day between 9 p. m. and 4 a. m. Especial attention is given to securing definite time intervals for each loading. It is proposed to make these observations once every month.

In connection with the above, a comprehensive survey of cracks developed in the different types of pavements has been undertaken. At different times each section is observed and all cracks noted. These cracks are all plotted on a large tracing, using lines of different kinds for designating the cracks as found at different times. In addition also a considerable number of representative cracks have been measured by micrometers, the measurements being taken day and night, one each week. This study covers both transverse and longitudinal cracks.

The traffic test of the road will be accomplished by means of a battery of 10 motor trucks driven by trained operators. The loading of the trucks will be increased after each 1,000 trips. The actual magnitude of the loads will be dependent upon the information secured from the above-described preliminary investigations, although the maximum wheel load will probably not exceed 12,000 pounds, which is 50 per cent greater than the legal Illinois wheel load.

The construction work on the road was supervised by Mr. E. M. Fleming and Mr. R. R. Benedict under the direction of Mr. B. H. Piepmeier, engineer of construction.

The research work is under the immediate direction of Mr. H. F. Clemmer, engineer of tests, with Mr. C. A. Hogentogler, highway engineer of the United States Bureau of Public Roads, cooperating.

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exempt. However, the court added that the State might impose a license tax upon the distribution and sale of gasoline in domestic commerce if it did not make its payment a condition of carrying on interstate commerce; but that the State of New Mexico had not done this by any act of legislation.

These decisions establish the right of the State to tax the use and sale of gasoline in the absence of inhibition against such tax in its own constitution.

As noted in the tabulation above the State of New Mexico has amended the 1919 act so as to except interstate business from its provisions. It also reduced the amount of the tax from 2 to 1 cent per gallon.

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ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS.

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets, nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

REPORTS

*Report of the Director of the Office of Public Roads for 1917. 6c.
Report of the Director of the Bureau of Public Roads for 1918.
Report of the Chief of the Bureau of Public Roads for 1919.
Report of the Chief of the Bureau of Public Roads for 1920.

DEPARTMENT BULLETINS.

Dept. Bul.*105. Progress Report of Experiments in Dust Prevention and Road Preservation. 1913. 5c.
*136. Highway Bonds. 25c.
220. Road Models.
*230. Oil Mixed Portland Cement Concrete. 10c.
*249. Portland Cement Concrete Pavements for Country Roads. 15c.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
314. Methods for the Examination of Bituminous Road Materials.
347. Methods for the Determination of the Physical Properties of Road-Building Rock.
*348. Relation of Mineral Composition and Rock Structure to the Physical Properties of Road Materials. 10c.
*370. The Results of Physical Tests of Road-Building Rock. 15c.
*373. Brick Roads. 15c.
386. Public Road Mileage and Revenues in the Middle Atlantic States, 1914.
387. Public Road Mileage and Revenues in the Southern States, 1914.
388. Public Road Mileage and Revenues in the New England States, 1914.
*389. Public Road Mileage and Revenues in the Central, Mountain, and Pacific States, 1914. 15c.
390. Public Road Mileage in the United States, 1914. A Summary.
*393. Economic Surveys of County Highway Improvement. 35c.
407. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
414. Convict Labor for Road Work.
*463. Earth, Sand-Clay, and Gravel Roads. 15c.
532. The Expansion and Contraction of Concrete and Concrete Roads.
*537. The Results of Physical Tests of Road-Building Rock in 1916, including all Compression Tests. 5c.
555. Standard Forms for Specifications, Tests, Reports, and Methods of Sampling for Road Materials.
583. Reports on Experimental Convict Road Camp, Fulton County, Ga.
586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916.
*660. Highway Cost Keeping. 10c.
670. The Results of Physical Tests of Road-Building Rock in 1916 and 1917.
*691. Typical Specifications for Bituminous Road Materials. 15c.
704. Typical Specifications for Nonbituminous Road Materials.
*724. Drainage Methods and Foundations for County Roads. 20c.
*Public Roads, Vol. I, No. 11. Tests of Road-Building Rock in 1918.
*Public Roads, Vol. II, No. 23. Tests of Road-Building Rock in 1919. 15c.

DEPARTMENT CIRCULAR.

No. 94. TNT as a Blasting Explosive.

FARMERS' BULLETINS.

F. B. *338. Macadam Roads. 5c.
505. Benefits of Improved Roads.
597. The Road Drag.

* Department supply exhausted.

SEPARATE REPRINTS FROM THE YEARBOOK.

Y. B. Sep. 727. Design of Public Roads.
739. Federal Aid to Highways, 1917.

OFFICE OF PUBLIC ROADS BULLETINS.

Bul. *45. Data for Use in Designing Culverts and Short-span Bridges. (1913.) 15c.

OFFICE OF PUBLIC ROADS CIRCULARS.

Cir.*89. Progress Report of Experiments with Dust Preventatives, 1907. 5c.
*90. Progress Report of Experiments in Dust Prevention, Road Preservation, and Road Construction, 1908. 5c.
*92. Progress Report of Experiments in Dust Prevention and Road Preservation, 1909. 5c.
*94. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1910. 5c.
*99. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1912. 5c.
*100. Typical Specifications for Fabrication and Erection of Steel Highway Bridges. (1913.) 5c.

OFFICE OF THE SECRETARY CIRCULARS.

Sec. Cir. 49. Motor Vehicle Registrations and Revenues, 1914.
*52. State Highway Mileage and Expenditures to January 1, 1915. 5c.
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.
63. State Highway Mileage and Expenditures to January 1, 1916.
*65. Rules and Regulations of the Secretary of Agriculture for Carrying out the Federal Aid Road Act. 5c.
*72. Width of Wagon Tires Recommended for Loads of Varying Magnitude on Earth and Gravel Roads. 5c.
73. Automobile Registrations, Licenses, and Revenues in the United States, 1916.
74. State Highway Mileage and Expenditures for the Calendar Year 1916.
*77. Experimental Roads in the Vicinity of Washington, D. C. 5c.

Public Roads Vol. I, No. 1. Automobile Registrations, Licenses, and Revenues in the United States, 1917.
Vol. I, No. 3. State Highway Mileage and Expenditures in the United States, 1917.
*Vol. I, No. 11. Automobile Registrations, Licenses, and Revenues in the United States, 1918. 15c.
*Vol. II, No. 15. State Highway Mileage and Expenditures in the United States, 1918. 15c.
Vol. III, No. 25. Automobile Registrations, Licenses, and Revenues in the U. S. 1919.
Vol. III, No. 29. State Highway mileage, 1919.
Vol. III, No. 36. Automobile Registrations, Licences, and Revenues in the United States, 1920.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH.

Vol. 5, No. 17, D-2. Effect of Controllable Variables Upon the Penetration Test for Asphalts and Asphalt Cements.
Vol. 5, No. 19, D-3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 20, D-4. Apparatus for Measuring the Wear of Concrete Roads.
Vol. 5, No. 24, D-6. A New Penetration Needle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D-8. Tests of Three Large-Sized Reinforced-Concrete Slabs under Concentrated Loading.
Vol. 10, No. 7, D-13. Toughness of Bituminous Aggregates.
Vol. 11, No. 10, D-15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.
Vol. 17, No. 4, D-16. Ultra-Microscopic Examination of Disperse Colloids Present in Bituminous Road Materials.

* Department supply exhausted.