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In This Issue

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THE STRUCTURAL DESIGN OF CONCRETE PAVEMENTS

BY THE DIVISION OF TESTS, BUREAU OF PUBLIC ROADS

Reported by **L. W. TELLER**, Senior Engineer of Tests, and **EARL C. SUTHERLAND**, Associate Highway Engineer

PART 4.—A STUDY OF THE STRUCTURAL ACTION OF SEVERAL TYPES OF TRANSVERSE AND LONGITUDINAL JOINT DESIGNS—Concluded[1]

JOINTS are needed in concrete pavements for the one purpose of reducing as much as possible the stresses resulting from causes other than applied loads in order that the natural stress resistance of the pavement may be conserved to the greatest possible extent for carrying the loads of traffic.

A joint is potentially a point of structural weakness and may limit the load-carrying capacity of the entire pavement.

Joints are classified by function as:

1. Those designed to provide space in which unrestrained expansion can occur.
2. Those designed for the relief or control of the direct tensile stresses caused by restrained contraction.
3. Those designed to permit warping to occur, thus reducing restraint and controlling the magnitude of the bending stresses developed by restrained warping.

Expansion joints should be provided at no greater intervals than about 100 feet in order to keep the joint openings from becoming excessive.

The spacing of contraction joints will be determined by the permissible unit stress in the concrete. If this is restricted to a low value, which is desirable, contraction joints should be provided at intervals of about 30 feet.

It is indicated that joints to control warping should be spaced at intervals of about 10 feet.

A free edge is a structural weak spot in a slab of uniform thicknesses, and it is necessary to strengthen the joint edges by thickening the slab at this point or by the introduction of some mechanism for transferring part of the applied load across the joint to the adjacent slab.

The doweled transverse joints investigated were quite effective in relieving stresses caused by expansion, contraction, and warping, but they were not particularly effective in controlling load stresses near the joint edge.

The dowel-plate joint tested had merit as a means for load transfer, though it offered more resistance to expansion and contraction than is desirable.

Aggregate interlock as it occurs in weakened-plane joints cannot be depended upon to control load stresses. Even when joints of this type are held closely by bonded steel bars there is wide variation in the critical stress value caused by a given load; therefore, it appears necessary to provide independent means for load transfer in plane-of-weakness joints.

Tongue-and-groove joints held together by bonded steel bars were found to be the most efficient structurally of any of the joints studied. However, modifications of the designs might improve their action.

THE SIGNIFICANCE of deflection data in connection with tests of the structural action of joints is a matter about which there seems to be a difference of opinion. A brief discussion of it at this point is pertinent.

The successive changes in curvature of the deflection (or elastic) curve of the slab are values of slope which, if determined with sufficient frequency and precision, may be used to form a slope curve. The changes in curvature of this slope curve, in turn, if determined with sufficient precision, give values of moment, a direct measure of stress. However, the determination of second differences, if these differences are to be significant, must be based upon a precise knowledge of the shape of the basic curve and accurate methods of determination of the changes in curvature.

It has not been found possible in this investigation to measure slab curvature with sufficient precision to permit the use of the deflection data as a basis for estimating absolute or even relative stresses at critical points. A comparison of the relative deflections and of the relative stresses in the vicinity of a load applied on one edge of two typical doweled joints will be shown later in this report and the data presented illustrate the point which has just been made. It is felt that the deflection data have definite value for certain purposes and complete deflection data were obtained in practically all of the tests. Main reliance has been placed upon the strain data, however, for comparisons that would show the relative structural efficiency of the various joints.

Before presenting the results of the strain measurements made in connection with the joint tests, it is desired to call attention to two conditions that affect directly the precision of the efficiency values which appear later in this discussion. In the first place, it should be remembered that the tests were made on specimens that were built and tested under field conditions. Certain unexpected variations in the deflection and strain data have consistently appeared when certain sections or certain panels of a given section were tested. These indicate that variations in the strength of the specimen or in the condition of support are present in spite of all the precautions taken to guard against them.

In the second place, the criterion that has been set up as a measure of joint efficiency on the basis of the stress data, while sound in principle, has one practical weakness that should be recognized. Although the critical stress values as determined from the strain measurements are of appreciable magnitude, being generally of the order of 250 to 350 pounds per square inch, when these values are used in the application of the efficiency formula the significant ratio is developed from differences in stress values, both in the numerator and in the denominator of the expression. The differences naturally are of much less magnitude that the stress values themselves and the result is that the ratio of differences is very sensitive to small changes in the stress values from which the differences were obtained. Thus variations in stress determination that are quite unimportant, insofar as the total value of the stress is concerned,

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[1] Because of its length, Part 4 is presented in two issues of PUBLIC ROADS. The first installment appeared in the September 1936 issue.

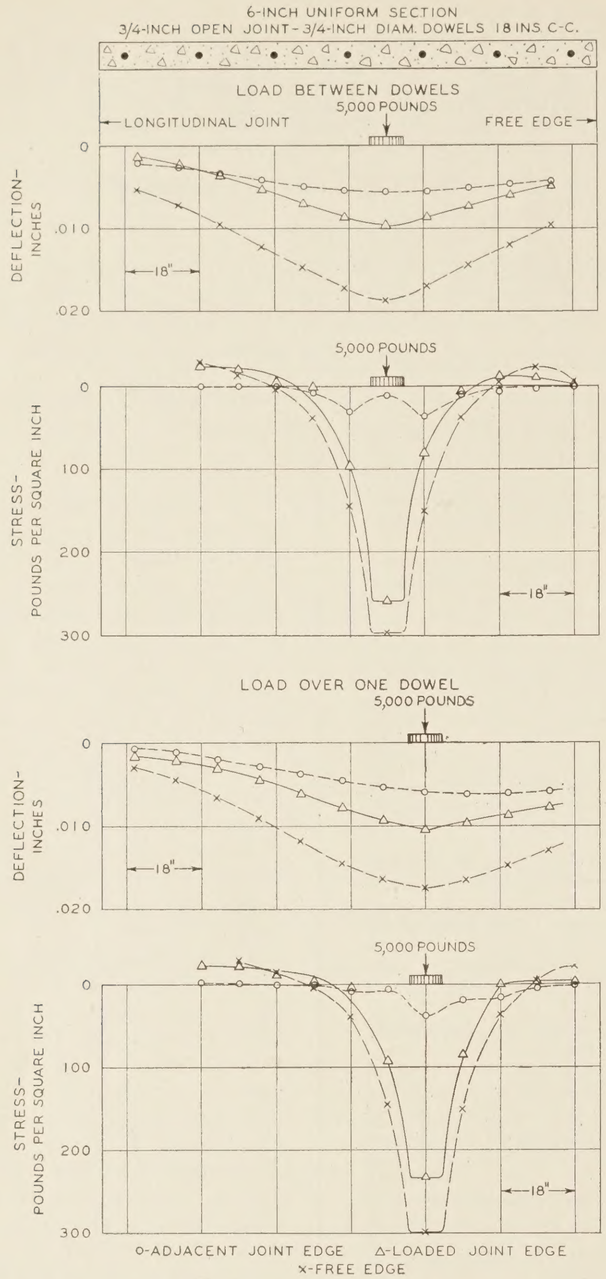

Figure 31.—Deflection and Stress Variation Curves at the Free and Joint Edges of a Typical Transverse Dowel Joint. Stress Values Above the Axis Indicate Tension, and Stress Values Below the Axis Indicate Compression in the Upper Surface of the Slab.

may be sufficient to cause appreciable variations in the ratio by which the structural efficiency is measured.

The stress values used in computing the efficiency values to be presented later were based on averages from tests made at not less than eight comparable points in order to minimize the effect of individual variations in the strain data and are believed to be quite well established. Still, a realization of the manner in which these values were derived will show the necessity for care in the use of individual figures, and will indicate the reasons for certain apparent inconsistencies in the test data.

The tests to determine the effectiveness of the various joints in relieving slab stress were divided into four general groups for convenience in presentation, as follows:

1. Tests to show the character of the stress and deflection variations parallel to the joint.
2. Tests to determine the effect of the transverse joint design on the critical stresses caused by a load acting near a transverse joint, but at a distance from a corner.
3. Tests to determine the effect of the longitudinal joint design on the critical stresses caused by a load acting near a longitudinal joint but at a distance from a corner.
4. Tests to determine the effect of the different joint designs, both transverse and longitudinal, on the critical stresses developed by a load acting on a slab corner.

Mention has already been made of the fact that, with a load acting at the edge of a pavement slab, it has been determined that the highest stress will be found directly under the load in a direction parallel to the edge of the slab. In making the stress measurements for loads applied at joint edges, the stress just mentioned is the critical stress, all others being of less significance. This critical stress was determined for each test at a joint edge and in addition the stress-variation curves were determined through the load position in a direction perpendicular to the joint and for some distance back on each slab.

REDUCTION IN DEFLECTION EXCEEDED REDUCTION IN STRESS

While the stress variation along the edge of the slab is of interest for the comparisons to be made, it was not considered sufficiently important to justify the amount of work that would be involved if these data were to be obtained for every joint. Stress-variation data along the edge were obtained only for one transverse joint with the 18-inch dowel spacing (section 10) and for the longitudinal joint with the 24-inch dowel spacing (section 9). For these two joints data were obtained for a load applied midway between dowels, directly over a dowel, and at a free end. The variations in stress on both the loaded panel and adjacent panel were determined in each case.

The deflection variation and stress variation along the free edge and the two edges of the transverse joint in section 10 are shown in figure 31, while similar data for the longitudinal joint in section 9 are shown in figure 32. The method of grouping makes it possible more easily to make comparisons between the influence of the design on deflection and that on stresses, comparisons that are of particular interest because they show why strain measurements furnish a better basis than deflection measurements for judging the ability of joints to perform their intended function of stress reduction.

If the relations between free-edge deflection and loaded joint-edge deflection are compared and if a similar comparison is made between free-edge stress and that developed at the loaded joint edge, for each of the two joints, it will be found that reductions in deflection and reductions in critical stress are as shown in table 8.

From these values it is apparent that the reduction in load deflection that is obtained with either of these joint designs is not a measure of the reduction to be expected in corresponding critical stress values.

If a similar study is made of the relative deflections and the relative stresses on the two sides of the joint when a load is applied on one of the sides, and ratios

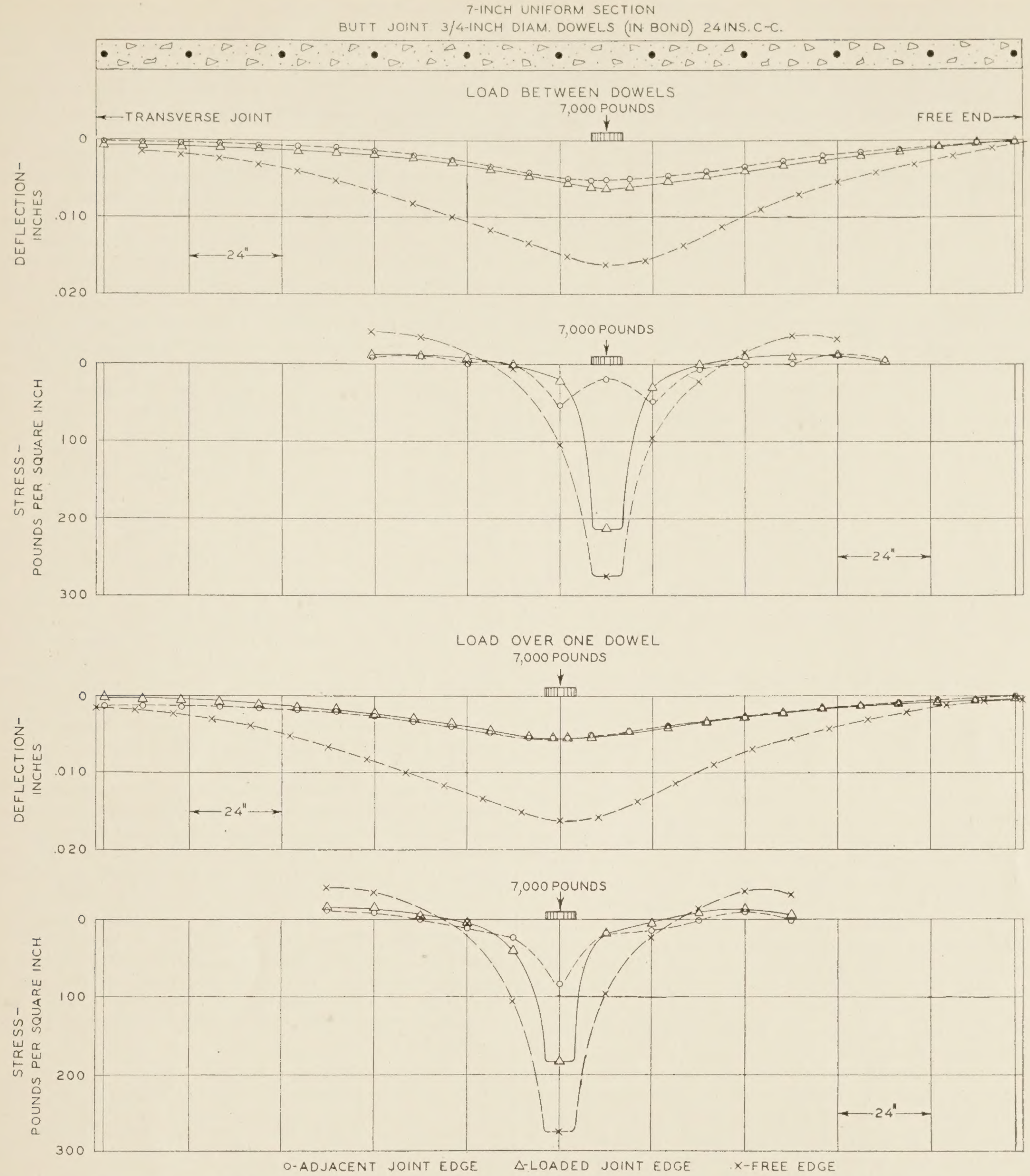

Figure 32.—Deflection and Stress Variation Curves at the Free and Joint Edges of a Typical Longitudinal Dowel Joint. Stress Values Above the Axis Indicate Tension, and Stress Values Below the Axis Indicate Compression in the Upper Surface of the Slab.

are calculated which express the maximum deflection, or stress, in the adjacent edge as a percentage of that found in the edge on which the load was applied, the ratios will have the values shown in table 9.

Again it is evident that the deflection relations are not a usable measure of the stress conditions that accompany them. The point is well illustrated in the case of the longitudinal joint with the load applied directly over a dowel. The deflection curves of the two slab edges are closely comparable, as nearly as can be judged by visual examination (see fig. 32), and the maximum deflection of each is identical. Yet the maximum stress in the loaded edge is more than twice that of the adjacent edge. This is direct evidence of the presence of changes in curvature that are not apparent in the deflection data and for which there is no dependable measure except strain data. Since the reduction of the critical edge stress is one of the chief functions of the joint, this is a very important fact and it has a direct bearing on methods of testing joints for structural efficiency. It emphasizes the impossibility of forming sound judgments regarding the effect of joint designs on stress from deflection data alone. The reasons for this apparent anomaly have already been discussed.

TABLE 8.—*Comparison of deflection reductions and stress reductions*

	Transverse joint (section 10)	Longitudinal joint (section 9)
	Percent	*Percent*
Load midway between dowels:		
Reduction in maximum deflection	49	60
Reduction in maximum stress	12	23
Load directly over a dowel:		
Reduction in maximum deflection	40	65
Reduction in maximum stress	22	33

TABLE 9.—*Comparison of deflection ratios and stress ratios between the loaded and adjacent joint edges*

	Transverse joint (section 10)	Longitudinal joint (section 9)
Load midway between dowels:		
Ratio of deflections (adjacent vs. loaded edge)	0.58	0.82
Ratio of stresses (adjacent vs. loaded edge)	.14	.23
Load directly over a dowel:		
Ratio of deflections (adjacent vs. loaded edge)	.58	1.00
Ratio of stresses (adjacent vs. loaded edge)	.16	.45

EFFICIENCIES OF VARIOUS TRANSVERSE JOINTS COMPARED FOR LOADS NEAR JOINT EDGES

There are other interesting points brought out in figures 31 and 32. The concentration of the critical stress along these joints is very clearly shown by the stress-variation curves. It will be noted that for these spacings practically all edge stress of any magnitude occurs within a distance of two dowel spacings in the case of a load applied over a dowel and within three dowel spacings for a load applied between dowels. The distribution of the deflection is much greater.

The position of the load with respect to the dowel not only affects the distribution of the stress but also the magnitude of the critical stress, the highest value being observed when the load was midway between the dowels, in each of the joints tested.

In comparing the data in figure 31 with the comparable data in figure 32 the greater stiffness of the longitudinal joint is evident both in the deflection and the stress relations. Because of the presence of the bonded bars a resisting moment is developed during the deflection of the longitudinal joint which accounts for the fact that a deflection reduction of more than 50 percent is obtained. The data indicate that the presence of this resisting moment has no important effect on the stresses in a direction parallel to the joint edge although it does affect the stresses in a direction perpendicular to the joint edge. The effect of the close proximity of the two slab edges in this joint is to make the steel bars more effective as shear units and this causes greater stress reduction, particularly when the load is applied over a dowel. This is shown by the comparative values in tables 8 and 9.

Finally, it is to be noted that for joints such as these, the stresses developed parallel to the joint in the edge of the adjacent slab are relatively quite low in magnitude.

The data which have just been presented serve two important purposes; first, they illustrate the necessity for stress determinations in a study of joint action; and second, they give a general picture of the stress conditions along the edge of the slab which is helpful in connection with the discussion of the other stress data which follow.

Figure 33 shows stress values, as determined from strain measurements in the vicinity of the load applied at the edge of a slab, either at a transverse joint (point G) or at a free edge (point I), for the purpose of studying the structural efficiency of the various joints from the standpoint of their ability to control critical load stresses. The method of placing the loads and of measuring the strains was previously explained in connection with figure 8. The curves connecting the circles show the stress variation along a line perpendicular to the joint and passing through the center of load application. The single values shown by the crosses indicate the maximum values of the stress at the edge of the slab in a direction parallel to the joint. These stresses reach a maximum at the point of load application in those cases where the load is at some distance from a corner.

In figure 8 points G and I are shown on the longitudinal centerline of the panel. Tests were made at these points and at many other points along the transverse joint or free edge and it was found that the edge condition shown by the typical data in figure 33 applies at all points along the edge except within a distance of approximately 3 feet of a corner. Within this distance there is a gradual transition from the edge to the corner condition. For the corner condition the bending stress under the load is negligible and the critical stress is found to be a tensile stress at some distance from the load and along the bisector of the corner angle.

The data in figure 33 show that the most important stress to be controlled by a transverse joint for a loading such as that at point G is that occurring directly under the load and in a direction parallel to the slab edge. Using the method of calculating structural efficiency from stress values that was described earlier in this report, the average values for each of the joints were determined. These values as given in table 10 are not based on the data shown in figure 33 together with the corresponding data for the center of the slab, but upon similar and much more extensive tests in which only the strains occurring directly under the load were measured.

TABLE 10.—*Efficiencies of the various transverse joints for controlling the stresses caused by loads placed near the joint edges*

Test section no.	Type of joint	Spacing of dowels	Joint opening	Joint efficiency				
				Winter	Summer	Average (various seasons)	Over dowels	Between dowels
		Inches	*Inches*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	Thickened end	None	½			57		
8	Dowel	36	½				46	8
6	do	27	½				31	6
9	do	27	¾				16	20
7	do	18	½				28	8
10	do	18	¾				40	28
4	Plane of weakness	18		71	66			
3	do	None		4	41			
2	Dowel plate		½			59		
5	do		¾			66		

The joint in section 1 differs from the others in that there is no connection between the two ends of the

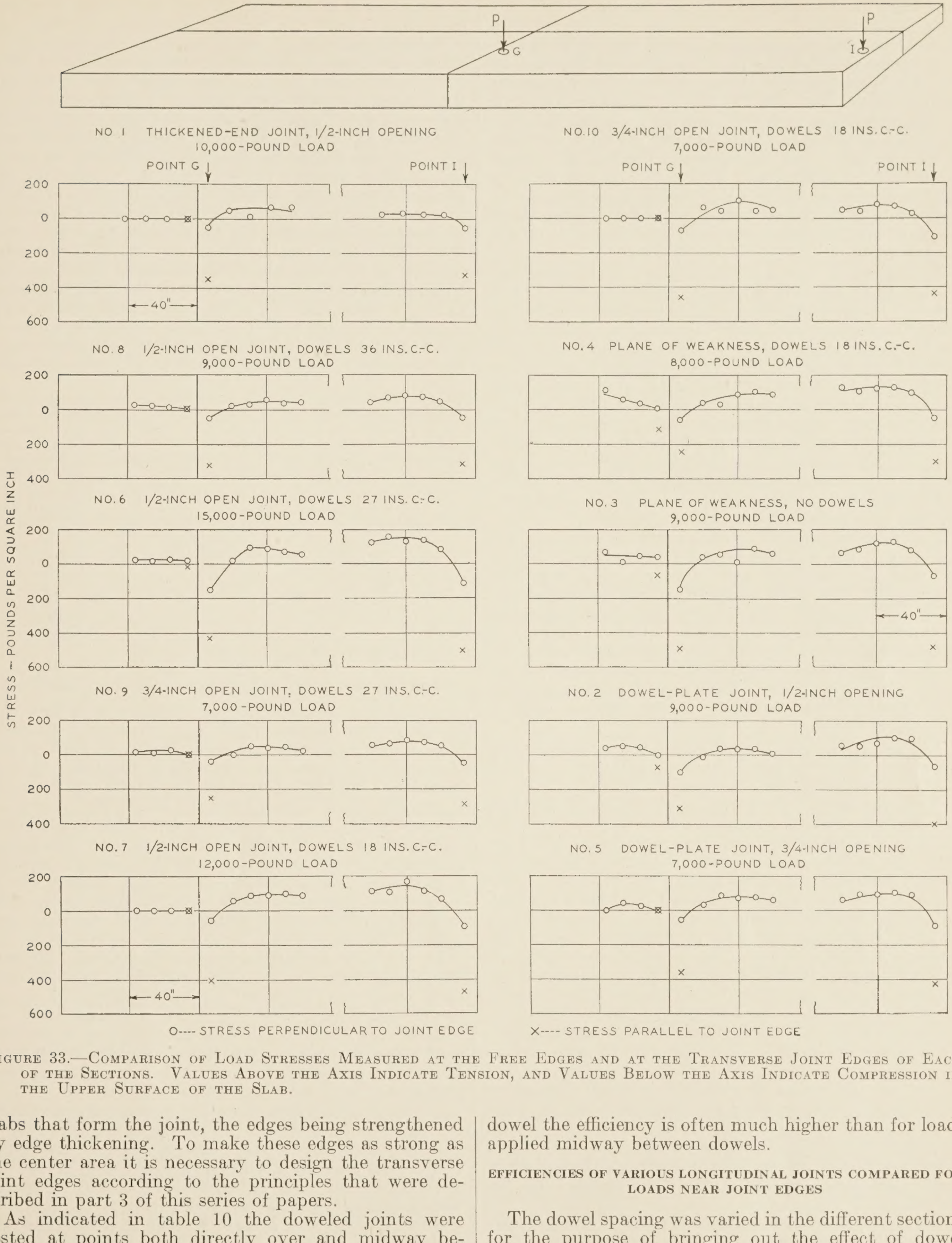

FIGURE 33.—COMPARISON OF LOAD STRESSES MEASURED AT THE FREE EDGES AND AT THE TRANSVERSE JOINT EDGES OF EACH OF THE SECTIONS. VALUES ABOVE THE AXIS INDICATE TENSION, AND VALUES BELOW THE AXIS INDICATE COMPRESSION IN THE UPPER SURFACE OF THE SLAB.

slabs that form the joint, the edges being strengthened by edge thickening. To make these edges as strong as the center area it is necessary to design the transverse joint edges according to the principles that were described in part 3 of this series of papers.

As indicated in table 10 the doweled joints were tested at points both directly over and midway between dowels. The efficiencies of these joints are generally low at all points, but for loads applied over a dowel the efficiency is often much higher than for loads applied midway between dowels.

EFFICIENCIES OF VARIOUS LONGITUDINAL JOINTS COMPARED FOR LOADS NEAR JOINT EDGES

The dowel spacing was varied in the different sections for the purpose of bringing out the effect of dowel spacing on structural efficiency. It has been learned during the testing of the sections that for edge tests the deflections are so small that the stiffness of the two slab ends, as determined by slab thickness, and the stiffness of the structural connection as determined by the width of the joint opening and by the spacing of the units in the case of the doweled joints, are two very important factors which affect the structural action of the joint. To study the matter of dowel spacing properly, the slabs should be of the same thickness and the joint openings should be the same throughout, leaving the single variable of dowel spacing. This does not mean that the data obtained are of no value but it does explain the apparently inconsistent relations which appear when the data are examined from the standpoint of dowel spacing alone.

The effect of the spacing of the dowels is largely eliminated in the data for loads applied directly over a dowel. The low efficiency for this loading indicates the inadequacy of a ¾-inch dowel installed in this manner for transmitting load across joint openings such as were used in this investigation. The efficiencies are somewhat higher for the ½-inch opening than for the ¾-inch opening although the variation in slab stiffness complicates the data. Some looseness of the dowels may have been present and deflection of the dowels certainly occurred, both of which would lower the efficiency of the joint and to the greatest degree in thick slabs. The matter of dowel spacing will be discussed on a theoretical basis later in this report.

The data in table 10 show a great difference in the efficiency of the weakened-plane joint, without dowels, in winter as compared with summer. The very low efficiency of this joint during the cold season results from opening of the joint as the pavement contracts. It would appear that aggregate interlock cannot be depended upon to transfer load effectively when the pavement is in a contracted condition even on relatively short slabs such as these. For longer slabs the reduction might be still greater, while for shorter slabs it might be expected to be less.

The efficiency of the weakened-plane joint with ¾-inch dowel bars at intervals of 18 inches was found to be high at all seasons of the year.

With the dowel plates, joint openings of one-half inch and three-fourths inch were used to determine the effect of this variable. It will be noted that the joint with the wider opening shows a slightly higher efficiency, contrary to what might be expected. The plate in this case was called upon to deflect a 6-inch slab across a ¾-inch opening, while in the other case a plate of the same size had to deflect a 7-inch slab across a ½-inch opening. The effect of the difference in joint opening is thus obscured by the complicating variable of slab thickness. Both joints appear to be quite efficient in slab edges of this general thickness.

Figure 34 shows typical stress data corresponding to those shown in figure 33 but obtained in tests at longitudinal joints, the loads being applied at points A and B. As stated previously, the stress conditions shown were found to apply at all points along the joint except within approximately 3 feet of a slab corner. The data in this figure indicate again that the critical stress for a load acting near a joint is found directly under the load and in a direction parallel to the slab edge.

The stress data in this figure are shown for both the constant-thickness and the thickened-edge slab. Since the stresses for loads applied at point A are affected by the slab thickness at this point, direct comparison of the stresses at points A and B does not give a true indication of joint efficiency for the thickened-edge slab.

Table 11 contains efficiency values for the longitudinal joints calculated in the same manner as those in table 10 for transverse joints. The stress values used in these computations were average values obtained in tests at a great many points. The loads were placed arbitrarily at points over and at various points between dowels in order that the final averages might be representative of average conditions along a joint of the particular type being tested. The difficulty mentioned in connection with thickened-edge slabs was overcome in the following manner. An average empirical relation was established between the interior and edge stresses on the constant-thickness slabs. This relation was applied to the interior stress of the thickened-edge slabs to determine what the edge stress would have been had the free edge been of the same thickness as the longitudinal joint edge, and this calculated value for free-edge stress was used in the efficiency formula.

TABLE 11.—*Efficiencies of the various longitudinal joints for controlling the stresses caused by loads placed near the joint edges*

Test section no.	Type of joint	Type of tongue	Spacing of dowels[1]	Joint efficiency
			Inches	*Percent*
3	Tongue	Rectangular	60	78
5	do	Triangular	60	75
10	do	Corrugated	60	72
4	do	Rectangular	None	50
9	Butt		24	52
8	do		36	42
2	do		48	51
1	do		60	47
6	Plane of weakness		60	44
7	do		None	39

[1] All dowels across longitudinal joints were fully bonded.

EFFECT OF DOWEL SPACING ON JOINT EFFICIENCY DISCUSSED

All of the tongue-and-groove joints that are held closed by the bonded bars appear to have relatively high efficiencies. The tongue-and-groove joint in section 4 has no dowel bars to hold it together. It was tested in a slightly open condition and it will be noted that, although it has a substantial tongue that is roughly rectangular in shape, a marked reduction in efficiency occurs when the bonded steel is omitted. It appears from this table that the shape of the tongue is of little importance in controlling load stresses so long as the joint edges are held together with bonded steel. The highest efficiency value found was with the joint containing the rectangular tongue and groove, however.

In the four butt-type longitudinal joints, the slab thickness at the joint edge was 7 inches in each case, each joint was separated by tarred felt, and ¾-inch dowels were used throughout. The dowels were deformed bars in bond but their function was to transfer load through shear. In all, 59 load tests were made on these four joints at various times and the loads were applied at various distances from a dowel bar.

From the strain data efficiency values were calculated for each of these tests. These efficiency values were grouped according to the distance between the center of the load and the nearest dowel and each group was averaged, from 4 to 16 values constituting a group. These average group values are shown in figure 35 plotted against the space between the load and the dowel and a curve has been drawn through the values. There is considerable dispersion among the values and the curve as drawn may not be correct as to shape. In

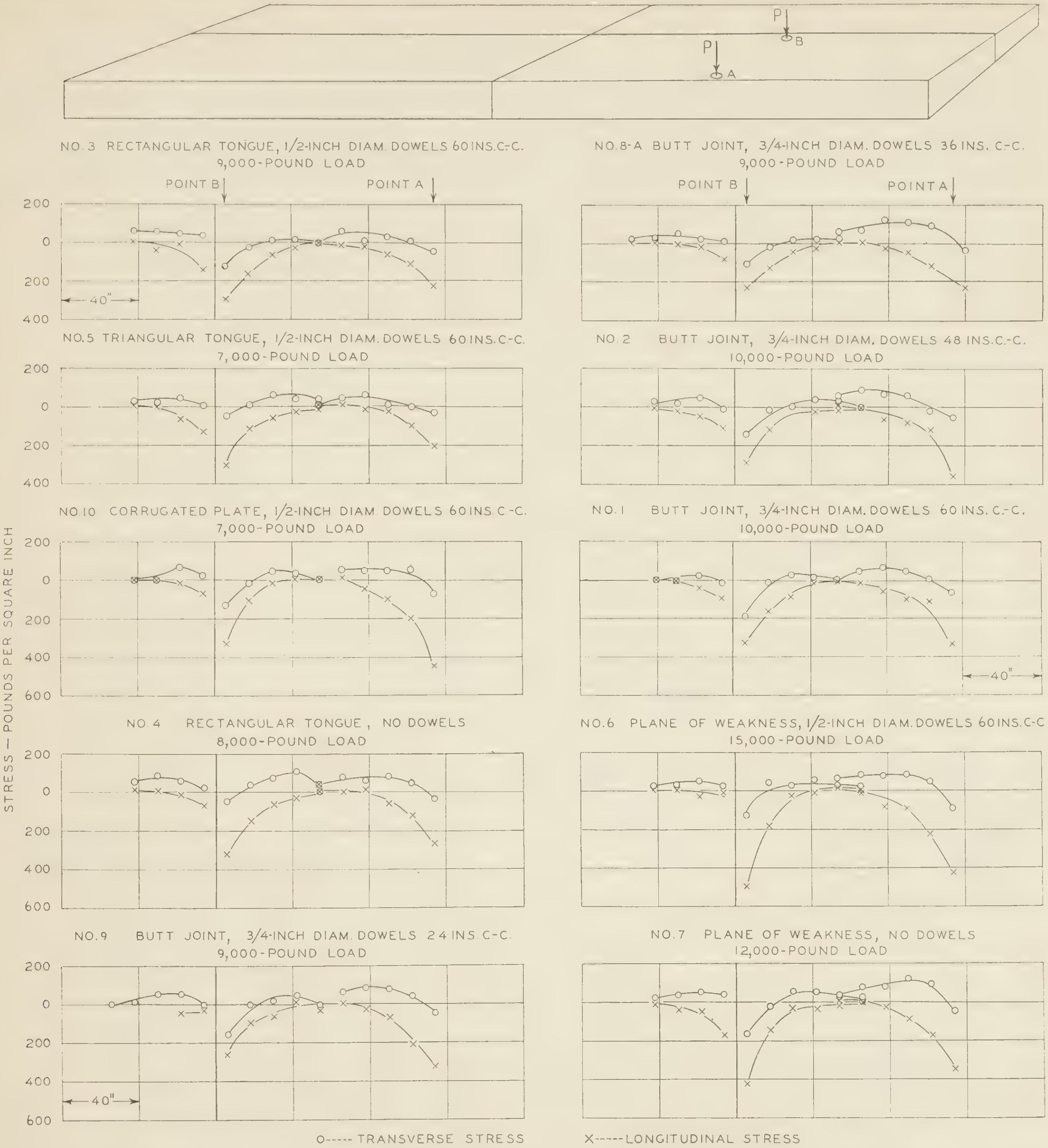

Figure 34.—Comparison of Load Stresses Measured at the Free Edges and at the Longitudinal Joint Edges of Each of the Sections. Values Above the Axis Indicate Tension, and Values Below the Axis Indicate Compression in the Upper Surface of the Slab.

spite of these deficiencies, it is believed that these data show a useful indication of the effect of dowel spacing on structural efficiency for a joint of such construction that little or no deflection of the load-transfer units can occur.

A comparison of the relative efficiency of the closed, longitudinal, butt joints with the open, transverse, expansion joints having the same dowel spacing shows that the efficiency of a given longitudinal joint is much higher than that of the corresponding transverse joint, particularly for loads applied between dowels. It is obvious that the conditions for load transfer through the dowels in these longitudinal joints are much more favorable than they are in any of the doweled transverse joints.

Neither the butt-type longitudinal joints as a group nor the weakened-plane longitudinal joints were found to have efficiencies comparable to the tongue-and-

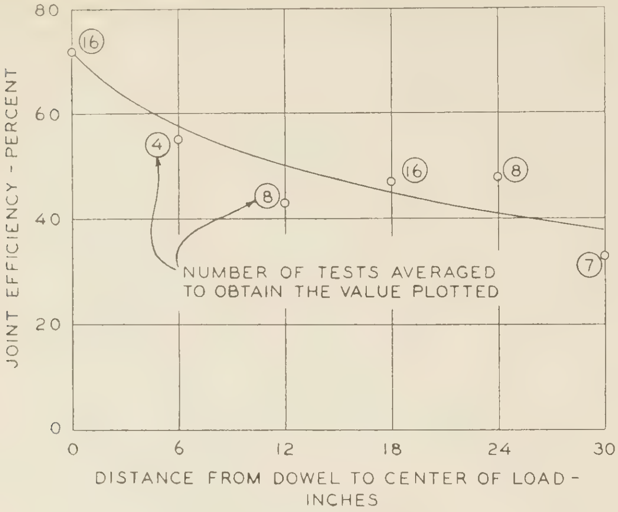

Figure 35.—Variation in Joint Efficiency With Distance Between Load and Nearest Dowel (From Tests of Longitudinal Butt Joints, Sections 1, 2, 8, and 9).

groove joints in controlling the stresses that occur directly under a load. It is perhaps surprising that the weakened-plane joint that is held closed by bonded steel bars (section 6) should show such low efficiency. It was found in testing these joints that, for loads at certain positions, the indicated joint efficiency was very high, while at other load positions the efficiency was practically zero. It was frequently noted that at a certain point this joint would be efficient when the load was placed on one side of the joint and inefficient when the load was placed directly opposite on the other side of the joint.

The load stresses that occur directly under a load are of a critical magnitude only over a small area and if the stresses are to be controlled by the action of the joint it is necessary that the joint be effective in transferring load in the immediate vicinity of the load. If the functioning of such a joint is dependent upon the interlocking of the broken edges, then the efficiency will depend upon the tightness of the contact and upon the peculiar form of the fractured face directly under the load. If these are favorable the efficiency may be quite high; if they are not then the joint will not reduce the critical stresses. It will be recalled in this connection that the bars in the longitudinal joint were 60 inches apart. In the transverse joint of the same type in which ¾-inch dowels at 18-inch intervals were used, the indicated efficiency was high under all conditions.

EFFECT OF JOINT DESIGN ON CONTROL OF CORNER STRESSES STUDIED

The discussion of the stress data has thus far been confined to the effectiveness of the different joint designs in controlling or reducing the critical stresses that occur when a load is applied at a joint edge but at a distance of 3 feet or more from any corner. With certain slab designs, as, for example, those of constant thickness, a critical stress may also be developed when a heavy load is applied at an unsupported corner. In this case the critical tensile stress is no longer found directly under the load but appears along the bisector of the corner angle in the upper surface of the slab and at some distance from the center of load application. The stress-reducing function of a joint design should extend to the relief of these corner stresses. Since under a given load the slab corner tends to deflect more than the edge, joints that are effective for the edge condition are quite likely to be effective near the slab corner also, but a joint that is quite effective in the corner region may be considerably less effective when the load is applied at an edge but away from a corner.

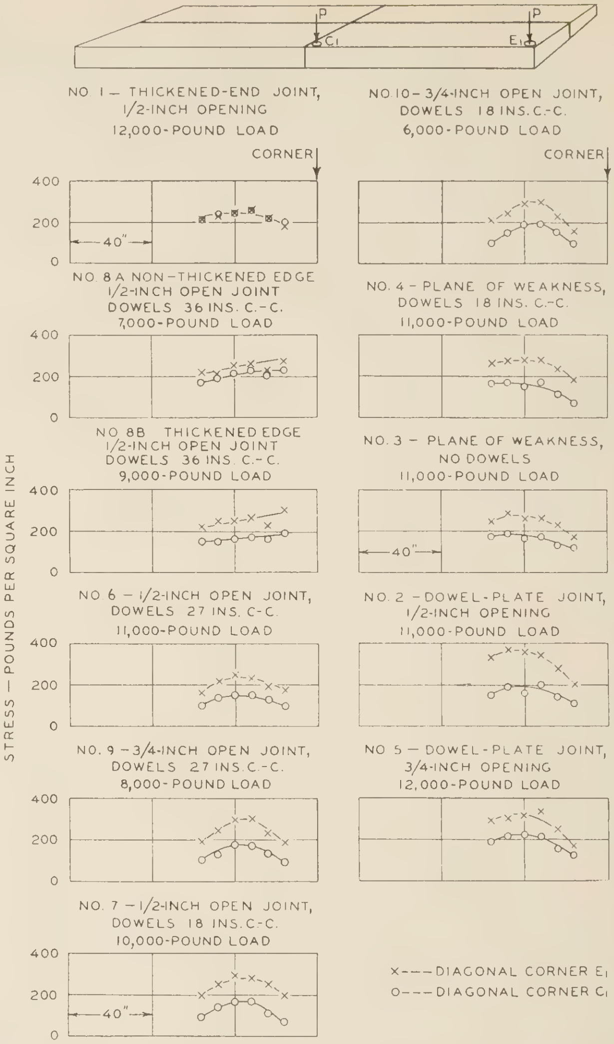

Figure 36.—Comparison of the Critical Load Stresses Measured at the Free and Transverse Joint Corners. Values Indicate Tension in Upper Surface of Slab.

Figure 36 shows stress data obtained from the load tests that were made for the purpose of determining the efficiency of the various transverse joints in controlling the critical corner stresses. Figure 37 shows similar data obtained in the same way in tests at the four longitudinal joints that were used in the constant-thickness sections. The reason that data are not given for the other sections has already been discussed.

The stress values shown in these two figures are the averages obtained from tests at four corners in each section. From them stress-reduction values were calculated for each of the joints tested and these are given in table 12. It should be kept in mind that the stress-reduction values shown in the table are not a measure of the general structural efficiency of the different joints but only an indication of the relative ability of the joints to control the critical stresses caused by a load acting at a slab corner. The values are simply the percentage of reduction of the free-corner stress obtained through the use of the various joint constructions.

It will be noted that there are no values in this table for sections 1 and 8. In section 1 the free and joint ends of the slab are of identical construction and the stresses in the free and test joint corners should be of the same magnitude for a given load. Section 8 has a lip-curb design and because of the difficulties in testing caused by the shape of the cross section and the fact that the number of corners available for comparisons are very limited, comparisons were not made.

Table 12.—*Reduction in corner stress caused by transverse and longitudinal joint action*

TRANSVERSE JOINTS

Test section no.	Type of joint	Spacing of dowels	Joint opening	Stress: At free corner	Stress: At joint corner	Stress: Difference	Reduction in corner stress
		Inches	*Inches*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Percent*
1	Thickened end	None	½				
8	Dowel	36	½				
6	do	27	½	247	154	93	38
9	do	27	¾	302	176	126	42
7	do	18	½	295	168	127	43
10	do	18	¾	299	195	104	35
4	Plane of weakness	18		280	172	108	39
3	do	None		283	186	97	34
2	Dowel plate		½	370	203	167	45
5	do		¾	336	225	111	33

LONGITUDINAL JOINTS

Test section no.	Type of joint	Spacing of dowels	Joint opening	Stress: At free corner	Stress: At joint corner	Stress: Difference	Reduction in corner stress
10	Corrugated tongue	60		298	150	148	50
9	Butt	24		302	136	166	55
6	Plane of weakness	60		247	134	113	46
7	do	None		295	180	115	39

Theoretically the maximum amount of load which can be transferred by a joint design can never quite equal 50 percent of that applied to the one side of the joint because of the eccentricity of the point of load application with respect to the joint. Under ideal conditions a transfer of approximately one half of the load to the adjoining slab should result in a corresponding reduction of approximately 50 percent in the critical stress. In the case of a corner this should apply also and as a matter of fact, because of the distributed nature of the bending that accompanies corner deflection, in practice it would be expected to apply even more to corners than to edges. It is probable, therefore, that the actual efficiency of the joints in reducing the critical stresses at corners is approximately double the values listed in table 12.

It was shown previously by the deflection data that it is not possible for a joint to have an indicated efficiency of 100 percent (based upon a comparison of deflections at the free and joint edges) unless the slab is in perfect contact with the subgrade. Since the slabs were unwarped when the corner loadings were applied and thus perfect contact with the subgrade did not exist, it is probable that the percentage of load actually transferred is somewhat more than one might assume from the stress reduction values given in table 12. The reasons for this have been discussed previously in connection with the application of the second method of analysis to the deflection data.

Considering all of the evidence regarding the ability of the various transverse and longitudinal joints to reduce or control the critical stresses resulting from a load applied near a slab corner, it is indicated that practically all of the joints have a relatively high degree of effectiveness.

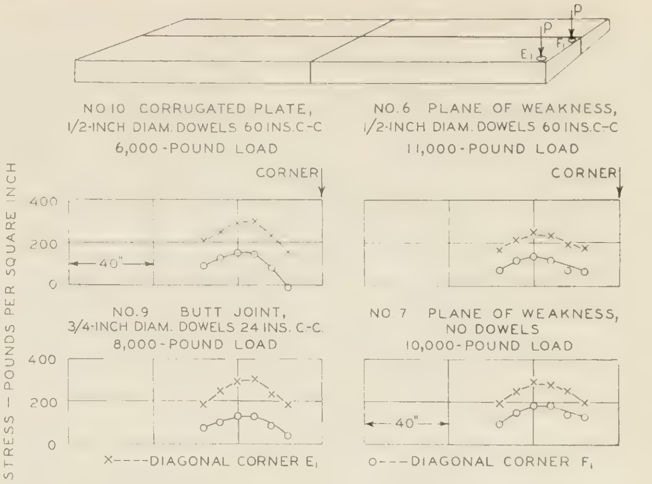

Figure 37.—Comparison of the Critical Load Stresses Measured at the Free and Longitudinal Joint Corners. Values Indicate Tension in Upper Surface of Slab.

EFFECT OF DOWEL SPACING ON JOINT EFFICIENCY DISCUSSED FROM A THEORETICAL STANDPOINT

The transverse joints of the weakened-plane type were tested during the winter when they were in the opened condition. However, the amount of opening resulting from temperature contraction was not large in slabs of this length. This probably explains the fairly high degree of effectiveness shown by the undoweled joint.

The dowel-plate joint having the ½-inch joint opening appears to be somewhat more effective in controlling corner stresses than does the similar joint with the ¾-inch opening. In the case of the doweled joints containing the ¾-inch diameter round bars the effect of joint opening is not definite, probably for the reasons previously discussed. The same is true for indications as to the effect of dowel spacing.

It will be noted that two of the longitudinal joints, on the basis of the corner stress-reduction data, appear to transfer a full half of the load across the joint to the adjacent slab (sections 9 and 10). Section 9 is a 7-inch uniform-thickness slab having a longitudinal joint of the butt type crossed by ¾-inch bonded dowels at 24-inch centers, while section 10 is a 6-inch uniform-thickness section having a longitudinal joint consisting of a corrugated, steel dividing plate and held together with ½-inch bars at 60-inch intervals. Thus, in each, conditions are favorable for the development of a resisting moment and a high degree of load transfer.

The effect of edge thickening in reducing the corner stresses of the thickened-edge slabs is of interest in connection with joint design even though it may not be considered an actual joint design problem. An indication of this effect may be obtained from the stress curves in figure 36 by comparing the stresses at the free corners of thickened-edge slabs with those at the corresponding point of comparable slabs of uniform thickness.

It has been shown that, for a number of reasons, it has not been possible during this investigation to develop from the test data as complete information regarding the proper dowel spacing to control efficiently the stresses that occur directly under a load applied near a

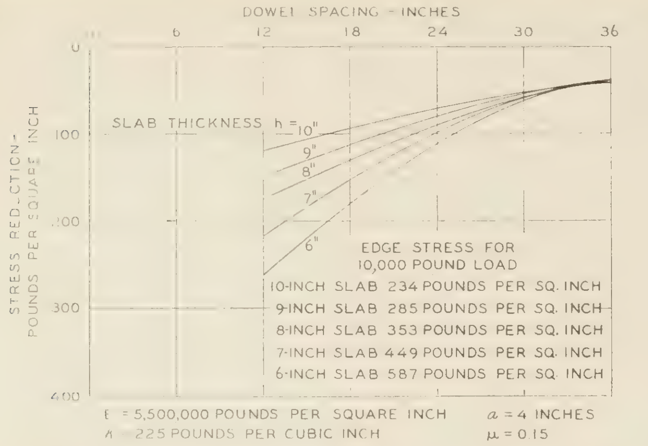

FIGURE 38.—EFFECT OF DOWEL SPACING ON REDUCTION OF EDGE STRESS COMPUTED BY WESTERGAARD'S EXACT METHOD. RELATIONS SHOWN FOR A COMMON LOAD.

joint as it is desirable to obtain. This was caused in part by the fact that most of the dowel spacings were too great to be effective and in part by the presence of other complicating variables in a number of the tests.

It is believed that a short discussion of the subject from a theoretical standpoint will help to clarify the general relations between load, stress, slab thickness, and dowel spacing.

Making use of the more exact formulas developed by Westergaard in his analysis of this subject,[2] that is, the formulas in which the reactions of the four dowels nearest the load are taken into account, the values that determine the sets of curves shown in figures 38 and 39 were computed. The constants used in the calculations were appropriate to the conditions of the tests at Arlington. In the analysis by Westergaard it was assumed that the dowels were of sufficient stiffness to cause the two sides of the joint to deflect equally. Since dowels do not perform in this ideal manner, it is to be expected that the theoretical stress reductions for given conditions will be greater than those that will be obtained in practice, with joints as they are constructed at the present time.

The stress reductions shown in figure 38 are for a constant load of 10,000 pounds applied on slabs of 6, 7, 8, 9, and 10-inch thicknesses. The stresses theoretically developed in the free edge of each slab by this same load are tabulated in the lower part of this figure.

In figure 39 similar relations are shown, but in this case the magnitude of the applied load was varied in order that the edge stress in each of the various thicknesses of slab would have a constant value of 300 pounds per square inch.

Both of these figures show very clearly that both the amount and the rate of stress reduction increase as the dowel spacing decreases. It is indicated that, even for the ideal condition represented by the basic specification of the analysis, dowels spaced 3 feet or more apart are of little value in reducing slab stresses. When the dowel spacing is 2 feet or less, the dowel reactions become more effective in reducing stress and the analysis shows that if dowels are to be of appreciable value in reducing edge stresses, they must be closely spaced, even when complete rigidity exists in the dowel.

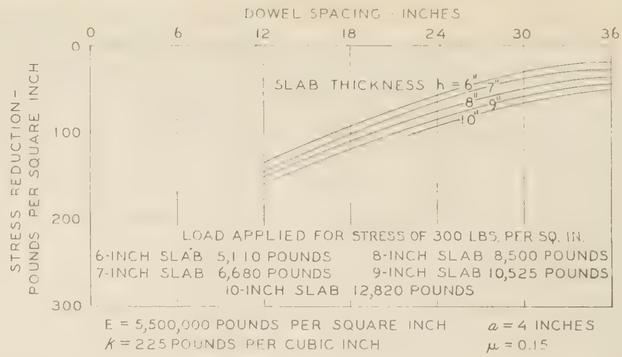

FIGURE 39.—EFFECT OF DOWEL SPACING ON REDUCTION OF EDGE STRESS COMPUTED BY WESTERGAARD'S EXACT METHOD. RELATIONS SHOWN FOR A COMMON EDGE STRESS.

Both theory and experiment show that a load that will produce a critical stress of 300 pounds per square inch in the free edge of a slab will cause a critical stress of slightly less than 200 pounds per square inch when applied in the interior of the slab (provided the slab is of uniform thickness). Thus in this type of slab complete continuity will effect a stress reduction of a little more than 100 pounds per square inch. There are a number of other factors that affect this relation somewhat but the above general statement is approximately true.

Figure 39 shows that, theoretically, in order to accomplish the same reduction with dowels that is obtained by the continuity of the slab (about 100 pounds per square inch), a dowel spacing of approximately 21 inches would be required with a slab 9 inches thick and a spacing of approximately 17 inches with a slab 6 inches thick.

The data presented in this report show that in joints of the types tested, the stress reductions to be expected in joints as actually constructed will fall considerably short of that theoretically possible.

If a doweled joint is to bring about a satisfactory control of edge stresses it would appear that the dowel units will have to provide more shear resistance individually and be spaced much nearer to each other than has been the practice in the past.

MEASUREMENTS MADE OF COMBINED STRESSES AT JOINTS

A pavement slab to be perfectly designed structurally should be so proportioned that a given load, wherever applied, would at all times produce no more than a selected maximum stress at any point. Such a design would make the most economical use of the material and would have no weak spots at which overstressing could occur and failure begin.

The load-carrying capacity of any pavement slab should be indicated by the most critical combinations of load and warping stresses at the different parts of the slab, and the more nearly the ideal design is approached the more readily will these combined stresses attain a common value. There is, however, one consideration that should be mentioned because it affects the generality of application of the statement that was just made. For a load placed at the edge of a slab or at an interior point the load stress is highly localized as has been shown in a number of the figures of this and the preceding papers. When a load is applied on the corner of a slab the distribution of the high stress values is considerably greater. It seems probable, therefore, that a combined stress having a magnitude

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[2] Spacing of Dowels, by H. M. Westergaard. Proceedings, Eighth Annual Meeting of the Highway Research Board, 1928, pp. 154–158. [Footnote 12 in the first installment of this paper (PUBLIC ROADS, September 1936, p. 147) is incorrect, and should refer to the above article.]

that would cause a structural failure in the case of a corner loading would not necessarily produce a structural failure when developed under the load in the case of an edge or interior loading. If this is true, a pavement slab should be so designed that the combined load and warping stress at the corner is less than at other parts of the slab.

Since the interior portion of the slab is inherently the strongest and comprises the greatest area, the object of the design should be to increase the load-carrying capacity of the free and joint edges and of the corners to equal that of the interior of the slab. With this thought in mind table 13 was prepared. The values in the four columns headed "Maximum load stresses" show the magnitudes of the maximum stresses for various positions of a given load, expressed as a percentage of those found for an interior position of this load (point H). The values shown in the columns headed "Warping stresses" are expressed in the same way and are taken from the maximum average warping stresses measured on the two test sections concerned and published in the second report of this series.

The first two columns of each group show data obtained from the thickened-edge slab (sec. 5) while the third and fourth columns contain similar values which apply to three points along the free edge of the 6-inch constant-thickness slab (sec. 10). Other factors being constant, these are the three points where the relations for a constant-thickness slab might be expected to be different from those for a thickened-edge slab.

The warping stresses are applicable only to slabs of the general dimensions tested in this investigation.

Table 13.—*Relation of both critical load and warping stresses at points near the free and joint edges of typical slabs compared to the stresses at the interior*

Load at point	Maximum load stresses (upper surface of slab) (percentage of that at point H on each section)				Warping stresses (percentage of that at point H on each section)[1]			
	Section 5		Section 10		Section 5		Section 10	
	Compression	Tension	Compression	Tension	Compression	Tension[2]	Compression	Tension
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
E		71		130	0	11		11
A	109	19	159	45	115		89	
C		48		88	0	11		11
I	159	48			22			
H	100	0			100			
G	120	34			22			
F	84	67			0	11		
B	115	26			89			
D	110	34			0	11		

[1] Warping stresses are for the same points in the upper surface of the slab for which load stresses are given and are for conditions of average maximum warping.

[2] Values are for stresses parallel to the bisector of the corner angle since they are to be combined with the load stresses in that direction.

It will be noted that two load stresses are shown for each point of load application on these two slabs except for points E and C. The values shown in the first column in each case are stresses in the top of the slab directly under the load. These are not shown for points E and C because of their very small magnitude. The second column in each case contains the maximum stresses occurring in the top of the slab at some distance from the area of load application. The efficiency of the longitudinal and the transverse joints naturally affects some of the values given so that relations shown in the table apply to pavements of equivalent cross section and joint efficiency.

The effect of edge thickening on the load and warping stresses at the various points is apparent if the values pertaining to them for section 5 are compared to those for the same points on section 10. Except in those cases where the edge thickening affects the relation, the values shown for points at the free edges and free ends of the sections would apply equally well for joints having little or no structural effectiveness. The effect of the joint design in section 10 in reducing load stresses is reflected in the comparative magnitude of the load-stress values at the corresponding points on the free and joint corners of this constant-thickness slab.

IMPORTANCE OF CONTROLLING LONGITUDINAL WARPING STRESSES EMPHASIZED

There is a small variation in the relation between the load-stress values at the various parts of a pavement slab at different seasons of the year. This will be discussed more thoroughly in the next paper of this series. The relations shown in table 13 for the critical stresses directly under the load are based on data obtained from a great many tests made during the winter months. The values shown for the less critical stresses (those not directly under the load) are based upon less extensive data obtained in tests made at various seasons of the year, although wherever possible the relations shown are averages from several tests.

In order to emphasize the importance of the data just shown and to present them in a more easily assimilated form, table 14 was prepared. In this table the critical combined stresses are given in absolute units and represent stresses that might reasonably be expected to develop in each of the two slabs under the action of a 7,000-pound load and temperature warping of average maximum intensity as determined during the course of this investigation. The values follow directly from the percentages given in the preceding table. In all cases except at the corners the stresses apply to afternoon conditions. For the corners the warping is that which occurs during the night. It was explained in a previous report that it was not possible to determine the corner warping stresses for a thickened-edge slab. For this reason it was necessary to apply to the thickened-edge slab the corner warping

Table 14.—*Combined critical load and warping stresses*[1] *at the midpoint and at points near the free and joint edges of panels of two of the test sections*

Load at point	Load stress[2]		Warping stress		Combined stress		Combined stress (percentage of that at point H)	
	Compression	Tension	Compression	Tension	Compression	Tension	Compression	Tension
	Lbs. per sq. in.	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Percent*	*Percent*
Section 5:								
E	0	176	0	40	0	216	0	36
A	268		413		681		112	
C		119	0	40		159		26
I	393		80		473		78	
H	247		360		607		100	
G	297		80		377		62	
F	207	165	0	40	207	205	34	34
B	285		320		605		100	
D	272	84	0	40	272	124	45	20
Section 10:								
E		321		40		361		60
A	393		320		713		117	
C		217		40		257		42

[1] Maximum stresses in upper surface of slab.

[2] The load stresses in each section were produced with a 7,000-pound load.

stresses determined from measurements on the corner of a constant-thickness slab. The magnitude of these stresses is so small that this method should introduce no error of consequence.

The warping stresses shown in this table are for slabs 10 feet wide and 20 feet long. It was brought out in the discussion of warping stresses in the second report that, for slabs of the thicknesses used, the maximum warping stresses are approximately as large as they would be for much longer slabs of the same width. The combined stresses shown in table 14 should therefore represent the condition where effective control of warping stress has not been provided.

There was no opportunity in this investigation to make an extensive study of warping stresses on short slabs, but the work that was done indicated that the magnitude of the critical warping stresses would be greatly reduced as the length of the slab was reduced below the 20-foot length used in this series of tests. For short slabs the values of the combined stress will tend to approach the value of the load stress alone.

It is obvious from table 14 that the most important step in the effort to balance the combined stress values is to reduce the warping stress at points A, H, and B. The most effective means for doing this seems to be by shortening the length of the slab. This has already been discussed in connection with cross-section design in the preceding paper and needs no further discussion here. The effect of edge thickening on the load and warping stresses was also discussed in a previous report.

One of the most difficult problems in connection with concrete pavement construction is the control of transverse cracking. It is important to control the critical load stress along a slab edge abutting a longitudinal joint because this stress combines directly with a warping stress that tends naturally to be high. The combined stress, being a longitudinal stress, is in a position to start the formation of a transverse crack if its value becomes excessive. Longitudinal joint designs of high structural efficiency are desirable therefore as an aid in controlling transverse cracking.

JOINTS SHOULD PERMIT FREE FLEXURE OF SLAB EDGES

The longitudinal joints in both sections 5 and 10 were very effective in reducing the stresses under the load and it is apparent from table 14 that, where the warping stresses are controlled, the cross section of a slab having a thickened edge and an efficient longitudinal joint is very well balanced. Because the width of the slab was but one half of its length, the warping stresses at points I and G are much smaller than those at points A and B. This probably explains why longitudinal cracking is seldom observed in slabs having a width of approximately 10 feet.

It is apparently unnecessary, in order to balance the general design of a pavement slab, to reduce the combined stresses at points I and G unless the warping stresses in the longitudinal direction are controlled. Where these stresses are controlled, leaving practically all of the flexural strength of the slab available for carrying load, then it becomes necessary to provide transverse joints that are effective in reducing the stresses directly under the load, when the load is near the joint, in order to make the load-carrying capacity of the slab at point G comparable to that at the interior point H.

The effect of edge thickening and of the joint construction on the stress conditions of the corners E, C, F, and D are well shown by table 14. The warping stresses at the corners are so low that, on the basis of combined stresses, the corners do not appear to be critical points. Because of the distribution of the maximum stress from a load applied at a corner and because of the greater likelihood of impact, weakened subgrade support resulting from the infiltration of water, and possibly other factors, it appears desirable to make the corners of the slab somewhat stronger in relation to the other parts of the slab than would appear to be necessary from the combined stress values in the table.

A comparison of the load stresses occurring along the bisector of the corner angle, for a load acting at point E on each of the two slabs, shows that edge thickening is very effective in reducing these stresses. The effectiveness of joints in controlling these stresses at joint corners was discussed earlier in this paper in connection with table 12.

It is interesting to note that at the inside corners, where the load stresses along the bisector of the corner angle are very low, the stresses directly under the load become relatively high. This is due to the action of the joints causing the slab at point D to behave more in the manner of the interior of the slab. One joint acting effectively will cause the stresses at this point to be distributed as at a free edge, while with both joints effective a stress distribution more like that which exists in the case of an interior loading is created. Thus the position and magnitude of the critical stress at a slab corner depend upon the action of the joint or joints at that corner. Joints that are very effective in controlling the stresses along the bisector of the corner angle may cause a critical stress condition under a load acting near the corner.

It has already been shown that, from the standpoint of reducing warping stresses, free action of the corners at point D is desirable. Such construction would likewise reduce the load stress just discussed and increase slightly the load stress along the bisector of the corner angle of the slab. Therefore, as far as both warping and load stresses are concerned, the joints should be so designed that resisting moments that prevent free flexure are not developed in the joint.

Earlier in this paper it was stated that joints are introduced into concrete pavements for the purpose of controlling certain stresses that are present from causes other than load, and that joints may be classified according to the stresses they are intended to relieve as follows:

1. Expansion joints to control the direct compression stress caused by expansion of the concrete.
2. Contraction joints to control the direct tensile stresses caused by contraction of the concrete.
3. Warping joints to control the bending stresses resulting from restrained warping.

Data developed during the course of this investigation and reported in this and the two preceding papers of this series permit certain general observations to be made and also suggest certain ways in which the joint designs that were tested may be improved.

SPACING OF EXPANSION, CONTRACTION, AND WARPING JOINTS SHOULD BE APPROXIMATELY 100, 30, AND 10 FEET, RESPECTIVELY

The proper spacing of joints is a matter concerning which there has frequently been a wide difference of opinion. The trend of thought as reflected in construction practice during the past was brought out in the historical review at the beginning of this paper. As recently as the December 1932 meeting of the Highway

Research Board, in a paper on the design of joints,[3] R. D. Bradbury stated that: "The proper spacing of transverse joints is largely a matter of judgment based upon experience". In other words, there was available no rational method by which the proper spacing of joints could be determined.

Since joints cost money it has frequently been the policy to install as few joints as possible and to have these of the cheapest type. It is well to remember, however, that the stress reductions accomplished by the introduction of the joint may be worth more in added load-carrying capacity than the cost of the joint installation. This study indicates that frequency of joints can increase the safe load-carrying capacity of a pavement without any increase in slab thickness. Also, frequent joints and the resulting short slab lengths simplify somewhat the structural requirements of transverse joint designs.

It is not the intention to suggest that as a result of this investigation it is now possible to determine rationally the proper spacing of joints under all conditions. Much additional information is needed before this desirable objective can be attained; particularly needed are data on the effects of radically different subgrade conditions and on a number of factors that affect warping stresses. However, the data already obtained make possible several useful generalizations relative to joints. The tests have shown that the distance between expansion joints will not be determined so much by the magnitude of the compressive stresses during expansion as it will by a consideration of the amount of horizontal movement that it is desirable to permit at any one joint. The data presented in the second report[4] show that for ordinary slab lengths the compressive stresses during expansion are relatively quite small, provided no restraint is offered at the slab ends.

Figure 40 has been prepared from data obtained during these studies to give an idea of the average changes in length that occur annually in concrete pavements from changes in the moisture state of the concrete and in the average temperature of the slab (fig. 40–A), and of those that occur daily from temperature change alone (fig. 40–B). The length changes are in inches and apply to a slab 100 feet in length. This graph shows that the rise in temperature from winter to summer caused an expansion of about 0.45 inch in this length of slab. During this same period a loss of moisture occurred which caused a contraction of about 0.15 inch. The net result of the combined annual volume changes was an expansion of about 0.30 inch from winter to summer. The daily changes in length are approximately 0.03 inch in winter and 0.08 inch in summer. The values apply exactly only to climatic conditions and to concrete having volume-change characteristics such as those which existed in these tests. However, there is nothing unusual about either.

It will be recalled that data presented in the second report showed that the test slabs at Arlington are gradually increasing in length. The ultimate extent of this growth cannot be predicted, but after four annual cycles of length change it amounted to approximately 0.17 inch in a 100-foot slab. Such a change when present will have to be cared for in the expansion-joint design.

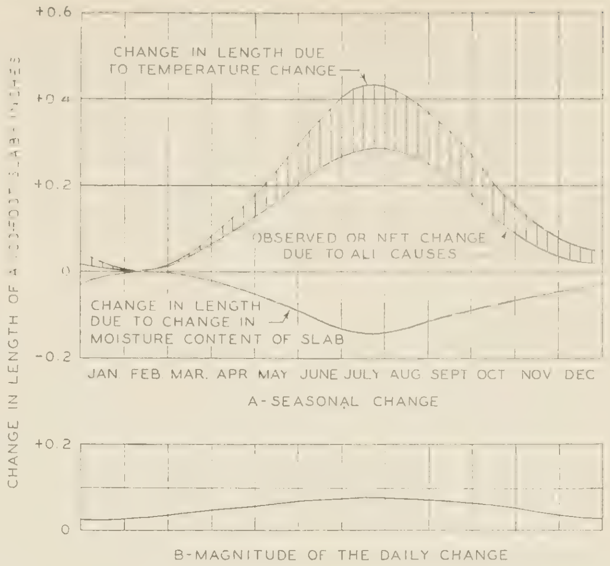

Figure 40.—Average Seasonal and Daily Changes in Length of a 100-Foot Slab Caused by Variations in Temperature and Moisture Content. (Based on Observed Movements.)

In view of the present knowledge on the subject, it seems reasonable to conclude that expansion joints should be provided at no greater than 100-foot intervals in order to keep the joint openings from becoming excessive.

The spacing of contraction joints, unlike that of expansion joints, will be determined by the permissible unit stress in the concrete. If this is restricted to a low value, as is most desirable because of its direct effect on load-carrying capacity, the test data indicate that the contraction-joint interval should be kept quite small, possibly of the general order of 30 feet.

In the second and third papers of the series it was shown that, if the stresses caused by restrained temperature warping are to be properly controlled, the length and width of the slab panels must be kept quite small. Although additional studies should be made to determine what the maximum dimensions should be for various slab thicknesses, the present data indicate that a satisfactory control of warping stresses would ordinarily be obtained if the maximum dimensions of the slab were 10 or 12 feet, indicating that the interval between warping joints should be of the same general order.

EDGE THICKENING AT JOINTS EFFECTIVE ONLY FOR SHORT SLABS

The joint tests in this investigation as originally planned did not include provision for a study of types and arrangement of joints to control warping stresses, and it has not yet been possible to conduct such a study. There are three arrangements that might be considered:

1. Placing joints that will both provide for expansion and relieve contraction stresses at intervals sufficiently small to control warping stress effectively.
2. Placing expansion joints at intervals sufficiently small to relieve contraction stresses and, between the expansion joints, placing joints intended to relieve warping stresses only.
3. Placing expansion joints at the proper intervals, between these placing the contraction joints at the intervals necessary to control tensile stress and, finally, between the contraction joints placing warping joints as frequently as necessary.

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[3] Design of Joints in Concrete Pavements, by R. D. Bradbury, Proceedings 12th Annual Meeting, Highway Research Board, 1932, part I, pp. 105–136.

[4] Structural Design of Concrete Pavements, (see fig. 23 and attendant discussion) Public Roads, vol. 16, no. 9, November 1935.

In deciding which of these different arrangements should be used and to what extent the ideal installation should be approached there are several factors to be taken into consideration:

1. The effectiveness of the proposed joints in reducing the stresses caused by restrainted warping;
2. The efficiency of the joints in reducing the critical stresses caused by a load acting near the joint;
3. The difficulty of maintaining the joints in a properly sealed and smooth condition;
4. Installation difficulties; and
5. Cost.[5]

The strengthening of slab edges at joints has been applied, in practice, to longitudinal joints and to a more limited extent to transverse joints. The application to longitudinal joints appears to have been successful but there has been some criticism of the attempts to use edge thickening at transverse joints because, on certain projects at least, it is reported that transverse cracks have formed within 3 or 4 feet of the transverse joints. The formation of these cracks is attributed in various ways to the presence of the thickened slab end.

In this investigation one of the sections was constructed with thickened ends and this section has been carefully studied over the entire period of the test. It was found that the thickened ends did not increase the resistance of the subgrade to horizontal slab movement because in slabs 20 feet long the subgrade adhered to the concrete and there was little or no sliding of the slab ends. The data obtained indicated no greater tensile stress in this slab, during contraction, than in one built without the thickened ends.

The design of edge thickening for balancing load stresses was described in the third paper of the series, and it was pointed out that edge thickening to be most effective should be limited to relatively short slabs because of the increased warping stresses that tend to develop under certain conditions. These considerations apply with equal force to both longitudinal and transverse joint edges. It is necessary that special care should be taken in the early curing period of such designs to insulate the slabs and prevent the formation of large temperature differentials. In the report of the curing experiments at Arlington[6] some years ago mention was made of transverse cracking which occurred close to the ends of several of the sections that were not protected from the sun's rays during the first 24 hours after placing. This cracking, which was similar in location to that reported on some of the thickened-end pavements, was attributed to high warping stress during the early period of strength development, pointing to the desirability of insulative coverings for curing concrete pavements.

With thickened-end slabs, blocking of the lower portion of the transverse joint with concrete spilled during construction or with solid matter entering after construction is likely to be a serious matter because of the eccentricity of thrust and consequent greatly increased bending moments that may develop near the joint during expansion of the slabs. It is especially necessary, therefore, that, where thickened ends are to be used at transverse joints, care should be taken to insure that there is space for free expansion at all times.

IMPROVEMENTS IN DESIGN OF DOWELED JOINTS RECOMMENDED

The doweled transverse joints tested were found to be effective in the two functions of permitting unrestrained expansion and contraction and in allowing the slab ends to warp freely. These joints as constructed in this investigation were not satisfactory, however, so far as their ability to reduce the stresses caused by load is concerned. For loads acting at joint corners fair reductions in the critical stress were obtained, and the same is true for loads applied directly over dowels, but for other conditions of loading the stress reductions generally were much smaller than is desirable.

Attempts to improve the doweled joint designs should begin with efforts to increase their effectiveness in reducing the critical stresses caused by a load placed near the joint but at a distance from a corner.

It is indicated that the doweled transverse joints as built and tested in this investigation have the following weaknesses:

1. The individual units were too widely spaced.
2. The individual units were not stiff enough effectively to transfer loads of the magnitude and under the conditions involved.
3. It is difficult to obtain complete and perfect embedment of a dowel bar.
4. Even if perfect embedment were obtained the unit bearing stress on the concrete is apt to be excessive when heavy loads are applied on one side of the joint.

The closest dowel spacing tested was 18 inches and it is evident from the data that, for dowel size, joint openings, slab thicknesses, and loads of the same general order as were used in the tests, this spacing is too great. It is not possible to state, from the test data, what the proper spacing should be in order to make this joint highly effective in relieving the important edge stresses. The minimum spacing of dowels will be determined by the magnitude of the critical stress caused by a load applied at the joint edge at a distance from a corner. If the spacing is close enough to control this stress satisfactorily, the stress conditions for a load acting at the slab corner will also be satisfactorily controlled, so long as no resisting moment is allowed to develop in the joint itself.

It has been shown previously by some of the load-deflection measurements that one very important cause of the low efficiency of the doweled joints in controlling load stresses is the lack of stiffness in the dowel itself. This suggests that the size or shape of the dowel should be changed, that the joint opening should be decreased, or that the bearing conditions of the dowel in the slab should be improved in order to increase the resistance to bending of the unit. Any great increase in the bending resistance of the joint is undesirable because it reduces the ability of the joint to relieve warping stress, one of its most important functions. It is necessary, therefore, to proceed cautiously with any changes tending to increase joint stiffness.

Tests made for the purpose indicated that, when the concrete around the dowel is placed with great care, little or no play between the dowel and the concrete existed. It is difficult to be certain that this condition will always be obtained in construction. Indeed, it is to be expected that it will not, unless unusual attention is given to it. Furthermore, although no thorough study has been made of the effect of continued service on the seating of dowels, there is good reason to believe that such usage tends to develop looseness.

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[5] For a discussion of current costs and other considerations, the reader is referred to a paper entitled "Developments in Transverse Joints and Fillers in Concrete Pavements and Bases" by R. E. Toms, presented before a meeting of the Association of State Highway Officials of the North Atlantic States, Baltimore, Md., Feb. 14, 1935. See also American Highways, Vol. 14, No. 2, April 1935, for a similar discussion by the same author.

[6] The Arlington Curing Experiments, by L. W. Teller and H. L. Bosley, PUBLIC ROADS, Vol. 10, No. 12, February 1930. pp. 218-219.

Under the small deflections of pavement slabs, continued good bearing is essential if the dowels are to maintain their original effectiveness. This suggests that some bearing other than that of the concrete should be provided in order to make the bearing conditions more effective and permanent. What the best form for such a device should be cannot be determined without more tests. Certainly there are problems connected with its design which will have to be worked out, and this is true also for the other possibilities that have been discussed.

The doweled joint is not an ideal type and probably will never approach closely to its theoretical efficiency, but there is little doubt that it can be improved considerably by correcting its recognized weaknesses. From the information at present available it seems probable that the greatest all-around effectiveness in a joint of this type will be had with dowel members that are not too stiff, that are spaced closely in a joint that is opened as little as possible, and with good bearing of the dowels in the slabs insured through the installation of an effective dowel seat.

FURTHER INFORMATION NEEDED ON ACTION OF VARIOUS JOINTS

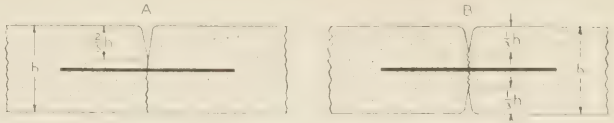
The tests made with the limited number of dowel-plate joints included in this investigation indicate that this type is quite effective in relieving warping stress and in reducing the critical stresses caused by loads acting near the joints. The continuous plate, as used in these tests, appears to control the stresses directly under a load more effectively than round dowels at any of the spacings tested.

The tests showed that the dowel-plate joints offer more resistance to expansion and contraction of the slab than do the joints containing the round dowels regardless of their spacing. The concrete was carefully placed around the dowel-plate covers at the time of construction. Because of the small space between the plate and the subgrade special manipulation was necessary but a satisfactory installation was obtained. There can be little doubt that the same tight gripping of the plate in its socket, which caused the resistance to slab movement just mentioned, is responsible for the effectiveness of the construction in reducing the edge stress.

Only two dowel-plate joints were studied and the information developed leaves unanswered a number of questions. For example, it is desirable to know what width and thickness of dowel plate will be most generally effective in slabs of different thickness. Also it is desirable that means be developed for effectively sealing the joint or by other means reducing corrosion of the dowel plate to a minimum.

The data indicate that the dowel-plate joint has considerable merit and that a more thorough study of its possibilities is warranted. Determination of its effectiveness after having been in service for some time would seem to be particularly important.

This investigation revealed that the weakened-plane tranverse joint without dowels is not effective in reducing the stresses directly under a load acting near the joint when the joint is open and may not be effective when the joint is tightly closed. It appears to be fairly effective in reducing corner stresses when closed but may become very ineffective when open. The fact that these joints sometimes do not function effectively though tightly closed is apparent due to an inclined fracture. The character of the support varies from side to side of the joint and from point to point along each side, being effective in some places and quite ineffective in others.



DOWEL BARS CLOSELY SPACED BUT NOT IN BOND

DOWEL BARS CLOSELY SPACED AND IN BOND

Figure 41.—Plane-of-Weakness Joints Designed to Permit Free Warping.

The weakened-plane transverse joint with dowel bars spaced 18 inches apart was found to be much more consistent in its behavior and fairly efficient in reducing corner stresses and stresses directly under the load. There is little to indicate that aggregate interlock can be depended upon to control the critical stresses caused by load under any conditions and this applies to the longitudinal as well as the transverse plane-of-weakness joints. It appears that to control the stresses effectively and thus strengthen the joint edge, the same type and character of edge support will be necessary with a weakened plane of the type tested as would be required with butt joints.

The weakened-plane joint will control warping stresses effectively if it is so designed that a resisting moment within the joint cannot be developed. In a warping joint, prevention of the development of a resisting moment may be accomplished in any one of three ways: (1) By preventing the steel dowels from taking tension through a destruction of bond on one or both halves of the dowel; (2) by preventing the concrete from developing compression by separating the two slab ends; or (3) by greatly reducing the length of the moment arm so that for a given joint deflection the magnitude of the resisting moment is greatly reduced even though the steel dowels take tension and the concrete surfaces are tightly interlocked.

Weakened-plane joints designed to prevent the development of large resisting moments during warping are shown in figure 41. It should be recalled that the downward warping of the slab edges normally exceeds the upward warping by a considerable degree and, further, that under the conditions that cause upward warping of the slab edges, the concrete is in a contracted state and the joints are opened, the dowels being without bond.

In this class only the longitudinal joints of sections 3, 4, 5, and 10 are considered. None of these was intended as an expansion joint and none of the designs included in this group could be expected to function satisfactorily as an expansion joint because the shape of the interlocking elements is such that separation horizontally is in each case accompanied by a separation vertically that would prevent effective load transfer by the joint.

Of the four joints considered, only that in section 4 could be expected to relieve direct tensile stress caused by slab contraction. This joint, it will be recalled, had a trapezoidal tongue roughly rectangular in shape although there is appreciable slope to the upper and lower faces. No dowels or tie bars cross the joint. At the time the load tests were made the joint was opened slightly so that the stress values obtained probably indicate the efficiency under critical conditions.

The joint was found to be fairly effective in reducing the critical corner stress, but, for loads applied at the joint edge at a distance from the corner, the efficiency

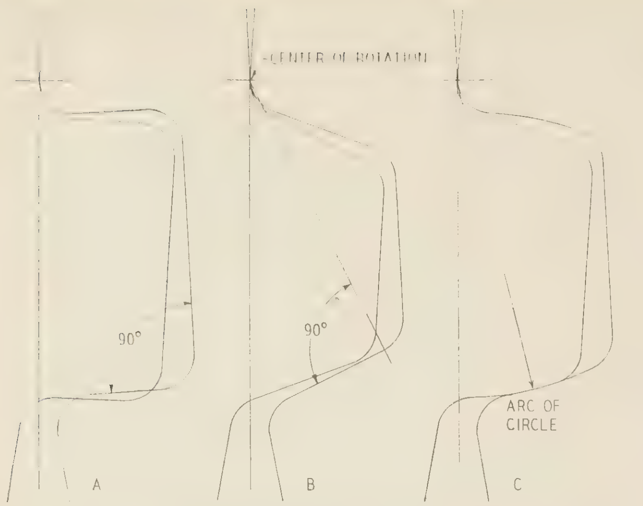


Figure 42.—Relative Displacements of the Various Parts of Tongue-and-Groove Joints During Downward Warping.

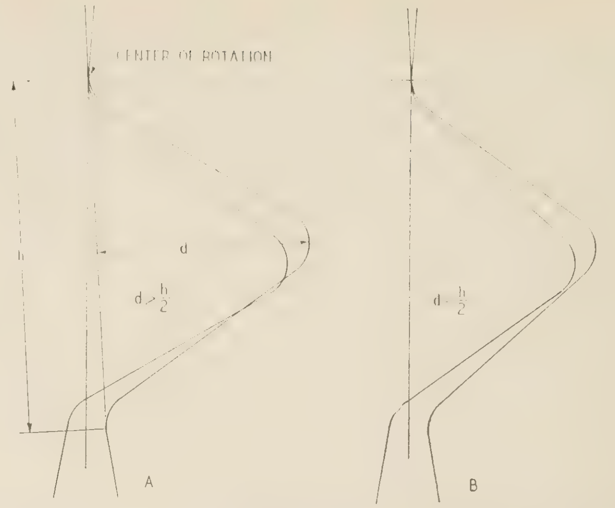


Figure 43.—Relative Displacements of the Various Parts of Two Triangular Tongue-and-Groove Joints During Downward Warping.

in reducing the critical stress is much less than it was found to be for the same type of joint held closed by bonded steel. This undoubtedly results from the tendency for the tongue to loosen as it is withdrawn from the groove and indicates the necessity for designing a different shape of tongue if this general type is to be considered as a contraction joint. Although a perfectly rectangular tongue section would probably be the most effective design for controlling load stresses, it would restrain warping and, probably to a lesser extent, free horizontal movement. It appears necessary, therefore, that the shape of the tongue and groove should depart from the perfectly rectangular form.

ACTION OF TONGUE-AND-GROOVE JOINTS DURING SLAB WARPING DESCRIBED

Figure 42 illustrates a simple method for determining graphically the relative movements of the two sides of three designs of tongue-and-groove joints during warping of the slab ends. It is assumed that in each design the ends of the two slabs both above and below the tongue and groove have been relieved by inclining the face of the edge slightly as shown in the section. The point of contact and probable center of rotation would be just above the tongue during downward warping and just below the tongue during upward warping, approximately as shown in the figure.

In the first design (fig. 42–A) the upper and lower faces of the tongue are parallel. It is apparent that as warping occurs the tongue will bind in the groove and will not be able to take the position that it would assume if unrestrained warping were to be permitted. Restraint is developed that will cause undesirable warping stress in the slabs near the joints and high local stresses in the elements of the joint itself.

In the second design (fig. 42–B) there is considerable slope to both the upper and lower faces of the tongue. When warping occurs there is a tendency for these faces of the tongue and groove to separate, depriving the joint of its ability to transfer load during small deflections.

Figure 42–C shows a section modified in accordance with the preceding discussion. The upper and lower surfaces of the tongue have been shaped so that neither excessive bearing pressures nor loss of contact should occur during slab warping. It is emphasized that this design is only a suggested application of the results of these tests and should be given an experimental verification before being recommended as a design suitable for contraction and warping joints.

Figure 43 is a similar study of the triangular shape for tongue-and-groove joints. For the assumed conditions it appears that if the depth of the tongue *"d"* is greater than approximately one-half of its height *"h"*, warping will cause high local bearing stress near the end of the tongue (fig. 43–A), while if the depth is less than about one-half the height, separation will occur as the slabs bend. This analysis indicates and the test data show that the triangular tongue and groove is likely to be less satisfactory during contraction or warping than the modified rectangular forms.

For the reasons just discussed in connection with the joints shown in figures 42 and 43, it is apparent that the corrugated plate used in the longitudinal joint in section 10 would be unsatisfactory as a contraction joint and would be less satisfactory than the modified rectangular tongue as a joint for the relief of warping stress. It is probable, however, that because of the many possible points of contact and lack of sharp corners, it will not be so likely to develop high local bearing stress as either the perfectly rectangular tongue or the deep triangular shape during warping.

The tongue-and-groove types, as a class, have been shown to be quite effective when constructed and tested in the manner described. The preceding discussion was intended to bring out the weak points of the designs in order that means may be found for improvements that will add to both the structural effectiveness and the durability of the joints.

The doweled transverse joints are not considered to be butt-type joints because of the wide joint opening. Only the four longitudinal butt-type joints found in sections 1, 2, 8, and 9 will be discussed. They are primarily joints for the relief of warping stress, being unable to function either as expansion or contraction joints because of the bonded dowels. Four different dowel spacings were used as was shown in figure 7. As stated earlier, it was not possible to determine the effectiveness of all of these joints in reducing corner stresses because a number of them were in thickened-edge slabs, but all of them were tested to determine their efficiency in reducing the stresses directly under the load when the load was applied along the edge but away from a corner. The results of these tests have been shown in table 11 and in figure 34 of this paper. The one joint of this type on which it was possible to make such determinations was found to be effective in reducing critical stresses for the corner loading.

PREVENTION OF RESISTING MOMENT NECESSARY IN DESIGN OF BUTT-TYPE JOINTS

So far as dowel spacing is concerned, butt-type longitudinal joints can be made more effective in their function of controlling load stress by the close spacing of dowels in the same manner as expansion joints. In the matter of dowel stiffness the situation is different, however, because the small opening between slabs greatly reduces dowel flexure, as was shown by all of the deflection data for these joints. It is probable that in longitudinal joints of the butt type the need for better bearing for the dowels is as great as in the doweled expansion joint and that the same general type of bearing should be provided.

If restraint to warping is to be eliminated, it is necessary to make some provision for preventing the edges of the abutting slabs from being pressed together during warping, particularly near the upper and lower surfaces of the slabs. This can be accomplished by the introduction of a compressible layer between the edges during construction, as was done in the case of the test slabs, or perhaps better by so shaping the slab edges that the necessary clearance will be provided in a manner similar to that suggested in connection with the plane-of-weakness joints.

The amount of steel that must be placed in a warping joint in order to hold the slab edges together depends primarily upon the amount of resistance to horizontal movement to be overcome and upon the unit stress permissible in the steel.

In joints that contain bonded steel the use of designs that do not permit large resisting moments to develop in the joint is desirable for two reasons. In the first place, the prevention of these moments relieves the concrete of the stresses arising from warping restraint and thus conserves its strength for load-carrying purposes. In the second place, the prevention of these moments will further protect the pavement structure by preventing the steel in the bonded dowels or tiebars from being overstressed in tension.

The amount of bonded steel likely to be used across a longitudinal joint will be sufficient to prevent large separations of the two slab edges during contraction, but will be insufficient to prevent some separation of the slab edges resulting from angular change during warping. Indeed it is desirable that the amount of restraint to these rotational movements during warping be kept as small as possible. A given temperature differential in the pavement tends to cause a given rotational movement of the abutting faces at the joint. If this rotation brings the concrete into tight contact, it develops compression in the concrete and this tends to separate the slab edges by a certain amount at the plane of the steel. For a given percentage of steel taking tension, the magnitude of the tensile stress developed in the steel when this given separation occurs will depend directly upon the effective length of the steel that is yielding under the tension.

If the bond is deliberately prevented for a few inches in the center of the bar, as for example, with a coating of bitumen, more bar length would be available to yield under the given force. The unit deformation in the critical section of the bar would be smaller, and the stress would be correspondingly reduced. The net result would be less restraint in the joint for a given temperature differential and a given percentage of steel. Furthermore, such a coating would protect from corrosion the most vulnerable part of the bar.[7]

With designs that will permit resisting moments to develop during warping it is not possible to calculate the amount of steel required, but with these moments eliminated the calculation becomes a relatively simple matter.

In the discussion of joints in this article there has been presented (1) a brief history of joint development up to the time at which this investigation was planned; (2) a description of the joints that were studied and of the manner in which they were tested; (3) a presentation and discussion of all pertinent data bearing upon the ability of the various joint designs to relieve the stresses caused by expansion, contraction, restrained warping, and applied load; and (4) a discussion of certain improvements in design suggested by the results of the tests.

CONCLUSIONS

The following statements give what are believed to be the most important conclusions to be drawn as a result of this study:

1. Joints are installed in concrete pavements for the purpose of conserving the natural flexural strength of the slab for its primary function of carrying loads. This is accomplished through the relief and control of the stresses caused by expansion, contraction, and restrained warping. Joints in concrete pavements should therefore be so designed and so spaced as to permit the entire pavement to expand, contract, and warp with a minimum of restraint.

2. While the proper spacing of joints to accomplish this end was not definitely determined by this investigation, it is indicated that joints to control warping should be spaced at intervals of the general order of 10 feet, that expansion will be satisfactorily cared for by suitable joints at intervals of approximately 100 feet, and that contraction joints should be installed at some lesser interval, the length of which must be such that the direct tensile stresses in the concrete are definitely limited to low values. Data presented in the second report of this series indicate that under the conditions of these tests a slab length of the order of 30 feet would accomplish this.

3. Since a free edge is a structural weak spot in a slab of uniform thickness, it is necessary to strengthen the joint edges by thickening the slab at this point or by the introduction of some mechanism for transferring a part of the applied load across the joint to the adjacent slab. Otherwise, the strength of the joint edge will determine the load-carrying capacity of the pavement.

4. The structural effectiveness of a joint design is measured by its ability to reduce the critical edge stress to a value equal to the critical stress which exists in the interior area of the slab.

5. The most critical stress caused by a load applied at a joint but away from a corner is that directly under the load in a direction parallel to the joint. It is especially desirable to control these stresses along a

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[7] The idea of coating the midsection of bonded bars with bitumen was suggested by Mr. Bengt Friberg.

longitudinal joint so as to limit the combined load and warping stress to a value that will be unlikely to cause transverse cracking.

6. The most critical stress caused by a load applied at the free corner of a slab of constant thickness is a tensile stress along the bisector of the corner angle and at some distance from the center of load application. Edge thickening reduces this critical stress considerably and at interior corners the action of the longitudinal and transverse joints frequently reduces the critical corner stress to relatively low values.

7. There is nothing in the results of these tests to indicate that edge thickening cannot be applied to the transverse edges of concrete pavement slabs with as much success as to the longitudinal edges. If the full benefits of edge thickening are to be obtained in either case, the slabs must be short.

8. The doweled transverse joints tested in this investigation were found to be quite effective in relieving the stresses caused by expansion, contraction, and warping. They were not particularly effective, however, in controlling the critical stress caused by a load applied near the joint edge.

9. The tests indicate that doweled joints as they are usually designed are deficient in two important respects:

   a. The individual units are not sufficiently close together to control effectively the stress developed directly under the load.

   b. For joint openings such as are usually employed in expansion joints, the individual dowels are not sufficiently stiff to transfer load effectively. Increasing the stiffness of the dowels will result in an undesirable increase in the restraint to warping offered by the joint and for this reason should not be carried too far.

10. The continuous plate key or dowel plate as used in these tests appears to have considerable merit as a means for load transfer. The joint as built for the tests offers more resistance to expansion and contraction than is desirable and for this and other reasons it is believed that a further study of the type should be made.

11. Aggregate interlock as it occurs in the weakened-plane joints cannot be depended upon to control load stresses. Even when joints of this type are held closed by bonded steel bars there is a wide variation in the value of the critical stress caused by a given load, from side to side of the joint and from point to point along it. For this reason it appears necessary to provide independent means for load transfer in plane-of-weakness joints.

12. The joints of the tongue-and-groove type that were held closed by bonded steel bars were found to be the most efficient structurally of any of those tested. It appears, however, that certain modifications of the designs might improve their action by permitting the slabs to warp more freely and at the same time maintaining the bearing between the tongue and the groove.

13. It was shown in the second report of this series that over a considerable period of time there may be a permanent increase in the length of the pavement slab. In designing the expansion joints for a pavement, consideration should be given to this possibility and some allowance made for it.

PUBLICATION ON HIGHWAY BONDS AVAILABLE

Highway Bond Calculations, by Laurence I. Hewes and James W. Glover, has recently been published by the United States Department of Agriculture. This publication consists of selected sections of Department Bulletin 136, Highway Bonds, as published in 1917, the supply of which has been exhausted for some years.

Sinking-fund, serial, and annuity bonds are described in detail and their relative merits are compared. Definitions of the terms involved are given, together with explanations and derivations of essential formulas. Numerous examples of typical problems and their solutions are presented. Several tables to seven decimal places for 60 intervals and 14 interest rates are included, making the publication a useful reference in making bond calculations.

Copies of Highway Bond Calculations may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 10 cents each.

HIGHWAY RESEARCH BOARD TO MEET IN NOVEMBER

The August 1936 issue of Public Roads carried on page 127 a notice of the Sixteenth Annual Meeting of the Highway Research Board. The notice was incorrectly headed "Highway Research Board to meet in December." As stated in the text of the notice, this meeting will be held in Washington, D. C., November 18–20, 1936.

DISPOSITION OF STATE MOTOR-CARRIER TAX RECEIPTS, 1934

[Compiled from reports of State authorities]

State	Net total receipts of calendar year	Adjustments due to undistributed balances, etc.[1]	Net total funds distributed [2]	Expenses of collection and administration	For State highway purposes							For local roads [6]				For other highway purposes (park and forest roads, etc.)	For nonhighway purposes				
					Construction, maintenance, and administration [3]	State-highway police [4]	Service of State highway obligations				Total for State-highway purposes	For work on county and local roads	Service of local-highway obligations	Total			To general funds [7]	For relief of unemployment or destitution	For education	For other purposes	Total
							State-highway bonds	State-assumed local obligations [5]	Notes and other short-term loans	Total											
Alabama	$68,491	−$4,053	$64,438	$17,201	$32,189						$32,189	$15,048		$15,048							
Arizona	105,141	−2,198	102,943	10,520	88,683	$3,546					92,229									[8] $194	$194
Arkansas	19,495		19,495	606	7,007		$5,295	$3,495	$2,568	$11,358	18,365							$524			524
California	1,955,747	−79,122	1,876,625	448,855	302,844		800,000			800,000	1,102,844	302,844		302,844						[9] 22,082	22,082
Colorado	186,066	−536	185,530	6,381	102,669						102,669	[10] 73,847		73,847			$2,633				2,633
Connecticut	156,609	4,350	160,959		56,770						56,770						[11] 104,189				104,189
Delaware	(12)																				
Florida	178,221		178,221	36,745									$131,197	131,197			[17] 7,696		$2,583		10,279
Georgia	208,953	−2,537	206,416	129,238	77,178						77,178										
Idaho	40,617		40,617	19,871	20,044						20,044	702		702							
Illinois	(13)																				
Indiana	24,845	−19,277	5,568	5,568																	
Iowa	382,637	−1,461	381,176	115,298								*265,878		265,878							
Kansas	628,827	−2,836	625,991	191,041	223,037	63,309		32,305		32,305	318,651	116,299		116,299							
Kentucky	204,325	33,103	237,428	76,274	161,097	57					161,154										
Louisiana	856		856	856																	
Maine	16,160	2,577	18,737	18,737																	
Maryland	(14)																				
Massachusetts	51,411		51,411														51,411				51,411
Michigan	296,584	−58,563	238,021	171,378	66,643						66,643										
Minnesota	17,215		17,215	17,215																	
Mississippi	73,309		73,309	1,353	342						342	*71,414		71,414			200				200
Missouri	325,556	−270,738	54,818	54,818																	
Montana	11,426	1,238	12,664	12,664																	
Nebraska	(12)																				
Nevada	138,947	−170	138,777		134,127	4,650					138,777										
New Hampshire	4,452		4,452	4,452																	
New Jersey	72,861		72,861		50,919						50,919	16,663	5,279	21,942							
New Mexico	67,299	10,929	78,228	12,350	52,245	13,633					65,878										
New York	(12)																				
North Carolina	204,154		204,154		69,301	966	78,887	4,013		82,900	153,167	[15] 42,268		42,268			8,719				8,719
North Dakota	15,281	2,153	17,434	14,896	2,538						2,538										
Ohio	360,219	123,898	484,117	95,680	214,835	9,283					224,118	164,319		164,319							
Oklahoma	610,043	−7,098	602,945	28,769	574,176						574,176										
Oregon	588,008	97,250	685,258	73,381	273,396	25,362	212,506			212,506	511,264	*99,855		99,855		$758					
Pennsylvania	1,977		1,977		1,211						1,211						766				766
Rhode Island	(12)																				
South Carolina	81,300	−15,102	66,198	13,264	47,082						47,082						[16] 5,852				5,852
South Dakota	264,073	21,985	286,058	27,409	247,849						247,849					10,800					
Tennessee	214,509	−20,324	194,185	52,335	79,088		6,446		4,662	11,108	90,196						42,327	9,327			51,654
Texas	52,115		52,115	48,465	3,650						3,650										
Utah	217,680	1,394	219,074	20,827	155,830	4,777					160,607						37,640				37,640
Vermont	(12)																				
Virginia	125,200	−10,396	114,804	17,328	74,065						74,065						23,411				23,411
Washington	186,227		186,227	186,227																	
West Virginia	(17)																				
Wisconsin	1,034,468	44,044	1,078,512	456,411													622,101				622,101
Wyoming	58,000		58,000	11,600	45,292	1,108					46,400										
District of Columbia	152,313		152,313														[18] 152,313				152,313
Total	9,401,617	−151,490	9,250,127	2,398,013	3,164,107	126,691	1,103,134	39,813	7,230	1,150,177	4,440,975	1,169,137	136,476	1,305,613		11,558	1,059,258	9,851	2,583	22,276	1,093,968

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[1] In many States amounts distributed during the calendar year differ from actual collections because of undistributed balances carried over and lags between accounts of collecting and expending agencies.

[2] In many States the proceeds of motor-fuel taxes, motor-vehicle fees, and motor-carrier taxes are placed in a common fund from which the distribution is made. In these cases the amounts distributed have been prorated in proportion to the receipts, not otherwise dedicated, from these three sources of revenue. See tables pp. 194–197.

[3] Includes funds allotted for expenditure on urban extensions of State highway system, where reported separately from other funds allotted for local roads and streets.

[4] In cases where expenses of State highway police are paid out of State highway funds without specific allocations, expenditures for this purpose have been prorated in proportion to receipts not otherwise dedicated. See tables pp. 194–197.

[5] County or local obligations assumed by State as reimbursement for local roads added to State system.

[6] In States indicated by star (*) the law provides that allotments for work on local roads or streets may also be used for service of local highway obligations, but amounts so used were not reported separately.

[7] Except as noted, to State general funds for nonhighway purposes. Payments to county or municipal general funds may have been distributed in part for highways, but amounts were not reported.

[8] For engineering purposes in connection with irrigation.

[9] To cities and counties for service of bonded debt.

[10] Funds allotted to counties for use on both State and local roads.

[11] To cities and towns.

[12] No special taxes on motor carriers reported.

[13] Receipts from weight tax on motor carriers, $5,747, included in motor-vehicle receipts, table on pp. 196–197.

[14] Ton-mile and passenger-mile taxes paid by motor carriers in lieu of registration fees are included in motor-vehicle receipts, table on pp. 196 and 197.

[15] For county roads under State control.

[16] To counties and cities.

[17] Certificate fees (ton-mile and passenger-mile) included with motor-vehicle receipts, table on pp. 196–197.

[18] To District of Columbia general fund. United States Treasury.

DISPOSITION OF STATE MOTOR-

[Compiled from reports of State authorities]

State	Net total receipts of calendar year [1]	Adjustments due to undistributed balances, etc. [2]	Net total funds distributed [3]	Expenses of collection and administration	For other administrative purposes [4]	For State highway purposes						
								Service of State highway obligations				
						Construction, maintenance, and administration [5]	State highway police [6]	State highway bonds	State-assumed local obligations [7]	Notes and other short-term loans	Total	Total for State highway purposes
Alabama	$9, 225, 917	−$70	$9, 225, 847	$14, 003		$2, 180, 231	$24, 030	$2, 406, 968			$2, 406, 968	$4, 611, 229
Arizona	3, 024, 187		3, 024, 187	40, 369		1, 702, 770	68, 076					1, 770, 846
Arkansas	7, 776, 558	429, 484	8, 206, 042	269, 491		2, 529, 328		1, 911, 151	$1, 261, 393	$926, 775	4, 099, 319	6, 628, 647
California	36, 442, 897	−62, 934	36, 379, 963	139, 112		24, 160, 567						24, 160, 567
Colorado	6, 445, 027	16, 811	6, 461, 838	83, 318		3, 151, 020						3, 151, 020
Connecticut	4, 849, 344	−144, 415	4, 704, 929	34, 014		4, 670, 915						4, 670, 915
Delaware	1, 187, 526		1, 187, 526	(14)		835, 037	82, 251	99, 133	171, 105		270, 238	1, 187, 526
Florida	16, 289, 940	6, 315	16, 296, 255	16, 645		6, 943, 560	38, 168		2, 322, 169		2, 322, 169	9, 303, 897
Georgia	14, 304, 590	−105	14, 304, 485	412, 842		9, 202, 722						9, 202, 722
Idaho	2, 853, 529	−23, 202	2, 830, 327	10, 628		2, 517, 209		214, 304			214, 304	2, 731, 513
Illinois	29, 214, 657	128, 210	29, 342, 867	148, 519		7, 950, 862						7, 950, 862
Indiana	17, 345, 642	30, 000	17, 375, 642	72, 642		8, 651, 500						8, 651, 500
Iowa	11, 027, 166	−39, 249	10, 987, 917	87, 830		2, 537, 242			3, 556, 845		3, 556, 845	6, 094, 087
Kansas	8, 546, 816	−43, 505	8, 503, 311	280, 746	$77, 553	4, 850, 122	63, 376		702, 503		702, 503	5, 616, 001
Kentucky	9, 055, 386	−3, 785	9, 051, 601	45, 057		9, 003, 333	3, 211					9, 006, 544
Louisiana	8, 909, 880	−526, 420	8, 383, 460	61, 000				6, 540, 484			6, 540, 484	6, 540, 484
Maine	4, 478, 037		4, 478, 037	11, 772		2, 758, 802	92, 788	1, 105, 835			1, 105, 835	3, 957, 425
Maryland	8, 291, 124		8, 291, 124	17, 300		2, 060, 078		1, 327, 722			1, 327, 722	3, 387, 800
Massachusetts	16, 951, 999		16, 951, 999	50, 000		3, 723, 746	171, 610	254, 733			254, 733	4, 150, 089
Michigan	20, 847, 905	58, 227	20, 906, 132	144, 757		9, 902, 072		4, 082, 060			4, 082, 060	13, 984, 132
Minnesota	10, 845, 376	−812, 747	10, 032, 629	(19)		6, 242, 404	138, 975					6, 381, 379
Mississippi	6, 859, 840	−1, 040	6, 858, 800	28, 834	90, 000	3, 604, 421	25, 192					3, 629, 613
Missouri	9, 681, 550	−8, 929	9, 672, 621	49, 180	98, 276	5, 108, 581	113, 736	4, 302, 848			4, 302, 848	9, 525, 165
Montana	3, 596, 007	−147, 804	3, 448, 203	20, 488		2, 384, 163		1, 043, 552			1, 043, 552	3, 427, 715
Nebraska	8, 587, 606		8, 587, 606	85, 760		5, 313, 653						5, 313, 653
Nevada	890, 589		890, 589	(21)		862, 071	1, 000		27, 518		27, 518	890, 589
New Hampshire	2, 795, 988		2, 795, 988	(22)		2, 069, 029		705, 392			705, 392	2, 774, 421
New Jersey	16, 787, 710	[24] 5, 376, 537	22, 164, 247	48, 355		7, 265, 174		7, 543, 463			7, 543, 463	14, 808, 637
New Mexico	2, 555, 614	191, 710	2, 747, 324	41, 220		1, 089, 295		1, 616, 809			1, 616, 809	2, 706, 104
New York [26]	43, 627, 570		43, 627, 570	90, 652		5, 152, 503		3, 627, 281			3, 627, 281	8, 779, 784
North Carolina	17, 050, 545		17, 050, 545	6, 094	21, 556	5, 546, 648	77, 342	6, 313, 892	321, 187		6, 635, 079	12, 259, 069
North Dakota	2, 218, 659	−3, 659	2, 215, 000	25, 000		1, 355, 988	2, 012			102, 000	102, 000	1, 460, 000
Ohio	37, 656, 775	−1, 578, 834	36, 077, 941	177, 017		15, 082, 308	254, 110					15, 336, 418
Oklahoma	10, 820, 684	382, 606	11, 203, 290	216, 414		5, 154, 528						5, 154, 528
Oregon	7, 215, 041	−26, 674	7, 188, 367	22, 400		3, 248, 815	196, 287	2, 525, 248			2, 525, 248	5, 970, 350
Pennsylvania	33, 356, 395	[30] −4, 786, 128	28, 570, 267	235, 391		21, 672, 868	702, 798	3, 088, 321			3, 088, 321	25, 463, 987
Rhode Island	2, 031, 526		2, 031, 526	(32)		1, 443, 728		301, 876			301, 876	1, 745, 604
South Carolina	7, 745, 565	−10, 579	7, 734, 986	(14)		747, 298		864, 372	4, 696, 837	135, 552	5, 696, 761	6, 444, 059
South Dakota	3, 784, 216	−84, 352	3, 699, 864	38, 255		1, 681, 277						1, 681, 277
Tennessee	14, 104, 099	−240, 960	13, 863, 139	142, 811		2, 704, 867		220, 444	1, 932, 685	2, 092, 143	4, 245, 272	6, 950, 139
Texas	31, 936, 718	−164, 444	31, 772, 274	224, 259		15, 774, 007			7, 887, 004		7, 887, 004	23, 661, 011
Utah	2, 489, 515	224, 699	2, 714, 214	(14)	14, 214	2, 619, 700	80, 300					2, 700, 000
Vermont	1, 942, 139	−237, 389	1, 704, 750	2, 000		415, 648		303, 816			303, 816	719, 464
Virginia	12, 496, 831	10, 666	12, 507, 497	[35] 164, 160	27, 325	6, 590, 047		264, 011			264, 011	6, 854, 058
Washington	11, 881, 753		11, 881, 753	19, 642		4, 850, 426						4, 850, 426
West Virginia	5, 612, 752		5, 612, 752	12, 663		2, 165, 984		2, 664, 352			2, 664, 352	4, 830, 336
Wisconsin	15, 345, 625	2, 599, 606	17, 945, 231	46, 080		8, 708, 953			2, 112, 075		2, 112, 075	10, 821, 028
Wyoming	1, 768, 243	−46, 246	1, 721, 997	7, 834		1, 159, 938	28, 372	112, 000			112, 000	1, 300, 310
District of Columbia	2, 132, 008	−206, 871	1, 925, 137	(14)								
Total	564, 885, 066	254, 530	565, 139, 596	3, 644, 554	328, 924	249, 345, 438	2, 163, 634	53, 440, 067	24, 991, 321	3, 256, 470	81, 687, 858	333, 196, 930

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[1] Amounts tabulated in this column differ from totals given in a previous table issued by the Bureau—State motor-fuel tax earnings, 1934, as actual collections rather than earnings of the calendar year are shown.

[2] In many States amounts distributed during the calendar year differ from actual collections because of undistributed balances carried over and lags between accounts of collecting and expending agencies. Proceeds of tax on gasoline used in aviation in Idaho, Michigan, Oregon, and Wyoming have been deducted as not being highway user taxes; also tax on nonhighway fuel in Ohio.

[3] In many States the proceeds of motor-fuel taxes, motor-vehicle fees, and motor-carrier taxes are placed in a common fund from which the distribution is made. In these cases the amounts distributed have been prorated in proportion to the receipts, not otherwise dedicated, from these three sources of revenue. See tables pp. 193, 196, and 197.

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

[5] Includes funds allotted for expenditure on urban extensions of State highway system, where reported separately from other funds allotted for local roads and streets.

[6] In cases where expenses of State highway police are paid out of State highway funds without specific allocations, expenditures for this purpose have been prorated in proportion to receipts not otherwise dedicated. See tables pp. 193, 196, and 197.

[7] County or local obligations assumed by State as reimbursement for local roads added to State system.

[8] In States indicated by star (*) the law provides that allotments for work on local roads or streets may also be used for service of local highway obligations, but amounts so used were not reported separately.

[9] In a number of States allotments for local road work may be used on city streets. This column shows allotments which were reported separately.

[10] Except as noted, to State general funds for nonhighway purposes. Payments to county or municipal general funds may have been distributed in part for highways, but amounts were not reported.

[11] Law in effect in 1934 provided that in counties of less than 18,000 population, 20 percent of the allotment could be used for schools. Amount so used not reported.

[12] For engineering expenses in connection with irrigation.

[13] Funds allotted to counties for use on both State and local roads.

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

[15] For Dade Memorial Park, $365: Division of Airways, $8,842.

[16] For construction of prison camps.

[17] To ports of New Orleans and Lake Charles Harbor for harbor improvement.

[18] To Conservation Department for oyster propagation, in consideration of fuel tax paid by motor workboats, $75,000; to Chesapeake Bay ferry companies, $35,040.

FUEL TAX RECEIPTS, 1934

[Compiled from reports of State authorities]

For local roads and streets [8]					For nonhighway purposes					
For work on county and local roads	For work on city streets [9]	Service of local highway obligations	Total	For other highway purposes (park and forest roads, etc.)	To general funds [10]	For relief of unemployment or destitution	For education	For other purposes	Total	State
[11] $4,600,615			$4,600,615							Alabama.
*906,932			906,932			$302,310		[12] $3,730	$306,040	Arizona.
966,476		$152,024	1,118,500			189,404			189,404	Arkansas.
*12,080,284			12,080,284							California.
[13] 1,508,500			1,508,500			1,719,000			1,719,000	Colorado.
										Connecticut.
										Delaware.
		4,644,337	4,644,337		$2,322,169			[15] 9,207	2,331,376	Florida.
2,301,013			2,301,013				$2,385,683	[16] 2,225	2,387,908	Georgia.
88,186			88,186							Idaho.
*6,173,917	*$6,954,228		13,128,145			1,810,880	6,304,461		8,115,341	Illinois.
6,921,200	1,730,300		8,651,500							Indiana.
*4,806,000			4,806,000							Iowa.
2,529,011			2,529,011							Kansas.
										Kentucky.
							890,988	[17] 890,988	1,781,976	Louisiana.
508,840			508,840							Maine.
1,377,151	2,397,517	988,356	4,763,024		12,960			[18] 110,040	123,000	Maryland.
2,237,374			2,237,374	$514,536	10,000,000				10,000,000	Massachusetts.
*6,772,993			6,772,993		4,250				4,250	Michigan.
*3,651,250			3,651,250							Minnesota.
*2,845,819			2,845,819					[20] 264,534	264,534	Mississippi.
										Missouri.
										Montana.
*2,870,491	317,702		3,188,193							Nebraska.
										Nevada.
		[23] 21,567	21,567							New Hampshire.
2,377,443		753,249	3,130,692			3,182,813	332,500	[25] 661,250	4,176,563	New Jersey.
										New Mexico.
*7,949,377			7,949,377		[27] 26,807,757				26,807,757	New York.[26]
[28] 3,382,986			3,382,986		1,380,840				1,380,840	North Carolina.
730,000			730,000							North Dakota.
[29] 6,695,750	[29] 4,782,960		11,478,710				9,085,796		9,085,796	Ohio.
*2,651,067			2,651,067					[20] 3,181,281	3,181,281	Oklahoma.
*1,186,604			1,186,604	9,013						Oregon.
*2,472,490	254,498		2,726,988	70,481				[31] 73,420	73,420	Pennsylvania.
						285,922			285,922	Rhode Island.
*1,290,927			1,290,927							South Carolina.
				73,259				[33] 1,907,073	1,907,073	South Dakota.
3,988,939			3,988,939		268,343	318,990		[34] 2,193,917	2,781,250	Tennessee.
							7,887,004		7,887,004	Texas.
										Utah.
983,286			983,286							Vermont.
[36] 5,435,891			5,435,891			11,732		[37] 14,331	26,063	Virginia.
*6,063,628			6,063,628			[38] 948,057			948,057	Washington.
[28] 769,753			769,753							West Virginia.
3,378,440	500,421		3,878,861	36,295	[39] 3,162,967				3,162,967	Wisconsin.
413,853			413,853							Wyoming.
	1,925,137		1,925,137							District of Columbia.
112,916,486	18,862,763	6,559,533	138,338,782	703,584	43,959,286	8,769,108	26,886,432	9,311,996	88,926,822	Total

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[19] Paid out of general revenue, $173,984.

[20] For service of general State debt.

[21] Paid out of general revenue; estimated expense, $2,696.

[22] Included with expenses of motor vehicle department. See following table.

[23] Pro rata share of $44,638 paid for interest on highway relief bonds, a State obligation issued for improvement of local roads.

[24] Return of loan made to sinking fund in 1933 from motor-fuel tax funds.

[25] For service of institution construction bonds, $326,475; reserve for service of unissued bonds, $244,775; to Department of Commerce and Navigation, $90,000.

[26] General fund appropriations for highway purposes have been credited against payments of motor-fuel tax and motor-vehicle fees to the State general fund, and prorated in proportion to net receipts not otherwise dedicated. See following table. General fund appropriations for State police, $2,223,955, are not included, as amount assignable to highway traffic purposes was not reported.

[27] Includes the following: Emergency 1-cent tax to State general fund, $14,542,523; net to State general fund after crediting expenses for highway purposes, $10,810,945; to general fund of New York City, $1,454,289.

[28] For county roads under State control.

[29] Under law effective in 1934 all or any portion of county and municipal allotments could be expended for work or poor relief. Amount so expended not reported. In cities situated on State highways one-sixth of municipal allotment to be used on urban extensions of State system.

[30] In addition to the change in undistributed balances this adjustment includes amount of loan from liquid-fuel tax fund to general funds for relief purposes, $1,650,000, and pro rata share of similar loan from motor license fund, $1,705,704. Law provides that these loans shall be repaid; they are therefore not included in the distribution.

[31] To Bureau of Aeronautics, $26,782; cooperative work other State departments, $46,638.

[32] Paid out of motor-vehicle fees, $15,315.

[33] To rural credit bond and interest fund.

[34] For service of general fund bonds, $1,994,470; service of Great Smoky Mountain Park bonds, $199,447.

[35] Appropriation for part of expenses of Division of Motor Vehicles, which collects the motor-fuel tax.

[36] For county roads under State control in all but three counties, $5,232,575; transferred to remaining three counties, $203,316.

[37] For aviation purposes.

[38] For service of $10,000,000 emergency relief bond issue, of which approximately $1,000,000 has been assigned to the State Highway Department for road work.

[39] Includes the following: To State general fund, $1,000,000; to towns, cities, and villages in lieu of personal property tax formerly imposed on motor vehicles, $2,162,967.

DISPOSITION OF STATE MOTOR-

[Compiled from reports of State authorities]

State	Net total receipts of calendar year [1]	Adjustments due to undistributed balances, etc.[2]	Net total funds distributed [3]	Expenses of collection and administration [4]	For other administrative purposes [5]	For State highway purposes						
						Construction, maintenance, and administration [6]	State highway police [7]	Service of State highway obligations				Total for State highway purposes
								State highway bonds	State-assumed local obligations [8]	Notes and other short-term loans	Total	
Alabama	$3,583,689	$610	$3,584,299	$264,033		$1,014,192		$1,617,075			$1,617,075	$2,631,267
Arizona	759,246	−15,743	743,503	138,859		580,178	$23,195					603,373
Arkansas	2,233,032		2,233,032	70,612		802,204		606,142	$400,665	$293,937	1,300,144	2,102,348
California	9,561,100	−202,086	9,359,014	1,798,349	$6,000	2,743,646	2,088,920					4,832,566
Colorado	2,148,657		2,148,657	243,235	33,888							
Connecticut	7,947,601	−482,562	7,465,039	748,397		3,590,663						3,590,663
Delaware	966,612		966,612	(15)		679,695	66,950	80,692	139,275		219,967	966,612
Florida	4,465,768	−12,857	4,452,911	314,907	152,616							
Georgia	1,192,854	5,136	1,197,990	148,360	38,324	1,011,061						1,011,061
Idaho	1,561,216	2,832	1,564,048	77,876		146,211						146,211
Illinois	18,284,195	847,005	19,131,200	1,158,468		5,903,274	846,754	8,231,100	441,015		8,672,115	15,422,143
Indiana	7,260,187	29,850	7,290,037	758,011		2,941,535	206,624					3,148,159
Iowa	9,475,978	−165,090	9,310,888	645,340		3,607,857			5,057,691		5,057,691	8,665,548
Kansas	3,277,935	13,569	3,291,504	216,801		1,830,897	23,924		265,192		265,192	2,120,013
Kentucky	3,152,115	−43,100	3,109,015	374,169		2,321,681	7,818					2,329,499
Louisiana	4,379,926	−43,430	4,336,496	137,458		3,419,772	291,416	312,850			312,850	4,024,038
Maine	3,096,369		3,096,369	89,653	12,231	1,849,687	62,212	741,426			741,426	2,653,325
Maryland	3,856,497	331,665	4,188,162	370,772	34,077	2,099,404	210,138	635,566			635,566	2,945,108
Massachusetts	7,070,766		7,070,766	1,362,468	35,000	3,060,842	141,060	209,385			209,385	3,411,287
Michigan	15,901,018	−188,394	15,712,624	1,053,714		100,000	200,000					300,000
Minnesota	6,866,573	14,452	6,881,025	484,732	360,000	2,145,855	47,773	2,162,000	1,626,425		3,788,425	5,982,053
Mississippi	1,950,393	811	1,951,204	96,445		170,383	1,232					171,615
Missouri	7,374,482		7,374,482	469,653		3,703,230	82,447	3,119,152			3,119,152	6,904,829
Montana	1,070,797		1,070,797	134,693								
Nebraska	1,895,889	16,107	1,911,996	78,819		559,629						559,629
Nevada	248,387	−1,559	246,828	17,975		81,461	25,455	121,937			121,937	228,853
New Hampshire	2,469,950		2,469,950	[17] 104,570		2,213,372	121,135	7,802			7,802	2,342,309
New Jersey	15,975,593		15,975,593	1,111,174		8,731,053						8,731,053
New Mexico	843,382	4,176	847,558	103,831		335,751						335,751
New York [20]	41,628,954		41,628,954	2,266,412		6,929,967		4,878,588			4,878,588	11,808,555
North Carolina	7,114,174		7,114,174	244,884		2,331,804	32,514	2,654,351	135,026		2,789,377	5,153,695
North Dakota	1,299,126	−15,103	1,284,023	84,023		100,000						100,000
Ohio	20,273,129	32,458	20,305,587	941,575		3,540,030	152,974					3,693,004
Oklahoma	3,524,084	56,748	3,580,832	641,805		1,209,660						1,209,660
Oregon	2,248,715	−79,482	2,169,233	275,741		858,447	51,866	667,256			667,256	1,577,569
Pennsylvania	32,795,312	[26] −1,934,296	30,861,016	1,532,656		24,577,379	796,985	3,502,205			3,502,205	28,876,569
Rhode Island	2,279,178		2,279,178	261,996	15,315	1,590,079						1,590,079
South Carolina	2,138,480		2,138,480	175,644		207,881	170,248	240,448	1,306,552	37,707	1,584,707	1,962,836
South Dakota	1,313,813	3,179	1,316,992	45,387		251,100						251,100
Tennessee	3,440,904	−15,070	3,425,834	181,710		2,255,986	181,418	183,860		132,996	316,856	2,754,260
Texas	14,719,736	1,271	14,721,007	857,105		4,373,572	231,323					4,604,895
Utah	965,601	−192,329	773,272	98,272		145,539	4,461	525,000			525,000	675,000
Vermont	2,157,314	14,366	2,171,680	108,000		503,751		368,215			368,215	871,966
Virginia	4,948,613	172,965	5,121,578	323,105		4,421,278	182,858	186,069			186,069	4,790,205
Washington	3,065,882		3,065,882	304,473	137,537	2,371,183	179,839					2,551,022
West Virginia	5,623,924		5,623,924	48,024		2,147,838	22,725	2,642,032			2,642,032	4,812,595
Wisconsin	10,050,779	1,658,863	11,709,642	642,275	35,000	5,681,393			1,379,389		1,379,389	7,060,782
Wyoming	448,642		448,642	10,000		266,133	6,509	166,000			166,000	438,642
District of Columbia	605,309		605,309	83,903	43,455							
Total	309,511,876	−185,038	309,326,838	21,700,364	903,443	119,406,553	6,460,773	33,859,151	10,750,630	464,640	45,074,421	170,941,747

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[1] Amounts given in this column differ in many cases from the totals of a previous table issued by the Bureau—State motor-vehicle receipts, 1934, which gives the receipts of the 1934 registration period.

[2] In many States amounts distributed during the calendar year differ from actual collections because of undistributed balances carried over and lags between accounts of collecting and expending agencies.

[3] In many States the proceeds of motor-fuel taxes, motor-vehicle fees, and motor-carrier taxes are placed in a common fund from which the distribution is made. In these cases the amounts distributed have been prorated in proportion to the receipts, not otherwise dedicated, from these three sources of revenue. See preceding tables.

[4] Collection expenses in many States include service charges deducted by county and local collectors. The amounts of such charges were estimated for Alabama, Florida, Kentucky, Ohio, Oklahoma, Tennessee, and Washington.

[5] Where reported separately from regular collection and administrative expenses of motor vehicle departments, funds allotted for collection of the motor-fuel tax, payments to auto theft fund, and miscellaneous expenses of motor-vehicle regulation are shown in this column.

[6] Includes funds allotted for expenditure on urban extensions of State highway system, where reported separately from other funds allotted for local roads and streets.

[7] In cases where expenses of State highway police are paid out of State highway funds without specific allocations, expenditures for this purpose have been prorated in proportion to receipts not otherwise dedicated. See preceding tables.

[8] County or local obligations assumed by State as reimbursement for local roads added to State system.

[9] In States indicated by star (*) the law provides that allotments for work on local roads or streets may also be used for service of local highway obligations, but amounts so used were not reported separately.

[10] In a number of States allotments for local road work may be used on city streets. This column shows allotments which were reported separately.

[11] Except as noted, to State general funds for nonhighway purposes. Payments to county or municipal general funds may have been distributed in part for highways, but amounts were not reported.

[12] To county and municipal general funds.

[13] For engineering expenses in connection with irrigation.

VEHICLE RECEIPTS, 1934

[Compiled from reports of State authorities]

For local roads and streets [9]				For other highway purposes (park and forest roads, etc.)	For nonhighway purposes					State
For work on county and local roads	For work on city streets [10]	Service of local highway obligations	Total		To general funds [11]	For relief of unemployment or destitution	For education	For other purposes	Total	
					[12] $688, 999				$688, 999	Alabama.
								[13] $1, 271	1, 271	Arizona.
						$60, 072			60, 072	Arkansas.
*$2, 722, 099			$2, 722, 099							California.
[14] 797, 936			797, 936		798, 541	275, 057			1, 073, 598	Colorado.
3, 125, 979			3, 125, 979							Connecticut.
										Delaware.
							$3, 985, 388		3, 985, 388	Florida.
								[16] 245	245	Georgia.
*1, 339, 961			1, 339, 961							Idaho.
2, 107, 751			2, 107, 751		442, 838				442, 838	Illinois.
1, 176, 614	$294, 154		1, 470, 768		1, 913, 099				1, 913, 099	Indiana.
										Iowa.
954, 690			954, 690							Kansas.
405, 347			405, 347							Kentucky.
	175, 000		175, 000							Louisiana.
341, 160			341, 160							Maine.
14, 979	823, 226		838, 205							Maryland.
1, 839, 074			1, 839, 074	$422, 937						Massachusetts.
*13, 979, 417			13, 979, 417		379, 493				379, 493	Michigan.
					54, 240				54, 240	Minnesota.
*1, 683, 144			1, 683, 144							Mississippi.
										Missouri.
913, 853	22, 251		936, 104							Montana.
1, 273, 548			1, 273, 548							Nebraska.
										Nevada.
		$23, 071	23, 071							New Hampshire.
5, 167, 136		905, 230	6, 072, 366	[18] 61, 000						New Jersey.
111, 266			111, 266		[19] 296, 710				296, 710	New Mexico.
*8, 936, 166			8, 936, 166		[21] 18, 617, 821				18, 617, 821	New York.[20]
[22] 1, 422, 203			1, 422, 203		293, 392				293, 392	North Carolina.
								[23] 1, 100, 000	1, 100, 000	North Dakota.
*[24] 11, 257, 904	4, 074, 984		15, 332, 888					[25] 338, 120	338, 120	Ohio.
*1, 729, 367			1, 729, 367							Oklahoma.
*313, 541			313, 541	2, 382						Oregon.
	288, 605		288, 605	79, 927				[27] 83, 259	83, 259	Pennsylvania.
						411, 788			411, 788	Rhode Island.
										South Carolina.
1, 009, 564			1, 009, 564	10, 941						South Dakota.
					223, 811	266, 053			489, 864	Tennessee.
*9, 259, 007			9, 259, 007							Texas.
										Utah.
1, 191, 714			1, 191, 714							Vermont.
						8, 268			8, 268	Virginia.
72, 850			72, 850							Washington.
[22] 763, 305			763, 305							West Virginia.
2, 226, 513	308, 744		2, 535, 257	23, 705	[28] 1, 412, 623				1, 412, 623	Wisconsin.
										Wyoming.
					[29] 477, 951				477, 951	District of Columbia
76, 136, 088	5, 986, 964	928, 301	83, 051, 353	600, 892	25, 599, 518	1, 021, 238	3, 985, 388	1, 522, 895	32, 129, 039	Total.

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[14] Funds allotted to counties for use on both State and local roads.

[15] Paid out of general revenue.

[16] For construction of prison camps.

[17] Includes expenses of motor-fuel tax collection.

[18] To Commission for Elimination of Toll Bridges.

[19] To State general fund, $111,266; to county general funds, $185,444.

[20] General fund appropriations for highway purposes have been credited against payments of motor-fuel tax and motor-vehicle fees to the State general fund, and prorated in proportion to net receipts not otherwise dedicated. See preceding table. General fund appropriations for State police, $2,223,955, are not included, as amount assignable to highway traffic purposes was not reported.

[21] Includes the following: Net to State general fund after crediting appropriations for highway purposes, $14,540,408; to New York City general fund, $4,077,413.

[22] For county roads under State control.

[23] To real estate bond and interest fund.

[24] General law provides that this allotment shall be used for highway purposes. It is provided, however, that during 1933, 1934, and 1935 amounts shall be paid to counties and townships, for other than highway purposes, equal to amounts which would have been produced by the 1930 levies on personal property for other than highway purposes. Amounts so diverted were not reported.

[25] For hospitalization of indigent persons injured in motor-vehicle accidents.

[26] Pro rata share of temporary loan from motor-license fund to general fund for relief purposes. Law provides that loan shall be repaid. It is, therefore, not included in the distribution.

[27] To Bureau of Aeronautics, $30,372; cooperative work other departments, $52,887.

[28] To towns, cities, and villages in lieu of personal property tax formerly imposed on motor vehicles.

[29] To District of Columbia general fund, United States Treasury.

DISPOSITION OF RECEIPTS FROM STATE

[Compiled from reports of State authorities]

State	Net total receipts of calendar year [1]	Adjustments due to undistributed balances, etc.[2]	Net total funds distributed	Expenses of collection and administration [3]	For State highway purposes						
					Construction, maintenance, and administration [4]	State highway police	Service of State highway obligations				Total for State highway purposes
							State highway bonds	State-assumed local obligations [5]	Notes and other short-term loans	Total	
Alabama	$12, 878, 097	−$3, 513	$12, 874, 584	$295, 237	$3, 226, 612	$24, 030	$4, 024, 043			$4, 024, 043	$7, 274, 685
Arizona	3, 888, 574	−17, 941	3, 870, 633	189, 748	2, 371, 631	94, 817					2, 466, 448
Arkansas	10, 029, 085	429, 484	10, 458, 569	340, 709	3, 338, 539		2, 522, 588	$1, 664, 953	$1, 223, 280	5, 410, 821	8, 749, 360
California	47, 959, 744	−344, 142	47, 615, 602	2, 392, 316	27, 207, 057	2, 088, 920	800, 000			800, 000	30, 095, 977
Colorado	8, 779, 750	16, 275	8, 796, 025	366, 822	3, 253, 689						3, 253, 689
Connecticut	12, 953, 554	−622, 627	12, 330, 927	782, 411	8, 318, 348						8, 318, 348
Delaware	2, 154, 138		2, 154, 138	(15)	1, 514, 732	149, 201	179, 825	310, 380		490, 205	2, 154, 138
Florida	20, 933, 929	−6, 542	20, 927, 387	520, 913	6, 943, 560	38, 168		2, 322, 169		2, 322, 169	9, 303, 897
Georgia	15, 706, 397	2, 494	15, 708, 891	728, 764	10, 290, 961						10, 290, 961
Idaho	4, 455, 362	−20, 370	4, 434, 992	108, 375	2, 683, 464		214, 304			214, 304	2, 897, 768
Illinois	47, 498, 852	975, 215	48, 474, 067	1, 306, 987	13, 854, 136	846, 754	8, 231, 100	441, 015		8, 672, 115	23, 373, 005
Indiana	24, 630, 674	40, 573	24, 671, 247	836, 221	11, 593, 035	206, 624					11, 799, 659
Iowa	20, 885, 781	−205, 800	20, 679, 981	848, 468	6, 145, 099			8, 614, 536		8, 614, 536	14, 759, 635
Kansas	12, 453, 578	−32, 772	12, 420, 806	766, 141	6, 904, 056	150, 609		1, 000, 000		1, 000, 000	8, 054, 665
Kentucky	12, 411, 826	−13, 782	12, 398, 044	495, 500	11, 486, 111	11, 086					11, 497, 197
Louisiana	13, 290, 662	−569, 850	12, 720, 812	199, 314	3, 419, 772	291, 416	6, 853, 334			6, 853, 334	10, 564, 522
Maine	7, 590, 566	2, 577	7, 593, 143	132, 393	4, 608, 489	155, 000	1, 847, 261			1, 847, 261	6, 610, 750
Maryland	12, 147, 621	331, 665	12, 479, 286	422, 149	4, 159, 482	210, 138	1, 963, 288			1, 963, 288	6, 332, 908
Massachusetts	24, 074, 176		24, 074, 176	1, 447, 468	6, 784, 588	312, 670	464, 118			464, 118	7, 561, 376
Michigan	37, 045, 507	−188, 730	36, 856, 777	1, 369, 849	10, 068, 715	200, 000	4, 082, 060			4, 082, 060	14, 350, 775
Minnesota	17, 729, 164	−798, 295	16, 930, 869	861, 947	8, 388, 259	186, 748	2, 162, 000	1, 626, 425		3, 788, 425	12, 363, 432
Mississippi	8, 883, 542	−229	8, 883, 313	216, 632	3, 775, 146	26, 424					3, 801, 570
Missouri	17, 381, 588	−279, 667	17, 101, 921	671, 927	8, 811, 811	196, 183	7, 422, 000			7, 422, 000	16, 429, 994
Montana	4, 678, 230	−146, 566	4, 531, 664	167, 845	2, 384, 163		1, 043, 552			1, 043, 552	3, 427, 715
Nebraska	10, 483, 495	16, 107	10, 499, 602	164, 579	5, 873, 282						5, 873, 282
Nevada	1, 277, 923	−1, 729	1, 276, 194	17, 975	1, 077, 659	31, 105	121, 937	27, 518		149, 455	1, 258, 219
New Hampshire	5, 270, 390		5, 270, 390	109, 022	4, 282, 401	121, 135	713, 194			713, 194	5, 116, 730
New Jersey	32, 836, 164	[23] 5, 376, 537	38, 212, 701	1, 159, 529	16, 047, 146		7, 543, 463			7, 543, 463	23, 590, 609
New Mexico	3, 466, 295	206, 815	3, 673, 110	157, 401	1, 477, 291	13, 633	1, 616, 809			1, 616, 809	3, 107, 733
New York [27]	85, 256, 524		85, 256, 524	2, 357, 064	12, 082, 470		8, 505, 869			8, 505, 869	20, 588, 339
North Carolina	24, 368, 873		24, 368, 873	272, 534	7, 947, 753	110, 822	9, 047, 130	460, 226		9, 507, 356	17, 565, 931
North Dakota	3, 533, 066	−16, 609	3, 516, 457	123, 919	1, 458, 526	2, 012			102, 000	102, 000	1, 562, 538
Ohio	58, 290, 123	−1, 422, 478	56, 867, 645	1, 214, 272	18, 837, 173	416, 367					19, 253, 540
Oklahoma	14, 954, 811	432, 256	15, 387, 067	886, 988	6, 938, 364						6, 938, 364
Oregon	10, 051, 764	−8, 906	10, 042, 858	371, 522	4, 380, 658	273, 515	3, 405, 010			3, 405, 010	8, 059, 183
Pennsylvania	66, 153, 684	[33] −6, 720, 424	59, 433, 260	1, 768, 047	46, 251, 458	1, 499, 783	6, 590, 526			6, 590, 526	54, 341, 767
Rhode Island	4, 310, 704		4, 310, 704	277, 311	3, 033, 807		301, 876			301, 876	3, 335, 683
South Carolina	9, 965, 345	−25, 681	9, 939, 664	188, 908	1, 002, 261	170, 248	1, 104, 820	6, 003, 389	173, 259	7, 281, 468	8, 453, 977
South Dakota	5, 362, 102	−59, 188	5, 302, 914	111, 051	2, 180, 226						2, 180, 226
Tennessee	17, 759, 512	−276, 354	17, 483, 158	376, 856	5, 039, 941	181, 418	410, 750	1, 932, 685	2, 229, 801	4, 573, 236	9, 794, 595
Texas	46, 708, 569	−163, 173	46, 545, 396	1, 129, 829	20, 151, 229	231, 323		7, 887, 004		7, 887, 004	28, 269, 556
Utah	3, 672, 796	33, 764	3, 706, 560	133, 313	2, 921, 069	89, 538	525, 000			525, 000	3, 535, 607
Vermont	4, 099, 453	−223, 023	3, 876, 430	110, 000	919, 399		672, 031			672, 031	1, 591, 430
Virginia	17, 570, 644	173, 235	17, 743, 879	531, 918	11, 085, 390	182, 858	450, 080			450, 080	11, 718, 328
Washington	15, 133, 862		15, 133, 862	647, 879	7, 221, 609	179, 839					7, 401, 448
West Virginia	11, 236, 676		11, 236, 676	60, 687	4, 313, 822	22, 725	5, 306, 384			5, 306, 384	9, 642, 931
Wisconsin	26, 430, 872	4, 302, 513	30, 733, 385	1, 179, 766	14, 390, 346			3, 491, 464		3, 491, 464	17, 881, 810
Wyoming	2, 274, 885	−46, 246	2, 228, 639	29, 434	1, 471, 363	35, 989	278, 000			278, 000	1, 785, 352
District of Columbia	2, 889, 630	−206, 871	2, 682, 759	127, 358							
Total	883, 798, 559	−81, 998	883, 716, 561	28, 975, 298	371, 916, 098	8, 751, 098	88, 402, 352	35, 781, 764	3, 728, 340	127, 912, 456	508, 579, 652

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[1] Amounts listed include receipts from (1) motor-fuel taxes, (2) motor-vehicle fees and fines, and (3) special imposts on motor vehicles operated for hire (motor-carrier taxes). See preceding tables, which give distribution of these three classes of receipts separately.

[2] In many States amounts distributed during the calendar year differ from actual collections because of undistributed balances carried over and lags between accounts of collecting and expending agencies. Adjustments also include deduction of receipts not classed as highway user imposts, as follows: Proceeds of tax on gasoline used in aviation in Idaho, Michigan, Oregon, and Wyoming, and proceeds of tax on non-motor-vehicle fuel in Ohio.

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

[4] Includes funds allotted for expenditure on urban extensions of State highway system, where reported separately from other funds allotted for local roads and streets.

[5] County or local obligations assumed as reimbursement for local roads added to State system.

[6] In States indicated by star (*) the law provides that allotments for work on local roads or streets may also be used for service of local highway obligations, but amounts so used were not reported separately.

[7] In a number of States allotments for local road work may be used on city streets. This column shows allotments which were reported separately.

[8] Except as noted, to State general funds for nonhighway purposes. Payments to county and municipal general funds may have been distributed in part for highways, but amounts were not reported.

[9] Law provided that part of county allotments could be used for schools. Amount not reported separately.

[10] To county and municipal general funds.

[11] For engineering expenses in connection with irrigation.

[12] To cities and counties for service of bonded debt.

[13] Funds allotted to counties for use on both State and local roads.

[14] To cities and towns.

[15] Paid out of general revenue.

[16] Includes $7,696 to cities and towns.

[17] For Dade Memorial Park, $365; Division of Airways, $8,842.

[18] For construction of prison camps.

[19] To ports of New Orleans and Lake Charles harbor for harbor improvement.

IMPOSTS ON HIGHWAY USERS, 1934

[Compiled from reports of State authorities]

For local roads and streets [6]				For other highway purposes (park and forest roads, etc.)	For nonhighway purposes					State
For work on county and local roads	For work on city streets [7]	Service of local highway obligations	Total		To general funds [8]	For relief of unemployment or destitution	For education	For other purposes	Total	
[9] $4,615,663			$4,615,663		[10] $688,999				$688,999	Alabama.
*906,932			906,932			$302,310		[11] $5,195	307,505	Arizona.
966,476		$152,024	1,118,500			250,000			250,000	Arkansas.
*15,105,227			15,105,227					[12] 22,082	22,082	California.
[13] 2,380,283			2,380,283		801,174	1,994,057			2,795,231	Colorado.
3,125,979			3,125,979		[14] 104,189				104,189	Connecticut.
										Delaware.
		4,775,534	4,775,534		[16] 2,329,865		$3,987,971	[17] 9,207	6,327,043	Florida.
2,301,013			2,301,013				2,385,683	[18] 2,470	2,388,153	Georgia.
*1,428,849			1,428,849							Idaho.
*8,281,668	*$6,954,228		15,235,896		442,838	1,810,880	6,304,461		8,558,179	Illinois.
8,097,814	2,024,454		10,122,268		1,913,099				1,913,099	Indiana.
*5,071,878			5,071,878							Iowa.
3,600,000			3,600,000							Kansas.
405,347			405,347							Kentucky.
	175,000		175,000				890,988	[19] 890,988	1,781,976	Louisiana.
850,000			850,000							Maine.
1,392,130	3,220,743	988,356	5,601,229		12,960			[20] 110,040	123,000	Maryland.
4,076,448			4,076,448	$937,473	10,051,411				10,051,411	Massachusetts.
*20,752,410			20,752,410		383,743				383,743	Michigan.
*3,651,250			3,651,250		54,240				54,240	Minnesota.
*4,600,377			4,600,377		200			[21] 264,534	264,734	Mississippi.
										Missouri.
913,853	22,251		936,104							Montana.
*4,144,039	317,702		4,461,741							Nebraska.
										Nevada.
		[22] 44,638	44,638							New Hampshire.
7,561,242		1,663,758	9,225,000	[24] 61,000		3,182,813	332,500	[25] 661,250	4,176,563	New Jersey.
111,266			111,266		[26] 296,710				296,710	New Mexico.
*16,885,543			16,885,543		[28] 45,425,578				45,425,578	New York. [27]
[29] 4,847,457			4,847,457		1,682,951				1,682,951	North Carolina.
730,000			730,000					[30] 1,100,000	1,100,000	North Dakota.
[31] *18,117,973	[31] 8,857,944		26,975,917				9,085,796	[32] 338,120	9,423,916	Ohio.
*4,380,434			4,380,434					[21] 3,181,281	3,181,281	Oklahoma.
*1,600,000			1,600,000	12,153						Oregon.
*2,472,490	543,103		3,015,593	150,408	766			[34] 156,679	157,445	Pennsylvania.
						697,710			697,710	Rhode Island.
*1,290,927			1,290,927		[10] 5,852				5,852	South Carolina.
1,009,564			1,009,564	95,000				[30] 1,907,073	1,907,073	South Dakota.
3,988,939			3,988,939		534,481	594,370		[35] 2,193,917	3,322,768	Tennessee.
*9,259,007			9,259,007				7,887,004		7,887,004	Texas.
					37,640				37,640	Utah.
2,175,000			2,175,000							Vermont.
[36] 5,435,891			5,435,891		23,411	20,000		[37] 14,331	57,742	Virginia.
*6,136,478			6,136,478			[38] 948,057			948,057	Washington.
[29] 1,533,058			1,533,058							West Virginia.
5,604,953	809,165		6,414,118	60,000	[39] 5,197,691				5,197,691	Wisconsin.
413,853			413,853							Wyoming.
	1,925,137		1,925,137		[40] 630,264				630,264	District of Columbia.
190,221,711	24,849,727	7,624,310	222,695,748	1,316,034	70,618,062	9,800,197	30,874,403	10,857,167	122,149,829	Total.

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[20] To Conservation Department for oyster propagation, in consideration of fuel tax paid by motor workboats, $75,000; to Chesapeake Bay ferry companies, $35,040.
[21] For service of general State debt.
[22] Interest on highway relief bonds, a State obligation issued for improvement of local roads.
[23] Return of loan made to sinking fund in 1933 from motor-fuel tax funds.
[24] To Commission for Elimination of Toll Bridges.
[25] Service of institution construction bonds, $326,475; reserve for service of unissued bonds, $244,775; to Department of Commerce and Navigation, $90,000.
[26] To State general fund, $111,266; to county general funds, $185,444.
[27] General fund appropriations for highway purposes have been credited against payments of motor-fuel tax and motor-vehicle fees to State general fund. General fund appropriations for State police, $2,223,955, are not included, as amount assignable to highway traffic purposes was not reported.
[28] Net to State general fund after crediting appropriations for highway purposes, $39,893,876; to New York City general fund, $5,531,702.
[29] For county roads under State control.
[30] For payments on real estate bonds.
[31] Law provided for diversion of county and municipal allotments for relief and general fund purposes. Amounts so used not reported separately.
[32] For hospitalization of indigent persons injured in motor-vehicle accidents.
[33] Undistributed balance adjustment, $1,430,424; temporary loans to State general fund for relief purposes, $5,290,000.
[34] To Bureau of Aeronautics, $57,154; cooperative work for other State departments, $99,525.
[35] Service of general fund bonds, $1,994,470; service of Great Smoky Mountain Park bonds, $199,447.
[36] For county roads under State control in all but three counties, $5,232,575; transferred to remaining three counties, $203,316.
[37] For aviation purposes.
[38] For service of $10,000,000 emergency relief bond issue, of which approximately $1,000,000 has been assigned to the State highway department for road work.
[39] To State general fund, $1,622,101; to towns, cities, and villages in lieu of personal property tax formerly imposed on motor vehicles, $3,575,590.
[40] To District of Columbia general fund, United States Treasury.

STATUS OF FEDERAL-AID HIGHWAY PROJECTS

1936-1937

AS OF SEPTEMBER 30, 1936

STATE	APPORTIONMENT	COMPLETED			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS
		Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	
Alabama	$ 5,208,287				$ 600,792	$ 300,396	23.2				$ 4,907,891
Arizona	3,564,709	$ 1,715,491	$ 1,342,097	97.9	693,818	569,235	18.9	$ 51,278	$ 36,469	0.5	1,616,908
Arkansas	4,275,929										4,275,929
California	9,508,671	2,550,716	1,461,159	63.9	7,942,378	4,562,251	207.4	3,404,308	1,962,007	96.3	1,523,254
Colorado	4,575,144	1,840,007	1,029,883	81.7	2,804,422	1,556,429	90.9	1,057,477	540,227	30.8	1,448,604
Connecticut	1,582,913	98,677	49,339	2.3	1,002,078	498,836	12.7	122,827	61,414	1.3	973,324
Delaware	1,218,750	239,537	119,769	30.3	314,121	157,061	9.8	297,184	143,247	9.2	798,674
Florida	3,315,558	674,678	337,339	23.8	418,048	209,024	12.5	373,758	186,879	10.5	2,582,316
Georgia	6,336,443	464,012	225,780	38.6	2,627,784	1,289,573	160.2	641,905	320,937	33.8	4,500,152
Idaho	3,065,304	1,034,361	613,014	141.3	2,128,079	1,273,647	141.8	376,210	225,123	32.7	953,520
Illinois	10,325,922	2,331,366	1,162,842	49.0	7,813,359	3,872,205	116.2	3,461,729	1,705,439	87.6	3,585,436
Indiana	6,184,258	2,848,317	1,422,739	95.9	3,346,325	1,673,054	111.7	4,134,654	2,066,528	103.2	1,021,936
Iowa	6,466,628	4,641,682	2,191,504	353.7	3,443,716	1,650,619	144.0	2,553,600	1,234,688	90.8	1,389,817
Kansas	6,631,085	1,793,775	896,253	379.5	4,491,006	2,219,056	462.7	2,583,651	1,291,775	191.4	2,224,001
Kentucky	4,611,955	1,930,787	946,458	128.8	312,862	156,431	14.6	1,318,263	654,685	49.3	2,854,381
Louisiana	3,557,930	1,317,155	658,577	48.6	1,255,693	627,846	42.6	688,056	344,028	16.1	1,927,478
Maine	2,177,197	1,562,025	780,215	45.1	353,803	176,902	13.5	624,164	312,082	15.2	907,999
Maryland	2,050,870				801,807	400,891	11.3	937,600	428,277	12.5	1,221,702
Massachusetts	3,485,364				607,382	303,691	5.1	4,245,162	2,072,581	15.6	1,109,092
Michigan	7,668,768	2,734,635	1,365,820	119.6	10,526,518	5,260,534	311.3	1,494,150	747,075	42.8	295,339
Minnesota	6,849,307	5,258,491	2,432,883	343.5	3,932,447	1,895,380	215.3	884,937	437,069	59.1	2,083,975
Mississippi	4,387,636							1,278,527	639,264	79.1	3,748,372
Missouri	7,601,200	2,358,122	1,174,934	329.8	5,710,371	2,855,188	249.1	3,299,430	1,649,426	178.7	1,921,653
Montana	5,122,333	3,034,250	1,698,744	347.4	1,816,992	1,017,334	88.7	1,691,764	909,027	122.0	1,497,229
Nebraska	5,167,930	1,195,001	597,421	79.8	3,533,477	1,772,321	318.7	771,157	385,579	55.3	2,412,610
Nevada	3,189,479	977,671	841,760	161.5	1,083,200	936,706	121.6	5,280	4,571		1,406,442
New Hampshire	1,218,750	606,373	296,960	19.2	310,662	155,034	5.9	153,317	76,580	1.9	690,177
New Jersey	3,352,469	565,970	282,965	12.0	2,519,053	1,172,996	27.8	840,561	420,280	4.6	1,476,227
New Mexico	3,990,023	1,968,542	1,196,172	158.9	2,016,709	1,248,630	139.1	826,005	495,025	82.0	1,050,197
New York	12,306,710	1,678,650	834,050	39.0	14,336,629	7,084,297	245.4	3,809,700	1,856,850	82.6	2,531,513
North Carolina	5,879,466	1,211,240	605,535	172.5	3,200,278	1,598,744	338.5	523,188	234,912	19.8	3,440,275
North Dakota	3,918,269				191,740	101,206	.1				3,817,063
Ohio	9,131,204	371,310	185,655	7.7	6,335,933	3,086,583	84.1	1,805,832	843,768	11.3	5,015,198
Oklahoma	5,884,927	1,641,493	862,294	58.1	1,831,441	960,167	64.6	1,569,552	769,283	57.6	3,293,183
Oregon	4,089,711	1,352,422	824,129	66.4	2,761,661	1,622,346	80.1	1,536,789	922,400	54.6	720,836
Pennsylvania	10,695,448	2,340,909	1,170,186	43.8	8,427,006	4,206,467	112.9	4,399,879	2,187,950	62.7	3,130,846
Rhode Island	1,218,750				208,875	104,437	3.4	243,555	121,778	2.8	992,535
South Carolina	3,381,337				2,429,867	1,104,160	177.6	1,640,210	731,758	161.0	1,545,419
South Dakota	4,078,647	854,323	468,425	98.4	577,260	345,728	94.6				3,264,493
Tennessee	5,268,270	1,704,450	851,653	72.1	841,758	420,869	29.6	399,154	199,577	16.6	3,796,171
Texas	15,548,821	7,791,060	3,886,592	427.9	6,813,093	3,387,335	352.1	666,017	332,133	22.9	7,942,760
Utah	2,826,960	1,455,473	1,043,447	117.4	625,542	448,669	22.9	405,733	292,745	31.6	1,042,098
Vermont	1,218,750	1,095,920	546,796	57.0	494,946	235,377	11.2	402,351	182,121	11.3	254,456
Virginia	4,559,200	814,162	404,727	29.4	2,605,223	1,302,610	98.6	2,160,115	1,080,057	82.5	1,771,806
Washington	3,904,738	1,975,267	1,039,603	72.8	2,980,111	1,567,071	111.9	840,750	442,000	45.7	856,064
West Virginia	2,716,754	168,656	84,328	7.2	1,326,321	663,144	48.4	665,550	332,775	17.2	1,636,507
Wisconsin	6,090,504	1,935,732	958,207	71.7	5,167,168	2,464,292	191.6	1,114,173	549,104	44.6	2,118,901
Wyoming	3,121,972	2,466,893	1,503,780	274.6	1,221,858	741,659	204.5	223,190	136,535	16.6	739,998
District of Columbia											
Hawaii	1,218,750				467,855	231,167	8.2	69,938	34,754	1.6	952,829
TOTALS	243,750,000	72,599,601	38,394,034	4,768.1	135,251,467	69,487,598	5,356.9	60,592,630	30,600,782	2,165.3	105,267,586

CURRENT STATUS OF UNITED STATES WORKS PROGRAM HIGHWAY PROJECTS

(AS PROVIDED BY THE EMERGENCY RELIEF APPROPRIATION ACT OF 1935)

AS OF SEPTEMBER 30, 1936

STATE	APPORTIONMENT	COMPLETED			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS
		Estimated Total Cost	Works Program Funds	Miles	Estimated Total Cost	Works Program Funds	Miles	Estimated Total Cost	Works Program Funds	Miles	
Alabama	$ 4,151,115	$ 101,939	$ 101,939	6.0	$ 3,810,847	$ 3,810,847	121.2	$ 78,320	$ 78,320	1.7	$ 160,008
Arizona	2,569,841	1,489,227	1,370,858	104.3	1,534,995	1,109,692	92.5				89,290
Arkansas	3,352,061	1,394,349	1,379,540	117.6	1,815,026	1,810,391	220.9	80,705	80,455	8.5	81,675
California	7,747,928	2,803,507	2,664,534	132.9	4,912,339	4,839,151	114.6	160,841	160,841	1.5	83,402
Colorado	3,395,263	1,235,463	1,234,656	71.9	839,734	839,734	26.2	60,717	60,717	6.0	1,260,155
Connecticut	1,418,709	16,288	15,885		464,899	443,314	3.7	245,716	245,616	2.4	713,894
Delaware	900,310	131,410	131,410	27.2	481,162	452,322	21.9	250,398	171,583	17.7	144,995
Florida	2,597,144	257,702	257,702	17.2	2,055,796	2,055,796	69.4	251,977	251,977	12.5	31,669
Georgia	4,988,967	321,413	320,725	14.7	607,657	607,657	48.8	518,414	518,414	27.2	3,542,171
Idaho	2,222,747	895,369	885,354	80.0	1,341,484	1,305,028	103.3				32,365
Illinois	8,694,009	2,911,003	2,910,672	174.9	5,409,679	5,409,679	276.0	345,252	345,252	16.6	28,406
Indiana	4,941,255	437,242	437,242	17.1	4,628,250	4,408,346	211.5	37,924	37,924	6.3	57,742
Iowa	4,991,664	1,469,869	1,398,800	240.0	3,378,116	3,291,084	229.1	376,771	296,826	43.9	4,955
Kansas	4,994,975	1,131,749	1,131,740	148.2	3,864,040	3,854,229	226.8	9,006	9,006	.2	
Kentucky	3,726,271	1,244,134	1,244,134	175.3	1,419,036	1,419,036	126.5	757,567	757,558	47.4	305,543
Louisiana	2,890,429	275,630	159,229	14.5	2,458,750	2,241,343	137.7	410,499	345,560	22.4	144,297
Maine	1,676,799	732,945	732,398	30.3	838,234	837,622	39.7	52,100	52,100	1.7	54,679
Maryland	1,750,738	60,038	60,038	3.0	381,130	370,616	13.6	1,021,267	868,441	25.0	451,643
Massachusetts	3,262,885				1,438,247	1,438,247	7.9	796,617	796,617	9.8	1,028,021
Michigan	6,301,414	3,260,700	3,260,700	154.4	2,872,721	2,812,691	129.9	55,700	55,700	4.6	172,323
Minnesota	5,277,145	2,969,108	2,572,500	547.0	2,627,986	2,215,522	323.9	867,609	474,973	41.2	14,150
Mississippi	3,457,552	719,422	718,452	62.9	2,305,857	2,302,431	136.9	162,219	162,219	16.1	274,450
Missouri	6,012,652	2,718,238	2,706,846	630.7	2,803,661	2,693,317	143.2	339,006	226,825	3.7	385,663
Montana	3,676,416	2,614,737	2,614,737	142.4	993,301	993,301	42.9				68,379
Nebraska	3,870,739	845,750	831,425	109.9	2,473,897	2,441,909	240.9	312,435	312,435	12.9	284,971
Nevada	2,243,074	1,470,400	1,430,585	64.6	473,737	467,194	24.0	77,629	77,629	2.6	267,667
New Hampshire	945,225	324,723	321,354	17.0	431,916	409,528	15.6				214,343
New Jersey	3,129,805	58,780	58,780	1.8	2,133,098	2,133,098	17.2	778,963	755,514	13.3	182,413
New Mexico	2,871,397	1,453,988	1,453,502	135.9	898,802	898,802	43.7	93,636	93,636	5.2	425,458
New York	11,046,377	2,705,568	2,676,182	44.7	8,392,705	8,008,329	123.2	359,809	351,959	2.5	9,906
North Carolina	4,720,173	551,112	551,112	27.1	3,386,648	3,354,047	238.7	695,295	602,423	21.7	212,591
North Dakota	2,867,245	374,763	374,601	72.3	2,034,980	2,030,451	201.4	259,893	259,893	35.3	202,300
Ohio	7,670,815	606,549	606,549	12.3	4,830,154	4,733,059	148.9	1,455,250	1,381,042	108.6	950,164
Oklahoma	4,580,670	692,033	690,423	66.6	2,415,714	2,413,098	227.5	927,489	927,489	87.5	549,661
Oregon	3,038,642	1,172,627	1,167,752	83.8	1,963,366	1,598,824	65.4	140,959	139,009	17.6	133,057
Pennsylvania	9,347,797	1,073,030	1,011,371	54.9	1,655,452	1,651,414	50.8	1,085,961	1,043,651	57.0	5,641,361
Rhode Island	989,208	470,166	468,554	9.5	510,981	510,981	9.3				9,673
South Carolina	2,702,012	469,591	456,514	51.3	1,671,161	1,605,655	151.5	196,306	191,852	19.8	447,991
South Dakota	2,976,454	1,087,296	1,087,296	240.9	1,283,251	1,283,251	179.7	317,440	317,440	41.9	288,467
Tennessee	4,192,460	905,360	905,360	36.1	1,810,211	1,810,211	74.5	582,465	582,465	24.7	894,424
Texas	11,989,350	7,786,971	7,076,306	717.9	5,254,549	4,753,964	391.3	117,411	101,811	8.7	57,269
Utah	2,067,154	1,007,085	962,757	118.1	894,005	778,821	62.8	185,682	185,609	7.6	139,968
Vermont	924,306	454,213	404,129	12.5	565,438	474,853	9.3	8,000	8,000		37,324
Virginia	3,652,667	1,653,573	1,599,960	622.0	1,449,486	1,429,711	362.6	410,719	410,719	55.0	212,277
Washington	3,026,161	1,928,666	1,738,958	128.7	1,314,585	1,123,219	33.9	146,120	146,120	2.1	17,864
West Virginia	2,231,412				1,677,312	1,673,772	69.8	445,251	444,511	20.4	113,129
Wisconsin	4,823,884	2,136,332	1,918,328	169.6	3,313,578	2,858,458	165.4	52,312	42,700	5.7	4,398
Wyoming	2,219,155	616,232	616,223	43.8	1,481,906	1,481,894	95.2	92,292	92,291	1.2	28,747
District of Columbia	949,496	968,869	944,839	8.5				25,011	4,295	.2	362
Hawaii	926,033	95,216	82,604	1.3	549,947	541,612	7.6	9,684	9,146		292,671
TOTALS	195,000,000	60,100,375	57,745,555	5,763.6	106,149,826	102,027,551	5,878.3	15,654,637	14,478,563	867.9	20,748,331

CURRENT STATUS OF UNITED STATES WORKS PROGRAM GRADE CROSSING PROJECTS

(AS PROVIDED BY THE EMERGENCY RELIEF APPROPRIATION ACT OF 1935)

AS OF SEPTEMBER 30,1936

STATE	APPORTIONMENT	COMPLETED					UNDER CONSTRUCTION					APPROVED FOR CONSTRUCTION					BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS
		Estimated Total Cost	Works Program Funds	NUMBER			Estimated Total Cost	Works Program Funds	NUMBER			Estimated Total Cost	Works Program Funds	NUMBER			
				Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise			Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise			Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	
Alabama	$ 4,034,617	$ 192,848	$ 192,848	4		3	$ 3,159,717	$ 3,159,717	32		1	$ 541,813	$ 541,813	5		7	$ 140,239
Arizona	1,256,099	398,678	394,443	5			723,343	711,898	7								149,758
Arkansas	3,574,060	807,299	804,562	21	2		1,869,002	1,863,714	27	3		790,441	789,527	8		29	116,257
California	7,486,362	1,128,082	1,102,777	9	5		6,286,139	6,067,159	43	2							316,426
Colorado	2,631,567	926,063	905,063	17			639,929	639,929	6	1							1,086,575
Connecticut	1,712,684						73,479	73,479		1		578,069	505,990	3	1		1,133,215
Delaware	418,239						143,486	120,000	1								298,239
Florida	2,827,883	376,085	376,085	3	2		1,544,580	1,542,270	16	3		471,191	471,191	11			438,337
Georgia	4,895,949	12,090	12,090	1			318,336	318,336	5	2		473,993	473,993	15			4,091,530
Idaho	1,674,479	608,364	608,364	10	1		508,469	508,469	7			32,026	32,026			18	525,620
Illinois	10,307,184	494,347	494,347	9			6,791,679	6,791,679	45	3		1,883,683	1,883,683	12	1		1,137,475
Indiana	5,111,096	123,346	123,346	3			4,747,743	4,624,624	34	11		413,314	89,585			161	273,541
Iowa	5,600,679	482,788	460,597	16	2		4,343,949	4,284,978	77	7		431,856	422,512	6	1	6	432,593
Kansas	5,246,258	510,952	510,952	7			4,661,942	4,606,514	45	1		128,792	128,792	3		3	
Kentucky	3,672,387	15,290	15,290	1			2,512,919	2,223,187	20			254,862	254,862	2	4		1,179,048
Louisiana	3,213,467						1,108,330	1,108,330	10	1		1,291,648	1,247,183	11	3		857,954
Maine	1,426,861	284,698	284,365	8			753,736	753,145	10			129,755	129,755	3		2	259,596
Maryland	2,061,751						477,688	469,649	4	2		1,061,147	1,038,679	4	2	18	553,423
Massachusetts	4,210,833	117,449	117,449	2			1,758,553	1,758,553	13	2		1,132,733	1,132,733	6	2		1,202,097
Michigan	6,765,197	1,122,725	1,122,725	14	3		5,026,327	4,981,827	28	4		400,100	400,100	1			260,545
Minnesota	5,395,441	808,291	808,291	32	1	19	3,305,846	3,299,750	47	8	21	614,462	614,462	4	1	1	672,938
Mississippi	3,241,475	25,677	25,677	2	1		2,230,582	2,230,582	45	2		323,769	323,769	5		1	661,447
Missouri	6,142,153	179,101	179,101	3			5,715,757	5,640,491	42			375,538	261,586	1		2	60,975
Montana	2,722,327	1,915,443	1,915,443	30	5		678,538	678,538	6	1		66,336	66,336	1			62,009
Nebraska	3,556,441	477,487	477,487	14			1,689,970	1,689,970	55	1	5	1,270,689	1,270,689	10	1	18	118,295
Nevada	887,260	306,096	306,096	7	2		599,335	577,534	4			3,630	3,630			5	
New Hampshire	822,484	151,745	151,745	1			350,493	350,493	4	2	1						320,246
New Jersey	3,983,826						1,492,673	1,492,673	9	2		1,097,620	1,097,620	8	1		1,393,534
New Mexico	1,725,286	370,259	370,259	8			1,079,279	1,079,279	8	1		72,213	72,213	1			203,534
New York	13,577,189	46,040	46,040		2		10,502,004	10,241,158	33	34		1,389,433	1,389,433	1	2		1,900,558
North Carolina	4,823,958	202,566	202,566	4	4		2,133,274	2,133,274	27	8		1,010,966	995,466	8	4	61	1,492,653
North Dakota	3,207,473	189,807	189,807	5			1,826,095	1,825,095	35	1		17,430	17,430	1			1,175,141
Ohio	8,439,897						2,982,291	2,834,726	20	2		2,628,393	2,542,404	15	3		3,062,767
Oklahoma	5,004,711	1,143,162	1,143,162	25	1		1,637,970	1,637,970	16	2		618,519	618,519	13	1		1,605,061
Oregon	2,334,204	192,665	192,665	2	2		2,192,229	2,067,518	14	4		74,021	74,021	1		2	
Pennsylvania	11,483,613	233,539	182,306	15			5,309,829	4,983,227	36	13		1,607,150	1,217,083	8	2		5,100,997
Rhode Island	699,691	236,879	236,879		1		418,195	417,129	4								45,683
South Carolina	3,059,956	255,347	252,043	8		2	1,432,872	1,424,890	20	7	1	334,714	334,584	8		49	1,048,439
South Dakota	3,249,086	356,492	356,492	14			1,291,117	1,291,117	29	1		540,610	540,610	11		30	1,060,866
Tennessee	3,903,979	139,050	139,050	5		3	567,566	567,566	9	2	1	1,396,578	1,396,578	16	1	17	1,800,785
Texas	10,855,982	1,550,651	1,550,651	29	4		6,935,498	6,929,123	82	10		2,062,227	2,009,265	13	1	164	366,943
Utah	1,230,763	31,146	29,757		1		762,088	754,041	11			324,648	308,000	2			138,965
Vermont	729,857	364,025	361,180	7	4		98,394	98,394		1		285,298	223,830	3	1	12	46,454
Virginia	3,774,287	316,040	316,040	13	1		1,679,882	1,570,018	27	2		694,339	694,335	15	3	12	1,193,894
Washington	3,095,041	434,369	429,569	7	3	2	2,416,857	2,416,432	15	8	3	4,290	4,290			2	244,750
West Virginia	2,677,937						618,942	618,942	6	1		716,838	716,838	14	1	4	1,342,157
Wisconsin	5,022,683	621,115	621,115	7			3,654,266	3,626,169	27	6		192,988	160,720	2			614,678
Wyoming	1,360,841	55,366	55,365	2			930,633	930,628	7			78,404	78,403	2			296,445
Dist. of Columbia	410,804						425,564	396,804	3								14;000
Hawaii	453,703						522,380	453,703	5								
TOTALS	196,000,000	18,203,462	18,064,089	370	47	29	112,929,765	110,864,691	1076	162	33	27,816,526	26,574,538	253	36	624	40,496,682

U. S. GOVERNMENT PRINTING OFFICE 1936

PUBLICATIONS *of the* BUREAU OF PUBLIC ROADS

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

ANNUAL REPORTS

Report of the Chief of the Bureau of Public Roads, 1924. 5 cents.

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

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

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

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

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

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

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

DEPARTMENT BULLETINS

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

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

TECHNICAL BULLETINS

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

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

MISCELLANEOUS PUBLICATIONS

No. 76MP . . The Results of Physical Tests of Road-Building Rock. 25 cents.

Federal Legislation and Regulations Relating to Highway Construction. 10 cents.

Supplement No. 1 to Federal Legislation and Regulations Relating to Highway Construction. 5 cents.

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

The Taxation of Motor Vehicles in 1932. 35 cents.

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

Highway Bond Calculations. 10 cents.

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

SEPARATE REPRINT FROM THE YEARBOOK

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

TRANSPORTATION SURVEY REPORTS

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

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

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

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

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

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

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

CURRENT STATUS OF UNITED STATES PUBLIC WORKS ROAD CONSTRUCTION

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

AS OF SEPTEMBER 30, 1936

STATE	APPORTIONMENTS		COMPLETED				UNDER CONSTRUCTION				APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS	
	Sec. 204 of the Act of June 16, 1933 (1934 Fund)	Act of June 18, 1934 (1935 Fund)	Total Cost	1934 Public Works Funds	1935 Public Works Funds	Mileage	Estimated Total Cost	1934 Public Works Funds	1935 Public Works Funds	Mileage	1934 Public Works Funds	1935 Public Works Funds	Mileage	1934 Public Works Funds	1935 Public Works Funds
Alabama	$ 8,370,133	$ 4,259,842	$ 15,258,420	$ 8,290,736	$ 3,480,875	759.0	$ 499,761	$ 52,665	$ 447,096	17.0		$ 304,982	2.5	$ 26,732	$ 26,889
Arizona	5,211,960	2,641,935	8,982,676	5,204,513	2,570,966	543.0	12,500		12,500					7,447	58,469
Arkansas	6,748,335	3,428,049	10,908,286	6,634,440	3,304,963	618.5	87,816		87,606	1.5	$ 70,814	18,148	3.2	43,081	17,332
California	15,607,354	7,932,206	30,595,484	15,589,248	7,751,647	760.9	115,026		115,016			820		18,105	64,723
Colorado	6,874,530	3,486,006	11,209,862	6,831,431	3,441,857	639.8								43,099	44,149
Connecticut	2,865,740	1,454,868	4,443,623	2,758,269	1,255,341	73.1	107,242	36,318	57,603	1.0	22,245			48,909	141,924
Delaware	1,819,088	923,395	2,676,358	1,818,804	815,188	128.3	53,319		53,319	.5		52,205	1.1	284	2,682
Florida	5,231,834	2,661,343	8,735,667	5,175,534	2,193,368	299.6	389,901		358,854	9.3		15,955	.8	56,300	93,165
Georgia	10,091,185	5,113,491	12,676,939	9,187,568	2,774,071	718.1	1,633,523	541,346	1,074,148	107.6	84,072	125,508	3.3	278,199	1,139,764
Idaho	4,486,249	2,277,486	6,741,735	4,416,568	1,904,256	500.9	346,409		342,613	.5	42,905	1,521		26,776	29,096
Illinois	17,570,770	8,921,401	24,887,419	16,828,002	7,140,842	670.2	2,574,610	680,180	1,688,110	46.7	15,674	18,214	5.4	46,915	74,235
Indiana	10,037,843	5,088,963	15,194,693	9,775,380	4,725,577	464.6	441,723	206,489	205,932	23.8		108,068		55,974	49,386
Iowa	10,055,660	5,118,361	15,428,980	10,055,161	4,777,361	1,221.9	361,891		341,000	5.4	499				
Kansas	10,089,604	5,117,675	15,328,260	10,002,650	5,011,108	1,131.1	226,121	77,553	60,318	14.4				9,401	46,249
Kentucky	7,517,359	3,818,311	11,796,442	7,448,139	3,459,949	806.7	318,148	59.003	241,546	6.1		37,329	2.1	10,217	79,488
Louisiana	5,828,591	2,963,932	8,971,463	5,755,322	2,591,893	249.9	174,054	56,550	117,504	9.5		223,172	11.6	16,719	31,363
Maine	3,369,917	1,711,586	5,232,163	3,346,881	1,657,506	193.1	7,234		7,234					23,036	45,846
Maryland	3,564,527	1,810,058	5,113,898	3,235,963	856,905	136.8	673,286	240,565	398,299	21.2		312,399	3.4	87,999	242,455
Massachusetts	6,597,100	3,350,474	9,840,762	6,552,733	2,635,951	115.2	443,755		443,755	.3		91,944	.1	44,367	178,824
Michigan	12,736,227	6,452,568	20,176,587	12,696,114	5,879,433	745.1	595,775	40,113	435,198	23.1		136,788	.4		1,149
Minnesota	10,656,569	5,425,551	16,082,221	10,515,640	4,758,425	1,625.8	500,948	60,099	382,030	22.0		17,660	1.3	80,830	267,435
Mississippi	6,978,675	3,540,227	12,401,629	6,723,551	2,717,281	707.6	930,998	188,860	742,138	36.4	3,960	41,111	1.7	62,304	39,697
Missouri	12,180,306	6,173,740	17,405,575	11,637,146	4,721,768	1,436.3	2,108,797	471,210	1,375,607	15.3		67,385		71,950	8,980
Montana	7,439,748	3,769,734	11,649,966	7,405,326	3,571,311	1,045.4	204,864	18,440	186,424	13.0				15,982	11,999
Nebraska	7,828,961	3,964,364	12,800,048	7,775,584	3,614,698	1,018.3	275,979		263,874	27.8	38,017	69,961	5.9	15,360	15,832
Nevada	4,545,917	2,302,356	7,091,816	4,545,917	2,272,477	760.4	25,004		25,004			3,450			1,425
New Hampshire	1,909,839	969,462	2,971,426	1,904,950	933,904	77.7	4,174		4,174			16,591	.5	4,888	14,793
New Jersey	6,346,039	3,220,879	7,890,090	6,050,468	1,334,004	81.1	2,313,106	100,118	1,684,378	14.3	103,825		1.3	91,629	202,497
New Mexico	5,792,935	2,941,700	8,750,864	5,742,415	2,801,073	743.6	90,789	40,093	38,402	6.0				10,427	102,225
New York	22,330,101	11,327,921	38,610,905	21,810,435	9,904,437	814.7	1,870,220	351,500	1,149,599	8.7	140,263	205,575	1.7	27,903	68,309
North Carolina	9,522,293	4,840,941	14,584,457	9,055,926	4,304,060	1,329.6	621,910	390,134	231,776	27.7	63,117	200,873	8.2	13,115	104,232
North Dakota	5,804,448	2,938,967	8,165,538	5,607,892	1,831,376	2,080.5	589,179	55,232	512,440	56.6	97,879	100,382	16.6	43,445	494,770
Ohio	15,484,592	7,865,012	23,853,335	15,324,142	6,727,618	771.2	1,093,416	101,165	964,126	23.7		59,160	1.4	59,285	114,109
Oklahoma	9,216,798	4,685,180	14,454,246	9,146,852	4,237,720	804.4	239,170	67,007	172,163	1.8		7,995	.4	2,938	267,302
Oregon	6,106,896	3,097,814	9,785,647	5,989,401	2,911,569	465.4	221,489	64,950	89,127	3.3		25,041		52,545	72,078
Pennsylvania	18,891,004	9,590,788	28,223,264	18,181,618	8,667,568	1,020.4	939,391	432,418	415,018	38.0	3,888	212,482	1.7	273,080	295,721
Rhode Island	1,998,708	1,014,572	3,140,657	1,998,708	1,008,873	89.1						3,806			1,893
South Carolina	5,459,165	2,770,954	7,666,465	5,233,441	2,158,259	609.9	480,000	98,074	371,116	15.2	118,761	150,063	4.0	8,889	91,516
South Dakota	6,011,479	3,047,643	9,100,736	5,777,486	2,747,494	1,529.1	356,426	143,433	212,993	49.5		26,867	13.7	90,560	60,289
Tennessee	8,492,619	4,302,991	13,183,797	8,492,619	3,670,429	483.6	468,716		468,716	9.0		113,346	9.5		50,500
Texas	24,244,024	12,291,253	37,666,237	23,907,965	11,879,917	2,776.9	613,756	284,494	294,051	9.2		500	7.1	51,564	116,785
Utah	4,194,708	2,132,691	7,191,769	4,160,916	1,991,960	590.6	180,018		140,731	.3	32,292			1,500	
Vermont	1,867,573	948,007	3,045,526	1,863,531	840,471	137.9	121,734	3,922	102,184	3.1				121	5,352
Virginia	7,416,757	3,765,387	11,589,851	7,298,833	3,342,708	598.7	159,266	704	158,562	21.8	86,473	176,315	28.9	30,748	87,802
Washington	6,115,867	3,106,412	9,369,903	6,100,928	3,022,950	302.7	46,596		46,596		11,114	13,022	.3	3,825	23,843
West Virginia	4,474,234	2,280,335	6,063,802	4,324,378	1,458,208	205.6	791,054	83,534	651,013	16.9		66,425	.7	66,322	104,689
Wisconsin	9,724,881	4,941,837	15,401,545	9,683,993	4,874,070	619.7	22,678		22,678			21,685		40,888	23,404
Wyoming	4,501,327	2,287,712	6,860,586	4,451,922	2,197,664	1,037.1	5,781	5,780		.3		38,485	.6	43,625	51,562
District of Columbia	1,918,469	973,842	2,740,809	1,909,584	831,090	20.7	137,889		137,889	1.5	8,885				4,863
Hawaii	1,871,062	949,778	2,693,451	1,870,384	264,953	51.1	650,835		647,003	4.7		14,000		678	23,822
TOTALS	394,000,000	200,000,000	614,635,878	386,095,407	173,827,392	34,610.9	25,126,277	4,951,949	17,977,463	714.0	944,683	3,099,233	139.4	2,007,961	5,095,912