Performance Data for Some Bituminous Concrete Overlays in Indiana

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Introduction

The bituminous concrete most used by the State of Indiana has been included in the standard specifications without essential change as to type at least since 1934. Until about 1948, this material was used primarily as the surfacing layers of high-type flexible pavements. In this application, the performance of the material was considered to be entirely satisfactory and the stability of the mixture was not questioned.

Since 1948, however, this bituminous mixture type has been used more and more for the resurfacing of deteriorated Portland cement concrete pavements. Also, in the period following the war and particularly in the last several years, the number and weight of heavy vehicles using Indiana highways has increased markedly. This change in the use of the material, coupled with the large increase in traffic might be expected to create problems that did not exist previously.

The bituminous-concrete overlay that has been used in Indiana usually is composed of two layers: (1) a binder or leveling course which has a maximum aggregate size of three quarters to one-inch, 65 per cent coarse aggregate (material retained on the No. 6 sieve), 35 per cent fine aggregate (essentially none of which passes the No. 200 sieve), and which contains 4.5 to 5.5 per cent asphalt by weight of the mixture, and (2) a surface course which has a maximum aggregate size of ½-inch, about 50 per cent coarse aggregate, 50 per cent fine aggregate and with about 3 per cent of the total passing the No. 200 sieve. It usually contains 6.0 to 7.0 per cent asphalt by weight of the mixture. The thickness to which each of the courses is laid is variable depending upon the condition of the road to be resurfaced, the expected traffic intensity and perhaps other factors, but a total thickness of 2½ inches composed of 1½ inches of binder and 1-inch of surface is not uncommon. The asphalt cement used is a 60-70 penetration grade.

The performance of Indiana's AH-binder and Type B surface as an overlay for Portland cement concrete has been the subject of such investigation in the past several years. The purpose of this paper is to summarize some of the results of a number of the field studies that have been made which deal with such things as the effect of thickness of lay and compaction. In addition, examples of some of the specific problems that have been encountered when using this type of mixture for an overlay are illustrated and steps that have been taken to solve the problems are enumerated. Finally, the current research on this subject is discussed by briefly describing some of the work in progress at the Joint Highway Research Project Laboratories.

Experimental Overlay—SR 37

Thickness design was a variable which was included in the construction of an overlay on State Road 37 between Elwood and Noblesville. This overlay built in 1950 has a standard thickness design of about 2½ inches composed of 150 pounds per square yard of binder and 100 pounds per square yard of surface. On sections 1,000 feet in length other thicknesses were employed as follows:

1. About 2 inches total, composed of 100 pounds per square yard of binder and 100 pounds per square yard of surface.
2. About 3 inches total, composed of 150 pounds per square yard of binder and 150 pounds per square yard of surface.
3. About 4 inches total, composed of 300 pounds per square yard of binder and 100 pounds per square yard of surface.

Concrete pavement with both jointed and non-jointed slab design is included in this part of State Road 37 and these experimental overlays of various thicknesses were constructed on each in order to study the effect of the type of concrete pavement on the performance of the resurfacing. This overlay on State Road 37 is now almost seven years old and, except for the presence of reflection cracks, the performance is satisfactory. Fig. 1 shows a view of the road on the jointed concrete section. This is a good example of the successful use of this type of overlay under moderate to heavy moving traffic conditions. Fig. 1 and subsequent illustrations showing condition of this road (Figs. 2 to 4) are from pictures which

Fig. 1. Bituminous concrete overlay on State Road 37.

were taken in March, 1957 when the overlay was about seven years old.

Effect of Overlay Thickness

All thickness designs on this road did not perform equally and there is evidence that heavy lays may be advantageous for some conditions. In Fig. 2, for example there is shown for the jointed concrete pavement a "typical" reflection crack in the 4-inch thick overlay on the left compared to a typical one in the 2-inch thick overlay on the right. The crack in the 2-inch thick overlay is more severe. It follows along the line of the joint and really is a system of multiple cracks with chunks of bituminous-concrete mixture beginning to be cracked off. The crack in the 4-inch thick overlay, however, is a meandering one. It is, for the most part, a single crack and there are no signs of ravelling associated with it.

Fig. 3 shows a similar comparison for the bituminous-concrete overlay placed on the concrete pavement without transverse joints. This concrete has a fairly short crack interval. Before and after surveys indicated that most of the cracks in the concrete were reflected in the overlay. It may be seen from Fig. 3, however, that these cracks are generally much less severe than those in the jointed

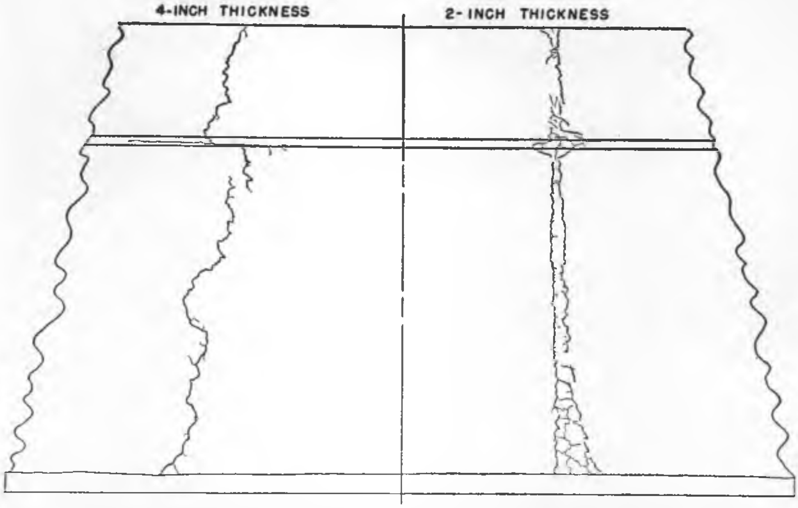

Fig. 2. Comparison of performance of 2″ and 4″ thick overlay on jointed concrete.

concrete section. Again, the performance of the 4-inch thick overlay is compared with the 2-inch thick one. The 4-inch thick section is on the left. The condition of the cracks indicates some advantage for the thicker lay. But the difference is not so great as for the case with jointed concrete pavement.

A comparison between the performance of the 3-inch thick overlay on jointed and non-jointed concrete is shown in Fig. 4. The jointed concrete is on the left and the non-jointed concrete is on the

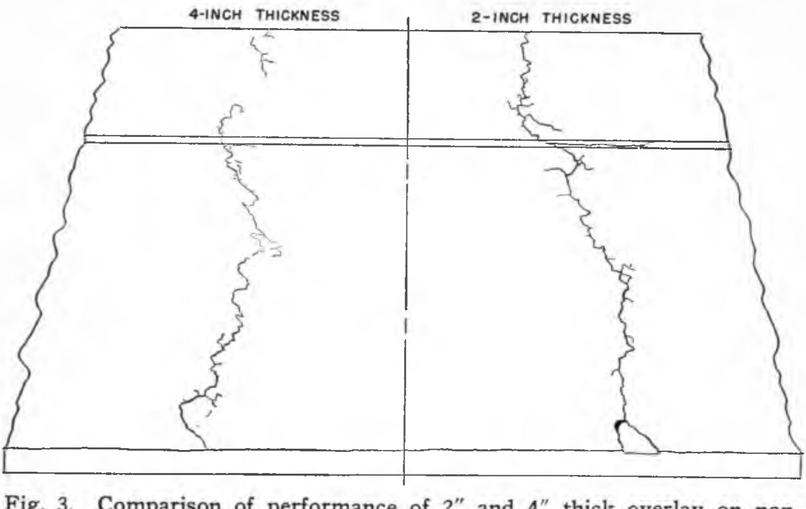

Fig. 3. Comparison of performance of 2″ and 4″ thick overlay on non-jointed concrete.

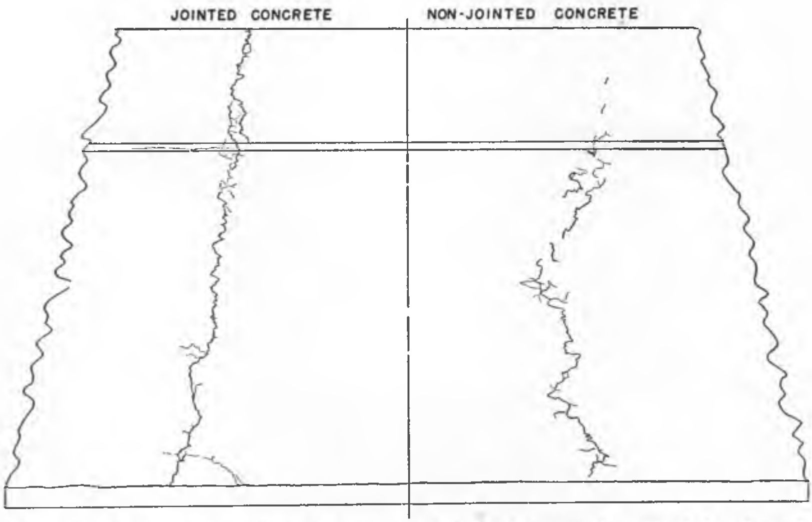

Fig. 4. Comparison of performance of 3" thick overlay on jointed and nonjointed concrete.

right. For this thickness, which is close to the standard design for the road, it is seen again that reflection cracking is less severe over non-jointed concrete.

Density Studies

Several additional studies were made on this section of State Road 37, one of which had to do with compaction of the bituminous concrete and subsequent densification of the mixture from traffic action. Samples of the mixture were obtained soon after construction from areas of the pavement which were in the wheel tracks of a traffic lane and from areas between the wheel tracks. These samples were taken in each of the three thickness designs and from the test sections on both jointed and non-jointed concrete. Also, the sampling was duplicated for the north-bound and south-bound traffic lanes. Density determinations were made on all samples. This procedure was repeated when the overlay was two years old and again when the overlay was five years old.

Table 1 shows the results of the first and second samplings tabulated so that a comparison may be made of density in the wheel tracks versus that between the wheel tracks. These results show binder and surface density values to be similar. In addition, it may be said that there appears to be no practical difference between the density results of the samples taken from the wheel tracks compared to those taken between the wheel tracks. Naturally, year to year differences are highly significant and these results show how a pavement densifies with repeated loads. They also show a trend toward uniformity of density that did not exist immediately after construction.

While considering practical and significant differences it should be recorded that analyses of variance were performed on the density results shown in Table 1. These analyses showed statistical significance over the whole table but, as sometimes happens, the differences declared to be significant by the analysis were not thought to be so in a pratcical sense. Subsequent observation of the road in succeeding years has justified this evaluation.

Tables 2 and 3 show two comparisons of the results for the three sampling periods. Table 2 shows a comparison of density values for various thickness designs over jointed and non-jointed concrete and Table 3 shows a similar comparison for the thickness designs in the north-bound and south-bound lanes. These density values in Tables 2 and 3 are for the combined binder and surface. Comparisons indicate that neither lane position nor concrete design appeared to affect the densification of the mixture in service.

Table 1

Density Test Results—Experimental Overlay, SR 37
Comparison of Density In and Between Wheel Tracks
Pounds Per Cubic Foot

			Thickness Design			
Layer	Age	Position	300# Binder 100# Surface	150# Binder 150# Surface	100# Binder 100# Surface	Average
Binder	0 to 3 Mos.	Wh. Trk.	141.4	139.8	139.5	140.2
		Bet. Trk.	141.0	138.4	139.2	139.5
	2 Yrs.	Wh. Trk.	145.4	145.2	145.2	145.3
		Bet. Trk.	145.4	144.6	145.0	145.0
Surface	0 to 3 Mos.	Wh. Trk.	138.9	142.9	139.2	140.3
		Bet. Trk.	139.5	144.4	139.6	141.2
	2 Yrs.	Wh. Trk.	146.4	146.6	144.7	145.9
		Bet. Trk.	145.1	147.4	145.3	145.9

Table 2

Density Test Results—Experimental Overlay, SR 37
Comparison of Density Over Jointed and Non-Jointed Concrete
Pounds Per Cubic Foot

Age	Concrete Type	Thickness Design			Average
		300# Binder 100# Surface	150# Binder 150# Surface	100# Binder 100# Surface	
0-3 Mos.	Jointed	141.2	141.8	137.3	140.1
	Non-Jointed	139.3	141.2	141.5	140.7
2 Yrs.	Jointed	146.0	144.7	143.9	144.9
	Non-Jointed	145.2	146.9	146.3	146.1
5 Yrs.	Jointed	147.3	147.9	145.9	147.0
	Non-Jointed	147.2	147.5	147.7	147.5

Table 3

Density Test Results—Experimental Overlay, SR 37
Comparison of Density in North and South-Bound Lanes
Pounds Per Cubic Foot

Age	Lane	Thickness Design			Average
		300# Binder 100# Surface	150# Binder 150# Surface	100# Binder 100# Surface	
0-3 Mos.	N.-Bound	140.1	141.3	139.0	140.1
	S.-Bound	140.4	141.4	139.8	140.5
2 Yrs.	N.-Bound	146.6	145.7	144.9	145.7
	S.-Bound	144.6	146.2	145.4	145.4
5 Yrs.	N.-Bound	147.6	147.7	146.8	147.4
	S.-Bound	146.9	147.8	146.9	147.2

Table 4 shows the results of the density tests for each thickness design and age and for each of the two separate positions, wheel track and between wheel tracks. The results shown are averages over samples from both the jointed and non-jointed sections and from both northbound and southbound traffic lanes. We may make this type of comparison since results shown in Tables 2 and 3 indicate that the density of the mixture was not influenced by concrete design nor by location in either traffic lane.

There are several interesting comparisons that may be made from these data. First, it can be seen that for any age and for each of the three thicknesses the density of the mixture in the wheel tracks is not substantially different from that between the wheel tracks. This may not be too surprising for the earlier stages (Table 1), but it was surprising to find that this homogeneity persisted for five years. It gives some indication concerning the plastic nature of this mixture. This plasticity has caused some distress in other locations, some illustrations of which are shown in Figs. 5 through 8.

In addition to the homogeneity of density, a simple calculation will show that over the five year period there was an overall increase in density of approximately 5 per cent. We would consider this to be rather high, especially considering that the base point for these calculations was a density that already included the effect of a month or two of traffic. It would appear that greater densification during construction would be desirable. This matter is of extreme importance for realistic bituminous mixture design to serve severe traffic conditions.

Table 4

Density Test Results—Experimental Overlay, SR 37
Summary Comparison
Pounds Per Cubic Foot

Age	Position	Thickness Design		
		300# Binder 100# Surface	150# Binder 150# Surface	100# Binder 100# Surface
0-3	Wh. Trk.	140.1	141.3	139.4
Mos.	Bet. Trk.	140.2	141.4	139.4
2	Wh. Trk.	145.9	145.9	145.0
Yrs.	Bet. Trk.	145.3	146.0	145.1
5	Wh. Trk.	147.6	147.9	147.2
Yrs.	Bet. Trk.	147.0	147.5	146.5

Overlay Performance Under Heavy Traffic

The progressive densification and performance of several overlays in the Calumet Area of the state also have been studied. The data from these locations are similar to those that were obtained from State Road 37. The results of density tests made on cores taken at these locations are shown in Table 5.

In this case, data are available from only two early samplings of these locations, but the trend appears to be similar to the previous one. The comparison between wheel-track and non-wheel-track positions has been omitted in this case because it again was found to be non-significant. These locations are under observation and another sampling is scheduled for the fall of 1957.

As was previously indicated, some problems have arisen in connection with the performance of these bituminous concrete overlays which in specific locations have assumed severe proportions. Some of these problems are shown in Figs. 5 through 8.

Evidence of lack of stability of some mixtures in some service conditions has been the development of ruts in the overlay in the wheel-track areas. This rutting, first investigated in the field in late 1953, was found to be present to some extent in many locations. It was present to an extent that could definitely be judged to be objectionable, however, in relatively few areas, each of which was subjected to much heavy, relatively slow-moving traffic. The condition was found to be the most severe at signalized intersections where the pavement and the overlay were subjected to stresses from braking traffic and to static loads.

Table 5

Density Test Results—Bituminous Concrete Overlays
In Calumet Area
Pounds Per Cubic Foot

Age	Location No. 1	Location No. 2	Location No. 3
1 to 3 Months	145.7	144.6	143.8
1 Year	149.6	150.0	148.5

An example of this is shown in Fig. 5 which is a view looking west at the westbound lanes of U. S. 12 and 20 near its intersection with Seventh Avenue just east of Gary. This picture was taken in November, 1953, at which time the overlay was three years old. The fact that the mixture had been subject to plastic movement seems evident from the pavement edge. The ruts were of the order of magnitude of a tenth of a foot. The mixture was literally being squeezed aside under the action of the wheel loads.

The same intersection in March, 1957, is shown in Fig. 6. This view was taken just across the road from the previous one. The marks in the wheel track areas are not mud or patches, they show the underlying concrete. In this instance, the rutting has progressed to the ultimate. The entire thickness of the mixture has been displaced.

It took at least two years for much evidence of instability to show in the case illustrated in Figs. 5 and 6. On another occasion the period was only a few months. Fig. 7 shows a view looking south on Indianapolis Boulevard from the intersection with 151st Street in

Fig. 5. Overlay performance at intersection.

East Chicago. Again, the plastic nature of the mixture is illustrated by the apparent flow of the bituminous concrete.

Other locations in the state where extremely severe traffic conditions exist have shown similar results. Fig. 8 shows one of two trenches cut for the full depth of the resurfacing across the outside lane of pavement on U. S. 40 near Indianapolis. The pavement distortion can be seen both from the cut face of the trench and from the water on the pavement which is ponded in the ruts in the wheel-track areas. This trench was cut approximately 750 feet back from the nearest signalized intersection. Another trench cut at the intersection showed more distortion than the case illustrated.

This trenching operation, in addition to enabling one to measure rutting, showed that the overlay had spread out in a transverse direction so that it extended some six inches beyond the edge of the

Fig. 6. Concrete exposed by rutting.

concrete to which it was placed during construction. Secondly, it was found from an examination of the sawed face that both the binder and surface layers were distorted in the wheel-track areas. Thirdly, and this is illustrated in Fig. 9, it was found from density measurements made on samples taken at closely-spaced intervals across the traffic lane that the density of the mixture was essentially the same regardless of sample position.

In Fig. 9 are grouped the density data for two-foot intervals across the trench. The low value that was observed near the pavement edge includes some samples that were obviously under-compacted.

All of these facts lead to the conclusion that the failures under consideration were caused by plastic flow. The realization of these failures and their nature lead the Indiana Highway Department to modify their bituminous concrete by several approaches. Asphalt content generally has been reduced in both the binder and surface layers. In some instances, the maximum aggregate size of the binder has been increased and the thickness of this layer increased with a corresponding decrease in surface-layer thickness. In other instances the ratio of coarse aggregate to fine aggregate has been increased in

Fig. 7. "Flow" of bituminous concrete.

both the binder and the surface. Perhaps these modifications will provide the solution. There have been overlays built incorporating one or more of these modifications which appear to be performing quite satisfactorily at the present time under severe service conditions.

An example of this is a section of Indianapolis Boulevard which was resurfaced in 1954 and which carries the traffic of U. S. 12, 20 and 41. This overlay, at the time of this writing is almost three years old and appears to be in excellent condition in spite of the rather severe service exposure.

Laboratory Research

In spite of this apparently satisfactory performance to date, however, it may be that an entirely new design concept is needed, if not immediately, then perhaps in the not too distant future. But accompanying a new or even modified design concept must be a better method of evaluating the mixture in the laboratory. The presently accepted strength tests for bituminous mixtures appear to be inadequate in certain cases.

Fig. 8. Trench cut in bituminous overlay.

For example, the mixture that rutted under traffic action until the underlying concrete showed through will meet the stability requirements of most of the standard acceptance tests. Yet under

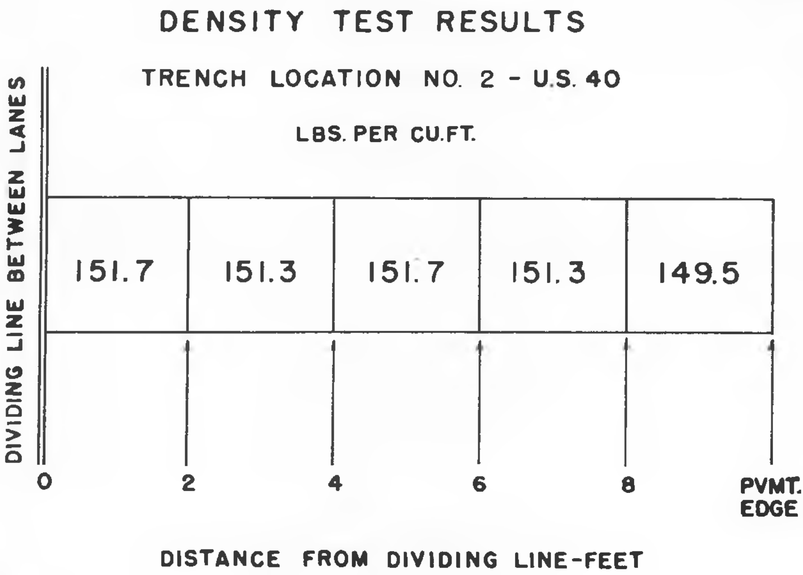

Fig. 9. Density test results.

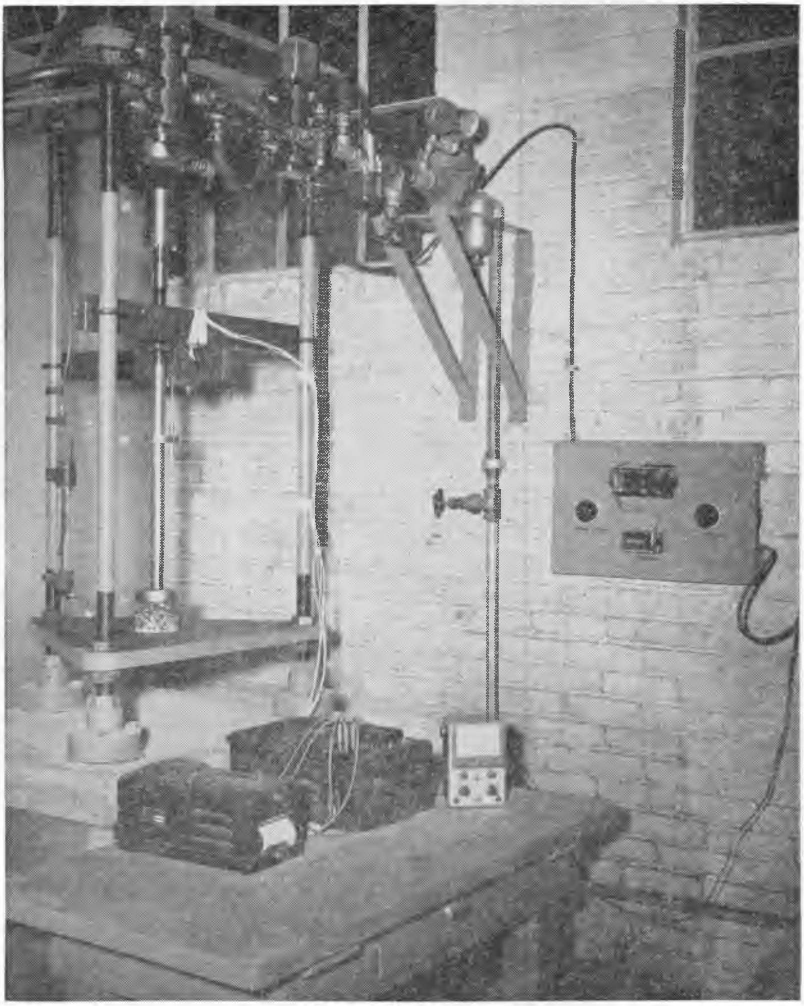

Fig. 10. Repeated load test apparatus.

some service conditions the mix is obviously overly plastic. Highway engineers are particularly concerned with obtaining a laboratory test method which would overcome the inadequacies of the present methods. There is a need for a test which would be capable of evaluating the plastic nature of a bituminous mixture under repeated applications of load. It is toward this goal that our current research work has been directed.

The equipment and test set-up that we have been using to measure the deformation characteristics of a bituminous-concrete specimen under repeated applications of load is shown in Fig. 10.

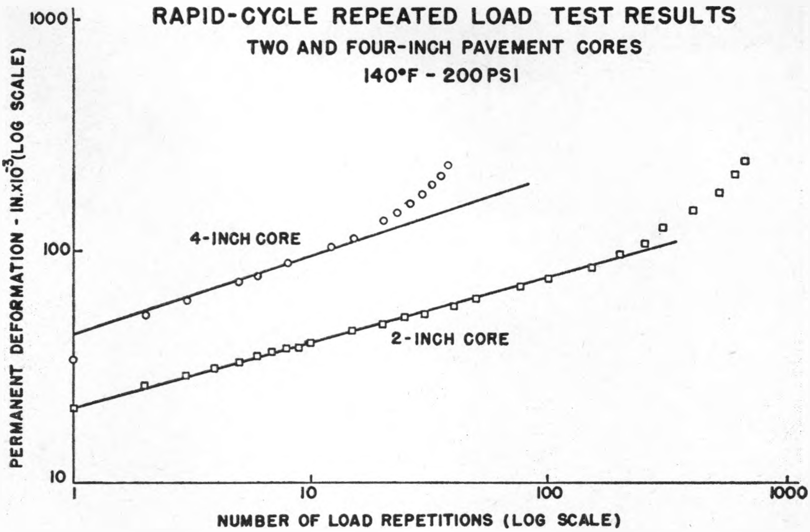

Fig. 11. Rapid-cycle repeated load test results.

Basically, this apparatus consists of an air motor mounted in a loading frame. Suitable valves and controls are present to admit compressed air to the air motor for a time interval which may be pre-set. The load is transmitted from the air motor to a shaft which in turn transmits load to the specimen. At the end of the pre-set time interval, during which the load is maintained constant, the inlet air valve to the motor closes and an exhaust valve opens, releasing the air, and hence quickly removing the load from the specimen. After another time interval which can also be pre-set, the cycle is automatically repeated. One can make this sort of test at various temperatures and with various loads. As the specimen is repeatedly loaded it accumulates a permanent deformation which may be comparable to the tendency to rut that has been observed.

By keeping a record of the accumulation of this permanent deformation during the test, one may plot a graph of the sort shown in Fig. 11. In this figure is shown a plot of log cumulative permanent deformation on the vertical scale versus the logarithm of the number of load repetitions on the horizontal scale. This particular illustration is from tests on 2- and 4-inch thick cores of AH-Binder and Type B surface tested at 140° F and under a contact pressure of 200 psi. Without going into any detail, we will comment only that it is believed that the slope of these lines and the point on the line at which the data begin their upward deviation may have some significance with respect to the potential ability of the mixture to withstand repeated applications of load. This test method is still in the development stage but it shows great promise. Perhaps at some future Road School there will be further progress to be reported on this subject.

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